Appendix C

Climate Change Projections, Impacts, and Adaptation

APPENDIX C
CLIMATE CHANGE PROJECTIONS, IMPACTS, AND ADAPTATION

C.1 INTRODUCTION

This report describes how climate may change in the San Diego region in the future due to the effects of global warming, and how those changes could affect each of the resource areas discussed in the Environmental Impact Report (EIR). The discussions of potential impacts of climate change on each resource topic in this report inform the resource area sections throughout Chapter 4, *Environmental Impact Analysis Approach,* of the EIR. The EIR sections evaluate whether *San Diego Forward: The 2021 Regional Plan* (the proposed Plan) would magnify a climate change impact (e.g., creating more housing development in high wildfire risk zones).

There is a higher degree of certainty for some future climate projections than others. Consequently, the specific impacts stemming from these projections can often be difficult to quantify. Thus, for several resource areas, there may be a range of generalized, qualitative climate-related impacts. For other resource areas more quantitative impact projections may exist. As a result, the degree of certainty around climate impacts will vary; the impacts described present the potential effects that climate change may have on the San Diego region.

C.2 CLIMATE CHANGE PROJECTIONS AND GENERAL IMPACTS ON THE REGION

Projected Changes in Climate for the San Diego Region

The findings below summarize the projected impacts of climate change in the San Diego region, as described in the 2018 *California's Fourth Climate Change Assessment: San Diego Region Report* (Kalansky et al. 2018) and original sources referenced in San Diego Association of Government's (SANDAG's) *Climate Change White Paper* (2018). Several of the climate projections discussed below reference Representative Concentration Pathways (RCPs), which are four different potential trajectories of greenhouse gas (GHG) concentrations between 2000 and 2100. RCPs were adopted by the International Panel on Climate Change (IPCC) in 2014 and are widely used to represent future concentrations of GHG emissions. RCPs 4.5 and 8.5 are the two RCPs referenced below. RCP 4.5 is often described as an intermediate pathway and RCP 8.5 as a high, but potentially realistic, pathway.[1] More information on RCPs can be found in van Vuuren et al. (2011).

Temperature

Annual average temperature for the San Diego region is projected to increase 4.8°F by 2050 under RCP 8.5 (CEP and SDF 2015); by 2100, projected temperature increases range from 4–6°F under the RCP 4.5 scenario or 7–9°F under the RCP 8.5 scenario (Kalansky et al. 2018). Coastal areas, due to the ventilation system provided by marine layer clouds, may be 0.9°F cooler than inland areas by 2050 (Kalansky et al. 2018).

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[1] The 2021 IPCC 6th Assessment Report was released August 9, 2021. In general, the report found that "Global surface temperature will continue to increase until at least the mid-century under all emissions scenarios considered…" and that "many changes in the climate system become larger in direct relation to increasing global warming." This EIA analysis does not incorporate the latest climate projections of climate change provided by the AR6 report.

Heat wave frequency, intensity, and duration are projected to increase, with the length of the heat wave increasing by 20–50 percent under a 6˚F annual average temperature increase (Kalansky et al. 2018). The region is projected to experience up to 15 extreme heat days by 2050; San Diego currently experiences an average of 2 extreme heat days per year, so this is a more than seven-fold increase (CEP and SDF 2015). By 2100 under RCP 8.5, the temperature of the hottest day of the year may also rise—by about 10°F for the coasts and about 7°F for the deserts (Kalansky et al. 2018).

Precipitation

In general, precipitation will remain highly variable but will contain more contrast, with wetter winters, drier springs and autumns, more intense precipitation events, and more frequent and severe droughts (Kalansky et al. 2018). The San Diego region is projected to experience 16 percent fewer rainy days and 8 percent more rainfall during the biggest rainstorms by 2050 (CEP and SDF 2015).

By 2100, the average wettest day every 5 years is projected to increase in rainfall by 10–25 percent under RCP 4.5 and by 15–30 percent under RCP 8.5. Stronger seasonal dryness may occur in the region due to longer dry warm seasons and increased evapotranspiration (Kalansky et al. 2018). Furthermore, a 12 percent decrease in runoff and streamflow is projected under RCP 8.5 due to less snowpack and greater evaporation (CEP and SDF 2015).

Sea-Level Rise

Sea levels in the San Diego region have already risen about 0.6 feet over the last century and are expected to rise even faster in the future (Kalansky et al. 2018). Both the Ocean Protection Council (OPC 2018) and Kalansky et al. (2018) provide sea-level rise projections for the San Diego region; see Table C-1.

Table C-1
Sea-Level Rise Projections

	OPC Sea-Level Rise Guidance (OPC 2018[1])	*San Diego Region Report* (Kalansky et al. 2018[2])
2030	0.4 to 0.6 feet (4.8 to 7.2 inches)	0.3 feet (3.6 inches)
2050	0.7 to 1.2 feet (8.4 to 14.4 inches)	0.7 to 0.8 feet (8.4 to 9.6 inches)
2100	1.1 to 3.6 feet (13.2 to 43.2 inches)	2.5 to 4.6 feet (30 to 55.2 inches)

[1] There is a 66% probability that sea-level rise will occur between these two values. Numbers for 2030 and 2050 consider RCP 8.5 projections, while numbers for 2100 consider both RCP 2.6 and RCP 8.5 projections. Projections are with respect to a baseline of the average relative sea level over 1991–2009.
[2] Lower limits are RCP 4.5 projections and upper limits are RCP 8.5 projections; numbers are in the 50th percentile likelihood. Projections are with respect to a baseline of the year 2000.

This rise is projected to occur more rapidly and be more uncertain in the second half of the century, and high tides, wind-driven waves, and storms may contribute to more extreme events along coastlines (Kalansky et al. 2018).

Wildfire

The San Diego region can expect a longer and less predictable fire season (CEP and SDF 2015). Santa Ana wind events, which are also projected to increase in frequency and intensity, may drive more frequent large, catastrophic wildfires due to drier autumns that occur before the peak of the Santa Ana wind season in December and January, and other factors, such as development and presence of dead fuels (Kalansky et al. 2018).

C.3 CLIMATE CHANGE IMPACTS ON RESOURCE TOPICS

Table C-2 summarizes the impacts of climate change on the resource topics discussed in this report. The sections that follow the table analyze each of the resource areas in more detail.

Table C-2
Summary of Potential Climate Change Impacts on Resource Topics

Resource Topic	Temperature	Precipitation	Sea-Level Rise	Wildfire
Aesthetics and Visual Resources	Damage to trees/ vegetation	Damage to trees/ vegetation	Coastline views altered	Damage to trees/ vegetation
Agricultural and Forestry Resources	Heat stress on crops and livestock	Insufficient water for crops	N/A	Damaged land from burning
Air Quality	Increased ozone formation; worsened indoor air quality	Increased dust; decreased rain to clear air	N/A	Increased particulate matter, leading to reduced air quality
Biological Resources	Species shifts from temperature changes; heat stress	Damage to riparian habitats; insufficient water for species from drought	Damage to coastal habitats and species from erosion and saltwater intrusion	Damage to habitats, species, and migratory pathways; vegetation shifts
Cultural Resources	Deterioration of cultural resources from heat stress	Erosion and damage to cultural sites and resources	Damage to coastal cultural sites	Damage to cultural sites or resources
Energy	Increased energy demand; decreased equipment efficiency	Reduced hydropower generation	Damage to coastal power plants and infrastructure	Damage to electrical infrastructure
Geology, Soils, and Paleontology	N/A	Increased occurrence of landslides; increased subsidence; damage to soil	Cliff erosion	Increased occurrence of landslides; damage to soil
Greenhouse Gas Emissions	Increase in GHG emissions due to increased cooling	Increased GHG emissions due to increased need for conveyance or	N/A	Increased GHG emissions from forests burned by increased wildfires

Resource Topic	Temperature	Precipitation	Sea-Level Rise	Wildfire
	and energy demand	treatment of water sources		
Hazards and Hazardous Materials	Increased human health hazard	Increased human health hazard; increased nonpoint source pollution causing health hazards	Potential disruptions to emergency response	Potential human health hazard
Hydrology and Water Quality	Altered rates of stratification; changes to lake nutrients, dissolved oxygen, and bacteria content	Heavier storms and more drought; decreased streamflow; increased risk of flooding; worsened water quality from flooding	Worsened groundwater quality from saltwater intrusion; increased risk of coastal flooding and tsunamis	Increased sediments in water from wildfire
Land Use	N/A	Reduced inhabitable land from inland flooding	Reduced inhabitable land from cliff erosion and coastal flooding	Reduced inhabitable land from wildfire
Mineral Resources	Damage to equipment, reduced work safety and efficiency	Damage to mining sites	Damage to coastal mining sites	Damage to mining sites
Noise and Vibration	N/A	N/A	N/A	N/A
Population and Housing	Urban heat island effect	Damage to/ destruction of homes from flooding; potential housing shifts	Damage to/ destruction of homes along coast	Damage to/ destruction of homes; potential housing shifts
Public Services and Utilities	Increased needs for emergency management, cooling facilities, and water treatment; worsened solid waste management efficiency	Increased emergency management needs; damage to facilities; increased water treatment required	Damage to coastal facilities; increased water treatment required	Increased emergency management needs; damage to facilities; increased water treatment required

Resource Topic	Temperature	Precipitation	Sea-Level Rise	Wildfire
Transportation	Damage to infrastructure; reduced safety and efficiency in maintenance	Damage to infrastructure	Damage to coastal infrastructure	Damage to infrastructure
Tribal Cultural Resources	Loss of material and ecological culture	Loss of material and ecological culture; loss of access to cultural sites; reduced water availability	Loss of material and ecological culture	Loss of material and ecological culture; damage to forest resources
Water Supply	Increased water demand and reduced imported water supply due to snowpack loss	Changes in water timing and availability; increased water demand and reduced imported water supply due to snowpack loss	Saltwater intrusion into coastal groundwater sources	N/A
Wildfire	Increased wildfire risk due to higher temperatures	Increased wildfire risk due to higher incidence of drought	N/A	Increased wildfire

Aesthetics and Visual Resources

There are limited studies on the effects of climate change on aesthetics, so it is difficult to draw firm conclusions about how climate change will affect aesthetics and visual resources in the San Diego region. This section qualitatively discusses selected potential aesthetic and visual impacts.

