San Francisco Bay is a natural treasure; and has long captured the imagination of our nation. This region boasts natural assets from the Golden Gate Bridge and vineyards in Napa to salt flats ringing the South Bay. The Bay Area has long attracted migrants and immigrants from around the country and around the world, and has nurtured innovative social, political, and economic movements throughout its history. From the Gold Rush to Silicon Valley, from social movements of the 1960s to climate justice leaders today, the Bay Area’s residents have lead the way in addressing the most challenging issues facing our times.

As the residents of the Bay Area have struggled and thrived, the balance between a critical ecological system and growing urban area has always been fragile. Human activities have severely limited wildlife habitat, wetlands and marshland around the Bay. Fortunately, over the last 20 years, that tide has begun to shift, with a much greater understanding of the benefits of a healthy bay, and investment in bay restoration.

Unfortunately, as the region slowly integrates this greater knowledge into planning and development efforts, the rapidly accelerating effects of climate change are threatening our local communities, the baylands and shoreline, and our critical infrastructure. We know we are facing a future of more extreme weather events and rising sea levels. We know these rapid changes threaten to overwhelm the resilience of the Bay’s ecosystems. Vulnerable shoreline communities that have already faced systemic inequities are likely to be hardest hit by climate change. San Francisco Bay’s shoreline ecosystems will be on the front lines of sea level rise and can play a role in protecting human communities.

To protect our local communities and economy from devastating impacts, and enable San Francisco Bay and its wildlife to survive and thrive, we can’t rely on our current systems. We’re just not prepared for these increasing threats that are hard to predict, cut across jurisdictional boundaries and exacerbate existing challenges that are both physical - i.e. seismic risks - and social – i.e. regional economic inequality. We must find ways to accelerate our commitment to reinstating, enhancing and replicating the natural processes that make this ecosystem and this region resilient.

Resilient by Design gives the Bay Area an opportunity to proactively prepare for sea level rise and other climate change impacts. People are looking to California now to provide leadership in how we protect our communities and adapt to climate change. Through the open and collaborative process of Resilient by Design, the solutions we generate together can provide a national model. Resilient solutions “by Design” will enliven the public’s imagination and ensure that the final projects provide technical solutions to climate threats, but also address multiple community concerns and enhance lives today and for generations to come.

The original Rebuild by Design, launched after Hurricane Sandy, was an innovative and successful new model for disaster recovery. Resilient by Design takes the concept to the next level, preparing for disaster before it happens through not just planning but actual implementation of on the ground projects. If we in implementing this project in this context, without the significant disaster recovery funds that were available after Hurricane Sandy, Resilient by Design can serve as a detailed model for regions throughout the country and the world looking to prepare for the coming effects of climate change.
Acknowledgements

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Resilient by Design Bay Area Challenge Executive Board
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Alexander Felson | Yale School of Architecture, Urban Ecology & Design Lab

Support for this Report:
The Rockefeller Foundation

Book and infographic design:
Shawn Hazen | HazenCreative.com

Special thanks also to Naomi Feger and Cristina Toms from the Regional Quality Control Board for their comments and contribution to the regulatory framework content.

Cover Photo: Dennis Hearne
The Resilient by Design Bay Area Challenge Briefing Book is intended as a reference guide for Design Teams as they embark on the Challenge. The aim is to provide compilation of useful existing resources and context pertaining to resilience in the Bay Area. While not comprehensive, we hope this document will serve as starting place for inquiry and a source of inspiration. We are excited to be on this journey with you.
The Challenge

How can building resilience at the community level be scaled to address regional challenges?

The seas are rising.

Here in California and across the globe, communities are feeling the impacts of climate change. Extreme weather events are increasing, and trends in precipitation and temperature are quickly departing from those that existed as human life emerged on this planet. Many scientists have now begun to refer to this new climate era as the Anthropocene, a distinct geomorphologic epoch shaped by human activity. While the continued transition away from fossil fuels and onto renewable energy sources continues to be critical, dovetailing climate mitigation and climate adaptation has become imperative.

Climate change has presented an opportunity to reimagine our relationship to the natural world and to each other. As we plan for the impacts of climate change in the Bay Area, we must seek transformational change toward true long-term prosperity. This transformation will require confronting our shared history, and centering social equity in our decision-making practices. When solutions center social equity, they are best positioned to result in positive outcomes across social-ecological systems.

The Resilient by Design Bay Area Challenge views climate adaptation as a tremendous opportunity to facilitate innovation. Our goal is to implement an iterative and collaborative design process that creates the opportunity for community collaboration at every stage. We believe that the best climate resilient design is informed by both professional expertise and local knowledge, and that planning for real world implementation should be central to this practice. By building on the work already happening at the community, city, and regional level, we can transform the process by which we arrive at built environment solutions to climate change.

What is resilience?

‘Resilience’ is the capacity of individuals and systems to respond to, thrive, and adapt in the face of chronic stressors and acute shocks. The concept of resilience is rooted in ecology, the study of the complex systems that create the fabric of life on our planet. As our knowledge of ecosystem processes has deepened, we have gained better insight into the adaptive and dynamic systems at work. While a beach or a forest can seem frozen in time, ecosystems and landscapes are ever-changing processes. They are systems of systems that create a whole. Simply put, no system of living things is ever static.

Social-ecological and urban-regional systems are no different. As we seek to address the complex problems that our neighborhoods, cities, and regions face, it is critical that we find new ways of harnessing our collective capacity for creative thinking and innovation. The changing nature of our world requires solutions as complex as the problems we need to solve.

Many frameworks and approaches have emerged to describe and plan for adaptive and resilient city systems. The Rockefeller Foundation’s 100 Resilient Cities defines Urban Resilience as “the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stressors and acute shocks they experience.” Resilience is thus key to responding to climate change impacts.
Today, humanity faces unprecedented risk. Urban populations have never faced so many shocks and stressors. Without strategic investment, cities struggle to adapt, respond, and recover from disaster. Today, humanity faces unprecedented risk. Urban populations have never faced so many shocks and stressors. Without strategic investment, cities struggle to adapt, respond, and recover from disaster.

Key adaptation planning documents and processes

**Federal**
The EPA previously released recommendations around climate resilience and adaptation planning solutions for local communities. The Climate Adaptation Resource Center may provide some helpful framing for the broader national context of climate adaptation. [https://www.epa.gov/arc-x/planning-climate-change-adaptation](https://www.epa.gov/arc-x/planning-climate-change-adaptation)

**State**
Cal-Adapt is an excellent resource for state level recommendations and policy considerations around adaptation and resilience. On the website, you can browse climate impacts research as well as download data and explore community challenges. [http://beta.cal-adapt.org/](http://beta.cal-adapt.org/)

**Local**
There are many climate resilience and adaptation planning processes underway in the Bay Area. Among them are the following:


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**Climate Adaptation in California**

From the landmark climate change Assembly Bill 32 in 2006 to Governor Brown’s recent agreement with China, California has positioned itself as an international leader on climate change. More recently, California has doubled down on its commitment to combating climate change by signing new climate emissions reduction goals with China through utilizing clean energy investments. In 2009, California began a statewide Climate Adaptation Strategy leading to the 2014 Safeguarding California Plan. The 2017 Update is in process now. Governor Brown signed Senate Bill 246 in 2015 to form a Climate Adaptation and Resilience Program to coordinate adaptation at state, regional, and local levels.

The 2013 California Climate Assessment outlined major areas of concern for climate impacts in the state, including drought, wildfire, and sea level rise. There are several major data sets being used to model the impacts of sea level rise. See the [Sea Level Rise and Flooding section](#) for further information.

Additionally, California Indian Tribes are creating climate adaptation plans that consider a wider history of landscapes and ecosystems that span thousands of years, that consider a wider ecosystem approach, and that seek to protect culturally significant physical features, medicines, subsistence foods and other culturally-imperative resources that rely on fragile threatened and interconnected bay area aquatic habitats. Co-management of environmental resources is preferred by many California Tribes who seek balance when faced with threats to cultural continuance because of climate change.

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Operational Landscape Units: The San Francisco Estuary Institute is conducting research funded by the San Francisco Regional Water Quality Control Board to define practical, science-based landscape units focusing on watershed, creek and baylands processes for the Bay Area. Called “Operational Landscape Units”, these units include baylands and shoreline areas. These approximately 30 OLU’s will facilitate a geographically-specific set of integrated adaptation strategies to address issues of both the natural and built environment. The project is in early stages, and will run through 2018. http://resilience.sfei.org


Resilience Atlas: The Resilience Atlas is an interactive mapping platform that visualizes the past, present and future conditions of the Bay’s edge and surrounding watersheds by combining layers of information, such as shoreline infrastructure, shoreline change over time, and sea level rise. The project aims to aid regional planning efforts, restoration managers, government organizations, nonprofits, and citizens and serve as a repository of scientific analysis. http://resilienceatlas.sfei.org

The Adapting to Rising Tides program of the San Francisco Bay Conservation and Development Commission (BCDC) is a comprehensive toolkit created to aid in decision-making processes around climate adaptation solutions. They provide data, strong analysis, and helpful guidance on reaching climate adaptation solutions. http://www.adaptingtorisingtides.org/

The Association of Bay Area Governments (ABAG) Resilience Program, now a part of the Metropolitan Transportation Commission (MTC), has created an adaptation clearinghouse for local governments to submit their resilience and adaption planning documents. http://resilience.abag.ca.gov/

ABAG also provides helpful analysis on the impacts of seismic and flooding risk to housing stock and potential mitigation strategies. http://resilience.abag.ca.gov/projects/stronger_housing_safer_communities_2015/

The Climate Readiness Institute has created a Climate Adaptation Planning Clearinghouse which can be a useful guide to additional planning processes underway.” http://www.adaptationclearinghouse.org/organizations/climate-readiness-institute-of-bay-area.html

Tribal

Many Bay Area Indian Tribes are also undergoing climate adaptation planning processes which will be explored in the collaborative research phase.

Resilience is equity

Planning for climate resilience starts with understanding the vulnerabilities our communities and ecosystems face. While the impacts of climate change will touch everyone’s lives, people who are most marginalized will be hit hardest. Resilience outcomes will therefore be tied heavily to the pre-existing vulnerabilities in a particular neighborhood or local jurisdiction. As Breakthrough Communities describes, “Hurricane Katrina and Superstorm Sandy highlighted how extreme weather events caused by climate change exacerbate inequities caused by society’s racism and classism, and how those inequities play out in survival, recovery and resilience.”

In planning for climate adaptation, it is critical that these underlying vulnerabilities be addressed, and that the process of planning for resilient solutions be grounded in community self-determination. NOAA’s U.S. Climate Resilience Toolkit describes it this way: “In climate adaptation, the higher vulnerability and risk of damage from storms for some populations is an issue of social equity. Additionally, the exclusion of people or groups from full participation in making decisions about climate adaptation based on their income, neighborhood, or social status is a social equity issue.”

Planning for resilience with communities that are most vulnerable to the impacts of climate change is critical to the success of climate adaptation efforts overall. The Resilient Communities Initiative has created a set of best practices that can serve as a helpful guide to the process of embarking on outreach to communities that are most impacted by climate change.
Objectives & Foundational Principles

Addressing multifaceted, dynamic issues through collaboration, coordination, and connection

Planning for sea level rise will require coordination and connection across many regional jurisdictions and complex local contexts. Managing and planning for resilience draws on the understanding of complex adaptive systems and seeks dynamic, multi-faceted solutions. Whereas often the goal in addressing ecological or societal issues is to narrow the scope of the problem enough to find a simple solution, resilience requires expanding the scope of the problem to achieve solutions with more dimensionality. By understanding complex problems in a complex system, we can better identify solutions that solve for many challenges at once.

Prepare communities for the future by addressing our shared history, and ecological, economic, and social vulnerabilities that exist today

Understanding history, context, and current vulnerability is critical to addressing current and future challenges. The 100 Resilient Cities Resilience Framework describes this principle as “reflective.” Individuals and institutions that are reflective use past experience to inform future decisions, and will modify standards and behaviors accordingly. For example, planning processes that are reflective are better able to respond to changing circumstances.

The history of the Bay Area is rich with lessons to inform our current practice. A critical piece of understanding our shared history is confronting the roots of systemic racism and addressing the enduring reproduction of marginalization in our city and regional systems. The challenges we face in planning for the sustainability of our bay ecosystems are similar to those we face in planning for equity and prosperity in our neighborhoods. As Breakthrough Communities explains, “The same policies that drove segregation and disinvestment in communities of color also generated suburban sprawl, excess driving and air pollution that threaten our health and contribute to the climate crisis. Because social inequality and environmental decline share common roots, they must be tackled together to find shared solutions.” Before solutions can be reached and a better future can be forged, it is critical to acknowledge both positive and negative aspects of our shared history, and work toward community cohesion.

