Developing Adaptation Strategies for San Luis Obispo County:

Preliminary Climate Change Vulnerability Assessment for Social Systems

May 5, 2010

EXECUTIVE SUMMARY

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This Executive Summary synthesizes a more comprehensive report for SLO County.
For more details and references please consult the companion document.

Introduction

San Luis Obispo County is home to a growing population with a vibrant economy and stunning natural resources. Climate change is expected to have varied effects on both the socioeconomic and natural systems of the county. This report describes the social systems of San Luis Obispo County (its people, economic sectors, and critical infrastructure and community services) and explores their potential vulnerabilities to the impacts of climate change. This report is intended to provide background information for a workshop involving county leaders and experts as they begin to develop strategies for climate change adaptation.

A previous report and workshop, organized by the National Center for Conservation Science and Policy (NCCSP) focused on potential climate change impacts and adaptation options for the county's species and ecosystems. A functional and healthy natural environment is a critical foundation for San Luis Obispo County's economy, quality of life, and the health and well-being of its residents. Ecosystems services, such as water filtration, flood abatement, carbon storage, pollination, and many others, are essential for a strong local economy and health communities. Climate change is expected to stress ecosystems and the services they provide to society. Thus, strategies are needed to reduce stresses from climate change and other sources in a cohesive manner, and to create more resilient natural and social systems.

To fully understand what climate change will actually mean for local communities, science-based projections of potential changes in the physical climate (given selected greenhouse gas emissions scenarios) are essential, but not enough. What is equally necessary to complement these scenarios of future climate (i.e., changes in temperature, rainfall, extreme events, and sea-level rise) is a better understanding of the current (and future) condition of the potentially affected natural and social systems.

In this report, we focus primarily, though not exclusively, on these on-the-ground vulnerabilities and how these vulnerabilities interact with climate change to produce impacts on social systems. By having a full understanding of current socioeconomic conditions throughout the county, local experts and leaders will be able to develop strategies that can yield benefits to the environment, economy and people regardless of precisely how climate change will unfold.

We summarize what is known about potential climate change impacts, and examine available information about

- demographics (wealth, race, education, special populations, etc.),
- locally important economic sectors (tourism, agriculture, fishing, etc.), and
- important infrastructure and community services (water supplies, transportation, and emergency management, etc.)

to better understand how the county and communities are vulnerable to climate change.

To present such a diversity of background information, this report is organized as follows. First, we will introduce a few concepts that are central to thinking about vulnerability and developing adaptation strategies. Key concepts include: vulnerability, exposure, sensitivity, adaptive capacity, coping, adaptation, and resilience. Second, we will present a summary of modeled climate change projections (biophysical impacts – temperature, rainfall, sea-level rise, etc.) for the region to remind readers of the potential risks the county may be exposed to. Finally, the core of the report will present information about the population, economic sectors, and water, infrastructure and supporting services. This information will be used to illustrate how certain demographic, socio-economic and other factors make the county's residents and economic activities more or less vulnerable to climate change. They will also indicate what capacities the county already has to draw on and could leverage to begin the process of adaptation.

What is vulnerability? What is adaptation?

For the purposes of this report, we employ the terminology used in the State of California's first Climate Adaptation Strategy (see box of definitions).

A ***climate change impact*** is an effect of climate change on the structure or function of a system.

Vulnerability – a system's susceptibility to harm or change as a result of its exposure, sensitivity, and adaptive capacity. *It is a function of the character, magnitude, and rate of climate change and of social and environmental characteristics of the system.*

Exposure is the nature and degree to which a system experiences a stress or hazard.

Sensitivity is the degree to which the system is impacted by a given stressor, change or disturbance.

Adaptive capacity *refers to* ability to cope with extreme events, to make adaptive changes, or to transform more deeply, including the ability to moderate potential damages and to take advantage of opportunities.

Adaptation is defined as any adjustment in natural or human systems in response to actual or expected climatic events or their effects, which may minimize harm or take advantage of beneficial opportunities.

Resilience is the ability of a system to absorb some amount of change, including shocks from extreme events, bounce back and recover from them, and, if necessary, transform itself in order to continue to be able to function and provide essential services and amenities.

Climate Change Impacts

Several studies conducted for the State of California provide a first-order indication of the potential climatic changes that San Luis Obispo County may expect in the future. In addition, the National Center for Conservation Science and Policy compiled a report, entitled *Projected Future Climatic and Ecological Conditions in San Luis Obispo County,* on climate change impacts specific to the county, projecting changes in temperature, precipitation, vegetation, wildfire, and sea level. Climate change could lead to the following potential changes in the county.

Higher Temperature

Downscaled climate change projections indicated that average temperatures are expected to increase countywide throughout this century. Average temperatures could increase by +2.1 to +3.9°F by 2035-45 and of +4.1 to +7.6°F by 2075-85, with summer temperature increases being larger than winter increases (Figure 1). Statewide studies project more frequent and severe extreme heat events. Inland areas will experience higher temperature increases than the coast, but both regions will experience substantial warming. If coastal fog decreases (as it has in Northern California), the coast will experience more significant temperature increases, for which the region's communities may not be prepared. Warming is expected to have negative impacts on human health, and increase the use of electricity and water (residential, commercial, and agricultural).

Rainfall Changes

Projections of rainfall are generally less certain than temperature projections. Recent statewide studies show that the typical Mediterranean pattern of dry summers and wet winters will persist in California, albeit with the dry period lengthening. Regardless of the greenhouse gas emission scenarios and models used, precipitation projections toward the end of the century show a drying trend (reductions of 5-15% of total rainfall). Droughts may become more frequent, longer and more severe.

Despite the overall drying trend in the long term, studies suggest that rainfall may occur in more intense downpours. Such extreme rainfall events pose greater challenges with runoff, sedimentation, limited soil water retention, and challenges for storage and flood management. As seen historically in southern and central California, extreme rainfall events that follow large wildfires, which have removed vegetation, especially on steep slopes, can lead to severe soil erosion, landslides, and resulting sedimentation of reservoirs, roads, and valleys. In addition, higher temperatures and a longer summer dry season will result in increased demand for water for ecosystem processes and human uses, adding to existing challenges to meet water supply needs for a growing population in the state and county.

More Wildfires

Climate change is projected to increase the annual acreage burned by wildfires statewide and in the county. Historically, the average annual area burned by wildfire was just under 4% of the county land area. By 2050, climate change studies show an increase to about 7% of the area burned, and up to 8.5% by the end of the century. This increase in acreage burned could have significant implications for the demand on emergency services, water supply, air quality and associated public health, native species and habitats, and rural and urban establishments, including increased risk for residences at the wildland-urban interface.

Faster Sea-level rise

Sea-level rise as a result of warming ocean waters (thermal expansion) and melting ice caps (especially Greenland and the West Antarctic Ice Sheet) are among the most certain consequences of climate change, yet accurate projections are currently hampered by scientists' inability to model ice sheet dynamics. Using the best available science, statewide studies conducted in 2009 project that sea level could rise 12 to 16 inches by 2050 above current levels. By the end of the century, these studies project a total sea-level rise of 3.3 - 4.6 feet (23 to 55 inches) above current levels. While the exact amount of sea-level rise is still up for debate, a more rapid increase than historically experienced is virtually certain. Sea-level rise along the coast of San Luis Obispo County could lead to the following impacts:

- Increased erosion of already retreating coastal bluffs and beaches, increasing the risk of cliff failures
- Coastal flooding with higher storm surges and flood elevations during coastal storms, potentially inundating valuable residential and commercial development, as well as transportation and infrastructure in low-lying areas
- Permanent inundation of coastal wetlands in the county, which serve as critical habitat, fish nurseries, flooding buffers, and areas for carbon storage (a mitigation strategy)
- Salt water intrusion into coastal freshwater wells that serve agriculture and local residents.

