Designing for the Future: A Climate-responsive and Adaptive Design Framework for Habitat Restoration and Recreation in the Rumney Marsh Area of Critical Environmental Concern (ACEC), Massachusetts, USA

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ABSTRACT

According to the U.S. Fish and Wildlife Service, the Rumney Marsh Area of Critical Environmental Concern (ACEC) north of Boston, has been considered as one of the most significant estuaries of biological importance in Massachusetts. The area comprises of approximately 400 ha of saltmarsh, tidal flats, and shallow sub-tidal channels. Our goal was to develop a landscape design strategy for the marsh that integrates research and design focused on improving habitat, creating recreational opportunities, and mitigating the long-term impacts of climate change. An evaluation of existing case studies on wetland development was developed as a matrix to guide the framework needed and learn how other projects address these issues. A thorough analysis of the site's quantitative and qualitative data was done to facilitate the process through which the design strategy could take place, focusing on the marsh by extending programs from the surrounding social context, while at the same time enhancing its ecological value, and preparing for climate change. By developing such strategies that are in tune with the environment and sensitive to the natural systems, our proposal tries to establish design interventions to allow access and recreational opportunities while still enhancing the marsh landscape ecology. Through this project, a method is developed to create an open space strategy that can support the diverse social interactions and ecological demands of such a wetland system.

INTRODUCTION

According to the U.S. Fish and Wildlife Service, the Rumney Marsh Area of Critical Environmental Concern (ACEC) is considered one of the most significant estuaries of biological importance in Massachusetts (Figure 1). In 1988, most of the marsh was identified as an Area of Critical Environmental Concern (Reiner 2012). The area comprises approximately 400 ha of saltmarsh, tidal flats, and shallow sub-tidal channels. A large variety of birds utilize and inhabit the area, including at least 5 species that are state listed as endangered, threatened, or of special concern. The salt marshes are also significantly important to the surrounding human population by providing significant flood storage capacity, absorbing water, and reducing swells associated with coastal storms. Recreation opportunities at the marsh include nature walking, birdwatching, hiking, boating, and fishing. The estuary provides shelter and nurseries for fish and shellfish as well as an important habitat for resident and migratory birds and other animals. However, in recent times, many areas within the marsh have been affected and degraded by filling, poor quality drainage material, illegal and toxic dumping, and other sources of pollution.

Marsh Migration. Climate change can adversely affect salt marshes in various ways, most significantly by forcing marsh vegetation to move upward and inland (Erwin 2009). Combined with urban development too close along the edge, this process produces "coastal squeeze" where the marsh does not have enough opportunity to migrate to areas of higher elevations (Rogers and Woodroffe 2015). Urban development such as hardscape edges, walls, and structures prevent the marsh from migrating landward. Many salt marshes have been reduced or lost, losing as a result their

Figure 1. Rumney Marsh Area of Critical Concern, located north of Boston, Massachusetts, USA. (Source: Google Earth)

ecosystem functions and their ability to protect against sea level rise, due to the lack of available space (Gulf of Maine Council on the Marine Environment 2008).

Besides increasing pollution and habitat loss, urban development in the coastal zones severely impacts the ability of salt marshes to respond to any kind of environmental change (Perillo et al. 2009). In normal conditions, the salt marsh can accommodate any kind of environmental fluctuation by migration given suitable elevations on adjacent lands. About 50% of the world's population is currently living in coastal zones and is increasing gradually. The entire human infrastructure restricts the migration of coastlines and coastal wetlands with the increase in sea-level rise. Consequently, ecosystems like Rumney Marsh are unable to adapt quickly enough to more rapid sea-level rise and the increasing frequency of storm surges, due to the dense habitation and intense economic activities within these zones (The Ramsar Bureau n.d.).

Managed Retreat and Realignment. When a system converts into a new functional state, this process is known as "transformation". The transformation of upland area into a salt marsh as a result of a salt marsh migration is a classic example. Climate adaptive efforts and actions can enable and facilitate this transition and help in the survival and sustainability of the coastal marsh system. These actions increase resistance and resilience and facilitate these very transformations (Wigand et al. 2017). "Managed realignment" is a planning policy adopted to provide opportunity for inward migration of marshes for it allows tidal waters back into former salt marshes (filled lowlands and tidally restricted wetlands) which helps them revert to salt marshes. In contrast, "managed retreat" requires giving up land to the sea (Doody 2013).

Siders (2013) identifies various legal tools which already exist that assist federal, state, and local governments to implement managed retreat along vulnerable coasts. These have been used by coastal communities in the United States and include publications, toolkits and websites describing legal, policy and regulatory tools.

Proper relocation plays an important role in managed retreat in a way that is beneficial to those who would be affected. Rather than waiting for a disaster to act, target development areas and areas of safe growth can be identified and elements of buyout programs to relocate affected people can be established by municipalities and states much in advance. Provision of incentives for relocating, assistance with down-payments for low- and middle-income groups and keeping the prices equal or less expensive than the acquired housing is an effective way to stay fair and just in the entire process. Incentivizing helps in creating and retaining a sense of community and this can be done by offering bonuses to owners to relocate to newly developed housing.

Effective measures include identifying and prioritizing areas that are most vulnerable and prone to repetitive loss, establishing deadlines for applications, and providing dedicated staff to help with processing applications. Moreover, educating homeowners on the danger and costs of living in a vulnerable area is vital and can be done by conducting an information campaign targeted in affected areas (Siders 2013).

OBJECTIVES

Our aim was to develop a landscape design strategy for Rumney Marsh that integrated research and design in harmony with the environment. We desired design interventions that would allow public access and recreational opportunities while enhancing long-term marsh ecology. This flexible design approach thus helps the marsh migrate while maintaining habitat and providing outdoor recreation in the era of climate change.

The goals of the project were to:

- predict change in the ecosystem due to sea level rise over the next 50 years;
- design holistic resiliency strategies to protect the functional qualities of the marsh;
- establish design interventions to allow access and educational opportunities while enhancing the marsh landscape community and ecology.

