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SHRINKING WETLANDS, SINKING CITIES
Why Preserving and Restoring Wetlands Can Help Save Our Coastal Cities

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ABSTRACT
As the Earth's climate changes and sea waters rise, the world's many coastal cities must get creative to stay afloat. Levees, floodwalls, and other man-made infrastructure are enormous cost burdens that continue to be overpowered by super storms and severe flooding. Planners and designers around the country are exploring methods to make coastal cities more resilient to these impending changes. One method for urban resilience that deserves more attention is the preservation and restoration of wetlands as a means to mitigate the effects of climate change. This paper aims to create an informative and comprehensive guide, and also to define the next steps and necessary research for wider adoption. Research methods that were used include literature review, in-depth review of two case studies, and interviews.

KEYWORDS: coastal resilience, landscape urbanism, climate change, soft infrastructure, urban resilience

1.0 INTRODUCTION
Wetlands are a powerful natural resource that should not only be protected, but also used as a viable method to mitigate the effects of climate change in coastal urban areas. The intent of this study is to create an informative and comprehensive guide to the current situation surrounding wetlands and climate change in coastal urban areas. The hope is that this research will serve as a platform for raising public awareness and encourage further research into these topics.

The methodology for this research begins with a brief introduction to wetlands and their significance, coastal climate change issues, and the role that wetlands can play in urban resilience. Next, a literature review of the current situation for coastal wetlands in the United States is explored: the threats they face, the laws in place to protect them, and the current research surrounding these issues. Two case studies provide a brief overview of how two very different coastal environments are dealing with wetlands and climate change. The well preserved and sparsely developed Georgia coast stands in sharp contrast to the densely developed coastline of New York City, but there are valuable lessons to be learned from the past, present, and future of both. The paper ends with a review of overall lessons learned and next steps to carry this research forward. Research methods for this paper included interviews with a diverse array of professionals and in-depth literature reviews of published sources.

2.0 SHRINKING WETLANDS, SINKING CITIES

2.1 Why Wetlands Matter
Wetlands matter a great deal to the human race, though we often fail to recognize it. The many functions of wetlands not only translate into direct economic and environmental benefits to coastal cities, but they can help offset some of the oncoming impacts of climate change.

Wetlands are the transitional zones between land and water. They are frequently inundated by surface and groundwater and support an abundance of vegetation adapted for life in saturated soil conditions. Wetlands are unique, highly productive ecosystems that are found at riparian margins all over the globe. There are many different types of wetlands, each with its own special ecology. For the purposes of this study, the focus will be on coastal wetlands, which may also be referred to as tidal marshes.

"Tidal (coastal) marshes occur along coastlines and are influenced by tides and often by freshwater from runoff, rivers, and ground water. Salt marshes are the most prevalent types of tidal marshes and are characterized by salt tolerant plants such as smooth cordgrass, saltgrass, and glasswort. Salt marshes have one of the highest rates of primary productivity associated with wetland ecosystems because of the inflow of nutrients and organics from surface and/or tidal water. Tidal freshwater marshes are located upstream of estuaries; tides influence water levels, but the water is fresh. The lack of salt stress allows a greater diversity of plants to thrive. Cattail, wild rice, pickerelweed, and arrowhead are common and help support a large and diverse range of bird and fish species, among other wildlife[1]." Forty percent of the wetlands in the continental U.S. are coastal wetlands, and 81 percent of those coastal wetlands are located in the southeast[2].

Wetlands provide many functions, all of which are extremely beneficial to urban environments. Wetlands functions can be placed into three primary categories: hydrologic, water quality, and habitat. Wetlands are complex systems that respond to a variety of processes; the functions within each category are heavily intertwined, creating a delicate balance within the ecosystem. If one function is compromised, wetlands are not able to maintain many of the other functions they provide. In other words, damage to any part of the ecosystem affects the overall performance of the entire system.

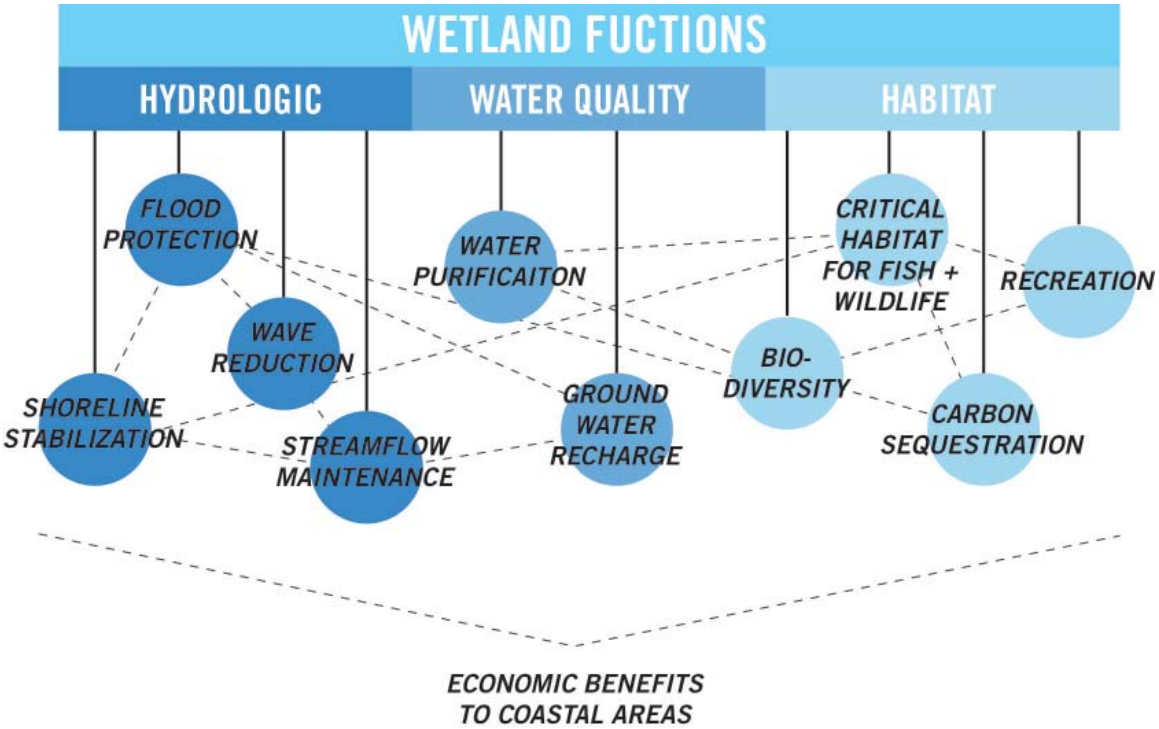

Figure 1: Diagram of wetland functions.

Climate change is affecting coastal cities on a global level through sea level rise and frequent storm events. The future of sea level rise and consequentially the fate of coastal cities is in our ability to lower global emissions. Despite the improved ability of models to reproduce historical rates of sea-level rise, some respected scientists maintain that even the new numbers are too low and the latest Intergovernmental Panel on Climate Change (IPCC) model does not account for permafrost thaw[3].