Sea-level rise could affect coastline appearance. Sea levels in the San Diego region are likely to rise 8.4 to 14.4 inches by 2050 (see Section F.2), potentially altering coastline views through enhanced coastal erosion and coastal flooding. However, it is not possible to draw specific conclusions on this effect or determine whether this aesthetic impact would be positive or negative. In addition, many local communities in California, including several in the San Diego region, are exploring options for protecting coastlines in response to sea-level rise. In general, adaptation options range from beach nourishment, to establishing natural barriers, to building seawalls or other barriers, to managed retreat from the coastline. Each of these options involves significant investment, negotiation, or consideration of impacts on residents. Seawalls and other engineered adaptation measures could alter coastline views.

Climate change could damage scenic natural resources such as trees and vegetation, including those within state scenic highways. The SANDAG region's natural scenic resources attract tourism and contribute to the health and well-being of residents and visitors. Potential impacts on natural resources are described in the sections that follow in greater detail.

Agricultural and Forestry Resources

Climate change may limit the availability and viability of agricultural land, due to higher temperatures, reduced availability of water for irrigation, changed pest and disease regimes, and destructive events like wildfire. Forests could also be negatively affected by high temperatures and wildfire, especially when these effects are combined with land use changes and poor management. In addition to potentially reducing agricultural and forest viability and production rates, climate change impacts on plant growth and soil microbial communities may also negatively impact soil carbon storage rates and levels (Bradford et al. 2016, Ren et al. 2020).

Higher temperatures may worsen crop yield and quality, decrease the number of pollinators available, decrease the number of "chill hours" needed for some crops to grow, increase evapotranspiration, and increase the spread of crop pests and diseases (Gonzalez et al. 2018). Higher temperatures can also cause heat stress on livestock, spread livestock diseases, or require higher costs in cooling livestock facilities; all of these may reduce livestock and dairy production (Bright et al. 2018). As noted in Section F.2, temperatures are projected to increase in the San Diego region in the future.

Water supplies and irrigation may be constrained in the San Diego region by 2050 due to fewer rainy days and a decrease in runoff and streamflow, as well as longer and more intense droughts (see Section F.2). Snowpack in the Sierra Nevada Mountains is also projected to melt earlier; projections for 2070–2099 indicate 35–52 percent of snowpack remaining by April 1, compared to the 100 percent remaining post-April 1 snowpack from 1961–1990. This projected difference in seasonal water availability can affect crop yield and quality, especially for crops that are more sensitive to the timing of rainfall and irrigation (Gonzalez et al. 2018).

Using the Cal-Adapt wildfire tool (Cal-Adapt 2021), the County of San Diego estimates a 40 percent increase in annual average acres of burned land by 2100 compared to the annual average between 1950 and 2005 under a high-emissions scenario (County of San Diego 2018). Rainstorms are projected to be heavier by 2050 (see Section F.2), which may result in more soil erosion. Furthermore, the increase in atmospheric carbon dioxide from climate change could accelerate the spread of weeds (Reidmiller et al. 2018). Thus, climate change is expected to have a negative impact on agricultural resources in the San Diego region.

Impacts of climate change can also result in conversion, or loss, of forest land. Forest lands in the San Diego region face some of the same threats listed for agriculture, including higher temperatures, wildfire, pests, drought, and flooding (Bright et al. 2018). In California, land use and forest management practices have led to the growth of trees that are less resilient to drought and wildfire (Bright et al. 2018). Certain tree species in Southern California, such as conifer forests, are especially vulnerable—warmer and drier climates in the past have increased the burn area of these forests by 650 percent. Wildfires in the southwestern United States can also convert forest to woodland or grassland (Melillo et al. 2014) and may have a positive feedback cycle on climate change by reducing the amounts of sequestered carbon. Forests in the United States absorb and hold about 16 percent of the carbon dioxide emitted in the country per year; burning this wood releases this carbon back into the atmosphere (Melillo et al. 2014). Warm temperatures and drought can also increase the spread of insect attacks, such as bark beetles, which have already killed off 102 million trees in California since 2010 (Bright et al. 2018). However, the consequences of climate change on forestry resources in the San Diego region have not yet been quantified.

Air Quality

Climate change may worsen air quality in the San Diego region by influencing ozone, wildfire, and indoor air pollution. Quantitative estimates of the extent of this impact are not available for the region. However, nationwide, assuming no change in regulatory controls or population characteristics, estimates of additional premature deaths per year by 2050 from combined ozone and particulate matter due to climate change range from 1,000–4,300 (Melillo et al. 2014).

Ozone forms through a combination of heat, precursor chemicals, and methane emissions (Reidmiller et al. 2018). Therefore, higher temperatures can lead to more ozone formation and thus to poorer air quality. Studies regarding the overall air quality impact on the San Diego region are not available. In general, given anticipated temperatures rises in the region (see Section F.2), higher temperatures will increase ozone (Pfister et al. 2014).

Wildfires can emit particulate matter, carbon monoxide, nitrogen oxide, and other volatile organic compounds, further worsening air quality. The negative health impacts of wildfire smoke can spread across the San Diego region, exacerbating respiratory and asthma-related conditions (Reidmiller et al. 2018). A significant increase in the areas of wildfire is also projected for the San Diego region (see Section F.2). Furthermore, precipitation during dry seasons, which can help fight wildfires and may play a part in clearing away air pollution (Kim et al. 2007), is projected to decrease from climate change (see Section F.2).

Droughts, which are anticipated to be longer and more severe in the region (see Section F.2), may also cause health and air quality issues by stirring up more dust. In the southwestern United States, this can be dangerous due to the spores of the fungi *Coccidiodes*, which cause valley fever and reside in indoor and outdoor dust (Crimmins et al. 2016). However, the consequences of climate change on drought and resulting outdoor air quality in the San Diego region have not yet been quantified.

Climate change may also worsen the intensity of odors coming from landfills. After heavy rains, the Miramar Landfill in the City of San Diego has received complaints of odors from residents living nearby (Patton 2019). Studies on landfill odors have also shown that odor pollution is worse in high temperatures, high humidity, and low air pressure (Ying et al. 2012). Because temperatures and intense precipitation are expected to increase in the San Diego region, this may exacerbate air quality issues due to landfill odors in the future.

Biological Resources

Climate change may result in significant impacts on biological resources, including adverse effects on habitats and wetlands, species health and productivity, and migratory pathways and timing. For example, a study of San Luis Obispo County found that sea-level rise along the coast could lead to increased erosion of coastal bluffs and beaches, coastal flooding, permanent inundation of coastal wetlands, and saltwater intrusion into freshwater supplies, all of which affect ecosystem health (Moser and Ekstrom 2012). (See Section F.2 for details about how climate conditions in the San Diego region are expected to change.)

Habitat – Upland and Inland

The combination of human-driven land use change and changing climatic conditions could negatively affect available habitat areas, including San Diego's scrublands and forests. As the habitat areas change, the species that depend on them could be negatively affected (USFWS 2010).

Shrublands are the most extensive vegetation type in the San Diego region, including coastal sage scrub and chaparral (Jennings et al. 2018). Coastal sage scrub habitats in the San Diego region support many plants, insects, mammals, and birds, including the Coastal California gnatcatcher, which is considered "threatened" under the Endangered Species Act, and the Quino checkerspot butterfly, which is considered "endangered" (Messner et al. 2011). According to EcoAdapt (2017), sage scrub habitat in Southern California is moderately vulnerable to climate change due to its sensitivity to climate stressors, exposure to projected climate change impacts, and moderate adaptive capacity. The area of chaparral and coastal sage scrub could decrease by 38–44 percent by 2070 (PRBO Conservation Science 2011). Higher temperatures and shifting rainfall patterns could affect plant germination, recruitment, and habitat composition (EcoAdapt 2017). Although sage scrub is adapted to wildfire patterns, increasingly severe or frequent wildfires could prevent the habitat from recovering, and it could create conditions conducive for invasive species (EcoAdapt 2017). Changes in fire intensity and frequency could result in a transition from scrublands to nonnative grasslands, which would change the habitat quality for native species (PRBO Conservation Science 2011, Jennings et al. 2018). However, no detailed modeling has been conducted to quantify the impact of climate change on scrubland in the San Diego region.

Additionally, climate change projections for California indicate that forest habitats will be substantially affected by rising temperatures and extended periods of drought (Messner et al. 2011). In particular, warmer winter temperatures are conducive for the survival and reproduction of pests that can cause damage to trees (Messner et al. 2011). Again, modeling has not been conducted to quantify what this impact would be for the San Diego region.

The projected habitat losses in Southern California may be more extensive when considered in conjunction with land-use change and development. There is the potential for compounding negative impacts on habitats. By 2050, ten species across California could lose more than 40 percent of their habitat due to the cumulative impact of climate change and development, and the impacts along the coast of Southern California are projected to be even more severe (Riordan et al. 2014). For example, areas of central California are suitable Cor sage scrub migration due to climate change. However, habitat fragmentation due to land-use change and other factors may reduce the ability for these species to seek refuge (EcoAdapt 2017). Detailed studies on the San Diego region have not been completed, so conclusions cannot be made for that specific region.