What are the best tools for conducting vulnerability assessments at the community level?
Acknowledging place and the First Nations of the Bay Area

The Resilient by Design Bay Area Challenge will be taking place on the ancestral homeland of some 80 Tribes, including descendents of the Ohlone (also referred to as "Costanoan") and the Miwok people. The majority of Bay Area Tribes are not state or federally-recognized, thus they receive none of the rights, benefits, compensations or protections afforded to Indian Tribes under US laws. It is important to acknowledge those indigenous to this place: how they survived disease and centuries of policies that resulted in genocide, displacement, and persecution and the ways in which they still survive and thrive throughout the Bay Area today. In the context of climate change, resilience, and the Bay Area, “place” is deeply connected to a powerful relationship between the Indigenous people and the land they come from, especially as it relates to “ancestral knowledge, cultural memory, and historical significance.” Despite colonialism and the history associated with it, those indigenous to the Bay Area continue to actively organize and advocate for their needs that almost always exist at the nexus of land and Indigeneity.

When considering this historical context, it is important to recognize that the repression of Bay Area Indigenous peoples is connected to the ongoing repression of the natural physical and aquatic landscapes, originally maintained by Bay Area Tribes. Communities who live in the Bay Area are more vulnerable to changes in climate change in part because of the destruction of these previous features and systems.

Integrating social and ecological systems through rigorous research and a strong understanding of ecosystems, local community, and government challenges

Despite being a highly urbanized and altered estuary, the San Francisco Bay has great potential for nature-based, multi-benefit design solutions integrated with the highly urbanized shore. The San Francisco Bay retains a vast core area of wetlands—some that are diked and others that are natural tidal marshes. These marshes have great value as self-maintaining shields for the shoreline. They knock down waves and reduce erosion during high water events. With sufficient sediment available, they can grow vertically with sea level rise and continue providing services, requiring little to no maintenance. Tidal wetlands also provide many other benefits, including nutrient processing, primary productivity, contaminant sequestration and breakdown, recreation opportunities, and support for threatened and endangered wildlife. Thus, they offer more value than many engineered, single-benefit solutions that require ongoing maintenance and retrofitting. Optimal designs for San Francisco are likely to fall along a continuum from fully natural to completely constructed.

Although natural processes cannot always be restored, they can often be enhanced or emulated, presenting many opportunities to create innovative approaches.
A remarkable alignment among scientists, government agencies and nonprofits around how to incorporate nature-based solutions was recently achieved for San Francisco Bay. Over 100 scientists and other experts, guided by a steering committee of government entities, created The Bayland Goals, a report on how to rethink bay wetlands restoration and shoreline design as the climate changes.1 This report offers 10 regional-scale recommendations and smaller-scale recommended actions for each segment of the shoreline, as well as the scientific bases for these guidelines.

The regional recommendations from the 2015 Bayland Goals Update to guide future Estuary restoration and enhancement projects include:

- **Restore** estuary-watershed connections
- **Design** complexity and connectivity into the Baylands landscape
- **Restore and conserve** complete tidal wetlands systems
- **Restore** baylands to full tidal action prior to 2030
- **Plan** for the Baylands to migrate
- **Actively recover**, conserve, and monitor wildlife populations
- **Develop and Implement** a comprehensive regional sediment management plan
- **Invest** in planning, policy, research and monitoring
- **Develop** a regional transition zone assessment program
- **Improve** carbon management

Considering the significant proportion of the Bay that is surrounded by marshes and mudflats and the significant efforts to restore these natural areas, the Bayland Goals, by a steering committee of government entities, created a comprehensive regional-scale management plan that guide future Estuary restoration and enhancement projects. Over 100 scientists and other experts, guided the strategic bases for these guidelines.

As the climate changes, the Bayland Goals call for rethinking bay wetlands restoration and shoreline design. The Bayland Goals, directed by a steering committee of government entities, created a comprehensive regional-scale management plan that guide future Estuary restoration and enhancement projects. Over 100 scientists and other experts, guided the strategic bases for these guidelines.

### Principles to sustain biodiversity and ecological functions

Ecosystems with the capacity to adjust and reassemble in response to significant changes are increasingly important to maintain biodiversity and ecological functions across our landscapes in the context of an uncertain future. Seven key mechanisms exist that contribute to the resilience of ecosystems, as defined by Landscape Resilience Framework report, which can be used to provide a holistic framework to consider potential actions likely to confer ecological landscape resilience. These principles include: setting, process, connectivity, diversity/complexity, redundancy, scale and people. When combined, these seven principles embody the most critical considerations when planning for ecological landscape resilience.10

**Merging local, regional, and international knowledge with technical expertise toward implementable and creative design-driven ideas**

Closely linked with understanding our history and social-ecological context is the practice of merging local knowledge with professional expertise. While historically professional expertise has been valued higher in the dominant narrative than local knowledge, that knowledge is critical to developing solutions to multifaceted problems that work for communities. Planning processes that value and integrate local knowledge can be more responsive to community needs and are much more likely to result in real world implementation.

In the Bay Area, several sea level rise and hazard mitigation planning processes are already integrating knowledge sharing processes between experts and community. For example, Shore Up Marin’s community tours bring city, county and other experts together with community members to tour impacted areas and share information with one another. Their current collaboration with Marin County Public Works and Marin City Community Service District on the Marin City Flood Study has been a particularly promising effort. Processes like these can serve as examples for potential engagement tactics.20
When it comes to the political and social dynamics that have shaped our land use policy, planning, and development, race and access to decision-making are key determinants. This is due in part to explicit and implicit exclusion of people of color from regional and city planning processes. The Bay Area exhibits highly racialized geographies, and is becoming increasingly ‘resegregated’ as housing pressures force low income and communities of color out of urban areas into outlying areas. Because of the persistent nature of racism within our institutions, it is critical to consider the ramifications of any large-scale decision making on communities of color. The Government Alliance on Race and Equity (GARE) provides a strong framework and set of tools for equitable governance and decision-making processes. They frame their approach to racial equity in this way:

**Why Lead With Race?**

- The Alliance leads with race, with the recognition that the creation and perpetuation of racial inequities has been baked into government, and that racial inequities across all indicators for success are deep and pervasive. We also know that other groups of people are still marginalized, including based on gender, sexual orientation, ability and age, to name but a few. Focusing on racial equity provides the opportunity to introduce a framework, tools and resources that can also be applied to other areas of marginalization. This is important because:
  - To have maximum impact, focus and specificity are necessary. Strategies to achieve racial equity differ from those to achieve equity in other areas. “One-size-fits-all” strategies are rarely successful.
  - A racial equity framework that is clear about the differences between individual, institutional and structural racism, as well as the history and current reality of inequities, has applications for other marginalized groups.
  - Race can be an issue that keeps other marginalized communities from effectively coming together. An approach that recognizes the inter-connected ways in which marginalization takes place will help to achieve greater unity across communities.
  - It is critical to address all areas of marginalization, and an institutional approach is necessary across the board. As local and regional government deepens its ability to eliminate racial inequity, it will be better equipped to transform systems and institutions impacting other marginalized groups.

The same must be true in planning for climate resilience. In May of 2017, the National Association of Climate Resilience Planners released their Community-Driven Resilience Planning Framework, which provides a useful guide to engagement at the local level. They identify integrating equitable planning practices and building community power as central to planning for resilience. Their framework outlines steps to take toward centering community needs, and reaching solutions that offer multifaceted solutions to complex and entrenched problems.
Responding and adapting to the impacts of climate change is at the core of this Challenge. This section will give an overview on climate change impacts faced in the Bay and corresponding consequences. The following sections will examine the Bay’s history and current context to deep our discussion of climate resilient design solutions in the Bay Area.

Bay Area communities face a range of natural hazards, including flooding, wildfires, earthquakes, landslides, and drought. Adaptations to these challenges will require flexible management approaches and an integrative perspective which considers the impacts of climate change on the Bay’s estuarine-river system from changing watershed and ocean factors. Safeguarding water quality, native species, critical infrastructure and vulnerable communities while promoting energy efficiency, water conservation, and health and wellbeing should all be considered in planning for resilience.

The following sections highlight some of the most relevant risks to guide design thinking for the Resilient by Design Bay Area Challenge, which include sea level rise and storm surge; combined tidal-fluvial flooding; groundwater flooding; heat and drought; water quality degradation; and seismicity and liquefaction.

It is important to note that this is not an exhaustive list, but rather a glimpse into the relevant areas of concern for the purpose of this design challenge. Many of the concerns and hazards described below are interconnected and pose amplified risks when overlapping in geography. Depending on the nature of the site analyzed, it may be necessary to analyze additional hazards outside of these categories before moving forward with a design idea or approach.

**Sea level rise and flooding**

As the atmospheric concentration of carbon dioxide (CO₂) continues to rise²⁵, sea level rise and flooding will disrupt our city and regional systems with...
increasing frequency. In order to just stabilize the concentrations of CO2 in our atmosphere, an almost immediate halving of carbon emissions would be required with additional cuts necessary to maintain stability.26 While emissions reductions must be achieved, even with continued success many of the Earth’s stores of carbon and methane may still be headed for our atmosphere. ‘Climate tipping points’ or positive feedback processes including ocean CO2 absorption decline, loss of global ice cover, and thawing permafrost may lead to even faster warming in the coming decades.27 With global demand for energy continuing to rise, there is not yet a clear end in sight for rising greenhouse gas emissions.

According to a recent report, emissions of the last decade position us along the highest scenario considered by the last IPCC report, RCP 8.5.28 If current emission trends continue through this century, Bay sea levels will likely rise 0.6–1.1 feet by mid-century and 1.6–3.4 feet by 2100 (Figure 8). There is a 1-in-20 chance that San Francisco will see a sea level rise of more than 4.4 feet by 2100 and a 1-in-200 chance that it will rise more than 6.9 feet (Table YY). Sea level will continue rising beyond 2100.

Total water level
In addition to sea level rise, a number of other factors influence water level including fluvial flooding, which together add to determine the Total Water Level (Figure 9). Storm surge, wave set-up and run-up are of great concern, as current projections show up to 3 feet of additional water level rise in the San Francisco Bay during storm events. El Niño/La Niña also influence Total Water Level, as the region receives about a foot of variation with fluctuations in temperature between the ocean and atmosphere. As the Total Water Level rises, the Bay will see an increase in ‘nuisance flooding’, flooding that causes inconvenience to the public.

The rate of global mean sea level rise has accelerated during the last two centuries. The rate will most likely continue to accelerate. The rate of global mean sea level rise has accelerated during the last two centuries. The rate will most likely continue to accelerate.

This map is for illustrative purposes only. It does not include storm surge, levees or combined flooding.
There are various helpful sea level rise viewers available online. With each viewer, care has to be taken to understand the assumptions or limitations behind the data used in the viewer. Some viewers and vulnerability assessments use a simple bathtub model of water inundating the land as sea level rises. Others account for the Total Water Level as mentioned above. The treatment of how water is routed by levees and berms also differs between viewers. The recent Our Coast Our Future viewer for San Francisco Bay includes both static (i.e. tides and global sea level rise) and dynamic components of water levels (i.e., storm surge and wave set-up and run-up), as well as explicitly models the flow of the flood waters. For more details, explore NOAA’s Sea Level Rise Viewer and Our Coast Our Future’s Flood Map to visualize the projected impacts of different sea level rise and storm surge scenarios for specific areas within the Bay.

Sea level rise will also impact the health of Bay wetlands. Wetlands provide many benefits such as habitat for abundant wildlife, open space for recreation, and clean water. Wetlands can provide protection from sea level rise and storm surge events by attenuating wave energy and absorbing water. Although many efforts are underway to restore wetland systems in the Bay, there are additional needs for sufficient migration space and sediment and organic matter inputs in order to keep pace with sea level rise. In the absence of sufficient space, sediment, and organic matter, many of the current wetlands and future restoration projects could be lost to rising tides, leading to a decrease in flood protection for communities and the loss of habitats for native species.

Combined tidal-fluvial flooding
Flood risks along creeks from storm events may increase due to more frequent extreme high sea level events leading to backwater effects along flood-prone areas. The head of tides will move further inland up the creeks and, during storm events, the higher tidal levels will reduce flow capacity in the creeks and increase the risk of flooding.

In addition, the duration of flooding events is likely to increase as extreme water levels increase and precipitation and storm surge events become more intense. More intense storms would produce higher peak flows in urbanized areas. This may result in increased in-channel erosion as sediment is scoured and vegetation washed out. Increased frequency of landslides and sediment erosion into flood control channels may be expected. Increased wildfire during the extended dry periods may also increase erosion that further reduces channel capacity. Increased storm intensity may also increase landslides and sediment transport into creeks.

Groundwater inundation
In addition to tidal and fluvial flooding, low-lying bay areas may also be vulnerable to groundwater inundation or localized flooding due to a rise of the groundwater table with sea level. The groundwater table close to the Bay typically lies above mean sea level and fluctuates with astronomical tides and El Niños. Amplitudes decrease exponentially with distance from the shoreline. Short-term, cyclic water-level changes in observation wells in the East Bay baylands are a pressure response to tides in San Francisco Bay. As sea level rises, the water table will rise and could eventually break out above the land.
Surface creating new wetlands and expanding others, changing surface drainage, saturating the soil, and inundating the land depending on local topography. Flooding could start sporadically, but will be especially intense seasonally when high tide coincides with rainfall events.