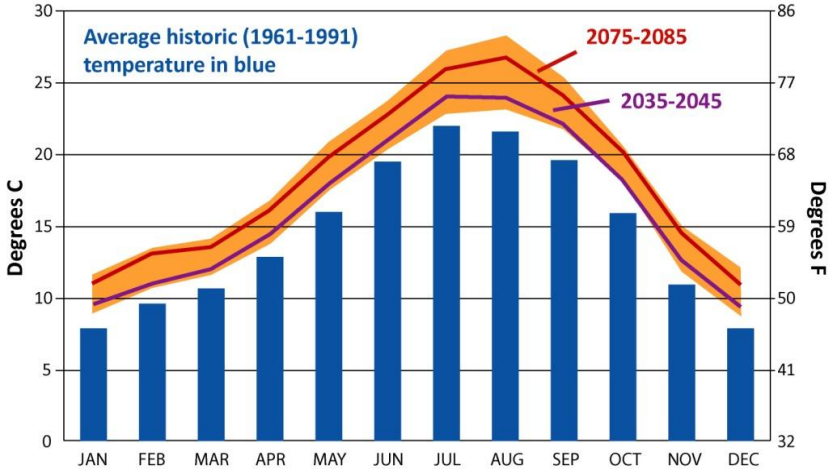

Figure 1. Temperatures are projected to increase significantly, especially in the summer. Dry periods will lengthen and precipitation is projected to decline. (Source: Koopman et al. 2010)

With this short summary of climate change projections and at least a qualitative assessment of potential physical and ecological impacts, we now turn to the potential impacts and vulnerabilities on the county's residents and communities.

Population and Communities

San Luis Obispo County is a predominantly rural county with several urban centers. Its population over the past few years has been growing at a moderate rate, and is expected to continue to do so. Most of this growth results from domestic immigration. Many new arrivals are retirees. The profile of the existing population, the amount of growth, and the type of incoming new residents are important to consider with respect to their vulnerability to climate change.

Public Health

Certain segments of the population commonly have higher than average sensitivity and exposure to climate variability and disasters (Table 1). We summarize these critical social vulnerability concerns below for specific climate change risks.

Greater Exposure to Heat and Flooding

Increasing heat extremes

Outdoor workers in farming or construction, especially in hotter inland areas, are more exposed to extreme heat than indoor workers. They have little incentive or opportunity to seek shade, rest, rehydrate, or avoid exposure altogether (Figure 2).

Figure 2. Outdoor workers are more exposed to heat and have little incentive to avoid it. (Photo: Wikimedia Commons)

Coastal flooding

The Pacific Institute's study on sea-level rise showed that there are 1,300 persons in the county residing in the areas affected by the 100-year coastal flood zone with a 55 inch (4.6 ft.) sea-level rise. Relative to other California coastal counties this number is low; thus the county may not be one of the priority regions for the State to assist in preparing for or recovering from such events.

Table 1: Examples of Climate-Related Extreme Events Interacting with the Three Components of Vulnerability

Components of Vulnerability	Climatic Risks	Population Particularly at Risk
Exposure	Floods Heat	Floodplain residents Outdoor workers
Sensitivity	Heat, Air pollution Heat	Infants Elderly
Adaptive Capacity	Heat, Floods	Institutionalized populations (e.g., persons with mental disabilities, prisoners) Socially excluded and economically marginalized groups

Inland flooding

Climate change is expected to lead to more extreme downpours and runoff, which can cause flooding along area creeks and rivers (e.g., the Salinas River), of roads, homes, and agricultural fields. If these events occur over several days and overwhelm the capacity of streambeds and reservoirs, there is risk of

dam failure and flooding. People living in low-lying areas, floodplains, and downstream of the Salinas Dam (Atascadero) and Lopez Dam (e.g., Arroyo Grande) are at particular risk.

Higher Sensitivity to Heat and Polluted Air

Heat extremes

Infants and those 65 years and older are physiologically more sensitive to high temperatures and may be less able to protect themselves from extreme conditions. Long-lasting heat waves and, in particular, very warm nights are particularly challenging for human health. The county has a relatively high population of persons over 65, which are concentrated in coastal areas, California Valley, and Lake Nacimiento (Figure 3).

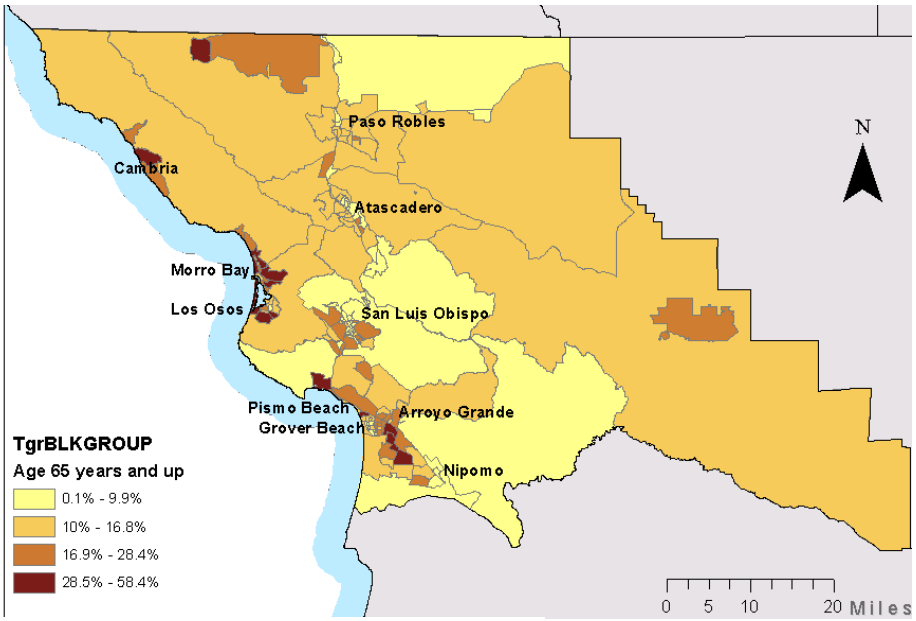

Figure 3: Percentage of the population 65 years and older (Source: Census 2000)

Air quality

Large wildfires are major contributors to air pollution problems in the county from ozone and from small particulate matter (PM2.5). Studies suggest that wildfires in California are likely to increase in severity and extent with climate change. In addition, climate change can increase the prevalence of allergens and the formation of ground-level ozone under higher temperatures. The risk of pulmonary health problems is increased particularly for children. One area already of particular concern in the county is Nipomo Mesa, which has particularly high values for PM10 airborne particular matter compared to the rest of the county and other California coastal regions.

Lower Adaptive Capacity to Deal with Extremes and Change

Common characteristics of society that indicate lower adaptive capacity and therefore greater vulnerability to climate change impacts include poverty and low income, age, lower educational attainment, race, linguistic isolation, university students, institutionalized populations, and females as head of households. These traits are unevenly distributed across the county.