Habitat – Riparian and Coastal

Sea-level rise, temperature, erosion, droughts, and precipitation-related flooding may all have far-reaching consequences for California's wetlands and riparian and coastal habitats (Griggs and Russell 2012). In riparian habitats, sea-level rise may increase saltwater intrusion into freshwater ecosystems, which may threaten species living in these environments (ICLEI 2012). Higher water temperatures in streams and estuaries, particularly in the San Diego region where water levels are relatively shallow, may cause thermal stress for species living there, making the habitat unsuitable (Jennings et al. 2018). Also, more frequent or intense drought conditions can change stream levels, particularly in areas with seasonal waterways like Southern California, which could damage riparian habitats (Hilberg et al. 2017, Jennings et al. 2018). The consequences of climate change on riparian habitats in the San Diego region have not been quantified, but given the impacts discussed in Section F.2, it is possible that they will be affected.

When sea level rises, intertidal coastal habitats are flooded more often. According to the *Sea Level Rise Adaptation Strategy for San Diego Bay*, habitat for endangered and threatened species is vulnerable to flooding due to sea-level rise and erosion, which would force species to shift habitats toward higher elevations or farther inland (ICLEI 2012). According to Messner et al. (2011), loss of rocky beach habitat is of particular concern in the San Diego region because the two main intertidal marine reserves, Cabrillo National Monument and Scripps Coastal Reserve, are bordered by steep cliffs and could lose much of their intertidal habitats by 2050. Thus, coastal habitats could be at risk due to sea-level rise. In San Diego County, 6.1 square kilometers of land with "Conserved" or "Highly Conserved" conservation management status are exposed to 2 feet of sea-level rise (Heady et al. 2018).

Sea-level rise is expected to increase coastal flooding and inundate existing wetland areas. According to Heberger et al. (2009), sea-level rise of 1.4 meters is estimated to flood about 150 square miles of land adjacent to current wetlands, possibly creating additional wetland areas or inundating existing areas. The San Diego region has 14 square miles of coastal wetlands (Heberger et al. 2009), and sea-level rise may force these existing coastal wetlands to move inland if there is available land and if no barriers impede movement. The region has 5.8 square miles of wetland migration area (or 3.4 percent of the total area in the state). In total, 64 percent of this area, or 3.7 square miles, is viable wetland habitat, and an additional 6 percent is viable with a loss of value (Heberger et al. 2009). Wetland migration into this area would increase competition for other land uses. Development in this buffer zone may impede inland migration and thereby contribute to the loss of valuable habitat. Conversely, some species may not be able to migrate quickly enough to keep pace with sea-level rise, and they may be damaged by permanent inundation. Increasingly, wetland areas in the San Diego region may become inundated, although the full significance of this impact is not well researched.

In the San Diego region, precipitation is highly variable year-to-year. More frequent or severe heavy precipitation events could have negative impacts on stream and riparian habitats due to increased streamflow. Additionally, many riparian systems in Southern California rely on seasonal flow for species breeding and rearing, which could be disrupted by changing precipitation conditions. Shifts in streamside ecosystems could have destabilizing effects on the banks and increase erosion problems. (Jennings et al. 2018.)

Species

The dynamics between climate conditions and ecosystem health are complex due to great interdependencies between different parts of the system. The full ramifications of climate change impacts on candidate, sensitive, or special-status species within the San Diego region are not known from the literature. However, some studies provide overarching projections of the impacts on plants and wildlife within the region that are useful for decision making. The San Diego region is a recognized biodiversity hotspot, with more taxa of plants and mammals than any other county in the country (Jennings et al. 2018). Climate change is projected to compound environmental stressors from human-caused disturbances, habitat fragmentation, and landscape changes (Jennings et al. 2018). Given the impacts described in Section F.2, changes such as warmer temperatures, more variable precipitation resulting in high intensity flooding, more frequent droughts, and destructive fires could all affect species success.

Although there is still uncertainty around how individual species will be affected by higher temperatures, studies suggest that species will shift their ranges northwards and to higher elevations (Jennings et al. 2018). If habitats within the region become unsuitable, species may die or relocate to new habitats. For example, projected changes in temperature would make the San Diego region surpass the threshold for the California owl (Jennings et al. 2018). Also in the region, animals and short-lived plants are expected to experience increased mortality and reduced reproductive success due to changes in temperature (Jennings et al. 2018). Examples of temperature-affected species include the endangered species: Laguna Mountains skipper and Hermes copper butterfly (Jennings et al. 2018). Extreme temperatures could also alter the timing of ecological phenomena, such as breeding, flowering, or the emergence of pests, and heat waves may increase mortality and decrease reproductive success (Jennings et al. 2018). The endangered Quino checkerspot butterfly (*Euphydryas editha quino*) may adapt to increased temperature and resulting impacts on larval mortality by shifting its elevational or latitudinal range; unfortunately, habitat degradation results in the inhabitability of these new ranges (Parmesan et al. 2014). The special-status species Otay tarplant (*Deinandra conjugens),* an annual herbaceous plant endemic to San Diego County, may be impacted by hotter and drier conditions that reduce germination rates or misalign plant phenology with pollinator phenology (USFWS 2009). Modeling has shown that increases in temperature combined with decreased precipitation significantly increases the probability for extinction of the endangered peninsular bighorn sheep (*Ovis canadensis nelson – population 2),* especially for those that inhabit lower elevations (University of California-Berkeley 2004). Thus, climate change may have a negative impact on biodiversity in the San Diego region.

While the exact nature of climate impacts on aquatic species within the San Diego region is not known at this time, warmer water temperatures and changes in the seasonal distribution of precipitation may affect them. Changes in seasonal streams and flow rates may disrupt riparian species (Jennings et al. 2018). Temperature and precipitation changes could affect aquatic species through degradation of aquatic ecosystems and the introduction of invasive species (California Natural Resources Agency 2009). Additionally, fish populations could be directly affected by changes in temperature and precipitation, affecting nutrient availability, shifting habitat, changing the food web, and reducing physical health (Moser and Ekstrom 2012). Projections indicate that the endangered fish species, the tidewater goby (*Eucyclogobius newberryi*), which inhabits the mouth of the San Luis Rey River, may be impacted by sea-level rise, as coastal lagoons become inundated and increase in salinity, interrupting the tidewater goby's reproduction process, which requires a specific salinity range (Cayan et al. 2006). Also, inundation of coastal wetlands may affect fish reproduction success and the food web indirectly (Moser and Ekstrom 2012). Because climate change may alter the hydrology of vernal pool habitat, the existence of special-status species such as the annual herb, spreading navarretia (*Navarretia fossalis),* is expected to be further threatened by drier conditions (USFS 2009). Bird species may also be impacted by altered hydrology, especially riparian-dependent species such as the endangered southwestern willow flycatcher (*Empidonax trailli extimus)* or the endangered least Bell's vireo (*Vireo belli pusillus*) (Gardali et al. 2012).

Droughts can also cause ecosystem damage, such as the oak tree die off during the drought of 2012–2016. Extreme drought events could change the habitat suitability to favor more deeply rooted and drought-tolerant species of plants, while also making plants more susceptible to pests and pathogens. In the San Diego region, animals that are dependent on arthropod populations may also be negatively affected by increases in droughts. (Jennings et al. 2018.)

Fire is a natural process that has shaped the region's plant communities and therefore its animal habitat (Jennings et al. 2018). However, more frequent or intense wildfires may shorten the interval between fires, preventing recovery of native vegetation (Jennings et al. 2018). Increased frequency of wildfire creates conditions for invasive species incursions and hybridization of some grass species, as is the case for the endangered species, San Bernardino blue grass (*Poa atropurpurea*); its largest known stands are found in the high fire-risk San Bernardino Mountains (USFS 2009).

Migratory Pathways

If habitats change and species face environmental stresses due to changing temperature and precipitation patterns, plant and animal species may migrate to new habitats. While animals can move rather quickly to new habitats, unless blocked by other factors, rapidly changing conditions may surpass the pace that vegetation can move. Some climates, such as alpine climates, could disappear entirely in the future, while desert climates could expand significantly (Moser et al. 2012). Some habitats may expand while others are lost (Moser et al. 2012). If there is no suitable habitat nearby, species will be unable to migrate. The extent to which habitat migration causes negative and/or positive impacts is unknown at this point, although studies tend to acknowledge risks to certain industries like agriculture or fishing.

Wildlife can move more quickly than vegetation when climate conditions change. However, animal species could face greater challenges due to climate change if they are unable to migrate to areas with suitable climatic conditions (Moser et al. 2012). Therefore, identifying and protecting migration corridors is important to allow species to move to suitable habitats (Moser et al. 2012). In addition to land migratory routes, the San Diego region is part of the Pacific Flyway, where many migratory birds stop to feed during their migrations. Changes in climate, such as rising temperatures and drought, are disrupting these migration patterns; species such as the house wren and the Cassin's kingbird are no longer migrating south in the numbers they did previously (Murphy 2018). According to the National Audubon Society, more than half of the bird species in North America could be at risk due to climate change, and more will be endangered due to habitat loss (Langham et al. 2015). Warmer temperatures may change the ranges and habitats of species that are important for feeding or nesting, which may endanger protected species that use these resources.

Cultural Resources

Sea-level rise presents a risk to cultural resources within the San Diego region, although the extent to which this will damage cultural resources is not known. According to a study by Lipps and Pedersen (2015), 4.6 feet of sea-level rise could affect 194 Native American cultural sites in Southern California. Additionally, historic districts could experience more frequent or severe flooding impacts due to sea-level rise. For example, the Cabrillo National Monument could be vulnerable to sea-level rise and increased storm frequency and intensity, although the extent of this risk is not fully understood (Smith 2018).

Changes in temperature and precipitation could also damage cultural resources, although the extent to which these could negatively affect archaeological and cultural resources in the San Diego region has not been quantified. Higher temperatures can cause faster rates of deterioration due to thermal stress and biological activity, more rapid decay of organic materials, heat stress on culturally significant vegetation, and loss of culturally significant habitat and species due to disease and temperature changes (Rockman et al. 2016). Heavy precipitation and flooding could damage cultural resources due to site erosion and destabilization, direct physical damage to the site, loss of artifacts due to flooding, and increased risk of post-flood subsidence (Rockman et al. 2016).