BUILDING A FOUNDATION FOR THE PLAN

Documenting Site History. Examining historical data can help us understand how tides influenced the area and where former wetlands were located and how they functioned during certain periods of time in the past. Examination of historical maps (Figure 2) and aerial imagery can describe

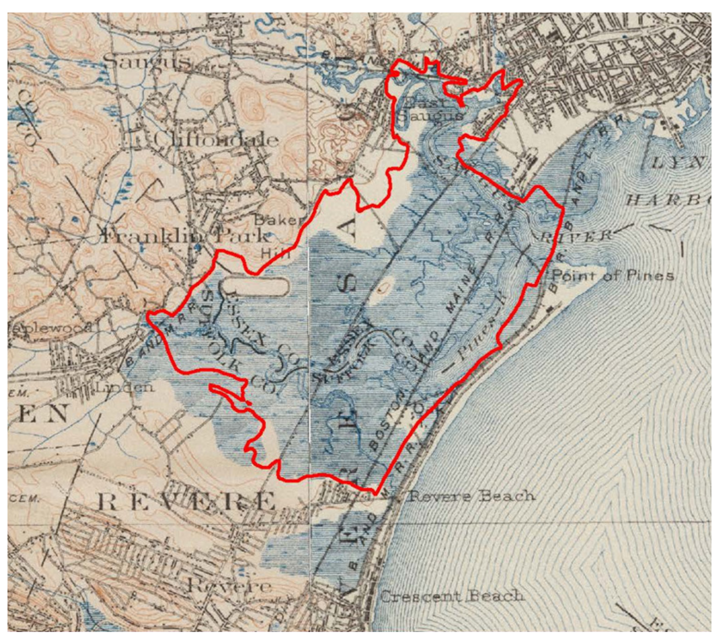

Figure 2. Rumney Marsh circa 1890–1900. The red boundary represents the current ACEC extent. (Source: MassGIS)

how land use patterns evolved and describe any disasters or events that led to a major change (Zedler 2001). Upon such observation, Rumney Marsh lost approximately half of its original area. Railroad and road construction in the 19th Century coupled with recent roadways, split the marsh into parts and altering its tidal hydrology. The construction of the Salem Turnpike in 1803 segmented the marsh into two parts. For an Interstate-95 (I-95) project, an embankment of about 4 km in length was created between 1967-1969. To make matters more exasperating, the project was not completed for which roughly about 50 hectares of marsh was filled. This embankment created a long continuous barrier across the Rumney Marsh, affecting drainage patterns and restricting tidal flow to about 180 hectares of wetlands (Reiner 2012).

Documenting and Predicting Sea Level Rise. Excessive erosion and increased flooding of vegetation inside and along the marsh are primary impacts of rising sea-levels. Under specific water depth ranges and salinity levels, emergent plants reproduce and grow and are adapted to those conditions. If water depths are more than the flood tolerance limits of such plants, these plants are prone to dying from excessive water. Increase in water depths also results in larger waves and erosion along the shore magnifies (Chabreck 1988). Before restoration, a detailed study of predicted changes in sea levels under various circumstances should be considered and evaluated before any restoration efforts need to begin. Consideration of all opportunities and constraints is imperative if the area is likely to change substantially within decades itself (Perillo et al. 2009).

Impacts of sea level rise on the land adjacent to the marsh are shown in Figure 3. Note the areas in darker blues are impacted the earliest. This approach helped identify priority areas and the order in which interventions needed to be made.

Storm Surge. Increase in storm surges has ecological consequences which are beyond linear and averaged projections (Perillo et al. 2009). Figure 4 illustrates the vulnerability of the marsh and adjacent areas to storm surges. Note that even a Category 1 hurricane can cause serious damage to the nearby areas, making them the most vulnerable and the earliest to be impacted.

Vulnerability. Clearly vulnerability increases with rising sea level. Residential development along Eastern Avenue, Revere Beach, those next to the Pines River and commercial areas including GE Aviation are the most vulnerable sites (Figure 5).

Wildlife and Recreation. Urban wetlands have an important advantage over other wetlands, primarily due to their location within the context of larger populated areas. Consequently, they are likely to have more visitors, and offer a great opportunity to provide education and increase the public's understanding of how these systems behave and concern for natural resource conservation (Callaway and Zedler 2004). As a result, salt marsh restoration projects can benefit through focused events, increased public participation within or along the marsh (Perillo et al. 2009). Wildlife populations that are supported by salt marshes offer benefits to the community through consumptive or non-consumptive uses such as birdwatching. See Table 1 for a list of characteristic plants and animals of Rumney Marsh.

The marsh is currently used actively by the community for recreation; thus, it is imperative to keep that crucial relation of the community with the marsh intact in the future. Residents and tourists will continue to enjoy visits to these marshes through trails and boardwalks, and activities like jogging, walking, birdwatching, or picnicking. Restored marshes can provide more recreational and educational value in this regard, as the cultural history and the restoration process has made them more interesting. Enhancing

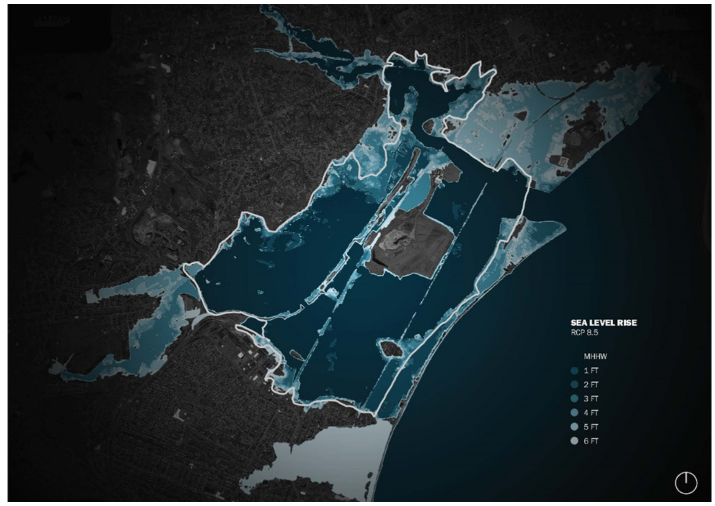

Figure 3. Predicted sea-level rise by 2090. Land becomes subject to inundation beginning at a 2-foot rise. Mean Higher High Water (MHHW) is obtained by averaging the highest of the two high tides per day (or the one high tide) over the same 19-year period. The Representative Concentration Pathways (RCPs) are a set of greenhouse gas emissions and concentration pathways. RCP 8.5 is a scenario in which the greenhouse gas emissions and concentrations increase considerably over time. (Source: NOAA). Land is shown as brown and the various shades of blue as sea levels rise (dark blue is the ocean).