Income, disaster readiness and response

Lower income often correlates with lower access to the necessary resources to prepare for or evacuate in the case of a disaster, or to invest in actions required to adapt to climate change (e.g., insulating one's house, elevating one's house above a given flood elevation, moving away from the high-risk fire zones).

Countywide median household income in 2000 was estimated to be $42,428 (median by census tract ranging from $7,171 to $70,000). The southwest portion of the county has the highest per capita income (along with Cambria), while the areas around Atascadero and Paso Robles have the lowest average per capita income (Figure 4). Per capita income

averages are depressed for the City of San Luis Obispo due to its high student population.

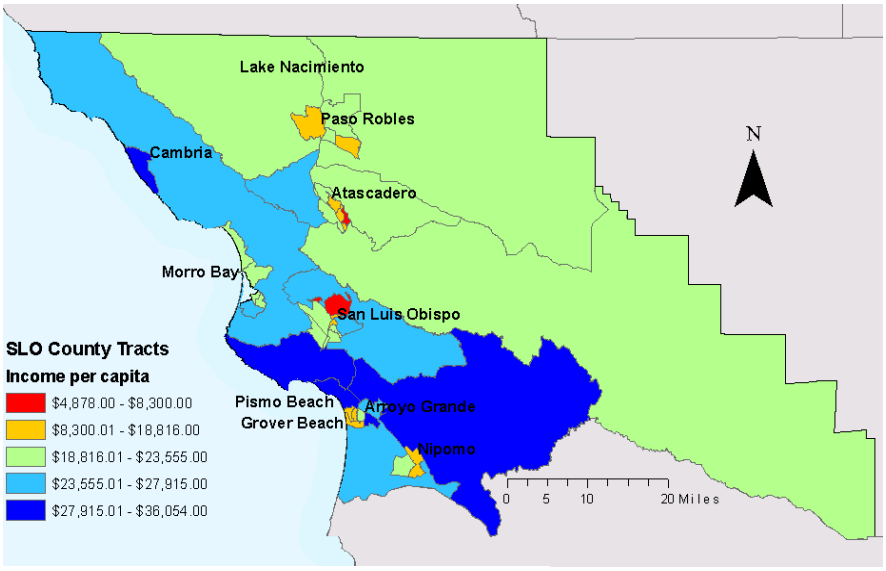

Figure 4: Per capita income by Census tract (Source: Census 2000)

What emerges from looking at the spatial distribution of income related information is that the highest concentration of low income and poverty can be found in urban centers of the county, especially the City of San Luis Obispo. In addition to the large student population, low-wage labor in the service industry may be particularly prevalent there, followed by low-wage farm labor in the more rural inland census tracts. Income is one of the most important indicators of lower adaptive capacity, and can be addressed through special needs-related programs or by creating opportunities for low-income populations to make a better living (e.g., through education and training programs, providing a living wage, diversifying the economy).

Education and ability to respond

Lower educational attainment often correlates with lower adaptive capacity to deal with extreme events. People with less education thus require a different level of attention and assistance from public agencies than those with greater resources of their own. Distribution of the percentage of people over 25 years old who have not graduated from high school is highest in tracts just south of the City of San Luis Obispo and just north of Cal Poly, Paso Robles, and Nipomo.

Race, poverty and flexibility to change

Minority populations tend to have lower capacity for responding to disasters and adapting to climate change than non-Hispanic whites. The most likely reason for the correlation between race and lower adaptive capacity is the disproportionate amount of poverty and often lower incomes among African Americans and Hispanics compared to white segments of the population. In minority populations where English is not the first language spoken, linguistic proficiency can also play a role. Other factors, such as being tightly embedded in social networks, may compensate to some extent. According to the census, high Latino/Hispanic populations reside in Paso Robles, Nipomo, Grover Beach, and to a lesser extent along the coast north of Morro Bay (Figure 5).

Age and limited mobility

Age can play a role not just in sensitivity but also in adaptive capacity. For example, the elderly are considered to be more vulnerable in emergency situations because of possible mobility challenges. Higher concentrations of elderly exist along the coast, especially Grover Beach, Pismo Beach, Avila Beach, Los Osos, Morro Bay and Cambria. Also, California Valley (in the Southeast of the county) shows a high proportion of people over 65 years old (Figure 2 above). When looking at the census

block group, this age group ranges from nearly 0% up to 58% of the total population. Pismo Beach has the highest proportion of the 65 and older age group (58.4%) (Figure 6).

The 2000 Census shows that more than 22% of the people living in California Valley (an outlier in the western part of the county) were 65 years and older. This community may be of particular concern during climate- and weather-related disasters (e.g., wildfires) because it is relatively remote and individuals themselves may be less mobile without outside assistance.

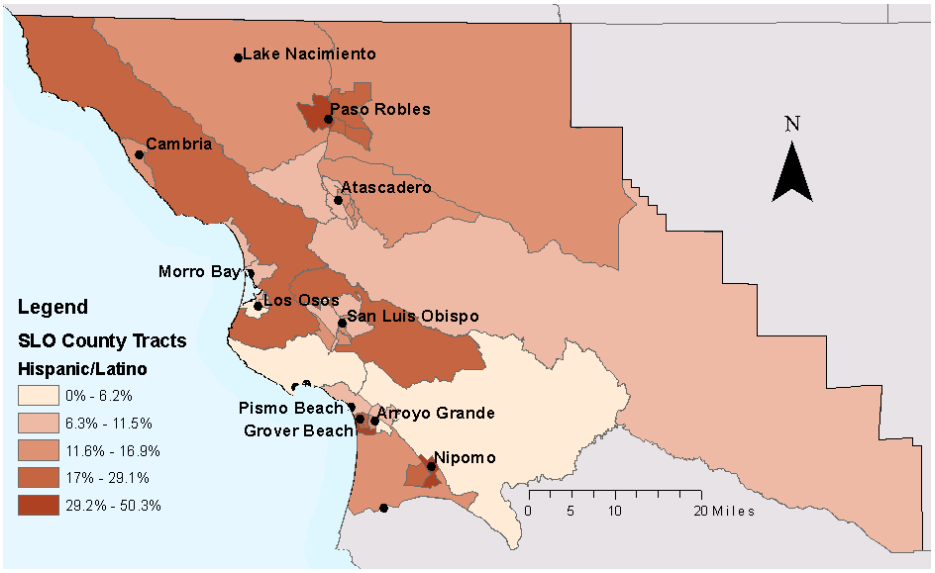

Figure 5. The geography of Hispanic/Latino populations in San Luis Obispo County by percentage of the total population (Source: Census 2000).

Institutionalized populations depend on help

Institutionalized populations are reliant on institutional provisions and the facility's response measures during times of disaster for support. California Men's Colony, located just north of the City of San Luis Obispo with a population of 7,000 minimum and medium security inmates, is close to a land slide risk zone marked as 'high potential'. The Atascadero State Hospital, located on the south end of Atascadero along Highway 101 with a population of approximately 1,050, is in the flood zone of Salinas Dam. On-campus housing at Cal Poly may also require special evacuation plans. Climate change studies for the state project an increasing severity of extreme rainfall events, increasing the risks for both institutions and demanding appropriate preparatory measures from these institutions to address the particular vulnerability of their residents to climate change-related extreme events.

Renters with limited control over housing

Housing also tends to be a factor in adaptive capacity. Home ownership versus renting with regard to adaptive capacity, indicates income status but also how much control individuals have over their housing, e.g., to make structural adjustments to their home for flood protection or insulation from heat, or whether they are able to modify vegetation surrounding the house (a form of protection from wildfire). There were an estimated 40% renters countywide, albeit with considerable variation.

