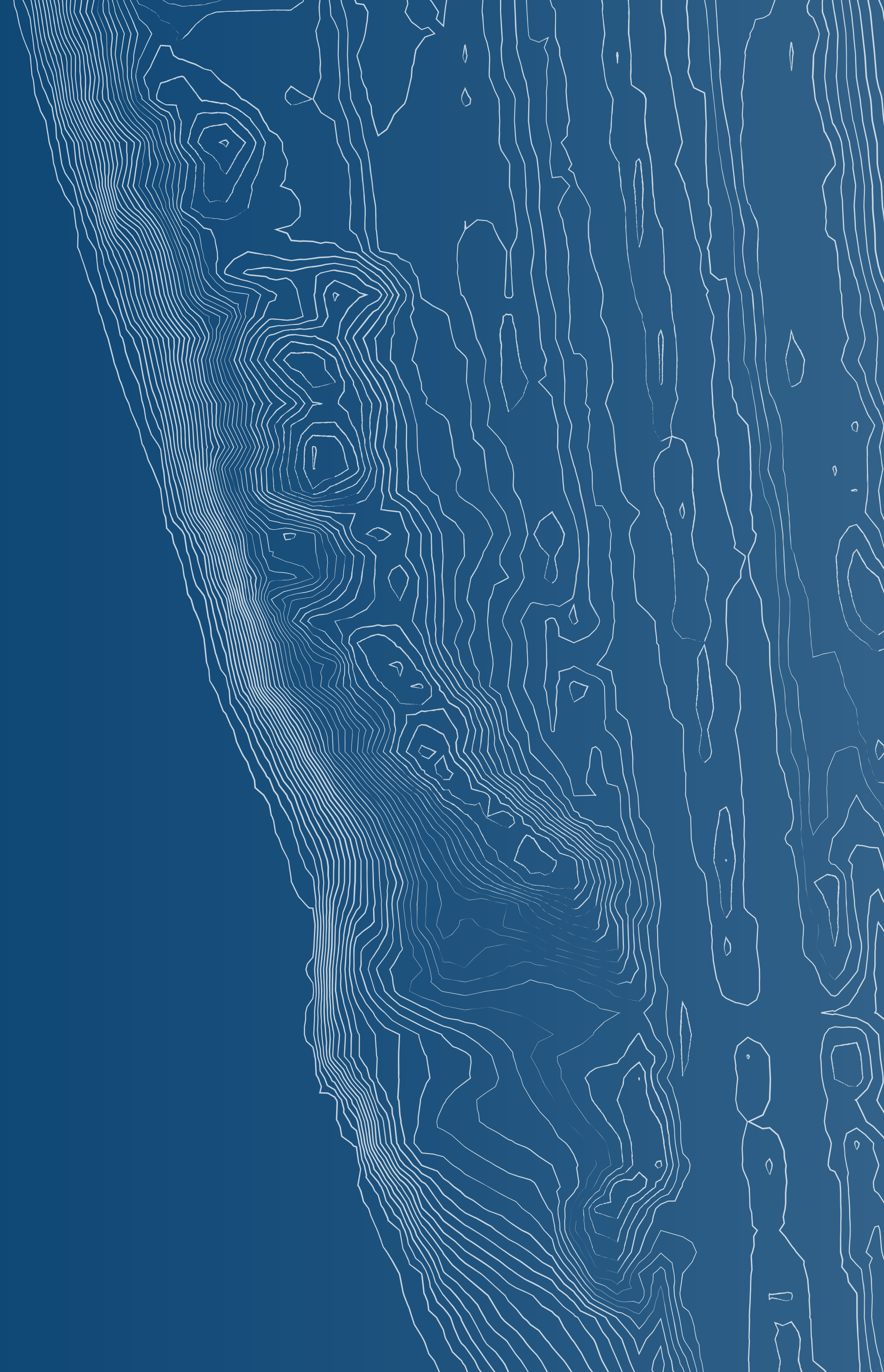
BEYOND THE SEAWALL

Sustainable Design Strategies for Beachfront Landscape



Independent Research Project 2016

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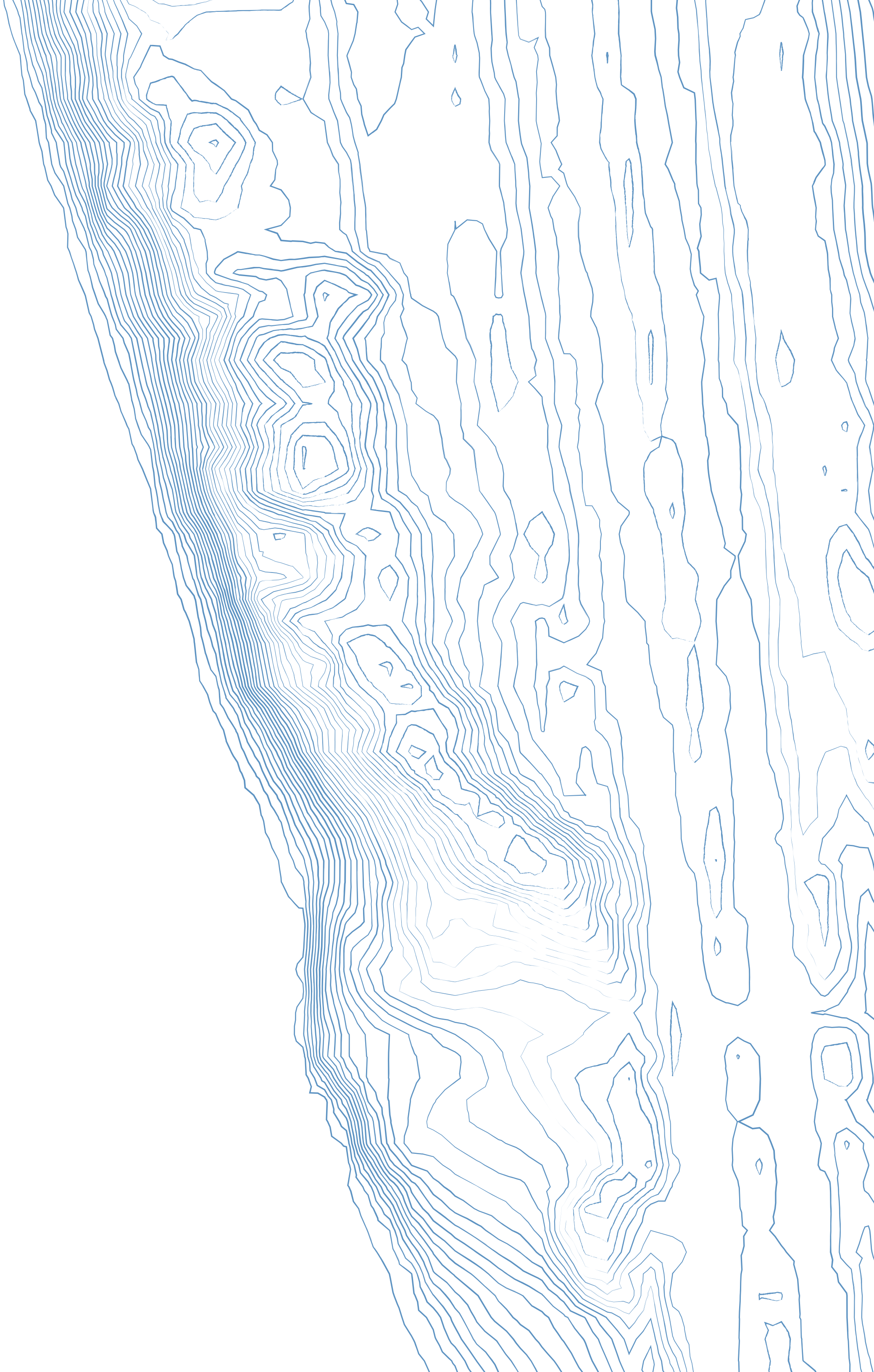

Independent Research Project 2016

BY **SHUYANG WANG**

Beyond the Seawall:
Sustainable Design Strategies for Beachfront Landscape

By Shuyang Wang

Submitted in partial satisfaction of the requirements for the degree of

BACHELOR OF SCIENCE IN LANDSCAPE ARCHITECTURE

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ABSTRACT

With predictions of the sea level rise and a higher frequency of extreme weather events, coastal landscapes face many issues including shoreline erosion and storm surges. However, conventional coastal defense methods such as constructing seawalls cannot effectively mitigate these issues over the long term. Heavily engineered structures disturb the natural processes of coastal environments and impede access to beachfront spaces. This research design project primarily investigates innovative and sustainable beachfront landscape design strategies for protecting coastal communities from hazards while providing secure and convenient access to beaches and encouraging new uses and programs at the waterfront.

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I am especially grateful for the valuable and constructive suggestions given by Michael Rios, Steve Greco, and Cory Parker during this independent project. Their willingness to give their time so generously is very much appreciated. Special thanks to my parents for their support and motivation as I pursued my studies at UC Davis. Finally, I would like to thank my classmates for their helpful feedback and encouragement during our time together in the program.


TURN TO CLEAR VISION
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Chapter One

INTRODUCTION

"CHANGE TO THE SEA AROUND US, CHANGE TO THE ATMOSPHERE ABOVE, LEADING IN TURN TO CHANGE IN THE WORLD'S CLIMATE, WHICH COULD ALTER THE WAY WE LIVE IN THE MOST FUNDAMENTAL WAY OF ALL."

— *Margaret Thatcher, 1989*

COASTAL HAZARDS

Coastal environments face a variety of natural hazards including storms, hurricanes, and tsunamis. These hazards are natural processes that have always affected coastal areas, however the impacts and associated costs of these hazards to humans have increased because of the growing conflict between development and insufficient protection. Currently, nearly 44% of the world's population lives within 150 kilometers of a coast, and that percentage is increasing (UN Atlas, 2010). High population density makes coastal communities especially vulnerable to natural hazards. Given current climate changes due to global warming, the effects of sea level rise and extreme weather will further amplify hazards that threaten coastal environments and the communities built in them (Gornitz, 2013). The impacts can be devastating as public spaces and infrastructure including roads, airports, and drainage facilities are inundated (figure 1-1). Although it is almost impossible to reverse the sea level rise, we can reduce the risks and mitigate potential losses using more scientific and sustainable environmental design and urban planning strategies.

COASTAL DEFENSES

Conventionally, humans construct coastal defense infrastructure such as seawalls to protect threatened development. For example, the Dutch are raising higher and higher defenses, consisting of dams, sluices, locks, dykes, levees, and storm surge barriers, to protect a large area of land around the Rhine-Meuse-Scheldt delta from the sea (Gornitz, 2013). Unfortunately, such solid and highly engineered structures can lead to the destruction of coastal landscapes and ecosystems associated with them and also create a physical or visual barrier, which impede access to coastal open spaces (figure 1-2). For instance, the Noriega Seawall along Ocean Beach in San Francisco blocks the shoreline from migrating inland, and beaches become submerged as the tidal zone advances to the wall (Griggs, 2010). Consequently, seawalls choke off public access to and along beaches.

