Chapter 8
Climate Change Adaptation

Photo: John Klingel

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8.1 Introduction

Climate change planning includes at least two distinct response categories—mitigation and adaptation. *Mitigation* refers to minimizing the magnitude of climate change, primarily through adopting GHG reduction strategies. However, even with the adoption of aggressive mitigation actions, climate change is already under way and cannot be completely avoided. *Adaptation* refers to actions taken to minimize the disruption resulting from the impact of these unavoidable climate change effects.

Although Marin County currently enjoys a relatively mild climate, climate change may exacerbate existing climate-related hazards in the county (such as an increased number of flooding incidences) or introduce new challenges (such as erosion or coastal flooding due to sea level rise). These climate change effects could have wide-ranging impacts across the county's various economic sectors. It is important that Marin County considers potential climate change vulnerabilities as it moves forward with other planning activities.

Marin County is a leader in climate change adaptation and has already taken great strides to begin to prepare the County for increased resilience to the likely impacts of climate change. A number of studies have been completed that evaluate various potential climate change impacts on Marin County, and some stakeholders are beginning to consider strategies for preparing for climate change. Although significant work remains to be done, these efforts provide a strong foundation for making Marin County more resilient to climate change.

This section includes a discussion of the observed and anticipated effects of climate change in the county, a discussion of existing efforts and suggestions for how those efforts can be replicated in other sectors or expanded and what additional efforts are needed, and a review of the sectors where potential impacts warrant an extensive vulnerability assessment to understand fully how specific assets are vulnerable and could benefit from adaptation actions. It also provides the County with a summary of what is known about the anticipated future local climate, an overview of what is being done to address the impacts, and suggestions about next steps.

8.2 How the Climate May Be Changing in Marin County

8.2.1 Observed and Projected Changes in Temperature, Precipitation, and Sea Level Rise

Current research efforts have shown that Marin County and the North Bay region have already experienced some changes in climate, including increases in temperature and precipitation. For example, minimum temperatures increased by 1.7°F between 1911 and 2000, while average

maximum temperatures have increased only 1.0°F over the same period (Flint et. al. 2011). Meanwhile, annual precipitation has also increased, with a 12% more rapid increase for the latter half of the century (Micheli, et al. 2012).[31]

Projections indicate that temperatures will continue to increase, and the region will most likely experience a shift to drier summers and wetter winters, characterized by heavier rain events. In addition, local sea levels will rise, as shown in Table 8-1. However, the North Bay region is situated in a transition zone between Washington and Oregon—where projections indicate a shift towards wetter and warmer conditions—and Southern California and Baja Mexico—where projections indicate a shift towards drier and warmer conditions. This geographic complexity increases the uncertainty regarding exactly how the county's climate may change in the future, particularly regarding precipitation projections, which are more sensitive to model assumptions than temperature projections. Precipitation projections for the region vary from decreases in precipitation to as much as a 15% shift towards a wetter climate (North Bay Climate Adaptation Initiative 2013a; Micheli, et al. 2012). Table 8-1 presents a summary of the projected shifts in ambient temperatures, changes in precipitation, and sea level rise for the North Bay, which includes Marin, Sonoma, and Napa Counties.

Table 8-1. Projected Climate Changes in the North Bay (including Marin County)

Climate Hazard	Projected Changes
Ambient Temperatures	• Average **maximum** temperatures are projected to increase between 2°F and 7°F by the end of the century (North Bay Climate Adaptation Initiative 2013a). • If current trends continue, the increase in **minimum** temperatures could exceed the increase in maximum temperatures.
Changes in Precipitation	• Precipitation projections vary between General Circulation Models (GCMs) and indicate that 21st-century precipitation projections indicate a 2–15% **increase** over the 20th-century average (Micheli et al. 2012). • Under some scenarios there could be a **decrease** in precipitation over the same period (North Bay Climate Adaptation Initiative 2013a). • Regardless of an overall increase or decrease, all scenarios project an increase in weather variability with a higher likelihood of an increase in frequency and intensity of extreme events, such as floods and droughts (Flint et al. 2012; North Bay Climate Adaptation Initiative 2013a) • Watershed models project **shorter wet winters** and **longer, drier summers** (North Bay Climate Adaptation Initiative 2013a)**.** • Expect heavier rain events (North Bay Climate Adaptation Initiative 2013a).
Sea Level Rise	• Potential for a range of 1.4 to 5.5 foot increase by the end of the century (Cayan et al. 2008; Knowles 2010, State of California Ocean Protection Council 2013). • More frequent flood inundation of low-lying areas of the North San Francisco Bay Estuary (San Pablo Bay) shoreline and coastal regions (Cayan et al. 2008; Knowles 2010).

[31] It should be noted that coastal marine influences and topographic variation result in high spatial variability within these shifts. Throughout the County, microclimates may experience different shifts, which should be considered during further studies that investigate the specific vulnerabilities of sector assets.