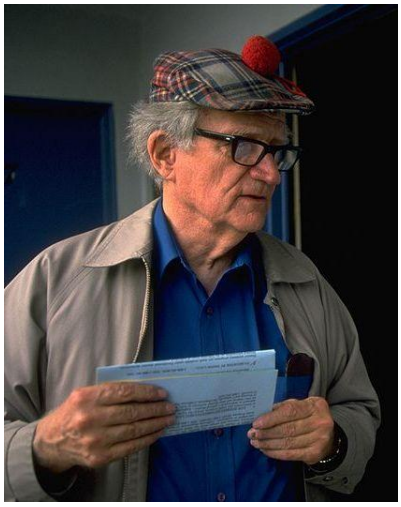

Figure 6. The elderly are more sensitive to heat, and maybe less mobile in case of disaster. (Photo: Wikimedia Commons)

Just northwest of Atascadero, Census tracts show only 11% renters, whereas in the area just north of the City of San Luis Obispo (where Cal Poly is) 99% of households rent (Figure 7). Other concentrations of renters can be found in the more populated areas of Paso Robles, Atascadero, Morro Bay, Pismo Beach, and Grover Beach.

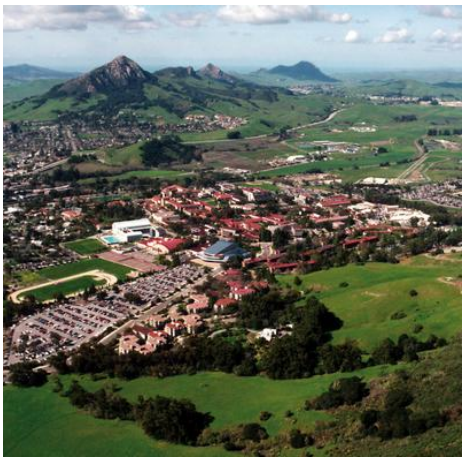

Figure 7. A high proportion of students, distant from home, in rental housing, prevails around Cal Poly. (Photo: Cal Poly Commons)

Students far from family and community

Students comprise another especially vulnerable population – often based far from home and their families and disconnected from their resident community. Students also may not have vehicles and a lower response rate to public warnings about emergencies. The county has a high proportion of students enrolled in college or graduate school. As of fall 2009, 19,325 students were enrolled at the State University (Cal Poly) and the Junior College (Cuesta). While most Cal Poly students are from within California, only 9% are from San Luis Obispo County, or from the neighboring counties, leaving a high proportion of students to not have families within a few hours driving distance.

Community organizations and social capital: Enhancing adaptive capacity

Social groups can be important resources for communities in cases of emergency. They provide resources and support and can help increase public awareness about what households and communities can do to cope with and adapt to the impacts of climate change. Trustful social relations are among the most important immaterial resources during times of stress and change. Social groups can develop strategies for helping individuals and families to become familiar with the risks, take actions to reduce their exposure, assist targeted populations during emergencies (e.g., a social buddy system during heat waves), and support each other in the aftermath of disasters to rebuild and bounce back more quickly.

San Luis Obispo County is rich in social organizations, including clubs, interest-based associations, and religious communities. Some 43% of the population identifies as religious and over half the religious population is Catholic. The county has 16 rapidly growing Catholic congregations with a total of 68,264 congregants. The second most dominant religious affiliation is Evangelical Protestant with 22,321 followers. Churches often serve as safe areas for evacuees in times of disasters, such as wildfires and flooding events. They provide emergency services and social and spiritual support. Some may also be particularly well positioned to reach into otherwise linguistically or culturally isolated segments of the population (e.g., especially Catholic churches with high Latino membership may be able to help get information about disaster preparedness and coping strategies to Spanish-speaking community members).

Summary: Uneven Social Vulnerability

To synthesize the factors affecting vulnerability, 32 Census variables commonly associated with low adaptive capacity and high sensitivity to climate-related disasters were combined. The result is an integrated impression of social vulnerability across San Luis Obispo County (Figure 8). Based on this analysis, the most vulnerable populations are located in the more populated regions of the county. One benefit of the county's existing

emergency preparedness structure is that each of these highly vulnerable populations are within regions in which emergency response time is fast. When considering additional exposure to climate change impacts, all coastal communities are exposed, but in light of sensitivities and adaptive capacities, Morro Bay, Cambria and Grover Beach are most vulnerable to flooding-related inundation during storm events (yellow, orange and red in the map below). There are also medium-high to high vulnerability populations at risk from landslides, including just north and east of the City of San Luis Obispo. Those vulnerable populations that are within or adjacent to high fire hazard severity zones include Atascadero, Nipomo, and Lake Nacimiento.

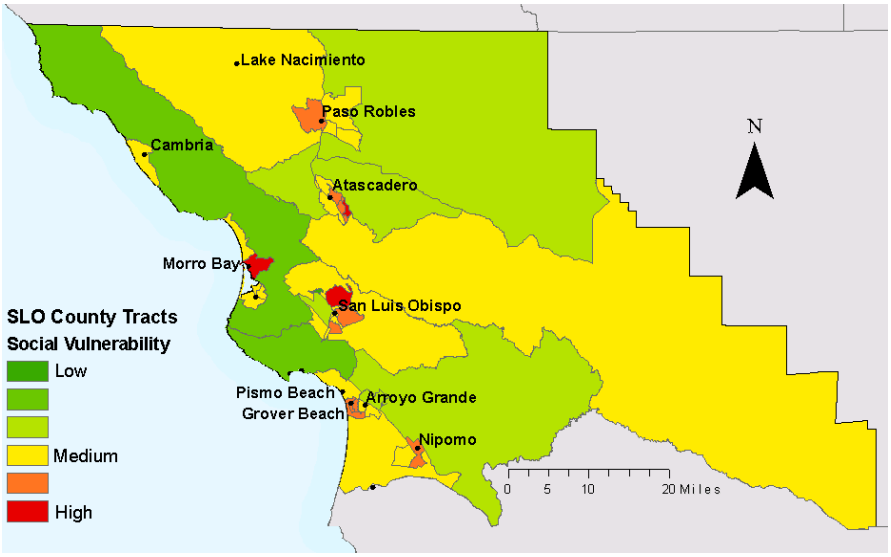

Figure 8: Areas determined most vulnerable include densely populated areas such as the City of San Luis Obispo, Nipomo, Grover Beach, Atascadero, Morro Bay, and Paso Robles. Unincorporated areas with medium social vulnerability include the southwest, Cambria, the coastal region south of Grover Beach, and the Lake Nacimiento area.

Economic Activities and Sectors

The major economic industries by employment in San Luis Obispo County include tourism, retail, service industries, government and agriculture. Of these, tourism and agriculture are most directly dependent on services that are sensitive to climate change (e.g., sea-level rise and related hazards affecting beaches; temperature and water supply changes affecting agricultural crops and cattle). Below, challenges to these economic activities are discussed including sector-inherent vulnerabilities.