FIGURE 1-1 Mud and debris flowed onto the inundated freeway after El Niño rainstorm (Los Angeles Times, 2016)

FIGURE 1-2 Massive concrete seawall along the coast and reduced beach space due to erosion (Granite, 2009)

FIGURE 1-3 Typical beachfront landscape (ELA Studio, 2015)

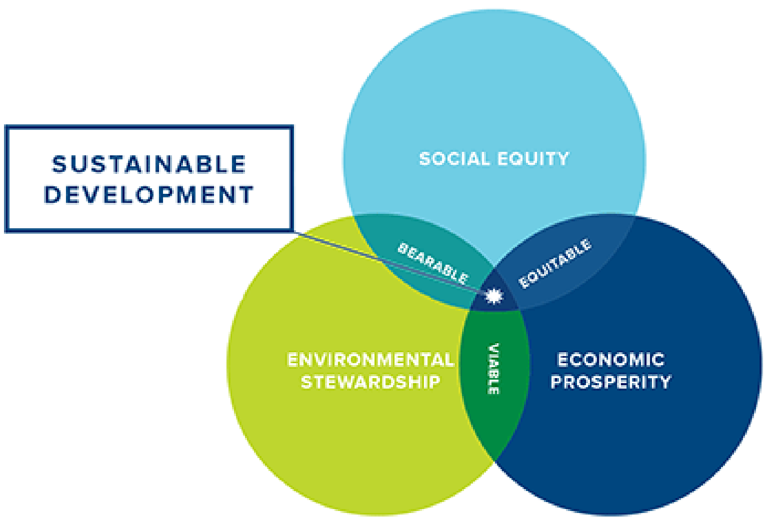


FIGURE 1-4 Three pillars of sustainable development (populationeducation.org, 2015)

BEACHFRONT LANDSCAPE

Beachfront landscapes, defined as part of a coastal community next to and directly facing the sea, are great public open spaces for coastal communities due to their great views, their adjacency to water, and the openness of the space. Coastal environments provide substantial economic, social, and quality-of-life benefits to both residents and visitors. However, due to the high risk of inundation, the lifestyles and public engagement patterns of coastal communities will inevitably be altered. Some existing activity patterns may not be feasible in a flood scenario; at the same time some new public engagement along the coast may emerge due to the new form of landscape and edge conditions.

SUSTAINABLE DEVELOPMENT

To seek ways to live with the rising water, coastal communities need to adapt more sustainable environmental design strategies to modify existing coastal landscapes to protect communities and infrastructure from natural hazards, while creating a valuable space for recreational, educational, and ecological purposes. It is paramount when addressing long-term sustainability to design and plan early, before environmental conditions worsen.

Chapter Two

PROBLEM STATEMENT

"WE CAN'T EXPECT TO TURN THINGS AROUND UNLESS WE PUT AN END TO TEMPORARY SOLUTIONS AND CREATE A LONG-TERM STRATEGY THAT TAKES THE ENVIRONMENT AND FUTURE RECREATIONAL USES INTO CONSIDERATION,"

— *Mayor Gavin Newsom, 2008*

CRITICAL ISSUES

HARD INFRASTRUCTURE: SEAWALL

Serving as abundant food sources and providing convenient access to transportation, coastal areas contribute many advantages to civilization. Since humans settled down along coastlines, they have made attempts to mitigate the effects of erosion and flooding by building engineered structures which define a distinct edge to keep water from entering a protected area (Weinthalk, Troell, & Nakayama, 2013). This conventional hard infrastructure, including seawalls, revetments, groins, breakwaters, and floodgates, have allowed permanent development to occur in areas that would otherwise be eroded or flooded periodically.

Among these hard flood-protection interventions, implementation of a seawall is one of the most common and popular practices, especially in urban and suburb coastal communities. Seawalls are vertical or near vertical massive concrete structures emplaced along a considerable stretch of shoreline at urban beaches. They are usually built parallel to the shore and aim to hold or prevent sliding of the soil, while providing protection from upland erosion, wave action, and storm surge flooding (UNFCCC, 1999). The physical form of seawalls range in various types and materials, including steel sheet pile walls, monolithic concrete barriers, rubble mound structures, brick or block walls or gabions (Kamphuis, 2000). Although a seawall will likely be successful in providing a robust solution to protect areas of human habitation, conservation, and leisure activities from action of tides and waves, it has some inevitable disadvantages to coastal environment, especially for long-term development. First, seawalls alter sediment transport processes between land and sea that can lead to an increase in coastal erosion. Wherever a hard structure is built along a coastline undergoing long-term erosion, the shoreline will eventually migrate landward to the structure. The effect of this migration will be the gradual loss of beach in front of the seawall as the water deepens and the shore face moves landward (figure 2-1). While private structures may be temporarily saved, the public recreational beach is lost (UNFCCC, 1999).

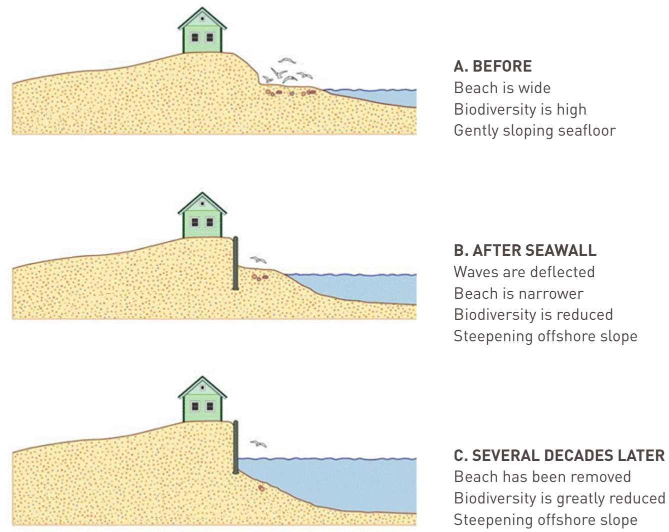


FIGURE 2-1 Beach loss eventually occurs in front of a seawall for a beach experiencing net longterm retreat (Pilkey & Dixon, 1996)

FIGURE 2-2 Reduced beach space for recreational uses after the construction of seawall, Galveston, TX (Granite, 2009)

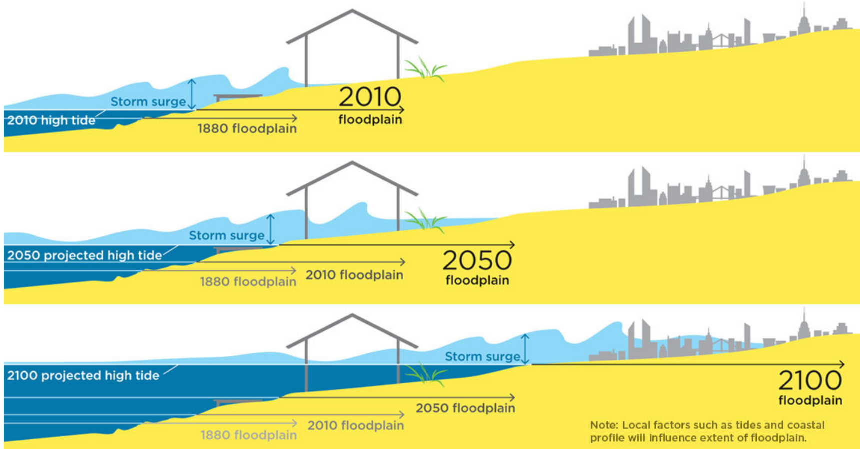


FIGURE 2-3 With higher global sea levels in 2050 and 2100, areas further inland would be at risk of being flooded (UCSUSA, 2013)

Second, seawalls block both physical and visual accessibility. Seawalls reduce beach access for handicapped people and for emergency services. The appearance of seawalls can be aesthetically displeasing which can further negatively affect beaches dependent upon a tourist economy. Furthermore, seawalls cut off the cultural connection between coastal communities and water and detract from a natural beach experience (figure 2-2). Third, a seawall has a negative impact to coastal ecosystem. Given that seawalls are heavily engineered, inflexible, and immovable structures, they can disrupt natural shoreline processes and cause a reduction in intertidal habitats such as wetlands, sandy beaches and saltmarshes. Compared to natural beaches, seawall-impacted beaches have reduced biodiversity and ecosystem services. In addition, a seawall will depreciate in value over time and thus require periodic and costly maintenance (UNFCCC, 1999).

SEA LEVEL RISE

Climate change has been shown to be accelerating, and precipitation rates are rising rapidly (Brown, 2014). Recent aerial footage and data reflect the fastest rate of sea level rise recorded in 15 years, lending scientists to project an increase of 0.5-1 meter in sea level by 2100 (figure 2-3). Coastlines throughout the world are very sensitive to changes in sea level. Every minutia of change can have profound impacts on the coastal communities. As a result, existing systems, primarily consist of engineered structures, might not meet the desired standards in the future. Conversely, hard coastal defense methods will make the situations even worse. For example, the existence of seawalls can increase flood risk (Cabi & Weiner, 2014). When seawalls fail, the result can be catastrophic. Compared to the scenario in which no seawall had been built, the force of waves will be more intense. It is critical that community planners make informed decisions when deciding how to react to rising sea levels. The ill-considered choices could lead down a path where beaches disappear, coastal tourism and fisheries suffer or where billions of dollars are lost to storm-damaged and flooded properties.

POSSIBLE RESPONSES

SUSTAINABLE ALTERNATIVES

Several new ideas have been proposed for soft coastal defense strategies, also called soft infrastructure, as solutions to the limitations of conventional hard methods (Pötz & Bleuzé, 2012; Brown, 2014; Freed et al., 2013). These strategies use natural landscapes and processes to provide dynamic coastal protection and other ecosystem services. Different from solid, disconnected structures, soft infrastructure form a network providing the ingredients for solving erosion and flooding challenges by building with nature. It is an approach to water management that protects, reinforces, restores, harnesses, or mimics the natural water cycle (Pötz & Bleuze, 2012). Common soft coastal defense methods along the coast include sand dunes, barrier islands, ribbed mussels, oysters reefs, and restored marshes. These measures attenuate waves in the event of a storm, protect inland areas from water inundation, and slow water run-off (Brown, 2014). For example, oyster reefs provide coastal protection via wave attenuation and erosion protection (Figure 2-5). Mangroves consisting of many different types of trees and shrubs that live in saline coastal habitats allow fine sediments to accumulate (Figure 2-6). Different from stable engineered structure, the soft alternative has the ability to self-recover. Similar to an organic entity, soft infrastructure can modify itself depending on the varying environment and create a dynamic balance. For example, a tidal marsh can change its form depending on water levels and thus provides various habitats for local fauna and flora (Rothstein, 2015).

COMBINATION APPROACHES

Based on a precedent project of the community of Howard Beach, a low-lying, densely populated neighborhood located on Jamaica Bay, New York, hybrid approaches that combine both soft and hard infrastructure could provide a cost-effective way to reduce flood risks at a neighborhood scale (Freed et al., 2013). The research team used hydrological modeling programs to create four scenarios—two were entirely based on soft infrastructure while the other two used combination methods— and evaluated each of them.

