

CLIMATE VULNERABILITY: AN INITIAL ASSESSMENT
for the
UNIVERSITY OF CALIFORNIA, BERKELEY

UC Berkeley Office of Sustainability Climate Readiness Institute The Green Initiative Fund
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Executive Summary

In 2007, the University of California, Berkeley published its first Climate Action Plan. The CalCAP Feasibility Study recommended the campus reduce greenhouse gas (GHG) emissions to 1990 levels by 2014, a goal that was reached in 2012. Recently, the University has expanded its efforts to include adaptation planning. Adaptation planning addresses how a system or population adjusts to climate change. The typical first step in the adaptation planning process is to conduct a climate vulnerability assessment.¹

This is UC Berkeley's first report to analyze how climate change will impact critical infrastructure and campus populations. It is also the first assessment of its kind for an institution in the UC system and will hopefully serve as a model for future efforts. Most climate vulnerability assessments that have been conducted to date are reliant on Census or World data to determine social vulnerability, which has limited applicability to universities. Additionally, universities often rely on a mix of on-campus and off-campus services for transportation, utilities, and critical services. These factors combined reveal a gap in the literature for a climate vulnerability assessment tool specific to universities. A climate change vulnerability tool specific to the needs of universities is proposed.

Section II outlines key climate change projections for the Berkeley region. The four climate change impacts discussed are: 1) temperature increases and heat waves 2) flooding and sea level rise 3) drought and precipitation and 4) wildfire. These were chosen due to the anticipated impacts that they will have to campus and the information published to date. Table 1 summarizes the key projections.

Table 1. Summary of Key Climate Change Projections

Climate Change Impact	Projection
Temperature & Heat Waves	<ul style="list-style-type: none">Increasing temperaturesIncreased frequency, duration, and intensity of extreme heat events
Flooding & Sea Level Rise	<ul style="list-style-type: none">Increased high sea level occurrencesIncreased flooding eventsGradual increase in sea level
Drought & Precipitation	<ul style="list-style-type: none">Increase in duration, frequency, and intensity of severe storm eventsImpacts of Sierra precipitation falling as rain rather than snow
Wildfire Risk	<ul style="list-style-type: none">Increase in conditions that result in wildfire risk

¹ (John Agard et al., 2014)

Section III examines how climate change will impact critical infrastructure. This section looks at: transportation, utility infrastructure and waste management, and emergency response and critical services. Table 2 summarizes the key findings for each of these sectors.

Table 2. Summary of Key Findings of Critical Infrastructure

Critical Infrastructure	Key Findings
Transportation	Storm surges and flooding are expected to significantly impact both road infrastructure and the public transportation networks in the area. These will cause disruption in the near term, whereas sea level rise and permanent inundation are primary concerns in the long-term.
Utility Infrastructure and Waste Management	Climate change could increase energy demand, decrease water supply, lead to overheating of existing data infrastructure, and increase flooding risk for the campus waste transfer station. PG&E and EBMUD are the main suppliers for campus electricity and water, and each have conducted their own vulnerability assessments. An area for further research would be a comprehensive assessment of the steam tunnels and data networks on campus.
Emergency Response and Critical Services	UC Berkeley has an extensive Emergency Response Operations plan. The designated Emergency Support Functions will assist campus in responding to any increase in weather-related disasters due to climate change.

Section IV addresses social vulnerability to climate change. A brief analysis is conducted with an established social vulnerability index which suggests that student populations are more vulnerable than the general population: there are high percentages of populations that qualify as below poverty, unemployed, and living in high density group quarters without access to a personal vehicle. While these characteristics may increase vulnerability, they have been developed with the general population in mind and do not account for the unique needs and characteristics of students. Therefore, additional metrics, including campus commuting behavior, residential distribution estimates, and UC Berkeley social services are discussed as important considerations for university sensitivity and adaptive capacity.

Section V outlines a general tool for universities to use when conducting a climate vulnerability assessment. A detailed table is presented with metrics to consider, with ratings assigned to each quantifying the level of difficulty in gathering the information.

Effective assessment of climate change vulnerability can minimize risk and maximize the positive impacts universities can have in leadership, capacity building, and offering of social services. This report is a key first step in adaptation planning for the University of California, Berkeley.

I. Introduction

IA. Moving from Mitigation to Adaptation

In 2007, the University of California, Berkeley published its first Climate Action Plan. The CalCAP Feasibility Study recommended the campus reduce greenhouse gas (GHG) emissions to 1990 levels by 2014, a goal that was reached in 2012. Since 2008, the University has published annual reports that assess ongoing efforts and GHG milestones. The University has a number of climate commitments and has worked to progress towards its updated goal of achieving carbon neutrality for building energy and fleet vehicle emissions by 2025. This area of climate change policy falls under the broader category of mitigation. Climate change mitigation can be defined as any action that decreases and/or avoids GHG emissions.²

Recently, the University has expanded its efforts to include adaptation planning. Adaptation planning addresses how a system or population adjusts to climate change.³ Climate vulnerability assessments are typically the first step in the adaptation planning process and this initial report serves to inform more in-depth vulnerability analysis in the coming years. Subsequent steps often include an adaptation plan, implementation, and monitoring and assessment (see Figure 1). Importantly, adaptation plans address long-term climate changes (such as sea level rise) as well as increased frequency in severe weather events in the short-term (such as heat waves). Effective monitoring reassesses the plans as the climate change science evolves and projections are updated with new research and modeling techniques.

Figure 1. Typical Climate Change Adaptation Planning Process



City and state agencies in California are increasingly focused on climate adaptation planning.⁴ California's first Climate Change Adaptation Strategy was published in 2009. In recent years, efforts in California have expanded from statewide reports to more local and detailed assessments. Senate Bill 379 (2015) requires the safety elements of general plans or local hazard mitigation plans to include climate adaptation and resiliency strategies. These plans must include: 1) a climate vulnerability assessment 2) adaptation and resilience goals and policies and 3)

² (John Agard et al., 2014)

³ (John Agard et al., 2014)

⁴ There are a number of resources for local governments and agencies to refer to when conducting their assessment. Main examples for reference in California and the U.S. include: The California Climate Adaptation Planning Guide (a four-part guide published in 2012, and the ICLEI-Local Governments for Sustainability Preparing for Climate Change: A Guidebook for Local, Regional and State Governments (2007). (California Energy Management Agency & California Natural Resources Agency, 2012) & (Snover et al., 2007)

feasible implementation measures.⁵ The City of Berkeley became one of the first cities in the state to incorporate climate change impacts in their Hazard Mitigation Plan in 2014.⁶

Universities are beginning to implement adaptation planning and are often coordinating with municipality and county efforts. Cornell University was one of the first in the country to include adaptation planning with the publication of its 2013 Climate Action Plan, which specifically called for a vulnerability assessment and coordinated efforts with the County's Hazard Mitigation Plan.⁷ Harvard University established a Climate Preparedness Working Group tasked with writing a vulnerability assessment, policies and standards, and identifying synergies with other agencies and institutions. MIT, Harvard, and the city of Cambridge, MA have partnered together to form the Cambridge Compact for a Sustainable Future to coordinate efforts. California State University is beginning adaptation efforts and hosted a symposium on "Climate Adaptation and Resilience Planning for Campuses" in 2016. As of 2017, 10 universities throughout California have committed to the Second Nature Climate Commitment program, which requires carbon neutrality goals and resiliency planning.⁸

This is UC Berkeley's first report to analyze how climate change will impact critical infrastructure and campus populations. It is also the first assessment of its kind for an institution in the UC system and will hopefully serve as a model for future efforts. Most climate vulnerability assessments that have been conducted to date are reliant on Census or World data to determine social vulnerability, which has limited applicability to universities. Furthermore, universities are often dependent on both on-campus and off-campus critical services. This report proposes a climate change vulnerability tool specific to universities.

The report is organized as follows:

- 1. Climate Change Projections for Berkeley:** What climate change impacts is campus exposed to? What areas of campus are most exposed to these impacts? This section looks at the following climate change-related risks and findings from recently completed reports:
 - a. Temperature Increases and Heat Waves
 - b. Flooding and Sea Level Rise
 - c. Drought and Precipitation
 - d. Wildfire
- 2. Climate Change Impacts on Critical Infrastructure:** What impacts will climate change have on critical infrastructure? Specifically, how will climate change impact:

⁵ (Jackson, 2015)

⁶ Other cities/counties in California that have completed comprehensive climate vulnerability assessments include the City of Long Beach (Aquarium of the Pacific (AOP), 2015), the City of Pacific Grove (EMC Planning Group Inc, 2015), Santa Clara County (County of Santa Clara Office of Sustainability, 2015). Several cities have also conducted studies focused on specific vulnerabilities, such as Santa Barbara's sea level rise vulnerability study (Gary Griggs & Nicole L. Russell, 2012).

⁷ (Cornell University, 2013)

⁸ (Elizabeth Chapin, 2016) & (Second Nature Inc, n.d.)

transportation, utility and waste infrastructure, emergency and critical services? The discussion draws from recently completed assessments by transportation and utility agencies as well as UC Berkeley's Office of Emergency Management.

3. **Social Vulnerability to Climate Change:** Who on campus may be the most vulnerable? What social services and educational functions must be considered to minimize institutional vulnerability to climate change? Established social vulnerability metrics are used to evaluate a census tract with campus residence halls. The limitations of these metrics are discussed and additional considerations are offered.
4. **Tool for Universities to Assess Vulnerability to Climate Change:** A specific framework is proposed to assist universities as they begin efforts to assess vulnerability to climate change.

While the need for a vulnerability study is an unfortunate reality, the importance of proactive planning is immeasurable. UC Berkeley is in a unique position to effectively minimize risk for students, faculty, and staff and to become a leader in climate change adaption planning.

IB. Analysis Framework

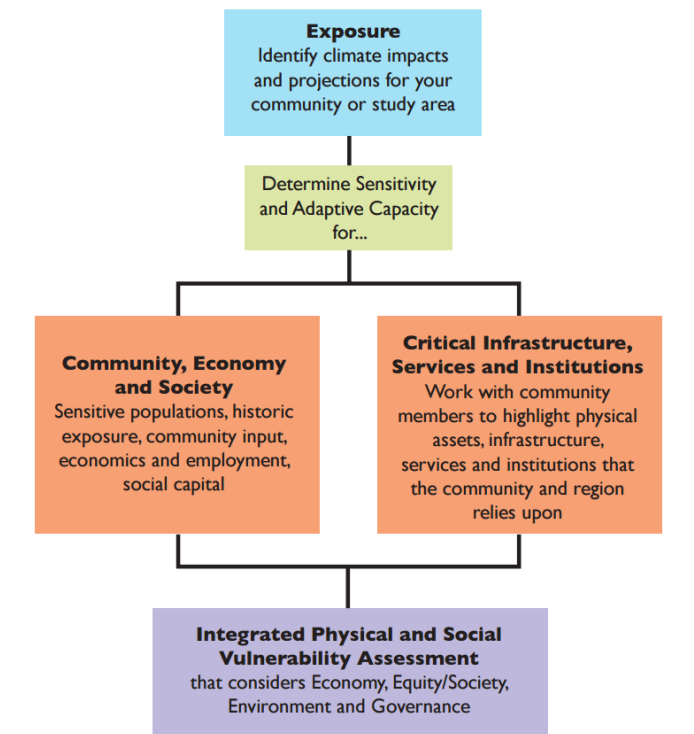
Vulnerability is the intersection of a number of different fields including climate change, risk management, governance, hazard mitigation, economic development, community organization, public health, equity, displacement, resiliency, and infrastructure. The Fifth Assessment Report by the International Panel on Climate Change (IPCC) defines vulnerability as:

VULNERABILITY:

“The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt” (International Panel on Climate Change, 2014)

There is an established structure for vulnerability assessments, as outlined in Figure 2. Assessments typically begin with an exposure analysis that identifies climate change projections for the study area (Section II of this report). This is followed by an evaluation of how these impacts will affect UC Berkeley's critical infrastructure (Section III) and campus populations and social services (Section IV). Vulnerability assessments often include a sensitivity analysis and adaptive capacity analysis. Sensitivity analysis identifies the temporal and spatial extent of the impact, its permanence, and the level of disruption to infrastructure and populations. Adaptive capacity analysis considers the ability for structures and/or populations to cope with the impact.

Figure 2. Framework for Integrated Vulnerability Assessment



Source: Heidi Nutters, 2012

There are qualitative and quantitative methods to conduct these analyses. To assess sensitivity for utility infrastructure, models using specific climate change scenarios can predict supply and demand. Surveys that ask about organizations' leadership ability, flexibility, and coping mechanisms can be used to understand an institution's adaptive capacity. GIS mapping that overlays climate change projections with infrastructure and/or populations can identify geographies of greatest concern. Social vulnerability indices typically use publicly available data to measure the intersection of a multitude of factors that influence risk and capacity and allow for comparison between geographies. Methodology is typically reliant on access to information. The UN has categorized different evaluation methods as top-down methods, which include climate change modeling and projections that require high capacity and access to effective data, and bottom-up methods that build upon the knowledge of existing communities and local institutions to develop adaptation strategies.⁹ There is no singular way to assess vulnerability to climate change and it is important to use a variety of methods in order to minimize research gaps.

The methods in this report include: synthesis of recently completed assessments, five semi-structured interviews, online climate change modeling tools, and the Center for Disease Control's Social Vulnerability Index.¹⁰ In addition, the limitations of existing social vulnerability assessments are discussed and a new tool is suggested specific to University student populations. A significant

⁹ (United Nations Framework Convention on Climate Change, 2007)

¹⁰ (Center for Disease Control, 2014)

amount of the information was provided by the Adapting to Rising Tides project, a federally-funded research endeavor led by the Bay Conservation and Development Commission (BCDC) to understand how sea level rise and flooding will impact major infrastructure in the East Bay. Findings from the City of Berkeley hazard mitigation plan (2014) and the Third California Climate Change Assessment (2012), which included a number of supplemental studies focused on the Bay Area, were also particularly adaptable to UC Berkeley. In addition to reports, information was gathered through expert interviews with the City of Berkeley, EBMUD, climate adaptation planning leaders, and climate scientists. Mapping was conducted using FEMA's flood hazard platform¹¹ and Cal-ADAPT was used to understand climate change projections.¹² Cal-ADAPT is an online tool developed by UC Berkeley's Geospatial Innovation Facility that projects climate change impacts to specified geographies (more detail on this in Section II). Recent state legislation requires that cities use Cal-Adapt to plan for climate change adaptation and risk management.

The vulnerabilities that are discussed were chosen due to the anticipated impacts that they will have to campus and the information published to date. The four climate change impacts discussed in Section II are: 1) temperature increases and heat waves 2) flooding and sea level rise 3) drought and precipitation and 4) wildfire. These impacts do not comprise the totality of how climate change will affect UC Berkeley and it is important to recognize that there are still considerable unknowns, in particular unknowns related to the extent of the impact, when severe risks will occur, and the effect of interaction between impacts. Social vulnerability is analyzed independent of the risk but chronic long-lasting impacts will likely affect populations differently than one-time events. Economic and food sector vulnerabilities are outside the scope of this analysis. As research evolves, it will be necessary to update this document with the most up to date climate change projections and vulnerability measurement tools to ensure effective response management.

This assessment is meant to inform future adaptation strategies and campus planning efforts and should not be construed as recommending any specific strategies. There is extensive literature, particularly in the emergency management field, for how universities can establish effective response systems.¹³ There is also a field dedicated to incorporating resilience to climate change into the built environment. These areas are outside the scope of this analysis.

The primary geographic scope of this analysis includes the main campus in Berkeley, CA, the University Village in Albany, CA which houses mostly graduate students and families, the Richmond campus, a 130-acre campus located west of Interstate 580, and the Lawrence Berkeley National Lab (see Figure 3). Clark Kerr (primarily used for undergraduate housing) is also highlighted on the map, but is incorporated with main campus analysis for purposes of this

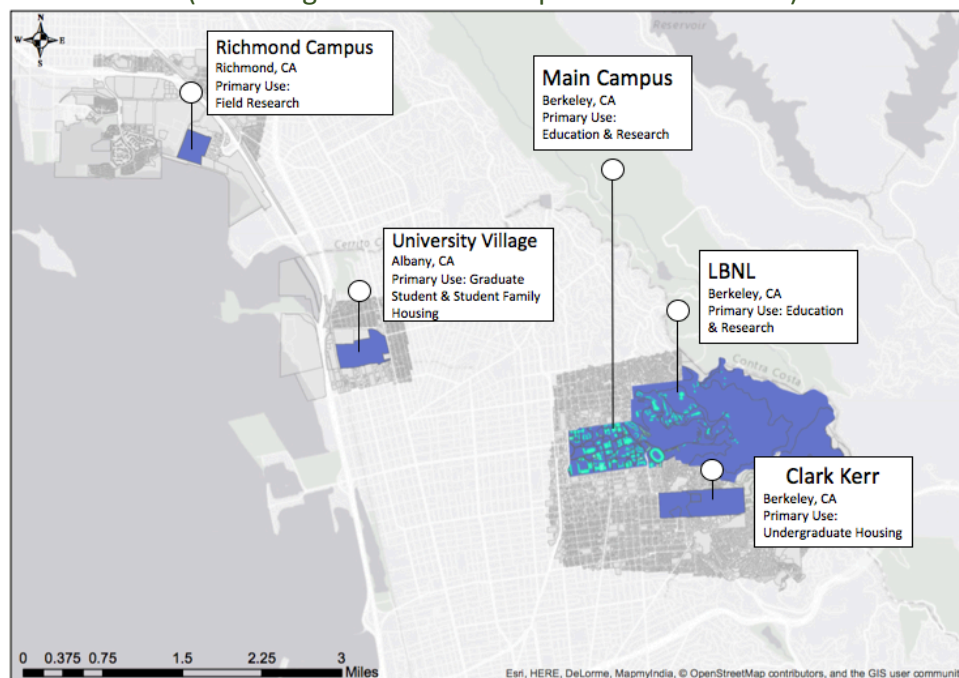
¹¹ FEMA maintains a web-based tool that identifies floodplains. The flood insurance rate maps (FIRM) are used in this report to highlight areas susceptible to flooding. (FEMA, 2017)

¹² (UC Berkeley Geospatial Innovation Facility, 2017)

¹³ (Jamie Lynn Auletta, 2012)

report. The geographic specificity of climate change impacts and understanding varies by risk and the information that is presented is dependent upon existing research.

Figure 3. Geographic Scope of Assessment
(Buildings on Main Campus Are Outlined)



IC. Opportunities and Challenges for Adaptation Planning at UC Berkeley

In order to plan effectively, it is important to consider both the opportunities and the challenges to developing and implementing adaptation policies at UC Berkeley (outlined in Table 3).¹⁴ Effective policies will leverage positive attributes and provide additional support in areas that may be more difficult.

