MANAGED RETREAT BY INTEGRATING PUBLIC PERCEPTION FOR URBAN COASTAL COMMUNITIES

by

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(Under the Direction of Jon Calabria)

ABSTRACT

As sea level continues to rise, strategies for managed retreat of development are imperative. This paper investigates two aspects of the human dimension, perception and attitudes, into a conceptual managed retreat scheme for urban communities vulnerable to inundation from adjacent coastal tidal marshes. The site includes Baylands Nature Preserve located in Palo Alto, CA. A survey was conducted to understand how users perceive and feel towards Baylands Nature Preserve, including their attitudes about salt marshes, concerns about climate change, and their preferences for climate adaptation strategies. The conceptual design proposal is dependent on whether or not respondents favored managed retreat for the study site. Since survey findings show a majority of respondents indicated support for managed retreat, the managed retreat scheme continued to support current user needs and values.

INDEX WORDS: Managed retreat, human dimensions, public perception, sea level rise, Palo Alto Baylands

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DEDICATION

I dedicate this thesis to my family, who has provided incredible encouragement throughout this process, and many friends who have continuously supported me in my postgraduate career.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Page

CHAPTER 1

INTRODUCTION

"We are the first generation to feel the impact of climate change and the last generation that can do something about it," quoted by Governor Jay Inslee of Washington State in the Showtime series, "Years of Living Dangerously" (Friedman, 2014). Many coastal communities are feeling the effects of climate change (Spalding et al., 2014) through sea level rise that impacts communities near tidal marshes. In addition to actual increase in water level, rising seas will push seawater farther up into estuaries, increasing salinity and changing inundation patterns (SFBJV, 2008). Plants and wildlife dependent on tidal wetland habitats will also be affected, since opportunities for upward marsh retreat is limited. If projections are accurate, the cumulative effect of these impacts could have significant consequences to tidal marsh plant communities, which are among the most productive ecosystems in the world. As the effects of climate change increase in severity, developing innovative, adaptive coastal intervention strategies to address climate change issues will become increasingly important, particularly for impacted urban areas adjacent to coastal shorelines.

Adaptive and innovative climate initiative approaches need more than scientific understanding and hard engineering approaches. They require consideration of the affected public (Roca and Villares, 2012) because coastal management actions and decisions, while requiring disciplines of science, are rooted in human preferences (Leschine, 2010). This is apparent when there is a societal or individual judgment of need, such as recognizing an ecosystem declining in resources or losing its ecological functions, in order to begin human interventions to address these environmental issues (Cairns, 1995). Environmental movements led by non-profit organizations, local citizens, and government agencies exemplify how public opinions are important, especially when political decisions will affect them the most.

The integration of human dimensions to coastal restoration approaches has been widely discussed in literature and studies suggest how this enhances natural science management decisions to improve restoration outcomes (Bauer et al., 2010; Carr, 1995; Endter-Wada et al., 1998; Leschine, 2010; NRC, 1992; NCCOS, 2007). Community values and preferences drive or prevent coastal planning and effectiveness, so understanding how people perceive and experience the local natural environment is integral to the success of a coastal restoration project (Leiserowitz, 2007). A restoration project lacking public support is less likely to succeed than one with stakeholder approval (Salz and Loomis, 2005). Therefore, incorporating elements of the human dimension, specifically perception and attitudes, provides insight on stakeholder needs and preferences and the types of trade-offs willing to be exchanged to obtain the desired benefits from the public. This is not only critical to sustaining resources, but also in a managed retreat scheme, a climate adaptation strategy that is heavily dependent on local public awareness, participation, and support.

Managed retreat is gaining attention, mostly in the United Kingdom and Europe, but less in the United States (Esteves, 2014; Linham and Nicholls, 2010). Although some form of retreat has been previously performed in the U.S., it is not a widely accepted strategy because it requires landowners to abandon property and is dependent on land availability, especially in densely populated coastal areas. However, managed retreat helps build resilience, prevents coastal development at risk of flooding, and reduces impacts of coastal hazards on infrastructure (Siders, 2013). It provides both coastal defense and conservation benefits, where coastal wetlands can become self-sustainable systems and require little maintenance as a coastal defense system (French, 2001; Rupp-Armstrong and Nicholls, 2007). Managed retreat may offer one of the best tools to mitigate coastal hazards and reduce losses of valuable assets at the same time (Neal et al., 2005). The repetitive loss associated with development along coastal areas adds to economic, social, and personal costs (Siders, 2013) and is a major expenditure of flood insurance funding. This is illustrated by the National Flood Insurance Reform Act of 2004, where the legislation recognizes any property that has received 4 or more claims payments for flood-insurance damage to be bought out or elevated (FEMA, 2005). Approximately 28,000 properties have been bought out or elevated in a five-year period (FEMA, 2005).

There are limitations to a managed retreat scheme and it should not be regarded as a universal strategy (Morris, 2013), recognizing that urban areas need both hard and soft engineering solutions, depending on local economic, social, and cultural contexts (DEFRA, 2001). Managed retreat should be part of a long-term comprehensive plan, rather than a scheme planned in isolation (Siders, 2013). Generally, humans have responded to climate change in three ways: protect, accommodate, and retreat (IPPC, 1990). Most of this paper focuses on managed retreat and methods of retreat design, but briefly discusses other climate adaptation strategies that contribute to the research and final design.

Many U.S. states have started efforts to address sea level rise, particularly California, a leader in climate change initiatives (California State Assembly, 2014). In California, climate change is a major priority and the State of California Sea-Level Rise Guidance Document was developed by the Coastal and Ocean Working Group of the California Climate Action Team (CO-CAT) for state agencies to integrate the effects of sea level rise in planning decisions

(California State Assembly, 2014). As a region of global importance, California must preserve important wetland ecosystems, including tidal marsh and mudflat habitats (Callaway et al., 2007). San Francisco Bay Area, in particular, has the opportunity to address projected impacts of climate change, moving beyond a reactive emergency framework of coastal response, such as coastal armoring and sea walls, and towards a proactive approach of planning before these impacts occur, including a managed retreat scheme (Slobig, 2014).

The focus of this thesis is Palo Alto Baylands Nature Preserve located in the southern shore of San Francisco Bay, one the remaining largest tracts of undisturbed marshland in the Bay Area and a major stopover on the Pacific Flyway during the winter bird migration season (City of Palo Alto, 2015) (Figure 1). Palo Alto Baylands Nature Preserve is the ideal site for this study because of its diverse land uses and its appeal to local people, through recreational amenities or commercial activities. There are non-profit and academic organizations that actively engage with the site, including volunteer events and educational tours. With a supportive community and ongoing public participation on site, City of Palo Alto can use public engagement, understand stakeholders' perceptions and attitudes, and integrate them into future planning goals of Baylands Nature Preserve. While there is currently no future plan to update the Baylands Master Plan, which was last revised in 2008, the new proposal of a Comprehensive Plan 2030 will address climate adaptation goals.

The City of Palo Alto uses a Comprehensive Plan to help guide preservation and development for the Palo Alto area and the Comprehensive Plan was last revised from 1998 to 2002. A proposed Comprehensive Plan 2030 for the City of Palo Alto is in progress, where a portion of the document will address environmental issues, including climate change strategies. While the Comprehensive Plan will not outline specific changes for Palo Alto Baylands, there is

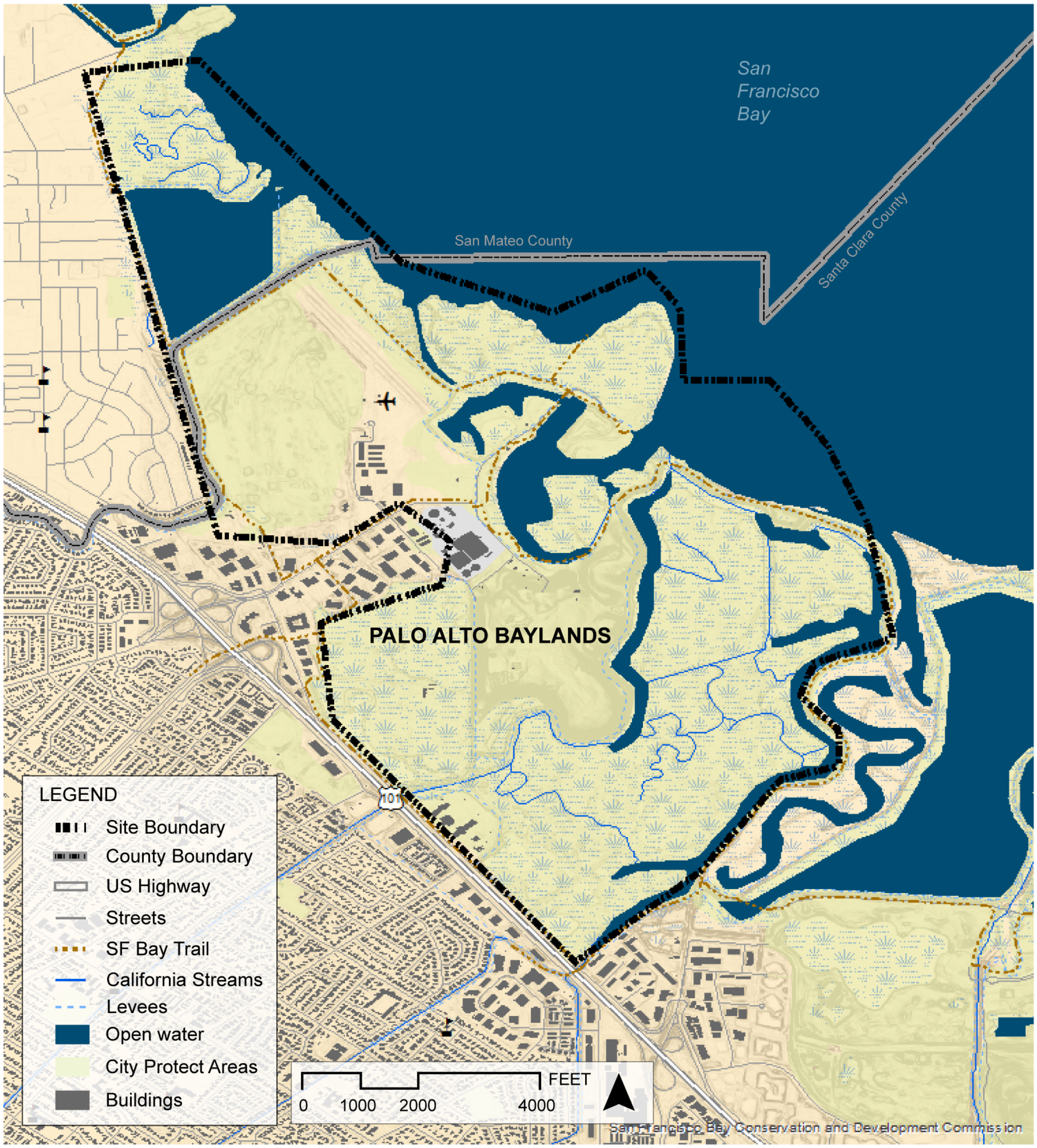

Figure 1: Composite map of Palo Alto Baylands (based on GIS data from BCDC, City of Palo Alto, and Cal-Atlas).

an opportunity to address projected impacts of sea level rise in future planning and design using a managed retreat scheme. The conceptual design proposal exemplifies how public perception and attitudes are integrated into a managed retreat approach for urban communities adjacent to coastal marshes in California in an effort to address projected impacts of sea level rise.

Integrating human perception and attitudes in a conceptual managed retreat scheme is meant to reflect stakeholder needs or improve support for managed retreat if a majority of survey respondents did not favor it. Because the conceptual design proposal is dependent on whether or not respondents favored managed retreat as an appropriate climate adaptation strategy for Palo Alto Baylands, understanding public perception and attitudes for the site is integral when proposing a managed retreat scheme. Incorporating public perception and attitudes in climate initiatives has not been given the attention it deserves, especially for an approach like managed retreat, which is heavily dependent on public awareness and support.

Sea Level Change and Impacts

The effects of rising sea levels are already visible such as the increasing erosion of beaches and the inundation of low-lying wetlands (Grannis, 2011). Due to rising global temperatures, the dominant contributors of global sea level rise are ocean thermal expansion and melting land ice flowing into the ocean (Church et al., 2013). Anthropogenic changes have significantly contributed to rising global temperatures (IPCC, 2013) and, regardless of the most optimistic mitigation schemes, impacts are likely to occur and intensify over the next decades (Spalding et al., 2014). Though, the magnitude and rate of change of sea level rise vary spatially and are difficult to predict at local scales (Cazenave and Llovel, 2010; Han et al., 2010; NRC, 2012). Change in sea levels impacts each coastal location differently because of varying conditions, such as shifting surface winds, the expansion of warming ocean water, and rising waters due to ice melting (Church et al., 2013). For the California coast, sea level rise depends on several regional factors, including ocean and atmospheric circulation patterns in the northern

Pacific Ocean, tectonic processes along the coast, and land ice mass changes from gravitational effects, as well as global mean sea level rise (NRC, 2012).

Since the late 19th century, global sea level has been rising as global temperatures started to increase (NRC, 2012). The IPCC (2007) estimated the global average sea level rose an average of 1.8 mm per year from 1961 to 2003, based on tide gages around the world. From 1993 to 2003, rates were faster, about 3.1 mm per year (IPCC, 2007). As a result of rising seas, storm surge, flooding, and erosion are likely to intensify and increase risks for loss of infrastructure, destruction of wetlands, and public healthy and safety (Grannis, 2011). Sea level rise increase alone can contribute to the loss of up to 22% of the world's remaining wetlands (SFBJV, 2008), and the combined effects of sea level rise, reclamation, and development in coastal areas may results in the loss of up to 70% of coastal wetlands (Nicholls et al., 1999). Furthermore, sea level rise adds to current and growing hazards for coastal communities, where approximately 3.7 million Americans live within 1 m of high tide and 22.9 million live within 6 m of high tide (Strauss et al., 2012). Compared to the global sea level rise at 1.7 to 1.8 mm/year, Palo Alto Baylands is below global average at 1.25 to 1.92 mm/year, based on mean sea level trend in Redwood City, California (NOAA, 2013).

Sea level rise has been considered a slow-moving emergency for California. In the past century, sea level has risen approximately 25.4 mm (8 inches) along the California coast and there have been general model scenarios that suggest the rate of increase will likely accelerate because of climate change in the coming decades (Pacific Institute, 2012). The National Resource Council (2012) projected sea levels to rise 4 to 30 cm (6 inches) by 2030, 12 to 61 cm (12 inches) by 2050, and 42 to 167 cm (36 inches) by 2100 for California (California State Assembly, 2014). Sea level rise for San Francisco Bay is predicted to range from 26 to 55 inches by 2100 and may contribute to losses of more than 60% of intertidal mudflats in the South Bay (SFBJV, 2008).

Coastal communities in San Francisco are already at risk for flooding and evidence supports these risks will increase in the future (Pacific Institute, 2012). With 1,000 miles of shoreline, the San Francisco Bay is vulnerable to numerous natural hazards, such as storms, extreme high tides, and rising sea levels due to global climate change (Pacific Institute, 2012). In the San Francisco Bay-Delta Estuary, higher floodwaters during the winter and an earlier spring will occur due to less snow and earlier melting of the Sierra snow pack, as well as later flows in late spring and summer (SFBJV, 2008). These effects can intensify salinity patterns and impact plant communities and ecological function of tidal marshes (SFBJV, 2008). Also, with extensive development along the San Francisco Bay shoreline, an estimated 6.8 million Californians live on the border of San Francisco Bay and this population is projected to grow (Pacific Institute, 2012; U.S. Census Bureau, 2000). Major transportation corridors and infrastructure are also located along the San Francisco Bay, providing substantial cultural resources, including tourism and recreational opportunities (Pacific Institute, 2012).

While hardening the shore and accommodation are options, retreat is preferred or necessary for many coastal areas (Kousky, 2014). Retreat design is an appropriate approach for urban communities vulnerable to inundation from adjacent coastal salt marshes.

Public Perception of Climate Change and Impacts

In the U.S., public concern about climate change impacts has fluctuated for the past few decades. Public knowledge about global warming was relatively limited in the United States before the mid-1980s (Bord et al., 1998). A peak of public interest and concern of global warming occurred in 1988, when severe drought and heat-wave indicated warmer weather patterns, but the sense of urgency faded when people experienced cooler, wetter summers (Bord et al., 1998). In comparison to other countries, such as Canada, European countries, South America, public concern ranges modest to low in the United States (Bord et al., 1998). Even though surveys suggest concern and awareness remains substantial in the U.S. (Bord et al., 1998), the beliefs about the occurrence of global warming significantly dropped between 2008 and 2010 (Borick et al., 2011).

Currently, 66% of registered voters believe global warming is happening and 56% are worried about global warming (Leiserowitz et al., 2014). Though, in the same study, a little over half (51%) believe human activities are responsible for global warming and only 22% believe it would impact jobs and the U.S. economy (Leiserowitz et al., 2014). Even though most Americans are aware of global warming and agree that climate change is somewhat of a problem, climate change is a relatively low national priority in comparison to other environmental and social concerns (Bord et al., 1998; Leiserowitz et al. 2006). These findings have important implications to coastal planning efforts because public perception can drive or hinder climate adaptation initiatives that are intended to address sea level rise. Also, the severe drought in California is adversely impacting coastal environments, where precipitation for the water year is 10 inches below normal (U.S. Drought Monitor, 2015). With a lack of public awareness and concern about the effects of climate change, it would be difficult to implement climate adaptation measures and maintain support for them in the long-term.

There is a lack of information about local perception on climate change impacts (Fatorić and Morèn-Alegret, 2013), and even less on climate adaptation strategies, despite compelling evidence of the observations and documentation of the Earth's changing climate. Local perception and attitudes provide an understanding of how affected urban communities would like to respond to changes in an adjacent coastal environment. Understanding how users view the natural environment can positively influence climate mitigation and adaptation strategies, sustaining ecological efforts and social benefits simultaneously.

Research Question and Goals

The primary research question for this thesis is: How can public perception and attitudes be integrated into a managed retreat design for urban salt marshes migrating inland? Sub-questions to the main research question are: What is the role of public perception on coastal marshes in urban communities exercising climate adaptation initiatives? How can public perception and attitudes help illustrate managed retreat as a strategic design, specifically to allow salt marsh migration and restoration within urban communities? How can a conceptual managed retreat design scheme reflect public perception and attitudes for Palo Alto Baylands Nature Preserve?

The focus of this thesis is to research two elements of the human dimension - perception and attitudes - and integrate them into a conceptual managed retreat scheme. In doing so, a survey was conducted to explore how people perceive Palo Alto Baylands, including their attitudes about salt marshes, their concern about climate change and sea level rise, and their preferences for climate adaptation strategies. More importantly, the survey was meant to identify whether or not respondents favored managed retreat as an appropriate climate adaptation for the study site. Understanding whether the public approves or disapproves managed retreat informs whether the conceptual managed retreat design scheme is reflective of current favorable attitudes or one that must overturn unfavorable ones. Thus, the conceptual managed retreat scheme would either reflect current user needs and values or attempt to improve support for the climate adaptation strategy through visual comparisons of different climate adaptation strategies at projected impacts of sea level rise. Because this is a projective design thesis, the last question is answered through a design application that synthesizes research and survey findings to show how a managed retreat scheme conceptually integrates public perception and attitudes at an existing preserve. The primary goal of the projective design is to restore intertidal habitats through the removal of existing commercial development, where areas of removal are determined by survey results and a suitability analysis.

Purpose of Research

The purpose of this study is to explore how two aspects of human dimensions, perception and attitudes, are integrated in a conceptual managed retreat design for coastal salt marshes migrating inland in an urban community. A survey was conducted to determine whether respondents supported managed retreat as an appropriate climate adaptation strategy for Palo Alto Baylands. If findings show respondents were favorable towards a managed retreat scheme, the conceptual design proposal would be a reflection of their preferences and opinions about how retreat should be implemented. On the other hand, if findings show respondents were not favorable towards a managed retreat scheme and preferred other adaptation strategies, the conceptual design proposal would attempt to improve support for managed retreat by including scenarios of different climate adaptation strategies and providing a visual comparison of how they would appear at the study site if each were individually implemented and were to adapt to projected sea levels. The conceptual design proposal is dependent on what the public perceives and wants, so understanding public perception and attitudes for a coastal area is important to identify stakeholder needs, which contributes to the overall success of the managed retreat scheme.

Significance of Research

The ultimate goal of this research is to provide a conceptual managed retreat design proposal for urban communities adjacent to coastal areas that is reflective of public perception and attitudes. Examining human dimensions are important as sea levels continue to rise. Public perception about adjacent coastal marshes drives human interventions, specifically retreat design, since the success of a managed retreat design is dependent on public approval. This study is relevant to the landscape architecture discipline because it focuses attention on understanding human dimensions and their role in salt marsh restoration design within the context of sea level rise, a topic lacking discourse. Interested professionals can use this thesis as a guideline for a climate adaptation strategy involving retreat design and human dimensions to make decisions.

Chapter Summaries

This thesis is divided into six chapters. Chapter 2 discusses the research methodology and the applicability to the design application by providing a detailed description of information collection, including survey and design methods.

Chapter 3 reviews the human dimensions of coastal adaptation, the social approach towards managed retreat, and the role of perception and attitudes in managed retreat. Chapter 3 also includes the definition of managed retreat, methods of a retreat scheme and precedent studies of managed retreat schemes involving salt marsh migration. A discussion section concludes the chapter and provides an interpretation and analysis of the information, as well as implications for the design application.

Chapter 4 details site history, inventory and existing conditions of Palo Alto Baylands. Results of the survey are also discussed in this chapter. Respondent results guided the projective design, which reflected user perception and attitudes because a majority of respondents indicated support for managed retreat as an important climate adaptation strategy for the study site. One conceptual managed retreat scheme was proposed at projected impacts of sea level rise for California.

Chapter 5 provides a suitability analysis and a conceptual design of a managed retreat scenario using projected sea level ranges and time trajectory, based on data collected from research. Design products include conceptual diagrams, a schematic plan, and diagrammatic sections. This chapter also provides an evaluation, including advantages and shortcomings, of the conceptual design proposal.

Chapter 6 concludes the thesis. It summarizes how a managed design scheme conceptually integrates public perception and attitudes for urban communities adjacent to coastal salt marshes. The chapter also provides implications, opportunities of further exploration from thesis findings, and a closing statement.

CHAPTER 2

RESEARCH METHODOLOGY

The overall research methodology is projective design. In this framework, research methods are tailored to a more scientific approach, leading to evidence-based design solutions and advancing research knowledge in the landscape architecture profession. Identifying appropriate methods based on this framework helps with the investigation of the main research question relevant to design interests and goals. This process of research frames the thesis to restructure a problem into a thoughtful opportunity through the generation of new knowledge and alternative futures.

Methods

Projective design is guided by research intent, and strategies are operational, interpretive or reflective (Deming and Swaffield, 2011). It is a process known as research by design, where design possibilities are explored in a systematic way, involving inductive (creativity of the individual designer) and deductive (testing established information) strategies (Deming and Swaffield, 2011). Projective design-based investigation uses a clear, systematic approach that frames the study and design into a series of methods. The primary research question is: how can public perception and attitudes be integrated into a managed retreat design for urban salt marshes migrating inland? Three sub-questions are used to answer the main question in order to guide the design application. First, what is the role of public perception on coastal marshes in urban communities exercising climate adaptation initiatives? This question is answered through a descriptive research strategy, in which information and data are collected using secondary sources, including peer-reviewed journal articles, previous studies, government reports, and other resources. Next, how can public perception and attitudes help illustrate managed retreat as a strategic design, specifically to allow salt marsh migration and restoration within urban communities? To answer this, specific concepts are adapted, based on further investigation using the secondary description strategy. Secondary description, classification, and interpretation strategies are combined. Classification is used to rearrange descriptive information, empirical observations, and geographic data to determine any meaningful ideas and concepts that may contribute to the final design. The classified data is analyzed and evaluated through interpretation. Conclusions and assumptions are made based on relationships, correlations, and conflicts found in the research.

Lastly, how can a conceptual managed retreat design scheme reflect public perception and attitudes for Palo Alto Baylands Nature Preserve? This question is addressed using a mixture of descriptive research, including gathering maps, direct observation, an online survey and individual interviews, and interpretation.

Survey Methodology

The Attitudes about Palo Alto Baylands Nature Preserve: A Research Study was conducted February 15 to March 17, 2015 using a web-based questionnaire of twenty-two questions (Appendix 1). The survey gathered information about use and perception of salt marshes at the Baylands. The survey also gathered opinions on the impact of climate change and projected impacts of sea level rise at the Baylands and preference and support for specific climate adaptation strategies for the Baylands.

The survey method uses a quantitative survey instrument to qualitatively explore human perception and attitudes towards Palo Alto Baylands Nature Preserve. Questions are designed to understand the preferences and opinions held by site users.

The first section seeks to understand the perceptions, values, and behaviors of respondents in regards to Baylands Nature Preserve. The second section asks about respondents' opinions about salt marshes for the site. The third section asks about the respondents' views about climate change and sea level rise, and preferences for climate adaptation strategies. The fourth section requests demographic information. The fifth section are open-ended questions to gauge remaining thoughts about Palo Alto Baylands Nature Preserve not addressed in the survey.

Due to time constraints and a lack of funding, the survey used convenience sampling and primarily gathers information about users of Palo Alto Baylands, rather than a representative sample of the general population. Because the survey intended to request information about the opinions and preferences of site users, those who reported never visiting Palo Alto Baylands were excluded from the results. A total of 58 out of 81 respondents completed the survey, with a breakoff rate at 28%.

Data was stored on the Qualtrics server. The data was encrypted, coded, and summarized in aggregate form. Only the advisor and co-investigator had access to the Qualtrics server. The stored data are responses to the survey questions ad all responses remained confidential and did not release individually identifiable information. Data was aggregated to develop a general discussion, analysis, and implications about findings. Data analysis was displayed using visual graphics, such as charts, but did not disclose any individually identifiable information.

Four sources of survey errors are coverage, sampling, measurement, and nonresponse (Dillman, 2007). Coverage error is defined as not allowing a chance to all members of the population to be sampled in the survey. While a potential source of coverage error is excluding non-Internet users since the survey was a self-administered Internet survey, coverage error is expected to be minimal because results would not differ significantly between Internet and non-Internet users in atitudes and perception towards the Baylands. Sampling error refers to making inferences based on the sample rather than the whole population. Results of the survey has a +/-13% margin of error, assuming a 90% level of confidence. Measurement error happens when a response from the participant is imprecise or inaccurate and the answer cannot be clearly interpreted, due to the poor wording of the survey question. To reduce measurement error, the questionnaire was designed using language that is readily understood and questions were organized by sections so questions were easily processed. Also, questions were phrased and structured by using simple words, being specific, and keeping them short. Nonresponse errors occur when sampled individuals did not respond to the survey and have different characteristics from those who did respond. This source of bias is impossible to rule out and findings may be biased because those who responded were people who cared enough to respond.

Design Methodology

A Geographic Information System (GIS) suitability analysis was performed to identify areas for wetland restoration and this informed the design proposal of the study site. Flood zone, slope, hydrologic group soils, and land cover were four cartographic data layers collected and used as the criteria to identify suitable areas for wetland restoration. The zone within the 100-year floodplain was an important factor in selecting a wetland location because frequent watering supports intertidal marsh habitats. Slope, while mostly flat at the Baylands, was considered to determine suitable areas for wetland restoration because wetlands are more likely to establish successfully on gentle slopes than steep ones. Hydrologic soil groups (HSGs), which include runoff potential, soil texture, and composition, were important because they affect water permeability and storage, which are crucial to wetland construction and restoration. Land cover was also important in determining suitable areas for wetlands, where areas with low intensity development, such as barren lands, were suitable areas to establish wetlands. The GIS suitability analysis, combined with research, informed the conceptual managed retreat scheme for the site. Projective design builds new knowledge and understanding about the ways human perception and attitudes are reflected in a managed retreat design through iterations of exploratory ideas.

Lastly, projective design was evaluated by assessing how the conceptual managed retreat design is reflective of public perception and attitudes gathered from the survey and research information. The design was evaluated for future climate adaptation planning that can assist local government and residents with a vision of managed retreat. Implications of research are provided to inform urban communities vulnerable to inundation from adjacent coastal marshes about important factors to consider when implementing a managed retreat scheme. Recommendations also guide future wetland management actions, promoting an approach that incorporates human dimensions, particularly public perception and attitudes. Existing and new knowledge from this study are meant to improve understanding at how public perception and attitudes positively interact and intervene with ecosystem processes and help facilitate the development of adaptive, effective, and sustainable adaptation strategies for urban communities adjacent to tidal marsh communities that are looking for non-obtrusive and natural measures to respond to projected impacts of sea level rise.

CHAPTER 3

INTEGRATING HUMAN PERCEPTION AND ATTITUDES IN MANAGED RETREAT

The inclusion of humans in climate change mitigation and adaptation efforts is increasingly apparent, progressing beyond conventional practices involving mostly natural science and technical solutions. Humans are inherently part of the whole ecosystem and considering the human dimension in restoration projects responding to climate change is fundamental in the development of adaptive, effective and sustainable management strategies (Endter-Wada et al., 1998; Leschine, 2010). Also, people differ in their beliefs and understanding about nature, as well as how the natural environment should be used (Cronon, 1996). Understanding the connection between human attitudes about the natural environment and environmental issues helps improve our understanding of climate change impacts, as well as approaches to mitigate adverse changes (NRC, 1992). Public opinions about climate change and sea level rise play a key role in the decision-making process, so climate initiatives involving aspects of the human dimension, especially public perception and attitudes, are essential because they promote or prohibit certain decisions and actions aiming to address management needs and climate impacts (Leiserowitz, 2007).

Integrating human perception and attitudes in the strategies and management of climate change is meaningful, especially for coastal communities vulnerable to sea level rise, flooding, and extreme weather patterns. As more people live in coastal communities, public attitudes and preferences regarding the adjacent natural environment will become increasingly important to assisting the restoration of ecological functions because they provide insight on how the public would like to respond to climate changes and whether they would support a climate adaptation strategy proposed by governing authorities. Public perception about coastal habitats, climate change impacts, and climate adaptation preferences contributes to effective climate interventions that help these ecosystems adapt to climate change, while still preserving ecological quality and function. Public perception and attitudes are particularly important in a managed retreat scheme, because the success of the climate adaptation strategy depends on public awareness and support for it. Understanding the influences behind the approval or disapproval about the application of managed retreat in a local coastal environment is crucial to the development and implementation of a managed retreat scheme. Based on respondents' attitudes towards the scheme, the conceptual managed retreat design proposal can either reflect current needs and values if a majority of respondents favor managed retreat or can showcase a visual alternative to current defenses over time with rising sea levels if a majority of respondents did not favor managed retreat.

This chapter reviews the human dimensions of coastal adaptation, with emphasis on human attitudes and perception, the social approach towards a managed retreat scheme, the role of perception and values in managed retreat, and a closing discussion about these aspects.

Human Dimensions of Coastal Adaptation

Climate initiatives considering human dimensions are gaining attention in the United States (NRC, 1992; Bauer et al., 2010; NCCOS, 2007). An understanding of how the public is likely to respond to climate initiatives is essential because it drives or inhibits political, economic and social decisions (Leiserowitz, 2007). While policy makers, scientific experts, and planning professionals develop and implement ideas about how to respond to climate change, the public, including non-experts and locals, provides helpful contributions to the development of climate change initiatives. Public perception and attitudes are important because decisions are based on guidance from people (NRC, 1992). Knowing what the public wants helps policy makers design policies that will be supported or at least tolerated (Bord et al., 1998). Furthermore, scientific and policy discussions of climate change can be better informed through increased understanding of public attitudes about climate change (Bord et al., 1998).

Research about human dimensions of climate adaptation strategies offers the opportunity to understand the role of public perception and attitudes in coastal communities engaging with climate adaptation responses. Understanding human dimensions enhances coastal decision-making and its scientific reasoning (NCCOS, 2007). The social aspect is of particular interest because humans are integral components of the ecosystem and including human dimensions in climate initiatives provides improved knowledge about public preferences and needs for coastal environments responding to impacts of climate change. While the relationship of human and nature is exceedingly complex and highly variable, further exploration can improve climate adaptation strategies and outcomes, maintaining coastal habitats to healthy, resilient conditions for many decades to come.

Climate adaptation strategies integrate public perception and attitudes to improve understanding of how people respond to climate impacts and initiatives. It is acknowledged that a close understanding of societies with climate change mitigation strategies implemented into projects are more likely to be successful, suggesting the integration of anthropologic perspectives (Barnes et al., 2013). Responses to environmental challenges should include stakeholders who drive decision makers, which indicates the notion to integrate elements of the human dimension, particularly perception and attitudes, in climate adaptation strategies because these influence the management and application of effective strategies for restoration, mitigation, and adaptation that were intended to lessen global and local impacts (Fatorić and Morén-Alegret, 2013). Meaningful stakeholder participation enhances coastal decision-making that incorporates ecosystem understanding (NCCOS, 2007). This allows urban communities adjacent to coastal marshes to apply local knowledge and directly participate in policy development for adaptive approaches (Spalding et al., 2014). Narratives and anecdotes based on local stakeholders' perceptions contribute to improved understanding of the relationship between climate change, the environment, and people (Fatorić and Morén-Alegret, 2013). Enhanced plans and designs, along with richer debates and discovery of new relationships, are likely to result by new knowledge from non-expert participants (Slobbe et al., 2006). For truly sustainable outcomes, coastal change and management decisions must integrate understanding the perspectives of the affected public (Milligan et al., 2009), so consideration of the public interest is required in adaptive and innovative approaches (Roca and Villares, 2012). Competition or conflicting opinions between diverse stakeholders is useful to sustaining resources, since it reveals flaws and imposes amendments to current and future management approaches (Barnes et al., 2005). Conflicting perceptions can be compromised through organizing management priorities (NCCOS, 2007). Therefore, climate initiatives are likely more successful with the input and cooperation of society (Cairns, 1995).

Climate change not only affects the natural environment, but also societies. The direct and indirect impacts of climate change are already affecting many aspects of public life, including the price, availability and origins of services and goods like energy, water and food. People's lifestyle significantly depends on the natural environment and this is already changing due to climate change effects. Thus, there is a growing need for both individuals and communities to adapt to changing conditions and become more resilient. (Esteves, 2014)

Resilience is defined as “the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks” (Walker et al., 2004, 2). In a general sense, an ecosystem is resilient if it is able to withstand disruption and has the ability to self organize and preserve its essential functions. Adaptation can influence resilience (Walker et al., 2004). The definition of climate adaptation is the “adjustments in ecological-social-economic systems in response to actual or expected climatic stimuli, their effects of impacts” (Smit et al., 2000, 255). Adaptation measures in response to rising sea levels have been categorized into three general schemes: protection, accommodation, and retreat (Figure 2) (IPCC, 1990). Protection involves hard infrastructure, like sea walls and dikes, and soft solutions to protect development from the sea (IPCC, 1990). Accommodation is to build with the water, creating floatable, floodable, or elevated development, and makes no attempt to prevent land from flooding (IPCC, 1990; Kousky, 2014). The third option, retreat, involves relocating people away from the coast, offering the opportunity to remove existing infrastructure (IPCC, 1990; Kousky, 2014). These adaptation measures have been pursued, some more than others, as a way to mitigate the negative impacts of sea level rise associated with climate change.