FIGURE 2-5 Artificial oyster reefs can prevent coastal erosion and grow fast in height to keep pace with sea level rise. (Netherlands Water Partnership, 2015)

FIGURE 2-6 People plant mangroves in the Philippines to protect coastal communities from the hazards of tsunami (Trowel Development Foudation, 2013)

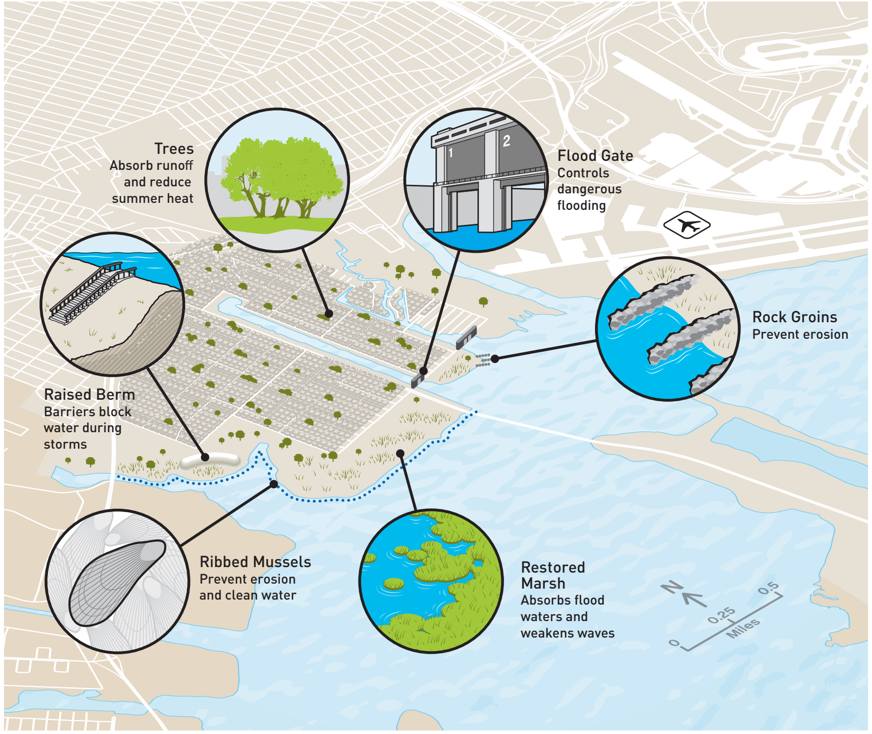


FIGURE 2-7 Soft and Hard infrastructure work together to protect coastal environment (Freed et al., 2013)

The soft/nature-based infrastructure options alone that are evaluated in this report cannot protect Howard Beach from major flood events given the existing urban conditions and flood risks. Whereas hybrid strategies that integrate natural and built infrastructure can offer significant protection to both high frequency, low impact flood events, and the current 100-year storm (figure 2-7). Combination strategies result in anticipated avoided losses from the current 100-year storm of $348 million and $466 million, respectively. This includes between $300-$400 million in avoided building damage (Freed et al., 2013). The soft/nature-based infrastructure elements of the integrated methods would likely lengthen the life and reduce annual maintenance costs of a local waterfront park and its protective berms through the reduction of wave energy and erosion. This project study discusses how natural defenses, in conjunction with engineered structures, can help protect coastal environments from the impacts of climate change.

TIME AND SPATIAL SCOPES

The element of time is always important in environmental design. Designers may need to adopt a much longer time frame to effectively engage the entirety of the ecological networks which structure our communities. Some loose-fit spaces may move around over time within our urban fabric, reflecting the dynamic, mixed, sometimes ambiguous landscapes which are likely to develop as expansive networks of infrastructure slice through and re-knit the existing fabric (Thompson, 2002). In dense coastal communities it is cheaper and more efficient to address flood risks at the neighborhood scale than to elevate each individual home above the FEMA base flood elevation (Freed et al., 2013).

Chapter Three

PURPOSE & QUESTION

"WHY SHOULDN'T TWENTY THOUSAND OF THE DWELLERS OF OUR CITY FIND THEIR WAY TO THE OCEAN BEACH EVERY SUNDAY AFTERNOON?"

— *San Francisco news-letter and california advertiser, 1880*

PURPOSE STATEMENT

Studies of coastal areas have been produced in many disciplines with distinct interests: biology, ecology, socio-economy, engineering, urban planning, architecture, landscape architecture, and many others. In the literature review, most authors point out that soft, green, or natural methods would be a good alternative to conventional engineered coastal defenses. However, the effectiveness and limitations of these soft coastal defense methods have yet to be defined, and methodologies to evaluate their performance and cost-effectiveness are in their infancy. For example, it is unclear how much protection from large storm events sand dunes can provide on their own (Pötz & Bleuze, 2012).

In addition, several sources point out that efforts to preserve the natural environment are mainly concerned with large, bio-diverse and relatively untouched ecosystems or with individual fauna or flora species. Much less attention is being paid to the nature close to where people live and work or to public open space in local communities and to their benefits. Reviewing the literature to understand sustainable coastal design strategies revealed that the social and cultural value of beachfront landscapes as public open space have not been addressed at a human scale in relation to adaptive planning.

Beachfront landscapes lying between developed areas and the ocean have been presumed to protect coastal communities from natural hazards and have the potential value of serving as public open space. However, in many coastal communities, beachfront landscapes are occupied by hard infrastructure such as seawalls and highways, which reduce their value.

Responding to these issues, the first purpose of this research design project is to explore alternative coastal defense strategies that protect coastal environments efficiently and have fewer negative impacts on coastal landscapes. Through analyzing the pros and cons of each potential strategy, a design prototype can be generated. For example, triggering an evolution of self-building beaches as a buffer between rising water and coastal communities can remove the barriers of hard infrastructure and create more soft landscape for both humans and wildlife.

In addition, many coastal communities have struggled to implement new strategies on the ground due to a deficiency in public input. To fill the gap, the second purpose of this project is to integrate social components to study how alternative coastal defense strategies modify or reshape coastal landscapes and create public open space for the residents of coastal communities and outside visitors. By overlaying social components such as community input and cultural considerations onto the physical forms, a comprehensive design proposal can be generated and applied at a specific study site. Taking a practical approach, the thesis attempts to be as feasible as possible instead of proposing abstract or conceptual images. The hope is that stakeholders and the general public will realize the current issues, understand the proposed design strategies, and shape their own agenda for a sustainable future.

RESEARCH QUESTION

PRIMARY RESEARCH QUESTION

How can sustainable design strategies for beachfront landscapes mitigate natural hazards while providing an accessible, secure, and multifunctional open space for the public, while adapting to rising sea levels?

SECONDARY RESEARCH QUESTIONS

- What are sustainable coastal defense strategies?
- How are they different from conventional methods such as seawalls?
- What are the physical, infrastructural, economic, and cultural aspects that must remain durable for coastal environments?
- What are the community's needs in regards to public open space?
- How can beachfront landscapes serve as public open space and continue providing functions and benefits to local residents and visitors?
- How does the process acknowledge the culture of coastal communities while developing their new identity associated with the rising water?

Chapter Four

RESEARCH METHODS

"RESEARCH IS TO SEE WHAT EVERYBODY ELSE HAS SEEN, AND TO THINK WHAT NOBODY ELSE HAS THOUGHT."

— *Albert Szent-Györgyi*

CASE STUDY

In this research design project, the case study approach is chosen as a primary methodology. The "case study" is a research strategy involving in-depth investigation of single events or instances within a similar field or theme, using multiple sources of research evidence (Yin, 2002). Case studies are useful in exploratory research for understanding existing phenomena for comparison, information, and inspiration. They can also be used to study the effects of change, new programs, and innovations. In this project, case studies of innovative coastal restoration and site design projects with similar conditions are a valuable tool for focusing research, discerning challenges, and understanding the potentials of different opportunities and strategies. However, when analyzing a specific site in the next stage, it is impossible to take a one-size-fits-all approach to design. Strategies would need to be localized, tailored to particular site conditions.

FIGURE 4-1 Plan of the Kustzone - Katwijk (OKRA, 2015)

FIGURE 4-2 Close view of the Kustzone - Katwijk (OKRA, 2015)

KUSTZONE - KATWIJK

LOCATION: Katwijk, Netherlands
AREA: 20 ha
PERIOD: 2013-2015
DESIGNER: OKRA

For the past ten years the Rijkswaterstaat, the Ministry of Infrastructure and the Environment, have been working to strengthen some weak links in the coast. Alongside building the required coastal defense, the coast zone investments also ensure that Katwijk remains a tourist destination and supporting the local economy of seaside towns. With the need to strengthen the Katwijk coast, care is taken to preserve the value of the existing town and, ultimately, how this can also be made stronger (OKRA, 2015).

In an interactive planning process OKRA defined the most important values of Katwijk; namely the relationship between the village and the beach. The chosen dyke-in-dune coastal defenses, a stone-lined embankment covered and reinforced by dunes, sufficient low dunes would be built with minimal disruption between town and beach. With this construction the City Katwijk could also realise an underground parking garage behind the dyke.

The dyke and garage are completely hidden from view by natural-looking dunes. An extensive network of paths has been built to connect village and beach, offering views of the sea. The highlight of the design is a broad dune transition that serves as a welcome space and event plaza, in total forming a vibrant heart for the coast of Katwijk coast (Landzine, 2015).

THE SAND MOTOR

LOCATION: Ter Heijde, Netherlands
AREA: 200 ha
DESIGNER: 2011

The Sand Motor consists of 21.5 million cubic metres of sand. Dredging vessels picked up the sand ten kilometres offshore and deposited it to form a hook-shaped peninsula between Kijkduin and Ter Heijde. The Sand Motor will gradually change shape before it is ultimately transformed into a new dune landscape and a wider beach. This approach to 'building with nature' allows the coast to extend in a natural way.

The Sand Motor leads to the creation of a unique natural and recreational area that the wind and the sea currents will transform continuously. The area is an appealing habitat for a range of flora and fauna.Visitors can enjoy the experience of the natural surroundings on and around the Sand Motor (Zandmotor, 2015).

The Sand Motor is a pilot project. Scientists studying this new approach to coastal defense and coastal maintenance are looking at the impact of the weather, the waves and the currents on the spread of the sand. But they are also monitoring the ecosystem, groundwater levels and the impact on the surroundings, such as recreation and bather safety. The Sand Motor is home to the 'Argus Mast', a 40-metre-high mast named after the giant from Greek mythology with 100 eyes, on which eight cameras have been installed to film changes on the Sand Motor.