Heat and drought
Climate change will alter regional patterns for temperature and precipitation, which will pose uncertain impacts to endemic species within the Bay and surrounding rivers. Average daily air temperatures are on the rise, causing higher evapotranspiration rates, which create uncertainties for snowpack reserves and future water supply. Similarly, average daily water temperatures are on the rise, causing long-term concerns for native species if temperatures surpass a specific threshold linked to high mortality rates. Examples of vulnerable endemic species include Delta smelt (Hypomesus transpacificus) and Chinook salmon (Oncorhynchus tshawytscha). Projected increases in estuarine salinity and decreases in suspended sediment concentrations will also have uncertain impacts on endemic species and habitats. Fish travel long distances through the Bay and Bay Delta into upper basin river and stream systems which means the health of the Bay and the Delta effects more than just the Bay Area. Similarly, all Tribes from the Bay Area throughout the Sacramento and San Joaquin River Basins may be affected as traditional foods are further threatened. Because of this inclusion of Tribes from the upper watersheds in climate adaptation planning is critical.

Water quality
Pollutants in water and sediment pose a threat to the health and survival of species at all levels of the Estuary’s food web. In an effort to protect them, water quality laws and regulations require that the Estuary be clean enough to support abundant, diverse native communities of plants and animals. However, human activities continue to add contaminants to the ecosystem via municipal and industrial discharges, agricultural and urban runoff, and other pathways. A multitude of legacy and emerging pollutants – including mercury, pesticides, pharmaceuticals, and waste – pose ongoing challenges. Thoughtful strengthening of regulations, restoration, enhancements and urban design, particularly the implementation of green infrastructure, can greatly reduce pollutant loads from the watershed to the Bay. There are a variety of tools available to regional planners to help site these types of projects.

The water quality in freshwater aquifers close to the Bay’s edge as well as the Bay itself are at risk from sea level rise and other stressors exacerbated by climate change. Near the Bay’s edge, groundwater reserves are more likely at risk of saltwater intrusion, typically a result of over-pumping. In some instances, sea level rise could pose pollution risks to the Bay by saturating subsurface contaminants suspected to persist from historical contamination sites such as the superfund site at Alameda Naval Air Station. In addition, leaching from landfills positioned around the Bay’s edge have potential to further decrease water quality.

Legacy pollution and site contamination
Legacy pollution, a term used to describe pollutants that were historically common in industrial practices before their negative impacts were understood, is another threat to water quality in the Bay. The main sources of legacy pollution are from historical mining, manufacturing and agricultural activities. Manufacturing to support wartime operations was especially active in the Bay Area during World War II, and these operations commonly used persistent pollutants such as PCBs, dioxins, furans and heavy metals. Legacy pollution and site contamination are an important factor when considering sea level rise adaptation strategies. Brownfield and Superfund sites are two common types of contamination sites, but terms used to describe contamination sites vary based on remediation status, the organizations involved in cleanup efforts and the sites, but terms used to describe contamination sites vary based on remediation status, the organizations involved in cleanup efforts and the sites. Brownfield and Superfund sites are typically positioned in urbanized areas and are an important factor when considering sea level rise adaptation strategies. Brownfield and Superfund sites are two common types of contamination sites, but terms used to describe contamination sites vary based on remediation status, the organizations involved in cleanup efforts and the type of contamination. Brownfield sites are generally properties that have the presence or potential presence of a contaminant, pollutant or hazardous
substance in need of remediation before development can take place. States or Tribes are typically the main entities involved in brownfield remediation and public programs exist to aid remediation efforts. When the federal government is or plans to be involved in a cleanup of contaminated land that is abandoned or uncontrolled, the site is designated as a Superfund site. Superfund sites undergo screenings and assessments to determine if the environmental or human health risk is enough to qualify it for the National Priorities List. If placed on the National Priorities List, the site will eventually receive federal funds to conduct remediation efforts.

Liquefaction
There is a greater than 70% chance that at least one major earthquake of magnitude 6.7 or greater will strike somewhere in the Bay Area within the next 25 years. The risk posed by such a quake is amplified in areas built upon bay mud or artificial fill, which are susceptible to land liquefaction. Seismic precautions need to be taken where appropriate and any land uses on bay mud or bay fill need to be evaluated for increased risks due to the nature of the development. For example, the Bay has numerous inactive landfills around its margin, some of which have been built in liquefactions zones. Sea level rise and seismic activity could undermine the integrity of the liners engineered to keep capped pollutants within landfills from entering the Bay or groundwater reserves. Excavation of landfill material would likely be very expensive and difficult to achieve without leaching toxic pollutants in the process, leading to increasing challenges to safeguard Bay water quality and human health.

Economic risk and development
Sea level rise and increased extreme storm and flooding events pose the threat of significant economic losses in the Bay Area. The California’s Flood Future Highlights document indicates that in the Bay Area Region, structures valued at $130 billion are located within a 500-year floodplain. Additionally, over one million Bay Area residents live within a 500-year floodplain, and these numbers are likely to increase due to expected growth in population and development in the region. Thus, a change in flood risk is a potential significant effect of climate change that could have great implications for the region.

In 2015, the Bay Area Council Economic Institute, California State Coastal Conservancy, AECOM, and other partners released the report Surviving the Storm, which concluded that within the Bay Area hydrologic region a 150-year storm event, under present-day sea levels, would cause an estimated $10.4 billion in economic damages, almost the same as the Loma Prieta Earthquake. The analysis used this ‘megastorm’ scenario to illuminate vulnerabilities and economic impacts from severe flooding events, especially those occurring at high tide. A critical note is that this analysis did not incorporate future sea level rise in its modeling, only storm surge, rainfall, and combined flooding data. The economic impact modeled used five key categories to assess potential vulnerability: structural damage, content damages (based on average contents by building type), air transportation delays, road transportation delays, and electricity service interruption.

### FIGURE 14: SUMMARY OF DAMAGES (MILLIONS OF DOLLARS)

<table>
<thead>
<tr>
<th>Damage Category</th>
<th>Estimated Damages (millions of dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural damages</td>
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</tr>
<tr>
<td>Contents damages</td>
<td>$4,180</td>
</tr>
<tr>
<td>Air transportation delay damages</td>
<td>$56</td>
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<tr>
<td>Road transportation delay damages</td>
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<td>Electricity service interruption costs</td>
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</tr>
<tr>
<td>Total</td>
<td>$10,401</td>
</tr>
</tbody>
</table>

### FIGURE 15: STRUCTURAL AND CONTENT DAMAGE ESTIMATES (MILLIONS OF DOLLARS)

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Alameda</td>
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<td>$1</td>
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<tr>
<td>Total</td>
<td>$5,932</td>
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<td>$10,112</td>
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</table>

### FIGURE 16: DEFINING LOWER-, MIDDLE AND HIGHER-WAGE JOBS IN THE BAY AREA

The following terms will be used throughout this report to describe primary segments of the income spectrum:

- **Lower-wage:** Less than $18 per hour (or less than about $36,000 per year)
- **Low-wage:** Less than $11.25 per hour
- **Moderate-wage:** $11.25 to $18 per hour
- **Middle-wage:** Over $18 per hour and up to $30 per hour (or between $36,000 and about $62,000 per year)
- **Higher-wage:** Over $30 per hour (about $62,000 per year)

Note that both low-wage and moderate-wage jobs are considered lower-wage jobs. Throughout this report, the term “lower-wage jobs” is used as a proxy for all jobs that pay less than $18 per hour.

### FIGURE 17: SPUR’s MAP OF LOWER-WAGE WORKERS’ PLACE OF RESIDENCE

*Lower-wage workers live in every part of the Bay Area and are not concentrated in certain neighborhoods. The density of lower-wage workers in areas like San Francisco mirrors the overall greater population density in those parts of the region.*

California boasts the 6th largest economy globally. According to numbers this July, the golden state boasts the 7th highest increase in gross state product and far exceeds the next closest state in GSP overall. The growth of the Bay Area is one piece of this continued increase in GSP. Recent economic growth in the Bay Area can be tied in large part to the rapid expansion of the tech industry, which has indirectly accelerated the growth of real estate and banking in the region. Jobs continue to grow in the Bay, with the highest increase in Oakland. Unemployment levels have reached the lowest levels since the 1990s. Understanding the spatial relationships between low and middle income workers and their places of work can inform opportunities to build resilient solutions and economic vitality for the region. The Bay Area has become more unequal: with the lowest and highest wage jobs growing, while middle-wage jobs are on the decline. A strategy developed by SPUR and the Economic Council highlights the need for ‘pathways to the middle’ or strategies to improve the growth of middle-income workers.
Figure 18: SPUR’s map of lower-wage workers place of work

“Jobs that pay low wages are located throughout the region and are closely correlated with where higher wage jobs are located.”47

<table>
<thead>
<tr>
<th>County Name</th>
<th>Value of Structures and Contents Exposed</th>
<th>Value of Crops Exposed</th>
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</table>

Figure 19: Flood hazard exposure in the nine-county bay area

Figure 20: Current map of bay shore infrastructure

The San Francisco Bay has a diversity of natural Bay shore types ranging from mudflats and marshes to bluffs and beaches. Similarly, the degree of urbanization varies from the crowded cities of the South Bay to the agricultural zone in the North Bay. As a consequence, the shoreline type reflects the variable setting around the Bay.46

Threats to infrastructure

Sea level rise and storm surge also threaten to inundate critical infrastructure, which could have widespread implications across the Bay. For example, many wastewater treatment plants are located along the shoreline or at the edge of the baylands, leading to future uncertainties in sewage disposal, nutrient flows and water quality impacts. Highways are also of great concern as intermittent or permanent inundation could delay emergency vehicles, overcrowd other transit systems and interrupt economic activities. The San Francisco, Oakland and San Jose International Airports are located in low-lying areas adjacent to the Bay, posing major economic concerns as these airports generate billions of dollars in annual business revenues and provide hundreds of thousands of jobs. Infrastructure in low-lying areas often relies on built bay shore features, such as levees and breakers, to reduce flood risk. Some infrastructure may be more vulnerable than others depending on the age, height, location, future maintenance and original design intent of the existing bay shore features (Figure 20).49
Transportation

The Adapting to Rising Tides program of BCDC has assessed potential vulnerabilities of transportation infrastructure in the Bay Area. MTC, BCDC, CalTrans and BART partnered to create technical reports and a briefing book that describe some of the vulnerabilities already identified, and potential impacts of a disruption on communities that rely on these modes of transportation. Three major areas of concern emerged from this study: the Bay Bridge touchdown focus area, Oakland Coliseum focus area, and the Hayward shoreline. The challenges faced in these three focus areas can illuminate potential vulnerabilities for other sites as well. Each area exhibits a confluence of resilience challenges that must be addressed including protecting critical infrastructure, managing for sea level rise across multiple land use typologies, and protecting community assets.51

Transportation infrastructure, access and equity

In planning for resilient transportation infrastructure, it is important to address the needs of vulnerable populations that rely on or could benefit from access to public transportation. Access to transportation can improve outcomes for health and wellbeing in disadvantaged communities. If the impacts and needs of disadvantaged communities are not considered, new transportation infrastructure interventions can reinforce ‘racialized geographies’ and widen inequality in access to food, jobs, housing, and other basic needs.52

PolicyLink, the Prevention Institute, and the Convergence Partnership issued a report on health and equity in transportation policy that illuminated key strategies for improved outcomes for communities. They outlined a useful set of criteria for assessing the equity of transportation projects and gave recommendations for increasing the positive impact for communities.53

Where climate adaptation interventions involve changes to transportation infrastructure, PolicyLink’s criteria can serve as a helpful guide for building resilience in social-ecological systems.

“Specifically, healthy, equitable transportation policy:

- Supports the development of accessible, efficient, affordable, and safe alternatives to car travel, and especially to driving solo. These alternatives enable everyone to walk more, travel by bicycle, and use public transportation more—in other words, to get around in ways that improve health, expand access to opportunity, and reduce toxic pollutants and greenhouse gas emissions.

- Works hand in hand with sustainable land use planning. Together, they encourage and support high-density, mixed-use, mixed income metropolitan development and affordable housing with good access to transportation options. Together, they focus, particularly, on underserved and economically isolated communities.

- Recognizes that income is important to health, and that good transportation has an impact on family income. Healthy, equitable transportation policy support systems that connect all people, especially low-income and underserved communities, to employment and other opportunities. It also encourages hiring low-income residents of color for well-paying jobs in...
**Storm and wastewater management**

Wastewater and storm water management systems will increasingly face threats from sea level rise, storm surge, and increased precipitation. The first of these threats is the overwhelming of pipe and pump capacity. Additionally, seawater could cause premature corrosion of pipes that are not meant to handle salt water.55

Water pumps and treatment systems rely on uninterrupted power in order to maintain proper function. If there is disruption in the power grid due to storm surge, high winds, or other weather-related disturbance and there is no alternative generation available, there may be dual threats of interrupted water and power infrastructure simultaneously. Additionally, water pumps that protect low-lying areas from flooding or storm surge inundation may be knocked out as well, increasing flood risk. Frequent flooding can exacerbate these issues, especially when chronic drainage issues are preexisting.

