HAZARDS AND CLIMATE RESILIENCE PLAN

THE CITY AND COUNTY OF SAN FRANCISCO

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City and County of San Francisco
Hazards and Climate Resilience Plan
March 26, 2020

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or through the Office of Resilience and Capital Planning

City Hall, Room 347
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San Francisco, CA 94102

Hazards and Climate Resilience Plan

In compliance with the Stafford Act and Disaster Mitigation Act, we are pleased to submit the City and County of San Francisco's Hazards and Climate Resilience Plan. In addition to serving as the five-year update to the 2014 Local Hazard Mitigation Plan, this plan also serves as the foundation for San Francisco's Community Safety Element and Climate Action Strategy updates. We took this opportunity to improve our understanding of San Francisco's vulnerabilities to natural hazards and develop a comprehensive approach to reducing risk. We sought to better understand not just the earthquake risk that has been a facet of life in San Francisco since the Great Earthquake of 1906, but also the climate change impacts that are bringing unprecedented challenges to San Francisco and across the State.

The Hazards and Climate Resilience Plan demonstrates San Francisco's commitment to creating and supporting resilient infrastructure, buildings, and communities in the face of increasing risks. Like San Francisco's previous hazard mitigation plans, the Hazards and Climate Resilience plan has a strong commitment to reducing damage to buildings and infrastructure. But with this update, we also emphasized supporting healthy homes and neighborhoods before, during, and after a hazard event. To achieve that, we involved more stakeholders than ever before, including adding the Public Health Department to the plan's leadership and conducting workshops with organizations that serve San Francisco's populations that are more vulnerable to hazards. We also made equity a key principle of how we develop the plan, the types of strategies we pursue, and how we implement them.

While this plan represents a commitment to reducing risks over the next five years and beyond, it also represents a civic conversation that will continue as we monitor the science and impacts of climate change and earthquakes. The ultimate goal is to enable our communities to project, adapt, and thrive regardless of the hazards we face.

We look forward to working with the Mayor and Board of Supervisors to advance and implement the important strategies in this plan.

Sincerely,

Naomi Kelly
City Administrator

Sincerely,

Mary Ellen Carroll
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Chapter 01

Introduction

One day if I go to heaven… I'll look around and say
"It ain't bad, but it ain't San Francisco"

-Herb Caen

Anyone who spends time in San Francisco quickly recognizes its incredible beauty. Dramatic landscapes and vistas, proximity to water, wonderful hills, mild weather, and rolling fog are all part of what make San Francisco such a great place to live. However, the same geologic and climate forces that create this setting also make us susceptible to natural disasters. Coping with, recovering from, and in many cases thriving after disasters are not new to San Franciscans.

The Great Earthquake of 1906, when a magnitude 7.9 earthquake and subsequent fires destroyed 80% of the city, as well as smaller earthquakes such as the Loma Prieta Earthquake of 1989 are present in peoples' minds. In recent years, new and unprecedented hazards have challenged San Francisco, from extreme heat in 2017 to unhealthy air quality in 2018 and 2019. Climate science tell us that these and other climate-related hazards, such as coastal flooding and drought, will be on the rise as greenhouse gas emissions drive higher temperatures, higher sea levels, and unpredictable precipitation patterns.

The Hazards and Climate Resilience Plan (HCR) captures our latest understanding of how hazards are intensifying along with the climate crisis and what we can expect in the years to come. It presents a strategy for how San Francisco will become a safer and more resilient place by mitigating the impacts of seismic, weather-related, combustion-related, and other hazards to our communities, buildings, and infrastructure, and adapting to what we cannot mitigate. This chapter describes the purpose, scope, and drivers of San Francisco's first Hazards and Climate Resilience Plan.

1.1 Purpose and Scope

Purpose

The City and County of San Francisco's HCR is a combined hazard mitigation and climate adaptation plan. It serves as the City's action plan for reducing the impacts of hazards that have long been a part of life in San Francisco, such as earthquakes and landslides, and hazards that are becoming more frequent and severe due to climate change, including flooding, drought, and extreme heat.

The HCR uses a scientific approach to assess the current and increasing risks facing San Franciscans today and in the years and decades to come. It includes goals and strategies to increase the resilience of San Francisco's infrastructure, buildings, and communities. In so doing, it also serves as a guide for decision makers as they commit resources to reduce the impacts of hazards on people, infrastructure, and the environment.

The HCR also serves as a guide for the broader community as to how the City is working to mitigate and adapt to natural disasters. This is through specific projects and programs that increase the resilience capacity of departments, non-profits, community groups, individuals, and other partners. Finally, the HCR seeks to encourage deeper levels of participation and collaboration on hazards and climate resilience planning.

The key drivers of hazard mitigation, climate adaptation, and resilience planning are described below.

Resilience Vision

The overall vision of the HCR is to make San Francisco resilient to immediate and long-term threats of climate change and natural hazards through actions to mitigate risks, adapt built and natural assets, and build a more equitable and sustainable city. This includes ensuring systems are in place so that individuals, communities, institutions and businesses survive, adapt, and thrive no matter the kinds of chronic stresses and acute shocks they experience. The HCR also coordinates with and supports the City's Climate Action Strategy, which outlines urgent strategies needed to reduce greenhouse gas emissions and minimize the severity of climate change and its associated impacts.

Guiding Principles

The following principles guided the development of the HCR, from scoping the assessment to evaluating and refining strategies.

- **Equity & Health:** Proactively work to eliminate racial or social disparities in the impacts of all hazards and/or the distribution of resilience benefits.
- **Community Cohesion:** Empower people and partnerships to reduce vulnerability and promote resilience at the building, block, and neighborhood level.
- **Affordability & Economic Viability:** Help residents and business stay and thrive in San Francisco.

- **Climate Mitigation:** Pursue hazard mitigation and climate adaptation strategies in ways that also help eliminate the greenhouse gas emissions, which drive climate change and worsen climate-related hazards.
- **Biodiversity & Connection to Nature:** Restore and leverage local ecosystems to help mitigate hazards and support climate adaptation, while ensuring all residents can access green spaces, parks, and natural habitats and experience nature every day.
- **Science-Grounded Innovation**: Closely monitor evolving climate and hazard-related science and modify approaches appropriately to maintain maximum effectiveness.
- **Good Governance:** Provide dependable and actionable information to foster transparency and openness

Hazard Mitigation Planning

The HCR serves as San Francisco's 2019 Hazard Mitigation Plan (HMP) update. It builds and expands the 2014 and 2008 HMPs and related efforts. Hazard mitigation is a process in which a jurisdiction identifies and profiles hazards that affect the area, analyzes the people and facilities at risk from those hazards, and develops mitigation actions to lessen or reduce the impact of profiled hazards. The jurisdiction's implementation of mitigation actions, which include long-term strategies that may involve planning, policy changes, programs, projects, and other activities, is the primary objective of this process.

Local hazard mitigation planning is governed by the Stafford Act, as amended by Disaster Management Act of 2000 (DMA 2000), and by federal regulations implementing the Stafford Act. As revised by DMA 2000, the Stafford Act requires state, local, and tribal governments to develop and submit for approval a mitigation plan that outlines processes for identifying the natural hazards, risks, and vulnerabilities of the jurisdiction. Federal Emergency Management Agency (FEMA) approval of such plans is a prerequisite to receiving federal pre- and post-disaster hazard mitigation assistance funding.

Climate Adaptation Planning

Climate adaptation planning strives to reduce the unavoidable impacts of climate change. Climate change is already affecting San Francisco and is projected to continue into the foreseeable future. Reducing global greenhouse gas (GHG) emissions may avoid some of more severe impacts, but given the amount of emissions already in the atmosphere and the current emissions trajectory, San Francisco will continue to see higher temperatures, sea level rise, and altered precipitation patterns. Chapter 03 provides more information on climate change projections and the implications for local hazards.

Local climate adaptation planning in California is governed by Senate Bill 379 (2016) which states that when a local jurisdiction updates its Hazard Mitigation Plan (HMP), it must also update the Safety Element of its General Plan to address climate adaptation and resilience strategies. The bill requires the update to include goals, policies, and objectives based on a climate change and vulnerability assessment. The State provides guidance and resources to undertake this type of planning through the online Cal-Adapt tool and the California Adaptation Planning Guide. The HCR builds on these tools and uses previous and ongoing climate adaptation planning in San Francisco, including the Sea Level Rise Action Plan and Sea Level Rise Vulnerability & Consequences Assessment. Linking the HMP to the Safety Element also makes the City and County eligible to be considered for part, or all, of its local-share costs on eligible Public Assistance funding to be provided by the State per Assembly Bill 2140.

Climate resilience planning in San Francisco is also driven by the City's commitment to develop a Climate Action Strategy aligned with the Paris Agreement, a global compact on climate change committing nations to ambitious efforts to keep global average temperature rise to well below two degrees Celsius relative to pre-industrial levels. The Agreement also commits to strengthening the ability of countries to deal with the unavoidable impacts of climate change through adaptation and increased resilience. That means that San Francisco is not only developing a strategy to reach net zero carbon emissions by 2050, but also developing a plan to increase resilience to the impacts of climate change through this HCR. All of this is set within the context of sustainable development and inclusivity for all communities.

Resilience Planning

Resilience describes the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow, no matter what kinds of chronic stresses and acute shocks they experience. Approaching challenges with a resilience lens calls for considering problems systematically to better serve residents today while also planning for the longer term. Resilience aims to bridge the gaps between social justice, sustainability, disaster recovery, and other areas. In San Francisco, the term climate resilience is being used to coordinate synergistic efforts that benefit mitigation and adaptation.

The HCR builds on San Francisco's 2016 resilience strategy, *Resilient SF*, which was produced in partnership with 100 Resilient Cities initiative funded through the Rockefeller Foundation. As over 90% of the strategies from Resilient SF are complete or underway, the HCR provides new direction for the City's resilience efforts over the next five years. It also takes a more in-depth focus on the shocks of natural hazards and climate change impacts, while continuing to develop solutions that also address the chronic stresses San Franciscans face day to day, including but not limited to:

- Unaffordability
- Social Inequity
- Aging Infrastructure
- Population Growth

As over 90% of the strategies from Resilient SF are complete or underway, this Plan provides new direction for the City's resilience efforts for the next five years. The City of San Francisco continues to be a part of efforts to support and promote resilience in the region, the State, and across the globe. Our current Chief Resilience Officer is the longest standing member of the State Interagency Climate and Adaptation Resilience Program Technical Steering Committee. San Francisco is also leading the way as one of two representatives for North America that is forming the new Global Resilience Cities Network (GCRN) to foster resilience in cities across the world by sharing best practices, training resilience officers, and bringing cities that are on the front lines of addressing climate change and implementing disaster mitigations programs together.

1.2 Key Changes Since 2014 Hazard Mitigation Plan

While mitigating our seismic risks remains a major priority, additional hazards and resilience priorities have emerged since 2014. These updates are organized under climate change, seismic, housing and homelessness, and progress on local mitigation efforts.

Climate Change

- Former Mayor Ed Lee convened the Mayor's Coordinating Committee on Sea Level Rise (SLR), which oversaw the development of the Sea Level Rise Action Plan in 2016 and updates to the Sea Level Rise Guidance for Capital Planning in 2015 and 2019, and the SLR Vulnerability & Consequence Assessment.
- Of recent note, the City experienced unprecedented extreme heat (hottest day on record: September 2017) and dangerous air quality (two weeks in November 2018) events. In December 2018, Mayor Breed issued Executive Directive 18-04 requesting that the Department of Emergency Management, the Department of Public Health, and the City Administrator's Office take action to strengthen the City's preparedness and response to air quality and other weather-related emergencies.
- In 2018, San Francisco helped develop and then participated in the regional Resilient by Design competition, funded by the Rockefeller Foundation and participating cities. One of the nine selected projects focused on the Islais Creek area of San Francisco, an area which is vulnerable to sea level rise and flooding. Proposed adaptation and resilience strategies also sought to create co-benefits like public open space and ecosystem restoration.

Seismic

- Studies have improved our understanding of the seismic vulnerabilities of the Embarcadero Seawall and voters overwhelmingly approved a $425 million bond in 2018 to begin to shore up sections that are most vulnerable.
- New studies have improved our understanding of the vulnerabilities of tall buildings and the locations of vulnerable concrete and steel buildings. In January 2019, Mayor Breed issued Executive Directive 19-01 to strengthen high-rise buildings and create

a recovery framework and downtown recovery plan in preparation for the next major earthquake.

- Update of the building-by-building HAZUS Earthquake Loss Estimation Model in 2017 and new or updated Seismic Hazard Ratings for over 50 buildings
- Approval of the Earthquake Safety and Emergency Response program bonds in 2014 for $400 million and Public Health and Safety Bonds in 2016 for $350 million by San Francisco voters

Housing and Homelessness

- Making San Francisco more affordable in a time of increased housing costs is a key priority, including adding more housing for low- and middle-income residents by streamlining bureaucracy and reducing permitting times while also investing in affordable housing.
- San Francisco faces a significant challenge with people experiencing homelessness. According to the 2019 Homeless Count and Survey, the homeless population has increased from 6,775 in 2015 to 8,011 in 2019. With limited resources and fewer connections to their communities, people experiencing homelessness are often the most vulnerable and at risk in a disaster or other emergency situations. Through improved coordination citywide and the development of Navigation Centers, existing Temporary Shelters and SAFE Navigation Centers, the City is having a significant impact in our ability to bring our unhoused neighbors indoors.
- The City launched the Healthy Streets Operations Center (HSOC) in January 2018 to coordinate responses to homeless encampments and quality of life issues.
- San Francisco voters passed affordable housing bonds in 2015 and 2019 for $310 million and $600 million, respectively.

Progress in Local Mitigation Efforts

Chapter 06 provides an inventory of all the hazards and climate resilience actions in progress, including the status of 2014 HMP actions. Particularly notable progress since 2014 includes:

- Implementation and near completion of the Soft Story Retrofit Ordinance
- Completion of Private Schools Earthquake Evaluation Program

- Development of the Tall Buildings Safety Strategy
- Development of the Sea Level Rise Vulnerability and Consequences Assessment
- Initiation of the Seawall Safety Program and Flood Study through the receipt of an Army Corps of Engineers New Start funding in 2018
- Implementation of the Ocean Beach Master Plan is underway
- Implementation of the Sewer System Improvement Program is underway
- Completion of the Resilient by Design Competition Islais Creek project and progress next steps through the Southeast Mobility Adaptation Strategy
- Initiation of the Waterfront Resilience Program
- Implementation of Vision Zero SF efforts to reduce pedestrian and bike deaths to zero is ongoing
- The 2014 HMP was use to inform updates to the 10-Year Capital Plan and the 2016 update to the Tsunami Annex and Winter Storm and Flood Annex of the Emergency Response Plan.

Key Updates from the 2014 HMP

This update includes more information on climate science and integrated, relevant climate information. For instance, poor air quality is now included as a hazard. In addition to a hazard-based analysis in Hazard Profiles, this the HCR also includes a sector-based assessment with an emphasis on seismic and climate hazards. An overview of this assessment is in Chapter 05 and the full results are in Appendix A. This update also includes an effort to reach stakeholder organizations that serve vulnerable populations to help ensure the HCR reflects their feedback. Finally, the strategies in Chapter 07 build on progress achieving the 2014 strategies and a better understanding of San Francisco's vulnerabilities and their consequences.

1.3 Scope

Planning Area

The Planning Area covered by the HCR includes the City and County of San Francisco, as shown on Figure 1-1. San Francisco is the only consolidated city-county in California; the City of San Francisco is the sole municipality located within the county. San Francisco County encompasses approximately 232 square miles, though land makes up only 47 of those square miles. Included within county boundaries are Treasure Island and the Farallon Islands. Unlike Treasure Island, the Farallon Islands are uninhabited, with the exception of the Southeast Farallon Islands where research residents stay.

FIGURE 1-1: HCR PLANNING AREA

In addition, the HCR Planning Team determined that it is important to the safety and resilience of San Francisco to address essential City-owned assets located outside county boundaries in its mitigation planning. The HCR begins this integration process by identifying hazard impacts to out-of-county assets in the Hazard Profiles (especially wildfire and drought). In addition, San Francisco International Airport (SFO) is assessed at the same level of detail as other in-county assets (see Appendix A). All other essential out-of-county assets are included in Appendix B: Out-of-Jurisdiction Assets and Primary Assets, with related strategies to improve the resilience of out-of-county assets in Chapter 07. Future HCR updates will continue to seek ways to incorporate out-of-county assets into the vulnerability analysis and other sections of the Plan as well.

All Hazards

This assessment takes an all-hazards approach with a greater focus on natural hazards and hazards influenced by climate change. Information on the hazards analysis is found in Chapter 04.

1.4 Key Concepts and Terms

- **Adaptability**: The ability, competency, or capacity of a system to adjust to climatic variables.
- **Asset:** a useful or valuable thing, person, or quality
- **Asset Class:** A categorization of multiple assets that are of similar type, or serve similar functional purposes
- **Baseline/Reference**: The baseline (or reference) is the state against which the change is being measured. It might be 'current baseline', in which case it represents observable, present day conditions. It might also be a 'future baseline', which is the projected future set of conditions excluding the driving factor of interest. Alternative interpretations of the reference conditions can give rise to multiple baselines.
- **Climate adaptation**: Measures taken to adjust human or natural system to reduce harm from the impacts of climate change; similar in use to hazard mitigation.
- **Climate projections**: The modelled change in climate variability.
- **Climate variability**: Variations in the mean state and other statistics (such as standard deviations, statistics of extremes, etc.) of the climate on all temporal and

spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability) or to variations in natural or anthropogenic external forcing (external variability).

- **Co-benefits**: Refers to environmental, social, or economic benefits that may be achieved as a result of initiating and implementing a hazard mitigation or adaptation strategy. Co-benefits are typically above and beyond the direct intention of the proposed strategy to address vulnerability, but often cost neutral.
- **Consequence**: The impacts to people, ecology, and economy if vulnerable assets are exposed to a hazard.
- **Emissions scenario**: A plausible representation of future greenhouse gas (GHG) emissions, based on a coherent and internally consistent set of assumptions about driving forces (demographic, socio-economic development, technological change, etc.) and their key relationships.
- **Exposure**: The extent to which an asset is situated in a place or setting that could be adversely affected by hazards.
- **Geographic Information Systems (GIS)**: A technological system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data. In the HCR, GIS is used to analyze the exposure of assets using layers of hazard data.
- **Hazard**: A source of potential danger or an adverse condition that could harm people, socioeconomic systems, or built and natural environments.
- **Hazard Mitigation**: Sustained actions taken to reduce or eliminate short- and long-term risks to life and property from hazards; also similar to adaptation.
- **Natural hazard**: A hazard that results from conditions in the natural environment, such as flooding. Humans may contribute to or exacerbate the hazard but cannot directly cause it.
- **Preparedness**: Actions that strengthen the City's capability to respond to disasters.
- **Resilience**: The capability of preparing for, responding to, and recovering from difficult conditions; the ability to bounce back after change or adversity. The HCR uses the term resilience actions, which encompass both hazard mitigation and climate adaptation.

- **Risk**: The chance that a given hazard could occur multiplied by the understood consequences of an impact on people, socioeconomic systems, or the built and natural environment.
- **Risk Management**: Regulatory controls, plans, policies, programs, projects, initiatives, and anything else employed to cost-effectively eliminate, avoid, or minimize risks.
- **Sea Level Rise Vulnerability Zone**: The coastal areas within the City and County of San Francisco understood to potentially face future flooding and inundation by a 100-year coastal flood event given 66 inches of sea level rise, a high-end scenario projected by the end of the century. Consistent effort has been made to integrate these projections into the City's planning process.
- **Vulnerability**: The extent to which people, socioeconomic systems, and the built and natural environments are exposed to a hazard and are unable to cope with the impacts.
- **Vulnerable populations**: Vulnerable communities experience heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to cope with, adapt to, or recover from climate impacts. These disproportionate effects are caused by physical (built and environmental), social, political, and/ or economic factor(s), which are exacerbated by climate impacts. These factors include, but are not limited to, race, class, sexual orientation and identification, national origin, and income inequality.

1.5 Document Overview

As a city and county with complex systems and multiple policy bodies and boards, the Hazards and Climate Resilience Plan covers a lot of ground. It is organized into the following chapters and appendices. A brief description of what each chapter contains includes:

Chapter 02: Planning Process provides an overview of the methodology, approach, and steps used to develop this plan

Chapter 03: San Francisco Risk Landscape provides the context for the vulnerability assessment and strategies that follow, describing key demographic, geographic, and economic trends and a summary of the eight city sectors used in the Vulnerability & Consequences Assessment.

Chapter 04: Hazard Analysis provides a hazards-based assessment, which includes information on the history, impacts, location, and probability of future events for the hazards identified This chapter also includes an overview of the implications of climate change on the hazards we experience in San Francisco.

Chapter 05: Vulnerability and Consequence Analysis includes an overview of the exposure assessment completed for all hazards and provides the results of the Vulnerability & Consequence profiles completed for 28 asset classes within eight sectors.

Chapter 06: Capabilities and Existing Action documents the abilities within the City and County of San Francisco to undertake future hazard mitigation and climate adaptation actions, existing actions underway, and the status of 2014 HMP actions.

Chapter 07: Strategy includes San Francisco's HCR goals and the complete set of strategies proposed to increase the resilience of buildings, infrastructure, and communities.

Chapter 08: Plan Maintenance describes how the City will maintain the HCR over the next five years.

Appendix A contains Vulnerability & Consequence Profiles for each asset class.

Appendix B lists out-of-county assets and primary out-of-county hazards.

Appendix C contains an overview and results from the stakeholder engagement process.

Appendix D covers the HCR maintenance documents, including the Planning Team Annual Review Questionnaire and the City and County of San Francisco Hazard Mitigation Action Progress Report

Appendix E details the local adoption process with relevant documentation.

Appendix F identifies detailed information on capabilities, revenue sources, and grant programs associated with mitigation plan requirement

Appendix H includes information on potential funding sources and estimated timelines for completion for strategies.

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Chapter 02

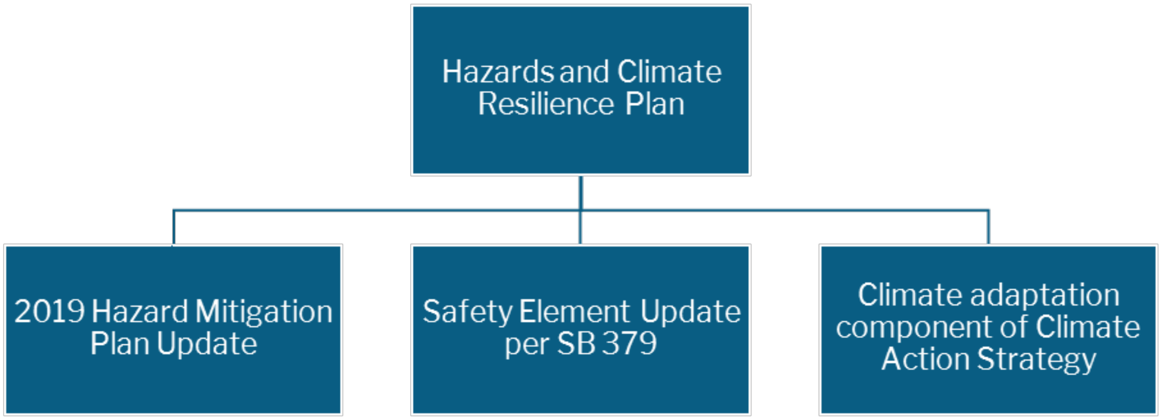
Planning Process

To create the HCR, the City and County of San Francisco developed a comprehensive approach to incorporate the feedback of departments and the larger San Francisco community to the greatest extent possible given time and resource constraints. This chapter describes the process used to develop the 2019 HCR, including engagement with stakeholders and the public.

2.1 Planning Process Overview

As illustrated in Figure 2-1, the HCR process meets three primary planning needs: (1) create a new 2019 HMP in compliance with state and federal requirements, (2) incorporate climate hazards into both the HCR and the Safety Element of the General Plan, and (3) add climate resilience and adaptation to the 2020 Climate Action Strategy.

FIGURE 2-1: HAZARDS AND CLIMATE RESILIENCE PLANNING NEEDS



The HCR development process also sought to achieve the outcomes listed below.

- Build greater understanding of San Francisco's hazard and climate risks among City leaders, staff, and stakeholders
- Provide strategic policy guidance and direction for ongoing and future citywide multi-hazard risk reduction efforts
- Build the capacity of City staff and partners to develop hazard and climate resilience actions and programs

2.2 City Agency Leadership and Engagement

The Office of Resilience and Capital Planning (ORCP) managed the HCR development process through a Steering Committee and a Technical Working Group involving several departments. Staff from these departments provided indispensable resources and support throughout the process. All the departments listed below sat on the Steering Committee. Those in bold also sat on the Technical Working Group.

- **Office of Resilience and Capital Planning (ORCP)**
- **Planning Department (Planning)**
- **Department of Public Health (DPH)**
- **Department of the Environment (SFE)**
- **Department of Emergency Management (DEM)**
- City Administrator – Steering Committee
- Public Works (Public Works) – Steering Committee
- Mayor's Office (MYR) – Steering Committee

The Technical Working Group met every two weeks and the Steering Committee met monthly.

Table 2-1 below is one of the Working Group's first deliverables. This table ensures consistency with the 2014 Hazard Mitigation Plan (HMP) and compliance with new actions necessary for the Hazards and Resilience Plan (HCR).

TABLE 2-1: SUMMARY OF UPDATES FROM 2014 HMP

2014 HMP	Necessary Actions	Location in 2019 HCR
Planning Process	Re-form Planning Team with expanded membership	Section 2.2, Appendix C
	Expand engagement with stakeholders, especially those that serve vulnerable community members	Section 2.3, Appendix C
Hazard Analysis and Vulnerability Assessment	Update discussion of climate science to reflect the latest science	Section 4.1
	Incorporate climate projections into relevant hazard profiles	Section 4.2–4.14
	Develop sector-based vulnerability assessment with clear issue statements	Chapter 05, Appendix A
Capabilities and Existing Actions Assessment	Update and simplify capabilities and actions that have been initiated since 2014	Section 6.1, Appendix F
Mitigation Strategy	Update goals	Section 7.1
	Update status of 2014 HMP actions	Section 6.2
	Develop new strategies that reflect priorities since 2014 and longer-term climate resilience needs	Section 7.3
	Update strategy evaluation criteria	Section 7.3

The Technical Working Group also led engagement with City agencies through a Planning Team, comprised of staff from over 28 agencies with expertise in hazards, asset management, and mitigation and adaptation capabilities. (See Appendix C for Planning Team roster). The Technical Working Group engaged the Planning Team over the course of six meetings summarized in Table 2-2 below and in the development and review hazard profiles, vulnerability and consequence profiles, and strategies.

TABLE 2-2: PLANNING TEAM MEETING TOPICS

Meeting #	Topics	Date
1	Project introduction, goals, and hazards	May 2018
2	Asset inventory vulnerability and consequences methodology	July 2018
3	Preliminary vulnerability and consequences findings	Sep 2018
4	Key Planning Issues and strategy development process	January 2019
5	Strategy review and refinement	April 2019
6	Citywide draft review	November 2019

When necessary, department staff with expertise on specific assets and vulnerabilities participated in the analysis. This included Animal Care and Control, Office of Community Investment and Infrastructure, San Francisco Public Library, and the SFPUC Water, Wastewater, and Power Divisions.

Agencies external to the City and County were also engaged to ensure that information regarding their assets and vulnerabilities was accurate. These included BART, Caltrain, Golden Gate National Recreational Area (GGNRA), PG&E, and San Francisco Unified School District (SFUSD).

Finally, it is important to note that ORCP staff held numerous smaller strategy sessions with the Board of Supervisors, commissions, and department heads to verify information collect feedback. These include the following:

- Mayor's Office
- San Francisco Board of Supervisors (BOS)
    - Supervisor Sandra Fewer
    - Supervisor Catherine Stefani
    - Supervisor Aaron Peskin
    - Supervisor Gordon Mar
    - Supervisor Vallie Brown
    - Supervisor Norman Yee
    - Supervisor Matt Haney
    - Supervisor Rafael Mandelman
    - Supervisor Hillary Ronen
    - Supervisor Shamann Walton
    - Supervisor Ahsha Safai
- Mayor's Office of Housing and Community Development (MOHCD)
- Neighborhood Empowerment Network (NEN)
- Office of the City Administrator
- Office of Workforce and Economic Development (OEWD)
- Port of San Francisco (Port) and Port Commission
- San Francisco Department of Public Health (DPH)
- San Francisco Department of the Environment (SFE)
- San Francisco Planning Department (Planning)
- San Francisco Department of Emergency Management (DEM)
- San Francisco Fire Department (SFFD)
- San Francisco Department of Technology (DT)
- San Francisco Public Utilities Commission (SFPUC) and PUC Commission
- San Francisco Department of Aging and Adult Services (DAAS)
- San Francisco Public Works (DPW)
- San Francisco Municipal Transportation Agency (SFMTA)
- San Francisco International Airport (SFO)
- San Francisco Police Department (SFPD)

2.3 Stakeholder and Public Engagement

This section describes opportunities for the public to provide feedback during the planning process and drafting stage, including engagement with stakeholders such as:

- Community based organizations (CBOs)
- Neighborhood serving organizations
- Interest organizations
- Neighboring jurisdictions
- Regional, State, and federal agencies

HCR Engagement Goals

The goal of the stakeholder and public engagement process is threefold; (1) share information about local risks (as outlined in the HCR); (2) solicit input from a broad community of San Franciscans on their values, concerns, and priorities; and (3) reflect public feedback in the HCR's strategies. To maximize the ways in which information gathered from community members can be used, additional information regarding overall City preparedness was also added. The process that included stakeholder engagement workshops and a community survey. Both the workshops and survey were designed to accomplish the following goals.

- Help the City understand peoples' experience with hazard events to inform how to improve the response to future hazards
- Gather community feedback on draft strategies to incorporate into the Hazards and Climate Resilience Plan
- Educate stakeholder groups about:
    - Hazard issues and impacts for San Francisco
    - Existing and planned work to increase resilience within San Francisco
    - Purpose and contents of the HCR Plan

Stakeholder Engagement Workshops

As a first step in the engagement process, the interdepartmental HCR team met with a group of CBO leaders that work on resilience in San Francisco to hear their advice on how best to achieve the HCR goals within the communities they serve. This meeting took place on February 28, 2019 and is documented in Appendix C. Based on the feedback from this meeting, the HCR team organized five thematic workshops with additional leaders of community based organizations, non-governmental organizations, and other groups that serve the San Francisco community, especially vulnerable populations. These workshops are summarized in Table 2-3 below and documented in Appendix C.

TABLE 2-3: SUMMARY OF STAKEHOLDER MEETINGS

Date	Theme/Topic	Examples of Unique Perspective for Each Group
July 9th	Business/ Commercial Properties	• Provided feedback on relative effectiveness and likely impacts of incentivizing or mandating specific strategies, including small businesses • Identified challenges and opportunities to partner with businesses in implementing strategies
July 9th	Housing Stakeholders and Residential Property Managers/ Owners	• Provided feedback on relative effectiveness and likely impacts of incentivizing or mandating specific strategies (e.g., installing or upgrading HVAC systems, communicating about hazards to residents/tenants) • Identified challenges and opportunities for implementing strategies in supportive housing
July 12th	Disability and Functional Needs (DAFN)/Older Adults	• Identified unique needs when responding to hazards (e.g., charge motorized wheelchairs' batteries, maintain power for residents with assisted respiration) • Emphasized the need to ensure that communication is accessible to people with a range of different disabilities
July 12th	Racial, Social, and Environmental Justice	• Emphasized the need to set up processes prior to a hazard to ensure that critical information about hazards reaches, and is easily understood by, low-income, immigrant, homeless, and other vulnerable communities • Provided additional information on how hazards impact vulnerable, disenfranchised, and under-resourced communities, as well as critical needs for these communities
July 16th	Children, Youth, and Families	• Identified challenges in keeping young people of different ages groups safe during and immediately following a hazard • Identified challenges and opportunities for implementing strategies in schools and out-of-school programming (e.g., summer camps, afterschool care)

Themes from Across Stakeholder Workshops

Stakeholders consistently expressed interest in learning more about the hazard risks relevant to the neighborhoods in which they work, as well as the City's recommendations (or general best practices) to prepare for the hazards they are most likely to experience. Many participants were excited to learn that the HCR would include maps with citywide risks and vulnerabilities. Many participants also wanted to know what the City considered to be key community facilities (both which specific facilities and more general types of facilities).

Recognizing the significant impacts that some hazards will have, and the many jurisdictions that will be involved in recovering from such hazards, participants emphasized how important it is for the City to support and participate in coordination planning between City departments, with overlapping jurisdictions (e.g., SFUSD, Port, National Park Service), with neighboring jurisdictions (e.g., Marin County, Daly City, San Mateo County, Alameda County), and potentially with geographically remote partners (for example, to provide supportive housing while the City and region recover from a major earthquake).

Workshop participants agreed that resources should be prioritized for and directed to vulnerable populations and the critical facilities that serve those populations. However, different stakeholder groups had different ideas of what populations are most vulnerable and what types of facilities are "critical." Participants in most workshops identified the importance of involving Single-Room Occupancy hotels (SROs) and temporary shelters, as well as residents who are currently experiencing homelessness, in the implementation of resilience strategies.

FIGURE 2-2: STAKEHOLDER ENGAGEMENT WORKSHOP

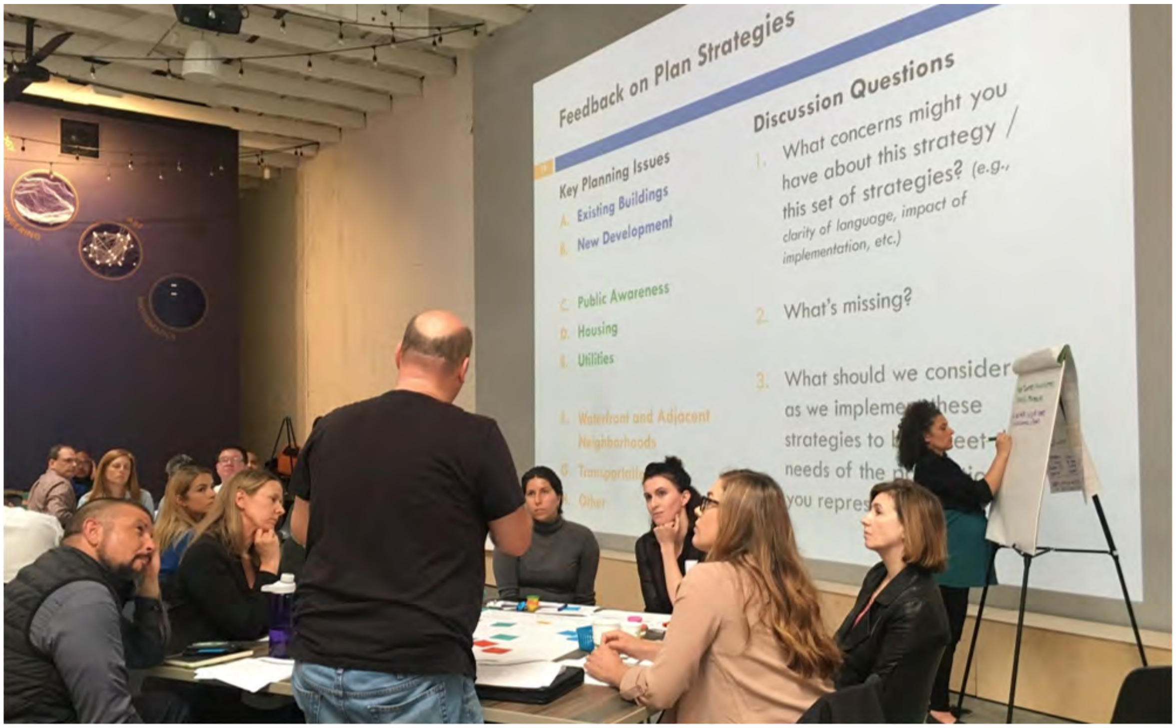


FIGURE 2-3: STAKEHOLDER ENGAGEMENT WORKSHOP

Public Engagement

The HCR development process offered several opportunities for members of the general public to provide their feedback during the drafting stage.

Webpage

A webpage for the Hazards and Climate Resilience Plan was launched in July 2019 on the OneSF website, which included information on the Plan update process and how community members could provide feedback and suggest changes to the Plan. In December 2019, the web page was updated to include the Draft Plan for public comment.

Survey

A public survey was distributed during the stakeholder workshops and available on the webpage from July 2019 to September 2019. All individuals who attended any of the stakeholder workshops and/or were invited to participate were sent the information to share with their colleagues, community members, and populations served by each of their organizations. City agencies and individual employees also encouraged their networks to participate in the survey. It was also advertised through City social media accounts. The survey had a total of 597 responses and the results of the survey can be found within the Community Engagement Report in Appendix C.

Community Engagement Highlights

The following are some of the highlights from the stakeholder workshops and survey:

Solutions Need to be Diversified, Multi-Pronged, and Coordinated. The most common theme from community engagement was that there is no "one-size-fits all" solution to addressing any of the hazards that may impact San Francisco. Workshop participants emphasized the importance of using different strategies to effectively engage with, communicate information to, and provide resources to the city's diverse communities. Workshop and survey participants also recognized the complexity and interdependence of the city's buildings, infrastructure, and economy, as well as how all of those impact residents.

Most Concerning Hazards. The vast majority of survey and workshop participants reported being the most concerned about earthquakes and poor/unhealthy air quality. Additionally, one in five survey respondents identified the following as one of the three hazards they are most concerned about: disease outbreaks, urban fires, drought, extreme heat, and flooding. Some workshop participants discussed concerns about hazardous materials and tsunamis.

Support for Improving Resilience of Key City Assets. Nearly all survey and workshop participants agreed that it is important for the City and County of San Francisco to improve the resilience of infrastructure (e.g., utilities and transportation), buildings (e.g., housing, existing buildings, new development), and communities (e.g., community connections, neighborhood preparedness).

Only **half** of survey respondents said they **know their neighbors well enough to help each other in an emergency.**

Importance of Community Cohesion. Workshop participants emphasized the importance of strengthening relationships and interactions within individual neighborhoods, at the block level, within large multi-unit buildings, and through face-to-face social networks. Only half of survey participants said they know their neighbors well enough to help each other in an emergency. Increasing relationships and connections between neighbors and community members helps ensure that vulnerable residents stay safe during and following a hazard event, as traditional communication and outreach strategies will not reach everyone. This may require expanding support for community-serving organizations that address neighborhood resilience.

Information about Hazards and Emergency Preparedness. Most survey participants get information about hazard events from AlertSF and/or social media, while some rely on television, radio, and personal contacts (e.g., friend, family member, neighbor). Workshop participants also identified methods and types of media that will be especially effective at reaching specific populations. Workshop participants were excited about the maps that will be shared with the Hazards and Climate Resilience Plan and how they and other community members will be able to use them to prepare for the specific types of hazards they are likely to experience.

[I am] extremely concerned about an earthquake and the potentially devastating impact it would have on the housing stock.

Survey Respondent

Level of Preparedness. Most survey respondents believe that they and the people they live with are prepared for extreme heat days, earthquakes, and poor/unhealthy air quality days, while fewer are prepared for flooding. At the same time, more survey respondents felt that their housing in San Francisco would be a safe place to stay during flooding and extreme heat while fewer felt it would be safe place during a poor/unhealthy air quality day or earthquake. Workshop participants requested more concise information about how the organizations, businesses, and facilities in which they work should prepare for emergencies with specific recommendations based on location in the city and the people served (e.g., how much water an afterschool program should store on site relative to the number of children served, what supplies are most important for managers of single-resident occupancy/SRO hotels to have available).

Experience with the Impacts of Hazards in San Francisco. More than half of survey participants shared how they, their homes, their workplaces, and their neighborhoods had been impacted by poor/unhealthy air quality, extreme heat, and earthquakes. Many respondents also reported how wind, storm flooding, hazardous materials, and urban fires have impacted them and their communities.

Presentations at Existing Public Meetings

City staff presented the Hazards and Climate Resilience Plan at several public meetings, including:

TABLE 2-5: PRESENTATIONS AT EXISTING PUBLIC MEETINGS

Date	Meeting Title	Notable Feedback
May 15, 2018	Disaster Council	Interest in future updates
Dec 11, 2018	Port Commission	Interest in future updates
April 10, 2019	Municipal Green Building Task Force	Interest in building codes that incorporate future climate conditions
May 6, 2019	Richmond Community Health Fair	n/a

Date	Meeting Title	Notable Feedback
October 22, 2019	Port Commission	Interest in future updates
November 14, 2019	SPUR Lunch Panel	Interest in planning for SLR, inclusion of businesses in strategy implementation, support for agency coordination
December 9, 2019	Capital Planning Committee	TBD
December 10, 2019	Public Utilities Commission	TBD

Engagement with Other Regional, State, and Federal Agencies

These agencies/jurisdictions were notified of the draft Plan and offered the opportunity to provide comment.

- Presidio Trust
- San Mateo County
- Daly City
- Oakland
- Alameda County
- Marin County
- GGNRA
- SPUR
- Bay Area Council

2.4 Existing Reports, Plans, and Other Resources

A key element of the planning process included drawing on existing resources regarding hazards, vulnerabilities, and potential strategies. The hazard analysis in Chapter 04 and

Vulnerability & Consequence Profiles in Appendix A include citations of source material and this section provides an overview of some of the key resources referenced in this Plan. Please note that this is not a complete bibliography and see footnotes/references section for additional resources used.

Local Resources

The following section highlights existing reports and studies developed by the City and County of San Francisco used during the Planning Process.

Sea Level Rise Vulnerability and Consequences Assessment (2019)

The Sea Level Rise vulnerability and consequences assessment was launched in response to the findings from the 2016 Sea Level Action Plan, to move the San Francisco towards the goal of having a citywide Sea Level Rise Adaptation Plan. The assessment identifies publicly owned infrastructure within the SLR Vulnerability Zone and assesses its vulnerability to short- and long-term inundation from coastal flooding and storm surges. Following this, consequences were identified for people (through the lens of society and equity), the economy, the environment, and governance. The resulting information was then consolidated into neighborhood profiles to describe the impacts to neighborhoods over time. Future efforts will develop neighborhood based adaptation solutions, incorporating robust neighborhood engagement.

Lifelines Restoration Project (2019)

The Lifelines Restoration Project aims to help the City and County of San Francisco recover more quickly from a major earthquake by assessing and improving the restoration performance of a variety of interdependent lifeline infrastructure systems. These systems include: electric power, natural gas, water and wastewater, telecommunications, highways and local roads, fuel, transit, airport, port, and fire suppression. These systems are critical for the recovery of hospitals, homes, businesses, non-profit organizations, and city government following a disaster. The project benchmarks current expected restoration performance based on interviews with subject matter experts, determines desired restoration performance based on public expectations and existing goals, and details prioritized strategies to achieve performance goals through a restoration performance improvement plan.

Here Today—Here Tomorrow: The Road to Earthquake Resilience in San Francisco, Community Action Plan for Seismic Safety (CAPSS) (2010)

The CAPSS provided information on the extent and impact of seismic-related hazards on San Francisco. The results of this analysis set the stage for the future actions and strategies that the City and County of San Francisco plans to pursue to furthering seismic resiliency.

Earthquake Safety Implementation Program: Workplan 2012–2042, City and County of San Francisco Workplan 2012–2042 (2011)

This document lays out a 30-year program of mitigation strategies and projects to be undertaken by the City and County of San Francisco to improve its seismic safety and resiliency; in essence, it operationalizes the insights and suggested strategies from the aforementioned CAPSS study.

Tall Buildings Safety Strategy (2019)

The Tall Building Safety Strategy is a part of the ongoing effort to improve the City's preparedness and ability to recover from major earthquakes. This strategy is comprised of 16 recommendations developed through the study of 156 tall buildings in San Francisco and represents a first-of-its kind effort to characterize and address the unique seismic risks of this subgroup of buildings. The initiatives suggested as a part of the Tall Buildings Strategy were integrated into the suggested strategies for hazard mitigation in the HCR .

Lifelines Interdependency Study (2014)

This study involved convening lifelines service providers, a lifelines Council, and the City and County of San Francisco to collaborate on disaster planning, restoration, and response to improve lifeline system reliability and post-disaster function.

SFPUC Climate Adaptation Plan (Draft)

This briefing booklet explains how climate change will impact SFPUC, its SSIP program, and San Francisco at large. The briefing booklet evaluates the climate-related vulnerabilities and risks across the entire combined stormwater and wastewater system, identifying assets that are at risk over the next century in order to recommend adaptation strategies to reduce those risks and protect those assets.

State and Regional Resources

2018 State Hazard Mitigation Plan

This draft report provides important current and historical information on the hazards facing the State of California, as well as the actions, resources, goals, and priorities the State takes into consideration when mitigating these hazards. For the 2019 HCR, hazard information was integrated where relevant to the City and County of San Francisco, for example, in the Large Urban Fire hazard profile.

Cal-Adapt

Cal-Adapt provides local jurisdictions across the state with robust information produced by the State of California's scientific and research community. In this way, it is a valuable and essential resource to glean local climate change impacts and facilitate understanding of the latest science and projections as the science advances. For the HCR, this was most essential for understanding projected changes in extreme heat and precipitation patterns, for integration into relevant hazard profiles.

California Adaptation Planning Guide (2013)

This planning guide is comprised of four complementary documents that support communities through an adaptive planning process to address climate change. It walks through an in-depth understanding of climate change impacts, with a focus on regional characteristics that vary across the state, as well as environmental and socioeconomic considerations. The guide also assists in thinking through the selection of adaptation strategies.

Hazard Mitigation and Climate Adaptation Risk Assessment (ABAG) (2017)

This document was created for the nine-county Bay Area in order to characterize its risk profile. This assessment provides vital information on the required information to perform actionable resilience, adaptation, and mitigation planning. The hazards addressed by ABAG overlap heavily with those addressed in the 2019 HCR, so provided a valuable starting point.

Integration with Current and Future Planning Processes

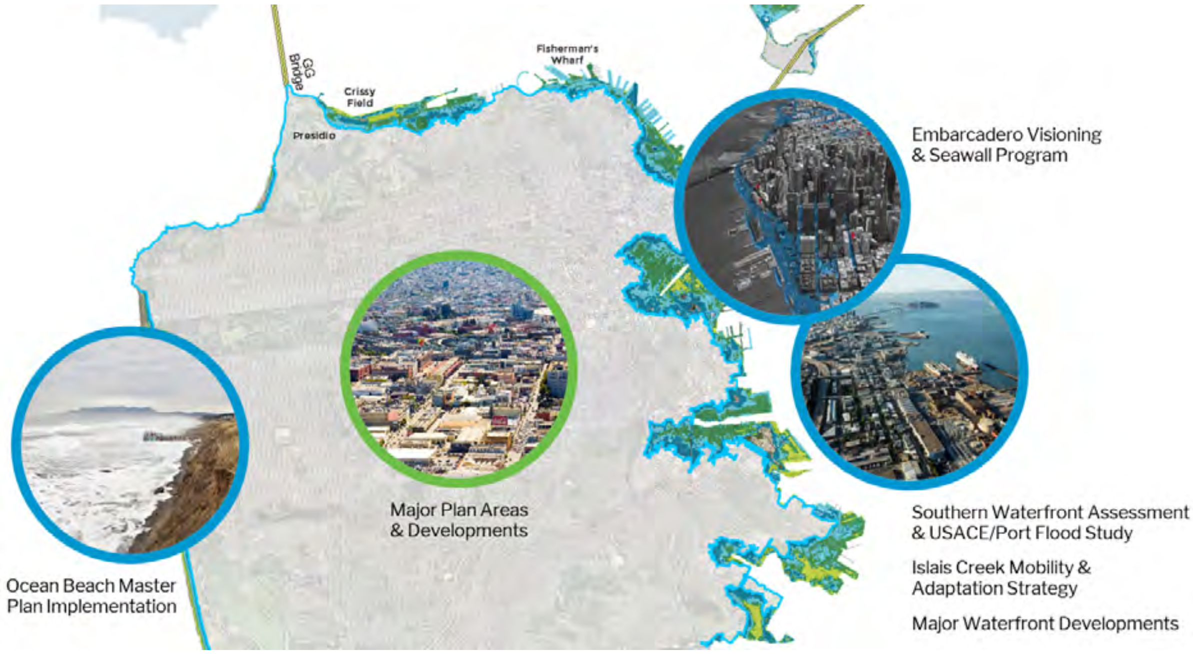
The HCR is a critical element in the City's climate resilience planning efforts, as illustrated in Figure 2-4. Findings from the Sea Level Rise Vulnerability & Consequences Assessment have been incorporated into the HCR, especially in Chapter 05 and

Appendix A. The ongoing effort to update the City's Climate Action Strategy (CAS) is coordinating with the HCR through a new Inter-Agency Climate Resilience Program aimed at improving the integration of climate adaptation and climate mitigation (greenhouse gas reduction) efforts. Upon the completion, key synergistic CAS and HCR strategies will be identified and pursued through a Citywide Climate Resilience framework.

FIGURE 2-4: RESILIENCE PLANNING AT THE CITYWIDE SCALE

The HCR also provides a framework for the City to track and communicate multi-hazard efforts at the project scale, such as the examples shown in Figure 2-5. These projects are also included as strategies in Chapter 07.

FIGURE 2-5: RESILIENCE PLANNING AT THE PROJECT SCALE



Chapter 03

San Francisco Risk Landscape

This chapter sets the scene for the subsequent hazard analysis, risk assessment, and strategy sections by describing the demographics, geography, and economy of the City and County of San Francisco. It also includes an overview of the assets at risk.

3.1 Geography

Overview

The City and County of San Francisco includes a peninsula surrounded by the Pacific Ocean on the west and the San Francisco Bay on the east, as well as the Treasure, Yerba Buena, and Farallon Islands. San Francisco sits north of San Mateo County, and it is separated from Marin County to the north by Golden Gate strait and Alameda County to the east by the San Francisco Bay. Located about 30 miles off the Pacific coast of San Francisco, the rocky and uninhabited Farallon Islands are a National Wildlife Refuge, and were originally established as a refuge for native birds in 1909 by Theodore Roosevelt.[1] Treasure and Yerba Buena Islands are located in the San Francisco Bay. Yerba Buena is a natural rocky island connected to the artificial Treasure Island, which was constructed in 1936 and was subsequently used for military operations. Treasure Island was recently redeveloped for housing and commercial use. The City and County covers approximately 47 square miles of land and 185 square miles of water, and has nearly 30 miles of shoreline.[2][3]

Natural Geography

San Francisco has a unique natural geography. Before the peninsula was developed, San Francisco featured numerous rocky hills cutting through miles of sand dunes to the north and west, and marshes and mudflats to the east along the Mission Creek and Islais Creek watersheds. San Francisco's sand dune ecosystem was the largest in the western hemisphere, stretching seven miles from Ocean Beach to the Financial District.[4] Mission Creek and Islais Creek fed the two largest creek and marsh watershed systems. Today, these creeks are largely capped, with landfill developed over what was once large swaths of wetland at the mouth of both creeks.[5] Despite the extensive infill and development of land and port area along the City's northern and eastern shorelines, there still exists important saltwater wetland habitat, including Heron's Head Park, Crissy Field, Yosemite Slough, and edges of the Mission Creek and Islais Creek channels,

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[1] https://www.gpo.gov/fdsys/pkg/FR-2005-05-31/pdf/05-10718.pdf
[2] https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk
[3] https://www.sftravel.com/article/san-francisco-fact-sheet
[4] https://sfenvironment.org/ecosystems/overview/ecosystems
[5] http://explore.museumca.org/creeks/SFTopoCreeks.html

which protect the coastline from severe weather, help to filter water pollutants, and provide habitat for hundreds of plant, bird, and fish species.[6]

Built Geography

San Francisco has been inhabited for more than 10,000 years, and was inhabited by the Ohlone people since about 740 AD. The Ohlone people in what is now San Francisco had dozens of village sites and practiced regular burning of the landscape to promote a plant and animal ecology that provided a regular food supply.[7] More drastic changes in the built landscape began to occur in the late 1700s when the Spanish came to occupy the peninsula, and developed settlements, missions, and military outposts.

In 1848, San Francisco became a part of California, and through the late 1800s San Francisco grew into a major city, overlaying a grid system on the city's steep hills, and pushing development further westward toward the ocean. During this time that the waterfront was developed and the massive seawall was built, creating hundreds of acres of prime real estate on the northern and eastern shoreline.[8] It was well into the middle of the 20th century that development of the Sunset District erased the last large swath of sand dunes in the west, and set the overall city building footprint we see today.[9]

Residential neighborhoods continue to dominate the western and southern districts, while the financial district and civic center in the northeastern quadrant form the economic engine of the city. The southeast quadrant contains the majority of the city's industrial use, including many city assets that support critical infrastructure operations, such as wastewater and mobility.

Future Development

Treasure Island, Mission Bay/SOMA, and Bayview Hunters Point have all seen and will continue to see tremendous growth and development over the next decades. These neighborhoods are all vulnerable shoreline communities located on landfill that could face serious challenges in the event of natural hazards, such as earthquakes and

[6] https://sfenvironment.org/ecosystems/overview/ecosystems

[7] https://www.nps.gov/prsf/learn/historyculture/indigenous-period.htm
[8] https://sfport.com/port-history
[9] http://www.foundsf.org/index.php?title=The_Sunset_District:_From_Dunes_to_Cityscape

flooding. In addition, the San Francisco seawall is undergoing initial planning for restoration, providing another opportunity for structural and environmental changes along the shoreline in the coming years. Where and how to develop affordable housing and middle-class jobs remains a pressing issue, and is likely to be the guiding force for development in the foreseeable future.

3.2 Demographics

Resident Population

San Francisco is the 2nd densest large city in the U.S. after New York City, with a population of more than 884,000 on less than 50 square miles of land. The city's population has seen a nearly 10% increase since 2010, and is projected to reach more than a million people by 2040.[10]

Non-Resident Population

In addition to residents, San Francisco hosts thousands of commuters and visitors each day. A 2010 American Community Survey report estimated a 21% population increase during the weekdays from commuting.[11] SF Travel also estimates an additional daily influx of 69,000 people who come to visit San Francisco for tourism or business travel, putting the City's daytime population at more than 1.1 million on average.[12]

Demographic and Socioeconomic Characteristics

Among all of San Francisco's residents, commuters, and visitors, certain populations are especially vulnerable in the event of a natural hazard. These include children and seniors, racial and ethnic minorities, people with pre-existing health conditions, and people with low income. More detailed descriptions of these groups and others can be found in the Vulnerable Populations section of the Vulnerability and Consequence Assessment in Chapter 05. The following provides broad descriptions of San Francisco residents' age, racial and ethnic composition, pre-existing health conditions, and income.

[10] https://mtc.ca.gov/sites/default/files/2-The_Bay_Area_In_2040.pdf
[11] https://www.census.gov/content/dam/Census/library/working-papers/2010/demo/top20-commuter-pop-change.pdf
[12] https://www.sftravel.com/article/san-francisco-fact-sheet

Age: Compared to California and the U.S. overall, San Francisco has greater variance in population age, with the highest proportion of residents in their thirties and just 13% of the population under 18 (compared to 23% in California and the US). Less than 5% of the population is under 5 years of age, and 15% are 65 years and over.[13] The very young and older adults are more vulnerable relative to the rest of the population due to their increased medical sensitivity, higher rates of dependency on others, and reduced levels of mobility. Over the next decades, the proportion of older adults in San Franciscans will increase substantially. By 2030, San Franciscans age 60 and over are projected to make up 27% of the population; by 2060, the percentage of San Francisco residents age 85 and over is projected to increase by about 400% since 2010.[14]

Racial and ethnic composition: The U.S. is projected to become majority people of color in the mid-2040s, a milestone passed in the Bay Area in the 2000s. In the region, Hispanic and Asian populations are steadily increasing, and white non-Hispanic and black population shares have been falling.[15] In 2017, San Francisco's racial and ethnic composition was as follows: 4% two or more races, or a race not listed by the American Community Survey; 5% black; 15% Hispanic (of any race), 34% Asian; and 41% white (not Hispanic).[16] White households represent 50% of total households in San Francisco.[17] Black populations have declined very rapidly to less than half their proportion in 1990. Without action, black populations are projected to continue to decline, and San Francisco is the only county in the Bay Area where white populations are projected to increase in future decades.[18]

Pre-existing health conditions: The U.S. Census classifies disability by six types: hearing difficulty, vision difficulty, cognitive difficulty, ambulatory difficulty, self-care difficulty, and independent living difficulty. For non-institutionalized San Francisco

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[13] American Community Survey 2017 5-Year Estimates, Table DP05. http://factfinder.census.gov (2019)

[14] State of California, Department of Finance, *P-2 County Population Projections by Age, 2010-2060*. Sacramento, California, May 2019.

[15] https://nationalequityatlas.org/sites/default/files/Final_9_County_BayAreaProfile.pdf

[16] American Community Survey 2017 5-Year Estimates, Table DP05. https://factfinder.census.gov/bkmk/table/1.0/en/ACS/17_5YR/DP05/0500000US06075 (Accessed 2019)

[17] American Community Survey 2017 5-Year Estimates, Table S1903. https://factfinder.census.gov/bkmk/table/1.0/en/ACS/17_5YR/S1903/0500000US06075 (Accessed 2019)

[18] https://bayareaequityatlas.org/indicators/race-ethnicity

residents, nearly 11% of the population has a disability in one or more of these categories.[19] Black and American Indian populations experience disability rates higher than the citywide rate, the rate for black populations is greater than 20%.[20] Additionally, over one third of populations aged 65 and over experience disability. This age group has especially high rates of ambulatory difficulty (24%) and independent living difficulty (20%).[21]

Those living with chronic diseases are also at heightened vulnerability during a hazard event. In addition to being medically sensitive, these individuals may rely on access to pharmaceuticals and/or medical facilities. 6.6% of adults in San Francisco have diabetes, 5.3% have heart disease, and 15.2% have asthma.[22] Black populations have much higher rates of these chronic diseases and have higher hospitalization rates. In 2014, black San Franciscans had 39.5 age-adjusted asthma hospitalizations per 10,000 residents, compared to 8.4 per 10,000 residents for Hispanic populations, which had the next highest hospitalization rate followed by Asian and white residents.[23]

Income: In 2017, American Community Survey 1-year estimates for median income per household in San Francisco was $110,816 (+/- 3,045),[24] with 5-year estimates at $96,265 (+/- $1349).[25] Median household income varies significantly by race and ethnicity. White non-Hispanic households have the highest median income of over $120,000/year, and black households the lowest at around $30,000/year.[26] Similar

[19] American Community Survey 2017 5-Year Estimates, Table S1810. https://factfinder.census.gov/bkmk/table/1.0/en/ACS/17_5YR/S1810/0500000US06075 (Accessed 2019)
[20] Ibid
[21] Ibid
[22] http://www.sfhip.org/?module=indicators&controller=index&action=indicatorsearch&doSearch=1&i=&l=275&primaryTopicOnly=&subgrouping=1&card=0&handpicked=0&resultsPerPage=150&showComparisons=1&showOnlySelectedComparisons=&showOnlySelectedComparisons=1&grouping=1&ordering=1&sortcomp=0&sortcompIncludeMissing=
[23] https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/EHIB/CPE/CDPH%20Document%20Library/County%20profiles/San%20Francisco%202016%20profile.pdf
[24] American Community Survey 2017 1-Year Estimates, Table S1901. https://factfinder.census.gov/bkmk/table/1.0/en/ACS/17_1YR/S1901/0500000US06075 (Accessed 2019)
[25] American Community Survey 2017 5-Year Estimates, Table S1903. https://factfinder.census.gov/bkmk/table/1.0/en/ACS/17_5YR/S1903/0500000US06075 (Accessed 2019)
[26] Ibid

disparities persist when looking at poverty status and race and ethnicity. While less than 12% of all San Franciscans were under the poverty line, over 30% of black or African American populations and between 13-28% of Pacific Islander populations were below the poverty level.[27] The City has a high rate of inequality with a Gini coefficient of .519 (the closer to 1, the closer to perfect inequality). This rate has steadily increased over the past decade, and is higher than both California's and the US's coefficients of .488 and.48 respectively.[28] To put this in perspective, according to the CIA World Factbook's rankings, if San Francisco were a country it would rank as the 11th most unequal country in the world.[29]

3.3 Economy

History

The California gold rush, the development of the transcontinental railroad, and a location on the Pacific Ocean helped San Francisco emerge as the economic engine of the west in the late 1800s. These factors facilitated opportunities for domestic and international trade, as well as migration, and many businesses that began in that time, such as Levi's, Ghirardelli's, and Wells Fargo, continue to be mainstays of the City's economy. The 1990s saw the beginning of the tech boom in the Bay Area, and this industry continues to fuel San Francisco's growth today.[30]

Current and Projections

Today, San Francisco is a global economic force. San Francisco serves as the headquarters for 12 Fortune 1000 companies,[31] and the City boasts the 2nd strongest economy in 2018, fueled by a booming tech industry that is buoyed by enormous venture capital investment.[32] Biotech and life sciences industries in particular are

[27] American Community Survey 2017 5-Year Estimates, Table S1701. https://factfinder.census.gov/bkmk/table/1.0/en/ACS/17_5YR/S1701/0500000US06075 (Accessed 2019)

[28] http://www.sfhip.org/indicators/index/view?indicatorId=288&localeId=275&comparisonId=7227

[29] https://www.cia.gov/library/publications/the-world-factbook/rankorder/2172rank.html

[30] http://sfced.org/why-san-francisco/a-brief-history/

[31] https://littlesis.org/lists/38-fortune-1000-companies-in-san-francisco/members

[32] https://www.businessinsider.com/san-francisco-area-best-us-economy-2018-4

expanding quickly in SOMA and Mission Creek's development zones.[33] 70% of San Franciscan adults have training beyond high school, and almost 50% speak at least two languages, highlighting the diversity and skill of San Francisco's labor market.[34]

San Francisco's major industries include technology, finance, and tourism. In the past decade, San Francisco regularly achieved the top spot in the nation as the fastest growing high-tech job market, and today the City is home to more than 300 IT firms that employ approximately 66,800 IT workers.[35][36] San Francisco is also the birthplace of the biotech industry and the location for nearly 300 biotech firms that benefit from relationships with programs at UC San Francisco, University of San Francisco, UC Berkeley, and Stanford. Venture capital for biotech in the Bay Area is second only to the software industry.[37]

San Francisco is considered the financial capital of the west, with securities and investments making up a sizeable portion of the City's professional service economy.[38]

In addition to the economic contributions of tech and finance, the tourism industry provides more than $9 billion in visitor spending annually to San Francisco's economy, with more than 81,000 jobs supported by tourism in 2017.[39]

Production, distribution, and repair (PDR) jobs are particularly important to provide employment to a broader swath of San Franciscans that are not in the professional and tech industries. PDR firms are often able to provide training on the job, as well as provide jobs that do not require advanced degrees. While the manufacturing sector in San Francisco has declined precipitously since the dot-com bust (65% reduction in employment from 1990-2015), the number of jobs has begun to stabilize and make small gains since 2010.[40] In particular, the food and beverage, apparel, and advanced manufacturing industries have made strides in growth and interest.[41]

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[33] http://sfced.org/why-san-francisco/a-brief-history/
[34] https://oewd.org/why-choose-sf
[35] http://sfced.org/san-francisco-named-number-1-high-tech-job-growth-market/
[36] http://sfced.org/why-san-francisco/sectors/information-technology/
[37] http://sfced.org/why-san-francisco/sectors/life-sciences-biotech/
[38] http://sfced.org/wp-content/uploads/2017/02/Financial-Professional-Services-Pitch-Sheet-2017.pdf
[39] https://www.sftravel.com/article/san-francisco-travel-reports-record-breaking-tourism-outcomes-2017-gives-projections-2018
[40] http://www.vitalsigns.mtc.ca.gov/jobs-industry
[41] https://oewd.org/sites/default/files/Documents/Make_to_Manufacture%20%282%29.pdf

Infrastructure Systems

Economic operations and growth depend on the many complex infrastructure systems that allow firms and consumers to maintain communications, transportation, energy, food, water, and sanitation. The following summarizes those systems that provide critical interconnections, namely transportation and communications. A more detailed explanation of city infrastructure is in Appendix A.

San Francisco is a part of a regional transportation system that depends on the coordination of several agencies to facilitate travel within a regional economy. In 2016, Bay Area residents boarded transit services (including rail, bus, and ferry) about 1.8 million times on a typical weekday.[42] These many services, including Muni, BART, Gold Gate Ferry, AC Transit, Caltrain, and Amtrak among others, provide critical transportation to both commuters and visitors.