FIGURE 4-3 The Sand Motor after realization (EcoShape, 2011)

FIGURE 4-4 The Sand Motor in 2015 (EcoShape, 2015)

FIGURE 4-5 Construction of the Hondsbossche and Pettemer Sea Defense (Boskalis, 2015)

FIGURE 4-6 Close view of the Hondsbossche and Pettemer Sea Defense (Boskalis, 2015)

HONDSBOSSCHE AND PETTEMER SEA DEFENSE

LOCATION: Between Petten and Camperduin, Netherlands
AREA: 326 ha
PERIOD: 2015-2016
DESIGNER: Boskalis

The plan presents an integrated vision on the long-term protection of the Dutch coast and its hinterland. On the protection of the Dutch coast it includes ten recommendations for adaptations, addressing the so-called 'weak links'. The plan urges the strengthening of these weak links so that they are able to withstand a 'super storm' - an event that is expected to occur once every 10,000 years. Safety is of the utmost importance, but other objectives also play a role in these coastal reinforcement projects. For example, the sand balance should be kept stable, the ecological quality must be improved, the economic continuity must be guaranteed and the spatial use must be optimized (Boskalis, 2015).

Boskalis already contributed to these projects with the reinforcement of the Delflandse coast and the creation of the Sand Motor. The Hondsbossche Sea Defense at Petten was considered the last weak link. The safety of the entire region, including large parts of the Dutch capital Amsterdam, depends on this dike, so it was paramount that a safer solution was found. Boskalis, in partnership with Van Oord, transformed the existing Hondsbossche and Pettemer Sea Defense into an unique beach and dune landscape. On the face of it, the new solution appears to be a softer alternative rather than making the defense even stronger. The old sea dike has disappeared behind the new dune and is no longer an active part of the coastal defense. But for cultural and historical reasons the straight, horizontal top line of the 12 meter-high dike continues to dominate the view from the polder.

AMAGER STRANDPARK

LOCATION: Copenhagen, Denmark
AREA: 346,000 m^2
PERIOD: 2003-2010
DESIGNER: Hasløv & Kjærsgaard

Amager Beach Park has been one of the largest urban recreational development projects, close to the city centre of Copenhagen. The beach park has transformed the coastal landscape of the city and the island of Amager facing the Sound. The new Amager Beach is designed to be a very special place in the city: a large-scale landscape that provides a contrast to the density of the Copenhagen waterfront.

Amager Beach has been used intensively since its opening. The bustling beach life actually started before the beach was fully finished. Modern people, up for something new, soon realised that this was the perfect place for outdoor activities. It is very clear that the simple concept of the Beach Park and its unique features provide a great setting for continued development of activities and architecture in the area. On warm summer days the old Amager Beach attracted thousands of people (Landzine, 2013).

The new Amager Beach Park does more than that. Some of its facilities have been carefully planned, but others are being developed as a kind of live discovery centre. The beach has become a 'place' in the city, a destination for excursions throughout the year: people go to the beach to enjoy the views late in the evening: people come here to walk, jog, and exercise or walk their dogs, alone or in the company of others. The beach has places where people meet and watch people and places for solitude. And here, in the midst of the city, nature is the great attraction. Not nature in a romanticized form, but a scenography composed of natural forces and the open horizon, which is in fact the new place's best quality (Landzine, 2013).

FIGURE 4-7 Bird's-eye view of Amager Strandpark (Hasløv & Kjærsgaard, 2010)

FIGURE 4-8 Close view of Amager Strandpark (Hasløv & Kjærsgaard, 2010)

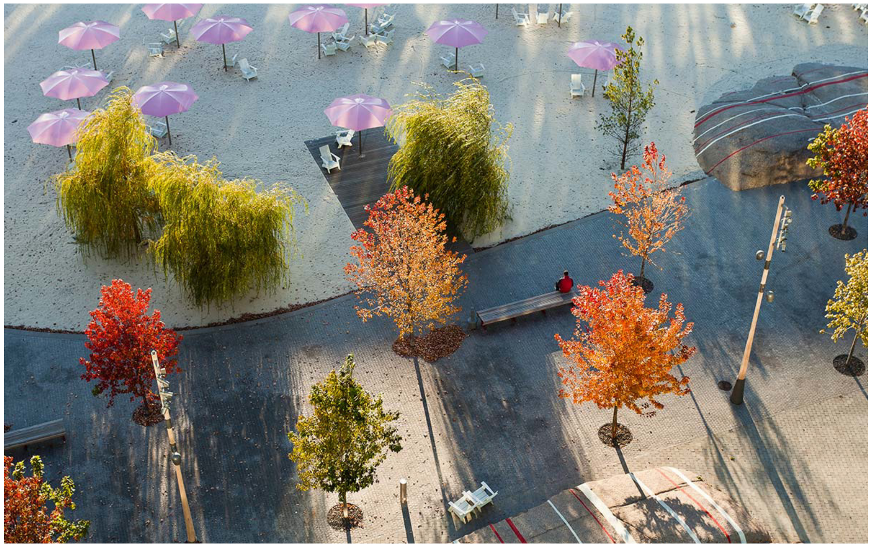


FIGURE 4-9 Bird's-eye view of Sugar Beach (Claude Cormier + Associés, 2010)

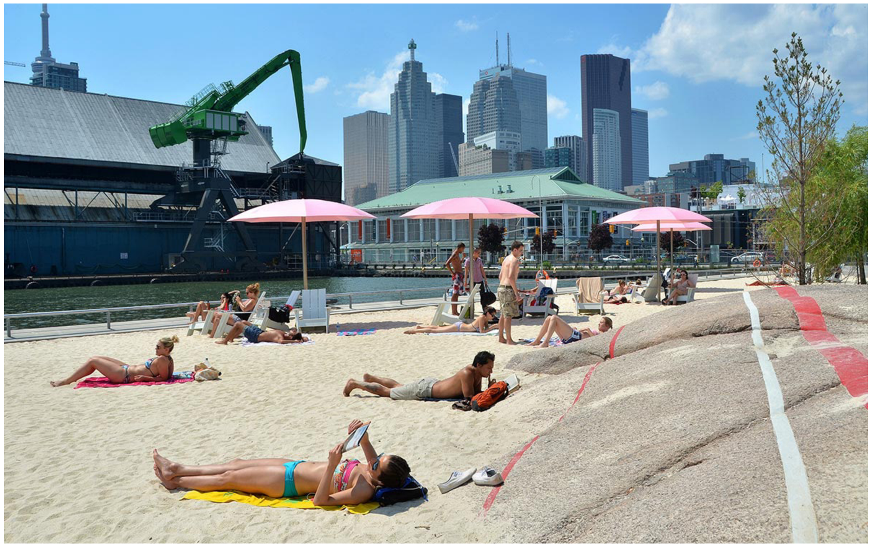


FIGURE 4-10 Close view of Sugar Beach (Claude Cormier + Associés, 2010)

SUGAR BEACH

LOCATION: Toronto, Canada
AREA: 8500 m^2
PERIOD: 2008-2010
DESIGNER: Claude Cormier + Associés

The Sugar Beach is an imaginative park that transformed a surface parking lot in a former industrial area in Toronto into a modern urban beachfront. The design draws upon the industrial heritage of the area and its relationship to the neighbouring Redpath Sugar factory (Claude Cormier + Associés, 2010).

The park features three distinct components: an urban beach; a plaza space, and a tree-lined promenade running diagonally through the park with a playful water feature in the shape of the iconic Canadian maple leaf. The 8,500 square metre park is the first public space visitors see as they travel along Toronto's Queens Quay from the central waterfront. The park's brightly coloured pink beach umbrellas and iconic candy-striped rock outcroppings welcome visitors to the new waterfront neighbourhood of East Bayfront (Landzine, 2014).

This case reminds that urban waterfront can be a playful destination. The beach allows visitors to relax and play in the sand or watch boats on the lake. The dynamic water feature, embedded in a granite maple leaf beside the beach makes cooling off fun for the public. The park's plaza offers a dynamic space for public events. A large candy-striped granite rock outcropping and three grass mounds give the public unique vantage points for larger events with the spaces between the mounds creating natural performance spaces for smaller events.Between the plaza and the beach, people stroll through the park along a granite cobblestone with maple leaf mosaic pattern. The promenade offers a shaded route to the water's edge providing the public with many opportunities along the way to sit and enjoy views to the lake, beach or plaza.

DATA COLLECTION

PHYSICAL DATA

To analyze the physical conditions of a study site, a great deal of quantitative and objective data is collected. Physical conditions in this project refer to the existing natural and developed environments of a beachfront landscape. These include the location of critical infrastructure, conservation areas, road access, and flood zones. Detailed Information on existing coastal defense structures is significant. By understanding various aspects of current protection methods, including their history, functions, costs, and sustainability, a preliminary assessment is conducted to guide future designs. In addition, considering high water level scenarios in the future, a diagram showing inundation from sea level rise occurring at a persistent elevation is generated based on sea level modeling.

By overlaying the physical conditions onto the sea level rise map, a vulnerability assessment that indicates design opportunities and constraints is produced. Comparing this assessment to the strategies discussed in the literature review and case studies allows for identifying comprehensive adaptation strategies for the study site. Data collected on physical conditions and analyzed in this research is primarily based on geographic information systems (GIS), and is gathered from city, county, and state websites. Onsite survey is also important to obtain specific data that is not available through GIS.

SOCIAL DATA

Considering future beachfront landscapes as valuable public open space of coastal communities, community input and data related to social aspects are important to gather. A community knows its public open space and its users best, and gathering input has a powerful impact on how well the environmental design responds to users' needs (Mean & Tims, 2005). Determining the requirements and preferences of residents and visitors and what they value most about their community significantly influences the priorities and delimitations in the design stage.

Compared to the linear methology of quantitative data collection, social data is more difficult to collect since it is relatively qualitative and subjective and each community is unique in cultural and social composition. For such qualitative analysis, interviews and questionnaires are good tools for collecting data. Onsite interviews can get primary data from the residents. According to the concept of community asset mapping (Dorfman, 1998), a map is needed in conducting surveys to give participants the opportunity to point to the spaces and places they value most. Online questionnaires, which can be administered at the same time as in-person gatherings, provide an opportunity to reach out to a different and broader group of individuals.

Both quantitative and qualitative data gathering are carried out simultaneously for the most part; however, the analyses occurr separately and are then combined.

SITE SELECTION

RATIONALE

First, the site is located near the shoreline since the study topic is closely related to coastal environments. The site is located in an urban context. Compared to large cities, smaller communities are less complicated with fewer variables or constraints and more feasible to survey, analyze and design. Second, to design a better public open space, understanding user's specific requirements is important. Public space works best where people are able to positively contribute to their everyday environments through their personal choices and actions. Third, since alternative strategies to conventional coastal defense structures are a major component of the research question, sites with damaged infrastructure or isolated beachfront landscapes are more suitable for experimental design to demonstrate the potential strategies. In addition, sites that not only serve the local population but also attract tourism are better choices because they maximize benefits.

SITE OVERVIEW

Ocean Beach is a 3.5-mile stretch of landscape along San Francisco's west coast, bordering the Pacific Ocean. It is adjacent to Golden Gate Park, the Richmond District, and the Sunset District (figure 4-11). The Great Highway runs alongside the beach, and the Cliff House and the site of the former Sutro Baths sit at the northern end. Ocean Beach draws a diverse population of more than 300,000 visitors each year to stroll, bike, surf, walk dogs and enjoy the stunning natural scenery. It is an important piece of the Golden Gate National Recreation Area, a wild landscape, an urban sea strand and a grand public open space. Ocean Beach is also home to major elements of San Francisco's wastewater and stormwater infrastructure, which protects coastal water quality.