Much of the perspectives and studies about human dimensions originated from federal resource agencies, such as U.S. Forest Service and National Oceanic and Atmospheric Administration (NOAA), and academia, mainly researchers from both natural and social science disciplines that were concerned about the accelerated rate human activities were driving global environmental change (Leschine, 2010; NRC, 1992). Agencies recognized early that

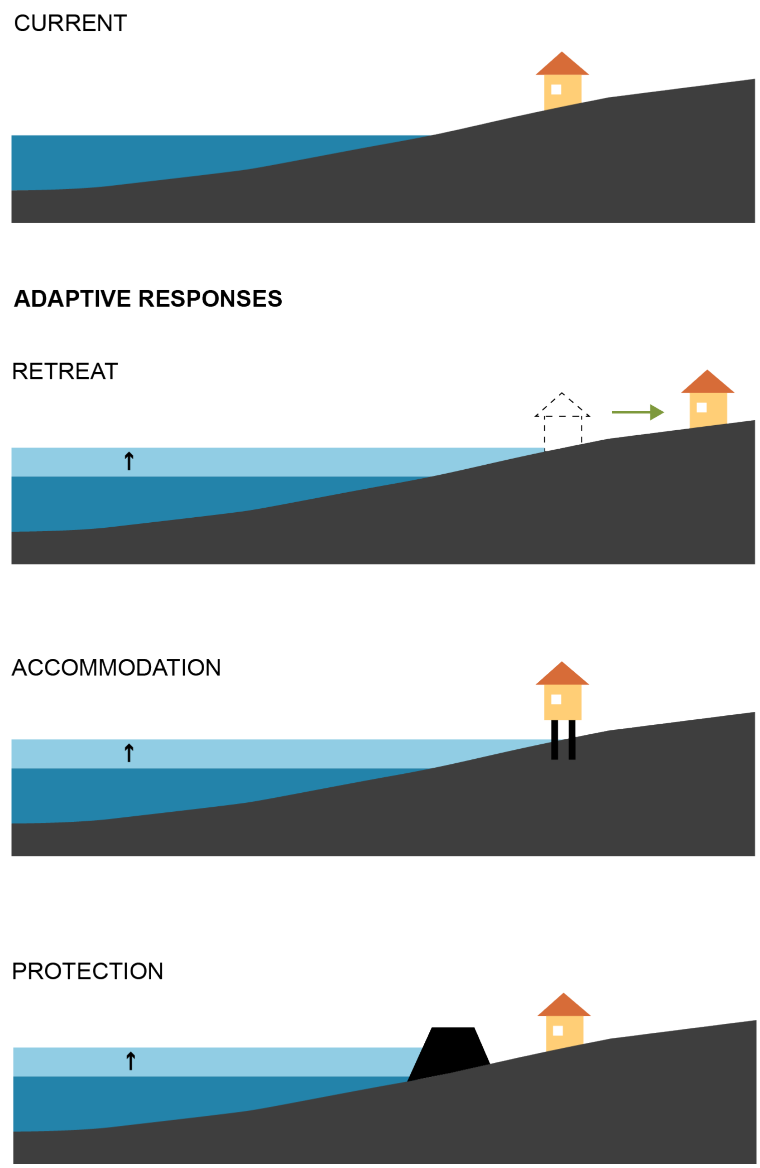

Figure 2: Schematic illustration of three general climate adaptation responses: retreat, accommodation, and protection (adapted from IPCC, 1990).

understanding the interactions of human systems and non-human systems helps build knowledge about global environmental change, such as how humans directly cause changes to the environment, how those outcomes affect human values, and how humans respond to these changes in an effective way (NRC, 1992).

Human Dimensions Defined

Human dimension, through the work of various individuals and groups, is broadly defined as:

> An integral component of ecosystem management recognizes that people are part of ecosystems, that people's pursuits of past, present, and future desires, needs and values (including perceptions, beliefs, attitudes and behaviors) have and will continue to influence ecosystems and that ecosystem management must include consideration of the physical, emotional, mental, spiritual, social, cultural and economic well-being of people and communities (USDA Forest Service 1994).

Two key ideas are central to this definition: people are an inherent component of ecosystems and ecosystem management is a human undertaking, one that pursues the well-being of people, communities, and ecosystems (Carr, 1995).

In the context of adaptation to climate change, it is important to clarify the differences between the terms "human dimensions" and "social science." "Human dimensions" is a concept that refers to the roles of humans in ecosystems and resource management and "social science" is a subset of social disciplines helpful for characterizing and anticipating the role of human in ecosystems and resource management (NCCOS, 2007). The essence of human dimensions is to understand interactions between humans and the environment, as well as producing social information about humans in ecosystems (Leschine, 2010). It is also a multidisciplinary practice, which strives to understand human-environment interactions in order to expand and provide support for resource management (Bauer et al., 2010).

Human dimensions are also characterized through three interactions between human systems and environmental systems and these are human causes, consequences, and responses to environmental changes (Figure 3) (NRC, 1992). Human dimensions research focuses on three points of interactions to increasing success of mitigating consequences from environmental

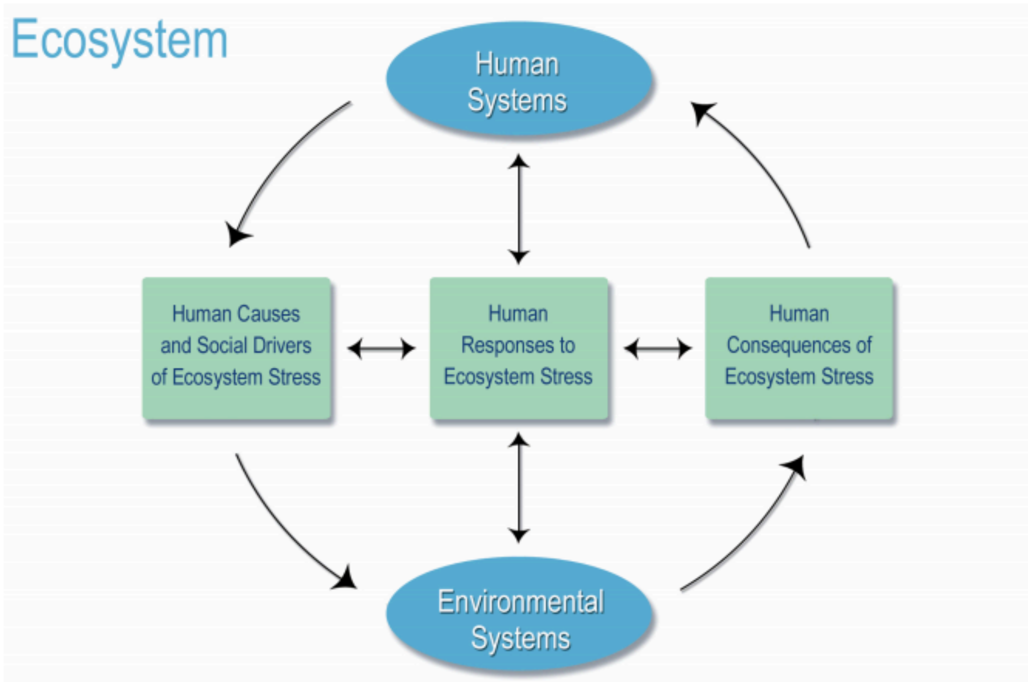

Figure 3: Diagram of human dimensions of ecosystems (NCCOS, 2007; adapted from NRC, 1992).

change. Human actions, including direct modifications, cause environmental change and examples include pollution and exploitation of resources (Bauer et al., 2010). The quantity, quality and sustainability of ecosystem services are then influenced by those changes in environmental systems (NCCOS, 2007). Supporting, provisioning, regulating, and cultural are common categories of ecosystem services and provide benefits such as nutrient cycling, food production, flood regulation, and aesthetics (MA, 2005). As a result, alterations in ecosystems services can lead to consequences, which may be desirable or undesirable, that affect human values (Bauer et al., 2010). Humans respond to ecosystem services in decline using mitigation and adaptation strategies to maintain human values (Bauer et al., 2010). These responses create planned or unforeseen outcomes and, in some instances, they may adversely impact ecosystem services (Bauer et al., 2010). Human causes, consequences, and responses are interconnected, because responses can modify causes to avoid or minimize unwanted outcomes (NRC, 1992).

Human dimensions focusing on human causes, consequences, and responses to environmental change involve contribution from interrelated disciplines in social and behavioral sciences, humanities, communication sciences, and interdisciplinary fields (Figure 4) (Bauer et al., 2010). This study fits between interdisciplinary studies and social and behavioral sciences because it seeks to integrate public perception and attitudes into a conceptual managed retreat design for coastal salt marshes migrating inland towards urban communities.

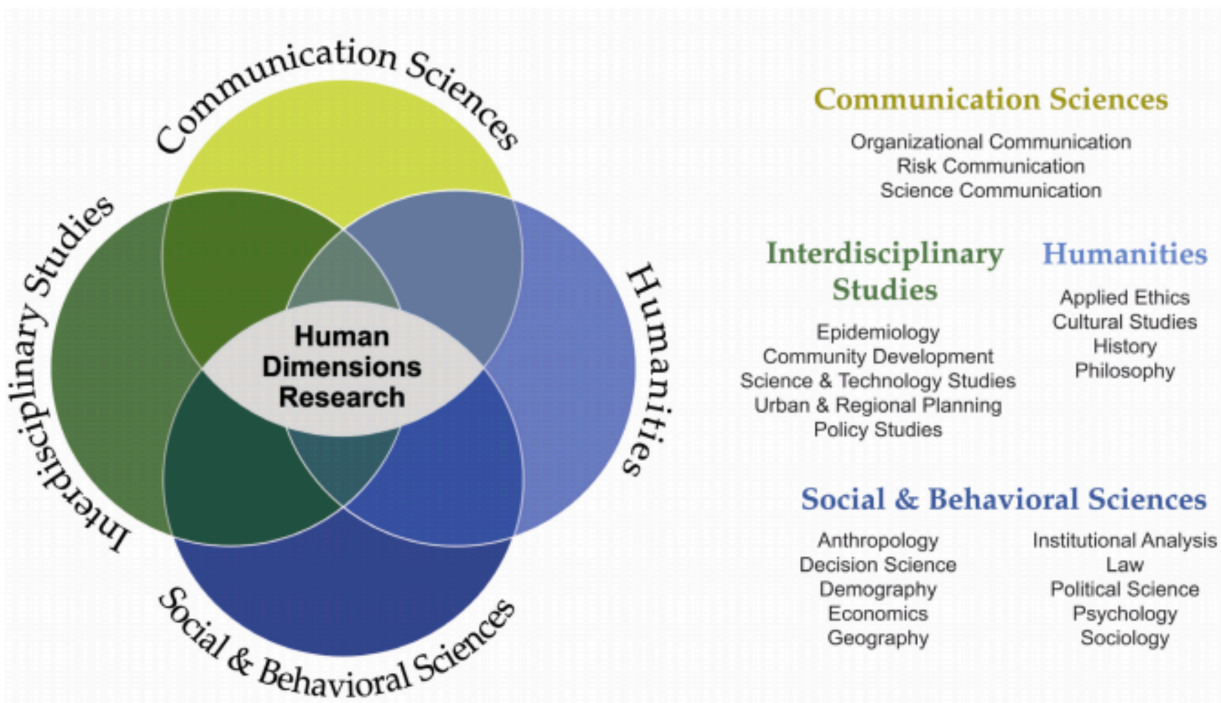

Figure 4: Diagram of diverse disciplines important to human dimensions of ecosystems (NCCOS, 2007).

Human Dimensions as a Part of Climate Initiatives

The role of human dimensions studies in ecosystems has been widely discussed in literature (Bauer et al., 2010; Carr, 1995; Casagrande, 1997; Egan et al., 2011; Endter-Wada et al., 1998; Higgs, 2003; Leschine, 2010; NCCOS, 2007; NRC, 1992). Most agree with the idea of integrating natural science with human dimensions studies (Endter-Wada et al., 1998; Bauer et al., 2010; Leschine, 2010). Yet, scientific research, for a long time, has neglected to integrate human dimensions and those applications that do involve human dimensions are either poorly incorporated or misunderstood (Endter-Wada et al., 1998; Leschine, 2010; Bauer et al., 2010). This is partly due to the traditional separation of ecological and social sciences (Liu et al., 2007) and from a lack of social science literacy (Bauer et al., 2010). If social aspects are considered, in most cases, they are only a component in the decision-making and political processes and do not directly contribute to the scientific understanding related to ecosystem management (Endter-Wada et al., 1998). Moreover, even less attention has been paid to the human dimensions of monitoring and assessment in ecosystems (Burger, 2003; Curado et al., 2013). These perspectives imply the need to clarify how human dimensions, particularly perception and attitudes, can make useful contributions to coastal wetland projects integrating climate adaptation strategies.

For example, human dimensions understanding supports natural science decision-making and contributes to effective ecosystem management (Endter-Wada et al., 1998; Leschine, 2010; NCCOS, 2007). Humans intricately connect with and influence ecosystems, so understanding these connections is essential in developing an adaptive and effective ecosystem management approach (Endter-Wada et al., 1998). More importantly, human dimensions research enhances coastal decision-making, especially when it integrates ecosystem understanding with meaningful stakeholder engagement (Endter-Wada et al., 1998; NCCOS, 2007). Stakeholder input regarding how people use the land and resources and their preferences on how it should managed or enhanced are necessary to maintain and preserve coastal environments (CRARM, 1996). Broader acceptance of management goals results from participatory decision-making and this indicates the effectiveness of improved management (NRC, 2008). In fact, the more people involved with the project, the greater the success of an intentional or designed project (Higgs, 2003). Therefore, human dimensions are important to consider for projects initiating climate adaptation strategies, especially sites where urban communities are adjacent to coastal marshes and involve approaches such as relocation, acquisition and retreat of development and, more importantly, people.

Managed Retreat as a Strategic Design

Most often, environmental disasters within coastal communities are handled in a recurring pattern of devastation and repair, where once a development is reconstructed after a previous destruction from a natural or human-induced disaster, the same site is damaged and then rebuilt again (Brennan, 2008). Dauphin Island, Alabama, is a representative case of this: in the past forty years, tropical storms have significantly destroyed the area ten times and the island was recovered even after Hurricane Katrina (Young and Coburn, 2012). People are becoming increasingly aware that maintaining coastal communities comes with economic, social, and personal costs, including loss of loved ones, people experiencing displacement, and personal items ruined, related to repeated coastal disasters (Siders, 2013). FEMA's Repetitive Loss (RL) strategy is an effort to reduce property damage and disruption to life caused by repeated flooding of the same property (FEMA, 2005). Flood control and stormwater management efforts have helped addressed repetitive losses, but if flood insurance claims of the same property due to flood-related events has been paid four or more times and the cumulative amount of claims exceeds the value of the property, then the property is bought out or elevated (FEMA, 2005).

Historically, coastal development has been encouraged by the government to support economic growth and expanded tax base, stressing the need for protective structures, including sea walls and hard armoring, to defend properties from flooding (Siders, 2013). Hard engineering structures and traditional 'hold-the-line' approaches have been the dominant means to protect coastal communities from the sea, particularly those in risk of losing valuable assets (Spalding et al., 2014; Esteves, 2014). These structures protect development behind them, but also increase erosion on adjacent properties and lose valuable coastal habitats as the sea rises to meet the wall (Kousky, 2014). Furthermore, overtopping waves over hard structures disrupt salinity loads in water content, affecting adjacent plant communities requiring specific flows of freshwater, saltwater, or both. In contrast to hard stabilization structures, coastal habitats offer natural protection from the sea, acting as a buffer between marine and terrestrial environments, but the impact of hard engineering has affected coastal dynamics in various ways, including the reduction of sedimentation and influencing the ability of the natural environment to adapt to changing conditions (Esteves, 2014). This has led to the destruction of natural habitats, where numerous communities and assets are located in hazard-prone areas (Esteves, 2014).

The limitations and costs associated with the retention and renewal of coastal defenses, including hard armoring, along a dynamic shoreline are becoming apparent (Ledoux et al., 2005; Siders, 2013). While 'hard' defenses are effective when it is not overtopped, these methods keep development at risk and even increase vulnerability in some instances (Neat et al., 2005). Furthermore, the substrate below hard defenses often erodes, which is a major reason to their capacity to fail and ongoing maintenance costs. Even though artificial protection of coastlines through hard engineering is possible, coastal defenses can easily be destroyed by extreme surge events and future disasters due to sea level rise associated with climate change (Roca and

Villares, 2012). The high economic costs, unintended environmental impacts, ongoing maintenance requirements, and the capacity to fail have led to a shift in moving beyond hold-the-line approaches to less obtrusive strategies (Esteves, 2014; Ledoux et al., 2005; IPCC 2007; Roca and Villares, 2012; Spalding et al., 2014).

The need to rethink current and future climate adaptation strategies is further illustrated through long-term uncertainties about providing safety for people living in communities adjacent to coastal marshes, increasing development along the coasts, and coastal biodiversity (Roca and Villares, 2012). Greater interest in soft solutions is also influenced by associated losses of storm protection, recreational use, and aesthetics (Neal et al., 2005). It is unrealistic to rely on 'hold the line' approaches for all of the developed coasts across the world (Neal et al., 2005), implying the need to turn increasingly to land use changes and towards more flexible and 'soft' alternatives (Siders, 2013). Soft engineering strategies, such as beach re-nourishment and dune restoration, are meant work with the natural dynamics to make room for water and sediment, benefiting coastlines to evolve more dynamically (Esteves, 2014; Roca and Villares, 2012). Yet, these approaches are temporary, require maintenance, and are costly. A soft engineering strategy that reduces maintenance, economic, and personal costs in the long-term is managed retreat.

Shifting the coastline landward is becoming an attractive concept in many parts of the world (French, 2006). The response strategy to "retreat" has been defined as the "abandonment of land and structures in vulnerable areas and resettlement of inhabitants" (IPCC, 1990, 23). The retreat option involves preventing development in coastal communities, allowing phase-out development to occur if it needs to be abandoned, or providing no direct government role over at-risk areas, with the exception of withdrawal of subsidies and provision of information about associated risks (IPCC, 1990). Retreat is also applied to setbacks or known to prohibit coastal property owners to build hard structures on the shoreline and imposing abandonment (Neal et al., 2005).

Managed Retreat Defined

There is an increasing need to consider managed retreat in coastal habitats, as it has been concluded by the Second Skidaway Conference on America's Eroding Shoreline that:

> …the American shoreline is retreating. We face economic and environmental realities that leave us two choices: (1) plan a strategic retreat now, or (2) undertake a vastly expensive program of armoring the coastline and, as required, retreating through a series of unpredictable disasters (Howard et. al, 1985).

The collective term, "managed retreat," is a coined phrase by Reed Noss of University of Central Florida and this phrase originally alluded to wildlife habitat corridors (Eaton, 2013). This is an enhanced version of the retreat approach, which refers to a combination of coastal zone management and mitigation strategies intended to relocate existing and planned development from coastal erosion and hazards (Neal et al., 2005). Managed retreat is different from basic shoreline retreat in that it encompasses a broader definition as a comprehensive management approach using basic concepts of retreat and it distinguishes the characteristics of the coastline while relocating development from threats (Dyckman et al., 2014).

Based on the philosophy of moving out of harm's way, managed retreat is a proactive strategy realizing that coastal dynamics should govern how they are maintained (Neal et al., 2005). Managed retreat is not an unplanned or forced retreat, but a planned removal from the coast, supporting structural removal from eroding shorelines and reducing risks of a flood event (Dyckman et al., 2014; Linham and Nicholls, 2010; Neal et al., 2005). Reducing risk to people, property, and infrastructure through planned retreat from hazard-prone areas is the primary purpose of managed retreat (Esteves, 2014). Managed retreat requires long-term planning to change existing land use planning in order to create room for the coastline to adapt to the rising sea and erosion (Esteves, 2014; Reisigner et al. 2014). In the context of climate change, it is an adaptive solution that promotes coastal sustainability and resilience, reducing economic costs associated with ongoing coastal defense maintenance, reducing vulnerability for development and people, creating space for coastal habitat restoration, and enhancing recreational values (Reisinger et al., 2014).

Advantages of Managed Retreat

While uncertainties remain in the application of managed retreat, this proactive, non-structural approach is much more cost effective than coastal armoring in the long run because it does not require continuous maintenance, redevelopment, or repair (Siders, 2013; EPA, 1995). Even though the experience in the implementation of managed retreat is fairly limited, the pursuit of managed retreat is increasingly prevalent in Europe and some areas in the U.S. have turned to some form of a retreat strategy, especially for at risk areas determined to have no long-term viability and where communities would largely benefit from retreat (Fang, 2014).

Managed retreat helps build resilience, prevent coastal development at risk of flooding, and reduce impacts of coastal hazards on infrastructure (Siders, 2013). It is a climate adaptation strategy that mitigates coastal hazards and reduces losses of valuable assets simultaneously (Neal et al., 2005). A long-term strategy of managed retreat can reduce public funding on vulnerable infrastructure, emergency response, and disaster recovery, as well as save lives, helping to reduce risks to property owners, neighbors, and first responders (Bova-Hiatt et al., 2014; Brower et al., 1987). A resident or business can avoid future risks of coastal hazards through relocation away from the risk area, creating the opportunity to develop innovative flood control techniques

(Bova-Hiatt et al., 2014). From this, it is clear there are several advantages of managed retreat, including reducing risks to buildings and people and building resiliency for individuals and communities. An equally important component of managed retreat is the opportunity to recreate coastal habitats, especially in estuarine environments.

Coastline retreat allows natural adjustment to sea level rises and flux in sediment supply (Neal et al., 2005). Intertidal habitats respond to sea level rise by landward accretion and migration, if not impeded by hard defense structures or coastal steepening (French, 2001; Rupp-Armstrong and Nicholls, 2007). Retreat is a relevant coastal management response in low-lying wetlands, since these areas are most vulnerable to inundation from sea level rise (Rupp-Armstrong and Nicholls, 2007). Coastal wetlands provide important functions, which is often undervalued, including supporting endemic plants, sustaining wildlife habitats for breeding and feeding, acting as nurseries for fish and pollution sinks, and providing flood protection (Rupp-Armstrong and Nicholls, 2007). Also, managed retreat within estuaries provides benefits such as creating additional space for nutrient sequestration and adjustments to change, along with reducing pressure on existing defenses (Townend and Pethick, 2002).

Managed retreat promotes the opportunity to create or restore coastal wetlands, particularly salt marshes, which are intertidal habitats that contribute to coastal protection (Spalding et al., 2014). Existing projects implementing some form of retreat strategy have shown positive outcomes in creating new habitats (Shih and Nicholls, 2007). Salt marsh is defined as a "halophytic grassland on alluvial sediments bordering saline water bodies where water level fluctuates either tidally or non-tidally," such as wind-driven areas (Mitsch and Gosselink, 2007). Managed retreat establishes a new coastline further inland and new defenses through the creation or restoration of salt marshes, forming a soft and more sustainable protection against rising seas (Roca and Villares, 2012).

Coastal wetlands absorb the initial ocean waves in the event of a storm, where salt marshes act as natural buffers against the sea (Mitsch and Gosselink, 2007). Salt marshes are a natural coping mechanism for extreme events and sea level rise because they allow room to expand for flood tides, reducing flooding risk landward (French, 2006; Roca and Villares, 2012). They also reduce wave energy, supply sedimentation, and reduce erosion (Spalding et al., 2014). By dissipating wave energy, salt marshes reduce the height of artificial defenses, which implies reduced costs for coastal defenses without needing to compensate for loss of high elevation habitats (Shih and Nicholls, 2007). Furthermore, salt marshes are intertidal habitats with the ability to respond rapidly to changing environmental conditions, like intense storms and rising sea levels, and coastal processes (French, 2001; Morris, 2013; Rupp-Armstrong and Nicholls, 2007).

Managed retreat provides both coastal defense and conservation benefits, where salt marshes become self-sustainable systems and require little maintenance as a coastal defense system (French, 2001; Rupp-Armstrong and Nicholls, 2007). Managed retreat involving salt marsh restoration offers a better chance of success since salt marshes have the ability to quickly respond and adapt to changes (Morris, 2013). Furthermore, if salt marshes increase in elevation and grow with sea level rise, then salt marshes may have an advantage over engineered coastal defenses (Spalding et al., 2014). Managed retreat is, therefore, a practical mechanism for creating inland intertidal habitat, especially salt marshes, and a long-term approach to increasing flood resiliency (Morris, 2013).

Managed retreat schemes are valuable in urban communities (Shih and Nicholls, 2007; Neal et al., 2005). Retreat in urban areas has the potential to achieve social benefits, such as improving public recreation and access and providing means to change public perception about the value of the local coastal environment (Shih and Nicholls, 2007). While some may argue that considering managed retreat may not be appropriate for development along urban coasts, managed retreat can be feasible and preferable for some communities (Neal et al., 2005). Moving large structures is technologically practical, as stated by the International Association of Structural Movers, so managed retreat should not be excluded as a coastal management tool (Neal et al., 2005). Managed retreat in urban areas creates certain opportunities, such as improved access, aesthetics, and recreational amenities, benefiting adjacent landowners and the local community (Shih and Nicholls, 2007). The unresolved issue with managed retreat mainly lies in economics (Neal et al., 2005).

Methods of Managed Retreat

Mitigation techniques of managed retreat include abandonment, relocation, setbacks, land acquisition, and avoidance. Abandonment can be part of a long-term planned strategy, following a "do nothing" approach, where there are no means to protect buildings from the sea. There are three types of relocation strategies: active relocation, passive relocation and long-term relocation. Active relocation involves actively moving development landward before it is damaged or threatened. Redeveloping a damaged structure in a new location that is not within the coastal hazard zone is considered passive relocation. Long-term relocation typically includes a general approach to determine zones most vulnerable to risks through known erosion rates or predicted flood levels using community zoning or land use plans. Relocation is not a new adaptation approach and began in the 19th century to relocate lighthouses in North America, including the famous Cape Hatteras, proving the feasibility and economic insight of this strategy. Setbacks are a tool to avoid development from hazard-prone areas or hazardous process, such as coastal erosion and storm surges. The setback distance varies and may not remain constant. Land acquisition is land acquired, through purchase or condemnation, by federal, state, and local government and usually provides conservation benefits, public access to the coast, recreational and tourism values, habitat protection, and aesthetic values. Avoidance implies the decision to not allow development in areas due to coastal hazards, critical habitats, or sediment sources and it is the best approach for undeveloped or little developed land. Relocation is the long-term solution for urban coastal communities and should integrate land use planning and zoning in a comprehensive, holistic approach. (Neal et al., 2005)

A Social Approach Towards Managed Retreat

The idea of retreating the coastline has been met with reluctance and doubt by both the government and private homeowners to abandon coastal properties or to convert developed land into flood protection zones (Siders, 2013). Managed retreat is not a popular climate adaptation strategy for people and a recent project implementing a retreat approach for a wetland in Europe has provoked intense social conflict (Roca and Villares, 2012). This is because one of the biggest social drawbacks of retreat is requiring the abandonment or relocation of existing development, affecting landowners and disrupting communities (Linham and Nicholls, 2010). Also, another social complication is the balance between wetland creation and the need to retain valuable cultural and historical sites (Linham and Nicholls, 2010). Therefore, understanding public perception and preferences about the local natural environment and managed retreat scenarios can help alleviate social conflicts and even improve public acceptance of managed retreat as a practical, adaptive strategy to mitigate climate change and sea level rise impacts.

While managed retreat provides a variety of advantages, the term “retreat” is often associated with a negative connotation (Esteves, 2014; Ford, 2014; Neal et al., 2005; Rupp-Armstrong and Nicholls, 2007). The phrase went out of favor in Europe and is now renamed as “managed realignment” (Rupp-Armstrong and Nicholls, 2007). Retreat, in its own nature, suggests defeat, illustrating the failure of the government to protect its citizens (Ford, 2014). The managed retreat approach also requires people to abandon ownership of coastal properties and most will resist doing so, unless they are fully compensated (Alexander et al., 2012). Because of this, managed retreat is a highly controversial topic in political and social arenas (Linham and Nicholls, 2010).

Public acceptance is an issue that needs to be addressed to implement managed retreat strategies (French, 2001; Linham and Nicholls, 2010; Myatt et al., 2003a; Townend and Pethick, 2002). The reasons for lack of acceptance are diverse, but may include the reluctance to lose property high in value and its development potential (Linham and Nicholls, 2010; Rupp-Armstrong and Nicholls, 2007). At times, local communities are unsure about the benefits of managed retreat and oppose to projects involving reduced access to trails or there is a concern over increased flood risk somewhere else in the same area (Siders, 2013). Public support for managed retreat depends on who will pay the costs, how compensation and land use rights are handled, land availability, and the preservation of cultural resources (Alexander et al., 2012; Reisinger et al., 2014; Siders, 2013). Decisions regarding coastal management approaches will become more difficult as time moves forward and there is strong evidence to show that unsupported coastal strategies are less likely to succeed than approaches supported by the public (Boya-Hiatt et al. 2014, Alexander et al., 2012).

As illustrated by the removal of buildings in Texas and Maui, there is a growing interest in pursuing managed retreat strategies within the U.S. (Esteves, 2014). Even though opinions are divided on whether implementation of managed retreat is increasing or not, most expect greater progress of managed retreat in future planning (Esteves, 2014). Acceptance of managed retreat by the public and stakeholders is increasingly important in delivering climate change adaptation outcomes. Because individuals and communities will most likely be affected by the managed retreat approach, their opinions and attitudes must be considered to identify how they would benefit from planned retreat. Early engagement with the public can lead to greater public interest and support because this can reveal how people perceive managed retreat and address common misunderstandings and false expectations (Esteves, 2014).

Public perception and attitudes about the natural environment are valuable in improving outcomes of restoration projects when used to better address public concerns (Bord et al., 1998; Endter-Wada et al., 1998; Hands and Brown, 2002). Thus, this research involves assessing user perception and attitudes of the study site through a web-based questionnaire, which guides the proposal of the conceptual managed retreat scheme. The survey determined whether or not respondents favored managed retreat as an appropriate strategy for the study site, so the conceptual managed retreat scheme is heavily dependent on respondents' approval or disapproval of the application of managed retreat. Understanding whether urban communities adjacent to coastal marshes approve or disapprove managed retreat allow for the opportunity to develop a conceptual design that continues to supports user needs and values or attempt to improve support for managed retreat by providing visual comparisons of different climate adaptation strategies at projected impacts of sea level rise.

Perspectives of Retreat

Perceptions of climate change have been studied more in developing countries than developed countries (Fatorić and Morén-Alegret, 2013), but there are fewer studies on climate adaptation strategies around the world. Until recently, several studies have concentrated on understanding public perception about using managed retreat as a climate adaptation strategy (Roca and Villares, 2012; Dyckman et al., 2014; Ryan et al., 2011). Though, there seems to be a greater interest from various researchers, especially the academic community, to understand the role of public perception in managed retreat schemes. A U.S. study distributed to the general population of 30 coastal states, including the Great Lakes, identified that the three most commonly used managed retreat tools were fixed setbacks, land acquisition, and avoidance (Dyckman et al., 2014). A recent study exploring perceptions of sea level risk and assessing managed retreat policy distributed to the Australian population found that respondents who are concerned or unsure about sea level rise risks may support an appropriately designed retreat scheme (Ryan et al., 2011). These two studies indicate that managed retreat tools are currently being implemented, and the strategy may be favored among those who are concerned or unsure about sea level rise risks.

A recent climate adaptation poll questioned Californians about their opinions on an induced retreat scheme, which is a forced removal of development due to climate impacts. Gfk Custom Research North America, a market research institute, performed a Stanford University Climate Adaptation National Poll (2013), where findings show that Californians are least supportive of adaptation strategies including purchasing coastal private property to induce retreat. Though, the results of the study also show that the California public does not strongly favor any one adaption option identified in the survey and generally supports prohibiting coastal development and improving future development and building codes (Stanford University Climate Adaptation National Poll, 2013). Furthermore, the survey concluded that the California public strongly favors taking proactive measures to prevent negative impacts of climate change (Stanford University Climate Adaptation National Poll, 2013). From this survey, it appears that even though retreat is an unpopular climate adaptation strategy, Californians do support some form of retreat, such as avoidance, and favor taking action now to prevent future impacts of climate change. In this regard, proactive planning integrating tools of retreat contribute to the support of managed retreat as an appropriate management strategy in some communities.

Precedent Studies

Managed retreat, in the form of managed realignment, has already been taken place in many areas of the United Kingdom and Europe, where 102 projects involving managed realignment were initiated since 2013 (Esteves, 2014). Managed realignment refers to the intentional and complete removal of an existing coastal defense, allowing flooding of a previously defended area (Linham and Nicholls, 2010). Methods of managed realignment include managed retreat, dike realignment, dike reopening, de-embankment and de-polderisation (Linham and Nicholls, 2010). Because most retreat projects have mainly been applied in North-West Europe to date, where saltmarshes are the dominant intertidal habitat (Linham and Nicholls, 2010), this section focuses on several studies in Europe, particularly the United Kingdom.

In 1995, the loss of salt marshes due to erosion and man-made sea defenses for the past 25 years and the growing pressures of increasing sea level rising at an accelerated rate led to the experimental case of managed realignment at Abbotts Hall Farm on the Backwater Estuary in Essex, UK (ECCR, 2014; Dixon et al., 1998) (Figure 5). The sea wall breaching allowed conversion of 80 hectares of agricultural land to salt marsh, mudflat, coastal grassland, and transitional habitats (ECCR, 2014). Factors such as low-lying land and flood frequency allowed the site to be suitable for managed realignment (Rupp-Armstrong and Nicholls, 2007). With an engaged community and good partnership with the Essex Wildlife Trust, the project was implemented within 3 years (Esteves, 2014). A source of funding for the project included landowner compensation involving payment to convert private property into habitats, illustrating how incentives such as compensation contribute to the willingness for landowners to relocate (Dixon et al., 1998).