Trucking, maritime transport, and airlines are also critical to regional goods movement, providing materials through supply chains as well as delivering finished goods to stores and consumers. In 2014, goods movement dependent industries accounted for a little more than half of San Francisco Bay regional economic output, and nearly a third of regional employment.[43] San Francisco's Port is an important part of regional goods movement, importing and exporting nearly 1.4 million tons of cargo in 2017.[44] San Francisco's airport, SFO, is a critical asset, not only as a large international airport for passengers, but also as the primary international air cargo hub for the region.[45] All forms of transportation require fuel and energy sources, as well as physical infrastructure, to operate, which may be vulnerable during a natural hazard event.

Telecommunications are critical for normal economic, civic, and healthcare operations as well as emergency response. Residents, businesses, and government agencies rely more than ever on data networks and the City has invested in the construction of more than 240 miles of fiber optic to ensure connection to critical public safety services, and has extended WiFi connection to dozens of parks, libraries, SFO, public schools, public

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42 http://www.vitalsigns.mtc.ca.gov/transit-ridership

43 http://www.dot.ca.gov/hq/tpp/offices/ogm/regional_level/FR3_SFBAFMS_Final_Report.pdf
44 https://sfport.com/sites/default/files/Maritime/Docs/Tonnage%20Report.pdf
45 http://www.dot.ca.gov/hq/tpp/offices/ogm/regional_level/FR3_SFBAFMS_Final_Report.pdf

housing, and Market Street.[46] A plan is in place to expand the fiber optic network to all residents, with free access to those below the poverty line, beginning in 2020.[47]

3.4 Assets

This section describes the asset sectors (key areas) and assets at risk that form the basis of the asset-based vulnerability assessment described in Chapter 05: Vulnerability and Consequences Assessment; i.e., those assets that are evaluated with full results and in-depth analysis presented in Appendix A. These assets span both public and private ownership but share an essential characteristic, they are essential to ensuring the delivery of vital services to the general public. These assets are segmented into different sectors for communication to relevant stakeholders (public stakeholders, City staff and decision makers, etc.).

People

Vulnerable Populations

Vulnerable populations refer to individuals within the city that are more susceptible to impacts from hazards because they have specific pre-existing conditions. Resilience in the face of hazards, particularly those influenced by climate change, are rooted in an interconnected set of conditions. Many of these are structurally determined, such as socioeconomic status, but others are particular to each individual, such as the prevalence of pre-existing health conditions. It's important to assess and understanding the ways that hazards can impact different particular groups in order to create more nuanced programs and strategies that consider the unique needs of different populations within the city.

Emergency Response Facilities

Critical Response Facilities

Critical response facilities are facilities that provide direct life safety, property, and environmental protection services essential to communities during and after an emergency or disaster. These include direct service facilities such as the city's police

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[46] http://tech.sfgov.org/sites/default/files/Document/SFDT%20CONNECTIVITY%20PLAN.PDF
[47] http://tech.sfgov.org/fiber

and fire department buildings as well as facilities responsible for strategic coordination, known as the Emergency Operations Center (EOC) and the Departmental Operations Centers (DOC).

Hospitals

Hospitals provide life-saving and life-sustaining services to protect the health and well-being of all San Francisco residents. These include a number of hospital facilities that operate across the city.

Other Emergency Sites

These assets are composed of the numerous public and private locations that are essential in supporting the cities communities during and after an incident. These include indoor/outdoor shelter sites for those displaced during events, the animal care and control facility that will be essential in managing the animal population of the city, as well as resource staging areas to potentially be used following a hazard event.

Public and Community Services

Municipal Buildings and Facilities

This asset class includes municipal offices, correctional facilities, and city-owned cultural centers, museums, and performance halls. These facilities serve the community in many different capacities and some have unique cultural and economic value while the services rendered out of these buildings and facilities cannot be easily replaced (in some instances).

Municipal Yards

Many departments in the City are responsible for providing numerous sustained services (such as public transit or access to parks). This necessitates unique maintenance and storage needs for vehicles and equipment which the City accommodates through the operation of specialized facilities. The San Francisco Public Works, San Francisco Municipal Transportation Agency, the Port of San Francisco, and the Recreation and Park Department all have yards that fall under this category of facility and are listed under this asset class.

Health Care Facilities

Formal hospitals are not the only facilities in San Francisco that provide life-saving and life sustaining services, rather there are a wide range of facilities that also provide similar or more specialized services that maintain the health and wellbeing of the city's residents. Primary care clinics, skilled-nursing facilities, pharmacies, and residential care facilities for the elderly all play a critical role in response to hazard events while also often acting as a point of service for some of the most vulnerable people in the city.

Food Distribution

Food distribution is composed of the numerous wholesale suppliers, grocery stores and charitable food distribution facilities that regulate the flow of food to communities throughout the city, provide food services for vulnerable populations, and ensure everyday access to this vital resource.

Education Institutions

Educational institutions include public and private K-12 schools, as well as public and private colleges and universities spread across the city. K-12 institutions are vital in that they provide education, nutrition, and basic health care to children and youth, including those who may be more vulnerable to climate impacts because of existing disparities. Higher education institutions provide career services, confer degrees, and foster research, in addition to providing nutrition, housing, and health services to many of their students. Education institutions are also major employers, especially large universities.

Community Centers

Community centers provide a location where community members can obtain resources and information, and participate in spiritual, educational, recreational, and/or political activity. These include libraries, recreation centers, senior centers, youth centers, neighborhood centers, and faith-based centers. Community centers are run by the City, NGOs and places of worship, and many are a part of organizational networks, such as the YMCA. Some are large facilities that contain fitness, open space, and kitchen amenities. Others operate in small to medium sized commercial properties or in traditional building types for places of worship. These facilities are essential to community cohesion and often offer vital services to the residents of San Francisco.

Housing

The housing stock of San Francisco ranges from simple older buildings built over a century and a half ago, to complex, modern high-rises. This variety in form supports the wide variety of people that rely on these buildings for their housing needs. Variety is also seen on the quality and affordability of this housing stock which has notable implications for the ability of this housing to withstand hazards.

Business and Industry

Commercial

Commercial buildings make up a significant portion of the city's economy and are notable in contributing the economic health and well-being of the city. These buildings consist of offices, retail spaces, hotels, and mixed-use properties. They can typically be found broadly across the entire city, however, they are densely concentrated in the Northeastern corner of the city.

Industrial

Industrial buildings are known as production, distribution, and repair building types. These buildings are often used for industrially intensive businesses, such as waste management or Port facilities. These businesses often support low-income workers and are geographically concentrated in the east and southeast neighborhoods of the city. The majority of these are privately owned.

Maritime

The maritime uses of the Port of San Francisco range significantly over the shoreline properties that it leases, manages, or directly operates for commercial and industrial activity. These consist of a series of shoreline piers on parcels along the eastern coast of the city. A variety of fishing, police, recreational, research, cruise shift terminal, cargo, and heavy industrial uses occupy these properties and, due to their proximity to the shoreline, they are particularly vulnerable to many hazards exacerbated by climate change. These assets also play an essential role in disaster response.

Contaminated Lands

Historical land use and development of the city, before the enforcement of modern environmental regulations, has left a legacy of contaminated lands in areas of the cities. Furthermore, these lands can often geographically coincide with vulnerable communities of color, due to patterns of environmental racism historically seen in this country. The City of San Francisco recognizes the need to vet, and ensure, that land slated for development has been adequately evaluate soil condition in advance of development. These lands are subject to a variety of local and federal programs based on previous ownership, contamination type, and remediation needs. Many of these areas can be found on land that was previously federally owned such as areas in Bayview Hunter's Point and Treasure Island.

Hazardous Materials Sites

Hazardous materials facilities are those that generate, store, transport, or treat any of the following kind of materials: radioactive, flammable, explosive, toxic, corrosive, or unsafe in other ways. These are often facilities such as gas stations, paint supply stores, manufacturing facilities, or other businesses that use these materials to provide a variety of goods and services. These facilities can be publicly or privately owned, and are strictly regulated through enforcement of state provisions by the San Francisco Department of Public Health Hazardous Materials and Waste Program.

Transportation

Roadways

Roadways facilitate residents, workers, and visitors traveling within and through San Francisco, which supports economic activity, goods movement, and quality of life. The roadway network links people with community facilities and services, jobs, family and friends, recreation, and other destinations within the city and throughout the Bay Area region. Roadways as an asset class includes traditional roads, bicycle and pedestrian infrastructure, on-street parking, and bridges (state and local). Roadways are integral to transportation, access, and connectivity throughout the city even though they are managed by a variety of local, state, and federal agencies.

Parking

Parking garages are multi-story concrete parking structures. Rather than being spread throughout the city, they are concentrated largely in the Northeastern part of the city. This asset refers to the public garages owned by the city but managed by a variety of different departments.

Transit Network

The transit network facilities the movement of residents, workers, and visitors traveling within and through San Francisco, supporting economic activity and quality of life. This is essential to connecting San Francisco's residents with services, jobs, family, recreation opportunities, and other destinations locally and regionally. The transit network includes systems managed by a variety of public entities, these include: SFMTA's Muni system, BART, Caltrain commuter rail, AC Transit, Sam Trans, and Golden Gate Transit.

Water Transportation

Water transportation consists of ferries, water taxies, and facilities for the docking of private vessels and motorized/non-motorized boats. This asset also includes the Ferry terminals, gangways, and external services required for the effective operation of these facilities. Ferry services are provided by the Water Emergency Transportation Authority (WETA), Golden Gate Ferry, Blue and Gold, and many smaller operators and not only are these valuable for everyday operation.

Airport

The San Francisco Airport is the largest of three airports in the Bay Area and provides a significant amount of commercial air travel to the region. The airport is located 11 miles outside of the City and County of San Francisco to the south, in San Bruno. This facility covers a vast area, predominately composed as reclaimed land through the filing of the Bay, and has a number of sophisticated utility systems and a large number of buildings to facilitate its day to day operations. These include the airfields, air traffic tower, terminals, utilities, and supporting structures required to process the large volume of air travel handled by the airport on a daily bases.

Utilities and Infrastructure

Power

Access to electrical power is essential to the continued operation of the communities of San Francisco. Many of the other assets listed in this chapter are heavily dependent external services, such as power, for their continued operation and to provide the goods and services that the city relies on. To achieve this provision, a combination of generation sources, substations, transmission lines, transmission poles and distribution lines are networked across the city. While distribution lines span the whole city, a large amount of this infrastructure is concentrated along the eastern edge of the city.

Natural Gas

While the city is committed to moving towards the phase out of natural gas as an energy source, in recognition of its commitments to addressing the climate crisis, many communities rely on natural gas for commercial, industrial, and domestic uses. Natural gas use is facilitated by a network of infrastructure production (originating out of state), interstate transmission lines, intrastate transmission lines, distribution lines, and natural gas stations spread across the city but predominantly located in the Southeast. This infrastructure is managed by Pacific Gas &Electric (PG&E), which is regulated primarily by the California Public Utilities Commission (CPUC).

Potable Water

The potable water system delivers water from a sophisticated, regionally connected collection of resources in order to meet the needs of San Francisco residents and businesses. Distribution pipelines, storage reservoirs, and groundwater well sites are essential components of the system. Operation of the system involves the use of pumping stations, geographically spread across the city, moving water over a range of elevations to serve a wide range of users. San Francisco's Public Utilities Commission (SFPUC) Water Enterprise is responsible for managing the transmission, treatment, storage and distribution of potable water in the City and County of San Francisco.

Emergency Firefighting Water System

The Emergency Firefighting Water System is a high-pressure firefighting water system was created to safeguard lives and property in the case of future earthquakes. It spans the breadth of the city, covering the east side extensively, with improvements to the Westside and Southern areas currently being identified for implementation. This system is essential to combatting large urban fires that may occur following a significant earthquake hazard event. The system is composed of reservoirs/tanks as the primary supply of water, however, it can also access water from the Bay as a secondary source through the use of pumping stations, manifolds, and drafting points. While the system is operated by the San Francisco Fire Department, it is managed by SFPUC.

Combined Sewer

San Francisco's combined sewer system treats combined wastewater from the stormwater runoff and sewage generated by the city in order to service the waste produced by the cities communities. Using gravity and an interconnected web of combined sewers, tunnels, and transport/storage boxes to intercept, store, and convey combined sewer flows throughout the City. Where gravity isn't sufficient to move this water around the system, or where weather conditions require the use of different facilities, force mains and pumping stations move wastewater to its eventual destination at one of three treatment facilities. Following treatment to nationally permitted standards, effluent is either discharged to the Pacific Ocean on the Western/Pacific shoreline or discharged to the Bay through outfalls located along the Bayshore. The system has a variety of components essential to in’s operation, ranging from sewer pipes and tunnels to the treatment plants that treat the water for discharge.

Shoreline Protection Infrastructure

Shoreline infrastructure provides a critical function to much of the city, including flood protection during storms and extreme tide events, habitat, recreation opportunities, and public access. It also supports key utility and transportation infrastructure, including BART, Muni, the Port maritime facilities and ferry transportation. During an emergency it supports emergency response and recovery operations. Shoreline protection around San Francisco is made up of a variety of shoreline types and conditions, including beaches and bluffs along the western and northern shoreline of San Francisco, which fronts the Pacific Ocean and structural protection in many forms along the eastern and southern shorelines of the city along the San Francisco Bay. The majority of San Francisco's shoreline protection infrastructure is owned by public agencies, including the Port of San Francisco and the Department of Parks and Recreation; and the National Park Service.

Communications

The City's communications asset class transmits voice, video and data communications by fiber infrastructure, cellular and radio communications, and inside wired infrastructure. San Francisco Department of Technology (SFDT) manages a wide array of communications systems including radio, TV, internet, City internal data network, public warning sirens, emergency call boxes, communication path for traffic signals and the Mayor's Emergency Telephone Systems (METS). In some instances, these communication channels leverage private communications operators' fiber networks and internet service. Key City owned systems include the municipal fiber optics network, data centers, and the 800Mhz radio system. Private communications systems are owned by a wide range of operators, including Verizon, AT&T, T-Mobile, also Comcast and these provide redundant access to the Internet for municipal services.

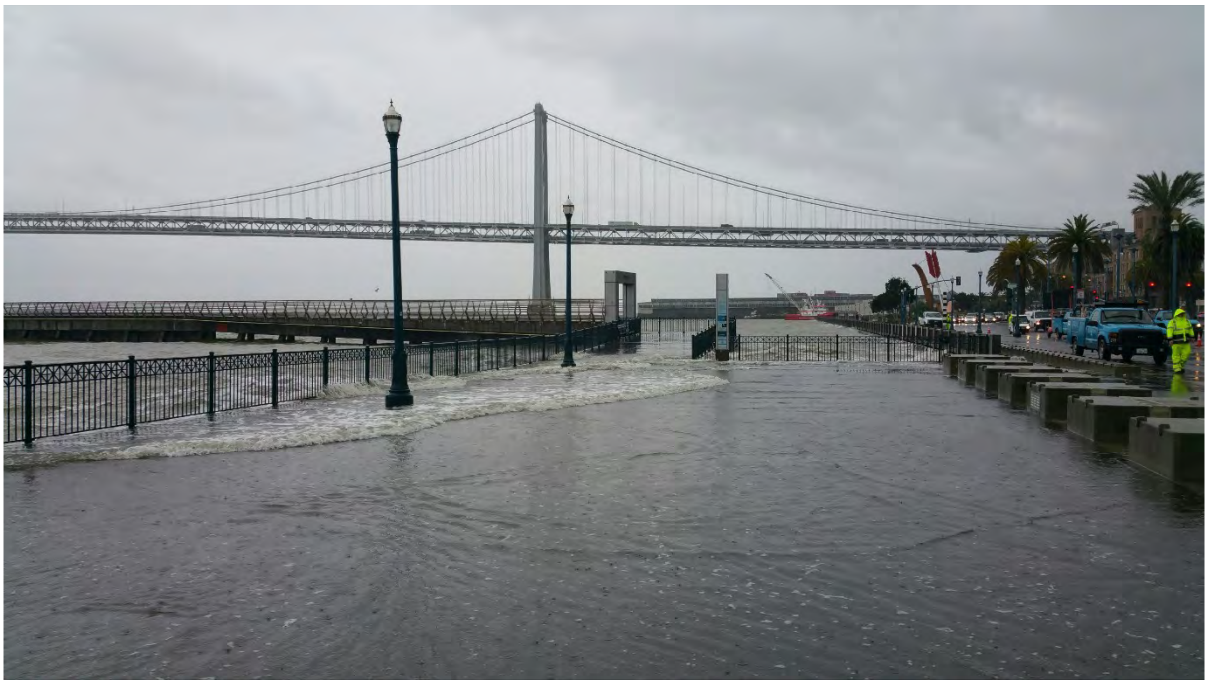
Open Space

Parks and Open Space

Equally as important as the buildings and infrastructure that make up our cities are the recreation and open space that stitches together our communities. These areas make significant contributions to the quality life of community residents and provide locations for recreation, activity, and peace and enjoyment from the sometimes over stimulating aspects of living in a thriving built environment. In addition, these spaces provide natural areas for native species to thrive, contribute to the environmental health of the city, and provide benefits to climate adaptation through the provision of ecosystem services. Scattered around the city, these areas are managed primarily by public agencies including federal, state, and local entities.

Chapter 04

Hazards Analysis



The HCR characterizes 13 hazards that impact San Francisco. Each hazard has a profile capturing the impact, the history of past hazard events, the location, severity, and probability of future events. The chapter also includes an overview of climate change science and how climate change influences hazards in San Francisco.

Earthquake	Tsunami	Landslide	Dam or Reservoir Failure	Flooding	High Wind	Extreme Heat	Drought	Large Urban Fire	Wildfire	Poor Air Quality	Pandemic	Hazardous Materials

4.1 Climate Change and Implications for Hazards

This section provides an overview of climate change and how it influences hazards in San Francisco now and into the future.

What is Climate Change?

Carbon dioxide is a naturally occurring gas produced by decay, fermentation, and combustion, and absorbed by plants through photosynthesis. Carbon dioxide is one of many greenhouse gases, which are chemical compounds that allows sunlight to reach the earth's surface in one form (as visible light), but absorbs reradiated energy (in the form of heat) from the earth and inhibits it from escaping the atmosphere.[1] Beginning in the 20th century, industrial emissions, energy production, transportation, agricultural production, as well as deforestation of the plants that absorb carbon dioxide has increased the concentration of these greenhouse gases in our atmosphere. As these greenhouse gases trap heat, global temperatures increase, and weather becomes more variable and extreme.[2]

Climate change is already happening. The National Ocean and Atmospheric Administration (NOAA) identifies 2015, 2016, 2017, and 2018 as the four hottest years in recorded history.[3] These extreme temperatures have a significant and cascading impact on global weather patterns. High temperatures melt polar ice caps and contribute to the thermal expansion of the oceans which cause global sea levels to rise. Warm ocean temperatures also increase evaporation, and this increased concentration of water vapor in the atmosphere changes rainfall patterns as storms and droughts both become more extreme. Climate change results in three important changes to the global climate system:

- Increasing temperatures
- Rising sea levels
- Changing precipitation patterns

[1] https://www.ncdc.noaa.gov/monitoring-references/faq/greenhouse-gases.php
[2] San Francisco Climate and Health Adaptation Framework
[3] https://www.noaa.gov/news/2018-was-4th-hottest-year-on-record-for-globe

Representative Concentration Pathways (RCPs)[1]

Considering future climate change hazards, as determined by climate model projections, requires an understanding of the assumptions that inform the projection models. These models aren't unknowable black boxes, Global Climate Models are a math-based simplification of four primary interactions driving climate change, namely: The Atmosphere, The Oceans, The Land, and Human Influences. These systems are all interconnected but human influences in these climate models are expressed as Representative Concentration Pathways (RCPs). RCPs assume different levels of human influence on the climate based on potential cumulative anthropogenic CO_2 emissions, from the year 2000 as a baseline:

- RCP 8.5 assumes anthropogenic global greenhouse gas emissions continue to rise over the next century (i.e., there are no significant efforts to limit or reduce emissions)
- RCP 6.0 assumed anthropogenic global greenhouse gas emissions peak in 2080 and then decline
- RCP 4.5 assumes anthropogenic global greenhouse gas emissions peak in 2040 and then decline
- RCP 2.6 assumes stringent emissions reductions, with anthropogenic global emissions declining by about 70% between 2015 and 2050, to zero by 2080, and below zero thereafter (i.e., humans would absorb more greenhouse gasses from the atmosphere than they emit).

While climate change may be global in scope, its impacts are local. The following sections discuss the implications that climate change has for hazards in San Francisco today and into the future.

Increasing Temperatures

As a result of climate change, we are already experiencing an increase in temperatures. From 1950 through 2005, the Bay Area saw an average annual maximum temperature increase of 1.7° F.[4] San Francisco reached an all-time high temperature of 106° F on September 1, 2017.[5] Scientists project that temperatures will continue to increase in the decades to come. As a result, San Francisco will experience more extreme heat days. In addition, higher temperatures can worsen drought and wildfires.

Projections

Average Temperature

- Average yearly temperatures are expected to increase between 1.3°F and 3.1°F by mid-century and 3.3°F and 5.5°F by end-of-century compared to 2010.[6]

Extreme Heat

- Baseline: An extreme heat day is any day when the maximum temperature reaches the 98th percentile of all temperatures for that particular region. In San Francisco, an extreme heat day is any day that surpasses 85°F. Between 1961 and 1990, San Francisco averaged about four extreme heat days per year. [7]
- Projection: Climate scientists project 15-40 extreme heat days per year by mid-century, and upwards of 90 extreme heat days per year by end-of-century.[8] Heat waves are similarly projected to increase in both frequency and severity.

Implications for Future Hazards

Higher temperatures influence several hazards, including:

- San Francisco will experience more extreme heat days and heatwaves will be longer. San Franciscans are particularly vulnerable to extreme heat (for additional information see Extreme Heat Hazard Profile).
- Drought and wildfires fires may become more frequent and severe. Higher temperatures increase evaporation, which dries out soils and vegetation,

[4] California National Resources Agency. California's Fourth Climate Change Assessment: San Francisco Bay Area Region Report. Retrieved from: http://www.climateassessment.ca.gov/regions/docs/20180827-SanFranciscoBayArea.pdf (Accessed: 9/10/2018)
[5] http://sanfrancisco.cbslocal.com/2017/09/01/excessive-heat-warning-declared-for-entire-bay-area/
[6] Scrips Institute of Oceanography, Cal-Adapt and California Nevada Applications Program. Temperature: Extreme Heat Tool, http://cal-adapt. org/temperature/heat/
[7] Scrips Institute of Oceanography, Cal-Adapt and California Nevada Applications Program. Temperature: Extreme Heat Tool, http://cal-adapt. org/temperature/heat/
[8] ibid

increasing the severity of drought and making the region more prone to wildland-urban-interface fires.[9] In addition, more wildfires can increase the occurrence of poor air quality events (For additional information see Drought Hazard Profile, Wildfire Hazard Profile, and Air Quality Hazard Profile).

Rising Sea Levels

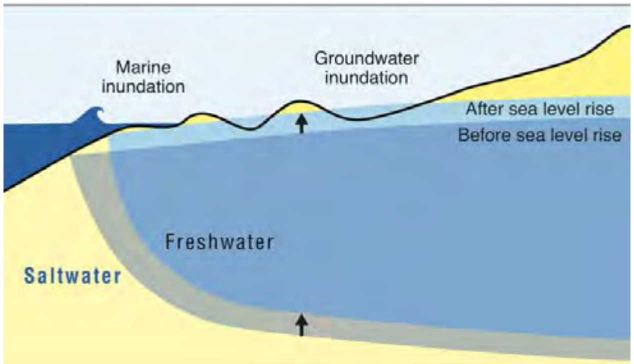
Rising sea levels will have implications for flooding and liquefaction risks. Sea levels in the bay area have already risen by as much as 8 inches in the last 100 years.[10] Low-lying areas not currently exposed to regular tides may become inundated. In addition, temporary coastal flooding events may happen more often, and the flooding may extend farther inland. Stormwater flooding may also increase as stormwater drainage capacity is reduced by higher sea levels. Higher sea levels will also elevate the groundwater table, increasing the susceptibility of soils to liquefaction during an earthquake and potentially compromising potable groundwater supplies in the future. Some areas of the city developed on bay fill zones also face the prospect of subsidence increasing the relative impact of SLR. Studies of the San Francisco waterfront found that subsidence rates of 10 to 20 mm per year can be observed as the mud and artificial fill that constitutes these areas consolidate and compact under the pressure of development.[11]

[9] Ekstrom, Julia A., and 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. California Energy Commission. Publication number: CEC-500-2012-071.

[10] California National Resources Agency. California's Fourth Climate Change Assessment: San Francisco Bay Area Region Report. Retrieved from: http://www.climateassessment.ca.gov/regions/docs/20180827-SanFranciscoBayArea.pdf (Accessed: 9/10/2018)

[11] California National Resources Agency. California's Fourth Climate Change Assessment: San Francisco Bay Area Region Report. Retrieved from: http://www.climateassessment.ca.gov/regions/docs/20180827-SanFranciscoBayArea.pdf (Accessed: 9/10/2018)

FIGURE 4-1
SEA LEVEL RISE DIAGRAM[12]



Projections

San Francisco relies on two primary documents to integrate sea level rise projections into adaptation and hazard mitigation planning. The first is the National Research Council's (NRC) 2012[13] report which provided the best available science on sea level rise at the time and was used to create the CPC SLR guidance[14] as well as the City's 2016 Sea Level Rise Action Plan. The second is the State of California Sea-Level Rise Guidance report (State Guidance) which is periodically updated. The 2018 update to the State Guidance integrates the latest findings from national and regional studies, uses a probabilistic projection method which differs from the NRC report, and includes an extreme, but unlikely, scenario referred to as H++. [15]

Figure 4-2 presents a rough comparison between the NRC 2012 and updated State Guidance sea level projections for 2100. The NRC 2012 values are compared to their most similar proxy in the State Guidance. For example, the unlikely but possible values represent the lower bound of the 2100 projection range for NRC 2012 (17 inches) and

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[12] UHM Coastal Geology Group

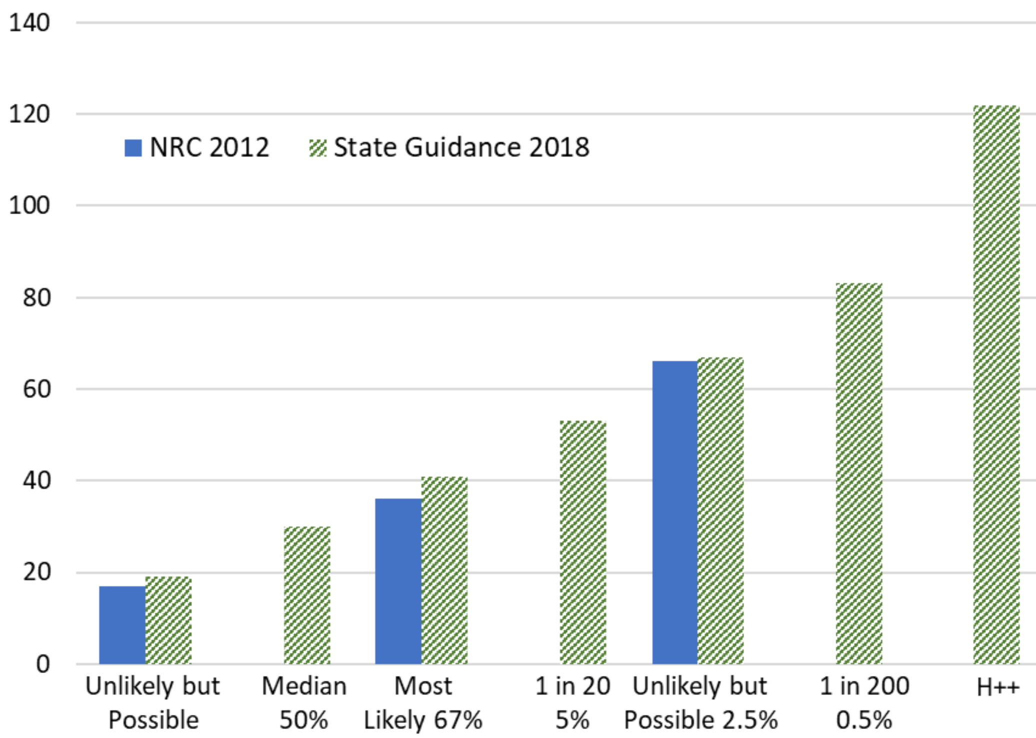
[13] National Research Council (2012). Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present and Future. Prepared by the Committee on Sea Level Rise in California, Oregon, and Washington, Board on Earth Sciences and Resources, Ocean Studies Board, and the Division on Earth and Life Studies.;

[14] Capital Planning Commission. *Guidance for Incorporating Sea Level Rise in Capital Planning In San Francisco: Assessing Vulnerability and Risk to Support Adaptation.* Accessed 10/5/2018. http://onesanfrancisco.org/sites/default/files/inline-files/Guidance-for-Incorporating-Sea-Level-Rise-into-Capital-Planning1.pdf. 2019 SLR checklist update: Adopted 07/22/2019 by the Capital Planning Commission (CPC)

[15] California Ocean Protection Council. *State of California Seal-Level Rise Guidance*. Accessed 10/5/2018. http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf

the State Guidance median projection for RCP 2.6 at 2100 (19 inches). These represent the lowest values presented in both documents for the end of the century. The most likely values include the most likely value recommended in NRC 2012 (36 inches) and the upper bound of the likely range recommended in the State Guidance (41 inches). The upper bound values include the upper bound of the projection range presented in NRC 2012 (66 inches), compared with the State Guidance projection that has a 2.5% probability of occurrence (67 inches). This probability value was selected for comparison because the projection range presented in NRC 2012 used a calculation based on two standard deviations (i.e., two standard deviations captures 95 percent of the data, or the values between the 2.5-percentile and the 97.5-percentile).

FIGURE 4-2
COMPARISON OF SEA LEVEL RISE PROJECTIONS BY NRC (2012) AND THE STATE GUIDANCE (2018)[16]



[16] The sea level rise projections from NRC (2012) are based on greenhouse gas emission scenarios published in 2000 for IPCC in the Special Report on Emission Scenarios (SRES). IPCC used the SRES approach in the Third and Fourth Assessment Reports published in 2001 and 2007, respectively. The projections in the State Guidance (2018) are based on the updated Representation Concentration Pathways (RCPs) adopted by the IPCC for the fifth Assessment Report in 2014. The assumptions and science behind the SRES and RCP approaches are very different; therefore, direct comparisons are challenging and should be considered for illustrative purposes only.

Although the NRC 2012 and State Guidance projections are similarly comparable, the State Guidance recommends using higher water levels. For example, the recommended upper bound number for long-range adaptation planning increases from 66 inches (NRC 2012) to 83 inches (State Guidance). In addition, the recommended most likely value of sea level rise increases from 36 inches (NRC 2012) to 41 inches (State Guidance). In addition, the latest update to the State Guidance includes a more extreme SLR scenario known as H++, which projects 122 inches of SLR at 2100 which peaks at 164 inches when coupled with a 100-year storm. This scenario is based on a future with rapid loss of the West Antarctic ice sheet, however, this scenario is highly uncertain and the subject of ongoing research. Therefore, the H++ scenarios is not used for planning or adaptation purposes at this time, but it does illustrate the inherent uncertainty in the practice of projecting SLR.

In light of the updated State Guidance and the evolving science on sea level rise[17], the CPC Guidance was updated in July 2019. The Sea Level Rise checklist has been updated to include the likely and 1-in-200 chance values for RCP 4.5 and RCP 8.5 based on the most recently updated science. Likely values for RCP4.5 are 33 inches and RCP8.5 is 41 inches which compares well with the existing NRC recommendation of 36 inches. However, NRC recommended using the upper range value of 66 inches of sea level rise by 2100 for adaptation planning. The 1-in-200 values for RCP4.5 and RCP8.5 exceed this, with 71 inches and 83 inches of sea level rise by 2100 respectively. This represents a notable increase in the amount for sea level rise recommended for use in adaptation planning.

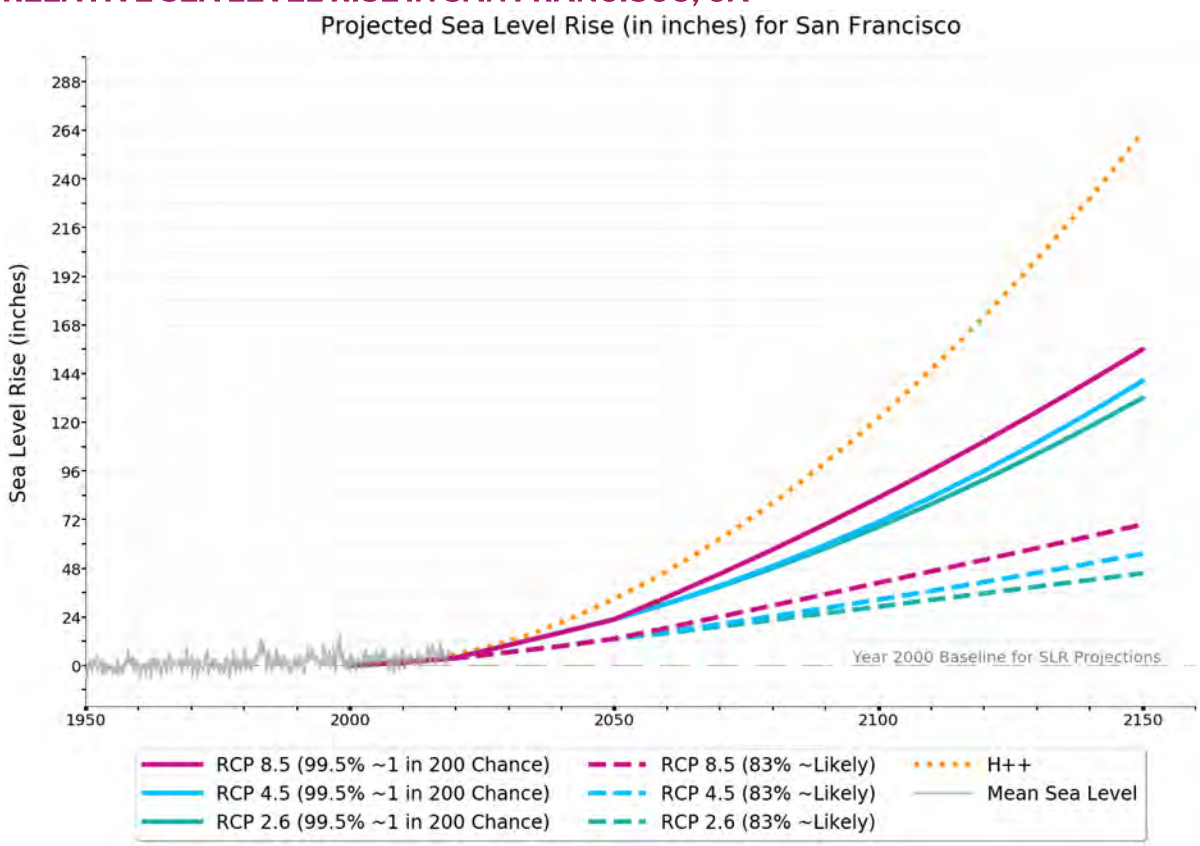
As this update occurred far into the development of this planning effort, the updated values were unable to be used in this assessment, therefore this report relies on the CPC Guidance values derived from the NRC 2012 report.

[17] Griggs, G, Árvai, J, Cayan, D, DeConto, R, Fox, J, Fricker, HA, Kopp, RE, Tebaldi, C, Whiteman, EA (California Ocean Protection Council Science Advisory Team Working Group). Rising Seas in California: An Update on Sea-Level Rise Science. California Ocean Science Trust, April 2017.

FIGURE 4-3
SEA LEVEL RISE PROJECTIONS BY NRC (2012) AND THE RISING SEAS (2017)[18]

Year	NRC 2012		RCP 4.5 Rising Seas 2017		RCP 8.5 Rising Seas 2017	
	Likely	Upper Range	Likely	1 in 200 Chance	Likely	1 in 200 Chance
2030	6	12	6	10	6	10
2050	11	24	13	23	13	23
2070	20	38	20	39	24	45
2100	36	66	33	71	41	83
2150	--	--	55	140	70	156

FIGURE 4-4
RELATIVE SEA LEVEL RISE IN SAN FRANCISCO, CA[19]



[18] This table demonstrated the different suggested values between the NRC report that underpinned the original CPC guidance and the values shown in the rising seas report (see previous citation) which formed the basis for the 2019 CPC guidance update.
[19] City and County of San Francisco, (Publication forthcoming). "Draft Sea Level Rise Vulnerability and Consequences Assessment"

For a more in-depth treatment of SLR Projections, see “Chapter 2: Sea Level Rise Climate Science and Scenarios” of the San Francisco’s Sea Level Rise Vulnerability and Consequences Assessment.[20]

For the exposure and vulnerability assessment in this report, we have selected two different sea level rise scenarios:

- **66 inches above MHHW**, which represents the 2050 upper-end SLR projection plus 100-year extreme tide or the 2100 upper-range SLR projection without extreme tide (NRC 2012)
- **108 inches above MHHW**, which represents 2100 upper-end SLR projection plus 100-year extreme tide (NRC 2012)

For more detailed mapping of SLR scenarios, please see the San Francisco Sea Level Rise Vulnerability & Consequences Assessment,[21] which uses 10 scenarios that represent a range of SLR projections aligning with the NRC (2012) SLR projections and the State Guidance (2018) projections and include storm surge events.

Implications for Future Hazards

Without action, a variety of hazards will increase as seas rise, including:

- Low-lying areas that are not currently exposed to tides will experience inundation during high tides in the long-term.[22] (For additional information see Flooding Hazard Profile.)
- Coastal flooding will become more frequent as Bay and sea levels occur more often. Coastal flooding will be more extensive and longer-lasting, especially during storm events.[23] (For additional information see Flooding Hazard Profile.)
- Stormwater flooding will increase as high bay levels can impede drainage of stormwater runoff.[24] (For additional information see Flooding Hazard Profile).

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[21] City and County of San Francisco, (Publication forthcoming). “Draft Sea Level Rise Vulnerability and Consequences Assessment”.
[22] City and County of San Francisco, 2016. “Sea Level Rise Action Plan.”
[23] Ibid
[24] Ibid

- Higher sea levels will also increase the elevation of the groundwater table, increasing the susceptibility of some soils to liquefaction during an earthquake.[25] (For additional information see Earthquake Flooding Hazard Profile).

Changing Precipitation Patterns

San Francisco precipitation levels have historically fluctuated between wet and dry extremes. Climate change will amplify this trend. As a result, San Francisco is projected to experience an increase in both flooding and drought.

Projections

Baseline: Although San Francisco has historically received on average 21 inches of rainfall annually, Bay Area precipitation levels are prone to large year-to-year variation.[26] California currently receives 35% - 45% of its annual precipitation from discrete storm events. These extreme storms events occur between November and March when atmospheric rivers transport water vapor from Hawaii across the Pacific Ocean towards the west coast of the United States.[27] Compared to other storm systems that originate in Alaska, atmospheric river storms are warm and wet and are associated with many of California's flood events. While 35% - 45% of California's annual precipitation comes from atmospheric river storms, they are responsible for nearly 80% of California's flooding because of both the quantity of precipitation these storms contain, and because these storms are less likely to result in snowfall because they have warmer water and can occur in spring or fall.[28] These storms may carry as much water as seven to fifteen Mississippi Rivers in a single event and often play a pivotal role in ending periods of drought[29].

Projection: Considering RCP4.5 mean projections, most regions of the state can expect to see at least modest increases in mean wet-season precipitation compared to

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[25] Adapting to Rising Tides, "Climate Impacts and Scenarios." http://www.adaptingtorisingtides.org/portfolio/climate-impacts-and-scenarios/
[26] NOAA National Center for Environmental Information Station ID CHCND:USW00O232272

[27] Dettinger, Michael, 2011. "Climate Change, Atmospheric Rivers, and Floods in California – A Multimodel Analysis of Storm Frequency and Magnitude Changes", *Journal of the American Water Resources Association*, Vol. 47, No. 3
[28] https://www.jpl.nasa.gov/news/news.php?feature=5648
[29] California National Resources Agency. California's Fourth Climate Change Assessment: San Francisco Bay Area Region Report. Retrieved from: http://www.climateassessment.ca.gov/regions/docs/20180827-SanFranciscoBayArea.pdf (Accessed: 9/10/2018)

historical amounts. However, the San Francisco Bay area is projected to see potential average late-century increases of up to 10.5 percent, the highest in the state, making the region most likely to see changes in future storm events.[30] This trend is also evident in the RCP8.5 projections that point to average wet-season mid-century changes as much as 10.3% and as much as 18.7% by late-century. These indicators represent a general trend towards more intense/frequent storms during the wet-season in the coming decades.

FIGURE 4.5
AVERAGE WET-SEASON PRECIPITATION CHANGE ACROSS THE STATE ASSUMING A RCP4.5 SCENARIO[31]

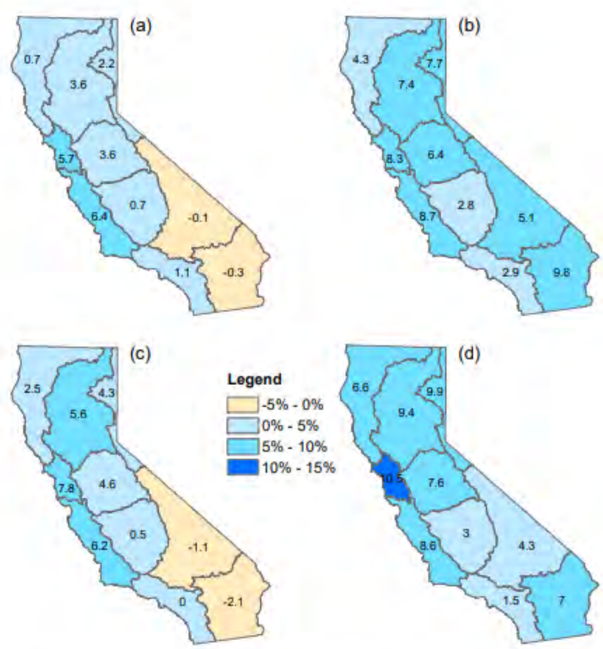

Figure 3: Percent Differences (%) between Historical and Mean RCP 4.5 Projections on (a) Annual Precipitation in Mid-Century, (b) Wet Season Precipitation in Mid-Century, (c) Annual Precipitation in Late-Century, and (d) Wet Season Precipitation in Late-Century.

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[30] He, Minxue, Andrew Schwarz, Elissa Lynn, Michael Anderson (California Department of Water Resources). 2018. Projected Changes in Precipitation, Temperature, and Drought across California's Hydrologic Regions. California's Fourth Climate Change Assessment. Publication number: CCCA4-EXT-2018-002.

[31] He, Minxue, Andrew Schwarz, Elissa Lynn, Michael Anderson (California Department of Water Resources). 2018. Projected Changes in Precipitation, Temperature, and Drought across California's Hydrologic Regions. California's Fourth Climate Change Assessment. Publication number: CCCA4-EXT-2018-002.

Year-to-year precipitation levels are expected to increasingly cluster around wet and dry extremes.[32] Precipitation is expected to become more variable in the future, with more rainfall occurring during extreme events, as higher temperatures can result in more water held in the atmosphere that is able to fall as rain. By the end of the century, atmospheric river storms are expected to provide nearly 50% of California's annual precipitation.[33] Under the RCP8.5 high-emissions scenario, severe storms with a return frequency of once every 200 years (a storm on the magnitude of the Great California Flood of 1862) could potentially occur every 40-50 years in the Bay Area by 2100.[34]

San Francisco gets 85% of its water from the Sierra Nevada.[35] According to a study by the UCLA Center for Climate Science, the snowpack in the year 2100 is expected to be 36 percent of the snowpack in 2000, which presents a major challenge for water management.[36]

Implications for Future Hazards

Changing precipitation patterns may influence several hazards, including:

- Concentrated precipitation in extreme events may increase stormwater flooding, especially along San Francisco's underground creeks and in San Francisco's natural drainage basins. (For additional information see Flooding Hazard Profile.)
- Concentrated precipitation in extreme events may also increase the risk of landslides. An increase in wildland-urban-interface fires also increases landslide risks. (For additional information see Landslide Hazard Profile.)
- In dry years, when coastal high-pressure systems do not dissipate during winter months, California may be subject to frequent and severe droughts. In addition, a

[32] Dettinger, Michael, 2011. "Climate change, atmospheric rivers, and floods in California – A Multimodel Analysis of Storm Frequency and Magnitude Changes", *Journal of the American Water Resources Association*, Vol. 47, No. 3
[33] Dettinger, Michael, 2011. "Climate Change, Atmospheric Rivers, and Floods in California – A Multimodel Analysis of Storm Frequency and Magnitude Changes", *Journal of the American Water Resources Association*, Vol. 47, No. 3
[34] California National Resources Agency. California's Fourth Climate Change Assessment: San Francisco Bay Area Region Report. Retrieved from: http://www.climateassessment.ca.gov/regions/docs/20180827-SanFranciscoBayArea.pdf (Accessed: 9/10/2018)
[35] San Francisco Public Utilities Commission - http://www.sfwater.org/index.aspx?page=355
[36] Reich, KD, N Berg, DB Walton, M Schwartz, F Sun, X Huang, and A Hall, 2018: "Climate Change in the Sierra Nevada: California's Water Future." UCLA Center for Climate Science.

reduced snowpack in the Sierras can exacerbate drought and compromise water supply. (For additional information see Drought Hazard Profile).

TABLE 4-5
SUMMARY OF CLIMATE CHANGE IMPLICATIONS FOR HAZARDS

Climate Change:	Increasing Temperatures	Rising Sea Levels	Changing Precipitation Patterns
Implications for Hazards:	More **extreme heat** days, making heatwaves more frequent and longer-lasting. **Drought** and **wildland-urban-interface fires** may become more frequent and severe.	More frequent, extensive and longer-lasting **coastal flooding**, especially during storm events. **Stormwater flooding** may increase as high bay levels can impede drainage of stormwater runoff. Higher groundwater table may **increase the susceptibility of some soils to liquefaction** during an earthquake.	Concentrated precipitation in discrete storm events may increase **stormwater flooding**. **Droughts** may be more frequent and severe. Reduced snowpack in the Sierras may also exacerbate **drought**.

Earthquake Hazard Profile

4.2 Earthquake

Earthquakes present one of the greatest risks to San Francisco's buildings, infrastructure and people. San Francisco has experienced several devastating earthquakes in its history, and there is a high likelihood of a large earthquake in the near future. An earthquake is a sudden slip on a fault in the earth's crust, and the resulting ground shaking and radiated seismic energy caused by the slip.[37] A fault is a fracture in the earth's crust where a block of crust on one side moves relative to the other.[38]

The energy released in earthquakes can produce different types of hazards. Groundshaking and Liquefaction are discussed in greater detail in this profile, while tsunami, earthquake-induced landslide, fire following earthquake (large urban fire), and dam failure are discussed in their own profiles. Each of which are discussed in greater detail in this section:

Ground Shaking

Impact Statement

All of San Francisco is susceptible to very strong to extreme ground shaking during a major earthquake. There is a 72 percent chance that an earthquake of moment magnitude (Mw) 6.7 or greater will strike the San Francisco Bay Region between now and 2043. A Mw 6.7 earthquake or above on one of the seven major faults in the Bay Area could result in very strong to severe shaking in the city, which in turn may result in widespread casualties and infrastructure damage. Though the impact of climate change on earthquakes has not been clearly established,[39] sea level rise may result in higher ground water tables, which may increase the areas of the city susceptible to liquefaction.[40]

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[37] United States Geological Survey (USGS) Earthquake Hazards Program, "Earthquake Glossary - Earthquake," accessed May 17, 2018, https://earthquake.usgs.gov/learn/glossary/?term=earthquake.

[38] USGS Earthquake Hazards Program, "Earthquake Glossary - Fault," accessed May 17, 2018, http://earthquake.usgs.gov/learn/glossary/?term=fault.

[39] Ilan Kelman, "Climate Change and the Sendai Framework for Disaster Risk Reduction," *International Journal of Disaster Risk Science* 6 (2015): 121, accessed May 22, 2018, https://link.springer.com/content/pdf/ 10.1007%2Fs13753-015-0046-5.pdf.

[40] Peter Quilter, Sjoerd van Ballegooy, and Marje Russ, "The Effect of Sea Level Rise on Liquefaction Vulnerability." *6th International Conference on Earthquake Geotechnical Engineering*, 1-4 November 2015, Christchurch, New Zealand.

Nature

The effects of large earthquakes can be felt far beyond the site of their occurrence. Earthquakes occur without warning and can cause significant damage and extensive casualties after just a few seconds. The most common effect of earthquakes is ground shaking. When an earthquake occurs, the energy from the quake radiates outward from the fault in all directions in the form of seismic waves. As seismic waves reach the earth's surface, they shake the ground and anything on it. Strong ground shaking may damage or destroy buildings and may injure or kill occupants. Ground shaking is the primary cause of earthquake damage to buildings and infrastructure.[41]

The severity of ground shaking in an earthquake depends on the magnitude of the quake, the distance from the fault, and local geologic conditions. We can anticipate the amount of shaking that may occur at a given location from a particular fault by knowing how long the fault is (which indicates earthquake magnitude), where the fault is (giving us the distance to any location), and the geological conditions at the site.[42] Soil type is one geological condition that may affect ground shaking. The velocity at which soil or rock transmits shear waves generated by earthquakes contributes to amplification of ground shaking. Shaking is stronger where the shear wave velocity is lower. Because soft soils have lower shear wave velocity, they amplify or increase ground shaking. As a result, earthquake damage is typically more severe in areas with soft soils.[43]

Table 4-7, below, shows soil types in the Bay Area and their shear wave velocity. San Francisco's predominant soil is Type D, but there are locations in the city with Type E soils. Both of these soil types amplify shaking. For a map showing soil types in San Francisco, see Figure 4-6 below.

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[41] USGS, Earthquake Hazards Program, "Soil Type and Shaking Hazard in the San Francisco Bay Area," accessed May 17, 2018, https://earthquake.usgs.gov/hazards/urban/sfbay/soiltype/.

[42] Southern California Earthquake Center (SCEC), "Earthquake Shaking - Accounting for "Site Effects," accessed May 17, 2018, http://scecinfo.usc.edu/phase3/overview.html.

[43] USGS, Earthquake Hazards Program, "Soil Type and Shaking Hazard in the San Francisco Bay Area."

FIGURE 4-6
SOIL TYPES IN SAN FRANCISCO

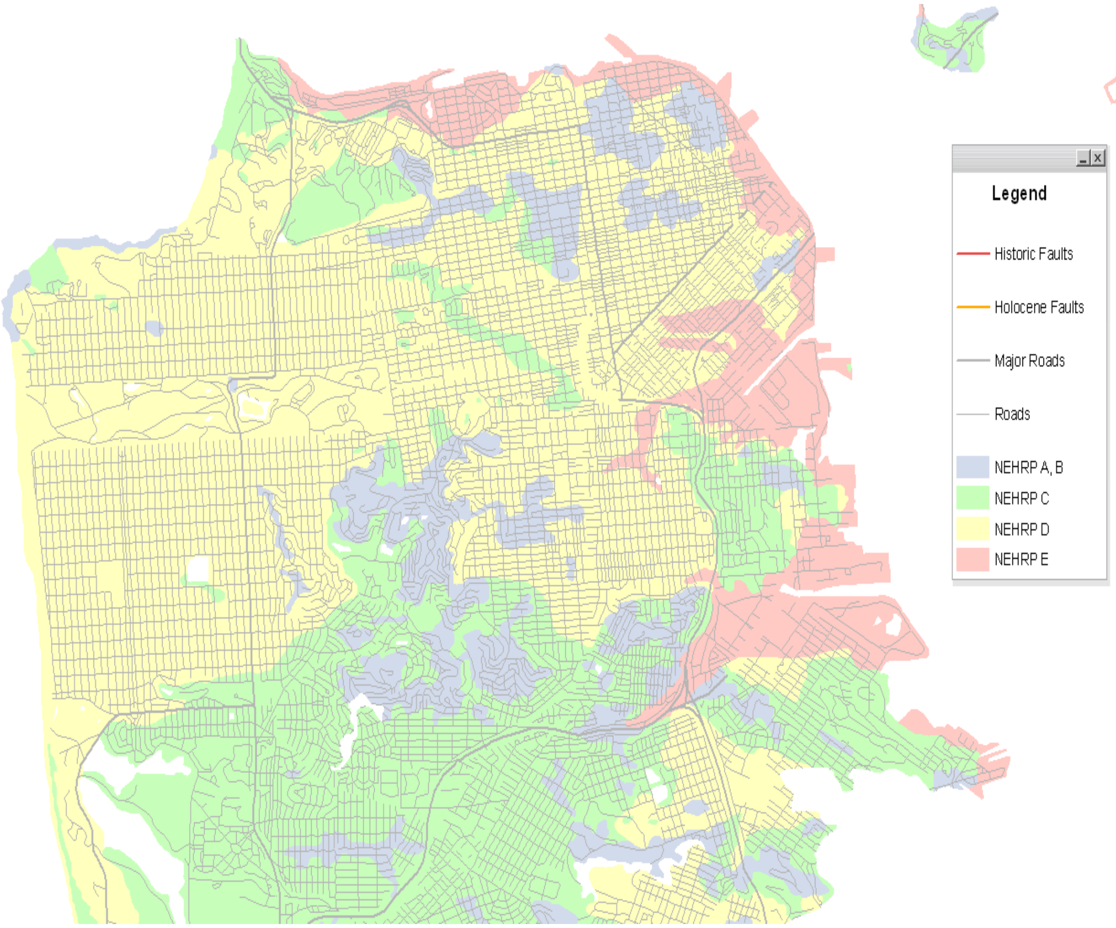

TABLE 4-7
SOIL TYPES AND SHAKING AMPLIFICATION[44]

Soil Type	Shear-Wave Velocity (Vs)	Soil Definitions
Type A	Vs > 1500 m/sec	Includes unweathered intrusive igneous rock. Occurs infrequently in the Bay Area. Soil types A and B do not contribute greatly to shaking amplification.
Type B	1500 m/sec > Vs > 750 m/sec	Includes volcanics, most Mesozoic bedrock, and some Franciscan bedrock. The Franciscan Complex is a Mesozoic unit that is common in the Bay Area.
Type C	750 m/sec > Vs > 350 m/sec	Includes some Quaternary sands, sandstones, and mudstones; Upper Tertiary sandstones, mudstones and limestone; Lower Tertiary mudstones and sandstones; and Franciscan melange and serpentinite.
Type D	350 m/sec > Vs > 200 m/sec	Includes some Quaternary muds, sands, gravels, silts and mud. Significant amplification of shaking by these soils is generally expected.
Type E	200 m/sec > Vs	Includes water-saturated mud and artificial fill. The strongest amplification of shaking is expected for this soil type.

The severity of an earthquake can be described in terms of intensity and magnitude. Intensity is the impact of an earthquake on the Earth's surface. Intensity measures the strength of shaking from an earthquake at a certain location as indicated by its effects on people, structures, and the natural environment. Intensity generally increases with the amount of energy released, which is proportional to the size of the earthquake, and decreases with distance from the quake epicenter.[45]

One scale used in the United States to measure earthquake intensity qualitatively is the Modified Mercalli Intensity (MMI) Scale. The MMI Scale consists of 10 increasing levels of intensity ranging from imperceptible shaking to building destruction.[46] MMI less than 6 does not generally damage buildings. Table 4-10 below shows the expected impacts

[44] USGS, Earthquake Hazards Program, "Soil Type and Shaking Hazard in the San Francisco Bay Area," accessed May 17, 2018, https://earthquake.usgs.gov/hazards/urban/sfbay/soiltype/

[45] USGS, "The Severity of an Earthquake," *General Interest Publication 1989-288-913*, accessed May 17, 2018, https://pubs.usgs.gov/gip/earthq4/ severitygip.html.

[46] USGS, Earthquake Hazards Program, "The Modified Mercalli Intensity Scale," accessed May 17, 2018, https://earthquake.usgs.gov/learn/topics/mercalli.php.

to building contents and common building types. For maps showing MMI for various earthquake scenarios that may impact San Francisco, see Figure 4-8 and Figure 4-9 below.

Ground shaking intensity can also be quantitatively measured in terms of acceleration, velocity, or displacement. Peak ground acceleration (PGA) is a common ground motion parameter used by engineers. PGA measures earthquake intensity by quantifying the rate of acceleration of the ground at a given location. Peak acceleration is the largest increase in velocity recorded by a particular geophysical instrument station during an earthquake.[47] PGA is expressed as a percentage of the acceleration of gravity (g): One g is an acceleration of 9.8 meters per second.[48]

Another means of measuring earthquake severity is Magnitude (M), which measures the size of an earthquake. The first magnitude scale was the Richter Scale, also known as local magnitude (M_L). Because the Richter Scale does not satisfactorily measure the size of larger earthquakes, it is no longer commonly used. The magnitude scale currently used by seismologists is the moment magnitude (Mw) scale.[49] The Mw scale, based on the concept of seismic moment, is uniformly applicable to all sizes of earthquakes.[50] Table 4-11 shows an approximate correlation between the Mw and MMI Scale for intensities typically observed at locations near the epicenter of earthquakes of different magnitudes.

[47] USGS, Earthquake Hazards Program, "Earthquake Glossary - Acceleration," accessed May 17, 2018, https://earthquake.usgs.gov/learn/glossary/?term=acceleration.

[48] USGS, Earthquake Hazards Program, "Earthquake Glossary – G or g," accessed May 17, 2018, https://earthquake.usgs.gov/learn/glossary/?term=G%20or%20g.

[49] USGS, Earthquake Hazards Program, "Measuring the Size of an Earthquake," accessed May 17, 2018, https://earthquake.usgs.gov/learn/topics/measure.php.

[50] USGS, Earthquake Hazards Program, "Earthquake Glossary – Magnitude," accessed May 17, 2018, https://earthquake.usgs.gov/learn/glossary/?term=magnitude.

FIGURE 4-8
PREDICTED GROUND SHAKING INTENSITY: 7.0 HAYWARD FAULT SCENARIO

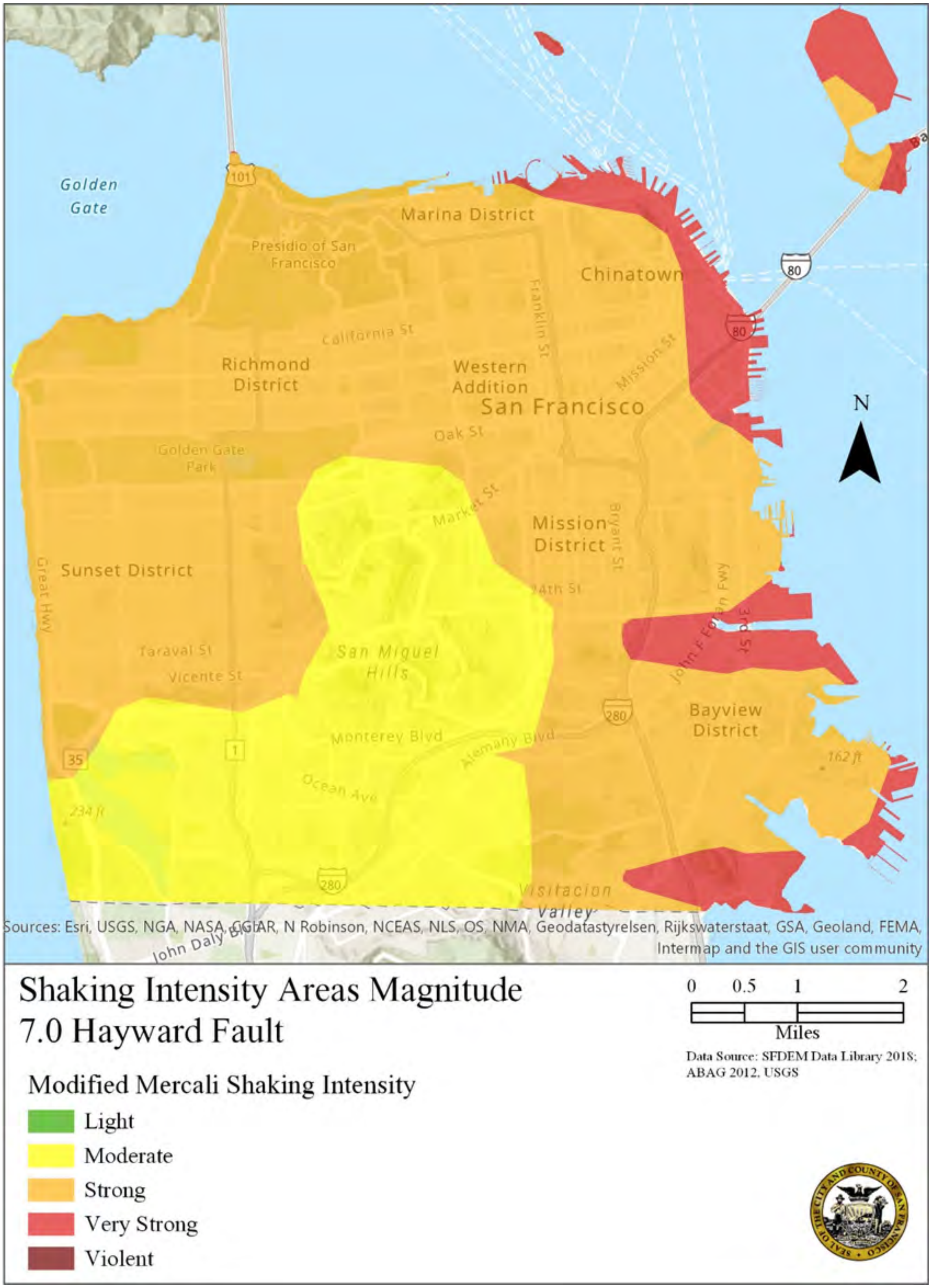

FIGURE 4-9
PREDICTED GROUND SHAKING INTENSITY: 7.8 SAN ANDREAS FAULT SCENARIO

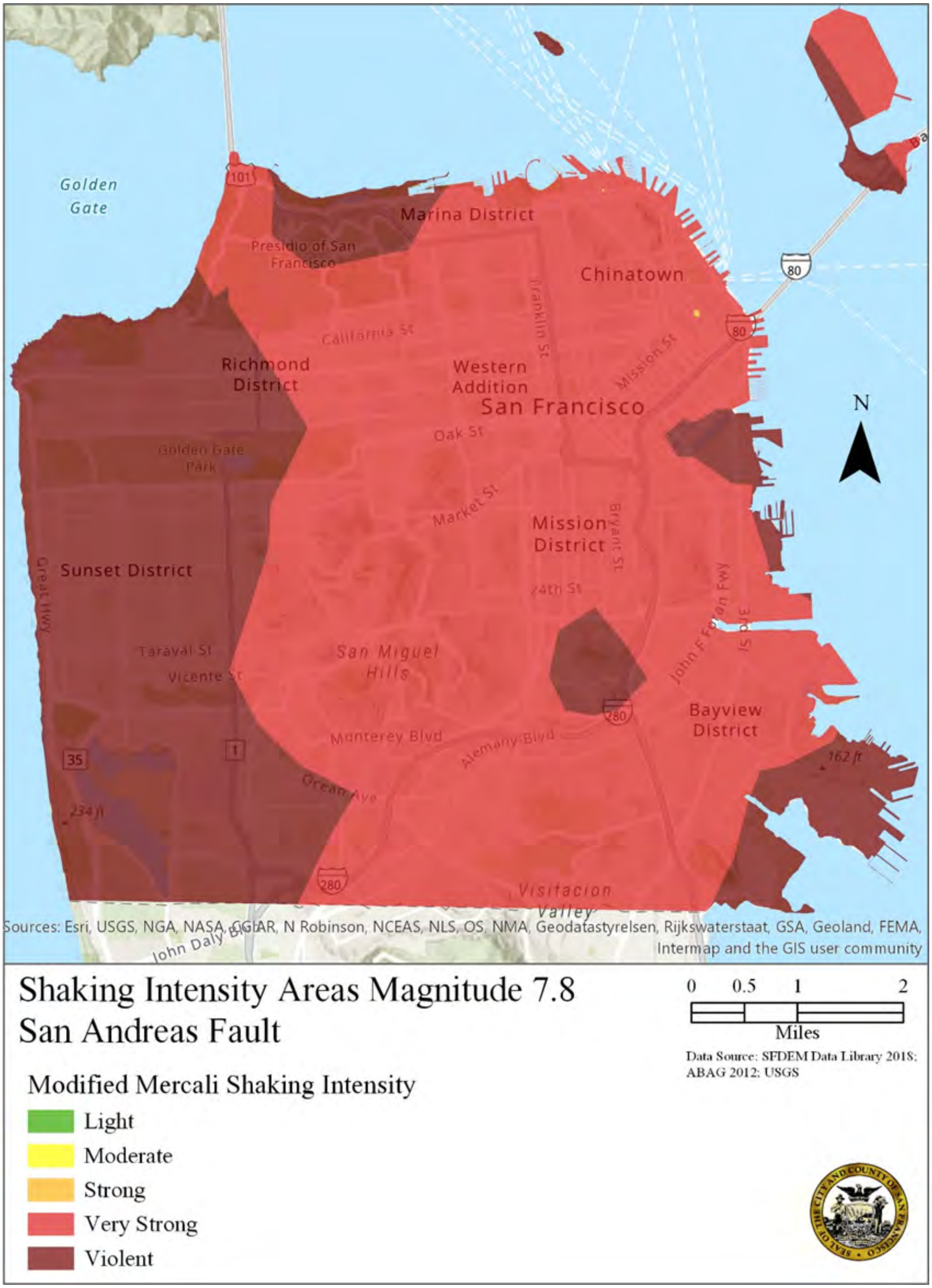

TABLE 4-10
SHAKING INTENSITY IMPACTS[51]

Intensity	Shaking	Intensity Description or Damage
I	Not Felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awaken. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awaken. Some dishes and windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Some things thrown from shelves, pictures shifted, water thrown from pools. Some walls and parapets of poorly constructed masonry buildings crack. Some drywall cracks. Some chimneys are damaged. Some slab foundations, patios, and garage floors slightly crack.
VII	Very Strong	Many things thrown from walls and shelves. Furniture is shifted. Poorly constructed buildings are damaged and some well- constructed buildings crack. Cornices and unbraced parapets fall. Plaster cracks, particularly at inside corners of buildings. Some unretrofitted soft-story buildings strain at the first-floor level. Some partitions deform. Many chimneys are broken and some collapse, damaging roofs, interiors, and porches. Weak foundations can be damaged.
VIII	Severe	Nearly everything thrown from shelves, cabinets, and walls. Furniture overturned. Poorly-constructed buildings suffer partial or full collapse. Some well-constructed buildings are damaged. Unreinforced walls fall. Unretrofitted soft-story buildings are displaced out of plumb and partially collapse. Loose partition walls are damaged and may fail. Some pipes break. Houses shift if they are not bolted to the foundation or are displaced and partially collapse if cripple walls are not braced. Structural elements such as beams, joists, and foundations are damaged. Some pipes break.
IX	Violent	Only very well anchored contents remain in place. Poorly constructed buildings collapse. Well- constructed buildings are heavily damaged. Retrofitted buildings damaged. Unretrofitted soft-story buildings partially or completely collapse. Some well- constructed buildings are damaged. Poorly constructed buildings are heavily damaged, some partially collapse. Some well- constructed buildings are damaged.
X	Extreme	Only very well anchored contents remain in place. Retrofitted buildings are heavily damaged, and some partially collapse. Many well- constructed buildings are damaged.