Ocean Beach is a challenging setting, exposed to the relentless pounding of ocean waves. Over more than a century, it has been pushed more than 200 feet seaward of its natural equilibrium (McLaughlin, 2012). Neighborhoods, roads, parks and infrastructure have been built close to the coastline, and seawalls and other structures have been installed to protect them. Erosion has taken a toll, and is likely to worsen with climate-related sea level rise. It is difficult to make choices about how to manage these hazards while maintaining valued resources. Deepening these challenges is the complex array of federal, state and city agencies that oversee Ocean Beach, each with different responsibilities and priorities.

A BRIEF HISTORY

Ocean Beach offers a sense of rugged wildness at the city's edge. But it is very much a managed landscape, shaped over time by a series of human interventions that reflect evolving perceptions of the beachfront landscape and its relationship to the city. A century ago, before the Richmond and Sunset Districts took shape in the "Outside Lands," Adolph Sutro's 1888 steam railway drew day-trippers through miles of sand dunes to his gardens and to Sutro Baths — at the time the world's largest natatorium.

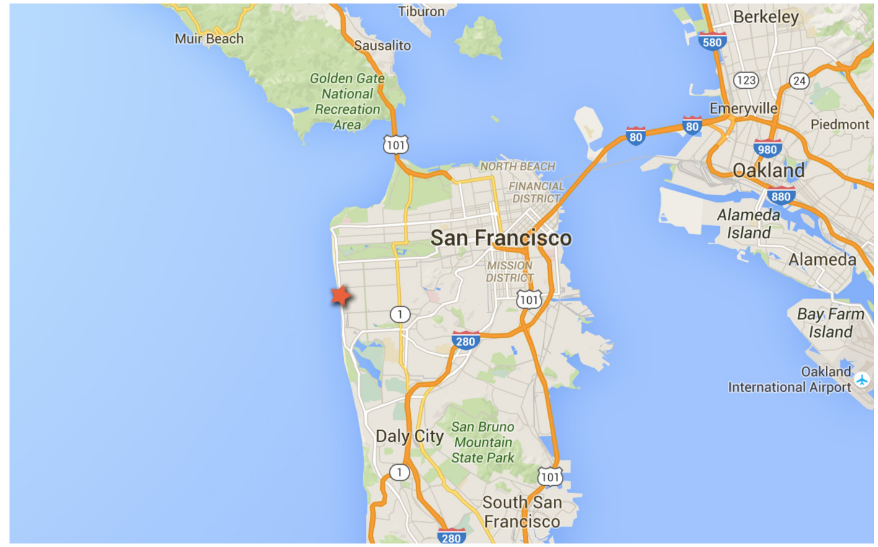


FIGURE 4-11 Location of Ocean beach (Google Maps, 2016)

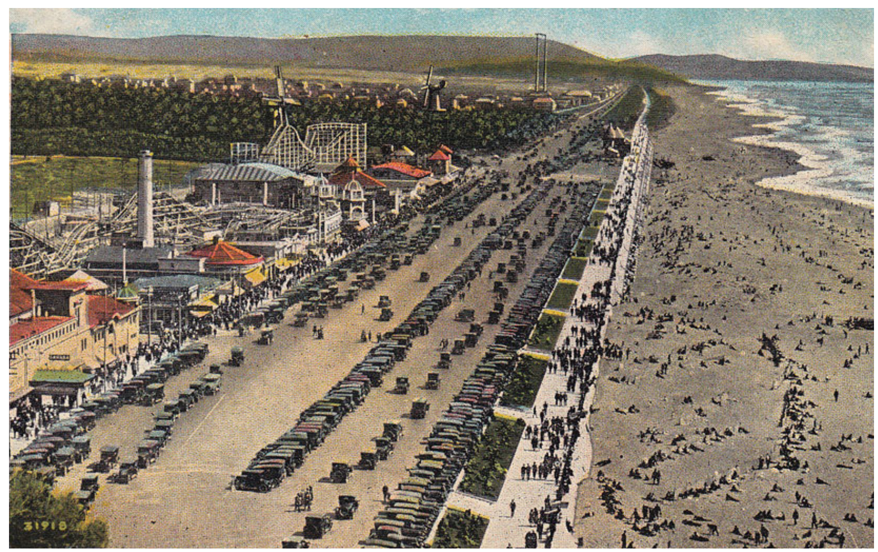


FIGURE 4-12 Ocean Beach from Cliff House on a old postcard, showing the Playland at the Beach (sanfranciscodays, 2010)

FIGURE 4-13 Aerial view of the Great Highway (USACE, 2007)

FIGURE 4-14 Seawall along the coast (Costales, 2007)

As cable cars and later trolleys took over, “Carville,” a settlement built of decommissioned horsecars,offered a destination for bohemians and bicycle clubs. Amusement concessions near Fulton Street were gradually consolidated into Chutes at the Beach, later Playland at the Beach (figure 4-12), which offered rides and games into the 1970s. This evolving cluster of beach amusements was a boisterous outpost of the city, and offered a transit-based escape for ordinary San Franciscans for whom tonier destinations were out of reach. As the automobile came to prominence, the soft sand and other fill was pushed seaward to create a “Great Highway”, which was improved, straightened and widened over several decades. Dune stabilization efforts, such as fences at the high-tide line, had begun at Ocean Beach in the 1860s. Efforts to widen the Great Highway by dumping fill began as early as 1890 with a series of improvements following over several decades (McLaughlin, 2012). In 1929, the Great Highway, Esplanade and O’Shaughnessy Seawall (with its unique and still extant equestrian ramp) were ceremoniously opened. This completed the Great Highway’s transition to an automobile expressway, touted as the widest paved roadway in the United States (figure 4-13).

The O’Shaughnessy Seawall also inaugurated serious efforts to resist coastal erosion. It was followed by the Taraval Seawall in 1941 and the Noriega, or “new,” Seawall in the 1980s. With the addition of boulder revetments south of Sloat Boulevard in the last 15 years, more than 10,000 feet of coastal armoring now lines Ocean Beach, with important implications for future coastal management (figure 4-14). Since the 1970s, significant amounts of sand have also been placed to counteract erosion.

As amusements and recreational facilities declined, Ocean Beach took on a new identity as a national recreation area, with the beach and dunes becoming federal property in 1975, and a new emphasis on natural resources and the beach’s wild character.

Chapter Five

DESIGN INTERVENTION

"PROGRESS IS IMPOSSIBLE WITHOUT CHANGE, AND THOSE WHO CANNOT CHANGE THEIR MINDS CANNOT CHANGE ANYTHING."

— *George Bernard Shaw*

FIGURE 5-1 Context map showing historic coastline (colored lines), major infrastructure, and the study area (Google Earth Pro, 2016)


SUNSET DISTRICT
SAN FRANCISCO ZOO
1850-1853
1873
Taraval Seawall (1941)
2012
1992
Noriega Seawall (1980s)
STUDY AREA
PACIFIC OCEAN

PHYSICAL DATA ANALYSIS

EROSION

The west coastline of San Francisco is artificially maintained about 200 feet seaward of its natural equilibrium. Sand was deposited in the late 19th and early 20th centuries to create level ground for the construction of the adjacent neighborhoods and the Great Highway. This new land was then stabilized with pavement and protected by several seawalls, but erosion has been a recurring issue from the beginning.

By overlapping historical maps showing various locations of the coastline, it is obvious that the south reach of Ocean Beach, starting from Noriega Street, is subject to erosion, where more sand is removed than deposited by waves and currents, and the shoreline recedes landward (figure 5-1). The past 15 years have seen several severe erosion episodes, typically during El Niño seasons. In the 2009–2010 winter alone, the coast eroded 40 feet inland, undermining parking lots and the shoulder of the Great Highway and resulting in closure of the southbound lanes for nearly a year (figure 5-2).

THE GOLDEN GATE LITTORAL CELL

The Golden Gate Littoral Cell is defined by a large, semicircular sandbar within which sand circulates with the currents and tides, by turns eroding and nourishing the beach (Figure 5-4). Within the cell, sand supply is relatively stable. Average longshore (lateral) currents at Ocean Beach carry sand northward, and it continues to circulate within the bar. South of Noriega, however, currents diverge and southward currents scour sand away and out of the cell, resulting in a net loss of sand and a narrowing beach (figure 5-4).

The U.S. Army Corps of Engineers annually dredges a marine shipping channel in the sandbar to allow access by large ships to the Golden Gate. This dredged sand — about 300,000 cubic yards each year represents a significant opportunity for beach nourishment, in which sand is placed on the beach to counteract the effects of erosion (EPA, 2010).

FIGURE 5-2 Erosion at Ocean Beach resulting from the 2009-2010 El Niño storm season (San Francisco Department of Public Works, 2014)

FIGURE 5-3 Boulder revetments at Ocean Beach (California Coastal Records Project, 2014)