The IPCC projects three feet of sea level rise by 2100, the sea having already risen four to ten inches this past century. For every foot of sea level rise, 100 feet of flooding can be expected[4]. One third of coastal land and wetland habitats are likely to be lost in the next 100 years if the level of the ocean continues to rise at its present rate[5]. This is of primary concern because two thirds of the world's largest cities (cities with more than five million people) are less than ten meters above sea level, which equates to more than one billion people across the globe and more than half of the U.S. population[6, 7].

Due to some of this data, coastal cities are beginning to develop strategies for urban resilience. Resiliency is the capability to withstand or recover quickly from difficult conditions. Urban resilience is the ability for cities to anticipate and respond to extreme weather events. Though many of the world's major cities are at risk of sea level rise, very few are aware of, or prepared, for the potential damage that rising seas and increased flooding may bring. Many of the functions of wetlands have the unique ability to offset many of the oncoming risks climate change brings to coastal cities. However, unless wetlands are properly preserved and restored, they are also at risk of destruction.

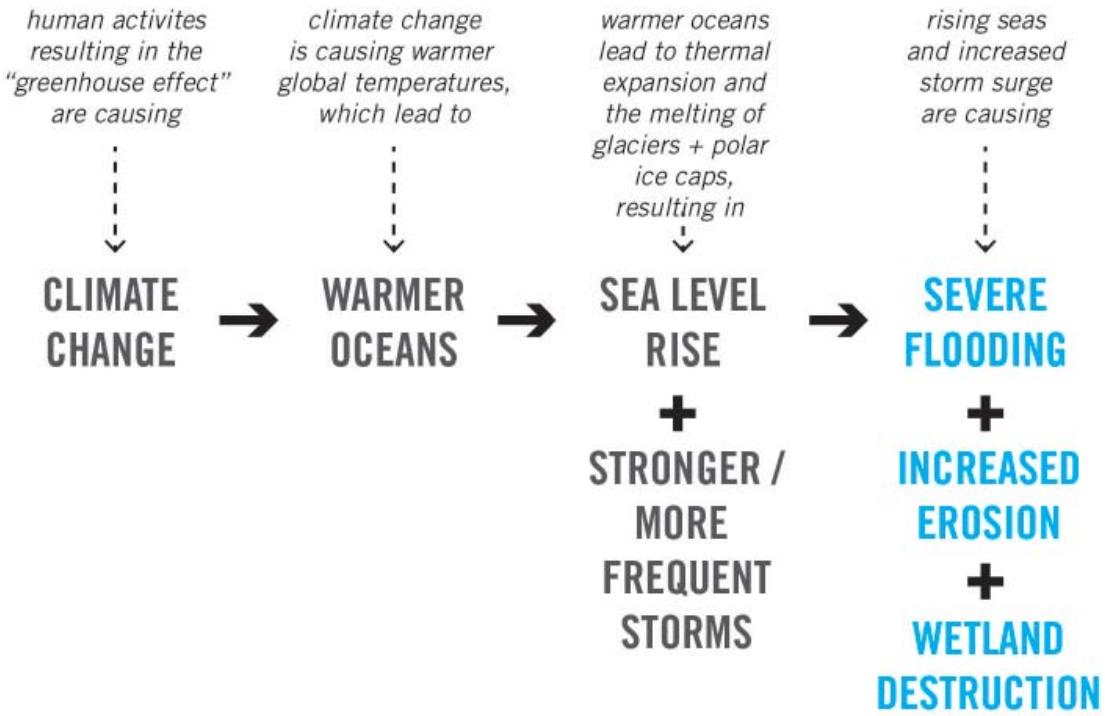

Figure 2: Impacts of climate change on wetlands[8].

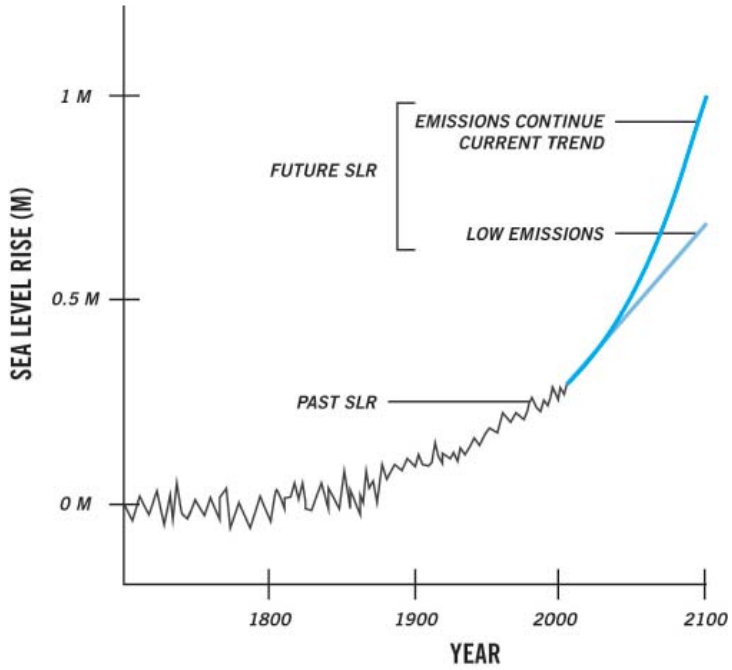

Figure 3: Projected sea level rise[4].

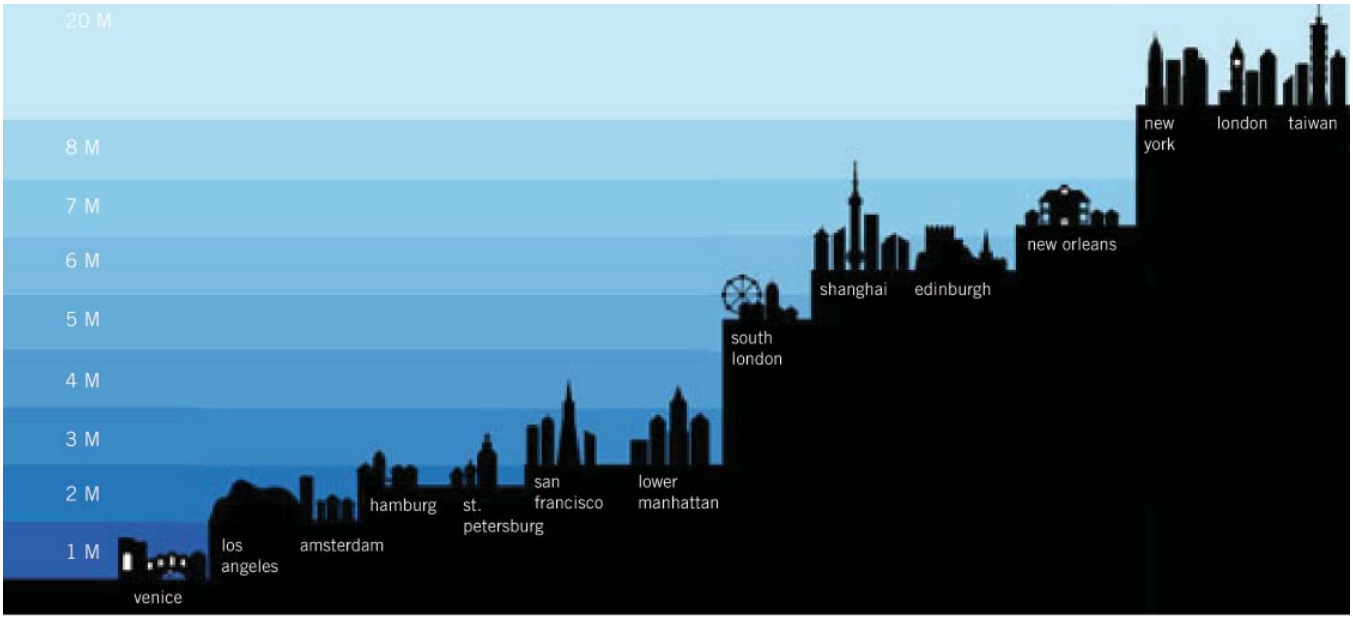

Figure 4: Sea level rise infographic[9].