Figure 4. Vulnerability to storm surge. Increasingly lighter colors reflect increasingly stronger storm effects. Land is shown as brown, and the various shades of gray reflect increasing impacts as sea levels rise. (Source: NOAA)

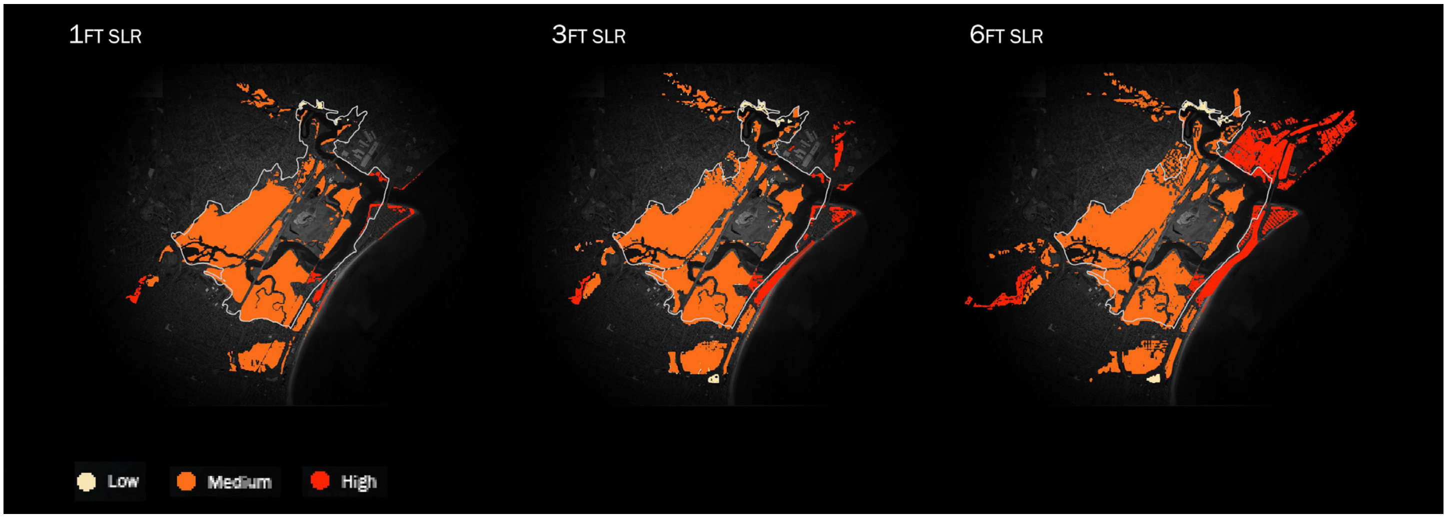

Figure 5. Social vulnerability; darker colors reflect increasing vulnerability. (Source: Surging Seas Risk Zone Map, Climate Central)

nature tourism activities, collaborating with educational institutions such as schools and colleges can become an important component of local economy (Chmura et al. 2012). Rumney Marsh and its unique past provide many similar challenges and opportunities.

THE DESIGN

Based on the sea level scenarios and project goals, a 100-year framework was devised for the marsh and the adjacent areas, recognizing that new opportunities or constraints may arise during the life of the marsh restoration project (Zedler 2001). In this case, an ash-landfill sits in the middle of Rumney Marsh (Figure 6), making that location ideal for a visitor center, as it remains above sea level throughout the period assessed for this project. This educational and research zone will eventually also hold a center for research and access to kayak, bike, and pedestrian trails.

Marsh Migration with Retreat. Four phases of retreat are suggested for the present and the years 2030, 2065, and 2090. As the years progress, the marsh gets converted into unconsolidated shore (less than 30% vegetation, e.g., tidal flat), and the retreated areas provide the opportunity for the marsh to migrate. Infrastructure removal and relocation is done in phases and the cleared areas allowed for natural vegetation to follow, coupled with manual planting of species to facilitate faster migration and desirable species and hopefully minimize colonization by common reed (*Phragmites australis*).

Planning Public Access for Rising Sea Levels. To provide continual public access to the marsh, four recreation plans were developed, each illustrating the present, 2030, 2065, and 2090 time periods. Land use activities adjacent to the marsh or near it may impede some restoration strategies. The fills and roadways that are present in and along a marsh restrict tidal flow and the movement of native vegetation and animal life (Zedler 2001). The 3.7-km

Table 1. Characteristic plants and animals of Rumney Marsh. (Sources: Walsh and Servison 2017; Saugus River Watershed Council n.d.).

Vulnerable birds	**Scientific Name**
American Black Duck	*Andropogon gerardii*
Willet	*Elymus virginicus*
Common Tern	*Panicum virgatum*
Marsh Wren	*Chamaecrista fasciculata*
Saltmarsh Sparrow	*Sorghastrum nutans*
Seaside Sparrow	*Echinacea purpurea*
Least Vulnerable birds	*Rudbeckia hirta*
Canada Goose	*Heliopsis helianthoides*
Red-winged Blackbird	*Asclepias syriaca*
Tree Swallow	*Monarda fistulosa*
Fish & Shellfish	
Winter founder	*Pseudopleuronectes americanus*
Alewife	*Alosa pseudoharengus*
American eel	*Anguilla rostrata*
Blueback herring	*Alosa aestivalis*
Ribbed mussel	*Geukensia demissa*
Soft-shelled clam	*Mya arenaria*
Razor clam	*Ensis leei*
Mammals	
Raccoon	*Procuon lotor*
Red fox	*Vulpes vulpes*
Muskrat	*Ondatra zibethica*
Meadow vole	*Microtus pensylvanicus*
Plants	
Spike grass	*Distichlis spicata*
Salt meadow hay	*Spartina patens*
Black grass	*Juncus gerardii*
Cordgrass	*Spartina alterniflora*

embankment restricts tidal flows across the marsh to three relatively small bridges at the major waterways and creeks of the Pines River. The MBTA North Shore Commuter line and Route 1A form a barrier isolating the Oak Island salt marsh from the main marsh system and significantly limiting the volume of tidal waters entering the marsh. The first step addresses the partial removal of a portion of the I-95 fill to restore tidal flow. However, some fill areas are retained for future marsh migration and in the meantime serve as upland habitat for wildlife.