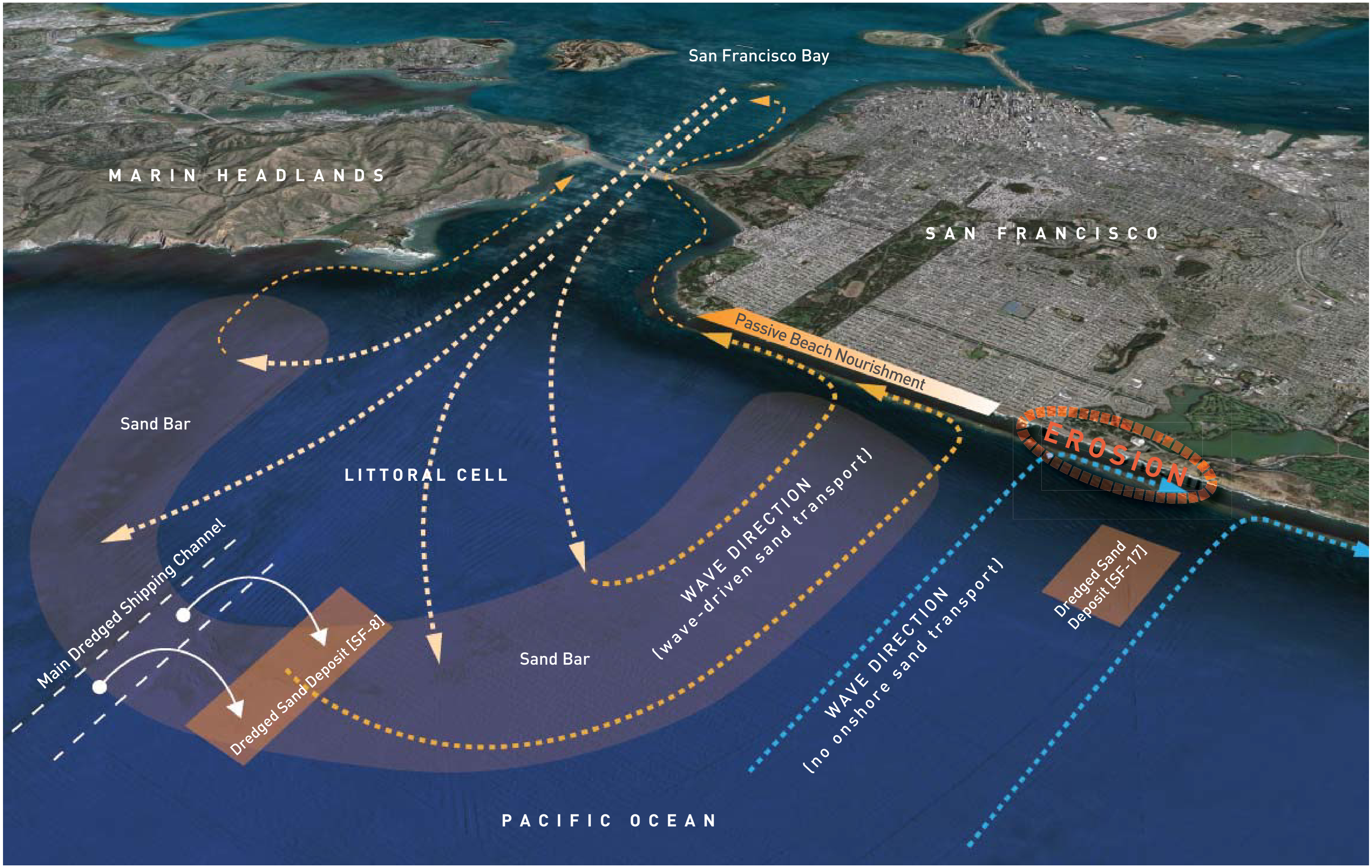


FIGURE 5-4 The Golden Gate Littoral Cell (SPUR, 2012)

Summrized from the previous analysis, the northern reach of Ocean Beach has been getting wider while the southern reach is narrowing as erosive forces scour away sand and bluffs, leaving less and less buffer between waves and critical infrastructure. The focus study area is then narrowed down to a portion of the soutern reach, from Noriega Street to Santiago Street, where the beach is protected by the Noriega Seawall (figure 5-1).

SEA LEVEL RISE

Sea level rise and its impact are fundamental challenges in planning for the future of Ocean Beach, as they directly inform the management of coastal hazards. As sea levels rise, the coastline recedes inland, further inundate or erode the beachfront landscape. Although there is a great deal of uncertainty about the timing and extent of climate-related sea level rise, there is considerable consensus on the general nature of its impacts.

The State of California's "Sea-Level Rise Interim Guidance Document" (2010), developed after a considerable interagency examination of the various available climate models, directs state agencies to plan for 14 inches of sea level rise by 2050 and 55 inches by 2100 (figure 5-6). It is also assumed that California will likely be subjected to increasingly frequent and severe coastal storm surges, which will be exacerbated by higher sea levels.

By overlapping future sea level rise predictions on to existing topography and water levels (figure 5-5), two comprehensive analytical diagrams are generated (figure 5-8, figure 5-9). Although in 2100, the sea level rise would not cause direct inundation to the residential area of the sunset district, a higher water level would diminish the beach along the coast to a large extent, from 90 feet to a mere 40 feet (figure 5-2). Consistent erosion and the negative impacts of seawalls would further amplify the result. In addition, the waves during storm surges will presumably impact the Great Highway (overtopping hazard), endangering transportation capacity during extreme weather events.

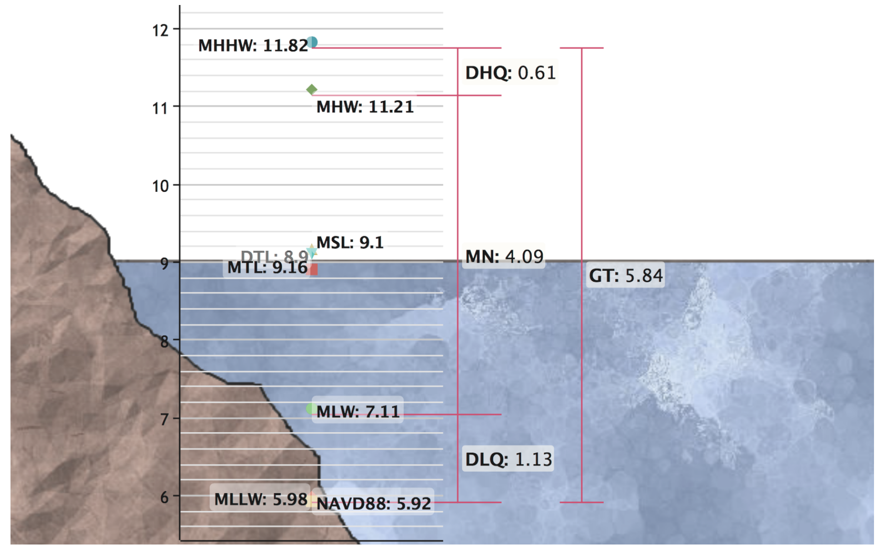


FIGURE 5-5 Datums for 9414290, San Francisco, CA, showing current water level heights (NOAA 2016) (see figure 5-8 for captions)

YEAR		AVERAGE OF MODELS	RANGE OF MODELS
2030		7 in (18 cm)	5-8 in (13-21 cm)
2050		**14 in (36 cm)**	**10-17 in (25-43 cm)**
2070	Low	23 in (59 cm)	17-27 in (43-70 cm)
	Medium	24 in (62 cm)	18-29 in (46-74 cm)
	High	27 in (69 cm)	20-32 in (51-81 cm)
2100	Low	40 in (101 cm)	31-50 in (78-128 cm)
	Medium	47 in (121 cm)	37-60 in (95-152 cm)
	High	**55 in (140 cm)**	**43-69 in (110-176 cm)**

FIGURE 5-6 Future sea level rise (State of California Sea-Level Rise interim guidance document, 2010)

FIGURE 5-7 The existing site conditions of the study area (nearmap, 2016)

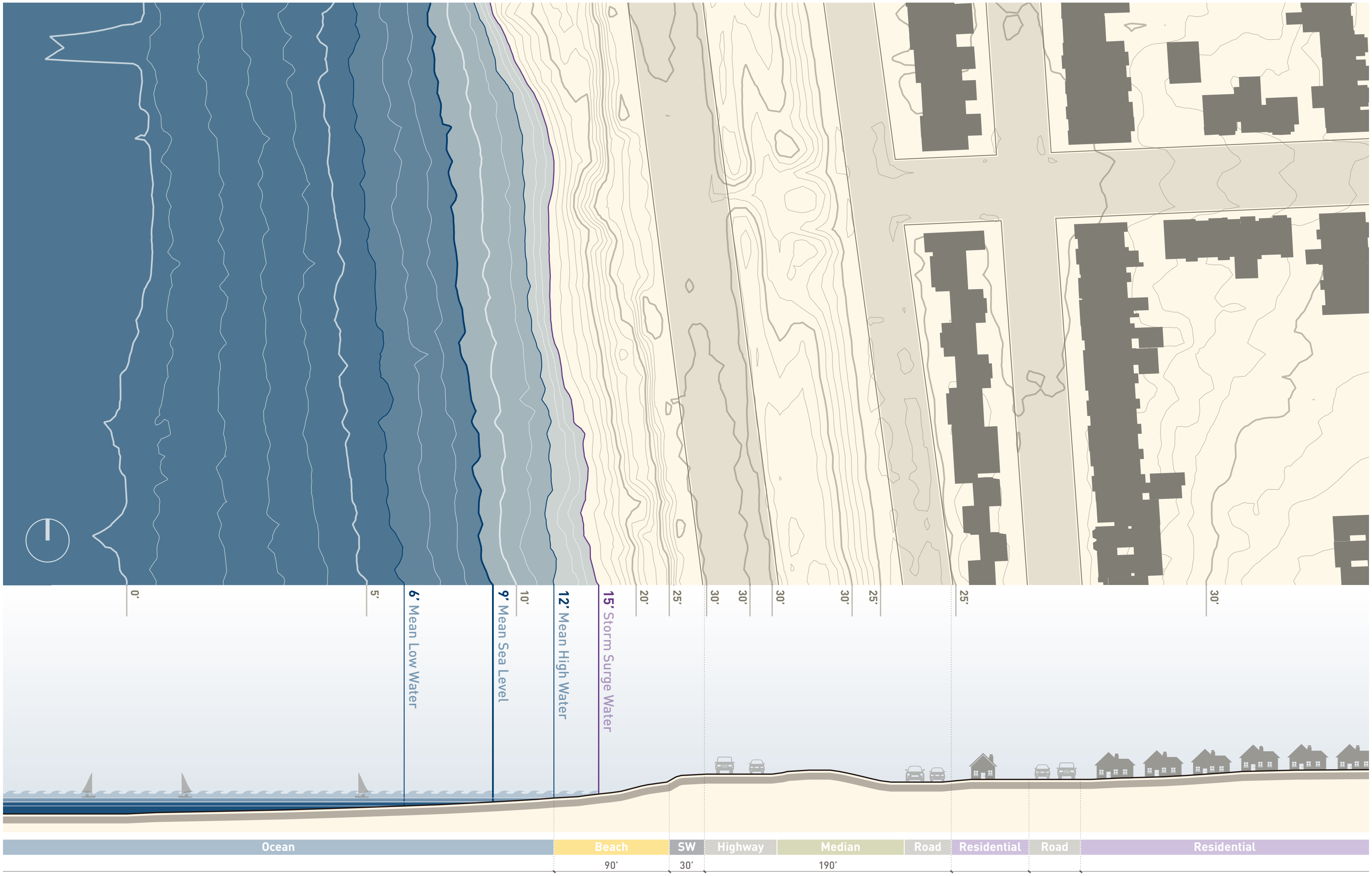


FIGURE 5-8 Typical section of beachfront landscape at present (USGS, 2016)

Mean Sea Level (MSL): A tidal datum. The arithmetic mean of hourly heights observed over the National Tidal Datum Epoch.
Mean High Water (MHW): The average of all the high water heights observed over the National Tidal Datum Epoch.
Mean Low Water(MLW):The average of all the low water heights observed over the National Tidal Datum Epoch.