2.2 Wetlands Significance

Wetlands are a complex, highly productive, and diverse ecosystem. They offer numerous ecological and economic values and benefit humans and wildlife alike. Until recently, wetlands were considered invaluable wastelands. Though our respect for wetlands has grown in the past few decades, our understanding of the complexities of wetlands is still developing. The more we discover, the more valuable wetlands become.

Wetlands provide extraordinary habitat and are some of the most biologically productive natural ecosystems in the world[10]. Often referred to as nature's kidneys, wetlands filter out toxins and pollutants and retain vital nutrients. Wetlands provide flood protection by functioning as natural sponges, absorbing and storing water and slowly releasing it. These natural functions create and save billions of dollars annually in the U.S.[11]

Though wetlands account for only five percent of the land area in the lower 48 states, they provide critical habitat for the following: 31 percent of plant species,[12] 95 percent of commercially harvested seafood (fish and shellfish),[13] 85 percent of waterfowl and other migratory birds, and 45 percent of threatened and endangered species[11]. $79 billion in annual revenue is generated from wetland-dependent species, accounting for 71 percent of the nation's commercial and recreational fishing industry. An estimated $59 billion in annual revenue is generated from wetland-related ecotourism such as hunting, fishing, bird-watching, and photography in 1991[13]. It is important to note that these economic facts are grossly outdated. Since this is the most current data found, it can be inferred that the economic importance of wetlands is highly undervalued. Wetlands purification properties can remove up to 60 percent of metals, 90 percent of sediment from runoff and 90 percent of nitrogen[14].

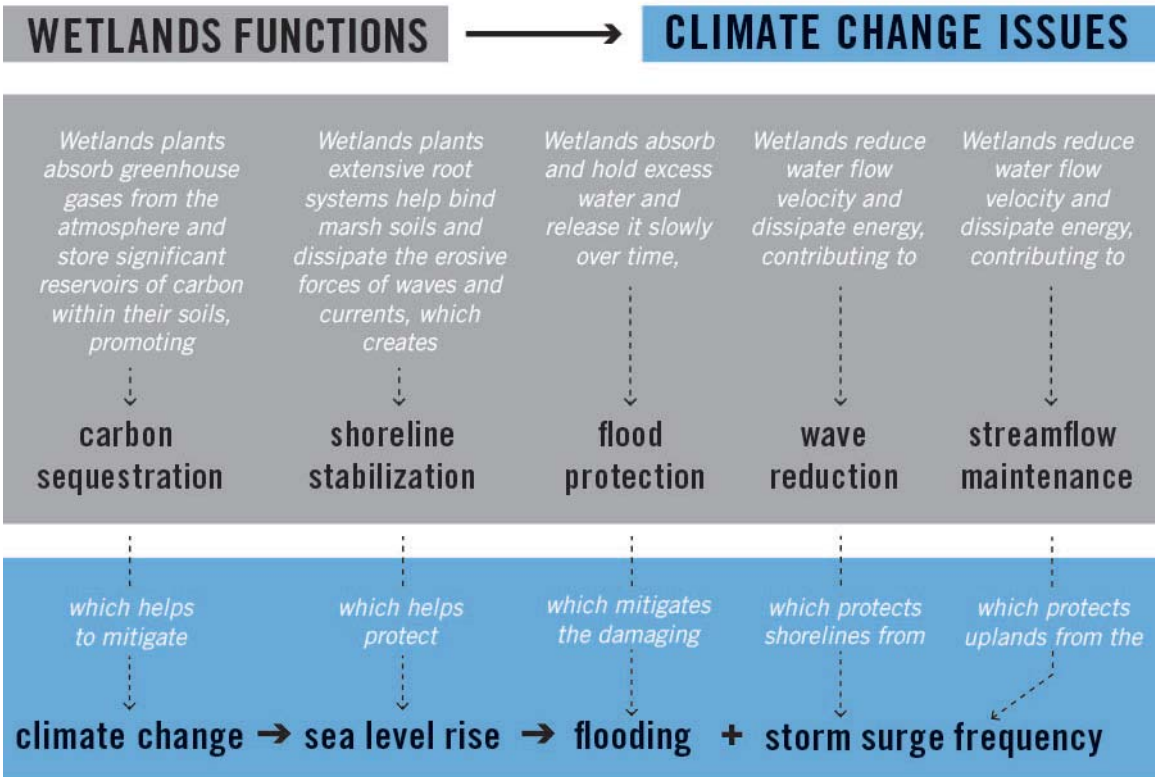

Figure 5: Wetlands and climate change.

The state of Georgia alone attributes $1 million in annual water pollution abatement costs for each 2,500 acres of wetlands[15]. One acre of wetlands can store 1-1.5 million gallons of floodwaters and maintain just 15 percent of watershed land area as wetlands decreases flood peaks by 60 percent[11]. The U.S. estimates $23.2 billion in annual savings in storm protection services due to wetlands reducing the severity of impacts from hurricanes,[16] and $5.7 million average annual increase in property damage for every loss of one-mile strip of coastal wetlands[17].

Though arguably all of wetlands functions are valuable to urban areas, the most compelling and potentially beneficial functions for coastal cities are hydrologic. Flooding in coastal areas already costs millions of dollars of damage each year (global flood damage in coastal cities is expected to reach U.S. $1 trillion per year as sea levels rise),[18] and the amount of physical and fiscal damage will only continue to increase due to climate change. Not only do wetlands help mitigate the effects of flooding, they provide a low cost alternative to other hard engineering strategies such as sea walls and flood gates while providing other environmental and economic benefits.

The most important hydrologic value wetlands provide is flood protection. "Almost any wetland can provide some measure of flood protection by holding the excess runoff after a storm and then releasing it slowly. The size, shape, location, and soil type of a wetland determine its capacity to reduce local and downstream flooding. While wetlands cannot prevent flooding, they do lower flood peaks by temporarily holding water and

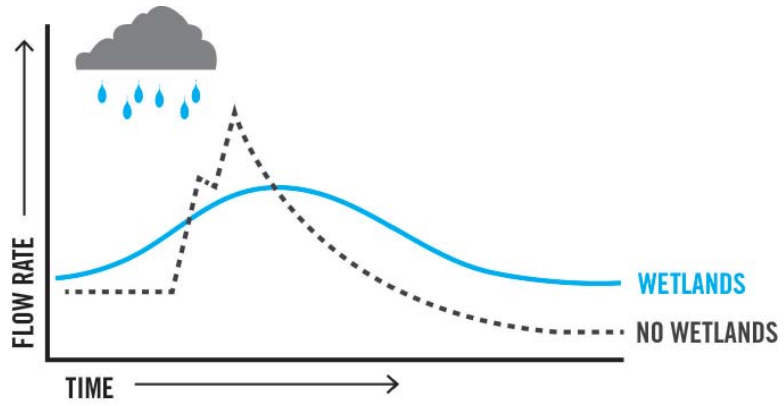

Figure 6a: Wetlands role in flood reduction[19].