Cultural resources in the San Diego region may also be threatened due to more intense or frequent wildfires as observed from past events. In 2002, the Pines Fire covered nearly 100 square miles in San Diego County. In the process of recovery, archaeologists identified 249 cultural sites within or immediately adjacent to the fire, and another 50 within the area of bulldozer activity, including rock shelters, Native American settlements, and rock art (Waechter 2012). Wildfires can increase damage to archaeologically relevant structures, alter the artifacts exposed to extreme heat, increase susceptibility to erosion and flooding, and exacerbate damages due to firefighting activities (Rockman et al. 2016). Wildfire could also damage historical structures or alter their distinct physical characteristics as older buildings may not have as robust defenses against wildfire as modern buildings (Rockman et al. 2016).

It is possible that sea-level rise, flooding, wildfire, and landslides could reveal or damage human remains. Remains exposed to the environment from climate hazards may then be further damaged by extreme weather. For example, changes in temperature and precipitation could speed deterioration and decay, cause thermal stress, and cause erosion (Rockman et al. 2016).

Energy

Climate change could lead to an increase in energy usage in California. For example, *Our Changing Climate 2012: Vulnerability & Adaptation to the Increasing Risks of from Climate Change in California* (Moser et al. 2012) explains that increases in average temperature and extreme heat events will drive up the demand for summer cooling. This can occur both in buildings and in transportation (e.g., personal vehicles, buses, subways, etc.). This will be exacerbated by new residential development and expanded use of air conditioning, should the net result of the growth of energy demand from new housing stock outpace energy efficiency gains in the existing housing stock. Growing demand will probably not be offset by the decreased heating needs in winter, particularly because California's residential sector uses relatively little electricity for heating (Moser et al. 2012). Climate impacts on other sectors may also increase energy demand. For example, drought conditions may cause more pumping, conveyance, or treatment of water, all of which require energy.

There have been some studies that have attempted to quantify the net effect on energy demand. However, some of these are increasingly dated, and none are focused specifically on the San Diego region. As a result, it is difficult to draw conclusions about how much energy usage in the San Diego region will increase due to climate change. However, these studies do provide some context to the potential extent of energy increases. These studies include the following:

- Auffhammer and Aroonruengsawat (2012) modeled energy demand increases of 18–55 percent by 2100 in California due to climate change, holding population constant. When considering a population increase of 0.18 percent per year, energy demand would increase by 65–70 percent during that timeframe. It is expected that demand for electricity will increase as households operate air conditioners more often and install air conditioners where few are used. However, their study did not account for energy efficiency improvements of buildings, equipment, or the electricity system.
- Guegan et al. (2012), citing Franco and Sanstad (2006), found that, relative to the base period 1961–1990, electricity demand in California would increase by 3.1–20.3 percent, and peak load would increase by 4.1–19.3 percent by 2100.
- The U.S. Environmental Protection Agency (EPA) report *Climate Change and Space Heating Energy Demand: A Review of the Literature* found that in warm weather (above 68°F/20°C), one degree of additional warming increases electricity use by 0–8 percent, although that estimate is nationwide rather than specific to the San Diego region (Ranson et al. 2014). By 2050, temperature in the San Diego region is expected to increase by 4.8°F under RCP 8.5 relative to 1985 (CEP and SDF 2015).

Climate change would cause impacts outside of increased demand for energy. For example, variation in rainfall may alter hydropower generation, storage potential, and generation capacity substantially. In particular, a summer water shortage is of concern because it reduces hydropower capacity when summer energy demand is the highest (Guegan et al. 2012). If hydropower is reduced, it is not clear what energy source would replace it, although the state's renewable energy requirements may help limit the extent that hydropower is replaced by fossil fuels. Moreover, the actual amount of reduction in hydropower due to climate change has not been quantified.

Finally, climate change could contribute to the need for new or expanded energy facilities, although there is insufficient research to draw definitive conclusions about the extent to which climate change would do so. Climate change could contribute to this impact via the following ways:

- The projected increase in demand due to climate change (discussed above) could necessitate the building or expansion of additional generation facilities.
- Additional transmission capacity might be needed, not only due to additional load needing to be transmitted, but also because higher temperatures reduce the carrying capacity of the transmission lines—which in turn may lead to greater generation needs. According to Bartos et al. (2016), by mid-century (2040–2060) in the United States, increases in air temperature may reduce transmission capacity in the

summer by 1.9–5.8 percent relative to the 1990–2010 base period. Simultaneously, peak summer loads may rise by 4.2–15.0 percent on average due to higher temperatures (Bartos et al. 2016). Sathaye et al. (2012) suggests a similar effect, estimating that climate change in California may reduce transmission capacity by 7–8 percent by the end of the twenty-first century.

- Higher temperatures can decrease generation capacity of natural gas-fired power plants, while increasing energy demand. Under a high emission scenario, generation capacity may decrease by 3–6 percent in California and reduce transformer and substation capability by 2–4 percent (Sathaye et al. 2012). A decrease in generation capacity may necessitate the expansion/building of additional facilities.
- According to the County of San Diego's Climate Action Plan (2018), wildfire can damage electrical infrastructure, including severing transmission lines when fire comes in direct contact with the lines and affecting transmission capacity due to heat and smoke. Key transmission corridors are vulnerable to more frequent wildfires. One study sited in *Our Changing Climate 2012: Vulnerability & Adaptation to the Increasing Risks of from Climate Change in California* found that some major transmission lines would face a 40 percent increase in the probability of wildfire exposure (Moser et al. 2012).
- Sea-level rise and increased storm frequency and/or intensity could affect coastal power plants, leading to flooding of some facilities. Additionally, offshore water intake pipes may be damaged by storm surge and debris (Perez 2009).
- According to Heberger et al. (2009), an estimated 1.4 meters of sea-level rise would accelerate erosion and result in a loss of 41 square miles of California's coast by 2100. Given a 1.4-meter sea-level rise scenario, a 100-year flood event could cause flooding at 30 California coastal power plants, with a combined capacity of more than 10,000 megawatts, and at least one natural gas storage facility by the end of the century; however, only one of these facilities is in the San Diego region.

Geology, Soils, and Paleontological Resources

Changes in precipitation patterns, as well as sea-level rise, could have geologic impacts on the San Diego region by inducing more landslides, land subsidence, and coastal erosion. Soil may also face erosion as well as nutrient loss, and destructive impacts like wildfire and flooding have the potential to damage both soils and paleontological resources.

Climate change could increase the occurrence of landslides in Southern California by worsening the weather conditions that lead to their occurrence. Periods of dryness followed by extreme precipitation events can cause conditions suitable Cor landslides. Also, wildfires in summer can burn away trees or vegetation that hold soil in place on slopes, and heavy rainfall in the winter may create a debris flow that then results in a landslide (Highland 2005). Both wildfires and storm intensity are projected to increase in the San Diego region by 2050 (see Section F.2), creating conditions that could bring more landslides to the area.

Climate change may also influence the geology of the land by worsening land subsidence, which occurs with excessive extraction of groundwater. Increased stress on groundwater supplies could result from longer and more intense droughts, increased evaporation, higher temperatures, and decreased precipitation and streamflow, all of which are expected to occur in the region (see Section F.2). In 2017, the San Diego County Water Authority sourced 3 percent of its supplies from groundwater. However, it intends to double this number by 2035 in an attempt to diversify its supply portfolio (SDCWA 2016).

Wildfires and heavy storms can damage soil structure, decrease moisture retention, and increase soil erosion. These changes can especially harm topsoil, which is important to the health of crops and vegetation (County of

San Diego 2018), and also remove soil that otherwise acts as carbon storage. Other effects of climate change, such as the warming of soils, may lead to higher decomposition rates, which release more carbon dioxide into the atmosphere (Melillo et al. 2014). However, the consequences of climate change on soils in the San Diego region have not yet been quantified.

Along the coast, sea-level rise in the region is expected to result in cliff erosion, further altering the geology. A projected increase in sea level of 1.6 to 6.6 feet along the Southern California coast could result in cliff retreats ranging from 62 to 135 feet by 2100 (Limber et al. 2018); those sea-level rise projections for all of Southern California are slightly higher than projections for just the San Diego region (see Section F.2). Coastal bluff erosion rates vary depending on sea-level rise, wave energy, coastal slope, beach width and height, and rock strength. Marine erosion can be concentrated at points due to wave refraction, and occurs more quickly in weaker rocks (Johnsson 2003). The timing of coastal bluff retreat or collapse is also dependent on specific geologic conditions: it may occur catastrophically through sudden slope failure or more gradually through erosion by marine, subaerial, and groundwater processes (Johnsson 2003). In 2018, U.S. Geological Survey (USGS) researchers combined five different computer models that forecast how cliffs retreat, producing a range of values for each section of coastline instead of each model yielding one number (Limber et al. 2018). A USGS research geologist noted that sea-level rise combined with coastal change, cliff retreat, and extreme storms could expose more than 250,000 residents and $50 billion in property to erosion or flooding in Southern California by the end of the century (USGS 2018).

One limit in the USGS study is that it does not factor in the linkage of long-term cliff retreat rates to annual landslide probabilities. Projected increases in extreme heat days, combined with decreased precipitation projected in the summer, can increase evaporation and the likelihood of drought and wildfires. Wildfires may precondition the landscape for cascading climate hazard events, with implications for both the proposed Plan and surrounding study area. For example, wildfires clear landscape and vegetation, which destabilizes the ground and can create hydrophobic soil (or water-repellant soil, due to the combustion of vegetative materials' resulting gas, which condenses and forms a waxy coating on the ground). In turn, hydrophobic soils increase the likelihood of a landslide during heavy precipitation events. Landslide sediments are often subjected to increased groundwater percolation, which tends to have a negative effect on the preservation of fossils, and gravitationally induced movements of sediment can also destroy fossil remains through abrasion and breakage. Further, when the original stratigraphic position of the sediments and fossils contained within are disturbed, there are varying degrees of scientific information loss with the severity of changes to the slide mass.

