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Bay Area Housing and Community Risk Assessment Project

Creating Safe Growth Strategies for the San Francisco Bay Area

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earthquake and hazards program
Association of Bay Area Governments

Table of Contents

I

EXECUTIVE SUMMARY

The risks posed by earthquakes and sea level rise to communities in the San Francisco Bay Area will increase in the future, as the Bay Area's population is projected to grow from 7 million to 9 million by 2040. Furthermore, approximately 80 percent of the Bay Area's future housing needs (as well as 66 percent of new jobs) will be accommodated in Priority Development Areas (PDAs) identified in Plan Bay Area, the region's long-range plan. Many of these areas of anticipated growth, particularly those along the Bay shoreline, are at risk from earthquake-induced liquefaction[1] and sea level rise. The consequences of earthquakes and sea level rise are particularly significant for residential land uses. In the wake of a major disaster, homes in the region will likely be seriously damaged and residents displaced.

1. Liquefaction is a phenomenon where saturated sand and silt take on the characteristics of a liquid during the intense shaking of an earthquake. As a result, the soil can lose its ability to support structures.

Not only is much of the region's housing vulnerable, but in many communities, elderly, low-income residents, people without automobiles, or renters might lack access to information and services, financial means, or physical capacity to prepare for, respond to, and recover from hazard events. These problems are significantly exacerbated when communities with these characteristics live in fragile housing stock (defined as 30 percent or more housing units within a block group identified as potentially vulnerable to flooding, liquefaction, or ground shaking hazard). Thus, keeping housing intact is fundamental to retaining all the region's residents in the wake of a disaster.

This project developed strategies that can help reduce the vulnerability of development in the Bay Area so that all growth is not only smart, but also safe. This project included two major phases:

1. Vulnerability assessment: The project team examined both housing vulnerability and community vulnerability. The team identified the characteristics of Bay Area housing and communities that increase their vulnerability to earthquakes and flooding and identified and assessed housing and community vulnerability at regional and community scales.
2. Strategy development: The team developed strategies that reduce housing and community vulnerability to help the region meet its resilience, sustainability, prosperity, and equity goals.

After identifying areas of the San Francisco Bay Area with the most vulnerable housing and communities, the project team developed 40 resilience strategies to help local jurisdictions reduce the vulnerability of housing and populations to earthquake-induced ground shaking and liquefaction, as well as to current and future flooding hazards. The project team considered existing policies, plans, and programs in the Bay Area, as well as existing federal and state legislation and designed strategies that would go above and beyond these basic safety standards. The goal was to create a new set of safe growth strategies that would increase regional resilience and ensure that people could either stay in their homes, or return to their homes more quickly after disasters. The safe growth strategies are also designed to ensure that local development is affordable, transit-accessible, and beneficial to the economy and environment. ABAG and BCDC incorporated these strategies into a manual to support action at the local level that will help the entire region become more resilient in the face of earthquakes and flooding[2]. This project strives to show that communities can plan for growth that meets residents' everyday needs while also making them safer from natural hazards. This project also provides a model other regions or communities could use to assess the vulnerability of their housing and residents and develop strategies to make development safer.

2. Association of Bay Area Governments. Stronger Housing, Safer Communities: Strategies for Seismic and Flood Risks, 2015. http://resilience.abag.ca.gov/projects/stronger_housing_safer_communities_2015/.

1

INTRODUCTION

This project focuses on a series of safe growth strategies that were produced by the U.S. Environmental Protection Agency (EPA) as part of the Smart Growth Implementation Assistance Program (see Appendix A for more on the program). The Association of Bay Area Governments (ABAG) and the San Francisco Bay Conservation and Development Commission (BCDC) requested assistance from EPA to ensure that housing built in the region's high-growth areas are safe from risks posed by earthquakes and flooding. ABAG is San Francisco's regional planning agency and BCDC was created by the California Legislature in 1965 to manage and regulate activities, including new development, along the shoreline of the bay. EPA partnered with the Federal Emergency Management Agency (FEMA) and hired AECOM and Laurie Johnson Consulting to help develop strategies to reduce regional vulnerability. The project team included staff from EPA, FEMA, ABAG, BCDC, AECOM and Laurie Johnson Consulting.

ABAG's Earthquake and Hazards Program and Planning and Research Department and BCDC's Adapting to Rising Tides Program organized a multi-agency project known as the Bay Area Housing and Community Multiple Hazards Risk Assessment. This overall effort consolidates funding and support from EPA, the U.S. Geological Survey (USGS), and the California Strategic Growth Council to:

- Understand the characteristics of San Francisco Bay Area housing and communities that increase vulnerability to earthquakes and sea level rise-related flooding.
- Identify and assess housing and community vulnerability at regional and community scales.
- Develop strategies that reduce housing and community vulnerability to help the region meet its resilience, sustainability, prosperity, and equity goals.

Although this project was conducted for the San Francisco Bay Area, other communities and regional governments can study the vulnerability assessment and safe growth strategies as a potential model to build resilience in their communities.

Background

The nine-county San Francisco Bay Area (Bay Area), home to approximately 7 million people, is the nation's fifth most populated metropolitan area. Its economy, culture, and landscape support prosperous businesses, vibrant neighborhoods, and productive ecosystems. However, the Bay Area is vulnerable to natural hazards such as earthquakes and sea level rise. Plan Bay Area[3] is the region's long-term land use plan and identifies locally determined Priority Development Areas (PDAs) where the majority of new housing and jobs will be directed in the next 30 years. Plan Bay Area is a Sustainable Communities Strategy, which is required by the state of California to meet the goals of Senate Bill 375 (SB 375)[4] to reduce the state's greenhouse gas emissions. Each of the state's 18 metropolitan areas are asked to develop Sustainable Communities Strategies to absorb future population growth in locations that are transit accessible to reduce greenhouse gas emissions from cars and light trucks.

Plan Bay Area defines PDAs as planned neighborhoods in Bay Area cities and towns designed so that new development is within walking distance of transit service and offer a wide variety of housing options and amenities such as grocery stores, community centers, and restaurants. PDAs were defined and selected by local communities and align transportation and housing plans in a single long-range land use plan. Plan Bay Area outlines PDAs for the Bay Area, and at the same time the plan emphasizes quality of life, access and mobility, public health, and livability in PDAs. Areas surrounding PDAs are also expected to experience significant development in the future. These areas of anticipated growth, particularly those along the Bay shoreline, are at risk from earthquake-induced liquefaction and sea level rise. See Appendix B for more details about the earthquake and flood risks in the Bay Area.

Because more development will be directed into the PDAs near the shoreline, more residents are projected to live in areas regularly inundated by sea level rise. The most significant population increases within the inundation zone (numerically) are in Santa Clara County, which is a low-lying and densely populated county. The least significant increases (numerically) are in Napa and Sonoma counties, which are both more sparsely populated in potentially inundated areas. The population in the portions of the PDAs that are vulnerable to inundation is projected to increase by 245 percent between 2010 and 2040.

3. Plan Bay Area is a long-range integrated transportation, land use, and housing strategy through 2040 for the San Francisco Bay Area. http://onebayarea.org/plan-bay-area.html.

4. California Air Resources Board, Sustainable Communities and Climate Protection Act of 2008, http://www.arb.ca.gov/cc/sb375/sb375.htm

The consequences of earthquakes and sea level rise are particularly significant for residential land uses. The weak links in the region's resilience are the physical vulnerability of the region's current housing and limitations on the capacity of people to recover by quickly moving back into their homes after a disaster. In the wake of a major disaster, homes in the region will likely be seriously damaged and residents displaced. Earthquake-induced liquefaction could cause costly damage to building foundations, while flooding could make many houses uninhabitable. Major damage to housing could force many residents to move to other areas of the region, and some might leave the region permanently. Businesses without enough employees or customers might also be forced to move elsewhere or shut down.

Multiple studies have shown that population loss after a disaster significantly slows recovery time.[6] In the Bay Area, much of the older, more affordable housing stock is vulnerable to damage from disasters. Many residents living in the Bay Area's most affordable neighborhoods might not have the resources to stay and rebuild if their homes are significantly damaged, as rebuilding housing can take years. Past disasters have also demonstrated that low-income or rental housing often gets demolished and rebuilt as market-rate housing, permanently changing community and regional demographics.

Not only is much of the region's housing vulnerable, but in many communities, low-income residents or overburdened populations,[7] such as the elderly, people without automobiles, or renters might lack access to information and services, financial means, or physical capacity to prepare for, respond to, and recover from hazard events. These problems are significantly exacerbated when people with these characteristics live in housing stock that cannot withstand earthquakes or floods. Thus, keeping housing intact is fundamental to retaining the region's residents. In the aftermath of natural disasters, the recovery of the region's economy depends on the recovery of its housing. If residents can stay in their homes, they will be better able to participate in rebuilding their neighborhoods and cities, go to work and support local business, and help the entire region recover faster.

If new development is directed to Priority Development Areas that are likely to be affected by earthquakes and/or sea level rise, the obvious solutions are to either reduce the amount of housing in hazard-prone zones or construct homes in a way that reduces their vulnerability to these hazards. This project developed strategies that can help reduce the vulnerability of new development in the Bay Area so that all growth is not only smart, but also safe.

This project included two major phases:

1. Vulnerability assessment: The project team examined both housing vulnerability and community vulnerability. The team identified the characteristics of Bay Area housing and communities that increase their vulnerability to earthquakes and flooding and identified and assessed housing and community vulnerability at the regional and community scales.

5. Liquefaction is a phenomenon where saturated sand and silt take on the characteristics of a liquid during the intense shaking of an earthquake. As a result, the soil can lose its ability to support structures.

6. Comerio, M. C., 1998. Disaster Hits Home: New Policy for Urban Housing Recovery. Berkeley, CA: University of California Press. Mileti, D. S., 1999. Disasters by Design: A Reassessment of Natural Hazards in the United States. Washington, DC: Joseph Henry Press. Aldrich, D.P. 2012. Building Resilience: Social Capital in Post-Disaster Recovery. Chicago, Il: University of Chicago Press.

7. In its Plan EJ 2014, EPA uses the term "overburdened" to describe "the minority, low-income, tribal, and indigenous populations or communities in the United States that potentially experience disproportionate environmental harms and risks as a result of greater vulnerability to environmental hazards. This increased vulnerability may be attributable to an accumulation of both negative and lack of positive environmental, health, economic, or social conditions within these populations or communities." EPA. Plan EJ 2014. 2011. http://www.epa.gov/environmentaljustice/resources/policy/plan-ej-2014/plan-ej-2011- 09.pdf.

2. Strategy development: The team developed resilience strategies that reduce housing and community vulnerability to help the region meet its resilience, sustainability, prosperity, and equity goals.

Although strategies developed for this project were focused on new development in PDAs (including new development, infill development, or significant modification to or conversion of existing development), development will also occur outside of these PDAs, and these strategies can also apply to new development in other parts of the Bay Area.

In addition, in California, where greenhouse gas reduction and climate change mitigation is a priority, these strategies are meant to carefully balance climate mitigation goals with the need to adapt to the climate changes that are likely to occur. PDAs are meant to help reduce the state's contribution of greenhouse gas emissions from cars and light trucks by directing new growth to areas that are walkable and transit-accessible. This project seeks to now address the potential climate change risks from sea level rise, alongside the earthquake risks that these PDAs may face. And throughout the project, the main goal is to consider how to make the Bay Area's residents less vulnerable to the effects of climate change and natural disasters, both now and in the future.

2

VULNERABILITY ANALYSIS

ABAG and BCDC conducted analyses to identify highly vulnerable neighborhoods in the Bay Area by investigating two types of vulnerability: housing vulnerability and community vulnerability. During the analysis, agency staff engaged topic experts and regional and local stakeholders in a Housing Indicator Working Group and a Community Indicator Working Group. ABAG and BCDC staff led three to four working group meetings to discuss the development and application of indicators in the vulnerability analysis.

The analysis concentrates on three aspects of vulnerability:

1. Identifying areas subject to hazards that have known potential to create damage at a level that could displace residents from their homes;
2. Housing types that are vulnerable to the natural hazard events identified; and
3. Community characteristics that makes it less likely that the population will be able to prepare for, respond to, or recover from a disaster.

A summary map, seen in Figure 2-1, combines these three aspects of vulnerability for the entire Bay Area. Appendix C provides detailed information on the vulnerability assessment and additional maps, but following are the key considerations for each of these vulnerability types.

Hazards

The vulnerability analysis considered three hazards: ground shaking, liquefaction, and flooding. The project team selected the hazard scenarios (summarized in Appendix C) that are most likely to affect both existing and future communities in the Bay Area.

Different earthquakes cause differing levels of ground shaking throughout the region. The project team selected shaking scenario maps from two previously modeled earthquake scenarios – a Magnitude 7.9 scenario on the San Andreas Fault[8] and a Magnitude 7.0 scenario on the Hayward Fault[9] – and determined areas likely to experience ground shaking hazard levels of MMI VIII or above in these scenarios.

The ground shaking hazard analysis only includes homes that are likely to be exposed to MMI VIII and greater ground shaking, as they are the most likely to be significantly damaged, thus displacing residents.

Liquefaction hazard levels[10] were determined based on liquefaction susceptibility combined with shaking intensity (MMI). For the purpose of this project, moderate or high liquefaction hazard areas were examined using MMI from the future earthquake shaking scenario maps for the two scenarios outlined above (a San Andreas or Hayward event), as they are the most likely to cause major building damage that displaces residents from their homes.

Any amount of flooding[11] has the potential to displace residents from their homes, as even short duration flooding can undermine building structures or create unsafe living conditions due to mold growth and contamination. Current flooding scenarios are based on published National Flood Insurance Program (NFIP) rate maps.

Future flooding scenarios are based on three regional inundation maps assuming a sea level rise of 24", 36", and 48" developed by NOAA.[13] These three inundation maps are used to represent different combinations of sea level rise and tide levels, including the daily high tide and a range of extreme tides that could occur during coastal storm surge events.

Figures 2-2 and 2-3 show results of the hazard component of the vulnerability analysis, which identified areas potentially exposed to ground shaking, liquefaction, and current and future flooding.

8. http://gis.abag.ca.gov/website/Hazards/?hlyr=northSanAndreas
9. http://gis.abag.ca.gov/website/Hazards/?hlyr=haywardSouthNorth&co=6001
10. http://resilience.abag.ca.gov/earthquakes/#LIQUEFACTION
11. More information about the flood risks for the Bay Area: http://resilience.abag.ca.gov/floods/
12. FEMA's Flood Map Service Center: http://msc.fema.gov/portal
13. NOAA's Digital Coast maps: http://coast.noaa.gov/slr/