To promote and facilitate pedestrian and bike access to Rumney Marsh, we suggest that a pedestrian and bike lane be created along the existing Salem Turnpike, connecting the existing Sea Plane Basin Trail to the visitor center. A proposed bike and pedestrian trail network would connect existing trails to the marsh and within the site. A kayak launch would be extended to the ash-landfill mound, where the visitor center is proposed.

By 2030, our model shows that there is a loss of trail networks at Revere Beach and Point of Pines, and by 2060, the Salem Turnpike becomes inaccessible to motor vehicles (assuming its surface is not raised). Access will then to be converted to a boardwalk, to maintain the connectivity and access to the marsh and the visitor center. By 2090, all vehicular access to the visitor center is lost (including bicycles) (please refer to the phases presented visually in the figures referenced below).

Design Focus Areas –We have identified four areas for design intervention.

Eastern Avenue. This edge of the marsh consists of residential development. For immediate interventions, creation of a vegetated berm is proposed. As the sea level begins to rise, and water levels begin to impinge on human structures and activities, areas must be prepared for retreat in phases. Conditions forcing this will include both surface water flooding sites as well as saltwater intrusion to groundwater. When the first phase has been relocated (see Figure 7), the berm is opened at regular intervals for sufficient tidal flow. Upon the retreat of the final phase, all existing infrastructure is removed to make way for the marsh (Figure 7).

Point of Pines. This is the beach with the sea on one side and the marsh on the other. As a result of sea level rise, it is impacted on both sides. For immediate interventions, the existing sea wall is realigned and moved back, and a buffer is created between the sea wall and the beach to mitigate the impacts of storms. The areas are prepared for retreat in phases and all seawalls are removed. Upon relocation, the marsh is allowed to migrate to the retreated areas (Figure 8).

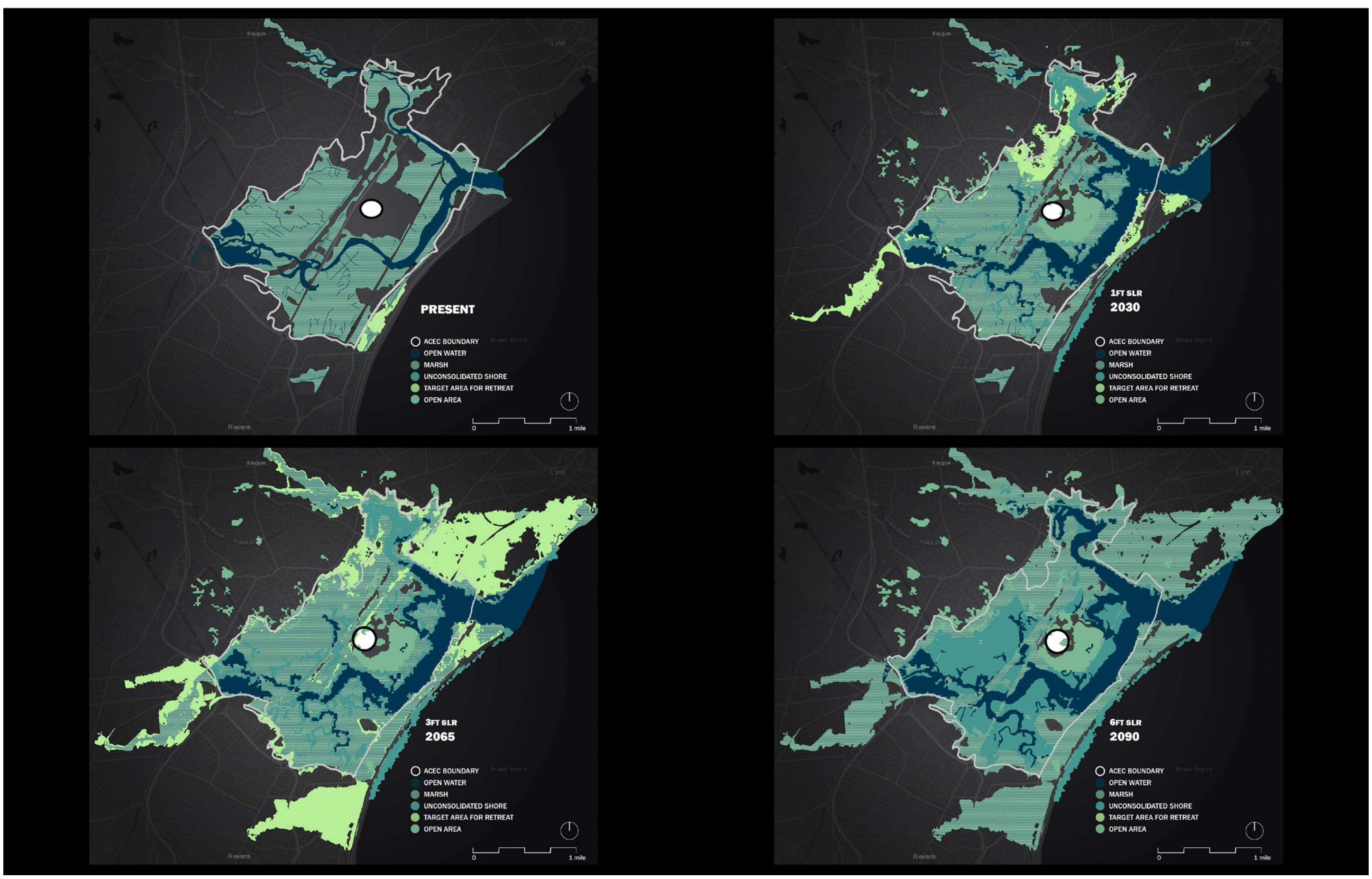

Figure 6. Location of the ash pile within Rumney Marsh (white circle). The area remains above sea level throughout the time frame of this project.