It is possible that sea-level rise, along with disaster events like flooding and wildfire, could damage paleontological resources. As with cultural resources, more intense and frequent wildfires and the fire recovery process could have negative impacts on resources within the San Diego region (Waechter 2012). Impacts similar to those discussed under *Cultural Resources* above could also adversely affect paleontological resources, although such impacts have not been discussed in the literature. For example, changes in temperature and precipitation could also damage paleontological resources by speeding deterioration and decay and causing thermal stress (Rockman et al. 2016). Additionally, heavy precipitation and flooding could cause erosion or direct damage to the resources. However, no studies investigate the extent to which paleontological resources could be affected by climate change.

Greenhouse Gas Emissions

Greenhouse gas emissions are responsible for climate change, but some impacts of climate change can also release more GHGs into the atmosphere, resulting in a positive feedback cycle. A biological example of this would be soil carbon sequestration; the combination of increased temperatures and decreased rainfall will likely result in decreased plant productivity and reproduction. As fewer or less robust plants pull less carbon dioxide out of the atmosphere, soil erosion and loss will increase and there will be less carbon from dead plants available to become incorporated into the soil, thus reducing soil carbon sequestration (Ren et al. 2020). An anthropogenic example is that hotter temperatures in the San Diego region may incentivize more people to use air conditioning more often; in the next decade, summer energy demand in California could increase by 1 gigawatt. This increase in energy use could release more GHGs if the energy is purchased from a carbon-based power plant (Moser et al. 2012). The projected growth in energy demand may be exacerbated by new residential development and expanded use of air conditioning and will likely not be offset by decreased heating needs in winter due to the relatively low use of electricity for heating in California (see *Energy* above for more details on how climate change may increase energy demand and associated GHGs).

Some adaptation measures to climate change can also have effects on energy use and, therefore, possible GHG emissions. The San Diego County Water Authority plans to increase its reliance on seawater desalination 2 percent by the year 2035 (SDCWA 2016). This water treatment process is highly energy-intensive, however; this could increase GHG emissions if the energy comes from a carbon-based source (Kelley 2011). For perspective, San Diego Gas & Electric, the largest utility in the San Diego region, draws at least 29 percent of its power from natural gas (CEC 2018), although this percentage may change in the future, as California has instituted a Renewable Portfolio Standard (RPS) of 50 percent by 2030 (CPUC 2018). Furthermore, the California Executive Order B-55-18, signed in 2018, mandates a goal for carbon neutrality by 2045. Thus, it is uncertain to what degree the region and state's mitigation practices will counteract the increase in GHG emissions from climate change.

Climate change may also increase the amount of GHG emissions associated with transportation. Impacts in the region—such as heavy rainfall, increased wildfire, and sea-level rise (see Section F.2)—can lead to landslides and flooding of road infrastructure. These may cause more traffic disruptions and congestion, which would increase commuting times and vehicle idling, and thus contribute more greenhouse gases (WSP 2018).

An increase in wildfire frequency and intensity brought about by climate change can also increase GHG emissions in the region. Fires that burn through forests remove trees that serve as carbon reservoirs. Forests in the United States absorb and hold about 11 percent of the carbon dioxide emitted in the country per year; burning this wood releases this carbon back into the atmosphere (Reidmiller et al. 2018). However, the consequences of climate change on the amount of GHG emissions from increased wildfires in the San Diego region have not yet been quantified.

Higher temperatures from climate change can harm some of the mitigation measures used to reduce GHG emissions. For example, attempts to use more solar energy to help reduce GHG emissions may be challenged by high temperatures, which can render solar panels less efficient (Omubo-Pepple et al. 2009). For perspective, San Diego Gas & Electric's power mix consists of 20 percent solar energy, though this may not be limited to photovoltaics (CEC 2018). However, the consequences of climate change on GHG mitigation techniques in the San Diego region have not yet been quantified.

Hazards and Hazardous Materials

Many of the impacts from climate change are hazardous to human lives and the infrastructure they depend upon. These impacts, which are projected to occur in the San Diego region, include higher temperatures, sea-level rise, and higher rates of coastal and inland flooding, tsunamis, and wildfire (see Section F.2). The region may also face various indirect impacts of climate change mentioned elsewhere in this report, such as worsened air quality, higher rates of temperature-related illnesses and diseases, landslides, and beach erosion. Climate change may also worsen hazards in the region associated with hazardous materials, sensitive infrastructure, dangers to public health, and obstructions of emergency response.

Flooding of hazardous material sites could introduce toxic substances to humans and the environment by contaminating drinking water supplies, buildings, and ecosystems. Such sites include Superfund sites, hazardous waste generators, facilities required to report emissions for the Toxics Release Inventory, facilities regulated under the National Pollutant Discharge Elimination System, major dischargers of air pollutants with Title V permits, and brownfield properties. Heberger et al. (2009) found no hazardous material sites in the San Diego region in areas vulnerable to a 100-year flood event. However, a 1.4-meter rise in sea level could bring 13 of those sites into areas vulnerable to a 100-year storm (Heberger et al. 2009). Note, however, that this 1.4-meter sea-level rise scenario is the upper limit of current estimates in the San Diego region (see Section F.2); it is not clear how many sites would be within the inundation zones under other scenarios. Thus, impacts of climate change would have an unknown impact on hazardous material sites in the San Diego region.

A combination of sea-level rise and storm flooding may obstruct emergency response vehicles and plans in the case of an emergency. In San Diego County, a 1.4-meter rise in sea level could make more vehicle infrastructure along the coast vulnerable to a 100-year storm. This sea-level rise would bring 8 miles of highways (compared to 0.62 mile in 2000), 57 miles of roads (compared to 12 miles in 2000), and 9.8 miles of railways (compared to 3 miles in 2000) into vulnerable areas (Heberger et al. 2009). Once again, this 1.4 meter of sea-level rise is in the upper limit of current estimates of sea-level rise in the San Diego region (see Section F.2), and it is uncertain if lower estimates will bring highways and roads into areas vulnerable to flooding from a 100-year storm. More frequent wildfires may also obstruct roads for emergency vehicles, though the probability and extent of this occurring is unknown.

Hydrology and Water Quality

Climate change could alter the hydrology in the San Diego region. CEP and SDF (2015) projects longer and more intense droughts, fewer rainy days, and more rainfall during the biggest rainstorms by 2050. These changes increase flooding to the region, which could lead to impacts on drainage, such as more soil erosion, mudflow, and landslides (County of San Diego 2018). Due to less snowpack and more evaporation, the San Diego region expects to see a decrease in runoff and streamflow (see Section F.2). Thus, climate change may have a negative impact on hydrology in the San Diego region.

Climate change can also worsen water quality in a variety of the region’s water resources through increased nonpoint water pollution during severe storm events, saltwater intrusion resulting from sea-level rise, sediments from increased incidence of wildfires, and higher temperatures. Heavier storms may decrease both beach and surface water quality because rainfall can cause runoff from nonpoint sources of contamination—such as trash, fertilizers, sediments, metals, sewage, and other fluids—which then drain into the ocean and streams. As a result, California health officials recommend that people stay out of beach waters for at least 3 days following rain events of at least 0.1 inch. In 2017–2018, beaches in San Diego County faced two closures and ten health warnings, and 24 sewage spills (totaling 187,001 gallons) reached a water body (Heal the Bay 2018). More intense rainstorms from climate change may worsen this hazardous runoff; the San Diego region may see 8 percent more precipitation during its heaviest storms (CEP and SDF 2015).

Along the coast, saltwater intrusion from sea-level rise can infiltrate groundwater, worsening the quality of this freshwater resource. Projected increases in wildfires across the region may also worsen water quality for surface waterways by increasing sediment flows (Meixner and Wohlgemuth 2004). Also, higher temperatures may alter rates of stratification in lakes, potentially removing dissolved oxygen and leading to excess nutrients in lakes (Melillo et al. 2014). These higher temperatures may also reduce general water quality by changing water chemistry and promoting growth of bacteria (Duran-Encalada et al. 2017), algae, and parasites (Major et al. 2011). However, the available literature has not quantified the extent to which this would affect water quality in the San Diego region.

Land Use

Climate change may pose threats to land use in the San Diego region by damaging or removing habitable land and physically dividing communities (e.g., through landslides), especially along the coast. The region expects to see increases in the intensity of wildfires and heavy storms that can lead to flooding, both of which may make some areas uninhabitable (CEP and SDF 2015). Indirect impacts, such as landslides and erosion, can also reduce available buildable land (County of San Diego 2018). Along the coast, sea-level rise in the region is expected to result in cliff erosion. A projected rise in sea level of 1.6 to 6.6 feet along the Southern California coast could result in cliff retreats ranging from 62 to 135 feet by 2100 (Limber et al. 2018). The upper range of these sea-level rise projections for all of Southern California are slightly higher than the upper range of projections for just the San Diego region (see Section F.2). However, studies have not quantified the extent to which climate change would affect land use in the region.

To respond to climate change, local governments in the San Diego region may build structures that increase the resilience of housing, infrastructure, and ecosystems. The County has already built some levees and structures to protect against flooding (County of San Diego 2018) and incorporated climate projections into projects, such as the North Coast Corridor Program, which considers sea-level rise adaptation in its analysis and design (SANDAG 2019). SANDAG has also produced a sea-level rise infrastructure guidance document titled *Regional Transportation Infrastructure Sea Level Rise Assessment and Adaptation Guidance for Transportation Infrastructure*, which analyzes potential sea-level rise impacts on transportation facilities (Dudek 2020). Other member cities may have resilience measures of their own. For example, the City of San Diego plans on having 35 percent canopy cover by 2035, which can reduce the urban heat island effect (City of San Diego 2018) and therefore provide greater thermal comfort under new climate conditions. However, it is unknown to what extent this would affect land use in the region.