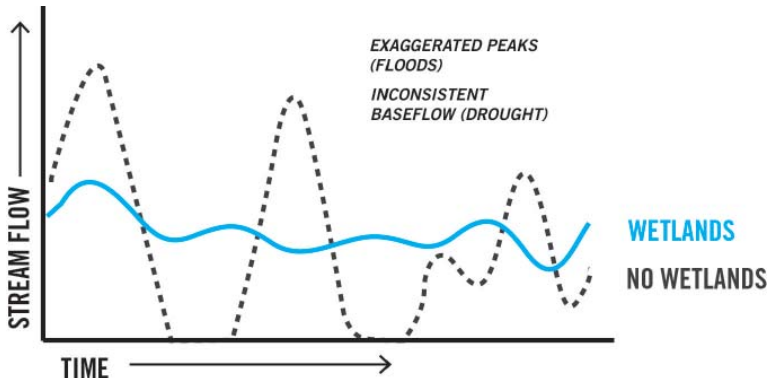

Figure 6b: Wetlands role in flood reduction[20].

by slowing the water's velocity. Wetland soil acts as a sponge, holding much more water than other soil types. Even isolated wetlands can reduce local flooding[21]." Wetlands also provide wave attenuation. Wetland vegetation decreases water velocities through friction and causes sedimentation in shallow water areas and floodplain wetlands, thus decreasing the erosive power of the water and building up natural levees. Finally, wetlands provide shoreline stabilization. Wetlands reduce shoreline erosion by stabilizing sediments and absorbing and dissipating wave energy. Wetland plants hold the soil in place with their roots, absorb the energy of waves, and break up the flow of stream or river currents. When vegetation is removed, stream banks collapse and channels widen and (or) deepen; removal of wetland vegetation can turn a sediment sink into a sediment source[22].

2.3 Wetlands Today

Wetlands today are highly misunderstood and undervalued. The public should be more informed and educated about the services and benefits that wetlands provide; particularly, more research should be done on the economic value of wetlands. Most urban areas have already destroyed a majority of their wetlands and development only continues to increase in coastal areas. In many instances irreversible damage has been done, such as landfilling. Many wetlands have been developed over, leaving little room for restored or new wetlands to grow. Wetlands also lack space to migrate inland due to rising salinity levels brought by sea level rise. Any hardened shoreline (a road or a seawall, for instance) means wetlands cannot move out of harm's

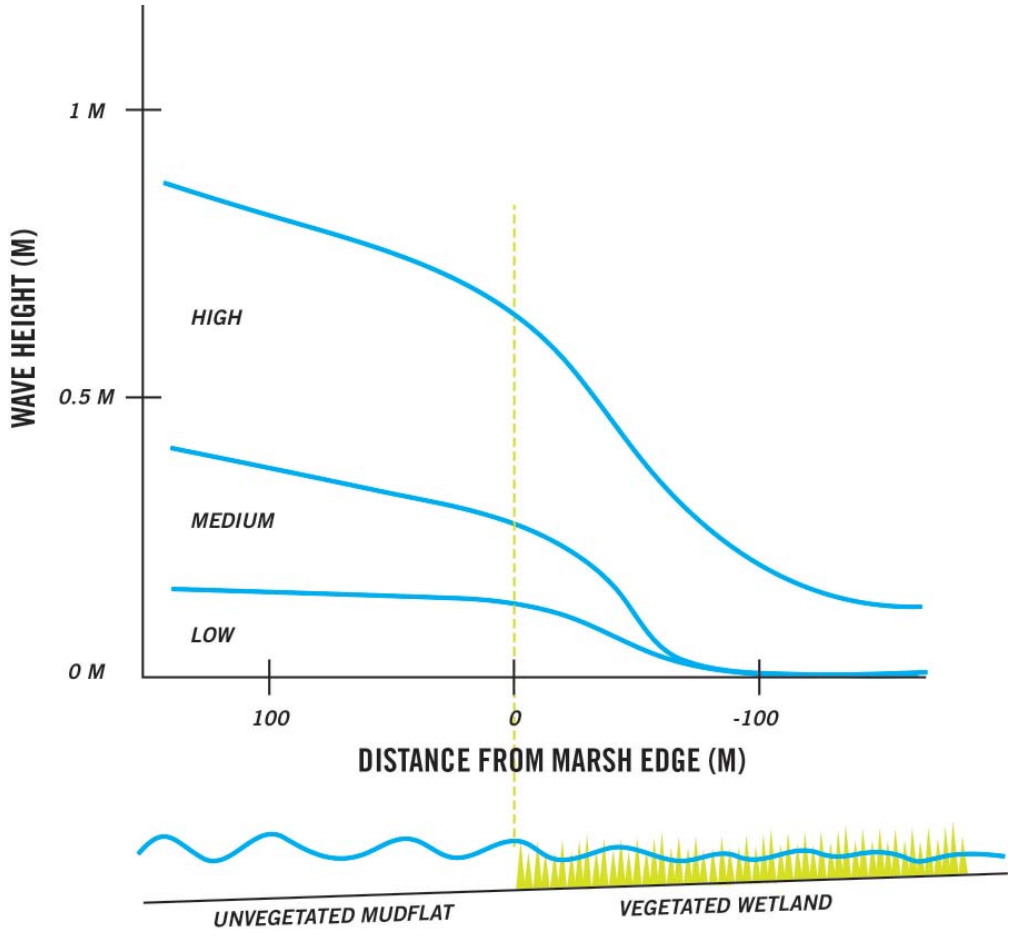

Figure 6c: Wetlands role in flood reduction[23].

way. Finally, research has been done on these topics, but the data is largely outdated and inconclusive. The bottom line is that there needs to be much more research regarding wetlands and climate change. Not only into how they can help coastal cities, but how they also can adapt to change.

Wetlands are threatened both globally and nationally. They are the second most endangered habitat in the world, behind only rainforests[24]. The U.S. estimates to have lost more than half of the country's native wetlands since 1600[25] and continues to lose 80,000 acres of coastal wetlands annually (that's the equivalent of losing one football field of wetlands every nine minutes)[26]. Between the years 1950-1970, the U.S. lost approximately 400,000 acres of wetlands per year[27].

The primary causes for wetlands loss are human activity (from urban and rural development) and from natural processes such as sea level rise and erosion. More than half of the U.S. population live in coastal areas. While non-coastal population growth has remained stable, coastal population growth rates have increased drastically over the past 30 years, with rates projected to continually increase.