[51] US Geological Survey (USGS). https://earthquake.usgs.gov/learn/topics/mercalli.php

TABLE 4-11
MAGNITUDE AND INTENSITY COMPARISON[52]

Moment Magnitude (Mw)	Modified Mercalli Intensity (MMI) Scale
1.0-3.0	I
3.0 - 3.9	II – III
4.0 - 4.9	IV – V
5.0 - 5.9	VI – VII
6.0 - 6.9	VII – IX
7.0 and higher	VIII or higher

History

The San Francisco Bay Area is located within the boundary between the Pacific and the North American tectonic plates, where the Pacific plate is slowly and continually sliding northwest and past the North American plate.[53] Historically, the San Andreas Fault system is the most active system in the Bay Area. This fault system is capable of generating very strong earthquakes of magnitude 7.0 or greater.

The last major earthquake on the northern portion of the fault occurred in 1906. Known as the Great 1906 San Francisco Earthquake, this event was centered off San Francisco's Ocean Beach, and lasted 45 to 60 seconds. The 1906 quake has been estimated at moment magnitude 7.7 to 7.9.[54] The quake was reported at the time to have resulted in 498 deaths in San Francisco and $80 million in earthquake damage to the region.[55] Later research has produced estimates of over 3,000 deaths in San Francisco from the 1906 earthquake.[56]

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[52] USGS. http://earthquake.usgs.gov/learning/topics/mag_vs_int.php

[53] USGS, *Earthquake Outlook for the San Francisco Bay Region 2014—2043*, by Brad T. Aagaard, James Luke Blair, John Boatwright, Susan H. Garcia, Ruth A. Harris, Andrew J. Michael, David P. Schwartz, and Jeanne S. DiLeo, Fact Sheet 2016-3020, (Reston, Virginia, 2016), 2, accessed May 21, 2018, https://pubs.usgs.gov/fs/2016/3020/ fs20163020.pdf.

[54] USGS, Earthquake Hazards Program, "1906 Earthquake: What was the magnitude?" accessed May 17, 2018, https://earthquake.usgs.gov/earthquakes/events/1906calif/18april/magnitude.php.

[55] USGS, Earthquake Hazards Program, "Casualties and damage after the 1906 Earthquake," accessed May 17, 2018, https://earthquake.usgs.gov/earthquakes/events/1906calif/18april/casualties.php.

[56] Gladys Hansen and Emmet Condon, *Denial of Disaster* (San Francisco: Cameron and Co., 1989), 14.

On October 17, 1989, San Francisco experienced the Mw 6.9 Loma Prieta Earthquake. The 1989 quake was centered near Loma Prieta peak in the Santa Cruz Mountains, approximately 60 miles south-southeast of San Francisco. The quake lasted only 15 seconds, but resulted in severe shaking in the San Francisco and Monterey Bay regions.[57] In San Francisco, Loma Prieta resulted in 12 deaths, 300 people injured, and $2 billion dollars in property damage.[58]

The largest earthquake since Loma Prieta was the August 24, 2014, South Napa Earthquake, a Mw 6.0 earthquake on the West Napa fault, which is part of the Calaveras Fault Zone system. The Napa quake resulted in two deaths and 300 injuries, and caused extensive damage in Napa, Solano, and Sonoma counties. It did not result in significant damage in San Francisco.[59]

As shown in Figure 4-12 below, the San Andreas and other regional faults, including the Hayward fault, have generated 70 recorded M 5.0 or greater earthquakes since 1800. Of these recorded earthquakes, three (1838, 1906, and 1989) registered at a M_L of 6.8 or greater. For further discussion of measurement of earthquake severity, see Ground Shaking, Nature, above.

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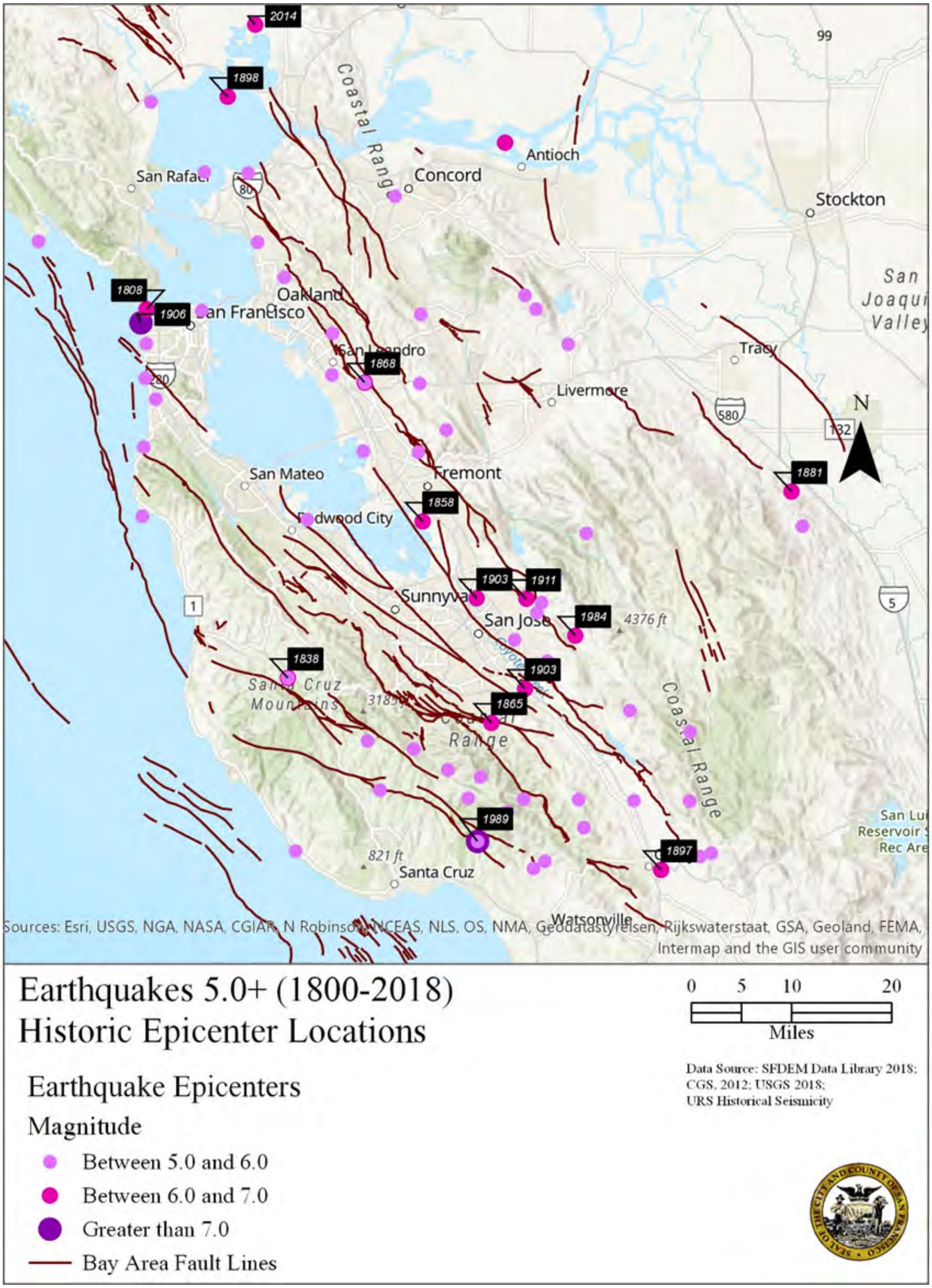
[57] USGS, Earthquake Hazards Program, “M 6.9 October 17, 1989 Loma Prieta Earthquake,” accessed May 17, 2018, https://earthquake.usgs.gov/earthquakes/events/1989lomaprieta/.

[58] California Senate Committee on Toxics and Public Management, "1989 Northern California Earthquake," California Senate Paper 228 (1989), 2, accessed May 21, 2018, https://digitalcommons.law.ggu.edu/cgi/viewcontent.cgi?referer=https://www.google.com/&httpsredir=1&article=1219&context=caldocs_senate. Dollar figures are in 1989 dollars. In 2018 dollars, this would represent over $4 billion in damage.

[59] See California Seismic Safety Commission and Pacific Earthquake Engineering Research Center, *The Mw 6.0 South Napa Earthquake of August 24, 2014: A Wake-up Call for Renewed Investment in Seismic Resilience Across California*, by Laurie A. Johnson and Stephen A. Mahin, CSSC Publication 16-03, PEER Report No. 2016/04 (2016), 1, accessed May 21, 2018, https://peer.berkeley.edu/publications/peer_reports/reports_2016/CSSC1603-PEER201604_FINAL_7.20.16.pdf.

FIGURE 4-12
EARTHQUAKES 5.0+ (1800-2018) HISTORIC EPICENTER LOCATIONS



Location

Though no known active faults are located within San Francisco County boundaries, San Francisco is susceptible to seismic hazards from numerous known faults in the Bay Area, and from potentially unmapped or undiscovered faults. Most of the known major faults in the Bay Area are strike-slip faults, which are vertical or nearly-vertical fractures where the ground generally moves horizontally.[60] The Bay Area also has several thrust or reverse faults, which are fractures where the ground generally moves vertically with a dip of 45 degrees or less.[61] The most active of the large strike-slip faults in the region are the San Andreas Fault and the Hayward Fault, which has three segments, including the Rodgers Creek Fault. Table 4-13, below, lists major Bay Area faults, their locations, and lengths within the Bay Area.

[60] USGS, Earthquake Hazards Program, "Earthquake Glossary – Strike-slip," accessed May 17, 2018, https://earthquake.usgs.gov/learn/glossary/?term=strike-slip.

[61] USGS, Earthquake Hazards Program, "Earthquake Glossary – Dip slip," accessed May 17, 2018, https://earthquake.usgs.gov/learn/glossary/?term=dip slip.

TABLE 4-13
MAJOR KNOWN FAULTS IN THE SAN FRANCISCO BAY AREA[62]

Fault Source	Location	Fault Type	Length (Miles)
Northern San Andreas	Northern California Coast	Strike-slip	294
Hayward-Rodgers Creek	Alameda, Contra Costa, Marin, Santa Clara, and Sonoma Counties	Strike-slip	118
Calaveras	Alameda, Contra Costa Counties	Strike-slip	81
Concord-Green Valley	Alameda, Contra Costa, Solano, Santa Clara Counties	Strike-slip	81
Greenville Fault	Alameda, Contra Costa, Santa Clara Counties	Strike-slip	34
San Gregorio	Marin, Monterey, San Mateo, Santa Cruz Counties	Strike-slip and reverse thrust	68
Mt. Diablo Thrust	Alameda, Contra Costa Counties	Thrust fault	20

Severity and Probability of Future Events

As noted earlier, the severity of an earthquake at a particular location can be expressed in terms of the MMI Scale. Figure 4-9 shows the shaking intensity for a Mw 7.9 earthquake on the northern segment of the San Andreas Fault, an event similar to the 1906 earthquake. Figure 4-8 shows the shaking intensity for a Mw 6.9 earthquake on the northern segment of the Hayward Fault. Figure 4-9 indicates that all of San Francisco is susceptible to very strong to extreme shaking. Figure 4-8 shows areas subject to very strong shaking in San Francisco including the Lake Merced area, Treasure Island, the Marina District, North Waterfront, Financial District North, Financial District South, South of Market (SOMA), Mission Bay, South Beach, Potrero Hill, Bayview District, and Hunters Point neighborhoods.

[62] USGS, Quaternary Fault and Fold Database of the United States; 2007 WGCEP, 2008, Uniform California Earthquake Rupture Forecast, Version 2 (UCERF 2): USGS Open-File Report 2007-1437 and California Geological Survey Special Report 203, 28, https://pubs.usgs.gov/of/2007/1437/

There is a strong likelihood that San Francisco will experience a significant earthquake from one of the known major faults in the next 30 years. In 2014, the Working Group on California Earthquake Probabilities (WGCEP) issued its Third Uniform California Earthquake Rupture Forecast (UCERF3). UCERF3 indicates there is a 72-percent chance that an earthquake of moment magnitude 6.7 or greater will strike the nine-county San Francisco region over a 30-year period (2014–2043) along one of the Bay Area fault systems identified in the forecast.[63] Figure 4-14 below, shows the earthquake outlook for major faults in the Bay Area as determined by UCERF3. The WGCEP expects to issue an updated earthquake rupture forecast in 2020 or later.[64]

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[63] Edward H. Field and 2014 Working Group on California Earthquake Probabilities (WGCEP), *UCERF3: A New Earthquake Forecast for California's Complex Fault System: Fact Sheet 2015–3009 (2015)*, 4, accessed May 18, 2018, https://dx.doi.org/10.3133/fs20153009.

[64] Dr. Edward Field, e-mail message to author, May 22, 2018.

FIGURE 4-14
EARTHQUAKE OUTLOOK FOR THE SAN FRANCISCO BAY REGION 2014–2043[65]

Map of known active faults in the San Francisco Bay region. The 72 percent probability of a magnitude 6.7 or greater earthquake includes the well-known major plate-boundary faults, lesser-known faults, and unknown faults. The percentage shown within each colored circle is the probability that a magnitude 6.7 or greater earthquake will occur somewhere on that fault system by the year 2043. The probability that a magnitude 6.7 or greater earthquake will involve one of the lesser-known faults is 13 percent.

[65] USGS, Earthquake Outlook for the San Francisco Bay Region 2014-2043, https://pubs.usgs.gov/fs/2016/3020/fs20163020.pdf

Liquefaction

Impact Statement

Liquefiable soils in San Francisco are generally found in water saturated sandy or silty soils or landfill along the Pacific coast and San Francisco Bay and in inland areas of fill in the Financial District, South of Market Area, the Mission District, Civic Center areas, and on Treasure Island. The area surrounding the San Francisco International Airport (SFO) in San Mateo County is also within the State liquefaction zone. Liquefiable soils must be shaken hard enough and long enough to trigger liquefaction. Given past instances of severe liquefaction during the Great 1906 and 1989 Loma Prieta Earthquakes, it is reasonable to assume that severe liquefaction will again occur in future earthquakes with strong shaking. As groundwater levels rise due to climate change-related sea level rise, liquefaction zones can be expected to increase in size. Conversely, for earthquakes occurring during a multi-year, severe drought, a low water table and dry ground may inhibit liquefaction that might otherwise occur during large earthquakes.

Nature

Earthquake-induced soil liquefaction is a leading cause of earthquake damage worldwide.[66] Liquefaction is a process in which water-saturated soil temporarily loses strength and acts as a fluid. Liquefaction can occur during earthquake shaking,[67] when seismic waves cause water pressure to increase to the extent that sand grains in the sediment lose contact with each other, leading the sediment to lose strength. Soil that has liquefied may lose its ability to support structures, cause it to flow down even very gentle slopes or to erupt to the ground surface in the form of sand boils. The ground surface may also experience settlement as a result of liquefaction; this phenomenon typically occurs in uneven patterns that damage buildings, roads and pipelines.[68]

The effects of liquefaction on buildings and other infrastructure can be extremely damaging, and may include cracking of foundations, damage to support structures, and

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[66] National Academies of Sciences, Engineering, and Medicine, *State of the Art and Practice in the Assessment of Earthquake-Induced Soil Liquefaction and Its Consequences* (Washington, DC, 2016), 1, accessed May 23, 2018, https://doi.org/10.17226/23474.

[67] USGS, Earthquake Hazards Program, "Earthquake Glossary – Liquefaction," accessed May 22, 2018, https://earthquake.usgs.gov/learn/glossary/?term=liquefaction.

[68] USGS, San Francisco Bay Region Geology and Geologic Hazards, "About Liquefaction," accessed May 22, 2018, https://geomaps.wr.usgs.gov/sfgeo/liquefaction/aboutliq.html.

even structural collapse. Such structural damage may in turn cause injuries to people and leave structures unusable.

Three factors are required for liquefaction to occur:[69]

1. Loose, granular sediment.
2. Saturation of the sediment by ground water.
3. Strong shaking.

Many areas of San Francisco have loose, sandy soils, or have been built up over "reclaimed" areas of human-made "fill." In these areas, ground water fills the spaces between sand and silt grains, making liquefaction more probable during strong shaking. All parts of San Francisco Bay have the potential to be shaken hard enough for susceptible sediment to liquefy.[70]

In most of the San Francisco Bay region, ground water is closest to the surface, where it can saturate younger sediment, in the winter and spring, during and following what is typically San Francisco's rainy season. In 1906, the region experienced a relatively dry rainy season. The 1989 Loma Prieta earthquake occurred at the end of the dry season in October, when ground water levels were relatively deep beneath the ground surface. Nevertheless, the city experienced considerable liquefaction-related damage as a result of both these earthquakes.[71]

History

The United States Geological Survey (USGS) has mapped liquefaction occurrences in San Francisco for earthquakes occurring in 1838, 1852, 1865, 1868, 1906, 1954, and 1989.[72] Detailed liquefaction maps for the 1906 earthquake show very high liquefaction susceptibility in areas along the Pacific Ocean and San Francisco Bay, including Treasure Island and small portions of Yerba Buena Island.[73] Detailed liquefaction maps

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[69] USGS, San Francisco Bay Region Geology and Geologic Hazards, "Factors of Liquefaction," accessed May 22, 2018, https://geomaps.wr.usgs.gov/sfgeo/liquefaction/factors.html

[70] USGS, San Francisco Bay Region Geology and Geologic Hazards, "Factors of Liquefaction."

[71] Ibid

[72] USGS, San Francisco Bay Region Geology and Geologic Hazards, "Earthquakes That Have Caused Liquefaction in the San Francisco Bay Area," accessed May 22, 2018, https://geomaps.wr.usgs.gov/sfgeo/liquefaction/ eq_caused.html

[73] USGS, San Francisco Bay Region Geology and Geologic Hazards, "Earthquakes That Have Caused Liquefaction in the San Francisco Bay Area, Locations of liquefaction features produced during the 1906 San Francisco earthquake," accessed May 22, 2018, https://geomaps.wr.usgs.gov/sfgeo/liquefaction/image_pages/ liqmap_16.html

for the 1989 Loma Prieta Earthquake show very high susceptibility to liquefaction in the same areas affected by the 1906 earthquake.[74]

A significant portion of the damage resulting from the 1906 earthquake was directly or indirectly related to liquefaction. Most liquefaction-related damage in the 1906 quake occurred in reclaimed areas that were once bay or marshland.[75] Liquefaction caused great damage to buildings and structures in areas like the Mission District and the Market Street area, including settlement, lateral spreading, and damage to water mains and sewers.[76] In addition, the catastrophic fires following the earthquake, which burned for the better part of three days, were so damaging in part because liquefaction-related damage to the city's water system severely limited the city's ability to fight the fires.[77]

After the 1989 Loma Prieta earthquake, liquefaction in the Marina District caused vertical settlement, lateral displacement of buildings, buckling of sidewalks, cracking of asphalt pavement, and breaking of water pipes and gas lines. Over 70 sand boils were reported in garages and backyards. Some of the sand boils were nearly four feet in depth. Liquefaction during the Loma Prieta quake also impacted the city's Auxiliary Water Supply System (AWSS), which provides San Francisco with water for firefighting purposes.[78] AWSS is currently referred to as the Emergency Firefighting Water System (EFWS).

Location

In both the 1906 and 1989 earthquakes, most liquefaction occurred in areas where significant local amplification of ground motion was caused by underlying soft sediment.[79] As shown on the following page, in Figure 4-15, the USGS and California Geological Survey (CGS) have mapped areas of liquefaction potential. Liquefiable soils in San Francisco are generally found in areas of landfill along the bay front, former bay inlets, and sandy low-lying areas along the ocean front. Locations subject to very high

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[74] USGS, San Francisco Bay Region Geology and Geologic Hazards, "Earthquakes That Have Caused Liquefaction in the San Francisco Bay Area, Locations of liquefaction features produced during the 1989 San Francisco earthquake," accessed May 22, 2018, https://geomaps.wr.usgs.gov/sfgeo/liquefaction/image_pages/ liqmap_17.html

[75] USGS, San Francisco Bay Region Geology and Geologic Hazards, "Liquefaction in Past Earthquakes," accessed May 22, 2018, https://geomaps.wr.usgs.gov/sfgeo/liquefaction/effects.html

[76] USGS, *The Loma Prieta, California Earthquake of October 17, 1989—Liquefaction*, Professional Paper 1551-B (Washington, DC, 1998), B37–B39, accessed May 22, 2018, https://pubs.usgs.gov/pp/1551b/report.pdf.

[77] USGS, San Francisco Bay Region Geology and Geologic Hazards, "Liquefaction in Past Earthquakes," accessed May 22, 2018, https://geomaps.wr.usgs.gov/sfgeo/liquefaction/effects.html.

[78] USGS, *The Loma Prieta, California Earthquake of October 17, 1989—Liquefaction*.

[79] USGS, *The Loma Prieta, California Earthquake of October 17, 1989—Liquefaction*, B3.

liquefaction susceptibility in San Francisco include areas of Ocean Beach in the Sunset and Richmond Districts and portions of the Presidio, Marina District, North Waterfront, the Financial District, South Beach, Mission Bay, the Central Waterfront (Dogpatch), Hunters Point, Candlestick Point, and Treasure Island. Inland portions of the city that also have very high liquefaction susceptibility include the South of Market Area (SOMA), the Stowe Lake area of Golden Gate Park, and Civic Center. In addition, the area surrounding the San Francisco International Airport (SFO), located in San Mateo County, is within the state's Seismic Hazards liquefaction zone, as mapped by CGS pursuant to the Seismic Hazards Mapping Act of 1990.[80]

[80] California Geological Survey, "Earthquake Zones of Required Investigation, San Mateo Quadrangle" (2015), accessed May 22, 2018, http://gmw.conservation.ca.gov/SHP/EZRIM/Maps/SAN_MATEO_EZRIM.pdf; Cal. Public Resources Code §§ 2690 et seq.

FIGURE 4-15
POTENTIAL LIQUEFACTION AREAS

Severity and Probability of Future Events

San Francisco has experienced severe liquefaction, and the attendant impact on infrastructure, in past major earthquakes in 1906 and 1989. As mentioned above, liquefaction can cause ground rupture, sand boils, ground subsidence, and lateral and vertical displacement of the ground. Given the fact that significant portions of the city are located on soft, sandy, liquefiable soils, it is reasonable to assume that severe liquefaction will occur in any future earthquake with strong shaking. SFO is located is another area that is likely to experience liquefaction in a major earthquake. As noted earlier, scientists have determined that there is a 72 percent chance of a Mw 6.7 or greater earthquake along one of the seven Bay Area fault systems in the 30-year period ending in 2043.[81] For further discussion of earthquake severity, probability, and response planning, see the City and County of San Francisco's Earthquake Annex.

Climate change can impact liquefaction from earthquakes. As groundwater levels rise due to sea level rise, liquefaction zones are expected to increase in size.[82] Conversely, for earthquakes occurring during a multi-year, severe drought, a drought-induced low water table and dry ground may inhibit landslide and liquefaction that might occur during large earthquakes, resulting in less damage than might otherwise take place.[83]

Related Hazards

Tsunami

A tsunami is a series of ocean waves caused by sudden movement of the sea floor, typically as a result of major earthquakes. Tsunamis also may be caused by undersea landslides or volcanic activity.[84] Earthquakes of Mw 7.5 or greater at plate boundaries

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[81] Field and WGCEP, *UCERF3: A New Earthquake Forecast for California's Complex Fault System*, 4.

[82] Poh Poh Wong, et al, 2014: "Coastal Systems and Low-Lying Areas," in 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*, by C.B. Field, et al., (eds.), (New York, NY, 2014), 383, accessed May 22, 2018, https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap5_FINAL.pdf; Capitol Corridor Joint Powers Authority, *Sea Level Rise Vulnerability Assessment*, Executive Summary (2014), ii, accessed May 22, 2018, http://www.adaptingtorisingtides.org/wp-content/uploads/2015/04/CCJPA-SLR-Vulnerability-Assessment_Final.pdf.

[83] USGS, "Science Features: South Napa Earthquake – One Year Later," accessed May 17, 2018, https://www2.usgs.gov/blogs/features/usgs_top_story/south-napa-earthquake-one-year-later/.

[84] National Oceanic and Atmospheric Administration (NOAA), "Tsunami," accessed May 23, 2018, https://www.tsunami.noaa.gov/.

located in subduction zones around what is known as the Pacific Ring of Fire may generate ocean-wide tsunamis. For further discussion, please see the Tsunami Hazard Profile.

Earthquake-Induced Landslide

A landslide is the downhill movement of ground typically caused by the action of gravity on weakened soil or rock. Slopes may be weakened by weathering, erosion, saturation, or the addition of weight from artificial fill, structures, or rock. Earthquake-induced landslides typically originate from steep, weakened slopes as a result of strong ground shaking. The most common earthquake-induced landslides include shallow rock falls, rock slides, and slides of earth and debris. For further discussion of landslide, see the Landslide hazard profile, below.

Reservoir Failure Following Earthquake

A reservoir failure involves structural collapse of a reservoir resulting in a release of water stored in the reservoir. Reservoir failure may occur as a result of an earthquake. For further discussion of reservoir failure following earthquake, see the Dam or Reservoir Failure hazard profile, below.

Fire Following Earthquake

While ground shaking may be the predominant agent of damage in most earthquakes, fires following earthquakes can also lead to catastrophic damage depending on the combination of building characteristics and density, meteorological conditions, and other factors. Fires following the 1906 San Francisco Earthquake led to more damage than that due to ground shaking. More recently, fires in the Marina District following the 1989 Loma Prieta Earthquake demonstrate that fires following earthquakes pose a significant hazard in San Francisco. For further discussion of fire following earthquake, see the Large Urban Fire hazard profile.

Landslide Hazard Profile

4.3 Landslide

Impact Statement

Landslides are most likely to occur on steep slopes on hills and cliffs and intermediate slopes with previous landslide deposits. In addition, weak saturated soils that are bordered by steep or unsupported embankments or slopes are prone to landslide. Given the dense urban nature of San Francisco, landslides can result in many casualties and in serious damage to homes and other infrastructure. Heavy rainfall events and wildland-urban interface fires are anticipated to become more frequent with climate change. Thus, San Francisco may experience an increase in the frequency of landslides in the future.

Nature

Landslide is a general term used to describe the downslope movement of soil, rock, and organic materials under the effects of gravity. It also is used to refer to the landform that results after such movement. Landslides can be classified into different types based on the type of material and the type of movement involved. In general, material in a landslide is either rock or soil, or both. Soil is described as earth if primarily composed of sand-sized or finer particles, and as debris if composed of coarser fragments. Type of movement refers to the actual mechanics of how the landslide is displaced. Movement categories are fall, topple, slide, spread, or flow. Thus, landslides are described using two terms that refer respectively to material and movement, such as rock fall or debris flow. Landslides may also encompass complex failures that involve more than one type of movement, such as rock slide-debris flow.[85]

Landslides are typically caused by the action of gravity on weakened soil or rock. However, most landslides have multiple causes. Slope movement occurs when forces acting down-slope exceed the strength of the materials that make up the slope. Causes include factors that increase the effects of down-slope forces and that contribute to low or reduced strength of slope materials. Landslides can be caused in slopes that are weakened because of rainfall, snowmelt, changes in ground water, erosion, earthquakes, disturbances by human activities, or a combination of these factors. Earthquake shaking

[85] U.S. Geological Survey (USGS), *The Landslide Handbook—A Guide to Understanding Landslides,* by Lynn M. Highland and Peter Bobrowsky. U.S. Geological Survey Circular 1325 (Reston, VA, 2008), 4–5, accessed May 24, 2018, https://pubs.usgs.gov/circ/1325/pdf/C1325_508.pdf.

and other factors also can induce landslides underwater called submarine landslides. Submarine landslides may trigger tsunamis that damage coastal areas.[86]

Slope saturation by water is a primary cause of landslides. This can occur in the form of intense rainfall, snowmelt, changes in ground-water levels, and water-level changes along coastlines, earth dams, and lake banks, reservoirs, canals, and rivers. Earthquakes in steep landslide-prone areas also greatly increase the chances that landslides will occur due to ground shaking or to shaking-caused expansion of soil materials, which allows rapid infiltration of water. Ground shaking due to earthquake can also cause rock falls.[87] San Francisco has experienced landslides, rockslides, and other types of ground failure due to moderate to large earthquakes and winter storms.

History

U.S. Geological Survey (USGS) records show that localized damage in the San Francisco Bay Area due to earthquake-induced landslides has been recorded since 1838 for at least 20 earthquakes. The 1906 earthquake generated more than 10,000 landslides throughout the region, killing 11 people and causing substantial damage to buildings and infrastructure.[88] The most significant landslides caused by the 1989 Loma Prieta earthquake were located in the Santa Cruz Mountains. However, landslides from the Loma Prieta earthquake were reported in in the Lake Merced area of San Francisco in the weakly-cemented sand, silt, and clay of the Merced Formation. These same materials also are believed to have produced several landslides in the 1906 earthquake and in the 1957 Daly City earthquake.[89]

Non-earthquake-induced landslides in San Francisco generally occur during or after prolonged winter rainstorms. On January 3–5, 1982, a catastrophic rainstorm over the Central California coast triggered landslides in San Francisco, which resulted in approximately $399,000 in damages in 1982 dollars ($1 million in 2018 dollars) to public and private property in San Francisco, predominantly to private residences. Most

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[86] USGS, "What is a landslide and what causes one?" Accessed May 24, 2018, https://www.usgs.gov/faqs/what-a-landslide-and-what-causes-one?qt-news_science_products=7#qt-news_science_products.

[87] USGS, Landslide Types and Processes, Fact Sheet 2004-3072 (2004), accessed May 24, 2018, https://pubs.usgs.gov/fs/2004/3072/pdf/fs2004-3072.pdf.

[88] David K. Keefer, "Landslides Synopsis," in *The Loma Prieta, California Earthquake of October 17, 1989: Strong Ground Motion and Ground Failure,* USGS Professional Paper 1551-C (Washington, DC, 1998), C1, accessed May 24, 2018, https://pubs.usgs.gov/pp/pp1551/pp1551c/pp1551c.pdf.

[89] Keefer and Manson, "Regional Distribution and Characteristics of Landslides Generated by the Earthquake," C21.

landslide damage was located in the Twin Peaks, Mount Davidson, and Glen Park areas.[90]

Winter rainstorms in December 1995 contributed to the collapse of a 100-year old sewer line, subsequently creating a landslide and damaging sinkhole. A couple structures were swallowed by the pit, 23 homes were evacuated, and utilities were temporarily disrupted for the entire neighborhood[91].

Landslides also occurred in February 1998, as a result of El Niño storms. El Niño is a disruption of the ocean-atmosphere system in the Tropical Pacific, which has important consequences for weather and climate around the globe. Between February 2, and February 26, 1998, landslides and minor debris flows were reported on steep slopes near Mount Sutro in Forest Knolls, Mount Davidson in the Miraloma Park neighborhood, and in the Twin Peaks, Diamond Heights, Potrero Hill, and Seacliff neighborhoods. These landslides caused an estimated $4.1 million in damages in 1998 dollars ($6.3million in 2018 dollars) to residential properties, and to the Olympic Club golf course.[92]

Nine years later, on February 28, 2007, after three days of rainfall, a 75-foot-wide mass of Telegraph Hill slid down a granite and sandstone slope above Broadway, between Montgomery and Kearny Streets. Approximately 120 people from a 45-unit condominium were evacuated until the property owner stabilized the hillside.[93] Similarly, on January 23, 2012, extensive rainfall resulted in a rockslide on Telegraph Hill, which crushed a car and required the partial evacuation of a condominium complex.[94]

In February 2016, during heavy precipitation associated with the 2015-2016 El Niño, a landslide in the Mount Davidson area of San Francisco destroyed one house, and damaged five others. However, it appears that this slide was due to human-caused

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[90] Stephen D. Ellen, et al., *Landslides, Floods, and Marine Effects of the Storm of January 3-5, 1982, in the San Francisco Bay Region, California* (USGS Professional Paper 1434) (1988), 198–200, accessed May 24, 2018, http://pubs.usgs.gov/pp/1988/1434/.

[91] Carl Nolte: SFgate. (1995) "Sea Cliff Mansion Tumbles into Hole/Aged Sewer Line Collapses under Home". Retrieved from: https://www.sfgate.com/news/article/Sea-Cliff-Mansion-Tumbles-Into-Hole-Aged-sewer-3017549.php

[92] John W. Hillhouse and Jonathan W. Godt, "Map Showing Locations of Damaging Landslides in San Francisco City and County, California, Resulting from 1997-98 El Nino Rainstorms," USGS MF-2325-G (1999), accessed May 24, 2018, https://pubs.usgs.gov/mf/1999/mf-2325-g/mf2325g.pdf.

[93] Robert Selna, et al., "Telegraph Hill Landslide Forces 120 from Homes," *San Francisco Chronicle*, February 28, 2007, accessed May 24, 2018, https://www.sfgate.com/news/article/Telegraph-Hill-landslide-forces-120-from-homes-2614672.php.

[94] CBS SF Bay Area, "Residents Near SF Telegraph Hill Landslide Allowed to Return," January 24, 2013, accessed May 24, 2018, http://sanfrancisco.cbslocal.com/2012/01/24/residents-near-sf-telegraph-hill-landslide-allowed-to-return/.

changes in the area. Public Works crews subsequently discovered and repaired a rupture in an eight-inch water main under a nearby street that is believed to have led to the slide.[95]

Location

According to the California Geological Survey (CGS), steep slopes on hills and cliffs and intermediate slopes with previous landslide deposits are highly susceptible to landslides. In addition, weak saturated soils that are bordered by steep or unsupported embankments or slopes are prone to lateral spreading, which is a type of landslide.[96] Seismic Hazard Zones, seen in Figure 4-16, show areas susceptible to earthquake-induced landslide in San Francisco. These areas include hills and cliffs in the Outer Richmond, Sea Cliff, Presidio, Lake Shore, Bayview Heights, Midtown Terrace, Twin Peaks, Clarendon Heights, Golden Gate Heights, Forest Hills, Diamond Heights, the Castro, Dolores Heights, Noe Valley, and Yerba Buena Island.

CGS has also developed a landslide susceptibility map that shows the relative likelihood of deep-seated landslides based on the location of past slides and on regional estimates of rock strength and steepness of slopes.[97] Slides are considered deep-seated if the slip occurs on a surface more than 10 to 15 feet below the ground.[98] The San Francisco-portion of this map is included in Figure 4-16. The map shows areas similar to those noted in the seismic hazard zone map mentioned above as susceptible to deep-seated landslides.[99]

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[95] KTVU2, "SF Landslide That Threatened Homes Appears More Man-Made than Natural," February 1, 2016, accessed May 25, 2018, http://www.ktvu.com/news/sf-landslide-that-threatened-homes-appears-more-man-made-than-natural; CBS SF Bay Area, "PG&E Sued Over Landslide That Destroyed San Francisco Home," October 18, 2017, accessed May 25, 2018, http://sanfrancisco.cbslocal.com/2017/10/18/pge-lawsuit-landslide-casitas-miraloma/.

[96] California Department of Conservation, California Geological Survey (CGS), *Guidelines for Evaluating and Mitigating Seismic Hazards in California*, Special Publication 117 (2008), 19–21, accessed May 25, 2018, http://www.conservation.ca.gov/cgs/Documents/SHZP_Webdocs/SP117.pdf.

[97] C.J. Wills, et al., *Susceptibility to Deep-Seated Landslides in California*, California Geological Survey (CGS) Map Sheet 58 (2011), accessed May 24, 2018, http://www.conservation.ca.gov/cgs/information/publications/ms/ Documents/MS58.pdf.

[98] Helen Gibbs, et al., "USGS Monitors Huge Landslides on California's Big Sur Coast, Shares Information with California Department of Transportation," accessed May 24, 2018, https://soundwaves.usgs.gov/2017/10/ fieldwork.html.

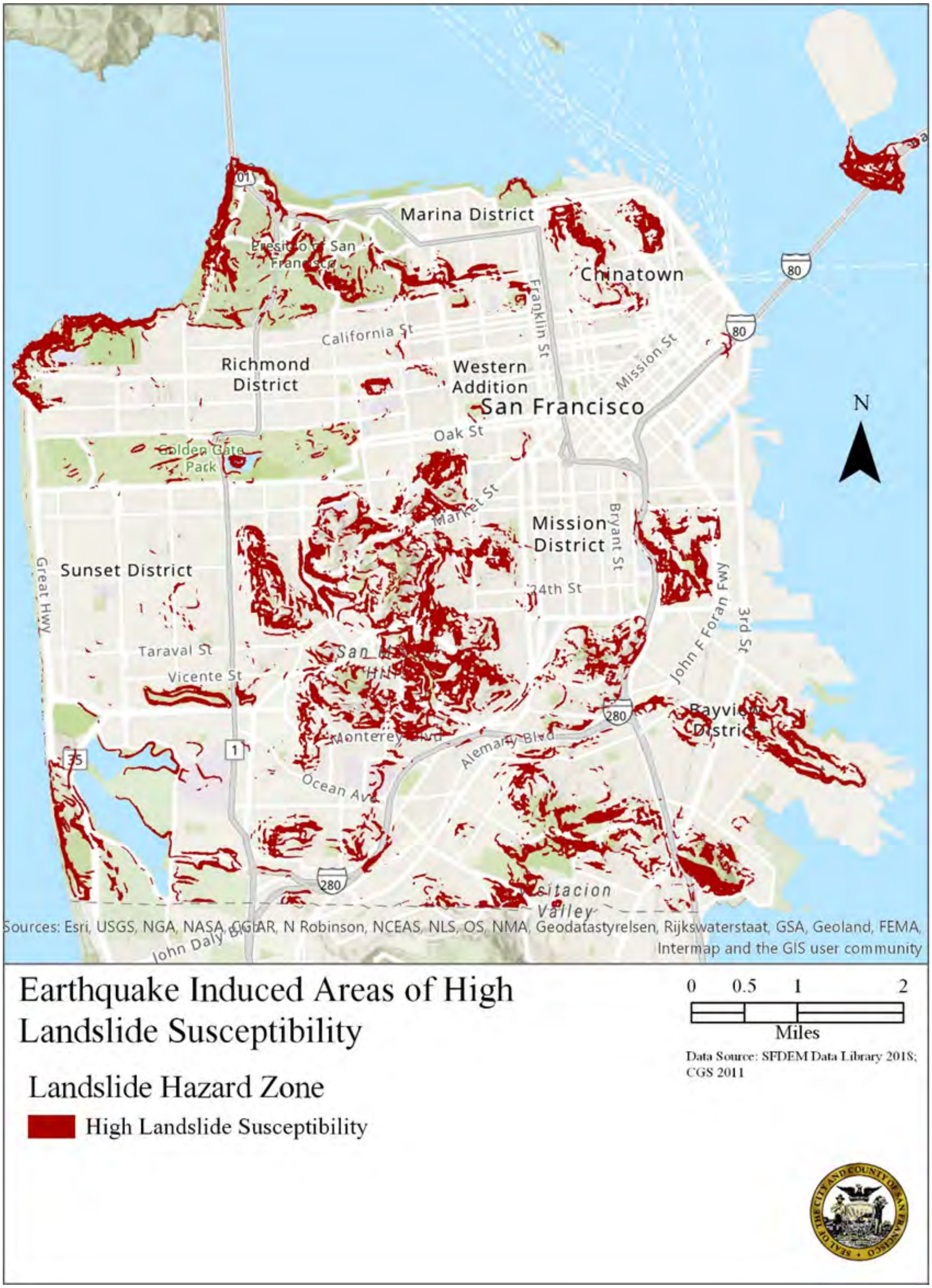
[99] Wills, *Susceptibility to Deep-Seated Landslides in California*. CGS intends this map to provide a general overview of where landslides are more likely to occur. It does not include information on landslide-triggering events such as rainstorms or earthquake shaking, nor does it address susceptibility to shallow landslides such as debris flows. It is not appropriate for evaluation of landslide potential at any specific site.

CGS has not prepared maps for San Francisco that identify hazards associated with non-earthquake induced landslides. However, in general, areas that are subject to landslides during earthquakes are also subject to landslides under other conditions. Thus, the earthquake-induced landslide map in Figure 4-16, seen below, is instructive as to the location of steep-sloped areas where landslides may occur due to heavy rainfall or other non-seismic conditions.

In addition, steep, recently burned areas are susceptible to debris flows within the first two years after a fire. Even modest rain storms during non-El Niño years can trigger post-wildfire debris flows.[100] Fire-related debris flows are likely to occur in steep, rural out-of-county areas where some city-owned infrastructure is located. Examples include the area surrounding Hetch Hetchy Reservoir and O'Shaughnessy Dam in Tuolumne County, California, which is part of the system that provides drinking water to city residents. For further discussion of wildland-urban interface fires, see the Wildland-Urban Interface profile.

[100] See USGS, Landslide Hazard Program, "Rainfall and Landslides in Northern and Central California," accessed May 25, 2018, https://landslides.usgs.gov/research/ca-rainfall/ncal.php; USGS, California Water Science Center, "Post-Fire Debris Flow," accessed May 25, 2018, https://ca.water.usgs.gov/flooding/wildfires-debris-flow.html.

FIGURE 4-16
EARTHQUAKE INDUCED AREAS OF HIGH LANDSIDE SUSCEPTIBILITY



Severity and Probability of Future Events

The severity of an earthquake-induced landslide depends on the landslide characteristics and materials and on the settings in which the landslide occurs. Shallow rock falls disrupted rock slides, and disrupted slides of earth and debris are the most common types of earthquake-induced landslides. Earth flows, debris flows, and avalanches of rock, earth, or debris typically transport material the farthest.[101] The USGS reports that landslides in San Francisco are typically narrower than 1,500 feet, or about one quarter of a mile.[102] Given the dense urban nature of the city, slides of this size could cause many casualties and serious damage to homes and other infrastructure.

USGS studies show that earthquakes as small as magnitude 4.0 may trigger landslides on susceptible slopes.[103] Larger earthquakes may generate thousands of landslides within the area impacted by the earthquake.[104] Whether a particular earthquake produces a landslide depends on slope material strength and configuration, pore-water pressure, and the level of ground motion.[105] Given the Working Group on California Earthquake Probabilities (WGCEP) finding of a 100 percent chance that the San Francisco region will experience a Mw 5 or greater quake between 2014 and 2044, and a 72 percent chance of a Mw 6.7 or greater earthquake in the region during the same period,[106] San Francisco is extremely likely to experience one or more earthquake-induced landslides from a major earthquake event.

Non-earthquake induced landslides are most likely to occur during winter storm events that produce heavy or prolonged rainfall. Based on past occurrences of El Niño-enhanced periods of precipitation, San Francisco can expect to experience rain-induced landslide every eight to 10 years.[107] These are periods, typically during winters, when a

[101] David K. Keefer, "Earthquake-Induced Landslides and Their Effects on Alluvial Fans," *Journal of Sedimentary Research*, Section A: Sedimentary Petrology and Processes 69(1) (1999), 84.

[102] Carl M. Wentworth, et al., Summary Distribution of Slides and Earth Flows in San Francisco County, California, USGS Open File 97-745 C, Sheet 6 of 11 (1997), accessed May 25, 2018, https://pubs.usgs.gov/of/1997/of97-745/sfdl.html.

[103] Keefer, "Landslides Caused by Earthquakes," 409; USGS, "Landslides 101, What is a landslide?" Accessed May 24, 2018, https://landslides.usgs.gov/learn/ ls101.php.

[104] Keefer, "Landslides Synopsis," C1.

[105] Keefer, "Landslides Caused by Earthquakes," 406.

[106] Edward H. Field and 2014 Working Group on California Earthquake Probabilities (WGCEP), *UCERF3: A New Earthquake Forecast for California's Complex Fault System,* Fact Sheet 2015–3009 (2015), 4, accessed May 18, 2018, https://dx.doi.org/10.3133/fs20153009.

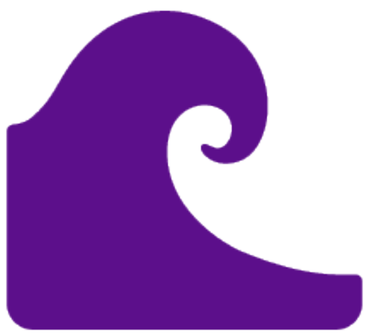
[107] Christopher C. Burt, "California: Waiting for El Nino," Weather Underground WunderBlog Archive, December 9, 2015, accessed May 25, 2018, https://www.wunderground.com/blog/weatherhistorian/california-waiting-for-el-nino.html.

strong El Niño increases the frequency and intensity of Pacific storms. In addition, areas burned as a result of wildfires are particularly susceptible to landslides depending on slope conditions and soil characteristics.

The Intergovernmental Panel on Climate Change (IPCC) has indicated with high confidence that urban climate change-related risks, including extreme precipitation, fires, and landslides, are increasingly affecting urban areas, resulting in widespread negative impacts on people and on local and national economies and ecosystems.[108] As both heavy rainfall and wildland-urban interface fires are anticipated to become more frequent with climate change, San Francisco may experience an increase in the frequency of landslides in the future.

[108] Aromar Revi, et al., "Urban Areas," Chapter 8 in *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, C.B. Field, et al. (eds.) (New York, NY, Cambridge University Press, 2014), 565, accessed May 25, 2018, https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap8_FINAL.pdf.

Tsunami Hazard Profile



4.4 Tsunami

Nature

A tsunami is a series of ocean waves caused by sudden movement of the sea floor, typically as a result of major earthquakes. Tsunamis also may be caused by undersea landslides or volcanic activity.[109] Earthquakes of Mw 7.5 or greater at plate boundaries located in subduction zones around what is known as the Pacific Ring of Fire may generate ocean-wide tsunamis.

San Francisco may experience tsunamis from three possible sources: (1) distant sources, such as large earthquakes near Japan, Alaska, or Chile; (2) regional sources, such as earthquakes in the Cascadia Subduction Zone, which begins off Humboldt County, California and extends north to British Columbia, Canada; and (3) near sources off the coast of Northern California, such as the Point Reyes Thrust Fault. For a list of tsunami types, their classification based on distance from San Francisco, how quickly they may arrive in San Francisco, and the likelihood of occurrence, see Table 4-17, below.

TABLE 4-17
TYPES OF TSUNAMIS THAT MAY BE EXPERIENCED IN SAN FRANCISCO

Tsunami Types	Source Event Distance from San Francisco	Time to Reach San Francisco	Likelihood of Occurrence
Distant Source	621 miles or more	4–21 hours	Moderate
Regional Source	Less than 621 miles	1–1½ hours	Moderate
Near Source	62 miles or less	10–15 minutes	Low

In the open ocean, tsunamis can travel over 500 miles per hour (mph)—the speed of a jet—and are barely perceptible to ships at sea. However, as tsunami waves reach shallow water, they slow in speed and grow in height. At the shoreline in San Francisco,

[109] National Oceanic and Atmospheric Administration (NOAA), “Tsunami,” accessed May 23, 2018, https://www.tsunami.noaa.gov/.

tsunami waves may range in height from a few inches to over 30 feet. The first wave is almost never the largest.[110]

Normal, wind-driven ocean waves move only the surface layer of the water. In contrast, tsunami waves are longer in length, and move the entire "column" of water from the ocean floor to the surface. As a result, tsunami waves have increased power to inundate or flood low-lying coastal areas, making tsunami waves more dangerous and destructive than normal ocean waves. In addition, unlike normal ocean waves, the wave period, or time between tsunami waves, may vary from a few minutes to up to two hours. Thus, damaging tsunami waves may last for hours or days,[111] though typically the largest, most damaging tsunami waves occur in the first five hours of a tsunami incident.[112] Tsunamis also can cause powerful, dangerous currents in harbors, ports, and other shoreline areas that may last for several days after the initial tsunami wave.

Tsunami inundation is the maximum horizontal distance reached by tsunami waves on shore. “Runup” is the maximum height and distance of tsunami-related water inundation onshore. Runup is measured vertically from a reference sea level, such as mean sea level. Inundation is measured horizontally from the mean sea level position at the water's edge.[113] For a visual representation of inundation and runup, see Figure 4-18, below.

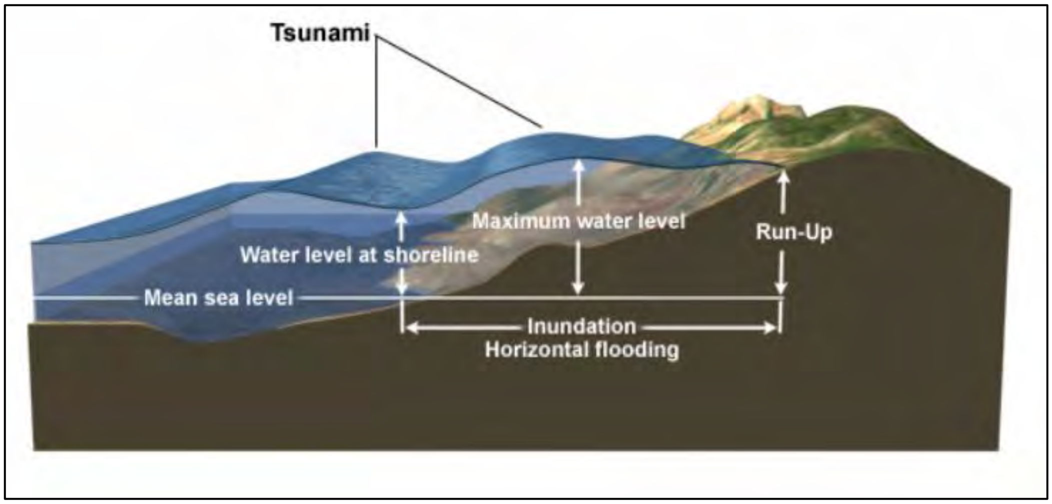
[110] U.S. Department of Commerce, NOAA/National Weather Service, U.S. Tsunami Warning System, “Tsunami Frequently Asked Questions,” accessed May 18, 2018, https://www.tsunami.gov/?page=tsunamiFAQ.

[111] Pacific Tsunami Warning Center (PTWC), “Frequently Asked Questions (FAQ),” How are tsunami waves different from normal ocean waves? accessed May 23, 2018, http://ptwc.weather.gov/faq.php.

[112] California Department of Conservation, California Geological Survey, *Tsunami Emergency Response Playbooks and FASTER Tsunami Height Calculation: Background Information and Guidance for Use*, by Rick I. Wilson and Kevin M. Miller, California Geological Survey Special Report 236 (Sacramento, CA, 2014), 15.

[113] See USGS, Pacific Coastal and Marine Science Center, “Life of a Tsunami—Starting Points,” accessed May 23, 2018, https://walrus.wr.usgs.gov/tsunami/basics.html; COMET Program, MetEd, *Community Tsunami Preparedness* (2d ed.) (2015), accessed May 23, 2018, http://www.meted.ucar.edu /tsunami/community/ print.htm#page_2.0.0.

FIGURE 4-18
TSUNAMI RUN-UP CROSS-SECTION[114]



Tsunamis not only affect beaches open to the ocean, but also may cause damage to bays, ports, harbors, tidal flats, and coastal inlets. Because of their long wavelengths, tsunami waves can wrap around and reflect off land masses. Thus, peninsulas, offshore islands, and human-made breakwaters may not provide protection from tsunamis.[115] In addition, it is important to note that tsunamis can cause damage even when they do not result in inundation. Because tsunamis can generate strong, powerful, currents that may last for many hours, they can result in significant damage to maritime assets, including ports, harbors, marinas, and vessels.[116]

History

Since 1850, 57 tsunamis have been recorded or observed in San Francisco Bay. None of these tsunamis resulted in inundation or in significant damage in San Francisco. Eleven of the tsunamis originated off Japan; all were generated by major earthquakes. Ten originated off Alaska; eight of these were caused by an earthquake, two were caused by earthquake and landslide. Eight tsunamis originated off Chile, all generated by earthquakes.[117]

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[114] © The COMET Program, *Community Tsunami Preparedness* (2d ed.) (2015), Hazards. https://www.meted.ucar.edu/tsunami/community/print.htm

[115] PTWC, "Frequently Asked Questions (FAQ)," What is the "wrap-around effect?" accessed May 23, 2018, http://ptwc.weather.gov/faq.php.

[116] Patrick J. Lynett, et al., *Assessment of the Tsunami-Induced Current Hazard*, Geophysical Research Letters, 41 (2014), 2048, accessed May 23, 2018, doi:10.1002/2013GL058680.

[117] NOAA, National Geophysical Data Center/World Data Service (NGDC/WDS): "Global Historical Tsunami Database," accessed May 23, 2018, doi:10.7289/V5PN93H7.

Only one tsunami originating along the Northern California Coast has been recorded. A 4-inch wave run-up was recorded at the Presidio gauge station shortly after the 1906 earthquake.[118] The 1906 earthquake is believed to have caused down dropping of the seafloor north of Lake Merced, between overlapping segments of the San Andreas Fault, generating a small tsunami.[119]

The magnitude 6.8 Hayward Earthquake of October 21, 1868 is reported to have produced a wave at the Cliff House that was 15 to 20 feet higher than usual. The likely cause of this tsunami was an earthquake-triggered submarine landslide.[120] The magnitude 9.2 Great Alaskan Earthquake generated a distant-source tsunami that produced maximum water heights over sea level of 1.13 meters (3.7 feet) as recorded on the tide gauge at the San Francisco Presidio near Crissy Field. However, the largest waves from the Great Alaskan tsunami occurred during low tide. Had these waves arrived at high tide, the absolute water level could have reached over 12 feet above sea level at the Presidio.[121]

Little damage occurred in San Francisco as a result of the tsunami generated by the Japan Tohoku earthquake of March 11, 2011. The Tohoku tsunami produced a maximum measured amplitude of 0.62 meters (two feet) at the San Francisco Marina, and estimated maximum currents of seven knots, or approximately eight miles per hour. Currents in excess of three knots are known to cause damage to fixed piers and structures, as well as present hazards to water navigation. Two piles were broken, and

[118] NOAA, NGDC/WDS: "Global Historical Tsunami Database."

[119] USGS, Pacific Coastal and Marine Science Center, "Tsunamis and Earthquakes, "Tsunami Record from the Great 1906 San Francisco Earthquake," accessed May 23, 2018, https://walrus.wr.usgs.gov/tsunami/1906.html.

[120] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, *Tsunamis Affecting the West Coast of the United States, 1806–1992*, by James F. Lander, Patricia A. Lockridge and Michael J. Kozuch (Boulder, CO, 1993), 18, 20, ftp://ftp.ngdc.noaa.gov/hazards/publications/Kgrd-29.pdf.

[121] Jose Borrero et al., *Numerical Modeling of Tsunami Effects at the Marine Oil Terminals in San Francisco Bay,* Report Prepared for California State Lands Commission, Marine Facilities Division (2006), 8, http://www.slc.ca.gov/Programs/MOTEMS/NumericalModeling.pdf.

boats keeled over in the San Francisco Marina.[122] Damage from the Tohoku tsunami was minimal in San Francisco because the largest surges occurred during low tide.[123]

Location

In 2009, the California Geologic Survey (CGS), the California Governor's Office of Emergency Services (Cal OES), and the Tsunami Research Center at the University of Southern California produced statewide tsunami inundation maps for coastal areas of California, including San Francisco and San Mateo Counties. The maps indicate coastal areas that could be flooded in an inundating tsunami. The state prepared the tsunami inundation maps to assist coastal communities in identifying tsunami hazards and in creating tsunami evacuation and response plans. The inundation lines shown on the maps represent the maximum considered tsunami runup based on several extreme but realistic tsunami scenarios.[124] Figure 4-19 shows the tsunami inundation map prepared for the City and County of San Francisco.

Areas within San Francisco susceptible to tsunami inundation include Pacific Coast areas of Lake Merced, the Sunset and Richmond Districts, Sea Cliff, and the Presidio. Areas adjacent to San Francisco Bay are also subject to tsunami inundation, including the Presidio, the Marina District, North Waterfront, Fisherman's Wharf, China Basin, Mission Bay, Potrero Hill, Bayview, Hunters Point, Treasure Island, and portions of Yerba Buena Island (see Figure 4-19 below).

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[122] California Natural Resources Agency, California Coastal Commission, "The Tohoku Tsunami of March 11, 2011: A Preliminary Report on Effects to the California Coast and Planning Implications," Attachment 5, Summary of California Damage (San Francisco, CA, 2011), 37, http://www.coastal.ca.gov/energy/tsunami/ccc_tohoku_tsunami_report.pdf; Rick Wilson, et al., *The Effect of the 2011 Tohoku Tsunami on the California Coastline* (poster, Annual Meeting, Seismological Society of America, Memphis, TN, April 13-15, 2011), accessed May 23, 2018, http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Documents/ssa_2011_california_tohoku_small.pdf.

[123] Rick I. Wilson and Kevin M. Miller, *Tsunami Emergency Response Playbooks and FASTER Tsunami Height Calculation: Background Information and Guidance for Use*, California Geological Survey Special Report 236 (Sacramento, CA, 2014), 19, accessed May 23, 2018, ftp://ftp.consrv.ca.gov/pub/dmg/pubs/sr/sr_236/ CGS_Special_Report_236.pdf.

[124] Rick I. Wilson, et al., *New Maximum Tsunami Inundation Maps for Use by Local Emergency Planners in the State of California, USA* (poster, American Geophysical Union Fall Meeting, San Francisco, CA, December 15-19, 2008), accessed May 23, 2018, http://www.conservation.ca.gov/cgs/geologic_hazards/Tsunami/Inundation_Maps/Documents/AGU08_tsunami_poster.pdf.

FIGURE 4-19
CITY AND COUNTY OF SAN FRACNISCO TSUNAMI HAZARD ZONES

Severity and Probability of Future Events

Inundating tsunamis are infrequent, but high impact events that may result in widespread damage and destruction in San Francisco. Injuries and deaths are one of the primary impacts of tsunamis. Drowning is the most common cause of death associated with tsunami.[125] Widespread damage to homes and businesses, and the resulting displacement of people in coastal areas are additional concerns after a destructive tsunami.[126] Damage to infrastructure from a flooding tsunami would be extensive, and could include impacts to roads, public transportation, power systems, and sewage treatment plants.[127] In addition, tsunami waves may damage building foundations, bridges, roads, and other structures.[128] Even a non-inundating tsunami can result in strong currents and rip tides that cause damage to vessels and maritime facilities in or near coastal waters. Currents of three knots (3.5 miles per hour) or more have resulted in damage to fixed piers and structures and may present navigation hazards to vessels in the area.

The primary tsunami threat to San Francisco is a distant-source tsunami generated by an earthquake in the eastern portion of the Aleutian-Alaska Subduction Zone. Data from the California Seismic Safety Commission indicates that since 1872, Alaska earthquakes have produced tsunami run-ups in the Bay Area ten times, for a recurrence interval of 14.6 years. Historically, the runup from these events has been only a few inches. However, the modeling used to create the 2009 state tsunami inundation maps indicates that an Mw 9.2 in the Central Aleutians, San Francisco's "worst-case" tsunami scenario, produced an estimated maximum tsunami wave runup elevation of 22 feet above mean sea level at Ocean Beach. As tsunami waves from this modeled event wrapped around the city and entered the Golden Gate, wave heights diminish to 11 feet above mean sea level at Aquatic Park, 8 feet above mean sea level at Treasure Island, and 6 feet above mean sea level at Candlestick Point.[129]

San Francisco also has a moderate risk of an earthquake-generated tsunami from a regional source. Our most likely regional source is an earthquake and tsunami in the

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[125] *Community Tsunami Preparedness*, 58.

[126] Centers for Disease Control and Prevention, Emergency Preparedness and Response, "Health Effects of Tsunamis," accessed May 20, 2015, http://www.bt.cdc.gov/disasters/tsunamis/healtheff.asp.

[127] *Community Tsunami Preparedness*, 58.

[128] Matthew J. Francis, *Tsunami Inundation Scour of Roadways, Bridges and Foundations: Observations and Technical Guidance from the Great Sumatra Andaman Tsunami*, EERI/FEMA NEHRP 2006 Professional Fellowship Report (Oakland, CA, 2006), 13.

[129] CGS, et al., "Tsunami Source Scenario Model Results for the San Francisco Bay Area."

Cascadia Subduction Zone (CMZ), a 600-mile fault approximately 70 to 100 miles off the Pacific coastline that runs from Cape Mendocino in Northern California to British Columbia. There have been 41 earthquakes in the last 10,000 years within the CMZ. The last earthquake in this area was an estimated magnitude 9.0 on January 26, 1700, which resulted in an ocean-wide tsunami. Currently, scientists predict that there is a 40 percent chance of an Mw 9.0 or greater earthquake in this fault zone in the next 50 years.[130]

San Francisco has a low risk of a near-source tsunami, given that the majority of the region's faults are strike-slip faults. The nearby Point Reyes Thrust Fault, San Gregorio Fault, and Hayward-Rodgers Creek Fault are all believed capable of producing a near-source tsunami affecting San Francisco. However, to date, none of these faults have produced local tsunamis. State tsunami modeling shows worst-case inundation from a near-source tsunami generated by the Point Reyes Thrust Fault of six feet above mean sea level at Ocean Beach, 4 feet above mean sea level at Aquatic Park, 3 feet above mean sea level at Treasure Island, and 3 feet above mean sea level at Candlestick Point.[131] A strike-slip fault event could produce a potential localized tsunami threat from an earthquake-induced landslide. However, the gentle topography of near-shore areas of San Francisco Bay and the lack of history of large landslides into the bay indicate that the risk of a landslide-generated tsunami into the Bay is low.[132]

The State of California, NOAA, and FEMA are currently developing probability-based tsunami inundation maps and products that can be used for site evaluation, land-use planning, and building design and construction. Release of these products is anticipated within the next year, depending on funding.[133]

For further discussion of tsunami severity, probability, and response planning see the City and County of San Francisco Tsunami Annex.