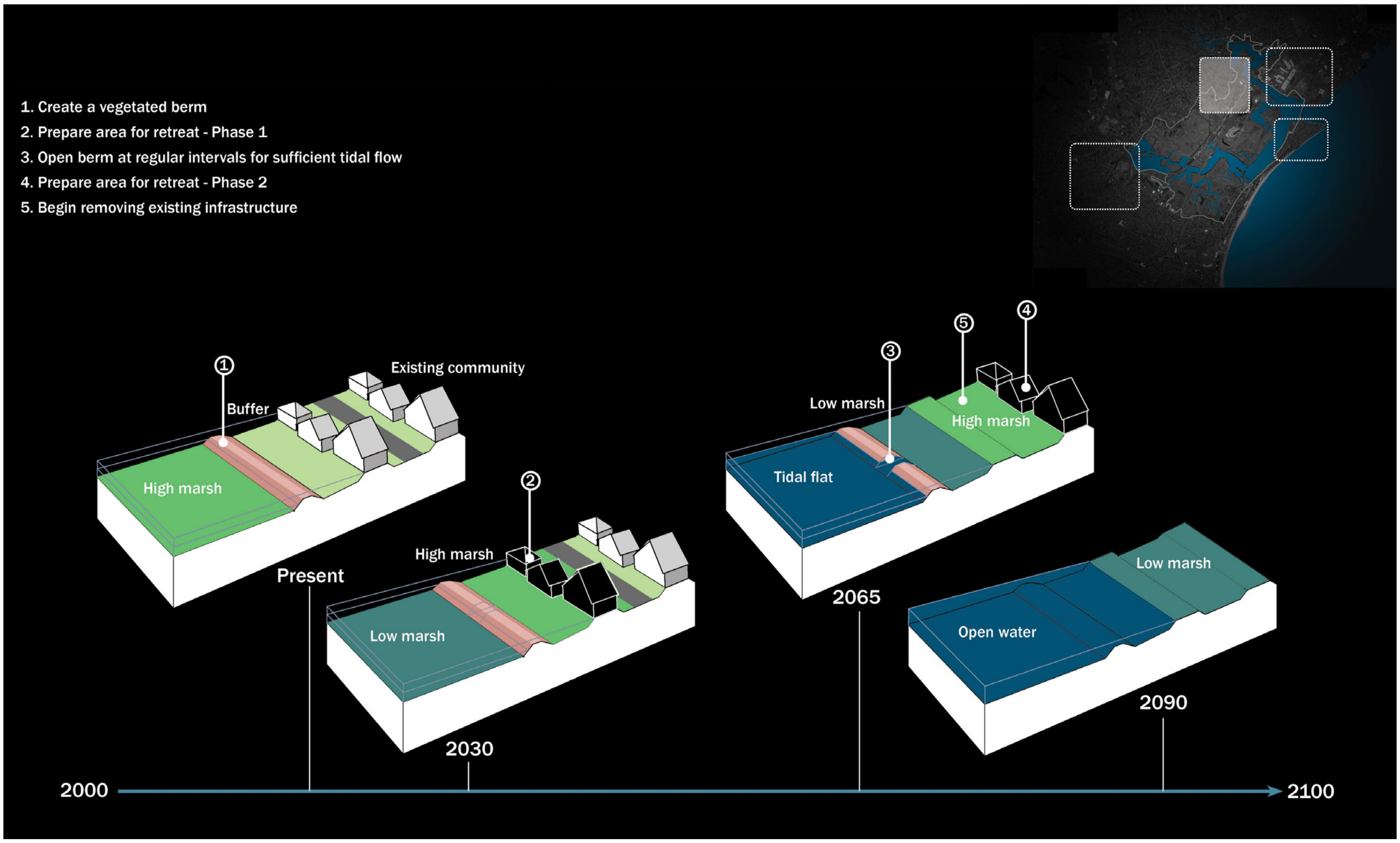

Figure 7. Strategy for retreat, in phases, for the Eastern Avenue section adjacent to Rumney Marsh. The highlighted box in the upper right corner indicates the location of the site.