Figure 2-1: Combined Results of Housing and Community Vulnerability Analysis

BAY AREA HOUSING AND COMMUNITY MULTIPLE HAZARD RISK ASSESSMENT

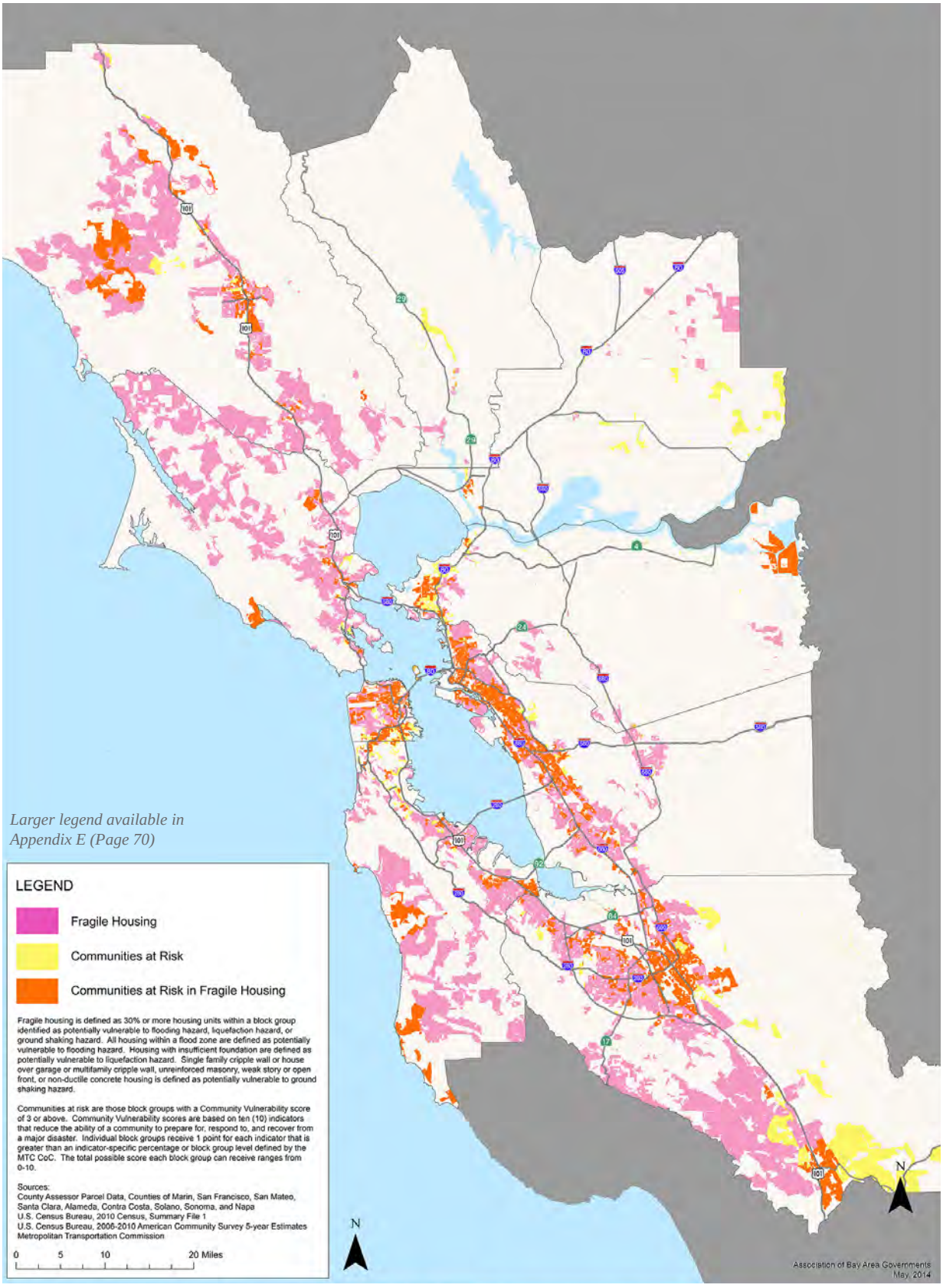


Figure 2-2: Flooding and Sea Level Rise Hazard Analysis

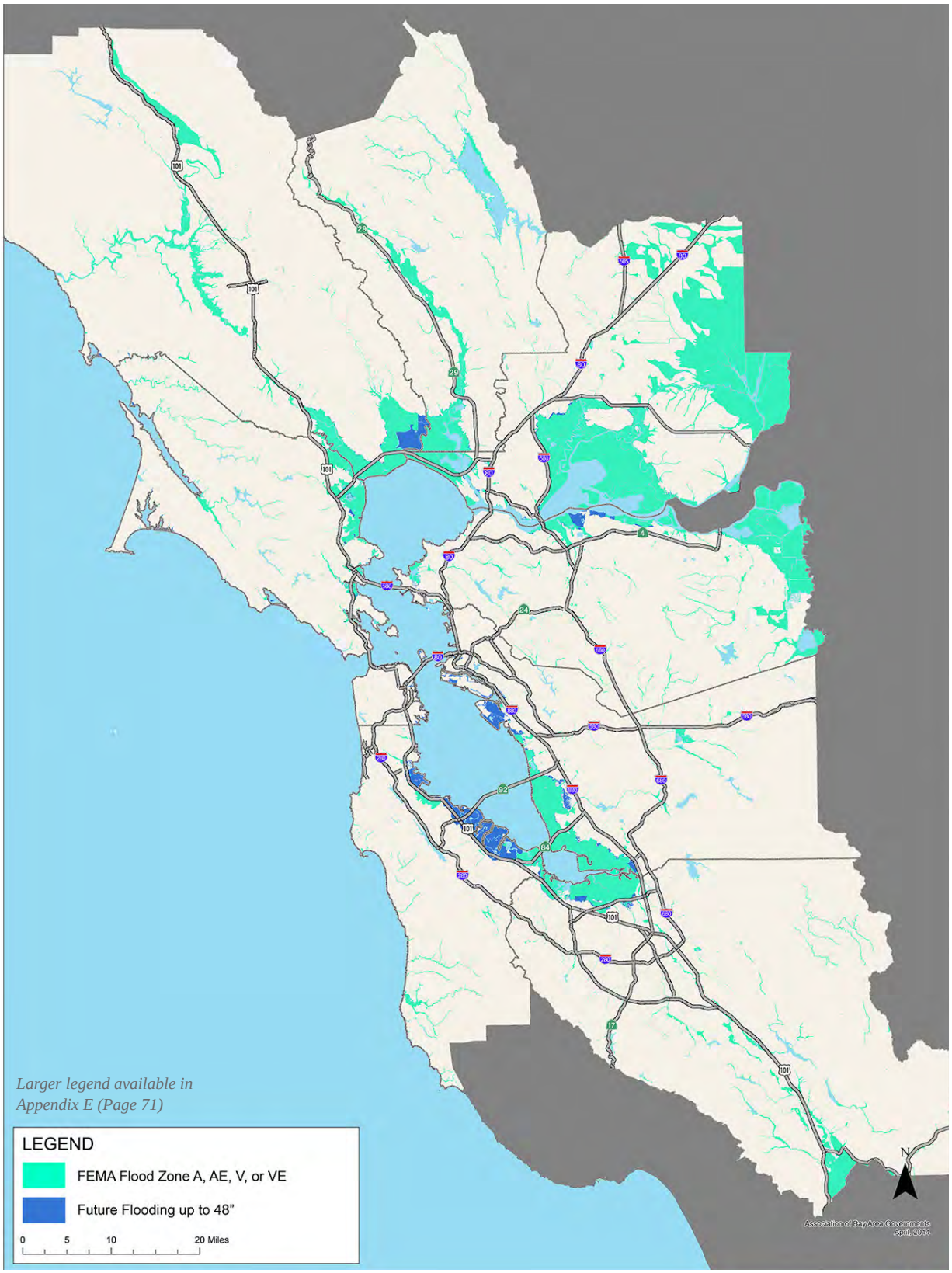


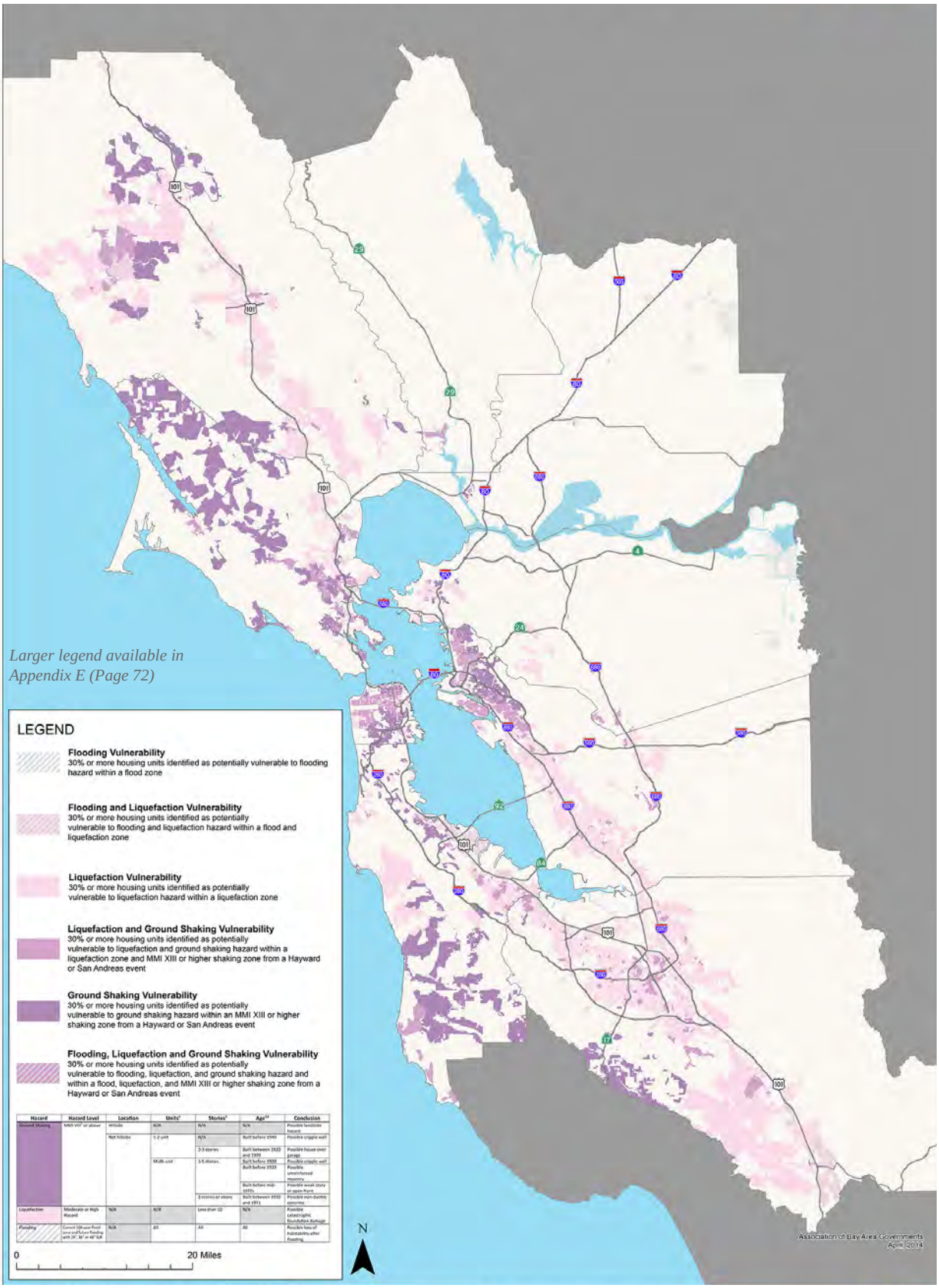
Figure 2-3: Ground Shaking and Liquefaction Hazard Analysis

Housing Vulnerability

Regional housing vulnerability was determined based on the eight potentially fragile building types. The presence of vulnerable housing is indicated if 30% or more of housing units in a block group are a fragile housing type located in an area of ground shaking, liquefaction, or flooding hazard.

The fragile housing typology is designed to identify subsets of the Bay Area housing stock that are likely to possess characteristics that increase their vulnerability. This method identifies only what are deemed as the most fragile common housing structure types found within the Bay Area due to likely poor structural performance in an earthquake (i.e., those conditions most likely to cause housing to be red-tagged, requiring either demolition or extensive and lengthy repairs). This method considers critical combinations of material, system, etc. that indicate high fragility. As key data such as structure type (wood frame, concrete, etc.) is not widely available, proxies such as size, age, number of stories, and location that are associated with the most common fragile housing types are used. As different hazards interact with building types differently, hazards including liquefaction, ground shaking, and flooding are examined separately.

Each fragile housing type was mapped at the block group level to identify block groups with the characteristic combinations associated with each fragile housing type. Only block groups exposed to the identified hazard level for ground shaking, liquefaction, and flooding are flagged; vulnerability is a combination of exposure and fragility. Figure 2-4 shows the results of the housing vulnerability analysis.


Larger legend available in Appendix E (Page 72)
LEGEND
Flooding Vulnerability
30% or more housing units identified as potentially vulnerable to flooding hazard within a flood zone
Flooding and Liquefaction Vulnerability
30% or more housing units identified as potentially vulnerable to flooding and liquefaction hazard within a flood and liquefaction zone
Liquefaction Vulnerability
30% or more housing units identified as potentially vulnerable to liquefaction hazard within a liquefaction zone
Liquefaction and Ground Shaking Vulnerability
30% or more housing units identified as potentially vulnerable to liquefaction and ground shaking hazard within a liquefaction zone and MMI XIII or higher shaking zone from a Hayward or San Andreas event
Ground Shaking Vulnerability
30% or more housing units identified as potentially vulnerable to ground shaking hazard within an MMI XIII or higher shaking zone from a Hayward or San Andreas event
Flooding, Liquefaction and Ground Shaking Vulnerability
30% or more housing units identified as potentially vulnerable to flooding, liquefaction, and ground shaking hazard and within a flood, liquefaction, and MMI XIII or higher shaking zone from a Hayward or San Andreas event
Hazard
Hazard Level
Location
Units
Stories
Age
Conclusion
Liquefaction
Moderate or High Hazard
N/A
N/A
Flooding
N/A
All
All
0
20 Miles
N
Association of Bay Area Governments
April 2014

Community Vulnerability

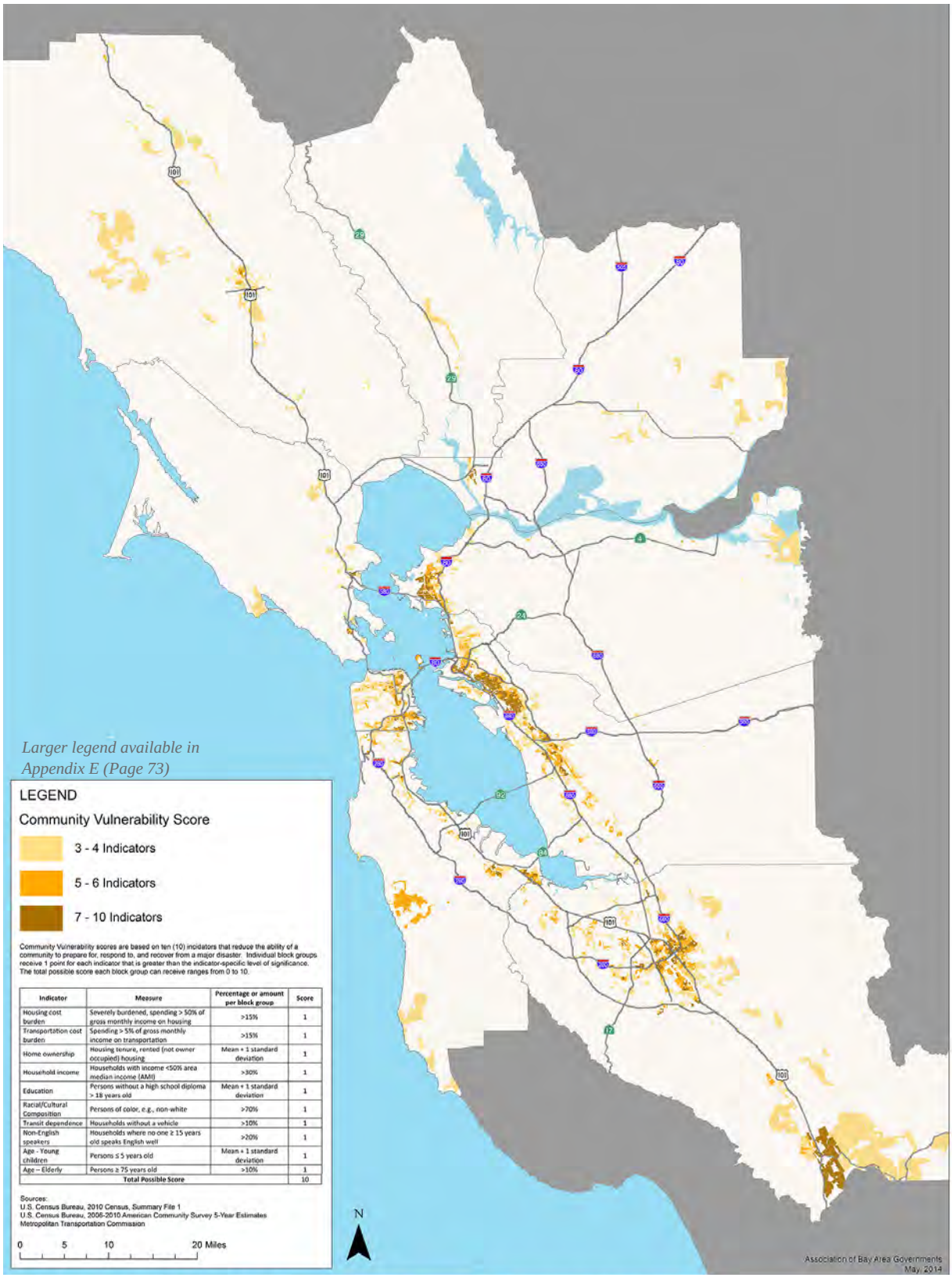
ABAG and BCDC determined community vulnerability based on 10 indicators. These indicators were selected because they were based on publicly accessible demographic data that could be applied at the regional scale. Community indicators include characteristics of individual residents that affect their ability to prepare for, respond to, and recover from a disaster. Though the indicators are largely applicable to individuals, collectively they present a picture of a community's vulnerability. The concentration of individuals exhibiting these characteristics is assumed to influence a community's ability to recovery after a disaster.

ABAG, BCDC, and the Community Indicator Working Group selected indicators based on regionally relevant research and their best professional judgment. Indicators include housing and transportation cost burden, home ownership, income, education, ethnicity and language vulnerabilities, and age-related vulnerabilities.