Table 3. Opportunities & Challenges for Adaptation Planning at UC Berkeley

Opportunities	Challenges
+ Access to Resources	- Off Campus and Long-Term Behavioral Changes
+ High Control over Facilities & Infrastructure	- Aligning Priorities
+ Long-Term Planning Capacity	- Uncertain Funding Future
+ Engaged Community	- Unclear Governance Structures for Climate Change Impacts External to Campus
+ High Collaboration Potential	
+ Clear Geographic Boundaries	

¹⁴ Based in part on notes from the Climate Adaptation and Resilience Planning for Campuses Presentation presented by The California State University

Opportunities

Access to Resources

UC Berkeley is an internationally recognized university and research hub. Leading researchers are studying the science of climate change and the policies needed to address mitigation and adaptation. As campus develops strategies moving forward, it will be critical to engage with these resources.

Control over Campus Facilities & Campus Infrastructure

One division controls capital projects and maintenance and operations for the academic facilities on the UC Berkeley campus. Comprehensive strategies can be implemented for a large amount of space with a coordinated management team that has significant capacity and experience.

Long-Term Planning Capacity

UC Berkeley was founded in 1868 and has become a world-renowned institution of research and higher education. Its institutional status provides a unique ability to conduct long-term planning and to have more certainty over future land use and population size. While there are a number of external factors that affect growth such as funding and California's population trends, campus leadership plays an important role in defining objectives.

Engaged Community

The campus has an engaged community: there are over 1,200 student clubs and organizations.¹⁵ Nearly 50 of these clubs are environmental groups. A 2012 study of graduating seniors found that 38% spent at least 6 hours a week participating in campus clubs or organizations.¹⁶ Community engagement can lower vulnerability and support effective adaptation strategy development and execution.

High Collaboration Potential

As part of the wider University of California system, UC Berkeley has the opportunity to collaborate with other institutions and to make significant positive change throughout the state. Other schools in the system can use this vulnerability assessment as guidance when creating their own. UC Berkeley is an internationally recognized public institution and the successful planning and implementation of adaptation strategies can provide examples for other institutions and public agencies.

Clear & Compact Geographic Boundaries

While climate change impacts are not affected by political boundaries, response mechanisms can be more effective with clearly defined geographies. This decreases the variability of climate change impacts on the physical infrastructure of campus and simplifies risk prioritization.

¹⁵ (UC Regents, 2016).

¹⁶ (University of California, Berkeley, 2012)

Challenges

Off Campus Behavior

While campus has a high level of control for on campus operations, it is harder to gather information about and/or influence off campus behavior, such as how people commute. It is crucial to assess the vulnerabilities of the networks and services that faculty, staff, and students depend on throughout their day both on and off campus and incorporate these networks into strategies.

Transient Populations

The high proportion of transient populations (i.e. students) creates barriers to establishing long-term behavioral change and to disseminating information on what to do in case of an emergency. Student leadership in organizations and students' priorities can change significantly year to year. Implementing policies that encourage more adaptive behavior (such as walking or biking) might require extensive ongoing outreach and emergency response plans might need to be reiterated annually, as students graduate and new students join the community.

Aligning Priorities

The University administration balances many institutional priorities in both its short-term and long-term planning goals. Incorporating climate change is an additional stressor to consider potentially without additional resources.

Uncertain Funding Future

State appropriations to the UC System have declined significantly in recent decades. Nearly a quarter of University of California revenues came from state appropriations in 2000-2001, but that number was down to 10% as of 2014-2015 (UC Regents, 2015). The uncertain future of funding will be a significant challenge in creating long-term adaptation strategies.

Unclear Governance Structures for Climate Change Impacts

The geography, duration, and intensity of climate change impacts vary greatly. This makes it difficult to identify what agency or institution is responsible for implementing policies. As previously stated, UC Berkeley students, faculty, and staff are reliant on many networks outside campus borders. Effective response will require unprecedented levels of coordination between agencies and/or new structures of governance.

II. Climate Change Projections for Berkeley

This summary focuses on four key climate change projections: temperature increases and heat waves, sea level rise and flooding, drought and precipitation, and wildfires. These areas were chosen due to the risk that they pose to the UC Berkeley campus and to the extensive regional research that has been conducted on them. Each of these risks vary in the threat that they pose, in the certainty of the science, and in their temporal impact: some are permanent, others regularly recurring events, and others with unpredictable frequency. While these risks are discussed separately, it is important to note that they are strongly interrelated and impacts in one area could affect impacts of another. There are other climate change impacts not explored here and it will be important for campus management to continue to reassess priorities as the research develops.

The climate change science summarized here is dependent on the research that is available to date. Information is on varying geographic scales and it is necessary at times to apply studies from broader geographies to local issues. The Intergovernmental Panel on Climate Change (IPCC) publishes the leading research on climate change globally. The IPCC published the Fifth Assessment in 2014 and the next update is planned for 2022. The U.S. National Climate Assessment Report was last published in 2014. As mandated by Executive Order #S-03-05, California conducts periodic assessments of the impacts of climate change on the state. The Third California Climate Change Assessment (2012) focused on climate change vulnerabilities and opportunities for adaptation. A number of research studies were completed in conjunction with the report, including a synthesis of findings focused on the Bay Area.¹⁷ In 2015, the State published the Climate Change Research Plan for California to initiate efforts for the Fourth Climate Assessment. The research plan identified key areas in need of further research to ensure compliance with climate goals and it is expected that the Fourth Climate Assessment will include a set of 35 new research studies on key adaptation topics.

Local organizations and institutions have also conducted research and hazard mitigation planning for climate change impacts. The City of Berkeley became one of the first cities in California to incorporate climate change impacts in its hazard mitigation plan in 2014. The San Francisco Bay Conservation and Development Commission (BCDC) and NOAA's office for Coastal Management (NOAA OCM) coordinated local and regional agencies to launch the Adapting to Rising Tides Pilot Project, an effort to plan for flooding and sea level rise on the Alameda County shoreline. Campus functions rely upon a number of external infrastructure and organizations, including the East Bay Municipal Utility District (EBMUD) for water services, the Bay Area Regional Transit (BART) system for transportation, and the Pacific Gas & Electric Company (PG&E) for energy services. Each of these institutions are developing their own response plans to climate change impacts and the findings are discussed in Section III.

¹⁷ (Julia A. Ekstrom & Susanne C. Moser, 2012)

Cal-Adapt was used to assess climate change projections specific for the UC Berkeley geography when applicable. The University's Geospatial Innovation Facility developed Cal-Adapt, a website funded by the California Energy Commission's Public Interest Energy Research (PIER) Program that applies statewide information to local grids. Cal-Adapt 2.0 is in beta stage and provides information from more models at smaller geographies using Localized Constructed Analogs (LOCA), which incorporates historical data to add geographic-specificity to climate projections.¹⁸ The emissions scenarios in Cal-Adapt 2.0 are RCP 4.5, where CO2 emissions peak around 2040 and then decline (low emissions scenario) and RCP 8.5 where emissions plateau around 2100 (high emissions scenario). The grid used to download data from Cal-Adapt 2.0 is for main campus, unless otherwise specified.

IIA. Temperature Increases & Heat Waves

Temperature Increases & Heat Waves Key Findings

Models predict that temperatures will gradually rise in Berkeley and that heat waves will increase in duration, frequency, and intensity. Berkeley has a lower extreme heat day threshold than other areas in the state at around 88 degrees. However, even slight temperature increases could have public health and infrastructure impacts (explored further in Sections III and IV).

Detailed Findings

Temperature trends have varied for different regions in the Bay Area based on coastal proximity but the East Bay has had some of the most significant warming trends.¹⁹ Temperatures in the campus region are projected to increase in both a low emissions and high emissions scenario. The annual mean temperature for 1980-2005 was 66.9, whereas the projected annual mean temperature for 2070-2099 is 73.1 degrees Fahrenheit.²⁰ Figure 4 shows the annual average maximum temperature for the two emissions models.

The IPCC estimates that heat waves will increase in duration, frequency, and intensity.²¹ Cal-Adapt shows that the extreme heat day threshold for the UC Berkeley campus area is 88.3 degrees.²² Historically, the campus region has had an average of four extreme heat days annually. This number is expected to increase to an average 9 extreme heat days in a low emissions scenario or 16 in a high emissions scenario for years 2070-2099. This is a lower high heat threshold and heat wave projections than other areas in the state, such as Stockton, where the

¹⁸ To learn more about LOCA, visit: <http://journals.ametsoc.org/doi/abs/10.1175/JHM-D-14-0082.1> (Pierce, Cayan, & Thrasher, 2014)

¹⁹ (Julia A. Ekstrom & Susanne C. Moser, 2012)

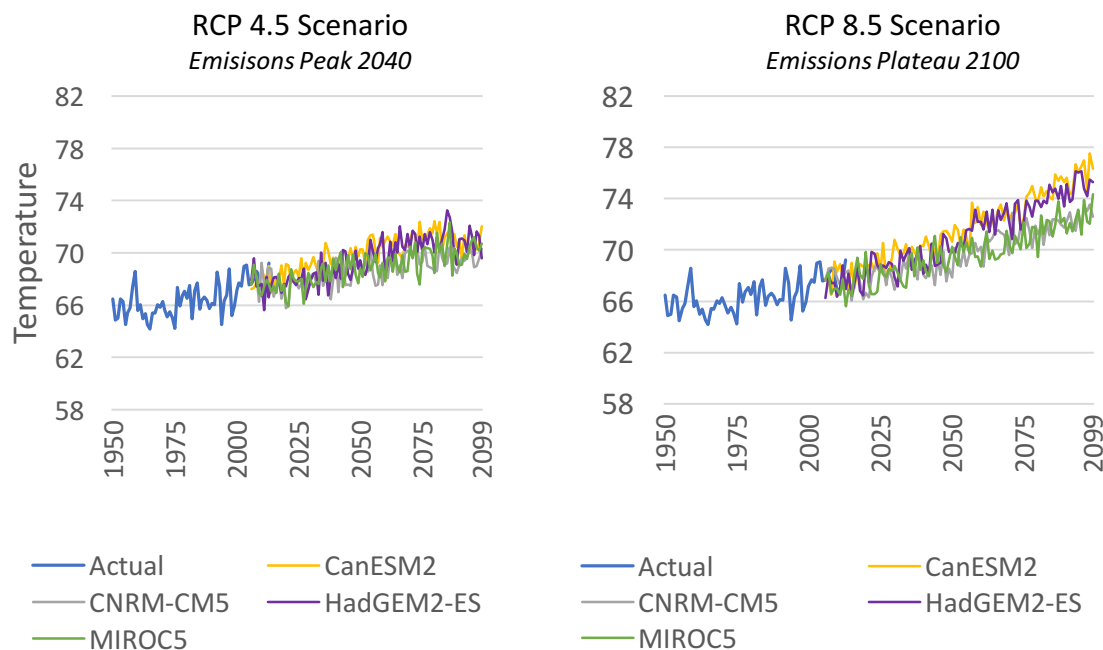
²⁰ (University of California at Berkeley Geospatial Innovation Facility, 2017)

²¹ (IPCC, 2007)

²² (University of California at Berkeley Geospatial Innovation Facility, 2017)

extreme heat threshold is 104 degrees, and the number of days could increase from an historical average of 4 to 24-40 days.²³

Figure 4. UC Berkeley Main Campus Region Annual Average Maximum Temperature Trends & Projections: 1950-2099



Source: Data from Cal-Adapt 2.0. California state agencies prioritized the above four emission models for research for the Fourth Assessment.²⁴

Increasing temperatures can have widespread impacts, which will be discussed further in Sections III (critical infrastructure impacts) and IV (impacts on populations). Increased heat puts pressure on electric demand and can cause infrastructure to fail due to various reasons, including transformers catching fire due to the inability to cool.²⁵ Heat waves can have major public health implications: the 2006 heat wave in California resulted in 650 deaths²⁶ and can affect people's ability to get to school or work. Additionally, warmer temperatures will impact precipitation (see below) and evaporation, affecting water supply, irrigation needs, and ecosystems. Research has found that the region may experience significant declines in native plant species and expansion of invasive species.²⁷

²³ (University of California at Berkeley Geospatial Innovation Facility, 2017)

²⁴ Cal-Adapt offers information on 10 of the 32 LOCA climate models. Four of the 10 are chosen as models for the Fourth Assessment. To learn more about these models and why they were chosen for California see: http://www.water.ca.gov/climatechange/docs/2015/Perspectives_Guidance_Climate_Change_Analysis.pdf (Climate Change Technical Advisory Group, 2015)

²⁵ (Miller, Hayhoe, Jin, & Auffhammer, 2008)

²⁶ (Heat Adaptation Workgroup, 2013)

²⁷ (Julia A. Ekstrom & Susanne C. Moser, 2012)

IIB. Sea Level Rise & Flooding

SEA LEVEL RISE & FLOODING KEY FINDINGS

It is anticipated that there will be a gradual increase in sea level, with increased high sea level occurrences and flooding events occurring in the more immediate future.

Detailed Findings

Sea levels have been increasing: along the west coast, sea levels are rising at a rate of 19 centimeters per century. Globally, sea level gauges have monitored increased rates of sea level rise in recent years: the 20th century rise averaged 1.7 mm per year, while the IPCC concluded that the rate was 3.1mm per year from 1993-2003.²⁸ High sea level occurrences have increased over the past century, with a twenty-fold increase in occurrences of levels above the 99.99th percentile at the San Francisco tide gauge.²⁹ Due to ice-melting and thermal expansion, sea levels have been predicted to rise between 30 and 45 cm by 2050 compared to 2000 levels and between 0.9 m to 1.4 m by 2100 for the California coast.³⁰ A 2017 study that used a new model based on previous real storm events, found that the Bay Area will be significantly impacted by sea level rise. With 0 m in SLR, inundated areas amount to 161 square miles, with a sea level rise of 1.41 m, 246 square miles are inundated (see Figure 5).³¹ New guidance on sea level rise projections is expected to be issued in 2017 and it is anticipated that the projections for 2100 will significantly increase, primarily as the result of new research on ice sheet melting.

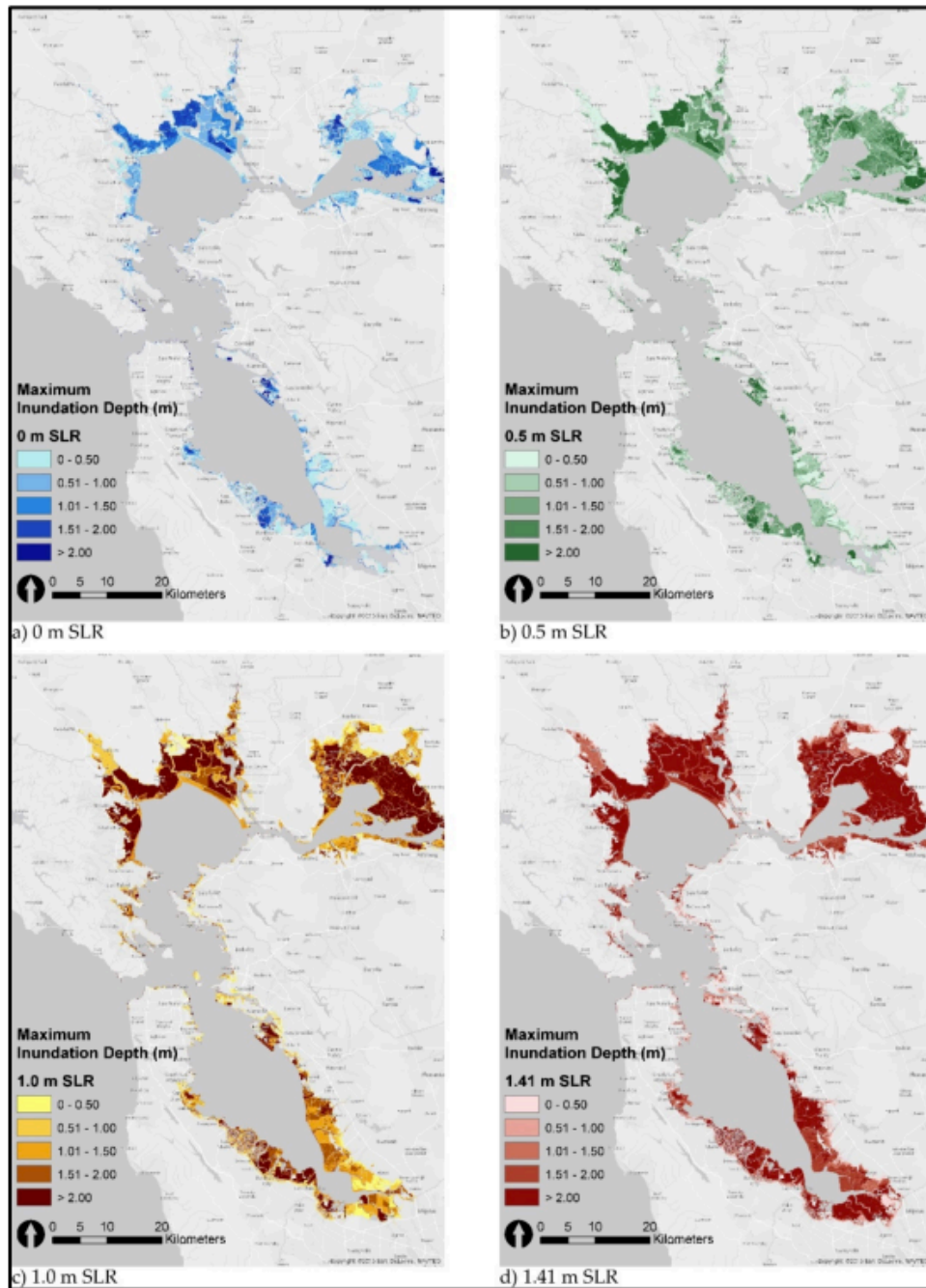
²⁸ (San Francisco Bay Conservation and Development Commission, 2011)

²⁹ (Cayan et al., 2008)

³⁰ (Dan Cayan, Mary Tyree, David Pierce, & Tapash Das, 2012)

³¹ (J.D. Radke et al., 2016)

Figure 5. Bay Area Sea Level Rise Scenarios

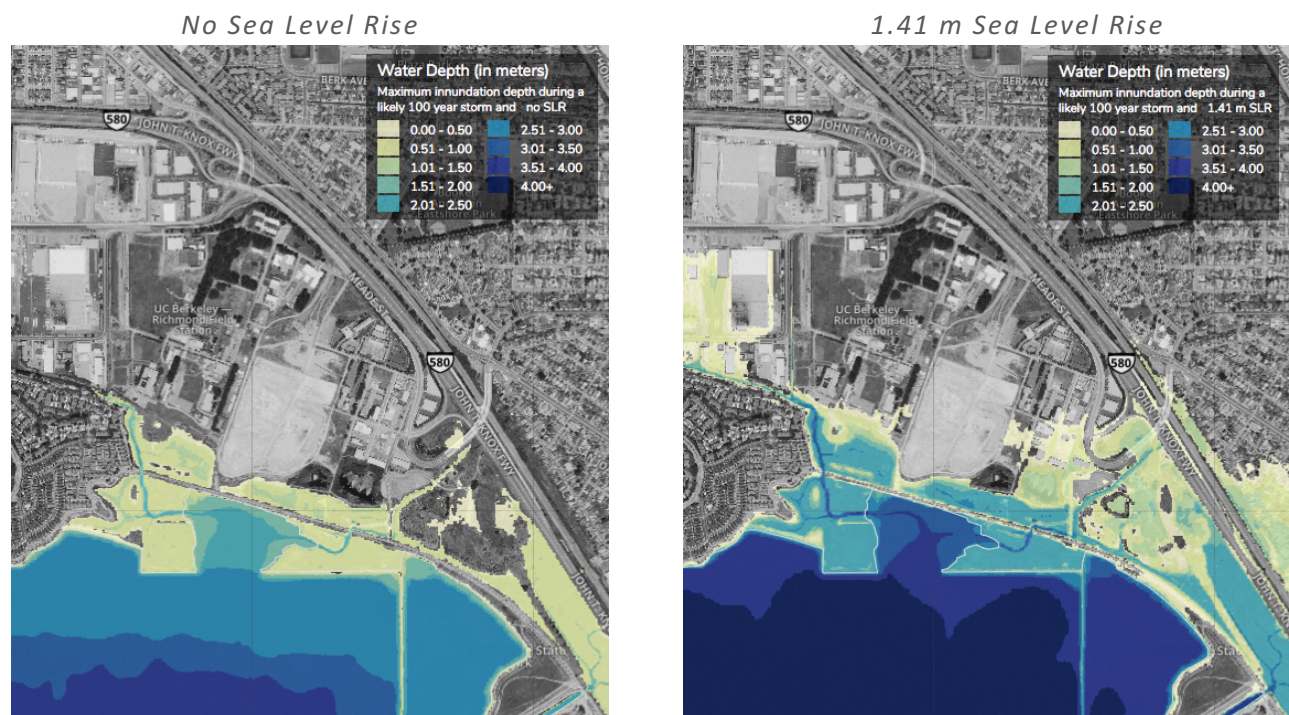


Inundation through $PWL_x = SLR_x + NESE_{100}$ (where $x = 0, 0.5, 1.0$ and $1.41m$)

Source: J.D. Radke et al., 2016

A slight increase in sea level rise could impact water drainage, increase overflow and runoff issues, and cause flooding and permanent inundation.³² Between 1950 and 2010, flooding from severe storms occurred an average 1.3 times per year and has been one of the most common disasters in the Berkeley area.³³ The expected increase in extreme high sea-level weather events and “atmospheric river events” (see below on Drought & Precipitation) will likely increase flooding occurrences. Sea level rise could impact Richmond Campus, which is low-lying alongside the Bay. The Richmond Campus has over 50 acres of tidal salt march and mudflats (Figure 6). Infrastructure that campus relies on, such as transportation, water supply, and treatment and waste management facilities, could also be impacted by sea level rise (see Section III).