Agriculture

Agriculture employs relatively few individuals, but generates significant value for the county. It also is the predominant land use with over 55% of land zoned for agriculture. The highest ranked crops by dollar amount are grapes (and wine), broccoli, strawberries, and cattle/calves. Climate change poses a serious threat to agriculture for San Luis Obispo County. These threats include the following:

- higher temperatures, including extreme temperatures, can negatively affect plant growth during various stages of their development (crops and forage), as well as cattle health and reproduction; inland areas will be affected more so than coastal areas by these temperature increases;
- reduced water availability as a result of (a) the projected decrease in snowpack as more precipitation falls as rain than as snow and (b) higher temperatures leading to higher evaporation from reservoirs and soils resulting in reduced reservoir storage and generally drier conditions; any decrease in total precipitation as projected by the latest climate change projections for the state would only exacerbate these declines in water supplies;
- more intense downpours can lead to fruit,

vegetable and flower damage and increase the risk of soil erosion;
- water use by crops and agricultural animals (for drinking and cooling) will increase as temperatures increase; and
- increased risk of pest infestations and spread of invasive plant species.

Many crops respond positively to elevated carbon dioxide under lower levels of warming, but this beneficial effect on growth and yields is limited quickly by higher levels of warming. A longer growing season, while potentially beneficial to farmers, may increase the overall demand for water. Finally, changes in coastal fog are still uncertain, but any reduction would lead to warmer coastal regions reducing the optimal growing conditions on which some crops such as Chardonnay wine grapes depend (Figure 9). Decreased coastal fog could also lead to higher agricultural demand for water in those areas.

Figure 9: White wine grapes require cooler temperature and thus are more commonly found along the coast, while red wines thrive in the hotter, inland regions of SLO County (Photo: Wikimedia Commons).

Farmers' ability to deal with these climatic changes depends on a number of factors. They reflect their exposure to climatic changes, their sensitivity to those changes, and their adaptive capacity, including:
- location (e.g., distance to coast, exposure, soils)
- types and diversity of crops grown and/or cattle raised
- current farming practices (e.g., soil and water conservation practices, organic vs. conventional farming) and willingness and ability to change these practices
- access to water resources, wells, and water rights
- financial resources to invest in technologies such as irrigation, cooling and farm equipment required for growing new or different crops
- dependence on income solely from farming vs. several income sources
- access to flood and drought insurance
- participation in farming cooperatives
- access to and use of climate-related information for advance planning, and
- market-, policy-related, or legal constraints on farming.

In general, smaller farmers with fewer financial, technological, and water resources, and farmers with fewer or less flexible response options, limited crop diversity, fewer risk sharing opportunities, and greater dependence on farm income tend to be more vulnerable to climate change. In 2002, over 54% of farmers in the county owned 50 acres or less. Just over 25% owned 180 acres or more.

The county's agricultural sector exhibits existing sensitivity to two main types of climate-related disturbances: water shortage drought and high temperatures. In October 2008, the USDA granted the County a disaster designation for losses caused by that year's drought and the extremely high temperatures experienced in June 2008, which allowed farmers and ranchers (with family-sized farming operations) to apply for emergency loans with low interest rates to cover losses that directly resulted from the designated disaster. Below, we highlight the most sensitive aspects of the agricultural sector in more detail.

Grapes

The quality of wine grapes in particular depends on certain climatic conditions, especially temperature, moderated by cool fog in summer months along the coast. Those areas are preferable for varieties such as Chardonnay (mainly in the southern wine regions), whereas inland areas grow varieties such as Cabernet Franc, Cabernet Sauvignon, and Zinfandel (they make up 80% of grapes grown in the region around Paso Robles).

Research to date is inconclusive whether yields of wine grapes will decrease or increase from changing seasonal temperatures. While reduced yields are a concern, the changing temperature patterns from climate change may have more considerable negative impacts on the all-important wine quality. The possible reduction in wine quality could have a greater economic impact than yields in coastal counties where high-quality wines are highly prized. Different wine varieties could be grown that are better suited to the future climate, and the economic impact depends on the alternative varieties grown. Recent growing seasons are indicative of the industry's vulnerability to changing conditions: The value of wine grape production in the county declined by 12% between 2007 and 2008 for climate-related reasons.

Cattle

Figure 10: Cattle health and reproductive success are sensitive to heat, while pasture land is sensitive to reduction in rainfall, CO_2 fertilization, a longer growing season and invasives. (Photo: USDA).

Cattle is a critically important component of the agricultural sector in San Luis Obispo County, with annual sales of more than $50 million. Climate change poses direct threats to this industry through heat extremes and higher demands on water resources, but also through changes to forage. Cattle are at heightened risk of mortality from increased temperatures and possible decreases in reproductive success (Figure 10). To avoid these risks, farmers can choose a variety of ways to keep cattle cool, ranging from manual hosing off to increased shading and air conditioning, although these adaptation options typically are labor intensive and/or require substantial economic resources (both for the initial investment and ongoing operating expenses).

Higher temperatures, lengthened growing season, invasive plant species, and the amount and timing of rains are among the key factors influencing the quality and quantity of forage. Statewide modeling studies suggest precipitation-driven declines of forage between 5% and 40% by the middle of the century, with resulting profit declines from livestock between $8 and $62 million. Inland areas of the county are among the hardest hit. The cattle industry of San Luis Obispo County has already experienced a recent decline due to low rainfall and water shortages, which reduced the available grass on pasture land. A statewide heat wave in 2006 and on-going drought resulted in a shortage of available grassland for cattle to forage. This shortage (along with high feed prices) forced cattle owners to sell calves 2-3 months early and under-weight. The below-average rainfall through 2008 continued to limit food and led to a substantial reduction in livestock industry in the county.

Fruits and Vegetables

Strawberry and vegetable crops will experience a lengthening growing season, increases in temperatures, the general drying trend and related risk of water shortages, as well as higher flood risks in alluvial valleys.

Crops grown in coastal areas will also be affected by sea-level rise driven land loss, flooding, and saltwater intrusion. Strawberries are among the most salt sensitive crops grown in California. A study conducted for the statewide climate impacts report for 2009 found that the county's strawberry yield may decrease by 10-15% by 2030-2050 due to climate change (Figure 11).

Figure 11. Strawberry varieties vary in their sensitivity to heat. Farmers may be able to switch to more heat-tolerant varieties as temperatures continue to increase. (Photo: NRCS)

Almonds and other nuts and fruits need a certain amount of winter chill hours, which are projected to decrease as the climate warms further. While chill requirements vary by variety, almonds require 100-500 chill hours, most peaches between 400-800 hours, and pistachios 600-1,500 hours. The higher these numbers, the greater the chance that the warming climate may restrict productive harvests. In addition, certain temperature ranges during particular months are critical for adequate development and ripening. Almonds, for example, are particularly sensitive to increases in nighttime temperatures; statewide yields of the no.1 perennial crop in California could decrease by about 10% by 2030, unless farmers adapt (e.g., by switching to less heat-sensitive varieties, or assisting in pollination success). Freestone peaches benefit from higher winter temperatures, but warming during the summer is extremely harmful.

Vegetable crops such as lettuce and broccoli prefer cool temperatures and may be particularly sensitive to increases in temperature, particularly early in the year. For example, the June 2008 heat wave reduced yields of many vegetable crops by 7%, highlighting existing sensitivities to extreme weather events that will likely increase with climate change. To buffer against these increases, farmers may choose to only grow these crops in the immediate coastal areas where cool ocean breezes and fog prevail, or switch to different crops. In addition to climate change impacts, other non-climate impacts such as fuel cost increases also have had a detrimental effect on crop growers.