Development in coastal areas puts stress on wetlands and often permanently alters the hydrology of a watershed through increased runoff and pollution[28]. "Coastal wetlands are naturally altered by high energy events such as erosion and inundation from sea level rise and storms. The impacts of these processes may be magnified by climate change and shoreline armoring. Estuarine wetlands typically protect the coastline from

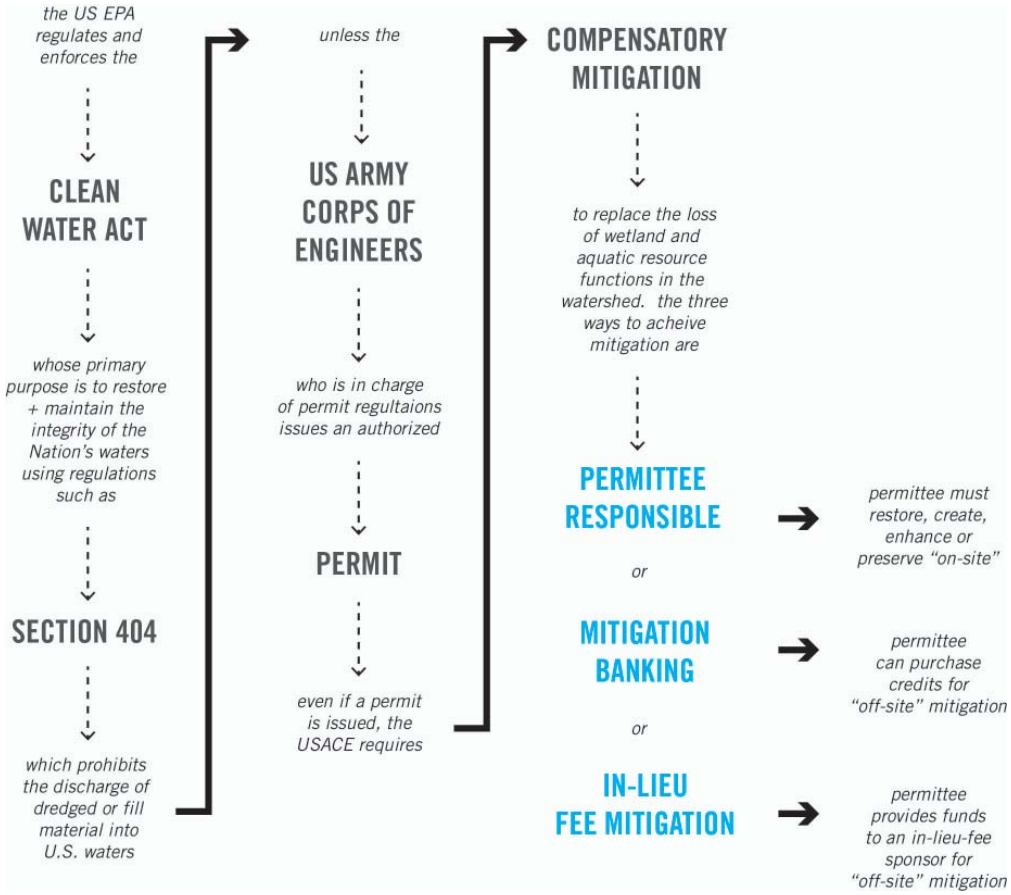

Figure 7: Wetlands protection flow chart[29].

erosion and flooding, but if sea level increases and development prevents inland migration of wetlands, more wetlands will be converted to open water[30]." In order to remain stable, marshes must either accrete sediment and organic material at the same pace as sea level rise or be able to migrate inland.

Wetlands today are protected federally and often additionally at the local level. The federal government protects wetlands through legislation, economic incentives, and acquisition. Wetlands are protected through the Environmental Protection Agency's Clean Water Act, but the protections can be overturned through a permitting process that requires "no-net-loss" mitigation. Though federal regulations protect wetlands nationally, many states and local counties have adopted stricter regulations and laws to protect their wetlands. Though this may seem like sufficient protection, there are still many issues involved. For one, having overlapping authorities with so many laws, regulatory entities, and wetland definitions can be confusing when determining who has jurisdiction over a specific wetland or activity and what procedures must be followed. Not only can it be confusing, it can be nearly impossible to enforce. As such, many wetlands protection regulations are loosely enforced and there is a significant amount of oversight in the required compensatory mitigation practices. Finally, governmental regulations and incentives are not enough to protect wetlands. Education of the public and of federal, state and local government entities will be key in preserving remaining wetlands.

There are other federal laws in place that indirectly protect wetlands by limiting coastal development in certain areas. These include the Coastal Zone Management Act (CZMA) and many Federal Emergency Management Agency (FEMA) sponsored regulations. "The CZMA outlines two national programs, the National Coastal Zone Management Program and the National Estuarine Research Reserve System. The 34 coastal programs aim to balance competing land and water issues in the coastal zone, while estuarine reserves serve as field laboratories to provide a greater understanding of estuaries and how humans impact them. The overall program objectives of CZMA remain balanced to preserve, protect, develop, and where possible, to restore or enhance the resources of the nation's coastal zone[31]." FEMA legislation include the Coastal Barrier Resources Act (CBRA), the NFIP Community Rating System (CRS), and the Biggert-Waters Flood Insurance Reform Act of 2012.

The CBRA, established in 1982, protects coastal areas that serve as barriers against wind and tidal forces caused by coastal storms and serve as habitat for aquatic species. The CBRA protects coastal areas from development by limiting federal financial assistance for development-related activities in designated areas[32]. The 1990 National Flood Insurance Program's CRS is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements. As a result, flood insurance premium rates are discounted to reflect the reduced flood risk[33]. The Biggert-Waters Reform Act calls on FEMA to make a number of changes to the way the NFIP is run. The new law encourages program financial stability by eliminating some artificially low insurance rates and discounts. Most flood insurance rates will now move to reflect full risk and flood insurance rates will rise on some policies. Incorporating flood mitigation strategies into the property can help lower insurance rates[34].

Wetlands scientific research developed fairly recently, with serious studies beginning in the 1970s and proliferating over the past two decades. Existing research centers include the USGS National Wetlands Research Center, the USFWS National Wetlands Inventory, and the Sea Level Affecting Marshes Model (SLAMM). "The mission of the National Wetlands Research Center (NWRC) is to develop and disseminate scientific information needed for understanding the ecology and values of wetlands and for managing and restoring wetlands, coastal habitats, and associated plant and animal communities throughout our world[35]." "The U.S. Fish and Wildlife Service's National Wetlands Inventory (NWI) has been producing wetland maps and geospatial wetland data for the United States since the mid-1970s. The focus has been on two fronts: map or digital database preparation and delivery to the public, and projecting and reporting on national wetland trends using a probability-based sampling design. The status of mapping has been made available through various media throughout NWI's 30-year history (e.g., state atlases, regional status maps, and now through the internet via the Wetlands Mapper online tool)[36]." SLAMM is a mathematical model developed in the 1980s that uses digital elevation data to simulate and project the potential impacts of sea level rise on wetlands and coastal areas. This valuable research tool is the first in its kind to address the future of wetlands due to climate change[37]. Although many universities and coastal research institutions have incorporated wetlands related studies into their programs, much more research is still needed to truly understand the values of wetlands.

2.4 The Georgia Coast

Georgia has 100 miles of coastline, which equates to five percent of the U.S. Atlantic coastline; however, Georgia has more than 33 percent of the remaining salt marshes on the Atlantic coast[38]. The state estimates to have 70 percent of its original coastal wetlands remaining, ranking 5th in the continental U.S. for original wetlands persevered[39]. The state links approximately $6 billion in economic benefits to the coastal marshes[40].