Figure 6. Richmond Campus & Sea Level Rise Projections



Source: Data from Cal-Adapt 2.0.

For main campus and University Village, the concern will be overflow or runoff from streams during storm events. Strawberry Creek runs through main campus. It is partially culverted and partially daylighted (Figure 7).³⁴ After a flood in 1962 that resulted in an estimated \$100,000 in damages to main campus (or just over \$800,000 in current dollars), a number of measures have been taken to decrease flooding hazards with concrete and stone retaining walls, artificial

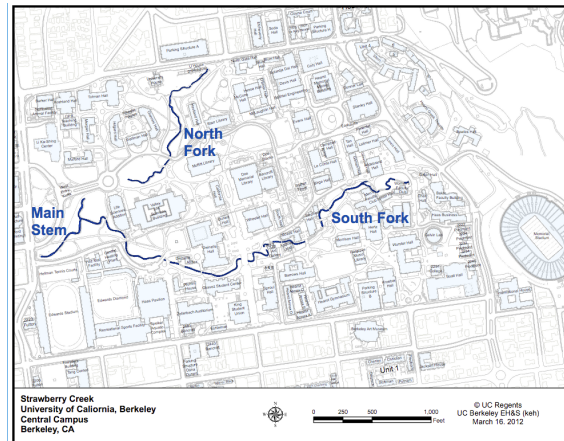
³² As defined by MTC: “‘Permanent inundation’ occurs when an area is exposed to regular daily tidal inundation. A permanently inundated area can no longer be used in the same way due to the frequency of its exposure to sea water...In contrast, ‘flooding’ occurs when an area is exposed to episodic, short duration inundation caused by storm events or extreme tide events of greater magnitude than normal tide levels...”; (Metropolitan Transportation Commission, Caltrans, San Francisco Bay Conservation and Development Commission, & BART, 2014)

³³ (Association of Bay Area Governors, 2010)

³⁴ (UC Regents, 2017)

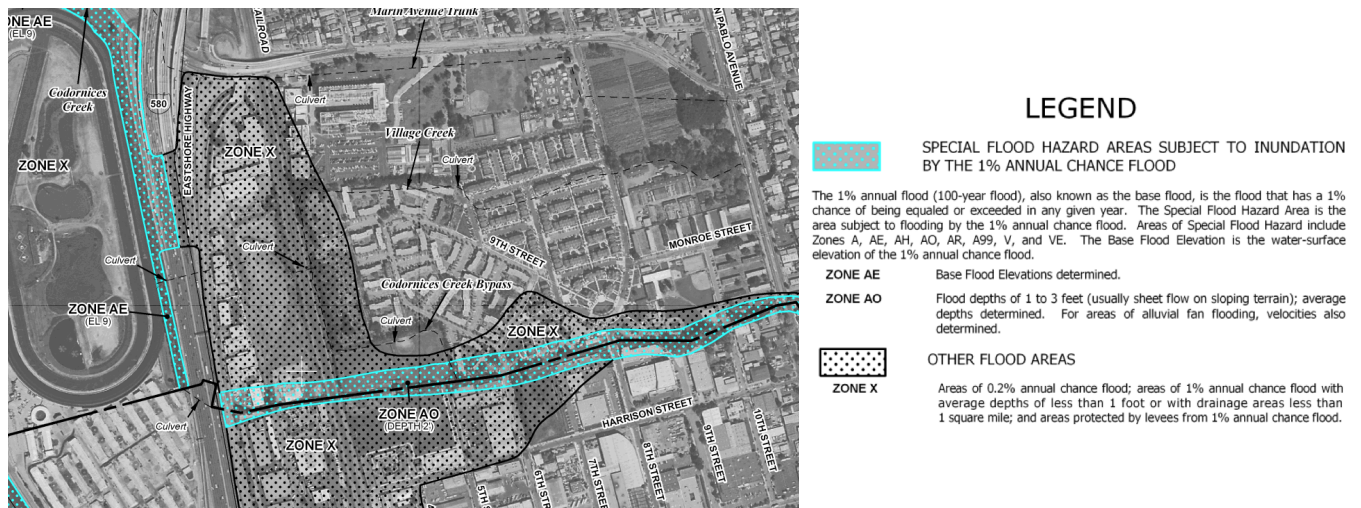
waterfalls and strategically placed logs.³⁵ The Federal Emergency Management Agency (FEMA) maintains publicly available Flood Insurance Rate Maps (FIRM) that show the floodplain boundaries for the probability of a flooding having a 1% annual chance of occurring (100-year flood) and a 0.2% annual chance of occurring (500-year flood).³⁶ Figure 8 shows the FIRM for the University Village in Albany, which was built on a marsh that drains to Codornices and Village Creek.³⁷ New construction for the site was approved in 2015.³⁸

Figure 7. Strawberry Creek through Main Campus



Source: University of California, Berkeley

Figure 8. University Village FEMA Flood Insurance Rate Map



Source: FEMA Flood Insurance Rate Maps

³⁵ (Steven Finacom, 1998)

³⁶ (FEMA, n.d.)

³⁷ (UC Regents, 2017)

³⁸ (Kate Williams, 2015)

IIC. Drought & Precipitation

DROUGHT AND PRECIPITATION KEY FINDINGS

Precipitation will increasingly fall as rain rather than snow and will increasingly occur during major storm events. One can look to the recent drought (2012-2016) and subsequent wettest year on record for northern California (2017) to understand the widespread impacts of extreme precipitation patterns.

Detailed Findings

On average, Bay Area precipitation is not expected to vary significantly with climate change.³⁹ Some estimates project a moderate increase: the average annual mean for 1980-2005 was 21.9 inches, and in RCP 4.5 the projected mean is around 25 inches for 2070-2099, and around 28 inches in RCP 8.5.⁴⁰ However, the main impacts relate to how precipitation will fall: 1) if it falls as snow or rain in the Sierra and 2) if it falls in major local storm events. Precipitation falling as rain rather than snow could reduce snowpack by 70 to 90 percent by 2100.⁴¹ This could impact water supply as nearly all of the City of Berkeley's water supply is provided from the Mokelumne River in the Sierra Nevada foothills. "Atmospheric rivers" are systems in the atmosphere that carry extreme moisture and supply 35-45% of the state's annual precipitation. It is projected that atmospheric river events will increase in both frequency and intensity with climate change.⁴² These events can lead to increased flooding and subsequent infrastructure issues.

Additionally, warmer temperatures will likely increase evapotranspiration rates and drought frequency could increase.⁴³ Periods of drought, decreased snowpack and earlier runoff, warmer temperatures, and longer summers, will all contribute to an increased reliance on groundwater. Increased reliance on groundwater requires significant investment in management of groundwater storage and recharge. Under average conditions, groundwater supplies nearly 40% of California's water needs.⁴⁴ This number increases during drought years, but overdraft comes with other challenges, such as land subsidence.⁴⁵ Sea level rise could also increase saltwater intrusion into groundwater reserves along the coast.⁴⁶

Recent events in the region can be looked to in order to better understand the impact of both extreme drought and precipitation. An increase in atmospheric river events contributed to 2017

³⁹ (Julia A. Ekstrom & Susanne C. Moser, 2012)

⁴⁰ (University of California at Berkeley Geospatial Innovation Facility, 2017)

⁴¹ (Sarah Lana, 2014)

⁴² (Julia A. Ekstrom & Susanne C. Moser, 2012)

⁴³ (Hayhoe et al., 2007)

⁴⁴ (California Department of Water Resources, 2015)

⁴⁵ A report completed by NASA after the most recent drought (2013-2015) found that parts of the San Joaquin Valley were sinking at unprecedented rates (with some areas sinking nearly two inches per month) NASA Jet Propulsion Laboratory, 2015)

⁴⁶ (Hoover, Odigie, Swarzenski, & Barnard, n.d.)

being the wettest year on record for northern California: there were roughly 30 atmospheric river events in the 2017 water year, compared to the usual dozen. Comparing 2017 to the second wettest year on record (1983), there is also a significant change in the amount that fell as snow.⁴⁷ In 2013, most of California had the lowest rates of precipitation on record. A “drought emergency” was declared and all 58 counties were federally designated as “natural disaster areas”.⁴⁸ The drought resulted in a statewide call to action for policies that reduce water use and improve groundwater management.⁴⁹ The State took actions to encourage groundwater supply management and continued water use reduction.⁵⁰ There have also been regional improvements in water management. In response to the 2013/2014 drought, the Bay Area’s largest water agencies worked together to form Bay Area Regional Reliability to enable exchange of water supplies during drought and emergencies.⁵¹

IID. Wildfire

WILDFIRE KEY FINDINGS

Climate change could increase wildfire risk as a result of warmer temperatures, longer summers, drought, vegetation changes, and possible wind pattern changes. However, since the region has experienced several significant fires in the past century, there has been significant investment into disaster management and wildfire prevention efforts.

Detailed Findings

Any increases in drought, higher temperatures, longer periods of warmer temperatures, and changes in wind pattern could affect wildfire risk in the Bay Area.⁵² Diablo winds, dry winds from the northeast, have historically been a major cause for fires in the East Bay hills and it is unclear how the frequency of these winds will change. However, it is projected that large wildfires in the state of California could more than double by 2100 and that the higher temperatures in the summer will lead to longer fire-risk seasons.⁵³ Studies that have analyzed the potential impact of climate change and growth scenarios on wildfires in the state have concluded that it is likely that there will be an increase in wildfire burned area, with an increase of 36% to 74% by 2085 in a

⁴⁷ In 1983, snowpack was 227% of normal, in 2017 it was 163% compared to normal. (Robert Monroe, 2017)

⁴⁸ (Stephanie C. Herring, Martin P. Hoerling, Thomas C. Peterson, & Peter A. Scott, 2014)

⁴⁹ State efforts to decrease water usage resulted in cumulative savings: between June 2015 and November 2016, water use savings were 22.6% compared to the same months in 2013. (George Kostyrko, 2017)

⁵⁰ Note the Sustainable Groundwater Management Act and Executive Order B-37-16

⁵¹ BARR includes EBMUD, the Marin Municipal Water District, The San Francisco Public Utilities Commission, the Santa Clara Valley Water District, Zone 7 Water Agency, and the Alameda County Water District (Bay Area Regional Reliability, n.d., Contra Costa Water District & East Bay Municipal Utility District, n.d.)

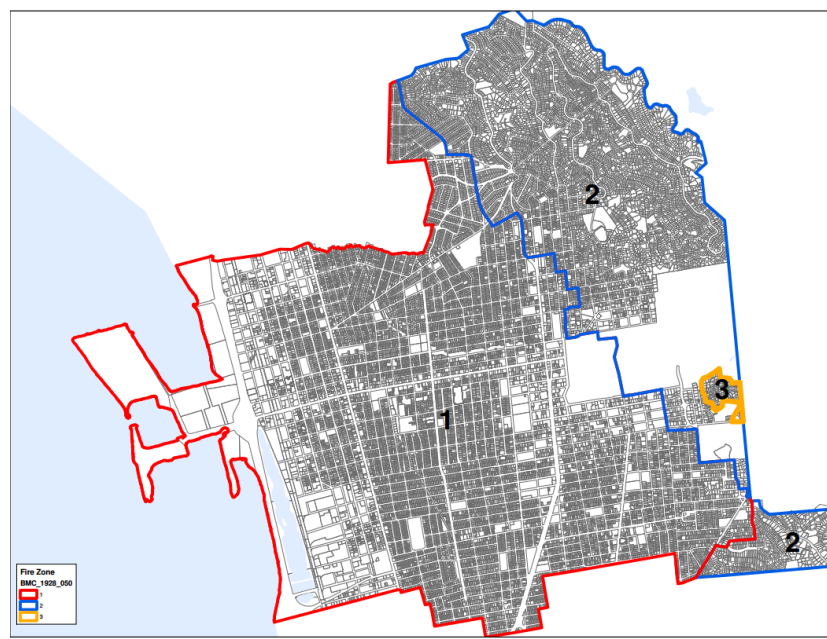
⁵² (Julia A. Ekstrom & Susanne C. Moser, 2012)

⁵³ (Sarah Lana, 2014)

high emissions scenario.⁵⁴ However, land use and development patterns affect the risk: it was found that if development is at a point of urbanization it can lower wildfire risk by eliminating vegetation, whereas development in areas that are less developed could increase vulnerability, exposure, and losses due to wildfire.⁵⁵

Part of main campus lies in Category 1 risk area (low risk), while part of it and the LBNL lie in Category 2 (see Figure 9). Changes in vegetation could affect risk. For example, an increase in invasive species such as the Eucalyptus, could increase wildfire risk. Campus originally received FEMA funding for a Hill Campus Fire Hazard Reduction Program which included grant money for Eucalyptus removal, trees which have been found to ignite spot fires. However, the program has been put on hold.⁵⁶

Figure 9. Fire Zones in Berkeley



Source: City of Berkeley

There have been several large fires in the UC Berkeley region over the last 100 years, resulting in extensive hazard mitigation planning and wildfire training for the area. The Tunnel Fire of 1991 in the Oakland and southeastern Berkeley hills was the most damaging wildfire in the state's records.⁵⁷ It destroyed 2,843 single-family dwellings and killed 25 people.⁵⁸ The fire was caused in part by a combination of high-risk conditions: a five-year drought, low humidity, and Diablo winds.⁵⁹ The other significant fire in the area was the 1923 Berkeley Fire, considered the 11th most damaging California wildfire. In 1970, Oakland had the Fish Ranch Road fire. All three fires

⁵⁴ (Westerling et al., 2011)

⁵⁵ (Westerling et al., 2011)

⁵⁶ (Alex Fang, 2016)

⁵⁷ (CalFire, 2016)

⁵⁸ (Donald R. Parker, 1992)

⁵⁹ (FEMA, 1991)

originated with similar conditions and were during times of Diablo winds. Berkeley also experienced a fire in Wildcat Canyon in 1980, although wind was not as strong a factor.⁶⁰

The Lawrence Berkeley National Laboratory (LBNL), which is managed by University of California on behalf of the United State Department of Energy (DOE), has conducted its own hazard mitigation planning. The lab has prepared a wildfire plan as mandated by federal DOE laws and has created an assessment of risks for the campus' assets. After the 1991 fire, the LBNL worked with other public entities to form the Hills Emergency Forum (HEF). The HEF is a collaboration between several agencies and cities including the City of Berkeley, Oakland, El Cerrito, the California Department of Forestry and Fire Protection, EBMUD and UC Berkeley. The campus also works with the Diablo Firesafe Council, which funds projects that reduce fire hazards.⁶¹

⁶⁰ (FEMA, 1991)

⁶¹ (Wildland Resource Management, 2014)

III. Climate Change Impacts on Critical Infrastructure

Section II summarized the most recent reports and models to understand some of the key climate change projections for Berkeley. This section explores how these climate change impacts will affect the critical infrastructure that is necessary for campus to operate. This section covers the following areas:

IIIA. TRANSPORTATION

IIIB. UTILITY INFRASTRUCTURE & WASTE MANAGEMENT

IIIC. EMERGENCY RESPONSE & CRITICAL SERVICES

IIIA. Transportation

TRANSPORTATION KEY FINDINGS

Storm surges and flooding are expected to significantly impact both road infrastructure and the public transportation networks in the area. These will cause disruption in the near term, whereas sea level rise and permanent inundation are primary concerns in the long-term.

Detailed Findings

Students, faculty, and staff rely on the road infrastructure and public transit networks to commute to campus (see Section III for more information on commute modes and areas of residence for campus populations). There have been a number of studies analyzing the impacts of climate change on transportation infrastructure in the Bay Area.⁶² The main climate change impacts to transportation networks are sea-level rise and storm surge, severe storms, increased precipitation, and increased temperature.⁶³ State and federal policies mandate that transportation agencies study the impacts of sea level rise and inundation, so the majority of research conducted to date is focused on these topics.⁶⁴ In 2011, Caltrans published “Guidance on Incorporating Sea Level Rise” to assist transportation agencies throughout the state in analyzing SLR impacts.⁶⁵ Since then, BART, Capitol Corridor, and the Metropolitan Transportation Commission (MTC) have all published reports dedicated to assessing climate change

⁶² Reports from: Capitol Corridor, Caltrans, MTC, BART

⁶³ (Greg S. Biging, John D. Radke, & Jun Hak Lee, 2012); Increased temperature can cause: “highway asphalt rutting, rail bucking, lack of ventilation on underground transit system, thermal expansion of bridges” (p. 8)

⁶⁴ California’s Executive Order S-13-08 (2008) required an assessment of “vulnerability of transportation systems to sea level rise”, and in 2011, the U.S. Department of Transportation directed agencies to “develop, prioritize, implement, and evaluate actions to moderate climate risks and protect critical infrastructure using the best available science and information.” (Governor Edmund G. Brown Jr., 2008); (US DOT FHWA, 2011)

⁶⁵ (Caltrans Climate Change Workgroup & HQ Divisions of Transportation Planning, Design, & Environmental Analysis, 2011)

vulnerability.⁶⁶ Findings from these reports for the transportation networks that students, faculty, and staff most heavily rely on are summarized below.