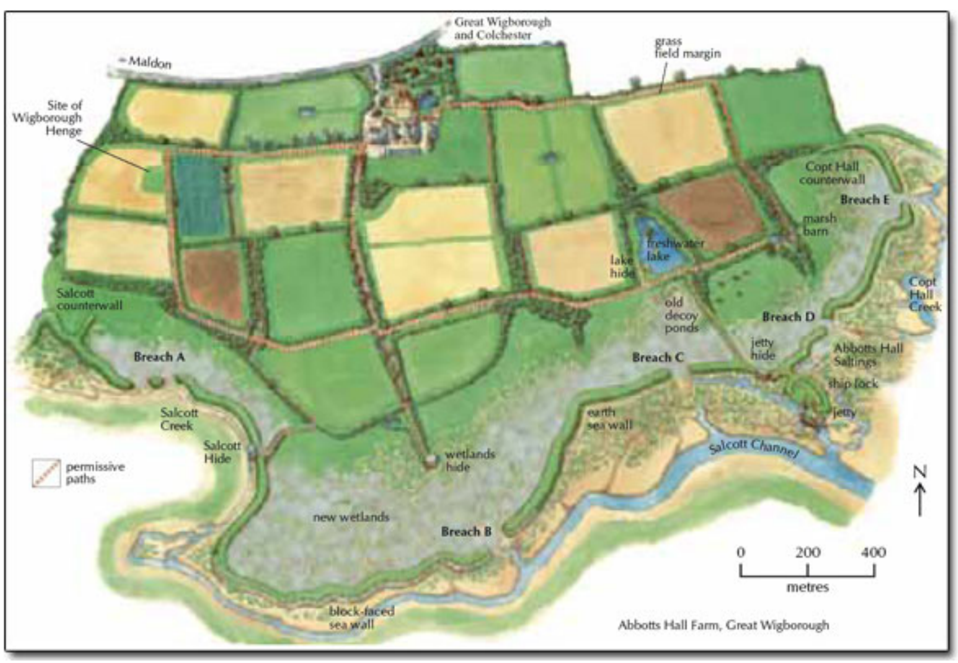

Figure 5: Schematic plan of managed realignment in Abbotts Hall Farm, Essex, UK (UK EA, 2010).

A 2002 managed realignment project involving the establishment of salt marsh habitat was implemented on the Freiston Shore in Lincolnshire, UK. Originally proposed due to increased erosion rates at the sea wall base, other motivations for implementing a managed realignment scheme included frequent storm surges, which were often overtopped and breached sea defenses by high spring tides, and the threat of accelerated sea level rise for communities on the low-lying coast. Existing sea defenses were breached, linear drainage channels were excavated, and a small saline lagoon was created. Due to partnerships between several governmental agencies and volunteer organizations, the project took six years to implement. The project experienced community opposition and the negative perception of stakeholders, from landowners to the public, possibly due to distrust of consulting authorities and organizations, low level of compensation for land release, and the perception that hard defenses provide absolute protection. (Friess et al., 2008)

Both studies show how a managed retreat scheme involves partnerships among local communities, governmental agencies, and volunteer organizations. Retreat was strategically planned and funded as a proactive climate adaptation strategy, requiring compromise between various stakeholder groups and the need to prioritize goals of the project. It also showed how the opinions and beliefs from local community members, either in favor or against the managed realignment project, are important factors to consider in a managed retreat scheme, because relocation decisions involving private properties affect landowners the most. Additionally, the creation of new wetland habitats associated with the two studies were efforts to provide natural flood protection, relocate private property away from areas at risk of flooding, and breach existing infrastructure. This illustrates how removing existing development in a managed retreat scheme is not only a means to protect people, but to restore habitats, providing conservation benefits and minimizing loss simultaneously.

A 2003 post-implementation questionnaire involving public perception of the managed realignment at Freiston Shore, Lincolnshire was conducted to identify factors that affect public awareness, understanding and acceptance of the scheme. Despite a majority of respondents indicating support for managed realignment, findings from the survey identified two major obstacles that deterred public acceptance, which were low political confidence, as well as lack of understanding of the scheme. Furthermore, most respondents expressed little concern about coastal flooding impacting their area. To address these concerns, another study commissioned by DEFRA showed early consultation and engagement activities with the local community had a positive impact. Their approach included individually targeting audience at small-scaled groups, such as businesses, organizations, and individuals, providing opportunities for increasing and improving understanding about managed realignment. Also, the survey concluded that awareness of managed realignment is influenced by demographics, club affiliations and proximity to the realigned site. (Myatt et al., 2003b)

Because those who oppose managed realignment tend to have low confidence in project authorities, along with the misconception of hard defenses and lack of information associated with the scheme (Myatt et al., 2003a, 2003b), improving communication and understanding between public and leading agencies help increase public acceptance of a planned retreat design. As a pro-active adaptation approach, managed retreat must also be pro-active in participation in order to be successful. Early stakeholder awareness and involvement help resolve misconceptions and address conflicts among local community members and policy makers. Therefore, the perception and attitudes of users toward a local natural environment and climate adaptation strategies are helpful in understanding how people perceive the site, climate change impacts and managed retreat. This understanding then guides how the managed retreat scheme should conceptually integrate public perception and attitudes, based on respondents' approval or disapproval of managed retreat.

The Role of Perception and Attitudes in Managed Retreat

Good restoration needs more than natural scientific understanding; it requires a broader perspective involving historical, social, cultural, political and aesthetic considerations (Higgs, 1997). These elements of the human system often interact with environmental systems and understanding these interactions contributes to informed knowledge about coastal restoration projects engaging in climate initiatives. The social aspect is an important factor in managing coastal environments because humans are integral components of the ecosystem and including human dimensions in ecosystem design can help reconnect people back with nature, as people live in places that are getting more urban and developed. Stakeholder perception and attitudes are important aspects of human dimensions research of coastal habitats and the two elements are further examined in this section.

The Role of Human Attitudes and Perception

Attitudes are shaped by human values (NCCOS, 2007). Values mean different things to different people and these are influenced by our culture, knowledge, and environmental context (Salz and Loomis, 2005). Human values differ among cultures, segments of societies, and stakeholder groups (Endter-Wada et al., 1998). Due to varied societal interests, people may view a prospective environmental change differently and may value change in a close location differently than a similar change at a farther region (Buckley and Haddad, 2006). While these statements are all true, values can be analyzed in groups for research purposes (NCCOS, 2007). Knowledge about how and why particular resource are used and how humans adapt and respond to changes in resource conditions is gained from studying how diverse groups and communities interpret and develop fondness to specific places or natural features (Endter-Wada et al., 1998). Identifying and describing how people feel about the environment can be a tool for managing coastal wetlands and, more importantly, climate change.

Incorporating a wide range of attitudes expressed by diverse stakeholders into management decisions also leads to improved understanding about how different people feel about the environment. Public attitudes provide insight on the ecosystem good and services desired and the kinds of compromises willing to be traded for those benefits; differences and conflicts in values and trade-off decisions are important to sustaining resources because they not only create awareness of flaws in current and proposed practices, but also increase the opportunity to rectify those errors (Barnes et al., 2005). Stakeholder attitudes also help enable understanding of how different groups perceive coastal resource conditions and management decisions, how these differences interact to influence coastal resource management planning and effectiveness, and how changing values, decision-making processes and results, and resource conditions interact among each other (Dietz et al., 2003). Restoration projects that incorporate community attitudes are more likely to succeed than those that do not (Salz and Loomis, 2005). Emphasizing human attitudes in restoration projects early on contribute to effective decision-making and the success of the project, considering how they need support from the community and various organizations, which all revolve in the system of human dimensions.

While it is evident that human attitudes are relevant in ecosystem restoration and management, the kinds of values held by local residents towards the environment will be diverse and community-based. However, early studies show that people value aesthetics of the landscape (Casagrande, 1997; Eaton, 1997; Nassauer, 1995). The presentation of nature is culturally interpreted, where people like to see well-manicured lawns in their front yards than a messy, indigenous plant community nearby the neighborhood (Nassauer, 1995). For instance, landscapes that do not fit conventional standards of natural beauty are an indication of neglect, when, in reality, those in their indigenous conditions are ones that do enhance ecological function and quality (Nassauer, 1995). Also, it has been reported by ecologists that beautiful natural environments implies that people are more likely to protect them (Eaton, 1997). Because people tend to be visually oriented, the success of an ecosystem may depend on designing it in a way where it meets aesthetic conventions and displays cues of human intention (Nassauer, 1995).

Another study supported how the appearance of the environment affected stakeholder attitudes and perceptions of the river, illustrating the significance of local residents values on aesthetics and nature (Casagrande, 1997). Redirecting ecological processes to benefit humans as a restoration goal can help reconnect residents with the non-human ecosystem (Casagrande, 1997). This not only increases human interactions with the natural environment, but also allows people to value the landscape more if their values are realized through ecosystem benefits.

Perception, a subset to human values, is pertinent to coastal wetland restoration and climate adaptation initiatives. How the public perceives landscapes may influence the management and application of effective strategies for restoration, mitigation, and adaptation that were intended to lessen global and local impacts (Fatorić and Morén-Alegret, 2013). Human perception is an important variable of societal values because its relationship with the environment can improve understanding at how people view nature and contributes to the success of both social and ecological goals in coastal wetland projects engaging with climate adaptation strategies.

Once a societal or individual judgment of need is recognized, a restoration project begins: the Kissimmee River in Florida was restored because of diminishing amenities perceived by society and the Guanacaste forest in Costa Rica was restored because an individual perceived that effective corrective strategies were necessary for the declining ecosystem to recover its ecological functions (Cairns, 1995). From these two examples, it suggests that human perception towards the environment is one of many factors that determine whether or not restoration will take place. If humans do not perceive an ecosystem needs modification or repair, then it is left alone; likewise, if humans perceive adverse changes to the environment, then restoration is incepted. Human perception not only influences the occurrence of restoration, but also affects how restoration is organized and implemented.

The popular assumption that public perceptions of nature are compatible with ecological and biophysical concerns commonly held by managers is often misleading (Gill, 2005). A study performed in the late 1980s uncovered how a majority of respondents held little regard on the concept of ecological communities and most assumed that weed growth indicated a lively and good condition of nature (Slattery, 1998). A 2003 study also produced similar findings, where people had little value for removing invasive and exotic plants, which is a restoration goal commonly ranked high by managers (Burger, 2003). People may have less appreciation of ecological concepts due to their low knowledge about them (Casagrande, 1995), signifying the need for public education about the importance of native vegetation. Also, ecological quality and function has the tendency to look unkempt and those with an uneducated eye may not realize this (Nassauer, 1995). The public perception's of 'natural' is different from the appearance of natural areas that have high ecological value and most people generally disapprove of these messy conditions (Hands and Brown, 2002). This makes it complicated for those who want to restore or develop new environments meant to enhance ecological quality because people seem to perceive nature with the picturesque, which is a culturally constructed concept (Nassauer, 1995). Restoration goals should reflect local stakeholders' perceptions because this helps put ecological quality and function in a recognizable context and allow people to perceive the societal benefits of the restored ecosystem. In effect, coastal wetland restoration incorporating stakeholders' perceptions can positively influence ecological processes, as well as strategies to mitigate and adapt to climate change.

Public perception is difficult to quantify, but studies show a shared consensus of the preferences local residents would like to see in the environment, including "cues to care," an enhanced landscape appearance, the removal of visual pollutants like trash, and improved recreational facilities (Burger, 2003; Curado et al., 2013; Hands and Brown, 2002; Nassauer, 1995). "Cues to care" is a concept derived from Nassauer (1995) describing a landscape with visual cues that displays human intention, such as wildlife houses and ornamental rocks, and research shows a significant preference for these visual cues, indicating the value of adding cultural elements in restoration (Hands and Brown, 2002). People tend to prefer an enhanced landscape with added color, a less cluttered look, and more human intentional cues than a natural indigenous community, but not looking too natural (Hands and Brown, 2002). The public is also less likely to enjoy a landscape that appears "trashed" than one that is aesthetically attractive (Zedler and Leach, 1998). Visual pollutants, like garbage and trash, are often a public concern and are most desired for improvements and prevention (Casagrande, 1997; Burger, 2003). Improved recreational facilities, such as better access to marshes (Curado et al., 2013), and passive activities, including walking, relaxing, and enjoying scenic views, are highly valued by respondents (Casagrande, 1996; Burger, 2003). Negative preferences, such as sparse vegetation, should also be considered (Hands and Brown, 2002). From these studies, it is apparent that visual appearance of a landscape is important to people and suggests that maintaining coastal wetlands according to public preferences is key in promoting and sustaining project goals involving climate adaptation strategies.

Historically, humans have depicted wetlands as wastelands and sources of disease, but this negative perspective seems to be shifting (Curado et al., 2013). In the 1940s, the disappearance and degradation of wetlands has led to major conservation efforts to reverse these changes, including the establishment of Ladd Marsh Wildlife Area in Oregon to protect wetland habitats for wildlife (ODFW, 2014). People appear to show a greater appreciation for wetlands because they can visually see the social values and benefits these ecosystems can provide. Increase visitor numbers to salt marshes results from aesthetic and recreational improvements (Curado et al., 2013) and, more importantly, positive perceptions of landscapes lead to better appreciation of nature and ongoing support for the project. Also, designing the coastal environment in a culturally attractive and familiar way will not greatly diminish the ecological quality of the landscape (Hands and Brown, 2002). This research about public perception and attitudes of landscapes implies the importance of responding to people's preferences into the planning, design, and management of urban communities adjacent to coastal wetlands in order to improve outcomes of wetland restoration integrating climate adaptation techniques, or let alone, a managed retreat scheme.

Summary

From these studies, local attitudes and visual preference of the natural environment are important factors influencing project outcomes and success. The appearance of landscapes are particularly important, where people generally prefer to see some sign of human intervention or care, such as less trash, and visual improvements, such as an enhanced environment. Since these visual cues often indicate ongoing maintenance for the landscape, people are willing to use and appreciate it more. Therefore, a coastal restoration project integrating stakeholder attitudes and perceptions is more likely to succeed than a conventional one involving mostly scientific understanding and objective goals. Also, what the public perceives and values may not always align with restoration goals encouraged by managers, so increasing public awareness and knowledge about ecological goals, along with education about a managed retreat scheme, can contribute to positive outcomes of the project. To do this, early consultation and pro-active engagement with local stakeholders about a managed retreat scheme that affects their community can improve public acceptance. Attitudes and perceptions differ across communities, so it is important to involve local stakeholders, who can potentially bring new information and richer discussions in the decision making process.

Conclusion

Stakeholder's attitudes and perceptions should be reflected in climate adaptation decisions because they contribute to ongoing public support for these initiatives and, more importantly, sustain coastal environments for future generations. A managed retreat scheme for urban communities adjacent to coastal marshes should integrate public perception and attitudes about the local coastal environment, climate change concerns, and climate adaptation preferences because they compel or prohibit climate initiatives. Because managed retreat is heavily dependent on public awareness and support in order to be successfully implemented, it is important to find whether or not the public favors managed retreat as a viable approach within a specific community. With this understanding, a conceptual managed retreat scheme can reflect preferences of those who support managed retreat or can showcase a visual alternative to current defenses over time with projected impacts of sea level rise for those who do not favor it. In the latter case, the conceptual design is meant to improve support and acceptance of managed retreat as an appropriate climate adaptation strategy for the site. Thus, gathering public opinion and attitudes about adjacent coastal areas, including climate change concerns and preferences for climate adaptation strategies, determine whether the conceptual managed retreat design scheme is reflective of current favorable attitudes or one that must overturn unfavorable ones regarding managed retreat.

Unlike accommodation and protection strategies, managed retreat is a soft engineering approach strongly influenced by social, political, and land ownership factors. Even with the best ecological and conservation intentions associated with managed retreat, public acceptance and understanding are necessary to overcome obstacles when implementing a managed retreat scheme. Public attitudes and perception are important aspects of human dimensions to consider, particularly because they influence project outcomes and success. From this, managed retreat tends to be a suitable approach for low-lying, coastal communities experiencing the threat of rising sea levels and when man-made structures are less than adequate to protection.

CHAPTER 4

PALO ALTO BAYLANDS AND USER ATTITUDES ABOUT MANAGED RETREAT

Human interaction with wetlands is complex as humans have historically viewed wetlands as a suspicious byproduct of nature and useless in their natural state. This led to the demise of wetlands, triggered by federal programs and legislation that encouraged their destruction and alteration. Currently wetlands are perceived as “kidneys of the landscape” and scientifically proven to be valuable for supporting biodiversity and providing important habitats for many plant and wildlife species. However, the lack of original wetlands today is a chilling reminder of our past misunderstandings and policy-making. Even though wetlands occupy approximately 3.5% of land area in the U.S., 50% of the 209 endangered species depend on wetlands for survival (Mitsch and Gosselink, 2007).

By 1985, approximately 56-65% of wetlands remain in North America (Mitsch and Gosselink, 2007). In the Midwestern parts of the U.S., including California, wetland losses of more than 80% were caused by agriculture production (Mitsch and Gosselink, 2007). The San Francisco Bay, once a region of rich biodiversity and extraordinary natural beauty, is now an intensive urban center of industry, agriculture, and commerce in less than two centuries (Goals Project, 1999). It is also considered one of the most altered estuaries in the nation today (Goals Project, 1999).

The issue of wetland management still remains, but it is our human attitudes and perceptions drive the process. Our predecessors’ ideas and perceptions of wetlands contributed to the land use management, signifying how human attitudes can heavily influence the fate of an ecosystem in a century's time. If human perception and attitudes are partially to blame, can they also be the cure? Understanding human perception and attitudes about adjacent coastal environments, climate change impacts, and a managed retreat scenario in an affected community help gauge whether the public are concerned about rising sea levels and their opinions about managed retreat. Assessing public preferences identifies whether a proposed managed retreat scenario is reflective of positive perception or needs to change disapproving attitudes about managed retreat of an individual coastal community. Integrating public perception and attitudes in a conceptual managed retreat scheme, as this thesis aims to explore, offers a long-term, alternative solution to hard defenses for urban communities adjacent to coastal marshes seeking less costly and environmentally damaging approaches to rising sea levels.

Historical Context

For centuries, humans have depicted wetlands as wastelands and eliminated them by draining and filling. This negative perception of wetlands became culturally accepted and was reinforced by English literature, which regularly referenced lagoons and swamps as dwellings for sinister creatures, and by the legislative actions of the U.S. federal government, which promoted wetland drainage for the next 120 years (Mitsch and Gosselink, 2007). Congress passed the Swamp Land Acts, the first of its kind, in 1849 that allowed reclamation of all swamp and overflow lands to the State governments (City of Palo Alto, 2008). "Reclamation," in this context, meant destroying and draining wetlands to reclaim those lands for development. Draining wetlands for settlement and agricultural purposes, thus, was the social norm in the 19th

century (City of Palo Alto, 2008) and, like many other estuarine environments, San Francisco Bay Estuary was not immune to these drastic changes.

Prior to the 1849 California Gold Rush, 200,000 acres of tidal marshes, including 80,000 hectares of salt marsh, lined the perimeter of the San Francisco Bay, providing rich habitats for diverse wildlife (Weeks, 2008; Williams and Faber, 2001). Yet, in 1848, the discovery of gold at Sutter's Mill vastly changed the landscape of the San Francisco Bay (Atwater et al., 1979; BCDC, 2007). Major modifications began during and after the Gold Rush, including converting tidal marshes for agriculture uses, salt production, and waste disposal (BCDC, 2007; USFWS, 2010). Once shunned, these tidal marshes were now being used as a commodity for profit (Josselyn, 1983). Between 1860 and 1910, many of the Bay's tidal marshes and mudflats were subject to filling, diking, or draining activities at an accelerated rate (Goals Project, 1999; Mitsch and Gosselink, 2007). Urban and commercial development resulted in loss of approximately 50,000 acres of tidal marsh (Goals Project, 1999). Ultimately, the rapid diking and filling led to about 95% of tidal marshes lost, where only 8% remaining are original pre-historical tidal marshes (Goals Project, 1999; Mitsch and Gosselink, 2007; Patton, 2002). The remaining marshes are now scattered in fragmented pieces along the bay edges with dikes adjacent to large tidal channels or mudflats (USFWS, 2010).

A shift in attitude on wetlands began in the 1960s and wetland protection was brought attention to the public and courts by hunters, sportsmen, and naturalist lobbies. The small resistance of wetland conversion was first met with doubt and animosity, but Americans increasingly became sympathetic towards conservationists. In response to bay filling, the "Save the San Francisco Bay Association" (now "Save the Bay") became the first modern grassroots environmental movement in the Bay Area. Around 1965, the State of California established the

Bay Conservation and Development Commission (BCDC) to provide planning and regulation for the shoreline, as well as public access, a first of its kind. BCDC eventually became a permanent regulatory agency in 1969 and since then, there has been an increase of public access from four miles to over 200 miles and even a small net gain in the size of the Bay. (City of Palo Alto, 2008)

Shortly after the success of passing legislations to protect wetlands, there were plans proposed to reverse environmental destruction by tidal wetland restoration (Williams and Faber, 2001). Through well-organized environmental groups, the first legislation aim at protecting wetlands successfully passed in 1966, which prohibited wetland filling in the saltwater areas of the bay (Williams and Faber, 2001). The nationwide preservation movement also effectively changed state laws and federal regulation, including the development of the 404 program of the Clean Water Act of 1972, where a permit is required to release dredge or fill materials into U.S Waters (City of Palo Alto, 2008). Notable victories were made when President Jimmy Carter issued an executive order in 1977 that protected wetlands from damaging impacts and when the U.S. Environmental Protection Agency initiated a 1989 policy goal of "no-net loss," a measure that aims to create new wetlands for those that are lost due to development and to maintain an overall constant amount of wetland acreage (Mitsch and Gosselink, 2007). Wetlands can still be impacted, but additional wetlands are required to replace those impacts (NRCS, 2015). In this sense, "no-net loss" refers to the replacement of impacted wetlands with another wetland of similar functions and values (NRCS, 2015). Now, federal, state, and local governments are undergoing efforts to reverse environmental damage and restore wetland habitat and ecosystem function through numerous restoration projects in the San Francisco Bay (Orlando et al., 2005).

San Francisco Bay

Interestingly, as this paper attempts to help mitigate impacts of rising seas, the historical evolution of the San Francisco Bay is closely associated with changes in sea level and tectonic processes. San Francisco Bay came to existence at a relatively recent geologic time, about 10,000 years ago, due to significant rising sea levels, at almost 30 m/year, and glacial melting (Figure 6). Due to the occurrence of rapid sea level rise, this event may have prevented the

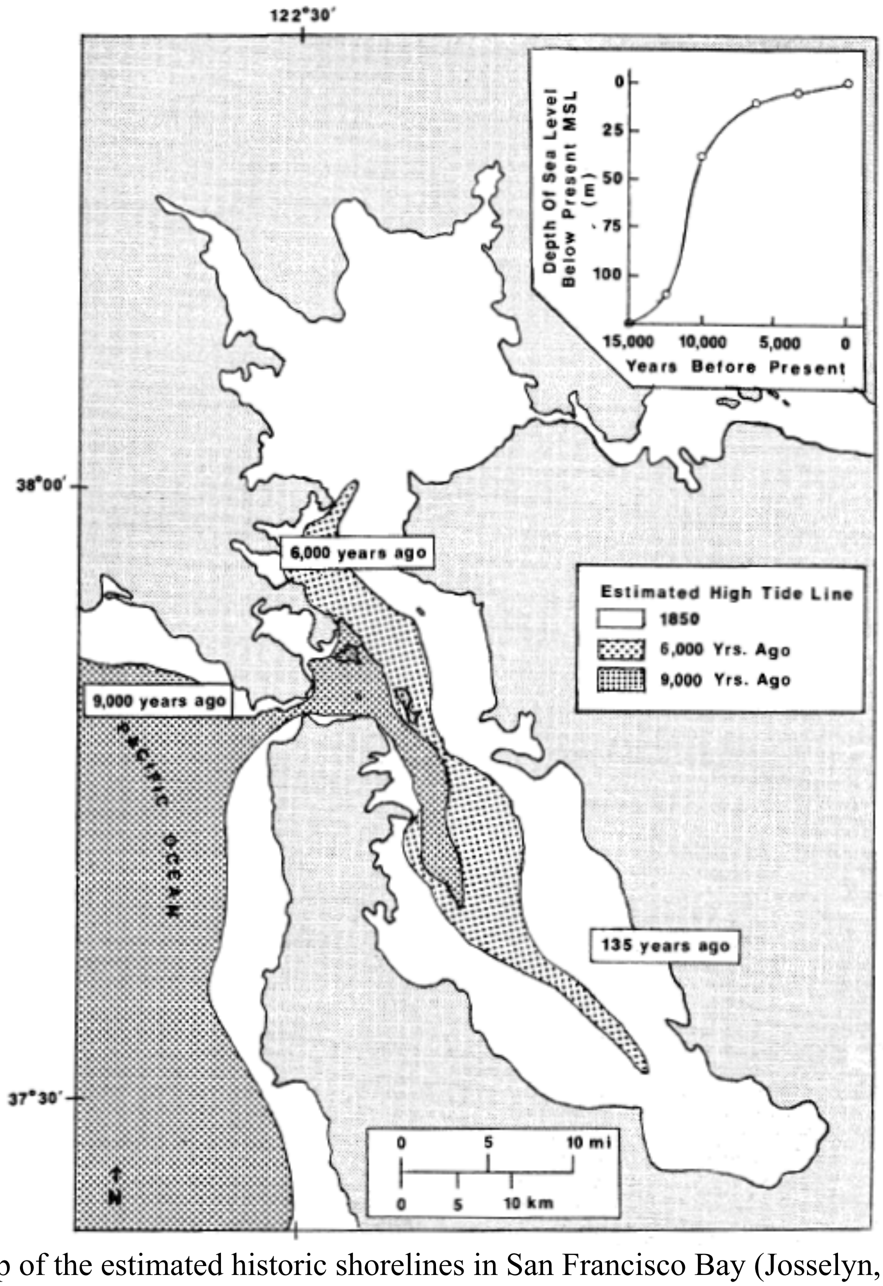

Figure 6: Map of the estimated historic shorelines in San Francisco Bay (Josselyn, 1983).

development of any extensive salt or brackish marshes. Decrease in rate of sea level rise began about 7,000 to 6,000 years ago from sedimentation rates exceeding sea level rise, which led to the development of intertidal mudflats. Records of the history of tidal marshes is fairly short, considering how the San Francisco Bay was discovered in 1769 and shoreline and inland water route investigation began 50 years later. (Josselyn, 1983)

Before the Gold Rush, there were many Native American tribes that have lived near the San Francisco Bay region for 4,000 years, where villages were spaced 3 to 5 miles apart (Goals Project, 1999). Prior to arrival of European settlement, approximately 20,000 to 25,000 Native Americans live in the Bay Area, harvesting abundant native fish and wildlife, such as mussels, clams, fish, water birds, and mammals (Goals Project, 1999). Spanish settlers came to establish ranches by 1800 after arriving 50 years prior (BCDC, 2007). Following the decline of Spanish missions during the Mexican revolution in 1821, land along the bay was used for cattle and sheep grazing by missionaries (Orlando et al., 2005). The events of the Gold Rush and the railroad populated San Francisco and people created more land to support the booming population growth (BCDC, 2007). In the 1850s, farmers started to dike and drain tidal marshes, activities that were promoted by U.S. legislation, and the filling of extensive tidal wetlands allowed land development of ports, freeways, bridges, rail lines and roads, providing groundwork for Bay Area to become central for major transportation (BCDC, 2007; Orlando et al., 2005). As a result of rapid diking, freshwater sources diverted away from the bay and its marshes, which have led to reduced high winter flushing flows, reduced sedimentation, and reduced variability in salt intrusion during the summer (Josselyn, 1983). Today, sedimentation and erosion are of greatest concern in the remaining marshes along the bay (Mitsch and Gosselink, 2007).

San Francisco Bay is not exactly a bay but an estuary where salt water and fresh water mix (City of Palo Alto, 2008). The land use and ecology of San Francisco Bay has gone through enormous changes, as early as the arrival of European settlements (Josselyn, 1983). Early descriptions of the bay by European explorers included records of its scenic landscape, such as the bountiful wildlife and plentiful timber, but provided little information on wetlands at the bay edges. Because anthropogenic changes have affected much of the prehistoric tidal wetlands, their appearance and function can only be inferred (Josselyn, 1983).

San Francisco Bay is an ecological treasure of biodiversity and provides vital habitats for an immense spectrum of wildlife and plant species (Patton, 2002). It is also known as one of the world's most urbanized estuaries, where the Bay's shoreline weaves a rich composite of landscapes; industrial areas, urban waterfronts, residential neighborhoods, and critical habitats coexist together and are intricately connected with one another (BCDC, 2011). With nearly a population of about seven million people, the San Francisco region provides a wide variety of natural resources and assets, including the bay shoreline, which has been keystone to the region's prosperity for the past 200 years (BCDC, 2011). Thus, the San Francisco Bay embraces biological, cultural, and economic importance for the region and protecting these resources is imperative, particularly when faced with an ongoing threat of climate change. Oceans have already warmed and sea levels are now rising at unpredictable rates, so it is essential to not only mitigate climate change, but also adapt to these inevitable impacts with planned and proactive climate adaptation strategies such as managed retreat.

South Bay

The tidal marshes around the southern portion of the San Francisco Bay were established approximately 4,000 years ago, following episodes of submergence (Atwater et al., 1979). From this, it can be inferred that marshes, including Palo Alto Baylands, originated nearly 2,000 years ago (Atwater et al., 1979). Marshes have either been filled or leveed and accidentally and intentionally created since the Gold Rush (Atwater et al., 1979). New marshland appeared to have been created by humans unintentionally supplying sediment to the bay and promoted deposition through levees and jetties (Atwater et al., 1979). The increased sedimentation, caused by upstream hydraulic mining for gold in the Sierra Nevada, contributed to the development of other marshes in the bay (Josselyn, 1983; Mitsch and Gosselink, 2007).

Because tidal marshes of the south bay did not have the appropriate conditions for agriculture use, such as, saline soils, little access to irrigation water, and high evaporation loss in the summer, their extensive natural crystallizing ponds were then recommended for salt production (Josselyn, 1983). Over 160 km^2 of wetlands in the south bay were diked into salt ponds by the 1930s (Josselyn, 1983). Thus, at least 11,000 hectares (27,000 acres) of extensive tidal marshes were converted into managed salt ponds in the south bay (USFWS, 2010). Even though 95% of tidal marshes have been diked or filled, many diked locations still have some marsh characteristics (Josselyn, 1983). South bay, particularly, has portions of diked salt ponds, remaining tidal marshes, and even a few preserved or restored wetlands (Josselyn, 1983).

Palo Alto Baylands

The Palo Alto Baylands was once filled with salt marsh around the 1900s, slightly spreading beyond the major U.S. 101 Highway (Figure 7). Fish, shellfish, small mammals and

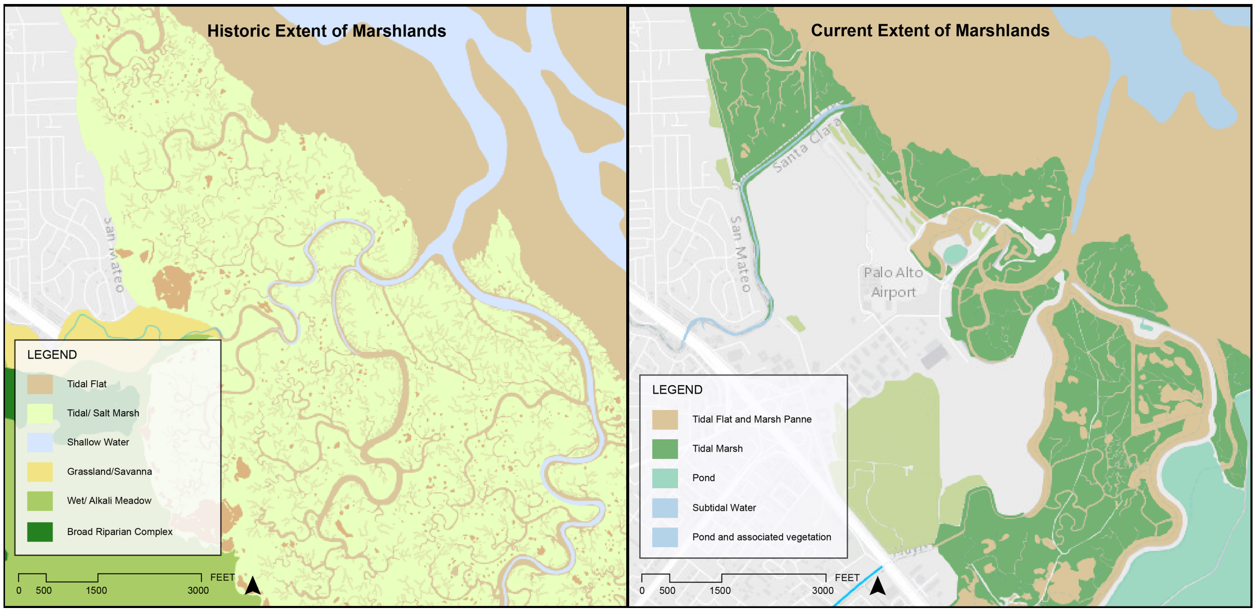

Figure 7: Maps displaying historic and current extent of marshland at Palo Alto Baylands (adapted from EcoAtlas, 2015).

fowl were sustenance from marshes for California natives. As the population in Palo Alto grew in the 1920s, so did the interest to use adjacent salt marsh areas for recreation, reclamation, and development. The City started to acquire land in the beginning of 1921 and had an estimate of 1,880 acres of the Baylands by 1960. The City had 23 transactions of acquisition and one condemnation. City planning for the baylands began in 1923, where John Fletcher Byxbee, Palo Alto's first City engineer, concocted a grand vision of mixed land use for the marshlands: a yacht harbor and clubhouse, commercial development, a sewage treatment plant, an airport, a playground, picnic areas, a golf course, a swimming pool, and wildlife preserves. The estimated cost of the proposal was $2.2 million at that time. (City of Palo Alto, 2007, 2008)

The yacht harbor was dredged first, followed by the creation of the clubhouse, swimming pool (now a duck pond), and saltwater lagoon in the early 1930s. The spoils of the harbor dredge were used to fill the area, opening an airport by 1934. In the same year, the construction of the sewage treatment was completed. (City of Palo Alto, 2008)

The higher marshes were already lost by the 1950s and there were no protection to the ones that remained. A $30 million development was proposed for the Baylands involving condominiums, a hotel, and a marina that would remove most of the remaining marshes. Harriet Mundy, Lucy Evans, Enid Pearson, and other local community members effectively opposed the development proposal. The three women were pioneers in advocating protection for the marshlands at Palo Alto and became successful at circulating a petition for the City Council to prevent any future development until the establishment of a Baylands Master Plan. (City of Palo Alto, 2008)

Most of the City-owned Baylands was dedicated as a park by Palo Alto in 1965. The ecological value of marshlands was gaining attention throughout the nation in the early 1960s and, as a part of the movement, the City was urged to build a marshland wildlife preserve and Nature Interpretive Center, named after Lucy Evans. The Lucy Evans Nature Interpretive Center was opened by 1969. The marsh area extending from Lucy Evans Nature Interpretive Center to Sand Point was later dedicated in 1982 as Harriet Mundy Marsh. The City declared Palo Alto Baylands Nature Preserve for park, conservation, or other open space activities in the 1970s. The 1978 Baylands Master Plan was later developed to provide guidelines for harbor dredging, disposal of solid waste, and the overall environmental quality of the Baylands. The park was originally named John Fletcher Byxbee Recreation Area and it is referred to Baylands Nature Preserve today for city publication purposes. (City of Palo Alto, 2007, 2008)

Site Inventory

The projective design study area is Palo Alto Baylands Nature Preserve located in Palo Alto, California, on the southern shore of San Francisco Bay (Figure 8). Palo Alto Baylands

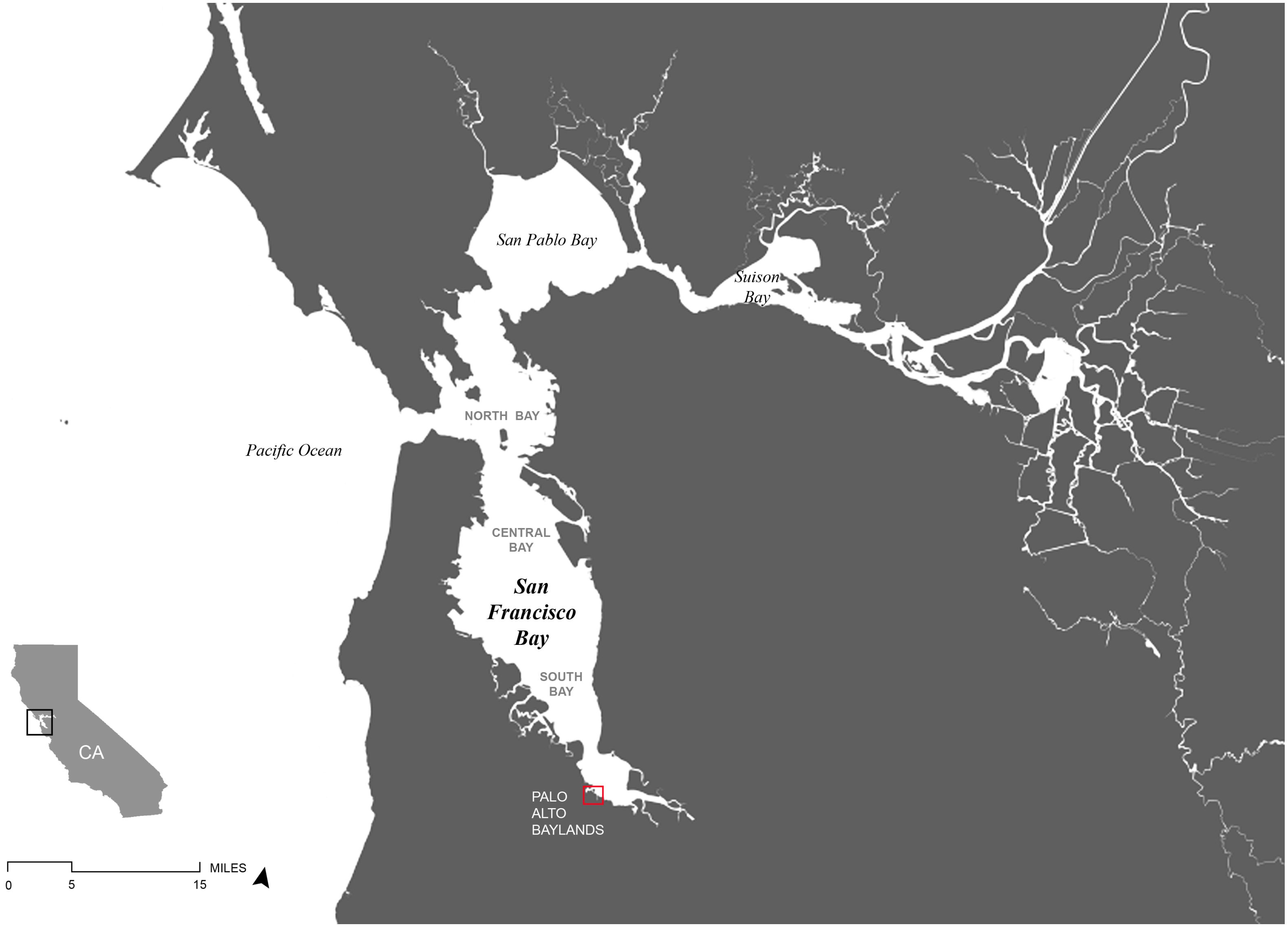

Figure 8: Vicinity map of Palo Alto Baylands illustrating regional context within the San Francisco Bay (adapted from EcoAtlas, 2015).