[130] Oregon Military Department, Office of Emergency Management, Hazards and Preparedness, "Cascadia Subduction Zone," accessed May 23, 2018, http://www.oregon.gov/oem/hazardsprep/Pages/Cascadia-Subduction-Zone.aspx.

[131] CGS, et al., "Tsunami Source Scenario Model Results for the San Francisco Bay Area."

[132] Burak Uslu "Deterministic and Probabilistic Tsunami Studies in California from Near and Farfield Sources", *Phd Diss*, 57–58, accessed May, 2018

[133] Kevin M. Miller, in discussion with author, May 23, 2018.

Flooding Hazard Profile

4.5 Flooding

Flooding is the accumulation of water where such accumulations do not normally occur, or the overflow of excess water from a stream, river, lake, reservoir, or coastal body of water onto adjacent floodplains. Floodplains are lowlands adjacent to water bodies that are subject to recurring floods. In most cases, floods are naturally occurring events that are only considered hazards when people and property are affected. This hazard profile focuses on the flood hazards that have the potential to occur within San Francisco county limits (coastal and stormwater) and a brief description of a flood hazard that may affect publicly-owned assets located outside county limits (riverine).

- **Coastal flooding** in San Francisco is generally caused by high tides, storm surge, and wave action associated with Pacific Ocean storms. These low-pressure storms typically occur from November through February and affect low-lying areas adjacent to the open Pacific Ocean coast and the San Francisco Bay shoreline. As sea level rises, temporary coastal flooding associated with low pressure storms will be more frequent, extensive, and longer lasting.[134] In addition, low-lying areas near the shoreline that are not currently exposed to tidal inundation could experience inundation during high tides if no adaptation strategies are implemented.[135] This hazard is described in greater detail below.

- **Stormwater flooding** occurs in San Francisco during some high precipitation storm events as rainfall runoff collects in areas that at one time were naturally-formed waterways but are now contained within the City's combined sewer and stormwater collection system. As a result, streets aligned with historic waterways and some low-lying areas are prone to collect stormwater. The stormwater accumulating on the surface and backups from the combined sewer-stormwater system may enter nearby structures, resulting in property damage. The risk of stormwater flooding may increase in the future due to more intense precipitation events and sea level rise. This hazard is described in greater detail below.

- **Riverine flooding** occurs when runoff from rainfall and snowmelt exceeds the carrying capacity of streams and rivers. San Francisco does not have significant riverine flood sources within the county limits, because few natural watercourses

[134] City and County of San Francisco, 2016. "Sea Level Rise Action Plan."
[135] Ibid

remain. However, some publicly-owned assets outside county limits are located in areas that are subject to riverine flooding. This hazard is not described in greater detail below given the focus of this report on assets within the County jurisdiction and SFO.

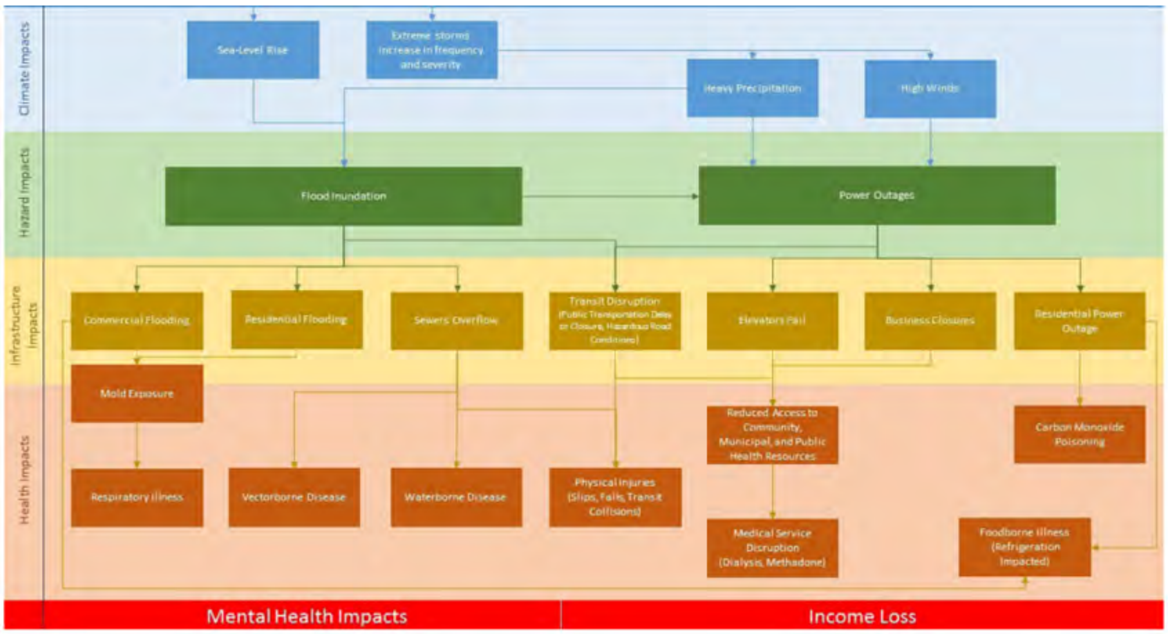
Physical damage from floods includes the following:

- Inundation of facilities, causing water damage to structures and contents.
- Impact damage to buildings, roads, bridges, culverts, and other facilities from high-velocity flow and waves, and from debris carried by floodwaters. Debris may also accumulate on bridge piers and in culverts, increasing loads on these features or causing overtopping or backwater effects.
- Erosion of stream banks and shorelines, undermining or damaging nearby facilities.
- Release of sewage and hazardous or toxic materials as wastewater treatment plants and other facilities are inundated, storage tanks are damaged, and pipelines back up or are severed.

Flooding is often associated with low pressure storms that bring high winds and power outages (more information in the Wind Hazard section). Floods pose threats to life and public safety; disrupt the normal function of a community; force people to leave their residences, sometimes permanently; cause economic losses through the closure of businesses and government facilities; damage and disrupt transportation and transit systems; and damage and disrupt communications and utilities. Floods may also result in health impacts such as respiratory illnesses, vector-borne diseases, water-borne diseases, physical injuries, and medical device interruptions (see Figure 4-20).[136] In addition, floods may result in significant expenditures for emergency response.

[136] San Francisco Department of Public Health, 2016. Climate and Health Understanding the Risk: An Assessment of San Francisco's Vulnerability to Flooding & Extreme Storms

FIGURE 4-20
CLIMATE AND HAZARD HEALTH IMPACT PATHWAYS[137]



Flooding, Extreme Storms, and Health Impacts

Coastal inundation and stormwater flooding can have profound impacts on the health of communities across San Francisco, particularly where vulnerable populations are geographically concentrated (See Vulnerable Populations Profile). To understand this risk, the San Francisco Department of Public Health created a flood vulnerability index in 2015 to determine which specific neighborhoods would likely see the largest impacts from current and future flooding. Indicators for this analysis included geographic location, living conditions, health conditions, and social vulnerability. The resulting map, seen in Figure 4-21 below, identified the following neighborhoods as particularly vulnerable to flooding events: The Pacific Coastline, the Southeastern quadrant of San Francisco, the Mission, and high-density areas such as South of Market, Chinatown, and the Tenderloin Neighborhoods.[138]

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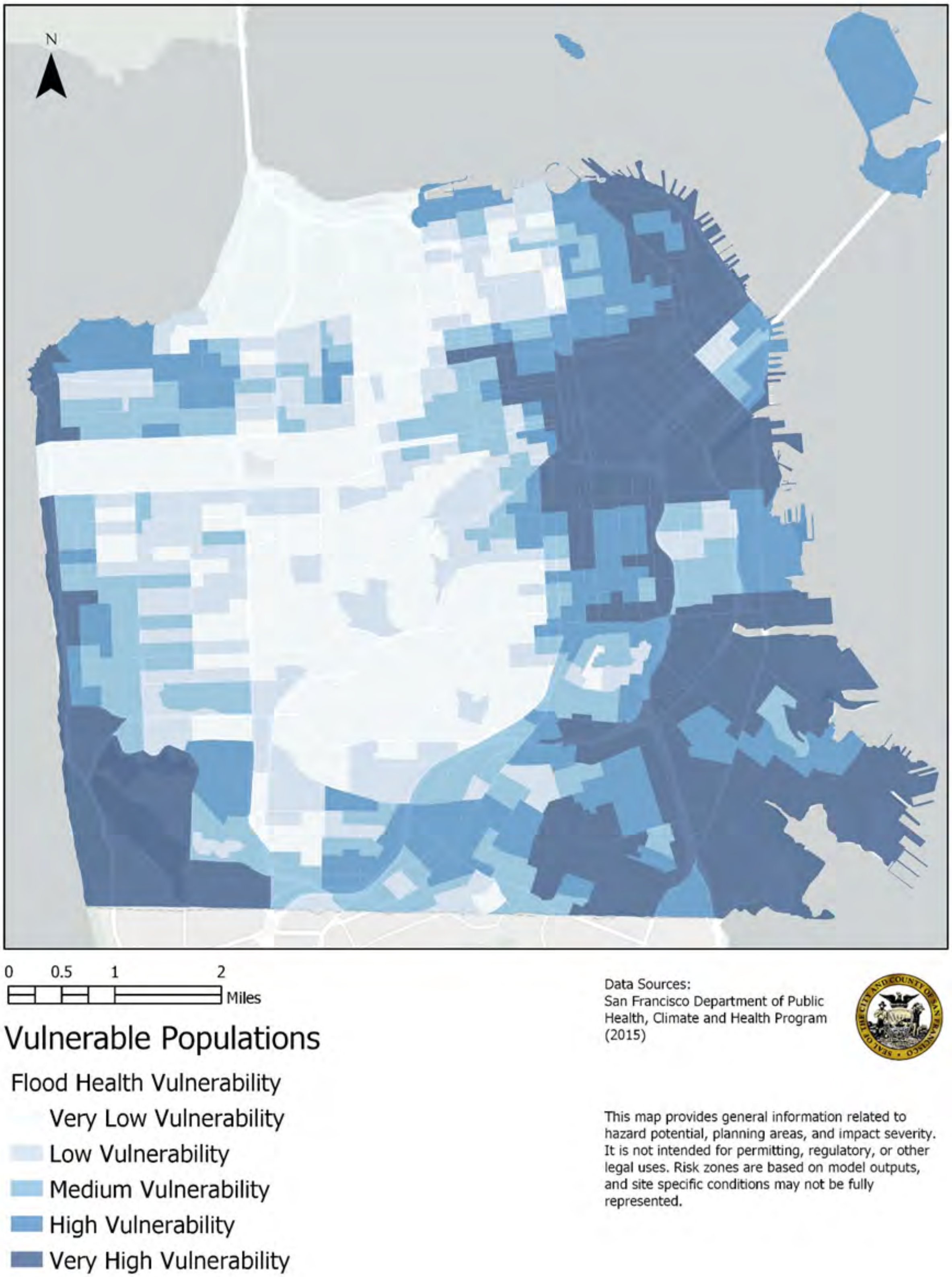
[137] Ibid
[138] San Francisco Department of Public Health. (2015). "San Francisco Flood Vulnerability: A Health Focused Assessment". Retrieved from: https://sfgov.maps.arcgis.com/apps/MapJournal/index.html?appid=69004eefbb3f4a27aa8b6c6566f8dc0b#

FIGURE 4-21
FLOOD VULNERABILITY INDEX



Coastal Flooding

Impact Statement

Currently, the shoreline of San Francisco Bay and the open Pacific Coast include areas that experience temporary flooding during extreme high tides and coastal storm events. As sea level rises, temporary coastal flooding will be more frequent and will inundate larger areas at greater depths and for longer durations. Areas that are particularly susceptible to increasing risk of coastal flooding due to sea level rise include Mission Bay, Islais Creek, Hunters Point, Candlestick Point, the Financial District, the Marina District, Treasure Island, and SFO. Coastal flooding can pose threats to life and public safety, cause physical damage to buildings and infrastructure, disrupt economic activity, and impair public health.

Nature

Coastal flooding in San Francisco is generally caused by the following phenomenon:

Annual high tide inundation (King Tides): King Tides are abnormally high but predictable astronomical tides that occur approximately twice per year. King Tides are the highest tides that occur each year when the gravitational influence of the moon and the sun on the tides are aligned, rather than opposed, and when the earth is at a point in its rotation which is particularly close to either the moon or sun. When King Tides occur during winter storms, the effects are particularly pronounced and make these events more dramatic. King Tides result in temporary flooding, often involving low- lying roads, boardwalks, and waterfront promenades. The Embarcadero waterfront (Pier 14) and the Marina area in San Francisco experience flooding under current King Tide conditions

Storm Surge: When Pacific Ocean storms coincide with high tides, storm surge due to meteorological effects can elevate Pacific Ocean and San Francisco Bay water levels, resulting in temporary flooding. Such storm surge events occurred on January 27, 1983, December 3, 1983, February 6, 1998, January 8, 2005, December 31, 2006, and December 24, 2012. Extreme high tides can cause severe flooding of low-lying roads, boardwalks, promenades, and neighborhoods; exacerbate coastal and riverine flooding and cause upstream flooding; and interfere with stormwater outfalls. The Ocean Beach area is prone to inundation and erosion associated with extreme high tides and storm surge.

El Niño winter storms: During El Niño,[139] atmospheric and oceanographic conditions in the Pacific Ocean bring warm, higher waters to the Bay Area and may produce severe winter conditions that bring intense rainfall and storm conditions to the Bay Area. Tides are often elevated 0.5 to 3.0 feet above normal along the coast for months at a time, and additional storm surge and wave setup during storm events can elevate water levels even further. El Niño conditions prevailed in 1977- 1978, 1982-1983, 1997-1998, and 2009-2010. The 2015-16 El Niño produced wave energy conditions that were 50% larger than typically seen in the San Francisco Bay Area, with a variety of consequences. Typical impacts include severe flooding of low-lying roads, boardwalks and waterfront promenades; storm drain backup; wave damage to coastal structures and erosion of natural shorelines (see Ocean Beach sidebar which highlights the power of coastal erosion).

Pacific Decadal Oscillation: Similar to the ENSO, this event references cyclical oceanic heating and cooling trends but on a longer time horizon than changes in the ENSO. These shifts occur over a 20 to 30-year period and, while typically less pronounced than the ENSO, persists for significantly longer.[140]

Ocean swell and wind-wave events (storm waves): Low pressure Pacific Ocean storms and strong thermal gradients can produce high winds that blow across the ocean and the Bay. When the wind blows over long reaches of open water, large waves are generated that impact the shoreline and cause damage. Typical impacts include wave damage along the shoreline, particularly to coastal structures such as levees, docks and piers, wharves, and revetments; backshore inundation due to wave overtopping of structures; and erosion of natural shorelines.

Physical damage from floods could include the following:

- **Inundation of facilities**, causing operational closures at critical transportation facilities such as SFO, the Port, BART, and various facilities operated by MTA.
- **Inundation and damage to various infrastructure** including buildings, roads, bridges, culverts, pump stations, support structures, parks, and open space.

[139] El Niño–Southern Oscillation (ENSO) is a natural oceanic-atmospheric cycle. El Niño conditions are defined by prolonged warming in the Pacific Ocean sea surface temperatures. Typically, this happens at irregular intervals of
two to seven years, and can last anywhere from nine months to two years
[140] AECOM, 2016. "Extreme Storms in San Francisco Bay – Past to Present". Retrieved from: http://www.r9map.org/Documents/Extreme_Storms_SF_Bay_Past_to_Present_FINAL.pdf

- **Overland flooding may block access** to underground utilities, may damage electrical boxes and substations causing prolonged power outages, and may damage pump stations and other electrical equipment resulting in equipment failure.

- **Release of sewage and hazardous or toxic material** when wastewater treatment plants, storage tanks and other facilities are inundated and compromised.

- **Erosion of natural shorelines and stream banks,** disruption of wetlands and natural habitats, and undermining of the support foundations and structures of important facilities

As sea level rises, temporary coastal flooding will be more frequent, extensive, and longer lasting.[141] In addition, low-lying areas that are not currently exposed to tides will experience inundation during high tides in the long-term if no adaptation strategies are implemented.[142]

History

Several areas along the shoreline are already experiencing periodic flooding and erosion, including: Ocean Beach on the Pacific Coast, which is subjected to significant coastal storms and waves; the Embarcadero, which is overtopped in several areas during the annual highest high tides, or King Tides; and San Francisco International Airport (SFO), which experiences wave overtopping of flood protection structures and inundation of low-lying areas.

Location

San Francisco is susceptible to coastal flooding along three sides of the city, with the open Pacific Ocean to the west and San Francisco Bay to the north and east.

<u>Flood Hazard Mapping Within the City and County of San Francisco</u>

San Francisco participates in the National Flood Insurance Program (NFIP). Under the NFIP, which is administered by the Federal Emergency Management Agency (FEMA), the federal government makes affordable flood insurance available in communities that

[141] City and County of San Francisco, 2016. "Sea Level Rise Action Plan."
[142] Ibid

participate in the program. In exchange, participating communities agree to adopt and enforce floodplain management requirements meeting the minimum NFIP criteria. San Francisco has participated in the NFIP since 2010 and has adopted a Floodplain Management Ordinance that meets NFIP requirements.

In support of the NFIP, FEMA publishes Flood Insurance Rate Maps (FIRMs) for participating communities. The FIRMs show areas that are subject to inundation during a flood having a 1% chance of occurrence in any given year (also referred to as the base flood or 100-year flood). Unlike other Bay communities participating in the NFIP, San Francisco does not currently have a final, published FIRM. In 2015, FEMA provided San Francisco with a "preliminary" or draft FIRM that is based on the following studies:

- Bay Area Coastal Study: This study includes analyses of coastal storm surge and wave hazards for the San Francisco Bay shoreline. FEMA used the analyses to develop flood hazard mapping for San Francisco's waterfront east of the Golden Gate Bridge, for Treasure Island, and for SFO.
- Open Pacific Coast Study: This study includes analyses of coastal storm surge and wave hazards for the open Pacific Ocean and the coastline. FEMA used the analyses to develop flood hazard mapping for the Pacific coastline of San Francisco west of the Golden Gate Bridge.

There are no natural riverine flood sources remaining within the county limits; therefore, FEMA did not complete an assessment if riverine flood hazards. Additionally, FEMA does not assess stormwater flooding, as this source of flooding is most directly related to the conveyance capacity of the City's sewer system and not a natural water body. The preliminary FIRM does not show flood hazard data for inland areas within the county limits; the FIRM only shows coastal flood hazard data for the Bay and Pacific coast shorelines.

FEMA is currently making final adjustments to the preliminary FIRM based on comments provided by San Francisco and plans to finalize and publish the effective FIRM in late 2018 or 2019. Because the FIRM is still in production, specific data elements shown on the preliminary FIRM could change before the FIRM is effective. However, the general location and extent of the SFHAs depicted on the FIRM are likely to remain consistent.

As described above, San Francisco adopted a Floodplain Management Ordinance in 2010, and uses that ordinance to regulate new construction and substantial improvement of buildings located in areas prone to flooding. Because FEMA has not yet published an effective FIRM for San Francisco, the City uses the "Interim Floodplain Map" as the basis for floodplain management. The Interim Floodplain Map is based on the preliminary FIRM data provided by FEMA.[143] Once FEMA has issued a Letter of Final Determination for the effective FIRM; the City will amend the Floodplain Management Ordinance to adopt the effective FIRM and use it for floodplain management purposes.

[143] The Interim Floodplain Map is available at https://sfgsa.org/san-francisco-floodplain-management-program.

FIRMs are organized on a countywide-basis and may include the following information:

- **Special Flood Hazard Area (SFHA)**: A SFHA is an area that is subject to flooding during the one-percent-annual-chance flood. The SFHA is the basis for the insurance and floodplain management requirements of the NFIP. A SFHA may be associated with a stream, river, lake, or other flooding source; or with a coastal flooding source, such as San Francisco Bay.
- **Base Flood Elevation (BFE)**: The BFE is the estimated flood elevation for the one-percent-annual-chance flood. The BFE is used for insurance ratings and for floodplain management.
- **SFHA zone designations**: An SFHA is defined using a zone designation that is based on the level of analysis used to establish the SFHA and the physical characteristics of the SFHA. "Zone AE" and "Zone VE" are used to represent flood hazards that were analyzed using detailed methods; whereas "Zone A" and Zone V" where determined by approximate methods. The zone designation also describes the type of risk associated with the flood hazard; it is used for insurance rating purposes and to determine the appropriate floodplain management requirements for structures located in that zone. "Zone AE" is used for inland flooding sources and for coastal flooding sources where waves are less than three feet in height. SFHAs in coastal areas where waves are three feet or greater in height are identified as "Zone VE" on the FIRM. The elevation of the flood hazard (i.e., 1-percent annual change flood elevation) is generally reported after the zone designation (e.g., Zone AE 12 represents an area with a flood hazard, with waves less than 3 feet, with a water surface elevation of 12 feet NAVD88). All flood elevations presented on the FIRM are rounded to the nearest whole foot.
- **Other flood hazard data**: The FIRM may also show other flood hazard data, such as "Shaded Zone X" floodplains associated with a flood having a 0.2 percent chance of occurrence in a given year (the 500-year flood), and "Zone X Protected by Levee" if a levee is accredited by FEMA as providing flood protection for the 1% annual flood.

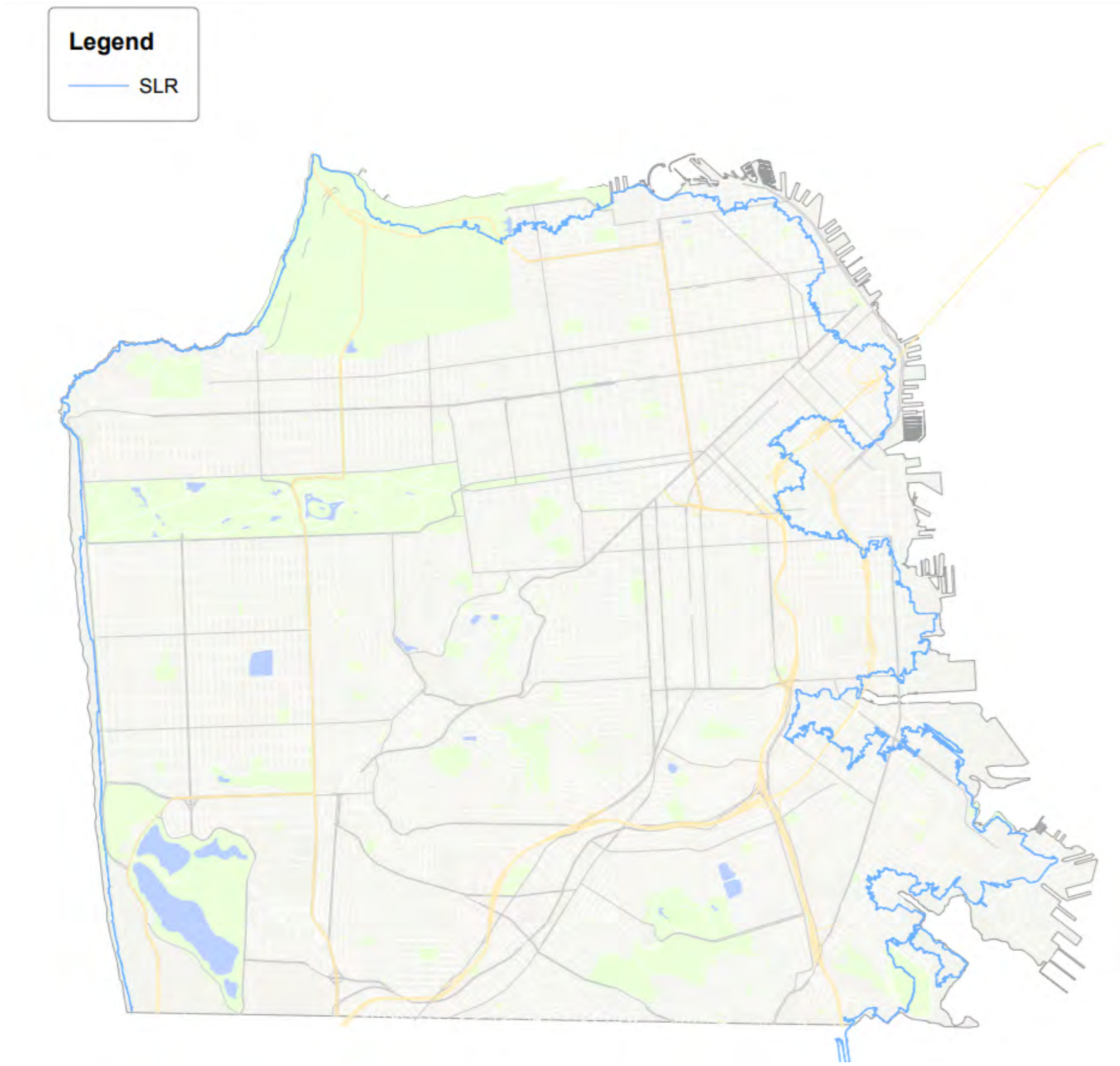
FIGURE 4-22
PRELIMINARY FLOODPLAIN HAZARD AREA

Sea Level Rise Vulnerability Zone

For long-range planning, Capital Planning Committee (CPC) Guidance defines a SLR Vulnerability Zone based on the 2012 National Research Council's (NRC) upper range (unlikely, but possible), end-of-century SLR estimate.[144] The Zone (see Figure 4-23) therefore includes shoreline areas that could be exposed to 66 inches of permanent SLR inundation combined with temporary flooding from a 100-year (1% annual chance) extreme tide if no adaptation measures or actions are taken.

[144] National Research Council, 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington. Past, Present, and Future.

FIGURE 4-23
SAN FRANCISCO SEA LEVEL RISE VULNERABILITY ZONE



Severity and Probability of Future Events

Floods are described in terms of their extent, including the horizontal area affected and the vertical depth of floodwaters, and the related probability of occurrence. Flood studies often use historical records, such as stream-flow and tide gages, to determine the probability of occurrence of floods of different magnitudes. The probability of occurrence is expressed as a percentage of the chance of a flood of a specific extent occurring in a given year. The magnitude of flood used as the standard for floodplain management in the United States is a flood having a probability of occurrence of one percent in any given year. This is known as the 100-year flood or base flood.

The most readily available source of information regarding the current one-percent-annual-chance flood hazard is the system of FIRMs prepared by FEMA (described above). FEMA has also created Increased Flooding Scenario Maps for the interior shoreline for all nine Bay Area counties, which are non-regulatory products that complement the FIRMs. These maps utilize the most up-to-date coastal floodplain mapping data based on FEMA's San Francisco Bay Area Coastal Study and provide additional information on how the 1-percent-annual-chance (i.e. 100-year) coastal floodplain may change with a 1-foot, 2-foot, and 3-foot increase in Bay water levels.

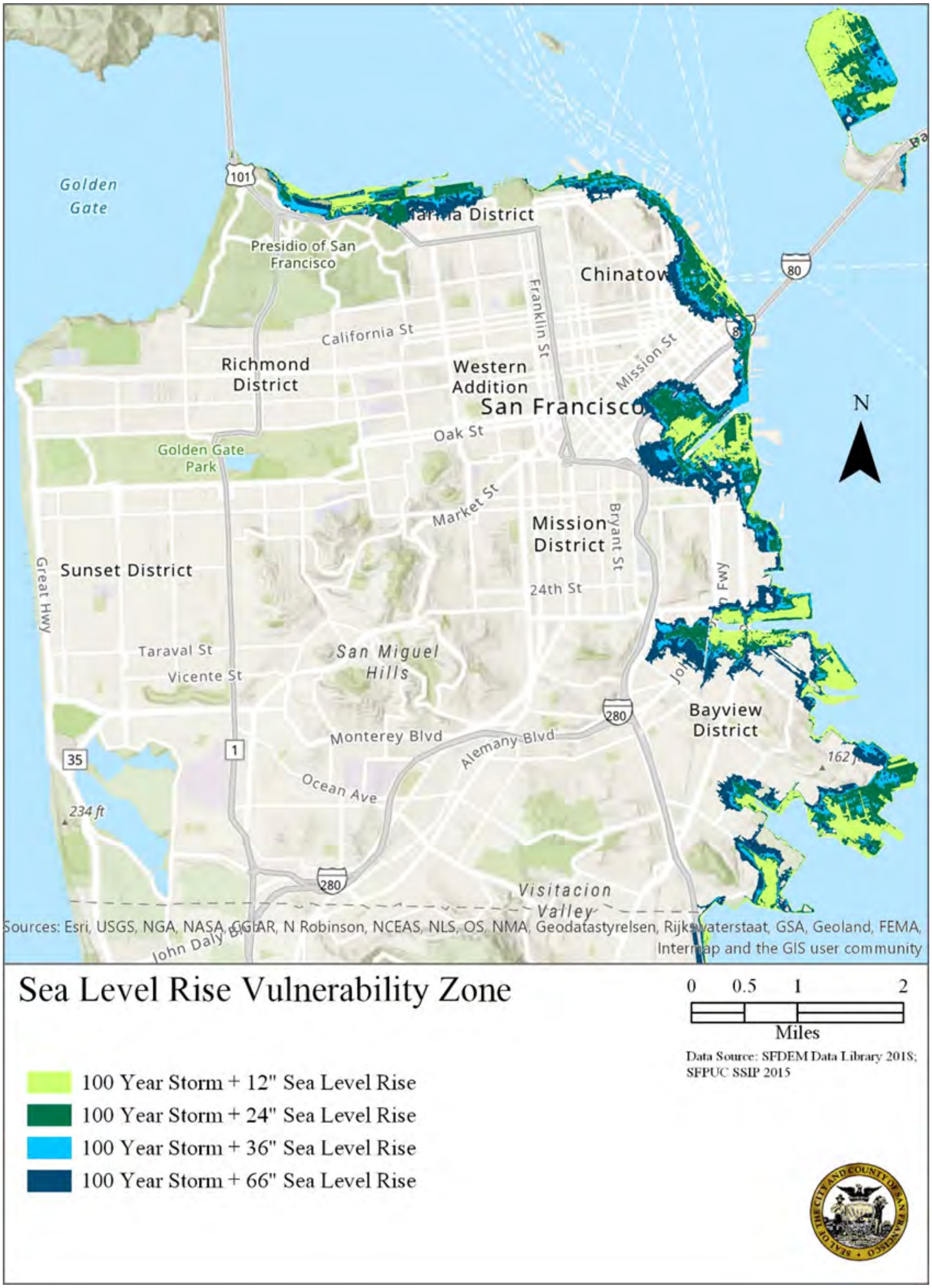
Projected sea level rise will worsen existing coastal flood hazards by increasing the elevation and frequency of flooding, extending the coastal flood hazard zone further inland, and accelerating shoreline erosion. Without action, a variety of coastal flood hazards will increase as seas rise, including:

- **Temporary coastal flooding** from extreme tides, storm surge, and large waves may increase in frequency and extent. Figure 4-24, seen below, shows the areas potentially exposed to temporary flooding during a 100-year storm with 12 to 66 inches of sea level rise.
- **Permanent inundation of areas currently not exposed to regular tides:** Sea level rise can cause areas that are not currently exposed to regular high tide inundation to be inundated regularly, resulting in the need to either protect or move people and infrastructure, and the loss of trails, beaches, vistas, and other shoreline recreation areas. Without action, up to six percent of San Francisco's current land could be permanently inundated by daily tides by the end of the century, including portions of Mission Bay, Central SOMA, and Hunters Point, and

areas adjacent to Islais Creek. Parts of the San Francisco International Airport could also be exposed to permanent inundation without action.

- **Shoreline erosion:** The Pacific coastline and some Bay shoreline areas, such as Crissy Field, are susceptible to increased erosion associated with extreme tides and increased wave action. Without protective action, rising seas will increase erosion hazards.
- **Elevated groundwater and increased salinity intrusion**: As sea levels rise, groundwater and salinity levels are also predicted to rise. This will cause damage to below grade residential and commercial spaces and infrastructure.

FIGURE 4-24
TEMPORARY COASTAL FLOODING IN SEA LEVEL RISE VULNERABILITY ZONE



Stormwater Flooding

Impact Statement

Stormwater flooding occurs during storm events as rainfall runoff collects in areas that at one time were naturally-formed waterways but are now contained within the City's combined sewer and stormwater collection system. The Islais Creek area (Cayuga/Alemany), South of Market, Inner Mission, and Civic/Center Western Addition include significant areas that are at risk of stormwater flooding during a 100-year storm, as well as during rainfall events that occur more frequently. Smaller areas across the city also experience temporary flooding during precipitation events.[145] As precipitation events may become more intense and sea level rises due to climate change, the frequency and extent of stormwater flooding may increase. Stormwater flooding can cause physical damage to buildings and infrastructure, disrupt economic activity, and impair public health.

Nature

As San Francisco has developed over time, its hilly topography has been largely paved over. During storms, runoff flows along streets aligned with historic waterways and in areas that are built on landfill. The stormwater accumulating on the surface and backups from the combined sewer-stormwater system may enter nearby structures, resulting in property damage, forcing people to leave their homes, and causing disruptions to businesses. Additionally, fast-moving water on the surface is a threat to public safety, even at shallow depths. San Francisco's stormwater infrastructure is sized for the current 5-year storm, so heavier precipitation events can lead to localized flooding.

Stormwater flooding can also be exacerbated by high tides. As the sewage and stormwater system reaches maximum capacity during heavy precipitation events, the effluent may be discharged directly into the bay. High water levels in the bay can slow these discharges, causing backups in the sewage and stormwater system. These backups can increase the extent and duration of stormwater flooding. This phenomenon will be exacerbated as sea level rises. Discharges to the bay can create a

[145] San Francisco Public Utilities Commission. "Flood Maps." http://sfwater.org/index.aspx?page=1229

pollution problem when the effluent carries untreated sewage and debris, chemicals, trash, and other pollutants that have collected on streets.

History

A query of the National Oceanic and Atmospheric Administration's Storm Events Database, indicates that San Francisco has 23 flood events from 1998 to 2018, primarily resulting in flooded roadways.[146] Several large storms in recent years have caused significant flooding in certain neighborhoods of San Francisco. Recently, two very large storms in December 2014 caused property damage, loss of business revenue, and other significant impacts in some low-lying areas. Many of these areas also flooded in an extreme storm in February 2004.[147]

Location

The SFPUC has developed a Draft 100-Year Storm Flood Risk Map (Draft Map) that shows areas of San Francisco where significant flooding from storm runoff is highly likely to occur during a 100-year storm. A "100-year storm" means a storm with a 1% chance of occurring in a given year. The SFPUC used computer modeling that simulates the Citywide operation of the stormwater system during a 100-year storm to identify areas subject to flooding.

The Draft Map shows parcels that are highly likely to experience "deep and contiguous" flooding during a 100-year storm. "Deep and contiguous flooding" means flooding that is at least 6-inches deep spanning an area at least the size of half an average City block. This Draft Map shows flood risk from storm runoff only. It does not consider flood risk in San Francisco from other causes such as inundation from the San Francisco Bay or Pacific Ocean.

Areas with stormwater flooding risks include the Islais Creek area (Cayuga/Alemany), South of Market, Inner Mission, and Civic/Center Western Addition.

Severity and Probability of Future Events

As sea level rises and precipitation events become more intense, stormwater flooding may increase in frequency and severity. More intense precipitation may lead to localized

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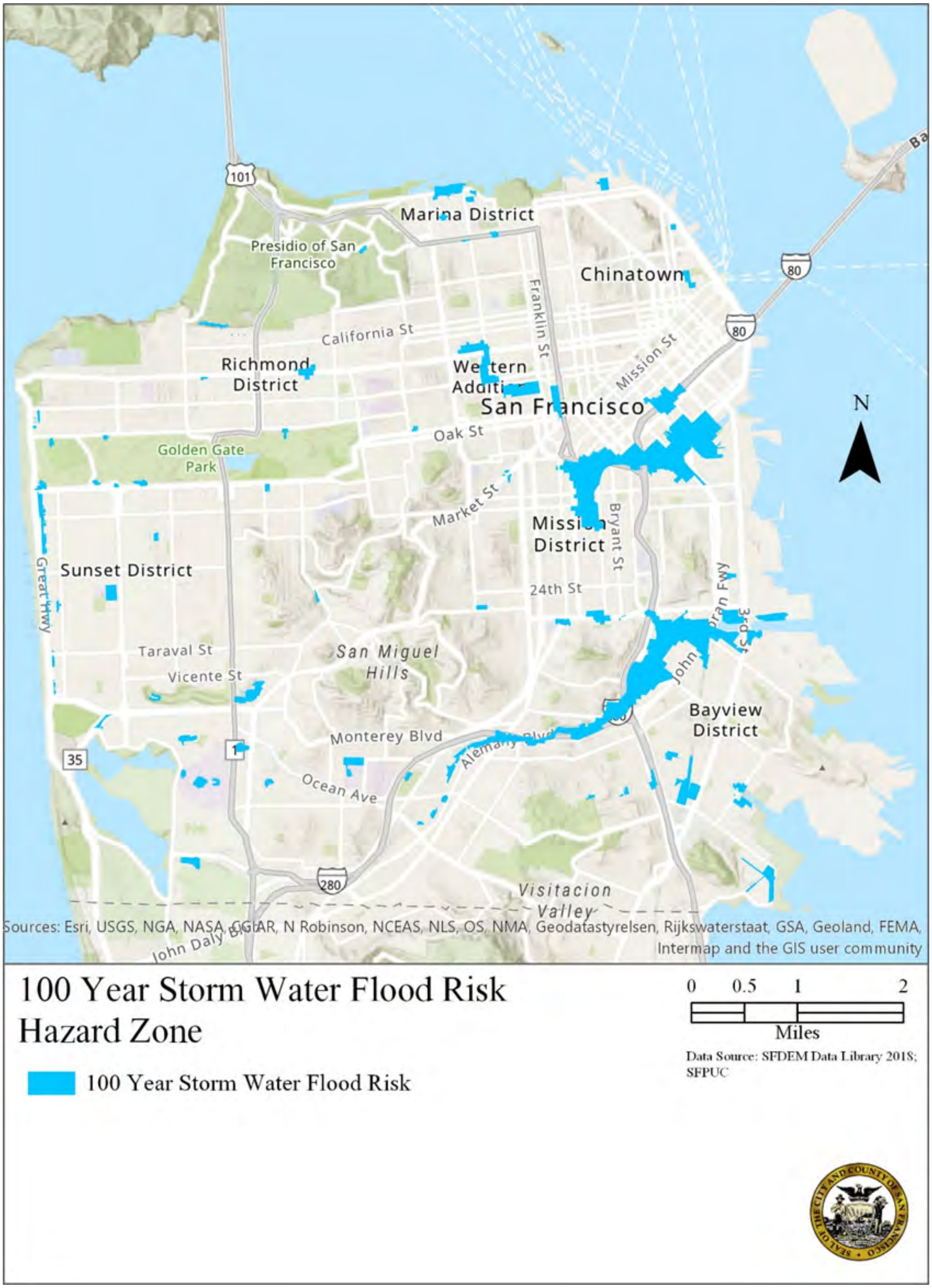
[146] National Oceanic and Atmospheric Administration. https://www.ncdc.noaa.gov/stormevents/
[147] San Francisco Public Utilities Commission, 2016. "Flood Resilience Report. Executive Summary." http://sfwater.org/Modules/ShowDocument.aspx?documentid=9127

flooding because stormwater infrastructure is sized for the current 5-year storm. This effect will be exacerbated as sea levels rise because higher Bay waters will further slow stormwater discharge. This effect will be particularly severe in low-lying coastal areas, but slow discharge rates could affect system-wide drainage rates and cause upstream flooding.

FIGURE 4-25
100-YEAR STORM FLOOD RISK HAZARD MAP



Dam or Reservoir Failure Profile

4.6 Dam or Reservoir Failure

Impact Statement

Dam or reservoir failure may impact the Sunset, Midtown Terrace, Twin Peaks, Clarendon Heights, and University Mound areas of San Francisco, where state-regulated reservoirs are located. Factors that increase the risk of dam or reservoir failure include the age of the structures and the likelihood of an earthquake. Climate change impacts, including changing precipitation patterns, may also increase the risk of dam or reservoir failure in and outside of the County.

Nature

A dam or reservoir failure is an unplanned release of water resulting from the structural compromise or collapse of a dam or other structural element, such as the wall of a tank. The Federal Emergency Management Agency (FEMA) classifies the causes of dam failures into five general categories:[148]

- **Hydrologic**: Dam failures caused by extreme rainfall or snowmelt events that can lead to natural floods. The main causes of hydrologic dam failure include overtopping, structural overstressing, and surface erosion due to high velocity flow and wave action. Overtopping due to inadequate spillway design, debris blockage of spillways, or settlement of the dam crest accounts for about 34 percent of all dam failures in the United States.

- **Geologic**: Includes failures due to piping and internal erosion, slope instability and hydraulic fracturing, long-term seepage of water in earthen dams, inadequate geotechnical design of the embankment and foundation, inadequate seepage controls, or increased load situations.

- **Structural**: Involves failure of a critical dam component. Structural failures may stem from inadequate initial design, poor construction, poor construction materials, inadequate maintenance and repair, or gradual degradation and

[148] Federal Emergency Management Agency (FEMA), *Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures*, FEMA P-946 (Washington, DC, 2013), 4-4–4-8, accessed June 5, 2018, https://www.fema.gov/media-library-data/96171edb98e3f51ff9684a8d1f034d97/Dam_Guidance_508.pdf; FEMA, *Living with Dams: Know Your Risks*, FEMA P-956 (Washington, DC, 2013) 9, 10, accessed June 4, 2018, https://www.fema.gov/media-library-data/20130726-1845-25045-7939/fema_p_956_living_with_dams.pdf.

weakening over time. Structural failures have caused about 30 percent of all dam failures in the United States.

- **Seismic**: In earthquake zones, seismic failures typically are related to ground movement or liquefaction. Liquefaction can cause immediate dam failure or can result in slumping that exposes the dam crest to overtopping and erosion. Seismic-induced piping can occur due to internal cracking caused by earthquake ground motion, which may cause a dam to shift, settle, or crack in a way that prevents the dam from performing as designed.
- **Human-caused**: Failures related to improper design, maintenance, or operation of a dam, or to terrorist acts.

The age of a dam or reservoir may make it more susceptible to failure. As dams get older, deterioration and repair costs increase. Common characteristics of older dams include:[149]

- Deteriorating metal pipes and structural components;
- Sediment-filled reservoirs; and
- Increased runoff from subdivisions and businesses built upstream.

The sudden release of water following a dam or reservoir failure has the potential to cause dangerous flooding, resulting in human casualties; economic loss, including property damage; and environmental damage.[150] In addition, dam or reservoir failure may result in lifeline disruption, including impacts on delivery of drinking water and electricity to areas served by the dam or reservoir.[151] Dam or reservoir failure can occur rapidly, providing little warning, thus leaving little time to evacuate people located downstream from or below the failing structure. Damage occurs as a result of the momentum of the sediment-laden water, flooding over channel banks, and the impact of the debris carried by the flow.

History

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[149] FEMA, *Living with Dams*, iii.

[150] Association of Dam Safety Officials, "What are the Top Issues Facing the Dam Community?" accessed June 5, 2018, https://damsafety.org/top-issues-facing-dam-community; FEMA, *Living with Dams*, 2, 3.

[151] See FEMA, *Living with Dams*, 1–3.

To date, there is no history of a dam or reservoir failure occurring within San Francisco boundaries. Nor is there a history of failures for dams or reservoirs located outside San Francisco that are owned by the city or by the SFPUC. However, on March 22, 2018, seepage was detected on the downstream face of the SFPUC-owned 60-foot earthen Moccasin Dam in Tuolumne County after heavy rainfall sent a major surge of water and debris into the Moccasin Reservoir. The seepage triggered activation of the Moccasin Dam Emergency Action Plan, which included evacuations of a downstream campground and fish hatchery close to the dam and prompted the closure of two nearby highways. The SFPUC drained the Moccasin reservoir into the larger Don Pedro Reservoir located downstream and conducted extensive inspections of the dam and its spillways. Though the dam itself never overtopped or failed,[152] cleanup and repair efforts cost approximately $43 million.[153]

Location

There are 15 reservoirs located within San Francisco County limits. Six San Francisco reservoirs are considered dams regulated by the California Department of Water Resources, Division of Safety of Dams (DSOD). Under California law, state-regulated dams are artificial barriers that impound or divert water and are 25 feet or more in height, or that store 50 acre-feet or more of water.[154] The state also regulates artificial barriers that are more than six feet in height, regardless of storage capacity; or that hold more than 15 acre-feet of water, regardless of height.[155]

State-regulated dams within San Francisco County limits are listed in Table 4-26, below. Each of these reservoirs are owned by the City and County of San Francisco and are managed by the SFPUC. Table 4-26 includes the names of the reservoirs and dams, the year of construction, the type of construction of the main dam, the reservoir capacity in acre-feet, and the dam height and crest length in feet. It also includes the DSOD assessment of downstream hazard. DSOD's categories for downstream hazard assessment are based on federal recommendations of low-, significant-, and high-

[152] See San Francisco Public Utilities Commission (SFPUC), News Releases, "Moccasin Reservoir Stabilized Following Threat of Dam Failure," March 22, 2018, accessed June 4, 2018, http://sfwater.org/index.aspx?recordid= 450&page=17; "Update on Status of Moccasin Dam and Reservoir," March 23, 2018, accessed June 4, 2018, https://sfwater.org/Index.aspx?page=17&recordid=452.

[153] San Francisco Chronicle, "March Storm Caused $43M in Damage at Moccasin Dam, Per SFPUC," May 2, 2018, accessed June 4, 2018, https://www.sfgate.com/news/bayarea/article/March-Storm-Caused-43M-In-Damage-At-Moccasin-12883240.php.

[154] See California Water Code § 6002.

[155] See California Water Code § 6003.

hazard potential classifications. However, DSOD has included a fourth category, "Extremely High," to identify dams that may impact highly populated areas or critical infrastructure or that may have short evacuation warning times. The assessment is not related to the condition of the dam or its auxiliary structures, or an indication of probability of dam failure.[156] State-regulated reservoirs within San Francisco County are located in the Sunset District (Sunset North and South), Midtown Terrace (Sutro), Twin Peaks, Clarendon Heights, and University Mound.

TABLE 4-26
STATE-REGULATED DAMS WITHIN SAN FRANCISCO COUNTY[157]

Reservoir Name	Dam Name	Year Built	Dam Type	Reservoir Capacity (ac-ft)	Dam Height/ Crest Length (ft)	Downstream Hazard
Sunset Reservoir	Sunset North Basin	1938	Earth	275	74/2,300	Extremely High
	Sunset South Basin	1960	Earth	268	34/ 980	Extremely High
Sutro Reservoir	Sutro Reservoir	1952	Earth	96	55/850	Extremely High
Twin Peaks Reservoir	Stanford Heights	1928	Earth	37	31/1,480	Extremely High
Summit Reservoir	Summit Reservoir	1954	Earthen Embankment	43	39/120	Extremely High
University Mound	University Mound North	1885	Earth	182	17/2,422	Extremely High

[156] California Department of Water Resources, Division of Safety of Dams (DSOD), *Dams Within Jurisdiction of State of California, Dams Listed Alphabetically by County* (Sacramento, CA, 2017), ii, accessed June 5, 2018, https://www.water.ca.gov/-/media/DWR-Website/Web-Pages/Programs/All-Programs/Division-of-safety-of-dams/Files/Publications/Dams-Within-Jurisdiction-of-the-State-of-California-Alphabetically-by-County.pdf; see FEMA, *Federal Guidelines for Inundation Mapping of Flood Risks Associated with Dam Incidents and Failures,* FEMA P-946 (Washington, DC, 2013), 6-4, accessed June 5, 2018, https://www.fema.gov/media-library-data/96171edb98e3f51ff9684a8d1f034d97/Dam_Guidance_508.pdf.

[157] California Department of Water Resources, Division of Safety of Dams, 2017

Reservoir Name	Dam Name	Year Built	Dam Type	Reservoir Capacity (ac-ft)	Dam Height/ Crest Length (ft)	Downstream Hazard
	University Mound South	1937	Earth	250	61/1,150	Extremely High

In addition, San Francisco is home to a number of smaller reservoirs that are not regulated by the state. Together with the state-regulated reservoirs shown in Table 4-26, these reservoirs are part of the SFPUC's San Francisco Retail Water System. This system includes 10 reservoirs and eight water tanks located within the city, which store water delivered by the Hetch Hetchy Regional Water System and the local Bay Area water system. The Hetch Hetchy Regional Water System provides the majority of San Francisco's drinking water.[158]

The City and County of San Francisco and the SFPUC also own a number of state-regulated dams located outside county boundaries. These dams and reservoirs are part of the Hetch Hetchy Regional Water System, which provides drinking water to other cities in the San Francisco Bay Area Region in addition to San Francisco. Dams and reservoirs in this system are located in Alameda, San Mateo, and Tuolumne Counties. Table 4-27, below, contains a list of these dams and reservoirs. For a map of the Hetch Hetchy Regional Water System see Appendix B.

[158] SFPUC, "San Francisco Groundwater Supply Project," accessed June 5, 2018, https://sfwater.org/index.aspx? page=1136.

TABLE 4-27
CITY AND SFPUC-OWNED, STATE-REGULATED DAMS OUTSIDE SAN FRANCISCO COUNTY[159]

Dam Name	County	Year Built	Dam Type	Reservoir Capacity (ac-ft)	Dam Height/ Crest Length (ft)	Downstream Hazard
Calaveras	Alameda	1925	Hydraulic Fill	100,000	210/1,200	Extremely High
James H. Turner	Alameda	1964	Earthen Embankment	50,000	193/2,160	Extremely High
Lower Crystal Springs	San Mateo	1888	Gravity	57,910	149/600	Extremely High
Pilarcitos	San Mateo	1866	Earth	3,100	103/520	High
San Andreas	San Mateo	1870	Earth Embankment	19,027	107/727	High
Cherry Valley	Tuolumne	1956	Earth and Rock	273,500	315/2,630	High
Early Intake	Tuolumne	1925	Constant Radius Arch	115	56/262	Low
Lake Eleanor	Tuolumne	1918	Multiple Arch	28,600	61/1,260	High
Moccasin Lower	Tuolumne	1930	Earth and Rock	554	60/720	High
O'Shaughnessy	Tuolumne	1923	Gravity	360,000	312/900	Extremely High
Priest	Tuolumne	1923	Hydraulic Fill	2,067	168/1,000	High

[159] California Department of Water Resources, Division of Safety of Dams, 2017

Extent and Probability of Future Events

In general, dam or reservoir failure is a low probability, high consequence event. Most of the dams and reservoirs making up the Hetch Hetchy Regional Water System are more than 85 years old. Damage to these structures could be caused by a major earthquake, by a severe storm with attendant runoff, by a slope failure, through terrorism, or by other means.

There is a 72 percent chance of magnitude 6.7 or greater earthquake occurring in the San Francisco Bay Area between 2014 and 2044.[160] In this regard, it is important to note that the SFPUC has performed, and continues to perform, extensive seismic work on its dams and reservoirs, including retrofits to the Sunset and University Mound reservoirs, upgrades to the water tanks within the city that make up the Emergency Firefighting Water System,[161] and the ongoing Calaveras dam replacement project.[162]

As required by California law,[163] the SFPUC has prepared inundation maps showing areas of potential flooding in the event of sudden or total failure of state-regulated dams or reservoirs located in and outside San Francisco. SFPUC has submitted the maps to the California Governor's Office of Emergency Services and to DSOD for approval. State-approved maps are available on the DSOD web site.[164] Figure 4-28, below, shows potential inundation areas for reservoirs within San Francisco. With a changing climate that includes an expectation of increased extreme weather events in California, including prolonged periods of drought and intense wet periods with less snowpack, dam operation becomes more difficult and the risk of dam failure from overtopping may increase.[165]

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[160] Edward H. Field and 2014 Working Group on California Earthquake Probabilities (WGCEP), *UCERF3: A New Earthquake Forecast for California's Complex Fault System,* Fact Sheet 2015–3009 (2015), 4, accessed May 18, 2018, https://dx.doi.org/10.3133/fs20153009.

[161] SFPUC, *Earthquake Safety and Emergency Response Bond Program 2010 & 2014 Quarterly Status Report* (March 2016) 2, 28, accessed June 5, 2018, http://www.sfearthquakesafety.org/uploads/1/9/4/3/19432507/ quarterly_status_report_jan_-_march_2016.pdf.

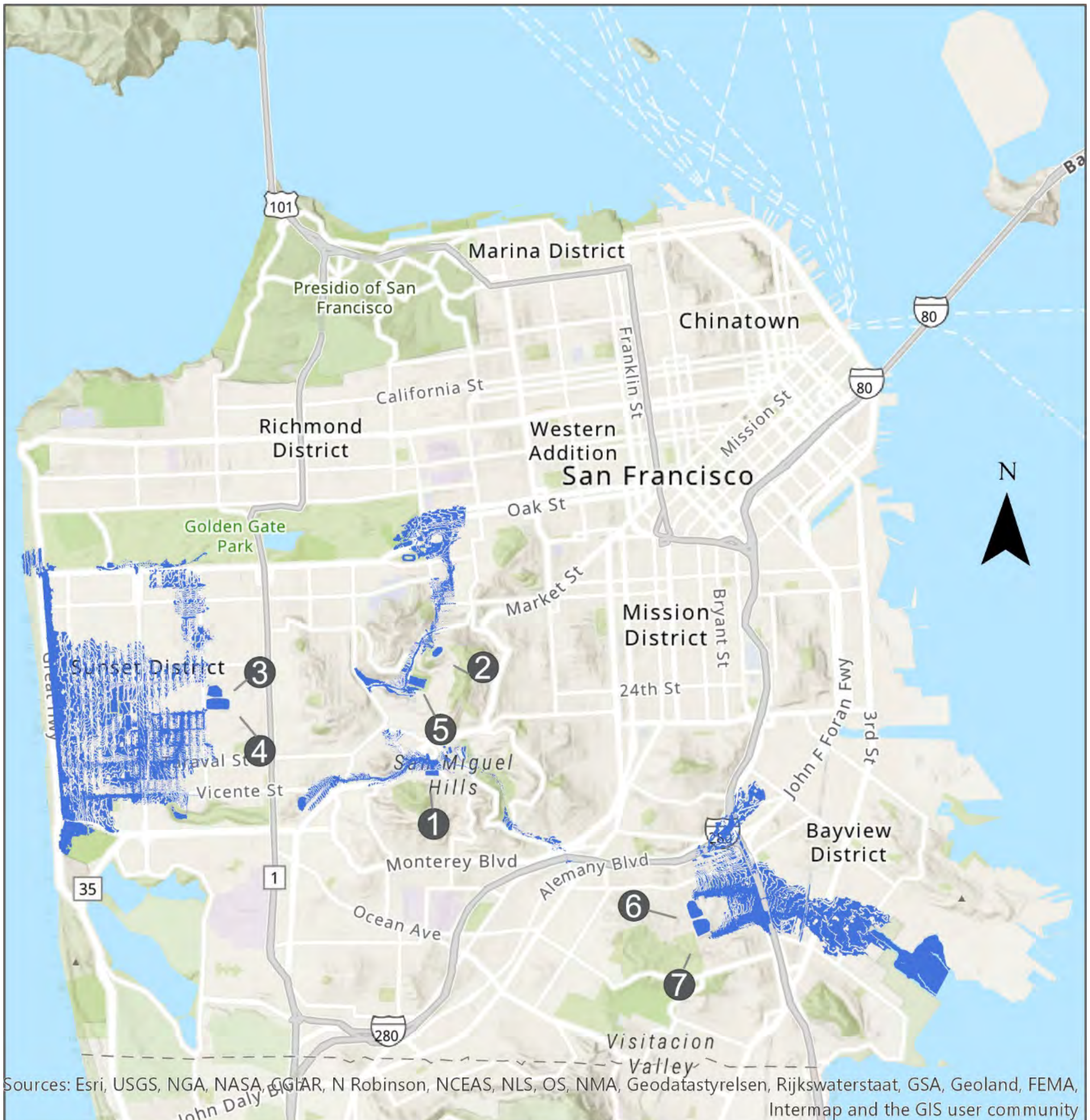
[162] SFPUC, "Calaveras Dam Replacement Project," accessed June 5, 2018, https://sfwater.org/index.aspx?page=979.

[163] See Cal. Water Code §§ 6160 et seq.; Cal. Govt. Code § 8589.5.

[164] See DSOD, Inundation Maps," accessed June 5, 2018, https://www.water.ca.gov/Programs/All-Programs/Division-of-Safety-of-Dams/Inundation-Maps.

[165] State of California, 2018. "2018 State Of California Multi-Hazard Mitigation Plan. Public Review Draft."

FIGURE 4-28
RESERVOIR INUNDATION HAZARD AREA



Reservoir Inundation Hazard Area

Reservoir Inundation Hazard Area

0 0.5 1 2
Miles

Data Source: SFDEM Data Library 2018; SFPUC 2018

Reservoir Key
1. Stanford Heights - Agua Way and Teresita Blvd.
2. Summit - La Avanzada St. and Palo Alto Ave.
3. Sunset North - 28th Ave and Ortega
4. Sunset South - 28th Ave and Quintara
5. Sutro - Clarendon Ave. and Olympia Way
6. University Mound North - University St. and Bacon St.
7. University Mound South - University St. and Bacon St.

Extreme Heat Profile

4.7 Extreme Heat

Impact Statement

Historically, San Francisco has experienced extreme heat events six to seven days per year, generally between May and October. Though an excessive heat event in San Francisco impact all areas of the city, it does not affect all inhabitants equally. The elderly, the very young, and those with chronic health problems are most at risk when extreme heat occurs. Neighborhoods with the greatest risk, based on sociodemographic characteristics, include Chinatown, SOMA, Tenderloin Center, Bayview/ Hunters Point, and the Mission District. Climate change is expected to increase the frequency and severity of extreme heat events. By 2100, the number of extreme heat days is projected to increase by 1.5 orders of magnitude to 90 days per year, up from around six currently.

Nature

Located at the north end of a peninsula and surrounded on three sides by San Francisco Bay and the Pacific Ocean, San Francisco is almost perfectly positioned for moderate temperatures year-round. Cool marine air and coastal fog keep the average summertime temperatures between 60- and 70-degrees Fahrenheit. The warmest time of year is typically the late summer and early fall when the fog is less pronounced. However, occasional heat events (defined below) do occur for San Francisco. Given that San Francisco has such a relatively mild climate, a sudden spike in temperatures has a much greater impact on local residents compared with noncoastal communities. Though air conditioning is the leading protective factor against heat-related illness and death, most residential units in San Francisco lack air conditioning.

According to the National Weather Service, extreme heat occurs when the temperature reaches extremely high levels or when the combination of heat and humidity causes the air to become oppressive and stifling. In San Francisco, heat or extreme heat is generated when a massive high-pressure ridge inhibits the normal onshore breezes, resulting in temperatures in the high 80s, 90s, and possibly the 100s. Generally, extreme heat is considered to be 10 degrees above the normal temperature over an extended period of time. In San Francisco, extreme heat events have been specified as occurring when daytime temperatures are at or above 85 degrees.[166] However, extreme heat can manifest itself in several other ways, including:

- A spell of sweltering humidity, which reaches levels commonly associated with moist tropical regions. Stress on the body can be exacerbated when atmospheric conditions cause pollutants to be trapped near the ground.
- An excessively dry condition, in which strong winds and blowing dust can worsen the situation.
- A rise in the heat index, the body's perception of the "apparent" temperature based on both the air's real temperature and the amount of moisture present in the air. Humidity and mugginess make the temperature seem higher than it is. In high humidity, an 85-degree day may be perceived as 95 degrees.

During heat or extreme heat events, local National Weather Service offices may issue heat-related messages as conditions warrant. Such messages include:

- **Excessive Heat Outlook**: Issued when the potential exists for an excessive heat event in the next three to seven days. An outlook carries a minimum 30 percent confidence level that the event will occur.
- **Excessive Heat Watch**: Issued when conditions are favorable for an excessive heat event in the next 12 to 48 hours. A watch is given when the level of confidence that the event will occur reaches 50 percent or greater.
- **Excessive Heat Advisory**: Issued when an excessive heat event is expected in the next 36 hours. An advisory is used for a less severe event that is not assumed to be life-threatening, when caution is advised to mitigate the event's impact.
- **Excessive Heat Warning**: The most serious alert, issued when an excessive heat event is expected in the next 36 hours, or such an event is occurring, is imminent,

[166] According to Cal-Adapt, an Extreme Heat day is defined as a day in April through October when the Maximum Temperature exceeds the location's Extreme Heat Threshold, which is calculated as the 98th percentile of historical maximum temperatures between April 1 and October 31 based on observed daily temperature data from 1961–1990.

or has a very high probability of occurring. A warning assumes the potential for health consequences due to extreme heat.

While extreme heat events are less dramatic, they are potentially more deadly. A California Energy Commission study indicates that over the past 15 years, heat waves have claimed more lives in California than all other declared disaster events combined.[167]

History

Using data from the National Weather Service (NWS), San Francisco's daily temperature has exceeded 100 degrees only 11 times between 1921 and 2017, for a recurrence interval of approximately once every 9 years. Between 1921 and 2017, the NWS observation site in downtown San Francisco has averaged 6.6 days per year with high temperatures at or above 85 degrees. However, 1984, 1995, and 1996 was an exception to this average: There were 17, 18, and 18 days, respectively, during those years when temperatures were at or above 85 degrees.

On the rare days when the temperature reaches 100 degrees, the health impact is extreme. On June 14, 2000, San Francisco experienced a 103-degree heat wave, the highest temperature ever recorded for San Francisco at the time. This heat event resulted in reports of 102 heat-related illnesses and nine deaths in San Francisco. During the 2017 Labor Day weekend, San Francisco experienced the highest temperature ever recorded, with temperatures of 106 degrees observed. It is estimated that during this event, at least three people died, and 50 people were hospitalized due to heat-related illness in the city. The number of 911 calls overwhelmed ambulances and forced San Francisco to request mutual aid from neighboring counties.[168] These numbers likely underestimate the event's health impacts, as exposure to extreme heat can exacerbate underlying health conditions, leading to hospitalization and even premature death.

Location

As previously note, though an excessive heat event in San Francisco impacts all areas of the city, it does not affect all inhabitants equally. The elderly, the very young, and those with chronic health problems are most at risk when extreme heat occurs. In addition,

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[167] Heat waves are three sequential extreme heat days and are also expected to increase.