The analysis conducted through this process is a high-level, regional screening for vulnerability and does not reflect qualitative characteristics that might increase or decrease vulnerability, such as community cohesion and high social capital (community capacity). The Community Indicator Working Group discussed many proxies for community cohesion, such as the presence of churches, neighborhood groups, and social services in a neighborhood. However, the connection between the presence of these entities and the actual community capacity in a neighborhood is not easily measured, so these measures were excluded from this analysis. Individual jurisdictions would need to account for qualitative characteristics when determining actual vulnerability and capacity for resilience within their communities. Figure 2 5 shows the mapped results of the community vulnerability analysis for the region.

Figure 2-5: Community Vulnerability Analysis Results

BAY AREA HOUSING AND COMMUNITY MULTIPLE HAZARD RISK ASSESSMENT



3

STRATEGY DEVELOPMENT

After identifying areas of the San Francisco Bay Area with the most vulnerable housing and communities, the project team developed a suite of implementation strategies to help local jurisdictions reduce the physical vulnerability of housing and populations to earthquake-induced ground shaking and liquefaction, as well as to current and future flooding hazards. ABAG and BCDC solicited regional input through a Project Advisory Committee and a series of stakeholder workshops that began in February 2014 and were completed in August 2014. Community members, elected officials, city and regional government staff, academics, and other experts provided feedback on different iterations of the strategies and helped the project team refine the final strategies list and content of each one.

In addition, three case study vulnerability profiles for portions of the cities of San Rafael, Oakland, and Richmond were used to more carefully consider how strategies might be applied in specific communities with identified vulnerabilities.

Regional stakeholders offered feedback on the proposed content for the resilience strategies, particularly on the importance of highlighting any co-benefits of the strategies, or potential for strategies to go beyond hazard mitigation to meet other local goals, such as for public health or safety. Stakeholders also suggested that the final manual, which can be found on ABAG's website, provide guidance to local communities about how to select and assemble a suite of strategies that would meet a particular jurisdiction's broader planning goals and objectives, such as open space preservation, economic development, or others. Stakeholders also recommended that strategies should not be completely confined to PDAs, and that adjacent communities should be considered as well. In particular, stakeholders expressed an interest in strategies that might be implemented at a larger scale to affect both new development and existing communities. For example, flood protection structures or shoreline improvements could simultaneously protect neighborhoods that include PDAs and areas not slated for high growth. Furthermore, local planners talked about the need to encourage collaboration between adjacent jurisdictions to ensure that a common standard of safety is applied throughout the region and especially among contiguous communities. This consistency might also ensure that development is not driven from one community with higher standards to another nearby with less stringent development standards.

Several local planners and officials raised concerns that building codes are already restrictive and expensive to implement and that local building officials and communities might be reluctant to add more building-related restrictions. Both developers and community activists voiced concerns about the costs that some of these strategies might impose on new development. Developers wanted to ensure that local governments consider the financing mechanisms needed to support these strategies (see Chapter 4 for more on financing mechanisms). Community activists and environmental justice organizations were concerned that new development might be built to be safe while existing housing remains vulnerable and that the costs of safer development might be passed on from landlords to tenants, potentially worsening housing affordability issues in the Bay Area.

Stakeholders were concerned that the strategies might discourage new development in PDAs because of a perception that they create barriers to development. Because the region's communities have selected PDAs as regional priority locations for new development, the project team agreed that strategies should be selected and implemented in a way that continues to encourage development in PDAs. Most stakeholders agreed that communication about these strategies would need to focus on the importance of both investing in transit-oriented, priority locations for new growth while also ensuring that these investments are made with good information about the risks and possible ways to mitigate those risks.

Existing Federal, State, and Local Regulations and Policies

As the project team developed the strategies to respond to identified vulnerabilities in the Bay Area, it considered the existing policies, plans, and programs already in place within the Bay Area, as well as existing federal and state legislation and designed strategies that would go above and beyond these basic safety standards. The goal was to create a new set of safe growth strategies that would increase regional resilience and ensure that people could either stay in their homes or return to their homes more quickly after disasters. The team considered the following goals to supplement current construction guidelines related to

building in earthquake and flood zones. For more details about the existing regulations and standards for building in earthquake zones and flood zones, see Appendix C.

Considering existing **earthquake-related mapping tools,** the team developed strategies to:

- Close the gaps in the current state seismic hazard mapping coverage in portions of eastern and northern Alameda County and eastern and southern Santa Clara County as well as all of Marin, Sonoma, Napa, and Solano counties.
- Evaluate and build upon the state's guidance for mapping and mitigating seismic hazards.
- Encourage local governments and other lead permitting agencies to develop their own locally specific seismic hazard maps to inform local decision-making.
- Considering existing earthquake-related building regulations, the team developed strategies to:
- Identify both structural and non-structural building weaknesses to seismic loadings that can be addressed by applying the strategies in Priority Development Areas.
- Identify structural design issues that are relatively common to residential construction, with an emphasis on items that would be particularly influenced by ground shaking in areas that are susceptible to liquefaction.
- Remedy the most common and widespread building construction deficiencies in terms of earthquake performance, such as:
  - > Inadequate partition wall anchorage and bracing.
  - > Utility connections at the building perimeter.
  - > High-risk construction behaviors such as incorporating significant structural irregularities into the design.
  - > Developing a large residential development with many occupants that conforms only to the minimum baseline performance (life safety standard) of the building code.
- Address primarily issues that affect new development, but also develop strategies for existing development.

Considering existing **flood-related regulations,** the team developed strategies to:

- Consider the adoption of floodplain management ordinances that are more stringent than minimum federal and state requirements to reduce risks both from current extreme flood events that could have wide-ranging and costly consequences (e.g., a 500-year event),[14] as well as from increased risk of coastal and riverine flooding that will increase as sea level rises.
- Go beyond FEMA's minimum National Flood Insurance Program (NFIP) requirements for first-floor elevations to be at the base flood elevation (BFE), to reduce the impacts from mid-century projected sea level rise.
- Consider flood-proofing requirements for all development in flood hazard zones, including those in the 500-year flood plain.
- Recommend that local governments participate in voluntary FEMA programs, such as the Community Rating System (CRS).
- Consider revising development codes to increase the minimum elevation requirements for habitable building space and sensitive building components.

Planning in Flood and Seismic Hazard Zones

Local governments in the Bay Area have many tools to guide planning through general and

14. A 500-year flood event has a 0.2% change of occurring in any given year.

specific plans, zoning codes, subdivision and improvement standards, overlay districts, and development guidelines. However, existing plans, land use designations, zoning regulations, and development standards in a community might not always promote safe new development or protect existing development from hazards. Existing zoning regulations and land use designations in a community could inadvertently allow or even encourage new development in hazardous areas. As a result, new development or redevelopment could happen in locations that are vulnerable to damaging seismic hazards, temporary flooding from storm surges, or permanent inundation from sea level rise. In addition, local jurisdictions might not have appropriate planning or zoning designations and/or development standards that allow the construction of temporary buildings, infrastructure, and public spaces that can temporarily help meet basic needs after a disaster, while rebuilding is occurring.

Considering **local planning and zoning tools,** the team developed strategies to:

- Review and update all tools to limit or prohibit development in unsafe locations, provide incentives for relocating existing development, and limit or prohibit redevelopment after a disaster in the highest hazard areas.
- Encourage developing or preserving open space, recreational amenities, and other community facilities in areas deemed unsafe for development.
- Implement overlay zoning districts to allow more flexible zoning provisions that enable safe and smart new development.
- Consider development code revisions to provide regulatory and financial incentives to developers and homeowners to direct more compact development away from the highest-risk areas and into lower-risk areas or areas where risks can be better managed.
- Propose that local jurisdictions incorporate in their local plans and development regulations allowance for temporary buildings, structures, and support infrastructure to continue to provide services to residents.

The resilience strategies in Chapter 4 take into consideration the current context for land use planning and hazard mitigation and work with existing mapping protocols, planning frameworks, and permitting processes to improve the resilience of any new development that occurs in the Bay Area.

4

RESILIENCE STRATEGIES

Introduction

This chapter provides 40 resilience strategies to address the housing and community vulnerabilities identified in Chapter 2. Local jurisdictions could use these strategies to plan safe and smart growth in the Bay Area. ABAG created a manual called, *Stronger Housing, Safer Communities: Strategies for Seismic and Flood Risks*[15] that discusses these 40 strategies in greater detail. ABAG is working to create an interactive strategies selection tool that will help guide local planners, decision makers, and community members as they seek to mitigate identified vulnerabilities.

15. Association of Bay Area Governments. Stronger Housing, Safer Communities: Strategies for Seismic and Flood Risks, 2015. http://resilience.abag.ca.gov/wp-content/documents/housing/Final%20Report/StrongHousingSaferCommunities_Strategies_3.16.15.pdf/.

The following headings are the major points of information provided for each strategy. And Table 4-1 provides a summary list of strategies, which are ordered and grouped according to whether they are appropriate for the state, regional, or local level.

Lead: Each strategy identifies the most practical level to lead the initiative: state, regional, or local. While these strategies emphasize actions that occur largely at the local level, some would require action at a higher level, such as the state. Strategies designated to be led by the state might require legislation, are actions that a state agency would undertake, or require coordinated effort between regions. In cases where the state is the most logical lead, regional and local governments can provide support. In some cases, state-level work, such as state-led mapping efforts, might be a prerequisite for regional or local action.

Regional bodies such as ABAG, MTC, or the Joint Policy Committee would be appropriate to lead some strategies. Regional leadership makes sense for efforts that should be consistent across the region (e.g., adopting retrofit standards) or for planning or actions that require coordination between multiple jurisdictions and special districts (e.g., shoreline protection). For certain actions, this regional work could spur local actions with policy, assistance, or information-sharing.

Target Development Type: This section indicates whether the strategy is geared towards protecting existing development or towards building safer, smarter new development. Most jurisdictions will likely have a mix of existing and new development in vulnerable areas, and this section can help jurisdictions decide where to use which strategy.

Hazard Addressed: Some of the strategies are designed to respond to one of the three specific hazards addressed in this project: ground shaking, liquefaction, or existing or future flooding. Jurisdictions can select only the strategies that apply to the specific hazards in their area. Other strategies are designed to respond to multiple hazards; jurisdictions would need to consider how to tailor the strategy to fit their specific hazards profile.

Community Vulnerability Addressed: Each strategy responds to the vulnerabilities identified through the regional housing and community vulnerability assessment. Some strategies address a specific community vulnerability (or vulnerabilities), in which case the vulnerability (or vulnerabilities) will be identified. For strategies that have a general communitywide benefit, specific community vulnerabilities are not identified here. Jurisdictions looking to address specific community vulnerability should look to this section to select strategies that specifically address that community vulnerability. This section is filled out only for strategies that have a direct benefit to that particular community vulnerability.

Fragile Housing Type Addressed: Some strategies are designed to directly address one of the fragile housing types identified in the assessment phase as likely to be found in the Bay Area and also to experience significant damage. If the strategy is tailored to one of these fragile housing types, it will be indicated here. Jurisdictions looking to address a specific fragile housing vulnerability should look to this section to select strategies that specifically address that fragile housing type. This section will be filled out only for strategies that have a direct benefit to that particular housing type.

Action Categories: This section identifies the type(s) of action that a jurisdiction might need to take to develop and implement the strategy.

Evaluation: Evaluation actions help jurisdictions better understand current levels of resilience and set a baseline against which to track future work. They can also provide insight into the status or effectiveness of existing programs, policies, or resources or provide data that help guide the direction or phasing of a program.

- Program/Operation: These actions would require a program with stakeholder support, resources, public involvement, and a defined outcome. Many of these actions would require local programs and might need assistance and coordination from the region.

- Plans and Policies: These actions would develop policies or plans that support building capacity on resilience and can be adopted at the local level. They could lead to Codes, Regulations, and Ordinances.
- Codes, Regulations, and Ordinances: These actions are the technical application of Plans and Policies. They are specific changes that alter the requirements in a jurisdiction, such as building codes or zoning codes.
- Coordination: Coordination actions involve bringing together multiple stakeholders to make common decisions that are mutually beneficial. These types of actions are most common in multi-jurisdictional issues such as flooding, and may be facilitated at the regional level.
- Education and Outreach: Education actions gather and communicate new information to help residents and other stakeholders and encourage voluntary actions to make housing more resilient.

Related Strategies: Many strategies work best when other strategies are also implemented, as they help gather information or could be more cost effective when coordinated. There are two types of related strategies: suggested prerequisites and other related strategies. Suggested prerequisites are strategies that make it easier to implement another strategy if they are implemented first. Other related strategies are those that might have a similar structure for implementation, cover related issues, or produce co-benefits.

Strategy descriptions also include important considerations for implementation, including governance or implementation issues, potential financing mechanisms, implementation partners, and examples from communities.

Guidance on Navigating Strategies

Similar strategies have been grouped together according to their most effective scale of action, from the state to the neighborhood levels. Table 4-1 below provides an explanation of the groupings along with summaries of the corresponding strategies.

Table 4-1: Housing and Community Risk Strategy List

Scale	#	Strategy Name	Strategy Summary
The following strategies involve complex research or regulations that would require initiative or buy-in from the state. Local jurisdictions should be aware of issues that need to be guided by the state and can support state action on these areas. These strategies are generally prerequisites for actions at the local level, or they help jurisdictions develop and implement specific actions.			
State	1	Complete seismic hazard mapping of urban and urbanizing areas	Encourage the California Geological Survey (CGS) to complete mapping of seismic hazard zones for the portions of the Bay Area that are not currently mapped or in the process of being mapped, with priority given to urban and urbanizing areas.
State	2	Evaluate current guidelines and state of practice for mapping, evaluating, and mitigating seismic hazards, particularly in multi-hazard areas	Through its authority under the State Seismic Hazard Mapping Act, encourage the California Geological Survey (CGS) to work with regional and local agencies and the geology/geotechnical community in the Bay Area to evaluate current guidelines, as well as the current state of practice, for mapping, evaluating, and mitigating seismic hazards, particularly in areas of expected growth that are also vulnerable to tsunami, flooding, and permanent inundation.
State	3	Develop education program(s) to encourage homeowners and renters to purchase hazard insurance	Create targeted education programs that encourage homeowners and renters to better understand their risk and make more informed decisions about the purchase of earthquake and flood insurance. This includes education about retrofitting versus insurance, understanding the site-specific hazards of their building, helping them understand what the costs and benefits are of purchasing insurance, and what is and is not covered by hazard insurance policies.
State	4	Improve the quality assurance of non-engineered retrofits by developing a statewide retrofitting license for contractors, with contractor training and technical materials	Develop a statewide program to train and license contractors in seismic retrofits to increase the number of skilled contractors, contractor knowledge, owner assurance and trust in retrofits, and consistency in retrofit quality throughout jurisdictions.

Scale	#	Strategy Name	Strategy Summary
The following strategies would require coordination beyond a single jurisdiction can provide because the issues extend beyond jurisdictional boundaries. In some cases, local action does not make sense without regional cooperation or coordination. In many cases, this regional work will then spur community-specific actions at the local level with policy, assistance, or information-sharing.			
Region	5	Establish a cooperative shoreline management program	Coordinate with government agencies, organizations, and landowners to establish and maintain a cooperative shoreline management program. This cooperative program could identify strategies for shared decision-making and funding to reduce current and future flood risks in a manner that balances equity, economic, and environmental considerations.
Region	6	Develop guidelines for the siting and design of transit-oriented development to reduce seismic and flood risks	Encourage the Metropolitan Transportation Commission to include an annex to its Station Area Planning Manual that contains guidelines for site planning and design techniques that could reduce risk to areas vulnerable to hazards such flooding, shaking, and liquefaction. The annex would be consistent with the overarching purpose of MTC Resolution 3434 Transit-Oriented Development (TOD) policy for regional transit expansion projects, taking into account techniques to ensure the safety of 42,000 new housing units along the region's major transit corridors.
Region	7	Encourage innovative insurance solutions at the state and federal levels, and in partnership with the private sector	Work with partners to encourage state- and federally mandated catastrophe insurance programs, such as the California Earthquake Authority. Better insurance solutions could enhance mitigation efforts by offering incentives such as building permit rebates, lower premiums or deductibles for retrofitted homes, state-level tax incentives, and state and federal grants to fortify homes and business.
Region	8	Advocate for changes to federal and state programs to improve multifamily rebuilding efforts	Partner with state and federal agencies to ensure multifamily housing receives a fair and equitable share of financial and technical assistance during rebuilding and recovery efforts.
Region	9	Decrease reliance on grid-supplied power and increase passive survivability	Lessen household energy demands on the grid through energy efficiency and/or on-site energy generation or storage to promote buildings that will maintain livable conditions in the event of extended loss of power or heating fuel. This can be done through incentives for residential energy efficiency retrofits, weatherization projects, building design standards that promote energy load reductions, and on-site generated electricity or bi-direction energy sources.