The gravity systems that drain stormwater from urban areas will also become less effective as bay levels rise. Stormwater discharges and pipes may allow backflow and serve as conduits for flood water. Flap gates that prevent the back flow of flood waters will remain closed for longer, resulting in ponding of water in local drainage systems. The potential impacts could be severe if flood conveyance channels and storm drains are overwhelmed, which will lead to the increase of flooding in low-lying areas.56

The combination of increased flood flows and higher water levels could result in the need to raise levees and flood walls in many places. This may increase the risk to communities and infrastructure as they become lower relative to the crest of the flood protection structure. If the structure does fail then the depth of water, and the consequent damage, may be greater. Changes may also be made higher up in the watershed to alleviate some of the combined flooding issues that may occur more frequently. For instance, floodplain restoration and reconnection, off-line detention higher up in the system and the increased use of pumping may alleviate some of these issues. All approaches will require increased coordination between different jurisdictions.57
While disadvantaged communities can benefit from investments, if their neighborhoods are not kept affordable at diverse income levels then community members are forced out by rising rents and property taxes as their neighborhood improves. Additionally, displacement patterns cause more greenhouse gas emissions by replacing low-income urban transit users with wealthier car-owners who use transit less frequently, and pushing former transit users to regional peripheries where they are forced to buy cars. Displacement also causes traumatic disruption of communities that have complex patterns of interdependence and threatens extended family support networks, harming social cohesion. The Investment Without Displacement network offers a clear understanding of how social equity and environmental goals overlap, aiming to keep deeply rooted communities in place, and getting people to drive less.65

Homelessness and climate impacts

The homeless population in the Bay Area is uniquely vulnerable to climate change and sea level rise. Given that they reside outdoors and frequently near bodies of water, they are on the frontlines of flooding impacts, heat emergencies and water shortages. Like residents of disadvantaged communities, homeless populations are experiencing a preview of impacts that will affect more of the population as the climate crisis progresses.

Many of the homeless population in the Bay Area have organized into ad hoc encampments with loose social and governance structures. Conditions are worse than refugee or disaster recovery camps. Ironically, because of how homeless populations are underserved, they may not have access to basic amenities such as running water, sanitation or adequate facilities for garbage and recycling. This can lead to a vicious cycle where trash can make its way into waterways, increasing flood risk and reducing water quality, then floods can sweep away more trash and possessions to further clog waterways and lead to more severe flooding. There are also frequent fires. To prevent these kinds of problems, the City of Oakland has begun regular trash collection at homeless encampments.67

Challenges faced by Bay Area First Nations

The majority of Tribes in the Bay Area are not federally recognized, nor do many of them have land bases, in the form of reservations or rancherias. The path to federal recognition and gaining a land base is a lengthy, costly, and complex process. Some Tribes have been engaged with this process for the last few decades if not longer. Take for example, the Muwekma Ohlone Tribe who has been engaged in the federal recognition process since 1995 and has yet to get recognized.68 In addition, the Federal Relocation Act of 1956, which was a part of the larger Indian termination policy era, numerous Native Americans were moved to select U.S. cities, including San Francisco, San Jose, and Oakland. Many of today’s inter-tribal elders and their descendants in the Bay Area were relocated during these ‘efforts to force assimilation’.69 National statistics on Native Americans are alarming: one in four Native Americans live in poverty and face a unique set of health problems, including high rates of diabetes, alcoholism, and youth suicide.70

“We still have a whole history of colonization that we’re trying to heal from. Dealing with the trauma of that, and actually re-awakening a whole generation of people to the fact that they’re indigenous. That there are obligations to this land that we still have to do as indigenous people. We have to bring back those songs, those healing dances, that language back, so that we can actually engage the land again in the healing process. That’s not just for us, it becomes an obligation for us to deal with this for all the people that now live here.” —Corrina Gould (Chochenyo and Karkin Ohlone; Co-founder of IPOC and the Sogorea Te’ Land Trust)

There are research and ongoing initiatives that address historical and contemporary trauma through culture, community, and land as interventions.71 An example of this is through the Native American Health Center of the Bay Area and their work with evaluating “community-defined evidence-based practices”, which is a part of a larger movement, that affirms the effectiveness of cultural practices (which include traditional ceremonies, dance, and medicine) in increasing and cultivating the wellness of Native American communities.72 Indigenous communities in the Bay Area have expressed needs for reclaiming ancestral land and sacred spaces, having places to gather in community, heal, and practice culture, and places to practice subsistence and stewardship.
Bay Area
History and Context

Regional environmental setting

Evolution and formation of the San Francisco Bay
The San Francisco Bay is part of a larger estuary that extends from the South Bay, Central Bay, San Pablo Bay, Suisun Bay, and inner Delta (Figure 23). Geology, sea level rise, ocean and tidal currents, waves, rivers, sediment transport, and biology shape the shoreline of the San Francisco Bay. More recently, intense modifications by people, including the filling, draining, and diking of wetlands together with extensive urbanization and farming have transformed the Bay and its ecology.

Geology, topography, and tectonics
From a geologic perspective, the Bay is a very young feature. It formed less than 10,000 years ago, when rising seas entered the Golden Gate—a gap in the outer Coast Range—and interior valleys (Figure 22). The Bay’s varied geology has led to a varied shoreline. In some places steep ancient headlands thrust into the Bay and its deeper waters, leaving little room for intertidal habitats. Elsewhere, wide valleys and alluvial fans have filled with more recent alluvium, creating broad, gently sloping plains with wide intertidal zones occupied by mudflats, marshes, and salt pannes (Figure 23). The hills that frame the Bay generally run parallel to major fault lines, most notably the Hayward and San Andreas faults (the latter generating the famous 1906 San Francisco earthquake) (Figures 24 and 25).

FIGURE 22:
SHORELINE CHANGE OVER 15,000 YEARS.
Since the last ice age, the seas have been moving steadily up and inland. The rate of advance inland along marsh edges is mediated by local factors such as sediment supply, shoreline modification, and hydrodynamics (adapted from Cohen and Laws 1992).25
History & context

Climate

The San Francisco Bay Area experiences a Mediterranean climate, characterized by hot dry summers, and mild rainy winters. The diverse topography of the Bay Area creates numerous microclimates in the region, with varying amounts of wind, rain, fog and heat throughout the year. On average, between 1890 and 2010, the occurrence of large events in the San Francisco Bay Area increased based on regional rainfall patterns, and this trend is projected to continue with climate change (however, the magnitude of these trends will depend on local rainfall patterns since rainfall trends are very heterogeneous throughout the region). As climate change progresses, the Bay Area may experience warmer, drier summers and fluctuating wet winter conditions. The impacts of climate change will likely alter stream flows and could have negative implications on native fish species and other wildlife. Other climate change trends for the Bay Area may include increasing water temperatures, prolonged growing seasons and earlier snowmelt runoff.

Watershed processes:

freshwater delivery and sediment supply

The Bay is the downstream end of an extensive estuary, where salt water from the Pacific meets freshwater flowing down from the Central Valley and from dozens of local streams that fringe the Bay. In total, the water from nearly half...
With pronounced change in sediment supply likely to occur in the future and in the context of accelerated sea level rise, the Bay is now generally considered to be sediment-starved. This is problematic, because sediment carried into the Bay by rivers and creeks provides substrate for marsh development and is an important component in the transport of nutrients within the Bay ecosystem. Though the majority of freshwater (close to 95%) delivered to the Bay comes from the Central Valley, in recent years the majority of suspended sediment (>60%) has come from the smaller local tributaries. This represents a shift from historical conditions, when the Bay’s suspended sediment supply was dominated by contributions from the Central Valley (a change largely driven by the exhaustion of sediment flowing through the system unscarred during the Gold Rush, dam construction, and river armoring). This shift increases the need to rethink the interfaces between local creeks and bayland habitats as well as how we manage dredged sediment. Reconnecting creeks to existing or restored adjacent baylands would allow sediment from the watershed and sediment scoured from the channel to be distributed across the baylands area that has been “opened” to these flows, promoting the delivery of precious sediment to where it is needed most (Figure 5). However, it is important to keep in mind that there are limitations to how sediment can be used depending on contaminants that may exist within sediment sources. Permitting challenges may arise if sediment quality does not adhere to federal, state and local water quality regulations.

**Tidal processes**

The Bay experiences mixed diurnal tides, meaning there are two unequal high tides and two unequal low tides approximately every 25 hours. Mean range of tides (the difference between mean high water and mean low water) at the Golden Gate Bridge is approximately 5.5 ft. As one moves from there to the Delta along the northern axis of the Bay, tidal range generally decreases. By the time one reaches Sacramento, the tidal range has decreased to about 1 ft. The opposite happens when one moves from the Golden Gate bridge towards the South Bay. Because the South Bay is a closed basin, tidal range is amplified to 8.5 ft at its southern end. Variation in tidal range and tidal prism—a related measurement of the amount of water moving into and out of an area with the tides—impacts the quantity and quality of intertidal habitats. Tides transport nutrients, sediment, salt, and other materials to and from the baylands; create gradients of moisture and energy; and provide the physical means for fish and other aquatic organisms to move across tidal habitats at high tides. The spring-neap cycle, driven by the gravitational pull of the moon, leads to the highest (spring) and the lowest (neap) tides each month. The highest astronomical tides of the year, referred to as king tides, usually occur in the winter months and provide a proxy for visualizing higher water levels in the future with sea level rise.
Indigenous peoples’ ecosystem management practices

As far back as 15,000 years ago or possibly earlier, Native Americans inhabited the territory known today as California. As sea level began to move steadily inland approximately 10,000 years ago during the end of the last ice age, the indigenous communities living in the region adapted to the changing shoreline and developed an intimate knowledge of the natural processes and functions of the baylands. In the 1700s, before European colonists arrived, the Bay Area was home to diverse indigenous communities as evidenced by approximately 78 different languages and 42 Individual Tribes (Figure 7). At the turn of the 1800s, there were more than 400 shellmounds (places that held villages, ceremonial sites, burial mounds, and were points to communicate with neighboring Tribes) that could be found along the shores of the Bay. Many of the shellmounds lie next to the coastline. Although precise estimates are not available, anthropologists suggest that 20,000 to 25,000 indigenous people lived in the Bay Area sometime before European colonization. Native wildlife of the region, including mammals, mussels, oysters, fish, clams and water birds, were commonly harvested. Wild plants were also harvested including native fruits and nuts (such as acorns). Fire management was also used to shape the landscape to control food plant production and maximize game though it was unlikely to have had a major impact on the baylands ecosystem as a whole. It is important to consider the intergenerational nature of these ecological practices, which are still actively used by Indigenous communities in the Bay Area. Traditional Ecological Knowledge (TEK) can be described as “a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmissions, about the relationships of living beings (including humans) with one another with their environment.” This pool of knowledge can encompass Indigenous observations and narratives, which most often
History & context

Include intergenerational knowledge on resource management, patterns, and practices. TEK is an acknowledgement of the interconnectedness of all the things; and in doing so it provides a practical foundation for how individuals, families, and communities can be well and thrive on the land on which they are situated.

Change in historical baylands

Between 1800 and 1998, 79% of tidal marsh and 42% of tidal flats were lost to diking and filling (Figure 30). Today, urban development, agriculture, diked wetlands and managed ponds (including industrial salt ponds) dominate the baylands, a stark departure from historical conditions. Although the existence of tidal marsh and tidal flats has changed dramatically since the 1800s, the physical processes that drive Bay habitat formation have largely remained the same. Understanding the historical conditions of Bay habitats offers insight into the physical conditions and processes (e.g., elevation, slope, tidal prism, sediment deposition, fresh water flows, salinity gradients, etc.) that drive the success of habitat restoration and enhancement efforts in San Francisco Bay.

Approximately 200 years ago, before European colonization, the baylands were dominated by two primary habitat types: tidal flats (including mudflats, sandflats, and shellflats), which covered 50,000 acres, and tidal marshes (including salt and brackish marshes), which covered 190,000 acres. Extensive tidal marsh habitat existed along the margins of the North Bay, South Bay and Suisun Bay, with small pockets of tidal marsh in coves and protected areas in the Central Bay and Carquinez Strait. Tidal flat habitat existed in each of the Bay’s four subregions, but the extent differed largely based on salinity levels because, under freshwater conditions, marsh vegetation tends to grow lower in the intertidal zone, reducing the width of the unvegetated flats. Suisun, the subregion with the largest freshwater influence, had little tidal flat habitat compared to the South Bay, the subregion with the highest salinity, which had a large portion of the Bay’s tidal flat habitat. Tidal flats also existed in portions of the North Bay and Central Bay resulting from an active supply of sediment and an environment that promotes sediment deposition. Other important historical baylands habitat types included sandy beaches, marsh pannes, tidal channels, and lagoons. The baylands also had strong connections to deeper subtidal habitats (such as eelgrass meadows, shellfish beds, and shoals) and upland habitats (such as riparian corridors, willow groves, wet meadows and vernal pools, and oak savannas), creating transition zones up to several miles wide that provided critical habitat, resources, and high-tide refuge for many species.