8.2.2 Potential Effects of Projected Climate Change on Marin County

Increases in temperature, changes in precipitation, and sea level rise could result in the increased frequency or intensity of certain climate hazards, including shifts in the water supply and demand, wildfires, extreme heat, and inland flooding. These changes have been highlighted in various efforts that are underway or recently completed as discussed below in Section 7.3. Shifts in the energy supply and demand and changes in the agricultural growing season present additional potential impacts in the county. Based on the geographic location and projected changes listed in Table 8-1, Marin County may be exposed to the following potential impacts from climate change.

8.2.2.1 Extreme Heat

Although Marin County has a mild Mediterranean climate, increases in the average maximum temperature may be coupled with increases in extreme heat. Efforts to project changes in temperature, such as the data shown in Cal-Adapt, indicate that the number of "extreme heat" days in Marin could increase more than ten-fold by the end of the century (Cal-Adapt 2014a)[32]. Extreme heat in this historically temperate climate may threaten human health, cause heat stress in animals, and shorten the expected lifespan or increase the need for repairs in the built environment.

8.2.2.2 Inland Flooding

Increased intensity of winter storm events combined with sea-level rise is likely to cause more frequent flooding, especially in low-lying areas. An increase in the variability of rainfall could contribute to an increase in the likelihood of the frequency and intensity of extreme events such as floods in the North Bay (Flint et al. 2012).

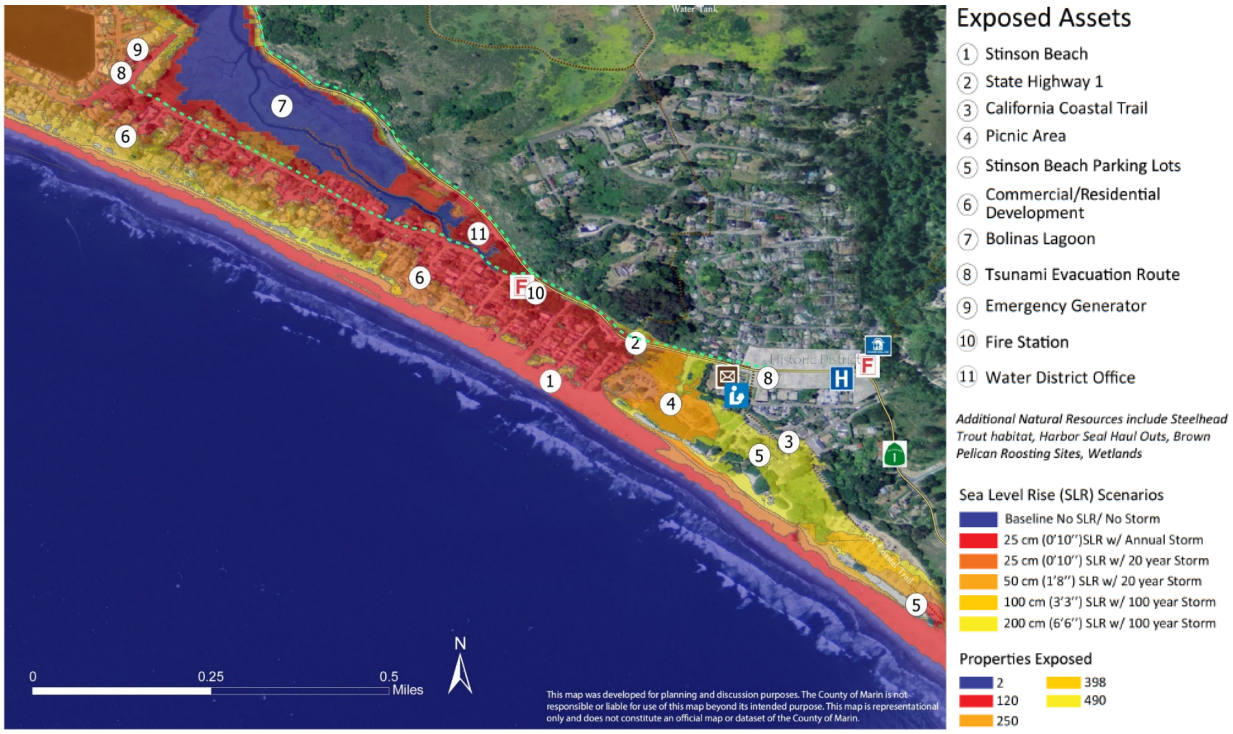
8.2.2.3 Sea Level Rise

Increased sea levels and elevations of storm surge could cause more area within the county to be temporarily or permanently inundated by salt and brackish waters. The exact amount of sea level rise to be experienced by Marin County will depend on many factors, but the State of California's *Sea Level Rise Guidance* document recommends that California agencies use a range of 4 to 30 centimeters (cm) by 2030, 12 to 61 cm by 2050, and 42 to 167 cm by 2100 (Ocean Protection Council [OPC] 2013). Local land subsidence and uplift will also influence the extent of inundation.