In 2011, Caltrans, BCDC and MTC compiled “Adapting to Rising Tides: Transportation Vulnerability and Risk Assessment Pilot Project”, a study piloting a risk assessment model developed by the Federal Highway Administration. Two sea level rise scenarios were analyzed for the Alameda shoreline: a high-end estimate of 16 inches by midcentury and a mid-range estimate for the high IPCC emissions scenario of 55 inches by the end of the century.⁶⁷ They ranked assets using exposure assessments (based on mapping the scenarios), sensitivity analyses (using age of facility, level of use, seismic retrofitting status, operating and maintenance costs, condition / remaining service life, liquefaction susceptibility, and foundation condition) and adaptive capacity scores (based on the level of service redundancy offered by other assets). After assessing vulnerability, assets were selected for risk assessment, which looked at the likelihood that a certain climate change impact would occur and the consequence to the region if inundation were to occur. Table 4 shows the key assets ranked with a “High Risk” rating.⁶⁸

Table 4. Asset Types with "High" Final Risk Rating

Code	Asset Category & Asset Types	Segments Chosen and Associated Future Projects	Final Risk Rating
Road Network (R)			
R-01	I-80 (includes part of I-580)	Powell Street to Bay Bridge Toll Plaza	High
R-02a	I-880	Oak St to 23rd Ave	High
R-02b	I-880	High St to 98th Ave	High
R-11	Posey Tube (SR 260) Webster St Tube (SR 61)	All, including approach ramps	High High
R-12	Bay Bridge (I-80)	From Toll Plaza until Alameda County boundary	High
T -01	BART Line 2a—Subgrade: Transbay Tube	Entire facility	High

Source: Metropolitan Transportation Commission, Caltrans, San Francisco Bay Conservation and Development Commission, & BART, 2014

In 2014, MTC led a Climate Adaptation Pilot Study funded by the Federal Highway Administration. This analysis built off the 2011 report with additional SLR inundation scenarios and with analysis of viable adaptation strategies for three case study areas.⁶⁹ Two of the case study areas could impact a number of Oakland and UC Berkeley commuters: the SF-Oakland Bay Bridge and the Oakland Coliseum Area.⁷⁰ The connection between I-880 from 7th street to the Toll Plaza on the Bay Bridge was a highlighted inundation area that has low adaptability due to lack of additional

⁶⁶ Capitol Corridor is not summarized here as it is not a top mode for UC Berkeley students, faculty, and staff. The report can be read at: http://www.adaptingtorisingtides.org/wp-content/uploads/2015/04/CCJPA-SLR-Vulnerability-Assessment_Final.pdf

⁶⁷ (Ashley Nguyen et al., 2011)

⁶⁸ (Ashley Nguyen et al., 2011)

⁶⁹ (Metropolitan Transportation Commission, Caltrans, San Francisco Bay Conservation and Development Commission, & BART, 2014)

⁷⁰ The report concluded that the best strategies were a living levee and offshore breakwater for the Bay Bridge, a slough and living level for the Coliseum Area, and a drainage study for Route 92.

capacity for alternative routes. In addition to looking at inundation and flooding exposure, the report assessed: informational vulnerability (challenges to obtaining the necessary information to address issues), governance vulnerability (barriers of management, funding, permitting that could prevent adaptation implementation), functional vulnerability (functional elements that impact adaptive capabilities), and physical vulnerability (physical characteristics that increase sensitivity to impact or limit ability to adapt).⁷¹

In 2013, BART published the San Francisco Bay Area Rapid Transit District (BART) Climate Change Adaptation Assessment Pilot as one of the Federal Transit Administration's (FTA) seven pilots to understand the impacts of climate change on public transit. The analysis looks at three main climate hazards: sea-level rise, flooding, and downpour. The agency chose to study assets along the East Bay coastline to build on existing research. The chosen assets were representative across BART's infrastructure so that the methodology and strategies could be adapted: a BART station (Lake Merritt), a track (Oakland west track portal), a power substation (Oakland Coliseum) and a control room (Fruitvale). It found an overall low adaptive capacity due to the difficulty of moving the facilities and high susceptibility to flooding due to below-ground facilities.⁷² BART is aiming to address these risks in part through the BART Facilities Standards, which require assets be designed with consideration for sea level rise, flooding, and heavy rain protection with varying levels dependent on the asset.⁷³

An oft-cited concern regarding BART resiliency is the singular Transbay tube under the Bay.⁷⁴ In the event that major climate events impact the tube, BART does not have redundant services, and as mentioned, the road network has limited additional capacity (particularly at the Toll Plaza). Efforts are underway to analyze how to increase capacity for Transbay commuting through ferry and bus services. There are also preliminary studies analyzing the feasibility of constructing a third Bay crossing to allow for redundancy and increased resiliency.⁷⁵

There is no study to date assessing the vulnerability of UC Berkeley parking garages, but it is important to consider that any low-lying or subterranean facilities may be particularly impacted by severe storm events.⁷⁶

⁷¹ (Metropolitan Transportation Commission, Caltrans, San Francisco Bay Conservation and Development Commission, & BART, 2014)

⁷² (BART, ARUP North America, & Parsons Brinckerhoff, 2013)

⁷³ (Metropolitan Transportation Commission, Caltrans, San Francisco Bay Conservation and Development Commission, & BART, 2014)

⁷⁴ (Matt Maloney, 2016)

⁷⁵ (UC Berkeley Transportation Studio, 2016); (Jeff Bellisario, Sean Randolph, Micah Weinberg, & Camila Mena, 2016); (Ratna Amin & Brian Stokle, 2016)
; (Joël Ramos & Clarrissa Cabansagan, 2017)

⁷⁶ A 2014 flooding event at University of California, Los Angeles caused by a water-main break, resulted in hundreds of cars trapped in parking garages and/or damaged due to flooding (Mark Mester & Christina Pascucci, 2014)

IIIB. Utility Infrastructure & Waste Management

UTILITY INFRASTRUCTURE & WASTE MANAGEMENT KEY FINDINGS:

Climate change could increase energy demand, decrease water supply, lead to overheating of existing data infrastructure and increase flooding risk for the campus waste transfer station. PG&E and EBMUD are the main suppliers for campus electricity and water, and each have conducted their own vulnerability assessments. An area for further research would be a comprehensive assessment of the steam tunnels and data networks on campus.

Detailed Findings

Campus utility and waste services are provided by both internal operations and external providers. The main external providers for energy and water are Pacific Gas & Electric (PG&E) and East Bay Municipal Utility District (EBMUD), respectively. A cogeneration plant northwest of the Haas Pavilion generates steam for heating, cooling, and lab equipment. The plant is owned and operated by a third-party. The steam is distributed through campus in underground tunnels. UC Berkeley owns and operates three auxiliary boilers that are turned on during times of high demand.⁷⁷ Campus operates a central data center, located in Earl Warren Hall on the northwest side of main campus. The University also manages its own waste, including landfilled waste, hazardous waste, composting, and recycling. There is no in-depth engineering assessment of how climate change will impact on-campus utility infrastructure. Particular vulnerabilities to consider include: the impact of heavy precipitation and flooding on low-lying or below-grade assets, transmission and distribution wiring and substations, pressures of increased demand, lab equipment failure, and risk of overheating during heat waves.

Pacific Gas & Electric (PG&E) provides natural gas for the cogeneration plant and electricity for the campus. PG&E conducted a climate vulnerability assessment in 2016, which analyzes the impacts of high tide and storm surges, heat waves, change in mean temperatures, drought, wildfire, and sea level rise on PG&E infrastructure. Warming temperatures and extended heat waves could increase electric demand, which could in turn put pressure on the grid, and increase the risk of blackouts and brownouts.⁷⁸ The risk of wildfire could increase with heat and drought and PG&E has incorporated fire management into operations and monitoring. Furthermore, drought will reduce hydroelectric generation and any decline in annual snow will impact state's reservoirs. PG&E has historically conserved water during the spring in reservoirs to use for hotter summer months and is working with the U.S. Geological Survey and the Department of Water

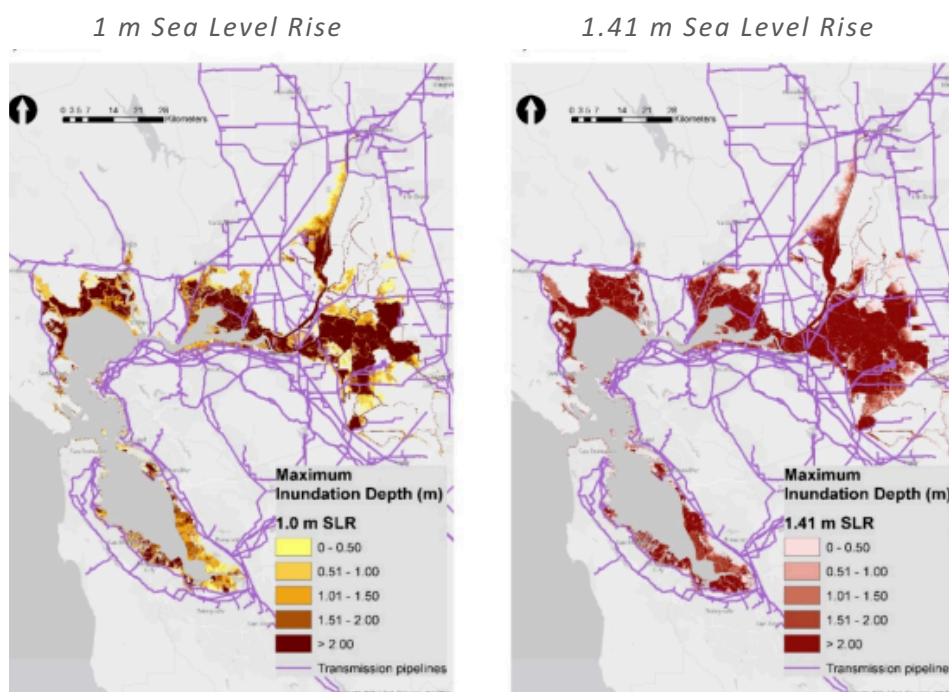
⁷⁷ (Angela Cheng, Emun Davoodi, Tiffany Deng, & Daniel Shen, 2012)

⁷⁸ Cal-Adapt was used to predict change in heat wave frequencies and number of extreme heat days; change in mean temperature estimates came from California's Third Climate Change Assessment; sea level rise forecasted was 24 inches for 2050, as provided by the CA Coastal Commission Sea Level Rise Guidance.

Resources to research and forecast impacts from climate change. Part of the strategy will include increased use of aquifers in northern California.⁷⁹

An assessment for California's natural gas transmission system was published in 2017.⁸⁰ A number of the state's pipelines are located along waterways, making them particularly susceptible to sea level rise and inundation. Increased frequency, duration, and/or depth of inundation as well as erosion and debris flows from storm surge might corrode or damage the pipelines and other elements of the transmission system such as pumps, compressor stations, and processing facilities. Increased hydrostatic load due to inundation might also cause infrastructure to buckle or crack. The assessment used real storm events to model inundation outcomes, allowing for existing flooding infrastructure (e.g. levees) to be taken into consideration when determining how a 100-year storm might affect infrastructure. In the Bay-Delta Pipeline, a sea level rise of 1.41 meters was found to result in inundation of 11.5% of the pipelines, half of which are PG&E gas pipelines (308 km of PG&E pipelines). The 1-meter and 1.41-meter SLR models with pipelines are shown below (Figure 10).

Figure 10. Bay-Delta Pipelines Affected by Sea Level Rise



Source: J.D. Radke et al., 2016

Research on how telecommunication, fiber optic lines, and data centers will be impacted by climate change is limited.⁸¹ Increases in temperature may result in equipment overheating, shorter equipment life spans, and health and safety risks to workers. Increased precipitation

⁷⁹ (Pacific Gas & Electric Company, 2016)

⁸⁰ (J.D. Radke et al., 2016)

⁸¹ (Peter Adams, Jennifer Steeves, Brian Ashe, John Firth, & Ben Rabb, 2014)

could lead to flooding of low-lying rooms or below-ground infrastructure storing equipment or conduits. Decreased precipitation and increased temperatures could increase fires. Generally, above ground infrastructure is vulnerable to extreme weather events.⁸²

Overall, power failures could increase due to warmer temperatures leading to increased cooling demands or equipment overheating, major weather events impacting power lines and other above-ground infrastructure, and inundation resulting in corrosion. Recent power outages demonstrate some of the effects of a brown- or black-out. In 2012, more than 20 buildings on campus experienced a 30-minute power outage due to an equipment malfunction.⁸³ In 2013, there was a campus wide outage as well as an explosion, caused by the failure of an electrical switch. Four people were injured, while at least 20 were stuck in elevators due to the outage. Students with mobility impairments were unable to leave buildings due to nonfunctioning elevators. The power failure seemed to have caused an ammonia leak in Latimer Hall, which required attention from the Berkeley Fire Department. Classes in affected buildings were canceled and lab operations were shut down; Cal Dining services were limited and some of the residence halls relied on backup generators. People were notified through the emergency text message system.⁸⁴ In 2015, a small fire in the Earl Warren Hall data center from a single overheated server triggered a campus wide network outage. The Berkeley Fire Department evacuated the building. There were no reported injuries. Within 24 hours, the data center was back up running but the University's Wi-Fi and CalNet took longer to come back online (everything was back up within a few days).⁸⁵

Campus water and wastewater services are provided by the East Bay Municipal Utility District (EBMUD). In 2008, EBMUD identified six areas of potential vulnerability to climate change: water supply, flood management, water demands, sea level rise, power generation, and water quality.⁸⁶ In 2014, EBMUD published an updated "Climate Change Monitoring and Response Plan" (the first report was completed in 2010). A sensitivity analysis was conducted to determine how increases in air temperature of 2 to 4°C would affect customer demands and the timing of runoff from the Mokelumne River as well as how 10-20% reductions in precipitation would reduce runoff. It was determined that reductions in carryover storage capacity could result in a "severe shortage of water".⁸⁷ Warmer climates were projected to increase water temperatures and demand, while flood control was projected to decrease with reductions in precipitation.

⁸² (Peter Adams, Jennifer Steeves, Brian Ashe, John Firth, & Ben Rabb, 2014)

⁸³ (Amruta Trivedi, 2012)

⁸⁴ (Megan Messerly & Jeremy Gordon, 2013); (Kimberly Veklerov, 2014), (Somin Park, 2013), (Sara Grossman, 2013)

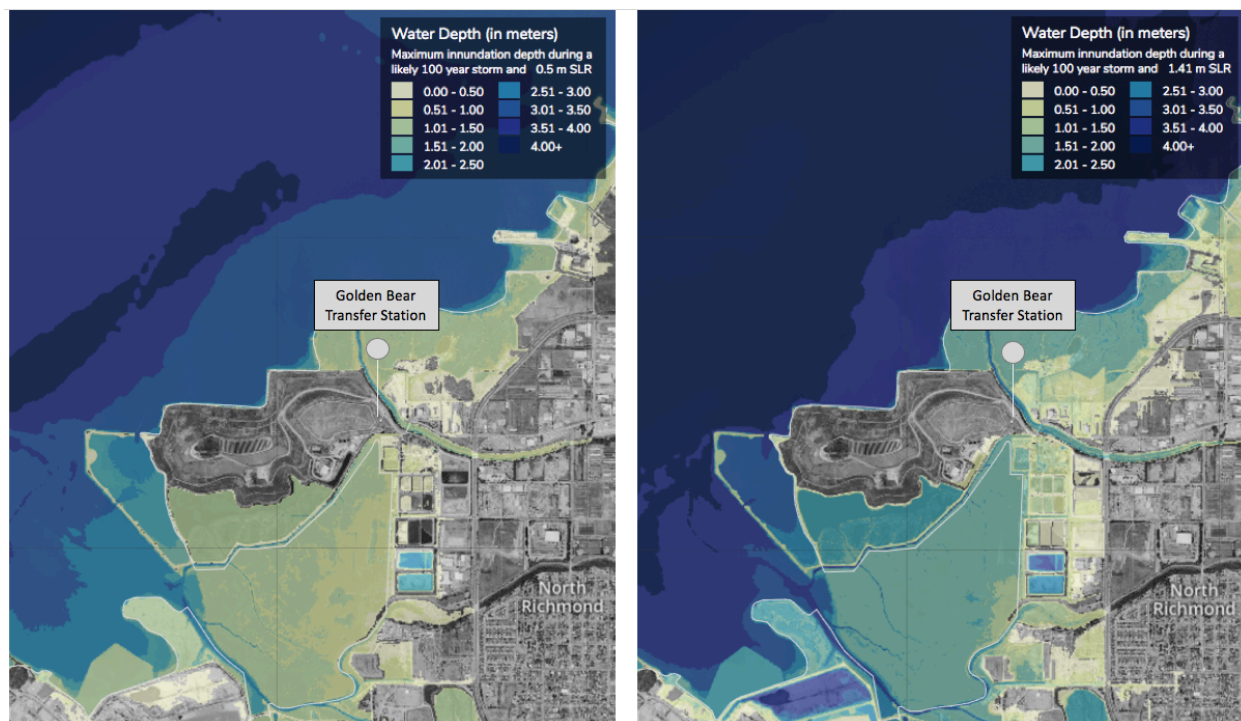
⁸⁵ (Lance Knobel, 2015), (Kimberly Nielsen, 2015)

⁸⁶ (EBMUD, 2017)

⁸⁷ Carryover storage is impacted by runoff occurring earlier as storage capacity will be used to address flood control in the winter limiting the runoff captured during the spring. In 70% of the analyzed years, carryover storage was reduced 12% for the 10% reduction in precipitation and 24% for the 20% reduction in precipitation. (EBMUD, 2017)

Campus waste goes to the Golden Bear Transfer Station and is then transported to Keller Landfill, located in Bay Point. Figure 11 shows how sea level rise might impact access to the Golden Bear Transfer Station with models of 0.5 m SLR and 1.41 m SLR. Environmental Health and Safety is responsible for handling campus hazardous waste. The primary hazardous waste facility is located on Frank Schlesinger Way near the campus steam plant where it is labeled and packaged. The hazardous material is then transported to different facilities to be treated depending on the type of waste. The Lawrence Berkeley National Lab has its own hazardous material facilities which is handled separately.

Figure 11. Golden Bear Transfer Station and Sea Level Rise Projections



Source: Cal-Adapt 2.0

IIIC. Emergency Response & Critical Services

EMERGENCY RESPONSE AND CRITICAL SERVICES KEY FINDINGS:

UC Berkeley has an extensive Emergency Response Operations plan. The designated Emergency Support Functions will assist campus in responding to any increase in weather-related disasters due to climate change.