Coastal and marine sectors

Fisheries, harbors and coastal tourism make up other important economies of the county. Although the commercial fishing landings and industry have recently declined (along with the other coastal fisheries in the nation), fishing still remains an economically and culturally important part of coastal San Luis Obispo County and could be significantly impacted by climate change.

Climate change will impact fish populations directly by warming ocean waters, changing currents (upwelling), affecting nutrient availability and the oceanic food web, and shifting habitats, and indirectly through impacts on fishing-related coastal infrastructure and inundation of critical nursery habitat (i.e., coastal wetlands). Changes in upwelling and higher ocean temperatures may negatively impact fish populations, but further research is necessary to understand how these factors impact species distributions and abundance, physical health, and food web interactions. In addition to food web and habitat changes, ocean acidification is expected to severely impact ocean and shellfish fisheries, as well as aquaculture (Figure 12).

Figure 12: Despite declining employment and landings, fishing remains an economically and culturally important part of coastal San Luis Obispo County. Climate change will affect fish populations, nursery habitats and coastal infrastructure for commercial and recreational fisheries. (Photo: Dwayne Oberhoff)

HARBOR INFRASTRUCTURE

Coastal storms can cause coastal flooding of low-lying areas (e.g., inundating economically important infrastructure such the harbors of Morro Bay and Port San Luis and related infrastructure). While there still is scientific uncertainty regarding changes in the frequency and intensity of coastal storms, a faster rate of sea-level rise will elevate the ocean baseline, leading to more frequent flooding and higher storm surges. The erosive impact of storms could also have severe impacts on coastal infrastructure and installations, thus requiring adaptive measures such as elevation, strengthening, flood protection, or relocation.

Tourism

Besides government, education and health care, tourism is the dominant economic service industry in San Luis Obispo County. Travel spending in 2007 was $1.21 billion. Tourism accounts for over 16,500 jobs (for the years 2001 to 2007). Many of the jobs are service-related and pay low wages considering the high cost of living in many of the coastal areas. Local government budgets depend heavily on tourism-related taxes, thus any potential declines in local tourism could have direct and indirect impacts on the regional economy.

The county's coastal tourism first and foremost relies on clean and beautiful beaches, scenic vistas and drives, and birds, wildlife and fish for recreational fishing, bird and whale watching and other activities. But tourism also requires critical infrastructure, services and establishments (e.g., coastal roads, hotels, restaurants, guided tours) to support the industry. Beaches will witness increased erosion and thus may require more frequent beach nourishment than has occurred in the county in the past, if physical conditions and economic cost-benefit analysis make such sand replenishment feasible.

Figure 13: Coastal vistas such as this from Morro Bay State Park attract visitors to San Luis Obispo and are essential to the region's quality of life and attractiveness. (Photo: Wikimedia Commons)

The county's agriculturally-based – i.e., largely wine-related – tourism may suffer if climate change causes large enough shifts in the industry to diminish its importance and impact on the landscape's character. Visitors' perceptions of reduced attractiveness of the region (e.g., eroded beaches, reduced fishing

opportunities, lower wine quality, wildfires) combined with broader, more remote socio-economic changes may be as or more important than the direct impacts from climate change.

Service employees in the tourism sector often earn relatively low wages, making them potentially more vulnerable to these changes and resulting in generally lower adaptive capacity than for better-earning individuals (see discussion above, Figure 13).

Supporting Infrastructure and Services

In support of people's daily life, well-being, safety, travel and participation in San Luis Obispo County's economic and recreational activities, the county provides a variety of infrastructure and community services. Many of them are susceptible to climate change, both directly and indirectly. First and foremost is the provision of the most essential resource for both urban and rural areas: water. In addition, we will discuss wastewater management, transportation, emergency preparedness and response systems, and energy.

Figure 14. The county largely depends on regional reservoirs and groundwater for its water supplies rather than the State Water Project. (Photo: Wikimedia Commons).

Water supply

Water supply shortages are a serious problem for many regions in the county and under the modeled climate change impacts these shortages are projected to get worse. Several areas in the county already experience summertime shortages (Figure 14). Some areas regularly borrow fresh water from emergency supplies that otherwise would remain on reserve for fighting fires. In addition, some communities rely on diminishing supplies of groundwater.

The State provides only a very limited amount of the county's water through the State Water Project. Instead, service sectors and communities rely on regional reservoirs and groundwater. Climate change projections summarized above suggest that the county will experience a longer dry summer season, and generally drying conditions, especially toward the end of the century (Figure 15).

Figure 15: Water supply shortages may be exacerbated by climate change (Photo: MS Word Clipart).

In addition, the region may see more severe rainfall events. Currently there is insufficient infrastructure to harness that momentary surplus of water. Higher temperatures, increasing wildfire risks, and continued population growth, suggest there will be a growing demand for water supplies while supplies are shrinking. The County has developed a master water plan to assess the existing infrastructure and improve the emergency preparedness for its water systems. Water needs to be managed in consideration of these climate change impacts, as well as to account for increased demands from higher population in coming years and likely increased demands from existing users as a reactive adaptive response

Table 2: County Water Sources and Supply-Related Challenges

City/town/area	Main water source	Current issues
Arroyo Grande	Lopez Lake (65%) and groundwater (35%)	Considering desalinization as additional water source for the future
Atascadero	Groundwater and underflow of Salinas River, Nacimiento project water (expected Summer 2010)	Unknown at time of report
Avila Beach	Lopez reservoir (41%) and State Water Project (59%)	Highest cost of water in the county
California Valley	Small isolated water systems	Water quality and lack interties with other water sources
Cambria	Groundwater	Limited groundwater supply has led to no new development permitted
Diablo Canyon Power Plant	Desalinization plant	Is not linked to any other fresh water source
Grover Beach	Lopez Lake and groundwater	Unknown at the time of report
Los Osos	Groundwater (Los Osos Valley Groundwater Basin)	Required to build sewage treatment plant; septic tank and saltwater intrusion into groundwater, threatening potable water supply; reduction in recharge
Morro Bay	Groundwater (Morro and El Chorro Creek underflows), State Water Project, and desalinated sea water	High cost of water
Nipomo	Groundwater	Complete dependency on groundwater; water shortage; saltwater intrusion
Oceano	Lopez Reservoir, groundwater, and State Water project.	Unknown at the time of report
Paso Robles	Groundwater (Paso Robles Basin) and Nacimiento water project (expected Summer 2010)	Groundwater basin in state of rapid decline
Pismo Beach	Lopez Lake, State water project, groundwater (Santa Maria Groundwater Basin)	Unknown at the time of report
San Luis Obispo City	Santa Margarita Lake, Whale Rock Reservoir, Nacimiento project (expected Summer 2010), water recycle program	Unknown at the time of report
San Miguel	Groundwater from Paso Robles groundwater basin	Groundwater basin is in decline and population is expected to increase in the area
San Simeon	Groundwater	At the most critical level for several years and no additional water supplies are readily available; no additional development is expected in the foreseeable future. A development moratorium has been in place in 1991.
Shandon	Small isolated water systems, Nacimiento water project (expected Summer 2010)	Increasing agricultural demands (changed from dry farms to vineyards, may change to alfalfa); no alternative supplies; isolated water systems lack interties
Templeton	Majority from groundwater or underflow of Salinas river, but also recycled water, Nacimiento water project (expected Summer 2010)	May need new water supplies to keep up with growing demands

Sources: See Technical Report for full list of references

to higher temperatures). Most – if not all – areas in the county have frequent problems with water shortages already. Table 2 shows water supply regions and their current issues.