Scale	#	Strategy Name	Strategy Summary
Region	10	Host a regional "Smart and Safe" growth design competition	Develop a regionwide design competition to promote innovative approaches to resilient design and new solutions to building compact, mixed-use, equitable development or redevelopment in a safe and smart manner in areas that are susceptible to multiple hazards.
The following strategies can be initiated and implemented at a local level. In many cases, local governments will have more success with these strategies if they coordinate with a regional body such as ABAG and coordinate across local governments; however, these partnerships are not a prerequisite for action.			
Strategy 11 is a prerequisite for strategies 13-21, as it would make them more effective.			
Local	11	Develop locally specific seismic hazard maps	Develop locally specific seismic hazard maps (beyond the regional seismic hazard maps created in this project) to improve mapping resolution and support more informed and nuanced decision-making about development and hazard mitigation, particularly in urban and urbanizing seismically hazardous areas.
The following strategies aim to minimize development in the highest-hazard areas. Strategies 15 and 16 provide specific actions that can be used to meet the goals of strategies 13 and 14. Strategy 12 would be a prerequisite to determine the highest-hazard areas within a jurisdiction.			
Local	12	Increase protection of critical facilities and lifelines in high-hazard areas	Local governments could require critical infrastructure and public-service facilities to be located or relocated outside high-hazard areas, or undertake seismic- and flood-related mitigation and other protective measures to enhance the structural integrity, overall performance, and functionality of facilities that must be located in high-hazard areas. The goal is to ensure the continuity of operations of critical facilities and lifelines essential to helping residents remain in their homes following a disaster and facilitating and expediting community and regional post-disaster recovery.
Local	13	Reduce or prohibit development in the most hazardous areas in PDAs while ensuring equity and beneficial use of these areas	Reduce or prohibit development in high hazard areas, incentivize relocation out of these areas, and reduce or prohibit rebuilding after a disaster. This strategy can preserve open space to use for flood mitigation and recreation on non-developable, high-hazard lands.
Local	14	Establish overlay zoning districts to help facilitate safe and smart new development	Establish overlay zoning districts, such as a Planned Unit Development (PUD) overlay district, to direct new development into less-hazardous areas on a particular site while also establishing special conditions for development in high-hazard areas.

Scale	#	Strategy Name	Strategy Summary
Local	15	Establish a transfer of development rights program to redirect development from high-hazard areas to preferred, low-hazard areas	Amend local development prevent or minimize the vulnerability of new development to codes to establish a transfer of development rights (TDR) program, which could place permanent conservation or hazard mitigation easements on properties in high-hazard areas to seismic and flood hazards.
The following strategies address the retrofit of fragile housing in seismic hazard areas. Strategy 12 is a prerequisite to identify high-hazard areas, and strategy 17 is a prerequisite for strategies 18 and 19. Strategies 18 and 19 are prerequisites for strategy 20, as locally appropriate.			
Local	16	Create a locally specific fragile housing inventory	Create and maintain a database that includes the type and location of fragile housing by building type, housing tenure (owner or renter), and the property's retrofit status. Creating the inventory would include developing and sustaining standardized, transferrable procedures for collecting and managing
Local	17	Develop and implement a soft-story retrofit program	Develop voluntary or mandatory retrofit program(s) to retrofit soft-story housing in areas where it makes up a large percentage of a jurisdiction's or a specific vulnerable community's housing stock. Pair programs with financing tools and incentives. Consider different incentives and financing tools for more vulnerable
Local	18	Develop and implement a cripple wall retrofit program	Develop a program to retrofit cripple wall housing in areas where it makes up a large percentage of a jurisdiction's or a specific vulnerable community's housing stock. Pair programs with financing tools and incentives. Consider different incentives and financing tools for low-income homeowners or
Local	19	Require hazard disclosure for renters	Develop policies that require residential property managers and landlords to disclose hazard risk information to renters in a manner similar to that required when residential properties are sold, as well as information about whether the property is included in a fragile housing inventory.
Local	20	Ensure major upgrades and repairs to existing buildings to account for seismic and flood-related hazards	Develop and adopt special repair and upgrade standards for existing buildings that are not typically part of hazardous building abatement programs and are also potential candidates for conversion to mixed-use or more compact residential use in PDAs. This strategy focuses on reducing the risks posed by existing fragile buildings by preparing for both seismic and flood-related hazards at the time of an upgrade (such as a mixed-use or residential conversion) or major repairs following a disaster.

Scale	#	Strategy Name	Strategy Summary
The following strategies aim to strengthen building standards for new construction in seismic hazard zones. Strategy 12 is a prerequisite to identify high-hazard areas and is especially crucial for strategies 22 and 23. In some cases, these strategies could also apply to major renovations of existing buildings.			
Local	21	Assign a higher seismic importance factor to new large-scale residential buildings	Amend the local building code to enhance structural and nonstructural design requirements for new, large residential buildings by adopting a higher seismic importance factor to improve their seismic performance level.
Local	22	Enhance minimum design requirements for new, small residential building foundations in liquefaction zones	Amend the local building code to require enhanced foundation design requirements for new, small residential development (e.g., single- or two-family dwellings) and for significant modifications to existing small residential development to limit foundation damage from liquefaction.
Local	23	Restrict use of significant structural irregularities in residential buildings	Amend the local building code to restrict the use of structural irregularities in the design of new residential construction, as well as existing residential construction subject to significant modification in areas with high or moderate shaking and liquefaction potential.
Local	24	Enhance minimum requirements for non-structural anchorage and bracing of interior partition walls in residential buildings	Amend the local building code to include enhanced non-structural anchorage and bracing requirements for interior partition walls in existing residential buildings in areas with shaking potential.
Local	25	Develop and adopt guidelines for building utility connections to incorporate earthquake safety features	Amend the local building code to require utility connections to buildings to incorporate safety features to prevent adverse impacts from earthquakes. Develop earthquake safety measures such as adequate displacement allowance for utility connections, if there are no existing guidelines.
The following strategies address flooding hazards and can be used to protect both existing and new housing.			
Local	26	Participate in FEMA's Community Rating System	Participate in FEMA's Community Rating System (CRS), a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements by reducing local flood insurance rates.

Scale	#	Strategy Name	Strategy Summary
Local	27	Reduce flood risk through integrated shoreline and watershed management	Develop a program to work with public and private landowners to decrease the risk of flooding by implementing engineered and nature-based shoreline protection projects in coordination with watershed management projects that reduce and/or store runoff during rainfall events and improve the condition of the flood plain.
Local	28	Increase standards in local flood plain management ordinances beyond the minimum requirements of the NFIP program	Adopt a flood plain management ordinance that exceeds the NFIP's minimum requirements to reduce risk from flood events that exceed the 1 percent annual chance (100-year) flood event. A strong flood plain management ordinance ensures that land use decisions account for current flood risks and consider more extreme events and/or future flood risk associated with sea level rise.
Local	29	Require flood-proof construction methods and techniques within and adjacent to special flood hazard zones	Amend the applicable local codes to require flood-proof construction techniques in structures in special flood hazard zones, high-hazard zones, and adjacent areas. Requiring flood-proofing techniques in these zones could reduce damage to a structure and its contents in the event of a flood. Requiring the same level of flood-proofing in areas adjacent to these zones could reduce damage in areas that flood in the future with sea level rise or flood events that exceed the 1 percent annual chance (100-year) flood conditions.
Local	30	Revise minimum building elevation standards and maximum building height limits for new development	Revise building standards to require habitable building space and sensitive building components to be elevated above current and future flood levels. At the same time, maximum building height limits could be increased to reduce conflicts where these codes are applied together.
Local	31	Incorporate sea level rise guidance into the capital planning process	City and county departments submit projects for incorporation into the local government's capital plan. The capital plan provides clear direction on how the local government's assets will be maintained and improved and identifies and prioritizes projects for funding in the capital plan's multiyear timeframe. The capital planning process can require all projects located within a specific sea level rise inundation zone to adhere to sea level rise vulnerability and risk assessment guidance. Plans can also identify appropriate resilience strategies.

Scale	#	Strategy Name	Strategy Summary
The following strategies provide policy tools that can be used in conjunction with financing mechanisms laid out in Table 4-2 to assist with costs associated with hazard abatement.			
Local	32	Create geologic hazard abatement districts to fund hazard mitigation	Establish Geologic Hazard Abatement Districts (GHADs) as a mechanism for raising funds and defining responsibility for the prevention, mitigation, abatement or control of geologic hazards, including landslides, land subsidence, soil erosion, earthquake, fault movement, or any other natural or unnatural movement of land or earth. Projects funded through these districts can include mitigation or abatement of structural hazards that are partly or wholly caused by geologic hazards and flood control structures.
Local	33	Create Mello-Roos Community Facilities Districts[16] to provide financing to property owners for resilience improvements	Collaborate among local governments and property owners to form a district in which property owners opt to participate. The district would use capital raised by issuing bonds to make resilience improvements, which is paid back through a property tax assessment.
The following strategies are actions jurisdictions can take before a disaster to help keep residents in their homes after a disaster. Many of the previous strategies that are aimed at limiting damage are prerequisites for these strategies.			
Local	34	Create a pre-disaster rebuild and recovery plan	Create a pre-disaster recovery plan that designates when, where, and how rebuilding will occur after a disaster; which areas will be rebuilt according to existing plans and codes and which will be re-planned; whether rebuilt homes will be encouraged or required to be strengthened against future hazard events; and who will be in charge of coordinating and overseeing the recovery process.
Local	35	Revise local plans and development codes to allow temporary land uses to facilitate and expedite post-disaster recovery	Revise local plans and development codes to permit interim or temporary land uses to support critical public facilities to facilitate and expedite recovery after a disaster event.
Local	36	Develop and implement a shelter-in-place program	Develop a comprehensive shelter-in-place program to allow residents to remain in their homes after a disaster. Establish engineering criteria to determine shelter-in-place capacity, develop acceptable habitability standards for sheltering in place, and prepare and adopt regulations that allow the use of these standards in a declared housing emergency period. Implement the program by creating public training materials, coordinating with post-disaster evaluation procedures, and setting up neighborhood support centers.

16. A Mello-Roos Community Facilities District (CFD) is a tax-based district which can generate capital that could be ear-marked for resiliency improvements within the district. Mello-Roos Community Facilities Districts (CFDs) are authorized under Section 26104 of the California Public Resources Code.

Scale	#	Strategy Name	Strategy Summary
Local	37	Improve the resilience of rental units and ensure they are rebuilt after loss or damage due to a natural disaster	Develop policies to ensure that rental units damaged during a natural disaster are replaced in kind (i.e., with a similar number or type) during rebuilding and recovery rather than being converted to owner-occupied properties.
Local	38	Protect housing affordability during recovery	Develop policies that protect affordable homes from being damaged by a natural disaster, mandate that affordable housing that is damaged be rebuilt as affordable housing, ensure funding streams are available for rebuilding damaged affordable housing, and encourage building new affordable housing to ensure that low-income residents can stay in the region.
The following strategies can be implemented most effectively with close coordination with neighborhood nonprofits and community organizations			
Neighborhood	39	Create a community capacity inventory	Develop a community capacity inventory by first defining the elements that should be included (such as critical facilities and community services), then developing and sustaining standardized, transferrable procedures for collecting and managing data. Partnerships with nonprofits such as Code for America could yield an open-source, collaborative format for collecting and sharing this information.
Neighborhood	40	Disseminate best available hazard and climate risk information through community-based organizations and non-traditional partners	Seek opportunities to expand existing, successful community-based programs (e.g., programs on crime, blight, education, or other important community issues) to better communicate hazard and climate risk information to community members.

Potential Financing Mechanisms

The project team identified financing mechanisms to implement the strategies. The financing mechanisms fall into two broad categories:

- Strategies related to planning, programs, and operations can be implemented through existing departments and programs, sometimes at no additional cost, or through new or expanded programs for which a budget must be found. Main funding sources include the general fund; fee-based special purpose funds; or state, federal, or private grants.
- Strategies related to capital expenditures involve capital expenditures that generally require more funding than planning, programmatic, or operational strategies. Depending on the strategy, funding can come from the private sector (e.g., individuals, a development company, or professional or philanthropic organizations), the public sector, or a cooperative effort among public and private actors.

Financing property-specific improvements and neighborhood-level or larger investments in infrastructure can be challenging in California. State legislation and ballot measures have put strict limitations on the ability of the state and local governments to raise capital to implement projects (and to mandate repayment schemes for the borrowing that typically is necessary). These limitations—and crises arising from natural disasters and other events—have driven a lot of innovation in financing mechanisms. The limitations make it difficult to use traditional mechanisms (specifically, raising capital by selling bonds that are paid back through an increase in property or sales taxes). Drawing from existing sales tax or property tax revenues from city and county general funds is generally considered untenable because of the existing fiscal constraints that most California cities face.

Table 4-2 lists examples of financing mechanisms, the agency normally responsible for administering the funds, the source of repayment, and the scale at which the mechanism is typically applied. In addition, the table identifies whether the mechanism requires voter approval for implementation, indicating its political complexity. The last column identifies by number the resilience strategies that might be financed by each mechanism. For detailed descriptions of the financing mechanisms and links to more information, see Appendix D.

Table 4-2: Financing Mechanisms

Name	Administrator	Source of Repayment	Area of Application	Voter Approval Considerations	Examples of adaptation strategies that can be financed by this mechanism (identified by strategy number)
City/County/ State Bond Program	City, County, Regional Agency, or State	General fund, sales tax, or hotel tax Service fees, property tax, tax increments	Citywide, Countywide, or Statewide	General obligation bonds require two-thirds voter approval. Revenue bonds require majority voter approval.	12, 20
Parcel or Sales Tax	City, County, Regional, or State	Parcel tax or sales tax	Citywide, Countywide, Region-wide, or Statewide	Parcel or sales taxes require two-thirds voter approval	None
Tax-based Special Districts	Special District	Ad-valorem property tax	Districtwide	Tax-based special districts need two-thirds voter approval to be able to levy special taxes.	12, 14, 32, 33
Fee-based Special Districts	Special District	Service fees	Districtwide	Fee-based special districts do not need voter approval to issue bonds for capital generation. Similarly, fees charged by special districts do not require voter approval as long as the fees are for a specific benefit, service, or product provided directly to the fee payer.	6, 12
Infrastructure Financing Districts	City or County	Property tax increments within the district	Districtwide	Property tax increments proposed by infrastructure financing districts require both local and countywide approval, where both jurisdictions forego general fund revenue to pay back infrastructure investments.	6, 14
Joint Powers Authorities (also known as Public Financing Authorities)	Joint Powers Authority appointed by City or County	Income from public project projects (e.g. income generated by a Port Authority by leasing space to businesses)	Multi-city, Countywide, Region-wide, District	This mechanism requires multi-jurisdictional buy-in before it can be implemented.	None

Name	Administrator	Source of Repayment	Area of Application	Voter Approval Considerations	Examples of adaptation strategies that can be financed by this mechanism (identified by strategy number)
Municipal Enterprise Funds	City, County, or utility	Users of Infrastructure Services (e.g., water, energy, etc.)	Citywide, Countywide, District	Fees charged by municipal enterprises do not require voter approval as long as the fees are for a specific benefit, service, or product provided directly to the fee payer.	12
Development and Construction Loans	Local or regional banks	Income from investment	Neighborhood wide	None	6, 14, 15, 20, 21, 22, 23, 24, 25, 28, 29, 30
Individual Home Improvement Loans or Commercial Renovation Loans	Local or regional banks, local, regional, state, and federal agencies	Individual or business income	Individual property owner or individual business	None	12, 20, 22, 23, 24, 25, 28, 29
Revolving Loan Fund (RLF) Programs	Local, regional, state, and federal agencies	Income from investment, individual and business income	Citywide, neighborhood wide, individual households and businesses	None	12, 23, 24, 25, 28, 29
Grant Programs	Local, regional state, or federal agencies, philanthropic organizations	None required	Citywide, neighborhood-wide	None	1, 2, 5, 6, 10, 11, 12, 20, 22, 23, 24, 25, 28, 29, 35

5

CONCLUSION

Reducing housing and community vulnerability and building regional resilience in the Bay Area involves strategies at every scale of governance, from the neighborhood to the state level. Recognizing the key role that regional and local governments can play in building resilience and using the strategies developed in this project, ABAG and BCDC have developed a manual to support action at the local level that will help the entire region become more resilient in the face of earthquakes and flooding.[17] The strategies developed in this project are an important addition to planning for future growth in the region, which to date has not included information about hazards or community vulnerability. Furthermore, many of the strategies are relevant not only to future growth, but also existing housing and communities.