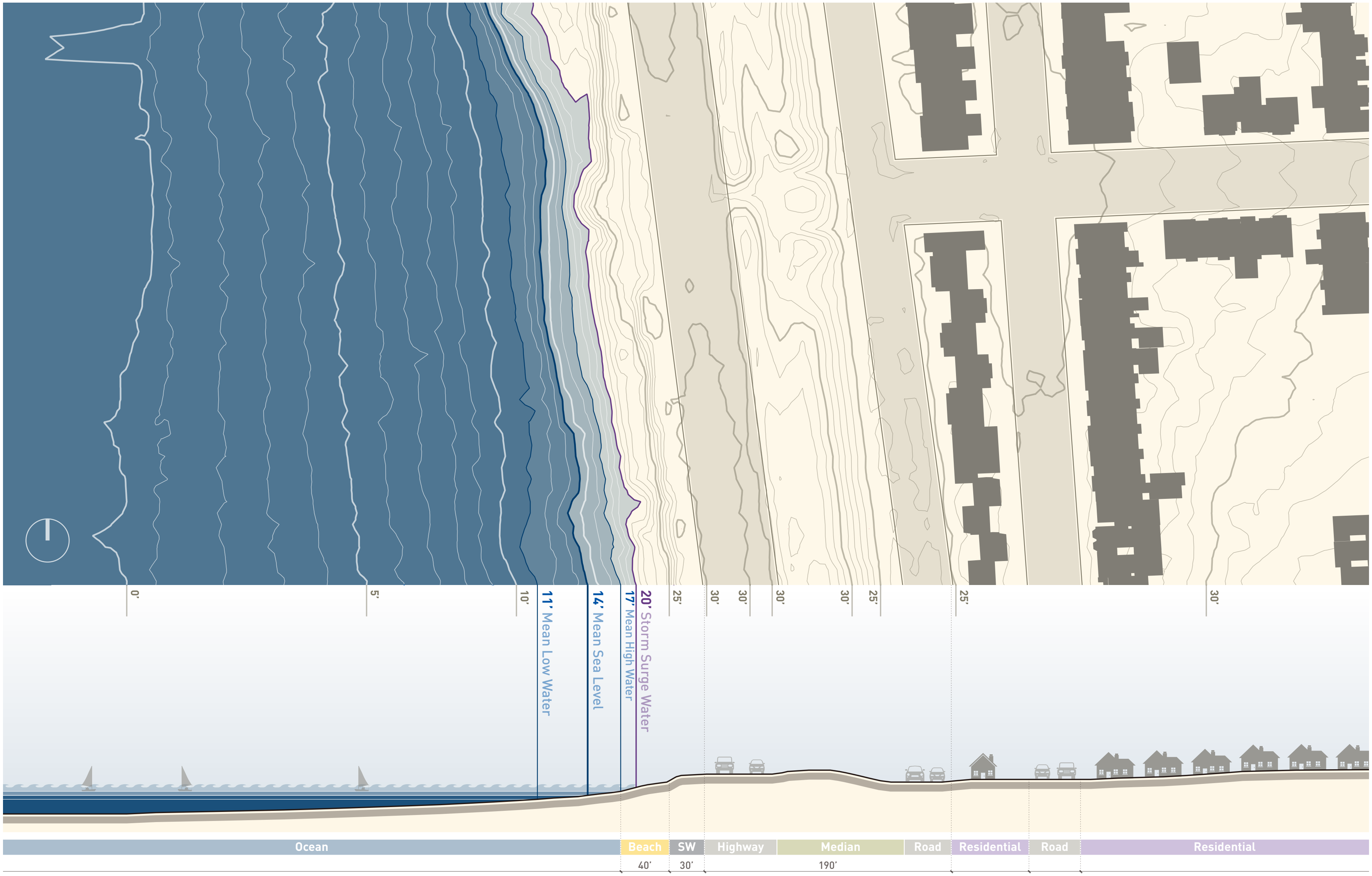


FIGURE 5-9 Typical section of beachfront landscape in 2100 (USGS, 2016)

National Tidal Datum Epoch:The specific 19-year period adopted by the National Ocean Service as the official time segment over which tide observations are taken and reduced to obtain mean values (e.g., mean lower low water, etc.) for tidal datums. It is necessary for standardization because of periodic and apparent secular trends in sea level. The present NTDE is 1983 through 2001 and is actively considered for revision every 20-25 years. Tidal datums in certain regions with anomolous sea level changes (Alaska, Gulf of Mexico) are calculated on a Modified 5-Year Epoch.

SOCIAL DATA ANALYSIS

On-site surveys and questionnaires are the primary methods to collect social data. The on-site survey was conducted on April 10, 2016, and 100 respondents filled out the questionnaire. Based on the data collected from the questionnaires, critical guidance and considerations are provided for the design stage.

69% of users on site are from the adjacent neighborhood (sunset district), while 31% are outside visitors, which indicates that the largest group of users is the local community (figure 5-10). It also reflects that compared to other tourism destinations along the waterfront in San Francisco, such as Fisherman's Wharf and Crissy Field, Ocean Beach is not well-known and less attractive. Under the question "What disappoints you about the experience on Ocean Beach?" the top answer is lack of amenities. Many users complained that the beach is not well maintained since there was a lot of trash on the ground. Basic amenities, such as restrooms, waste collection, seating, and retail are in limited supply. In addition, some visitors mentioned that the beach space is too narrow and that there is no gathering space, such as a plaza. Under the question "What is the biggest attraction that you come to Ocean Beach?" the top answer is wildness and ruggedness of nature. People escaping from urban settings want to enjoy the raw and open beauty of beachfront landscapes. Respondents expressed their desire for improving some of the beach's facilities, but insisted that maintaining the unique character by not "prettying up" the beach was crucial. In addition, most of the visitors know that the sea level is rising; however, few of them can imagine Ocean Beach would be affected and beach space would disappear if no action is taken. It is a good opportunity to inform the public of the consequences of rising sea levels through environmental design.

Good landscape design has the power to strike that balance — to solve problems and serve needs while speaking to the soul of a place. When designing the new beachfront landscape, it is important to keep a good balance to preserve and celebrate the raw and open beauty of beachfront landscapes while welcoming the broader public. To be successful, improvements need to accommodate and balance a wide range of users, from surfers to families, bird-watchers to cyclists. It is necessary to preserve the current activity pattern of locals and regular users while enhancing the capacity to accommodate large events.

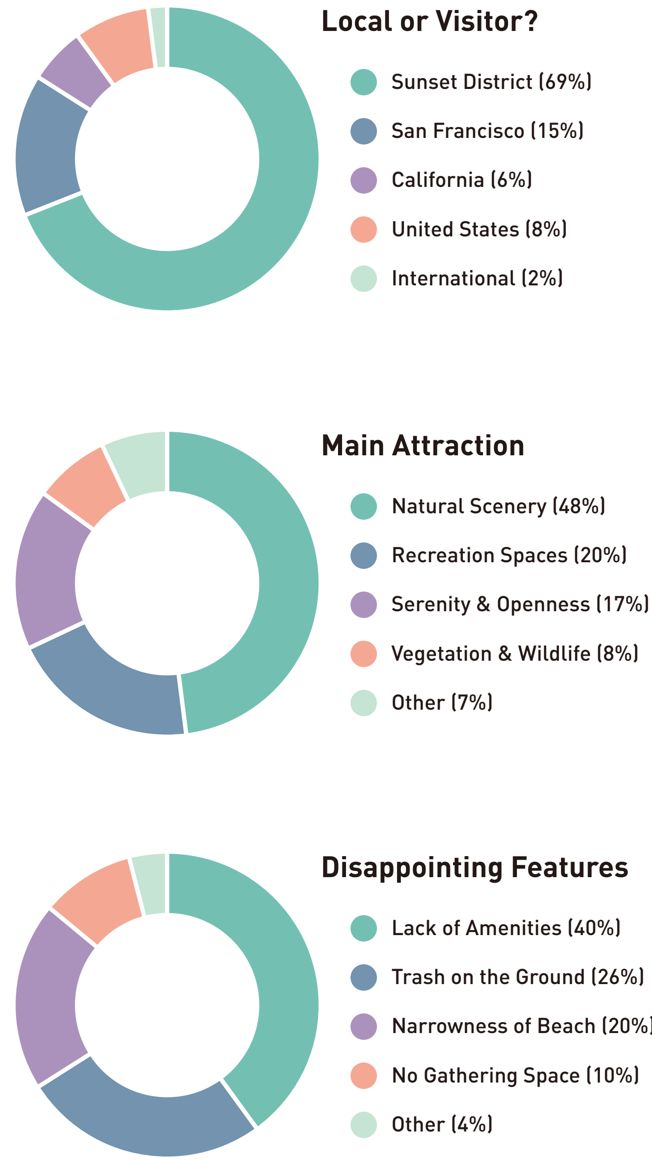


FIGURE 5-10 Statistics data based on questionnaire survey

FIGURE 5-11 Statistics data based on questionnaire survey showing desired amenities and activities of 100 respondents

DESIGN STRATEGIES

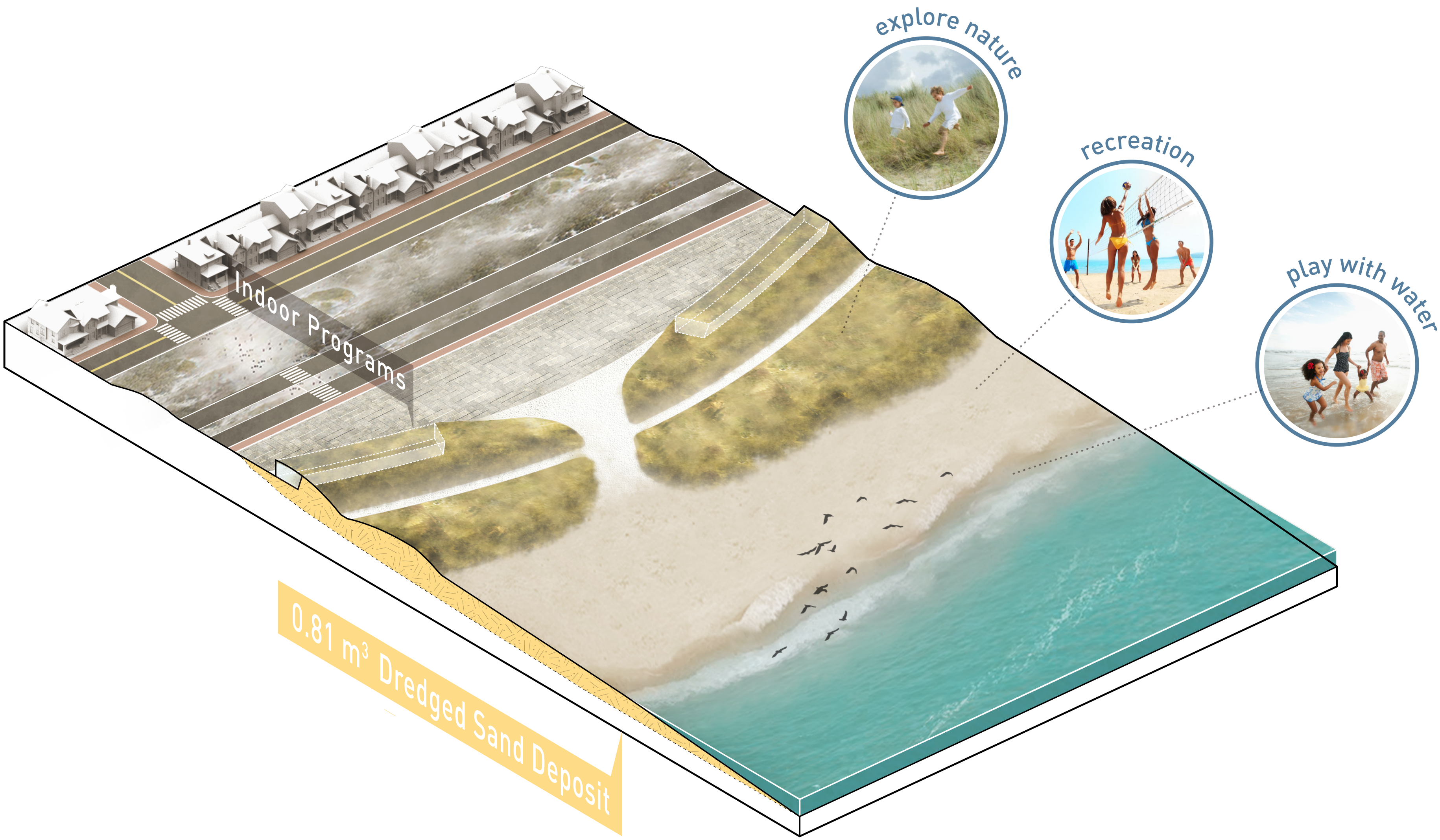
The first step is to widen and refurbish the beach by depositing 0.81 million cubic meters of sand along the coastline. The new beachfront area would have a total width of 500 feet. An undulating dune landscape is then created by shaping the sand and planting native vegetation, resulting in a natural and dynamic appearance. A pathway network connecting the beach to the Great Highway is created, allowing visitors to experience the dunes. These new pathways have a gentler slope, which increase accessibility, especially for disabled users. Three linear plazas are created to serve as gathering spaces. On the dunes, seating features, recreational fields, and observation platforms are implemented to better facilitate the use of the site.