The entire north county inland (i.e., San Miguel, Paso Robles, Templeton, Atascadero, Shandon, Creston and Santa Margarita) relies on groundwater extraction. Some of these areas show signs of water shortage already, and lack of monitoring inhibits better planning for the future. Scientific study of the impacts of climate change on groundwater resources is very limited to date, but higher evaporation rates, more intense rainfall events that cause higher runoff rather than recharge, and increasing use by agriculture and residential users can be expected to result in negative impacts.

In addition to water shortages, reports for coastal areas across the state express concern for saltwater intrusion into water supplies due to sea-level rise. The county already experiences saltwater intrusion as a result of groundwater overpumping. Sea-level rise-driven saltwater intrusion into coastal aquifers with shallow water tables, such as Los Osos, will worsen this problem.

Wastewater

Climate change could impact wastewater treatment and infrastructure in two ways. First, as intense rainfall events are expected to increase, extreme runoff periods will also become more common. During such storms, the runoff could impede the proper functioning of the county's many onsite septic systems or overwhelm sewers and centralized sewage treatment plants. As a result untreated water with the full load of toxics and organic waste could enter streams and coastal waters. Second, while the Pacific Institute determined that no wastewater treatment plant will be affected by a 100-year flood after 55 inches of sea-level rise, leach fields and treatment ponds near the coast might be at flood risk. Such flooding could cause wastewater that is not completely treated to flow into coastal waters.

Transportation

The main transportation infrastructure of the county – its roads, airport, and railway – is in various ways susceptible to the impacts from climate change. Transportation routes in the county are exposed to several climate change impacts, including sea-level rise and related erosion and cliff failures, heat extremes, flooding/inundation, and increased wildfire and associated problems with soil erosion and landslides). Increased severity of storms could increase flooding of important transportation routes during intense rainfall and runoff events, by causing dam failure of reservoirs, or from coastal flooding. Increased severity of heat extremes may damage existing roadways and railways.

In the past wildfires have led to closures of important evacuation routes and climate change is projected to result in more fires in the region. Post-fire soil erosion and landslides can damage roadways and other infrastructure (e.g., culverts).

Transportation infrastructure is particularly sensitive to climate-related disasters. There are very few routes in and out of the county, and if one gets cut off due to fire, landslides, or flooding alternative evacuation routes need to be provided and communicated to the public.

The Pacific Institute estimated 28 miles of roads in the county (26% of which are highways, the highest proportion of highway at risk in any of California's counties) would be affected by sea-level rise. Areas of particular exposure to sea-level rise (and associated storms/waves) are Highway 1 and possibly 101 at Pismo Beach, and Highway 1 at Cayucos and several areas of the same highway in and north of Cambria and San Simeon. Several of the latter portions of highway are already vulnerable to flooding, but this would be exacerbated by sea-level rise unless the road is relocated.

One major obstacle for San Luis Obispo County's adaptation efforts for its transportation infrastructure is the fact that the county currently is not marked as one of the state's priority regions for infrastructure protection from climate change impacts.

While this non-priority status means that the county's transportation infrastructure is not as vulnerable to climate change impacts as other regions in California, it could have major implications in terms of receiving State funding and other support for adaptation of this infrastructure.

Emergency Preparedness and Services

Well functioning emergency planning, preparedness, and services are critical in times of disaster such as floods, fires, or earthquakes. Climate change is likely to lead to an increase in the number of climate-related disasters, increasing the demand for emergency services. Over time, this implies a need for increasing budgets and contingency planning to continue to be able to respond effectively.

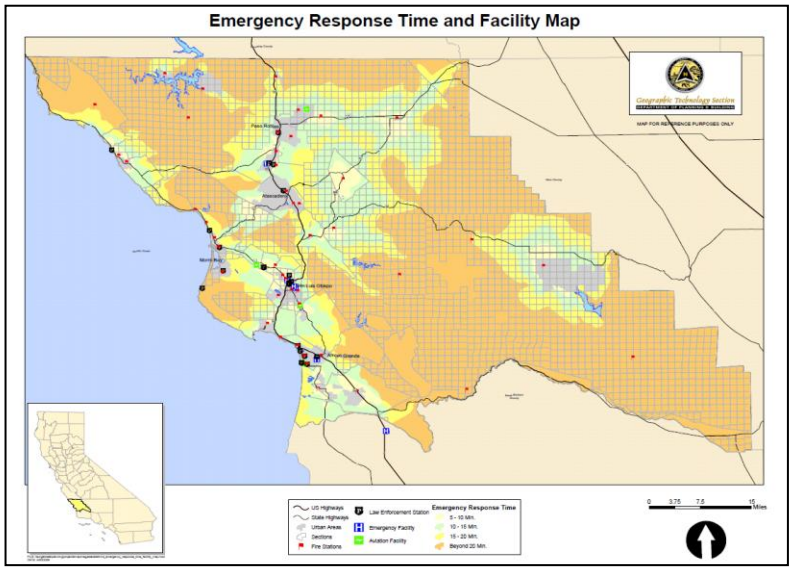

Figure 16: San Luis Obispo County emergency response time and facility map shows slower response time to more remote/rural areas of the county (Source: SLO County Planning Department).

The current emergency response time and facilities across the county have been mapped (Figure 16); the map shows that response time is fast for highly populated regions yet over 20 minutes in the more isolated rural regions, creating geographic differences in response capacities and thus in vulnerability. Big institutions such as Cal Poly and the state hospital have their own (albeit coordinated) emergency response plans.

Preparedness for Natural Disasters

Flooding and Levee Failure

Climate change is projected to intensify the hydrological cycle and thus lead to an increase in intense downpours in California, even if the overall amount of precipitation changes little or only slightly toward the end of the century. Historically, flooding in the county has been the direct result of high rainfall events. While this is currently considered a medium hazard risk based on the county's 2005 risk assessment, climate change will likely increase the vulnerability if it increases the severity of such events.

The San Luis Obispo County Dam and Levee Failure Evacuation Plan describes the existing flood vulnerabilities from potential dam breaks. Even without more refined climate projections for rainfall in the region, statewide studies anticipate more extreme/severe rainfall from storms; therefore, management could expect an increased risk of dam breaks. There are two potential dam ruptures that would have major impact to life and property, according to the County's Evacuation Plan: Lopez Dam and Salinas Dam. In addition, the report notes specifically that the Santa Maria River Levee is not likely to withstand a 100-year flood. Given that Santa Barbara County is responsible for the levee, this flood risk raises the need for San Luis Obispo County to work with neighboring counties in order to develop adaptation strategies that adequately protect county residents.

Landslides

Landslides often follow heavy rains, especially in areas previously affected by forest fires and in mountainous terrain where the soil is exposed. Given that both wildfires and the severity of heavy rains may increase with climate change, landslide risks may also increase with climate change. Figure 17 below shows the degree of landslide risk based on current conditions. Those areas that are red or orange are areas at especially high risk (exposure). The map suggests that major sections of Highway 1, 101, 41, 46, and 166 (the latter runs along the southern edge of county) are in high landslide risk zones, thus affecting transportation infrastructure, major traffic arteries, and the county's emergency response capability.