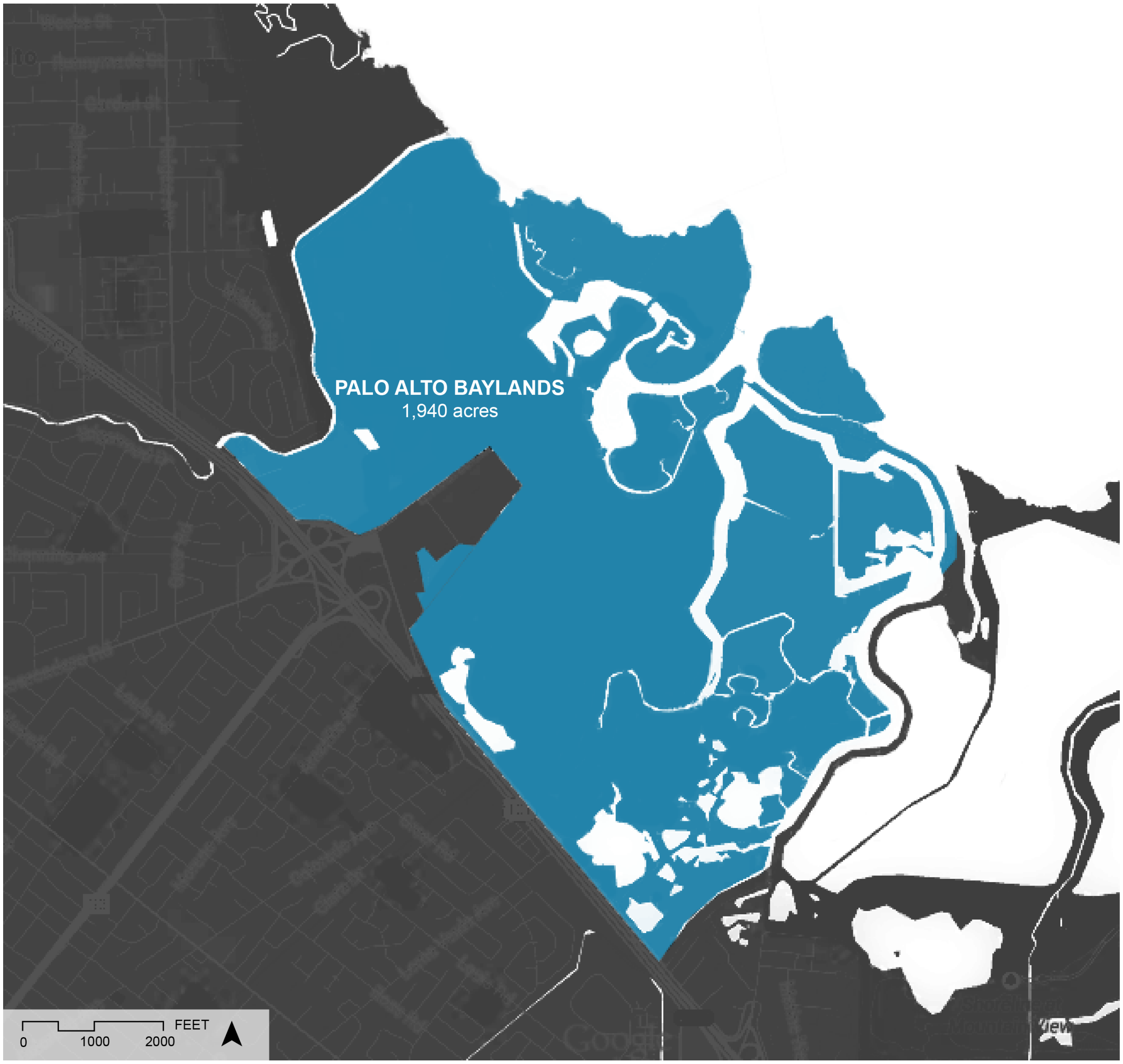

Figure 9: Map showing Palo Alto Baylands in blue (adapted from Google Maps, 2015).

Nature Preserve consists of 1,940 acres of diverse land use, including artificial and nature features, and 15 miles of trails for walking, running or biking (Figure 9) (City of Palo Alto, 2007, 2015). The site has both freshwater and saltwater marshes situated along the bay edges, along with creeks, sloughs, and a flood basin (Horii, 2010). Natural areas are adjacent to neighboring commercial land uses, including a former landfill, a private airport, a sewage treatment plant, a former yacht harbor area, a duck pond, public picnic areas, an athletic center, a nature center, and a municipal golf course (Figure 10). Palo Alto Baylands is also about 4 miles northeast of Stanford University and is in close proximity with numerous technology corporations, including Facebook and Hewlett-Packard. The unique interplay of urban development, preserved marshes,

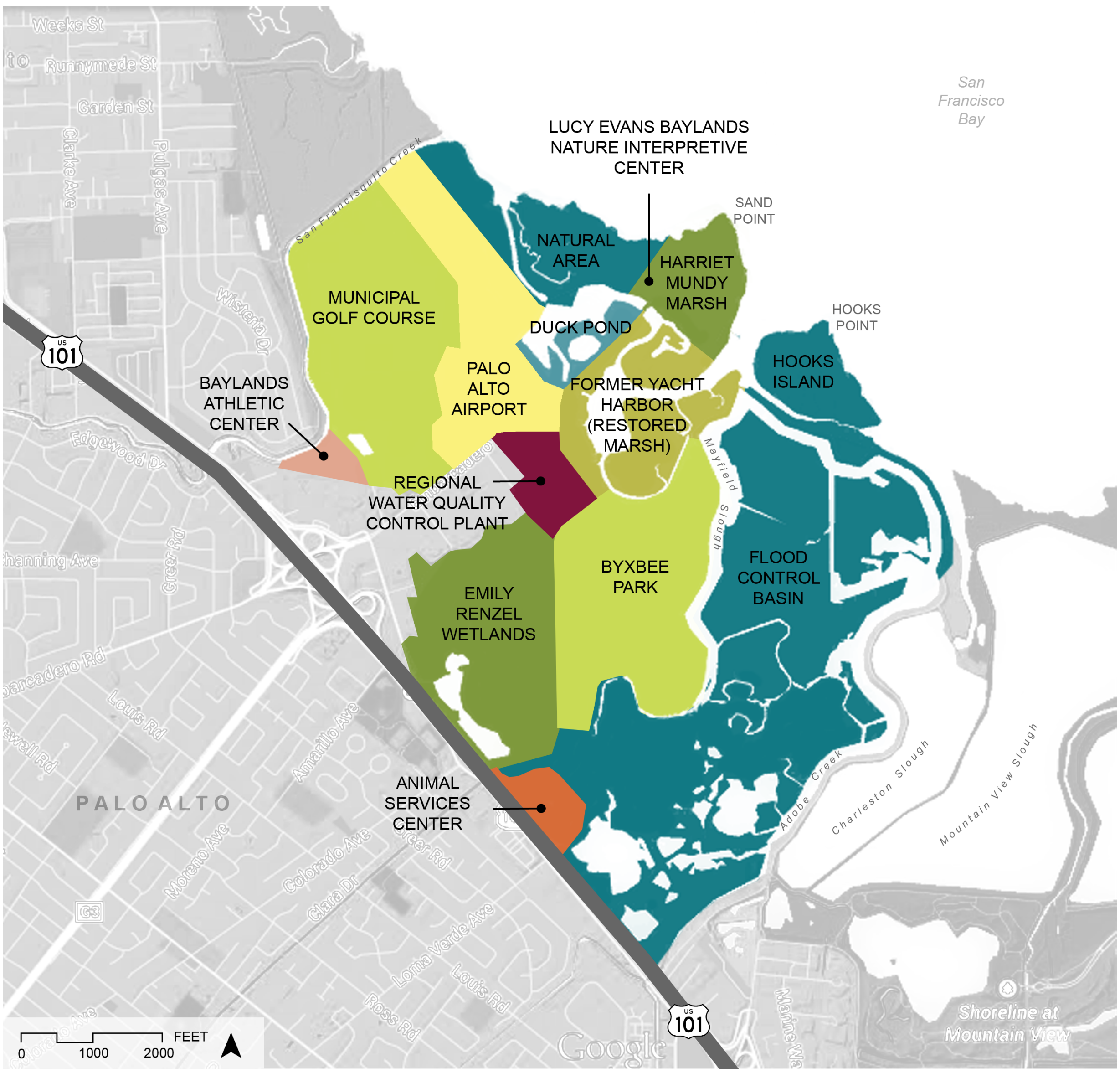

Figure 10: Map of areas identified at Palo Alto Baylands Preserve (adapted from Google Maps, 2015).

and park area adds an interesting complexity to the research, where people, nature, and wildlife are adjacent to each other, creating the opportunity to develop a design where the space can accommodate ecological and social needs, as well as rising sea levels. The disparate land uses are not studied enough as a combined unit because studies generally focus on a specific marsh or a site associated with a particular land type, not at a tract scale. The Baylands is considered one of the most important natural areas in the Bay Area, where large population of bird species use the site for a major migratory stopover, including the Pacific Flyway, and is a popular bird watching spot (Horii, 2010).

Palo Alto Baylands is the ideal site for the study because of its diverse land uses and is a popular destination for many in the Bay Area. There are currently non-profit and academic organizations that actively engage the site, including volunteer events and educational tours. With a supportive community and ongoing public participation on site, the City of Palo Alto has the opportunity to engage with stakeholders and integrate their perceptions and attitudes into future planning efforts of Palo Alto Baylands. Understanding human dimensions is necessary to not only maintain the ecological functions and quality of the site, but also help the baylands adapt to rising sea levels for habitat, wildlife, and people.

Demographics

There has been a vast increase in the population of the San Francisco Bay Area within 100 years, with over 6.8 million people in 2003, indicating a high population growth within a century (Orlando et al., 2005; U.S. Census Bureau, 2004). Along with the population increase, enormous areas of natural habitat have been lost (Nichols and Wright, 1971; Dedrick and Chu, 1993). Approximately 79% of salt marshes have been lost since the 1800s (Orlando et al., 2005).

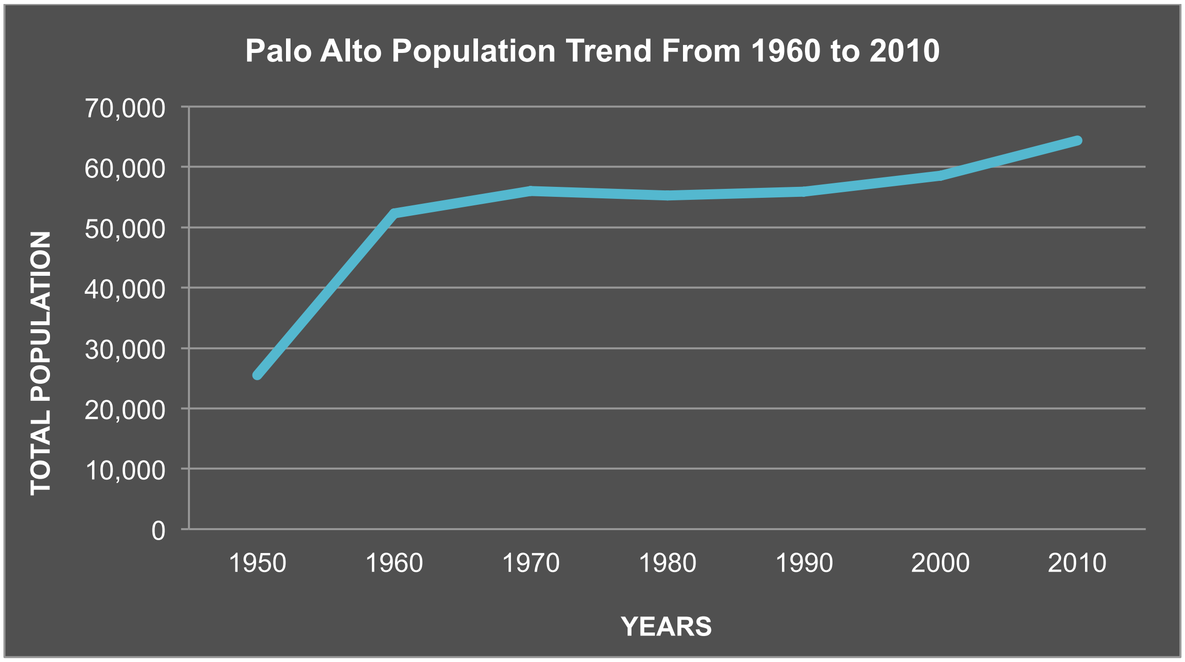

Figure 11: Total population trend of city of Palo Alto from years 1960 to 2010, based on U.S. Census Bureau data.

According to the U.S. Census Bureau, the city of Palo Alto has an estimated total population of 64,403 in 2010 and the total population is projected to continually increase at a gradual pace since the 1970s (Figure 11). A majority of the population is 35 years or older, indicating there are a greater number of middle-aged people than young adults in the city of Palo Alto (Figure 12). Based on the demographic profile, the population of Palo Alto is fairly educated, since a significant portion of the population (25 years of age or older) in the city of Palo has received a high school degree or higher (97.5%) or have received a bachelor's degree or higher (79.8%). About 5.7% of the population is living below poverty level, which is relatively low compared to California's average of 15.9%. Approximately 55% of the Palo Alto population owns a home and the median household income is $121,465. The majority of the population is White, but this has declined a little bit since 2000; there has been a dramatic increase of Asian American population living in the city of Palo Alto, as well as gradual increase of other ethnic groups since 2000 (Figure 13). (U.S. Census Bureau, 2010)

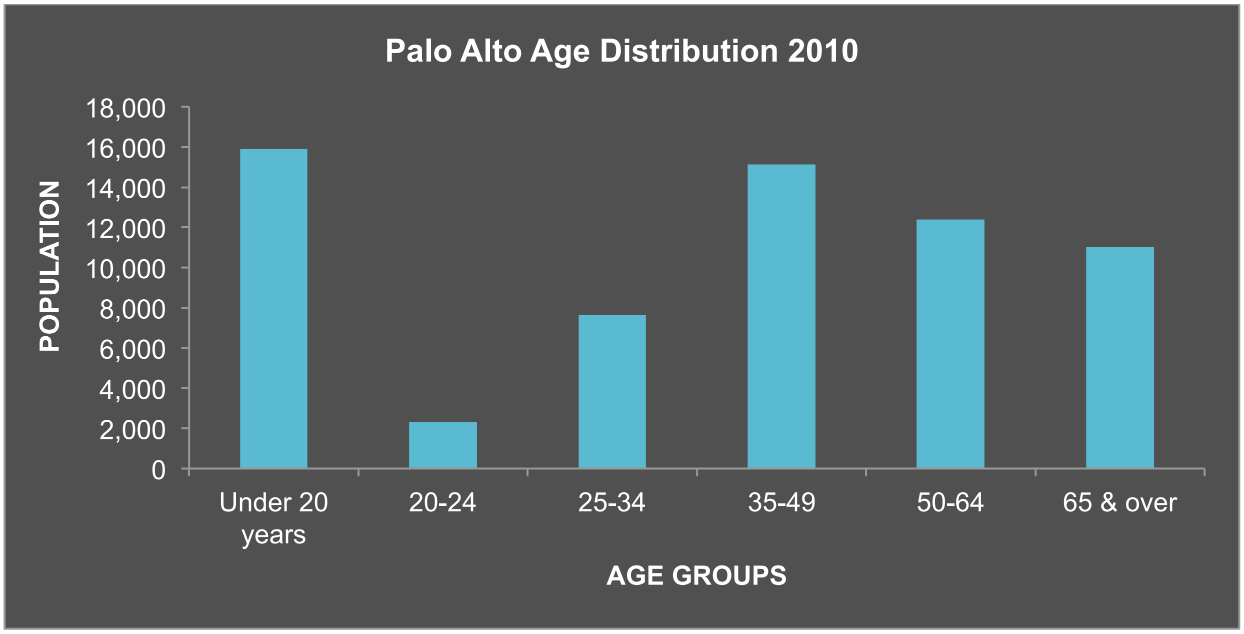

Figure 12: Age distribution of city of Palo Alto based on U.S. Census Bureau 2010 data.

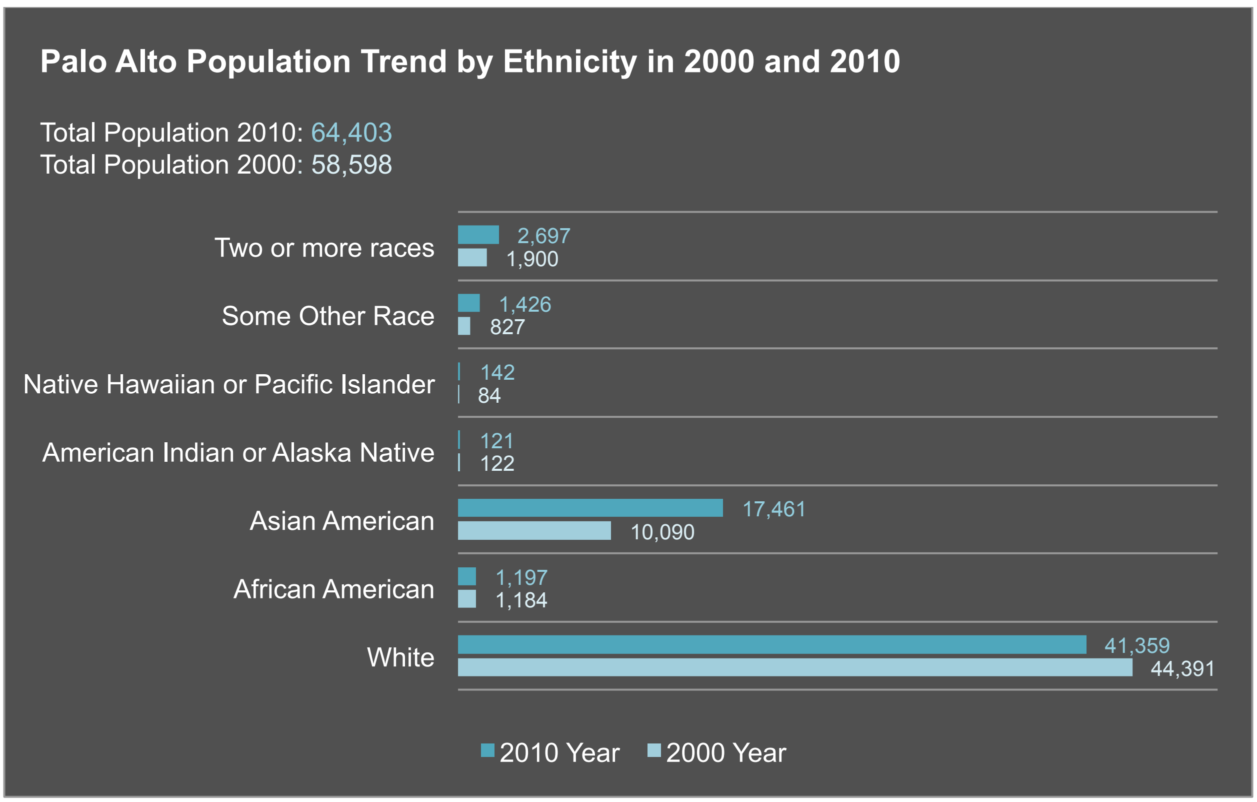

Figure 13: The population trend of city of Palo Alto by ethnic groups in years 2000 and 2010, based on U.S. Census Bureau data.

The population of Palo Alto City is growing at a gradual pace, with well educated, above average income earners, and are likely to be 25 years of age or older. Specifically for census tract 5046.01 (U.S. Census Bureau, 2010), which is where the Baylands Nature Preserve is located, the distribution of age and ethnic groups is similar to the city population (Figure 14 and Figure 15). This implies the population living in this area is area is predominately white, are 25 years of age or older, and are important stakeholders to the adjacent bay shoreline because they will be affected by future changes at Palo Alto Baylands. There are high and medium densities of population surrounding Palo Alto Baylands, due to its vicinity to residential housing, commercial development, and institutions, which are mostly intersected by a major freeway (Figure 16).

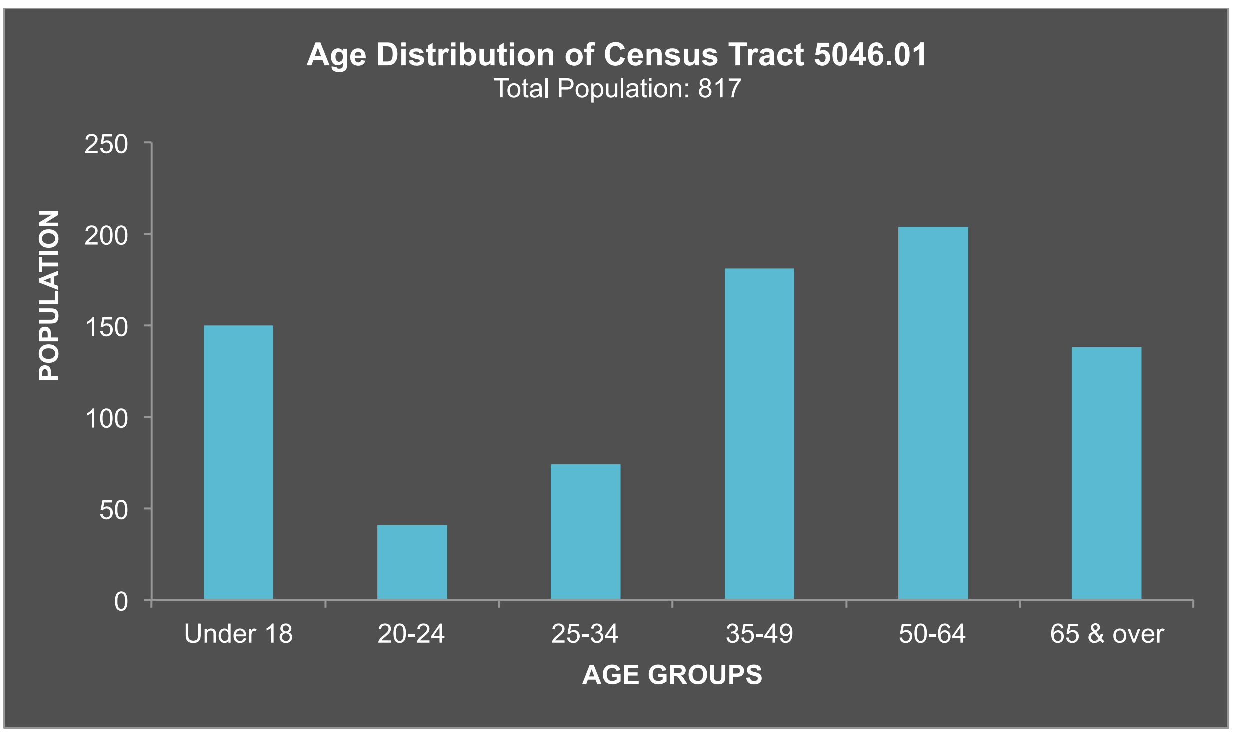

Figure 14: Age distribution of census tract 5046.01, where Palo Alto Baylands is located, based on U.S. Census Bureau 2010 data.

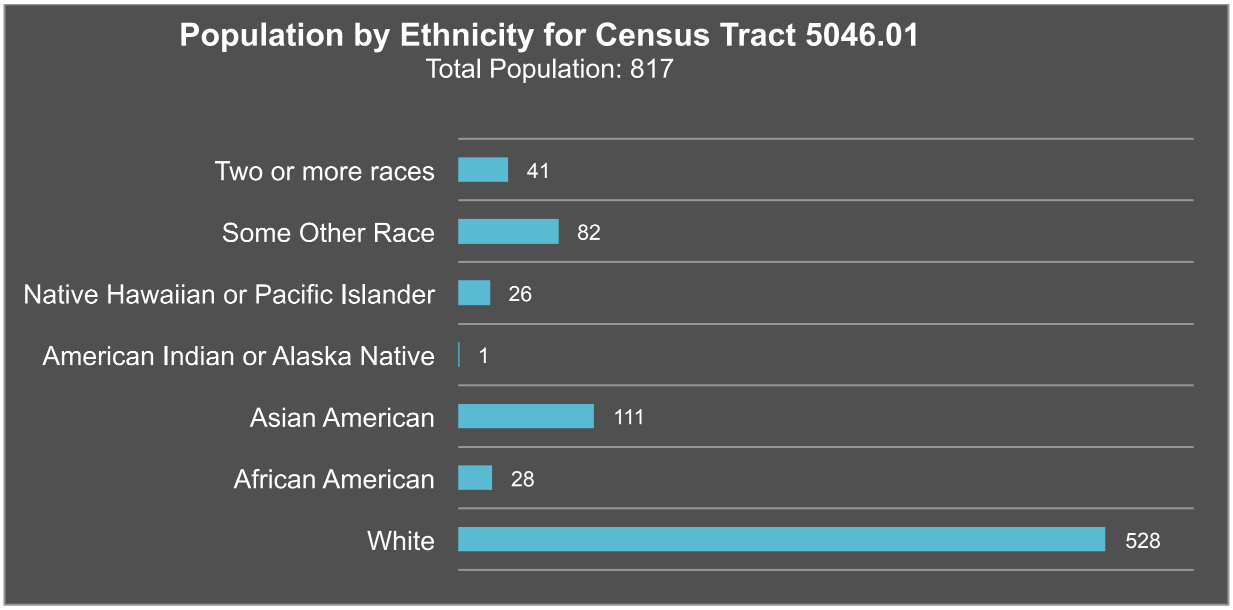

Figure 15: Current population categorized by ethnicity for census tract 5046.01, where Palo Alto Baylands is located, based on U.S. Census Bureau 2010 data.

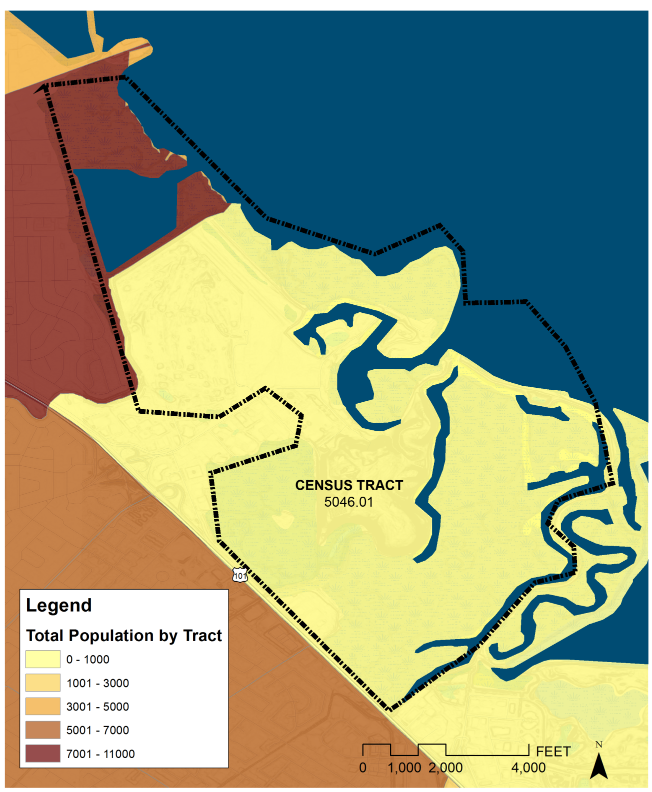

Figure 16: Map of population distribution of Census Tract 5046.01 and surrounding areas (GIS data adapted from U.S. Census Bureau).

Land Use

Land use has not changed Palo Alto Baylands after Byxbee's elaborate proposal to create a destination of commercial spaces, park land, and natural areas. Based on aerial maps from 1948

Figure 17: Four aerial maps of Palo Alto Baylands showing 66 years of land use change (accessed Google Earth 2/2015).

to 2014, showing changes to Palo Alto Baylands over time (Figure 17). Several areas of Palo Alto Baylands have been restored, including the Emily Renzel Wetlands in 1992, the former yacht harbor into marsh and and upland grasslands, and the Former ITT Property restored into freshwater and salt water marsh habitats (City of Palo Alto, 2008). Also, in 1991, a former landfill was converted into a rolling pastoral park, now called Byxbee Park.

For the past decade and a half, there has been little change to the land use at Palo Alto Baylands. Currently, land use within the Baylands composes of wetlands and development (Figure 18). Several areas along the northeastern shoreline edges of Palo Alto Baylands have been restored to natural areas by the early 1990s, so much of the bay shoreline are now "Emergent Herbaceous Wetlands," where more than 80% of vegetative cover are perennial herbaceous vegetation and the soil or substrate is covered with water. A small part along the shoreline are "Woody Wetlands," where more than 20% of vegetation cover consists of forest or shrubland vegetation and is periodically saturated or covered with water. Byxbee Park is covered with "Herbaceous" land cover, where more than 80% of total vegetation is dominated by gramanoid or herbaceous vegetation. (NLCD, 2011)

The municipal golf course is considered "Developed/Low Intensity," which include areas with both constructed materials and vegetation and have 20% to 49% of impervious surfaces of the total cover. Palo Alto Airport has "Developed, High Intensity" land cover, indicating it is a highly developed area and impervious surfaces account for 80% to 100% total cover, and "Developed, Medium Intensity" land cover, where the area consists of constructed materials and vegetation and the total cover has 50% to 79% of impervious surfaces. Theses highly developed areas tightly surround the Palo Alto Baylands. (NLCD, 2011)

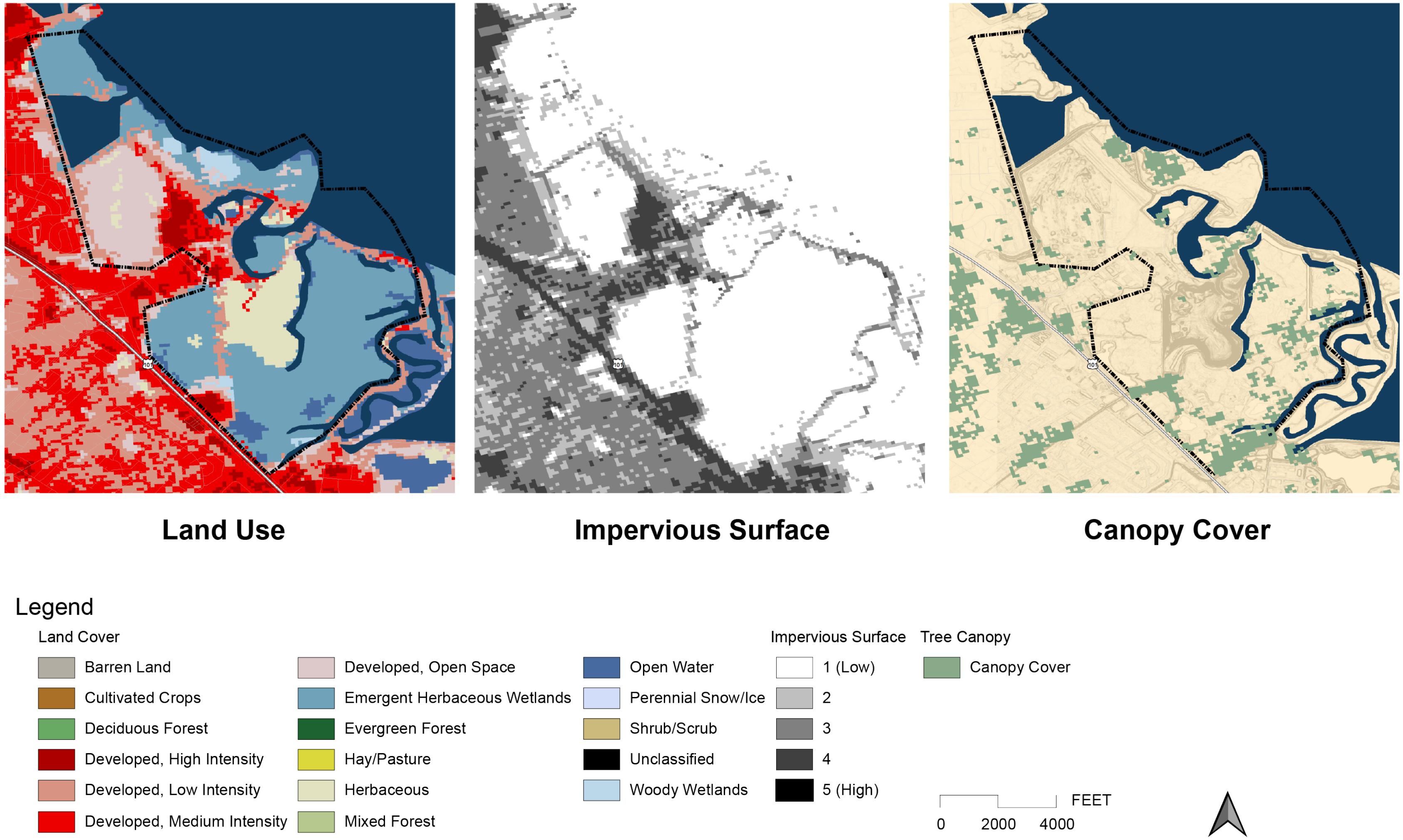

Figure 18: The image displays current land use, impervious surface, and canopy cover maps of Palo Alto Baylands (GIS data adapted from NLCD, 2011).