In the 1850s, the diking and draining of tidal marshes around the Bay became common practice to make land for agriculture and salt production. As the population of the Bay Area grew throughout the 1900s, the filling of baylands to create land for development also became commonplace, leading to large losses in tidal marshes and tidal flats. A legislative moratorium against filling the Bay was passed in 1961, which led to the creation of the Bay Conservation and Development Commission, a permanent state agency that regulates development along the shoreline. Although stricter environmental regulations to protect the baylands evolved between the 1960s and 1990s that slowed losses in tidal

Figure 29: Historical Habitat extent of the San Francisco Bay Estuary (circa 1800).
marsh and tidal mudflat habitat, significant losses had already occurred. By 1998, approximately 150,000 acres of tidal marshes and 21,000 acres of tidal flats were lost compared to historical conditions (ca. 1800). The remaining tidal marshes have generally become more fragmented and isolated, arranged in smaller patch sizes than were found historically with less “core” habitat, situated farther from other patches, and leveed off from upland habitats. These changes in habitat configuration likely reduce the quality of habitat for wildlife, compounding the problem of overall habitat loss.

Habitat loss and degradation is worrisome because the baylands provide some form of food, shelter, or other benefits to approximately 500 species of fish, amphibians, reptiles, birds, and mammals, and at least as many invertebrate and plant species. At least 90 species of plants and animals found in the nine counties that border the Bay are endemic. At least 90 species living in and around the Bay are also listed as threatened or endangered under the Endangered Species Act. Among the most iconic of these species are the Ridgway’s Rail and Salt Marsh Harvest Mouse—the conservation of these two species motivated much of the initial efforts to preserve and restore bayland habitats. The Bay is also a key location on the Pacific Flyway for migratory birds and a nursery for Dungeness crab, halibut, and Pacific salmon fisheries.

Although vast wetland areas have been lost since the 1800s, Bay wetland restoration efforts have significantly progressed since the inception of the 1999 Baylands Ecosystem Habitat Goals Project (Goals Project) and the more recent 2015 Baylands Ecosystem Habitat Goals Science Update (Science Update), which recommended reestablishing 100,000 acres of tidal wetlands in the Bay. Since the publication of the original Goals Project, approximately 12,000 acres have been restored and an additional 30,000 acres are in the process of being restored (Figure 30). The Science Update identifies the latest scientific findings and recommended actions to support continued restoration and ecological enhancements in the face of increasing challenges from climate change and other urban stressors. Following the key guiding principles of the Goals Project, resilient ecological systems should be self-maintaining and highly functional, support native species over non-natives, and prioritize biological communities over individual species. In 2016, voters in the nine Bay Area counties approved a $12 parcel tax, known as Measure AA, to fund over $500 million of bay enhancement and habitat restoration projects over the next 20 years, beginning in 2018. Measure AA funding will further Bay wetland restoration and work towards improving the ecological integrity of the baylands.

Figure 30: Habitat extent of the San Francisco Bay Estuary in 2009.
The San Francisco Bay (as we know it today) began to form approximately 10,000 years ago when the planet experienced a period of warming that marked the end of the last ice age. Mudflats and tidal marshes first formed around the edge of the Bay approximately 2,000 to 3,000 years ago.15

10,000 years ago

15,000 years ago

For 15,000 years or possibly longer, Native Americans inhabited the Bay Area, with the territory known today as California. Estimates by anthropologists suggest that the Bay Area was one of the most densely populated regions in North America. Although exact numbers are not available, 20,000 to 25,000 Native Americans likely inhabited the area before European settlers arrived.16,17

1850s

The digging and draining of tidal marshes around the Bay started in the 1850s and 1860s to create land for agriculture and salt production. This practice is the main reason for the significant decrease in size of the Bay from historical conditions. Many of the agricultural areas adjacent to the baylands were converted to residential and industrial uses in the 20th century due to population growth.18

1900s-1950s

Throughout the first half of the 1900s, the Bay was generally considered a dumping ground for trash. Trash dumps located at the edge of the Bay became commonplace. Many still exist as landfills. Industrial, waste, trash, and agricultural runoff draining into the Bay led to significant water quality degradation, threatening the health and survival of species at all levels of the Estuary’s food web.19,20

1930–1950

Racially restrictive land covenants. Land covenants restricting ownership of property by race are commonplace. Many of these land covenants have not been removed from current deeds and other documentation.21

1950s

By the 1950s, approximately 50,000 acres of tidal marsh remained in the Estuary, about one-quarter of the historical tidal marsh extent (Bayland Goals 1999). Habitat losses of this scale contributed to population declines of native fish and wildlife species that inhabit or rely on the baylands such as the Ridgway’s rail, California least tern, and Chinook salmon.22

1970s

The environmental movement began in the 1960s with the advent of Rachel Carson’s “Silent Spring” and gained momentum through the 1970s with the inception of federal environmental regulations. The Clean Water Act was passed into law in 1972 to address growing public concern about water pollution. Shortly thereafter, in 1973, Congress passed the Endangered Species Act to protect native plants and animals in danger of becoming extinct.23,24

1998

By 1998, approximately 79% of tidal marsh and 42% of tidal flats had been lost to diking and filling. Tidal habitat restoration efforts in the Bay accelerated upon completion of the 1999 Baylands Ecosystem Habitat Goals Project. This was the first comprehensive vision of how to restore the baylands ecosystems. This report recommended a target of 100,000 acres of bay tidal marsh, a goal that continues to guide restoration projects today.25

2002

The South Bay Salt Pond Restoration Project began in 2002 to restore much of the converted salt ponds in South San Francisco Bay back to tidal marsh. When complete, the project will restore approximately 15,100 acres of tidal marsh, mudflat, and other wetland habitats.26

2007–2010

Mortgage crisis (and disproportionate impact on communities of color) 2007–2010. Following a legacy of inequitable housing access, communities of color are hit particularly hard by the impacts of the subprime mortgage crisis.27

2015

In 2016, voters in the nine Bay Area counties approved a $13 billion tax to fund over $500 million of bay enhancement and habitat restoration projects over the next 20 years. Following the 1989 report, the Baylands Ecosystem Habitat Goals Science Update, published in 2015, outlined new habitat restoration and enhancement guidelines to add to the original 1999 report. The Update incorporates the latest scientific understanding of climate change and other key drivers to maintain a resilient bayland ecosystem through 2100.28

Present

The Bay Area faces many challenges from sea level rise and other climate related issues that threaten critical infrastructure (e.g., roads, railroads, wastewater treatment plants, sewers, systems, etc.), vulnerable communities, and important ecosystem functions. The Resilient by Design competition comes in an era marked by adaptive management, multi-benefit infrastructure, and re-envisioning our relationship to the baylands in an effort to support and adapt to a changing Estuary.
Environmental justice and resilience in the bay area

The Bay Area has a long and rich history of grassroots racial, social, and economic justice organizing that has won many victories, helped launch the national movements, and has brought about systemic changes in industry and government policies and practices. In considering the Bay Area context, it is important to touch on the history of key environmental justice fights in the region.

In the mid 1980s, the movement for environmental justice began to take its current shape in the Bay Area and across the country, with advocates fighting a long-standing pattern of systemic racism in the siting of toxic facilities in their communities, and the resulting impacts on health. As individual communities around California and around the country began to challenge the companies, policies and decisions that led to environmental pollution in local neighborhoods, in 1987 the Commission on Racial Justice of the United Church of Christ (CRJ-UCC) released a landmark report, "Toxic Wastes and Race in the United States," which documented the racial and socio-economic characteristics of communities where hazardous waste sites were located. This document served as a powerful tool to highlight what communities fighting these issues across the country had asserted for decades – the disproportionate impact of pollution on communities of color and the need for addressing systemic racism in the siting of toxic facilities. More recently, the CRJ-UCC has noted that, "Climate change and global warming bring an additional peril to communities of color or poor communities all over the world. Many who live near the coasts or in lower-lying areas will be the first to feel the effects of rising temperatures and oceans. They will not have the resources to make choices that others can make and may lose their homes and their livelihoods and will be displaced as environmental refugees." The environmental justice movement has worked not only to confront racism in government policies and industry decisions leading disproportionate impacts of pollution on low income communities, but also to highlight the failure of many environmental organizations to address these issues. In 1991, community leaders and grassroots activists from the Bay Area and across the country participated in the First National People of Color Environmental Leadership Summit in Washington DC. They joined in drafting and adopting the Principles of Environmental Justice. Since then, The Principles have served as a defining document for the growing grassroots movement for environmental justice.

The preamble of The Principles stated clearly why so many people from diverse communities and Native Nations united to launch a national movement:

WE, THE PEOPLE OF COLOR, gathered together at this multinational People of Color Environmental Leadership Summit, to begin to build a national and international movement of all peoples of color to fight the destruction and taking of our lands and communities, do hereby re-establish our spiritual interdependence to the sacredness of our Mother Earth; to respect and celebrate each of our cultures, languages and beliefs about the natural world and our roles in healing ourselves; to ensure environmental justice; to promote economic alternatives which would contribute to the development of environmentally safe livelihoods; and, to secure our political, economic and cultural liberation that has been denied for over 500 years of colonization and oppression, resulting in the poisoning of our communities and land and the genocide of our peoples, do affirm and adopt these Principles of Environmental Justice.

Environmental justice successes around the bay

Cleaning up toxic sites near homes and businesses and protecting communities against future risks is often a decades-long effort, placing a significant burden on local community leaders and neighborhood-based organizations to hold political and industry leaders accountable. Bay Area environmental justice organizers have persisted throughout the last few decades to ensure that accountability. These efforts have built up networks of activists and community leaders working to ensure development, adaptation and restoration projects incorporate community concerns and protect the region’s most vulnerable residents. Examples of successful efforts include communities of color in Bayview-Hunters Point in San Francisco, who began organizing to confront government agencies and private industries that contributed to the many pollution sources plaguing their community to go unaddressed in the early 1980s. Their efforts eventually lead to the closure and cleanup of the PG&E Hunters Point power plant in 2006 after years of sustained effort. During this time fights also sprang up against oil refineries, chemical plants and other polluting industries in the East Bay, from West Contra Costa County to Richmond to continued efforts, through both advocacy and legal action, to reduce the toxic impacts of Bay Area refineries. In West Oakland earlier this year remediation finally began on the AMCO Chemical Superfund site, almost 30 years after it closed. And along with mitigating the negative impacts of existing refineries, local community leaders are working proactively to move toward cleaner and more sustainable energy sources, to both reduce local air pollution impacts and reduce the overall climate impacts of fossil fuels.
history of local community members tenaciously advocating for protecting their community’s access to nature and open space, throughout years of development threats.139 “Everybody neglects the need of low-income communities to access to quality of life,” says Mr. Dotson, remembering the community using the adjacent open space for fishing, swimming and nature viewing.140

Now the restored marsh is designed to be a self-sustaining wetland complex that will filter polluted run-off and provide high quality habitat for threatened and endangered species. The park addition is designed to accommodate for sea-level rise resulting from climate change through 2080. This includes infrastructure design such as elevated trails and planning wildlife habitats so that even if some areas are submerged, the area can still sustain diverse species. The final restored area will also include interpretive exhibits and a 1.5-mile extension of the San Francisco Bay Trail, helping to close the remaining 10 miles of Bay Trail gaps within Richmond’s current 32 miles of existing trail, and providing the first safe, non-motorized access to Point Pinole Regional Shoreline.141

Groups led by indigenous peoples in the Bay Area have built movements to advocate for the return and protection of native lands and for environmental remediation. In 2016, approximately 150 years after the Kashia Tribe in Sonoma County were forced to retreat inland to a tiny, water-poor reservation of just over 40 acres, the newly established Kashia Coastal Reserve restores ownership of coastal lands to the Kashia, protects important cultural sites, and provides a place to connect present and future generations of the Kashia with their heritage. The Tribe will manage the property as a demonstration forest and as a gateway for educating and engaging the public about the history and practices of native people in the area.142

The California Indian Environmental Alliance (CIEA) coordinated the language development and Tribal engagement of two new statewide beneficial uses which can protect water quality standards under the Clean Water Act: “Tribal Cultural Uses” and “Tribal Subsistence Fishing.” These were adopted by the State Water Resources Control Board and approved by the EPA in 2017.

Looking toward the future

As a result of the power and victories of the environmental justice movement, environmental justice is recognized in many jurisdictions as a legal designation. In California law, “Environmental Justice” is defined as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies. (Cal. Gov. Code, § 65040.12, subd. (e).) However, even where explicit environmental justice policies are present, implementation of and compliance with these policies and laws remains mixed.

More recently, environmental justice groups in the Bay Area have turned to climate adaptation planning to assert the values of climate justice. According to Breakthrough Communities, “a global climate justice movement is emerging, demanding fairness in the distribution of the benefits and burdens of climate change processes.” In step with this international movement, many social and environmental justice organizations in the Bay have become active in advocating for climate justice, equitable adaptation, and inclusive resilience planning advocacy. Likewise new groups and coalitions have formed to address the climate and flooding challenges of disadvantaged and environmental justice communities, including advocacy on hazard mitigation, flooding and emergency preparedness.
current conditions & Future Threats

Current ecosystems and ecological vulnerabilities

Bayland habitats and ecosystems

The tidal marshes, tidal flats and native wildlife are integral pieces of the San Francisco Bay's identity and provide multiple benefits to the region. Recreational value, flood protection, clean water, wave attenuation, and abundant wildlife support are some examples of the additional value the Bay's estuarine ecosystems provide to the people and wildlife in the region. Significant change has taken place along the Bay shore. Much habitat has been lost, novel ecosystems such as diked wetlands and agricultural baylands have been created, and processes that sustain the baylands — such as sediment transport to build marshes and freshwater delivery to maintain gradients that promote biodiversity — have been disrupted. Changes in climate, with likely associated greater frequency and severity of storms, flooding, droughts and heat waves will further stress Bay ecosystems and their food webs.