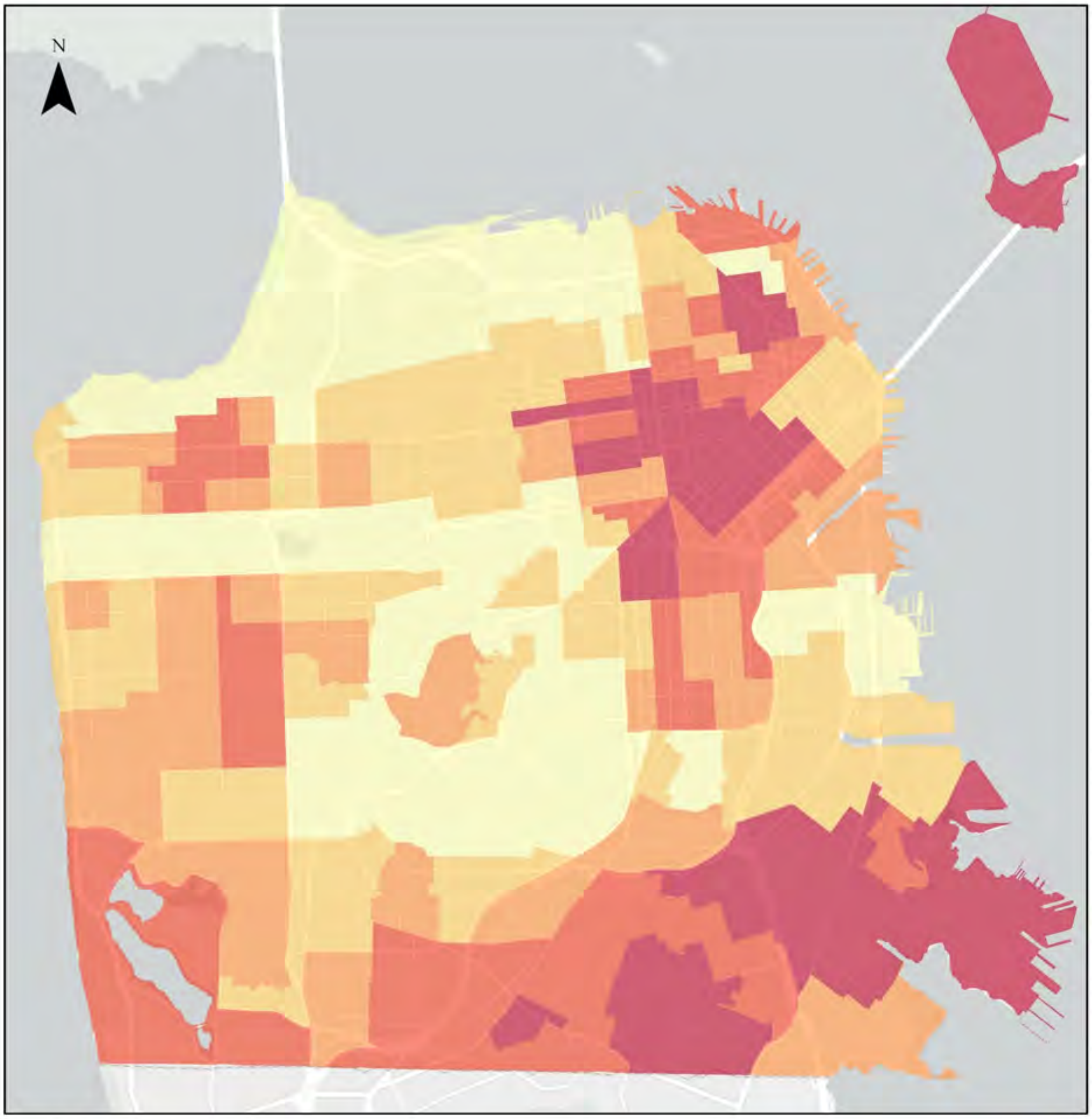
[168] There were 1,342 emergency calls on Friday, September 1, and 1,413 emergency calls on Saturday, September 2, the most since New Year's Eve 2012.

environmental exposure factors affect vulnerability to extreme heat. These factors include air quality, tree density, and proximity to parks/green space. Housing can also modify the relationship between temperature and heat-related illnesses. This is often called the Urban Heat Island (UHI) effect, which describes the temperature difference between dense urban areas and their more forested outer limits, where more intense urbanization contributes to increased relative temperatures. Due to the unique pattern of urbanization in the San Francisco bay area, temperatures can vary significantly over even small geographic scales. For example, the localized UHI in Downtown San Francisco contributes to a 1° C temperature increase relative to North Beach or Russian Hill, areas less than 1 km away[169]. This effect exacerbates extreme heat hazards by contributing to the duration and severity of individual extreme heat events in different parts of the City, posing significant health risks to the residents of various neighborhoods.

Using socioeconomic and census tract data for the entire city, the San Francisco Department of Public Health has developed a Heat Vulnerability Index to determine which neighborhoods have the highest concentration of residents at risk in excessive heat events. This index considers the following indicators: exposure to extreme heat, population sensitivity, and adaptive capacity. A map showing areas of vulnerability is shown in Figure 4-29). Neighborhoods with the greatest risk include Chinatown, SOMA, Tenderloin, Bayview/Hunters Point, and the Mission District. However, health impacts are anticipated for every neighborhood in the city.

[169] CalEPA, *Creating and Mapping an Urban Heat Island Index for California,* accessed September 21, 2018, *https://calepa.ca.gov/wp-content/uploads/sites/6/2016/10/UrbanHeat-Report-Report.pdf*

FIGURE 4-29
HEAT VULNERABILITY INDEX



0 0.5 1 2
Miles

Vulnerable Populations

Extreme Heat Health Vulnerability

Some Health Impacts

Most Health Impacts

Data Sources:
San Francisco Department of Public Health, Climate and Health Program (2019)

This map incorporates exposure, sensitivity, and adaptive capacity indicators to create a Heat Health Vulnerability Index. The index assesses which neighborhoods are most vulnerable to the health impacts of extreme heat

The purpose of the Index is to predict the distribution of health impacts in San Francisco. While this Index predicts certain neighborhoods to have a greater concentration of extreme heat health impacts, we anticipate health impacts in every neighborhood and all neighborhoods must prepare their vulnerable residents for these health impacts.

Severity and Probability of Future Events

Historically, San Francisco has experienced temperatures in excess of 85 degrees six to seven days per year, generally between May and October. Climate change is expected to increase the frequency and severity of extreme heat events. Since 1920, average annual temperatures have been increasing across California, including the San Francisco Bay Area. Average yearly temperatures are projected to increase between 1.3°F and 3.1°F by mid-century 3.3°F and 5.5°F by end-of-century compared to 2010. Annual extreme heat days are expected to increase from about six currently, to 15-40 by 2050, up to 90 per year by 2100.[170] Heat waves are similarly expected to increase in both frequency and severity.

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[170] Scripps Institute of Oceanography, Cal-Adapt and California Nevada Applications Program. *Temperature: Extreme Heat Tool,* http://cal-adapt.org/temperature/heat/

Drought Hazard Profile

4.8 Drought

Impact Statement

California's Mediterranean climate is typified by dry summers followed by long, wet winters, thus making the state particularly susceptible to drought and flooding. The majority of San Francisco's water is brought to the city from the Hetch Hetchy watershed located in the Sierra Nevada Mountains through a complex series of reservoirs, tunnels, pipelines, and treatment systems.[171] As a result, changes in precipitation in the Sierra Nevada impacts the water supply in the Bay Area. Climate models project that a warming planet will lead to changes in precipitation distribution, including a reduced Sierra snowpack and earlier melting of the snowpack.[172]

Nature

The broad definition of drought is insufficient water over a prolonged time period. Drought condition indices typically consider the following factors: hydrological, meteorological, soil moisture, and applicable snowpack levels.[173] A drought occurs when there is a prolonged period of dryness in which precipitation is less than expected or needed in a given geographic location or climate over an extended period of time. In California, droughts typically occur in the winter, because winter is California's primary precipitation or wet season. During drought winters, the high-pressure belt that sits off the west coast of North America, and typically shifts southward during the season, remains stationary. As a result, Pacific storms that would normally approach the northern California coast are diverted elsewhere, depriving the Sierra Nevada mountain range of its normal winter storm activity and precipitation.

The San Francisco Bay Area and much of the state depend on spring runoff from the Sierra Nevada snowpack to replenish the water supply. Dry winters mean reduced snowpack. When dry winters occur over consecutive years, or when water demand increases beyond supply, drought is the result. Drought is a gradual phenomenon that may span multiple seasons and years.

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[171] San Francisco Public Utilities Commission, "About Us: Overview", accessed September 28, 2018, https://sfwater.org/index.aspx?page=355

[172] Reich, KD, N Berg, DB Walton, M Schwartz, F Sun, X Huang, and A Hall, 2018: "Climate Change in the Sierra Nevada: California's Water Future." UCLA Center for Climate Science.

[173] California National Resources Agency. California's Fourth Climate Change Assessment: San Francisco Bay Area Region Report. Retrieved from: http://www.climateassessment.ca.gov/regions/docs/20180827-SanFranciscoBayArea.pdf (Accessed: 9/10/2018)

Drought is often measured in terms of its effect on crops, or in terms of its environmental impact, such as livestock deaths, wildfire, impaired productivity of forest land, damage to fish habitat, loss of wetlands, and air quality effects. Drought may also be measured by its social effects, including economic and physical hardship and increased stress on residents of a drought-stricken area. In San Francisco, the primary impact of drought is reduced availability of water for residential and commercial use.

History

California's Mediterranean climate is typified by dry summers followed by long, wet winters, thus making the state particularly susceptible to drought and flooding. According to the Climate Readiness Institute at UC Berkeley, 10-year droughts occurred across the west in previous millennia.[174] In modern history, droughts exceeding three years are relatively rare in northern California.[175] To date, San Francisco County has not been declared a Presidential disaster area as a result of drought. However, statewide droughts have been declared in 1976-1977, 1987-1992, 2008, and 2013-2016. In 2013, the United States Department of Agriculture declared the state a drought disaster area to provide relief for farmers and for the agriculture industry.

In the winter of 2013, California experienced record warmth and dryness with some locations in northern California experiencing 50 consecutive days with no measurable precipitation. Governor Jerry Brown issued a proclamation of emergency in January 2014 that ordered state agencies to take specific actions and called on Californians to voluntarily reduce their water usage by 20 percent[176].

In January 2014, the SFPUC called on its retail customers to reduce water use by at least 10 percent. In February 2014, Mayor Edwin M. Lee issued an executive directive requiring all City departments to develop individual water conservation plans and take immediate steps to achieve a mandatory 10 percent reduction in their water consumption. In August 2014, the SFPUC imposed a mandatory reduction of 10% on outdoor irrigation of ornamental landscapes or turf with potable water by retail

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[174] Climate Readiness Institute, *Bay Area Water Future* by William D. Collins, accessed 10 June 2015 http://climatereadinessinstitute.org/wp-content/uploads/2015/06/Collins-CRI-Water-Future.compressed.pdf
[175] California Governor's Office of Emergency Services, *2018 California State Hazard Mitigation Plan*, accessed http://www.caloes.ca.gov/for-individuals-families/hazard-mitigation-planning/state-hazard-mitigation-plan
[176] ibid

customers. Starting in July 1, 2015 the reduction was increased from 10% to 25%.[177] In response to these measures, single-family households reduced their water use by 16 percent compared to 2013.[178]

Early seasonal rain in the winter of 2014 helped alleviate some of the drought conditions, however, January 2015 was considered the driest January since meteorological records have been kept. Governor Brown signed emergency legislation to fast track more than $1 billion in funding for drought relief and critical water infrastructure projects. Despite record breaking summer heat, Californians continued to meet and surpass the Governor's 25 percent water conservation mandate, with a 31.3 percent reduction in July.[179]

Rain and snow levels in 2016 improved, but not enough to draw the state out of the drought. Moisture deficits across the state following the 2012-2016 drought had not been seen in the last 1,200 years and precipitated a 1 in 500 year low in the Sierra snowpack.[180] Fortunately, 2017 brought significant precipitation and the Governor ended the drought state of emergency on April 7, 2017 for all counties except Fresno, Kings, Tulare, and Tuolumne. Though the emergency declaration is over, water reporting requirements and prohibitions on wasteful practices such as hosing off sidewalks, and irrigating turf in public street medians remain in effect for all Californians. [181]

Although the severely dry conditions that afflicted much of the state starting in the winter of 2011-2012 are gone, damage from the drought will linger for years in many areas. The drought reduced farm production in some regions, killed an estimated 100 million trees, harmed wildlife and disrupted drinking water supplies for many rural communities.

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[177] San Francisco Public Utilities Commission, Water *Resources Division Annual Report Fiscal Year 2014-15,* accessed https://sfwater.org/modules/showdocument.aspx?documentid=8207
San Francisco Public Utilities Commission, Water *Resources Division Annual Report Fiscal Year 2015-16,* accessed https://sfwater.org/Modules/ShowDocument.aspx?documentid=9999
[179] California Governor's Office of Emergency Services, *2018 California State Hazard Mitigation Plan,* accessed http://www.caloes.ca.gov/for-individuals-families/hazard-mitigation-planning/state-hazard-mitigation-plan
[180] California National Resources Agency. California's Fourth Climate Change Assessment: San Francisco Bay Area Region Report. Retrieved from: http://www.climateassessment.ca.gov/regions/docs/20180827-SanFranciscoBayArea.pdf (Accessed: 9/10/2018)
[181] ibid

Location

Drought is not localized to San Francisco, but occurs simultaneously across the region, and may extend statewide or across a larger expanse of western states.[182] The majority of San Francisco's water is brought to the city from the Hetch Hetchy watershed located in the Sierra Nevada Mountains through a complex series of reservoirs, tunnels, pipelines, and treatment systems.[183] As a result, shortages in precipitation in the Sierra Nevada impacts the water supply in the Bay Area. Because so much of the city's water is generated from outside of the City, drought must be considered a regional hazard that is not confined to a single geographic area.

Severity and Probability of Future Events

Drought is difficult to measure due to its diverse geographical and temporal nature and its operation on many scales. Despite that difficulty, various indices for measuring and characterizing drought can be useful. The most commonly used are the Palmer Drought Indices (Palmer Z Index, Palmer Drought Severity Index, and Palmer Hydrological Drought Index) and the Standardized Precipitation Index. For example, the Palmer Index shows that San Francisco's climate division, the central coastal zone that extends south to San Luis Obispo, experienced severe drought conditions in April 2013 and had improved to near normal by April 2018 following two years of healthy precipitation. Despite the improved precipitation conditions in 2017 and 2018, it is unknown how long such a period may last or when another drought event may begin.

A significant body of climate research indicates that extended periods of drought followed by increased precipitation are more likely to occur in the future. A recent UCLA study indicates that such dry-to-wet precipitation events are projected to increase over the next century.[184] Long-term climate forecast models suggest that a warming planet will lead to changes in precipitation distribution, including a reduced Sierra snowpack and earlier melting of the snowpack.[185] With projected drier conditions and increasing

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[182] Association of Bay Area Governments, *San Francisco Bay Area Risk Profile 2017*, accessed http://resilience.abag.ca.gov/wpcontent/documents/mitigation_adaptation/RiskProfile_4_26_2017_optimized.pdf
[183] San Francisco Public Utilities Commission, "About Us: Overview", accessed September 28, 2018, https://sfwater.org/index.aspx?page=355
[184] Daniel Swain et.al, "Increasing Precipitation Volatility in Twenty-First-Century California", *Nature Climate* Change accessed September 28, 2018, https://www.nature.com/articles/s41558-018-0140-y
[185] Reich, KD, N Berg, DB Walton, M Schwartz, F Sun, X Huang, and A Hall, 2018: "Climate Change in the Sierra Nevada: California's Water Future." UCLA Center for Climate Science.

population, managing drought and water supplies in California may become more challenging.

According to the U.S. Drought monitor, as of March 17th 2020, 27.8% of the state is experiencing DO (abnormally dry conditions) with 46.3% of the state experiencing D1 (moderate drought conditions).[186] The overall outlook is "Drought development likely" in the short term for the San Francisco area and much of northern/central California, as forecasted precipitation is not likely to make up for current deficits.[187] Part of the San Francisco Bay Area and Sierra Nevada are in a "Drought persists" condition.

It can be difficult to determine exact probabilities of future droughts due to their nature, but studies have shown, while natural variability in precipitation is the primary driver for droughts, anthropogenic warming (as detailed in the extreme heat hazard section) is likely to increase the likelihood of extreme droughts in California.[188] It has also been found that when precipitation deficits occur at the same time as warm conditions, as is increasingly likely, drought occurrence is twice as likely.[189]

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[186] United States Drought Monitor, Accessed: 3/23/2020, retrieved from: https://www.drought.gov/drought/states/california

[187] National Weather Service: Climate Prediction Center. *U.S. Monthly Drought Outlook: Valid for March 2020.* Accessed: 3/23/2020. Retrieved from: https://www.cpc.ncep.noaa.gov/products/expert_assessment/mdo_summary.php

[188] Williams AP, Seager R, Abatzoglou JT, Vook BI, Smerdon JE, Cook ER. (2015). *Contribution of Anthropogenic Warming to California Drought During 2012-2014*. Retrieved from: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015GL064924

[189] Diffenbaugh NS, Swain DL, and Touma D. (2015) *Anthropogenic warming has increased drought risk in California*. Retrieved from: https://www.pnas.org/content/112/13/3931

Wildfire Hazard Profile

4.9 Wildfire

Impact Statement

Within San Francisco, a small portion of the Crocker Amazon neighborhood has been designated as a high fire hazard area. Moderate fire hazard areas in the city designated by the state include wooded areas such as Mounts Sutro and Davidson, as well as Yerba Buena Island. Significant portions of the Hetch Hetchy Regional Water System in San Mateo, Santa Clara, and Tuolumne Counties are also located in state-designated very high fire hazard areas. Though the probability of wildfires or wildland-urban interface fires within San Francisco is low, it remains high for areas outside the county where city-owned infrastructure is located. Global warming and lower precipitation rates due to climate change are expected to increase the risk of damaging fires in Northern California.

Nature

A wildfire is an unplanned, uncontrolled fire in an area of combustive vegetation or fuel.[190] Wildfires typically occur in forests or other areas with ample vegetation. Relatedly, Wildland-urban interface (WUI) fires are wildfires that spread into communities.[191] The WUI is an area where houses meet or are interspersed with undeveloped wildland vegetation.[192] In these areas, wildfires can cause significant property damage and may present an extreme threat to public health and safety.[193] Both wildfires and WUI fires can be caused by human activities, such as arson, campfires, or trees being blown into power lines, and by natural events such as lightning strikes.[194]

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[190] Judith R. Phillips, "Natural Disasters: On Wildfires and Long-Term Recovery of Community-Residing Adults," in *Traumatic Stress and Long-Term Recovery: Coping with Disasters and Other Negative Life Events*, Katie E. Cherry ed. (Switzerland: Springer International Publishing, 2015), 25.

[191] Samuel L. Manzello and Stephen L. Quarles, *Summary of Workshop on Structure Ignition in Wildland-Urban Interface (WUI) Fires*, National Institute of Standards and Technology (NIST) Special Publication 1198 (2015), 1, accessed May 30, 2018, https://nvlpubs.nist.gov/ nistpubs/SpecialPublications/NIST.SP.1198.pdf.

[192] V. C. Radeloff, et al., "The Wildland-Urban Interface in the United States," *Ecological Applications* 15, no. 3 (2005), 799, accessed May 30, 2018, https://www.nrs.fs.fed.us/pubs/jrnl/2005/nc_2005_radeloff_001.pdf.

[193] U.S. Department of Agriculture (USDA), *The 2010 Wildland-Urban Interface of the Conterminous United States*, Abstract, accessed May 31, 2018, https://www.fs.fed.us/nrs/pubs/rmap/rmap_nrs8.pdf.

[194] William M. Kramer, *Disaster Planning and Control* (Tulsa: PennWell Fire Engineering Books, 2009), 142.

The following three factors contribute significantly to wildfire behavior and can be used to identify wildfire or WUI fire hazard areas:[195]

- **Topography**: Topography is the shape of land, including its elevation or height above sea level; slope, or the steepness of the area; aspect, the direction a slope faces; and features such as canyons, valleys, and rivers. Topographical features can help or hinder the spread of fire. For example, the steeper a slope, the faster fire will travel up the slope. South-facing slopes are also subject to more solar radiation, making them drier and thus intensify wildfire behavior.

- **Fuel**: Fuels are combustible materials. The composition of vegetation or other fuel in the area, including moisture level, chemical makeup, and density, determines its degree of flammability. Dense or overgrown vegetation increases the amount of fuel for the fire. The ratio of living to dead plant matter is also important. Accelerated plant growth during rainy winter seasons can become particularly dried out during summer dry months contributing to fire risks as autumn winds fan small spot fires into potentially large firestorms[196]. The risk of fire increases significantly during periods of prolonged drought, as the moisture content of both living and dead plant matter decreases, where a disease or infestation has caused widespread damage, or where anthropogenic forest management practices have allowed fuel to build up.

- **Weather**: Weather Characteristics such as temperature, humidity, wind, and lightning impact the probability of ignition and spread of fire. Extreme weather, such as high temperatures and low humidity, can lead to extreme wildfire activity. In contrast, cooling and higher humidity often mean reduced wildfire occurrence and easier containment.

Even small fires can cause significant property damage and casualties. This is especially true in WUI areas where structures and other human development abut or intermingle with wildland vegetation and may also become fuel. The indirect effects of wildfires can

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[195] California Department of Forestry and Fire Protection (CAL FIRE) et al., *Living with Wildfire in Northwestern California*, 2nd ed. (2017), 13, accessed May 21, 2018, http://www.fire.ca.gov/HUU/downloads/Living_w-Wildfire_NW_CAL_April2017.pdf; National Park Service, "Wildland Fire - Learning In Depth: Wildland Fire Behavior," accessed May 31, 2018, https://www.nps.gov/articles/wildland-fire-behavior.htm.

[196] California National Resources Agency. California's Fourth Climate Change Assessment: San Francisco Bay Area Region Report. Retrieved from: http://www.climateassessment.ca.gov/regions/docs/20180827-SanFranciscoBayArea.pdf (Accessed: 9/10/2018)

also be disastrous. Besides stripping the land of vegetation and destroying forest resources, large, intense fires can harm the soil, waterways, and the land itself. Soil exposed to intense heat may lose its ability to absorb moisture and support life. Exposed soils erode quickly and enhance siltation of rivers and streams, which in turn enhances flood potential, harms aquatic life, and degrades water quality. In addition, because fires strip property of vegetation and root systems that normally retain soil, they increase a community's susceptibility to landslides and debris flows.[197]

History

The California Department of Forestry and Fire Protection (CAL FIRE) has no record of any wildfires or WUI fires occurring within San Francisco from 1943 through 2016, the period during which the agency has maintained statistics.[198] Given that San Francisco is a highly-urbanized area, CAL FIRE has also characterized the city as a low vegetative fuels hazard area.[199] However, wildfire and WUI fire do pose a risk for city-owned assets outside San Francisco's limits.

The Rim Fire, which began on August 17, 2013, in Tuolumne County, burned over 257,000 acres and threatened the Hetch Hetchy Regional Water System, which provides approximately 85 percent of San Francisco's total water needs. Though the Rim Fire reached the edges of the Hetch Hetchy Reservoir watershed, it did not impact water quality or water delivery operations. However, as of June 2017, the San Francisco Public Utilities Commission reported cumulative total expenses of approximately $23.8 million for facilities and infrastructure damage and costs related to emergency response due to Rim Fire damage.[200]

The City and County of San Francisco declared a local emergency due to the Rim Fire on August 22, 2013. The Governor of California issued a state emergency proclamation for the fire on the same day, and on August 23, 2013, submitted a request for a federal fire

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[197] Daniel G. Neary, Kevin C. Ryan, Leonard F. DeBano, eds., *Wildland Fire in Ecosystems: Effects of Fire on Soil and Water*, General Technical Report RMRS-GTR-42, vol. 4 (Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 2008) 51, 105, accessed May 31, 2018, https://www.fs.fed.us/rm/pubs/ rmrs_gtr042_4.pdf.

[198] See Cal FIRE, "Historical Wildfire Activity Statistics," accessed May 30, 2018, http://www.fire.ca.gov/ fire_protection/fire_protection_fire_info_redbooks.

[199] Cal FIRE Fire and Resource Assessment Program, "Characterizing the Fire Threat to Wildland-Urban Interface Areas in California," 4, accessed May 30, 2018, https://frap.fire.ca.gov/projects/wui/525_CA_wui_analysis.pdf.

[200] KPMG, "San Francisco Water Enterprise and Hetch Hetchy Water and Power: Statement of Changes in the Balancing Account, June 30, 2017," 18, accessed May 31, 2018, https://sfwater.org/modules/showdocument.aspx? documentid=12148.

management assistance declaration. A Fire Management Assistance declaration, FEMA-5049-FM, was issued on the same day, making FEMA funding available to reimburse up to 75 percent of the eligible firefighting costs for managing, mitigating, and controlling the fire. On December 13, 2013, the President of the United States issued Major Disaster Declaration DR-4158 for the Rim Fire, making it possible to obtain federal Public Assistance for repairs or replacement of damaged public facilities, and to undertake hazard mitigation projects to reduce the long-term risk to life and property from future fires.[201] To date, approximately $23 million in Public Assistance grants have been made available to the state for the Rim Fire. Almost $18 million has been made available for emergency work; $3.6 million has been made available for permanent work.[202]

Wildfires and WUI fires need not occur within San Francisco to impact our jurisdiction. In early October 2017, smoke from wildfires and WUI fires in Napa, Sonoma, and Solano Counties in Northern California converged over San Francisco and other Bay Area counties. These fires introduced levels of particulate matter pollution that the Bay Area Air Quality Management District (BAAQMD) indicated were unprecedented for the Bay Area.[203] As a result, from October 9th through 18th, the BAAQMD issued a number of health advisories and "Spare the Air Alerts" urging residents and visitors to limit outdoor activities and reduce exposure to smoke by remaining inside with windows closed.[204] The poor air quality, coupled with high temperatures in the city, prompted San Francisco's officials to make a number of public libraries available as filtered-air sites for residents and visitors,[205] and to activate the city's Emergency Operations Center from October 9 to 14, 2017.[206] A 2018 survey of local air quality managers identified wildfires

[201] FEMA, Federal Aid Programs for the State of California, HQ-13-127 Factsheet (2013), accessed May 31, 2018, https://www.fema.gov/news-release/2013/12/13/federal-aid-programs-state-california-declaration.

[202] FEMA, California Rim Fire (DR-4158), accessed May 31, 2018, https://www.fema.gov/disaster/4158.

[203] Bay Area Air Quality Management District (BAAQMD), "Health Advisory, Spare the Air Alert," October 10, 2017, accessed June 4, 2018, http://www.baaqmd.gov/~/media/files/communications-and-outreach/publications/news-releases/2017/2017_092_staalert_healthadvisory_101017-pdf.pdf?la=en.

[204] See, e.g., BAAQMD, "Smoke Advisory," October 9, 2017, accessed June 4, 2018, http://www.baaqmd.gov/~/ media/files/communications-and-outreach/publications/news-releases/2017/smoke_171009-pdf.pdf?la=en; "Health Advisory, Spare the Air Alert," October 10, 2017, accessed June 4, 2018, http://www.baaqmd.gov/~/ media/files/communications-and-outreach/publications/news-releases/2017/2017_092_staalert_healthadvisory_ 101017-pdf.pdf?la=en.

[205] See San Francisco Department of Public Health, "Public Health Advisory," October 9, 2017, accessed June 4, 2018, https://sfdem.org/article/public-health-advisory.

[206] San Francisco Department of Emergency Management, *City and County of San Francisco Department of Emergency Management 2017 Annual Report*, 11, accessed June 4, 2018, https://sfdem.org/sites/default/files/ DEM_2017_Annual_Report.pdf.

as the number one environmental event impacting air quality of districts' across the state[207]

Additionally, while voluntary, the regional mutual aid policy that the City has with surrounding counties means that even fires occurring outside of San Francisco proper has implications for our department's resource utilization. Mutual aid is intended to ensure that adequate resources, facilities, and other emergency support are provided to jurisdictions whenever their own resources prove to be inadequate to cope with a given situation at no charge to the receiving jurisdiction[208]. On July 23rd, the Carr Fire began in Shasta and Trinity County. Before being contained on August 30th it burned over 229,651 acres of wildland, caused the evacuation of 38,000 people, and required support from nearly every bay area county (including San Francisco) in the form of equipment and personal.[209]

Location

In 2007, pursuant to state law, CAL FIRE adopted Fire Hazard Severity Zone FHSZ maps for State Responsibility Areas (SRAs), the areas in California where the state is financially responsible for the prevention and suppression of wildfires. The maps use a fuel ranking assessment methodology that assigns a rank—moderate, high, or very high—based on expected fire behavior for unique combinations of topography and vegetative fuels under a given severe weather condition, including wind speed, humidity, and temperature.[210] CAL FIRE also has developed FHSZ maps for Local Responsibility Areas (LRAs) within California. LRAs include incorporated cities such as San Francisco, where fire protection is typically provided by a city fire department. The LRA fire hazard zone maps developed by CAL FIRE use an extension of the SRA FHSZ model, which reflects flame and ember intrusion from adjacent wildlands and from flammable vegetation in urban areas.[211]

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[207] Julia A. Ekstrom & Louise Bedsworth (2018) Adapting air quality management for a changing climate: Survey of local districts in California, Journal of the Air & Waste Management Association, 68:9, 931-944, DOI: 10.1080/10962247.2018.1459325

[208] City and County of San Francisco Emergency Response Plan. ESF#4: Firefighting Annex. Retrieved from: https://sfdem.org/sites/default/files/FileCenter/Documents/25-ESF%204%20-%20Firefighting%20Annex.pdf

[209] San Francisco Examiner: Bay City News. "Bay Area fire departments help battle raging Carr Fire". Retrieved from: http://www.sfexaminer.com/bay-area-fire-departments-help-battle-raging-carr-fire/

[210] CAL FIRE, "Wildland Hazard and Building Codes, Fire Hazard Severity Zone Development," accessed May 31, 2018, http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones_development.

[211] CAL FIRE, "Wildland Hazard and Building Codes, Fire Hazard Severity Zone Maps," accessed May 31, 2018, http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones.

The current CAL FIRE hazard map indicates that San Francisco has no Very High Fire Hazard Severity Zones in its LRA. However, as shown in Figure 4-30, CAL FIRE has designated a small portion of the Crocker Amazon neighborhood as a high fire hazard area. Moderate fire hazard areas include wooded areas near Fort Funston and Lake Merced in the Stonestown District; Stern Grove in the Central Sunset District; Mount Davidson and Glen Canyon Park in the Miraloma and Diamond Heights neighborhoods; the Forrest Knolls and Midtown Terrace neighborhoods; wooded areas of Sutro Heights, Lincoln Park, the Presidio, and Fort Mason; and Bayview Park and Candlestick Point Recreation Area in the Bayview-Hunters Point Districts of San Francisco. Yerba Buena Island has also been designated by CAL FIRE as a moderate fire hazard area.[212]

City-owned infrastructure located outside San Francisco County are also located in areas that are susceptible to wildfire or to WUI fire. Among these facilities are significant portions of the Hetch Hetchy Regional Water System, including the Crystal Springs Reservoir and Watershed in San Mateo County, parts of which are located in or near a very high fire severity zone (VHFSZ); the Moccasin Powerhouse and Reservoir, Priest Reservoir, Kirkwood Powerhouse, Holm Powerhouse, and O'Shaughnessy Dam, in Tuolumne County, all of which are located in a VHFSZ; and the Calaveras Dam located in Alameda County, which is located in a high fire severity zone. For a map showing the Hetch Hetchy Regional Water System and fire severity zones, see Appendix B.

Extent and Probability of Future Events

While it is difficult to attribute an individual fire event to climate change, the risk of wildfires increase due to climate change because of higher temperatures increasing the length of the fire seasons, creating drier fuels, and decreasing forest health.[213] At the local scale, urbanization has a demonstrated influence on WUI fire hazards. As development is sited in previously uninhabited wildlands, more ignition events can be expected to occur. Conversely, as semi-dense areas increase density these areas can actually expect a reduction in the number of fire events. This implies that land use considerations are essential for the city and region as they consider wildland/WUI fire hazards.[214] Figure 4-29, seen below, displays the extent of wildfire hazards in San

[212] CAL FIRE, "Wildland Hazard and Building Codes, San Francisco County FHSZ Map," http://www.fire.ca.gov/fire_prevention/fhsz_maps_sanfrancisco.
[213] California Natural Resources Agency & California Emergency Management Agency. California Adaptation Planning Guide. 2012. Sacramento.
[214] California National Resources Agency. California's Fourth Climate Change Assessment: San Francisco Bay Area Region Report. Retrieved from: http://www.climateassessment.ca.gov/regions/docs/20180827-SanFranciscoBayArea.pdf (Accessed: 9/10/2018)

Francisco. In general, the susceptibility for wildfires dramatically increases in the late summer and early autumn as vegetation dries out, decreasing plant moisture content and increasing the ratio of dead fuel to living fuel. Common causes of wildfires include arson and negligence. Though there is no historical record of a wildfire occurring in San Francisco, the impacts of climate change, including the probable increase in extreme heat days in the future, gives San Francisco a moderate risk of a future wildfire or WUI fire event. The probability of a future wildfire or WUI fire in out-of-county areas where city-owned assets are located is high.

Wildfire activity in California has increased over the past 10 years. This increase has been particularly severe in forested areas of the Sierra Nevada and Coast Ranges of Northern California. Researchers have attributed this increase to warmer spring and summer temperatures; lower precipitation rates; reduced snow pack and earlier snow melts; and longer, drier summer fire seasons in some middle and upper elevation forests. These trends are expected to continue under accepted climate change scenarios, leading to further increases in the risk of large, damaging wildfires in areas where city-owned infrastructure is located.[215]

Figure 4-30 details the wildfire hazard zones in San Francisco. Wildfire severity refers to the likelihood that a given area will burn over a 30 to 50 year period, taking into account the amount of vegetation, the topography and weather (temperature, humidity, and wind).[216] The hazard severity does not consider modifications to the area, such as fuel reduction.

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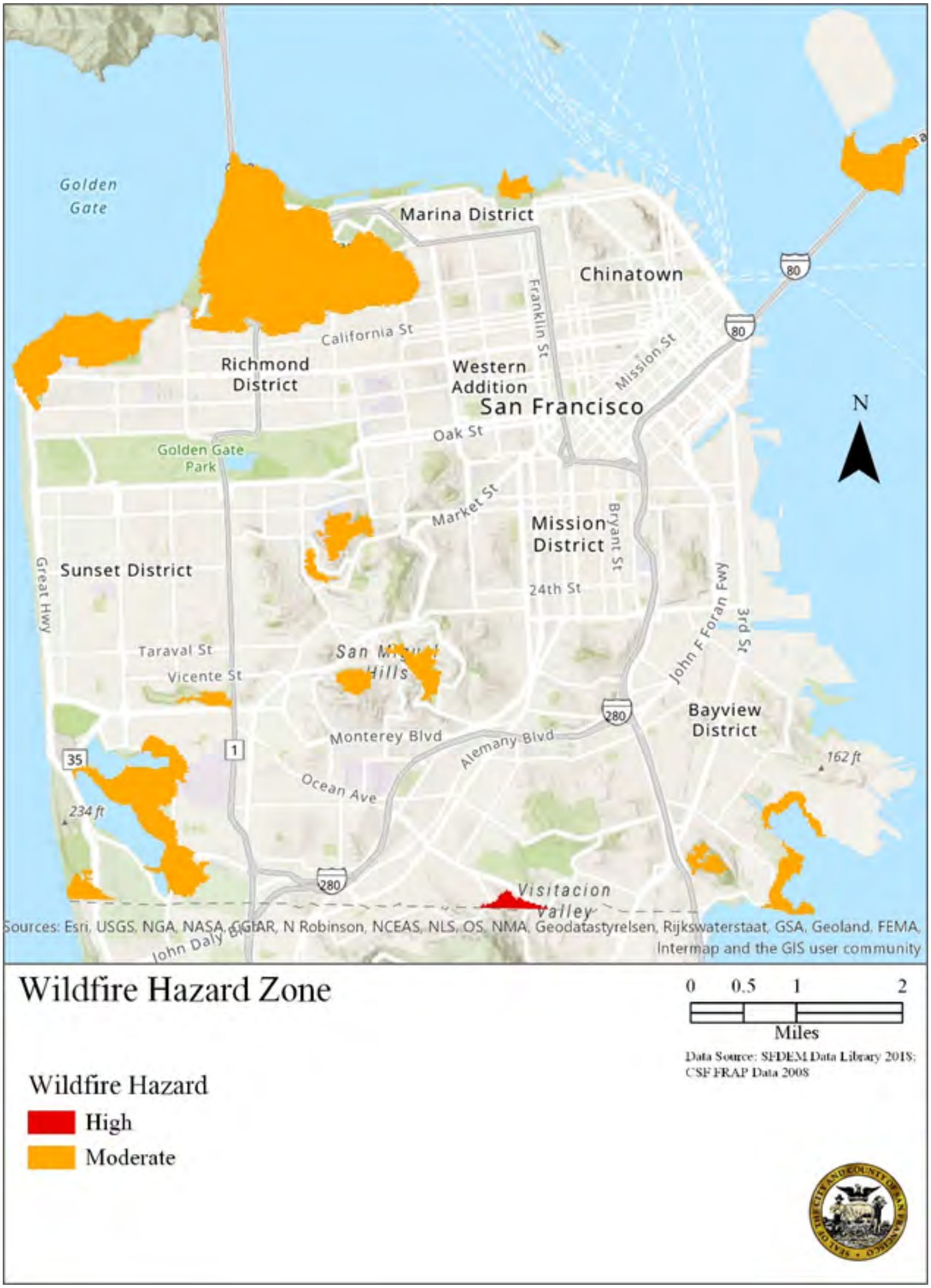
[215] Anthony Westering and Benjamin Bryant, "Climate Change and Wildfire in California," *Climatic Change* 87 (2008), S231-232, accessed June 4, 2018, http://tenaya.ucsd.edu/~westerli/pdffiles/08CC_WesterlingBryant.pdf; see John T. Abatzogloua and A. Park Williams, "Impact of Anthropogenic Climate Change on Wildfire Across Western US Forests," *Proceedings of the National Academy of Sciences* 113, no. 42 (2016), 11770,11775, accessed June 4, 2018, http://www.pnas.org/content/pnas/113/42/.11770.full.pdf.

[216] Cal FIRE, "Fire Hazard Severity Zones Maps," https://osfm.fire.ca.gov/divisions/wildfire-planning-engineering/wildland-hazards-building-codes/fire-hazard-severity-zones-maps/.

FIGURE 4-30
CITY AND COUNTY OF SAN FRANCISCO WILDFIRE HAZARD ZONE



Large Urban Fire Profile

4.10 Large Urban Fire

Impact Statement

Most of San Francisco is believed to have a moderate risk of large urban fires, but areas believed to be at greatest risk include the North Waterfront, South Beach, Mission Bay, Potrero Hill, Hunters Point, Civic Center, Downtown, Tenderloin, and Hayes Valley neighborhoods. The most likely cause of large urban fire in San Francisco is a severe earthquake (fire following earthquake), which has the potential to cause severe damage to buildings and infrastructure. When making decisions about capital projects, maintenance, operations, and investments in the City's fire fighting systems, the San Francisco Fire Department (SFFD), San Francisco Public Utilities Commission (SFPUC), and San Francisco Public Works (SFPW) utilize a model that reflects the fires that could arise after a 7.8 earthquake on the San Andres fault.

Nature

A Large Urban Fire is a large destructive fire that spreads across one or more city streets.[217] If not contained, a Large Urban Fire may expand uncontrollably beyond its original source location to engulf adjoining areas. Conflagrations can have many causes, including:[218]

- As secondary events to disasters such as earthquake (fires following earthquake), tsunami, flooding, and lightning strikes.
- Criminal acts, such as arson, acts of terrorism, or civil unrest;
- Residential accidents, including improper use of electrical and heating appliances, improper storage or handling of flammables, faulty connections, grease fires, misuse of matches and lighters, or improper disposal of charcoal and wood ashes;
- Industrial accidents, such as hazardous material incidents, explosions, and transportation accidents.

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[217] Introduction to *Fire Following Earthquake*, ed. Charles Scawthorn, John M. Eidinger, Anshel Schiff (Reston, VA: American Society of Civil Engineers, 2005), 1.

[218] William M. Kramer, *Disaster Planning and Control* (Tulsa: PennWell Fire Engineering Books, 2009), 138–140.

Fire following earthquake: The process by which an earthquake triggers fires and a community suppresses those fires consists of the following interrelated events[219]:

- Occurrence of the earthquake: earthquake shaking causes damage to buildings and contents, including knocking things over (such as candle or lamps.)
- Ignition: Ignition sources include overturned heat sources, gas-related sources, abrades and shorted electrical wiring, spilled chemicals, and friction of things rubbing together.
- Discovery: In the confusion following an earthquake, discovery may take longer than it would otherwise.
- Report: Communications system dysfunction may delay reports to the Fire Department.
- Response: In the aftermath of a damaging earthquake, the response of the Fire Department may be impeded by other emergencies the firefighters must respond to, such as building collapse.
- Suppression: Numerous factors, including water supply functionality, building construction type, building density, wind and humidity conditions, manpower and equipment deployed affect success of suppression.

History

San Francisco was devastated by six major fires during the California Gold Rush era, from 1849 to 1855.[220] These fires destroyed significant portions of the city, and thus are considered "great fires." The largest fire to affect San Francisco to date occurred as a result of the Great San Francisco Earthquake of 1906. On the morning of April 18, 1906, a Mw 7.8 earthquake shook the San Francisco Bay region. Within two hours of the quake, 52 fires had ignited within San Francisco. The fires quickly spread throughout the northeastern portion of the city, burning an area covering approximately 4.7 square miles, and destroying 80 percent of the 28,000 buildings lost due to the quake. The

[219] Applied Technology Council, 2017. "Study of Options to Reduce Post-Earthquake Fires in San Francisco."
[220] Virtual Museum of the City of San Francisco, "Early History of the San Francisco Fire Department," accessed May 29, http://guardiansofthecity.org/sffd/history/volunteer_department.html.

1906 earthquake severely damaged the city's water system, limiting firefighters' ability to suppress the fires.[221]

Construction of San Francisco's Auxiliary Water Supply System (AWSS), now referred to as the Emergency Firefighting Water System (EFWS), was completed in 1913 with the goal of avoiding such devastation in the aftermath of another earthquake. The city also has developed a Portable Water Supply System (PWSS) as a backup to the EFWS and the Municipal Water Supply System. The PWSS consists of a hose tender, large-diameter hose, portable hydrants, pressure reducing valves, and other fittings, allowing the Fire Department to pump water from San Francisco Bay, from underground cisterns positioned around the city, or from other bodies of water.[222] When making capital project, maintenance, and operational decisions, the SFFD, SFPUC, and SFPW utilize a model that reflects the large urban fire that could arise after a 7.9 earthquake on the San Andres fault. Over the past decade, the city has undertaken a major effort to upgrade the Emergency Firefighting Water System.[223]

Working together, the SFFD, SFPUC, and SFPW have completed the following in the past 8 years:

- 95% completion of the $4.8 billion Water System Improvement Program (WSIP), providing robust seismic upgrades to the pipelines, reservoirs, and infrastructure that supply water to San Francisco and the EFWS (the SFPUC's Regional Water System is the primary source of water for the EFWS);
- Added a larger pipe to increase the speed of re-filling the Twin Peaks EFWS reservoir from the 11-million-gallon Summit Reservoir;
- Connecting the 70-million-gallon South Basin of the University Mound Reservoir to EFWS (expected completion in 2018);
- Replaced the engines and installed remote control capabilities for Seawater pump station #1 to allow for remote operation;

[221] Charles Scawthorn, Thomas D. O'Rourke, and Frank T. Blackburn, "The 1906 San Francisco Earthquake and Fire—Enduring Lessons for Fire Protection and Water Supply," *Earthquake Spectra* 22, no. S2 (2006), S135–S139.
[222] Scawthorn, O'Rourke, and Blackburn, "The 1906 San Francisco Earthquake and Fire—Enduring Lessons for Fire Protection and Water Supply," S150–S151.
[223] San Francisco Public Utilities Commission, "Emergency Firefighting Water System," accessed May 29, 2018, https://sfwater.org/index.aspx?page=467.

- Installation of 30 new cisterns (with 15 of these cisterns installed in the Sunset and Richmond districts);
- Reliability upgrades at the three primary source supplies – Twin Peaks Reservoir, Ashbury Heights Tank, and Jones Street Tank;
- Completion of 6 pipeline and tunnel projects;
- Motorizing critical seismically-reliable valves for remote control, and improving the electronic control system of the valves; and
- Began structural and seismic upgrades of Seawater pump station #2 (expected completion in 2020);
- Began designing the installation of the Potable EFWS to provide high-pressure fire suppression for the Westside of San Francisco;
- Began designing the installation of a pump station at Lake Merced to feed into the Potable EFWS; and
- Began investigating the installation of a seawater pump station at Ocean Beach to serve as a secondary source of water for fire suppression for the Westside.

San Francisco's most recent large urban fire incident occurred as a result of the Loma Prieta earthquake on October 17, 1989. A total of 41 fires were reported in San Francisco following the Loma Prieta earthquake; 27 of the 41 fires occurred within seven hours of the quake.[224] Of the 41 fires, 14 were due to electric wiring and equipment, 11 resulted from gas or electric stoves, and four were caused by water heaters or other gas appliances.[225] The largest fires occurred in the Marina District, resulting in the destruction of four buildings. The Fire Department utilized the fire boat Phoenix and the PWSS to prevent the Marina fire from becoming a conflagration. The Fire Department also relied on the AWSS to fight the Marina District fires, but water main breaks in the system several miles from the fires impaired its functionality.[226] The

[224] Jamshid Mohammed, Sam Alyasin, D. N. Bak, *Investigation of Cause and Effects of Fires Following the Loma Prieta Earthquake*, National Science Foundation Report IIT-CE-92-01 (1992), 4, 19, accessed May 29, 2018, https://nehrpsearch.nist.gov/static/files/NSF/PB93120046.pdf

[225] Ibid.

[226] Scawthorn, Eidinger, and Schiff, eds., *Fire Following Earthquake*, 29–31.

Fire Department reported fire losses due to the earthquake of over $10 million,[227] or $19.1 million in 2018 dollars.

Table 4-30 below shows the number of actual working fires and greater alarms that the San Francisco Fire Department has responded from 2008 through 2017. During this 10-year period, there were four five-alarm fires, and 16 four-alarm fires.

TABLE 4-30: SAN FRANCISCO WORKING FIRES AND GREATER ALARMS, 2008-2017[228]

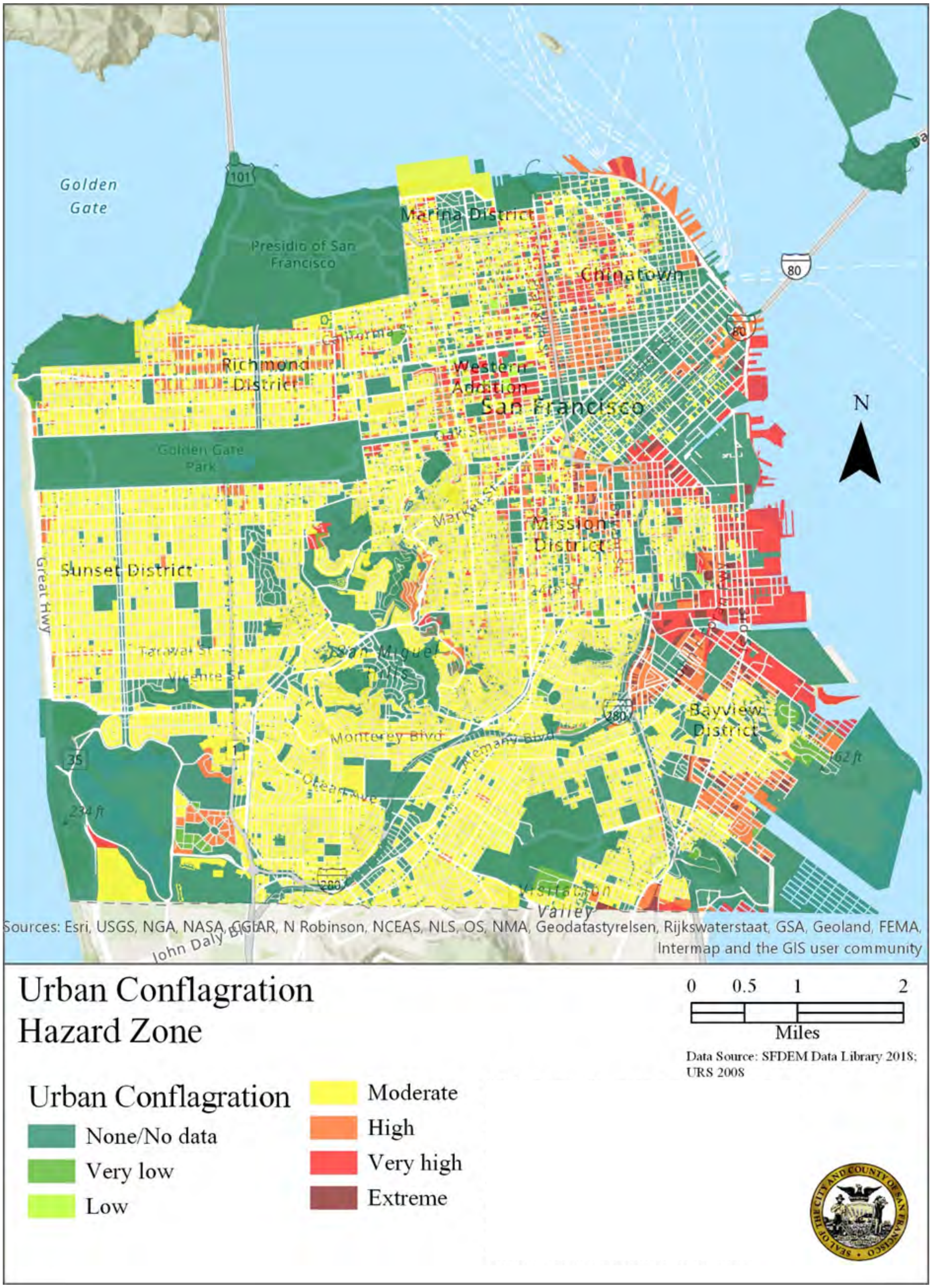
YEAR	Alarm Level 1	Alarm Level 2	Alarm Level 3	Alarm Level 4	Alarm Level 5	TOTAL
2008	278	24	4	1		**307**
2009	213	13	8	1		**235**
2010	208	14	2	1		**225**
2011	217	20	6	2	1	**246**
2012	166	27	4	6		**231**
2013	216	21	6	1		**244**
2014	188	12	7		2	**209**
2015	164	20	4	2		**190**
2016	155	13	3	1	1	**173**
2017	157	20	1	1		**179**

[227] Virtual Museum of the City of San Francisco, "Report on the Operations of the San Francisco Fire Department Following the Earthquake and Fire of October 17, 1989," Introduction, accessed May 29, 2018, http://www.sfmuseum.net/quake/report.html.
[228] San Francisco Fire Department 2018

Location

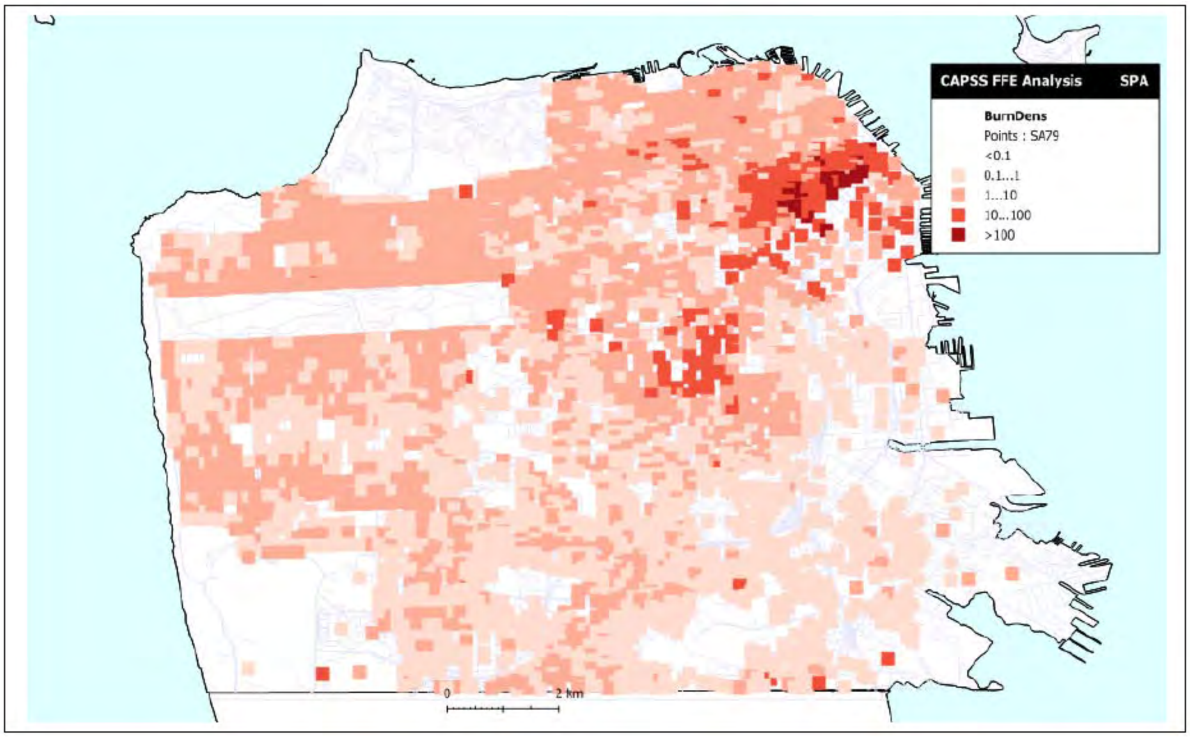
Figure 4-31, seen below, shows large urban fire hazard areas for all parts of the city for which Assessor parcel data is available. This model considers building construction material, land use, and structural age. For construction material, wood frame structures were assumed to be more vulnerable to conflagration than other structure types. Similarly, commercial and industrial land uses were calculated as a higher risk of large urban fires. Finally, older structures were assumed to have a high conflagration risk, as they pre-date modern fire codes. Areas within San Francisco believed to be at greatest risk for large urban fire include the North Waterfront, South Beach, Mission Bay, Potrero Hill, Hunters Point, Civic Center, Downtown, Tenderloin, and Hayes Valley neighborhoods.

FIGURE 4-31
LARGE URBAN FIRE HAZARD ZONES



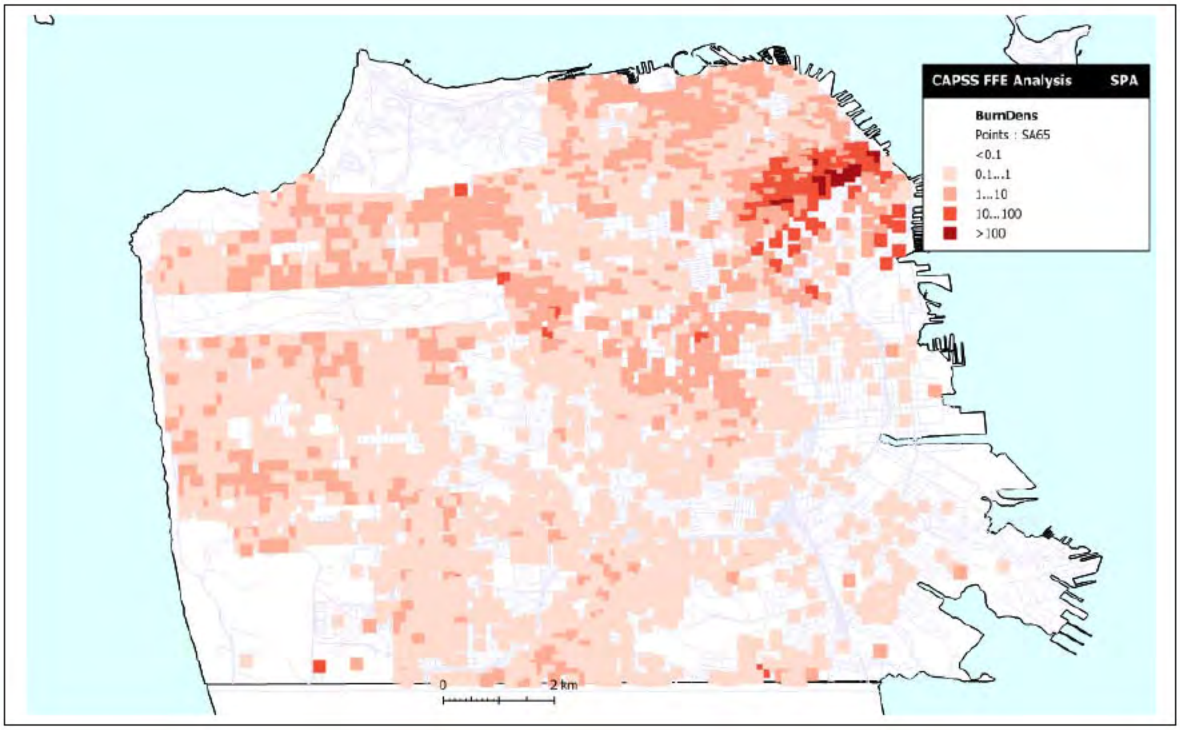
Fire following earthquake: In 2010, the Community Action Plan for Seismic Safety (CAPSS) Program produced a detailed study of the scope of the city's fire following earthquake hazard and risk. Figures 4-32 and 4-33 illustrate the geographic distribution of potential building losses (in 2010 dollars) due to fire following earthquake.

FIGURE 4-32: DISTRIBUTION OF BURN DENSITY PER BLOCK (MILLIONS $) IN 7.9 SAN ANDREAS SCENARIO[229]



[229] Scawthorn, 2010. "Analysis of Fire Following Earthquake Potential for San Francisco, California."

FIGURE 4-33: DISTRIBUTION OF BURN DENSITY PER BLOCK (MILLIONS $) IN 6.9 HAYWARD FAULT SCENARIO[230]



Severity and Probability of Future Events

Given the 72 percent chance of a magnitude 6.7 or greater earthquake in the San Francisco Bay Area between 2014 and 2044,[231] the most likely scenario leading to large urban fire in San Francisco is a severe earthquake in the Bay Area, particularly on the North San Andreas Fault zone. Because San Francisco's building stock is composed predominantly of wood, the fires resulting from such earthquakes may cause far more damage. Based on a detailed study of the scope of the city's fire following earthquake risk, an estimated 68-120 ignitions may occur in a 7.9 earthquake on the San Andreas fault resulting in an estimated $4.1 - $10.3 billion in losses. An estimated 27-68 ignitions may occur due to a 6.9 earthquake on the Hayward fault, resulting in an estimated $1.3 - $4.0 billion in damages.[232]

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[230] Ibid

[231] Edward H. Field and 2014 Working Group on California Earthquake Probabilities (WGCEP), *UCERF3: A New Earthquake Forecast for California's Complex Fault System,* Fact Sheet 2015–3009 (2015), 4, accessed May 18, 2018, https://dx.doi.org/10.3133/fs20153009.

[232] Applied Technology Council, 2017. "Study of Options to Reduce Post-Earthquake Fires in San Francisco."

Based on the working fire and greater alarm statistics set forth in Table 5-9 above, during the ten-year period from 2008 through 2017, the San Francisco Fire Department responded to an average of 224 actual working fires per year. During this same period, there were approximately four single-alarm fires every week. Larger fires—two-alarms or greater—occurred an average of 25 times annually. It is also noteworthy that the total number of actual working fires has steadily fallen from 307 in 2008 to 179 in 2017, a decrease of 42 percent.

For discussion of wildfire and wildland-urban interface fires, see the Wildfire Hazard Profile.

High Wind Profile

4.11 High Wind

Impact Statement

Although San Francisco experiences winds throughout summer, especially in the afternoon and early evening, the most disruptive "high winds" occur either with strong storms in the winter or spring, or in late fall as part of the warm "Diablo winds". Storm-related wind can down trees or power lines and contribute to electrical outages. When these storm-related winds hit 100mph along the coast or at higher elevations, they may become hazardous, especially for big rig trucks on bridges. The "Diablo winds" can stoke fires in nearby counties and transport smoke to San Francisco. Winds year-round can transport pollens and contribute to allergies.

Nature

Winds are horizontal flows of air that blow from areas of high pressure to areas of low pressure. Wind strength depends on the difference in pressure between the high- and low-pressure systems and the distance between them. A steep pressure gradient results from a large pressure difference or short distance between these systems, causing high winds.

The National Weather Service (NWS) defines "high winds" as sustained wind speeds of 40 miles per hour (mph) or greater lasting for one hour or longer, or winds of 58 mph or greater for any duration. The NWS issues a wind advisory when there are sustained winds of 25 to 39 mph, or gusts to 57 mph. A wind storm is an incident exceeding those values as measured by weather observation equipment, or as indicated by damage consistent with such wind speeds.

During the summer months in San Francisco, temperature and pressure differences between the Pacific Ocean and the interior valleys of California create strong afternoon and evening sea breezes. These westerly winds flow across the Golden Gate and through breaks in the high terrain of the Coast Range, often reaching afternoon speeds of between 20 and 30 mph. Normally, San Francisco's hilly terrain breaks up strong winds, but occasionally strong storms with significant wind gusts halt normal activity in the city, and cause widespread power line damage and electrical outages due to toppled trees and broken limbs.

In addition, the typical summer weather pattern of cooler, more humid air flowing in an easterly direction from the ocean to inland areas reverses. These hot, dry offshore winds from the northeast, which typically occur in the Bay Area during the spring and fall, are known as "Diablo winds." Diablo winds can be quite strong, with gusts up to 40 mph. Diablo winds are most common in the fall when the jet stream dips farther south, and alternating areas of high and low pressure affect California. Fall is also the time of year when wildlands and the urban-wildland interface are particularly dry. Dry land cover, when combined with hot dry Diablo winds, may result in high fire danger. This was the meteorological scenario leading to the Oakland Hills firestorm in October 1991 and the North Bay fires in 2017.

History

In San Francisco, high winds associated with cyclonic systems and their cold fronts occur in the winter, generally between the months of November through March (refer to Table 4-34). On average, there have been 1.2 wind storm events per year. Data from the Golden Gate Weather Service on some of the larger, more recent, high wind storm events in San Francisco is presented in Table 4-35 below. NOAA's National Climatic Data Center has recorded 83 significant wind storm incidents in the San Francisco region from 1948 through 2017 as measured by wind gusts above 58 mph.[233] During these events winds predominantly blew from the south and west (refer to Table 4-36).

TABLE 4-34
HIGH WIND EVENTS BY MONTH, 1948-2017[234]

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Count of Events	16	14	6	7	3	4	0	0	0	5	8	20
Pct. of Events	19%	17%	7%	8%	4%	5%	0%	0%	0%	6%	10%	24%

[233] These events were observed at NOAA's San Francisco International Airport Station. Wind data from San Francisco proper was not available.
[234] Based on observations from San Francisco International Airport Station
Source: National Centers for Environmental Information, NOAA. 2018. Accessed June 15, 2018

TABLE 4-35
SELECT HIGH-WIND EVENTS[235]

	Dec. 22, 1955	Oct. 12, 1962	Mar. 31, 1982	Dec. 22, 1982	Dec. 12, 1995	Dec. 16, 2002	Jan. 4, 2008	Oct. 13, 2009	Jan. 8, 2017
San Francisco 24-Hour Rain Total	2.57"	3.11"	2.57"	2.00"	3.27"	2.07"	2.01"	2.48"	1.62”
SFO Maximum Sustained Wind	42 mph	43 mph	47 mph	47 mph	54 mph	43 mph	53 mph	41 mph	44 mph
Peak Bay Area Wind	90 mph	86 mph	81 mph	100 mph	103 mph	91 mph	87 mph	77 mph	77 mph

TABLE 4-36
HIGH WIND EVENTS BY WIND DIRECTION, 1948-2017[236]

Wind Direction (degrees)	Northerly-north to south (316-365, 0-45)	Easterly-east to west (46-135)	Southerly-south to north (136-225)	Westerly-west to east (226-315)
Count of Events	0	1	58	22
Percentage	0%	1%	70%	27%

Location

235 Golden Gate Weather Services, Bay Area Storm Index [http://ggweather.com/basi_archive.htm]
236 Based on observations from San Francisco International Airport Station
Source: National Centers For Environmental Information, NOAA. 2018. Accessed June 15, 2018

San Francisco as a whole is subject to strong southeasterly winds associated with powerful winter cold fronts. However, strong sea winds from the Pacific Ocean generally have a greater impact on the west side of San Francisco. Each year, at least one winter storm typically results in closure of the Great Highway, when wind gusts deposit large amounts of sand on the roadway. The Great Highway runs along the Pacific Ocean on the western boundary of San Francisco through the Outer Sunset and Outer Richmond Districts.

Severity and Probability of Future Events

Storms combining strong winds with heavy rain have the largest impact on San Francisco during the winter months. Wind gusts of 40 mph have the potential to bring down trees and branches and to trigger power outages leaving thousands of people without electricity. Based on previous wind events, San Francisco can continue to expect to experience at least one winter wind storm annually.

Sustained winds of more than 50 mph have been recorded in San Francisco during various Pacific Storms. During isolated storm incidents, gusts may peak at more than 100 mph along the coast and at higher elevations. In such conditions, Bay Area bridges become hazardous, especially for big rig trucks that may overturn on bridges during high wind events.

Climate change is expected to modify San Francisco's wind, the extreme storms that generate the most severe winds, and the impact of wind on San Francisco. While climate scientists project climate change to generally reduce wind in the United States, the pineapple-express extreme storms that generate the most severe wind in the San Francisco Bay Area are expected to increase in both frequency and severity[237]. Similarly, there is some evidence that climate change will lengthen the "Diablo winds" fire season[238]. Additionally, drought-like conditions may impact San Francisco's urban forest and make trees more vulnerable to winds.