Land and structures in low-lying coastal areas may need to be reassessed to accommodate changes in the shoreline. Figure 8-1 shows potential sea level inundation for Stinson Beach under different sea level rise and storm scenarios For additional examples of sea level rise inundation maps, please see Appendix E.

[32] Data displayed in the Cal-Adapt Extreme Heat Tool have been provided by Scripps Institution of Oceanography.

Figure 8-1. Example Inundation Zone: Sea-Level Rise Exposure and Asset Identification Map for Stinson Beach, Marin County Under Different Scenarios



Source: Marin County, 2014

8.2.2.4 Shift in Water Demand and Supply

A shift in precipitation patterns and extended periods of drought would limit the available supply of water. By the end of the 21st century, under either high- or low-rainfall scenarios, warming is projected to amplify late-season climatic water deficit by 8%–21% (Micheli et al. 2012).[33] To compound the impact, increased temperatures and low soil moisture increase the demand for water as people require more water for their gardens, agriculture, and other uses. Simultaneously, an increase in heavy rainfall events may elevate turbidity resulting in freshwater resources that require additional processing for residential and industrial uses.

8.2.2.5 Wildfires

Increased temperatures and shifts in precipitation patterns, which may include extended dry spells, could create conditions that may increase the risk of wildfire danger in Marin County. As wildfire risk is projected to increase moderately in Marin County by the end of the century, wild-urban interface fires can cause major damage to the build environment and natural heritage, as seen in the 1991 Oakland Hills fire and the 2008 Santa Rosa fire (Cal-Adapt 2014c).

[33] Late-season climatic water deficit is a measure of drought stress on soils.

8.2.2.6 Change in Habitats and Ecosystems

Changes in habitats and ecosystems could result from changes in temperatures, precipitation, and the potential competition from colonizing species. The natural heritage and parks in the county may change. Projections suggest that future conditions may be more similar to the current conditions in Santa Barbara County, which could result in a significant transition in the local forests (North Bay Climate Adaptation Initiative 2013b).

Aquatic ecosystems may also be affected, through mechanisms such as ocean acidification, increased temperatures, changes in upwelling, and changes in nutrient loading. The response of the ecosystem to these changes is complex. Habitats for certain flora and fauna may shift geographically (or become less available), triggering impacts on the species that coexist or depend on those flora and fauna. The exact impact that climate change could have on Marin's marine ecosystems is unknown at this point, but species potentially at risk may include: the oysters farmed near Marin's coast, which are sensitive to ocean acidification due to their calcium carbonate shells; and seals, whose pups cannot swim nor climb on rocks and thus depend on sandy shores for survival—sandy shores that could be reduced as sea levels rise (Largier et. al. 2010).

8.2.2.7 Shift in Energy Demand and Supply

Increased temperatures and a decreased (or inconsistent) water supply could have a negative impact on the availability of energy. Some power plants require large amounts of water for cooling and higher temperatures could result in demand spikes that exceed production or available supply. Low-lying generation facilities and distribution equipment could be inundated with storm surges and sea level rise. Although there are no electric generation facilities in Marin County, changes in energy supply and demand could lead to higher energy prices, brownouts, or other impacts that affect Marin.

8.3 Status of Adaptation Efforts in Marin County

8.3.1 Efforts Under Way

There are many adaptation efforts already underway in Marin County. The County has proven to be a leader in thinking about adaptation and taking action to increase resiliency of local resources. The *Marin County Climate Adaptation/Resilience Snapshot* that was compiled by the Bay Area Climate & Energy Resilience Project (BACERP) in March 2014 provides a summary of the efforts that are completed or underway (Bay Area Climate & Energy Resilience Project 2014). Additionally, the *Climate Adaptation—Sea Level Rise White Paper* prepared by the City of San Rafael in January 2014 provides a review of federal, state, and regional level efforts and legislation that address sea level rise (City of San Rafael 2014). It reviews the current and recently completed studies and strategies in the county and region. These reports contain a more comprehensive list of adaptation initiatives in Marin County, but some example adaptation initiatives include those listed below.

- In November 2014, the **Marin County Board of Supervisors** allocated one-time funding of $250,000 to establish a countywide multi-jurisdictional partnership to complete a climate change vulnerability assessment and coordinate the various entities engaged in climate and sea level rise planning and education. The County is also seeking matching grant funding from the Coastal Conservancy to support this project.