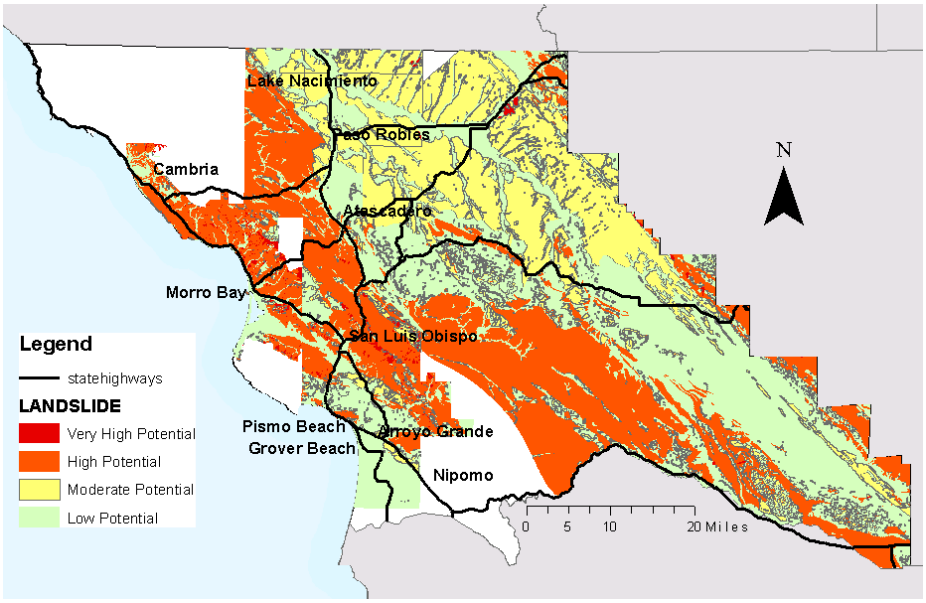

Figure 17: Landslide risk across San Luis Obispo County (Source: San Luis Obispo County, Dept. of Planning and Building 2001).

Wildfire

Wildfires are a hazard of major concern in the county given that the region is "one of the worst fire environments in the State of California for large damaging wildfires." The risk of fires is highest in the late summer and fall, making this the historical "fire season." Not only do wildfires require a large amount of financial, water and human resources to fight (Figure 18), they also put ecosystems, their services, and important infrastructure at risk. The Highway 41 Fire in 1994, for example, shut down two major highways, caused power outages, and destroyed radio and TV communication towers, cutting off communication to residents, and even hampering some fire fighting communication.

Wildfires can cause harm to people, housing, commercial and industrial structures, and agriculture (burning crops, harming soil and water). According to State maps showing fire hazard severity zones, San Luis Obispo County has several high hazard zones along the coast and in inland mountain ranges, while the northwestern part of the county and some southern portions experience no to low fire hazards. Most of the areas designated as very high severity hazard for fire are in the Santa Lucia Mountains and also include the region surrounding Atascadero. These areas combine risk factors such as high vegetation fuel, topography (steep slopes make fires burn faster), and human proximity. Interestingly, fire stations are unevenly distributed across the county, and some high-hazard fire areas have no or only very few fire stations.

Projections show that climate change will increase the frequency and size of wildfires in the western United States in general and in many regions across California. The county's existing vulnerabilities to wildfires thus will likely be exacerbated by climate change by increasing the length of the dry summer and fire season, and related changes in

vegetation. As pines are replaced by oaks and grassland, for example, fire is likely to speed the conversion. Confounding factors that increase vulnerabilities of certain areas (such as the City of San Luis Obispo) include the following:

- Urban areas are taking water stored away for fire emergencies to use in residential areas (see water supply discussion above).
- Some areas have longer response times than others, including Diablo Canyon, which includes critical electrical grid infrastructure surrounded by dense vegetation.
- Population growth in the county could increase ignition risks and make fuel conditions more dangerous.

Figure 18: Wildfire is projected to increase in SLO County as temperatures increase, extremely hot days become more frequent, and the vegetation and soils dry out more readily. (Photo: U.S. Forest Service)

By contrast, some areas in the county have demonstrated lower risk to wildfires than others based on their microclimate (the coastal region tends to be cooler with more moisture, creating lower risk), lower density of development, and type of vegetation.

The county already takes a number of steps to reduce its vulnerability to fire, but wildfires are inevitable in the region given its exposure and sensitivity derived from the climate, topography, and vegetation. Wildfire is also a vital component of the county's natural ecosystems. Strategies for preparing for increasing fires in the future are presented in the County's Local Mitigation Hazard Plan: communities should design buffer zones surrounding areas to reduce fuel adjacent to high population centers, provide sufficient emergency water supply (although this presents a critically limiting factor as climate change continues); and build and remodel existing structures to be more fire resistant. Prescribed burning that supports natural systems while preventing catastrophic fire is another important tool.

Energy: Nuclear Power Plant and Electricity Transmission

Energy-related infrastructure is another important lifeline for the county. Maybe the foremost interest and importance is the Diablo Canyon Nuclear Power Plant (Figure 20). It is located directly along the shoreline and uses seawater intake for cooling. While highly fortified by seawalls, the facility itself and the infrastructure upon which it depends is directly exposed to the onslaught from coastal storms, flooding, and erosion, which will be exacerbated by sea-level rise. Thus, the facility will need to examine its preparedness and protection.

Figure 19: The Diablo Nuclear Power plant is directly exposed to the onslaught from coastal storms, flooding and erosion, which will be exacerbated by sea-level rise. (Photo: Wikimedia Commons)

Conclusions

Climate change will impact San Luis Obispo in a variety of ways, some potentially severe, with direct impacts on its people, economic sectors, its supporting infrastructure and services, as well as the natural environment on which much of the county's economy, rural character, and quality of life depends. The impacts to these sectors will differ based on current and future vulnerabilities to weather- and climate-related changes and extreme events in San Luis Obispo County. This report revealed the following critical vulnerabilities:

- Differential social vulnerabilities, with the elderly, infants, socially and culturally isolated individuals, and outdoor workers – especially in the hotter inland areas – experiencing relatively greater exposure, sensitivity and/or lower adaptive capacity.
- Social vulnerabilities vary with regard to different climate-related hazards. A growing and aging population will exacerbate the challenges, while economic prosperity and well-functioning social networks could reduce these vulnerabilities.
- Several institutionalized populations are of special concern due to their location in flood, landslide and fire risk zones (college, prison), and the challenge of evacuating large numbers of people in short periods.
- Important regional agriculture – particularly wine and cattle – through its dependence on scarce water resources and sensitivity to heat is highly vulnerable to climate change, especially smaller farmers, with less diverse crops and limited resources.
- Coastal residents along eroding beaches and cliffs and in low-lying areas are particularly vulnerable to sea-level rise and related hazards such as flooding, erosion and cliff failure. While many coastal residents are wealthy, many are also elderly and depend on coastal transportation (and evacuation) routes that are at risk from multiple climate-sensitive hazards (erosion, flooding, wildfires, and landslides).
- Crucial supporting infrastructure and services will experience greater demands or challenges as climate change-related risks grow, including for already scarce water supplies, transportation and energy infrastructure, and emergency preparedness and services.

Clearly, the county faces many challenges, albeit surmountable ones with timely and adequate planning and preparation. While difficult choices will need to be made, City and County governments are in the advantageous position of beginning their adaptation efforts early. Adaptation efforts carefully vetted against other policy goals, including greenhouse gas mitigation efforts, pose an important opportunity to move San Luis Obispo County toward greater long-term environmental, social, and economic sustainability.

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