[237]Kristopher Karnauskas, Julie Lundquist, and Lei Zhang (2018) Southward shift of the global wind energy resource under high carbon dioxide emissions. *Nature Geoscience, 11,* 38-43.
[238] Henry Fountain, "California winds are fueling fires, It may be getting worse", *New York Times,* accessed October 11, 2017, https://www.nytimes.com/2017/10/11/climate/caifornia-fires-wind.html.

Poor Air Quality Profile

4.12 Poor Air Quality

Impact Statement

Air quality is closely associated with public health. Exposure to pollutants increases rates of allergies, bronchitis, asthma attacks and other respiratory illnesses, heart disease and other cardiovascular illnesses, and is an environmental risk factor connected to premature birth and low birth weight, mental health conditions, and many cancers. Although all together San Francisco enjoys clean air relative to other urban areas in the country, current air pollution is not evenly distributed. In San Francisco, air pollution is influenced by proximity to freeways and other high-density arterials, industrial activity, and maritime activity. San Francisco is also vulnerable to air quality impacts of wildfires. Although it is unlikely a wildfire occurs within San Francisco's city limits, smoke from wildfires elsewhere may be transported into the City and significantly impact San Francisco's air quality.

Nature

The Air Quality Index (AQI) measures air quality for the five pollutants regulated by the Clean Air Act: ground-level ozone, particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide[239].

- **Ground-level ozone** is created through a chemical reaction between sunlight, nitrogen oxide, and volatile organic compounds (VOCs), which are chemicals emitted from cleaning supplies, glues, paints, pesticides, and other household materials. Ground-level ozone is the main ingredient of smog.
- **Particulate matter (PM)** includes vehicle emissions and other fuel combustion, smoke from fireplaces or wildfires, dust, molds, and pollens. Particulate matter is organized by size, as emissions tend to be fine PM (<2.5 micrometers in diameter), while dusts, molds, and pollens tend to be coarse (<10 micrometers in diameter).
- **Carbon monoxide** is an odorless gas byproduct of combustion and is released by the burning of gasoline, kerosene, oil, propane, coal, and wood.

[239] https://airnow.gov/index.cfm?action=aqibasics.aqi

- **Sulfur dioxide** is a gas byproduct of industrial activities that involve the burning of materials that contain sulfur such as coal, oil, and gas. Sources of sulfur dioxide include power plants and other industrial activities.
- **Nitrogen dioxide** is another byproduct of the burning of fossil fuels and is largely emitted from cars, trucks, and power plants.

The AQI provides each pollutant a score 0 – 500. A score of 100 approximates the federally set EPA National Ambient Air Quality Standards (NAAQS). The AQI is presented as the highest score of the 5 pollutants. San Francisco generally enjoys good air quality as a dependable ocean breeze regularly dissipates pollution. However, when coastal high-pressure systems or inversion layers trap pollutants, San Francisco can experience short-term spikes in AQI.

History

According to data supplied by the Bay Area Air Quality Management District (BAAQMD), San Francisco enjoys good air quality a majority of the year, with AQI rarely above national standards. This data can be found in Table 4-37 below. Because there is only one air quality station in San Francisco, AQI measurements do not take into account AQI variation throughout the City, and homes adjacent to high-density arterials, industrial uses, or maritime uses may have AQIs significantly higher than those reported below.

In 2018, a wildfire in Butte County coincided with the westward “Diablo Winds” and funneled wildfire smoke south and west through the delta into the San Francisco Bay. A high-pressure system off the coast blocked San Francisco’s normal ocean breezes and trapped the wildfire smoke in the Bay Area. San Francisco’s AQI was over 150 for 12 straight days, peaking at 228. This wildfire smoke emergency caused significant disruption as schools were canceled. It is likely that the wildfire smoke emergency impacts were not evenly distributed as residents with access to air filtration were less exposed to wildfire smoke.

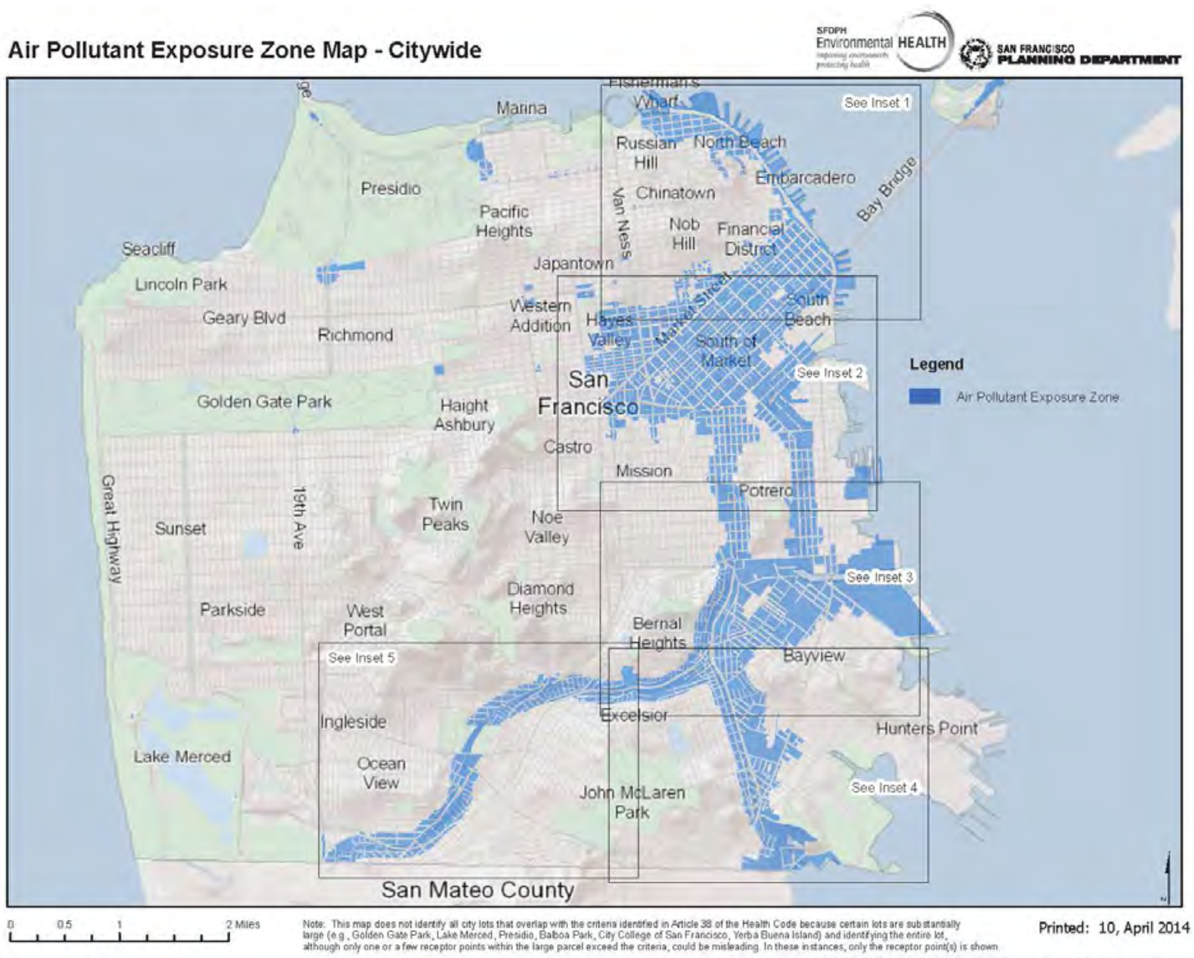
TABLE 4-37
SAN FRANCISCO AIR QUALITY INDEX (AQI)

San Francisco	Total Days	Good	Moderate	Unhealthy for Certain Groups	Unhealthy	Very Unhealthy
Year		0 - 50	51 - 100	101 - 150	151 - 200	200 - 300
2018	360	272	74	2	11	1
2017	365	276	82	7		
2016	365	310	55			
2015	365	300	65			
2014	365	309	56			
2013	364	254	109	2		
2012	361	291	68	2		
2011	365	252	111	2		
2010	365	249	113	3		
2009	365	196	164	5		
2008	366	223	140	3		
2007	365	281	79	5		
2006	363	264	95	4		
2005	365	288	70	7		
2004	366	243	116	7		
2003	365	294	66	5		
2002	365	273	71	14	7	
2001	365	291	61	10	3	
2000	366	277	83	6		

Location

In 2014, BAAQMD, the San Francisco Planning Department, and the San Francisco Department of Public Health identified neighborhoods most exposed to air pollution. The Air Pollution Exposure Zone (Figure 4-38) identifies air pollution exposure based on cancer risk, PM2.5 concentration and proximity to freeways and other high-density arterials. New construction in the air pollution exposure zone is regulated under Article 38 and is required to have adaptive infrastructure and safe construction practices to protect against the health impacts of air pollution. According to the air pollution exposure zone map, neighborhoods particularly impacted by air pollution include Bayview/Hunters Point, SOMA, Central Market/Tenderloin, and the Financial District.

FIGURE 4-38
ARTICLE 38 CITYWIDE MAP



Severity and Probability of Future Events

While San Francisco's air quality will remain above current EPA standards, climate change is likely to increase concentrations of both ground-level ozone and $PM_{2.5}$ which will increase morbidity and mortality in San Francisco.

- Climate change is expected to exacerbate yearly fluctuations in precipitation. During especially dry years, drought can impact air quality. The 2011-2016 drought contributed to the deaths of an estimated 66 million trees in the Sierra Nevada forests. Future droughts will have similar impacts and create conditions for more frequent and intense wildfires[240].
- PM is likely to be impacted by climate change. PM levels are strongly affected by local weather patterns such as precipitation, wind speed, and vertical mixing. Increased mixing height, or the height of the air layer closest to the ground, and wind speeds have been shown to significantly reduce PM concentrations. However, atmospheric stagnation, characterized by low wind speeds and little vertical mixing, has been shown to be correlated with increased PM levels in Canadian cities[241], and is predicted to increase regionally as a result of modern climate change.
- Temperature increases are also expected to alter the growing season for allergen-producing plants.
- As climate change increases temperatures, hot and dry temperatures will accelerate the creation of ground-level ozone.

Additionally, the largest increases in ozone levels from climate change will also occur in areas where ozone is already high, meaning that those same communities that are affected most by current pollution will also suffer the worst of the changes. So, while the research suggests that average increases in ozone and PM levels will be relatively small,

[240] USDA Office of Communications *Forest Service Survey Finds Record 66 Million Dead Trees in Southern Sierra Nevada.* U.S. Forest Service. https://www.fs.fed.us/news/releases/forest-service-survey-finds-record-66-million-dead-trees-southern-sierra-nevada

[241] Cheng, C. S. (2005). *Differential and combined impacts of winter and summer weather and air pollution due to global warming on human mortality in south-central canada.* (No. 6795-15-2001/4400011). Toronto, CAN: Toronto Public Health.

it is also clear that the impact of those increases will not be evenly distributed and can have significant effects on vulnerable populations.

Pandemic Hazard Profile

4.13 Pandemic

As of this writing, the COVID-19 pandemic is currently underway. The pandemic started in Wuhan China in late December and has since spread to nearly every country in the world. On March 16, 2020, Mayor Breed, along with 5 other Bay Area counties, issued shelter in place orders for all residents for three weeks. On March 19, 2020 Governor Newsom issued shelter in place orders for the whole state with no determined end date. More than a dozen states have since followed suit. As of March 24, 2020, California has had 2,246 cases and 43 deaths. San Francisco currently has 152 known cases and no deaths.[242] Due to a lack of available testing, it is widely understood that the actual number of cases is likely much higher and best estimates are 11 times higher than the official numbers.[243] Worldwide, there have been more than 392,700 cases and 17,200 deaths as of March 24, 2020.[244] Worst case estimates are that between 160 million and 214 million people in the United States could be infected over the course of the epidemic.[245] The epidemic could last for months to over a year, with infections scattered in time and severity across communities. As many as 200,000 to 1.7 million people could die. Those most at risk include the elderly and those with underlying health risks, such as heart and lung disease. Those estimates don't take into account quarantining and social distancing measures taken to suppress the virus, reducing the number of infections and spreading it our over more time to reduce strain on the healthcare system. The shelter in place order currently in effect in California is widely seen as an aggressive measure that will improve outcomes, but how successful it will be remains to be seen.

Impact Statement

The current pandemic is expected to last for months to over a year. The likelihood of future pandemics of this intensity is currently unknown, however the probability for a

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[242] San Francisco Department of Public Health. Retrieved from https://www.sfdph.org/dph/default.asp. Accessed March 24, 2020.

[243] Glanz, J. et al. (March 24, 2020) "Coronavirus Could Overwhelm U.S. Without Urgent Action, Estimates Say" *New York Times*. Retrieved from https://www.nytimes.com/interactive/2020/03/20/us/coronavirus-model-us-outbreak.html

[244] Serrano, A. et al. (March 24, 2020) "Coronavirus live updates: Olympics officially postponed; Bay Area tolls stop accepting cash" *San Francisco Chronicle*. Retrieved from https://www.sfchronicle.com/bayarea/article/Coronavirus-live-updates-Surgeon-General-warns-15151165.php?t=471f7906f9

[245] Fink, S. (March 18, 2020) "Worst-Case Estimates for U.S. Coronavirus Deaths" *New York Times*. Retrieved from https://www.nytimes.com/2020/03/13/us/coronavirus-deaths-estimate.html

naturally occurring moderate outbreak of pandemic influenza is considered high. Throughout the last century, there have been five other influenza pandemics of varying severity, and a future pandemic is a near certainty. Daily impacts of moderate to severe flu will primarily impact human health, health services, and public health systems. It must be noted that the cumulative impact will likely be much more significant, as influenza pandemics typically last 6-12 weeks.[246] Currently, little is known about the potential impact of climate change on future pandemics.

Pandemics severely strain the healthcare system by causing prolonged patient surge. Because of their frequency, duration, and scale, pandemics are one of the greater public health threats to the City and County of San Francisco; this threat has only increased with the rise in population density and international travel.

Nature

A pandemic is an epidemic of an infectious disease occurring worldwide, or over a very wide area, which crosses international boundaries and affects a large number of people. Pandemic influenza is one of the most pressing public health planning needs today. Even with a "moderate" pandemic, the cumulative effect on health and health care would be dire. For example, the 1918 "Spanish Flu," which had a 30 percent attack rate and a 2 percent case fatality rate, was defined by the Center for Disease Control (CDC) as a moderate event.

Pandemics are hazards that have a long duration. Though daily impacts may be low, cumulative impacts are likely to be overwhelming for both the health system and the community. During a moderate pandemic, San Francisco could see a sustained increase in intensive care unit admissions, in emergency department (ED) admissions, in patients needing to be placed in respiratory isolation, and in deaths. Capacity to provide medical care, including basic emergency medical system (EMS), hospital ED services, and isolation rooms, will be reduced. At the same time, a higher than usual absenteeism rate for all employees is expected. It is estimated that there would be an 18 percent decrease in workers secondary to being ill with the flu, with effects compounded over time. This would have dramatic consequences both for the health care system and for the community in general.[247]

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[246] San Francisco Department of Public Health, Public Health and Medical Hazard Risk Assessment (2013), *Internal Document*.
[247] San Francisco Department of Public Health, Public Health and Medical Hazard Risk Assessment (2013), Internal Document., Public Health and Medical Hazard Risk Assessment (2013), *Internal Document*.

Compared to the 1918 pandemic event, an influenza pandemic today could have far-reaching, negative consequences for the health and well-being of San Francisco's residents and for the economic and social stability of the Bay Area. Our population includes more elderly than it did in the past. Our ability to respond effectively to a pandemic is also limited. Our health care system today has little surge capacity. "Just-in-time" ordering of needed supplies has replaced the warehousing of critical items onsite for most businesses and governmental organizations. In addition, unlike citizens in 1918, we are not accustomed to following government restrictions such as the rationing of goods and services.

History

In addition to COVID-19, there have been five other pandemics since 1900. From April 12, 2009 to April 10, 2010, CDC estimated that between 151,700 and 575,400 people worldwide died from 2009 H1N1 virus infection during the first year the virus circulated. Additionally, CDC estimated that 80 percent of (H1N1)pdm09 virus-associated global deaths were in people younger than 65 years of age, which differs from typical seasonal influenza epidemics during which about 70 percent to 90 percent of deaths are estimated to occur in people 65 years of age and older. In the United States estimates included 60.8 million cases, 274,304 hospitalizations, and 12,469 deaths due to the (H1N1)pdm09 virus. In San Francisco, 208 hospitalizations and 60 intensive care unit (ICU) or fatal cases were reported during the 2009 H1N1 Pandemic.

Because pandemics are recurring events, it is not a question of whether there will be another pandemic; the question is when the next pandemic will occur and how severe it will be. Previous pandemics occurred in 1918-1920, 1957-1958, 1968-1969, 1977-1978, and 2009-2010. The 1918-1920 Pandemic, often referred to as the Spanish Flu, was unusually severe and had a high mortality rate. It is estimated that the 1918 Pandemic killed up to one percent of the world's population, or 40,000,000 people worldwide, including more than 500,000 in the United States.

Location

By definition, a pandemic is a global event; San Francisco as a major center for domestic and international tourism and business would expect to be significantly affected by a pandemic flu. The World Health Organization (WHO) classifies pandemics according to phases. Phase 1 starts with the virus circulation among domesticated or wild animals prior to human infection. Additional phases coincide with community level outbreaks in multiple countries in multiple WHO regions, culminating with Phase 6. A Phase 6 Pandemic involves a virus that is widespread, with human-to-human transmissibility.

Since travelers and residents are free to travel throughout the city, it is anticipated that from a hazard mitigation perspective, San Francisco will be uniformly affected geographically. However, based on the actual pandemic virus, certain populations within San Francisco may have different morbidity and mortality than the general population. In general, the following groups tend to be at higher risk for seasonal influenza complications: individuals with specific chronic medical conditions; children younger than five years old, with children younger than two at special risk; adults 65 years of age and older; pregnant women; American Indians; and Alaskan Natives.

Severity and Probability of Future Events

In the short term, it is certain that the COVID-19 pandemic will be here for the coming months to a year or more. The fact that we are experiencing a pandemic this year does not decrease the likelihood of experiencing another pandemic (with different strain) next year.[248] Based on the Bay Area Regional Risk Assessment conducted in 2013, the probability of a naturally occurring, mild to moderate pandemic affecting San Francisco is considered high. In many respects, the City and County of San Francisco is more vulnerable to a pandemic today than it was in 1918. Population density in the city is higher than in 1918, and people in the Bay Area travel more internationally and come into contact with far more people on a daily basis than did people in 1918.

The extent of a pandemic depends on the actual virus involved. The 2009 H1N1 Pandemic was generally considered mild, with a very low case fatality rate; it is estimated that 0.001 percent to 0.007 percent of the world's population died of respiratory complications associated with the (H1N1)pdm09 virus infection during the first 12 months the virus circulated. In contrast, the 1918 Pandemic had a higher case fatality rate, with a reported 1-3% mortality rate worldwide. As stated earlier, based on the CDC's scale, the 1918 Pandemic is considered a moderate pandemic influenza.

[248] Sandman, P. (February 27, 2007) "A severe pandemic is not overdue - it's not when but if" Center for Infectious Disease Research and Policy: Weekly Briefing. Accessed March 24, 2020. Retrieved from http://www.cidrap.umn.edu/news-perspective/2007/02/severe-pandemic-not-overdue-its-not-when-if

The speed of onset of a Pandemic also varies depending on the particular influenza virus, how rapidly it spreads, the availability of vaccines and antivirals, and the effectiveness of medical and non-medical containment measures. Some influenza strains remain at early phases, with no human-to-human transmission for many years, while others move through the stages to become a pandemic relatively quickly. Global travel and movement of populations speeds up the spread of disease.

Pandemics are likely to last between six and 12 weeks, and typically come in two to three waves over a three- to 18-month period. The second wave may occur several months after the first wave. The level of illness during the second wave is often more severe than that in the first wave.

Hazardous Materials Release Profile

4.14 Hazardous Materials Release

Impact Statement

According to state & local databases there are approximately 2,700[249] Hazardous Materials facilities throughout San Francisco. An accidental hazardous materials release can occur wherever hazardous materials are manufactured, stored, transported, or used. The majority of these facilities are located along the east/south east portion of the city; therefore, the risk is greatest in that part of the city.

Nature

Hazardous materials have properties that make them potentially dangerous and harmful both to human health and to the environment. An accidental hazardous material release can occur wherever hazardous materials are manufactured, stored, transported, or used. Depending on the substance involved, the release may affect nearby populations and may contaminate critical or sensitive environmental areas. The universe of hazardous materials is large and diverse. Hazardous substances can be in liquid, solid, or gas form, and can include toxic chemicals, radioactive materials, infectious substances, and wastes.

Over the past 25 years there has been heightened awareness and attention paid to the health hazards posed by toxic materials. During this period, many federal, state, and local regulations governing hazardous materials have been put into place. These regulations are continually updated and augmented. The Hazardous Materials and Waste Program at the San Francisco Department of Public Health (DPH) implements six state environmental mandates and two local mandates regulating hazardous materials activities. DPH environmental health staff inspect regulated businesses at least once every three years.

A release of hazardous materials can occur from any of the following:

- Fixed facilities such as refineries, storage facilities, manufacturing facilities, warehouses, wastewater treatment plants, swimming pools, dry cleaners, automotive sales and repair, and gas stations.

[249] Josuwa Bernardo (SFDPH), *SF Hazardous Materials Sites*, 2018, Distributed by California State Water Resource Board (SWRCB). Email Correspondence regarding compiled data.

- Highway and rail transportation, such as tanker trucks and railcars transporting hazardous materials.
- Commercial maritime transportation, including transportation of petroleum products by barges and ocean-going tankers and spills associated with petroleum terminals.
- Air transportation involving cargo packages.
- Pipeline transportation of substances such as petroleum products, natural gas, and other chemicals.

Though large petroleum storage or manufacturing facilities are typically located outside of residential areas, pipelines are ubiquitous in our communities. Virtually all natural gas, which accounts for about 28 percent of energy consumed annually in the United States, is transported by transmission pipelines.

History

Hazardous materials incidents impacting the San Francisco Bay Area have occurred as a result of spills from commercial and recreational vessels in the San Francisco Bay; from transportation accidents that resulted in petroleum spills; from sewer breaks and overflows; and from various accidents or incidents related to the manufacture, use, and storage of hazardous materials by industrial and commercial facilities. One of the most publicized incidents occurred on November 7, 2007, when the container ship Cosco Busan struck the Delta Tower of the San Francisco - Oakland Bay Bridge during a thick fog. Over 53,569 gallons of heavy fuel oil, often referred to as "bunker fuel," spilled into San Francisco Bay, soiling San Francisco's western, northern, and northeastern coastline, as well as other shorelines throughout the Bay Area. The spill impacted birds, marine mammals, fish, and humans, and required clean-up and response efforts from local, state, and federal authorities.

More recently, October 30, 2009, another tanker vessel, the Dubai Star, spilled over 400 gallons of intermediate fuel oil during a refueling incident just south of the Bay Bridge. The spill affected more than 10 miles of shoreline, from just north of the east approach to the Bay Bridge to San Leandro Bay along the Alameda County coastline. The impact included bird mortalities, as well as beach and fisheries closures.

The National Response Center (NRC), which serves as the sole national point of contact for reporting all oil, chemical, radiological, biological, and etiological discharges into the environment in the United States, shows that from 2002 through 2012, a total of 806 hazardous material incidents were reported in the study area. Of this number, 586 were water-related incidents including bilge oil, gasoline, hydraulic oil, jet fuel, and diesel oil spills. Common causes of these incidents included operator error and equipment failure. During this same 10-year period, NRC data also indicates that there were 45 rail-related incidents, and 49 land-based, non-rail spill incidents. According to NRC, for the year 2017, there were at least 30 reported material incidents in San Francisco that received federal notice[250]

Location

An accidental hazardous material release can occur wherever hazardous materials are manufactured, stored, transported, or used. In San Francisco, a hazardous material event is most likely to occur within the City's industrial area, which is concentrated in the southeast part of the city. The primary PG&E gas transmission pipeline also runs through the southeast part of the city.

In addition, a variety of transportation corridors traverse the city. Though federal regulations impose restrictions on the use of certain routes to transport hazardous materials within the city, vehicles using San Francisco's transportation corridors commonly carry a variety of hazardous and highly flammable materials, such as gasoline, petroleum products, and other chemicals known to cause human health problems. Similarly, container ships, car carriers, tankers, and other types of vessels constantly move through the shipping channels of San Francisco Bay, presenting a risk to the local marine environment in the event of a spill. Hazardous materials also are transported to and from, are used, and are stored at the San Francisco International Airport (SFO) and at adjacent airport facilities just south of San Francisco.

Severity and Probability of Future Events

The geographic and economic characteristics of San Francisco make it likely that hazardous materials releases will continue to occur. Based on statistics maintained by DPH, from 2007 through 2017, there were 413[2] hazardous materials incidents requiring a response in San Francisco. San Francisco's commercial sector and transportation

[250] United States Coast Guard, "2017 Report" accessed September 25, 2018. (*National Response Center*, http://www.nrc.uscg.mil/)

routes share space with several bodies of water, wetlands, environmentally sensitive areas, and a densely-populated urban environment, creating areas of great potential risk for a hazardous materials release. Moreover, SFO, a large international airport, is just a few miles from downtown San Francisco. Thus, the threat to San Francisco of a hazardous material incident impacting land, sea, or air remains high.

Hazardous material releases are notable among the hazard profiles this plan addresses because of the degree to which it can be expected to occur in combination with other hazards. For example, as flooding increases in occurrence there will likely be an increased number of hazardous material incidents due to the compromise of coastal/floodplain storage infrastructure

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Chapter 05

Vulnerability and Consequence Assessment

To develop the HCR Vulnerability and Consequences Assessment, City staff relied on the risk assessment process developed by the Association of Bay Area Government's (ABAG) Resilience Program and Adapting to Rising Tides (ART), which closely follows FEMA's Local Mitigation Planning Handbook. The assessment described in this chapter provides a comprehensive understanding of the vulnerabilities of San Francisco's assets to the natural hazards identified in Chapter 04, as well as the broader consequences that can occur as a result. Understanding how specific hazards affect assets and identifying potential consequences is key to developing and implementing resilience strategies and actions.

5.1 Assessment Overview

The assessment process has three primary components: multi-hazard exposure assessment, vulnerability and consequence profiles, and key planning issues.

Multi-Hazard Exposure Assessment

The assessment started with an exposure assessment for natural hazards that have spatial data available to better understand the geographic scope of hazards in San Francisco and the potential scale of impact. This assessment evaluated the exposure of San Francisco's population, households, critical response facilities, and commercial and industrial parcels. Exposure refers to the potential for an asset to experience a physical hazard, such as shaking from an earthquake or getting wet from a coastal flood event. Exposure is estimated in GIS by analyzing the overlap between hazard areas and asset location. The results of this assessment can be found in section 5.2.

Vulnerability & Consequence Profiles

Next, the project team developed a more in-depth risk assessment through the development of Vulnerability and Consequences Profiles for 29 asset classes across eight different sectors. The asset classes are described in Chapter 3 and the profiles can be found in Appendix A. In order to provide detailed risk assessment information on a large number of asset classes, the Vulnerability and Consequence profiles are focused on a limited set of hazards. The project team focused on groundshaking and liquefaction due to the high level of exposure across all assets and high level of risk ($3.08 Billion estimated economic impact to general fund facilities in San Francisco according to latest Hazus study). The team also decided to focus on weather and combustion-related hazards that are projected to become more severe due to climate change, namely flooding, extreme heat, and fire and air quality. The Vulnerability and Consequence Profiles include the results of an exposure analysis performed using GIS and characterize vulnerability by identifying how an asset class will be affected by a hazard and the ability to adjust based on the following four categories:

- **Physical**: the conditions or design aspects that make assets particularly vulnerable
- **Functional**: the functions, roles, or relationships that make assets particularly sensitive or limit their ability to adjust to a hazard event

- **Informational**: challenges in obtaining the data and information necessary to sufficiently understand and/or manage vulnerabilities
- **Governance**: challenges with management, regulatory authority, or funding options.

The consequences assessment identifies broader impacts if an asset is damaged or its function disrupted. Three categories of impacts have been identified:

- **Society and Equity**: impacts to health and safety, community networks, mobility, affordability, and workforce opportunities
- **Economy**: property and infrastructure damage, interruption of economic activity, and loss of revenue
- **Environment**: impacts to water, air, and/or soil, biodiversity, public access, ecosystem service benefits

Key Planning Issues

Key Planning Issues highlight the findings of the Vulnerability and Consequence Profiles and communicate vulnerabilities that cut across multiple sectors, hazards, or geographies. The Key Planning Issues highlight significant or near-term vulnerabilities that require coordination between numerous asset managers, issues that may cluster in a particular geography, and vulnerabilities that require regulatory changes to solve. They are used to support the development of cross-cutting strategies and are described in section 5.3.

5.2 Multi-Hazard Exposure Assessment

The City conducted an exposure assessment for any of the identified hazards that have a defined geographic spatial extent and high-quality spatial data available, often produced by a State agency. Table 5-1 describes the hazard scenarios and data sources used in the exposure assessment. This analysis was conducted in 2018 and 2019 using publicly-available data sources. In the table below, shaking intensity is represented for two Earthquake scenarios: San Andreas Fault M7.8 and Hayward Fault M7.0 events. Accounts of assets subjected to varying levels of shaking intensity are cumulative for each scenario.

TABLE 5-1
HAZARDS AND SCENARIOS USED IN EXPOSURE ASSESSMENT

Hazard	Scenarios / Zones	Data Source
Groundshaking	San Andreas 7.8	USGS, ABAG (2018)
	Hayward 7.0	USGS, ABAG (2018)
Liquefaction	Liquefaction Zone	USGS (2018)
Landslide	Earthquake Induced Landslide Zone	USGS, California Department of Conservation (2018)
Tsunami	Inundation Zone	California Department of Conservation (2018)
Coastal Flooding	100-Year Coastal Flood Zone	FEMA National Flood Hazard Layer (2018)
	100-Year Storm + Mid-Century Sea Level Rise (~24 inches)	BCDC: ART Sea Level Rise Maps (2018)
	100-Year Storm + End-of-Century Sea Level Rise (~66 inches)	BCDC: ART Sea Level Rise Maps (2018)
Stormwater Flooding	100-Year Stormwater Flood	SFPUC 100-Year Storm Flood Risk Map (2018)
Reservoir Failure	Inundation Area	DEM Data Library (2018)
Wildfire	High	Cal Fire FRAP (2018)
	Moderate	Cal Fire FRAP (2018)

Exposure Summary

The multi-hazards exposure assessment includes exposure of overall population, households, critical response facilities, commercial parcels, and industrial parcels. This set of assets provides a high-level view of the potential impacts to the population and building stock, including our critical emergency response facilities and takes into account changes in development since the 2014 HMP. Table 5-2 and the descriptions below summarize the results the exposure assessment.

Seismic

Nearly all of San Francisco's population, critical facilities, and commercial and industrial parcels would be exposed to violent or very strong ground shaking from a M7.8 earthquake on the San Andreas fault. In the event of a M7.0 earthquake on the Hayward fault, 4% of the population would be exposed to very strong shaking and 72% would be exposed to strong shaking. 12% and 17% of the total population may be exposed to liquefaction or landslide hazards respectively. Over half of all industrial parcels and almost a third of all commercial parcels are located within liquefaction hazard zones. 39% of critical facilities are also located in liquefaction hazards zones.

Flooding

Currently, approximately 1,400 people would be exposed to coastal flooding during a 100-year flood, based on preliminary mapping performed by FEMA. Currently, San Francisco is working with FEMA to update the preliminary maps but these have not been finalized at the time of this report. As discussed in Chapter 04, this mapping covers the Pacific coastal area, the Bay shoreline, the Port, and the Airport, leaving out inland waterways that are vulnerable to stormwater flooding in the city. The SFPUC has developed a Draft 100-Year Storm Flood Risk Map that shows areas of San Francisco where significant flooding from storm runoff is highly likely to occur during a 100-year storm. According to this mapping, almost 24,000 people could be exposed to stormwater flooding during a 100-year storm.

Projected sea level rise will worsen existing coastal flood hazards by increasing the elevation and frequency of flooding and extending the coastal flood hazard zone farther inland. Exposure to coastal flooding during a 100-year storm could increase to 29,000 by end-of-century due to sea level rise, not accounting for potential population growth.

Currently only three critical facilities would be exposed to coastal flooding in a 100-year flood. However, this figure could increase to 20 by end-of-century due to sea level rise. While exposure of commercial and industrial parcels to coastal flooding with mid-century sea level rise appears to be limited at 3% and 10% respectively, in raw numbers this represents hundreds of parcels that would be potentially inundated. By late-century, this could increase to at least 1,000 commercial and industrial parcels due to sea level rise.

National Flood Insurance Program (NFIP)-insured structures

San Francisco is a participant in the National Flood Insurance Program (NFIP), which is managed by FEMA and provides flood insurance for applicable properties based on a risk mapping process. The City has adopted a Floodplain Management Ordinance that is intended to reduce the risk of damage from flooding within the city and facilitate administration of this program at the local level. According to the National Flood Insurance Program Redacted Claims Dataset, San Francisco does not have any structures within the county that have been repetitively damaged. [1]

Wildland-Urban Interface Fire

The general population, households, critical response facilities, industrial parcels, or commercial parcels are not significantly exposed to wildland-urban interface fire risks.

Limitations

Several hazards analyzed in Chapter 04 do not have spatial data available by which to analyze different areas of exposure, including extreme heat, poor air quality, and high wind. This does not mean that these hazards do not have impacts on San Francisco's buildings, infrastructure, and communities. As such, exposure is only one component of vulnerability and risk. To that end, the hazards analysis in Chapter 04 provides one lens and the Vulnerability and Consequences Assessment provided in Appendix A provides a second lens.

[1] FIMA NFIP Redacted Claims Data Set: https://www.fema.gov/media-library/assets/documents/180374

TABLE 5-2: CITYWIDE HAZARD EXPOSURE

Hazard	Population (864,000 Total)		Households (384,000 Total)		Critical Response Facilities (95 Total)		Commercial Parcels (6,300 Total)		Industrial Parcels (2,100 Total)	
	#	%	#	%	#	%	#	%	#	%
Seismic										
San Andreas 7.8 - Violent	218,100	25%	78,200	20%	17	18%	900	14%	200	7%
San Andreas 7.8 - Very Strong	643,000	74%	305,800	80%	78	82%	5,400	86%	1,900	93%
Hayward 7.0 - Very Strong	32,500	4%	24,900	6%	13	14%	500	8%	300	15%
Hayward 7.0 - Strong	620,700	72%	288,200	75%	69	73%	5,000	81%	1,700	81%
Liquefaction Zone	108,000	12%	74,900	19%	37	39%	2,000	32%	1,200	58%
Flooding										
100-Year Coastal Flood Zone	1,400	0%	1,200	0%	3	3%	-	0%	100	3%
100-Year Storm + 24 inches SLR	15,300	2%	12,200	3%	12	13%	200	3%	200	10%
100-Year Storm + 66 inches SLR	29,000	3%	22,100	6%	20	21%	500	8%	500	22%
100-Year Stormwater Flood	23,700	3%	12,600	3%	9	9%	300	5%	300	14%
Wildland Urban Interface Fire										
Wildland Urban Interface Fire - High	900	0%	200	0%	0	0%	-	0%	-	0%
Wildland Urban Interface Fire - Moderate	10,300	1%	2,800	1%	1	1%	-	0%	-	0%
Other Hazards										
Tsunami	18,800	2%	10,200	3%	12	13%	100	1%	100	5%
Dam or Reservoir Failure	58,900	7%	19,000	5%	7	7%	400	6%	200	11%
Landslide	149,300	17%	62,000	16%	9	9%	200	3%	100	3%

5.3 Key Planning Issues

The Waterfront and Adjacent Neighborhoods: San Francisco's waterfront communities may be exposed to multiple hazards, including flooding, liquefaction, tsunami and extreme heat. These areas include a mix of densely populated neighborhoods (existing and planned), vulnerable populations, and critical infrastructure, including transit, shoreline protection, and stormwater/wastewater that could have citywide or regional consequences if impacted by a hazard event.

New Development: Major development projects are planned in areas that may be exposed to hazards, including coastal flooding and liquefaction. While new construction is built to modern building codes and is therefore more resilient than older buildings, codes do not take into account future climate hazards and seismic codes are designed for life safety rather than recovery. Even if new development projects are more resilient to hazards, surrounding public assets such as transportation, utilities, and parks may remain vulnerable, potentially impacting current and future residents and businesses.

Existing Buildings: San Francisco has an aging building stock with nearly half of housing units constructed before 1940 and barriers to improving its resilience. The City is working to address seismically vulnerable buildings through the Earthquake Safety Implementation Program (ESIP). In addition, many older buildings were not designed to be resilient to climate hazards, such as extreme heat, poor air quality, and flooding and the City does not have policies in place to address improvements.

Housing: Hazards and climate change will put additional stress on San Franciscans that are already under pressure from the housing crisis (affordability, crowding, displacement) and the overall high cost of living. This is particularly acute for people who are unsheltered, in unstable housing situations, and renters. Some residents also have limited resources for coping with disruptions in housing, employment, childcare, and transportation, many of which could occur following a hazard event.

Transportation: On a daily basis, and in response to and recovery from a hazard event, San Franciscans depend on reliable, affordable, and accessible transportation. In addition, the functionality of many City and community assets depends on transportation access. Critical transportation assets are vulnerable to current and future hazards and disruption could have citywide and regional consequences. These considerations relate to city's climate goals of achieving 80% sustainable trips (walking, biking, public transit) in a world with more frequent climate hazard events.

Utilities: Utilities are critical for daily needs of households and businesses and disruption can have significant consequences for public health and the economy. In addition, utility restoration following a disaster is critical for recovery. The SFPUC has made significant improvements and more are planned/underway through Sewer System Improvement Program (SSIP), Water System Improvement Program (WSIP), and the Emergency Firefighting Water System (EFWS). Even with major improvements, elements of these utility systems may remain vulnerable to hazards. For some systems, there are limited alternatives and redundancies so reducing damage and disruption is critical.

Table 5-2 shows the legend for the hazard icons shown in each Key Planning Issue. The thirteen hazards addressed by the HCR Plan are displayed in a light gray tone in each Key Planning Issue. The icons displayed in a solid color indicate the hazard(s) that are applicable to a particular issue. The colors are associated with the primary hazard groups. The "All Hazards" group is indicated by displaying solid icons for all thirteen hazards.

TABLE 5-2 HAZARD ICON LEGEND

Earthquake	Tsunami	Landslide	Dam or Reservoir Failuure	Flooding	High Wind	Extreme Heat	Drought	Large Urban Fire	Wildfire	Poor Air Quality	Pandemic	Hazardous Materials
Geological				**Weather-related**				**Combustion-related**			**Biological / Toxic**	

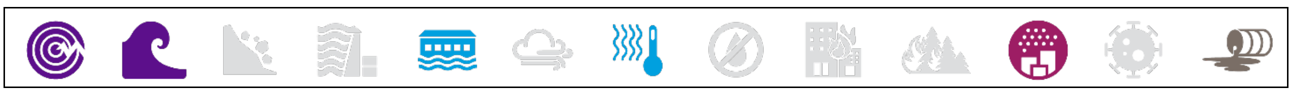
The Waterfront and Adjacent Neighborhoods

San Francisco's waterfront communities may be exposed to multiple hazards, including flooding, liquefaction, tsunami and extreme heat. These areas include a mix of densely populated neighborhoods (existing and planned), vulnerable populations, and critical infrastructure, including transit, shoreline protection, and stormwater/wastewater that could have citywide or regional consequences if impacted by a hazard event.

Geographies

- Significant vulnerabilities and consequences have been identified in the Embarcadero/Financial District, Mission Bay, and Islais Creek.
- Ocean Beach is vulnerable to erosion.

Hazards



Sectors

Sector	Asset Class
Transportation	Public Transit, Roadways (including bridges), SFO, Water-Based Transportation
Utilities & Infrastructure	Stormwater/Wastewater, Shoreline Protection
Housing	Multi-family, Affordable
Business & Industry	Commercial, Industrial, Maritime

Vulnerabilities

- The legacy of building on fill makes the waterfront more susceptible to seismic and flooding hazards.
- Current and former industrial uses of waterfront areas can lead to issues around soil contamination and hazardous materials. Sea level rise may exacerbate these issues.
- Transportation and utilities especially face exposure to flooding near creeks, including Mission Creek and Islais Creek.

- The efficacy of several stormwater outfalls may be vulnerable to flooding due to SLR.
- Wastewater infrastructure is vulnerable to erosion events at Ocean Beach.
- Embarcadero Station, T-Third, and Caltrain may be vulnerable to future coastal flooding due to SLR.
- Embarcadero roadway is currently subject to flooding during King Tides and flooding will become more frequent and severe due to future SLR.
- Until the Seawall Safety Program undertakes improvements, the seawall remains seismically vulnerable, which has implications for nearby utilities, transportation assets, and buildings.
- Staging areas and transportation assets along the waterfront play a critical role in emergency response after a major hazard event.
- Emergency Firefighting Water System (EFWS) manifolds are vulnerable to SLR and critical for fire response in these neighborhoods.
- Integrating near-term seismic and long-term flooding strategies can be challenging.

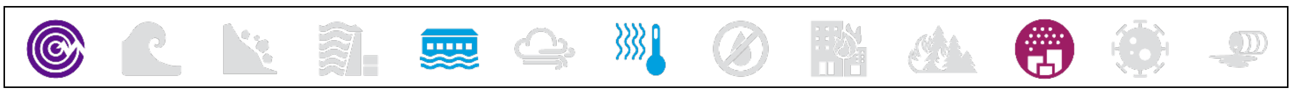
New Development

To accommodate a growing population, major development projects are planned in areas that may be exposed to hazards, including coastal flooding and liquefaction. While new construction is built to modern building codes and is therefore more resilient than older buildings, codes do not take into account future climate hazards and seismic codes are designed for life safety rather than recovery. Even if new development projects are more resilient to hazards, surrounding public assets such as transportation, utilities, and parks may remain vulnerable, potentially impacting current and future residents and businesses.

Geographies

- Citywide
- Particularly: Downtown, Southeast, Waterfront

Hazards



Sectors

Sector	Asset Class
Housing	Multi-Family, Affordable
Population	Vulnerable Populations
Business and Industry	Commercial

Vulnerabilities

- The current seismic code focuses on life safety rather than recovery. As a result, buildings may be damaged and not be occupied during a long repair period.
- New developments along the Bay shoreline may be designed to accommodate SLR through elevation/construction methods, but the existing transportation and utility systems that service them are not necessarily resilient. This may create dysfunctional "Islands of Resilience."
- New developments that make resilience improvements to the public realm will need to tie into existing portions of the public realm without similar investments (e.g. sidewalk and street elevations.)

- Need to consider the implications of additional code requirements on construction costs and the affordability of housing.
- Different property types have different challenges. Need to consider renters vs. owners, affordable vs. market rate.
- Building code does not adequately address future or current extreme heat and poor air quality.

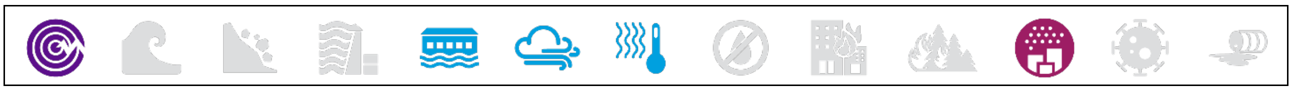
Existing Buildings

San Francisco has an aging building stock, with nearly half of housing units constructed before 1940, and barriers to improving its resilience. The City is working to address seismically vulnerable buildings through the Earthquake Safety Implementation Program (ESIP). Many older buildings were not designed to be resilient to climate hazards, such as extreme heat, poor air quality, and flooding, and the City does not have policies in place to address improvements.

Geographies

- Citywide

Hazards



Sectors

Sector	Asset Class
Housing	Single-Family, Multi-Family, Subsidized Affordable
Business & Industry	Commercial, Industrial, Maritime
Public & Community Services	Municipal Buildings, Educational Facilities, Community Health Facilities
Emergency Response	Critical Response Facilities, Other Emergency Sites

Vulnerabilities

- Seismic codes are designed for life safety rather than recovery, so repairs and re-occupation following an earthquake may take an extended period of time.
- Private schools are not required to be upgraded to the same earthquake standard as public schools.
- Older concrete and steel buildings are vulnerable to damage in an earthquake.
- The City lacks comprehensive data on the seismic vulnerability of private buildings, including those that have performed seismic retrofits.

- Most buildings are not built to withstand any amount of flooding, as current construction materials, siting, and design standards do not consider potential exposure to either water or salt.
- Historic buildings/districts often have preservation-related design restrictions, so changes to improve resilience may be limited. Damage could lead to permanent loss of unique historic resources and impact tourism.
- Older, un-weatherized buildings (typically also without air conditioning) can lead to unhealthy conditions for occupants during extreme heat events.
- The City is working to improve the readiness of its buildings to serve as clean air and cooling centers for residents and City staff.
- The City lacks up-to-date data on privately-owned shelter facilities needed to inform resilience improvements.
- There is no comprehensive resilience design code, especially for climate hazards, which outline what municipal and private buildings need to do, and the associated costs/benefits.

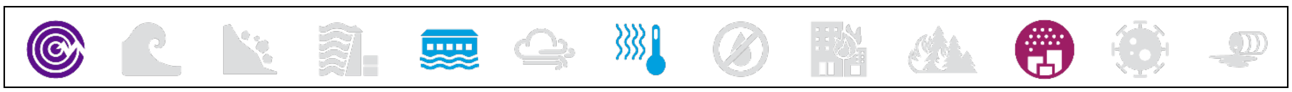
Housing

Hazards and climate change will put additional stress on San Franciscans that are already under pressure from the housing crisis (affordability, crowding, displacement) and the overall high cost of living. This is particularly acute for people who are unsheltered, in unstable housing situations, and renters. Models predict significant damage to housing in a major earthquake, further exacerbating existing vulnerabilities. Some residents also have limited resources for coping with disruptions in housing, employment, childcare, and transportation, many of which could occur following a hazard event.

Geographies

- Citywide

Hazards



Sectors

Sector	Asset Class
Populations	Vulnerable Populations
Housing	Single Family, Multi-Family, Subsidized Affordable
Public and Community Services	Residential Care Facilities for the Elderly

Vulnerabilities

- Currently, the majority of low-income renters and homeowners (< 80% adjusted median income (AMI) are housing cost burdened (> 30% of income spent on housing).
- New models predict that in a magnitude 7.8 San Andreas earthquake, 18,300 residential buildings could be damaged in San Francisco, temporarily or permanently displacing 20% of all households.
- Nearly 12,000 multi-family units are exposed in both the 100-year stormwater flood zone and coastal flood zone with 24” SLR.

- Sixty percent of subsidized affordable housing units are located in 5 neighborhoods: Bayview Hunter's Point, Mission, South of Market, Tenderloin, and Western Addition.
- The share of subsidized affordable housing exposed to flooding hazards is higher than market rate housing. The SLR vulnerability zone (66 inches) contains over 4,000 subsidized affordable units.
- Unhoused populations (concentrated in SOMA, Rincon Hill, Civic Center, Potrero Hill, Bayview Hunters Point, Visitacion Valley) are among the most vulnerable San Franciscans. During hazard events, this population has limited resources to evacuate, communicate, and shelter. Unhoused populations often rely on informal networks rather than traditional support providers.
- As neighborhoods change, longstanding community relationships can break as people leave or neighborhood dynamics shift.
- The loss of affordable housing can also lead to the loss of services located in housing, such as residential care facilities for the elderly and childcare.

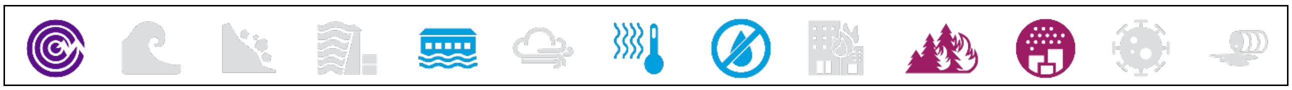
Public Awareness and Communications

The City needs better messaging on how it is addressing hazards and climate change impacts citywide and how different efforts relate to each other. Residents and other stakeholders may not understand how the City is working to increase resilience and how they can participate. Residents may also lack information on how to prepare for climate hazards events that are becoming more frequent.

Geographies

- Citywide

Hazards



Sectors

Sector	Asset Class
People	General Population, Vulnerable Populations
Emergency Response	Critical Response Facilities, Other Emergency Sites

Vulnerabilities

- Over the past 2 years, San Francisco has experienced extreme weather events, highlighting the importance of preparedness and public communications strategies.
- The lack of timely information may lead to avoidable health impacts.
- Emergency services may be strained if residents have not been empowered to help themselves during a hazard event.
- Need to avoid conflicting messaging for different hazards that are likely to occur at the same time.
- Residents receive information from a variety of sources, including TV, radio, print media, social media and word-of-mouth. Understanding these platforms and networks, particularly culturally-specific platforms, is essential to effectively communicate.

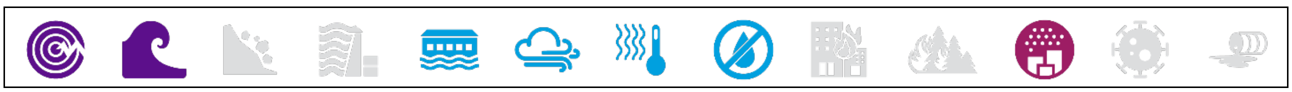
- There is also a nexus between populations that face greater vulnerabilities to hazards and climate change but are less likely to receive information about how to respond during hazard events.
- Communication strategies need to be tailored for specific populations.

Transportation

On a daily basis, and in response to and recovery from a hazard event, San Franciscans depend on reliable, affordable, and accessible transportation. In addition, the functionality of many City and community assets depends on transportation access. Critical transportation assets are vulnerable to current and future hazards and impairment could have citywide or regional consequences. These considerations relate to city's climate goals of achieving 80% sustainable trips (walking, biking, public transit) in a world with more frequent climate hazard events.

Geographies

- Citywide
- Particularly: Waterfront



Sectors

Sector	Asset Class
Transportation	Roadways, Public Transit, SFO, Water-Based Transportation
Emergency Response	Critical Response Facilities, Other Emergency Sites

Vulnerabilities

- Residents depend on public transit for access to critical facilities during and after a hazard event, including cooling, heating, air quality centers.
- Current roadway flooding impacts safety and access for bicyclists, pedestrians, and motorists. This issue may become more severe in the future with SLR and intense precipitation events.
- Embarcadero Station and parts of Muni T-Third and Caltrain may be exposed to future flooding due to SLR. MUNI Metro East light rail and Ocean Blvd see current impacts from King Tides and winter storm flooding.
- Air quality and extreme heat events impact biking, walking, and transit use due to health concerns.

- Roadways and transit equipment/facilities are vulnerable to damage from liquefaction, especially if underground utilities and fuel tanks are damaged; damage to SFMTA maintenance facilities can also impact transit operations.
- Debris and interruptions of overhead wires and power sub-stations from earthquakes and high winds may impact roadway accessibility and transit function.
- BART access to SFO may see disruption in a strong shaking event and some SFO terminals may be vulnerable to damage if they have not been recently seismically retrofitted. Runways may be vulnerable to liquefaction and strong shaking damage as well.
- Bridges have limited redundancy. Third Street, with two bascule bridges that may be exposed to future flooding due to SLR, is one of the primary north-south corridors in the southeast.
- Access to water-based transportation may be impacted by liquefaction damage in an earthquake. This may affect emergency response efforts.

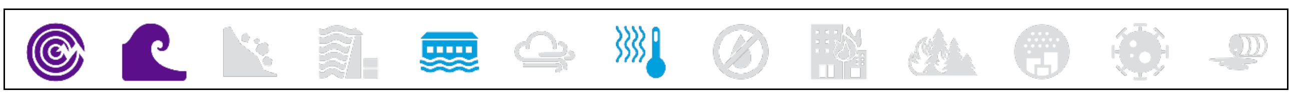
Utilities

Utilities are critical for daily needs of households and businesses and disruption can have significant consequences for public health and the economy. In addition, utility restoration following a disaster is critical for recovery and there are many interdependencies. The SFPUC has made significant improvements and more are planned/underway through Sewer System Improvement Program (SSIP), Water System Improvement Program (WSIP), and Emergency Firefighting Water System (EFWS). Even with major improvements, elements of these utility systems may remain vulnerable to hazards. For some systems, there are limited alternatives and redundancies (e.g. potable water), so reducing damage and disruption is critical. The Lifelines Restoration Performance Project is taking a deeper dive of the issue of lifeline utilities and recommended actions to improve restoration timelines for earthquakes.

Geographies

- Citywide
- Particularly: Waterfront

Hazards



Sectors

Sector	Asset Class
Utilities and Infrastructure	Stormwater/Wastewater, Potable Water, Emergency Firefighting Water System (EFWS), Power, Natural Gas
Emergency Response	Critical Response Facilities, Other Emergency Sites

Vulnerabilities

- The stormwater/wastewater and potable water systems may be vulnerable to future coastal flooding due to sea level rise, particularly sensitive assets in low-lying areas.

- Stormwater/wastewater, potable water, EFWS and other utility systems (including reservoirs) may experience damage during a significant earthquake event.
- Damage to natural gas infrastructure can lead to an urban conflagration.
- Compared to other utilities, water and natural gas systems have relatively longer restoration timelines following an earthquake due to complex reconstruction needs.
- The electric power grid is currently strained during extreme heat events. These events are projected to increase in the future, potentially leading to brownouts or blackouts.
- Public transit is highly dependent on electric power.

Chapter 06

Capabilities Assessment

This chapter describes San Francisco's existing authorities, policies, programs, and resources and its ability to expand on these policies and programs to advance resilience. Section 6.1 describes the City's roles in mitigation and activities underway. Section 6.2 provides an update to the actions identified in the 2014 Hazard Mitigation Plan. These two sections highlight capabilities and resources to address hazards and the stage for the strategies in Chapter 07.

San Francisco has a long history of learning from natural disasters. As a result, the City has developed extensive codes, policies, programs, projects, and studies that are recognized around the globe. An example is the Emergency Firefighting Water System (EFWS) that was designed before, but constructed after, the Great Earthquake of 1906, when over 80 percent of San Francisco was destroyed. The investments in EFWS paid-off 83 years later when the fireboat and other aspects of the system were needed put out large fires resulting from collapsed soft-story buildings and broken gas mains. As a result of those collapsed buildings, San Francisco implemented a mandatory soft-story retrofit program that will be completed in 2020. The program dramatically improves the safety of nearly 5,000 buildings and more than 111,000 residents.

Other programs put in place after the 1989 Loma Prieta Earthquake include over $20 billion in capital improvements, a completed Unreinforced Masonry Building retrofit ordinance, regularly updated building codes, performance-based design for tall buildings, and community-based resilient hubs that cover a large portion of the city. The city also just completed a first-of-its-kind study of how tall buildings will perform in an earthquake and how they will affect surrounding neighborhoods.

San Francisco has also been aggressive in its efforts to adapt to the impacts of climate change. These include capturing rainwater and reducing runoff, restoring natural areas, planting trees, preserving biodiversity and open space, creating sea level rise guidelines, and putting together a sustainability plan for the most vulnerable neighborhood in the city, Chinatown.

6.1 SF Government Activities

The City and County of San Francisco plays a variety of roles with respect to how it develops and implements measures to increase resilience to hazards. These roles are categorized under five areas:

1. Funding and Finance;
2. Public Asset Owner;
3. Community Services Delivery;
4. Research, Planning, and Guidance; and
5. Adopts & Enforces Regulations.

The following describes the capabilities under each of these areas and includes examples of each capability. A more comprehensive list of each capability is available in Appendix F.

Funding and Finance

Given that San Francisco is one of the most expensive places in the world to live and build, the ability to have strong funding and financial mechanisms is critical to San Francisco's mitigation efforts. The City's **10-Year Capital Plan** and **its 5-Year Financial Plan** lay the foundation for hazard mitigation and climate adaptation funding. The Capital Plan establishes policies to fund large- and small-scale projects and incorporates life-safety, resilience, and sustainability in its core funding principles. The Financial Plan lays out policies to meet San Francisco's obligations and ensure sufficient rainy-day reserves and financing is available in the case of a large disaster or other emergency. These tools have helped San Francisco improve its infrastructure while maintaining the highest bond ratings possible.

The Office of Resilience and Capital Planning (ORCP) that is part of the City Administrator's Office oversees the 10-Year Capital Plan. ORCP updates the Capital Plan every odd numbered year. The FY 2020-2029 Capital Plan projects $39 billion in funding. The 5-year Financial Plan is jointly developed by the Controller's Office, the Mayor's Budget Office, and the Board of Supervisor's Budget Analyst's Office. Like the Capital Plan, they update the Financial Plan every odd-numbered year.

Both the Capital Plan and the Financial Plan use a wide range of revenue sources for infrastructure and services. The most common sources are general fund revenue, General Obligation bonds, Certificates of Participation, revenue bonds, general taxes, fees, and grants. Descriptions of these revenue sources can be found in Appendix F.

Opportunities for Expansion/Improvement

Despite a strong economy, the City and County still has unfunded needs. For example, the Capital Plan defers $5 billion in identified needs from General Fund departments. In an environment where needs exceed public funding capacity, developing innovative financing mechanisms is necessary. Secondly, climate adaptation projects involve multiple agencies and complex improvements that anticipate future changes to the environment. The City and County will increasingly need to coordinate complicated multi-agency adaptation projects, such as the Embarcadero Seawall and Ocean Beach. Lastly, the City can consider expanding financial incentives for private mitigation actions. The City currently offers Property Assessed Clean Energy (PACE) financing for soft-story retrofits and will need to consider additional financial incentives and programs for future mitigation and retrofit efforts.

Public Assets Owner

As an owner and builder of buildings and infrastructure, San Francisco has strong programs, mechanisms, and staff expertise to design, develop, construct, and maintain its assets. The buildings (vertical assets) range from public restrooms to complex hospitals and sewer treatment facilities. The infrastructure (horizontal assets) range from local streets to regional water delivery and transportation networks. Taking care of our capital infrastructure is an important part of building a resilient city. The City and County of San Francisco strives to maintain and improve existing assets and design new ones to withstand future hazards and serve the public's needs no matter what kinds of chronic stresses or acute shocks they face.

An example of San Francisco's mitigation capabilities for its buildings includes the **Neighborhood Fire Stations Program,** which addresses the most urgently needed repairs and retrofits to critical firefighting facilities and infrastructure. This program is funded by Earthquake Safety and Emergency Response (ESER) bonds that are placed on the ballet every six years or so.

An example of San Francisco's mitigation capabilities for its infrastructure is the **Sewer Safety Improvement Program,** a 20-year $7 billion citywide investment to upgrade San Francisco's aging sewer infrastructure to ensure a reliable, sustainable, and seismically-safe sewer system for generations to come.

Opportunities for Expansion/Improvement

The City and County can continue to retrofit vulnerable assets, especially for impacts that are new or increasing, such as sea level rise, extreme heat, and poor air quality.

Community Services Delivery

The City and County of San Francisco offers many services that assist vulnerable populations, helping them access services that reduce their vulnerability before and after a natural disaster. These services include increasing public awareness of hazards and empowering communities to care of and advocate for themselves.

The San Francisco **Homeless Outreach Team** is a collaboration between DPH, HSA, SF Public Library and the non-profit Public Health Foundation Enterprises. The program aims to engage and stabilize the most vulnerable and at-risk homeless individuals and to help prevent the harmful effects of homelessness. Through outreach, medical services, engagement, and advocacy, the program is dedicated to transitioning individuals into stable living and healthcare environments with access to services that promote greater health and housing retention, and reduce vulnerability and the need for emergency services.

The Mayor's Office of Housing and Community Development promotes **Stable and Healthy Housing** by funding non-profit partner organizations to provide essential and high-quality public services. These services include eviction defense and tenant counseling, information and counseling about housing programs, and population-specific housing support.

The **Neighborhood Empowerment Network's** Empowered Communities Program leverages a community development approach to advance a neighborhood's disaster resilience. By fusing together methods such as human centered design, collective impact and experiential leadership development, the program empowers neighborhoods to craft and implement culturally competent strategies that strengthen their capacity to negotiate times of stress and protect the health and well-being of all residents, especially the vulnerable. San Francisco has nine community based resident hubs and is in the process of developing several more.

Opportunities for Expansion/Improvement

The City can continue to improve the resilience of the facilities that provide services to vulnerable populations, such as shelters and subsidized affordable housing. The City can also consider ways to increase the resilience of leased facilities, such as public health clinics. Furthermore, the City can add capacity to expand the Empowered Communities Program and provide additional services for vulnerable populations during extreme weather events.

Research, Planning, and Guidance

The City and County of San Francisco invests in innovative hazards and climate change research that directly inform policies, programs, and services. The City consistently strives to better understand the local impacts of hazards and climate change, such as sea level rise and extreme heat, given San Francisco's unique local characteristics including a highly developed bay shoreline, dense urban form, and old and historic building stock.

The Department of Public Health developed the **Climate and Health Program** to develop solutions to support healthy and climate-ready communities. The Program has produced vulnerability assessments on heat and flooding and developed education and outreach materials.

Starting in 2014, and updated in 2015 and 2019, The City and County of San Francisco developed **Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco** to provide direction to all departments on how to incorporate sea level rise into new construction, capital improvement, and maintenance projects. The guidance includes steps for assessing and adapting projects to the impacts of sea level rise. It helps project managers and others doing construction in San Francisco to apply the latest sea level rise projections and guidance from the State to their projects.

Published in 2011, the **Community Action Plan for Seismic Safety (CAPSS)** created a 30-year plan to mitigate the risk San Francisco faces from earthquakes. CAPSS studied four probable earthquake scenarios and found that they could devastate the city's housing stock and have long-term implications on the City's affordability to middle- and low-income residents. Hundreds of people could be killed and thousands injured. The price tag of earthquake damage would be many billions of dollars. Taking action before an earthquake strikes is far less costly than repairing the damage, both in terms of dollars required and the social impacts. The CAPSS advisory committee, a diverse group of San Francisco residents, met over 30 times to develop recommendations. CAPSS continues to be the guiding document for San Francisco's on-going efforts and is implemented through the **Earthquake Safety Implementation Program.**

Opportunities for Expansion/Improvement

As climate change impacts increase, research will continue to be essential to ensure that the City can be proactive. Capital planning guidance can be expanded for additional climate stressors beyond sea level rise. The City can also continue to follow the CAPSS work plan, moving into more complex vulnerable building types, such as unreinforced concrete and steel moment frame buildings, that will have their own research needs to develop policies and programs.

Adopts and Enforces Regulations

San Francisco adopts regulations that govern the construction of buildings, the form of urban development, and natural resource protection, among others. Regulations are one of the primary mechanisms the City has for achieving mitigation and adaptation of privately owned buildings. For example, San Francisco passed a **Soft Story Retrofit Ordinance** in 2013 which mandates retrofits to wood-frame buildings of two or more stories with five or more residential dwelling units built before 1978 that are vulnerable to potential collapse in an earthquake. This program improves the safety of nearly 5,000 buildings and more than 111,000 residents.

In 2012, San Francisco adopted the Onsite Water Reuse for Commercial, multi-family, and Mixed-Use Development Ordinance, commonly known as the **Non-Potable Ordinance.** This amended the health code to allow for the collection, treatment, and use of alternate water sources, such as graywater, rainwater, and foundation drainage, for non-potable applications in individual buildings and at the district scale. This is a mandatory requirement for all new construction of 250,000 square feet or more.

Opportunities for Expansion/Improvement

Building and planning codes could be improved to better accommodate flooding, extreme heat, and poor air quality. Additional service level standards for utilities and building performance standards in light of expected earthquakes can also be further developed. In a City where the cost of construction is extremely high, any additional regulations need to be carefully studied to understand potential impacts to housing costs and impacts to low-income owners and renters.

6.2 Status of 2014 HMP Actions

In order to assess progress on local mitigation efforts, the 2019 HCR process involved reviewing the action plan detailed in the 2014 HMP in order to track updates for each of the projects pursued by departments across the City. Table 6-1 displays the status of all of these projects, including whether they are completed, delayed, or currently ongoing.