Invasive species

As one of the most heavily invaded estuaries in the world, invasive species are a large ecosystem management concern in the Bay. Invasive species, which refer to non-native plant and animal species which often possess characteristics (i.e., fast growth, quick maturation, large numbers of offspring) thought to damage native ecosystem dynamics by overwhelming and displacing native species. With the potential to change habitat structure and outcompete native species for resources, invasive species can lead to conversion of native habitats to low-quality habitat types and dramatic reductions in endemic species populations. Some of the most notable species in terms of impact on the Bay ecosystem include non-native cordgrass (Spartina alterniflora) and Asian clam (Potamocorbula amurensis). Spartina alterniflora was introduced from the east coast and has proliferated in the Bay by converting mudflat and small tidal channel habitats to dense marsh of generally low habitat value to many native species. In 1986, Potamocorbula amurensis was introduced in the Bay and, since its filter feeding exceeds phytoplankton production rates, primary productivity levels experienced five-fold reductions in low-salinity areas within one year, dramatically altering ecosystem structure. Although most invasive species are challenging to eliminate completely, long-term management efforts should outline strategies to reduce or control invasive species in Bay ecosystems to protect endemic species. Climate change presents additional challenges and unknowns with invasive species management since changing environmental conditions (e.g., air and water temperatures, Bay salinity and suspended sediment concentrations etc.) could lead to an expansion in habitat range for invasive species as well as less suitable habitat conditions for endemic species.

How will climate change impact the viability of both endemic and invasive species?
Natural processes governing the bayland habitats and ecosystems

Tidal baylands are dynamic and depend on their sustaining and interacting processes. Understanding and managing for these processes is of high importance as sea level rise becomes an increasing threat to bayland and marsh loss.

The dominant processes that govern the distribution of the complete tidal marsh ecosystem in space and time primarily include the rate of sea level rise, the supply of sediment, local topography, subsidence, wave energy, space for migration, and resident plant communities.

Processes that sustain or degrade marshes

Some definitions related to sustaining or degrading processes:

**Migration:** Movement of baylands to higher elevations, determined by rate of rise in sea level, supply of sediment, existing vegetation, local elevation gradients, hydrology and subsidence of marshlands.

**Erosion:** Loss of sediment from the outer surface of baylands; wave energy drives erosion typically at the border between tidal flats and subtidal area.

**Progradation:** When marshes and mudflats accrete sediment and organic matter, they horizontally extend into subtidal areas. The rate of this process depends on the rate of erosion, sediment supply and biological interactions.

**Drowning:** Wholesale loss of baylands due to submersion of lower elevation tidal habitat, resulting in habitat change (typically referring to change from tidal marsh to tidal flat, or tidal flat to subtidal habitat).

**Accretion:** Related to progradation, except referring to the vertical raise of tidal wetlands as a result of both organic and inorganic matter and sediment (similarly this refers to the conversion of tidal flat to tidal marsh or subtidal habitat to tidal flat).

As a side note, managed marsh systems that are not subject to equivalent tidal processes do not behave equivalently. Diked baylands, where water levels are heavily managed, do still endure subsidence and erosion. However, levees and water control structures constrain the resilience of these systems given their isolation and heavy modification. Disconnection from both sediment supply networks and exchange associated with tidal action may constrain these systems' capacity for adaptive change.150

**Components of a complete Baylands ecosystem**

The baylands comprise a broad spectrum of habitat types. The full gradient encompasses subtidal eelgrass and oyster beds, tidal flats, tidal wetlands and the estuarine-terrestrial transition zone. Clearly delineating where one habitat ends and another begins is a challenging exercise, as these ecosystems exist based on complex and heterogeneous environmental gradients. Considering the ecosystem in totality, or as a “complete tidal wetland system,” is useful (Figure 31). This way, the individual constituent habitats, their ecotones and their synergy in provision of ecological functions and services are all illustrated.152

Managed habitats, not described in full detail here, also can provide significant habitat value. These habitats, which include diked baylands, and managed ponds, cumulatively make up nearly 95,000 acres according to 2009 estimates. Managed ponds, in particular, can support abundant wildlife such as waterfowl. These habitats should also be considered when managing for complete tidal wetland systems.151

**Subtidal habitats**

Deep bays and channels can generally be characterized as the deepest portions of the Bay to 18 feet below mean lower low water (MLLW), while shallow bay and channel habitat transition from this point to the lowest elevation of the diurnal tides (MLLW).149 The bay leans shallow — shallow water habitats make up about two thirds of the subtidal area, while deep bay habitat comprises the remaining third. These habitats serve as important habitat for large aquatic invertebrates, water birds and some marine mammals, and are used as migratory corridors by anadromous fish. Eelgrass beds exist in shallow bay habitats, which provide critical habitat many species of fish, invertebrates and birds, including spawning grounds for the Pacific herring and feeding grounds for least terns. The subtidal habitats (e.g., oyster beds and eelgrass) found in this zone also provide important regulatory processes by breaking up wind waves, acting as a protective buffer to other surrounding inland tidal
Tidal flats (mudflat)

Tidal flats exist between the lowest elevations of the tides and Mean Tidal Level (MTL), and range from sandflats, mudflats and shellflats depending on existing sediment, with mudflat being the most common. According to 2009 estimates, tidal flats encompass about 34,000 acres around the bay,160,161 and occur more often in saline compared to brackish area.162 Tidal flats are inundated twice daily by the tides, creating foraging habitat for different species during different parts of the day depending on inundation levels. Mudflats are colonized by a variety of invertebrates. Sturdy Rounder, staghorn sculpin, longfin smelt and many other species of fish feed in this area during periods of high tide. During low tide, this zone becomes prime foraging grounds for shorebirds like the western sandpiper, dunlin and semipalmated plover. Wind waves and tidal action cause sediment resuspension and delivery in this zone which provides a means for marsh accretion and critical material flows between habitats. Mudflats also act as a buffer by attenuating wind waves before they reach adjacent tidal marsh.162 The movement of this habitat will depend on the rate of sea level rise, sediment supply, vegetative structure and wind.161,162

Tidal marsh

Tidal marshes are wetlands in which inundation is governed by the tides. This habitat type is found in baylands between mudflats and the highest tidal extent, as well as the tidal-influenced sections of streams. Plant communities in this habitat type are driven by a variety of factors as discussed previously, including but not limited to salinity, rate of sedimentation, erosion and wave energy. Salinity is higher in the North, Central, and South bays, while more freshwater input creates more brackish tidal marsh in Suisun, stretches of the Petaluma and Napa rivers, as well as portions of the South Bay. Marsh extent varies by salinity, occurring lower in the intertidal zone in fresher waters. Tidal marsh is located in its largest patch in San Pablo Bay and the Petaluma River, and is relatively absent in the Central Bay.161

According to 2009 estimates, over 44,000 acres of tidal marsh habitats exist around the Bay.160 These habitats can generally be considered in three zones delineated by tidal elevation and distance from shore. Low tidal marsh is found between the bayward marsh edge and mean high water, serving as marsh interface with the tidal flats and experiencing the highest levels of salinity. This area is frequently dominated by Pacific cordgrass. Middle marsh (marsh plain) is found in the intermediate zone, between mean high water and the even higher Mean Higher High Water. This plain is comprised of such vegetation as pickleweed and marsh gumplant. High marsh is found from this latter boundary to the highest margin of the marsh. The high marsh serves as an ecotone and transition into the adjacent uplands. Elevation drives the local extent of these zones – in higher slope areas such as the Central Bay, the zone is quite narrow, while in lower gradient areas such as Suisun, the zone could be longer than several hundred yards.164

Tidal marshes have a variety of important components including tidal

channels and, sometimes, pans or pannes (natural ponds in the marsh plain). Tidal channels are filled as tides rise. Large channels often have smaller tributaries that spread water throughout the marsh. Channels tend to be more sinuous in flattter marshes, and denser in more saline marshes. Tidal marshes are zones of significant productivity. Such areas provide nursery habitat, food and refuge for a variety of fish and wildlife. The marshes of San Francisco Bay are also particularly unique in their biodiversity – high levels of endemism are present in these communities. Fish species vary by locale – gobies, sculpin and three-spined stickleback are found in the North Bay, while topsmelt, gobies and staghorn sculpin are found in the Central and South Bay and smelt and salmon are found in Suisun. Bird species associated with these habitats include California black rail, Northern Harrier, Great Egret, as well as the Alameda, San Pablo and Suisun song sparrows. Small mammals include the salt marsh harvest mouse, salt marsh wading shrew and Suisun shrew. Larger predators such as coyote occupy middle and high marsh. Even harbor seals spend time in tidal marsh, in particular in the South Bay. Tidal marshes provide many important services, including carbon sequestration,167 pollution and nutrient filtration/absorption, as well as protection from storm surge and flooding. Tidal marsh migration will depend on the rates of sea level rise and accretion of inorganic and organic matter.
soil type and vegetation association. Further, the t-zone itself evolves and migrates over time. With sea level rise, current uplands will become future marshlands in areas of shallow-sloped topography. Managing land use to buffer t-zone migration space and managing sediment supply for wetlands reinforcement will help ensure resilient future complete tidal marsh ecosystems. 

The t-zone provides numerous ecosystem services: buffering - pollution control, invasive species control, erosion control; flood risk management; sea level rise accommodation as discussed; groundwater recharge; carbon sequestration; and support for wildlife - refuge from tides and predation, movement across habitat types and landscape complexity to support diversity. The exchange of freshwater to saltwater creates a gradient that promotes biodiversity. Many species of terrestrial and aquatic wildlife, including birds of prey and salmon, move between the baylands and its local watersheds. This link between baylands and local watersheds is important in provisioning many ecosystem services, including exchange of resources such as water, sediment, energy, plants and other animals. 

Adjacent uplands take many different habitat forms and comprise a mosaic depending on local geography and diverse vegetation is supported. Some common habitat types include riparian forest and willow groves along streams, and vernal pools, grasslands, oak savanna and woodlands and mixed evergreen forest. Upland habitats are an integral part of the baylands ecosystem as they provide important foraging, roosting, and breeding habitat for many species of amphibians, reptiles, birds, and small mammals that frequent the baylands. Uplands provide many similar services to the t-zone, including carbon storage in soils and vegetation, fresh water supply, flood risk reduction downstream, and production of wood and food such as cattle.

Future threats to ecosystems

The baylands face numerous, severe threats in the coming decades. The region’s ecosystems and the processes that sustain them have been lost, fragmented or degraded. Habitat loss and fragmentation continues under development and land conversion, and degradation continues with the spread of invasive species, emission of pollutants, and disruption of sustaining processes such as sediment and freshwater delivery. As a result, threatened and endangered species, as well as a general abundance and diversity of native wildlife are under threat. Climate change, driving rising sea levels and increased frequency and severity of stressful weather events and disturbances, threaten ecosystem integrity. The many services provided by our ecosystems – ranging from flood protection to pollution control – are at risk as a consequence.

However, opportunities remain. Large-scale re-conversion efforts of salt ponds are occurring in the South Bay to restore vast acreage of lost tidal marsh, and more opportunities remain for future acquisition and restoration. Disrupted processes, also, can be improved. The use of dredged sediment for engineering, navigability or flood control projects can be delivered downstream to help build marshes at the Bay’s edge. Planning with foresight to address these threats by considering t-zone geography, holistic management across habitat types, sediment supply and freshwater delivery will create the most resilient future baylands.

Social vulnerability

Social vulnerability

The terminology related to social vulnerability varies. In the context of hazard mitigation and resilience planning it often applies to populations with less capacity to prepare for, respond to, and recover from a harmful event, such as a flood. Examining social vulnerability indicators can be a powerful tool for developing climate resilience solutions that create positive outcomes for vulnerable communities. Assessing social equity to understand climate risk is complementary to environmental justice movement.

Approaches to understand and classify social vulnerability vary. Some of these approaches include map-based screening tools, which identify geographic locations with populations that exhibit characteristics of heightened vulnerability. Each of the screening tools includes data about population characteristics, and some include environmental hazard data. These data sets and associated viewers are primarily used in research and planning. In some cases, vulnerability designation is tied to funding sources. These tools represent just one method to locate areas that may need support and it does not serve as a comprehensive description of communities.

Social vulnerability screening tools and application to sea level rise in the SF Bay Area

Screening tools exist to help identify locations where more attention may be needed. Critical consideration in choosing the best vulnerability screening tool to use is necessary, as they are not all intended for the same use. Each has been designed to answer different research and policy questions. A description of these tools, their intended purpose, and where to access the data are included.