17. Association of Bay Area Governments. "Stronger Housing, Safer Communities. Strategies for Seismic and Flood Risks." 2015. http://resilience.abag.ca.gov/projects/stronger_housing_safer_communities_2015/

Local jurisdictions are encouraged to conduct more in-depth local analysis based on this project, for example by considering the methods and outcomes of the regional analysis in their Local Hazard Mitigation planning process. Local jurisdictions can also begin using the strategies based on the initial regional analysis even without local analysis. The region can use the outcomes of this project to incorporate resilience into region-wide policies on planning for future growth through Plan Bay Area and in helping jurisdictions decide where and how to grow. Assistance implementing strategies will be provided to local jurisdictions by ABAG through its Regional Resilience Plan throughout 2015 and 2016.

The suite of strategies developed by this project are not intended as a one-time effort or a complete set of tools. As communities gain more experience with assessing vulnerability and implementing strategies they may have additional insights to offer on potential actions, or recommendations for modifying the strategies recommended here. ABAG's ongoing Resilience Program is one vehicle through which new lessons at the local level can be communicated to a broader audience. EPA and FEMA will continue to work with ABAG and BCDC to understand how these strategies are being implemented and how federal policies and programs can continue to support more resilient communities nationwide.

APPENDIX A

EPA SMART GROWTH IMPLEMENTATION ASSISTANCE

Communities around the country are looking to get the most from new development and to maximize their investments. Frustrated by development that gives residents no choice but to drive long distances between jobs and housing, many communities are bringing workplaces, homes, and services closer together. Communities are examining and changing zoning codes that make it impossible to build neighborhoods with a variety of housing types. They are questioning the fiscal wisdom of neglecting existing infrastructure while expanding new sewers, roads, and services into the fringe. Many places that have been successful in ensuring that development improves their community, economy, and environment have used smart growth principles to do so (see box).

Smart Growth Principles

Based on the experience of communities around the nation, the Smart Growth Network developed a set of ten basic principles:

- Mix land uses.
- Take advantage of compact building design.
- Create a range of housing opportunities and choices.
- Create walkable neighborhoods.
- Foster distinctive, attractive communities with a strong sense of place.
- Preserve open space, farmland, natural beauty, and critical environmental areas.
- Strengthen and direct development towards existing communities.
- Provide a variety of transportation choices.
- Make development decisions predictable, fair, and cost effective.
- Encourage community and stakeholder collaboration in development decisions.

Source: Smart Growth Network. "Why Smart Growth?" (2006) www.smartgrowth.org/why.php.

Smart growth describes development patterns that create attractive, distinctive, and walkable communities that give people of varying age, wealth, and physical ability a range of safe, convenient choices in where they live and how they get around. Growing smart also means that we use our existing resources efficiently and preserve the lands, buildings, and environmental features that shape our neighborhoods, towns, and cities.

However, communities often need additional tools, resources, or information to achieve these goals. In response to this need, the Environmental Protection Agency (EPA) launched the Smart Growth Implementation Assistance (SGIA) program to provide technical assistance—through contractor services—to selected communities.

The goals of this assistance are to improve the overall climate for infill, brownfields redevelopment, and the revitalization of non-brownfield sites—as well as to promote development that meets economic, community, public health, and environmental goals. EPA and its contractor assemble teams whose members have expertise that meets community needs. While engaging community participants on their aspirations for development, the team can bring their experiences from working in other parts of the country to provide best practices for the community to consider.

For more information on the SGIA program, including reports from communities that have received assistance, see www.epa.gov/smartgrowth/sgia.htm.

For more information on the Partnership for Sustainable Communities, see www.sustainablecommunities.gov.

APPENDIX B

BACKGROUND ON BAY AREA EARTHQUAKE AND FLOOD RISKS

Earthquakes in the Bay Area result from accumulation of energy as the Pacific Plate slides past the North American Plate. Previous earthquakes such as the 1906 earthquake caused extensive damage in San Francisco, Oakland, San Jose, and Santa Rosa. More recently, the 1989 Loma Prieta earthquake caused extensive damage near the epicenter in the Santa Cruz Mountains, as well as in Oakland and San Francisco more than 70 miles away. Additionally, 22 moderate to great earthquakes (over magnitude 6.0) have affected the Bay Area; 22 such events have occurred in the last 160 years, for an average of one every seven years. Future large earthquakes are a certainty, and the overall probability of a magnitude 6.7 or greater earthquake in the Greater Bay Area is 63 percent.[18]

18. Field, E., et al. "The Uniform California Earthquake Rupture Forecast Version 2." United States Geological Survey. 2008. http://pubs.usgs.gov/of/2007/1437.

In addition to earthquakes, the Bay Area is also vulnerable to projected impacts of climate change. According to 2014 projections, climate change could cause the Bay to rise by 12 to 24 inches by mid-century and by 36 to 66 inches by the end of the century.[19] This rise means that today's floods will likely be the future's high tides, and areas that currently flood only every 10 to 20 years might flood during high tides, bringing many cascading impacts such as mobilization of contaminants, saltwater intrusion, and increased erosion. These flood-prone areas are home to more than 250,000 residents who could be directly affected. Many others, including workers, could be indirectly affected by reduced access to important services, such as transit and commercial centers, health-care facilities, and schools.

In Plan Bay Area, sea level rise impacts to the Bay Area were examined for informational purposes as part of the plan's Environmental Impact Report (EIR)[20] although not required by the California Environmental Quality Act. A summary of the findings from the report is provided here to indicate how many people both within and outside of areas of future development will be in projected inundation zones (See Table B 1 and Table B 2). The sea level rise impact analysis carried out for the EIR considered the inundation associated with 24 inches of sea level rise at Mean Higher High Water (MHHW, which is defined as the highest "average" daily tidal inundation to which an area could be subjected under future conditions), as presented in the National Oceanic and Atmospheric Administration's (NOAA's) Sea Level Rise and Coastal Flooding Impacts Viewer. This extent of inundation is used as a surrogate for 12 inches of sea level rise at mid-century, coupled with a king tide event, which is the highest high tide currently seen. This scenario was selected because it represents a level of future inundation by bay waters that could be expected to occur multiple times each year even without extreme coastal storm surge events, particularly during the winter, when king tides typically occur. Portions of the PDAs that intersect the inundated areas and the low-lying, hydraulically disconnected areas[21] were identified to estimate the potentially affected population. The total affected population in each of the nine Bay Area counties was also estimated, because while development will be focused within PDAs, development will ultimately occur both within and outside of PDA areas.

A 24-inch rise is just one of the sea level rise scenarios used in this project (see Chapter 2) to identify vulnerable populations and future development. It is included here to provide context, particularly in relation to Plan Bay Area and proposed development in the Bay Area.

19. National Research Council. Sea-Level Rise for the Coast of California, Oregon, and Washington: Past, Present, and Future. 2012. http://www.nap.edu/catalog/13389/sea-level-rise-for-the-coasts-of-california-oregon-and-washington.

20. Plan Bay Area. Plan Bay Area Environmental Impact Report, Section 2.5 Climate Change and Greenhouse Gases. July 2013. http://onebayarea.org/pdf/Draft_EIR_Chapters/2.5_Climate_Change.pdf.

21. Low-lying, hydraulically disconnected areas have ground elevations below the protected future sea level rise water surface elevations, but they are not inundated because they do not have a direct hydraulic connection to the Bay. They are protected from inundation by levees, embankments, or other topographic features. However, these areas are at risk of inundation if an existing structure fails or is not properly maintained.

Table B-1: Total Population within PDA and Mid-century Sea Level Rise Inundation Zone

County	Year 2010	Year 2040	% Increase	Numerical Increase
Alameda	<10	100	1,470%	90
Contra Costa	300	490	65%	190
Marin	120	430	245%	300
Napa	<10	10	630%	10
San Francisco	30	970	2,730%	940
San Mateo	210	710	250%	510
Santa Clara	2,240	9,880	340%	7,630
Solano	1,680	3,240	90%	1,570
Sonoma	<10	20	320%	10
Total	**4,600**	**15,850**	**245%**	**11,250**

Source: Plan Bay Area EIR, 2013[22]

Table B-2: Total Population within County* & Mid-century Sea Level Rise Inundation Zone

County	Year 2010	Year 2040 Proposed Plan	% Increase	Numerical Increase
Alameda	1,450	1,630	10%	180
Contra Costa	750	1,360	80%	610
Marin	11,170	12,380	10%	1,210
Napa	100	120	20%	20
San Francisco	340	1,930	480%	1,600
San Mateo	50,680	56,320	10%	5,640
Santa Clara	11,930	26,820	130%	14,890
Solano	1,790	3,370	90%	1,580
Sonoma	130	170	20%	30
Total	**78,340**	**104,090**	**30%**	**25,750**

* Includes all population within each county that is within the sea level rise inundation zone, including population within and outside of the PDAs.
Source: Plan Bay Area EIR, 2013[23]

22. Plan Bay Area Environmental Impact Report. Chapter 2.5, Table 2.5-13. July 2013. http://onebayarea.org/pdf/Draft_EIR_Chapters/2.5_Climate_Change.pdf.

23. Plan Bay Area Environmental Impact Report. Chapter 2.5, Table 2.5-15. July 2013. http://onebayarea.org/pdf/Draft_EIR_Chapters/2.5_Climate_Change.pdf.

APPENDIX C

FURTHER DETAIL ON THE VULNERABILITY ANALYSIS

Hazards Statements

The vulnerability analysis considered three hazards: ground shaking, liquefaction, and flooding. The project team selected the hazard scenarios (summarized in Table C-1) that are most likely to affect both existing and future communities in the Bay Area.

Table C-1: Description of Hazards Used in the Vulnerability Analysis

Hazard Type	Fragile Housing Type
Ground Shaking	MMI VIII[24] or above, from expected ground shaking from a M7.9 (San Andreas Fault) or M7.0 (Hayward Fault)
Liquefaction	Moderate hazard
	High hazard
Flooding	Current 100-year flood zone
	Future sea level rise of 24 inches
	Future sea level rise of 36 inches
	Future sea level rise of 48 inches

Ground Shaking

The areas that are likely to experience ground shaking hazard levels of MMI VIII or above were determined using future earthquake shaking scenario maps from two earthquake scenarios: a magnitude 7.9 scenario on the San Andreas Fault and a magnitude 7.0 scenario on the Hayward Fault. These scenarios were selected because these faults are the most likely to generate a magnitude 6.7 or greater earthquake in the Bay Area (31 percent probability for the Hayward Fault and 21 percent probability for the San Andreas Fault). These faults are likely produce earthquakes with the most impact on the Bay Area, affecting the largest geographical areas and the most residents, and affecting areas where housing is most concentrated. Previous research[25] indicates that at MMI VIII, the number of homes red-tagged (meaning they are unsafe to reoccupy) jumps significantly.

The analysis includes only homes that are likely to be exposed to MMI VIII and greater ground shaking, as they are the most likely to be significantly damaged, thus displacing residents. While damage will occur at lower levels of ground shaking, it is less likely to force residents from their homes.

Liquefaction

Liquefaction hazard levels were determined based on liquefaction susceptibility[26] combined with MMI using the correlation outlined in Table C-2.[27] This project examined moderate or high liquefaction hazard areas using MMI from the future earthquake shaking scenario maps for San Andreas or Hayward events, as they are the most likely to cause major building damage that displaces residents from their homes.

24. Magnitude (M) and Intensity (MMI) measure different characteristics of earthquakes. Magnitude measures the energy released at the source of the earthquake. Magnitude is determined from measurements on seismographs. Intensity measures the strength of shaking produced by the earthquake at a certain location. Intensity is determined from effects on people, human structures, and the natural environment and is measured using the Modified Mercalli Intensity Scale (MMI).

25. Association of Bay Area Governments. "Shaken Awake! Estimates of Uninhabitable Dwelling Units and Peak Shelter Populations in Future Earthquakes Affecting the San Francisco Bay Region." 1996.

26. USGS Open-File Reports 00-444 and 2006-1037

27. ABAG. "The Real Dirt on Liquefaction, A Guide to the Liquefaction Hazard in Future Earthquakes Affecting the San Francisco Bay Area." 2001

Table C-2: Definition of Liquefaction Hazard

MMI Shaking Intensity	Liquefaction Susceptibility Category		
	Moderate	**High**	**Very High**
VII – Strong			Moderate Hazard
VIII – Very Strong	Moderate Hazard	Moderate Hazard	Moderate Hazard
IX – Violent	High Hazard	High Hazard	High Hazard
X – Very Violent	High Hazard	High Hazard	High Hazard

Flooding

ABAG and BCDC determined that any flooding exposure has the potential to displace residents from their homes, as even low-level flooding can undermine building structures or create unsafe living conditions due to mold or other contamination. The flooding scenarios are based on National Flood Insurance Program (NFIP) rate maps. This analysis included all Special Flood Hazard Areas, as defined by Federal Emergency Management Agency's NFIP, which are subject to inundation by a 1 percent annual chance flood (Zones A, AE, AH, AO, AR, A99, V, and VE) (see Table C-3).[28]

Table C-3: Special Flood Hazard Area Zones[29]

Zone A	No Base Flood Elevations determined
Zone AE	Base Flood Elevations determined
Zone AH	Flood depths of 1 to 3 feet (usually areas of ponding); base flood elevations determined
Zone AO	Flood depths of 1 to 3 feet (usually sheet flow on sloping terrain); average depths determined. For areas of alluvial fan flooding, velocities also determined.
Zone AR	Special Flood Hazard Areas formerly protected from the 1% annual chance flood by a flood control system that was subsequently declassified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1% annual chance or greater flood.
Zone A99	Area to be protected from 1% annual chance flood by a Federal flood protection system under construction; no Base Flood Elevations determined
Zone V	Coastal flood zone with velocity hazard (wave action); no Base Flood Elevations determined.
Zone VE	Coastal flood zone with velocity hazard (wave action); Base Flood Elevations determined

28. The 1 percent annual flood (100-year flood), also known as the base flood, is the flood that has a 1 percent chance of being equaled or exceeded in any given year. The base flood elevation is the water-surface elevation of the 1 percent annual flood.

29. Federal Emergency Management Agency. Flood Zones. https://www.fema.gov/floodplain-management/flood-zones. Accessed February 10, 2015.

Future flooding scenarios are based on three regional inundation maps (assuming a sea level rise of 24, 36, and 48 inches) developed by the National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center.[30] These maps represent different combinations of sea level rise and tide levels, including the daily high tide and a range of extreme tides that could occur during coastal storm surge events. Table C -4 shows the possible combinations. For example, a map showing inundation from 24-inch sea level rise can also represent 12-inch sea level rise and a 1-year extreme tide, 6-inch sea level rise and a 2-year extreme tide, or no sea level rise and a 5-year extreme tide.

Table C-4: Matrix showing combinations of Sea Level Rise and Extreme Tide Level

		Extreme Tide Level						
Sea Level Rise*	**Water Level above daily high tide**	**1-yr**	**2-yr**	**5-yr**	**10-yr**	**25-yr**	**50-yr**	**100-yr**
+0	0	12	18	24	30	36	42	48
+6	6	18	24	30	36	42	48	54
+12	12	24	30	36	42	48	54	60
+18	18	30	36	42	48	54	60	66
+24	24	36	42	48	54	60	66	72
+30	30	42	48	54	60	66	72	78
+36	36	48	54	60	66	72	78	84
+42	42	54	60	66	72	78	84	90
+48	48	60	66	72	78	84	90	96

*All values are in inches above Mean Higher High Water (North American Vertical Daturn 1988).
Source: AECOM, 2014[31]

Table Map Key **Color Code and Map Scenario (inches above MHHW)**

24 **36** **48**

30. NOAA Digital Coast. Sea Level Rise and Coastal Flooding Impacts Viewer. http://coast.noaa.gov/digitalcoast/tools/slr. Accessed February 10, 2015.

31. AECOM. Adapting to Rising Tides Alameda County Shoreline Vulnerability Assessment Report, Draft May 2014.

Mapping and Analysis

The vulnerability mapping and analysis are summarized in Table C-5. Figures C-1, C-2, and C-3 show the results of the community vulnerability analysis in three communities: Oakland, Richmond, and San Jose.

Mapping housing and community indicators at a block group level presented some issues of concern as well as some potentially misleading information. For example, block groups with fewer people but a large area that were flagged with indicators made it appear as though vulnerable populations lived in areas that were, in reality, largely open space (for example, the Presidio in San Francisco or Point Reyes in Marin County). Many working group members were concerned that this could be confusing and misleading and lead people to think there were vulnerabilities in locations that are actually safe.