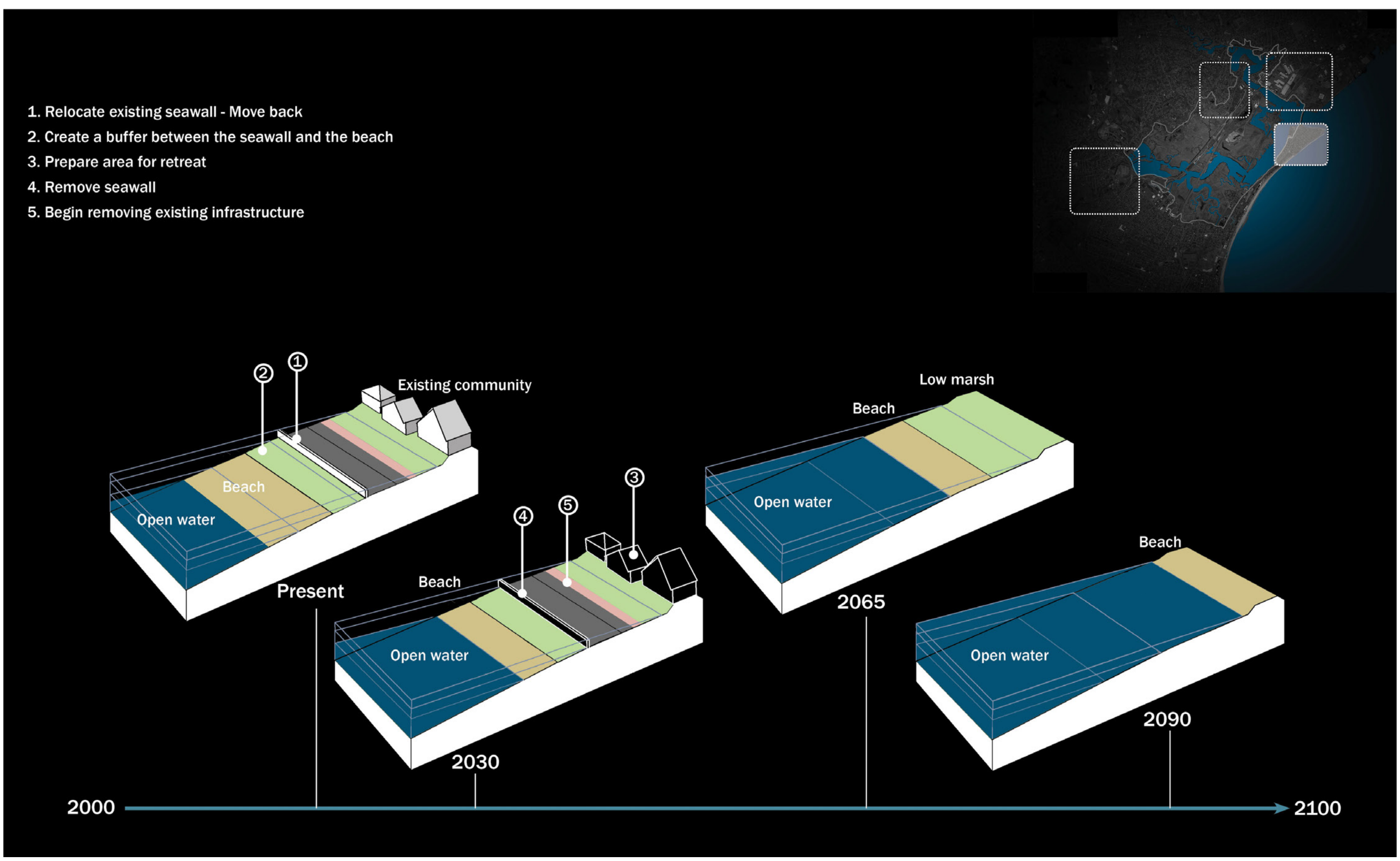

Figure 8. Strategy for retreat for the Point of Pines section adjacent to Rumney Marsh. The highlighted box in the upper right corner indicates the location of the site.

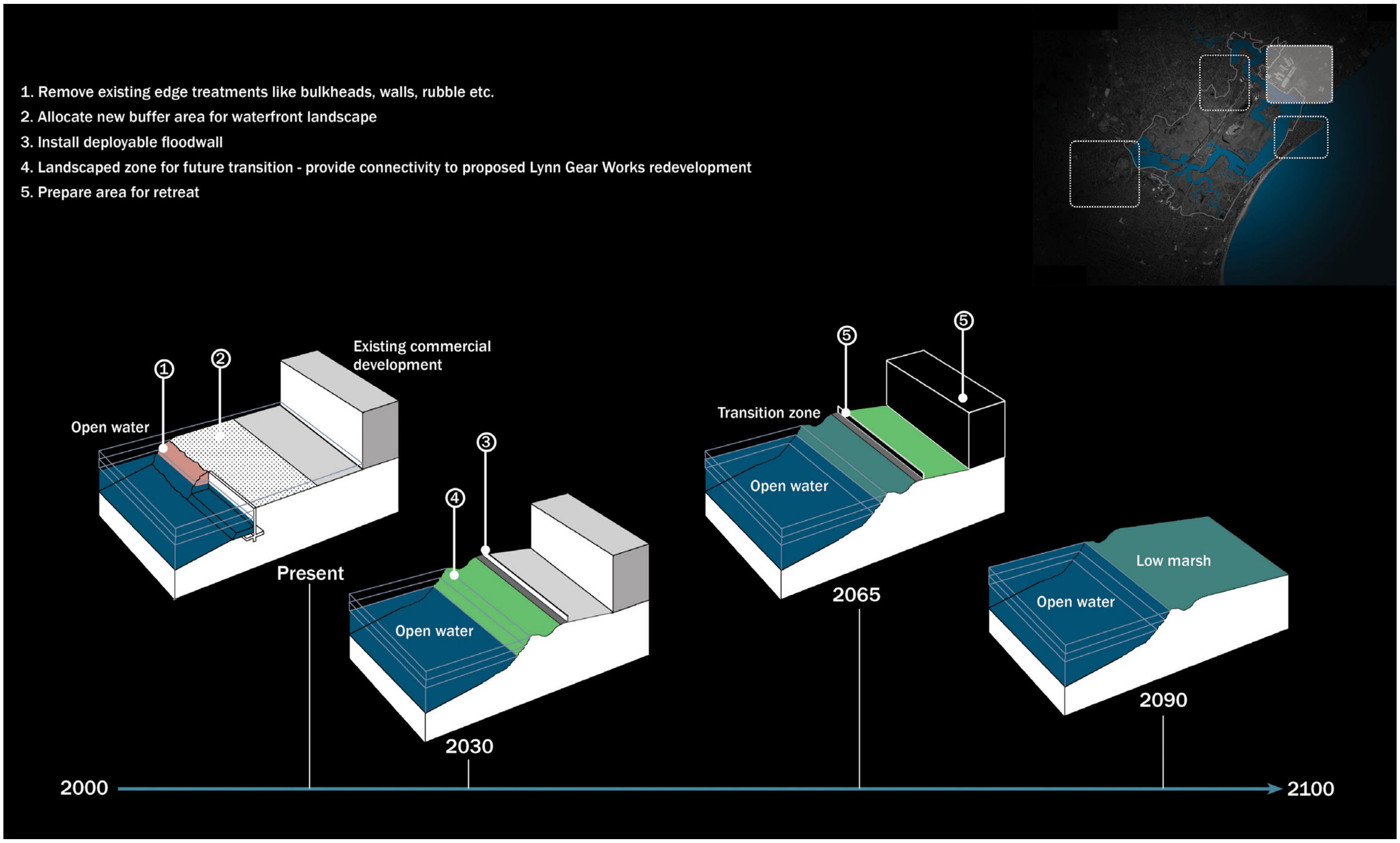

Figure 9. Strategy for retreat for the Riverworks section adjacent to Rumney Marsh. The highlighted box in the upper right corner indicates the location of the site.