Mineral Resources

Climate impacts such as wildfires and flooding may affect mineral resources by damaging mining sites (ICMM 2013). However, studies have not quantified the extent of these effects in the San Diego region.

Noise and Vibration

No studies were found that investigate the impacts of climate change on noise and vibration.

Population and Housing

Climate change-related disasters, such as flooding, wildfire, and sea-level rise, can destroy homes and threaten displacement. For example, a 2015 study looking at the effects of a potential El Niño storm found that 54,560 residents in the San Diego region (1.75 percent of the regionwide population), in 21,706 housing units, reside in areas that are susceptible to flooding during heavy storms and 100-year flood events. These areas include floodplains and places near coastal inlets and rivers and are mostly spread throughout the region (NUSIPR 2015).

Population and housing could be affected by increases in wildfire. In San Diego County, under a high-emissions scenario, the Cal-Adapt wildfire tool estimates a 40 percent increase in annual average acres of burned land by 2100 compared to the annual average between 1950 and 2005. In 2010, 91 percent of residents in the unincorporated county lived in wildfire areas marked Very High, High, or Moderate Risk; and increased wildfire incidence may worsen these risks (County of San Diego 2018). Thus, the effects of climate change may have a negative impact on housing in the San Diego region.

Compared to flooding and wildfire, the housing exposed to sea-level rise is lower—7,498 people live in areas at risk of inundation from a 4.6-foot rise in sea level (County of San Diego 2018). While this is a small percentage of the region's population overall, this impact could be significant for local communities on the coast. Current projections of sea-level rise for the region place the maximum at 4.6 feet by 2100 (see Section F.2). An assessment of costs from coastal flooding–related damage to private residential and commercial structures found that in Carlsbad, a 100-year storm could result in losses of $1.1 million by 2050, and chronic inundation could result in losses of $37.1 million by 2100. In Del Mar, damage to private residential and commercial structures from a 100-year storm can currently result in losses of $46.7 million (Nexus Planning & Research 2017).

High temperatures may make certain parts of the San Diego region more uncomfortable or more damaging to human health than others, possibly resulting in population or housing shifts. Because of the urban heat island effect, although the San Diego region may experience a 4.8°F increase in temperature from climate change by 2050 (see Section F.2), and dense urban areas may feel much hotter (Reidmiller et al. 2018). Threats from flooding, storms, and wildfire may also potentially lead to housing shifts. An analysis of nationwide differences in home price appreciation between 2007 and 2017 found that there was a slight correlation between homes exposed to high wildfire, flooding, and hurricane surge risk and a decrease in house prices. Homes in high-risk areas are worth less than they were a decade earlier, indicating that people are starting to consider climate change impacts when buying houses (Flavelle and McCartney 2018). However, it is uncertain if this pattern will affect population or housing shifts in the San Diego region in a similar way.

Public Services and Utilities

Public Services

Public services in San Diego include fire and police protection, emergency response services, schools, libraries, and recreation facilities. Climate change, particularly extreme events, could increase the demand on some public services, although the extent of this impact has not been quantified. For example, higher demand on public services can be expected to combat increased severity and frequency of wildfires, extreme heat events, flooding, or landslides; this increased demand could conceivably require expanded or additional public service facilities. Moreover, the existing facilities themselves may experience impacts; according to Kalansky et al. (2018), critical facilities at risk from both flood (0.5-foot exposure threshold) and wildfire (50 percent burned threshold) could increase by the end of the century, which could lead to losses of over $1.7 billion. Projected increased damage to public facilities may put more strain on facility maintenance services that must respond to requests for repairs on public property. These departments may have to conduct more upkeep on County-owned buildings due to a projected increase in damages from climate hazards.

As temperatures warm and landscapes experience longer dry seasons, wildfire risks are likely to increase (see Section F.2). With climate change, more resources will be needed for fire management (Kalansky et al. 2018). More frequent or severe wildfires may strain existing fire-fighting capacity, requiring the expansion of fire stations or the addition of new facilities and operations. As development continues, particularly dense development, fire risk increases (Kalansky et al. 2018). Compounding impacts of climate change and development may require additional facilities to be built, although this has not been discussed in the literature. However, Kalansky et al. (2018) acknowledges that more modeling work is required to understand the vulnerability of critical assets, including public services like hospitals and fire stations, to increased wildfire risk.

During extreme heat events, which are expected to become more severe (see Section F.2), additional cooling centers may be required to prevent heat-related illnesses or fatalities. In 2017, a heat wave in the San Diego region closed 85 schools to protect children from the extreme heat (Kalansky et al. 2018). This type of event could become more common, particularly threatening disadvantaged communities and vulnerable populations, including children, elderly, and homeless populations. Often, public facilities, such as libraries and community centers are used as cooling centers (Kalansky et al. 2018). Increases in extreme heat could require additional public facilities to be made available near disadvantaged and vulnerable populations for cooling centers.

Climate change is included in the region's hazard mitigation plans because of the expected increase in hazard events, including floods, landslides, extreme heat, and sea-level rise. Emergency response to severe events may require greater emergency management capacity from the region (Kalansky et al. 2018). Also, there may be a greater need for monitoring and assessments to provide hazard warning and preparation (Kalansky et al. 2018).

Additionally, climate change conditions, such as sea-level rise and flooding, could contribute to deterioration or damage of existing public facilities. Across the state, damages due to inundation from 50 centimeters of sea-level rise could reach $18 billion dollars, some of which could include damages to public facilities, although this impact has not been separately quantified (Kalansky et al. 2018). Assessments of damage to public infrastructure in some San Diego County cities have been conducted; for example, damage to city structures in the City of Del Mar may result in losses of $1.7 million under a current 100-year storm (Nexus Planning & Research 2017). The City of Del Mar also conducted a Coastal Hazards, Vulnerability and Risk Assessment, and found that the City's fire station is vulnerable to even relatively low levels of sea-level rise, which could inhibit fire response capacity in the future (Kalansky et al. 2018). If buildings become inundated or temporarily flooded, new construction may be required to repair, retrofit, or relocate facilities, although the extent of climate impacts on public facilities is not discussed in the literature.

Climate change impacts may also damage recreational facilities and parks through destructive hazards such as wildfire, flooding, and landslides. Coastal parks and facilities, such as the Waterfront Park in the City of San Diego, may be particularly vulnerable to inundation from sea-level rise and coastal flooding (County of San Diego Parks and Recreation 2019). Climate hazards that affect outdoor conditions, such as extreme heat, air quality from wildfires, and heavy precipitation, may also influence the number of people who visit parks and recreational centers. Indoor centers may see a rise in visitation as people prefer to exercise away from climate hazards, or both inside and outside centers may see a dip in visitation if extreme weather makes it difficult to go outside altogether.

Utilities

Utilities in the San Diego region, including wastewater collection and treatment, stormwater drainage, and solid waste management systems, may face risks and challenges from climate change. According to the *Sea Level Rise Adaptation Strategy for San Diego Bay*, stormwater management and wastewater collection and treatment are two vulnerable sectors to sea-level rise (ICLEI 2012). For example, impacts on wastewater collection and treatment include increased treatment costs or more extensive treatment processes caused by reduced water quality due to higher temperatures, more sedimentation and runoff due to extreme precipitation, increased contaminant levels due to droughts, and sedimentation due to wildfires. Stormwater drainage and facilities may be physically damaged, and existing capacity may be strained or exceeded due to changing precipitation or flooding patterns, although the impacts within the San Diego region have not been well documented. Lastly, climate change may make solid waste management collection and processing more challenging due to impeded access to collection routes, degradation of landfill sites, and other impacts. The consequences of climate change on public services and utilities in the San Diego region have not yet been quantified; however, the subsections below posit some potential impacts.

Wastewater Collection and Treatment

Although no research was found on the impacts of climate change on wastewater treatment within the San Diego region, it is possible that higher temperatures would increase treatment costs or require changes in operations. The costs could increase because higher air and water temperatures reduce water quality and quantity by changing water chemistry, promoting bacterial growth, and increasing evapotranspiration (Duran-Encalada et al. 2017). Warmer temperatures also increase the solubility of contaminants in the water supply and can lead to biological and chemical degradation by aiding the growth of more algae, microbes, and parasites (Major et al. 2011). These changes could make it costlier to treat wastewater.

Both extreme precipitation and drought can cause challenges for wastewater treatment facilities. Extreme precipitation may cause more intense or frequent floods, which may overwhelm the current wastewater intake systems (Major et al. 2011). Drought conditions could reduce the inflow of water, which increases the concentration of pollutants, including salinity, in the wastewater treatment stream (Tran et al. 2017). Increased pollutants can make it more expensive or demanding to treat water to the necessary level (Tran et al. 2017). Drought impacts on Southern California's wastewater treatment facilities have been documented in some studies, but the full extent in the San Diego region is not known at this time.

Sea-level rise can also cause several problems for wastewater treatment, including overwhelming capacity and making treatment more difficult. As with extreme precipitation, sea-level rise could increase the risk of flooding or of overloading the treatment system. According to the *Sea Level Rise Adaptation Strategy for San Diego Bay*, sanitary sewers in low-lying locations could be vulnerable to floodwater inflow that could exceed system capacity, potentially resulting in the discharge of wastewater into the Bay (ICLEI 2012). Also, the wastewater collection system surrounding the Bay could be vulnerable to permanent inundation (ICLEI 2012).

Water quality in the watershed may be reduced after more frequent or intense wildfires due to erosion and sedimentation (EPA 2015). Although the impacts in the San Diego region were not found in the reviewed literature, it is possible that degraded water quality from saltwater intrusion, greater contamination from pollutants, and sedimentation from wildfires may require more extensive water treatment processes to reach the required quality for discharge. If freshwater availability is reduced due to climate change, there may be a demand for more water recycling to meet irrigation and non-potable water needs. In this case, there could be increased pressure on wastewater treatment plants to process and recycle water for these purposes (Major et al. 2011), although demand could potentially be met by other means.