Existing Wetland Habitats

Palo Alto Baylands, as the name implies, consists of two bayland habitats: tidal baylands and diked baylands. Tidal flat, tidal marsh, and lagoon are examples of tidal baylands habitats. South Bay has the greatest acreage of tidal flats, compared with the other subregions of the San Francisco Bay because tidal flat habitats naturally occur in saline areas. A majority of intertidal flat habitat occurs on the Bay edges and the rest are located along the shallow tidal channels. Twice a day, high tides flow over tidal flats, where they become feeding grounds for fish and worm species of foods produced on the mud flats or from the shore. When not inundated, tidal flats become a rich source of food for diverse shorebird species, especially mud flats. Even though mud flats may not look aesthetically appealing, they are a vital piece to Bay Area's ecology, in which abundant birds, fish, and mammals depend on for food. It is estimated that

Figure 19: The photo shows flat habitat at Palo Alto Baylands during the winter season (image taken by the author).

Palo Alto Baylands mud flats support over 100,000 shorebirds during the winter migratory season. Mudflats typically are located where the shore slopes gradually into the bay and plants will not grow (Figure 19). (City of Palo Alto, 2008; Goals Project, 1999)

Tidal marsh is “a frequently or continually wetland characterized by emergent herbaceous vegetation adapted to saturated soil conditions” (Mitsch and Gosselink, 2007, 32). There are two types of marshlands at the Baylands, which are salt water and fresh water, and are not visually distinctive (Figure 20) (City of Palo Alto, 2008). Salt marshes are one of the most productive natural areas in the environment: a cordgrass marsh plant itself has seven times the food value than an acreage of wheat (City of Palo Alto, 2008).

Diked baylands are wetlands that were previously tidal but isolated from tidal influence due to dikes or levees, but still retain wetland characteristics (Goals Project, 1999). These can be

Figure 20: The photo captures a tidal marsh at Byxbee Park in Palo Alto Baylands during the winter season (image taken by the author).

waterfowl, shorebirds, and small mammals that historically used habitats within tidal marshes (USFWS, 2010). The Baylands have diked marshes and are not intensively managed (Goals Project 1999). They are seasonal wetlands because rainfall and runoff from adjacent lands are their primary water sources (Goals Project, 1999). Nevertheless, they are subject to problems, including subsidence, decreasing drainage efficiency, salt accumulation (USFWS, 2010).

Vegetation Communities

Vegetation communities at Palo Baylands include tidal salt marsh, tidal brackish marsh, diked salt marsh, diked brackish marsh, riparian areas, and non-native grasslands (Figure 21)

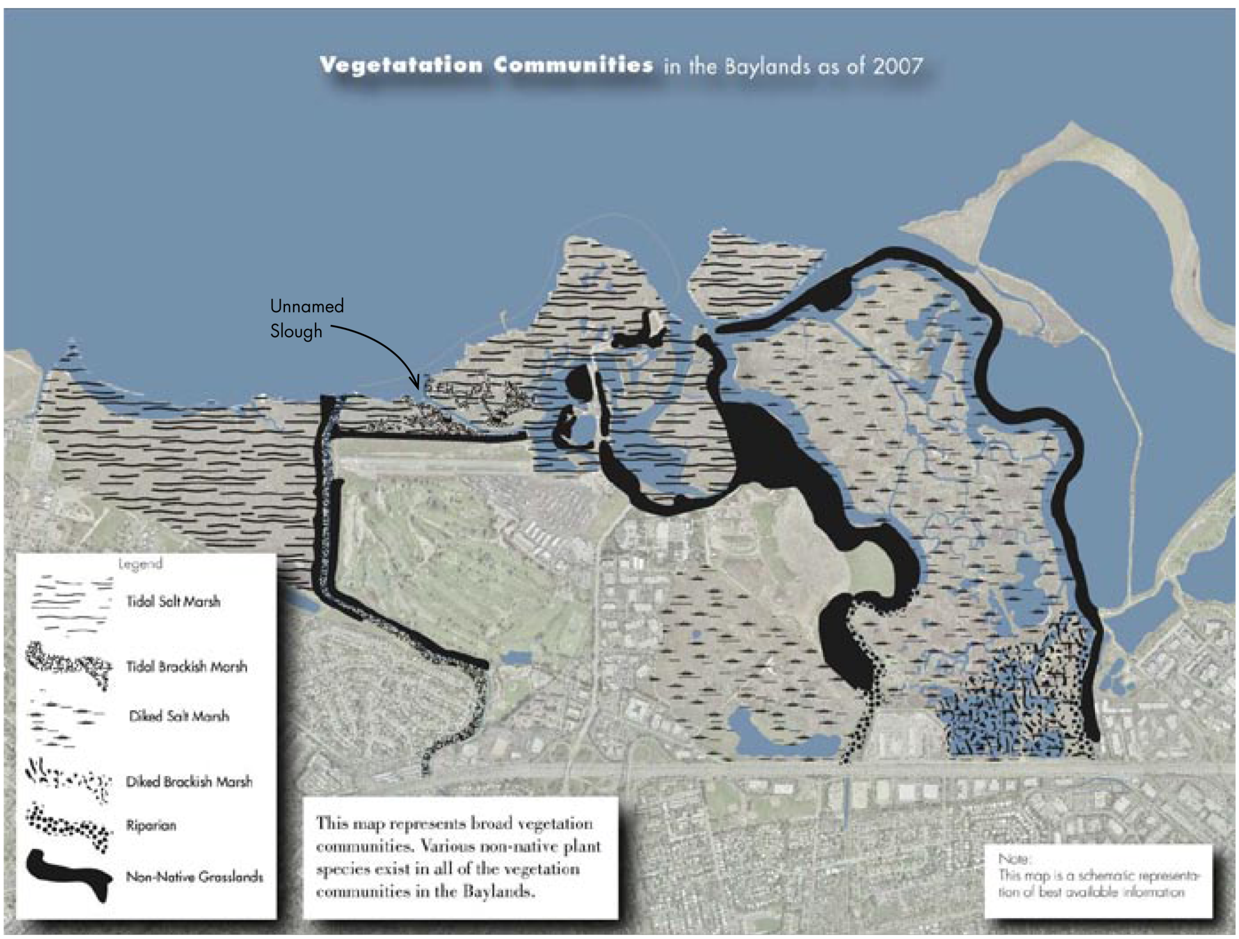

Figure 21: The schematic map broadly illustrates various wetland communities at Palo Alto Baylands (City of Palo Alto, 2008).

(City of Palo Alto, 2008). Salt marsh communities contain low-growing grasses and herbaceous (not woody) perennials that can stand from a few inches tall to 3 feet in height (BCDC, 2007). Tidal salt marshes are typically dominated by two perennial species, Pacific cordgrass (*Spartina foliosa*) and Pickleweed (*Sarcocornia pacifica),* occurring in the low marsh area approximately between MTL and MHW (Figure 22 and Figure 23) (BCDC, 2007; Goals Project, 1999). Pacific cordgrass occurs in the low marsh zone, perennial pickleweed (*Salicornia virginica*) occurs in middle marsh zone, and saltgrass (*Distichlis* spicata) dominates the high marsh zone (PWA and Faber, 2004). The Pacific cordgrass is usually the primary colonizer and intermixes with the annual Pickleweed, particularly in areas of depression in the marsh plain (Goals Project, 1999). Several studies support that the Pacific cordgrass grows well at salinities less than 15 ppt, but can continue to grow in saline areas as high as 35 ppt at reduced rates (Josselyn, 1983).

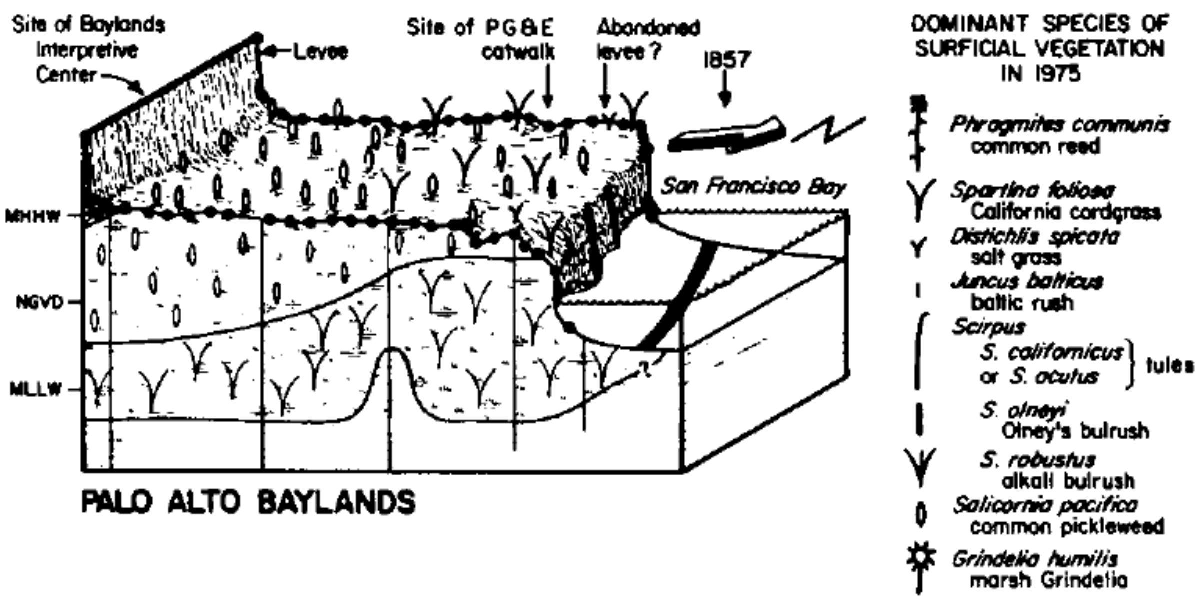

Figure 22: The profile image illustrates the species of vegetation at Palo Alto Baylands relative to water levels (Goals Project, 1999).

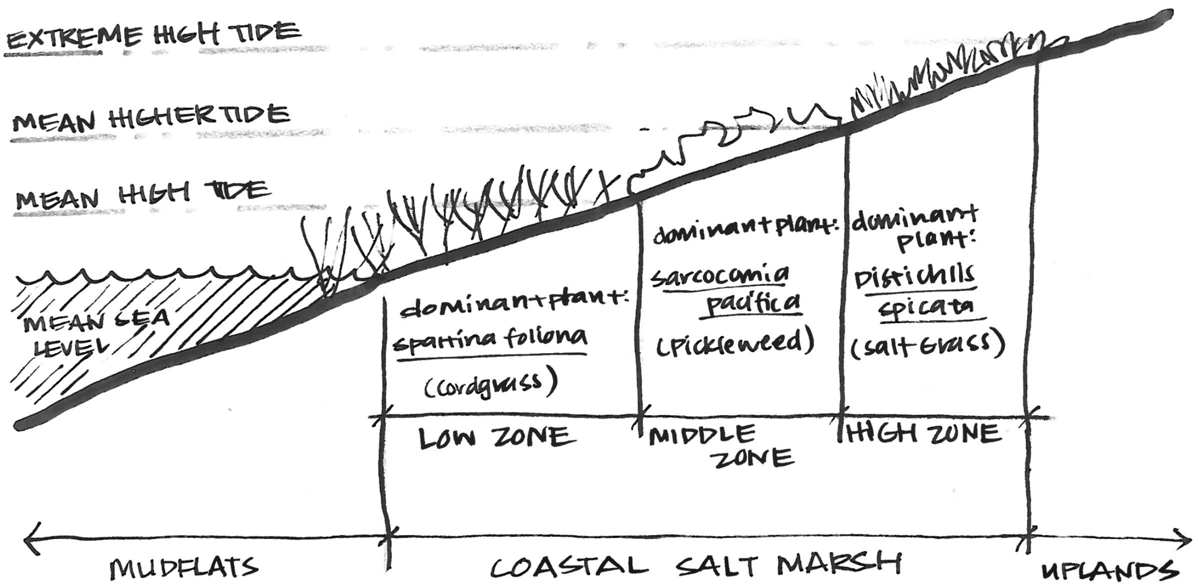

Figure 23: Schematic section of plant species relative to intertidal zones at Palo Alto Baylands relative to the water levels (adapted from BCDC, 2007).

Pickleweed covers the most area in salt marsh habitats of the bay than any other species and can still grow in diked wetlands because of its tolerance to high salinities during dry periods. Other halophytes associated with pickleweed are found as patches within the pickleweed marsh or borders upland marshes and these include sea arrowgrass (*Trichochin maritima*), Jaumea (*Jaumea carnosa*), and marsh rosemary (*Limonium californicum*). (Josselyn, 1983)

Brackish tidal marsh is associated with vegetation that grows under mixed tidal and freshwater conditions and typically has a salinity range of approximately 3 to 25 ppt. It is usually prevalent near river and creek discharges and this is evident at Palo Alto Baylands, considering the existing brackish tidal marsh is in the vicinity of San Francisquito Creek. San Francisquito Creek is currently impaired, based on water quality data reported under Section 303(d) of the Clean Water Act and causes of impairment are diazinon (from pesticides), sedimentation and siltation, and trash. Species composition in tidal brackish marsh varies more than tidal marshes due to difference in the amount of runoff, salinity gradients, and precipitation cycles. Typical dominant species in tidal brackish habitats are Alkali Bulrush (*Bolboschoenus maritimus*), California Tule (*Schoenoplectus californicus*), and cattails (*Typha* spp). The upper marsh edges have the highest plant species diversity in both tidal and brackish marshes. (EPA 2010; USFWS, 2013)

Sedimentation

The effects of American colonization in the past 200 years have changed the sediment budget, as well as salinity distribution (PWA and Faber, 2004). Sediment concentration has been decreasing from historic levels, indicating there may not be enough sedimentation for wetlands to accrete and may be slower than the pace of sea level rise (SFBJV, 2008). Reduced rate and availability of sedimentation remains a problem for San Francisco Bay and this deficit is the most prominent constraint in wetland restoration for the south bay (Goals Project, 1999; Mitsch and Gosselink, 2007; Patton, 2002). Suspended sediment from hydraulic mining during the Gold Rush has been declining, most likely due to dam construction, flood control, water diversions and other management actions in watersheds (Goals Project, 1999; BCDC, 2011). As a result of dams, flood flows are reduced which limits the capacity of rivers to carry sediment from the Delta to the Bay (BCDC, 2011). Reduced water flows and impoundment and retention of sediments in reservoirs also contribute to declining sediment availability (Cohen, 2010). This indicates that the time frame of restoration will need to be tied to the availability of sediment, so large scale tidal marsh restoration may take several decades to occur (Goals Project, 1999). Also, the further the marsh is away from the sediment supply, the less sediment concentration it will receive, so sediment loads are usually lowest for interior marshes (PWA and Faber, 2004).

Sedimentation is an important component of tidal baylands: tidal flats and tidal marshes will erode or not form if an environment lacks regular supply of sediment (Goals Project, 1999). Tidal marshes depended on sedimentation to form along the San Francisco Bay edges (Josselyn, 1983). Adequate supply of sediments allowed tidal wetlands to form over previous tidal flats, when sea level rise slowed 6,000 years ago (Atwater et al., 1979). The inflow of sediment eroded from Central Valley river watersheds sustained habitats of marsh, mudflat, and tidal channels for over thousands of years, transported by large winter floods from the Sacramento and San Joaquin Rivers (Willams and Faber, 2004). Water flow, such as freshwater flows, tidal currents, and waves, producing and transporting inorganic silts and clays are one source of sediment for the baylands (Goals Project, 1999). This includes sediment annually coming from the drainage basin of Sacramento and San Joaquin Rivers, supplying about 85% of total input (Josselyn, 1983). Though, a small amount of sediment actually reaches to the baylands and the remains are either transported to the ocean or fall at the bottom of the San Francisco Bay (Goals Project, 1999). The second source is organic sediments generated by plant grown in the baylands (Goals Project, 1999).

Floods help create new surface land and sedimentation to occur (Josselyn, 1983). If enough sedimentation is provided to flat, low-lying lands in the South Bay, it can allow tidal marshes to expand and move landward; however, land availability for new tidal marshes may be limited in dense urban areas (Goals Project, 1999). Low-lying wetlands are subject to constant influx of sediment, are able to fill quickly, and sediment supply remains steady even if wetlands are converted to a different use (Josselyn, 1983). For instance, the former yacht harbor (now named restored harbor marsh) previously had deposition rates exceeding 60 centimeters a year (Josselyn, 1983).

<u>Challenges to Salt Marsh Restoration</u>

The wetland ecosystem at San Francisco Bay continues to display remarkable resiliency despite drastic anthropogenic changes throughout history, as well as the growing pressures of sea level rise (BCDC, 2011). There are conditions and factors that further threaten tidal marsh ecosystems and species specific to the wetlands of San Francisco Bay (USFWS, 2010), such as subsidence, mercury contamination, salinity changes, urbanization effects, and endangered and invasive species.

Subsidence

Marsh is substantially lower than the minimum elevation for marsh vegetation to grow and colonize, unless ground elevations can be raised from fill material (BCDC, 2011; PWA and Faber, 2004). The rapid diking of marsh plains for agriculture use and salt pond production 35 to 135 years ago has led to subsidence, ranging from 2 to 6 feet for diked tidal marshes around the Bay (BCDC, 2011; PWA and Faber, 2004). South Bay in particular, subsidence is more pronounced due to water withdrawals from groundwater and soil compaction and has reached at maximum of approximately 15 feet, resulting in less salinity for most marshes (Atwater et al., 1979; Goals Project, 1999; Josselyn, 1983; PWA and Faber, 2004). Subsidence for the past 50 years in South San Francisco Bay has also contributed to the conversion of cordgrass-pickleweed marshes to brackish species marshes of bulrush and cattail species (PWA and Faber, 2004).

Additionally, with sea level rise occurring for the past 100 years, land surface is about 0.5 feet lower within the tidal frame (PWA and Faber, 2004). Between 1954 and 1965, Palo Alto Baylands experienced subsidence caused by water withdrawals from groundwater, descending the tidal marsh to a lower level, which probably explains the unusual existence of California cordgrass on tidal marsh plain today (Atwater et al., 1979). Though, the majority of marshes remain at or near MHHW, implying that sedimentation has generally prevented further subsidence, amounting approximately 1 meter since 1931 (Atwater et al., 1979).

Mercury Contamination

Mercury is "Bay water quality enemy number one" (Davis et al. 2007). Due to historic mercury and gold mining, mercury concentrations exceed standards in the Bay and continue to flow downstream from upstream sources into the estuary (Cohen, 2010; USFWS, 2010). In California, approximately 12,000 metric tons of mercury was used in the Sierra Nevada to extract gold and now has spread in Bay sediment (BCDC, 2011; Cohen, 2010). Abandoned mercury mine sites and urban runoff also contribute to mercury loads (Davis et al., 2003). Inorganic mercury in this sediment can be transformed to methylmercury, a highly toxic contaminant, exacerbated by increased acidity (BCDC, 2011).

While 2% of total mercury in methylmercury, this form of mercury in the Bay is of greatest concern because methylmercury concentrations can biomagnify in the food web and is a neurotoxin which harmfully affects early stages of human and animal development (Cohen, 2010). Conversion of inorganic mercury to methylmercury can increase by restoration activities, where an increase in wetland acreage can cause a regional increase in mercury bioaccumulation (Davis et al., 2003; Palaima, 2012). A study showed that wetland restoration increased mercury concentration in bird eggs and fish after restoration occurred, due to several factors associated with changes in water chemistry, not trophic ecology (Ackerman et al., 2013).

Additionally, wetlands are a major source area of methylmercury, producing more methylmercury than open water in San Francisco Bay (Palaima, 2012). Tidal marshes often provide favorable conditions for methylmercury to form and accumulate, based on evidence of high mercury concentrations discovered in various fish species in San Francisco Bay (USFWS, 2010). Methylmercury can significantly affect viability of California clapper rail eggs, a federally listed endangered bird species (USFWS, 2010). South bay tends to have higher mercury concentrations than other bay subregions (Schwarzbach, 1999).

As previously stated, the Bay is losing sediment, suggesting that increasing rates of erosion of Bay bottom sediments can release mercury concentrations hidden in those trapped layer for many decades (Cohen, 2010; Patton, 2002). Therefore, upland migration of wetlands requiring fill material must carefully be assessed for contaminants.

Anthropogenic effects

Extensive urban and industrial development has led to the destruction of about 95% of wetlands in California (Patton, 2002). Development is often located adjacent to the baylands and along the Bay shoreline, impacting may of the ecosystem's plant communities and availability of upland edge for tidal habitats (BCDC, 2011; Goals Project, 1999). Upland transition zones of wetlands have high species diversity and are refuge areas for endangered species, such as the salt marsh harvest mouse and the California clapper rail, during high tides (BCDC, 2011). As sea level rises, upland areas have the potential to evolve into tidal marsh habitat, but these transition zones have been mostly lost because of development and are now only a few feet of vegetation along a steep slope of a levee (BCDC, 2011). With extensive urbanization on the uplands of the bay shoreline, landward marsh retreat opportunities are limited (SFBJV, 2008). Furthermore, close vicinity of urban areas to the Bay drastically limits the adaptive capacity of the ecosystem and the potential for habitat restoration meant to provide compensation for altered temperatures, salinity, and sediment (BCDC, 2011).

The effects of urbanization increase impervious surfaces, construction of drainage systems, culverts, and channelization in Bay watersheds (BCDC, 2011). Water flow and sediment from watersheds are impacted by urban development (BCDC, 2011). This can cause distribution of hazardous wastes, urban runoff, water diversion and discharge of sewage effluents, adding more stress to the natural environment (Josselyn, 1983). Stormwater runoff, which is originated from urban areas and rural settings, bring a variety of pollutants to the baylands, such as metals and nutrients, and alter freshwater inputs (Goals Project, 1999; USFWS, 2010). Wastewater discharges affect salinity levels in tidal waters, which is detrimental to the California clapper rail and other species (USFWS, 2010). Another effect of urbanization is the withdrawal of groundwater, which has caused subsidence of tidal wetlands in Palo Alto Baylands (Josselyn, 1983). Pacific cordgrass (*Spartina foliosa)* has recolonized former pickleweed extant plant communities *(Salicornia virginica*) (Atwater et al., 1979).

Urban development has fragmented most of the contiguous shoreline habitats of the Bay (BCDC, 2011), where remnants of tidal marshes are highly impacted by human activity (Josselyn, 1983). Habitat fragmentation can isolate wildlife corridors, dividing once extensive habitats into small, discontiguous spaces (USFWS, 2010). Smaller habitat areas reduce tidal marsh populations, as well as habitat features needed by a species throughout its lifetime (USFWS, 2010).

Endangered and Invasive Species

Tidal marshes have low bird diversity because of the specialized environment involving high salinity and frequent inundation, but are home to a high proportion of endemic subspecies that have adapted to these harsh conditions (SFBJV, 2008). In 1970, two important wildlife species were designated as federally endangered: the California clapper rail (*Rallus longirostrus obsoletus)* and salt marsh harvest mouse (*Reithrodontomy raviventris*) (USFWS, 2013). The California clapper rail are endemic to tidal and brackish marshes, dependent on pickleweed marshes with high salinity, in San Francisco Bay and now occurs less than 10 percent of its

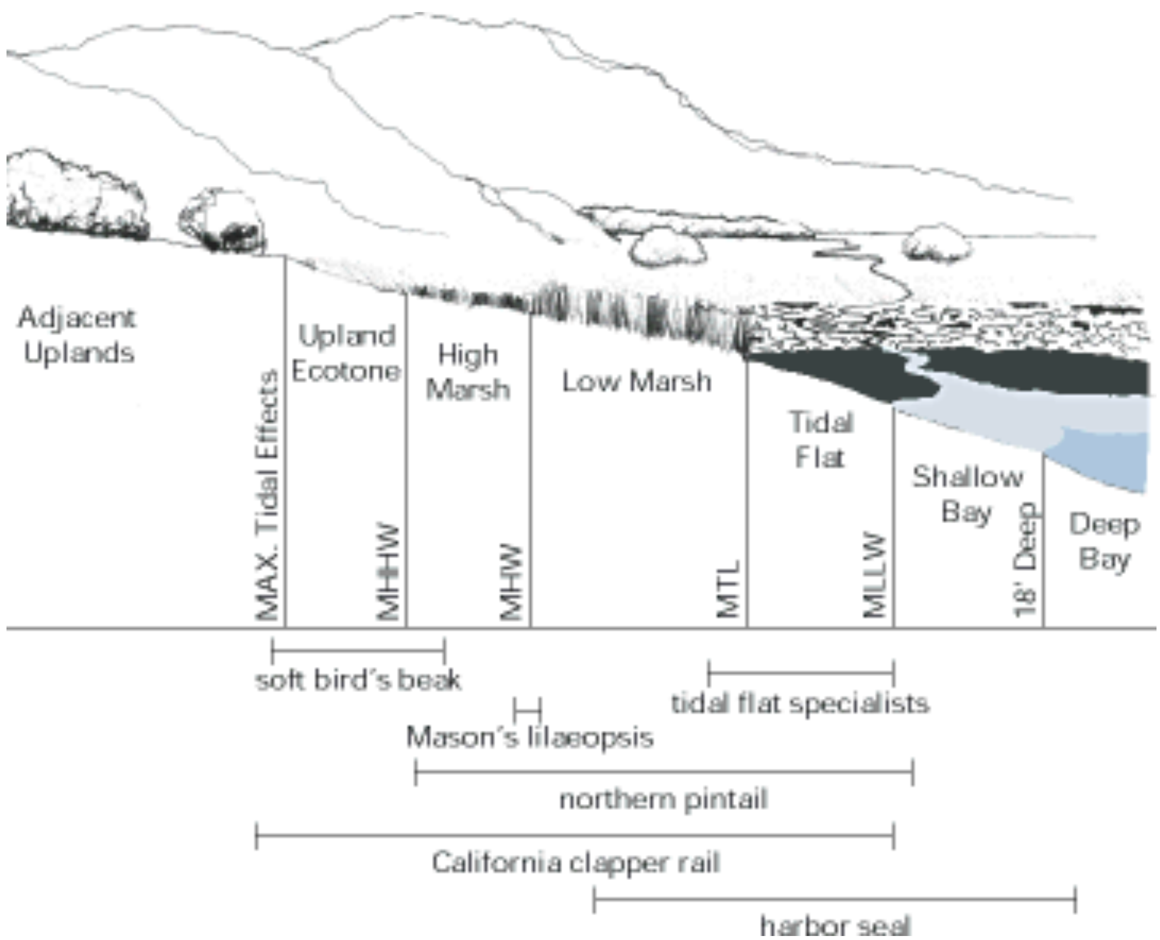

Figure 24: The cross-section image shows a typical cross section of plants and wildlife inhabiting different areas of the intertidal zone in marshes at San Francisco Bay (Goals Project, 1999).

former geographic range (SFBJV, 2008; USFWS, 2013). They reside in more saline marshes of the Bay, including salt marshes at Palo Alto Baylands, and are found in large tidal marshes with well-developed channel systems (Goals Project, 1999). Clapper rails are non-migratory, spend their life span in the marshes of the bay, and rarely move between marshes during breeding season because they have a small habitat range of a few acres (Figure 24) (Davis et al., 2003). They are a struggling species due to loss of habitat, isolated tidal marsh fragments, invasive species, and predation (Pitkin and Wood, 2011; Schwarzbach, 2003; USFWS, 2010). The lack of extensive tidal marsh habitat is the ultimate limiting factor for the species' recovery and the narrow, fragmented patches close to urban areas have diminishing habitat quality (USFWS, 2010). Also, dikes create an artificial gateway for terrestrial predators and the invasion of the Smooth cordgrass (*Spartina alterniflora*) may impair habitats for California clapper rails (USFWS, 2010). Mercury may also affect the endangered California clapper rail (Cohen, 2010). Even though tidal marshes at Palo Alto Baylands have limited habitat extent, they are the most productive and densely populated marshlands for California clapper rails in the entire Bay. Rising seas will become a challenge for clapper rails to survive when they are pushed into marginal habitats (Pitkin and Wood, 2011).

Like the clapper rail, the salt marsh harvest mouse occurs almost exclusively in salt and brackish marshes of San Francisco Bay. In general, they are restricted to saline or subsaline marsh habitats and population viability are limited by lack refuge from high tides and escape habitat. Increase populations of invasive *Spartina* over mudflats and marsh plains can destruct or degrade native habitat for tidal marsh plants and animals, where extensive habitat and food plant (*Sarcocornia*) critical for salt marsh harvest mouse survival would be lost to the exotic species invasion. Sea level rise is a severe threat for South San Francisco Bay since landward retreat opportunities of habitats are constrained. (USFWS, 2010, 2013)

The eastern cordgrass (*Spartina alterniflora*) is a non-native species that is most abundant in the San Francisco Bay, threatening population of native plant species by invading and changing ecosystems. The eastern cordgrass is originally from the East Coast and was deliberately introduced to the Bay Area to stabilize flood-control levees by the Army Corps of Engineers in the 1970s. Yet, the eastern cordgrass started to cross-pollinate with the California native cordgrass, dramatically altering vegetation structure, species competition, and composition within native plant communities. They are considered the greatest threat to native salt marsh management and restoration in San Francisco Bay. It is taller, grows faster and more densely, and occupies a wider tidal range than the native Pacific cordgrass. Also, non-native animal predators, such as red fox and Norway rats, prey on native mammal species in the south bay of San Francisco Bay. (Martin, 2005; USFWS, 2010)

Summary

Even with only 200 years of settlement history, San Francisco Bay has been greatly impacted by human alterations to the landscape, where people are responsible for 79% of tidal marsh loss (Goals Project, 1999). This created a chain reaction of natural habitat loss, modified ecosystem cycles, wetland degradation, and diminishing native species population. San Francisco Bay is a vital resource for a variety of wetland habitats and diverse wildlife, but it is simultaneously facing both regional (sediment loss and mercury contamination) and global (climate change and rising sea levels) challenges.

Palo Alto Baylands, in particular, is one of the few remaining sites in the bay with remaining bayland habitat and specifically provides valuable resources for migratory birds, endangered species, and native marsh vegetation. Even though it is in close proximity to urban development and a busy highway, much of the natural areas remain intact and four areas at the baylands have been restored to a wetland or converted to an open park. Because of restoration activities, natural areas are covering more acreage than existing commercial development at Palo Alto Baylands, which is a remarkable feat as city population is projected to gradually increase for the next several years. Yet, the Baylands is also facing its own site-specific challenges, including subsidence of low-lying mudflats and tidal marshes making them vulnerable to permanent inundation, which will need to be addressed as sea levels are expected to rise.

Wetland loss is closely associated to population density (Mitsch and Gosselink, 2007), and, with a growing human population of San Francisco Bay, land availability for wetland restoration opportunities becomes scarce. As increasing urban development is needed to accommodate greater population demands, the biggest threat to tidal marsh ecosystems is not environmental or global factors, but humans. Anthropogenic changes have scarred much of the natural environment and have left tidal marsh communities along the bay shorelines in fragile conditions, while still showing incredible resiliency and adaptability. Though, because the ecosystem of San Francisco Bay is considered largely a managed environment (BCDC, 2011), human interventions are needed to help these systems respond and adapt to changes and impacts, while preserving ecological function and quality to maintain healthy species population.

Historic sea level rise is largely responsible for how the San Francisco Bay appears today; the natural environment of the bay is dynamic and constantly changing. While rising sea levels today is mainly due to anthropogenic effects, it is happening and may continue to occur, despite efforts to protect assets behind hard-engineering structures or other protective measures. These are temporary solutions to a natural, environmental occurrence that has existed many centuries ago for San Francisco Bay and rising seas will persist, particularly when human activities continue to carry on and human population progressively grows.

In this light, retreat is not regarded as a surrendering option, but one that allows sea level rise to naturally occur and uses salt marshes to respond to these changes. The role of public perception and attitudes contribute to the longevity and success of wetland restoration projects not only to save critical tidal marsh habitat from rising sea levels, but also sustain them for the future. Managed retreat is ecologically beneficial because it allows for the opportunity to remove existing infrastructure, which creates room for tidal marshes to migrate landward before potential risk of permanent inundation due to rising seas, even with growing population and increasing urban density.

To increase the success of a managed retreat scheme, public perception and attitudes must be considered. Determining whether the public favors or does not favor managed retreat guides how the conceptually managed retreat scheme should be designed. The survey was conducted to identify this, along with gathering information about how users felt towards salt marshes, climate change impacts, and climate adaptation strategies for Palo Alto Baylands. Depending on the respondents’ attitudes towards managed retreat, the conceptual managed retreat scheme is either a reflection of current favorable attitudes or a remedy to change unfavorable perceptions about this climate adaptation strategy.