TABLE 6-1:
STATUS OF ACTIONS FROM 2014 HMP

Action #	Action Description	Status
1.A	Create a joint Planning Department (Planning)-Department of Building Inspection (DBI), GIS-based pre-computer system tying hazard areas such as liquefaction, lateral spread, landslide, or Special Flood Hazard Area (SFHA) to Assessor's Parcel Numbers (APNs) for new construction and major remodels in those areas.	Delayed
1.C	Implement Auxiliary Water Supply System (AWSS) Planning Study recommendations to rehabilitate the system, seismically brace weak pipes and cisterns, construct new cisterns, and make other improvements to ensure its continued operation after a disaster.	On schedule
2.A	Refine inventory and/or develop replacement values for all CCSF-owned facilities and their contents to help CCSF better understand the values of assets at risk.	On schedule
2.F	Develop criteria for high priority neighborhoods where microgrids can provide a strategic and critical difference for community energy emergency resilience. Identify up to 10 neighborhoods and specific areas for development of microgrids. Develop an implementation plan and funding plan for each microgrid.	Completed
3.A	Continue to hold workshops and advance implementation of the Mandatory Soft Story Retrofit Ordinance.	On schedule
3.B	Relocate the Office of Chief Medical Examiner (OME) to a seismically safe facility of about 45,000 square feet.	Completed

Action #	Action Description	Status
3.D	Relocate the San Francisco Police Department (SFPD) Forensic Services and Traffic Company to a seismically safe, 105,000 square foot building.	On schedule
3.H	Seismically upgrade the Treasure Island Causeway to preserve critical lifeline access to the island and to protect the utility corridor that runs under the causeway.	On schedule
3.I	Continue to develop the Building Occupancy Resumption Program (BORP) program for critical CCSF facilities and privately-owned buildings, and expand BORP to more buildings in CCSF, as appropriate.	On schedule
3.J	Continue to use FEMA-developed HAZUS and similar models and tools to guide emergency and capital planning decisions.	On schedule
3.K	Update or assign an additional 50 Seismic Hazard Ratings (SHR) to city-owned buildings using the City's rating system.	Completed
3.N	Seismically retrofit or upgrade seismically deficient Recreation and Parks Department (RPD) facilities and shelters.	Ongoing
4.B	Implement Phase I of the Sewer System Improvement Program (SSIP), including Low Impact Development (LID) projects, and conduct public outreach and Urban Watershed Seminars in the eight urban watershed areas of CCSF. Publish watershed design tools and website resources devoted to green infrastructure.	On schedule
4.E	Continue the Great Highway Long-Term Stabilization program to respond to continuing beach erosion impacts along the Great Highway at Ocean Beach south of Sloat Boulevard.	On hold
4.H	Develop a public outreach and awareness program about heat and human health. Ideas include media announcements; public information about heat effects and cooling centers; outreach visits to the elderly, homeless, and other vulnerable populations; community resilience efforts; etc.	Completed

Action #	Action Description	Status
4.I	Upgrade segments of the San Francisco International Airport (SFO) shoreline protection system that do not meet regulatory freeboard requirements when compared to the one-percent-annual-chance stillwater elevation. Address gaps in the system that could allow the entry of floodwater; and address openings for stormwater drainage that do not have closure devices, which could allow the entry of floodwaters. Upgrade seawalls to address sea level rise.	Ongoing
4.L	Perform annual maintenance of the Crystal Springs, Calaveras, and San Antonio watersheds to construct fire breaks, mow areas of grass, and clear around assets to prevent wildfire damage and mitigate wildfire hazards.	Ongoing
4.M	Upgrade storm drainage outfall pump stations 1A, 1B, and 1C to protect the SFO airfield from 100-year floods and sea level rise.	Delayed
5.A	Complete the Calaveras Dam retrofit, as part of the Water System Improvement Program (WSIP).	Completed
5.B	Implement recommended Buffer Zone Protection measures for predesignated critical facilities and infrastructure.	No longer pursuing
5.C	Develop and implement a public outreach campaign to educate property owners, and to enable removal of household hazardous waste from homes and businesses to prevent toxic spills, fires, environmental exposure, and health hazards in case of disaster.	On schedule
5.D	Implement physical security upgrades at all new WSIP facilities.	On schedule

Chapter 07

Strategy

The strategy chapter represents San Francisco's blueprint to reduce vulnerabilities identified in the Vulnerability and Consequences Assessment and increase its resilience to hazards. The approach is more comprehensive than previous Hazard Mitigation Plans, as the number of mitigation strategies has more than doubled, from 40 to over 95. The strategy development process has also been more rigorous, consisting of the following components that are described in detail in the subsequent sections:

- Hazards and Climate Resilience Goals
- Developing strategies, including evaluation
- Strategies for near-term implementation
- Additional strategies for consideration

7.1 Hazards and Climate Resilience Goals

The goals build upon related citywide planning documents, including the 2014 Hazard Mitigation Plan. The goals in the 2019 HCR include a greater emphasis on equity, partnerships, and public engagement in addition to San Francisco's ongoing commitment to reducing damage and disruption from hazards.

- **Protect the public health, safety, quality of life, environment, and economic and social capital of San Francisco** by reducing the risk of damage and disruption from hazards.
- **Build and support the capacity of City government and the greater San Francisco community,** to prevent, protect against, respond to, mitigate, and recover from hazards.
- **Advance local, regional, State, federal, private, and community collaborations and partnerships** to deliver actionable, effective, and innovative risk reduction solutions and data to support decisions.
- **Proactively seek to address racial, health, and economic inequities of hazard impacts. and advance equity** through the just distribution of risk reduction and resilience benefits.
- **Increase public awareness of hazards, risks, and City action to build resilience** through education, empowerment, and engagement.

7.2 Developing Strategies

The Planning Team in partnership with numerous departments developed the HCR development strategies over the course of several months (see Chapter 02: Planning Process). Planning Team members and their colleagues submitted strategies that reflect existing departmental plans and priorities, as well as forward-looking ways to address the vulnerabilities identified through the Vulnerability and Consequences Assessments (see Appendix A for details). To ensure that strategies build upon the City's existing actions and capabilities for implementation, the Team referenced the Capabilities Assessment from Chapter 06. Additionally, as described in Chapter 02, community-based organizations (CBOs) were consulted during the stakeholder engagement process to gather feedback from organizations that directly serve the public, with an emphasis on vulnerable communities that are more at risk from the effects of natural hazards. Recommendations and insights from this stakeholder engagement process have been integrated into existing strategies or as added new strategies.

Evaluation Criteria

The draft strategies submitted by the Planning Team were evaluated across six criteria types: environment, society and equity, economic, feasibility, governance, and disaster lifecycle. Table 7.1 describes the criteria. The purpose of the evaluation was to help develop multi-benefit strategies and ensure that all strategies consider the key lenses of equity, sustainability, and governance/implementation. The evaluation process also provided an opportunity to revise, clarify, and improve the strategies.

TABLE 7-1: STRATEGY EVALUATION CRITERIA

TYPE	CRITERIA	GUIDING QUESTIONS
Environment	Greenhouse gas emissions	Does the strategy reduce, eliminate, or sequester GHG emissions?
	Energy use	Does the strategy reduce energy use, such as through energy efficiency or conservation of resources?
	Water use	Does the strategy reduce water use, especially potable water?
	Ecological function	Does the strategy improve air, water, or soil quality, or enhance habitat health and biodiversity?
Society & Equity	Public health	Does the strategy improve health outcomes, such as reduced hospitalizations and chronic illnesses and increased life expectancy?
	Safety	Does the strategy reduce the risk of injury or death?
	Benefits targeted to vulnerable populations	Does the strategy benefit populations that are more sensitive to hazards and climate change or disproportionately impacted? For example, does the strategy reduce existing socio-economic disparities?
	Community cohesion and capacity	Does the strategy enhance connections between neighbors and organizations and their ability to work together to achieve common goals?
	Public awareness of hazards	Does the strategy enhance public awareness of current and future hazards and climate change and City/community resources available?
	Community stabilization	Does the strategy help residents and businesses stay in their neighborhood for the long term?
Economic	Household costs	Does the strategy lower household costs, such as housing, transportation, energy, and childcare?
	Service disruptions	Does the strategy reduce disruption to utilities, transportation, and social services (e.g., schools)?
	Buildings and infrastructure damage	Does the strategy reduce damage to buildings and infrastructure (e.g., either acute damage or longer-term stress to buildings and systems)?

TYPE	CRITERIA	GUIDING QUESTIONS
	Job creation	Does the strategy create good jobs; e.g., jobs at a range of education/skill levels and at a living wage with benefits?
Feasibility	Existing staff/administrative capacity and skills	Does the City have existing staff with the needed capacities, skills, and knowledge to undertake this strategy and/or access to needed technical support?
	Political support	Is there political will and leadership (e.g., elected officials, community-based, executives) for this strategy to succeed?
	Existing funding capacity	Are there existing means/capacity to fund this strategy?
	Legal/existing authority and jurisdiction	Does the legal authority exist to undertake this strategy?
Governance	Diverse representation	Is the planning and implementation of this strategy inclusive of the range of populations and stakeholders that would be affected by it?
	Partnerships & collaboration	Does the implementation of the strategy leverage and enhance partnerships and collaboration?
Disaster Lifecycle	Disaster recovery	Does the strategy support the community's or City's efforts to rebuild better after a disaster and revitalize effected systems, including housing, health, economy, and natural and cultural resources?
	Disaster response	Does the strategy support response during or immediately following a hazard event to save lives and prevent further property damage?
	Disaster preparedness	Does the strategy support individuals, households, or communities in developing plans for what to do or where to go during a hazard event and/or improve their chances of successfully dealing with an emergency?
	Mitigates multiple hazards	Does the strategy prevent or reduce the impacts of multiple hazards?

7.3 Strategies

As mentioned above, the 2019 HCR addresses a wide range of vulnerabilities. The Plan includes over 95 near-term strategies that contribute to a more resilient city. The strategies are organized into three domains:

(IN) ***Resilient infrastructure*** covers all transportation and utility systems, public ways, and built infrastructure, such as the seawall, natural areas, open spaces, and the associated biological and ecological resources; often, referred to as "horizontal" development.

(B) ***Resilient Buildings*** covers all public and private residential, commercial, and institutional buildings; often referred to as "vertical" development.

(C) ***Resilient Communities*** covers all residents, workers, and visitors including the various communities, associations, neighborhoods, and districts that make up San Francisco. A resilient community enhances the probability that people can withstand hazard impacts and thrive after experiencing shocks and stresses.

The strategies are then further organized by primary hazard groups. While many them address more than one hazard, each strategy is assigned to groups based on the predominant hazard the strategy addresses. If a strategy equally addresses all hazards, then the strategy is placed in the all-hazards group. The hazard groups are as follows:

1. Geological

a. Earthquake
b. Tsunami
c. Landslide
d. Dam or reservoir failure

2. Weather-Related

a. Flooding
b. High Wind
c. Extreme Heat
d. Drought

3. Combustion-Related

a. Large Urban Fire
b. Wildfire
c. Poor Air Quality

4. Biological & Toxic

a. Pandemic
b. Hazardous Materials

5. All-Hazards

Each strategy is assigned a code/number that identifies its domain and primary hazard group. Some strategies are assigned a sub-strategy number, if they are closely associated with other strategies and/or are considered a specific instance or sub-strategy of an overall umbrella strategy.

Domain code
Primary hazard group number
Strategy number (2 digits)
Sub-strategy number (2 digits)

IN-1.03.01

Table 7-2 outlines the comprehensive set of HCR strategies, including the strategy number (domain and hazard), title, and lead department(s). The strategies are clustered by domain and organized within each domain by primary hazard group.

TABLE 7-2: STRATEGIES TABLE OF CONTENTS

IN: RESILIENT INFRASTRUCTURE

1. GEOLOGICAL		LEAD
IN-1.01	Conduct a seismic assessment of critical City assets along the Southern Waterfront	Port
IN-1.02	Conduct a research project for earthquake mitigation of marine structure piles	Port
IN-1.03.01	Develop technologies, systems, and capacity to treat sanitary sewage at SFO	SFO
IN-1.03.02	Develop redundant and resilient electrical power capacity and distribution at SFO	SFO/SFPUC
IN-1.04	Conduct a Risk and Resilience Assessment and Emergency Response Plan for the City's water infrastructure system	SFPUC
IN-1.05	Complete the Lifelines Restoration Performance Project and implement recommendations	ORCP
IN-1.06	Increase the resilience of the Municipal Fiber Optic Network	SFDT
IN-1.07	Increase the resilience of the 911 Radio System	SFDT
IN-1.08	Implement multi-hazard mitigation improvements for harbor dock infrastructure	Port/RPD
IN-1.09	Develop a hazard mitigation and emergency response evacuation plan for SF Zoo	SF Zoo/RPD
IN-1.10	Implement the East Harbor Renovation Project	Port/RPD
IN-1.11	Implement a Security Strategy for SFMTA	SFMTA

IN: RESILIENT INFRASTRUCTURE (CONTINUED)

	2. WEATHER-RELATED	LEAD
IN-2.01	Develop projects to address flooding around Islais Creek	Planning
IN-2.02	Develop a process to move utilities from under pier structures	Port
IN-2.03	Continue to implement the Ocean Beach Master Plan	SFPUC
IN-2.04	Adapt shoreline parks to sea level rise and salt water intrusion, using marshes and plant diversity	RPD
IN-2.05	Assess the current stormwater catchment potential of open space managed by the Recreation and Parks Department	RPD
IN-2.06	Expand the StreetTreeSF Climate Resilient Tree Planting Initiative	Public Works
IN-2.07	Complete the Extreme Precipitation Study	SFPUC
IN-2.08	Complete a comprehensive assessment of combined flood risks for San Francisco	SFPUC
IN-2.09	Develop multi-hazard resilience design guidelines for capital planning that addresses climate action goals	Port
IN-2.10	Explore increasing tree canopy and shade structures in parks	RPD
IN-2.11	Assess current plant palettes and tree canopy needs to increase consideration of future climate conditions in the selection options	RPD
IN-2.12	Diversify water supply options year-round by improving the use of new water sources and drought management	SFPUC
IN-2.13	Develop a strategy to conserve and monitor water use by capital projects	Public Works/SFPUC
IN-2.14	Develop a Long-term Vulnerability Assessment and Adaptation Plan for the Hetch Hetchy Regional Water System	SFPUC
IN-2.15	Implement a Coastal Multimodal Resilience Strategy	SFMTA
IN-2.16	Strengthen citywide efforts to conserve, restore, and steward biodiversity	SFE

	3. COMBUSTION-RELATED	LEAD
IN-3.01	Complete studies, analysis, and capital projects to improve and expand the Emergency Firefighting Water System (EFWS)	SFPUC
IN-3.02	Improve the capacity of the Portable Water Supply System to fight fires following earthquakes and other large urban fires	SFFD
IN-3.03	Continue to mitigate wildfire hazards in SFPUC-owned watersheds to protect source water quality and minimize risk to SFPUC water and power infrastructure	SFPUC
IN-3.04	Improve Fire Prevention in Recreation Areas	RPD

IN: RESILIENT INFRASTRUCTURE (CONTINUED)

	4. ALL HAZARDS	LEAD
IN-5.01	Conduct a system-wide multi hazard vulnerability and operational assessment for Muni	SFMTA
IN-5.02	Reduce seismic and flood risk along three miles of the San Francisco Waterfront from Fisherman's Wharf to Mission Creek	Port
IN-5.03	Continue to advance Sewer System Improvement Program (SSIP) projects to meet level-of-service objectives	SFPUC
IN-5.04	Implement the Pipe Replacement Prioritization Program	SFPUC
IN-5.05	Continue to improve power distribution infrastructure to support new development and increase resilience	SFPUC
IN-5.06	Enhance flood and earthquake resilience of regional dams and ancillary facilities	SFPUC/DSOD
IN-5.07	Develop a Citywide Climate Resilience Framework	ORCP
IN-5.08	Implement SFMTA Communications & IT Strategy	SFMTA
IN-5.09	Implement SFMTA Asset Management & State of Good Repair Strategy	SFMTA
IN-5.10	Implement SFMTA Transit Fixed Guideway Strategy	SFMTA

B: RESILIENT BUILDINGS

1. GEOLOGICAL		LEAD
B-1.01.01	Assess and seismically retrofit municipal buildings	ORCP
B-1.01.02	Seismically improve the Port's Department Operations Control Center, Headquarters, and Joint Operations Control facilities	Port
B-1.02	Develop an earthquake risk improvement program for non-structural components of municipal buildings	ORCP
B-1.03	Develop a voluntary program for seismic retrofits of one- to four-unit wood frame, soft-story buildings	ORCP/DBI
B-1.04	Implement the Tall Building Strategy to address the seismic vulnerability of buildings taller than 250 feet	ORCP/DBI
B-1.05	Extend and improve the Building Occupancy Resumption Program (BORP)	DBI
B-1.06	Complete the Mandatory Soft-Story Retrofit program (pre-1978 buildings with 5+ units and 2+ stories)	DBI
B-1.07.01	Develop a program (standards and guidance) to screen, evaluate, and retrofit older steel buildings	ORCP/DBI
B-1.07.02	Develop a program to screen, evaluate, and retrofit non-ductile concrete buildings	ORCP/DBI
B-1.08	Implement the SFMTA Parking Strategy	SFMTA

2. WEATHER-RELATED		LEAD
B-2.01	Develop multi-hazard resilience design guidelines for municipal buildings	ORCP
B-2.02	Review the Guidance for incorporating sea level rise into capital planning	ORCP
B-2.03	Develop a program to analyze, identify, and evaluate properties at risk of stormwater flooding	SFPUC
B-2.04	Implement floodproofing and elevation projects for properties at risk of stormwater flooding citywide	SFPUC

3. COMBUSTION-RELATED		LEAD
B-3.01	Study emergency clean air and cooling capacity at key community facilities	DPH
B-3.02	Increase privately-owned building weatherization rates	SFE
B-3.03	Support increased building electrification (fuel switching) and mechanical upgrades	SFE

B: RESILIENT BUILDINGS (CONTINUED)

5. ALL HAZARDS		LEAD
B-5.01	Amend the capital improvement program for transportation facilities to consider hazard mitigation opportunities	SFMTA
B-5.02	Install solar + storage systems at critical facilities	Public Works
B-5.03	Secure a resilient public safety training facility for SFFD	SFFD
B-5.04	Increase resilience and operation efficiency of maintenance yards	Public Works
B-5.05	Explore options to use Recreation Centers as public respite facilities	RPD
B-5.06	Develop comprehensive and coordinated code amendments for multi-hazard resilience of private development	Planning

C: RESILIENT COMMUMITIES

1. GEOLOGICAL		LEAD
C-1.01	Address seismic retrofit needs within San Francisco's affordable housing stock	MOHCD
C-1.02	Develop a Downtown Recovery Strategy	ORCP
C-1.03	Improve San Francisco's Implementation of the State's Safety Assessment Program	ORCP/DBI
C-1.04	Develop a post-hazard Open for Business campaign	OEWD
C-1.05	Continue to meet housing production goals	MOHCD
C-1.06	Develop a public outreach campaign and wayfinding plan for tsunami awareness and evacuation procedures	DEM
C-1.07	Assess vertical evacuation options in high-hazard areas and guidance for large-building refuges	DBI/DEM
4. BIOLOGICAL & TOXIC		**LEAD**
C-4.01	Expand household hazardous waste collection efforts	SFE
C-4.02	Replace mercury-containing lighting in preschools and daycare centers	SFE
C-4.03	Explore toxins abatement workforce development programs	OEWD
C-4.04	Improve citywide resilience to pandemics and infectious diseases	DPH

C: RESILIENT COMMUMITIES (CONTINUED)

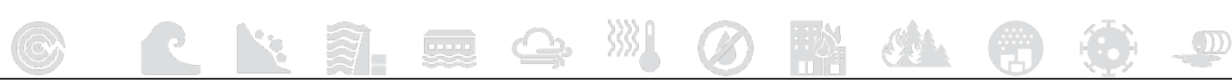
5. ALL HAZARDS		LEAD
C-5.01	Identify and create Clean Air/Cooling Hub (CACH) Public Respite Facilities	ORCP
C-5.02	Develop a Homelessness Disaster Response Plan	HSH
C-5.03	Support volunteer emergency preparedness, response, and recovery programs, including the Neighborhood Emergency Response Team (NERT) and Auxiliary Law Enforcement Response Team (ALERT)	SFFD/SFPD
C-5.04	Create a program to coordinate existing City programs providing in-home and resident-facing services related to hazard and climate mitigation	DEM/DPH
C-5.05	Develop a Preparedness Equipment Purchase Program to direct and fund the purchase of climate preparedness equipment	DEM/DPH
C-5.06	Expand the Neighborhood Empowerment Network (NEN) Empowered Communities Program (ECP) to additional neighborhoods	NEN
C-5.07	Perform gap analysis of vulnerable populations (i.e., Access and Functional Needs) and available City services	MOD
C-5.08	Develop a community-based capacity building initiative	MOD
C-5.09	Establish an Evacuation Strategy for people with access and functional needs	DAAS/MOD
C-5.10	Continue Small Business COOP Assistance	OEWD
C-5.11	Support the Small Business Development Center	OEWD
C-5.12	Establish disaster relief funding and small business resilience fund	OEWD
C-5.13	Expand layoff outplacement services	OEWD
C-5.14	Expand Women's Entrepreneurship Fund	OEWD
C-5.15	Study the overlap between vulnerable populations and vulnerable buildings	Planning/ DPH/ORCP
C-5.16	Develop and manage a system for hazard and climate resilience data	ORCP/SFDT
C-5.17	Develop a communications strategy for citywide climate resilience efforts	ORCP
C-5.18	Improve San Francisco's climate health research capacity	DPH
C-5.19	Develop and implement a Centralized Air Quality and Extreme Heat Preparedness campaign	DPH
C-5.20	Implement SFMTA's Traffic Signals Strategy	SFMTA
C-5.21	Improve and prepare behavioral health services for hazard events	DPH
C-5.22	Continue to build trust between the Police Department and the communities they serve	SFPD

7.4 Strategy Descriptions

The strategy descriptions in the following section identify the vulnerabilities the strategy addresses, lead agency and potential partners, SF government activity, estimated costs, and key planning issue(s) associated with the strategy. The strategies in this section are near-term strategies that the City aims to make progress on in the next five years.

Strategy Key

The example table and associated text below describe the different components and level of detail that can be found in each strategy description.

<table>
<tr><th>CODE #</th><th colspan="3">Strategy Name</th></tr>
<tr><td colspan="2">KEY PLANNING ISSUES:
Connection to one of six key planning issues from Chapter 05</td><td colspan="2">VULNERABILITY ADDRESSED:
Describes the issue from the vulnerability and consequences assessment that the strategy seeks to address</td></tr>
<tr><td>LEAD:
Agency in charge of implementing
PARTNERS:
Agencies or other groups as potential partners</td><td colspan="3">STRATEGY SUMMARY:
Short description of the strategy</td></tr>
<tr><td colspan="2">COST:
Low / Med / High (described below)</td><td>SF GOVERNMENT ACTIVITY:
Public Assets Owner (described below)</td><td>STATUS:
New / Scaling / Sustaining (described below)</td></tr>
<tr><td colspan="4">Applicable hazards:
</td></tr>
</table>

Cost

The costs indicated for the strategies represent the rough order-of-magnitude resources that may be required to implement the strategy. For ongoing strategies, the cost of implementation may be fully or partially funded. For new or proposed strategies, funds may not be committed and are subject to approval through the City's capital planning and budgeting process.

Strategy costs are indicated at one of the following three levels:

- Low: $0–$500K
- Medium: $500K to $5M
- High: $5M and above

SF Government Activity

Each strategy is associated with a type of government activity that refers to how it is put into action in relation to San Francisco's capabilities to influence resilience. See Chapter 06 for a description of these activities. The activities included the following:

- Funding and Financing
- Public Assets Ownership
- Community Services Delivery
- Research, Planning & Guidance
- Adoption & Enforcement of Regulations

Strategies that encompass more than one government activity are assigned to the activity that most directly engages or impacts stakeholders. For example, a new regulation that might require research before implementation, is assigned to "Adopt & Enforce Regulations" because of the impact that a regulation has on the applicable population.

Strategies that involve the planning, design, construction, and/or operation of public facilities are assigned to the "Public Assets Owner" activity, even though, to a great extent, the ownership of a facility could be considered a subset of the activity "Community Services Delivery".

Status

This section of the strategy description indicates whether the strategy is a completely new initiative (new), an activity that the City will be scaling up or expanding (scaling), or an existing activity that the City is sustaining (sustaining).

Applicable Hazards (Icons)

Table 7-3 shows the legend for the 13 hazard icons shown at the bottom of each strategy. Hazards that are applicable to the specific strategy are shown in color whereas non-applicable hazards are faded out. The color coding matches the primary hazard groups. The “All Hazards” group is indicated by displaying icons in color for all thirteen hazards and by the green color bar around the strategy code.

TABLE 7-3: HAZARD ICON LEGEND

Earthquake	Tsunami	Landslide	Dam or Reservoir Failuure	Flooding	High Wind	Extreme Heat	Drought	Large Urban Fire	Wildfire	Poor Air Quality	Pandemic	Hazardous Materials
												
Geological				Weather-Related				Combustion-Related			Biological & Toxic	

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Geological

IN-1.01	Conduct a seismic assessment of critical City assets along the Southern Waterfront	
KEY PLANNING ISSUES: Waterfront	**VULNERABILITY ADDRESSED:** A number of critical Port, industrial, shoreline protection, and emergency response facilities and services may be damaged and disrupted in a seismic event, including the freight rail, Piers 80–96, and Pier 50.	
LEAD: Port **PARTNERS:** Planning, SFMTA, SFPUC, OCRP	**STRATEGY SUMMARY:** The Port of San Francisco has many facilities in the area south of Mission Bay, providing critical services to the community, City, and Port. The Port has conducted a broad assessment of seismic risks in the area from Fisherman's Wharf to Mission Bay and is currently refining that assessment under the Seawall Earthquake Safety Program. However, there is a need for assessment of the area from Mission Bay to Heron's Head Park.	
COST: Low: $0–500K	**SF GOVERNMENT ACTIVITY:** Public Assets Owner	**STATUS:** New

IN-1.02	Conduct a research project for earthquake mitigation of marine structure piles	
KEY PLANNING ISSUES: Waterfront	**VULNERABILITY ADDRESSED:** Most of the Port assets and services sit on piers over the Bay. These assets and services: historic districts, areas of significant assembly, critical emergency response, and local and regional transportation infrastructure are vulnerable to earthquake damage.	
LEAD: Port **PARTNERS:** UC System, other west coast cities/ports, FEMA	**STRATEGY SUMMARY:** Many ports and military installations located along the U.S. west coast have been identified as national critical infrastructure by DHS FEMA. These nationally significant ports are vulnerable to impacts from seismic events. Mitigation measures for restoration of piles after an earthquake requires increased understanding of this infrastructure. This strategy would establish a research program to explore the weaknesses and best practice repair methods for this infrastructure.	
COST: High: $5M and above	**SF GOVERNMENT ACTIVITY:** Public Assets Owner	**STATUS:** New

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Geological

IN-1.03.01	Develop technologies, systems, and capacity to treat sanitary sewage at SFO	
KEY PLANNING ISSUES: Utilities, Waterfront	VULNERABILITY ADDRESSED: Sanitary sewer conveyance has reached its 40-year useful life and will hit threshold capacity. There is no redundant system in the event of a failure.	
LEAD: SFO PARTNERS:	STRATEGY SUMMARY: San Francisco International Airport's (SFO) long-term plan is to have the technologies, systems, and capacity to treat sanitary sewage for the SFO's growth through 2040, and to comply with current and upcoming State of California sewage treatment requirements.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining

IN-1.03.02	Develop redundant and resilient electrical power capacity and distribution at SFO	
KEY PLANNING ISSUES: Utilities	VULNERABILITY ADDRESSED: Sanitary sewer conveyance has reached its 40-year useful life and will hit threshold capacity.	
LEAD: SFO, SFPUC PARTNERS:	STRATEGY SUMMARY: The long-term plan for SFO is to have fully redundant 12 kilovolt electrical power feeds from two separate sources with the capacity to provide power to SFO through 2040. The two substations feeding SFO will have redundant transformer capacity and cabling into SFO. Planning will occur in 2019–2020 and design/construction in phases from 2021–2025. This strategy is part of the SFO's FY19/20 Infrastructure Capital Improvement Program.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Geological

IN-1.04 Conduct a Risk and Resilience Assessment and Emergency Response Plan for the City's water infrastructure system

KEY PLANNING ISSUES:
Utilities

VULNERABILITY ADDRESSED:
SFPUC Water Enterprise critical assets and infrastructure, regionally and in-city, might face risks and gaps in the system and processes, from natural and malevolent hazards.

LEAD:
SFPUC

PARTNERS:

STRATEGY SUMMARY:
SFPUC will comply with EPA's America's Water Infrastructure Act by conducting an all-hazards Risk and Resiliency Assessment (RRA) and exploring risks and gaps in the systems and processes, from natural and malevolent hazards. SFPUC will analyze resilience of pipes, physical barriers, source water, raw water collection and intake; pretreatment, treatment, storage and distribution facilities; and electronic, computer, and other automated systems. SFPUC will evaluate monitoring practices, financial infrastructure, storage and handling of chemicals, and operation and maintenance of the system. Emergency Response Plans will be updated based on recommendations from the RRA.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Medium: $500K to $5M	Public Assets Owner	Sustaining

IN-1.05 Complete the Lifelines Restoration Performance Project and implement recommendations

KEY PLANNING ISSUES:
Utilities

VULNERABILITY ADDRESSED:
Depending on severity and building type, damages can lead from short- to long-term closure. The shutdown of financial institutions and other global companies might have economic impacts that are felt worldwide.

LEAD:
ORCP

PARTNERS:
DEM, SFPUC, Public Works, private utilities

STRATEGY SUMMARY:
Following a disaster, the timely restoration and recovery of hospitals, homes, businesses, non-profit organizations and government of San Francisco depend on lifeline systems such as transportation, communication, water and wastewater, electricity, natural gas, and fuel. The Lifelines Restoration Performance Project will develop a simple infrastructure resilience assessment framework to establish performance goals—that is, desired targets for system recovery timelines following a scenario earthquake event, evaluate the current state of performance for specific systems in that earthquake, and recommendation actions to achieve desired restoration times.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Low: $0–500K	Research, Planning, & Guidance	Sustaining

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Geological

IN-1.06 Increase the resilience of the Municipal Fiber Optic Network

KEY PLANNING ISSUES:
Utilities

VULNERABILITY ADDRESSED:
Damage and disruption to San Francisco's commercial buildings can disrupt residents' work and workplace social networks, and can prompt widespread short-term unemployment

LEAD:
SFDT

PARTNERS:
SFMTA, SFPUC, SFFD, Joint Pole Assoc., PG&E

STRATEGY SUMMARY:
The City has a fiber network connecting almost all critical facilities and systems. A breakdown of this system due to a hazard event could result in a breakdown of communication between City departments, buildings, and the public for several days; severely affecting disaster response. Presently, there are no staff authorized to maintain or repair the fiber network. Authorizing two fiber crews consisting of ten employees to install redundant fiber paths and a well-designed backup microwave link will ensure enhanced reliability and resilience for fiber infrastructure in case of a major disaster.

COST:
High: $5M and above

SF GOVERNMENT ACTIVITY:
Public Assets Owner

STATUS:
New

IN-1.07 Increase the resilience of the 911 Radio System

KEY PLANNING ISSUES:
Utilities

VULNERABILITY ADDRESSED:
911 Radio System is the primary means of communication for law enforcement agencies and for field staff of City departments. The Radio System has several critical components that are vulnerable to major disasters that will severely impact 911 dispatch and response.

LEAD:
SFDT

PARTNERS:
SFMTA, SFPUC, SFFD, Joint Pole Assoc., PG&E

STRATEGY SUMMARY:
The 911 Radio System consists of ten widely distributed, interconnected, fixed radio sites that are vulnerable to hazards. A power failure will shut the system down if the emergency generators are not promptly refueled. Acquiring additional fuel trucks will increase the fuel capacity of the system. Adding fixed and mobile radio sites will also ensure enhanced reliability and resiliency of the system in case of disaster.

COST:
High: $5M and above

SF GOVERNMENT ACTIVITY:
Public Assets Owner

STATUS:
New

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Geological

IN-1.08 Implement multi-hazard mitigation improvements for harbor dock infrastructure

KEY PLANNING ISSUES:
Waterfront

VULNERABILITY ADDRESSED:
San Francisco's "worst-case" tsunami scenario, ranging from 22 feet above mean sea level at Ocean Beach to 6 feet at Candlestick Point, will severely impact people and infrastructure located in low-lying coastal areas.

LEAD:
Port, RPD

PARTNERS:
DEM, TIDA, California Tsunami Program

STRATEGY SUMMARY:
The California Tsunami Program has developed harbor-specific analyses and improvement reports that identify where improvements might be needed. These measures would reduce vessels from becoming dislodged during high wave/current events and reduce docks being jammed, damaged, and free floating during high wave/current events. Installation of dock pile reinforcement and extenders will reduce floating docks from becoming loose during high/rising water events (including tsunamis, King tides, and long-term sea level rise). Increased strengthening of wharf/pier connectors will reduce the failure of these structures during high-water events.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Medium: $500K to $5M	Public Assets Owner	Sustaining

IN-1.09 Develop a hazard mitigation and emergency response evacuation plan for SF Zoo

KEY PLANNING ISSUES:
Waterfront, Existing Buildings

VULNERABILITY ADDRESSED:
Tsunami mapping indicates that flooding might impact large portions of the San Francisco Zoo. Such flooding could cause loss of life of people and animals, and damage to Zoo facilities.

LEAD:
SF Zoo, RPD

PARTNERS:
DEM, SFE, CA Tsunami Program

STRATEGY SUMMARY:
The combined factors of coastal flooding from sea level rise, King tides, and tsunamis could put the San Francisco Zoo at risk of flooding. Hazards could be compounded by having to evacuate patrons, animals, and Zoo personnel with only hours to complete the process. The City should develop a plan for response and evacuation of visitors and animals alike. Planning and hard counter-measures could greatly reduce the exposure to flooding and potential complications of tsunami events.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Medium: $500K to $5M	Public Assets Owner	New

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Geological

IN-1.10	Implement the East Harbor Renovation Project	
KEY PLANNING ISSUES: Waterfront	**VULNERABILITY ADDRESSED:** Tsunami scenarios, ranging from 22 feet above mean sea level at Ocean Beach to 6 feet at Candlestick Point, might severely impact maritime facilities at the Port, the East Marina Small Craft Harbor (a.k.a. Gas House Cove) and West Marina San Francisco Yacht Harbor, Pier 1 on Treasure Island, and South Beach Harbor Marina.	
LEAD: Port, RPD **PARTNERS:** SFPUC, DEM, TIDA, CA Tsunami Program	**STRATEGY SUMMARY:** Reinforce harbor and marina fuel and sewage docks with pump-out stations, where they exist, in San Francisco maritime areas. Add protective measures—such as automatic fuel or sewage shutoff valves, hardened but flexible fuel/sewage transmission pipes, and floating debris protection devices—to reduce the potential for damage and dispersal of hazardous substances.	
COST: High: $5M and above	**SF GOVERNMENT ACTIVITY:** Public Assets Owner	**STATUS:** New

IN-1.11	Implement San Francisco Metropolitan Transportation Agency (SFMTA) Security Strategy	
KEY PLANNING ISSUES: Transportation	**VULNERABILITY ADDRESSED:** Transit stations rely on electric power, communications systems, and the sewer system to operate. There are typically no redundancies in regards to these external services.	
LEAD: SFMTA **PARTNERS:**	**STRATEGY SUMMARY:** This strategy maintains the crucial security and emergency management systems that make the City's transportation system safe, reliable, and more resilient in the face of natural disasters. The San Francisco Metropolitan Transportation Agency (SFMTA) seeks to ensure the safety and security of its passengers and operational facilities through on-going monitoring and surveillance, implementation of security projects, and coordination with the City's Department of Emergency Management. This strategy will implement short-term projects that improve security and reduce risks from natural disasters and other emergency situations. Funding for this strategy is included in the FY2019–FY2023 Capital Improvement Program.	
COST: Medium: $500K to $5M	**SF GOVERNMENT ACTIVITY:** Public Assets Owner	**STATUS:** Sustaining

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Weather-Related

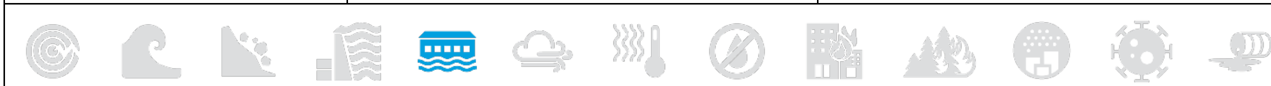
IN-2.01	**Develop projects to address flooding around Islais Creek**	
KEY PLANNING ISSUES: Waterfront	VULNERABILITY ADDRESSED: Numerous transportation assets in the vicinity of Islais Creek would be subjected to flooding from urban precipitation and sea level rise in the future.	
LEAD: Planning PARTNERS: Port, SFMTA	STRATEGY SUMMARY: In coordination with the Port, SFMTA, and other partners, the Planning Department will create designs for priority projects that address current and future flooding concerns while addressing other neighborhood and citywide goals, as identified through the ISMAS process. These designs will come from extensive public process and benefit an underserved neighborhood, as well as citywide infrastructure and biodiversity by incorporating ecosystem services.	
COST: Medium: $500K to $5M	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining

IN-2.02	**Develop a process to move utilities from under pier structures**	
KEY PLANNING ISSUES: Waterfront	VULNERABILITY ADDRESSED: The Port has a number of piers with under-pier utilities that are at risk from storm events and sea level rise. As water levels rise, the window for maintenance and replacement work decreases, while damage to and disruption of the utilities increases.	
LEAD: Port PARTNERS:	STRATEGY SUMMARY: Many ports and military installations located along the U.S. west coast have been identified as nationally critical infrastructure by FEMA. These nationally important ports are vulnerable to impacts from seismic events. Mitigation measures for restoration of piles after an earthquake requires increased understanding of this infrastructure. This strategy would establish a research program to explore the weaknesses and best practice repair methods for this infrastructure.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: New

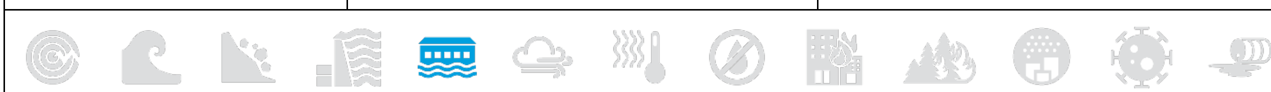
DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Weather-Related

IN-2.03	Continue to implement the Ocean Beach Master Plan	
KEY PLANNING ISSUES: Waterfront	VULNERABILITY ADDRESSED: Climate-induced sea level rise and severe erosion are threatening the southern portion of Ocean Beach, with implications for recreation amenities and major infrastructure that reduces risk to water quality and the environmental and public health for the City and County of San Francisco	
LEAD: SFPUC PARTNERS: Public Works, SFMTA, RPD, GGNRA, SF Zoo	STRATEGY SUMMARY: The SFPUC will serve as the lead agency for the Ocean Beach Climate Change Adaptation Project addressing sea level rise, erosion, and shoreline protection at the southern end of Ocean Beach. Each partner agency will be responsible for funding the components of the project that fall within their jurisdiction. The main strategies include managed retreat, asset protection through grey infrastructure, and natural adaptation measures that improve public access and habitat quality. The project is divided into short-and long-term improvements. The short-term improvements are meant to improve interim conditions while the long-term project is under development.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining



IN-2.04	Adapt shoreline parks to sea level rise and salt water intrusion, using marshes and plant diversity	
KEY PLANNING ISSUES: Waterfront	VULNERABILITY ADDRESSED: Coastal flooding due to sea level rise could eventually drown shoreline habitats resulting in the loss of critical ecosystem services and biodiversity. Flooding can negatively impact planted areas and trees and saltwater flooding is especially damaging to planted areas.	
LEAD: RPD PARTNERS: Port, USACE	STRATEGY SUMMARY: Develop a framework for making vegetation throughout the park system, including shoreline parks with marshes, better able to cope with future climate and sea level rise conditions, including repetitive salt water exposure. Some elements are already in place as the Recreation and Parks Department (RPD) plants wind- and salt-tolerant plants near the coast; however, this approach needs to be formalized. Additionally, co-benefits to biodiversity should be considered.	
COST: TBD	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: New



DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Weather-Related

IN-2.05	Assess the current stormwater catchment potential of open space managed by the Recreation and Parks Department	
KEY PLANNING ISSUES: Utilities	**VULNERABILITY ADDRESSED:** Planted areas and sports fields are sensitive to flooding and extremely sensitive to saltwater flooding. Damage due to flooding will increase operations and maintenance costs.	
LEAD: RPD **PARTNERS:** SFPUC	**STRATEGY SUMMARY:** Open space, especially in vegetated park land, offers existing stormwater catchment for the city. This strategy will measure and catalogue how much water is absorbed at RPD sites, consequently contributing to a better understanding of the value of park spaces in stormwater runoff mitigation. Additionally, it will formalize the installation of new permeable hardscapes where stormwater could be reduced. Washington Square Park, Alamo Square, Alta Plaza, and Jefferson Square are all examples where this approach has been pursued, benefiting water conservation. Models of hardscape projects that have been converted to water infiltration projects include the Crocker Amazon Soccer parking lot and Golden Gate Park Dog Training Facility.	
COST: TBD	**SF GOVERNMENT ACTIVITY:** Public Assets Owner	**STATUS:** New

IN-2.06	Expand the StreetTreeSF Climate Resilient Tree Planting Initiative	
KEY PLANNING ISSUES: N/A	**VULNERABILITY ADDRESSED:** Extreme heat can damage vegetation over extended periods, impacting the function of ecosystems and, thereby, reducing the efficacy of the ecosystem services they provide.	
LEAD: Public Works **PARTNERS:** OEWD, City agencies with streetscape projects, Non-Profit	**STRATEGY SUMMARY:** SFPW's Bureau of Urban Forestry (BUF) maintains the City's 125,000 street trees. The StreetTreeSF Climate Resilient Tree Planting Initiative will reduce neighborhood vulnerability to climate threats while meeting the San Francisco Urban Forest Plan's goal of growing the street tree population by half. Tree planting will prioritize neighborhoods with low tree canopy rates, those most vulnerable to extreme heat, and public health/air quality disparities. Species will be selected with a climate adaptation and mitigation focus to promote carbon sequestration, pest and disease resilience, drought tolerance, urban heat island reduction, and stormwater filtration.	
COST: High: $5M and above	**SF GOVERNMENT ACTIVITY:** Public Assets Owner	**STATUS:** Scaling

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

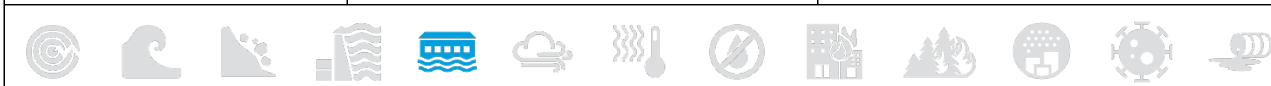
Primary Hazard Group: Weather-Related

IN-2.07 Complete the Extreme Precipitation Study

KEY PLANNING ISSUES:	VULNERABILITY ADDRESSED:
Utilities	Modeling the effects of climate change on intensifying mid-latitude cyclone and atmospheric storm events is essential to understanding future impacts to critical infrastructure in the San Francisco Bay Area.

LEAD: / PARTNERS:	STRATEGY SUMMARY:
LEAD: SFPUC PARTNERS: Port, SFO, ORR	One of Lawrence Berkeley National Laboratory's (LBNL's) missions is to perform innovative research that enhances understanding of a broad range of scientific disciplines, including climate change related modeling. To advance their modeling expertise, LBNL is collaborating with San Francisco via the SFPUC to help advance their high-resolution models. The improved models will help answer the question of how much more intense future precipitation events will be in a warmer world.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Medium: $500K to $5M	Research, Planning & Guidance	Sustaining

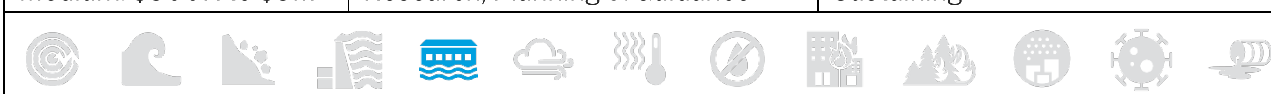


IN-2.08 Complete a comprehensive assessment of combined flood risks for San Francisco

KEY PLANNING ISSUES:	VULNERABILITY ADDRESSED:
New Development	Understanding and planning for combined flood risk from coastal flooding (including sea level rise), extreme precipitation, stormwater, and groundwater is important for San Francisco. There is no current effort to asses combined flood risk.

LEAD: / PARTNERS:	STRATEGY SUMMARY:
LEAD: SFPUC PARTNERS: ORCP, Public Works, SF Planning (Pending scope)	Flood risk in San Francisco takes several forms, including coastal flooding from extreme tides/storms and sea level rise, extreme precipitation, stormwater, and groundwater. A combined flood risk analysis and assessment could result in a more comprehensive understanding of current and future flood risks and consequences, and the best strategies to reduce risk. It would be beneficial to conduct combined flood risk analysis within the next three years, in advance of strategies being developed in coastal flood risk projects. There is no current effort to assess combined flood risk. Stakeholders engaged in HCR strategy review stated the importance of including groundwater in this analysis process as well.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Medium: $500K to $5M	Research, Planning & Guidance	Sustaining



DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Weather-Related

IN-2.09	Participate in US Army Corps of Engineers (USACE)/Port Flood Study	
KEY PLANNING ISSUES: Waterfront	VULNERABILITY ADDRESSED: San Francisco's waterfront and shoreline currently floods in several locations of the southern waterfront and areas around the Ferry Building, which impacts numerous community services.	
LEAD: Port PARTNERS: City Depts, regional agencies, businesses and Non-Profits	STRATEGY SUMMARY: The US Army Corps of Engineers (USACE)/Port of San Francisco Flood Study will identify the flood risks to the San Francisco waterfront from Aquatic Park to Heron's Head Park and determine the federal economic interest at risk from flooding in the study area. The three- to five-year study funds the assessment of the flood risk and the identification of alternatives that become eligible for federal funding. The goals of the Flood Study include understanding the flood risk and identifying flood risk reduction alternatives; identifying community, stakeholder, and resource agency priorities and issues; developing alternatives to meaningfully reduce flood risk up to 2080, considering flood risk to 2130; identifying critical assets and services in the federal Interest; and identifying local priorities.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Research, Planning & Guidance	STATUS: Sustaining

IN-2.10	Explore increasing tree canopy and shade structures in parks	
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: Many open-air park amenities might be subjected to exposure to uncomfortable temperatures during extreme heat events. This situation can lead to reduced use of parks during extreme heat events.	
LEAD: RPD PARTNERS: Friends of Urban Forest, Capital Planning	STRATEGY SUMMARY: Many park open spaces do not offer areas of respite from extreme heat events that are increasingly more frequent due to climate change. RPD will develop procedures during the planning phase of capital projects to examine, analyze, and incorporate shading elements (where applicable) to ensure some shade is available for park uses if desired. Examples could include built shade structures or trees of a certain size, growth, and placement that provides shade over time in specific locations (e.g. children's play areas, plazas, DPAs, etc.)	
COST: TBD	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: New

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Weather-Related

IN-2.11	Assess current plant palettes to consider future climate conditions in plant selection
KEY PLANNING ISSUES: N/A	**VULNERABILITY ADDRESSED:** Maintaining park tree canopies will be increasingly difficult as the climate changes and weather becomes more extreme.
LEAD: RPD **PARTNERS:** Public Works Bureau of Urban Forestry	**STRATEGY SUMMARY:** This strategy focuses on maintaining existing tree canopy within recreation areas and ensuring that all vegetation selection in parks is informed by the changing climate. In order for RPD to sustain its current canopy, it will need to examine what planting palettes work for the next 100 years of a changing climate condition. There are currently replanting programs that exist, but they must explicitly consider future climate conditions and prioritize maintaining a robust tree canopy.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
TBD	Public Assets Owner	New

IN-2.12	Diversify water supply options year-round by improving the use of new water sources and drought management
KEY PLANNING ISSUES: Utilities	**VULNERABILITY ADDRESSED:** The majority of San Francisco's water is brought to the city from the Hetch Hetchy watershed located in the Sierra Nevada Mountains. A significant body of climate research indicates that extended periods of drought followed by increased precipitation are more likely to occur in the future.
LEAD: SFPUC **PARTNERS:** DPH, DBI	**STRATEGY SUMMARY:** The SFPUC's Water Supply Improvement Program (WSIP) is a $4.8 billion, multi-year, capital program to upgrade the Regional Water System (RWS). The SFPUC undertook the WSIP to ensure the ability of the RWS to meet Level of Service (LOS) goals for water quality, seismic reliability, delivery reliability, and water supply. The Water Supply LOS goal stated in WSIP is to meet customer water needs in non-drought and drought periods.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
High: $5M and above	Public Assets Owner	Sustaining

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Weather-Related

IN-2.13 Develop a strategy to conserve and monitor water use by capital projects

KEY PLANNING ISSUES:	VULNERABILITY ADDRESSED:
Utilities	Drought can impact Public Works' core services. Without ensuring activities that support core services of Public Works do not contribute to the increasing scarcity of water resources, the Department contributes to this risk.

LEAD / PARTNERS	STRATEGY SUMMARY:
LEAD: Public Works, SFPUC **PARTNERS:** IDC/BDC clients, City agency building operators	The Public Works Water Conservation Strategy aims to promote water conservation among Public Works' capital projects and ongoing operations and maintenance. This strategy includes monitoring and auditing of existing water usage in landscape maintenance, street cleaning operations, and building operations. Water conservation techniques are incorporated into landscape, building, and infrastructure design; promoting climate appropriate and native plant selection that promotes biodiversity; high-efficient irrigation infrastructure; low-water fixtures in building design; and expanding existing infrastructure for grey water or recycled water systems.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Medium: $500K to $5M	Public Assets Owner	Sustaining

IN-2.14 Develop a Long-term Vulnerability Assessment and Adaptation Plan for the Hetch Hetchy Regional Water System

KEY PLANNING ISSUES:	VULNERABILITY ADDRESSED:
Utilities	The water supply of the Hetch Hetchy Regional Water System (RWS) is vulnerable to drought, climate change, water demand, new regulations, and infrastructure failure.

LEAD / PARTNERS	STRATEGY SUMMARY:
LEAD: SFPUC **PARTNERS:** Bay Area Water Supply & Conservation Agency (BAWSCA)	The SFPUC Water Enterprise is conducting a long-term vulnerability assessment to its Levels of Service (LOS) for the Hetch Hetchy Regional Water System (RWS). To address the challenge of planning for uncertain factors and risks, a vulnerability-based planning approach will explore a range of future conditions to identify vulnerabilities, assess the risks associated with these vulnerabilities, and later develop an adaptation plan that is flexible and robust to a wide range of future outcomes. The plan will guide water supply decisions of the RWS over the next 50 years or longer.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Medium: $500K to $5M	Public Assets Owner	Sustaining

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Weather-Related

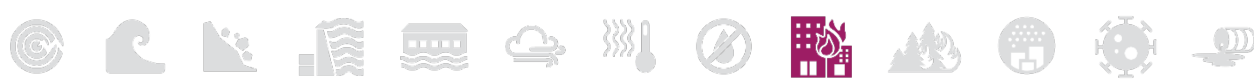
IN-2.15	Implement a Coastal Multimodal Resilience Strategy	
KEY PLANNING ISSUES: Transportation	**VULNERABILITY ADDRESSED:** This strategy seeks to increase the resilience of critical response facilities, municipal facilities, municipal yards, roadways, parking, and the public transit network.	
LEAD: SFMTA **PARTNERS:** Port, Planning, ORCP, Public Works	**STRATEGY SUMMARY:** This strategy is a capital facility improvement program area that assesses, studies, plans, and implements improvements to the multimodal transportation system that are vulnerable to flooding. This strategy includes technical studies and vulnerability and risks assessments that reduces flood risk to the multimodal transportation system. Examples of this work include implementing the Ocean Beach Master Plan and coastal planning efforts such as the Flood Study and Islais Creek Adaptation Study.	
COST: Medium: $500K to $5M	**SF GOVERNMENT ACTIVITY:** Public Assets Owner	**STATUS:** Sustaining

IN-2.16	Strengthen citywide efforts to conserve, restore, and steward biodiversity	
KEY PLANNING ISSUES: N/A	**VULNERABILITY ADDRESSED:** As a result of historic undervaluing in planning and decision making, biodiversity is in crisis. Biodiversity provides vital ecosystem services that the City relies on and must be more fully integrated into decision making processes for effective stewardship.	
LEAD: SFE **PARTNERS:** Various public and private agencies	**STRATEGY SUMMARY:** The Inter-Agency Biodiversity Working Group (IBWG), convened by SFE, will continue to implement the San Francisco Biodiversity Policy. The working group created a citywide biodiversity vision with five supporting goals. One of the goals is Resilience in a Living City, leveraging natural ecosystems to conserve water, prevent flooding, manage pests, and improve air quality. The IBWG has identified potential new initiatives that will promote local nature, ecosystem restoration, and biodiverse greening while also advancing climate resilience. These key opportunity efforts will be further refined and prioritized for incorporation into department work plans.	
COST: Low: < $500k	**SF GOVERNMENT ACTIVITY:** Public Assets Owner	**STATUS:** New

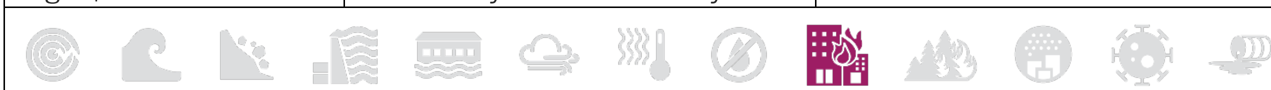
DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Combustion-Related

IN-3.01	Complete studies, analysis, and capital projects to improve and expand the Emergency Firefighting Water System (EFWS)	
KEY PLANNING ISSUES: New Development, Utilities	**VULNERABILITY ADDRESSED:** San Francisco faces seismic risk and urban conflagrations that could occur following a seismic event. Without reliable fire suppression water systems, the City could be vulnerable to major damage from fires after a large seismic event and non-earthquake, multiple-alarm fires.	
LEAD: SFPUC **PARTNERS:** SFFD, Public Works, DEM, ADM	**STRATEGY SUMMARY:** Working collaboratively, the San Francisco Public Utilities Commission (SFPUC), San Francisco Fire Department (SFFD), and San Francisco Public Works (Public Works) are completing studies and analysis, and implementing capital projects, to improve and expand the Emergency Firefighting Water System (EFWS). For upcoming EFWS capital investments, the three agencies are placing an emphasis in areas of the City where there is limited access to the EFWS. One potential conceptual project includes over 13 miles of seismically resilient pipeline connected to two new pump stations, for the purpose of providing high-pressure fire suppression to underserved areas.	
COST: High: $5M and above	**SF GOVERNMENT ACTIVITY:** Public Assets Owner	**STATUS:** Scaling



IN-3.02	Improve the capacity of the Portable Water Supply System to fight fires following earthquakes and other large urban fires	
KEY PLANNING ISSUES: Utilities	**VULNERABILITY ADDRESSED:** Fires following an earthquake have the potential to cause severe damage to buildings and infrastructure.	
LEAD: SFFD **PARTNERS:** DEM, SFPUC	**STRATEGY SUMMARY:** Portable Water Supply System (PWSS) hose tenders are key pieces of equipment that allow the Fire Department to provide high-pressure and high-volume water to fight large fires from any water source, even when the potable or auxiliary water pumps and pipes are damaged or not functioning due to loss of power. This is especially important for fighting fires following earthquake and fires in tall buildings. PWSS is an important resource for areas that are not served by the Emergency Firefighting Water System (EFWS) or in areas where the EFWS might be damaged after an earthquake (e.g., liquefaction zones). A 2011 analysis recommended that the City have 20 hose tenders.	
COST: High: $5M and above	**SF GOVERNMENT ACTIVITY:** Community Services Delivery	**STATUS:** New



DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: Combustion-Related

IN-3.03	Continue to mitigate wildfire hazards in SFPUC-owned watersheds to protect source water quality and minimize risk to SFPUC water and power infrastructure	
KEY PLANNING ISSUES: Utilities	VULNERABILITY ADDRESSED: Significant portions of the Hetch Hetchy Regional Water System in San Mateo, Alameda, Santa Clara, San Joaquin, and Tuolomne counties are located in State-designated high- or very high-fire hazard areas. Wildfire could damage potable water infrastructure and/or degrade source quality, and potentially risk drinking water delivery operations.	
LEAD: SFPUC PARTNERS: National Forest Service, CalFire, county agencies	STRATEGY SUMMARY: SFPUC staff and contractors regularly manage vegetation in SFPUC watershed and right of way (ROW) lands in an effort to mitigate fire hazards and protect water quality. In addition to vegetation management to mitigate fire hazards, SFPUC staff also coordinate internally with federal, State, and local first responders to refine and practice fire-related response procedures and protocols. SFPUC is currently updating its Wildfire Mitigation Plan that describes efforts related to electrical infrastructure only, to reflect new jurisdiction under the California Public Utilities Commission.	
COST: Medium: $500K to $5M	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining

IN-3.04	Improve fire prevention in recreation areas	
KEY PLANNING ISSUES: Existing Buildings	VULNERABILITY ADDRESSED: Wildland open space, particularly Glen Canyon, Presidio, and other grassland open space, are vulnerable to direct fire.	
LEAD: RPD PARTNERS: SFFD, DEM	STRATEGY SUMMARY: Creating defensible space around structures is a strong, proactive management tool to use in fire prevention. This strategy would focus on reducing fire fuel on RPD property that is within 30 feet of structures. Continuing this strategy and enforcing this policy creates defensible spaces around built structures. RPD already maintains properties in line with State law and the California Department of Forestry and Fire best practices.	
COST: TBD	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: All Hazards

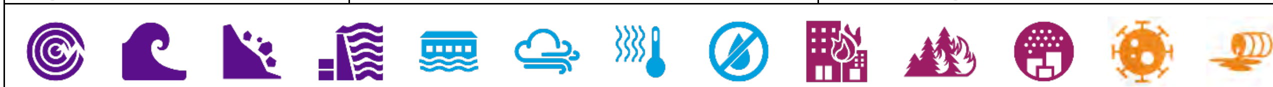
IN-5.01	Conduct a system-wide, multi-hazard vulnerability and operational assessment for Muni	
KEY PLANNING ISSUES: Transportation	VULNERABILITY ADDRESSED: This strategy seeks to minimize the impact of a number of hazard and climate stressors to ensure resiliency of critical infrastructure and maintenance of SFMTA/Muni-delivered public transportation service.	
LEAD: SFMTA PARTNERS: Public Works, SFPUC, Planning, regional - agencies	STRATEGY SUMMARY: This strategy proposes a system-wide, multi-hazard vulnerability and operational assessment for the Muni-operated public transportation system. This strategy would include technical studies and vulnerability and risks assessments to better understand the threat and impact of various hazards to critical infrastructure and services, identifying key actions, capital improvements, and service delivery strategies to mitigate these risks. Stakeholders engaged in HCR strategy review expressed that not all neighborhoods are well-served by public transit and/or do not have accessible or affordable transportation options; this isolation increases vulnerability.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: New

IN-5.02	Reduce seismic and flood risk along three miles of the San Francisco Waterfront from Fisherman's Wharf to Mission Creek	
KEY PLANNING ISSUES: Waterfront	VULNERABILITY ADDRESSED: The Embarcadero Seawall is over 100 years old and is at significant risk from a seismic event and future flooding. Significant damage could result in loss of service for major citywide and regional transportation and utilities, economic centers, and emergency response facilities, and cause loss of life.	
LEAD: Port PARTNERS: City depts., regional planning agencies	STRATEGY SUMMARY: The estimated cost to reduce the seismic and current and future flood risks to the Embarcadero Seawall portion of the San Francisco Waterfront is approximately $5 billion. The first phase of the Embarcadero Seawall Program includes program development, vulnerability and consequences assessment, robust engagement, alternatives development, and the delivery of a first project or suite of projects designed to reduce risk to life safety and emergency response. The Embarcadero Seawall Program is a 30-year program of safety improvements as part of a port-wide resilience framework.	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: All Hazards

IN-5.03	Continue to advance Sewer System Improvement Program (SSIP) projects to meet level of service objectives	
KEY PLANNING ISSUES: Utilities	VULNERABILITY ADDRESSED: The combined sewer system has a high exposure to seismic hazards. Coastal flooding will increasingly become an issue as sea level rises, particularly for sensitive assets in low-lying coastal areas, including outfalls, pump stations, and force mains.	
LEAD: SFPUC PARTNERS: Public Works, Port, SFMTA	STRATEGY SUMMARY: The SFPUC is implementing the Sewer System Improvement Program (SSIP), a 20-year, citywide investment starting in 2012 to upgrade aging infrastructure to address challenges including seismic vulnerability, climate change, localized flooding, and water quality. These improvements achieve LOS objectives for a five-year, three-hour storm event and seismic resilience, ensuring treatment of flows within 72 hours of a major earthquake or a catastrophic event. New facilities will be built using a climate change design criterion and using green infrastructure. The first phase includes 70 projects around the City that represent a $2.9-billion investment.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining



IN-5.04	Implement the Pipe Replacement Prioritization Program	
KEY PLANNING ISSUES: Utilities	VULNERABILITY ADDRESSED: The Bay Area is vulnerable to significant seismic, landslide, tsunami, and extreme storm events. The aged nature of infrastructure can leave many of the City's pipes and underground infrastructure vulnerable to these events.	
LEAD: SFPUC PARTNERS: SFFD, DPH, DEM, NERT, Bay Area Peninsula agencies	STRATEGY SUMMARY: The SFPUC prioritizes water pipelines for replacement based on risk scores and condition assessments. San Francisco's distribution system pipes are categorized by risk and consequence of failure, and larger transmission mains are seismically hardened when replaced. San Francisco's Emergency Fire Water System (EFWS) is prioritized for expansion or replacement with seismically reliable pipelines based on post-seismic, fire-fighting demand analysis. Large regional transmission water mains undergo rigorous condition assessment to prioritize replacement; these pipes are seismically strengthened when replaced or upgraded.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: All Hazards

IN-5.05	Continue to improve power distribution infrastructure to support new development and increase resilience	
KEY PLANNING ISSUES: Utilities	VULNERABILITY ADDRESSED: Underground distribution systems and substations can be difficult to replace in the event of a catastrophic failure and might require very expensive specialized parts, making them more difficult to restore.	
LEAD: SFPUC PARTNERS: PG&E	STRATEGY SUMMARY: By building a new electric distribution infrastructure backbone (electric distribution duct bank and transmission level substation), the City can avoid costly upgrades to PG&E's system and provide reliable power to new developments along the central and southeast waterfront. New investments will ensure the City can provide resilient customer service by incorporating on-site distributed resources and through redundancy of the system. This strategy provides SFPUC with the ability to implement various City objectives independent of PG&E, including environmental objectives. Stakeholders engaged in HCR strategy review stated the importance of addressing power demands, brownouts, and outages.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Scaling

IN-5.06	Enhance flood and earthquake resilience of regional dams and ancillary facilities	
KEY PLANNING ISSUES: Utilities	VULNERABILITY ADDRESSED: With extreme storms increasing from climate change and the consistent seismic vulnerability of the west coast, dam/embankment failure caused by over topping from probably maximum flood (PMF) or embankment failure caused by maximum credit earthquake (MCE) are current risks.	
LEAD: SFPUC, DSOD PARTNERS: Downstream municipalities	STRATEGY SUMMARY: The State's Division of Safety of Dams (DSOD) classifies downstream hazard potential based on loss of life, economic loss, and environmental damage resulting from a hypothetical dam failure. For dams classified as "High" and "Extremely High," SFPUC will update seismic stability analysis against the maximum credible earthquake (MCE) and evaluate the hydraulic adequacy against the probable maximum flood (PMF) for embankment and spillway. The analysis will identify deficiencies to be addressed through the Capital Improvement Program (CIP).	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: New

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: All Hazards

IN-5.07	Develop a Citywide Climate Resilience Framework	
KEY PLANNING ISSUES: All	VULNERABILITY ADDRESSED: Climate change impacts every aspect of society, requiring a cross-disciplinary, coordinated approach to building effective resilience. This situation can be challenging given the range of departments working on the issue.	
LEAD: ORCP PARTNERS: Planning, SFE, SFPUC, DBI, Port	STRATEGY SUMMARY: This Climate Resilience Framework will connect synergistic climate adaptation (Hazard and Climate Resilience Plan) and mitigation strategies (Climate Action Strategy) and establish coordinated goals, principles, and evaluation criteria that enables implementation to maximize co-benefits and avoid conflicts. Through strategic financial analysis and stakeholder engagement it will provide a policy framework for staff coordination and executive consensus around prioritizing City climate resilience actions and identifying funding sources. This strategy will also establish a set of benchmarks and a public dashboard that tracks and reports progress	
COST: TBD	SF GOVERNMENT ACTIVITY: Research, Planning, & Guidance	STATUS: New

IN-5.08	Implement SFMTA Communications and IT Strategy	
KEY PLANNING ISSUES: Transportation	VULNERABILITY ADDRESSED: This strategy seeks to increase the resilience of critical response facilities, municipal facilities, municipal yards, roadways, parking, and the public transit network.	
LEAD: SFMTA PARTNERS:	STRATEGY SUMMARY: This strategy enables the SFMTA to recover quickly from natural disasters that affect the SFMTA's communications and information technology assets. The SFMTA maintains a wide array of critical communications and IT assets across the City, from Wi-Fi and telephone systems at worksites to the fiber network comprising the internal communication backbone of the Muni Metro system. This strategy will implement short-term projects that bolster the resiliency of SFMTA Communications and IT assets. Funding for this strategy is included in the FY2019–FY2023 Capital Improvement Program.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining

DOMAIN: RESILIENT INFRASTRUCTURE (IN)

Primary Hazard Group: All Hazards

IN-5.09	Implement SFMTA Asset Management and State of Good Repair Strategy	
KEY PLANNING ISSUES: Transportation	VULNERABILITY ADDRESSED: Pavement and track exposed to high temperatures over long periods of time can deform, affecting rail lines and overhead catenary system poles. Additionally, exposure of streetcar cable lines will also likely accelerate corrosion.	
LEAD: SFMTA PARTNERS:	STRATEGY SUMMARY: The SFMTA developed a 10-Year Asset Management Strategy in 2018 to incorporate asset management into capital, operation, and maintenance activities. The purpose of this strategy is to maintain SFMTA's assets in a State of Good Repair, thereby bolstering the resilience of the City's transportation system to climate change and natural disasters. Since 2010, the SFMTA has made a commitment to spend an average of $250 million per year on State of Good Repair needs that are essential to ensuring the safe and reliable functioning of the transportation system. Funding for this strategy is included in the FY2019–FY2023 Capital Improvement Program.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining

IN-5.10	Implement SFMTA Transit Fixed Guideway Strategy	
KEY PLANNING ISSUES: Transportation	VULNERABILITY ADDRESSED: Pavement and track exposed to high temperatures over long periods of time can deform, affecting rail lines and overhead catenary system poles.	
LEAD: SFMTA PARTNERS:	STRATEGY SUMMARY: This strategy ensures that SFMTA's Transit Fixed Guideway system is well-built, maintained and resilient to hazard events. Muni's Transit Fixed Guideway light rail, streetcar, and historic cable car services are a crucial component of transportation in San Francisco. Projects in the Transit Fixed Guideway capital program include: investing in new train control technology, track replacement, maintenance facility upgrades, and maintaining Muni's 163 miles of overhead wires. Funding for this strategy is included in the FY2019–FY2023 Capital Improvement Program.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining

DOMAIN: RESILIENT BUILDINGS (B)

Primary Hazard Group: Geological

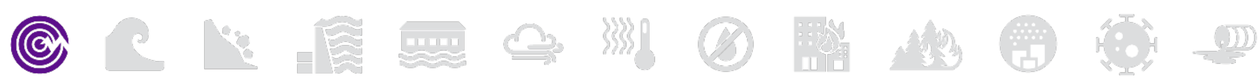
B-1.01.01	**Assess and seismically retrofit municipal buildings**	
KEY PLANNING ISSUES: Existing Buildings	VULNERABILITY ADDRESSED: Community members rely on services provided by the City. The consequences of municipal building disruption are more severe for residents who are resource-constrained.	
LEAD: ORCP PARTNERS: BOS, ADM, MYR, Budget Office, Public Works, all impacted	STRATEGY SUMMARY: ORCP uses seismic hazard ratings, HAZUS, and other analytical tools to assess risk and prioritize seismic-strengthening projects within the public facilities portfolio. This strategy allows for effective prioritization that ensures retrofits first work to reduce life safety risk and then to minimize potential interruptions to essential services for San Francisco's most vulnerable populations. Known priority buildings at the time of the HCR's publication include 170 Otis, Kezar Pavilion, the Hall of Justice, the City's homeless shelters, as well as the City's temporary shelters.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: New

B-1.01.02	**Seismically improve the Port's Department Operations Control Center, Headquarters, and Joint Operations Control facilities**	
KEY PLANNING ISSUES: Existing Buildings, Waterfront	VULNERABILITY ADDRESSED: The Port has significant exposure to seismic hazards. Damage to Port facilities would impact many people at the time of the event and after the event if the Department Operations Centers (DOCs) and Joint Operations Center (JOC) are not functioning.	
LEAD: Port PARTNERS: DEM, SFPD, SFFD, CPC	STRATEGY SUMMARY: The Port oversees two DOCs and one JOC facility on its properties. It is important to reduce damage and disruption to these facilities due to the role that the Port plays in emergency response, and the number of people that work, live, and travel through the waterfront. Implementation of seismic improvements to Pier 1, which serves at the headquarters for the Port and the Department Operations Center, will ensure seismic performance of the building after a seismic event, as well as explore opportunities for sea level rise adaptation.	
COST: Medium: $500K to $5M	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: New

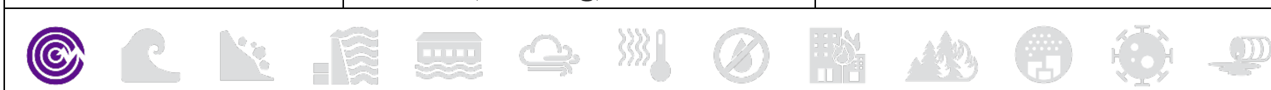
DOMAIN: RESILIENT BUILDINGS (B)

Primary Hazard Group: Geological

B-1.02	**Develop an earthquake risk improvement program for non-structural components of municipal buildings**	
KEY PLANNING ISSUES: Existing Buildings	VULNERABILITY ADDRESSED: The California Building Code is designed to protect lives, not to protect against damage that would cause business interruption. Non-structural failures have accounted for the majority of earthquake damage in several recent U.S. earthquakes.	
LEAD: ORCP PARTNERS: Public Works, RPD, RPD, Port, SFPUC, SFO, SFMTA	STRATEGY SUMMARY: San Francisco has proactively worked to reduce the risk posed by future earthquakes through policies, program, and regulations, but these actions have not comprehensively addressed “nonstructural components,” including architectural features and mechanical, electrical, plumping, and data systems. A non-structural earthquake risk improvement program will focus on reducing risk within the City’s portfolio of buildings. Non-structural improvements are relatively simple and low cost but significantly reduce damage and improve the likelihood of rapid re-occupancy following an earthquake.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Public Assets Owner	Status: New



B-1.03	**Develop a voluntary program for seismic retrofits of one- to four-unit wood frame, soft-story buildings**	
KEY PLANNING ISSUES: Housing, Existing Buildings	VULNERABILITY ADDRESSED: Wood frame, multi-family buildings built before 1995 with parking or retail on the ground floor (a.k.a. soft-story buildings) are known to experience ground floor collapse or tilt in an earthquake.	
LEAD: ORCP, DBI PARTNERS: OEWD, Office of Small Business, private owners & tenants	STRATEGY SUMMARY: To reduce risks from earthquakes, the City will encourage or require owners to evaluate and retrofit one–four unit soft-story, wood frame buildings. The Department of Building Inspection will perform outreach to educate homeowners and contractors about the risks, responsibilities, and opportunities through this program. A permit tracking tool will be developed in order to ensure compliance and track outcomes for those that have opted to participate. (This strategy is related to ESIP Tasks A.1.c, B.3.b, and B.2.c)	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Research, Planning, & Guidance	STATUS: New



DOMAIN: RESILIENT BUILDINGS (B)

Primary Hazard Group: Geological

B-1.04 Implement the Tall Building Strategy to address seismic vulnerability of buildings taller than 250 feet

KEY PLANNING ISSUES:	VULNERABILITY ADDRESSED:
Existing Buildings	Depending on severity and building type, damage can lead to short- to long-term closures. Shutdown of financial institutions and other global companies can have economic impacts that are felt worldwide.