Wetlands loss in Georgia has been caused by coastal development, pollution, and natural processes. Coastal development has remained minimal until recent years. However, Georgia's coastal population has seen phenomenal growth in the past few decades and it continues to grow (the coastal population is expected to double between 2000 and 2030), to the detriment of wetlands[41]. Georgia is home to two major ports, Savannah and Brunswick. The manufacturing industries located near these ports have led to damaging pollution in the surrounding waterways, resulting in marsh destruction and groundwater contamination. There are 65 hazardous waste sites in Georgia's six coastal counties, 58 of which are located in port cities. There are four superfund sites along the coast, all located in Brunswick[42]. The Georgia coast has a dynamic sand-sharing system, in which natural processes of erosion and accretion take place. Though Georgia's coast experiences a lot of natural erosion, it has been exacerbated in recent years by rising sea levels, increased development, and hard infrastructure such as sea walls, bulkheads, and jetties. As such, the amount of erosion has far surpassed the amount of accretion[43].

Georgia's wetlands have benefited from favorable land ownership patterns and early public awareness, advocacy and state legislation. Coastal Georgia's land ownership patterns have resulted in many benefits for the coastal wetlands. To this day, a vast majority of coastal land remains undeveloped. Much of the coastal uplands are owned by large timber companies, and a majority of Georgia's islands are federal and state conservation areas. Only three percent of land in Georgia's coastal counties is developed; development is primarily located around Savannah, Brunswick, and St. Mary's[44]. Eugene Odum, referred to as the father of modern ecology, was a researcher and ecologist at the University of Georgia from 1940 - 1980. In the late 1960s, Odum led a campaign called "Save Our Marshes," in which he and his students educated the public about the value of wetlands. Odum's work created enough public momentum to stir up support in the Georgia legislature[45]. The Coastal Marshlands Protection Act, passed in 1970, was a direct result of this public awareness and advocacy. The Coastal Marshlands Protection Act and the later Shore Protection Act (1979) were way ahead of their time in recognizing the importance of protecting coastal ecosystems. They both acknowledge that these natural resources (Georgia's marshlands and sand sharing system) are important resources that would be costly and difficult, if not impossible, to replace if lost[46]. This foresight has led to Georgia's marshes being some of the most well preserved in the country.

Although Georgia's wetlands are well protected, there are a number of looming threats including climate change inaction, legislative roll-backs, a current lack of public awareness, increasing shoreline hardening, imprudent development decisions, and the Savannah Harbor Expansion Project (SHEP). Though there is ample evidence that Georgia's seas are rising steadily, a majority of the state does not recognize climate change as an issue. Studies of sea level at Fort Pulaski in Savannah show that the sea level is rising at a rate of approximately 0.03 meters per year, with the rate expected to increase exponentially in the coming years[47]. Georgia is one of few coastal states that has not created or adopted a climate change action plan. Because Georgia is not addressing climate change at a state level, and because coastal development is a strong economic driver for the state, the very laws that have so well preserved the Georgia marshes are now being threatened. There have been numerous proposals in the past decade to diminish and relax these laws. Advocacy organizations now have to spend their time fighting these roll-backs when their time should be spent trying to strengthen these laws. The UGA River Basin Center, part of the Eugene Odum School of Ecology, has conducted research on climate change and sea level rise and what that may mean for the Georgia coast. The center has modeled a one meter sea level rise, identifying areas of vulnerability and land cover changes. Much of the currently undeveloped drylands of Georgia's coastal counties are at high risk, with up to eight percent projected to disappear in the next 100 years. Much of this land is currently slated for future development projects[48]. The public needs to be informed of the risks associated with their properties, and future land development decisions should be based on research such as this. Another impediment, shoreline hardening, has become a popular method in Georgia to mitigate damage caused by rising water levels. Hardened shorelines, such as sea walls, increase erosion along shorelines and cause significant disruption in wetland migration. Sea walls not only increase erosion of the shore in front of them, but they cause hyper erosion of shorelines adjacent to where

they end. This forces neighboring properties to either allow their land to erode, or put in place their own sea wall, thus continuing and exacerbating the cycle[49].

Although Georgia's marshes are well preserved, recent development decisions do not always follow this precedent. Georgia's marsh hammocks, small bits of marshy land barely above sea level, have been identified as one of the most endangered landscapes in America[50]. However, that does not stop developers from continually attempting to capitalize on any piece of waterfront property. The most recent example is a narrow spit on Sea Island that has been proposed for a subdivision development of eight houses. Despite being located in the FEMA floodplain and on an actively eroding beach (the shore has eroded 100 feet in the past ten years), plans are currently under review by the local city council[51]. Finally, the Savannah Harbor Expansion Project (SHEP) may have the biggest, and potentially most devastating, impact on Georgia's marshes throughout the state's history. SHEP Environmental Assessment Reports show that the harbor deepening will significantly alter the surrounding waterways and increase salinity levels. Half of the project's $652 million price tag will be spent solely on mitigating and compensating for the projected harmful effects on surrounding water quality, fisheries, and wetlands[52]. SHEP is also controversial within the community because there is no evidence that the proposed changes will actually bring in more economic activity.

Georgia's next steps in wetlands preservation should involve public awareness and community involvement, research and advocacy partnerships, policy changes, incentives, and a holistic, regional approach. The first and most important step is informing and educating the public about why these issues are important. Without public support, the Georgia coast is in dire risk. It is also important to engage local communities in conversations about the potential risks and the methods and measures to plan for and evaluate what climate change means for them. Though much more research is needed, some research is currently being conducted. Research institutions and advocacy groups should form partnerships to inform and educate the public and local governments. A scientific basis is needed in order to gain any traction; we need to be able to say that because of this data, we believe this is what should be done. An informed public voice stands a great chance of influencing local and state policy to save our coastal resources, as it has in the past. Georgia needs to strengthen current policies and propose new ones that protect precious resources and limit harmful development. Incentives such as the FEMA Community Rating System should be looked into as ways for local communities to become more resilient and save money. Finally, as with all sustainable systems, no part of the Georgia coast can be looked at in isolation. Coastal collaboration is the key to the future. Local and state governments, nonprofits and advocacy groups, research institutions, communities, private companies, and individuals must come together to create and carry forward a plan to limit imprudent decision-making and preserve the Georgia coast.

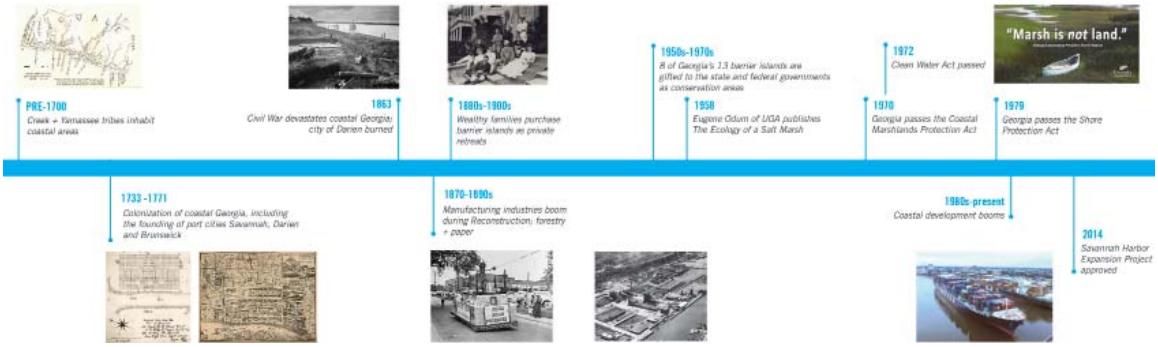

Figure 8: Georgia wetlands timeline.