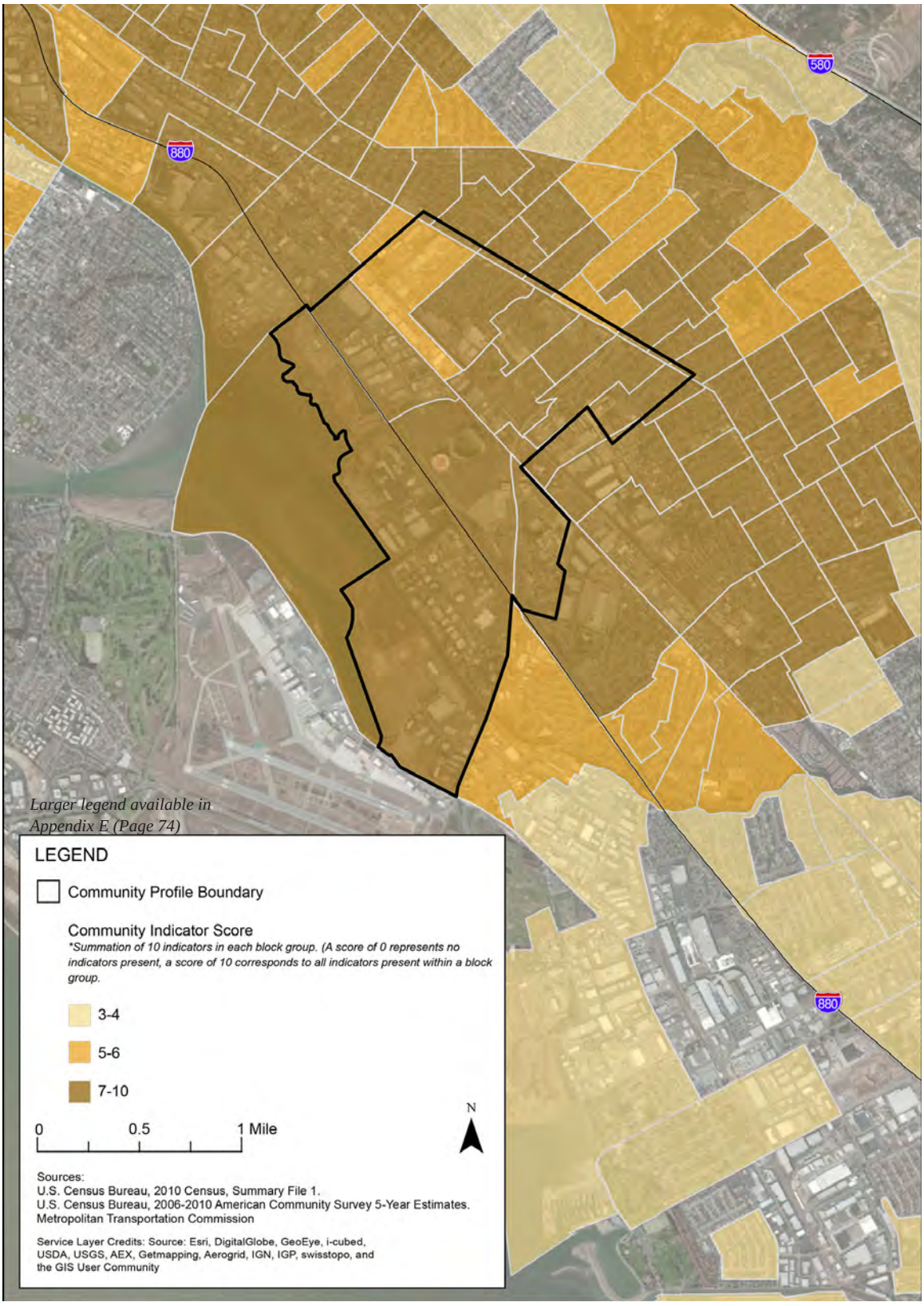
In response, staff developed a masking layer to exclude certain unpopulated or lightly populated areas. The mask layer includes blocks with no households, airports, conservation easements, state-protected areas, large landmark areas, and areas with no hazards.

Table C-5: Description of Vulnerability Maps

Hazard(s)			=	**Hazard(s)**	Areas potentially exposed to ground shaking, liquefaction, and current and future flooding
Hazard(s)	+	Community Vulnerability	=	**Communities At Risk**	Communities exposed to hazards that are less able to prepare, respond, and recover
Hazard(s)	+	Vulnerable Housing	=	**Fragile Housing**	Housing that will likely be damaged if exposed to a hazard
Community At Risk	+	Fragile Housing	=	**Communities At Risk**	Communities that are less able to prepare, respond, and recover and that are potentially living in fragile housing

Figure C-1: Community Vulnerability Analysis Results for Oakland

BAY AREA HOUSING AND COMMUNITY MULTIPLE HAZARD RISK ASSESSMENT



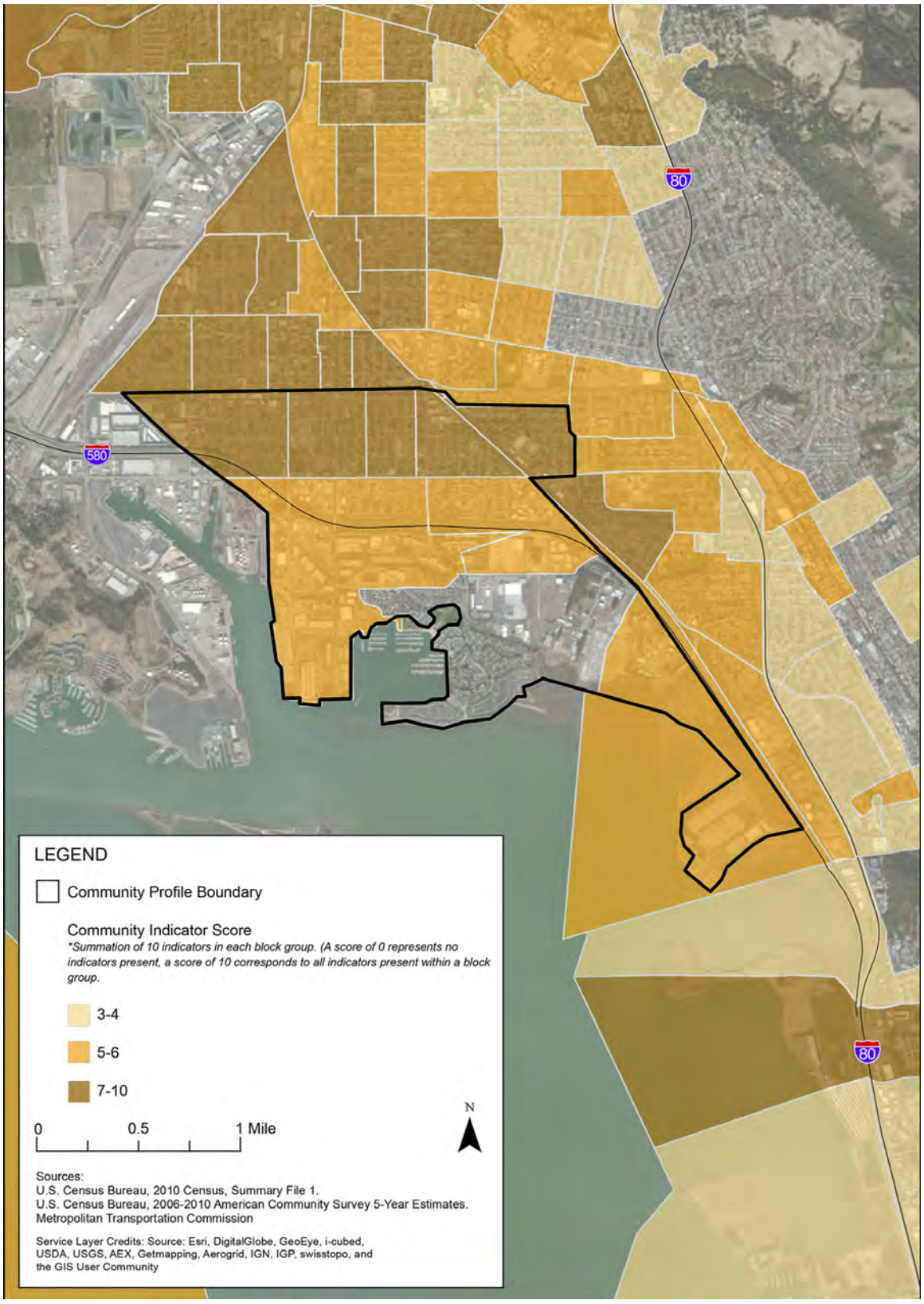
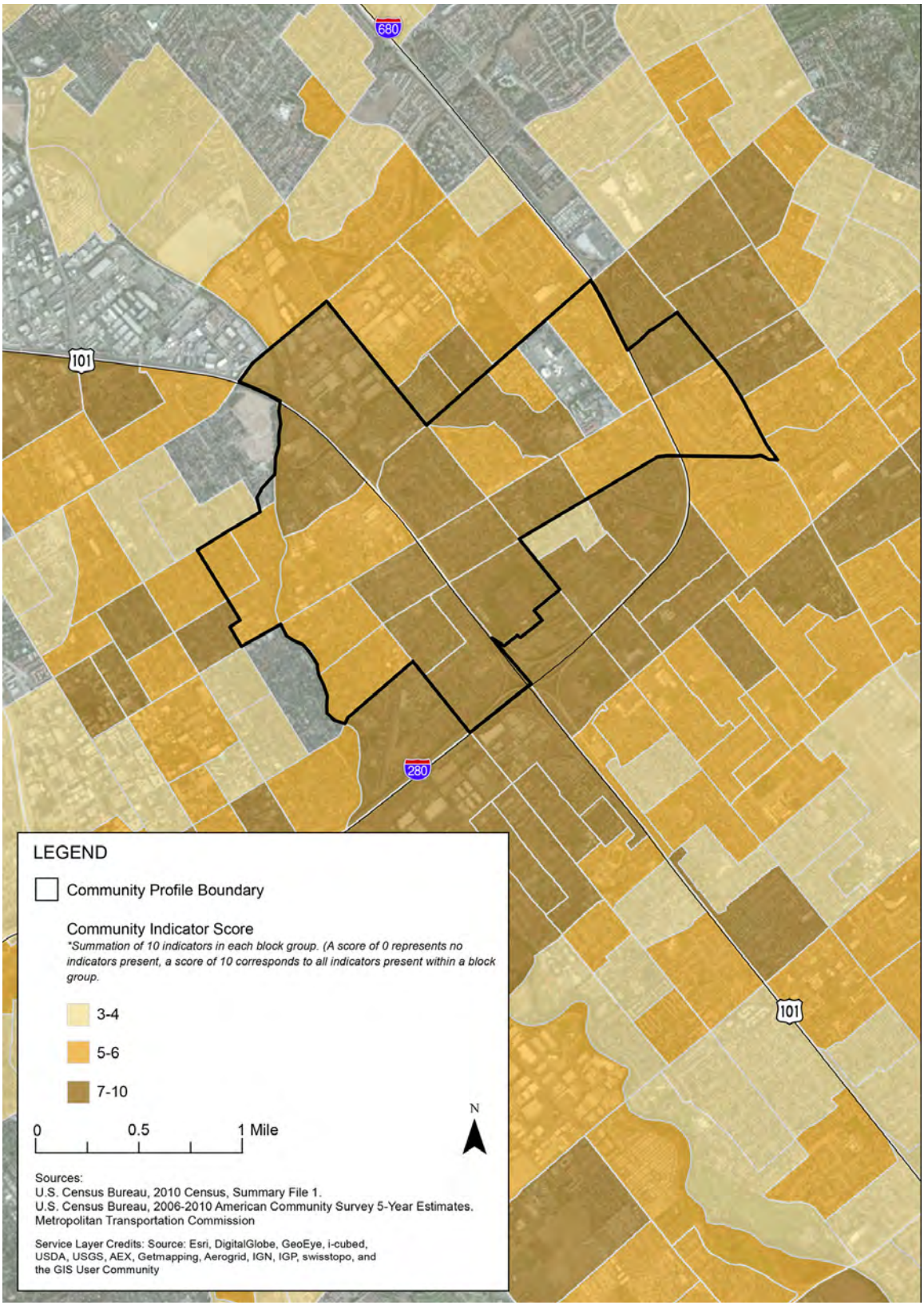

80
580
80
LEGEND
Community Profile Boundary
Community Indicator Score
*Summation of 10 indicators in each block group. (A score of 0 represents no indicators present, a score of 10 corresponds to all indicators present within a block group.
3-4
5-6
7-10
0
0.5
1 Mile
N
Sources:
U.S. Census Bureau, 2010 Census, Summary File 1.
U.S. Census Bureau, 2006-2010 American Community Survey 5-Year Estimates.
Metropolitan Transportation Commission
Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, i-cubed, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure C-3: Community Vulnerability Analysis Results for San Jose

BAY AREA HOUSING AND COMMUNITY MULTIPLE HAZARD RISK ASSESSMENT



Caveats and Uncertainties

The hazards selected for the vulnerability analysis have been simplified and do not represent the full spectrum of hazards and potentially catastrophic risks in the Bay Area. The analysis was designed to understand the greatest concentrations of vulnerability on a regional scale, but more detailed analysis could be conducted at a local level considering more site-specific hazards. In the case of ground shaking, while the faults selected represent the majority of risk in the Bay Area, several other faults could cause ground shaking at levels that could significantly affect housing. Additionally, jurisdictions might have more detailed soil analyses that offer a better understanding of liquefaction risk or have records of past liquefaction patterns. In the case of flooding, jurisdictions might choose to include additional flooding hazard areas based on their on-the-ground knowledge of the existence and condition of flood control structures or inland flooding risks.

Jurisdictions could also choose to include other hazards not included in this analysis, such as dam inundation, wildfire, or secondary hazards such as earthquake-induced landslide or a fire following earthquake. Additional and more detailed vulnerability analyses can be incorporated at the local level through the Hazard Mitigation Planning process or other local planning and hazard review processes. In addition, it is assumed that the effects of liquefaction could be exacerbated under future sea level rise due to the already high groundwater table rising in line with the sea level. Increased liquefaction potential would be expected in cases where shoreline assets rest on or contain potentially liquefiable materials that, with sea level rise, would become more saturated or would be introduced to groundwater and saturation. The result of increased liquefaction potential would be reduced stability, with loss of material strength in the susceptible materials due to seismic shaking.[32]

The analysis focused mainly on housing and its residents. Many other factors besides the physical integrity of a house influence a resident's ability to stay in a home following a disaster, including impacts to infrastructure and availability of utilities; jobs; and resources that fulfill daily needs, such as grocery stores, hardware stores, and medical and childcare facilities. While these factors are extremely important, they are only touched upon briefly in this project in order to keep the scope of the project focused on the core factors that allow a resident to stay in their home following a disaster.[33]

Indicator Development

ABAG and BCDC developed measureable vulnerability indicators for the Bay Area, including indicators of housing vulnerability and community vulnerability. First, ABAG and BCDC staff conducted an extensive literature review to document existing indicators and assess their usefulness. Staff then engaged topic experts and regional and local stakeholders in a Housing Indicator Working Group and a Community Indicator Working Group. ABAG and BCDC staff led three to four working group meetings to discuss the development and application of the indicators. The two working groups helped create a set of guidelines for selecting indicators. These guidelines stated that indicators should:

- **Be numerically measurable.** The data must be quantified in some way that indicates relative severity or concentration in a given area as compared to another given area. U.S.

32. MTC, BCDC, Caltrans, AECOM, 2010. Adapting to Rising Tides: Transportation Vulnerability and Risk Assessment Pilot Project. http://www.mtc.ca.gov/planning/climate/RisingTides-TechnicalReport.pdf.

33. For more information on infrastructure and utility resilience, please see: http://resilience.abag.ca.gov/projects/transportation_utilities_2014/

Census Block Groups[34] were a primary level of analysis for determining concentrations and severity.

