Disclaimer: This report and recommendations made within have not been considered and adopted by the Kiawah Town Council. In the coming months, the Town Council, with the involvement of other community entities, will review the recommendations in the full report and develop a strategy to meet the challenges.

Flood Mitigation and Sea Level Rise Adaptation

for Kiawah Island, SC

Prepared by

The Flood Mitigation and Sea Level Rise Adaptation Subcommittee
of the Town of Kiawah Island's
Environmental Committee

Town of Kiawah Island, South Carolina

September 4, 2018

The Committee is grateful to the following individuals external to the Kiawah Island community for reviewing this report and providing their advice and guidance.

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INTRODUCTION

Kiawah Island continues to be a place of natural beauty enjoyed by both residents and visitors. The Vision of the Town of Kiawah Island, as stated in the 2015 Comprehensive Plan "… is a residential community incorporating a world-class resort and a unique, vibrant shopping village within a natural maritime setting that is being preserved and enhanced for current and future generations." This report is an effort to ensure that Vision is fulfilled.

Kiawah Island is a barrier island, and as is true for all of the Low Country, it is not immune to trends affecting the regional coastline. In the last few years, Kiawah Island has been impacted by occasional, heavy flooding of low-lying roads and yards during major rain storms, particularly when storm water drainage systems backed up during high tides. A one-foot increase in sea level over the last 100 years has been documented for the Charleston area. Over the next 100 years the consensus of almost all scientific studies projects both a substantial increase in the rate of sea level rise (SLR) as well as increasing periods of drought broken by periods of intense rainfall.

In the spring of 2017, the Town of Kiawah Island's Environmental Committee formed a subcommittee to proactively identify steps our community could take to address increased flooding frequency and adapt to future water level changes. This report attempts to identify ways in which Kiawah might be impacted by rising seas and changing weather patterns, to assess Kiawah's potential vulnerabilities to those changes, and to suggest practical actions that Kiawah might take to mitigate those vulnerabilities and ensure a prosperous future. Recognizing that the Town of Kiawah Island is unique because most of its residents and infrastructure lie within a private gated community, the subcommittee expanded its membership to include other property owners and representatives of the Kiawah Island Community Association (KICA), the Kiawah Island Conservancy, and the Architectural Review Board (ARB).

We jump-started our work by learning from others. We held discussions with neighboring communities such as the City of Charleston, Beaufort County, Folly Beach, and Seabrook Island and gathered information on their sea level rise adaptation plans. During the course of the year we worked with managers and experts from the Town, KICA, the Kiawah Island Utility, the ARB, Berkeley Electric Cooperative, and locally prominent architects. We consulted with current and former scientists from the South Carolina Sea Grant Consortium, the College of Charleston, the South Carolina Department of Natural Resources (SCDNR), the National Oceanic and Atmospheric Administration (NOAA), the SC Department of Health and Environmental Control's Office of Ocean and Coastal Resource Management (SCDHEC-OCRM), and Coastal Science & Engineering. We reviewed a number of major reports on sea level rise developed by state, federal, and international scientific organizations and tracked a wide range of literature on the subject. We established a working relationship with a Geographic Information Systems (GIS) professor from the College of Charleston whose maps and models we believe will be very important to Kiawah's planning process for flood mitigation and adaptation going forward. The results of this effort are presented in the following report. We expect that it will be informative and hope that its recommendations will prove useful for planning Kiawah's future.

The report does not attempt to sugar-coat the challenges being faced by all southeastern coastal communities. The good news is that there are many practical and useful actions Kiawah property owners and governing bodies can take to preserve our fully functioning and beautiful island. Compared to perhaps all other barrier island communities, Kiawah is in an enviable position to address these challenges. It is a small, relatively homogeneous community and that gives it flexibility to act. Kiawah's financial resources and its broad base of experience and expertise gives it the ability to solve tough problems. Although its governing structure is a bit more complicated than most communities, that is also an asset. KICA can undertake actions that are difficult for a municipal jurisdiction like the Town to accomplish. Similarly, the Town has responsibilities and authorities that a private HOA does not.

Our Committee is a diverse group, like the Kiawah community. Throughout the process of developing this report, the Committee members tackled many issues. Honest differences in opinion surfaced and questions about a variety of matters, including climate change and mechanisms driving sea level rise, remain. However, there is total agreement among all Committee members that we must unite to address the risks of increased flooding and future sea level rise. All individuals on the Committee respected each other's integrity, and everyone compromised somewhat in order to achieve this final report. The challenges we face are too important to do otherwise. In turn, the Committee believes that the leadership of the island is also capable of uniting and collaborating in order to develop solutions for the significant issues that confront all of us.