- Marin County's **"Collaboration: Sea-level Marin Adaptation Response Team" (C-SMART)** is an intergovernmental/public-private partnership that is working to develop an understanding of how sea level rise (SLR) may affect coastal area homes, schools, roads, public facilities, natural resources and habitat areas, when these impacts might occur, how they might change over time, and how to prepare for them.
- The County's **Southern Marin Sea Level Rise Pilot Project** addresses how the climate change impacts of sea level rise will affect the future of Southern Marin communities, infrastructure, ecosystems and economy, and what strategies the County can pursue to reduce and manage these risks. The project area encompasses the Richardson Bay shoreline, from the Sewerage Agency of Southern Marin treatment plant in Mill Valley to Marin City.
- The **Bay Conservation and Development Commission (BCDC)** is tasked with providing regulatory authority over the San Francisco Bay. BCDC has produced maps of sea level rise for informational purposes that are intended to encourage further and more detailed local study. In 2011, BCDC prepared a vulnerability assessment, *Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on the Shoreline* (San Francisco Bay Conservation and Development Commission 2011).
- **California Coastal Commission** is a state agency that provides planning and regulatory authority over the California coastline. The California Coastal Commission released *Draft Sea Level Guidance* in 2013 to provide local governments with recommendations on how to address sea level rise in Local Coastal Programs (California Coastal Commission 2013).
- The **Marin Municipal Water District is a partner in the North Bay Climate Ready project** aimed at developing a regional vulnerability assessment for selected Marin, Sonoma and Napa public agencies in order to help local government and agency staff implement informed and effective climate adaptation strategies and responses. The vulnerability assessment is scheduled for completion in 2016 and will examine potential changes in temperature and water supply, groundwater recharge, drought stress, and others variables for a range of climate scenarios. This project is coordinated by the **North Bay Climate Adaptation Initiative (NBCAI)**, a coalition of natural resource managers, policy makers and scientists working together to implement effective adaptation strategies for North Bay ecosystems and watersheds. The data products produced by North Bay Climate Ready will address a range of scenarios for the Marin landscape.
- The *Vegetation and Biodiversity Management Plan* (draft released in October 2013) is a prime example of how the County is incorporating climate change impacts and hazards into its long-range and comprehensive planning efforts (Marin County Parks and Marin County Open Space District 2013).
- The December 2012 publication of *San Francisco Estuary & Watershed Science* included a peer reviewed article by Elisabeth Micheli et al. (2012) titled, *Downscaling Future Climate Projections to the Watershed Scale: A North San Francisco Bay Case Study*. This study provides an in-depth discussion on the approaches and benefits of using downscaled data to predict temperature and precipitation changes.

8.3.2 Additional Efforts Needed

Marin County has been proactively addressing climate change on many fronts, but additional efforts are needed to understand the county's vulnerabilities and take action to address these vulnerabilities. Important additional efforts include a countywide vulnerability assessment, improved collaboration among stakeholders, and the establishment of additional funding sources to support adaptation initiatives.

8.3.2.1 Countywide Vulnerability Assessment

Although a large number of adaptation activities are under way, there has not been a consolidated look across sectors and climate change stressors at the vulnerabilities of Marin County. Vulnerability assessments thus far have been limited to certain geographic areas and/or specific climate stressors (e.g., sea level rise). A more comprehensive countywide vulnerability assessment would help highlight where resources should be focused under adaptation planning efforts. A countywide understanding of vulnerabilities will help ensure that adaptation resources are being deployed in an effective and efficient manner. Furthermore, effective adaptation requires coordination across many different stakeholders within a county, and a "big picture" understanding of the sectors and geographic locations that are most vulnerable would help demonstrate where coordination and collaboration are most needed.

A comprehensive vulnerability assessment is also an important resource for garnering public support for adaptation efforts. A countywide assessment would show, in clear terms, the locations that are particularly vulnerable, which could motivate communities to take action. They are less likely to take action if the threat of climate change is vague and not made specifically relevant to them.

8.3.2.2 Collaboration

Climate change has the potential to affect a wide variety of communities, stakeholders, and industries. Leaving each community or stakeholder group to address adaptation on its own would lead to inefficient and less effective adaptation strategies. It is better to address adaptation through a coordinated effort of communities and stakeholders.

To undertake this work, a broad range of groups that have an interest in the county will need to work together to identify and implement creative solutions. Under the discussion of each sector in Section 8.4, the key stakeholders and agencies are noted, highlighting the fact that there are many stakeholder groups with a vested interest in increasing the resiliency in each sector. In addition to developing an approach that reaches across agencies within the county, it may be essential to engage businesses, municipal governments, residents, and federal, state and regional agencies in developing a locally feasible implementation plan. Throughout the process of conducting a vulnerability analysis, assessing the sensitivity of systems, and developing an adaptation action plan, the relevant list of stakeholders should be reviewed and engaged.

As part of an effort to collaborate, the County and municipalities could benefit from agreeing to use the California sea level rise projections (as outlined in the *State of California Sea-Level Rise Guidance Document*) in long-range planning efforts (State of California Ocean Protection Council 2013). Although the state has not released similar guidance for temperature increases and precipitation changes, the County and municipalities could agree to adopt a set of local projections and commit to

incorporating those projections into long-range planning efforts. In addition to selecting a set of projections, the government entities would also need to agree upon how to define "long-range" planning efforts.