2.5 New York City

New York City (NYC) has an estimated ten percent of original wetlands still remaining[53]. Nearly three million New York City residents live in flood evacuation zones[54]. Hurricane Sandy alone cost the city an estimated $19 billion in economic damage[55].

Primary causes of wetlands loss in NYC include landfilling, development, and pollution. Until the late 1970s, wetlands in NYC were regarded as additional land for development. The city began filling in wetlands as early as 1660 and these patterns of landfilling did not stop until Battery Park City was completed in 1970. A majority of NYC's flood zones are located in historic wetlands and areas that were previously water[56]. Pollution is another huge issue in NYC's waterways. NYC has a combined sewer system, which means waste water and stormwater runoff both flow through the same pipes; NYC has 490 combined sewer overflow (CSO) outfalls. In the event of heavy rainfall, these pipes overflow and the heavily polluted water flows directly into the surrounding waterways; as such, the city has never been in compliance with the Clean Water Act[57]. Wetlands can normally absorb and filter these pollutants, but if the pollutants exceed the carrying capacity of the wetlands, then the ecological functions will diminish over time. NYC now has two superfund sites, one of which is the Gowanus Canal.

Until the 1970s, protection for wetlands in NYC did not exist, which is why so few remain today. When the environmental movement brought about the notion of ecological consciousness into urban areas, nonprofit groups began to fight for the little that was left of the city's extensive historic tidal wetlands. Acquisition and preservation of the city's remaining wetlands began in the late 1970s and continues to this day; the city now owns 97 percent of its remaining wetlands[56]. After Hurricane Sandy, the city began seeking strategies to mitigate flooding brought on by extreme weather events. Wetlands are now not only being protected and preserved, but the city is exploring ways to restore historic wetlands where possible and construct new wetlands where necessary.

In 1984, Parks Commissioner Henry J. Stern founded the Natural Resources Group (NRG) with the aim to conserve and restore NYC's natural resources. This group began the trend of acquiring lands for preservation[58]. In 1987, the Trust for Public Land (TPL) and NYC Audubon began a program called "Buffer the Bay," in which they identified open space near the bay for acquisition and restoration; since then, many of the identified lands have been acquired[59]. In 2005, Mayor Bloomberg created the Wetlands Transfer Task Force to inventory city-owned wetlands and transfer them to the Department of Parks and Recreation. Today 97 percent of coastal wetlands and 79 percent of freshwater wetlands are publicly owned. The three main entities with ownership are the New York City Department of Environmental Protection (DEP), the New York City Department of Parks and Recreation (DPR) and the National Park Service (NPS)[56]. In 2007 Mayer Bloomberg released PlaNYC in an effort to make NYC more sustainable in the coming years. In 2011 an updated report was released, and in 2012 the SIRR report (Special Initiative for Rebuilding and Resiliency) was released, post-Sandy, to address resilience issues. A huge factor in the PlaNYC report deals with stormwater management and green infrastructure to reduce the amount of polluted runoff that enters the waterways. Wetlands have been receiving a lot of attention as a way to control stormwater and mitigate runoff[60]. One of the many initiatives of the PlaNYC is the NYC Wetland's Strategy to address protection and restoration issues. Key strategies include strengthening protection and acquisition efforts, developing a mitigation strategy for the city, promoting restoration projects, improving mapping and monitoring, and developing a research agenda to address wetlands challenges facing the city[56].

NYC's wetlands primary challenges are funding and space issues. Currently there is no dedicated funding mechanism for restoration projects. The maintenance, stewardship, and restoration of wetlands and natural areas require significant financial resources. Protection and restoration in New York City is particularly expensive, due to the city's high land values and limited space, ranging from $290,000 - $2,000,000 per acre. Cost-effective opportunities for restoration are increasingly difficult to find today, with high costs (and sometimes environmental impacts) of fill removal, site constraints, limited space, and competition for land. The highly developed shorelines of NYC have allowed for little to no transition area between land and water, preventing inland migration of adjacent wetlands. Even development that took place after federal or state wetland regulations were in place have not left much transition area for inland migration. State law requires a 150 foot transition area in New York City and 300 feet elsewhere; however, even recent permitted fill activity has been allowed much closer to the wetland boundary[56].

Despite issues and threats, NYC has had a number of successful restoration projects including Jamaica Bay and the Staten Island Bluebelt. Jamaica Bay, an

18,000 acre wetlands estuary, is NYC's largest remaining wetlands complex. Though surrounded by development, manufacturing, and an airport, the estuary remains richly productive and a home to diverse wildlife. In the early 1990s, the wetlands were disappearing at an alarming rate due to surrounding development and pollution; if left alone, the wetlands were projected to be lost entirely by 2025. Because Jamaica Bay is one of the last remnants of its kind in the city, it has been the focus of many preservation and restoration efforts. The city, non-profits, and community volunteers have restored hundreds of acres in the bay to date[61]. Jamaica Bay is also home to the Jamaica Bay Science and Resilience Institute, a CUNY (City University of New York) Initiative that is the first center wholly focused on the study of resilience in the world[62]. The Staten Island Bluebelt is a great example of cost effective stormwater management through wetlands preservation and restoration. The Bluebelt aims to preserve natural drainage corridors such as streams, ponds, and wetlands in order to convey, store, and filter stormwater runoff. The program saves tens of millions of dollars in hard infrastructure costs, while also preserving open space and wildlife habitat[63].

NYC also employs innovative strategies to experiment with ideas and solutions. In 2010, the Museum of Modern Art (MoMA) invited five design teams to re-imagine NYC in response to sea level rise in a project called Rising Currents. Architecture Research Office (ARO) and dlandstudio developed an "ecological infrastructure" for Lower Manhattan of green streets and a graduated edge that works within the city's existing infrastructure. The new coastal edge consists of a porous park network, wetlands, and marshes. The remaining four teams developed similar concepts of soft infrastructure approaches, such as barrier islands, oyster and subway car reefs, and wetlands[64]. One of the city's superfund sites, the Gowanus Canal, is now a pilot project for wetlands as green infrastructure. Susannah Drake's firm, dlandstudio, in collaboration with city planners and politicians have set plans for the Gowanus Canal "SpongePark," an 1,800 square foot stormwater management park. The small park is designed to capture and filter stormwater runoff while also creating public space to bring people closer to the water. Funded through grants by the city, the park will cost $1.5 million and serve as a prototype for green infrastructure and constructed wetlands for the city[65].