For evaluating social vulnerability to sea level rise, it is important to collect the data that is specifically relevant to flood risk. The San Francisco Bay Conservation and Development Commission (BCDC) Adapting to Rising Tides (ART) Program has created such a dataset through extensive stakeholder input and research, described in Section C. The data represents characteristics of individuals and households that may affect ability to prepare for, respond to, and recover from a flood event.

The BCDC social vulnerability dataset—Community Indicators for Flood Risk—makes calculations and determines thresholds based on data from the nine-county bay area region. Many of the other tools work at the state or national scale, and therefore generate percentiles of vulnerability for a given location relative to the rate in the state or country. When working with score-based tools such as looking at income, housing costs—it is more accurate to compare Bay Area geographies with Bay Area geographies.

It is important that methods of computation used in the screening tool are clear and that the full range of data is available to the user—not just the data
points which have met the screening tool's threshold or are above a certain percentile. In particular, local-scale analyses will benefit from having full access to the complete data to meet their diverse needs. Conducting supplemental analysis to the screening analysis can provide a more comprehensive understanding. The screening tools generate a total vulnerability “score,” which may or may not satisfactorily represent vulnerability in any given location. Access to each individual data point may be beneficial in clarifying and deepening understanding. In some screening tools, the user is unable to disaggregate the data points, or unable to access the full dataset.

BCDC community indicators for flood risk:

Background and use:
The Resilience Program at the Association of Bay Area Governments and Adapting to Rising Tides (ART) Program at San Francisco Bay Conservation and Development Commission partnered on the 2015 Stronger Housing, Safer Communities project to better understand and characterize housing and community vulnerability to flooding and earthquakes, and to develop strategies to reduce these vulnerabilities. An advisory committee of recognized experts, including community advocates, developed criteria for vulnerabilities and strategies based on professional experience, local knowledge, and consultation of academic and federally sponsored research. Indicators were developed as a regional screening tool to help identify neighborhoods where community members may be at greater risk. This approach does not, however, reflect qualitative characteristics that may increase or decrease risks, such as community cohesion and social capital (i.e., community capacity). The indicators for community vulnerability were updated in 2016, will undergo another round of stakeholder review as part of the current ART Bay Area project, and will be continually updated as social vulnerability knowledge evolves. The total number of characteristics may increase depending on working group input and improvements in data availability. This methodology is appropriate for local to regional scale planning, but should not be used for project reviews or environmental assessments.

Description of data:
The Community Indicators for Flood Risk data is comprised of population characteristics uncoupled from environmental hazards. This allows for flexibility in evaluating exposure to a variety of hazards. Depending on the project, different overlays of sea level rise, FEMA flood zones, location of brownfields, and other flooding-related hazards can be applied to this community dataset. Indicators were measured and analyzed using a triggering level methodology developed by the Metropolitan Transportation Commission (MTC) to identify Communities of Concern (CoC). The triggering level methodology identifies US Census block groups that have a concentration of individuals or households with a particular characteristic. The triggering levels, which are reported as a percentage, are determined for each indicator by calculating the regional mean + ½ standard deviation. ArcGIS layers for each indicator are available for use in mapping and analysis and can be downloaded from the ART Program’s Maps and Data Products page. For each block group, the layers contain the total count

### RESEARCH QUESTION
What will be the lasting impacts of this challenge? What types of community capacity building could be achieved?

### Community Vulnerability and Sea Level Rise in the Bay Area

**Number of Indicators:**
- 3 - 4
- 5 - 6
- 7 +

**Inches of Sea Level Rise:**
- 12
- 66

Community indicators represent characteristics that may reduce ability to prepare for, respond to, and recover from flood event.

**10 Indicators include populations or households which are:**
1. Renters
2. Under 5
3. 75 and over
4. Very low income
5. Without a vehicle
6. Communities of Color
7. Housing cost burdened
8. Limited English speaking
9. Transportation cost burdened
10. Without a high school degree
of individuals or households with each indicator, the total population and number of households, the percentage of individuals or households with each indicator, and whether the percentage is at or above the triggering level (1=has met trigger, 0=has not), as well as the reliability of the data for each indicator (1=reliable, 0=not reliable). Reliable data is defined as having a coefficient of variation less than 40%. The database includes data as it was received from the census, so that other types of analyses can be performed in addition to the threshold screening methodology described above. Local-scale analyses will benefit from having access to all data, and not only those which have met the threshold.

The table below provides information about each indicator, including the measure used, the source of data, and the triggering level (reported as a percentage). In addition, an unweighted score of 1 was assigned to each indicator for use in composite mapping of block groups with 3 or more indicators.

**Additional community vulnerability screening tools:**

- **US Environmental Protection Agency EJSCREEN:** Background and use: Under Executive Order 12898, Federal Actions To Address Environmental Justice In Minority Populations and Low-Income Populations, all federal agencies “collect, maintain and analyze information assessing and comparing environmental and human health risks borne by populations identified by race,
current conditions & Future Threats

EJSCREEN includes 11 indicators for environmental hazard, 6 demographic indicators, and 11 environmental justice indexes, which combine each environmental hazard with demographic information. Data is reported out in percentiles, which are available both relative to the US and relative to each state. See tables below for data included.

EJSCREEN includes 6 indicators on demographics:

1. Percent Low-Income: The percent of a block group’s population in households where the household income is less than or equal to twice the federal “poverty level.”

2. Percent Minority: The percent of individuals in a block group who list their racial status as a race other than white alone and/or list their ethnicity as Hispanic or Latino. That is, all people other than non-Hispanic white-alone individuals. The word “alone” in this case indicates that the person is of a single race, not multiracial.

3. Less than high school education: Percent of people age 25 or older in a block group whose education is short of a high school diploma.

4. Linguistic isolation: Percent of people in a block group living in linguistically isolated households. A household in which all members age 14 years and over speak a non-English language and also speak English less than “very well” (have difficulty with English) is linguistically isolated.

5. Individuals under age 5: Percent of people in a block group under the age of 5.

6. Individuals over age 64: Percent of people in a block group over the age of 64.

Description of data:

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Metroplitan Transportation Commission Communities of Concern

Background and use:
The Metroplitan Transportation Commission (MTC) is the regional transportation planning, financing, and coordinating agency in the Bay Area, and developed the Communities of Concern (CoC) designation through a regional equity working group process. The CoCs can exhibit vulnerabilities now and to future growth impacts, and inform the equity analysis of Plan Bay Area 2040—the combined Sustainable Communities Strategy and Regional Transportation Plan for the San Francisco Bay Area, which works to reduce greenhouse gas emissions through transportation and land use required by SB 375, the Sustainable Communities Act (Chapter 728, Statutes of 2008). Additionally, in establishing local funding priorities for One Bay Area Grants, projects located in a CoC are “favorably considered.”

Description of data:
Communities of concern designation is given to census tracts that have a concentration of both minority and low-income residents, or that have a concentration of low-income residents and any three or more of the following six disadvantage factors: persons with limited English proficiency, zero-vehicle households, seniors aged 75 years and over, persons with one or more disability, single-parent families, and renters paying more than 50 percent of their household income on housing. Concentration thresholds are between the regional average and one standard deviation for each disadvantage factor. Data is from the US Census American Community Survey 5-year estimates for 2005–2009 and 2010–2014.

<table>
<thead>
<tr>
<th>Disadvantage Factor</th>
<th>Share of Regional Population 2009</th>
<th>Share of Regional Population 2014</th>
<th>Concentration Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minority</td>
<td>54%</td>
<td>59%</td>
<td>70%</td>
</tr>
<tr>
<td>Low-Income</td>
<td>23%</td>
<td>25%</td>
<td>30%</td>
</tr>
<tr>
<td>Limited English Proficiency</td>
<td>9%</td>
<td>9%</td>
<td>20%</td>
</tr>
<tr>
<td>Zero-Vehicle Household</td>
<td>9%</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Senior</td>
<td>6%</td>
<td>6%</td>
<td>10%</td>
</tr>
<tr>
<td>People with a Disability</td>
<td>18%</td>
<td>9%</td>
<td>25%</td>
</tr>
<tr>
<td>Single-Parent Family</td>
<td>14%</td>
<td>14%</td>
<td>20%</td>
</tr>
<tr>
<td>Cost-Burdened Renter</td>
<td>10%</td>
<td>11%</td>
<td>15%</td>
</tr>
</tbody>
</table>

Bay Area Air Quality Management District (Air District) Community Air Risk Evaluation (CARE) Program

There is a variety in the amount of air pollution, and therefore health impacts, that different communities around the bay endure. The goals of the CARE Program are to:

- Identify areas where air pollution contributes most to health impacts and where populations are most vulnerable to air pollution. CARE Communities are designated in geographic locations where there are concentrations of high atmospheric air toxic/particulate matter and sensitive populations (seniors, children, and low income). Online mapping tool and data: http://www.baaqmd.gov/plans-and-climate/community-air-risk-evaluation-care-program

- Apply sound scientific methods and strategies to reduce health impacts in these areas.

- Engage community groups and other agencies to develop additional actions to reduce local health impacts. (http://www.baaqmd.gov/plans-and-climate/community-air-risk-evaluation-care-program)

CA Department of Water Resources (DWR) Disadvantaged Communities (DAC) and Economic Distressed Area (EDA) Mapping Tools

Background and use:
CA Proposition 50 and Proposition 84, and the corresponding creation of Integrated Regional Water Management (IRWM) planning groups, significantly altered California’s approach to water management. As these programs evolved, a growing gap emerged between the activities of the traditional water community and the needs of disadvantaged communities and the people that live and work there. In response to these concerns, DWR initiated seven IRWM disadvantaged community grant projects, representing a diverse socio-economic landscape, to identify more effective means of engaging with and responding to the water-related needs of disadvantaged communities. The DWR Proposition 1 IRWM Disadvantaged Community Involvement Program is designed to ensure the involvement of disadvantaged communities (DACs), economically distressed areas (EDAs), or underrepresented communities (collectively referred to as DACs) in IRWM planning efforts. Grants awarded through Proposition 84 and Proposition 1 IRWM include requirements to benefit DACs and EDAs.

Description of data:
Proposition 84 IRWM Guidelines (2015) defines disadvantaged communities. Census Place, Census Tract, and Census Block Groups with annual median household income (MHI) less than 80% of the statewide level receive DAC designation, and census geographic areas with annual MHI less that 60% of the statewide level receive Severely Disadvantaged Communities (SDAC) designation. The tool used data from the US Census American Community Survey 5-year estimates for 2010–2014.

- DAC mapping tool: http://gis.water.ca.gov/app/dacs/
- DAC data download: https://d3-water.ca.gov/owncloud/index.php/s/xz1U3UA6VRV7tsQ/download
- DWR Proposition 1 IRWM Disadvantaged Community Involvement Program is designed to ensure the involvement of disadvantaged communities.
2. Unemployment rate at least 2 percent higher than the statewide average.
3. Low population density.

EDA mapping tool: https://gis.water.ca.gov/app/edas/

US Center for Disease Control Social Vulnerability Index (SoVI): Developed by the Geospatial Research, Analysis and Services Program in Agency for Toxic Substances and Disease Registry. SVI 2014 uses ACS 2010-2014 data and is available for counties. A previous version is available for 2010 Census Tracts. SoVI® uses the statistical procedure principal component analysis to generate social vulnerability scores. SoVI® is a comparative index and its scores are relative. The total SoVI® score is represented as a numeric value, but it has no inherent mathematical properties. Because the score is a relative score and not an absolute score it cannot be used to compare two places directly (e.g. a county with a SoVI® score of 10 does not have double the vulnerability of a county with a SoVI® score of 5). SoVI® scores are used to show the relative placement of a county relative to others on the continuum of scores with variable ranges. As such, SoVI® scores should be classified (e.g. by standard deviation) for mapping and analysis purposes or can be examined using percentile ranks. Explanation of methodology is available here: http://svi.cdc.gov

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1. Socioeconomic Status:
   - Below Poverty
   - Unemployed
   - No High School Diploma

2. Household Composition and Disability:
   - Aged 65 or Older
   - Aged 17 or Younger
   - Older than Age 5 with a Disability
   - Single-Parent Households

3. Minority Status and Language:
   - Minority
   - Speak English “Less than Well”

4. Housing and Transportation:
   - Multi-Unit Structures
   - Mobile Homes
   - Crowding
   - No Vehicle
   - Group Quarters

### Health Inequity and Outcomes Frameworks

Climate change, including sea level rise, will pose significant health risks, especially to vulnerable populations. The process of designing for increased community resilience provides important opportunities to mitigate risk, optimize adaptation and thereby not only prevent adverse health outcomes but also promotes health and related social outcomes.