Detailed Findings

UC Berkeley is reliant upon a number of critical services that operate both on and off campus. Off campus services include the Berkeley Fire Department, Oakland Fire and other fire agencies which respond to campus fire. Police matters are handled by the University of California Police

Department with cooperation with the City of Berkeley Police Department. On campus health and counseling services are provided by the Tang Center. The nearest emergency rooms external to campus are at Alta Bates and Summit Hospital.⁸⁸

In 2012, UC Berkeley increased efforts towards emergency response preparedness.⁸⁹ The UC Berkeley Office of Emergency Management developed a comprehensive Emergency Response Plan in 2014, which in part was built off lessons learned from the 2013 explosion. The Plan outlines four institutional response priorities:

1. Protection of Life Safety
2. Incident Stabilization
3. Property and Environment Preservation
4. Mission Continuity / Resumption⁹⁰

Campus is divided into 180 Emergency Management Areas, each with a designated emergency response location. Campus departments and units were grouped together into Emergency Support Functions (ESFs) to identify responders. There is a dedicated ESF for Infrastructure and Utilities, responsible for conducting assessments, overseeing repairs, managing debris removal, and restoring service.⁹¹ The Communications ESF is to provide and coordinate voice and data communications during emergencies, assess damage and/or restore communications and technology infrastructure (see Figure 12 for ESF teams).⁹² Campus also has a Crisis Communication Plan and alert system in place to reach students, faculty and staff.⁹³ The primary Emergency Operations Center is in Warren Hall.⁹⁴ Environmental Health & Safety within the Office of Emergency Management has worked to address biosafety for campus labs and has established a High Containment Lab Oversight Group. EH&S also develops trainings including for laboratory safety, and fire and life safety training.⁹⁵ Research facilities and certain departments on campus have often created their own plans to prepare for potential risks, such as the Lawrence Berkeley National Laboratory Wildland Fire Management Plan.

⁸⁸(University Health Services, 2017) For a full list of care centers in the area visit:

<https://uhs.berkeley.edu/medical/urgent-care/local-emergency-and-urgent-care-centers>

⁸⁹ (Somin Park, 2014)

⁹⁰ (Office of Emergency Management, 2014)

⁹¹ (Office of Emergency Management, 2014)

⁹² (Office of Emergency Management, 2014)

⁹³ (Office of Emergency Management, 2014)

⁹⁴ (Kathleen Tierney, 2014)

⁹⁵ (Office of Emergency Management, 2016)

Figure 12. Emergency Support Functions Overview

ESF #	ESF Name	Roles and Responsibilities	Coordinating Unit
1	Transportation	<ul style="list-style-type: none"> Manage the movement of people, materials, and resources Coordinate transportation resources, including mutual aid and private sector resources 	Parking and Transportation (P&T)
2	Communications	<ul style="list-style-type: none"> Ensure the provision and coordination of voice and data communications in support of response operations Facilitate the restoration of the communication infrastructure 	Information Services and Technology (IST)
3	Infrastructure and Utilities	<ul style="list-style-type: none"> Protect, assess, and restore critical campus infrastructure Coordinate debris management operations Assess, repair, and restore energy and utility infrastructure and coordinate restoration with utility providers 	Real Estate (RE)
4	Fire-Fighting	Provided externally by Berkeley Fire Department, Oakland Fire, and other responding agencies	N/A
5	Emergency Management	<ul style="list-style-type: none"> Coordinate activities to support preparedness Maintain, activate, and support the campus EOC Coordinate requests for off campus assistance 	Office of Emergency Management (OEM)
6	Mass Care and Sheltering	<ul style="list-style-type: none"> Coordinate emergency mass care operations, including feeding and sheltering Coordinate long-term housing needs 	Residential and Student Service Programs (RSSP)
7	Resource Management	<ul style="list-style-type: none"> Identify, procure, and coordinate resource identification Coordinate personnel augmentation Manage volunteer and donations <p>Note: Resource Management is coordinated through the EOC Logistics and Finance/Administration Sections</p>	Procurement Services
8	Public Health and Medical	<ul style="list-style-type: none"> Coordinate public health response Provide disaster medical triage Coordinate medical transport Provide mental health services Manage mass fatality response operations 	University Health Services (UHS)
9	Urban Search and Rescue	Provided externally by Berkeley Fire Department and other responding agencies.	N/A
10	Hazardous Materials	<ul style="list-style-type: none"> Coordinate hazardous materials response and cleanup 	Environment, Health & Safety (EH&S)
11	Animal Welfare	<ul style="list-style-type: none"> Coordinate animal and plant disease response Coordinate care of research animals and other sheltered animals 	Office of Laboratory Animal Care (OLAC)
12	Energy	Represented by ESF 3: Infrastructure and Utilities	N/A
13	Public Safety	<ul style="list-style-type: none"> Coordinate law enforcement activities Provide security in support of response operations Coordinate mass notification system operations 	University of California Police Department (UCPD)
14	Recovery	<ul style="list-style-type: none"> Coordinate campus recovery initiatives Coordinate construction and/or restoration of campus facilities. <p>Note: A Recovery Coordinating Unit will be assigned by the Crisis Management Team based on the nature of the emergency</p>	To be assigned by the CMT
15	Public Affairs	<ul style="list-style-type: none"> Provide emergency public information and protective actions guidance Coordinate media and community relations 	Public Affairs (PA)

Note: Support Units to each ESF will be determined when the respective ESF annex is completed. Appendix C includes potential support units for each ESF.

Source: Office of Emergency Management, 2016

IV. Social Vulnerability to Climate Change

This section explores how climate change impacts will affect the students, faculty, and staff on campus. It also identifies key social and institutional services that UC Berkeley provides to the community. It is organized as follows:

IVA. MEASURING SOCIAL VULNERABILITY

IVB. APPLICATION OF METRICS TO UC BERKELEY & LIMITATIONS

IVC. ADDITIONAL SOCIAL VULNERABILITY CONSIDERATIONS FOR UC BERKELEY

IVA. Measuring Social Vulnerability

Social vulnerability to climate change can be defined as “the interplay of social, economic and demographic characteristics that determine the resiliency of individuals and communities to climate change.”⁹⁶ Assessments often use a combination of Census metrics to determine sensitivity and adaptive capacity, and populations that are most at-risk are determined by mapping high sensitivity to low adaptive capacity (see Figure 13).⁹⁷

Figure 13. Sensitivity & Adaptive Capacity Matrix

		Sensitivity: Low → High			
		S1	S2	S3	S4
Adaptive Capacity: Low ↓ High	AC0	V3	V4	V5	V5
	AC1	V2	V3	V4	V5
	AC2	V1	V2	V3	V4
	AC3	V1	V1	V2	V3

Figure 1: Adapted ICLEI Vulnerability Assessment Matrix (source: Kleinfelder adapted from ICLEI))

Source: City of Cambridge & Kleinfelder, 2015

The complexity of social vulnerability makes it difficult to quantify and it has been the focus of research in many different fields.⁹⁸ In the disaster management / ecology / climate change field, two schools of thought developed in the 1970s and 1980s: 1) the behavioral paradigm and 2) the structuralist paradigm. The behavioral school of thought believed that failure to cope with major disasters was due to poor perception of risk, while the structuralist attributed vulnerability to social and economic conditions.⁹⁹ An example of this latter paradigm comes from a 1976 article

⁹⁶ (Cox, et al 2006) (Heidi Nutters, 2012)

⁹⁷ (City of Cambridge & Kleinfelder, 2015)

⁹⁸ (Moret, 2014)

⁹⁹ (Moret, 2014)

in Nature titled: “Taking the Naturalness out of Natural Disasters”, which noted that “Precautionary planning needs to be totally integrated into planning for real development, which means the necessary concentration on the vulnerability of a population to future disaster can only be done successfully through an understanding of the marginalization process.”¹⁰⁰ This structuralist school of thought has become more developed in recent years.

Research has found that people of color and low income populations will carry a disproportionate burden of the impact of climate change, referred to as the “climate gap”. There are many factors that contribute to this.¹⁰¹ Racial and ethnic minorities are more likely to live in poverty, ethnic communities often have lower access to jobs and services, and non-English speaking immigrants have greater vulnerability to disaster.¹⁰² Discrimination is often embedded into the built environment in ways that increase risk: for example, real estate discrimination can result in minority populations being confined to more hazardous areas.¹⁰³

There exists some literature dedicated to student population vulnerability in the field of emergency management, but it is limited. Existing studies have identified the following areas as particular vulnerabilities to consider for students: previous life and disaster experience, financial burdens, the psychological stresses of adjusting to college life, gaps in social networks, and cultural and language differences. These factors contribute to how students, as a population, may be more vulnerable in how they perceive risk, experience disaster impacts, and respond in the wake of a disaster. For example, limited life experience make it more likely that students have an imbedded optimism that makes them less aware of risk, lack of experience in a given region can lead to unawareness of particular threats or students feeling overly fearful, and limited finances can lower access to necessary resources in responding to emergency situations.¹⁰⁴

Metrics to quantify vulnerability however, have mostly been developed for the general population. The University of South Carolina Hazards and Vulnerability Research Institute created a commonly used standardized Social Vulnerability Index (SoVI®) methodology to address the intersection of vulnerable characteristics in a singular metric. First published in 2003, the authors note that: “socially created vulnerabilities are largely ignored, mainly due to the difficulty in quantifying them.”¹⁰⁵ The original SoVI® used 42 socioeconomic variables from US Census and County Data books combined into 11 independent factors.¹⁰⁶ In 2010, the index was updated to address the introduction of data from the American Community Survey (ACS) and new research. The updated index (SoVI® 2010-2014) uses 29 variables that combine into 8 components: 1) wealth, 2) race and social status, 3) elderly residents 4) Hispanic ethnicity and lack of health insurance 5) special needs populations 6) service sector employment 7) Native American populations and 8) gender.

¹⁰⁰ (Phil O’Keefe, Ken Westgate, & Ben Wisner, 1976)

¹⁰¹ (Rachel Morello-Frosch, Manuel Pastor, James Sadd, & Seth B. Shonkoff, 2009)

¹⁰² (Susan L. Cutter, Christopher T. Emrich, Jennifer J. Webb, & Daniel Morath, 2009)

¹⁰³ (Susan L. Cutter, Christopher T. Emrich, Jennifer J. Webb, & Daniel Morath, 2009)

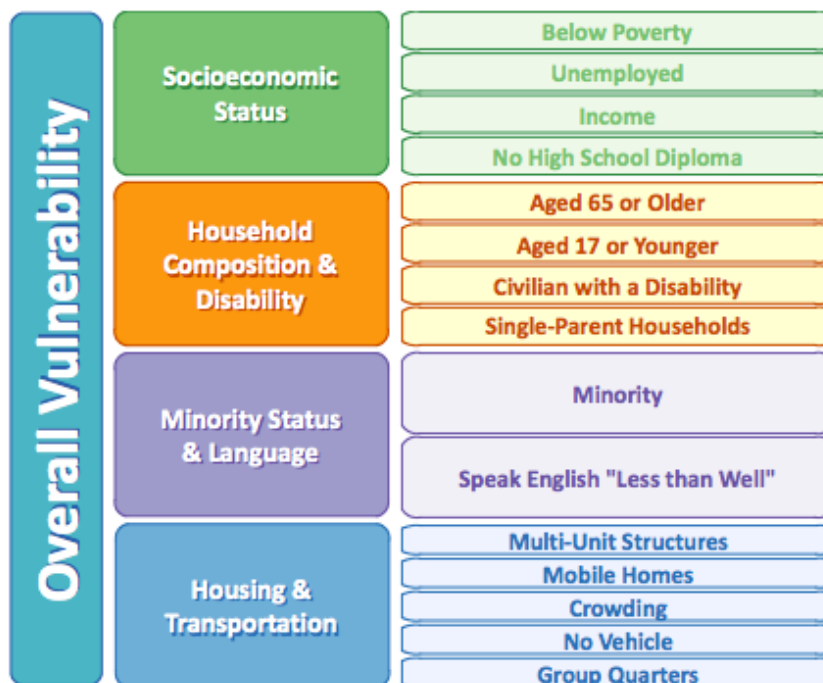
¹⁰⁴ (Jamie Lynn Auletta, 2012)

¹⁰⁵ (Susan L. Cutter, Bryan J. Boruff, & W. Lynn Shirley, 2003)

¹⁰⁶ (Susan L. Cutter, Christopher T. Emrich, Jennifer J. Webb, & Daniel Morath, 2009)

There are many different established indices of social vulnerability.¹⁰⁷ In 2012, the Pacific Institute conducted a social vulnerability assessment for climate change for the state of California.¹⁰⁸ The researchers developed their own index, which combined 19 indicators into one vulnerability score. The Center for Disease Control (CDC) has developed their own social vulnerability index (variables shown in Figure 14) and maintains an online mapping dashboard for people to conduct analyses for their own areas. This SVI is used by federal agencies, including the Agency for Toxic Substances and Disease Registry and the National Oceanic and Atmospheric Administration.

Figure 14. CDC Social Vulnerability Index



Source: Centers for Disease Control and Prevention / Agency for Toxic Substances and Disease Registry / Geospatial Research, Analysis, and Services Program Social Vulnerability Index

IVB. Applications of Metrics to UC Berkeley & Limitations

Several social vulnerability assessments have been conducted for the region and are summarized below. In addition, a brief analysis is conducted using the CDC Social Vulnerability Index for a

¹⁰⁷ See the U.S. Army Corps of Engineers Institute for Water Resources published a whitepaper in 2013 on a comparison between the tools:

http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/Social_Vulnerability_Analysis_Tools.pdf (C. Mark Dunning & Susan Durden, 2013) or Oregon's Risk Assessment model that distinguishes between several state indices (Oregon Partnership for Disaster Resilience & University of Oregon, 2013)

¹⁰⁸ (Heather Cooley, Eli Moore, Matthew Heberger, & Lucy Allen, 2012)

Census tract that houses a number of UC Berkeley. Following this analysis is a discussion of the limitations of existing social vulnerability indices.

The Adapting to Rising Tides (ART) project conducted a social vulnerability assessment for populations living along sections of the Alameda County shoreline. The report emphasized the importance of incorporating equity considerations into social vulnerability studies and recommended that studies include: socio-economic analyses of vulnerable communities, an understanding of historic exposure and response to hazards that have occurred in the past, and analysis of the needs and resources of communities. “*Addressing Social Vulnerability and Equity in Climate Change Adaptation Planning*” (2012) looked at two inundation scenarios: 16-inch and 55-inch sea level rise combined with extreme storm events.¹⁰⁹ The report assesses risk for residents in Alameda, Emeryville, Hayward, Oakland, San Leandro, San Lorenzo and Union City and does not include Berkeley. Data sources used to assess social vulnerability came from the 2000 US Census using the Social Vulnerability Index metrics used by the Office for Coastal Management of the National Oceanic and Atmospheric Administration (NOAA) Department (these metrics were established by the University of South Carolina Hazards & Vulnerability Research Institute).

The Center for Disease Controls’ Building Resilience Against Climate Effects (BRACE) five-step framework is focused on public health.¹¹⁰ The California Department of Public Health and UC Davis used the CDC’s Building Resilience Against Climate Effects (BRACE) framework for Alameda County (2017).¹¹¹ The CalBRACE report for Alameda County assesses vulnerability using health metrics such as heat-related ER visits, adult obesity, people living with a disability, people with multiple chronic conditions, and households with air conditioning. They found that in 2010, 5% of Alameda County’s population lived in a high-risk wildfire area, while 6% live in a 100-year flood area and 55-inch Sea Level Rise-projection area (55-inches was used as the 2100 prediction but recent projections assume 66 inches).¹¹²

Using the Center for Disease Control’s Social Vulnerability Index, it is possible to analyze the vulnerability for tract 422800. This tract was selected as an illustrative example to demonstrate the application of an established SVI as it is where a number of undergraduate students live (see Figure 15). The CDC tool reports that this tract ranks in the top third quantile of overall vulnerability. Six of the 15 SVI metrics were flagged (Table 5), meaning that measures were in the 90th percentile or above of social vulnerability for all tracts in the country. The CDC SVI (and most recognized SVI metrics) suggests that student populations are more vulnerable than the general population: there are high percentages of populations that qualify as below poverty, unemployed, living in high density group quarters without access to a personal vehicle. While these characteristics may imply increased vulnerability, they have been developed with the general population in mind. They do not account for the unique lifestyle situation of students.

¹⁰⁹ (Heidi Nutters, 2012)

¹¹⁰ (Arie Ponce Manangan et al., 2014)

¹¹¹ (Neil Maizlish, Dorette English, Jacqueline Chan, Kathy Dervin, & Paul English, 2017)

¹¹² (Neil Maizlish, Dorette English, Jacqueline Chan, Kathy Dervin, & Paul English, 2017)

Figure 15. Census Tract 422800

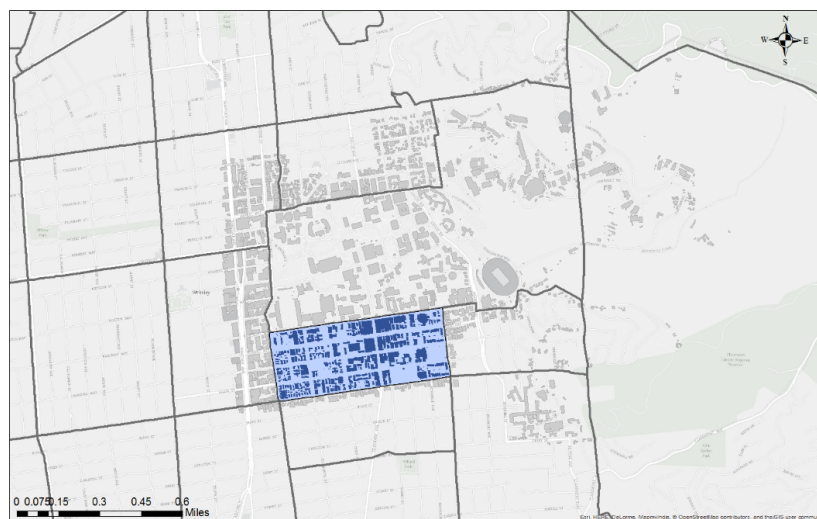


Table 5. Flagged Social Vulnerability Index Metrics for Census Tract 422800

Measure (2010-2014 ACS)	Percentage /Number	MOE	Percentile Rank among CA tracts
Persons below poverty estimate	39.0%	9.3%	94 th
Civilian (age 16+) unemployed estimate	18.8%	6.0%	90 th
Per capita income estimate	\$13,848	\$1,889	91 st
Housing in structures with 10 or more units estimate	63.5%	10.7%	95 th
Households with no vehicle available estimate	42.9%	9.4%	98 th
Persons in group quarters estimate	48.2%	13.3%	98 th

Source: Center for Disease Control, 2014

There are a number of limitations to existing indices. These metrics allow for geographic comparisons between counties in the U.S. but do not account for geographically varying vulnerability factors. As the ART analysis recognizes, Census data is typically several years outdated, certain populations that might be the most vulnerable (such as homeless populations) are not fully captured, and the geography is limited to block or tract level, eliminating the variability between populations within geographies.¹¹³ Using geographic assessments, if the percentage of the population that is considered vulnerable is small, it is typically not flagged or identified as a priority area of concern. However, this should not mean that those people should

¹¹³ ¹¹³ (Heidi Nutters, 2012)

not be considered. For example, in tract 422700, 4.9% of the civilian noninstitutionalized population was estimated to have a disability and 0.8% were single parent households with children under 18. While these lower percentages result in these metrics not being ‘flagged’ under the CDC SVI terms, it is important that these people are still accounted for in determining strategies. In general, social vulnerability indices separate people from the built environment, which can hinder the effectiveness of adaptation strategies. For example, in addition to considering populations with disabilities, buildings should be classified based on if they have ADA accessibility.