New York City's next steps in wetlands preservation and restoration should include a realistic analysis of at-risk areas, policy and funding mechanisms, and holistic, regional strategies. As climate change threats mount, it is important to reevaluate and revisit building in flood zones. High level analysis of at-risk areas should be conducted (what infrastructure will be affected, what will be lost in the event of another Sandy, etc.). The storms will continue to come; the question is, will we continue to take a reactionary stance, or will we be proactive about mitigating further losses? Wetlands restoration is incredibly expensive in NYC's dense urban environment due to issues such as high property values and constant stressors from development and pollution. Newly constructed and restored wetlands must be monitored and maintained, as they often take one to two years to mature. Current restoration efforts have been funded through grants and nonprofits, but if restoration is to make a real difference there needs to be an established funding mechanism for the city. The City of New York should develop a wetlands mitigation bank in order to make more substantial wetlands restoration

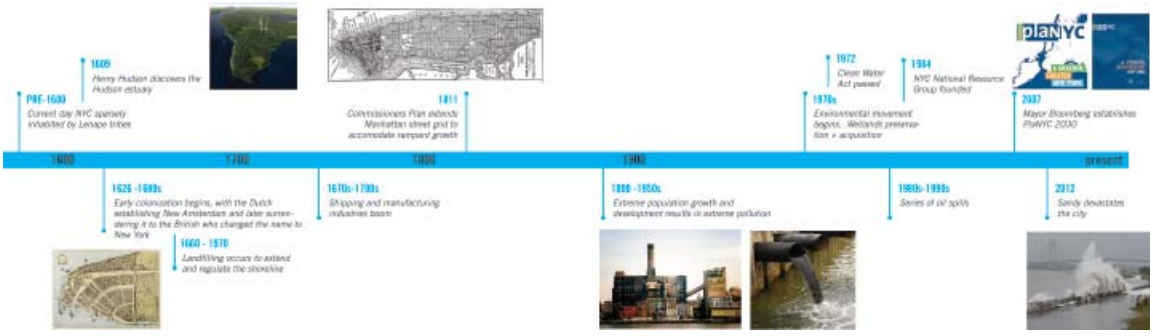

Figure 9: New York City wetlands timeline.

efforts. Mitigation banks are one way to provide a stable funding mechanism for substantial restoration projects. Finally, NYC should work together with its watershed neighbors: upstate New York, New Jersey, and Connecticut. The city is not an isolated piece of land, but part of an intricate estuary network. Climate change and sea level rise should be addressed at the larger scale in order to be more impactful.

3.0 CONCLUSION

Wetlands are a smart, cost-effective tool for urban designers and planners to use in urban areas as a means to reduce flooding, filter pollutants, create habitat, and provide open space.

The two case studies chosen were extreme situations, as most other coastal cities will fall somewhere between the two. The Georgia coast had the foresight to protect their valuable coastal resources, but now faces the risks of overturning their progress for short-term gains. We can learn from Georgia's amazing preservation strategies and their now on-going battle to continue what they started. NYC has the opposite situation. Where they were once blind to the values of their natural resources, they have come an incredibly long way in the past 40 years to shift the mindset towards preservation and restoration. We can learn from NYC's unfortunate historic decisions and now from their progressive strategies for urban resilience.

A number of conclusions have been drawn from this research. First, wetlands are still undervalued. The general public is still not aware of the many services and values wetlands provide and how they can benefit coastal areas, especially economically. Because of this, wetlands are still disappearing at a shockingly high rate, despite regulations put in place to protect them. Second, wetlands are in danger from humans and sea level rise. Wetlands are a fragile ecosystem that are upset by stressors from development and pollution. Wetlands are put at further risk from inundation due to sea level rise; ordinarily wetlands would migrate inland, but most coastal areas are highly developed and prevent this. Third, wetlands decrease the need for hard infrastructure in coastal urban areas, while saving money and improving the environment at the same time. The hydrologic values of wetlands can play a significant role in reducing coastal flooding and future investments in shoreline protection, while providing environmental benefits. Additional research is still needed to better understand and support the efficacy of flood and storm surge mitigation. Fourth, prevention is better than recovery. This is true for wetlands, which take a lot of time and money to restore, but is also true for coastal cities preparing for climate change. Much focus is placed on reactionary tactics such as adaptation strategies. More research, time, and energy should be put into preventative measures: not degrading valuable ecosystems that protect our shores, not building in floodplains, etc. Fifth, well preserved places (such as Georgia) should not be imprudent. While well preserved places will certainly not have as many issues in dealing with climate change as other more unfortunate communities, it does not mean that they have earned the right to be foolhardy. No matter the state of your coast, long-term goals should guide decision making, and never short-term profit making. Finally, poorly preserved places (such as New York City) should restore and construct. Highly developed urban coastal environments that either do not have many wetlands left or do not have ample space for wetlands should consider restoring and constructing wetlands and other soft infrastructure where possible as a means to offset the effects of climate change.

To realize success in preserving and restoring coastal wetlands, a number of next steps should be taken. Scientists and researchers should communicate information about coastal hazards and potential risks to communities and wetlands to government agencies and the public in order to heighten awareness and encourage responsible policies and decision-making. Coastal communities should plan and develop strategies for prevention and adaptation in order to mitigate further losses and build more sustainable, resilient communities. At-risk properties and infrastructure should be identified and measures and methods should be developed in order to protect these areas from future development. Government agencies should accept their responsibilities for using and providing the best information and recommendations for future land use decisions and regulations in high-risk coastal areas. Existing policies and regulations in place to protect wetlands should be strengthened and strongly enforced. Clear procedures and coordination at all levels of government are necessary. Mitigation requirements and permits should be strongly enforced and should be monitored for one to two years following implementation in order to ensure that the mitigation does in fact offset the loss and or damage done. Local and state governments, nonprofits, and communities should work together at the watershed level to develop a regional vision and approach to preserving coastal communities and resources. Collaboration across stakeholders is critical to developing impactful strategies for dealing with climate change and protecting coastal resources. Coastal areas should

incentivize "the right thing" by using a combination of regulatory and economic policies, such as FEMA's Community Rating System. In other words, communities that strive to make their cities and homes more resilient should be rewarded. Wetlands preservation and restoration could be one such incentive. Grants or legislation should provide funding to state and local governments to research and take stock of their current wetlands and to experiment and perfect mitigation and restoration practices in their areas.

Finally, the real key to success in understanding the fate and future of coastal wetlands is in more research. Though a variety of research is currently underway, much more is needed to understand the role of wetlands in urban areas and to influence public policy and funding for wetlands preservation and restoration projects. The following are specific types of research that would be incredibly helpful in this moving forward.

First, the role and efficacy of wetlands in storm surge mitigation is still unclear. Research needs to be conducted in the areas of wave attenuation and how much space (acres or miles of wetlands) are actually needed to be most effective to mitigating these issues. Second, highly developed coastal areas are exploring various edge typologies as ways to address sea level rise and storm surge. More research needs to be conducted on the effects that hardened shorelines have on surrounding areas (erosion, wetlands migration), as well as how effective "living shorelines" (shorelines with soft infrastructure) are in comparison to hard infrastructure. Third, wetlands restoration and constructed wetlands are still fairly recent sciences; experiments should be conducted to find the best and most cost effective ways to implement these measures. How long do constructed wetlands take to mature? How much space is needed for wetlands to perform well, at various scales? Fourth, monitoring and assessment needs to become more regularized. Both historic and new wetlands should be mapped, inventoried, monitored, and assessed on a regular basis. Finally, more research, such as the SLAMM model should be conducted as the effects of sea level rise on marshes are still not clearly understood. How much inundation can marshes handle? Will increased salinity levels affect performance? More localized research is needed as well; can marshes in this area migrate? Is there an opportunity for a migration corridor?

These are just a few examples of questions raised and research needed. Research and information sharing hold the answers to these questions and the key to the future of not only wetlands, but our coastal cities across the globe.

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