Flooding and erosion exacerbated by climate change may present other physical risks to facilities and equipment of the utility. Erosion could wash away soils that support or cover infrastructure (ICLEI 2012), although this risk has not been quantified in the San Diego region.

Stormwater Drainage Facilities

Changes in the timing and intensity of precipitation, as well as sea-level rise, could affect stormwater management in the San Diego region (County of San Diego 2018).

While total annual precipitation may not change in the San Diego region, the pattern of precipitation may. As noted in Section F.2, more intense precipitation events could occur, and the San Diego region's current stormwater system may not be equipped to handle the quantity of runoff from a particular event (County of San Diego 2018, Ascent Environmental Inc. 2017, Tuler 2016). When not sufficiently managed, stormwater can flood and erode roadways, and transport debris and sand that block drainage systems/culverts. If the stormwater system is overwhelmed, this could increase the likelihood or severity of flooding (Tuler 2016, Major et al. 2011). Changes in the timing and intensity of precipitation may overwhelm the current stormwater system, although this risk has not yet been quantified.

According to ICLEI (2012), storm sewers around the San Diego Bay are highly vulnerable to flooding and inundation due to sea-level rise. Sea-level rise could exacerbate the flooding impacts of extreme precipitation. As sea levels rise, storm drain outfalls are inundated and unable to handle precipitation events (Tuler 2016). Due to impeded drainage, higher sea levels may exacerbate riverine flooding as well (Ascent Environmental Inc. 2017). Sea-level rise may overwhelm stormwater system capacity in the San Diego region, although the risk has not yet been quantified for the whole region.

Flooding and erosion exacerbated by climate change may present other physical risks to facilities and equipment of the utility. Erosion could wash away soils that support or cover infrastructure (ICLEI 2012), although this risk has not been quantified in the San Diego region.

Solid Waste Management

Little information is available on how climate change may affect solid waste management, including waste collection, recovery, recycling, and composting, within the San Diego region. However, several resources describe potential impacts that may be relevant. The extent to which these impacts would occur in the San Diego region is not addressed in the literature.

Higher temperatures could have impacts on waste collection, processing, and disposal. Decomposition rates, odor, and pest activity may increase under higher temperatures, which could necessitate more frequent waste collection. Also, higher temperatures could overheat collection vehicles or processing equipment. (USAID 2012.)

Extreme precipitation events could cause flooding along collection routes, access roads, and facilities. Sea-level rise may narrow collection routes, damage low-lying processing facilities, and lead to material damage of coastal solid waste management facilities. (USAID 2012.)

Flooding and erosion exacerbated by climate change may present other physical risks to facilities and equipment of the utility. Erosion could wash away soils that support or cover infrastructure (ICLEI 2012), although this risk has not been quantified in the San Diego region.

Transportation

Climate change could impact transportation infrastructure and operations, as well as transportation use behavior. For example, sea-level rise may cause erosion and increase the frequency or duration of flooding on roads, which disrupts functionality and damages infrastructure (County of San Diego 2018, Biging et al. 2012). For example, an assessment of damage costs on city transportation infrastructure in Carlsbad found that bluff erosion could result in losses of $5.8 million by 2050 (Nexus Planning & Research 2017). Flooding and inundation on roads and railways, and in subway tunnels may cut off access to local transportation facilities and damage components exposed to more frequent inundation (ICLEI 2012, Biging et al. 2012). More frequent and intense rainfall may cause bridge scour due to erosion of sediment and increase streamflow, which could exacerbate bridge damages (Biging et al. 2012, Reidmiller et al. 2018). Also, saturated soils may destabilize the substructure of transportation infrastructure and cause pavement degradation (ICLEI 2012). Extreme events and higher sea levels could disrupt segments of transportation corridors, leading to longer travel times (Moser et al. 2012). Flooding could cause damage and delays at ports and airports, negatively affecting commerce and flight plans, and higher tides at ports could contribute to erosion and cause periodic traffic disruptions (Biging et al. 2012).

In addition to flooding, higher temperatures can damage and degrade pavements, railroad tracks, and other infrastructure, as well as present safety concerns for passengers and employees. Under extreme high temperatures, joints on bridges and highways may expand/contract and pavement may deteriorate more rapidly, and pavement binders may not remain intact (Reidmiller et al. 2018, WSP 2018). Rail tracks can buckle under high temperatures and airplanes may face challenges due to hot weather (Reidmiller et al. 2018). The impacts of climate change on transportation are complex, and although these impacts have been explored to some degree within the San Diego region, their extent requires further investigation.

The projected increase in climate impacts may increase maintenance requirements and costs to repair damage to transit infrastructure and roadways. Extreme heat and precipitation events may also necessitate changes in maintenance schedules to work around heavy rainfall and protect outdoor workers from extreme heat (WSP 2018).

Additionally, higher temperatures and changes in precipitation may change transit ridership, bicycling, and walking patterns (Melillo et al. 2014). The literature does not make conclusions about whether the impacts of climate change could increase vehicle miles traveled (VMT); however, if changes in climate cause people to drive rather than walk or take alternative forms of transit, it is possible that VMT would increase. However, if people adapt by moving closer to work or working from home, VMT may not increase. specifically studied within the San Diego region.

Increasing wildfire frequency and intensity may pose threats to driver safety, operations, and infrastructure. Wildfires could cause additional traffic, block roads, and require detours, in addition to reducing visibility due to smoke (WSP 2018). Additionally, wildfires may contribute to landslide exposure, which can damage transportation infrastructure (WSP 2018).

Tribal Cultural Resources

There is limited research on climate impacts on tribal cultural resources (TCRs) in the San Diego region; however, there is some information about national impacts that could be relevant to tribes in the region. Climate change could pose various physical, economic, and social threats to TCRs (Marchand et al. 2017). Potential climate impacts include loss or damage of material culture; losses of ecological resources, including agricultural land, traditional foods, forests and forest products; threats to tribal rights to fish, hunt, and gather; and loss of water supplies (Marchand et al. 2017, NWIFC 2016). While many similar impacts could occur for the general population, they may be more severe for indigenous populations who are more socio-economically vulnerable (Marchand et al. 2017).

Sea-level rise and coastal erosion could damage or destroy coastal TCRs that are exposed to temporary or permanent coastal flooding (NWIFC 2016). Above-ground structures may be particularly exposed to coastal flooding, but a rising water table or salinization of water could potentially affect below-ground TCRs, such as archeological resources.

Extreme precipitation events may lead to more severe, more extensive, or more frequent flooding events on tribal lands. To the extent that TCRs are exposed to these floods, the TCRs may be physically damaged from the water or the debris it carries, or from the resulting erosion (Curry et al. 2011; Flanigan, Thompson, and Reed 2018). Extreme precipitation can also contribute to soil destabilization and landslides, which could damage or destroy TCRs.

Changes in temperature and precipitation could also damage cultural resources, although the extent to which these could negatively affect archaeological and cultural resources in the San Diego region has not been quantified. If freeze/thaw cycles become more frequent or dramatic, which can happen under warming scenarios, when temperatures rise above freezing during the day and then dip below freezing at night, rather than just staying below freezing, this can physically damage TCRs. Freeze/thaw cycles negatively affect stone and brick buildings structures (Rockman et al. 2016). Higher temperatures can cause faster rates of deterioration due to thermal stress and biological activity, more rapid decay of organic materials, heat stress on culturally significant vegetation, and loss of culturally significant habitat and species due to disease and temperature changes (Rockman et al. 2016). Heavy precipitation and flooding could damage cultural resources due to site erosion and destabilization, direct physical damage to the site, loss of artifacts due to flooding, and increased risk of post-flood subsidence (Rockman et al. 2016).

More frequent and intense wildfires may damage or destroy TCRs (Rockman et al. 2016, Curry et al. 2011, NWIFC 2016), particularly above-ground TCRs. Wildfires can increase damage to archaeologically relevant structures, alter the artifacts exposed to extreme heat, increase susceptibility to erosion and flooding, and exacerbate damages due to firefighting activities (Rockman et al. 2016). Wildfire could damage historical structures or alter their distinct physical characteristics as older buildings may not have as robust defenses against wildfire as modern buildings (Rockman et al. 2016). Wildfires can also contribute to soil destabilization and landslides, which present risks to TCRs (Santin and Doerr 2016, NWIFC 2016).

It is possible that sea-level rise, flooding, wildfire, and landslides could reveal or damage human remains. Remains exposed to the environment from climate hazards may then be further damaged by extreme weather. For example, changes in temperature and precipitation could speed deterioration and decay, cause thermal stress, and cause erosion (Rockman et al. 2016).

Water Supply

Climate change may have an impact on both imported and local water supplies for the San Diego region. Supply could be reduced by changes in snowpack and snowpack melt, which would affect the timing of water availability, reduced precipitation, increased evaporation from higher temperatures, and saltwater intrusion due to sea-level rise. Meanwhile, demand could be increased due to evapotranspiration and drought.

Effects such as reduced snowpack and precipitation, as well as more precipitation falling as rain rather than snow in the mountains, can decrease water supplies coming from the mountain ranges. These effects reduce the amount of runoff and streamflow from melted snow, potentially decreasing this source of water. Such changes have already affected the Colorado River, which has seen a decline in streamflow by 16.5 percent between 1916 and 2014; over half of this decline can be attributed to warming temperatures (Xiao et al. 2018).

A shift in the timing of melting snowpack can also affect supplies (CEP and SDF 2015). This snowpack usually melts in the spring and summer, releasing water when it is most needed; however, snow has melted earlier in recent years, reducing the amount of water available later in the year (Reidmiller et al. 2018). Snowpack in the Sierra Nevada Mountains is also projected to melt earlier; projections for 2070–2099 indicate 35–52 percent of snowpack remaining by April 1, compared to the 100 percent remaining post-April 1 snowpack from 1961–1990 (Gonzalez et al. 2018). The San Diego region draws from mountain water; the San Diego County Water Authority (SDCWA) bought 40 percent of its water from the Metropolitan Water District (MWD) in 2017 (SDCWA 2016). MWD draws from the Sierra Nevada mountain range and the Colorado River, which is also supplied by mountain water.