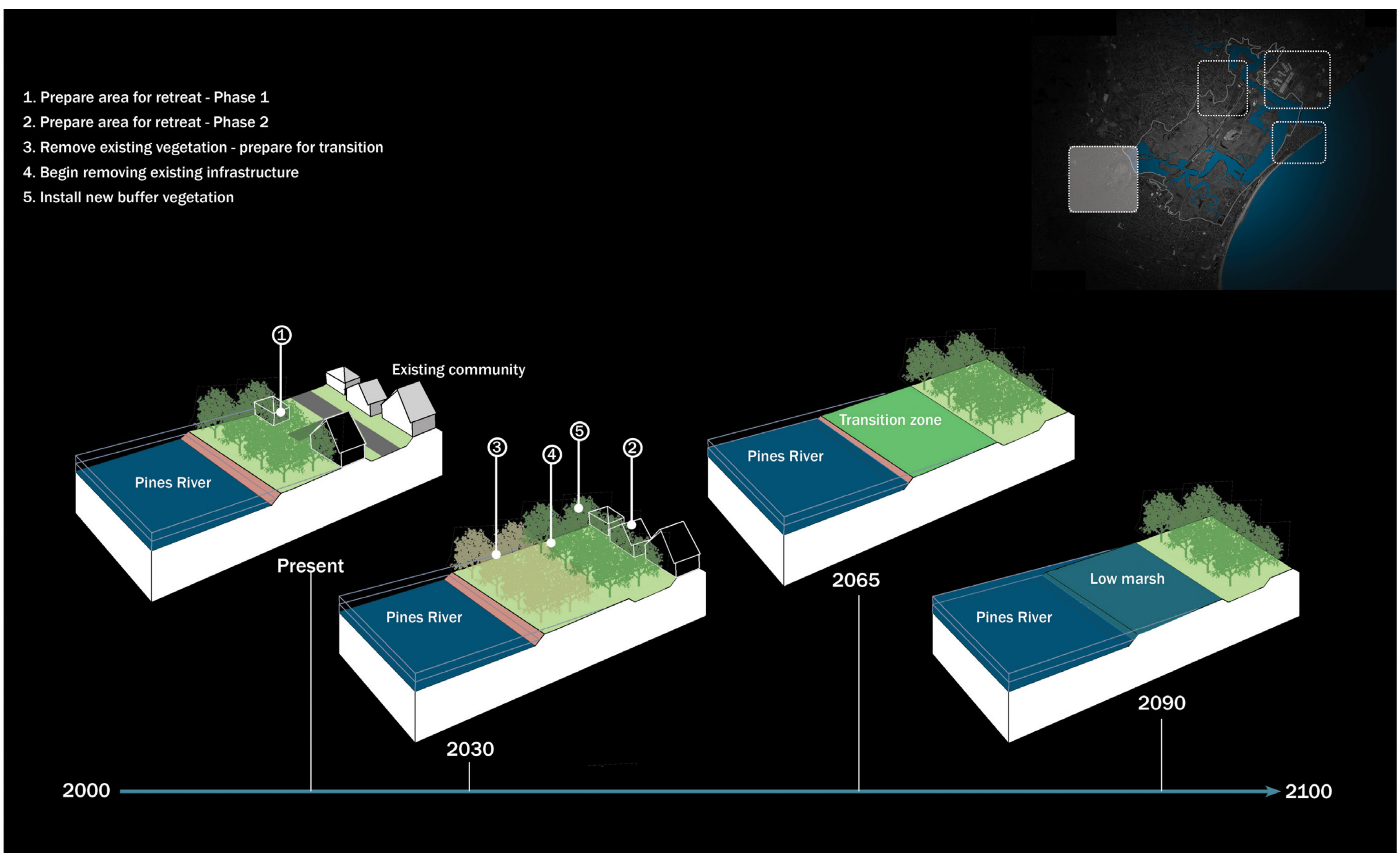

Figure 10. Strategy for retreat for the Pines River section adjacent to Rumney Marsh. The highlighted box in the upper right corner indicates the location of the site.

Riverworks. This edge of the marsh is aligned with commercial development as well as the GE Aviation plant. For immediate interventions, we suggest that all existing edge treatments like bulkheads, walls and rubble be removed and the edge softened through the creation of a buffer area for waterfront landscape. A deployable floodwall is installed to combat floods and storm surges. This buffer zone helps in future transition, with the proposed Lynn Gear Works redevelopment, which retains the marsh edge. By 2065, the area becomes prone to sea level rise and is marked for retreat (Figure 9).

Pines River. This side of the marsh is low-lying and hence retreat measures are immediate. Retreat follows in multiple phases, and any non-wetland is removed, since it is not suitable for saturated soils. Upon complete relocation, all existing infrastructure will be removed. New planting is installed further inland, and a transition zone is created for the marsh to follow, with buffer (Figure 10).

Focus Areas – Recreation. For recreation, two areas are identified for action.

Visitor Center. The landfill mound will house the visitor center and a center for research with parking, vehicular, pedestrian, bike, and kayak access. Observation towers and pedestrian trails and loops are added along the edge of the mound for enhanced visitor experience and recreational opportunities including sightseeing and birdwatching. A fishing deck, an event area and a nature play area are also proposed in this zone. An upland area is also planted to create habitat. To ensure services are functional in the future as well, we suggest that the visitor center use solar energy, and the channel with the kayak launch be dredged to facilitate water transport. By 2090, the turnpike is underwater, and a boardwalk is constructed for pedestrian and bike access, while vehicular access is lost (Figure 11).

Sea Plane Basin Trail. This is an existing trail that abruptly ends before entering the marsh. It is proposed that the trail is continued through existing uplands and a pedestrian bridge and further connected to the turnpike, which in turn supports pedestrian and bike movement. In 2090, the turnpike and the trails convert to a floating boardwalk (Figure 11).