8.3.2.3 Funding

Another significant challenge will be to identify funding sources for the vulnerability assessment, developing an adaptation plan, and implementing actions. By establishing buy-in across agencies, in the business community, and among residents, the County may be able to identify a broader range of funding sources. The County may seek opportunities for public-private partnerships, have enough buy-in to pass a ballot measure to collect revenue, or identify opportunities to integrate adaptation into existing efforts that have co-benefits such as turning an area with high risk of sea level rise–related inundation into a scenic trail or park. Creative approaches to funding may help engage a larger community and identify opportunities for additional co-benefits.

8.4 Potential Impacts of Climate Change on Marin County's Sectors and Potential Adaptation Actions

This section discusses the potential impacts of important sectors to the aforementioned climate hazards. Each sector is introduced by a brief overview of the relevant features of that sector in Marin County, highlights of the climate hazards with the highest potential to cause damage, a discussion of current activities, and which agencies or groups would be integral in developing and implementing specific adaptation actions. Table 8-2 provides a high-level list of potential adaptation actions for each sector; see Appendix A for additional detail. This list provides suggested actions to increase resiliency; however, this is not an exhaustive list and is only intended for guidance and to initiate a discussion with relevant stakeholders after a comprehensive vulnerability assessment is completed.

The review is intended to provide high level guidance for the County and not rate the relative potential impacts. The information does not state whether these impacts are likely to occur, and likelihood cannot be assessed given the inherent uncertainty of greenhouse gas projections, climate models, and the associated impacts on assets and services. The evaluation is based on research and professional expertise and provides a discussion of general sensitivities that may be a concern in the county. A detailed vulnerability assessment by sector would be required to identify where the county's specific vulnerabilities lay.

Table 8-2. Example Adaptation Actions by Sector[34]

Sector	Potential Adaptation Actions
Cross-Cutting	• Select set of climate projections upon which to base future planning decisions. • Conduct detailed vulnerability assessment by sector or geographic region within the County. • Evaluate vulnerability of planning decisions based on the selected climate projections. • Integrate adaptation actions into planning processes (i.e., wildfire preparedness, water management, hazard preparedness, comprehensive planning, etc.) and infrastructure decision-making (i.e., locating and designing roads). • Encourage zoning and planning decisions that limit building of infrastructure in areas at risk for sea level rise, flooding, or landslides. Also encourage planning decisions that increase redundancy of critical infrastructure types. • Work with other institutions to develop cost-effective, comprehensive arrangements for monitoring the changes in local climate factors such as precipitation, fog, heat patterns, storm frequency and severity, flood flows, areas inundated and sea level. • Begin monitoring climate- and weather-related damages and costs to help understand the costs of inaction. Monitoring is also critically important for determining the appropriate pace and timing of adaptation actions, especially for actions requiring long lead-time and high cost alternatives.
Water	• Implement water conservation measures to mitigate demand. • Anticipate higher water treatment costs. • Incorporate design standards to slow surface water runoff. • Review and update coastal flood protection measures. • Introduce erosion control measures. • Review and update forest management practices.
Natural Heritage	• Monitor existing and emerging species. • Increase habitat connectivity and establish habitat corridors. • Increase the availability of shade and water at recreational facilities. • Acquire and protect areas where marsh can migrate upland as inundation increases. • Create “no-wake zones” to reduce erosion. • Consider water needs of plants when landscaping.

[34] This table represents example adaptation measures that could be implemented by Marin County. A more complete list is presented in Appendix A. A more complete vulnerability and adaptation analysis is needed to determine which adaptation measures should be recommended.

Sector	Potential Adaptation Actions
Transportation	• Develop plan to address worker safety with regards to extreme heat. • Review guidelines for materials and equipment to ensure they can withstand increased maximum temperatures. • Protect sensitive equipment and update maintenance schedule to address more rapid deterioration of materials. • Make Public Service Announcements about closures and plan for detours. • Reroute or elevate roads and improve drainage on existing roads. • Establish redundant routes. • Adapt marine facilities (e.g., ferry terminals). • Conduct post-event evaluation and maintenance to ensure all facilities are up to standard for safe operations and use after extreme events (i.e., fire, flood, heat wave, etc.).
Agriculture	• Adjust growing season and planting methods or select varieties of plants that are heat resistant. • Grow different varieties of plants and crops that are more tolerant to variability or projected climate conditions. • Develop plan for animal safety in the event of an extreme event such as a flood, storm surge, or extreme heat. • Use buffers to modify and reduce fertilizer and pesticide application to address potential increases in polluted agricultural runoff from floods, inundation, and erosion. • Develop carbon farming and wetland restoration along Marin's bayshore to restore wetlands, sequester atmospheric carbon, and accrue significant quantities of carbon-rich soil to increase shoreline elevation and buffer storm surges.
Energy	• Add peak generation, power storage capacity, and distributed generation. • Implement improved cooling flow technologies and procedures to reduce water needs. • Institute technologies and procedures to increase reliability of the energy supply during heat waves and/or drought years. • Reduce energy demand through energy efficiency.
Human Health	• Early warning systems for heat waves and unsafe swimming conditions. • Make cooling facilities available for residents. • Stagger activities like construction to cooler times of day. • Monitor air quality concentrations. • Monitor coastal conditions and reduce discharge of warm water and fertilizers upstream. • Educate public on preparedness for hazards. • Develop contingency plan at hospitals and for patients that receive care at home for situations with loss of power.