Such social vulnerability indices are particularly limited when applied to university populations. Often, students, faculty, and staff are traveling to campus from many different Census tracts, resulting in insufficient applicability of Census data. Vulnerability indices that focus on elderly and young children or that use metrics of poverty will miss large percentages of the student body. International students, students who list their parents address, students without stable housing situations, or students without documentation may not be captured in Census data. Students who do not speak English well may be limited in how they can respond to the Census. Finally, while a main benefit of Census-based indices is readily available data, additional considerations that are important for understanding the vulnerabilities of specific populations may not be captured. Below is a discussion of additional social vulnerability considerations for UC Berkeley.

IVC. UC Berkeley Additional Social Vulnerability Considerations

Additional social vulnerability metrics for UC Berkeley can be categorized into two areas 1) campus populations and 2) social and educational services. While there are often limitations to what information can be gathered, particularly for students, there are several ways to address this, including: expanding future methods to include interviews and focus groups, identifying the social and educational services even when data on specific populations cannot be collected, and recognizing that often it is not necessary to answer *who* or *how many* but just to answer *what are the possibilities?* For example, it is not necessary to know how many people speak English as a second language, only that some people may speak Spanish and emergency notification strategies can then include Spanish. Qualitative assessments of governance structures and social capital are not included here and should be the subject of future research. This discussion offers insight into the information that is available and provides recommendations for additional information to consider when developing strategies. A full table of metrics can be found in Section V.

An important question to begin with is: Who uses campus? It is possible to answer this question but with the recognition that some people and organizations that use campus may not be captured. In Fall of 2015, there were 16,000 faculty and staff at UC Berkeley. There were also approximately 37,000 students at UC Berkeley, nearly a third of which were graduate students. Graduate and undergraduate students are considered together in the below discussion as many of the questions are the same. Each demographic may have particular vulnerabilities that they are more susceptible to: graduates likely have more educational attainment and possibly more experience with risk / emergency. Graduates may be more likely to have jobs outside of school

and families to consider. Undergraduates might be more likely to live on campus / near campus. However, each of these vulnerabilities can be asked through the individual metrics rather than by dividing the population into graduate and undergraduate.

Campus commuting surveys can identify which infrastructure networks should be assessed (as discussed in Section III) and which populations may be more vulnerable to disruptions in transit network functioning. Every few years, UC Berkeley's Office of Physical and Environmental Planning conducts a commuting survey. The 2016 survey was sent to 23,321 people and received a total of 6,186 responses (Table 6). While this information is only a sliver of the campus population, it is the most comprehensive information collected about travel behavior.

Table 6. Campus Survey Profile

	Students	Faculty/Staff
Total	37,086	15,984
Survey Sample	13,953	9,368
Survey Responses	2,635	3,551

Source: Campus Commuting Survey

Faculty and staff are more susceptible to climate change impacts to transportation, as a higher percentage of these populations drive alone or take BART to campus. Undergraduates and graduates reported high levels of walking and biking. The top three modes are shown below by campus affiliation (Table 7). Bikers and walkers have higher adaptive capacity than populations dependent on transit and road infrastructure.¹¹⁴ However, different climate change impacts will affect populations differently. A major heat wave or heavy rain could limit people's ability to walk or bike to campus, while flooding and sea level rise could hinder infrastructure operations.

Table 7. Weekday Commute Modes 2016

Undergraduate (N = 953, 13% response rate of sample)	Graduate (N = 1,682, 26% response rate of sample)	Faculty (N = 817, 27% response rate of sample)	Staff (N = 2,734, 43% response rate of sample)
Walk: 63%	Walk: 25%	Drive Alone: 34%	Drive Alone: 38%
AC Transit: 11%	Bike: 24%	Bike: 18%	BART: 21%
Bike: 9%	AC Transit: 20%	Walk: 11%	Bike: 11%

Source: Campus Commuting Survey

Answering the question of where people live is very helpful to understand vulnerabilities and response strategies. It allows for better understanding of Census data application (i.e. it would be difficult to apply census data for faculty and staff), understanding of the extent to which

¹¹⁴ Infrastructure takes a long time to repair, so damages can negatively impact people's access to campus for longer periods of time. After Hurricane Sandy, more than half of the crossings from New Jersey to Manhattan were completed by pedestrians and cyclists, allowing people to get to work during a time when the subway was shutdown.

(City of Cambridge & Kleinfelder, 2017)

transportation modes could shift (i.e. from driving alone to walking), and the proximity of social services to campus populations (i.e. health services in Berkeley / Berkeley Hills / Albany are important for students). Future steps for campus should include collecting information on students living on-campus, which would allow for better emergency response management in areas that campus has more control over.

From the commuting survey results, it is possible to estimate residential distribution. The top residential locations are outlined below (Table 8). Over three-quarters of the students responded to live in Berkeley, the Berkeley Hills or Albany, along with nearly one-third of the faculty / staff population. Six percent of students and 17% of faculty / staff respondents commute from Oakland. However, there was significant variety, with over 21 areas reporting more than 1% of responses.

Table 8. Top Residential Locations for Campus Populations
(Estimated from Survey Results)

Location	Students	Faculty/Staff
Berkeley/Berkeley Hills/Albany:	77%	31%
Oakland/Piedmont/Montclair:	6%	17%
San Francisco:	2%	7%
Total % Accounted for in Top Three	85%	55%

Source: Campus Commuting Survey

There are a number of additional metrics to consider when assessing sensitivity and adaptive capacity for campus populations but often these considerations have limited information available. Students that have children might have less flexibility in how they respond to an emergency event. The University has a significant number of students that are not from the area. As emergency management literature has suggested, these students might have greater sensitivity and lower adaptive capacity for a number of different reasons. International students and students who speak English as a Second Language may face cultural and/or language barriers. Undocumented students may feel uncomfortable interacting with public officials or accessing health services or other critical services. Students who did not grow up in Berkeley may have limited local knowledge, which can sometimes help in responding to emergency situations.

There is a wide range of physical and mental ability for campus populations and it is important to consider the variety of possible disabilities that could impact people's vulnerability. It is possible to do this using information from the University's Disabled Students Program. It is not necessary to find out detailed information, but it would benefit the University to establish main categories of impairments to consider when developing adaptation strategies. Health issues can have varying impacts on students' vulnerability and adaptive capacity. Students with asthma or other respiratory challenges might have difficulty walking or biking to school on days with high heat or pollution. Evacuation strategies in case of an emergency should always account for students with auditory and mobility impairments.

Access to resources is critical to lowering sensitivity and increasing adaptive capacity. This access can manifest in a myriad of ways. Students that do not have access to the financial resources that they need might feel greater stressors: whether they are living in poverty, are foreign students, or simply do not have bank access. Many students work while they are going to school and might be impacted if they can no longer access their jobs or their professional position is interrupted. Some students may be homeless and/or do not have access to regular shelter, which makes them particularly vulnerable to climate events. Students that do not have access to a cell phone or to regular internet may have limited ability to receive emergency notifications.

Additionally, students that feel disconnected from family and friends and/or have limited support networks will have greater vulnerability. Emphasizing strategies that center around support building and access to social services can offer assistance. Institutions are recognized as key actors in enhancing social capacity and facilitating adaptation efforts. They can address structural inequalities, increase access to different social groups, and operate as meeting spots and safe havens during emergencies.¹¹⁵ In addition to being an academic and research institution, UC Berkeley offers a number of social services. Identifying these resources and prioritizing them in adaptation planning can lower sensitivity and increase adaptive capacity of campus and community populations.¹¹⁶ Table 9 outlines highlighted social and educational resources UC Berkeley offers. Table 10 includes additional data pieces about campus buildings that could be collected to inform future adaptation strategies.

Table 9. Highlighted Social & Educational Services at UC Berkeley

Metric	Detail
<ul style="list-style-type: none"> • Safe Spaces & Student Services (consider for support networks) 	<ul style="list-style-type: none"> • University Village Albany Front Office • ASUC Student Union (Eshleman, MLK) • Anthony Hall • Sproul Hall • Cesar Chavez • International House
<ul style="list-style-type: none"> • Daycare Services (consider for students with family obligations) 	<ul style="list-style-type: none"> • 2339 Haste Street (Haste Street) • 2427 Dwight Way (Dwight Way) • 2900 Dwight Way, 2601 Warring Street (Clark Kerr Campus) • 1123 Jackson Street, Albany (University Village (UVA)) • 2425 Atherton Street (Harold E. Jones Child Study Center)

¹¹⁵ (Arun Agrawal, 2008) & (City of Cambridge & Kleinfelder, 2015)

¹¹⁶ The Vulnerable Population Ranking Memorandum chapter for the Cambridge, MA Climate Vulnerability Assessment maps out youth centers, recreational areas, post offices, public libraries, community-based services, vulnerable population support services, and faith-based organizations. Additionally, the report maps buildings that have basements and buildings with central air conditioning, two key built environment components when considering adaptive capacity.

<ul style="list-style-type: none"> • Food pantries and student cafeterias (consider for food access) 	<ul style="list-style-type: none"> • Student Food Pantry (1600 Sacramento St, Berkeley) • Bear Pantry: University Village Albany Front Office
<ul style="list-style-type: none"> • Recreational / athletic sporting events (consider for AC options / large crowd needs) 	<ul style="list-style-type: none"> • University Football Stadium (can hold over 63,000)¹¹⁷ • The Recreational Sports Facility has several large gymnasium spaces. It also has an authorized U.S. Government Passport Acceptance facility
<ul style="list-style-type: none"> • Faith-based organizations: Churches, mosques, synagogues (consider for support networks) 	<ul style="list-style-type: none"> • There are 64 groups on campus that fall under the category of Spiritual Student Organizations. The City of Berkeley has a number of Churches, Mosques and Synagogues, many of which are within walking distance of the campus.

Table 10. Additional Building Information to Collect

Additional Building Information to Collect
<ul style="list-style-type: none"> • What buildings on campus have high cooling needs (for research, lab animals, high student use)?
<ul style="list-style-type: none"> • What buildings can stay open 24/7?
<ul style="list-style-type: none"> • What buildings have ADA accessibility?
<ul style="list-style-type: none"> • What buildings have air conditioning?

¹¹⁷ (University of California, Berkeley, n.d.)

V. Tool for Universities to Assess Vulnerability to Climate Change

Climate vulnerability assessments have been completed for global climate change events (such as sea level rise)¹¹⁸, for municipalities, and for agencies. Universities are starting adaptation planning efforts and several institutions in the U.S. have identified the need for a climate vulnerability assessment. The established metrics to assess social vulnerability have been developed with the general population in mind and often rely on Census data. However, students are a unique subset of the general population and it is important to incorporate additional considerations when assessing social vulnerability at universities. Additionally, universities often rely on a mix of on-campus and off-campus services for transportation, utilities, and critical services. These factors combined reveal a gap in the literature for a climate vulnerability assessment tool specific to universities.

Effective assessment of climate change vulnerability is an important step towards minimizing risk and maximizing the positive impacts universities can have in leadership, capacity building, and offering of social services.

STEP 1: IDENTIFY KEY CLIMATE CHANGE RISKS FOR THE REGION

For this step, it is recommended to use research that has been conducted to date. Specific reports to look to include: hazard mitigation plans, state / national climate change assessments, IPCC reports. In California, Cal-Adapt can be used to assign existing research and projections to highly localized areas.

STEP 2: COLLECT INFORMATION ON CRITICAL INFRASTRUCTURE, CAMPUS POPULATIONS, AND SOCIAL / INSTITUTIONAL SERVICES

Identify the services that campus relies on in order to function (critical infrastructure). Research existing studies for this infrastructure, model and map vulnerabilities where existing research is limited, and highlight gaps where future research is needed. Collect information on previous disasters that campus has faced to understand vulnerabilities and campus' capacity to respond in case of emergency. Finally, gather information on campus populations and identify particular social vulnerabilities for university students, faculty, and staff.

A table is outlined below with metrics to consider (Table 11). Each metric has been rated with a level of difficulty for gathering the data, and some may not be possible to collect. Difficulty can be rated high if data is available but data collection requires intensive resources (time and money) or if information is not accessible. These metrics do not account for many of the qualitative factors that might significantly impact an institution's sensitivity and adaptive capacity

¹¹⁸ The first global climate vulnerability assessment was completed in 1993 for sea level rise (Hoozemans, Stive, & Bijlsma, 1993).

such as institutional governance structures and cooperation and coordination with the surrounding region.

Metrics that are difficult to collect should not be ignored. Instead, adaptation strategies should either recommend other ways to collect or measure the information or assume flexibility to account for lack of information. Information on campus populations will often be particularly challenging to collect. Methods such as focus groups and interviews may be helpful. In general, as mentioned in Section IV, for campus population information it is not necessary to know *how many* people or *who* but rather *what are the possibilities*? For example, it is not necessary to know how many people speak English as a second language, only that a significant number of people speak Spanish. Emergency notification strategies can then include Spanish. Finally, the social and educational service data is easier to collect and can support areas that might be more difficult to gather information on for campus populations.

Table 11. Metrics to Consider when Assessing University Vulnerability to Climate Change

Area	Metric	Difficulty Level of Gathering Data
Critical Infrastructure	<ul style="list-style-type: none"> How do people get to campus? (Both Critical Infrastructure and Campus Populations) 	<ul style="list-style-type: none"> Medium
	<ul style="list-style-type: none"> Where does campus water come from? 	<ul style="list-style-type: none"> Low
	<ul style="list-style-type: none"> Where does campus gas and electricity come from? What infrastructure is above-ground (susceptible to major storms)? What infrastructure is below-ground (susceptible to flooding/SLR)? 	<ul style="list-style-type: none"> High
	<ul style="list-style-type: none"> Where does campus waste go? 	<ul style="list-style-type: none"> Low
	<ul style="list-style-type: none"> Where are hazardous material facilities located? 	<ul style="list-style-type: none"> Low
	<ul style="list-style-type: none"> Where are the main data centers? 	<ul style="list-style-type: none"> Low
	<ul style="list-style-type: none"> Who is responsible in case of emergency (e.g. fire)? Collect campus emergency operations plan. 	<ul style="list-style-type: none"> Medium
	<ul style="list-style-type: none"> Where are critical health services located? 	<ul style="list-style-type: none"> Low
	<ul style="list-style-type: none"> What are past critical issues/emergencies that campus has faced? How has campus responded? 	<ul style="list-style-type: none"> Low
	<ul style="list-style-type: none"> What buildings on campus have high cooling needs (for research, lab animals, high student use)? (Both critical infrastructure and Social/Educational Services) 	<ul style="list-style-type: none"> Medium
Campus Populations	<ul style="list-style-type: none"> Who uses campus? (Graduate/Undergraduate/Staff/Faculty/Community Organizations?) 	<ul style="list-style-type: none"> Medium
	<ul style="list-style-type: none"> Where do people live? (on-campus/off- campus/far from campus?) 	<ul style="list-style-type: none"> Medium

	<ul style="list-style-type: none"> How do people get to campus? (Both Critical Infrastructure and Campus Populations) 	<ul style="list-style-type: none"> Medium
	<ul style="list-style-type: none"> Do people have childcare responsibilities to consider? 	<ul style="list-style-type: none"> Low
	<ul style="list-style-type: none"> What are people's first languages? 	<ul style="list-style-type: none"> Medium
	<ul style="list-style-type: none"> Who might not know the area/region? 	<ul style="list-style-type: none"> High
	<ul style="list-style-type: none"> What are people's access to supper networks? 	<ul style="list-style-type: none"> High
	<ul style="list-style-type: none"> Are there possibly undocumented populations? 	<ul style="list-style-type: none"> High
	<ul style="list-style-type: none"> What types of disabilities might people have? 	<ul style="list-style-type: none"> Medium
	<ul style="list-style-type: none"> Do people have access to cell phones/emergency alert and notification systems? 	<ul style="list-style-type: none"> High
	<ul style="list-style-type: none"> Do students have outside professional obligations? 	<ul style="list-style-type: none"> High
	<ul style="list-style-type: none"> Do people have access to food? 	<ul style="list-style-type: none"> Medium
	<ul style="list-style-type: none"> Do people have access to financial services? 	<ul style="list-style-type: none"> High
	<ul style="list-style-type: none"> Do people have access to stable housing? 	<ul style="list-style-type: none"> High
	<ul style="list-style-type: none"> Do people have access to health services? 	<ul style="list-style-type: none"> Low
Social & Educational Services	<ul style="list-style-type: none"> What buildings on campus have high cooling needs (for research, lab animals, high student use)? (Both critical infrastructure and Social/Educational Services) 	<ul style="list-style-type: none"> High
	<ul style="list-style-type: none"> What buildings have ADA accessibility? 	<ul style="list-style-type: none"> Medium
	<ul style="list-style-type: none"> What buildings have air conditioning? 	<ul style="list-style-type: none"> High
	<ul style="list-style-type: none"> What buildings hold safe spaces? (LGBTQ, Multicultural Centers, Gender Resource Centers, African American Student Centers, International Student Centers) 	<ul style="list-style-type: none"> Low
	<ul style="list-style-type: none"> What buildings hold religious functions? 	<ul style="list-style-type: none"> Low
	<ul style="list-style-type: none"> Where are daycare services located? 	<ul style="list-style-type: none"> Low
	<ul style="list-style-type: none"> What buildings can stay open 24/7? 	<ul style="list-style-type: none"> Medium
	<ul style="list-style-type: none"> Where are pharmacies and grocery stores? 	<ul style="list-style-type: none"> Low
	<ul style="list-style-type: none"> Where are food pantries and student cafeterias? 	<ul style="list-style-type: none"> Low
	<ul style="list-style-type: none"> Where are recreational/athletic sporting events held? 	<ul style="list-style-type: none"> Low

Bibliography

- Adapting to Rising Tides. (2016). Maps and Data Products « Adapting to Rising Tides. Retrieved October 27, 2016, from <http://www.adaptingtorisingtides.org/maps-and-data-products/>
- Adapting to Rising Tides. (n.d.). *Existing Conditions and Stressors - Community Land Use, Facilities and Services*. San Francisco Bay Conservation and Development Commission. Retrieved from http://www.adaptingtorisingtides.org/wp-content/uploads/2015/04/CommunityLandUse_ECS.pdf
- Alex Fang. (2016, September 20). UC Berkeley delays fire mitigation project after termination of funding. Retrieved April 25, 2017, from <http://www.dailycal.org/2016/09/20/uc-berkeley-delays-fire-mitigation-project-termination-fema-funding/>
- Amruta Trivedi. (2012, November 29). Campus hit by early-morning power outage. Retrieved April 24, 2017, from <http://www.dailycal.org/2012/11/29/campus-experience-early-morning-power-outage/>
- Angela Cheng, Emun Davoodi, Tiffany Deng, & Daniel Shen. (2012). *Steam Emissions of UC Campus: Mitigating Climate Impacts; UC Berkeley Climate and Greenhouse Gas Emissions Research / Analysis* (CE268E - Civil Systems and the Environment). Berkeley, CA: University of California, Berkeley. Retrieved from http://sustainability.berkeley.edu/sites/default/files/Final_Steam_Report_2012.pdf
- Aquarium of the Pacific (AOP). (2015). *City of Long Beach Climate Resiliency Assessment Report*. Aquarium of the Pacific (AOP). Retrieved from [http://www.aquariumofpacific.org/downloads/AOPs_2015_Report_on_Resiliency_\(1-7-16\).pdf](http://www.aquariumofpacific.org/downloads/AOPs_2015_Report_on_Resiliency_(1-7-16).pdf)
- Arie Ponce Manangan, Christopher K. Uejio, Shubhayu Saha, Paul J. Schramm, Gino D. Marinucci, Claudia Langford Brown, ... George Luber. (2014). *Assessing Health Vulnerability to Climate Change: A Guide for Health Department* (Climate and Health Technical Report Series). Atlanta, GA: Center for Disease Control. Retrieved from <https://www.cdc.gov/climateandhealth/pubs/AssessingHealthVulnerabilitytoClimateChange.pdf>
- Arun Agrawal. (2008). *The Role of Local Institutions in Adaptation to Climate Change* (IFRI Working Paper No. # W081-3). University of Michigan: School of Natural Resources and Environment, University of Michigan. Retrieved from <http://www.umich.edu/~ifri/Publications/W0813%20Arun%20Agrawal.pdf>
- Ashley Nguyen, Brenda Dix, Wendy Goodfriend, Joe LaClair, Lindy Lowe, Stephen Yokoi, & Richard Fahey. (2011). *Adapting to Rising Tides: Transportation Vulnerability and Risk Assessment Pilot Project* (Adapting to Rising

Tides). San Francisco Bay Conservation and Development Commission, MTC, Caltrans. Retrieved from http://www.adaptingtorisingtides.org/wp-content/uploads/2015/04/RisingTides_BriefingBook_sm.pdf

Association of Bay Area Governors. (2010). *Appendix C: Natural Hazard Risk Assessment* (2011 Regional Hazard Mitigation Plan). San Francisco, CA: Association of Bay Area Governments & Resources for Community Development. Retrieved from <http://resilience.abag.ca.gov/wp-content/documents/ThePlan-C-2010.pdf>

Barker, D., & McGregor, D. F. M. (1995). *Environment and Development in the Caribbean: Geographical Perspectives*. Press, University of the West Indies.