Survey Background

Respondent Demographics

The data collected is based on a small representative sample of 57 adults, aged 18 or older, residing in the Bay Area (Table 1). Survey respondents had an equal participation from

Summary of Respondent Characteristics

	N	%
Total	57	100
Sex		
Male	28	49
Female	28	49
Did not disclose	1	2
Age		
25-34	9	16
35-44	9	16
45-54	14	25
55-64	12	21
65-74	9	16
75-84	3	5
Did not disclose	1	2
Education		
Some high school	1	2
Some college	2	4
Trade/Technical/Vocational Training	2	4
College graduate	18	32
Some postgraduate work	9	16
Post graduate degree	25	44
City		
Palo Alto	29	51
Outside of Palo Alto	27	47
Did not disclose	1	2
Race/Ethnicity		
Asian or Asian American	2	4
Hispanic or Latino	3	5
Non-Hispanic White	46	81
Did not disclose	6	11

Table 1. Summary of respondent characteristics from survey.

both genders (48% male; 48% female; 2% did not disclose), tend to be middle-aged or older, and tend to have a college degree or higher. Approximately 51% of respondents live in Palo Alto, with the remaining 47% living outside of the city (2% did not disclose). A majority of survey respondents were non-hispanic white (81%) and a few were Hispanic/Latino (5%) or Asian or Asian American (4%) or did not to disclose their ethnicity (11%).

Survey Results

Use and Views About Palo Alto Baylands

Respondents were asked how frequently they visited the site on an average basis (Figure 25). Most respondents regularly visit the Baylands, usually once a month or more (82% male; 64% female). Nearly half of male respondents reported visiting the site a few times a week (43%) and the same frequency was slightly less for female respondents (32%).

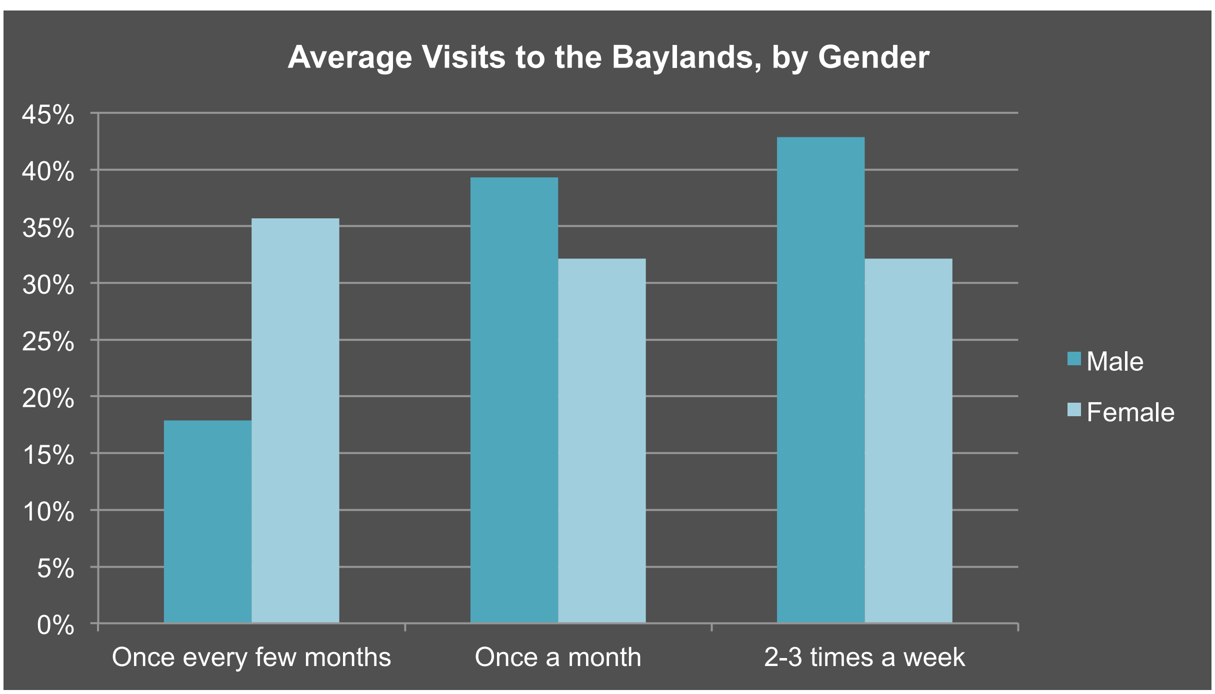

Figure 25: Average visits to Palo Alto Baylands by gender.

Respondents were provided a list of specified activities and asked to identify activities they performed at the Baylands, with the option of entering non-specified activities (Figure 26). The primary uses at the Baylands were hiking (47% male; 31% female) and bird watching (36% male; 23% female), as well as photography (18% male; 11% female). Respondents who used the Baylands for running (22% male; 4% female) were much more likely to be male, while picnic and sailing or kayaking activities tend to be activites engaged by females. Restoration work was also noted as an activity for males (7% male; 1% female) and events related to tour walks and volunteering tend to be reported by females (5% female; 2% male).

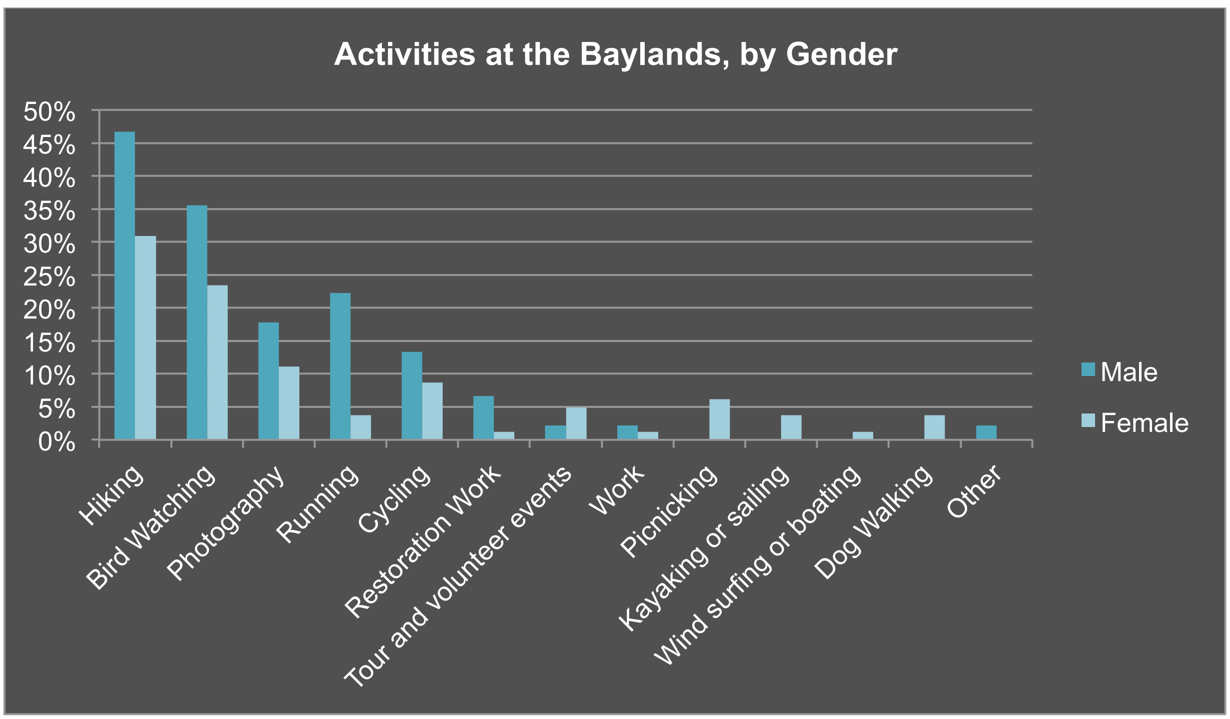

Figure 26: Activities performed at the Palo Alto Baylands by gender.

When asked to click three most important areas at the Baylands using a map image, the most important areas selected were Byxbee Park (18%) and Lucy Evans Baylands Nature Interpretive Center (16%) (Figure 27). Other areas that participants regarded as particularly important were the Restored Harbor Marsh (12%) and Flood Control Basin (12%).

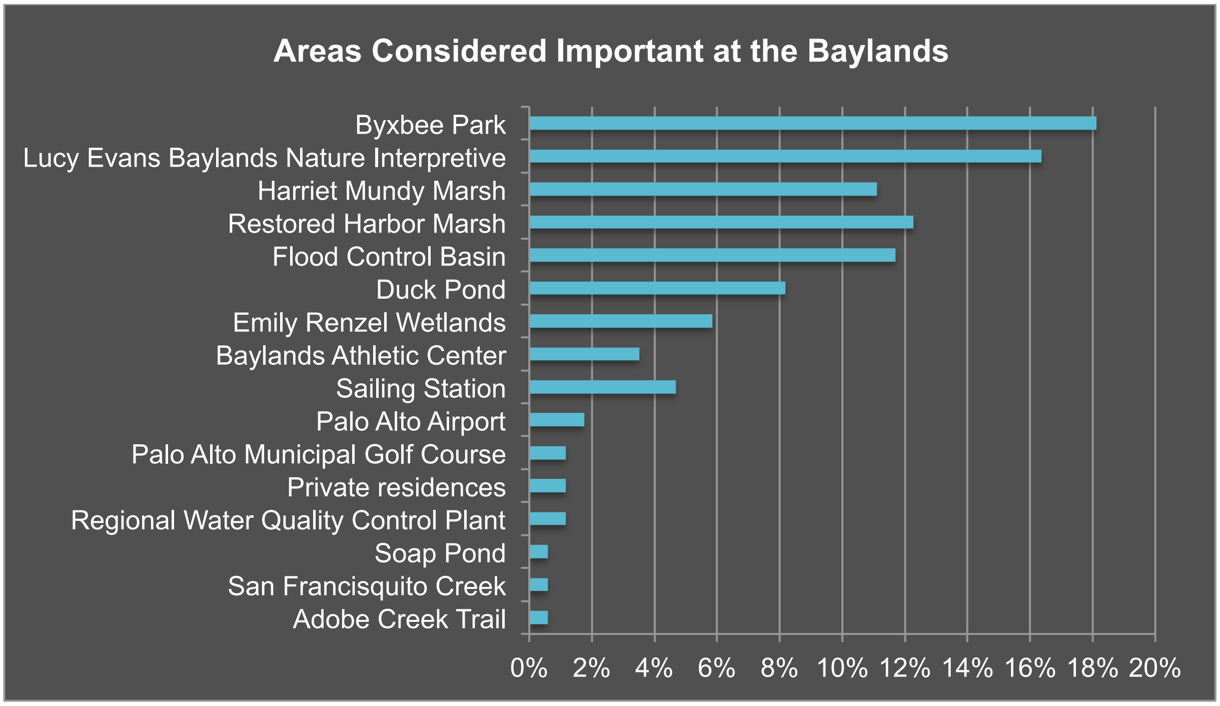

Figure 27: Areas selected on a map of the Baylands that were considered most important.

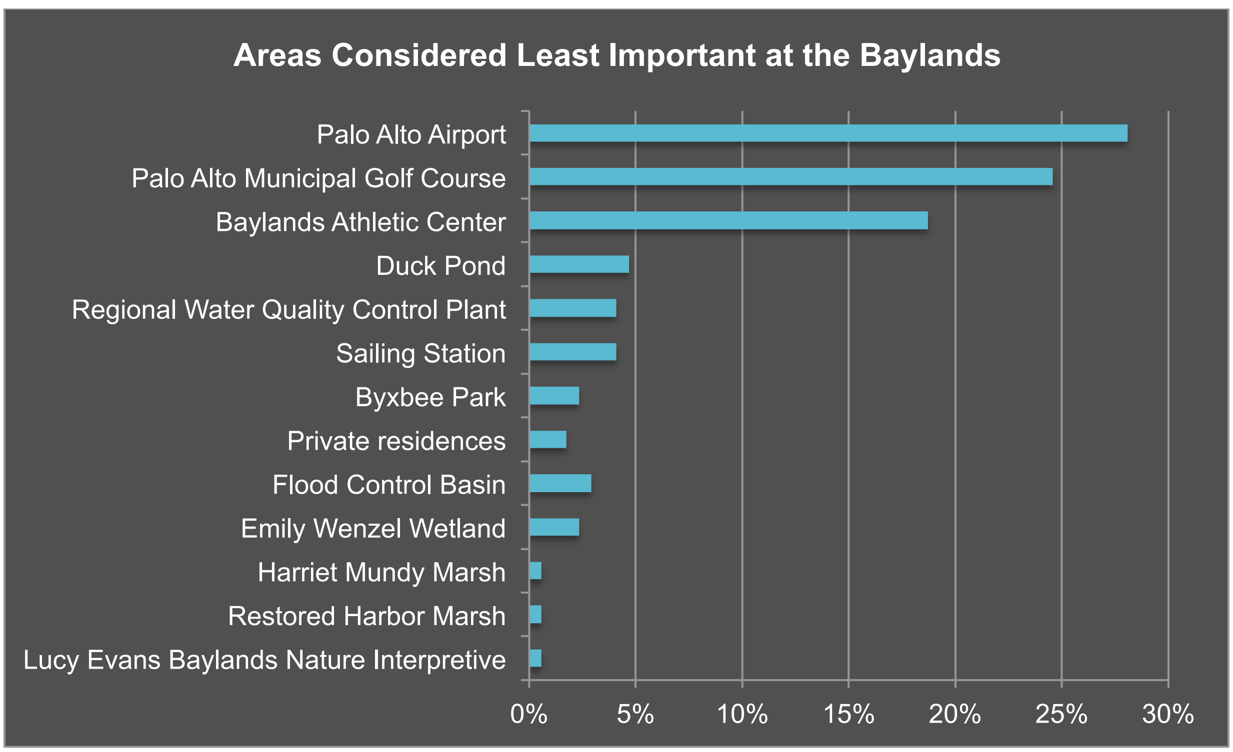

Figure 28: Areas selected on a map of the Baylands that were considered least important.

Using a second map, the least important areas selected were Palo Alto Airport (28%), Municipal Golf Course (25%), and Baylands Athletic Center (19%) (Figure 28). Slightly less favorable areas were the Duck Pond (5%), the Regional Water Quality Control Plant (4%) and the Sailing Station (4%).

Perceptions about Salt Marshes

Participants were asked to select the most and least attractive salt marshes at three different locations at the Baylands based on three images. The results were mixed in indicating the most attractive marsh, but more than half viewed marshes with brown colored vegetation as least attractive (58%) (not graphed).

A majority of total respondents reported that salt marshes are very important (74%) or important (14%) in providing flood protection at Palo Alto Baylands (Figure 29).

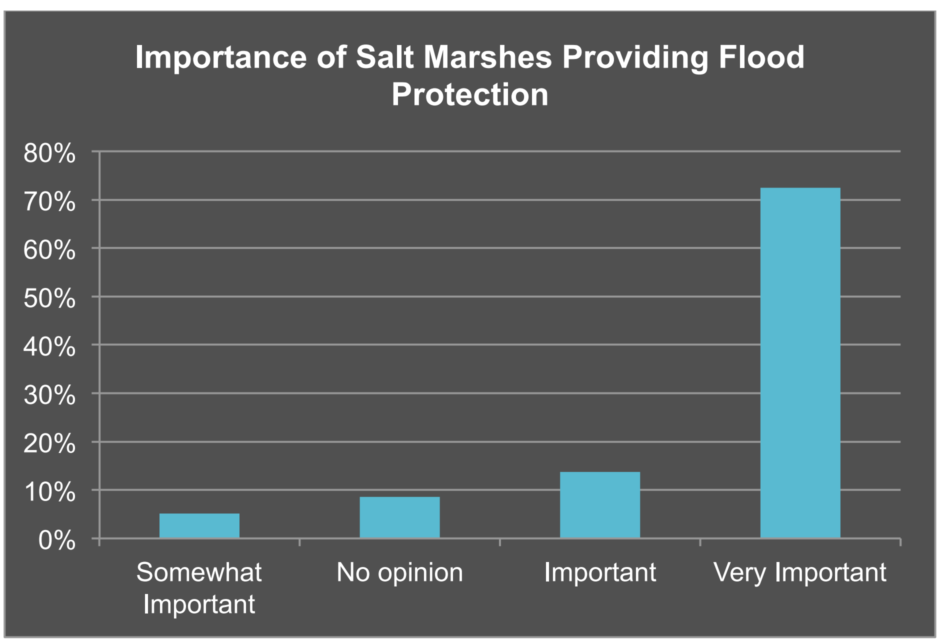

Figure 29: Respondents' ranking on the importance of salt marshes providing flood protection at Palo Alto Baylands.

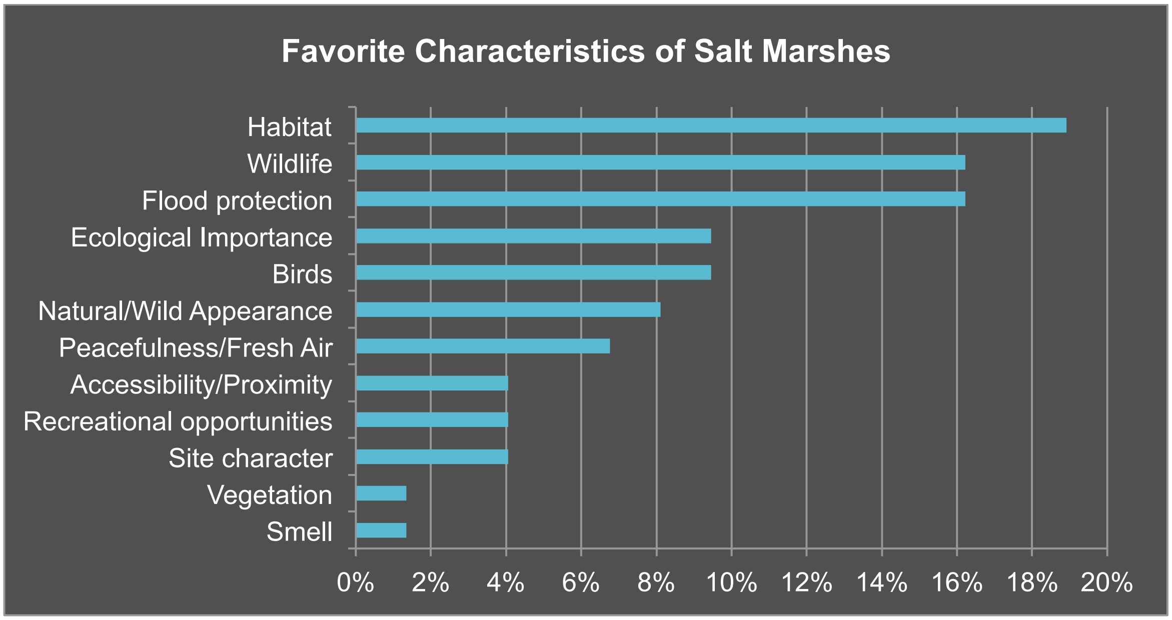

Figure 30: Aggregated responses of what respondents liked about salt marshes.

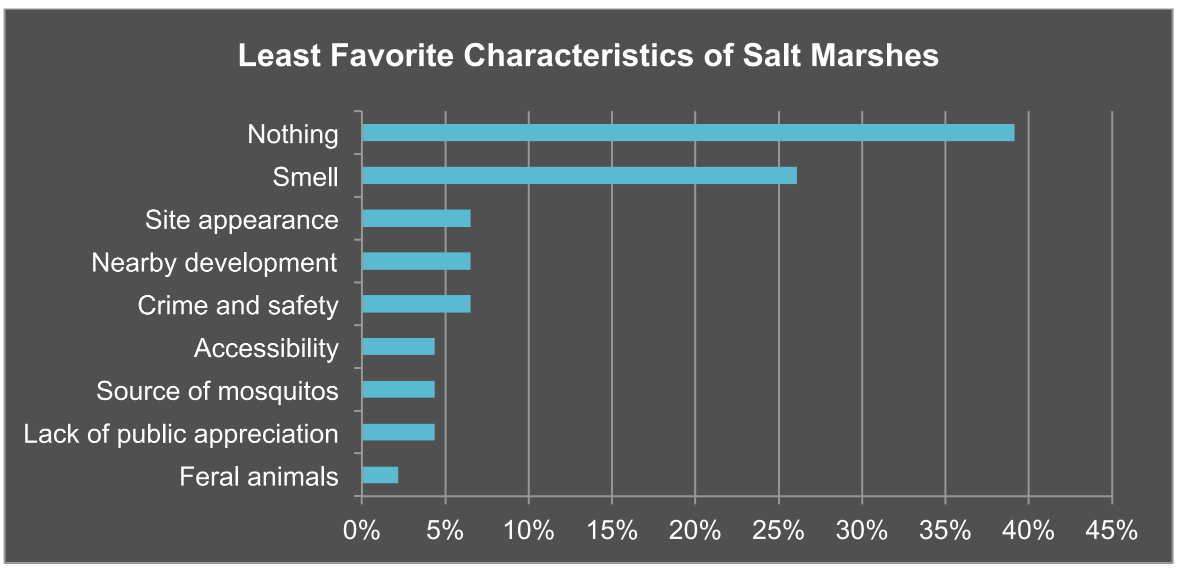

Figure 31: Aggregated responses of what respondents did not like about salt marshes.

Respondents were asked to note what they liked about salt marshes and the most commonly cited characteristics were habitat (19%), wildlife (16%), and flood protection (16%) (Figure 30). Other characteristics of salt marshes that respondents regarded as positive were ecological importance (9%), birds (9%) and natural/wild appearance (8%). Respondents were also asked what they did not like about salt marshes and a majority of them reported nothing (39%) and several reported the dislike of smell (26%) (Figure 31). Other less favorable qualities about salt marshes were site appearance (7%), such as looking muddy, nearby development (7%) and crime and safety (7%).

Beliefs About Climate Change

Respondents were asked when they think climate change will start to substantially negatively impact Palo Alto Baylands (Figure 32). Most respondents believe climate change will negatively impact Palo Alto Baylands now (35%). Almost identical percentages of respondents also believe climate change will occur in 10 years (28%) or in 25 years (26%) and a few reported in 50 years (9%). There was little variance in respondent answers according to age, but it can be observed that respondents from all age groups believe climate change will negatively impact Palo Alto Baylands in 25 years (Figure 33). Also, all respondents aged 75-84 believe climate change will negatively impact the Baylands in 25 years (100%).

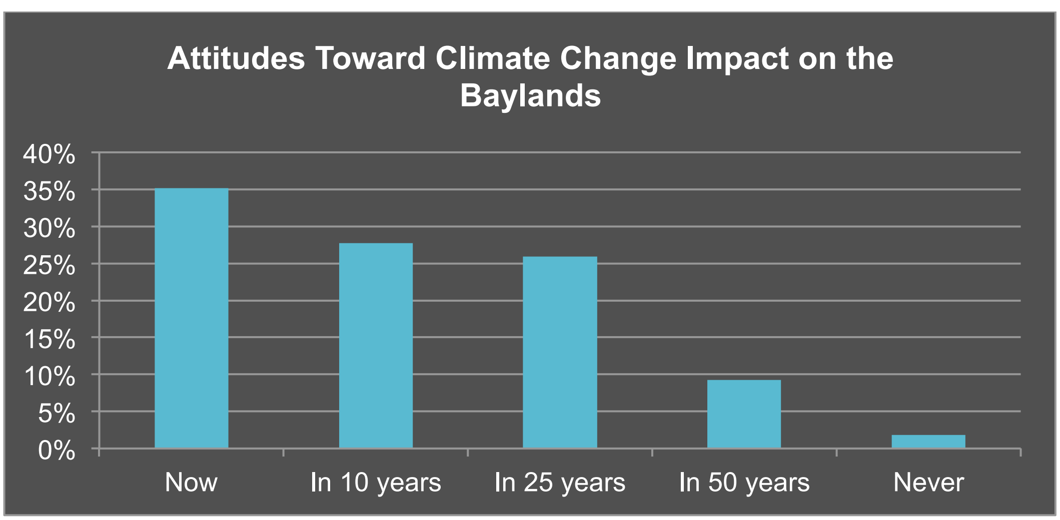

Figure 32: Respondents' beliefs about when climate change will negatively affect Palo Alto Baylands.

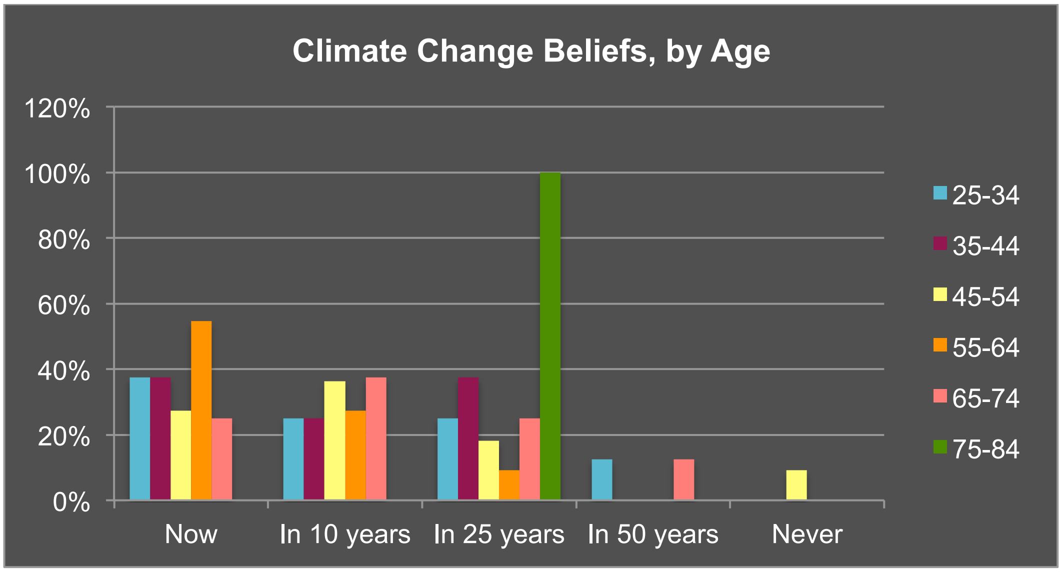

Figure 33: Respondents' beliefs about when climate change will negatively affect Palo Alto Baylands, by age.

Respondents were given a sea level projection for the state of California and were asked if they regarded sea level rise as a problem at Palo Alto Baylands. A majority of total respondents believe sea level rise is a problem at Palo Alto Baylands (89%) and few reported it is not a problem (11%) (Figure 34).

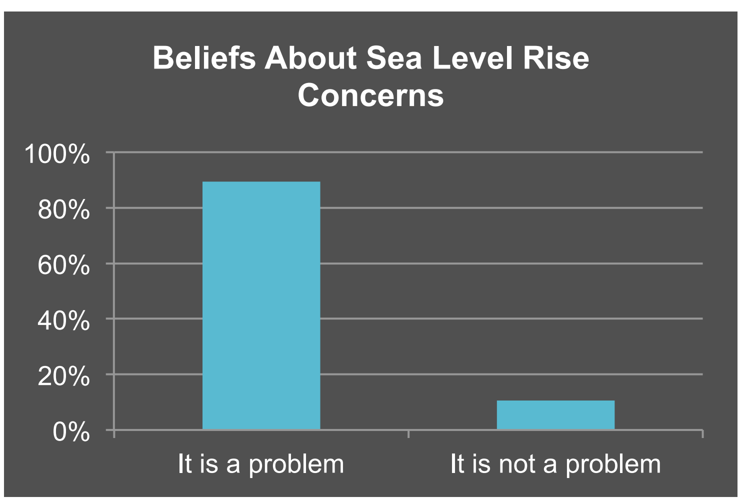

Figure 34: Respondents' beliefs about sea level rise concerns at Palo Alto Baylands, in the context of a given projection for the state of California.

Preferences for Climate Adaptation Strategies

Participants were asked which general climate adaptation strategies managers should pursue to mitigate sea level rise at Palo Alto Baylands if economic costs were not an issue, with brief definitions of each strategy provided (Figure 35). A little over half of total respondents preferred managers should pursue managed retreat in the given context (51%), while some favored accommodation (32%). Protection was the least favored climate adaptation strategy (18%). Respondents from all age and education groups showed preference to managed retreat and respondents of all age groups also favored accommodation as a suitable climate adaptation strategy managers should pursue (Figure 36 and Figure 37). A little over half or more respondents from age groups 75-84 (67%), 45-54 (57%), 55-64 (58%), 25-34 (56%) favored managed retreat and less favored by respondents aged 35-44 (22%) and 65-74 (44%).

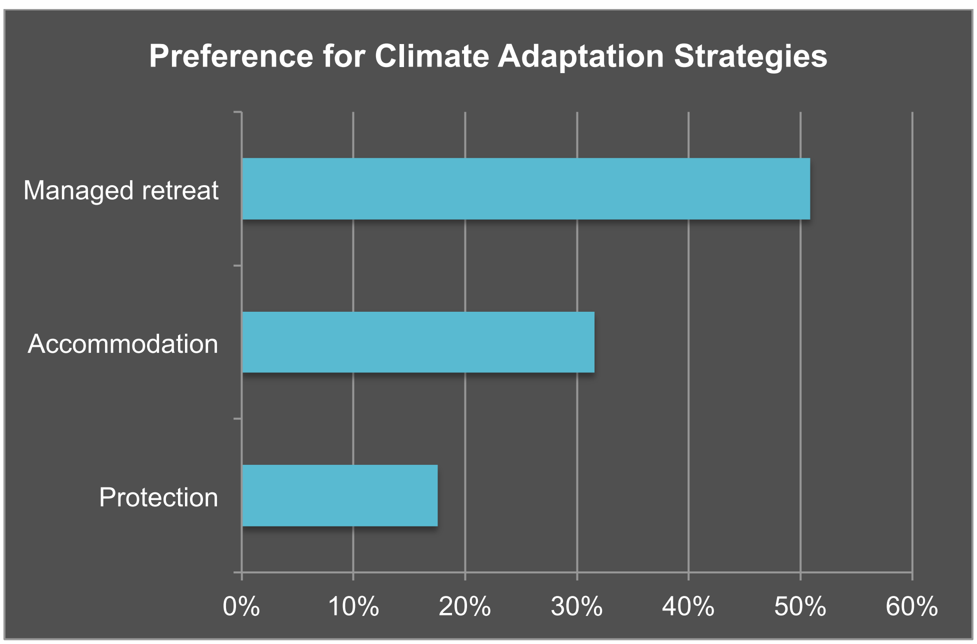

Figure 35: Respondents' preference for climate adaptation strategies managers should pursue to mitigate sea level rise at Palo Alto Baylands, if economic costs were not an issue.

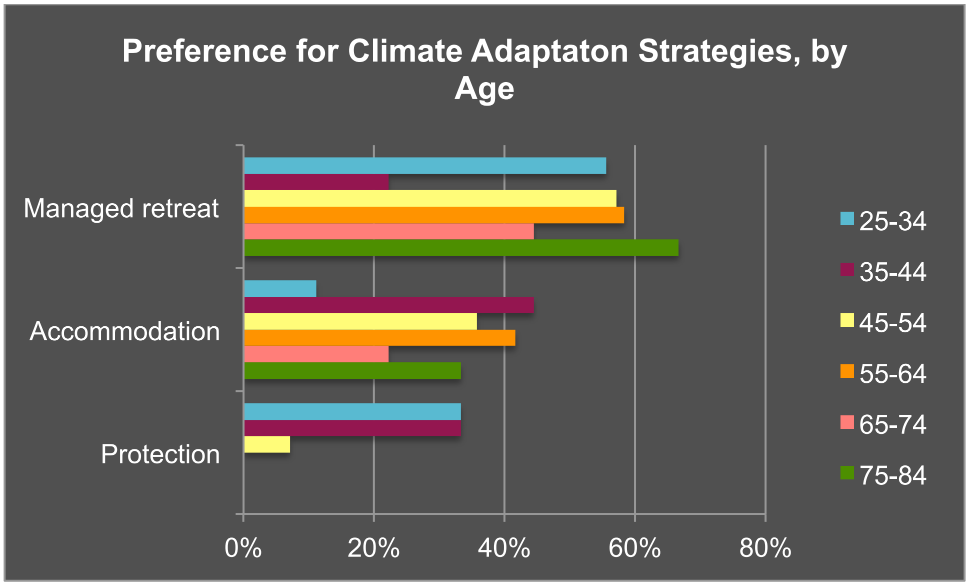

Figure 36: Respondents' preferences for climate adaptation strategies, by age.

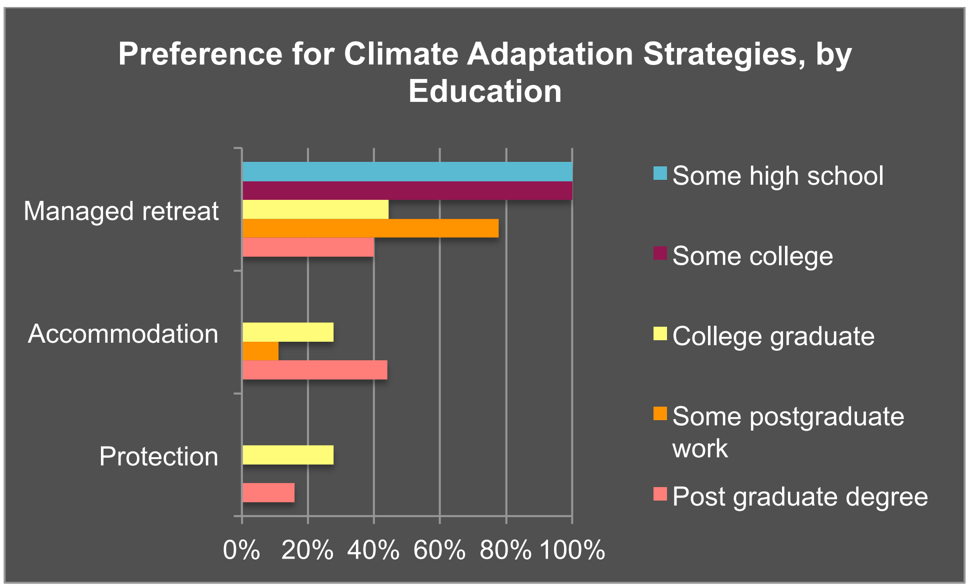

Figure 37: Respondents' preferences for climate adaptation strategies, by education.

The next two questions uses the respondents' preferred climate adaptation strategy from the previous question to gauge their selected preference for other conditions. Participants were asked if they believe the previously selected climate adaptation strategy is important for Palo

Alto Baylands and most respondents who preferred managed retreat or accommodation in the previous question believe their selected strategy remains important for Palo Alto Baylands (97% managed retreat; 95% accommodation), while a few disagree (5% accommodation; 3% managed retreat) (Figure 38). A majority of respondents who selected protection indicated the strategy was important for Palo Alto Baylands (80%), while a few disagreed (20%).