- **Be based on data that are accessible and available.** Many highly desirable indicators could provide insight, but if data supporting them are not available, they are not useful. It is useful, however, to make note of desirable data that are not currently available. Accessible and available information is defined as:
  - > Regionally, publicly available: The data are consistently available for all (or most parts) of the Bay Area, and they are not proprietary or private data. Others can replicate the analysis without special privileges.
  - > Geo-referenced: The data must have an assigned geographic location so they can be mapped. The analysis is a spatial analysis; therefore, spatial data must be available.
  - > Reasonable scale: The data must be manageable in scale; too much detail can confuse the main purpose of the indicators, and too little detail could make the data lose meaning.
  - > High quality: The data are consistent and reliable, the margin of error is acceptable, and the format is clear and usable. The data are accurate, and data sets are largely complete (though some projection is acceptable).
- **Be representative of efficient, comprehensive coverage of vulnerability.** Overlaps or highly correlated indices should be minimized to capture the most comprehensive measures of vulnerability with the fewest number of indicators.
- **Directly affect vulnerability.** The indicator directly affects one of three primary factors of vulnerability: exposure, sensitivity, or adaptive capacity.[35] The indicator can either directly increase or decrease vulnerability.
- **Be clear as to how and why the indicator affects vulnerability and at what scale (i.e., individual, community, access, or organizational/institutional).[36]** Unclear correlations between the indicator and its impact on vulnerability are not useful or defensible.
- **Be able to guide strategy development and lead to effective policy.** Each indicator of vulnerability should correlate to a feasible action that can affect that indicator and reduce the vulnerability it represents.
- **Represent the highest priorities for vulnerability reduction.** Indicators should target the most significant characteristics that have the greatest potential to improve resilience.

Housing Vulnerability

Regional housing vulnerability was determined based on the eight potentially fragile building types commonly found in the Bay Area, as defined in Table C-6. The presence of vulnerable housing is indicated if 30 percent or more of housing units in a U.S. Census block group are a fragile building type located in a potential ground shaking, liquefaction, or flood hazard zone.

34. U.S. Census Block Groups are statistical divisions of census tracts, defined to contain between 600 and 3,000 people, used to present data and control block numbering.

35. San Francisco Bay Conservation and Development Commission. "Assessing Climate Change Vulnerability & Risk." Adapting to Rising Tides. December 2011. http://www.adaptingtorisingtides.org/wp-content/uploads/2012/05/Bintliff-Assessing-Vulnerability-Risk-FINAL-20120118.pdf.

36. Dwyer, A., et al. "Quantifying Social Vulnerability: A methodology for identifying those at risk to natural hazards." Geoscience Australia. 2014.

Table C-6: Definition of Fragile Housing Type Correlated with Hazard Type

Hazard Type	Fragile Housing Type
Ground Shaking MMI XIII or above	Hillside
	Single-family cripple wall[37]
	Single-family house over garage
	Unreinforced masonry
	Multifamily cripple wall
	Multifamily weak story or open front
	Multifamily non-ductile concrete[38]
Moderate Liquefaction Hazard	Insufficient foundation to withstand liquefaction, e.g., less than 10 floors
High Liquefaction Hazard	
Current flood zone	All housing types
Future flooding with sea level rise (24, 36, and 48 inches)	

ABAG and BCDC staff reviewed several Bay Area-focused reports and worked with the Housing Indicator Working Group to identify eight fragile housing types (Table C-6) in the region. Because there is no comprehensive dataset on residential construction types for the whole Bay Area, these eight housing types were selected based on some known structural characteristics common throughout the Bay Area that increase their vulnerability. The resulting fragile building typology identified subsets of the residential building stock that were likely to have a critical combination of these vulnerability characteristics. As key data such as structure type (e.g., wood frame, concrete) were not widely available, proxies such as size and location that are associated with the most common fragile housing types were used. Liquefaction, ground shaking, and flooding were examined separately because they have different impacts on different building types. The working group developed Error! Reference source not found. to identify the characteristics of the eight fragile housing types.

37. A cripple wall usually occurs between the first floor and the foundation and is less than full story height. It is generally the weakest part of older buildings.

38. Non-ductile concrete buildings were largely constructed between the 1930s and 1970s, before upgraded seismic safety codes in the mid 1970s requiring new concrete buildings to be better constructed.

Table C-7: Characteristics Used to Identify Fragile Housing Types in the Bay Area

Hazard	Hazard Level	Location	Units[3]	Stories[3]	Ages[3,4]	Conclusion	Notes
Ground Shaking	MMI VIII[2] or above	Hillside	N/A	N/A	N/A	Possible landslide hazard	Hillside homes might also have structural damage due to ground shaking
		Not hillside	1-2 unit	N/A	Built before 1940	Possible cripple wall	Bedroom communities, rare in city centers and dense suburbs[1] Older, more established regions (e.g., San Francisco and Alameda counties)[2]
				2-3 stories	Built between 1920 and 1970	Possible house over garage	Dense pre-1950s suburbs (e.g., San Francisco) Post 1950s suburbs with attached multicar garages1 Highly prevalent in more recently urbanized areas (e.g., Santa Clara and Contra Costa counties)[2]
			Multi-unit	3-5 stories	Built before 1920	Possible cripple wall	Pre-1920's neighborhoods[1]
					Built before 1933	Possible unreinforced masonry	1% of total regional housing stock, most significant in San Francisco and Alameda counties[2]
					Built before mid-1970s	Possible weak story or open front	Pre-1950: mixed or high-density suburban neighborhoods (e.g., Berkeley, San Francisco) Post-1950: also found in large subdivision developments (e.g., Fremont, Hayward) 1 Pre-1940: Significant in older cities – over 10% in San Francisco Post-1940: Fairly prevalent, especially in San Mateo County[2]

Hazard	Hazard Level	Location	Units[3]	Stories[3]	Ages[3,4]	Conclusion	Notes
				3 stories or above	Built between 1950 and 1971	Possible non-ductile concrete	High-density suburban neighborhoods[1]
Liquefaction	Moderate or High Hazard	N/A	N/A	Less than 10	N/A	Possible catastrophic foundation damage	Structural irregularities might also influence performance of buildings in liquefaction areas. New construction could follow new guidelines to limit these irregularities; more research is needed
Flooding	24", 36", or 48" flooding or FEMA 100-year flood plain	N/A	All	All	All	Possible loss of habitability after flooding	All housing types are susceptible to damage. Mobile homes could be more susceptible to significant damage; however, mobile home data are difficult to find at a regional level. Wave action could also influence damage.

[1] David Bonowitz, Structural Engineer, Working Group Member notes, January 14, 2014.

[2] ABAG "Shaken Awake! Estimates of Uninhabitable Dwelling Units and Peak Shelter Populations in Future Earthquakes Affecting the San Francisco Bay Region." 1996.

[3] County Assessor Data

[4] American Community Survey, 2013

Each fragile housing type was mapped to identify U.S. Census block groups with the combinations of vulnerability characteristics associated with each fragile housing type. Only block groups exposed to the identified hazard level for ground shaking, liquefaction, and flooding are flagged. Block groups are identified as potentially vulnerable if 30 percent or more of the housing units are considered fragile. While isolated building damage or low levels of building damage are potentially devastating to individual residents, concentrations of damage are far more likely to stall recovery and affect entire communities. However, this methodology does not account for mixed neighborhoods that might contain several fragile housing types, none of which individually reach the 30 percent concentration, but combined might make up 30 percent or more of the housing stock. This finer-grained analysis could be done at a local scale with more refined data about residential buildings.

Community Vulnerability

ABAG and BCDC measured and scored indicators using a method developed by the Metropolitan Transportation Commission (MTC) to identify Communities of Concern (CoC).[39] In this method, U.S. Census block groups received a score of 1 point for each indicator that is greater than a certain percentage of the block group population (as defined by the MTC CoC). The percentage can vary by indicator. For example, block groups with more than 10 percent of individuals over 75 years would receive a score of 1. For indicators that were not identified in the MTC CoC and therefore did not have a pre-identified percentage, block groups received a score of 1 point for each indicator that is greater than the mean for that block group plus one standard deviation (this is consistent with the method used by the MTC CoC process). In both cases, this is meant to identify block groups with higher-than-average concentrations of the particular indicator, meaning they might have higher concentrations of vulnerable residents. The total possible score each block group could receive ranged from 0 to 10 (see Table C-8). The criteria established for this project were based on previous studies and prior research and are for planning purposes only. These thresholds and criteria should not be used in project review or environmental assessment.

Table C-8: Indicators of Community Vulnerability

Indicator	Measure	Percentage or Amount per U.S. Census Block Group	Score
Housing cost burden	% household monthly housing >50% of gross monthly income	>15%	1
Transportation cost burden	% household monthly transportation costs >5% of gross monthly income	>15%	1
Home ownership	% not owner occupied housing	Mean + 1 standard deviation	1
Household income	% households with income less than <50% AMI	>30%	1
Education	% persons without a high school diploma > 18 years	Mean + 1 standard deviation	1
Racial/Cultural Composition	% non-white	>70%	1
Transit dependence	% households without a vehicle	>10%	1
Non-English speakers	% households where no one ≥ 15 speaks English well	>20%	1
Age – Young children	% children < 5 years	Mean + 1 standard deviation	1
Age – Elderly	% elderly, > 75 years	>10%	1
		Total Possible Score	10

39. MTC defines communities of concern relating to minority residents (70 percent of community being considered), low-income residents (90 percent), residents who do not speak English well or at all (30 percent), households with no car, seniors aged 75 years or more, persons with a disability, single-parent households, and cost-burdened renters.

Each indicator was mapped at the block group level, and indicators in each block group were added for a total score. Scores were grouped into three bins: three to four indicators, five to six indicators, and seven to ten indicators. Block groups with fewer than three indicators were determined to have minimal vulnerabilities, while block groups with seven or more indicators have the highest vulnerability level.

Risk Statements

As part of the vulnerability assessment process, and in addition to the vulnerability maps, ABAG and BCDC developed risk statements to inform the strategy development process. These risk statements were:

Ground shaking can damage cripple wall and house-over-garage single-family homes. Many established residential neighborhoods have single-family homes that could be significantly damaged during an earthquake, including homes with short, unreinforced walls that raise the first floor 1 to 5 feet above ground level (i.e., cripple walls) and those that are two or more stories with garages or other large openings on the first floor. Renters and owners of single-family homes that are not retrofitted, and people who do not have hazard insurance, could be displaced from their existing neighborhood and could have a difficult time rebuilding or finding a replacement home. Some residents might also struggle to find housing that is affordable and near the jobs, schools, medical facilities, and other services on which they rely.

Ground shaking can damage weak-story, concrete, and cripple wall multifamily housing. Several multifamily housing types can collapse if not properly retrofitted, including those with parking or retail on the ground floor (i.e., weak story or open front), ones built from concrete that is not properly reinforced (i.e., non-ductile), or ones that have short, unreinforced walls that raise the first floor 1 to 5 feet above ground level (i.e., cripple walls). Depending on the number of units, damage to multifamily housing could displace many residents. In addition, multifamily housing does not always receive a large share of state or federal financial and technical assistance during recovery efforts and therefore might not always be rebuilt in a timely manner.

Housing is generally built to life-safety standards rather than shelter-in-place standards. Newly constructed housing built to life-safety standards can still be damaged during an earthquake. For example, modern building codes generally do not address liquefaction risk since it is not a life-safety consideration. As a result, some residents will not be able to shelter in place or remain in their homes, and they might need to undertake extensive repairs or rebuilding.

Most foundations cannot withstand liquefaction. Homes located where soils are susceptible to liquefaction (e.g., along the bay shoreline or on fill) could experience significant enough damage during an earthquake to become uninhabitable. Most single- and multifamily homes under 10 stories are unlikely to have foundations stable enough to withstand liquefaction even if they can withstand ground shaking.

Most houses cannot withstand any amount of flooding. If exposed to flooding, most housing built in the Bay Area will be damaged, as current construction materials, siting, and design standards do not consider potential exposure to either water or salt. As sea level rises, housing of all types in FEMA-identified Special Flood Hazard Areas will be at greater risk of flooding, and housing in low-lying areas not currently at risk might begin to experience flooding.

Houses with habitable space or critical equipment below grade are at risk from flooding. Homes with habitable living space or critical building equipment below grade are likely to be significantly damaged by flooding. Neighborhoods with existing drainage problems (e.g., Bay Area homes that experience street or basement flooding during current rainfall events or when groundwater levels are high) will be at even greater risk as the bay rises.

Many community members have limited resources. Many Bay Area residents that live in areas at risk from natural disasters are resource-constrained, including households that are low- and very low-income, households of all income levels that are housing and transportation cost burdened, and transit-dependent households that do not own a car. Resource-limited households are less able to prepare for natural disasters and, if displaced from damaged homes.

Housing affordability is an existing challenge that could hinder recovery. Housing affordability for both renters and owners is an existing challenge in the Bay Area that could compound the number of residents displaced by a natural disaster. Much of the region is already cost-burdened with regard to housing, spending 30 percent or more of their income on housing. For others, the amount spent on housing is fairly stable, either through rent-control policies or because they own their homes and their property tax burden is relatively stable. Loss or damage of housing that results in increased costs to either renters or homeowners will likely increase the number of permanently displaced Bay Area residents as finding housing that is affordable and near jobs, schools, medical facilities, and other services on which they rely will be challenging.

Renters have limited ability to improve their housing resilience. Many Bay Area residents who live in areas at risk from natural disasters are renters. Renters have a limited ability to improve the housing in which they live and often do not have hazard insurance to protect themselves and their belongings in case of a disaster. Communities with a large number of renters, and in particular resource-limited renters, will likely need to assist these residents both during a disaster (e.g., with shelter-in-place facilities) and after the disaster, by identifying interim, affordable housing to keep renters from being permanently displaced from the community because their homes were damaged.

Many community members have limited or inadequate information about hazards. Access to timely, correct, and meaningful information both before and after a natural disaster can be challenging in all communities, particularly ones that are ethnically and culturally diverse and where many households do not speak English as their primary language. Additionally, in the Bay Area, many of these same community members are resource-constrained renters who are often living in overcrowded housing. Damage to housing during a natural disaster can lead to a significant amount of displacement and a struggle to find housing that is affordable and near enough to jobs, schools, medical facilities, and other services.

Information on elderly and very young community members is limited. Up-to-date and easily accessible information about the number of elderly and very young people living in a community can be challenging to find, particularly during a disaster when it is most needed. It can be difficult to evacuate these community members, especially if they need specialized equipment or supervision, and shelter-in-place facilities need to be prepared to both house them safely and maintain communication with concerned family members.

APPENDIX D

DETAILED DESCRIPTIONS AND REFERENCE MATERIAL FOR FINANCING MECHANISMS

This appendix provides detailed descriptions and reference materials for the financing strategies in Table 4-2 of Chapter 4. These financing strategies are most applicable in the State of California.

Detailed Descriptions and Reference Material for Financing Mechanisms

City, County, or State Bond Program: Bond programs are a framework under which cities or counties have the authority to issue bonds along with a list of the specific public purposes for which the funds can be used. General obligation bonds are backed by general funds, which consist of various sources such as property taxes. Revenue bonds are backed by revenues guaranteed by the issuing entity, usually through the provision of a specific service (e.g., wastewater treatment or energy supply). In rare cases, revenue bonds can be backed by sales taxes, fuel taxes, or hotel occupancy taxes. More information on the bond issuance process can be found here:

MSRB. Issuing Municipal Securities. http://www.msrb.org/EducationCenter/Issuers/Issuing.aspx

Parcel or Sales Tax: Voter-approved parcel or sales taxes are a form of revenue where investments are made over time. They are slightly different from a revenue bond program in that investments are made incrementally rather than by generating an upfront pool of capital. The following resource provides an overview of voter approval requirements for local taxes:

Legislative Analyst Office. "A Look at Voter-Approval Requirement for Local Taxes. 2014. http://www.lao.ca.gov/reports/2014/finance/local-taxes/voter-approval-032014.pdf

Tax-based and Fee-based Special Districts: Special districts are defined by state law as agencies of the state that provide governmental or proprietary functions within limited boundaries. Special districts are unique governmental entities, governed by a board, that deliver specific public services to a geographically limited area. The seed financing for special districts can come from either general obligation bonds or revenue bonds issued by the special district. The bonds can be paid back by exercising special taxes on taxpayers within the special district. Alternatively, bonds can also be paid back by user fees or service charges levied by the special district if the district runs enterprise activities or delivers specific services. Special districts that generate revenue by exercising special taxes are defined in this report as tax-based special districts. Special districts that generate revenue by levying user fees or service charges are defined here as fee-based special districts. The following resources provide more background information on special districts:

California Special Districts Association. Special Districts. http://www.csda.net/special-districts/

California Special Districts Association. "CSDA Guide to Special District Laws and Codes." 2007. http://www.csda.net/wp-content/uploads/2014/01/SD_LawsCodes.pdf

Senate Local Government Committee. "What's So Special About Special Districts: A citizen's guide to special districts in California." 2010. http://www.csda.net/wp-content/uploads/2013/04/WhatsSoSpecial_2010.pdf

Mello-Roos Community Financing Districts are also a special district and was one of the strategies developed for this project. To read more about the strategy, please see: Association of Bay Area Governments. "Stronger Housing, Safer Communities: Strategies for Seismic & Flood Risks." 2015. http://resilience.abag.ca.gov/projects/stronger_housing_safer_communities_2015/