BART, ARUP North America, & Parsons Brinckerhoff. (2013). *San Francisco Bay Area Rapid Transit District (BART) Climate Change Adaptation Assessment Pilot* (No. 74). Federal Transit Administration. Retrieved from http://ntl.bts.gov/lib/55000/55500/55557/FTA_Report_No._0074.pdf

Bay Area Regional Reliability. (n.d.). Bay Area Regional Reliability – Reliability – A Regional Approach. Retrieved April 23, 2017, from <http://www.bayareareliability.com/>

Bell, E., Cai, D., Dunn, L., & Keene, R. (2012). Greenhouse Gas Emissions Inventory & 2050 Projections. Retrieved from http://sustainability.berkeley.edu/sites/default/files/Final_CalCAPProjectionsGroupReport_2012.pdf

Birkmann, J., Cardona, O. D., Carreño, M. L., Barbat, A. H., Pelling, M., Schneiderbauer, S., ... Welle, T. (2013). Framing vulnerability, risk and societal responses: the MOVE framework. *Natural Hazards*, 67(2), 193–211. <https://doi.org/10.1007/s11069-013-0558-5>

Bruce Riordan, Brooke Solomon, & Thayer White. (2016). *Climate Change & Bay Area Human Health Facts, Figures and Science-Based Storylines*. Climate Readiness Institute & University of California. Retrieved from <http://bayplanningcoalition.org/wp-content/uploads/2016/09/CRI-Climate-Bay-Area-Health-V1.2-Sept-2016.pdf>

C. Mark Dunning, & Susan Durden. (2013). *Social Vulnerability Analysis: A Comparison of Tools*. U.S. Army Corps of Engineers Institute for Water Resources. Retrieved from http://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/Social_Vulnerability_Analysis_Tools.pdf

Cal-Adapt 2.0: Download Data for Annual Averages of Temperature and Precipitation. (n.d.). Retrieved April 22, 2017, from <http://cal-adapt.org/blog/2016/feb/16/cal-adapt-20-download-annually-averaged-climate-pr/>

CalFire. (2016). *Top 20 Most Damaging California Wildfires*. CalFire. Retrieved from http://www.fire.ca.gov/communications/downloads/fact_sheets/Top20_Damaging.pdf

California Climate Change. (n.d.). Public Health and - California Climate Change. Retrieved October 27, 2016, from http://www.climatechange.ca.gov/adaptation/public_health.html

California Climate Change Assessments. (n.d.). Retrieved October 27, 2016, from http://www.climatechange.ca.gov/climate_action_team/reports/climate_assessments.html

California Department of Water Resources. (2015). *Drought in California*. Sacramento, CA: California Department of Water Resources. Retrieved from http://www.water.ca.gov/waterconditions/docs/DWR_DroughtBroch_070815-web.pdf

California Drought Information | USGS California Water Science Center. (n.d.). Retrieved April 25, 2017, from <https://ca.water.usgs.gov/data/drought/>

California Energy Management Agency, & California Natural Resources Agency. (2012). *California Adaptation Planning Guide: Planning for Adaptive Communities*. Retrieved from http://resources.ca.gov/docs/climate/01APG_Planning_for_Adaptive_Communities.pdf

California Natural Resources Agency. (2009). *2009 California Climate Adaptation Strategy*. California Natural Resources Agency. Retrieved from http://resources.ca.gov/docs/climate/Statewide_Adaptation_Strategy.pdf

California State University. (2016, July). *Climate Adaption and Resilience Planning for Campuses*.

Caltrans Climate Change Workgroup, & HQ Divisions of Transportation Planning, Design, & Environmental Analysis. (2011). *Guidance on Incorporating Sea Level Rise: For use in the planning and development of Project Initiation Documents*. Caltrans. Retrieved from http://www.dot.ca.gov/ser/downloads/sealevel/guide_incorp_slr.pdf

Cayan, D. R., Bromirski, P. D., Hayhoe, K., Tyree, M., Dettinger, M. D., & Flick, R. E. (2008). Climate change projections of sea level extremes along the California coast. *Climatic Change*, 87(1), 57–73. <https://doi.org/10.1007/s10584-007-9376-7>

Center for Disease Control. (2014a). ATSDR - The Social Vulnerability Index (SVI). Retrieved April 23, 2017, from <https://svi.cdc.gov/>

Center for Disease Control. (2014b). Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Geospatial Research, Analysis, and Services Program: Social Vulnerability Index [2014] Database [California]. Retrieved April 23, 2017, from <http://svi.cdc.gov/SVIDataToolsDownload.html>

City and County of San Francisco Sea Level Rise Committee. (2014). *Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco: Assessing Vulnerability and Risk to Support Adaptation*. San Francisco, CA:

- City and County of San Francisco. Retrieved from <http://onesanfrancisco.org/wp-content/uploads/Sea-Level-Rise-Guidance.pdf>
- City of Cambridge, & Kleinfelder. (2015). *Vulnerable Population Ranking Memorandum (Prepared as Part of the Climate Change Vulnerability Assessment)*. Cambridge, MA. Retrieved from <https://www.cambridgema.gov/CDD/Projects/Climate/~media/8FA4C85FCCFA4043B779729B05999361.ashx>
- City of Cambridge, & Kleinfelder. (2017). *Climate Change Vulnerability Assessment*. Cambridge, MA. Retrieved from <https://www.cambridgema.gov/CDD/Projects/Climate/climatechangeresilianceandadaptation>
- Climate Change*: (n.d.).
- Climate Change Technical Advisory Group. (2015). *Perspectives and Guidance for Climate Change Analysis*. Sacramento, CA: California Department of Water Resources. Retrieved from http://www.water.ca.gov/climatechange/docs/2015/Perspectives_Guidance_Climate_Change_Analysis.pdf
- Contra Costa Water District, & East Bay Municipal Utility District. (n.d.). Bay Area Regional Reliability Interties - EBMUD/CCWD — Bay Area IRWMP. Retrieved April 23, 2017, from <http://bairwmp.org/projects/bay-area-regional-reliability-interties-ebmud-ccwd>
- Cornell University. (2013). *2013 Climate Action Plan Update & Roadmap 2014-2015*. Cornell University. Retrieved from http://csc-production.s3.amazonaws.com/2014/04/15/02/46/38/230/CAPUpdate2013Roadmap2014_2015.pdf
- County of Santa Clara Office of Sustainability. (2015). *Silicon Valley 2.0 Climate Adaptation Guidebook*. Santa Clara County: County of Santa Clara Office of Sustainability. Retrieved from https://www.sccgov.org/sites/osp/Documents/150519_ExecSum_FINAL.pdf
- Dan Cayan, Mary Tyree, David Pierce, & Tapash Das. (2012). *Climate Change and Sea Level Rise Scenarios for California Vulnerability and Adaptation Assessment* (California Climate Change Center White Paper No. CEC-500-2012-008). Scripps Institution of Oceanography, California Energy Commission.
- Donald R. Parker. (1992). *The Oakland-Berkeley Hills Fire: An Overview*. Oakland, CA: Oakland Office of Fire Services. Retrieved from <http://www.sfmuseum.org/oakfire/overview.html>
- Douglas Wallace. (2016, July). *Bay Area Regional Reliability*. Retrieved from <http://bacwa.org/wp-content/uploads/2016/07/BARR-Presentation-to-BACWA-07-15-16.pdf>
- East Bay Municipal Utility District. (2014). *2014 Climate Change Monitoring and Response Plan*. East Bay Municipal Utility District. Retrieved from <http://www.ebmud.com/about-us/sustainability/climate-change/>

EBMUD. (2017). East Bay Municipal Utility District : Climate change. Retrieved April 24, 2017, from <http://www.ebmud.com/about-us/sustainability/climate-change/>

Elizabeth Chapin. (2016, August 23). Campuses Join National Climate Commitment. Retrieved April 17, 2017, from <https://www2.calstate.edu/csu-system/media-center/Pages/Campuses-Join-National-Climate-Commitment.aspx>

EMC Planning Group Inc. (2015). *City of Pacific Grove Climate Change Vulnerability Assessment*. Monterey, CA: EMC Planning Group Inc. Retrieved from <http://www.cityofpacificgrove.org/sites/default/files/general-documents/local-coastal-program/pg-lcp-final-vulnerability-assessment-011515.pdf>

Eric Bell, Delphine Cai, Laurel Dunn, & Robert Keene. (2012). *Greenhouse Gas Emissions Inventory*. UC Berkeley Office of Sustainability. Retrieved from http://sustainability.berkeley.edu/sites/default/files/Final_CalCAPProjectionsGroupReport_2012.pdf

Fabian Nunez, & Fran Pavley. AB 32 Assembly Bill, Pub. L. No. 32 (2006). Retrieved from http://www.leginfo.ca.gov/pub/05-06/bill/asm/ab_0001-0050/ab_32_bill_20060927_chaptered.html

FEMA. (1991). *The East Bay Hills Fire* (U.S. Fire Administration No. USFA-TR-060). FEMA. Retrieved from <https://www.usfa.fema.gov/downloads/pdf/publications/tr-060.pdf>

FEMA. (2017). National Flood Insurance Program: Flood Hazard Mapping | FEMA.gov. Retrieved April 22, 2017, from <https://www.fema.gov/national-flood-insurance-program-flood-hazard-mapping>

FEMA. (n.d.). Flood Insurance Rate Map (FIRM). Retrieved April 23, 2017, from <https://www.fema.gov/flood-insurance-rate-map-firm>

Five Milestones of Emissions Management. (2016). Retrieved October 30, 2016, from <http://iclei.usa.org/programs/emissions-management/5-milestones/>

Folland, S., & Rocco, L. (2013). *The Economics of Social Capital and Health: A Conceptual and Empirical Roadmap*. World Scientific.

Gary Griggs, & Nicole L. Russell. (2012). *City of Santa Barbara Sea-Level Rise Vulnerability Study* (No. CEC-500-2012-039). University of California, Santa Cruz & California Energy Commission. Retrieved from <http://www.energy.ca.gov/2012publications/CEC-500-2012-039/CEC-500-2012-039.pdf>

George Kostyrko. (2017, January 4). California Drought: Statewide Water Savings Nearly Reach 19 Percent in November; Most of State Still Experiencing Drought Conditions. Retrieved April 23, 2017, from <http://drought.ca.gov/topstory/top-story-68.html>

- Gordon, R. Bill Text - AB-1482 Climate adaptation., Pub. L. No. 1482 (2015). Retrieved from https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160AB1482
- Governor Edmund G. Brown Jr. Executive Order S-13-08 (2008). Retrieved from <https://www.gov.ca.gov/news.php?id=11036>
- Greg S. Biging, John D. Radke, & Jun Hak Lee. (2012). *Impacts of Predicted Sea-Level Rise and Extreme Storm Events on the Transportation Infrastructure in the San Francisco Bay Region* (No. CEC-500-2012-040.). University of California, Berkeley: California Energy Commission.
- Hayhoe, K., Wake, C. P., Huntington, T. G., Luo, L., Schwartz, M. D., Sheffield, J., ... Wolfe, D. (2007). Past and future changes in climate and hydrological indicators in the US Northeast. *Climate Dynamics*, 28(4), 381–407. <https://doi.org/10.1007/s00382-006-0187-8>
- Heat Adaptation Workgroup. (2013). *Preparing California for Extreme Heat: Guidance and Recommendations*. California Climate Action Team. Retrieved from http://www.climatechange.ca.gov/climate_action_team/reports/Preparing_California_for_Extreme_Heat.pdf
- Heather Cooley, Eli Moore, Matthew Heberger, & Lucy Allen. (2012). *Social Vulnerability to Climate Change in California* (No. CEC-500-2012-013). Oakland, CA: California Energy Commission. Retrieved from <http://pacinst.org/app/uploads/2014/04/social-vulnerability-climate-change-ca.pdf>
- Heidi Nutters. (2012). *Addressing Social Vulnerability and Equity in Climate Change Adaptation Planning*. San Francisco Bay Conservation and Development Commission. Retrieved from http://www.adaptingtorisingtides.org/wp-content/uploads/2015/04/ART_Equity_WhitePaper.pdf
- Hoover, D. J., Odigie, K. O., Swarzenski, P. W., & Barnard, P. (n.d.). Sea-level rise and coastal groundwater inundation and shoaling at select sites in California, USA. *Journal of Hydrology: Regional Studies*. <https://doi.org/10.1016/j.ejrh.2015.12.055>
- Hoozemans, F. M. J., Stive, M. J. F., & Bijlsma, L. (1993). Global vulnerability assessment: Vulnerability of coastal areas to sea-level rise. *Coastal Zone '93. Vol. I; Proceedings of the Eighth Symposium on Coastal and Ocean Management, July 19-23, 1993, New Orleans, Louisiana 1*, 390-404. (1993). Retrieved from <http://repository.tudelft.nl/islandora/object/uuid:efbf1131-826c-4f9e-a582-eca6872a7523?collection=research>
- Inman, M. (2011). Opening the future. *Nature*, 1(1), 7–9. <https://doi.org/10.1038/nclimate1058>

- IPCC. (2007). *Climate Change 2007: Synthesis Report* (Contribution of Working Groups 1, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change) (p. 104). Geneva, Switzerland. Retrieved from https://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_full_report.pdf
- Jackson, H.-B. Bill Text - SB-379 Land use: general plan: safety element. (2015). Retrieved from https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201520160SB379
- Jamesine Rogers, James Barba, & Fiona Kinniburgh. (2015). *Risky Business: The Economic Risks of Climate Change in the United States*. Risky Business. Retrieved from <http://riskybusiness.org/site/assets/uploads/2015/09/California-Report-WEB-3-30-15.pdf>
- Jamie Lynn Auletta. (2012). *Disaster Vulnerability of University Student Populations*. University of South Florida. Retrieved from <http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=5156&context=etd>
- J.D. Radke, G.S. Biging, M. Schmidt-Poolman, H. Foster, E. Roe, Y. Ju, ... U. Garcia I. Reeves. (2016). *Assessment of Bay Area Natural Gas Pipeline Vulnerability to Climate Change* (No. CEC-500-2017-008). University of California, Berkeley: California Energy Commission. Retrieved from <http://www.energy.ca.gov/2017publications/CEC-500-2017-008/CEC-500-2017-008.pdf>
- Jeff Bellisario, Sean Randolph, Micah Weinberg, & Camila Mena. (2016). *The Case for a Second Transbay Transit Crossing*. Bay Area Council Economic Institute. Retrieved from http://www.bayareaeconomy.org/wp-content/uploads/2016/02/BACEI_TransbayCrossing_Feb2016b.pdf
- Joël Ramos, & Clarrissa Cabansagan. (2017). *Crossing Together: Equity considerations for a second transbay crossing*. Transform. Retrieved from http://www.transformca.org/sites/default/files/2nd%20Crossing%20Equity%20Report%20FINAL_0.pdf
- John Agard, E. Lisa F. Schipper, Joern Birkmann, Maximiliano Campos, Carolina Dubeux, Yukihiro Nojiri, ... Asuncion L. St. Clair (Eds.). (2014). WGII AR5 Glossary. In *Climate Change 2014: Impacts, Adaptation, and Vulnerability, Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, United Kingdom: Cambridge University Press. Retrieved from http://ipcc.ch/pdf/assessment-report/ar5/wg2/drafts/fd/WGIIAR5-Glossary_FGD.pdf
- Julia A. Ekstrom, & Susanne C. Moser. (2012). *Climate Change Impacts, Vulnerabilities, and Adaptation in the San Francisco Bay Area: A Synthesis of PIER Program Reports and Other Relevant Research* (No. CEC-500-2012-071).