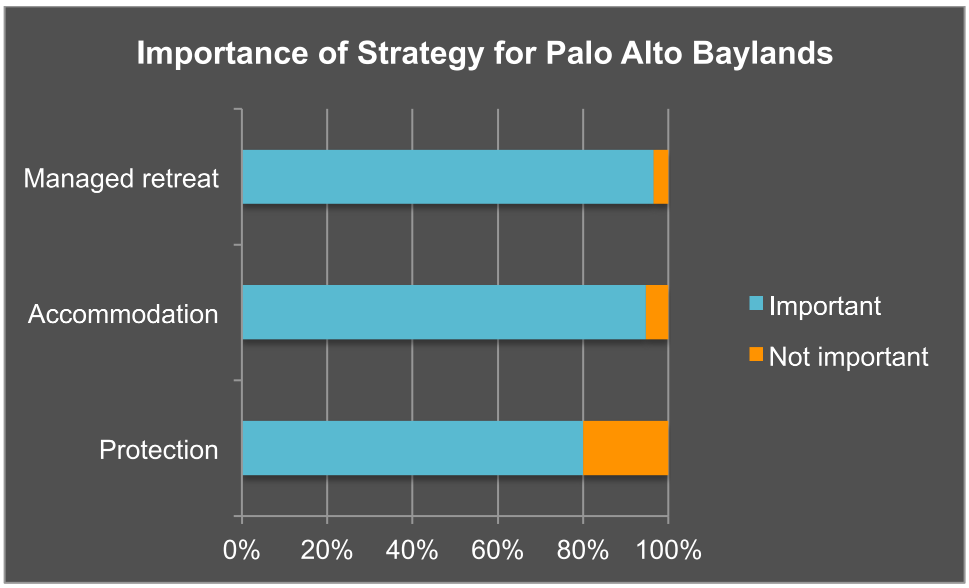

Figure 38: Respondents' belief in the level of importance of a previously selected climate adaptation strategy for Palo Alto Baylands.

Respondents were also asked if they would support the same climate adaptation strategy as a primary action to preserve salt marshes. All respondents who have selected accommodation in their previous response would support this climate adaptation strategy as a primary action to preserve salt marshes (100%) (Figure 39). Most respondents would support managed retreat (93%) and less for protection (70%) as a primary action to preserve salt marshes, while some did not provide a response (10% protection; 7% managed retreat).

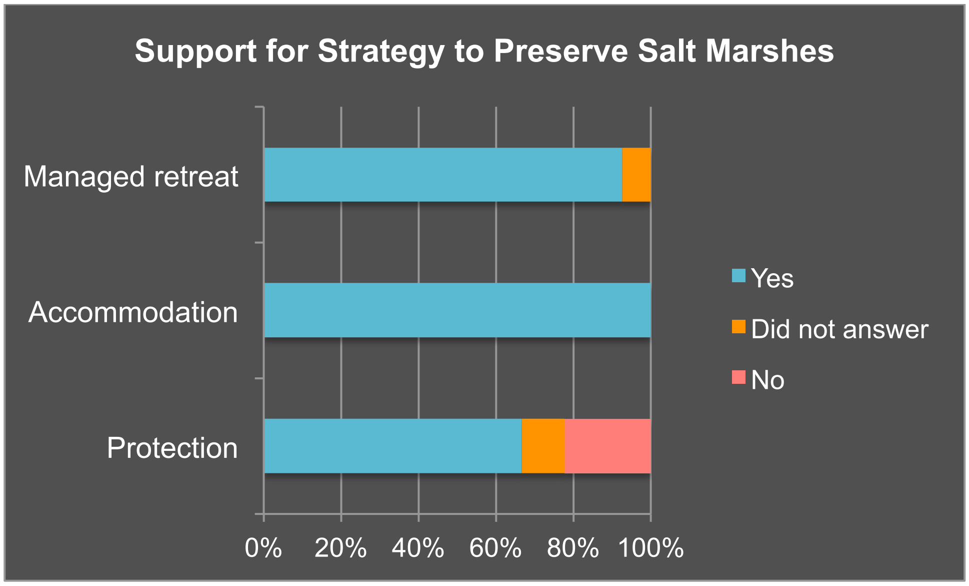

Figure 39: Respondents' support of a previously selected climate adaptation strategy as the primary action to preserve salt marshes.

Participants were given three options of removing existing commercial development in a managed retreat scenario at Palo Alto Baylands and more than half of total respondents reported to remove most existing commercial development (56%) (Figure 40). Several chose some

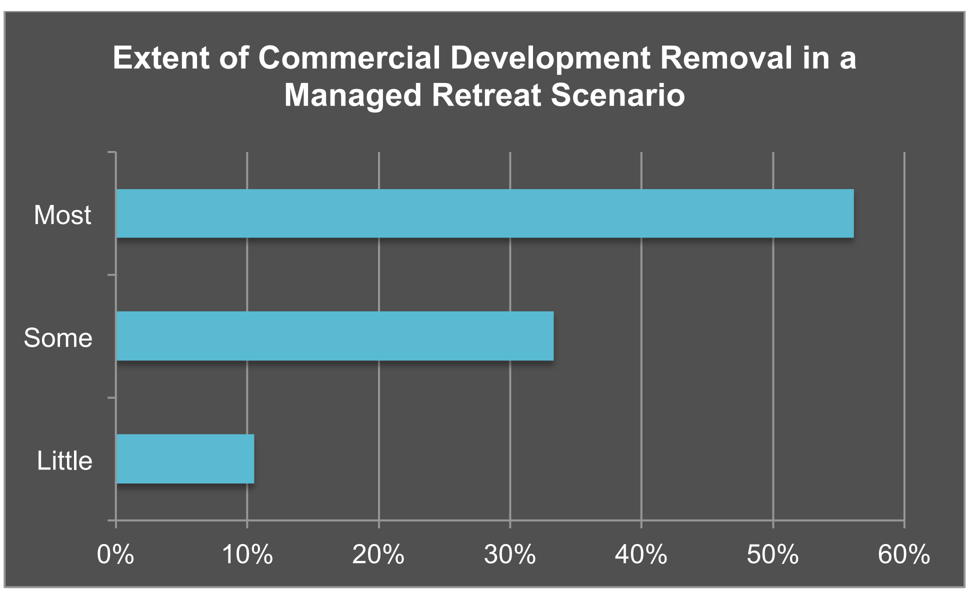

Figure 40: Respondents' extent of removing existing commercial development in a managed retreat scenario at Palo Alto Baylands.

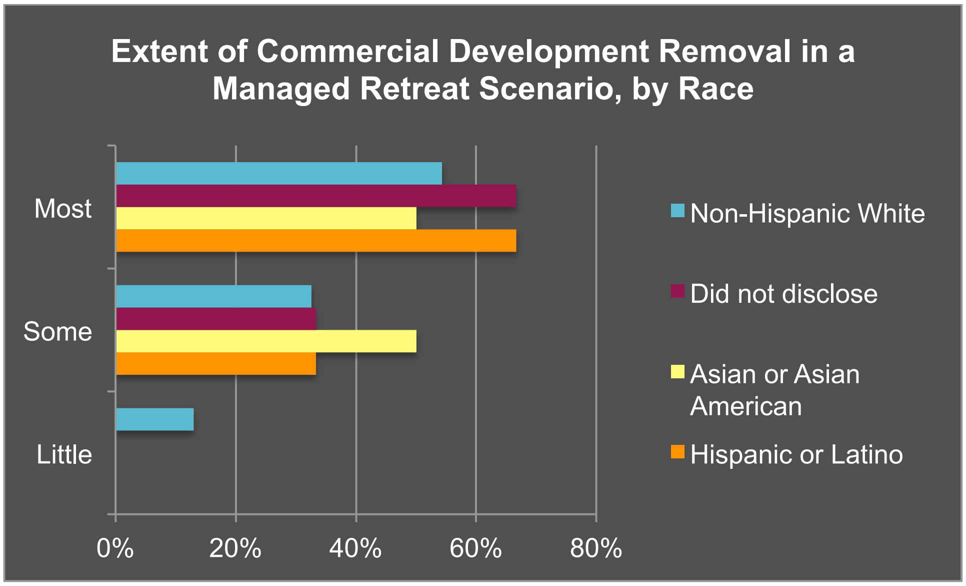

Figure 41: Respondents' extent of removing existing commercial development in a managed retreat scenario at Palo Alto Baylands, by race.

removal of existing commercial development (33%) and the least favorable scenario was little removal of existing commercial development (11%). Respondents from different ethnic backgrounds support most or some removal of existing commercial development (Figure 41).

Discussion

The survey results can be useful for future climate adaptation efforts. For one, a large majority of respondents believe climate change is happening now and within 10 years, implying there is a substantial awareness about climate change across different age groups, ethnicity, and educational levels, as well as high concern about sea level rise at the Baylands. Second, higher percentages of respondents indicated their approval for managed retreat if it provided ecological values, such as mitigating rising sea levels and preserving salt marshes, and removed existing commercial development. These findings show how users are supportive to the idea of a managed retreat scenario, especially for a site of ecological importance with immense community support, even if it is situated in a dense, highly urbanized space. The likelihood of primacy effect, which is the tendency for the respondent to remember options appearing first in a list and increasing the likelihood to select these choices, was reduced for this question because the managed retreat definition and option were displayed last in each provided list.

Use and Perceptions about Palo Alto Baylands

The sample from the Bay Area reported visiting Palo Alto Baylands Nature Preserve often, generally for multiple recreational activities, restoration projects, or work. Not surprisingly, hiking and bird watching are the two most popular activities reported, considering how there are fifteen miles of existing multi-use trails and a large resident population of birds at the Baylands. Favorite characteristics of the Baylands were diversity of wildlife, birds, continued protection of habitat, recreational opportunities, scenic views, and close proximity to the bay. Respondents expressed a few concerns to be addressed, including lack of improvements to recreational amenities, shortness of staff, and loud airport noise. Current community outreach and engagement may not be sufficient enough to support the work needed on site, such as maintenance and restoration, a perception illustrated by volunteer coordinators and staff members from individual discussions.

Important areas at the Baylands respondents indicated by answers, were the Lucy Evans Baylands Nature Interpretive Center and Byxbee Park, most respondents regarded one or more existing wetlands as especially important. With 91% of respondents reported attaining a college degree or higher, this perception is consistent with previous studies illustrating increased knowledge of wetlands with increasing educational level (Curado et al., 2013). Respondent answers also indicated the least important areas were existing urban development at the

Baylands, noting their close proximity to natural areas and airplane noise based on written comments.

Attitudes About Salt Marshes

Respondent attitudes towards salt marshes were generally positive and indicated a broad level of understanding about the benefits salt marshes could provide, from important habitats to recreational opportunities. Positive attitudes about wetlands appear to be outweighing negative perceptions, based on a recent study about public perception and uses of salt marshes where 77% of respondents believe marshes were not sources of infection and 80% of respondents reported salt marshes are beautiful ecosystems (Curado et al., 2013). Marshes with color were perceived to be more attractive than a marsh with less colored vegetation, a perception in agreement with past studies (Hands and Brown, 2002). A large majority of respondents agree salt marshes at the Baylands are important in providing flood protection, which indicates there is considerable ecological knowledge about salt marshes among respondents. Furthermore, the positive qualities about salt marshes most commonly cited by respondents were related to ecological functions, such as providing important habitat, wildlife sanctuary, and flood protection. Aesthetic features, recreational opportunities, and site uniqueness were also reported, but cited less.

Only a few reported the dislike of smell from marshes and a mosquito source, suggesting the positive perceptions towards salt marshes gradually outweigh negative attitudes. Based on respondent answers, there is a substantial appreciation of natural areas, including salt marshes, at Palo Alto Baylands mostly due to their ecological significance, as acknowledged by respondents, and the recreational opportunities and scenic views they provide.

Climate Change Awareness and Impacts

Respondents are aware climate change will substantially negatively impact Palo Alto Baylands now or within the next few decades, while only a few reported it will start to occur by midcentury or it will not occur at all. Beliefs about the negative impacts of climate change to the Baylands did not differ in regards to gender, ethnicity, or educational level of respondents, but it can be noticed that older respondents are aware and showed concern about climate change, in contrast to findings from previous studies showing lower level of concern and awareness about climate change in older respondents compared to those who were younger (Fatorić and Morèn-Alegret, 2013; Kellstedt et al., 2008).

Many indicated their concern of a 16” (40 cm) sea level rise by midcentury for the state of California at Palo Alto Baylands. There was little difference in concern about sea level rise projection among ethnicity, educational level, and age.

Preferences of Climate Adaptation Strategies

Managed retreat was favored by a little over half of total respondents as a climate adaptation strategy managers should pursue to mitigate sea level rise for Palo Alto Baylands if economic costs were not considered. Almost one-third of total respondents would support accommodation and some respondents favored protection as a mitigation strategy. In contrast to the findings from the Stanford University Climate Adaptation California Poll (2013) that showed Californians are least supportive of adaptation strategies involving purchasing private property to induce retreat, a majority of survey respondents supported a managed retreat scheme if it helped mitigate sea level rise and was the primary option to preserve salt marshes. There appears to be a correlation of high appreciation to the Baylands and support for managed retreat because this climate adaptation strategy has the capacity to protect such values. From this, it can be discerned that managed retreat would more likely supported by the local public if it provided mitigation and preservation benefits that sought to protect wildlife, birds, and habitats, which were commonly reported as important characteristics of the Baylands by respondents. Additionally, at least 89% of total participants would consider some or most removal of existing commercial development in a managed retreat scenario. Respondent attitudes towards managed retreat were generally positive and most were willing to remove commercial development in order to allow a managed retreat scheme.

Conclusion

Gathering opinions and preferences of users about Palo Alto Baylands, including climate change concerns and climate adaptation strategies for the site, were important to understanding whether respondents supported managed retreat or not. Survey findings show that managed retreat is more favorable over protection and accommodation possibly due to its correlation with respondents' high appreciation for the site, where this strategy maintains ecological benefits, such as flood protection and important habitats for wildlife and birds. Also, protection and accommodation strategies may be less desirable, particularly in a restored and natural environment. In this regard, a majority of respondents support managed retreat because it creates opportunities for salt marsh landward migration through the removal of existing commercial development and mitigates the effects of sea level rise. Most respondents seem to acknowledge the ecological benefits of managed retreat, often correlated with increasing educational level, and view it as a suitable climate adaptation strategy for an existing preserve that continues to protect critical habitats, endangered species, and diverse bird populations.

The survey identified that most respondents favored managed retreat as an appropriate climate adaptation strategy for Palo Alto Baylands, where a little over half of respondents indicated support for managed retreat. Thus, based on respondents' favorable attitudes toward managed retreat, the conceptual managed retreat scheme is designed as a composite reflection of aggregated values and preferences of respondents. These include ecological values, such as the continued protection of critical habitats for wildlife and bird populations, and aesthetic values, such as keeping recreational and public engagement opportunities intact. With respondents already indicated support for managed retreat, the next question is, how can it be implemented?

CHAPTER 5

CONCEPTUAL DESIGN APPLICATION

The synthesis of managed retreat research coupled with survey findings about public perception and attitudes about Palo Alto Baylands Nature Preserve was applied to a projective site design for the Baylands. The purpose of the design is to provide a conceptual managed retreat scheme that is reflective of respondents' preferences and perceptions identified from the previous chapter. The goal of this design is to integrate those perception and attitudes into a managed retreat scenario, while anticipating landscape changes and trajectory in the context of rising sea levels, as an effort to maintain and increase public support and acceptance of managed retreat as a suitable climate adaptation strategy for Palo Alto Baylands.

Site Analysis

As previously stated, Palo Alto Baylands Nature Preserve consists of development, park land, and preserved habitats. It includes Byxbee Park (a former landfill), the Palo Alto Municipal Golf Course, Palo Alto Airport, Restored Harbor Marsh (former yacht harbor), Regional Water Quality Control Plant, Flood Control Basin, Duck Pond, Emily Wenzel Wetlands (former ITT property), and Harriet Mundy Marsh. Facilities indicated by survey respondents as important were the Lucy Evans Baylands Interpretive Center and Byxbee Park. Primary uses of the Baylands include hiking and bird watching, as well as photography and running, indicated by responses from the survey and research. These use patterns were considered in the projective design of the conceptual managed retreat scenario.

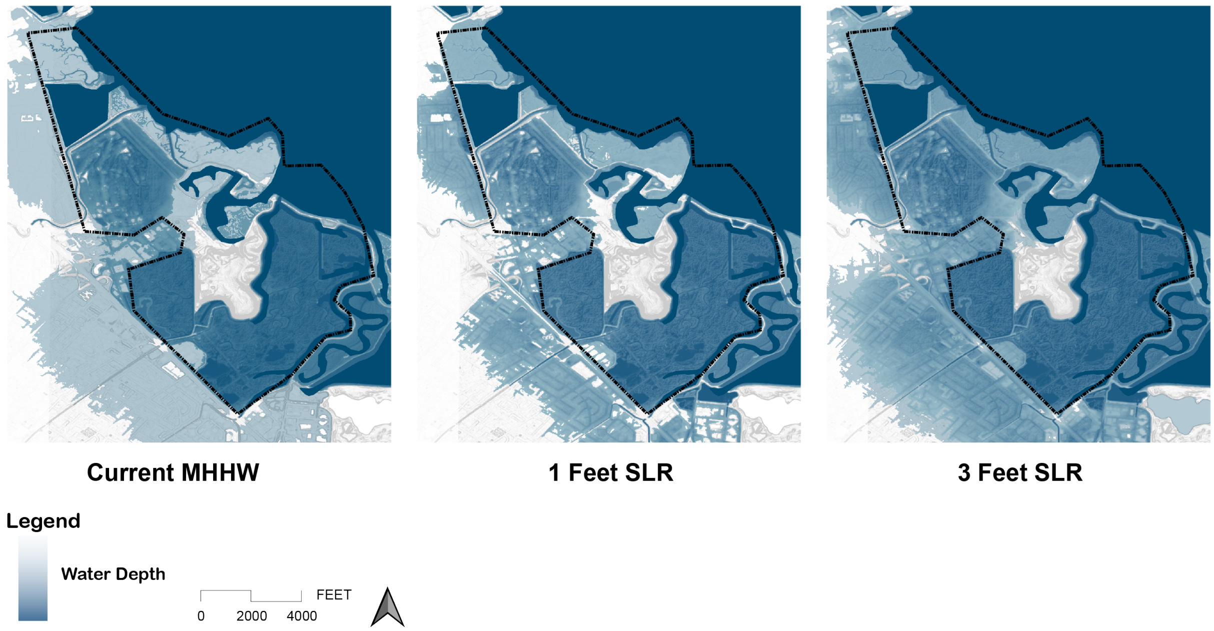

Figure 42: Sea level levels at current Mean Higher High Water (MHHW), at 1 feet sea level rise, and at 3 feet sea level rise projections, based on NOAA GIS data.

Sea level rise projections at current levels, 1 feet (12") of sea level rise, and 3 feet (36") of sea level rise show increasing areas of flooding and water depth patterns (Figure 42). With little intervention at current Mean Higher High Water (MHHW) conditions, possible areas of inundation are the Flood Control Basin, Emily Wenzel Wetlands, Palo Alto Airport, and Palo Alto Municipal Golf Course. Other areas of potential flooding are the Duck Pond and small portion of the Restored Harbor Marsh. Low-lying areas prone to flooding include some residential and urban development adjacent to the U.S. 101 Highway. At a 3 feet (36") sea level rise, the potential of flooding extends throughout most areas of Palo Alto Baylands, excluding Byxbee Park, and expands beyond the U.S. 101 highway, affecting greater areas of residential and urban development adjacent to the Baylands. At a 36" sea level rise, inundation is likely to occur in the Flood Control Basin and Emily Wenzel Wetlands and flooding expands further inland, impacting residential, commercial, institutional, and recreational spaces beyond the U.S.

101 Highway. Without land use changes or effective protection measures, these scenarios have a greater probability of occurring, as sea levels are rising at an accelerated rate. An average rate of 0.05 inches of sea level is expected to rise annually, based on monthly mean sea level data collected from 1974 to 2013.

The study site is a relatively low-lying area of gradual slopes, with the exception of Byxbee Park (former landfill) rising about 50 feet above surface grade. These conditions make marshes along the bay edge prone to flooding and with higher water levels, water flow of three creeks – Matadero Creek, Adobe Creek, and San Francisquito Creek - will be constrained, increasing the likelihood of flooding in other areas of the Baylands. Furthermore, understanding critical wildlife areas, including low and high tide areas, are important to the design application because this informs where potential migration of wetland habitats can occur and how these changes affect current species migration and movement patterns (Figure 43).

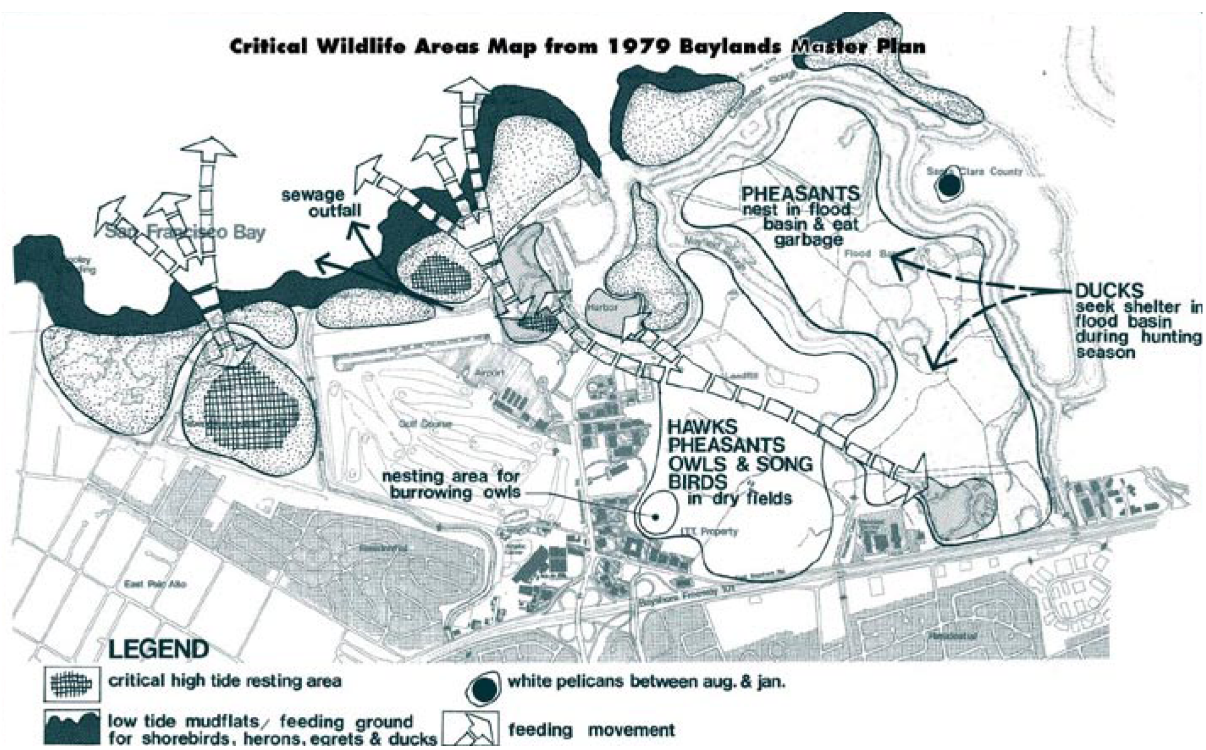

Figure 43: The schematic map depicts critical wildlife areas from the 1979 Baylands Master Plan (City of Palo Alto, 2008).

Six inventory maps using GIS were compiled to show elevation, drainage class, 100-year flood zone, land cover, runoff potential, and hydrologic soils of Palo Alto Baylands (Figure 44) (ESRI, 2011). Topography at the Baylands is mostly flat and bathymetric map surveys have shown the water depth of the surrounding bay is fairly shallow, approximately 10 feet below water surface. A majority of wetland areas at Palo Alto Baylands have very poor drainage class (the frequency and duration of wet periods), where water infiltrates slowly that free water remains at or very close to the surface level, and this is a typical characteristic of marshes. Because of low infiltration rates when wet, these areas with Group C/D soils have high runoff potential, consisting mostly clay soils. Also, the drastic grade change and steep slopes of Byxbee Park contribute to high runoff flows.

Other poorly drained areas are the Palo Alto Airport, Golf Course, Regional Quality Control Plant, and private residences, which may be suitable areas for marsh migration. These areas have Group B soils and have very low runoff potential. Moderately well drained areas include the Baylands Athletic Center and the U.S. 101 Highway ramp, with Group C soils and very low runoff potential. Byxbee Park is fairly well drained, with medium runoff potential and Group C soils.

The Flood Hazard map shows areas of inundation that have a 1% of occurring in any given year and, by midcentury, flooding from high tides are expected to occur within the 100-year flood plain (BCDC, 2011). Areas within the 100-year floodplain include Palo Alto Baylands, the U.S. 101 Highway, and urban development adjacent to the highway. As a rough estimate, areas in the 100-year flood plain are at risk for inundation with a 16” sea level rise (BCDC, 2011). Also, prolonged deep flooding increases as sea level continues to rise (USFWS, 2010).

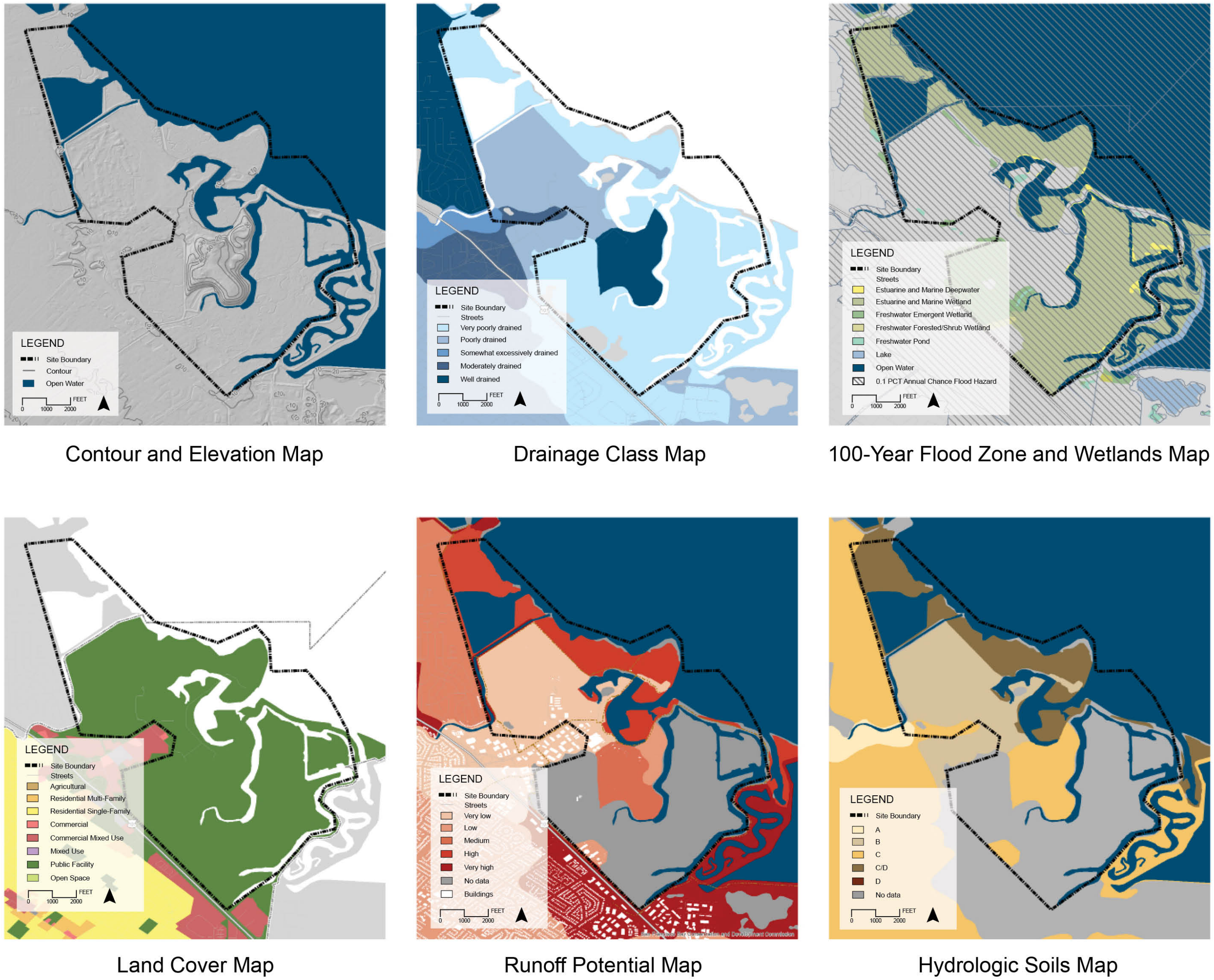

Figure 44: Six site inventory maps showing elevation, drainage class, 100-year flood event, land use, runoff potential, and soil groups.

The maximum precipitation level can reach 15 to 16 inches annually, based on trends from 1981 to 2010; however, California faces one of the most severe droughts to date and this has affected restoration projects involving establishment of new native vegetation along Palo Alto Baylands, as indicated by a discussion with a restoration specialist (Kreidler, N., personal communication, February 6, 2015). For example, in the past few years due to drought, water requirements were higher in order for the newly planted native vegetation to make it through, even though these plant species are considered low-maintenance and drought-tolerant. Other environmental concerns include removal of invasive plant species crowding the shoreline and reducing pollution at the tide gates at the Palo Alto Baylands.

Suitability Analysis

A site suitability analysis was performed to identify areas to construct and restore new wetlands at Palo Alto Baylands using the spatial analyst tool from GIS (Figure 45) (ESRI, 2011). Four cartographic data layers were included in the suitability analysis: land cover, flood hazard zone, hydrologic group soils, and slope. The spatial analysis process involved classifying feature data into four groups, where 4 is the most suitable and 1 is the least suitable. A weighted overlay of all reclassified datasets was performed, where flood hazard zone had 30% influence, hydrologic soils had 25% influence, slope had 20% influence, and land cover had 25% influence.

Datasets were reclassified to a common measurement scale. For land cover, most suitable areas were barren land, cultivated crop areas, and agriculture land. The least suitable land cover was developed areas, with areas of open water and wetlands had a scale value set to restricted. The most suitable hydrologic soils were Groups C and D because these areas had low water permeability and moderately high runoff potential when wet, which are ideal conditions for

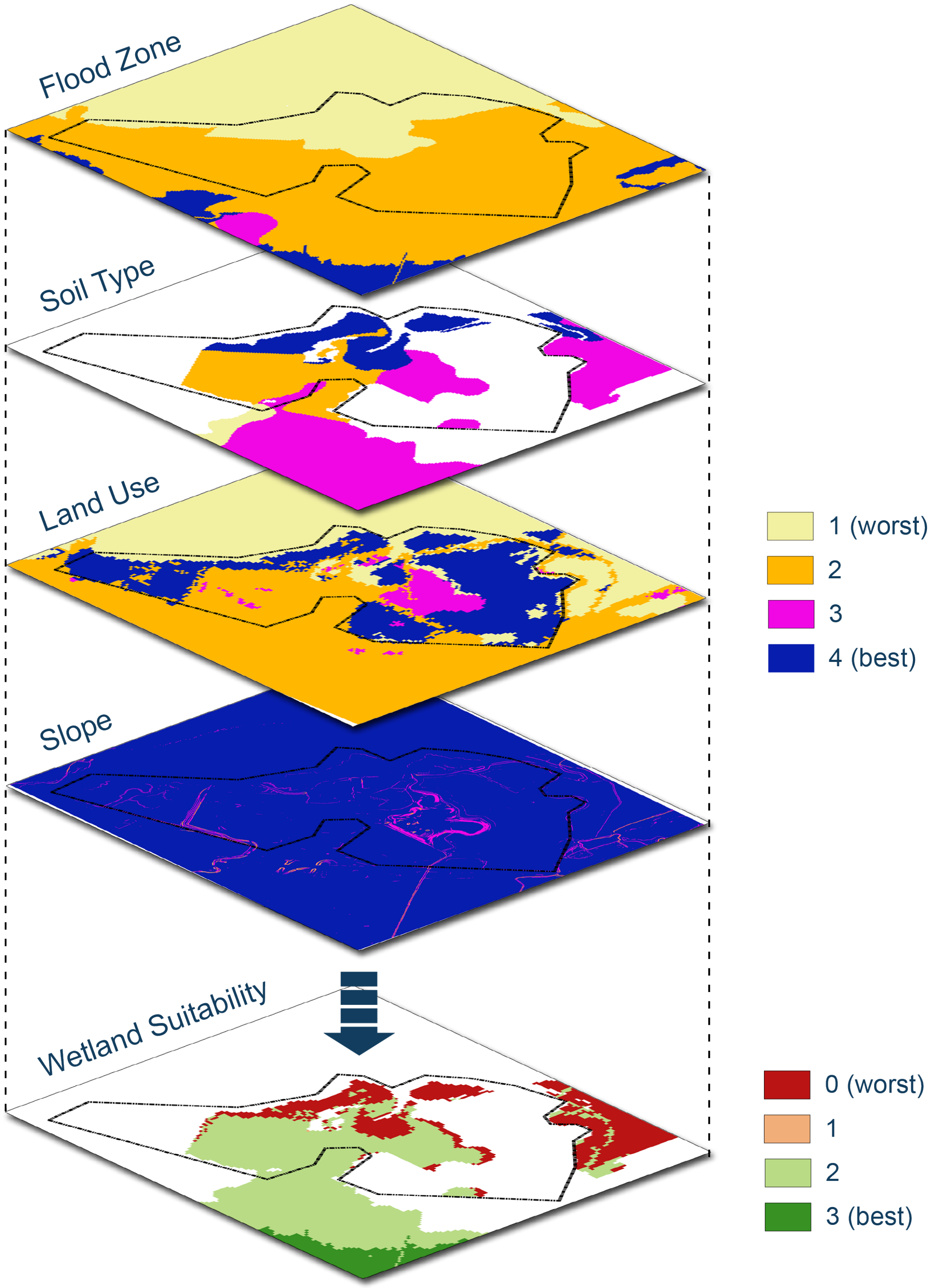

Figure 45: Weighted overlap results after four reclassified maps of slope, hydrologic soils, flood zone, and land use.

wetland restoration. The least suitable hydrologic soils were Group A soils, where areas with this soil group have low runoff potential and high water permeability, which are not ideal conditions for the creation of wetlands. Flood hazard areas with a Zone X label were most suitable because they were identified as areas of moderate flood hazards, having a 0.2 percent-annual-chance or a 500-year flood event. Flood hazard areas with a Zone A label were least suitable because these areas were identified of having a flood event with a 1-percent change of occurring in any given year. Most suitable slopes were under 5% change in grade, while least suitable slopes were about 50% grade. Under these weighted inputs, the overlay produced the most suitable areas for wetland restoration outside of the Palo Alto Baylands boundary, yet the next favorable areas were Palo Alto Airport, Municipal Golf Course, Regional Water Quality Control Plant, and Byxbee Park.

Design Process

Prior to the survey, early schematic sketch of the managed retreat scheme include areas to retain, remove, or keep in Palo Alto Baylands. Responses from the survey later guided the conceptual design development, where Palo Alto Airport and Municipal Golf Course would be removed, as they were indicated to be the least favorable areas at the Baylands, and restored as salt marsh wetlands. From the research, retreat should not be pursued as an individual strategy, but one that is part of a comprehensive climate adaptation strategy. Therefore, conceptual ideas of marsh terraces and floating wetlands to trap sedimentation, as well as enhanced berms for flood control were first established (Figure 46).