Sector	Potential Adaptation Actions
Built Environment	• Update building codes to require structural adaptations to withstand flood inundation • Support use of adaptable building construction types for remodels and new construction • Increase setbacks/elevations for beach and bluff-top development in coastal communities. • Develop managed realignment/relocation plans which could include transfer of development credits, acquisition and conservation easements. • Create natural protection systems in coastal areas which could include beach/dune restoration (addition of sand and vegetation) and offshore bio-beds (kelp, sea grass, oyster beds, etc.) • Construct structural coastal protections including seawalls, groins, emergent breakwaters, artificial reefs and perched beaches.

This section also notes the general coordination and research activities, and the likely actors to oversee those activities, that would need to be conducted to begin preparing for these changes. It is important to understand that this high-level coordination and research are important first steps for effectively and efficiently adapting. Specific adaptation strategies that are common to each sector are highlighted in Table 8-2 and detailed in Appendix A; however, more detailed analyses on specific vulnerabilities of Marin County, and potential costs and benefits of each adaptation measure, are needed to determine which actions should be implemented in Marin.

8.4.1 Water

The Marin Municipal Water District provides drinking water to 186,000 customers in central and southern Marin County (including incorporated areas). Approximately 75% of the drinking water comes from the seven reservoirs that capture rainwater on 21,600 acres of protected watershed on Mt. Tamalpais. Additional water resources are imported from the Russian River in Sonoma County (Marin Municipal Water District 2014). The North Marin Water District provides service to approximately 61,000 customers in the city of Novato and several small improvement districts near the coast (North Marin Water District 2014). The Stinson Beach County Water District serves the residents of Stinson Beach. Additional small districts serve the communities along the Pacific coast.

Concerns regarding water are typically associated with three main and time-variable aspects: quantity, quality, and demand.

Increased temperatures and extreme heat could decrease water supplies as evapotranspiration and the demand for water increases. Secondary sources of water and conservation measures can help offset these impacts. Additionally, higher temperatures decrease dissolved oxygen levels in water, which can reduce water quality and require higher costs for treatment.

Flooding may cause shifts in peak water flows, shifting the quantity of water in streams and rivers. Water management practices that store water onsite (such as low-impact development) can help reduce these shifts in peak flows. Increased runoff and flooding may also move pollution into the waterways and require additional treatment costs. Similarly, sea level rise could impact quality of water and increase concerns related to saline intrusion and potential leach field impacts.

Increased erosion from wildfires in the watershed and the use of chemicals from fighting fires may directly impact the water quality. Additionally, as energy prices increase, the cost of pumping and delivering water could also increase.

An assessment of the existing facilities, distribution networks, and land uses will be necessary to understand the extent to which the water supply in Marin County will be impacted by climate change impacts. The **Marin Municipal Water District, North Marin Water District,** and **Marin County Flood Control and Water Conservation District** will likely be the primary group interested in fully understanding the risks associated with climate change.

8.4.2 Natural Heritage

Marin County has a rich natural heritage with regional and community parks, neighborhood parks, with 34 open space preserves that span 19,300 acres, 190 miles of unpaved public trails, 21,000 acres of protected watershed on Mt. Tamalpais and in west Marin owned by the Marin Municipal Water District, and federal and state parklands and preserves(Marin County 2008a). These lands provide vital ecosystem services that clean the air and water; contribute to the quality of life of residents, employees, and visitors; and provide critical habitat for native plants and animals (Marin County 2008b). Currently the County is home to a variety of forests that include oaks, Douglas fir, the iconic redwoods, and a diverse mix of hardwoods typical of the Coast Range mountains (North Bay Climate Adaptation Initiative 2013b). Although riparian areas, including streams, creeks, and rivers, account for a small portion of the land area in the county, these areas provide critical services for plant and animal species (North Bay Climate Adaptation Initiative 2013c).