LEAD:	STRATEGY SUMMARY:
SFMTA PARTNERS: DBI, DEM Planning, SFE, SFPUC	This strategy would include technical studies and vulnerability and risks assessments to better understand the threat and impact of various hazards to critical infrastructure, operations, and services. This strategy would also include development of a hazard mitigation plan, which would identify key actions, capital improvements, and service delivery strategies, and an implementation plan for delivery of priority actions and strategies.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Medium: $500K to $5M	Research, Planning & Guidance	New

B-1.05 Extend and improve the Building Occupancy Resumption Program (BORP)

KEY PLANNING ISSUES:	VULNERABILITY ADDRESSED:
Existing Buildings	Damage and disruption to San Francisco's commercial buildings can disrupt residents' work and workplace social networks and can prompt widespread short-term unemployment.

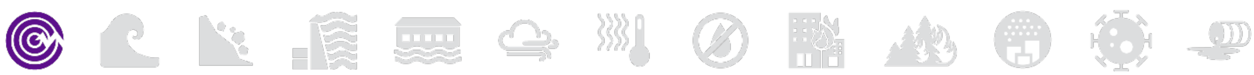
LEAD:	STRATEGY SUMMARY:
DBI PARTNERS: ORCP, Public Works, building owners & tenants	BORP allows for building owners to arrange in advance for post-earthquake safety inspections using their own contracted inspectors. Participation is currently voluntary. The Department of Building Inspection (DBI) approves each participating building's application and pre-certifies the owner's inspection team. Most BORP participants are downtown office buildings. BORP addresses many of the problems associated with applying the general Safety Assessment Program to tall or otherwise complex or recovery-critical buildings. (This strategy is related to Tall Buildings Recommendations 3B)

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Medium: $500K to $5M	Research, Planning & Guidance	Scaling

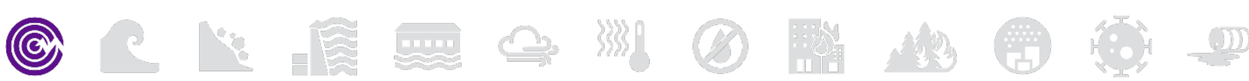
DOMAIN: RESILIENT BUILDINGS (B)

Primary Hazard Group: Geological

B-1.06	**Complete the Mandatory Soft-Story Retrofit Program (pre-1978 buildings with 5+ units and 2+ stories)**	
KEY PLANNING ISSUES: Existing Buildings	VULNERABILITY ADDRESSED: Multi-family housing buildings vulnerable to damage in earthquake shaking.	
LEAD: DBI PARTNERS: ORCP	STRATEGY SUMMARY: The San Francisco Mandatory Soft-Story Retrofit Ordinance applies to wood frame buildings of three or more stories (or two stories over a basement that extends above grade) containing five or more residential dwelling units, where the permit to construct was applied for prior to January 1978 and the building has not yet been seismically strengthened. Currently, 4,921 buildings are subject to the program. Seventy-six percent of applicable buildings are in compliance as of October 2019. (This strategy is related to ESIP Task A.3.a)	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Adopt & Enforce Regulations	STATUS: Sustaining



B-1.07.01	**Develop a program (standards and guidance) to screen, evaluate, and retrofit older steel buildings**	
KEY PLANNING ISSUES: Existing Buildings	VULNERABILITY ADDRESSED: Older steel frame buildings constructed prior to 1990s have known deficiencies, including welded steel connections that can fracture in strong shaking and contribute to building damage or collapse.	
LEAD: ORCP, DBI PARTNERS: SFO, building owners & tenants	STRATEGY SUMMARY: Steel buildings built between the mid-1960s and 1990s might be constructed using weld detailing techniques that can contribute to significant damage or collapse in an earthquake. Other types of older steel buildings are also known to be vulnerable to damage in earthquakes as well.	
COST: Medium: $500K to $5M	SF GOVERNMENT ACTIVITY: Adopt & Enforce Regulations	STATUS: New



DOMAIN: RESILIENT BUILDINGS (B)

Primary Hazard Group: Geological

B-1.07.02	Develop a program to screen, evaluate, and retrofit non-ductile concrete buildings	
KEY PLANNING ISSUES: Existing Buildings	VULNERABILITY ADDRESSED: Some older concrete buildings constructed prior to 1980 have non-ductile detailing and other deficiencies that have resulted in building collapse in previous earthquakes. These buildings tend to be mid-rise buildings. Approximately 3,400 such buildings exist in San Francisco.	
LEAD: ORCP, DBI PARTNERS: SFO, building owners & tenants, engineering firms	STRATEGY SUMMARY: Some older concrete buildings constructed prior to 1980 have non-ductile detailing and other deficiencies that have resulted in building collapse in previous earthquakes around the world. These buildings tend to be mid-rise buildings. Approximately 3,400 such buildings exist in San Francisco (residential and nonresidential), but it is not yet known what percentage of these pose a collapse risk in an earthquake. To address this issue, mandatory screening, evaluation, and retrofit of older concrete buildings should begin in 2020. (This strategy is related to ESIP Task B.2.a and C.2.a).	
COST: Medium: $500K to $5M	SF GOVERNMENT ACTIVITY: Adopt & Enforce Regulations	STATUS New

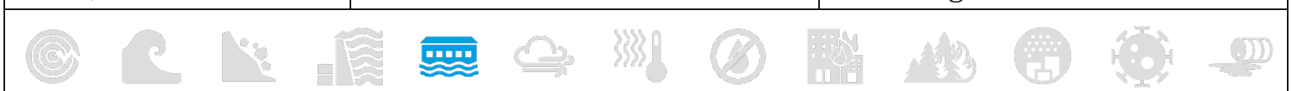
B-1.08	Implement the SFMTA Parking Strategy	
KEY PLANNING ISSUES: Transportation	VULNERABILITY ADDRESSED: Many parking structures were constructed prior to 1975 and have not been seismically retrofitted. However, some of the oldest, most heavily used structures have received some manner of retrofitting.	
LEAD: SFMTA PARTNERS:	STRATEGY SUMMARY: The purpose of this strategy is to ensure that SFMTA parking and street assets are structurally sound, accessible, well-ventilated, and can withstand earthquake activity. The SFMTA manages on- and off-street public parking facilities that serve San Francisco residents, visitors, and businesses. This strategy will implement short-term upgrades and improvements, including a multi-hazard vulnerability and operational assessment, to its public parking garages to make them seismically sound. Funding for this strategy is included in the FY2019–FY2023 Capital Improvement Program.	
COST: Medium: $500K to $5M	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining

DOMAIN: RESILIENT BUILDINGS (B)

Primary Hazard Group: Weather-Related

B-2.01	Develop multi-hazard resilience design guidelines for municipal buildings	
KEY PLANNING ISSUES: New Development	VULNERABILITY ADDRESSED: There is a lack of information and guidance on how municipal buildings and facilities should address a range of climate hazards in their planning and design, including cost-benefit methodology.	
LEAD: ORCP PARTNERS: Public Works, Planning, SFPUC, Port, SFMTA, SFO, etc.	STRATEGY SUMMARY: Developing multi-hazard capital planning guidelines, rooted in the current and future needs of a climate resilient city, is essential to meet the sustainability and climate action goals of the city. This strategy includes performance guidelines for climate and seismic hazards, including flooding, extreme heat, and drought. The strategy might also include risk analysis and adaptation, architectural/engineering standards (building electrification systems, solar and energy storage, heating, venting, and air conditioning system coordination across units in large buildings, etc.), and inform capital priorities for adaptation. The guidelines should offer a cost-benefit analysis process to help project managers decide what resilience strategies to pursue, including non-capital-	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: New

B-2.02	Review the Guidance for incorporating sea level rise into capital planning	
KEY PLANNING ISSUES: New Development	VULNERABILITY ADDRESSED: As sea level rises, temporary coastal flooding will be more frequent and will inundate larger areas at greater depths and for longer durations. Coastal flooding can cause physical damage to municipal buildings and infrastructure, resulting in disruption to critical services.	
LEAD: ORCP PARTNERS: CPC, Planning, Public Works, SFPUC, SFMTA, Port	STRATEGY SUMMARY: The Sea Level Rise Capital Planning Guidance was developed in 2014 and updated in 2015. The Guidance is being updated in 2019 with the latest State-produced sea level rise science. Project managers for capital projects over $5 million will continue to use the Guidance and checklist, ensuring that sea level rise projections are incorporated into asset design and that vulnerability, risk, and adaptive capacity of the asset are taken into consideration. The City will continue to improve implementation of the guidance, provide training for project managers, and analyze data collected from the effort. This strategy will inform the development of multi-hazard, climate resilience guidelines to be adopted citywide.	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining



DOMAIN: RESILIENT BUILDINGS (B)

Primary Hazard Group: Weather-Related

B-2.03 Develop a program to analyze, identify, and evaluate properties at risk of stormwater flooding

KEY PLANNING ISSUES:	VULNERABILITY ADDRESSED:
Existing Buildings	Numerous residential and commercial buildings throughout San Francisco are at risk due to flooding that occurs when heavy precipitation generates runoff that exceeds the capacity of the City's stormwater system.

LEAD / PARTNERS	STRATEGY SUMMARY:
LEAD: SFPUC PARTNERS: Planning, DBI, Assessor	SFPUC is considering a program through which property owners affected by stormwater management would receive grants to reduce risk of flood damage. This proposed strategy will develop the framework for the grant program. The strategy will include analysis, identification, and evaluation of potential floodproofing and elevation projects. Preliminary cost-benefit analyses will also be performed. Specific projects will be separately implemented, based on interest from property owners.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Low: $0–500K	Research, Planning & Guidance	New

B-2.04 Implement floodproofing and elevation projects for properties at risk of stormwater flooding citywide

KEY PLANNING ISSUES:	VULNERABILITY ADDRESSED:
Existing Buildings	Numerous residential and commercial buildings throughout San Francisco are at risk due to flooding that occurs when heavy precipitation generates runoff that exceeds the capacity of the City's stormwater system.

LEAD / PARTNERS	STRATEGY SUMMARY:
LEAD: SFPUC PARTNERS: Assessor, DBI, Planning, SFO	SFPUC is considering a program through which property owners affected by stormwater management would receive grants to reduce risk of flood damage. This strategy includes the implementation of floodproofing, elevation, and acquisition projects based on interest from property owners. The City will work with interested property owners to assess eligibility for the program; evaluate options; develop the scope and cost; and, if federal funding is being contemplated, perform the required cost-benefit analysis and environmental impact analysis reviews.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
High: $5M and above	Adopt & Enforce Regulations	New

DOMAIN: RESILIENT BUILDINGS (B)

Primary Hazard Group: Combustion-Related

B-3.01	**Study emergency clean air and cooling capacity at key community facilities**	
KEY PLANNING ISSUES: Existing Buildings	**VULNERABILITY ADDRESSED:** In non-weatherized buildings without adequate cooling systems, vulnerable populations are at increased risk of health impacts. The vast majority of these community facilities do not have air conditioning, and only certain sites have mechanical ventilation.	
LEAD: DPH **PARTNERS:** SFUSD, DCYF, ORCP, HSA, MOHCD, RPD, SFE, LIB	**STRATEGY SUMMARY:** The study and eventual deployment of emergency clean air and cooling capacity at primary care clinics, in a common room of multi-unit housing developments (and especially those buildings that house populations vulnerable to health impacts of extreme heat and wildfire smoke) and in auditoriums/community space at schools and daycare facilities. San Francisco is particularly vulnerable to extreme heat, most heat-related health impacts happen at home, and there are significant barriers (transportation, messaging, and programming) that limit the effectiveness of cooling or clean air centers. The vast majority of San Francisco Unified School District facilities do not have air conditioning, and only certain sites have mechanical ventilation.	
COST: Medium: $500K to $5M	**SF GOVERNMENT ACTIVITY:** Research, Planning & Guidance	**STATUS:** New

B-3.02	**Increase privately-owned building weatherization rates**	
KEY PLANNING ISSUES: Housing, Existing Buildings	**VULNERABILITY ADDRESSED:** Older buildings not well-insulated or air-sealed expose inhabitants (especially vulnerable populations) to constant levels of local air pollution and increased risks during poor air quality and extreme heat days.	
LEAD: SFE **PARTNERS:** DPH, SFPUC, BayREN, PG&E, ORCP	**STRATEGY SUMMARY:** Building weatherization reduces energy use and greenhouse gas emissions while providing health and resilience benefits. Providing the general public with more information connecting weatherization to protection from hazards and more technical/financial assistance can increase rates of weatherization. Currently, vulnerable populations might face barriers to weatherizing their living spaces. A cross-departmental study can identify and strategically prioritize sites where weatherization investments will result in widespread improvements for underserved and/or vulnerable populations. Stakeholders engaged in HCR strategy review stated the importance of financial assistance for sites that cannot easily afford these building improvements.	
COST: Low: $0–500K	**SF GOVERNMENT ACTIVITY:** Community Services Delivery	**STATUS:** Scaling

DOMAIN: RESILIENT BUILDINGS

Primary Hazard Group: Combustion-Related

<table>
<tr><th>B-3.03</th><th colspan="3">Support increased building electrification (fuel switching) and mechanical upgrades</th></tr>
<tr><td>KEY PLANNING ISSUES:
Existing Buildings</td><td colspan="3">VULNERABILITY ADDRESSED:
Loss of utility service due to catastrophic events will result in loss of building functionality, including heating and cooling, lighting, refrigeration, and plug loads (devices). It is likely that gas outages will take much longer to bring back online than electric power outages (weeks compared to days). Both power supplies can cause or exacerbate urban fires; buildings and infrastructure that use natural gas might be prone to explosions as well.</td></tr>
<tr><td>LEAD:
SFE
PARTNERS:
Public Works, SFO, SFUSD, SFPUC, OEWD, DPH</td><td colspan="3">STRATEGY SUMMARY:
Building electrification (generally, switching from fossil fuel combustion for building uses such as space and water heating to high-efficiency refrigeration-based technologies such as heat pumps) supports resilience in multiple ways. High-performance all-electric buildings can come back online quicker than mixed-fuel buildings, following catastrophic events. For critical facilities, electric buildings might be better able to take advantage of on-site solar energy stored in batteries (see Solar and Storage Strategy). Older buildings in San Francisco might not have mechanical cooling systems, and more frequent extreme heat days in the future would increase the need for mechanical cooling. Stakeholders engaged in HCR strategy review stated the importance of financial assistance for building upgrades, such as fuel switching.</td></tr>
<tr><td>COST:
Low: $0–500K</td><td colspan="2">SF GOVERNMENT ACTIVITY:
Community Services Delivery</td><td>STATUS:
Scaling</td></tr>
</table>

DOMAIN: RESILIENT BUILDINGS (B)

Primary Hazard Group: All Hazards

B-5.01	Amend the capital improvement program for transportation facilities to consider hazard mitigation opportunities
KEY PLANNING ISSUES: Transportation, Existing Buildings	VULNERABILITY ADDRESSED: The majority of buildings in municipal yards are un-retrofitted, and many structures were built during the 1940's and 50's.
LEAD: SFMTA PARTNERS: Public Works, SFPUC, Planning, RPD, MOHCD,	STRATEGY SUMMARY: This strategy is a capital facility improvement program assessing, studying, planning, and implementing improvements to SFMTA's capital facilities. Improvements range from near-term workspace improvements, to long-term, comprehensive redevelopment of SFMTA's real property. This strategy includes mitigations from various hazards, implemented during the design phase of facility improvements. Projects are also prioritized based on a combination of factors relevant to SFMTA needs. In addition, SFMTA might consider exploring options that co-locate Paratransit assets to shift more of their fleet locally as opposed to being sited in Brisbane

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
High: $5M and above	Public Assets Owner	Scaling

B-5.02	Install solar and storage systems at critical facilities
KEY PLANNING ISSUES: Existing Buildings	VULNERABILITY ADDRESSED: Following an earthquake, flood, or other disaster, continued operation of shelters and critical emergency management facilities is essential. Currently, gas and electric networks can require days or weeks to recover from a disaster.
LEAD: Public Works/varies PARTNERS: ORCP, SFE, SFPUC, public building owners/operators (Port, SFMTA, RPD, DBI), DPH	STRATEGY SUMMARY: This strategy seeks funding to install solar and storage systems at studied critical facilities. Previous studies conducted for the San Francisco Department of the Environment (SF Environment) Solar and Storage for Resilience Project examined the use of stand-alone solar electric generation with battery storage to provide resilient post-disaster power to critical facilities. The project team created representative emergency power profiles for 67 shelters, and visited 18 buildings, spanning 11 supervisor districts. To address the high capital cost of deploying this large resource, the project team investigated various financing options, with a public-private partnership, which was found to be a viable pathway.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Medium: $500K to $5M	Public Assets Owner	Scaling

DOMAIN: RESILIENT BUILDINGS (B)

Primary Hazard Group: All Hazards

B-5.03 Secure a resilient public safety training facility for San Francisco Fire Department (SFFD)

KEY PLANNING ISSUES:
N/A

VULNERABILITY ADDRESSED:
Several emergency response facilities may be vulnerable to coastal flooding due to their location, including the San Francisco Fire Department (SFFD) Training Center located on Treasure Island.

LEAD:
SFFD

PARTNERS:
SFPD, SHF

STRATEGY SUMMARY:
Currently, training for SFFD is split between one facility in the Mission District and another facility located on Treasure Island. With the future vulnerability of the Treasure Island site to impacts of sea level rise, SFFD would be without an adequate amount of space for its training needs by as early as 2024, unless a new facility is constructed. The City is exploring sites to develop, meeting these evolving training needs. By constructing a state of the art, seismic and climate resilient facility, SFFD can continue to train professionals skilled in mitigating the impacts of hazards within the City.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
High: $5M and above	Public Assets Owner	New

B-5.04 Increase resilience and operation efficiency of maintenance yards

KEY PLANNING ISSUES:
Existing Buildings

VULNERABILITY ADDRESSED:
Lack of information and guidance on how municipal buildings and facilities should address a range of climate hazards in their planning and design.

LEAD:
Public Works

PARTNERS:
RPD, SFMTA, SFE, SFPUC, Port

STRATEGY SUMMARY:
Public Works maintenance yards are outdated, centralized, and in need of replacement. Replacement with new facilities equipped for climate and seismic resilience will modernize maintenance yards for the challenges of the 21st century. These improvements include design specifications for on-site solar and battery systems, on-site water recycling/storage, high-performance building systems allowing operations in line with net-zero carbon commitments, as well as resilient landscaping for stormwater management. Decentralizing yards to smaller satellites across the City also increases staff and fleet fuel efficiencies. This strategy provides resiliency along short-term, long-term, and crisis timelines.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
High: $5M and above	Public Assets Owner	New

DOMAIN: RESILIENT BUILDINGS

Primary Hazard Group: All Hazards

B-5.05	Explore options to use Recreation Centers as public respite facilities	
KEY PLANNING ISSUES: Existing Buildings	VULNERABILITY ADDRESSED: In non-weatherized buildings without cooling capabilities, services could shut down during high heat events. High heat events can also cause power outages for centers without backup power sources.	
LEAD: RPD PARTNERS: DEM, DPH, ORCP	STRATEGY SUMMARY: The changing climate has meant a changing role for departments across the city. This strategy develops a cohesive framework, with City partners, for how Recreation and Park facilities (recreation centers, pools, plazas) should act as emergency and weather event refuges. The goal will be to establish the role of park open spaces and indoor facilities in an emergency event and during extreme weather events. Elements to consider range from installing air filtration for poor air quality days, misters in plazas for extreme heat events, offering free pools during extreme heat events, and designing future centers for enhanced seismic resilience.	
COST: TBD	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: New

B-5.06	Develop comprehensive and coordinated code amendments for multi-hazard resilience of private development	
KEY PLANNING ISSUES: New Development	VULNERABILITY ADDRESSED: Private buildings (residential, commercial, and industrial) are not necessarily designed to accommodate flooding, extreme heat impacts, poor air quality, and other natural and climate hazards.	
LEAD: Planning PARTNERS: DBI, SFE, Port, SFO, private property owners	STRATEGY SUMMARY: In coordination with SFE and DBI, the Planning Department will develop multi-hazard Planning and Building Code amendments for new construction, additions, and substantial renovations in identified hazard areas. This strategy will include opportunities for new development to include dedicated storage space for emergency equipment and supplies, include solar + storage, function as a temporary shelter or respite facility, enhance biodiversity, and/or include climate resilience initiatives within community benefit agreements. The feasibility study will include a cost-benefit analysis regarding housing costs and supply, as well as potential benefits or impacts to low-	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Adopt & Enforce Regulations	STATUS: New

DOMAIN: RESILIENT COMMUNITY (C)

Primary Hazard Group: Geological

C-1.01	Address seismic retrofit needs within San Francisco's affordable housing stock
KEY PLANNING ISSUES: Housing	VULNERABILITY ADDRESSED: Much of San Francisco's housing stock is in need of structural retrofits and life/safety improvements. Loss of affordable housing due to damage from an earthquake would have a severe impact on vulnerable populations.
LEAD: MOHCD PARTNERS: DBI, community development organizations	STRATEGY SUMMARY: The San Francisco Mayor's Office of Housing and Community Development (MOHCD) manages acquisition and rehabilitation programs that provide funding to non-profit organizations to acquire older, rent-controlled properties, rehabilitate them, and preserve them as permanent affordable housing. This strategy will use FEMA hazard mitigation funding to subsidize these developers to perform necessary retrofits, thereby reducing potential displacement of renters of damaged housing following earthquake events and reducing the necessity of landlords raising rents for building improvements.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
High: $5M and above	Community Services Delivery	New

C-1.02	Develop a downtown recovery strategy
KEY PLANNING ISSUES: Existing Buildings, New Development	VULNERABILITY ADDRESSED: Damage to downtown high-rise structures can lead to long-term disruption of whole neighborhoods. This situation could have impacts on housing, employment, and economic opportunity for thousands of
LEAD: ORCP PARTNERS: Public Works, DBI, DEM, Port, Planning, SFE, SFPUC	STRATEGY SUMMARY: The work that the City has done around tall buildings focuses on the buildings themselves, with little consideration for how the building fits into the surrounding neighborhood. This work does not consider how tall buildings interact with other structures around them and the relationships between businesses, residents, workers, and the critical infrastructure that allow the Financial District and adjacent neighborhoods to thrive. To this end, this strategy calls for the creation of a downtown recovery strategy for these areas to address the interconnection between tall buildings and their surrounding neighborhoods.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
TBD	Community Services Delivery	New

DOMAIN: RESILIENT COMMUNITY (C)

Primary Hazard Group: Geological

C-1.03	Improve San Francisco's implementation of the State Safety Assessment Program

KEY PLANNING ISSUES:
Existing Buildings

VULNERABILITY ADDRESSED:
Damage and disruption to San Francisco's commercial buildings can disrupt residents' work and workplace social networks, and even prompt widespread short-term unemployment. The shutdown of many financial institutions and other global companies in the event of severe shaking and liquefaction might have serious economic impacts.

LEAD:
ORCP, DBI

PARTNERS:

STRATEGY SUMMARY:
The Safety Assessment Program (SAP) is run by the California Office of Emergency Services (CalOES). DBI is charged with implementing San Francisco's participation in the program. The City should develop its own procedures suited to San Francisco's tall buildings, develop a plan to use specially qualified SAP volunteers for certain complex buildings, and clarify and update roles and responsibilities for post-earthquake emergency response and safety inspection (This strategy is related to Tall Buildings Recommendations 3A and 3C)

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
High: $5M and above	Community Services Delivery	Sustaining

C-1.04	Develop a post hazard Open for Business campaign

KEY PLANNING ISSUES:
N/A

VULNERABILITY ADDRESSED:
Damage and disruption to San Francisco's commercial buildings can disrupt residents' work and workplace social networks, and even prompt widespread short-term unemployment. The shutdown of many financial institutions and other global companies in the event of severe shaking and liquefaction might have serious economic impacts.

LEAD:
OEWD

PARTNERS:
DPH, business associations

STRATEGY SUMMARY:
San Francisco should work with stakeholders to identify partners and potential funding sources that will allow the City to implement a public information campaign after a disaster. Target audiences can include regional tourists, national and international tourists, conventions and business meetings, and business leaders. This campaign will reduce the economic damages and impacts of large-scale hazard events.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
TBD	Community Services Delivery	New

DOMAIN: RESILIENT COMMUNITY (C)

Primary Hazard Group: Geological

C-1.05	Continue to meet housing production goals	
KEY PLANNING ISSUES: Housing	VULNERABILITY ADDRESSED: San Franciscans are already under pressure from the housing crisis and overall high cost of living. This is particularly acute for people who are unsheltered, in unstable housing situations, and renters. It increases community vulnerability to hazards and climate change.	
LEAD: MOHCD PARTNERS: OCII, DBI, Planning, non-profit housing developers	STRATEGY SUMMARY: The City has a goal to create 30,000 housing units, 30 percent of which are permanently affordable and 50 percent of which are middle income by 2020. These homes serve families, seniors, essential City workers, and people formerly experiencing homelessness. Living in an affordable home increases one's ability to cope with impacts of a hazard event. Stakeholders engaged in HCR strategy review stressed the importance of building housing that meets the needs of San Francisco's vulnerable populations.	
COST: High: $5M and above	SF GOVERNMENT ACTIVITY: Research, Planning & Guidance	STATUS: Sustaining

C-1.06	Develop a public outreach campaign and wayfinding plan for tsunami awareness and evacuation procedures	
KEY PLANNING ISSUES: Waterfront	VULNERABILITY ADDRESSED: San Francisco's "worst-case" tsunami scenario produced an estimated maximum tsunami wave run-up elevation of 22 feet above mean sea level at Ocean Beach.	
LEAD: DEM PARTNERS: Port, RPD, Public Works, SFMTA, CA Tsunami Program,	STRATEGY SUMMARY: New scientific information and maps showing increased coastal flood potential from separate and combined factors, including sea level rise, King tides, and tsunamis. The areas at greatest risks include low-lying, waterfront areas with a relatively high vulnerability. Public awareness is key to saving lives during extreme events. Visible signage on kiosks, sidewalks, and streets will help direct egress and save lives during these events.	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Research, Planning & Guidance	STATUS: New

DOMAIN: RESILIENT COMMUNITY (C)

Primary Hazard Group: Geological

<table>
<tr><th>C-1.07</th><th colspan="3">Assess vertical evacuation options in high-hazard areas and guidance for large-building refuges</th></tr>
<tr><td colspan="2">KEY PLANNING ISSUES:
Waterfront, Existing Buildings</td><td colspan="2">VULNERABILITY ADDRESSED:
San Francisco’s "worst-case" tsunami scenario produced an estimated maximum tsunami wave runup elevation of 22 feet above mean sea level at Ocean Beach.</td></tr>
<tr><td>LEAD:
DBI, DEM
PARTNERS:
MOD, DPH, Public Works, NEN, SFFD, CA Tsunami Program, BOMA, BART, NERT</td><td colspan="3">STRATEGY SUMMARY:
The combined factors of coastal flooding from sea level rise, King tides, and tsunamis indicate residents, visitors, and businesses are at risk during extreme weather events. Low-lying areas are particularly at risk (Market Street area in the Financial District, Treasure Island, etc.). In areas where high ground is not immediately available, vertically evacuating and seeking refuge in tall buildings might be the best option. Where horizontal evacuation is not possible, vertical evacuation facilities will be necessary for life safety, especially for people with disabilities or access and functional needs.</td></tr>
<tr><td colspan="2">COST:
Medium: $500K to $5M</td><td>SF GOVERNMENT ACTIVITY:
Research, Planning & Guidance</td><td>STATUS:
New</td></tr>
</table>

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: Biological & Toxic

C-4.01	Expand household hazardous waste collection efforts	
KEY PLANNING ISSUES: N/A	**VULNERABILITY ADDRESSED:** If household hazardous waste is disposed of improperly, these products end up in the landfill or down the drain where they can leach toxic chemicals and heavy metals into soil and groundwater.	
LEAD: SFE **PARTNERS:** Recology SF, Public Works, DEM, DPH	**STRATEGY SUMMARY:** This strategy expands education of San Francisco residents about the importance of removing Household Hazardous Waste (HHW) prior to (and in preparation for) a hazard event and promotes San Francisco's established programs for proper management of HHW. The focus of this outreach campaign is expected to be the HHW Home Collection Service that is currently underutilized by SF residents.	
COST: Low: $0–500K	**SF GOVERNMENT ACTIVITY:** Community Services Delivery	**STATUS:** Scaling

C-4.02	Replace mercury-containing lighting in preschools and daycare centers	
KEY PLANNING ISSUES: Existing Buildings	**VULNERABILITY ADDRESSED:** Most, if not all, San Francisco preschool and daycare facilities use fluorescent lighting. In a major earthquake or other disaster, mercury-containing lights can break and expose small children, one of the most vulnerable populations, to the long-term effects of mercury.	
LEAD: SFE **PARTNERS:** DCYF, DPH, Recology SF, First 5 San Francisco, SFUSD	**STRATEGY SUMMARY:** Most, if not all, of the 350 preschool and daycare facilities licensed by the State of California in San Francisco use fluorescent lighting. Fluorescent lighting contains mercury, a well-known and potent neurotoxin. In a major earthquake or other disaster, an unpredictable number of these mercury-containing lights can be expected to break, subjecting children to the long-term effects of mercury exposure. This strategy would remove this lighting from identified day care and pre-schools and replace them with LEDs, therefore reducing risk and helping the City meet its greenhouse emissions goals. This strategy can serve as a pilot program to evaluate the costs and other barriers to replacing mercury-containing lighting in elementary and high schools, and other institutional locations where children are present.	
COST: Low: $0–500K	**SF GOVERNMENT ACTIVITY:** Community Services Delivery	**STATUS:** New

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: Biological & Toxic

C-4.03	Explore toxins abatement workforce development programs
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: In some instances, the presence of toxic material spills following hazard events can disrupt the ability of individuals to shelter in place. This situation can create more dangerous situations for community members in their homes.
LEAD: OEWD PARTNERS: Public Works, DPH	STRATEGY SUMMARY: Pursuing development of a workforce training programs for lead/asbestos, or other toxic waste abatement targeting properties impacted by floods, sea level rise, and fires will offer opportunities to gain economic empowerment to communities as they simultaneously grapple with increasing weather-related impacts as these events become more frequent with climate change.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
TBD	Community Services Delivery	New

C-4.04	Improve citywide resilience to pandemics and infectious diseases
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: Pandemics and infectious diseases can quickly overwhelm the healthcare system and lead to significant economic and social disruptions across the entire city for prolonged periods of time.
LEAD: DPH PARTNERS: HHS, DEM, OEWD, DPW, SFMTA	STRATEGY SUMMARY: Implementing the physical, social and economic strategies needed to reduce the likelihood of and lessen the impacts of future pandemics and infectious diseases will improve San Francisco's ability to protect the health and social wellbeing of San Francisco's residents, workers, visitors and economy.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
TBD	Community Services Delivery	New

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: All Hazards

C-5.01	Identify and create Clean Air/Cooling Hub (CACH) Public Respite Facilities	
KEY PLANNING ISSUES: Existing Buildings	VULNERABILITY ADDRESSED: Climate change is expected to increase the frequency and severity of extreme heat events. By 2100, the number of extreme heat days is projected to increase by 1.5 orders of magnitude to 90 days per year, up from around six currently.	
LEAD: ORCP PARTNERS: SFPL, DEM, RPD, ADM, Public Works, DPH	STRATEGY SUMMARY: As part of the Mayoral Directive on Air Quality Emergencies, this strategy relates to performing a feasibility assessment and subsequent implementation plan for improvements to publicly- and privately-owned buildings, in order for their operation as public respite facilities during future poor air quality or extreme heat events. Measures identified in the SF Fellows preliminary report will be the main focus of the feasibility assessment and the implementation plan.	
COST: Medium: $500K to $5M	SF GOVERNMENT ACTIVITY: Public Assets Owner	STATUS: Sustaining

C-5.02	Develop a Homelessness Disaster Response Plan	
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: Unhoused populations are among the most vulnerable San Franciscans. Without stable shelter options, this population is often more exposed to hazard events.	
LEAD: HSH PARTNERS: DPH, DEM, ORCP	STRATEGY SUMMARY: In the event of a disaster, homeless people are among the most vulnerable populations to experience impacts. To address this, HSH is working with consultants from the Technical Assistance Collaborative (TAC) to develop a Homelessness Disaster Response Plan. The plan will identify key recommendations and next steps for HSH and partners to plan for, mitigate, and respond to the unique needs of this population during a large-scale disaster.	
COST: TBD	SF GOVERNMENT ACTIVITY: Community Services Delivery	STATUS: New

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: All Hazards

C-5.03	Support volunteer emergency preparedness, response, and recovery programs including the Neighborhood Emergency Response Team (NERT) and Auxiliary Law Enforcement Response Team (ALERT).	
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: In the event of a major disaster, emergency response personnel might have limited capacity to respond to all needs of the community due to multiple competing demands and/or damage to emergency response facilities.	
LEAD: SFFD/SFPD PARTNERS: DEM, (VOAD), MYR, ORCP private funders	STRATEGY SUMMARY: SFFD routinely conducts Neighborhood Emergency Response Team (NERT) training. This training educates people about disaster preparedness for hazards that might impact their area and trains them in basic disaster response skills, such as fire safety, light search and rescue, team organization, and disaster medical operations. This strategy supports the NERT program, its growth in participation and retention. This will include increasing funding and staffing to a level commensurate with the work of daily operations as well as community engagement and training. The overall aim of the effort will increase the overall program from less than 1 percent of residents trained within 3 years to 5 percent of residents.	
COST: Medium: $500K to $5M	SF GOVERNMENT ACTIVITY: Community Services Delivery	STATUS: Sustaining

C-5.04	Create a program to coordinate existing City programs providing in-home and resident-facing services related to hazard and climate resilience	
KEY PLANNING ISSUES: Housing, Existing Buildings	VULNERABILITY ADDRESSED: This strategy seeks to improve the City's capacity and streamline its efforts to improve the resiliency of San Francisco homes and residents, especially vulnerable populations, to many of the hazards included in this plan.	
LEAD: DEM, DPH PARTNERS: HSA, ORCP, MOHCD, SFE, DBI	STRATEGY SUMMARY: This strategy creates an interdepartmental effort coordinating existing City programs providing in-home and resident-facing services. Opportunities in City services would be identified for existing programs, including climate resilience and emergency preparedness opportunities. This strategy will include a training program to engage multi-unit landlords, particularly those serving vulnerable populations. By working with existing programs, age-related emergency preparedness education can be included for City staff on home assessments.	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Research, Planning & Guidance	STATUS: New

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: All Hazards

C-5.05 Develop a Preparedness Equipment Purchase Program to direct and fund the purchase of climate preparedness equipment

KEY PLANNING ISSUES:
N/A

VULNERABILITY ADDRESSED:
This strategy aims to build citywide resiliency by improving the City's ability to respond in emergency events.

LEAD:
DEM, DPH

PARTNERS:
Public Works, ORCP, SFE, SFFD

STRATEGY SUMMARY:
As climate change increases the prevalence and intensity of hazards such as extreme heat events and air quality events, a Preparedness Equipment Purchase Program would help fund the purchase of climate preparedness equipment to ensure City departments have equipment on-hand for deployment. This equipment can be used to augment and bolster the flexibility of the City's response to current and future extreme weather and hazard events.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Low: $0–500K	Community Services Delivery	New

C-5.06 Expand the Neighborhood Empowerment Network (NEN) Empowered Communities Program (ECP) to additional neighborhoods

KEY PLANNING ISSUES:
N/A

VULNERABILITY ADDRESSED:
Many communities lack the hyper-local connections between individuals and community organizations that is essential to safety navigate hazard events. Building this social connection is a viable means of increasing individual resiliency.

LEAD:
NEN

PARTNERS:
ADM, DEM, NERT, CBO's, private businesses

STRATEGY SUMMARY:
The Neighborhood Empowerment Network (NEN) Empowered Communities Program (ECP) provides neighborhoods with a comprehensive toolkit of programs, strategies, and resources that advance the overall resilience of their community at the individual, organizational, and community levels. Building on FEMA's Whole Community Approach, the lessons learned from Hurricane Katrina, and a growing body of academic research, the ECP fuses together modern community organizing techniques with classic emergency management goals. Expanding this effort would increase the capacity of neighborhood leaders to advance their community's resilience.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Low: $0–500K	Community Services Delivery	Scaling

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: All Hazards

C-5.07	Perform gap analysis of vulnerable populations (i.e., Access and Functional Needs) and available City services	
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: Many buildings have significant maintenance needs, require adaptations for changing climates, and could need significant repairs following a	
LEAD: MOD PARTNERS: DAAS, DPH, CON, DEM, Age & Disability Friendly	STRATEGY SUMMARY: Conduct a study to better understand vulnerable populations (i.e. Access and Functional Needs) that are not connected to community partners, service providers and/or City social service agencies. The study might also include a potential assessment tool for identifying those people at most risk as well as recommendations for best practices reaching these populations.	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Community Services Delivery	STATUS: New

C-5.08	Develop a community-based capacity building initiative	
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: CBOs often lack the resources to preemptively invest in hazard mitigation and emergency preparedness without municipal assistance.	
LEAD: MOD PARTNERS: DAAS, DPH, SFCARD, DEM, NEN, RTSF, H4H, Age & Disability Friendly	STRATEGY SUMMARY: Building the capacity of community-based partners to develop their own emergency preparedness plans for the individuals, households, and/or neighborhoods that they serve, is an important means for the City to prepare its small business community to endure hazard events. This strategy is a key component of promoting neighborhood level resiliency.	
COST: Medium: $500K to $5M	SF GOVERNMENT ACTIVITY: Community Services Delivery	STATUS: New

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: All Hazards

C-5.09	Establish an evacuation strategy for people with Access and Functional Needs	
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: In the event of an evacuation, the length of time necessary to evacuate large volumes of people, coupled with the potentially short period of time available to safely evacuate, leads to populations with limited mobility or medical conditions being particularly at risk.	
LEAD: DAAS/MOD PARTNERS: Age and Disability Friendly SF, DEM, MOD, SFFD, DBI, DPH	STRATEGY SUMMARY: Vulnerable populations are acutely impacted by disasters and can often face unique challenges. By developing a coordinated evacuation strategy, with consideration for the needs of populations with access and functional needs, support for this population can be effectively communicated to the public in case evacuation procedures need to be pursued.	
COST: Medium: $500K to $5M	SF GOVERNMENT ACTIVITY: Community Services Delivery	STATUS: New

C-5.10	Continue Small Business Continuity of Operations (COOP) Assistance	
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: Small businesses may lack the resources to preemptively invest in hazard mitigation or lack the resources to whether long-term business disruption without municipal assistance.	
LEAD: OEWD PARTNERS: DEM, SBDC, GO-Biz, FEMA	STRATEGY SUMMARY: Vulnerable populations rely on specialized services and goods that may not be available elsewhere. Identifying these businesses and developing resources to support them in the development of a Continuity of Operations (COOP) plan will ensure that they are able to continue to provide these services in the aftermath of an emergency.	
COST: TBD	SF GOVERNMENT ACTIVITY: Community Services Delivery	STATUS: Sustaining

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: All Hazards

C-5.11	Support the Small Business Development Center (SBDC)	
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: Small businesses may lack the resources to preemptively invest in hazard mitigation or lack the resources to weather long-term business disruption without municipal assistance.	
LEAD: OEWD PARTNERS: SBDC, USSBA, GO-Biz	STRATEGY SUMMARY: Small businesses face many particular challenges following a disaster event. This strategy will develop a plan to rapidly scale capacity of the Small Business Development Center (SBDC) to provide post-disaster support to small businesses following a significant event. Additionally, this strategy will intentionally include a focus on targeted networking opportunities to support childcare facilities to navigate permitting needs and challenges resulting from a disaster, as this market segment is known to face this challenge.	
COST: TBD	SF GOVERNMENT ACTIVITY: Community Services Delivery	STATUS: Sustaining

C-5.12	Establish disaster relief funding and small business resilience fund	
KEY PLANNING ISSUES: Existing Buildings	VULNERABILITY ADDRESSED: Small businesses may lack the resources to preemptively invest in hazard mitigation or lack the resources to whether long-term business disruption without municipal assistance.	
LEAD: OEWD PARTNERS: MEDA, CON	STRATEGY SUMMARY: Explore the ability to offer grants, low-interest loans, and other technical assistance related to preventing closure of businesses impacted by natural disasters or fire. Grants could cover eligible, unmet rehabilitation repair, replacement, and mitigation needs or projects that will increase sales, increase foot traffic, and retain and create jobs.	
COST: TBD	SF GOVERNMENT ACTIVITY: Community Services Delivery	STATUS: New

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: All Hazards

C-5.13	Expand layoff outplacement services
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: Damage to downtown high-rise structures can lead to long-term disruption of whole neighborhoods. This could have impacts on housing, employment, and economic opportunity for thousands of residents.
LEAD: OEWD PARTNERS: EDD, Chamber, GO-Biz, Bay Area Council, SVLG, SFMade, SBDC	STRATEGY SUMMARY: This strategy would aim to preemptively support those workers facing layoffs following a disaster event, in order to reduce the potential economic disruption that could ripple through communities following these events. A primary focus would be to enable affected workers to return to work as quickly as possible organize with partners to provide services to businesses and affected employees to ensure a transition that is as seamless as possible.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
TBD	Community Services Delivery	Scaling

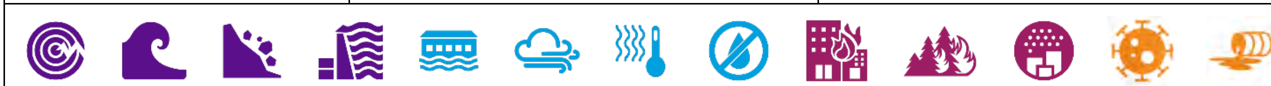
C-5.14	Expand Women's Entrepreneurship Fund
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: Small businesses may lack the resources to preemptively invest in hazard mitigation or lack the resources to whether long-term business disruption without municipal assistance.
LEAD: OEWD PARTNERS:	STRATEGY SUMMARY: Significant literature exists detailing the role that women have in supporting our communities. By economically empowering woman, we are providing communities with more stability pre-disaster, so that disruptions will be reduced following a disaster. This strategy would provide micro-grants to women-owned small businesses operating in San Francisco for projects that will have a transformative impact on businesses' ability

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
TBD	Community Services Delivery	Scaling

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: All Hazards

C-5.15	Study the overlap between vulnerable populations and vulnerable buildings	
KEY PLANNING ISSUES: Housing, Existing Building	VULNERABILITY ADDRESSED: Private buildings (residential, commercial and industrial) are not designed to accommodate flooding, future heat impacts, poor air quality, and other natural and climate hazards. Vulnerable populations are disproportionately impacted by climate and other natural hazards and have fewer resources to make climate resilient home and business improvements.	
LEAD: Planning/ DPH/ORCP PARTNERS: DBI, SFPUC, SFE, MOHCD,	STRATEGY SUMMARY: Study the overlap between vulnerable populations and vulnerable building types for natural and climate hazards. This will help identify property types and locations that may be particularly vulnerable (such as permanent affordable housing, SRO's, etc.) to hazards and may need public subsidy or technical support to equitably pursue resilience measures. Public engagement efforts to date have identified specific vulnerabilities to consider, from San Franciscans who rely on electricity for their medical needs, to inaccessible routes of emergency evacuation.	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Research, Planning & Guidance	STATUS: New



C-5.16	Develop and manage a system for hazard and climate resilience data	
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: Quickly accessing hazard and asset GIS data is a challenge for many departments. As assessments relating to hazards and climate change become more common, the need for data for analysis and mapping will increase.	
LEAD: ORCP/DT PARTNERS: DEM, Planning, DPH	STRATEGY SUMMARY: ORCP, Planning, and DEM have collected robust GIS data relating to hazards (seismic, SLR, etc.) and relevant assets. To benefit future projects and implementation of the HCR, a system needs to be established to organize, maintain, and make this data accessible to other departments. This benefits future projects involving neighborhood-level hazard or asset specific vulnerability assessments. Publishing non-sensitive data through a public data/mapping sharing platform will be pursued to improve accessibility for community-based organizations the general public. Analysis will also be produced at the neighborhood scale for dissemination.	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Research, Planning & Guidance	STATUS: New

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: All Hazards

C-5.17	Develop a communications strategy for citywide climate resilience efforts
KEY PLANNING ISSUES: N/A	**VULNERABILITY ADDRESSED:** The City lacks clear messaging on how it is addressing hazards and climate change impacts citywide and how different efforts relate to each other. As a result, residents and other stakeholders may not understand if/how the City is working to increase resilience and how they can participate.
LEAD: ORCP **PARTNERS:** Planning, Port, SFE, DPH, SFPUC	**STRATEGY SUMMARY:** Department Public Information Officers will create coordinated messaging, content, and materials that communicate citywide climate resilience efforts. Materials may include FAQs, presentation slides, and handouts/pamphlets. These materials will augment communications for projects relevant to climate resilience so that it is clearer to the public how they relate to the citywide framework for action. Existing organizations, associations, and informal networks will assist in dissemination of information, reaching communities at the hyper-local level. Interfacing with the NEN Healthy Homes Program and specifically targeting vulnerable populations, such as SRO occupants, should also be components.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Low: $0–500K	Research, Planning & Guidance	New

C-5.18	Improve San Francisco's climate health research capacity
KEY PLANNING ISSUES: N/A	**VULNERABILITY ADDRESSED:** This strategy seeks to address all climate change-related hazards by understanding their impact on behavioral health and children/youth, while also better identifying and filling gaps in the City's emergency response Critical Partner's List.
LEAD: DPH **PARTNERS:** Varies	**STRATEGY SUMMARY:** Interventions to protect the public from the health impacts of climate change-related hazard events will be most successful if based on data-informed research and best practices. The SF Climate and Health Program has developed a range of resources. As the health impacts of climate change become more significant, it is important that San Francisco's climate health research capacity scales appropriately. As climate change advances, research is an essential pursuit to ensure that the City can be proactive in protecting residents from its impacts.

COST:	SF GOVERNMENT ACTIVITY:	STATUS:
Low: $0–500K	Research, Planning & Guidance	Scaling

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: All Hazards

C-5.19	**Develop and implement a Centralized Air Quality and Extreme Heat Preparedness campaign**	
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: This strategy would improve overall outreach and education coordination in the City and with media and community group partners. This will improve the effectiveness of City messaging, reduce public confusion in emergencies and ignorance of hazards, and build capacity citywide for preparedness efforts.	
LEAD: DPH PARTNERS: DEM, ORCP, CBOs, SFE, Public Works, PIOs, Public Government Affairs Staff	STRATEGY SUMMARY: This strategy seeks to improve community engagement and education efforts. A centralized Air Quality and Extreme Heat Preparedness campaign, would partner with community-based, City, and regional partners to unify messaging around health impacts, vulnerable populations, preparedness best practices, and available emergency and information services.	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Research, Planning & Guidance	STATUS: New

C-5.20	**Implement SFMTA's Traffic Signals Strategy**	
KEY PLANNING ISSUES: Transportation	VULNERABILITY ADDRESSED: The roadway depends on electric power for lights and signals and for the overhead power lines of the electric trolley system.	
LEAD: SFMTA PARTNERS:	STRATEGY SUMMARY: The purpose of this strategy is to increase the resilience of the City's traffic network by upgrading traffic signals and signal infrastructure and by mitigating risks. Traffic signals are integral to the smooth functioning of the transportation system. By upgrading, renovating, and replacing traffic signals and signal infrastructure, this strategy will improve mobility, improve communication in an emergency event, and increase the safety of San Francisco roadways. Funding for this strategy is included in the FY2019–FY2023 Capital Improvement Program.	
COST: Medium: $500K to $5M	SF GOVERNMENT ACTIVITY: Community Services Delivery	STATUS: Sustaining

DOMAIN: RESILIENT COMMUNITIES (C)

Primary Hazard Group: All Hazards

C-5.21	Improve and prepare behavioral health services for hazard events	
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: Studies have shown that 25 to 50% of people exposed to natural hazard events are at an increased risk of experiencing anxiety, PTSD, and suicide. As climate change increases the frequency of hazard events, we must scale our behavioral health services to balance these increased demands with our current needs.	
LEAD: DPH PARTNERS: DEM, HSH NEN, MOD, CBOs, DAAS	STRATEGY SUMMARY: The objective of this strategy is to review current San Francisco Department of Public Health plans that support the demand for behavioral health services before, during, and after hazard events, and, as appropriate, identify additional activities to help ensure local behavioral health services are able to be scaled to meet this increased demand.	
COST: Low: $0–500K	SF GOVERNMENT ACTIVITY: Community Services Delivery	STATUS: Sustaining

C-5.22	Continue to build trust between the Police Department and the communities they serve	
KEY PLANNING ISSUES: N/A	VULNERABILITY ADDRESSED: Strong relationships between the police and the community are critical to preparing and recovering from hazards. The Department of Justice (DOJ) identified the need to improve trust in the San Francisco Police Department (SFPD) through better community policing and engagement, enhanced accountability, reductions in biased policing, revised practices in the uses of force, and hiring and recruitment strategies reflective of San Francisco's diversity.	
LEAD: SFPD PARTNERS: CBOs	STRATEGY SUMMARY: As first responders, it is important that law enforcement officers develop strong relationships with communities before a disaster strikes. Implementing the recommendations made by the DOJ along with other efforts to build trust between the SFPD and all communities is vital to effective disaster mitigation, response, and recovery.	
COST: TBD	SF GOVERNMENT ACTIVITY: Community Services Delivery	STATUS: Sustaining

7.5 Additional Strategies for Consideration

During the strategy development process, additional strategies were suggested that the City will continue to consider for implementation in subsequent Plan updates. These may be longer-term strategies or strategies that do not yet have a clear implementation path for the next five years.

Additional Strategies

Recommended Lead	Strategies for Consideration
SFMTA/CTA	Engage private transportation providers, such as transportation network companies (TNCs), micro-mobility companies, and shuttles regarding operations during a hazard event, especially to prioritize vulnerable people.
SFMTA/CTA	Improve transit affordability, especially during a hazard event, such as free public transit on Spare the Air Days.
SFCTA/Planning	Inventory multi-hazard vulnerability and risk assessments for regional transit systems serving San Francisco and co-create a regional hazard mitigation plan with relevant agencies.
MOD	Develop an inventory of accessible vehicles and a coordinated plan to share resources during a hazard event.
DT	Improve the technology and security of the Outdoor Public Warning System.
SFMTA	Continue to implement Vision Zero to improve the safety of city streets.
DBI/Planning	Streamline the permitting process for buildings to make resiliency-related improvements.
DPH/SFPUC	Better understand and mitigate the potential risks surrounding toxic waste and flooding and communicate that information to the public.
MOHCD/Rent Board	Develop strategies to address the vulnerability of renters to displacement following a major disaster.
Planning/SFE	Develop and apply an ecosystems services framework to climate adaptation plans and investments.
HSA/MOD/DPH	Coordinate with residential property managers that serve vulnerable populations to systematize how residents with access and functional needs are identified, how property managers use that information to conduct wellbeing checks, and how property managers communicate information to emergency responders.

Port	Understand the flooding risk of industrial facilities on the waterfront and develop resilience strategies, especially to prevent contamination.
DPH/Real Estate	Improve the resilience of the City's leased facilities to better serve the public during hazard events
Port/DBI/ORCP	Conduct groundwater data collection and modeling efforts to better understand the impacts of rising groundwater at the shoreline, including liquefaction risks.
RPD/SFPUC	Explore opportunities for stormwater catchment and non-potable reuse by considering the use of larger structures such as cisterns for lower-elevation areas within parks
Planning	Review and update the General Plan as needed to support climate resilience throughout the city.
Planning/SFE/SFPUC	Develop a Cool and Living Roof initiative for extreme heat.
SFMTA	Implement the Communications & IT Vision: Disaster Recovery/Continuity Plan.
SFMTA	Implement Security Vision: Market Street Natural Hazard Mitigation, Threat and Vulnerability Assessment Implementation, Subway Flooding Prevention, Preparedness, and Mitigation, and Incident Management Planning and Response.
SFMTA	Implement State of Good Repair & Asset Management Vision: Develop Phase II & III of the 10-Year Asset Management Strategy.
SFMTA	Implement parking facility structural and seismic upgrades.
SFMTA	Scale Building Progress Program: modernize municipal yards and facilities.

Chapter 08

Plan Maintenance

In creating the HCR, San Francisco is also committing to a formal plan maintenance process. The purpose is to ensure the 2019 HCR plan remains an active, viable document, and that the mitigation strategies it sets forth are updated and tracked through implementation.

As discussed in Chapter 02, the Plan is the result of a collaborative process involving the HCR Planning Team, Technical Working Group, and Steering Committee, with coordination and oversight by ORCP. These bodies will continue to play a role in the plan maintenance process, which includes efforts to (1) monitor, evaluate, and update the HCR Plan, (2) incorporate the requirements of the HCR Plan into existing planning mechanisms, and (3) continue to engage communities by including them in the plan maintenance process. The section below describes these in more detail.

8.1 Monitoring, Evaluation, and Updates

To maintain this momentum and to build on previous hazard mitigation planning successes, ORCP and DEM will continue to convene the Planning Team once per year as a primary method of monitoring, evaluating, and updating the HCR.

ORCP will send out the Planning Team Annual Review Questionnaire, found in the 2019 document Appendix D, to evaluate the planning process, hazard analysis, capability assessment, vulnerability and consequences analysis, and mitigation strategies. ORCP will compile responses and share feedback during the annual meeting.

As part of the annual review process, agencies and departments will fill out the HCR Plan Action Progress Report for the strategies for which they are the lead department. This Progress Report, found in the Appendix D, requests information on progress in implementing the mitigation strategy, any changes in scope, identified impediments, and potential approaches for resolving impediments. ORCP will compile, summarize, and share the results of the Progress Reports with the Interim Planning Team at the annual meeting.

The Planning Team will then decide if the HCR needs to be updated in less than the five-years set by the Stafford act.

In order to prepare for the five-year update of the HCR Plan, the Planning Team shall commence the following activities by 2023.

1. Complete the Annual Review Questionnaire and review the previous questionnaires
2. Thoroughly analyze and update the risk of natural hazards in the Planning Area
3. Provide a detailed review and revision of the mitigation strategies
4. Prepare new mitigation action plans
5. Prepare an updated draft plan and submit it to Cal OES and FEMA for preliminary review
6. Submit the updated draft HCR Plan to the Board of Supervisors and Mayor for adoption
7. Submit the updated HCR Plan to FEMA for final approval
8. The Planning Team is also committed to integrating out-of-county assets into the risk assessment analysis of the future update of the HCR Plan

8.2 Integration into Other Planning Mechanisms

The 2019 Hazard and Climate Resilience Plan integrates with several City and County of San Francisco planning activities including those described below.

Climate Action Strategy

The 2020 Climate Action Strategy will not only provide a blueprint for achieving net zero carbon emissions by 2050, but also how the City will adapt to the unavoidable impacts of climate change. The climate adaptation strategies from the HCR will be integrated into a combined strategy for eliminating carbon emissions and adapting to climate change impacts.

Community Safety Element

The Community Safety Element of the General Plan will be updated to incorporate relevant objectives and policies from the HCR.

Capital Planning

The 10-Year Capital Plan includes funding principles to make trade-offs between competing needs. "Protects Life Safety and Enhances Resilience" will continue to be Funding Principle #2 and the projects identified in the HCR will be considered in the planning process.

Emergency Management

Information from the HCR will be integrated into future updates of emergency management planning documents, such as the Emergency Response Plan, Disaster Debris Management Plan, and Earthquake Annex.

Disaster Recovery Planning

Vulnerability information from the HCR will be incorporated into the Downtown Recovery Plan and mitigation goals and strategies will be considered in the Disaster Recovery Framework as post-disaster investments may provide an opportunity to incorporate more resilient building and infrastructure systems.

8.3 Continued Public Participation in Plan Maintenance

The HCR is meant to be a living document rather than a document that is only updated every five years. In order to keep the public involved in this on-going process, ORCP will:

- Maintain a publicly accessible copy of the plan available online
- Post notice of any changes to the plan on the website
- Create a system for feedback and publicize opportunities for feedback

Integrate HCR materials and public feedback into related and on-going public engagement activities.

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