Other impacts of climate change, such as reduced precipitation, increased evaporation, and increased drought, can also reduce water volumes in water sources. These changes would affect the Colorado River (CEP and SDF 2015), groundwater supply, and other surface water sources (SDF 2008).

Sea-level rise could result in saltwater intrusion along coastline water sources. Saltwater intrusion degrades freshwater supply, decreasing the amount of drinking water available to the San Diego region. Saltwater intrusion would affect the Bay-Delta (Kibel 2015), which MWD also sources from, as well as groundwater wells located along the coast (USGS n.d.).

Future water supplies are also vulnerable to impacts of climate change although the San Diego region plans on diversifying its water portfolio, and the net impact has not been quantified. The SDCWA plans on reducing its reliance on MWD sources to 2 percent of its supplies by 2035. However, the other two imported water sources that feed the San Diego region (the Imperial Irrigation District Transfer and the All American & Coachella Canal Lining, which made up 38 percent of the region's water supplies in 2017 and will constitute 45 percent of the supply by 2035) still originally source their water from the Colorado River (SDCWA 2016).

Part of the region's future water supply plan includes increasing reliance on local water supplies, from 22 percent in 2017 to 51 percent in 2035 (SDCWA 2016). The increase in extraction from local groundwater may result in subsidence, permanently reducing availability of groundwater supply (Melillo et al. 2014). Other supplies, such as seawater desalination, consume large amounts of energy, a resource that may also be compromised by climate change (see *Energy* above) (Kelley 2011). The largest-growing water supply that the County plans on drawing from is potable reuse, from 0 percent in 2017 to 17 percent by 2035 (SDCWA 2016). Not much research exists on the effects of climate change on potable reuse, so the impact this will have on the San Diego region's water supply is unknown.

Climate change impacts such as drought and evapotranspiration may increase water demand due to increased demand across sectors, including agricultural demand for irrigation to make up for lack of rainfall and to adjust to higher temperatures, and household demand. Christian-Smith et al. (2012) forecast a 10 percent increase in urban demand due to climate change by 2055 in California under a medium-to-high emissions scenario, without water conservation strategies. Because many water distributors across California other than SDCWA also buy from MWD, this statewide increase in demand can put stress on water supplies. In the San Diego region specifically, the demand totaled 477,000 acre-feet in 2017, while the demand forecasted in 2035 will total 632,000 acre-feet under RCP 8.5, having increased from a combination of population growth, rising temperatures, and more drought and evaporation (SDCWA 2016). This increase in demand may come from all sectors (though residential use dominates), where higher temperatures, drought, and evapotranspiration may require various operations to source more water (Christian-Smith et al. 2012). However, the exact increases in water demand in the region resulting from climate change are not quantified.

Wildfire

Due to its semi-arid climate, shrubland, and the nearby presence of the Santa Ana winds, the San Diego region experiences wildfire, and the high temperatures and droughts caused by climate change could increase their intensity or frequency. By 2050, the fire season in the San Diego region may be longer and less predictable, with larger and more catastrophic fires, and climate change may drive factors that may worsen wildfires, such as more frequent and intense dry Santa Ana winds, drier autumns, and increased development and presence of dead fuels (CEP and SDF 2015, Kalansky et al. 2018). The annual average of acres burned was 21,042 between 1950 and 2005. Under a high-emissions scenario, the Cal-Adapt wildfire tool anticipates an annual average of 20,972 acres of burned land by 2050 (a negligible decrease) and 29,499 acres by 2100 (a 40 percent increase). Under a low-emissions scenario, the tool estimates an annual average of 17,971 acres burned by 2050 (a 14.6 percent decrease) and 24,546 acres by 2099 (a 16.6 percent increase) (County of San Diego 2018). Thus, climate change is expected to increase wildfire occurrence in the San Diego region in the longer term.

In addition, installation of above-ground electrical distribution infrastructure in rural areas and high fire-risk areas could increase the risk of ignition, such as from downed wires or sparks from faulty infrastructure (Mitchell 2013). Combined with climate change effects that can increase wildfire risk, this could potentially result in more wildfires in the future. Also, as impervious surfaces continue to increase, this could worsen impacts of flooding and runoff. Climate change is also expected to increase risk of flooding and landslides in the future due to increased frequency and intensity of extreme precipitation events. Furthermore, climate change may increase the potential for heavy rainfall to occur after wildfire, resulting in potential landslides as flooding washes away soil destabilized from wildfire (Bedsworth et al. 2018).

C.4 CLIMATE CHANGE ADAPTATION INITIATIVES

Since the first “Safeguarding California” statewide climate adaptation strategy was produced in 2009, state agencies, and regional and local organizations have assessed climate risks and produced a variety of guidance documents on adapting to climate change across different sectors. SANDAG’s 2018 *Climate Change White Paper* summarizes the key adaptation initiatives at the state, regional, and local levels that are relevant for the San Diego region. The discussion below summarizes the information in that white paper.

At a state level, the most recent guidance for how to assess climate vulnerability and develop an adaptation framework and strategies is the 2020 update to the *California Adaptation Planning Guide* (OES 2020). The guide lays out a step-wise assessment process. Additionally, state agencies have produced numerous guidance documents on considering climate change adaptation in planning and decision making, including:

- The California Coastal Commission *Sea Level Rise Policy Guidance* (2015) recommends steps for addressing sea-level rise through Local Coastal Programs and Coastal Development Permits, and their 2017 *Draft Residential Adaptation Policy Guidance* discusses sea-level rise adaptation strategies related to residential development. In 2018 the Coastal Commission adopted a Science Update to the Sea Level Rise Policy Guidance that synthesizes the best available sea-level rise science. The update includes sea-level rise projection tables recommended for use in the 2018 Ocean Protection Council *Sea Level Rise Guidance* for use in planning, permitting, investment and other decisions.
- The *Safeguarding California Plan* (Bright et al. 2018) includes adaptation measures for 10 sectors.
- The *California Water Plan Update* (2018) and *California Water Action Plan* (2016 update) provide resources for handling climate impacts on water resources.

At the regional level, SANDAG is undertaking a number of initiatives through implementation of the 2015 Regional Plan (currently undergoing a 2021 update), which recognizes the risks climate change presents to the region. In an effort to develop strategies to enhance the region's adaptive capacity, SANDAG has also produced studies and guidance for adaptation at the regional level, such as *Regional Transportation Infrastructure Sea Level Rise Assessment and Adaptation Guidance for Transportation Infrastructure*, which analyzes potential sea-level rise impacts on transportation facilities (Dudek 2021).

Some local governments are including climate adaptation strategies in their Climate Action Plans, general plans, local hazard mitigation plans, and/or updates to their Local Coastal Programs (LCPs). There is also a requirement to include adaptation strategies in local planning-level documents, including general plans and hazard mitigation plans. State-level legislation (SB 379) requires that local jurisdictions include climate adaptation and resilience strategies in the general plan safety element. Legislative requirements are summarized below.

- **SB 379**
  - Requires the safety element to be reviewed and updated as necessary to address climate adaptation and resiliency strategies.
  - Requires the update to include a set of goals, policies, and objectives based on a vulnerability assessment, identifying the risks that climate change poses to the local jurisdiction and the geographic areas at risk from climate change impacts.
  - The safety element update must include:
  - A vulnerability assessment identifying the risks that climate change poses to the local jurisdiction.

    a) A set of goals, policies, and objectives based on a vulnerability assessment for the protection of the community.
    b) A set of feasible implementation strategies to carry out the goals, policies, and objectives.

- **SB 1035** (climate change impacts provisions)
  - Requires review and revision of the safety element to identify new information to address flooding and fires.

- **SB 182**
  - Requires updating planning requirements to reduce development pressure in high-fire risk areas.

The *San Diego Region Report* (Kalansky et al. 2018) also lists some of the ongoing adaptation initiatives that agencies and local governments are undertaking in the San Diego region, as follows.

- *Coast:* Several local governments are conducting or have completed vulnerability assessments, LCPs with sea-level rise vulnerability analyses, Land Use Plan (LUP) updates, and other coastal adaptation planning efforts, such as coastal protection structures and restoration programs. In particular, public agencies have begun to explore more natural adaptation approaches, such as living shorelines.
- *Infrastructure:* Green streets in the region are designed to help with stormwater management and accommodate more diverse transportation options.
- *Emergency management:* The County's Office of Emergency Services is working with regional partners on communication systems that give emergency warnings to the public. The University of California, San Diego has developed a program to better monitor weather conditions to inform hazard warning.

- *Ecosystems:* Natural resource management in the region's national forests are conducting extensive tree and plant restoration to recover from wildfire, as well as reducing the risk of wildfire ignition in national forest areas.
- *Water:* To adapt to climate change impacts such as drought, the SDCWA is carrying out water efficiency and conservation programs, diversifying its water portfolio to include more local sources, undertaking more collaborative and holistic management and planning, analyzing the effects of climate change on its supplies, and considering climate change impacts in its initiatives, such as its Integrated Regional Water Management Program (IRWMP).
- *Energy:* San Diego Gas & Electric (SDG&E) has built a microgrid, which can operate independently from the main power grid, for Borrego Springs. This microgrid can provide power in case of an emergency; this option is being explored for future locations.
- *Wildfire:* To mitigate wildfire risk, SDG&E has invested in grid resiliency and modernizing energy assets and uses tools to assess wildfire threats.
- *Health:* The County of San Diego is working on better communicating health risks from heat events and natural disasters to the public, especially for vulnerable communities. The County also has programs to mitigate impacts of vector-borne diseases from the spread of mosquitos, and programs to provide cooler green space and improved air quality.

Please see SANDAG (2018) and Kalansky et al. (2018) for more details about adaptation initiatives at the state, regional, and local levels. Specific adaptation measures can be found within the referenced resources.

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