California Energy Commission. Retrieved from <http://www.energy.ca.gov/2012publications/CEC-500-2012-071/CEC-500-2012-071.pdf>

Kate Williams. (2015, June 24). University Village, Sprouts get (final) green light. Retrieved April 24, 2017, from <http://www.berkeleyside.com/2015/06/24/university-village-sprouts-get-final-green-light/>

Katharine Hayhoe, Daniel Cayan, Christopher B. Field, Peter C. Frumhoff, Edwin P. Maurer, Norman L. Miller, ... Julia H. Verville. (2004). Emissions pathways, climate change, and impacts on California. *Proceedings of the National Academy of Sciences of the United States of America*, 101(34), 12422–12427.
<https://doi.org/10.1073/pnas.0404500101>

Kathleen Tierney. (2014, April 27). UC Berkeley opens new Emergency Operations Center in Warren Hall. Retrieved April 24, 2017, from <http://www.dailycal.org/2014/04/27/uc-berkeley-opens-new-emergency-operations-center-warren-hall/>

Kennedy/Jenks Consultants. (2013). *San Francisco Bay Area Integrated Regional Water Management Plan*. Retrieved from http://bairwmp.org/docs/2013-bairwm-plan-update/2013-final-plan/San%20Francisco%20Bay%20Area%20IRWMP%20Final_September%202013.pdf

Kimberly Nielsen. (2015, September 23). After data center fire, campus officials plan out responses to technical emergencies. Retrieved April 24, 2017, from <http://www.dailycal.org/2015/09/23/after-data-center-fire-campus-officials-plan-out-responses-to-technical-emergencies/>

Kimberly Veklerov. (2014, February 12). UC Berkeley administrators identify shortcomings after Sept. 30 explosion. Retrieved April 24, 2017, from <http://www.dailycal.org/2014/02/12/uc-berkeley-administrators-identify-shortcomings-sept-30-explosion/>

Kuo, P. (2014). Should UC Berkeley Use Community Choice Aggregation (CCA) to Achieve Zero-Carbon Electricity By 2025? Retrieved from http://sustainability.berkeley.edu/sites/default/files/peida_kuo_ce268_proj_uc_berkeley_cca.pdf

Lance Knobel. (2015, September 19). Small fire knocks out UC Berkeley's computers, WiFi. Retrieved April 24, 2017, from <http://www.berkeleyside.com/2015/09/19/small-datacenter-fire-knocks-out-cals-computers-wifi/>

Lynn, K., MacKendrick, K., Donoghue, E. M., & others. (2011). *Social vulnerability and climate change: synthesis of literature*. US Department of Agriculture, Forest Service, Pacific Northwest Research Station Portland, OR.
Retrieved from <http://ai2-s2-pdfs.s3.amazonaws.com/8e92/59142581dfe2ef502722d8258b9e88f31092.pdf>

- Mark Mester, & Christina Pascucci. (2014, August 4). UCLA Flood: More Than 300 Damaged Cars Can Be Picked Up Tuesday. Retrieved April 24, 2017, from <http://ktla.com/2014/08/04/ucla-flood-more-than-300-damaged-cars-can-be-picked-up-tuesday/>
- Matt Maloney. (2016, April 13). Core Capacity Transit Study Memorandum: Revised Transbay Corridor Problem Statement. Retrieved from http://mtc.ca.gov/sites/default/files/CCTS_TransbayProblemStatement_FINAL.pdf
- Matthew Rodriquez, & Lauren Zeise. (2017). *Update to the California Communities Environmental Health Screening Tool: CalEnviroScreen 3.0*. California Environmental Protection Agency & Office of Environmental Health Hazard Assessment.
- Megan Messerly, & Jeremy Gordon. (2013, September 30). UC Berkeley officials declare emergency after explosion by California Hall. Retrieved April 24, 2017, from <http://www.dailycal.org/2013/09/30/campus-wide-power-outage-disrupts-classes-early-monday-evening/>
- Merriman, P. A., & Browitt, C. W. A. (1993). *Natural Disasters: Protecting Vulnerable Communities : Proceedings of the Conference Held in London, 13-15 October 1993*. Thomas Telford.
- Metropolitan Transportation Commission, Caltrans, San Francisco Bay Conservation and Development Commission, & BART. (2014). *Climate Change and Extreme Weather Adaptation Options for Transportation Assets in the Bay Area Pilot Project*. San Francisco, CA: Metropolitan Transportation Commission.
- Miller, N. L., Hayhoe, K., Jin, J., & Auffhammer, M. (2008). Climate, Extreme Heat, and Electricity Demand in California. *Journal of Applied Meteorology and Climatology*, 47(6), 1834–1844.
<https://doi.org/10.1175/2007JAMC1480.1>
- Moret, W. (2014). *Vulnerability assessment methodologies: A review of the literature* (No. AID-OAA-LA-13-00001). Washington, D.C: USAID. Retrieved from https://www.microlinks.org/sites/default/files/resource/files/Vulnerability%20Assessment%20Literature%20Review_1.pdf
- NASA Jet Propulsion Laboratory. (2015, August). NASA: California Drought Causing Valley Land to Sink. Retrieved April 23, 2017, from <http://www.jpl.nasa.gov/news/news.php?feature=4693>
- Natural Resources Defense Council. (2014). *Safeguarding California: Reducing Climate Risk*. California Natural Resources Agency. Retrieved from http://resources.ca.gov/docs/climate/Final_Safeguarding_CA_Plan_July_31_2014.pdf

Neil Maizlish, Dorette English, Jacqueline Chan, Kathy Dervin, & Paul English. (2017). *Climate Change and Health Profile Report: Alameda County*. Sacramento, CA: Office of Health Equity, California Department of Public Health.

Office of Emergency Management. (2014). *Emergency Operations Plan*. Berkeley, CA: University of California, Berkeley. Retrieved from <http://oem.berkeley.edu/sites/default/files/emergencyoperationsplan.pdf>

Office of Emergency Management. (2016). *Berkeley Office of Emergency Management Annual Report FY16*. Berkeley, CA: University of California, Berkeley. Retrieved from <http://www.ehs.berkeley.edu/sites/default/files/lines-of-services/about-ehs/2016AnnualReport.pdf>

Office of Energy and Sustainable Development. (n.d.). Climate Action Plan - City of Berkeley, CA. Retrieved November 1, 2016, from <http://www.cityofberkeley.info/climate/>

Office of Environment, Health & Safety. (2007). *University of California, Berkeley Strawberry Creek Hydrology- 2006 Status Report*. Berkeley, CA: University of California, Berkeley. Retrieved from <http://strawberrycreek.berkeley.edu/naturalhistory/documents/SCMP2006Hydrology2007.12.pdf>

Office of Physical and Environmental Planning. (2016). *2015-2016 University of California, Berkeley Commuting Survey*.

Oppenheimer, M., Campos, M., Warren, R., Birkmann, J., Luber, G., O'Neill, B., & Takahashi, K. (2014). Emergent risks and key vulnerabilities. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, ... L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1039–1099). Cambridge, United Kingdom: Cambridge University Press.

Oregon Partnership for Disaster Resilience, & University of Oregon. (2013). *Oregon Risk Assessment: A New Model*. Retrieved from http://www.oregon.gov/LCD/HAZ/docs/2015ORNHMP/App_9.1.15_New_RA_Model_Report_fv_OPT.pdf

Paavola, J., & Adger, W. N. (2006). Fair adaptation to climate change. *Ecological Economics*, 56(4), 594–609. <https://doi.org/10.1016/j.ecolecon.2005.03.015>

Pacific Gas & Electric Company. (2016). *Climate Change Vulnerability Assessment*. PG&E. Retrieved from http://www.pgecurrents.com/wp-content/uploads/2016/02/PGE_climate_resilience.pdf

Pascal Polonik. (2015). *Climate Change in Berkeley: Effects and Adaptations*. University of California, Berkeley. Retrieved from http://sustainability.berkeley.edu/sites/default/files/climatechangeberkeleyedited_1.pdf

- Peter Adams, Jennifer Steeves, Brian Ashe, John Firth, & Ben Rabb. (2014). *Climate Risks Study for Telecommunications and Data Center Services*. General Services Administration. Retrieved from <https://sftool.gov/Content/attachments/GSA%20Climate%20Risks%20Study%20for%20Telecommunications%20and%20Data%20Center%20Services%20-%20FINAL%20October%202014.pdf>
- Phil O’Keefe, Ken Westgate, & Ben Wisner. (1976). Taking the naturalness out of natural disasters. *Nature*, 260. <https://doi.org/10.1038/260566a0>
- Pierce, D. W., Cayan, D. R., & Thrasher, B. L. (2014). Statistical Downscaling Using Localized Constructed Analogs (LOCA). *Journal of Hydrometeorology*, 15(6), 2558–2585. <https://doi.org/10.1175/JHM-D-14-0082.1>
- Rachel Morello-Frosch, Manuel Pastor, James Sadd, & Seth B. Shonkoff. (2009). *The Climate Gap: Inequalities in How Climate Change Hurts Americans & How to Close the Gap* (The Program for Environmental and Regional Equity (PERE)). University of Southern California. Retrieved from https://dornsife.usc.edu/assets/sites/242/docs/The_Climate_Gap_Full_Report_FINAL.pdf
- Ratna Amin, & Brian Stokle. (2016). *Designing the Bay Area’s Second Transbay Rail Crossing: How to ensure reliable transit and a connected region*. SPUR. Retrieved from http://www.spur.org/sites/default/files/publications_pdfs/SPUR_Designing_the_Bay_Area%27s_Second_Transbay_Rail_Crossing.pdf
- R.H. Moss, A.L. Brenkert, & E.L. Malone. (2001). *Vulnerability to Climate Change: A Quantitative Approach* (No. DE-AC06-76RLO 1830). U.S. Department of Energy. Retrieved from http://www.globalchange.umd.edu/data/publications/Vulnerability_to_Climate_Change.PDF
- Robert Monroe. (2017, April 13). Northern California Just Surpassed the Wettest Year on Record. Retrieved April 26, 2017, from <https://scripps.ucsd.edu/news/northern-california-just-surpassed-wettest-year-record>
- San Francisco Bay Conservation and Development Commission. (2011). *Living with a Rising Bay: Vulnerability and Adaptation in San Francisco Bay and on its Shoreline*. San Francisco, CA: San Francisco Bay Conservation and Development Commission. Retrieved from <http://www.bcdc.ca.gov/BPA/LivingWithRisingBay.pdf>
- San Francisco Bay Conservation and Development Commission. (2012). *Adapting to Rising Tides Vulnerability and Risk Assessment Report*. San Francisco Bay Conservation and Development Commission. Retrieved from http://www.adaptingtorisingtides.org/wp-content/uploads/2015/04/CommunityLandUse_VR.pdf

San Francisco Bay Conservation and Development Commission. (2016). *Oakland/Alameda Resilience Study*. San Francisco Bay Conservation and Development Commission. Retrieved from <http://www.adaptingtorisingtides.org/wp-content/uploads/2014/12/Oakland-Alameda-Resilience-Study-Final.pdf>

San Francisco Planning Department. (2016). *San Francisco Sea Level Rise Action Plan*. City and County of San Francisco.

Sara Grossman. (2013, October 1). Most power on campus back to normal; some buildings remain without power. Retrieved April 24, 2017, from <http://www.dailycal.org/2013/10/01/uc-berkeley-back-normal-buildings-remain-without-power/>

Sarah Lana. (2014). *City of Berkeley: 2014 Local Hazard Mitigation Plan*. Berkeley, CA: City of Berkeley. Retrieved from http://www.ci.berkeley.ca.us/uploadedFiles/Fire/Level_3_-_General/2014%20LHMP.pdf

Sean Randolph, Tracey Grose, Saori Hamidi, Adrian Covert, Amy Hutzal, Matt Gerhart, ... Xiau Wu. (2015). *Surviving the Storm*. San Francisco, CA: Bay Area Council. Retrieved from <http://documents.bayareacouncil.org/survivingthestorm.pdf>

Second Nature Inc. (n.d.). Second Nature. Retrieved April 17, 2017, from <http://secondnature.org/>

Shirley Qian. (2014). *Sea Level Rise Vulnerability Assessment* (Adapting to Rising Tides). Capitol Corridor Joint Powers Authority. Retrieved from http://www.adaptingtorisingtides.org/wp-content/uploads/2015/04/CCJPA-SLR-Vulnerability-Assessment_Final.pdf

Snover, A. K., Whitely Binder, L., Lopez, J., Willmott, E., Kay, J., Howell, D., & Simmonds, J. (2007). *Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments*. Oakland, CA: ICLEI - Local Governments for Sustainability. Retrieved from <http://cses.washington.edu/db/pdf/snoveretalgb574.pdf>

Somin Park. (2013, December 16). Dirks states Sept. 30 explosion likely caused from short in electrical switch. Retrieved April 24, 2017, from <http://www.dailycal.org/2013/12/16/dirks-explosion-likely-caused-short-electrical-switch/>

Somin Park. (2014, February 28). UC Berkeley prepares for earthquakes by improving faults in emergency procedure. Retrieved April 24, 2017, from <http://www.dailycal.org/2014/02/28/campus-makes-effort-improve-faults-emergency-procedure-preparation-earthquakes/>

Stephanie C. Herring, Martin P. Hoerling, Thomas C. Peterson, & Peter A. Scott (Eds.). (2014). Explaining Extreme Events of 2013 from a Climate Perspective. *Bulletin of the American Meteorological Society*, 95(9), S1–S96. Retrieved from <http://journals.ametsoc.org/doi/pdf/10.1175/1520-0477-95.9.S1.1>

- Steven Finacom. (1998). The Strawberry Creek Flood of 1962. *Chronicle of the University of California*, 1(1). Retrieved from <http://strawberrycreek.berkeley.edu/history/documents/StrawCk1962ColumbusDayStorm.pdf>
- Susan L. Cutter, Bryan J. Boruff, & W. Lynn Shirley. (2003). Social Vulnerability to Environmental Hazards*. *Social Science Quarterly*, 84(2), 242–261. <https://doi.org/10.1111/1540-6237.8402002>
- Susan L. Cutter, Christopher T. Emrich, Jennifer J. Webb, & Daniel Morath. (2009). *Social Vulnerability to Climate Variability Hazards: A Review of the Literature*. Columbia, SC: Hazards and Vulnerability Research Institute, University of South Carolina. Retrieved from <http://citeseerx.ist.psu.edu/viewdoc/download;jsessionid=41D6A9A89946F8AA5F3793AC66A2E794?doi=10.1.1.458.7614&rep=rep1&type=pdf>
- Susanne Moser, Julia Ekstrom, & Guido Franco. (2012). *Our Changing Climate 2012: Vulnerability & Adaptation to the Increasing Risks from Climate Change in California* (No. CEC-500-2012-007). California Energy Commission. Retrieved from <http://www.energy.ca.gov/2012publications/CEC-500-2012-007/CEC-500-2012-007.pdf>
- Sutherst, R. W. (2004). Global Change and Human Vulnerability to Vector-Borne Diseases. *Clinical Microbiology Reviews*, 17(1), 136–173. <https://doi.org/10.1128/CMR.17.1.136-173.2004>
- UC Berkeley Geospatial Innovation Facility. (2017). Cal-Adapt -- Exploring California's Climate Change Research. Retrieved October 27, 2016, from <http://cal-adapt.org/>
- UC Berkeley Transportation Studio. (2016). *Third Crossing Studio*. Berkeley, CA: University of California, Berkeley. Retrieved from <http://thirdcrossing.org/>
- UC Regents. (2015, December 23). UC revenue and enrollment trends. Retrieved December 3, 2016, from <https://www.universityofcalifornia.edu/infocenter/uc-revenue-and-enrollment-trends>
- UC Regents. (2016). Clubs & Organizations | UC Berkeley Office of Undergraduate Admissions. Retrieved December 3, 2016, from <http://admissions.berkeley.edu/clubs>
- UC Regents. (2017). Creeks of UC Berkeley. Retrieved April 23, 2017, from <http://creeks.berkeley.edu/>
- United Nations Framework Convention on Climate Change. (2007). *Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries*. Bonn, Germany: United Nations Framework Convention on Climate Change. Retrieved from http://www.preventionweb.net/files/2759_pub07impacts.pdf

United Nations Framework Convention on Climate Change. (n.d.). IPCC Common Methodology. Retrieved from https://unfccc.int/files/adaptation/methodologies_for/vulnerability_and_adaptation/application/pdf/ipcc_common_methodology.pdf

University Health Services. (2017). Local Emergency and Urgent Care Centers (Off Campus) | University Health Services. Retrieved April 24, 2017, from <https://uhs.berkeley.edu/medical/urgent-care/local-emergency-and-urgent-care-centers>

University of California at Berkeley Geospatial Innovation Facility. (2017a). Annual Averages. Retrieved April 23, 2017, from <http://beta.cal-adapt.org/tools/annual-averages/#climatevar=tasmax&scenario=rcp45&lat=38.5938&lng=-121.4687&boundary=locagrid&units=fahrenheit&uri=%2Fapi%2Flocagrid%2F37907%2F>

University of California at Berkeley Geospatial Innovation Facility. (2017b). Extreme Heat. Retrieved April 23, 2017, from <http://beta.cal-adapt.org/tools/extreme-heat/#climatevar=tasmax&scenario=rcp85&lat=38.5938&lng=-121.4687&boundary=locagrid&units=fahrenheit&uri=%2Fapi%2Flocagrid%2F37907%2F>

University of California, Berkeley. (2012). *Berkeley Undergraduate Portfolio*. Berkeley, CA: University of California, Berkeley. Retrieved from <http://opa.berkeley.edu/sites/default/files/UndergraduateProfile.pdf>

University of California, Berkeley. (2017a). Back-Up Child Care. Retrieved April 24, 2017, from <http://backupchildcare.berkeley.edu/>

University of California, Berkeley. (2017b). UC Berkeley Food Pantry – Battling food insecurity and malnourishment. Retrieved April 24, 2017, from <https://pantry.berkeley.edu/>

University of California, Berkeley. (n.d.). California Golden Bears - Facilities. Retrieved April 26, 2017, from <http://www.calbears.com/sports/2013/4/17/208213293.aspx>

US DOT FHWA. (2011, June). [Archived] US DOT Policy Statement On Climate Change Adaptation - Policy And Guidance - Resilience - Sustainability - Environment - FHWA. Retrieved April 24, 2017, from https://www.fhwa.dot.gov/environment/sustainability/resilience/policy_and_guidance/usdot.cfm

U.S. Global Change Research Program. (2014). *Third National Climate Assessment*. Washington, D.C. Retrieved from <http://nca2014.globalchange.gov/report>

Veerabhadran Ramanathan, Juliann E. Allison, Maximilian Auffhammer, David Auston, Anthony D. Barnosky, Lifang Chiang, ... Bryon Washom. (2015). *Executive Summary of the Report, Bending the Curve: 10 Scalable Solutions for*

Carbon Neutrality and Climate Study. University of California. Retrieved from http://uc-carbonneutralitysummit2015.ucsd.edu/_files/Bending-the-Curve.pdf

Vicki Kramer. (n.d.). *Impact of Climate Change on Vector-Borne Diseases*. Retrieved from http://oehha.ca.gov/media/13human_kramer.pdf

Westerling, A. L., Bryant, B. P., Preisler, H. K., Holmes, T. P., Hidalgo, H. G., Das, T., & Shrestha, S. R. (2011). Climate change and growth scenarios for California wildfire. *Climatic Change*, 109(1), 445–463.
<https://doi.org/10.1007/s10584-011-0329-9>

Wieckowski, B. Bill Text - SB-246 Climate change adaptation. (2015). Retrieved from https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB246

Wildland Resource Management. (2014). *Lawrence Berkeley National Laboratory Wildland Fire Management Plan*. Berkeley, CA: Lawrence Berkeley National Laboratory.