Figure 46: Site analysis and conceptual design for the Baylands.

Design Proposal

The proposed managed retreat scheme is based on sea level rise projections at 6” by 2030, 12” by 2050, 36” by 2100 (NRC, 2012). The main goal of the conceptual managed retreat design is to protect and restore tidal wetlands as an effort to support and sustain existing wildlife, birds, and habitats as sea level continues to rise (Figure 47). This involved removal of existing commercial development, primarily the Palo Alto Airport and Municipal Golf Course, since they were identified by survey responses as least favorable areas at the Baylands, in order to allow room for marsh migration and wetland restoration. Because many respondents indicated their high appreciation for wildlife and birds, the proposed areas for salt marsh restoration allow increased recreational opportunities for bird watching and wildlife visibility. The proposed wetlands create additional low and high tide areas, increasing habitat range for endangered species and refuge areas during high flooding periods and predation. Also, the proposed areas for marsh restoration are located further inland, providing additional acreage for upland and ecotone habitats for vegetation and endangered terrestrial species between natural spaces and existing urban development. The fill material from the former airport and golf course are used to create slopes for upland habitat and a tiered wetland defense system, so inundation occurs mainly on low marsh areas and along the shoreline edges.

To trap sedimentation, submerged aquatic sea grass beds are proposed in the subtidal areas near the shoreline. The common eelgrass (*Zostera marina*) provides an important habitat for a wide variety of shellfish and fish in the San Francisco Bay. The San Francisquito Creek is widened to naturally catch and disperse sedimentation across adjacent marshes and develops into a more natural form than a straight, narrow channel. The effluent that currently impairs water quality in San Francisquito Creek are treated by adjacent wetlands, mitigating contamination to

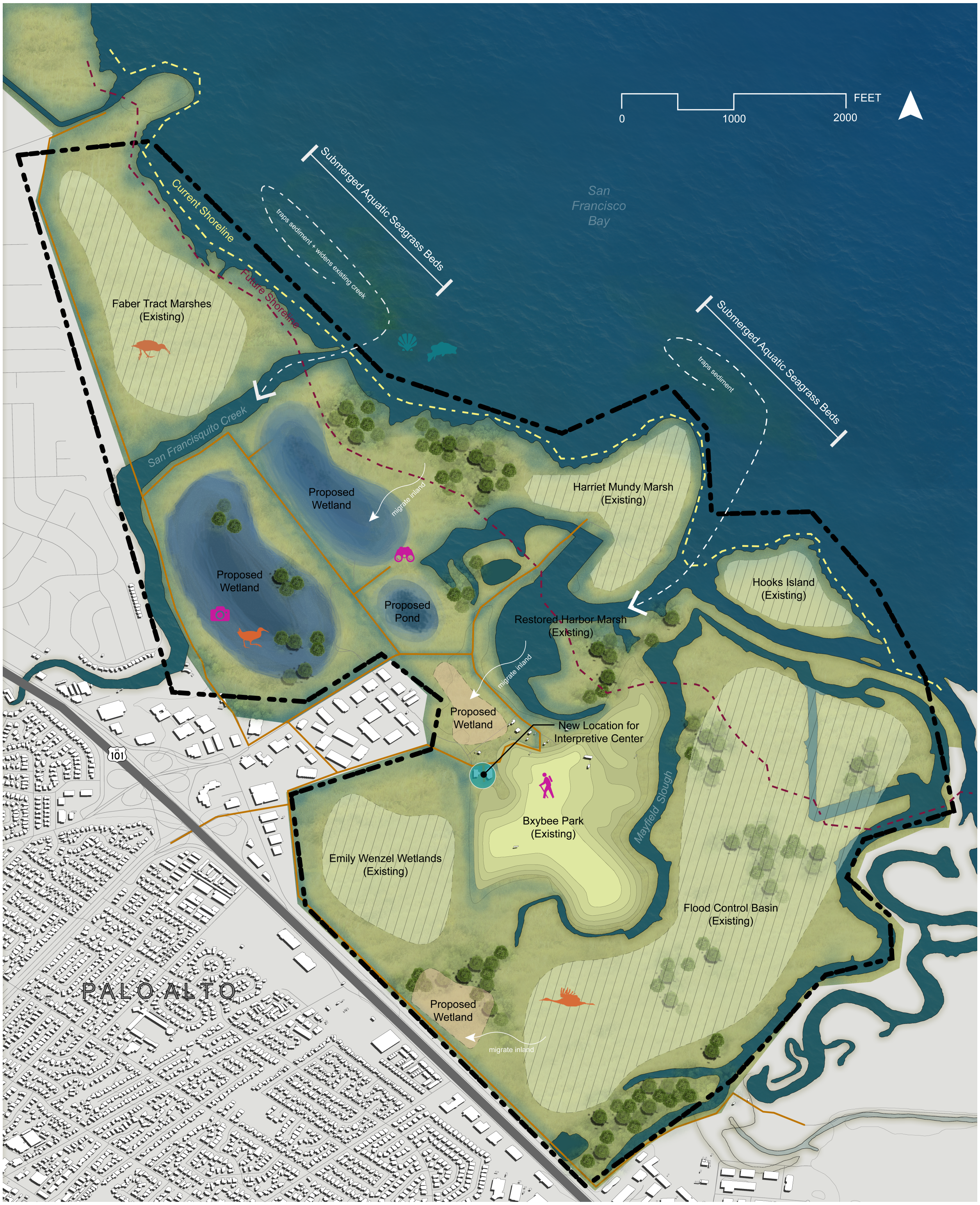

Figure 47: Proposed schematic plan for Palo Alto Baylands.

the San Francisco Bay. Because levees are integral flood protective measures to the Baylands and exist as a pathway for some pedestrian paths, the plan proposes an enhanced levee system with a berm on the flooding side to help mitigate flood impacts (Figure 49). The San Francisco Bay Trail, a regional pedestrian trail, is relocated further inland and surrounds the proposed wetlands, to reduce flood risk. Two open boardwalks extending out to the shoreline are proposed, because several respondents have indicated it was a recreational amenity that was no longer being offered at the Baylands. The Lucy Evans Baylands Nature Interpretive Center and the Environmental Volunteers EcoCenter have been relocated to the northwest side of Byxbee Park, as this area has less risk for flooding. The Regional Water Quality Control Plant and MSC Animal Services are phased out for removal out of the 100-year floodplain to continue wetland restoration at the Baylands.

The conceptual managed retreat scheme also recognizes the establishment of an adjusted shoreline, as rising sea levels continue and flood frequencies intensify (Figure 48 and Figure 49). While tidal marsh wetlands act as buffers to flood protection, the conceptual design proposal predicts permanent inundation will occur in a few areas at the Baylands due to subsidence and low sedimentation rates. However, the proposed salt marsh habitats at a higher elevation, which uses fill from the former golf course and airport, are meant to prevent further permanent inundation from occurring as sea level rises more than 3 feet from current MHHW levels. The proposed wetlands protect newly established critical wildlife habitats for endangered species and native plant communities, even at sea levels rising to 55 inches.

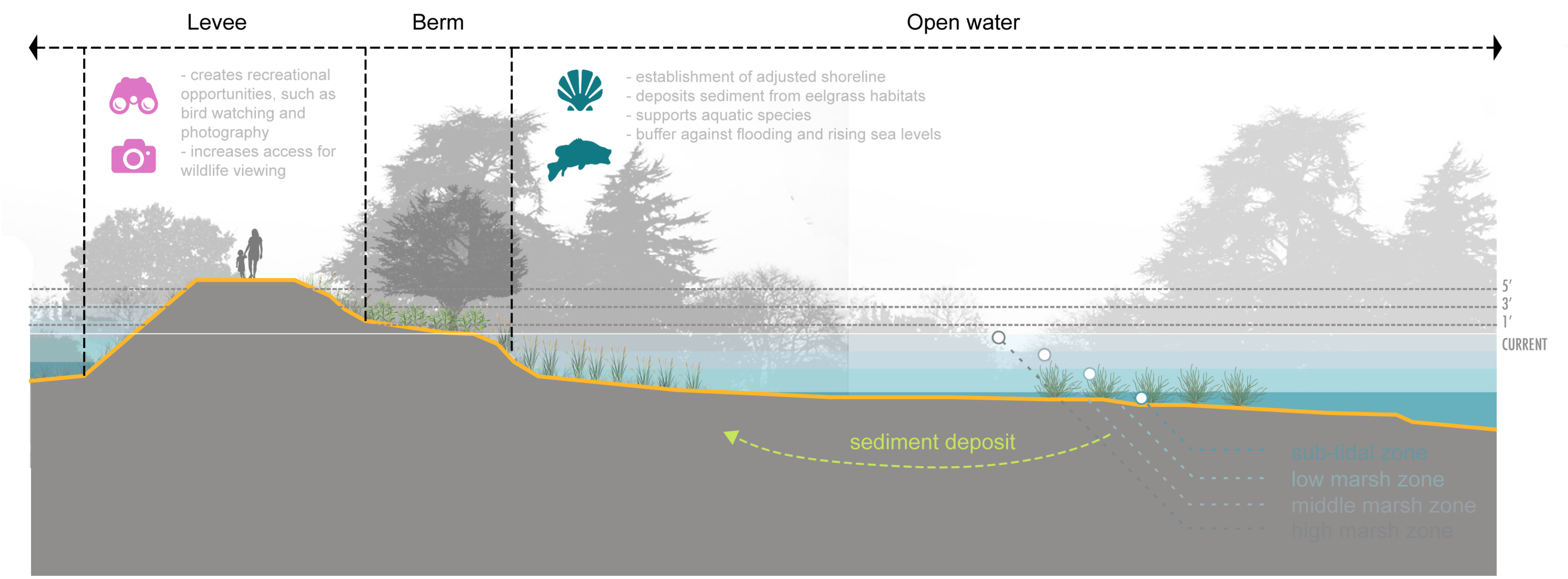

Figure 48: Proposed schematic coastline section of managed retreat scheme, showing first line of natural coastal defense and its support for ecological processes. The section is vertically exaggerated for clarity.

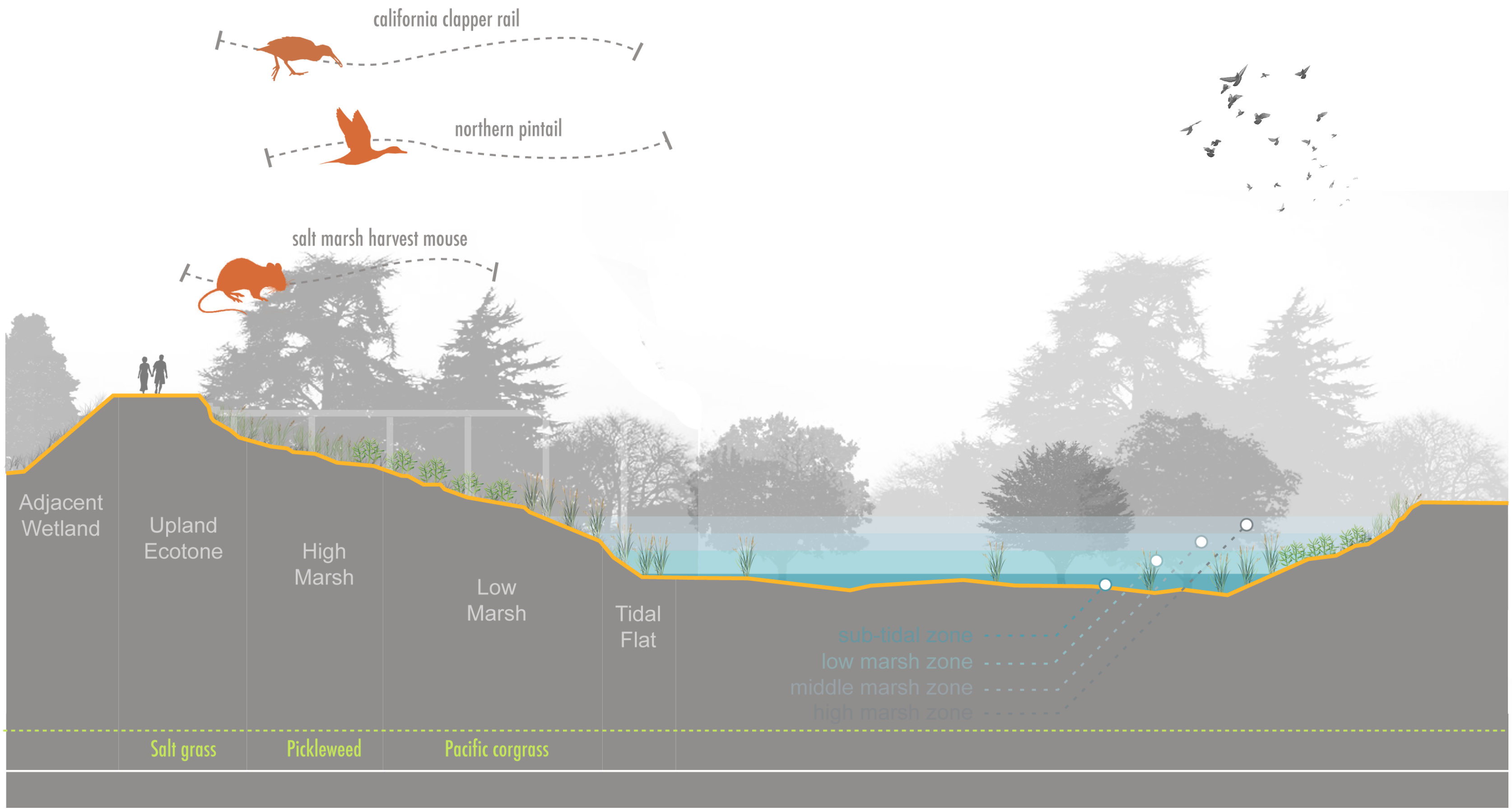

Figure 49: Proposed schematic wetland section of managed retreat scheme, showing second line of natural coastal defense and the creation of new intertidal habitats for birds, plants, and wildlife species. The section is vertically exaggerated for clarity.

Alternative Design Scheme

Because a majority of users highly value Palo Alto Baylands and most indicated support for a managed retreat scheme, the proposed conceptual design is a reflection of favorable needs and values shared by most users. In many other coastal environments adjacent to private urban development, for instance, shared public values and interests may not be this easy and clear. Rather, public opposition to managed retreat still exists and unshared values must be acknowledged, especially in situations where people are reluctant to relinquish private property for land acquisition. Also, in urban communities with low ecological level about the natural environment and climate adaptation strategies or do not show concern about climate change impacts, there is a tendency to prefer protection or accommodation to protect development from rising seas. In some cases, the public may have misconceptions about managed retreat and distrust project authorities implementing climate initiatives. To achieve a positive outcome for homeowners, a creative solution is necessary to improve acceptance of a managed retreat scheme that reduces flood risks and losses associated with projected impacts of rising sea levels while strategically financing compensation funds in the event of dramatic flood occurrences.

A major incentive for landowners to relocate is financial compensation. Sources of funding can be achieved at the grassroots level when local planning bodies proactively pursue funding, raise revenue through fundraising or other opportunities, and seek funding at local and regional scales. Furthermore, financial trade-offs can help alleviate federal funds and insurance payments. For instance, if a private property were damaged because of a flood-related event, compensation can be given for the house to be elevated or relocated. However, if homeowners are unwilling to have the house elevated or relocated, they will not receive allocated funding to repair the house and will need to pay for the damages themselves. Creative financing associated with coastal flood events will become increasingly important, as disasters become more costly to repair and federal funding and resources are limited.

Evaluation

The primary goal of the projective design is to restore wetland habitats through the removal of existing commercial development, along with addressing site-specific issues such as decreased sedimentation rates and subsidence. The managed retreat scheme conceptually visualizes how the Baylands would be affected by a rises in sea level and explored how the retreat approach can potentially adapt to these changes. As shown in the conceptual plan, managed retreat allows for restoration of wetlands and this, in turn, maintains critical habitats for wildlife and plant communities struggling to adapt to rising seas.

There are several advantages to the proposed conceptual design. For one, the conceptual managed design is a composite reflection of the research, including survey responses and wetland GIS suitability analysis. Public attitudes about the Baylands and perception about salt marshes were integrated into the conceptual managed retreat design, such as increasing recreational opportunities, like wildlife viewing and bird watching, as well as protecting wildlife and preserving critical habitats by proposing new salt marsh wetlands through the removal of least favorable areas at the Baylands identified through survey responses. The managed retreat scheme also meets ecological and social needs, maintaining benefits to wildlife, habitats, birds and people. Furthermore, the conceptual design promotes the treatment of water quality through the proposal of new wetlands and the accumulation of sedimentation through natural hydrological processes.

The two shortcomings of the conceptual managed retreat scheme are the exclusion of economic costs to relocate publicly-owned commercial development and the expectation that some existing low-lying marshes are permanently inundated. While the conceptual managed retreat design primarily focuses on the removal of public commercial facilities, not private property, this illustrates one way in which people, based on the survey sample, are willing to relocate development as an effort to protect and preserve important tidal marsh habitats. Because a majority of respondents from the survey already indicated support for a managed retreat scheme, the conceptual design is a reflection of perception and attitudes of respondents, where preservation and ecological values are continuously protected in the proposal. If a majority of respondents did not favor managed retreat, the conceptual design would have attempted to improve support for managed retreat by including alternative scenarios of protection and accommodation and providing a visual comparison of how the three general climate adaptation strategies would appear at Palo Alto Baylands if it were individually implemented and how each would adapt to projected sea levels.

CHAPTER 6

CONCLUSION

Conclusion

Adapting and planning for sea level rise is important as climate change impacts are threatening urban communities adjacent to coastal salt marshes. Soft engineering alternatives are becoming popular alternatives to hard engineering solutions, since they are often less expensive, require little maintenance, and have less damaging impacts to the environment. While not commonly pursued in the U.S. and often regarded as a sign of defeat, managed retreat is a climate adaptation strategy that should not be performed as a reactive approach to coastal flooding, as illustrated by FEMA's repetitive loss program and precedent studies of coastal properties enduring repeated disasters. Rather, there is an opportunity for the public to consider managed retreat as a proactive, effective approach to coastal disasters, before it happens.

Managed retreat differs from two other general climate adaptation measures, protection and accommodation, in that it requires support and engagement of stakeholders because it involves removal of development, such as private or public property. The survey was an opportunity to explore how current users of Palo Alto Baylands felt about sea level rise, salt marshes, and climate adaptation preferences for the site. Respondents showed concern about climate change and believe it is occurring now or within 10 years, implying there is substantial understanding that climate change is or will happen in their lifetime. Also, if economic costs were not an issue, most respondents were more likely to favor managed retreat as a climate adaptation strategy to preserve salt marshes and mitigate sea level rise impacts for Palo Alto

Baylands. The notion for respondents to support managed retreat seems to be correlated with the high appreciation for the site. Many respondents show a high appreciation of existing habitat and wildlife at the Baylands, so supporting local values in climate adaptation objectives can increase public approval for objectives related to those values. Protection and accommodation are still favorable among several respondents, and should still be considered as part of an overall plan to mitigate climate change impacts, where other alternative approaches are also presented.

The projective design has conceptually proposed a managed design scheme that is a reflection of public perception and attitudes already indicating support for managed retreat, maintaining and protecting ecological values reported by respondents for Palo Alto Baylands. Removal of existing development was necessary in a managed retreat scheme to allow marsh migration and restoration and areas that were removed were justified from the research and survey.

The main research question of this thesis is, How can public perception and attitudes be integrated into a managed retreat design for urban salt marshes migrating inland? Public perception and attitudes are integrated in a managed retreat scheme as a proactive climate adaptation strategy when urban communities show a high appreciation of adjacent coastal ecosystems and care about protecting existing ecological values and important habitats. A managed retreat scheme is more likely to be accepted as a preferred strategy over protection or accommodation if project goals align with desirable ecological values from the public, such as restoring salt marsh habitats, in an existing preserved environment.

This research has several implications for urban communities adjacent to coastal salt marshes seeking for a climate adaptation strategy that requires less maintenance and reduces environmental impacts. Managed retreat is one approach that has the capacity to be socially, economically, and ecologically viable. From the research, public support for managed retreat is site-specific and must be understood on a case-by-case basis. Also, dense urban communities adjacent to coastal environments that need to adapt to rising seas will not strictly disregard managed retreat as a suitable strategy and may, in fact, be preferred over protection and accommodation. Lastly, a high appreciation for an adjacent coastal area may contribute to support for a managed retreat scheme, so those who care about the site are likely to support a design proposal that aims to protect existing ecological and social values, even if it required the removal of existing commercial development. Recommendations for next steps are a relocation plan for the publicly-owned commercial development that were removed in the managed retreat conceptual design proposal and a comparison of economic costs between inaction and retreat for Palo Alto Baylands through anticipated rising sea levels over time.

Changing sea levels requires a change in the traditional way we respond to negative effects of climate change. The purpose of adaptation is to adjust to different climate conditions, so there is an increasing need to work with these changes, not against them. A survey conducted for a specific coastal environment nearby dense urban communities in California has shown that there is interest and support for managed retreat, even when a previous survey found that Californians were least favorable of an induced retreat scheme. Because managed retreat has the capacity to protect ecological values, such as allowing the ocean reclaim land while also creating intertidal salt marsh zones, it can be a favorable approach for urban communities that show a high appreciation of adjacent coastal environments. Managed retreat, in particular, promotes the creation of tidal marshes that act as natural coastal defenses, rather than relying on hard artificial structures. In this context, we can let our own guard down in order to allow a better guard up.

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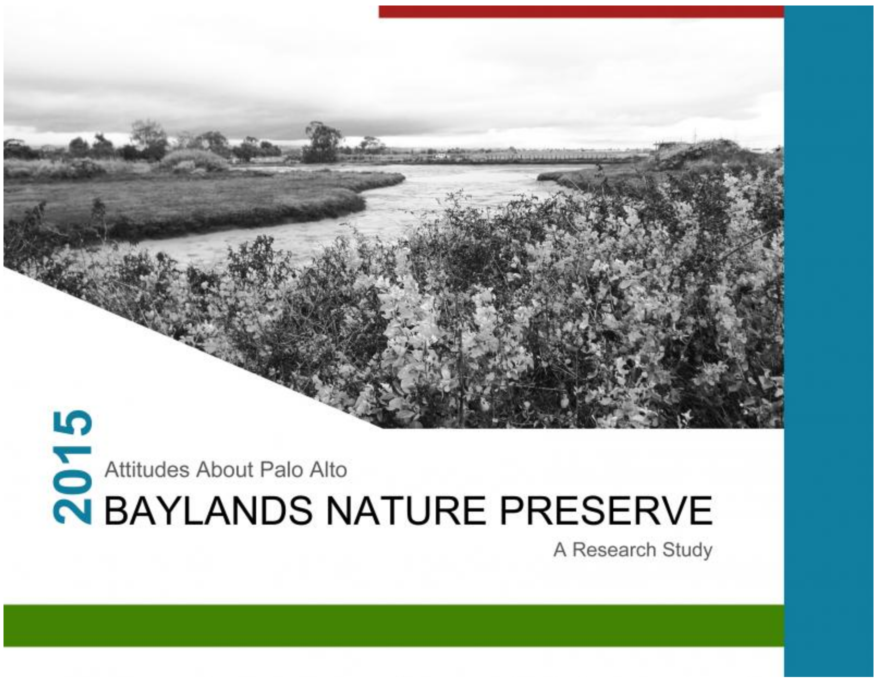
APPENDIX A

ATTITUDES ABOUT PALO ALTO BAYLANDS NATURE PRESERVE QUESTIONNAIRE



Online Consent Form

I invite you to participate in a research study entitled “Attitudes About Palo Alto Baylands Nature Preserve: A Research Study." My name is Hiu Ting Li and I am a graduate student studying user perceptions in the preserve as part of my Masters of Landsacpe Architecture Degree in the College of Environment and Design at The University of Georgia.

You must be 18 years of age or older to participate. Your participation will require approximately 10 minutes and is completed online. There are no known risks or discomforts associated with this survey.

Taking part in this study is completely voluntary. If you choose to be in the study you can withdraw at any time without adversely affecting your relationship with anyone at The University of Georgia. Your responses will be kept strictly confidential, and digital data will be stored in secure computer files. Any summary of this research that is made available to the public will not include your name or any other individual identifying information.

If you have any questions about this research project, please feel free to call me at (510) 565-0657 or send an e-mail to tingli@uga.edu. Questions or concerns about your rights as a research participant should be directed to The Chairperson, University of Georgia Institutional Review Board, 609 Boyd GSRC, Athens, Georgia 30602; telephone (706) 542-3199; email address irb@uga.edu.

I have read and understand the above consent form, I certify that I am 18 years old or older and, by clicking the "Next" button to enter the survey, I indicate my willingness voluntarily take part in the study.

SECTION I:

This section asks your use and opinions about Palo Alto Baylands Nature Preserve.

1. On average, how often do you visit Palo Alto Baylands Nature Preserve?

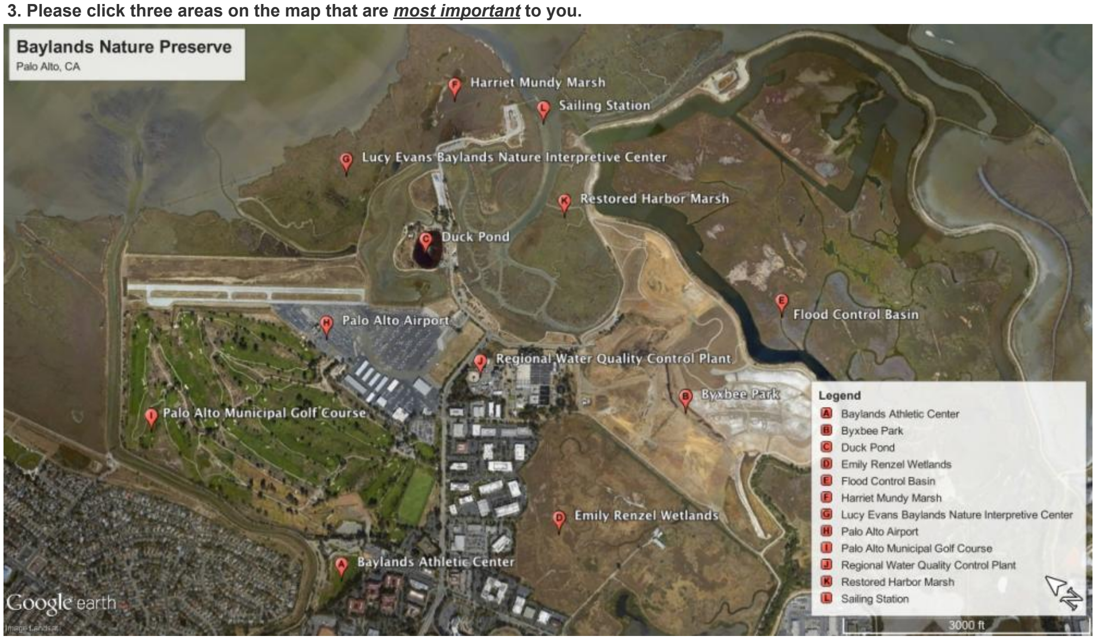
- ○ Never
- ○ Once every few months
- ○ Once a month
- ○ 2-3 times a week

2. Which of the following activities do you go to Palo Alto Baylands Nature Preserve for? (Check all that apply.)

- ☐ Hiking
- ☐ Fishing
- ☐ Bird Watching
- ☐ Running
- ☐ Cycling
- ☐ Photography
- ☐ Picnicking
- ☐ Wind Surfing or Boating
- ☐ Kayaking or Sailing
- ☐ Something else (Please specify): ______

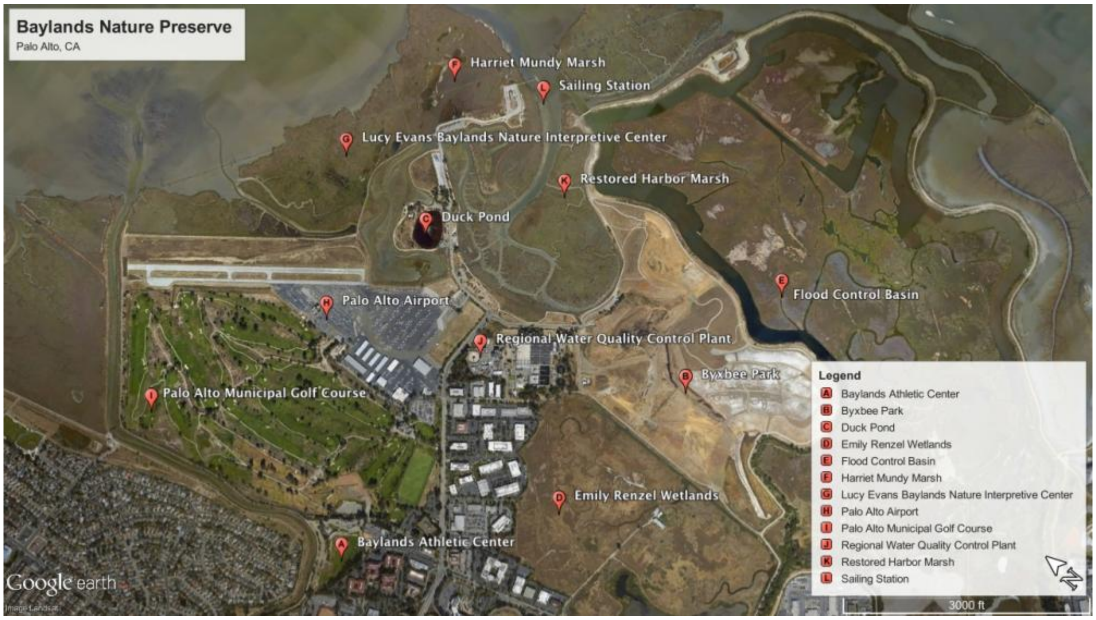
For Question 3, please refer to the following map of Palo Alto Baylands Nature Preserve to answer the question.

3. Please click three areas on the map that are *__most important__* to you.



For Question 4, please refer to the following map of Palo Alto Baylands Nature Preserve to answer the question.

4. Please click three areas on the map that are *__least important__* to you.



SECTION II:

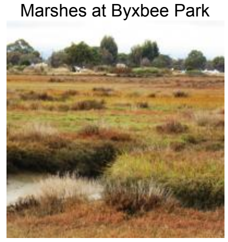
Next, this second section will ask about your perception and preferences about salt marshes at Palo Alto Baylands Nature Preserve.

5. In your opinion, which salt marsh is the *most attractive*?

Harriet Mundy Marsh

○

Marshes at Byxbee Park



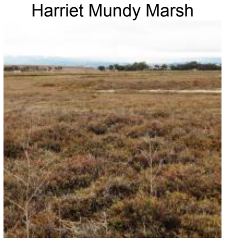
○

Marsh near Yacht Harbor

○

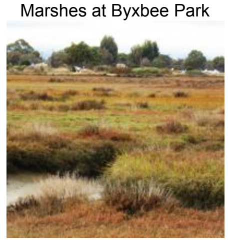
6. In your opinion, which salt marsh is the *least attractive*?

Harriet Mundy Marsh



○

Marshes at Byxbee Park



○

Marsh near Yacht Harbor

○

7. How important are salt marshes to you in providing flood protection at Palo Alto Baylands Nature Preserve?

○ Not important

○

Somewhat Important
No opinion
Important
Very Important

8. What do you like about salt marshes?

9. What do you not like about salt marshes?

SECTION III:

This section asks about your views toward climate change and sea level rise at Palo Alto Baylands Nature Preserve.

10. When do you think climate change will start to substantially negatively impact Palo Alto Baylands Nature Preserve: now, in 10 years, in 25 years, in 50 years, in 100 years, or never?

Now
In 10 years
In 25 years
In 50 years
In 100 years
Never
I don't know

11. For the state of California, sea level is projected to rise 16" (40 cm) by midcentury.

Do you regard sea level rise as a problem at Palo Alto Baylands Nature Preserve?

Yes
No

Questions 12 to 15 will ask your opinion about the following climate adaptation strategies. For reference, brief definitions are provided.

Protection: construct engineering structures, such as hard armoring and sea walls.

Accommodation: create elevated, floatable, or floodable development, such as raising building or land heights, allowing structures to float above water surface, or structures designed to withstand flooding.

Managed retreat: relocate development landward.

12. If economic costs were not an issue, which adaptation strategy should the managers pursue to mitigate sea level rise for Palo Alto Baylands Nature Preserve?

Protection
Accommodation
Managed retreat

For reference, the definition of protection is provided.

Protection: construct engineering structures, such as hard armoring and sea walls.

13. In your opinion, do you think protection is an important climate adaptation strategy for Palo Alto Baylands Nature Preserve?

Yes
No

For reference, the definition of protection is provided.

Protection: construct engineering structures, such as hard armoring and sea walls.

14. If protection is the primary option to preserve salt marshes, would you support this action?

- Yes
- No

For reference, the definition of accommodation is provided.

Accommodation: create elevated, floatable, or floodable development, such as raising building or land heights, allowing structures to float above water surface, or structures designed to withstand flooding.

13. In your opinion, do you think accommodation is an important climate adaptation strategy for Palo Alto Baylands Nature Preserve?

- Yes
- No

For reference, the definition of accommodation is provided.

Accommodation: create elevated, floatable, or floodable development, such as raising building or land heights, allowing structures to float above water surface, or structures designed to withstand flooding.

14. If accommodation is the primary option to preserve salt marshes, would you support this action?

- Yes
- No

For reference, the definition of managed retreat is provided.

Managed retreat: relocate development landward.

13. In your opinion, do you think managed retreat is an important climate adaptation strategy for Palo Alto Baylands Nature Preserve?

- Yes
- No

For reference, the definition of managed retreat is provided.

Managed retreat: relocate development landward.

14. If managed retreat is the primary option to preserve salt marshes, would you support this action?

- Yes
- No

For reference, the definition of managed retreat is provided.

Managed retreat: relocate development landward.

15. Which of the following scenarios would you choose if managed retreat affected existing commercial development at Palo Alto Baylands Nature Preserve?

- Little removal of commercial development
- Some removal of commercial development
- Most removal of commercial development

SECTION IV:

These questions request information about you.

16. What is your gender?

- Male
- Female
- Other

- Prefer not to answer

17. What is your age?

18. What is the highest education level you have completed?

- Some high school
- High school graduate
- Some college
- Trade/Technical/Vocational Training
- College graduate
- Some postgraduate work
- Post graduate degree
- Prefer not to answer

19. What is the zipcode of your primary residence?

20. Which category best describes you?

- American Indian or Alaska Native
- Hawaiian or Pacific Islander
- Asian or Asian American
- Black or African American
- Hispanic or Latino
- Non-Hispanic White
- Prefer not to answer

SECTION V:

This last section requests for your opinion about Palo Alto Baylands Nature Preserve.

21. What is your favorite thing about Palo Alto Baylands Nature Preserve?

22. Do you have any comments or suggestions you would like to add about Palo Alto Baylands Nature Preserve that were not included in this survey?