Infrastructure Financing Districts: Infrastructure financing districts are a type of special district that can be created to finance a project or portion of a project located in a redevelopment project area or former redevelopment project area. Infrastructure financing district law now provides a mechanism to finance projects that would previously have been financed by redevelopment agencies before they were eliminated. Local agencies can now form an infrastructure financing district over a redevelopment project area to finance redevelopment projects that were not completed before the dissolution of

redevelopment agencies. The seed financing for these districts comes from infrastructure bonds that are eventually paid back by increments in property taxes. These infrastructure districts are different from tax-based special districts in that they require approval by both city and county ruling agencies (i.e., a city council and board of supervisors) to divert general fund proceeds back to the specific district. The following resource provides more information on infrastructure financing districts:

California Legislative Information. Senate Bill S-33 on Infrastructure Financing Districts. http://www.leginfo.ca.gov/pub/13-14/bill/sen/sb_0001-0050/sb_33_cfa_20130307_114113_sen_comm.html

Joint Powers Authorities: Joint Powers Authorities or Public Financing Authorities are legal entities formed by representatives of multiple public agencies to fund a public project capable of generating income, establish a common approach to work on a common problem, or act as a representative body for a specific activity. The seed financing for these entities comes from revenue bonds that are paid back by the revenue generated by projects financed by the public funding authority. The following resource provides more information on Joint Powers Authorities:

Senate Local Government Committee. "Governments Working Together: A Citizen's Guide to Joint Powers Agreements." 2007 http://senweb03.senate.ca.gov/committee/standing/GOVERNANCE/GWTFinalversion2.pdf

Municipal Enterprise Funds: Municipal enterprise funds are generated by a local government through user fees charged for services provided by the local government. Municipal enterprise funds can establish an accounting mechanism that sets aside generated revenues separately with their own financial statements, rather than pooling them with the revenues and expenses of other government activities. Enterprise funds can allow a city to generate revenue through user fees to cover the costs of providing a service to the public and allow those who use the service to pay for it directly. The following resource provides more information on

Municipal Enterprise Funds: Government Information Division, Office of the State Auditor, State of Minnesota. "Special Study: Municipal Enterprise Activities." 2004. http://www.osa.state.mn.us/reports/gid/2004/enterprise/enterprise_04_overview.pdf

Development and Construction Loans: Development loans are an advance of funds, secured by a mortgage, to finance making, installing, or constructing the improvements necessary to convert raw land into construction-ready building sites. In other words, a development loan takes an unimproved parcel and breaks it into several smaller, improved parcels upon which homes or commercial buildings will be constructed. Construction loans are an advance of funds to finance the construction of various types of real estate, such as multifamily homes, hotels, retail, office space, and industrial buildings. The following is an example of a construction loan product: LISC. "Lending Product: Construction." http://www.lisc.org/docs/brochures/financial/construction.pdf

Individual Home Improvement Loans or Commercial Renovation Loans: Home improvement loans and commercial renovation loans allow individual home owners and businesses to finance renovations, retrofits, modernization, and remodeling. The following resources provide more details on these types of loans: Home improvement loans: Hartman, D. and Demand Media. "Home Guides. What is Required for a Home Improvement Loan?" SFGate. http://homeguides.sfgate.com/required-home-improvement-loan-9417.html

Home improvement loan program example: Sonoma County Community Development Commission. Housing Rehabilitation. http://www.sonoma-county.org/cdc/cdrehab.htm

Commercial renovation loan program: U.S. Small Business Administration. U.S. Small Business Administration Loan Funds Available to

Purchase Commercial Real Estate." http://www.sba.gov/content/u-s-small-business-administration-loan-funds-available-purchase-commercial-real-estate

Revolving Loan Funds: A revolving loan fund offers capital for projects that can provide a return on investment. The interest and principal payment on the loaned capital is then used to finance similar projects, thus creating a self-replenishing pool of capital for similarly themed projects. Revolving loan funds provide below-market-rate financing for projects such as building or repairing sewage systems, drainage systems, buildings, or parks. Development revolving loan funds are typically intended to augment, not replace, private borrowing for development purposes. The following resource provides more information on revolving loan funds: Council of Development Finance Agencies. CDFA Spotlight: Revolving Loan Funds (RLFs). http://www.cdfa.net/cdfa/cdfaweb.nsf/ordredirect.html?open&id=rlffactsheet.html

Grant Programs: Grant programs are financial awards are given by federal, state, or local governments or philanthropic organizations for projects that serve a specific public purpose. Grants are typically not expected to be repaid by recipients.

- State Grants
  - > The California Disaster Recovery Initiative Program assists counties and cities with physical and economic recovery from federally declared disasters. See Calfornia Department of Housing and Community Development. State of California Disaster Recovery Initiative Program. http://www.hcd.ca.gov/fa/dri.html.
  - > The California Hazard Mitigation Grant Program provides grants to state and local governments to implement long-term hazard mitigation measures after a major disaster declaration. See California Emergency Management Agency. Hazard Mitigation Grant Program (HMGP). http://hazardmitigation.calema.ca.gov/grant_programs/hazard_mitigation_grant_program_hmgp.
  - > California Strategic Growth Council grants include the Sustainable Communities Planning Grant and Incentives Program, which funds plans that lead to reductions in greenhouse gas emissions; the Urban Greening Planning Program, which assists entities with developing a master urban greening plan; and the Affordable Housing and Sustainable Communities Program, which funds land use, housing, transportation, and land preservation projects to support infill development. See California Strategic Growth Council. http://sgc.ca.gov.
  - > The Strong-Motion Instrumentation and Seismic Hazards Mapping Fund supports seismic hazard mapping. See California Department of Finance. State of California Manual of State Funds. http://www.dof.ca.gov/accounting/manual_of_state_funds/index/documents/0338.pdf
- Federal Grants
  - > FEMA offers a range of grants including those for preparedness (non-disaster), hazard mitigation, and disaster assistance. See Federal Emergency Management Agency. Grants. http://www.fema.gov/grants.
  - > The U.S. Department of Housing and Urban Development's Community Development Block Grant program provides communities with resources to address a wide range of community development needs. See U.S. Department of Housing and Urban Development. Community Development Block Grant Program- CDBG. http://portal.hud.gov/hudportal/HUD?src=/program_offices/comm_planning/communitydevelopment/programs.
  - > Economic Development Administration grants include the Economic Development Assistance Program, which supports construction, technical assistance, and revolving loan fund projects to implement economic development strategies in distressed communities. See U.S. Economic Development Agency. Latest EDA Grants. http://www.eda.gov/grants.

APPENDIX E

BUILDING IN EARTHQUAKE AND FLOOD ZONES

This appendix describes detailed information about existing California and federal regulations and standards for new development in areas with earthquake and flood risks.

Building in Earthquake Zones

Where to build (or not build)

The 1990 Seismic Hazard Mapping Act requires the State Geologist and California Geological Survey (CGS) to prepare maps of seismic hazard zones, identifying the areas that are susceptible to strong ground shaking, earthquake-induced landslides, liquefaction, or other ground failures. CGS also prepares maps of active faulting as defined by the Alquist-Priolo Earthquake Fault Zoning Act.

In the Bay Area, CGS has prepared state seismic hazard zone maps for faulting, liquefaction, and earthquake-induced landslide hazards in San Francisco and parts of Alameda, Santa Clara, and San Mateo counties. CGS is collecting geotechnical reports and landslide inventories in San Mateo and Contra Costa counties and plans to release updated liquefaction and earthquake-induced landslide hazard maps for these counties in mid-2015.

How to build

In California, the design and construction of buildings must use the California Building Code, with the majority of structures designed for life-safety performance of both the structural and non-structural elements. In general, new buildings that adhere to the California Building Code should exhibit acceptable seismic performance, but some might experience limited structural damage in addition to non-structural failures. The California Building Code and American Society of Civil Engineers Standard 7-10 sets specific seismic design criteria for structures that fall under specific risk categories, such as risk category II for standard-occupancy buildings, risk category III where a higher level of protection is required (e.g., high-occupancy buildings that pose a substantial hazard to human life in the event of failure), and risk category IV (e.g., essential buildings).

Small-scale residential development is typically designed and constructed in accordance with the California Residential Code (Title 24, Part 2.5). Foundation design according to this code might not provide sufficient performance if earthquake-induced liquefaction occurs, unless the local building official requires a project-specific evaluation of these issues per Title 24, Part 2.5, section R401.4. The evaluation could be triggered if the site is located in a CGS Zone of Required Investigation and would lead to a process that is more in line with Title 24, Part 2 (California Building Code). The majority of earthquake damage to existing construction in recent U.S. earthquakes has come from non-structural failures, due to the greater frequency of lower magnitude events that exceed the capacity of these items but do not exceed the threshold for significant structural damage. In existing residential construction, the interior walls are frequently attached to the ceiling, relying on the ceiling "diaphragm" for lateral support. During strong shaking, the ceiling can prove to be inadequate, and compression can result in local failures, which in turn can lead to lateral instability and collapse of the wall and/or the adjacent portion of ceiling.

Building in Flood Zones

Where and how to build

Most communities at risk from existing coastal or riverine flooding have regulations in place that meet minimum federal and state requirements. Federal requirements set by FEMA are based on existing coastal and riverine flood hazards studies, many of which are decades out of date and therefore do not take into account recent changes in sea level or precipitation patterns. FEMA is conducting detailed coastal engineering analyses and mapping of the San Francisco Bay shoreline, which will result in revised and updated Flood Insurance Rate Maps for each of the nine counties.

Current floodplain management ordinances require first-floor elevations of structures to be at or above the FEMA base flood elevation, which is calculated based on the 1 percent annual chance (100-year) flood elevation as shown on a Flood Insurance Rate Map. However, current codes are unlikely to require similar standards in areas at risk of future flooding due to sea level rise and changing storm surge levels. Most local building codes in the Bay Area do not currently require flood-proof construction in flood zones. Recognizing the limitations of its guidelines and community members' lack of awareness about flood hazards, FEMA offers several voluntary programs to local governments through which they can exceed minimum FEMA requirements and increase community awareness.

APPENDIX F

RESOURCES

This appendix provides general resources used to inform strategy development.

Earthquake Hazard

California Geological Survey. *Recommended Criteria for Delineating Seismic Zones in California.* Special Publication 118. Sacramento, California: California Geological Survey. 2004. http://www.conservation.ca.gov/cgs/shzp/webdocs/Documents/SP118_Revised.pdf.

California Geological Survey. *Guidelines for Evaluating and Mitigating Seismic Hazards in California.* Special Publication 117A. Sacramento, California: California Geological Survey. 2008. http://www.conservation.ca.gov/cgs/shzp/webdocs/Documents/SP117.pdf.

Field, E. et al. "The Uniform California Earthquake Rupture Forecast Version 2." USGS. 2008.

Perkins, J. et al. "Shaken Awake! Estimates of Uninhabitable Dwelling Units and Peak Shelter Populations in Future Earthquakes Affecting the San Francisco Bay Region." ABAG, 1996.

Perkins, J. "The Real Dirt on Liquefaction, A Guide to the Liquefaction Hazard in Future Earthquakes Affecting the San Francisco Bay Area." ABAG. 2001.

United States Geological Survey [USGS], "Maps of Quaternary Deposits and Liquefaction Susceptibility in the Central San Francisco Bay Region, California." *Open-File Reports 00-444.* 2000 http://pubs.usgs.gov/of/2000/of00-444/

United States Geological Survey [USGS], "Maps of Quaternary Deposits and Liquefaction Susceptibility in the Central San Francisco Bay Region, California." *Open-File Reports 2006-1037.* 2000. http://pubs.usgs.gov/of/2006/1037/

Tyler, Martha Blair, and Spangle Associates. 1995. *Look Before You Build, Geologic Studies for Safer Land Development in the San Francisco Bay Area.* U.S. Geological Survey Circular 1130. Public Issues in Earth Science. Washington D.C.: U.S. Government Printing Office.

Sea Level Rise

Jensen, P. "Climate Adaptation – Sea Level Rise." The Department of Public Works, City of San Rafael. January 2014. http://www.marinwatersheds.org/documents/201401SanRafaelsealevel-issues-paper.pdf.

Grannis, J. "Adaptation Tool Kit: Sea Level Rise and Coastal Land Use. How Governments Can Use Land-Use Practices to Adapt to Sea-Level Rise." Georgetown Climate Center. 2011. http://www.georgetownclimate.org/sites/www.georgetownclimate.org/files/Adaptation_Tool_Kit_SLR.pdf.

National Oceanic and Atmospheric Administration (NOAA) Sea Level Rise and Coastal Flooding Impacts Viewer, http://coast.noaa.gov/digitalcoast/tools/slr/.

National Research Council. Sea-Level Rise for the Coast of California, Oregon, and Washington: Past, Present, and Future. 2012. http://www.nap.edu/catalog/13389/sea-level-rise-for-the-coasts-of-california-oregon-and-washington.

San Francisco Bay Conservation and Development Commission, "Assessing Climate Change Vulnerability & Risk." *Adapting to Rising Tides,* December 2011. http://www.adaptingtorisingtides.org/wp-content/uploads/2012/05/Bintliff-Assessing-Vulnerability-Risk-FINAL-20120118.pdf.

Regional Plans

Association of Bay Area Governments. "Taming Natural Disasters: Multi-Jurisdictional Local Hazard Mitigation Plan for the San Francisco Bay Area." 2010. http://resilience.abag.ca.gov/mitigation/.

ABAG, MTC. "Plan Bay Area: Building on a Legacy of Leadership. Regional Transportation Plan and Sustainable Communities Strategy for the San Francisco Bay Area 2013-2040." 2013. http://files.mtc.ca.gov.s3.amazonaws.com/pdf/Plan_Bay_Area_FINAL/pbafinal/index.html.

Plan Bay Area. "Plan Bay Area Environmental Impact Report, Section 2.5 Climate Change and Greenhouse Gases." July 2013. http://onebayarea.org/pdf/Draft_EIR_Chapters/2.5_Climate_Change.pdf, Accessed 05 February 2015.

Social Vulnerability and Social Equity

Byers, et al. "Life and Death from Unnatural Causes, Health and Social Inequity in Alameda County." 2008.

Dwyer, A., et al. "Quantifying Social Vulnerability: A methodology for identifying those at risk to natural hazards." *Geoscience Australia.* 2014.

Fazeli, B. "Cumulative Impacts: Changing Regulatory Culture to Address Environmental Injustice and Environmental Racism." Communities for a Better Environment. 2009.

Pastor et al. "Equity Issue Brief: Advancing Environmental Justice through Sustainability Planning, for the Sustainable Communities Initiative." 2012.

Schwind, K. "Mapping Our Future: A work plan for public engagement & equity in climate adaptation planning in the San Francisco Bay Area." Bay Localize for the Joint Policy Committee. 2013.

Indices and Indicators

Foster, Kathryn A. "Resilience Capacity Index." University of Buffalo Regional Institute, State University of New York. http://brr.berkeley.edu/rci/.

Star Communities. "STAR Community Rating System, Version 1.0." 2012.

Multi-Hazard Planning

Florida Department of Economic Opportunity and Florida Division of Emergency Management. Post-disaster redevelopment planning: Addressing adaptation during long-term recovery http://www.floridajobs.org/fdcp/dcp/PDRP/Files/PDRPSeaLeveRiseAddendum.pdf.

Johnson, Laurie, Laura Dwelley Samant, and Suzanne Frew. "Planning for the Unexpected: Land-Use Development and Risk." 2005. Planning Advisory Service 531. Chicago, IL: American Planning Association. www.planning.org.

NOAA & EPA. "Achieving Hazard-Resilient Coastal & Waterfront Smart Growth." 2011. www.coastalsmartgrowth.noaa.gov.

Olshansky, Robert B., and Jack D. Kartez.. "Managing Land Use to Build Resilience." In *Cooperating with Nature: Confronting Natural Hazards with Land-Use Planning for Sustainable Communities.* 1998. Natural Hazards and Disasters. Washington D.C.: John Henry Press.

Rockaway Waterfront Alliance. "Planning for a Resilient Rockaway: A Strategic Planning Framework for Arverne East." 2013. http://www.rwalliance.org/rwa/projects/arverne_east_strategic_planning/.

SPUR. "On Solid Ground." 2013. San Francisco, CA: SPUR. http://www.spur.org/publications/spur-report/2013-02-06/solid-ground.

The Earth Institute, Columbia University. "Resilient Sustainable Communities: Integrating Hazard Mitigation & Sustainability into Land Use." 2012. http://www.earth.columbia.edu/sitefiles/file/education/documents/2013/Resilient-Sustainable-Communities-Report.pdf.

Smart Growth
PROGRAM
www.epa.gov/smartgrowth