Slight shifts in the growing season, ambient air temperature, and water temperatures can have dramatic impacts on natural resources. For example, one of the most significant shifts projected for the area is that much of the woody forest vegetation that is characteristic of the county may be replaced by chaparral shrub cover that is more characteristic of coastal climates further south, such as Santa Barbara (North Bay Climate Adaptation Initiative 2013b). Shifts in conditions may provide environments that are more favorable for heat-tolerant invasive species. Inundation from flooding and sea level rise may destroy or damage habitats, marshes, beaches, and recreational areas. Droughts may limit the water available in lakes or streams that can be used by aquatic species and may cause a shift towards more drought tolerant tree and plant species. Wildfires may destroy critical habitats for species and damage recreational facilities.

The first step in many of the adaptation actions, identified in Appendix A, is to begin (or continue) species monitoring to understand precisely how the changes are impacting the natural heritage. As concerns about wildfires increase in the area, it will be important for the departments responsible for preserving open space work in coordination with the fire department.

The preliminary draft of the *Vegetation and Biodiversity Management Plan* (released October 29, 2013) responded to guidance from the 2007 *Marin Countywide Plan*, which promoted the keeping the community safe from climate change (Marin County Parks and Marin County Open Space District 2013; Marin County Community Development Agency 2007). This current draft includes a section on management for climate change within chapter 3. The section on management of vegetation responses to climate change includes a plan to expand monitoring and adaptive management practices to respond to climate change and sea level rise (Marin County 2008b). The Marin County Watershed Program has identified tools such as Our Coast Our Futures' sea level rise visualization tool, which helps planners understand how changes will impact tidal marsh habitat and bird species over the next 100 years (Point Blue Conservation Science 2013).

Marin County Parks and Open Space District, Marin Municipal Water District, and **Marin County Watershed Program** will likely be the primary groups responsible for implementing the appropriate adaptation options, based on the vulnerability assessment presented in the 2013 *Vegetation and Biodiversity Management Plan* (Marin County Parks and Marin County Open Space District 2013). Countywide plans may also include coordination with the **Community Development Agency**, **Marin County Fire Department, Marin Audubon Society, Marin County Flood Control and Water Conservation District,** and other groups including National and State Park agencies that are active in preserving the county's natural heritage**.**

8.4.3 Transportation

The Marin County transportation network consists primarily of roads and bicycle and pedestrian facilities. Highway 101 is the main thoroughfare that runs North-South through the eastern portion of the County. Highway 1 is a scenic road that follows the Pacific Coast. In 2003 the Sonoma-Marin Area Rail Transit (SMART) district was established and will provide 70 miles of passenger rail service that will run from Cloverdale in Sonoma County to Larkspur Landing in Marin County. Phase 1 is scheduled to begin service in late 2016 (Sonoma Marin Area Rail Transit 2014). In addition to terrestrial transportation services, there are three ferry services that transport pedestrians (and cyclists) by boat. The Blue and Gold Fleet provide service between Tiburon, Sausalito, Angel Island, and San Francisco. Golden Gate Transit transports people between Larkspur, Sausalito, and San Francisco. The Angel Island Ferry operates between Tiburon and the state park on Angel Island (Marin County 2014).

The transportation network in Marin County could be affected by several climate impacts. Transportation infrastructure, such as roads, bridges, and rail, require significant capital investments and generally has long life expectancies; it is likely that these systems will be impacted by climate hazards. Extreme heat events, wildfires, flooding, and sea level rise may cause direct damage or destruction to the transportation network or temporarily disrupt services. Such extreme events may also introduce personal risk to workers or increase the need for maintenance and repairs. Changes in the cost of fuel may increase the demand for public transportation or alternative transportation options, such as walking and biking. Certain sections of Highway 101 are extremely vulnerable to sea level rise, and many communities have only one entrance/exit in case of emergency.

Transportation Authority of Marin (TAM) and **Transportation Planning (a division of Public Works)** will likely be the primary groups in the county that are most interested in understanding the specific vulnerabilities for transportation assets in the county. Countywide plans may also include coordination with the **Community Development Agency**, **Bicycle Advisory Group, SMART, Marin County Flood Control and Water Conservation District,** and **the ferry service providers.** Beyond the County, regional agencies, including the **Association of Bay Area Governments (ABAG)** and **Metropolitan Transportation Commission (MTC)** will likely be involved in the vulnerability assessment and resulting adaptation recommendations to understand how risks in Marin County's network will impact surrounding municipalities.

8.4.4 Agriculture

Livestock and dairy are the primary agricultural products in Marin County. The vast majority of the 167,000 acres of land that are zoned "Agricultural" (about 50% of the land area in the county) are used for seasonal grazing of dairy, cattle, and sheep (University of California Cooperative Extension,

no date). There are 255 agricultural operations in the county, of which 191 are considered small or mini-farms (University of California Cooperative Extension, no date). Over 75% of the agricultural gross value comes from livestock-related production. The remaining production comes from approximately 12% in field crops, 5% in fruit and vegetable crops, 6% in aquaculture, and the remaining 1% in nursery crops (Marin County 2013).