CONCLUSION

The way we live in the future is going to be hugely impacted by climate change. The effects of sea-level rise and climate change are already showing around the world in various ways (e.g., Sintayehu 2018, Khatib 2023). The infrastructure originally designed to operate indefinitely is gradually proving otherwise. The cities we live in are not prepared for the upcoming changes and accompanying problems. Rather than preparing for the future, we spend more on repairing damage caused by disasters. The time has come for our leaders to reallocate finances to reduce the risks arising from future climate change (Table 2).

By developing strategies that are sensitive to the behavior of natural systems, our proposal tries to establish design interventions to allow access and recreational opportunities while enhancing the marsh landscape and ecology. This project creates an open space strategy that can support the diverse social interactions and ecological demands of the marsh. We suggest, in coastal regions, that we need to allow for the inevitable transition of the land, retaining its place in the ecology of a dynamic coastline, while keeping the connection to the community intact.

In the era of climate change, we are left with two choices – we can either fortify, with expensive but temporary solutions and its associated consequences, or we can choose to adapt and retreat, thereby maintaining the ecological health of the marsh and its access to the community. Marsh behavior is a complex process. Various factors influence the functioning and future migration of these areas. Further research can be done to examine multiple factors such as the effects of increased CO_2 levels or altered sediment accretion rate on the marsh ecosystem and biological communities.

It is abundantly clear that we need infrastructure that is not only resilient but also provides economic sustainability, safety, and assurance that the money is spent in the right direction. Innovation and new technology are of utmost importance in this regard. Tough decisions will need to be made for the benefit of the people and communities of the future. Some areas near the marsh are too vulnerable to future disasters and changes despite our best efforts to protect the status quo. Such infrastructure and housing need to move away from the approaching dangers, yet the shore can be opened to the public. As discussed in this paper initially, authorities and governments may encounter many obstacles in implementing strategies (e.g., laws, policies, zoning) and the challenges of working with existing landowners but work along those lines must start now.

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Table 2. Costs and lifespans of stabilization from Koch (2010).

Type	Cost Per Linear Foot	Projected Lifespan
New Seawa	$6789	30+
Concrete Bulkhead	$1,022	30+
Living Shoreline	$361	Indefinite

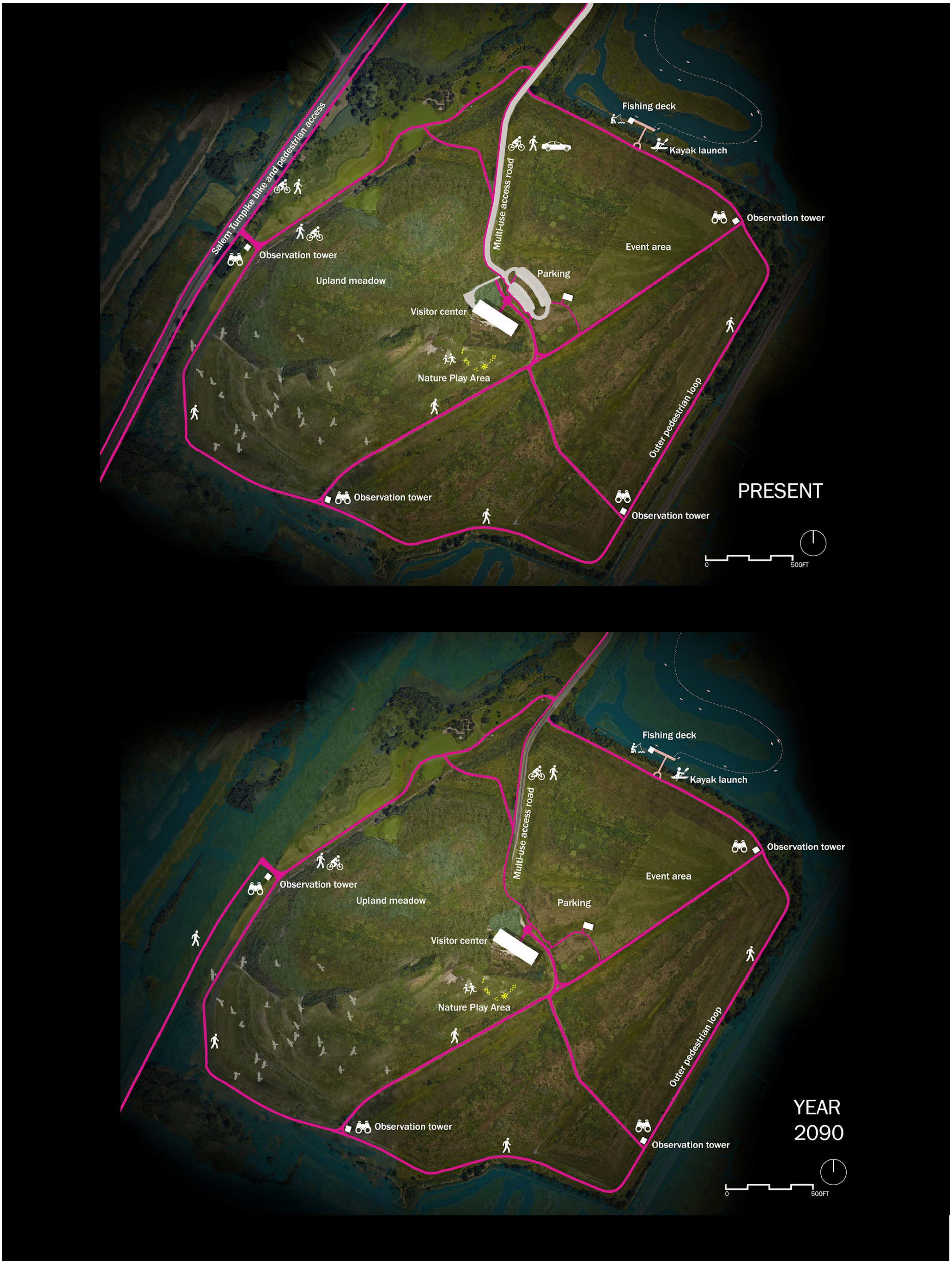

Figure 11. Recreation designs for present conditions and 2090.

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