To incorporate indoor programs such as an educational center, retail, and restrooms in a better way, an innovative intervention is created. The interior spaces are integrated into the landform with glass facades and entrances facing east. When storm events happen and waves sweep towards land, interior spaces are relatively safe with the protection of dunes. When people are in the dune and beach area, they cannot see the hidden structures, which preserves the natural scenery with a minimum of artificial elements.

Inspired by the Sand Motor project in the Netherlands (page 19), a "mini sand motor" is created by depositing sand dredged from the shipping channel (figure 5-4). This man-made peninsula built of sand will change its shape through time: as the waves hit it, the sand will be spread across the shoreline by the ocean's currents. This experimental intervention creates a continuing source for beach self-building process, which is a climate-robust and environment-friendly means of countering coastal erosion while providing new areas for nature and more types of recreation (Ecoshape, 2014). As the disturbance frequency is much lower than traditional beach nourishment, nature has more time to develop new ecosystems with augmented biodiversity.


MASTER PLAN
PLATFORM
PLAZA
DUNE
BEACH
SAND MOTOR

AXON SECTION




A
A'
SITE LIMITS
CURRENT COASTLINE
30
20
25
40
▼ 41'
▼ 36'
▼ 45'
▼ 42'
▼ 36'
▼ 22'
▼ 30'
▼ 28'
▼ 45'
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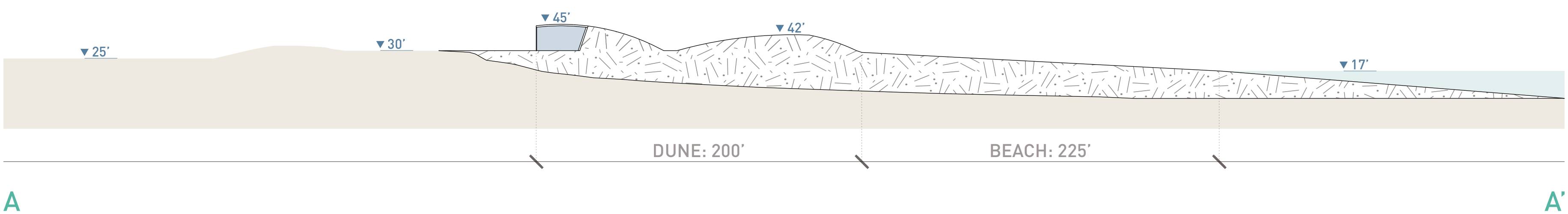
▼ 16'
▼ 17'


▼ 25'
▼ 30'
▼ 45'
▼ 42'
▼ 17'
DUNE: 200'
BEACH: 225'
A
A'

PERSPECTIVE

Chapter Six

CONCLUSION

"AN ESTUARY DEMANDS GRADIENTS NOT WALLS, FLUID OCCUPATIONS NOT DEFINED BY LAND USE, NEGOTIATED MEMENTS NOT HARD EDGES. IN SHORT IT DEMANDS THE ACCOMMODATION OF THE SEA NOT THE WAR AGAINST IT."

— *Anuradha Mathur and Dilip Da Cunha*

OUTCOME

This research design project consists of a physical and vulnerability analysis as well as community inputs in order to develop integrated sustainable strategies for adaptive design of beachfront landscapes. These strategies transform an edge condition to a valuable place for humans, wildlife, and the environment. A seed intervention can be put in place to trigger a process driven by the natural forces such as water and wind movements. In contrast to conventional coastal defense strategies, such as building seawalls, a much softer and process-driven solution, consisting of dune and sand motor, will make the waterfront space more accessible and user-friendly.

This project answers the research question by achieving two goals. The first goal is to design a sustainable beachfront landscape that is adaptive to erosion, sea level rises, and storm surges. The second goal is to transform the study site, Ocean Beach, from an under-utilized space to an attractive place by integrating recreational and educational programs. The intervention of sand motor informs the public that the beach, shoreline, and the sea level are consistently changing, which enhance the environmental awareness of coastal communities.

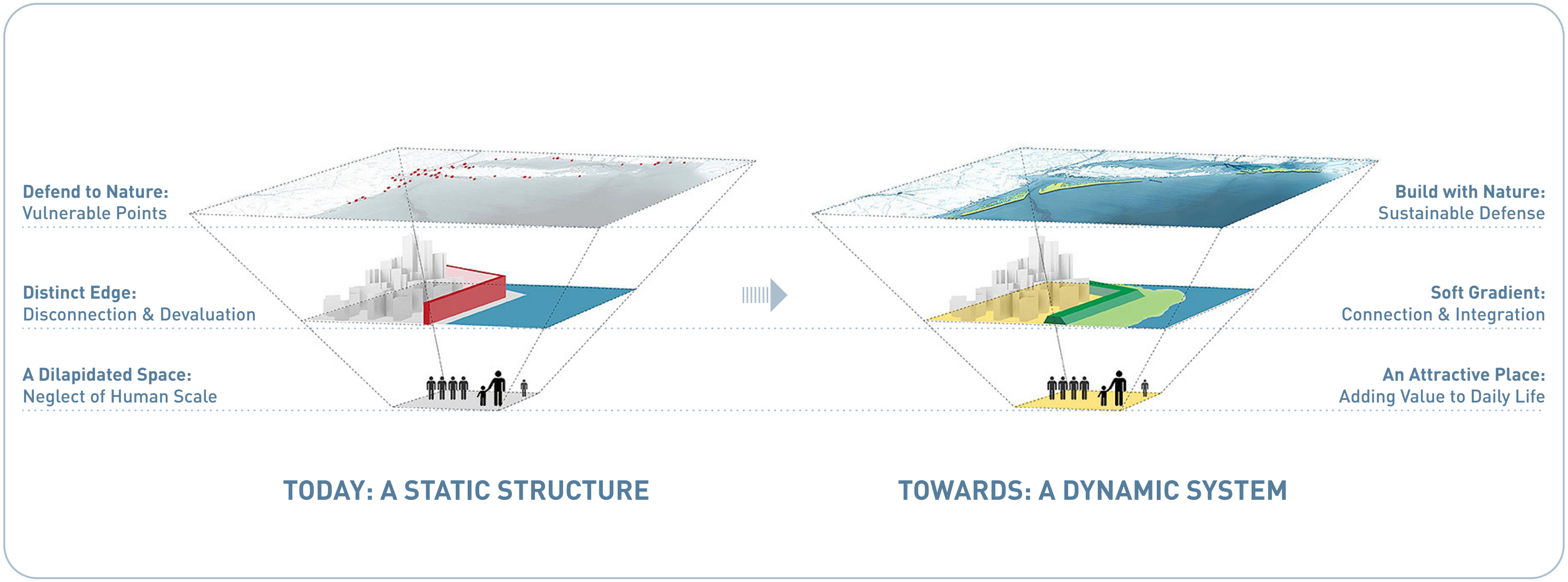
In the future, the beachfront landscapes will act as a buffer between the rising water and coastal communities, with layered systems of the beach, dunes, sand motor, promenade, observation platforms, and other public amenities. During and after disasters, beachfront landscapes help to minimize damage and support recovery; during non-disaster times, their values shift from the narrow focus on protection to recreation. By engaging the community, the beachfront landscapes become public open space for coastal communities and a cultural value integral to the daily life of residents, which represent stewardship of water and nature.

LIMITATION

The effectiveness and limitations of these sustainable design strategies have yet to be defined, and methodologies to evaluate their performance and cost-effectiveness are in their infancy due to the lack of time, quantitative data and analysis, and specialist knowledge. For example, it is unclear how much protection from extreme weather events sand dunes can provide on their own and how much time the sand motor takes to develop into different shapes.

CONTRIBUTION

The proposed design in this thesis will not solve all of the issues that coastal communities are facing in the context of sea level rise and higher frequency of extreme weather. However, the study provides an example for understanding how sustainable design strategies of beachfront landscapes can be utilized. This project also delivers a critical message that it is significant to address long-term sustainability and plan early before conditions worsen. In addition, this project offers guidance to other coastal communities with similar conditions, articulating a clear vision of alternative coastal environments.


Defend to Nature:
Vulnerable Points
Distinct Edge:
Disconnection & Devaluation
A Dilapidated Space:
Neglect of Human Scale
Build with Nature:
Sustainable Defense
Soft Gradient:
Connection & Integration
An Attractive Place:
Adding Value to Daily Life
TODAY: A STATIC STRUCTURE
TOWARDS: A DYNAMIC SYSTEM

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APPENDIX:

SAMPLE QUESTIONNAIRE

1. Where do you come from?

a. Sunset District
b. Elsewhere in San Francisco
c. Elsewhere in California
d. Elsewhere in United States
e. Outside the United States

2. How often do you visit this site?

a. Every Day
b. Several Times a Week
c. Several Times a Month
d. Less than Once a Month
e. This is My First Visit Here

2. What do you think the main attraction of this site is?

a. Recreation Spaces
b. Natural Scenery
c. Serenity & Openness
d. Vegetation & Wildlife
e. Other

3. What do you think the most disappointing feature is?

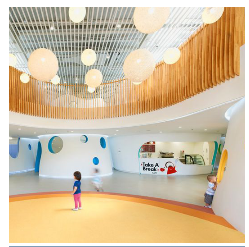
a. Lack of Amenities
b. Trash on the Ground
c. Narrowness of Beach
d. No Gathering Space
e. Other

5. What are your desired amenities for this site? (check two)


Art Installation


Beach Volleyball


Restrooms


Educational Center


Farmers Market

Retail


Gathering Space


Promenade


Seating