Since the majority of agricultural activity in the county is related to livestock production, it will be particularly important to understand how climate hazards may impact the health and safety of cattle and sheep. Extreme heat may cause animals to experience heat exhaustion, stress, or death; increase their vulnerability to disease; reduce fertility; and limit milk production. Impacts on grazing crops could require ranchers to provide animals with more imported feed. To combat the impacts of extreme heat, individual farmers and ranchers may benefit from increasing ventilation in barns, expanding animal access to water, and providing additional areas that can provide shade and cooling. As temperatures and precipitation patterns change, new disease vectors may be introduced that further threaten the health of livestock. Monitoring and developing plans for addressing outbreaks could help halt the spread of any such diseases.

Flooding, sea level rise, and wildfires may cause direct impacts on cattle, agricultural lands, equipment, and water quality. While it may be possible to move cattle and equipment in the event of temporary inundation or a wildfire, these hazards could also result in permanent damage or destruction that could result in more permanent disruptions in the industry. Physical barriers and flood mitigation strategies can be used to minimize the impacts of extreme events. A plan to prevent and contain wildfires could help avoid the potential impacts of wildfires on agriculture.

Agricultural uses require large amounts of water that could be limited during a drought. During periods of limited resources, the cost of water may increase. A lack of access to water can result in dehydration for animals and reduced yields or plant death for crops.

To understand the specific vulnerabilities associated with climate impacts in Marin County, a comprehensive vulnerability assessment is necessary. The **County Department of Agriculture** and **independent farmers and ranchers** could take a lead on conducting a vulnerability assessment and identifying the appropriate adaptation options that are appropriate for the region. Collaboration with the **Marin Municipal Water District**, **Marin County Fire,** the **Community Development Agency,** and **Marin County Flood Control and Water Conservation District** could help to develop plans that are integrated into the countywide plans.

8.4.5 Energy

While wildfires, sea level rise, and flooding in Marin County have the potential to disrupt energy distribution, significant changes in temperature and extreme heat events across the region could result in larger systematic problems such as brownouts. A significant increase in energy demand could decrease efficiency, increase overall costs, and disrupt service. Backup power generation, redundancy, and distributed energy production (i.e., solar panel installation) could help minimize peak loads.

PG&E and **Marin Clean Energy (MCE)** along with **independent energy consumers** may be the primary groups interested in understanding the local vulnerabilities and potential options for implementing adaptation actions. Countywide plans may also include coordination with the **Community Development Agency** and the **Marin Builders Association** who may play a significant role in influencing local energy efficiency standards and design requirements**. PG&E, MCE and the Marin Energy Watch Partnership** currently provide assistance and incentive funding to help residents and businesses reduce energy needs.

8.4.6 Human Health

Overall, County residents have generally good health (Marin County Health & Human Services 2014). The population in the county is aging, with approximately 18% being 65 years of age or older, compared to about 12% for the rest of California (U.S. Census Bureau 2014). More than 23% of the population over 5 years old speaks a language other than English at home, and the median household income exceeds that of the state (U.S. Census Bureau 2014). During the 2008–2012 reporting period, about 7.5% of the population lived below the poverty level, compared to a 15.3% statewide average (U.S. Census Bureau 2014). The human health risks associated with climate change in the county are consistent with those in other areas of the country.

Although the residents of Marin County experience generally good health, extreme heat events could put additional stress on the healthcare network. Wildfires, flooding, sea level rise, and the availability of water may cause increases in physical injury and mental health stress. Local changes in the temperature and precipitation patterns are unlikely to have a major impact on the availability of food for the general public, since most food is imported from areas beyond the County. However, a statewide shift in the growing season could impact the cost and availability of some food in the county. Adaptation efforts may focus on ensuring that adequate services would be delivered if an extreme event were to occur in the county.

Currently Marin Grassroots is working with vulnerable communities to understand their primary concerns with regards to sea level rise. Across California, health advocates and the CalBRACE program[35] are quantifying the climate benefits of various health strategies by forecasting exposures and population vulnerabilities at a local/regional level, conducting a health risk assessment, assessing interventions, and developing an implementation plan. These efforts will contribute to making the public health system more prepared for the impacts of climate change.

Marin Health and Human Services, local hospitals (including Marin General and Kaiser Permanente), and **health centers** could be the primary groups that may lead the implementation of the CalBRACE model in the county. Countywide plans may also include coordination with the **Community Development Agency**, **senior living facilities, community service centers,** and the **California Department of Public Health.**

[35] CalBRACE (Building Resilience Against Climate Effects) is a program of the California Department of Public Health with funding from the Centers for Disease Control (CDC). The program provides resources and technical assistance for the state and local public health departments to build climate adaptation capacity and enhance resilience at the local and regional levels.