Just as environmental inequities follow the geographies of vulnerable populations, so does health inequity. The Bay Area Regional Health Inequities

### Variables Used in SoVI®

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MGRENT</td>
<td>Median gross rent for renter-occupied housing units</td>
</tr>
<tr>
<td>MGEDAGE</td>
<td>Median age</td>
</tr>
<tr>
<td>MHSEVAL</td>
<td>Median dollar value of owner-occupied housing units</td>
</tr>
<tr>
<td>PERCAP</td>
<td>Per capita income</td>
</tr>
<tr>
<td>PPLRT</td>
<td>Average number of people per household</td>
</tr>
<tr>
<td>OAGED</td>
<td>Percentage under 5 years or age 65 and over</td>
</tr>
<tr>
<td>OASIAN</td>
<td>Asian population</td>
</tr>
<tr>
<td>OBLACK</td>
<td>African American (Black) population</td>
</tr>
<tr>
<td>OCIVL</td>
<td>Civilian labor force unemployed</td>
</tr>
<tr>
<td>OED2</td>
<td>Percentage over 25 with less than 12 years of education</td>
</tr>
<tr>
<td>QSEL</td>
<td>Population speaking English as a second language with limited English proficiency</td>
</tr>
<tr>
<td>QEXTRCT</td>
<td>Employment in extractive industries (fishing, farming, mining etc.)</td>
</tr>
<tr>
<td>QFEM</td>
<td>Female</td>
</tr>
<tr>
<td>QFEML</td>
<td>Female participation in the labor force</td>
</tr>
<tr>
<td>QFEMHL</td>
<td>Families with female-headed households with no spouse present</td>
</tr>
<tr>
<td>QHGSP</td>
<td>Hispanic population</td>
</tr>
<tr>
<td>QMOHO</td>
<td>Population living in mobile homes</td>
</tr>
<tr>
<td>QHISP</td>
<td>Native American population</td>
</tr>
<tr>
<td>QHISP</td>
<td>Housing units with no car available</td>
</tr>
<tr>
<td>QHISP</td>
<td>Population living in nursing facilities</td>
</tr>
<tr>
<td>QHISP</td>
<td>Persons living in poverty</td>
</tr>
<tr>
<td>QRENTER</td>
<td>Renters-occupied housing units</td>
</tr>
<tr>
<td>QRENTER</td>
<td>Families earning more than $200,000 per year</td>
</tr>
<tr>
<td>QRENTER</td>
<td>Employment in service occupations</td>
</tr>
<tr>
<td>QRENTER</td>
<td>Households receiving Social Security benefits</td>
</tr>
<tr>
<td>QRENTER</td>
<td>Unemployed housing units</td>
</tr>
<tr>
<td>QRENTER</td>
<td>Population without health insurance (COUNTY SoVI® ONLY)</td>
</tr>
<tr>
<td>HOSPITALS</td>
<td>Community hospitals per capita (COUNTY SoVI® ONLY)</td>
</tr>
</tbody>
</table>
Social cohesion

While vulnerability indicators can help prioritize community needs, a broader view of community assets and resilience is also critical. As Eric Klinenberg discusses in Heat Wave: A Social Autopsy of Disaster in Chicago, social cohesion can have a significant mitigating effect on the impacts of climate change on communities. His research showed that while overall communities that have less access to capital and adequate housing fare worse in extreme climate events, some communities that exhibit these same characteristics are better equipped to care for their most at-risk. The difference is the presence of social cohesion.\(^{116}\)

The influence of social cohesion on a community’s capacity for resilience is critical to consider in shaping climate adaptation interventions. Solutions that drive forces that make social cohesion more difficult—such as gentrification, may lessen the communities’ underlying resilience to acute shocks and chronic stressors. Conversely, climate adaptation design interventions that promote social cohesion may have additional benefits to resilience.
Natural and Nature-Based Climate Adaptation Strategies

Natural and Nature-Based Features

Considering the significant proportion of the Bay that is surrounded by marshes and mudflats and the significant efforts to restore these natural areas over the last 5 decades, there has been a considerable amount of attention paid to how these wetlands will evolve in the future and the role they may play in future adaptation strategies. The role of natural and nature-based features (NNBF) is being closely examined in the Bay and there are a number of pilot projects in the Bay that will provide useful information on how natural features may contribute to the resilience of the shoreline. The BCDC’s Innovative Wetland Adaptation Techniques Project (BCDC 2013) provides a recent overview of the role that the natural shoreline can contribute to adaptation strategies. For instance

Reduce nearshore wave energy

Low-created berms constructed from coarse gravel or oyster shell are potential alternatives to conventional offshore breakwaters, e.g., rock or concrete armor units. Berms would be able to adjust to rising sea level by naturally rolling landward, driven by wave forces. They may also enhance rather than conflict with ecological and aesthetic objectives. A pilot project is currently under way in San Rafael.

Stabilize with a coarse beach

Coarse beaches are a natural and very effective form of shoreline protection that adjusts to local wind-wave conditions, including those during extreme events. Unlike typical engineered revetment systems, such as riprapped levees, adjustments in beach morphology are an inherent characteristic of the coarse beach system and not an indication of failure.

Recharge mudflat and marsh

Many tidal marsh ecosystem services are a function of the elevation and inundation regime, and therefore are dependent on the marsh maintaining its position in the tidal frame. Vertical marsh accretion rates are dependent on the local supply of sediment. A number of methods have been suggested to increase the local concentration of fine sediment in the water column to support vertical marsh accretion. These recharging methods are not aimed at increasing the total sediment supply; rather the approach is to focus available sediment supply to specific locations.

Improve sediment pathways

Tidal channels link the baylands to the watersheds and Bay, acting both as pathways for nutrients and sediment and habitat for plants and wildlife. Natural, natural marshes tend to have complex dendritic channel networks; these have often been leveed and simplified. These channels convey turbid water into the marshes, allowing sediment deposition to occur at high water. The rate of vertical accretion therefore depends on the distance from a channel, and if channel density is low, parts of the marsh may be poorly supplied with fine sediment and thus have low rates of vertical accretion.

Increase transition zone

This measure creates an estuarine-terrestrial transition zone on fill slopes located landward of the existing tidal marsh and bayward of the flood risk management levee. There may be opportunities to fill man-made ponds (such as salt or oxidation ponds) located between the levee and the outboard marsh to avoid placing fill directly on wetland habitats. Transition zone slopes would create a habitat type that is missing in many parts of the Bay due to diking, and provide gently sloping uplands to allow for upland transgression, buffering the tidal marsh from coastal squeeze between a rising Bay and steep levee slopes.

Realign levees

Realignment of the flood risk management levee to a location further inland is complementary to the aforementioned transition zone slope measure as it provides additional space for upland transgression. Realignment would increase the distance between the Bay and shoreline development, allowing for the dissipation of wave energy over distances of several hundred feet or more and allowing the construction of much lower levees inland.

FIGURE 43: FRAMEWORK FOR STRENGTHENING SOCIAL RESILIENCE AMIDST CLIMATE CHANGE AND STORM EVENTS

- **Community Risk**
  - Decreases in community risk correlate with increasing social resilience and decreases in vulnerability.
  - Community risk is a function of hazard, vulnerability, and capacity. Decreasing hazard and vulnerability while increasing capacity will reduce community risk.

- **Strategies**
  - **Adaptation**
    - Increase Adaptive Capacity
    - Prevent physical injury
    - Prevent social isolation
    - Prevent immediate physical harm
    - Prevent social and economic harm
  - **Mitigation**
    - Implement emergency risk reduction measures
    - Reduce nearshore wave energy
  - **Engagement**
    - Community participation in decision-making and implementation of adaptation strategies
  - **Prevent**
    - Prevent loss of life
    - Prevent property damage

- **Impact**
  - Increased community resilience
  - Increased social resilience
  - Increased economic resilience

- **Factors**
  - **Social Networks & Stress Reduction**
    - Mental & physical wellbeing
  - **Factors**
    - **Access to Health & Social Services**
    - Safety
  - **Social Capital**
    - **Stewardship**
    - **Social Capital**
    - **Social capital**
    - **Social capital**
  - **Environmental Conditions**
    - Healthy environment
    - Health status
  - **Public Health Infrastructure**
    - Mobility/disability
    - Occupation
  - **Public Health Infrastructure**
    - Communication/connectivity
    - Access to emergency infrastructure

- **Strategies**
  - **Strengthening social conditions**
    - Community risk. Risk is a function of hazard, vulnerability, and capacity. Decreasing hazard and vulnerability while increasing capacity will reduce community risk.
  - **Adaptation capacity**
    - Preventing increased community risk that decreases social resilience or increases vulnerability.
  - **Engagement**
    - Community participation in decision-making and implementation of adaptation strategies
  - **Prevention**
    - Prevent loss of life
    - Prevent property damage

- **Impact**
  - Increased community resilience
  - Increased social resilience
  - Increased economic resilience

- **Factors**
  - **Social Networks & Stress Reduction**
    - Mental & physical wellbeing
  - **Factors**
    - **Access to Health & Social Services**
    - Safety
  - **Social Capital**
    - **Stewardship**
    - **Social capital**
    - **Social capital**
  - **Environmental Conditions**
    - Healthy environment
    - Health status
  - **Public Health Infrastructure**
    - Mobility/disability
    - Occupation
  - **Public Health Infrastructure**
    - Communication/connectivity
    - Access to emergency infrastructure

- **Strategies**
  - **Strengthening social conditions**
    - Community risk. Risk is a function of hazard, vulnerability, and capacity. Decreasing hazard and vulnerability while increasing capacity will reduce community risk.
  - **Adaptation capacity**
    - Preventing increased community risk that decreases social resilience or increases vulnerability.
  - **Engagement**
    - Community participation in decision-making and implementation of adaptation strategies
  - **Prevention**
    - Prevent loss of life
    - Prevent property damage

- **Impact**
  - Increased community resilience
  - Increased social resilience
  - Increased economic resilience

- **Factors**
  - **Social Networks & Stress Reduction**
    - Mental & physical wellbeing
  - **Factors**
    - **Access to Health & Social Services**
    - Safety
  - **Social Capital**
    - **Stewardship**
    - **Social capital**
    - **Social capital**
  - **Environmental Conditions**
    - Healthy environment
    - Health status
  - **Public Health Infrastructure**
    - Mobility/disability
    - Occupation
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Bayfront Regulatory Considerations

Largely due to the lack of environmental protections for much of the modern Bay’s history, major laws and regulations were passed protecting the Bay, the water quality within it, and the species that live around it. These were important for halting filling of the Bay (MacAttee Pets Act), halting the dumping of pollutants into the Bay (Clean Water Act), and protecting the endangered species that live in and around the baylands (Endangered Species Act). These laws, and others, drive many of the regulations and requirements that are necessary when making changes to the shoreline, or incoming water bodies. However, the threat of sea-level rise changes the needs and the context around the regulatory environment. As stated by Lubell 2017, “fragmented permitting and administrative procedures require substantial time...to complete, which may delay or block implementation, increase costs, or produce conflicting recommendations.”

Here is a synopsis of the major agencies at play along the Bay shore, their jurisdictions, and the laws and permit requirements that govern them. The complexities around the regulatory environment in the San Francisco Bay should not be understated, and must be understood when proposing designs.

The National Environmental Policy Act (NEPA) (all federal agencies) Requires federal agencies to assess the environmental impacts of their proposed actions and to avoid or mitigate those impacts.

California Environmental Quality Act (CEQA) (all state agencies) Requires state and local agencies to identify the significant environmental impacts of their actions and to avoid or mitigate those impacts, if feasible.

US Rivers and Harbors Act (USACE) Prohibits construction of obstacles to navigation of federal waters without federal congressional approval.

National Pollutant Discharge Elimination System (SWRCB, RWQCB) Protects federal waters from impacts of discharges of contaminants from point sources.

Clean Water Act Sections 404 and 401 (USEPA, USACE) Protects federal waters from the impacts of dredging and discharges of contaminants.

Waste Discharge Requirements (SWRCB, RWQCB) Protects state waters from impacts of point source discharges of contaminants exempt pursuant to Subsection 2090 of Title 27 and not subject to the federal Water Pollution Control Act.

Endangered Species Act (USFWS, NMFS) Provides permits to protect federally protected species of plants and wildlife, including anadromous and estuarine fishes.

McAttee-Pets Act (BCDC) Establishes BCDC as an regulatory agency charged with regulating fill and use of the Bay and bayshore.

San Francisco Bay Plan (BCDC) Details the policies that guide BCDC’s regulatory and planning work (i.e. bayfill, public access, climate change, etc.) and maps that show these policy applications around the Bay and bayshore.

Endangered Species Act (CPWDF) Provides permits to take state-protected species of plants and wildlife including anadromous and estuarine fishes.

Building Code (all agencies) Provides a minimum standard for building design and construction and provides specific requirements for seismic safety, excavation, foundations, retaining walls and site demolition, while also regulating grading activities, including drainage and erosion control.

Alquist-Priolo Earthquake Fault Zoning Act (all agencies). Prohibits the location of structures designed for human occupancy across active faults and regulates construction within fault zones with regard to surface fault rupture.

Seismic Hazards Mapping Act (all agencies). Requires the State of California to identify and map areas that are at risk for these hazards and require cities and counties to regulate development in the mapped seismic hazard zones.

Governor’s Executive Order B-30-15 (all agencies) Calls for state agencies to take climate change into account in their planning and investment decisions (for example, pending state law requiring local climate change plans).

Local codes and ordinances (cities, counties, and special districts) Numerous and variable across municipalities and counties. Can include setback, building height limits, neighborhood reviews, etc.
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