The bottom line is that we can capitalize on our assets, choose to tackle the challenges of sea level rise head-on, and work vigorously and publicly to make Kiawah the best adapted and most resilient community on the East Coast. If we do, Kiawah will remain the premier residential-resort destination that we all know and will be widely recognized as a leader among all coastal communities for ensuring that it is adapted to changing environmental conditions for decades to come. This report outlines the current status of this ongoing work. We encourage you to get informed, get involved, and give us your feedback and ideas.

Town of Kiawah Island
Flood Mitigation and Sea Level Rise Adaptation
Subcommittee of the Environmental Committee

EXECUTIVE SUMMARY

This report is timely because of Kiawah's recent experience with storm-related flooding in 2015, 2016, and 2017, and Charleston's well-publicized problem of nuisance flooding. Sea levels are definitely rising as measured by NOAA tide gauges and satellite altimetry, and the Southeast coast has recently been particularly vulnerable due to effects of the Gulf Stream, the El Nino Oscillation, and the North Atlantic Oscillation. While the exact rate of future sea level rise is uncertain, nearly all modeled scenarios indicate that it will accelerate during the coming decades. While many areas are already experiencing flooding challenges, recent research by multiple sources suggests that Kiawah Island, as well as the rest of the South Carolina coast, will face significant flooding challenges during the next 30 years. Both drought and intense rainfall events are projected to become more frequent, and while the number of hurricanes should not increase, they may be larger and slower-moving, resulting in very heavy precipitation.

A subcommittee of the Town of Kiawah Island's Environmental Committee was formed in the spring of 2017 to study the impacts of flooding and sea level rise on the island, to identify areas of concern, and to make recommendations for action. It focused on an intermediate rate scenario of sea level rise and a time frame of 30 to 50 years, i.e. a sea level rise of 1.5 to 2.5 feet during this time period. This was grounded on summaries of the best science available from the federal government and international organizations, and is similar to the standard adopted by the City of Charleston. The Committee considered impacts of tidal or nuisance flooding, storm surge, extreme precipitation events, simultaneous occurrence of these, and the role of sea level rise in exacerbating their impacts. There are seven areas of the island infrastructure, outlined below, that will require the attention of the Town, KICA, the ARB, property owners, and other island entities in the short or long term. Each of these topics is organized in a standard format: S**ignificance**, **Current Status on Kiawah**, **Concerns**, **Recommendations**, **Responsibilities and Partners**, and **Recommended Readings/Additional Information**.

First, a well planned and executed **stormwater management system** is critical to handling flooding events on the island. Kiawah is fortunate to have an extensive system of interconnected ponds that can accommodate a rainfall event equivalent to a 100-year flood. Stormwater moves through the ponds and leaves the island through outfalls into the marsh and river. In the future, higher tides will decrease the effectiveness of the pond system by slowing the flow of water from the ponds into the outfalls and out to the estuary. Work to repair clogged and deteriorating pipes is underway and will improve the flow of water into ponds and drainage system. The Committee believes that continued attention to the integrity of the drainage system through reviews of the appropriate size, proactive maintenance and necessary repair and replacement of pipes is critical. The Committee supports current plans to automate outfall gates and encourages consideration

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of one or more additional outfalls. Other recommendations relate to reducing the obstruction of drains, swales, and pipes, investigating the use of physical structures in localized areas to slow nuisance flooding or storm surges, using the best available GIS tools to improve stormwater drainage, working with neighborhoods on location-specific challenges, adopting principles of low impact development, and planning for the resources to support these efforts.

Second, Kiawah needs to evaluate its entire **road system** and take actions to ensure main arteries remain passable to emergency vehicles after an event and accessible to residential vehicles after storm damage is minimized. Planning needs to look several decades into the future, not just at immediate flooding problems. High resolution GIS analyses can assist in the planning process. Any modification to roadways or the surrounding landscape associated with flooding sources may have negative impacts on surrounding properties and these must be factored into planning. Other recommendations include the use of leisure trails for emergency vehicle access, developing a system to warn property owners and guests of specific road sections likely to flood during an approaching or on-going storm, placing water-depth markers along critical sections of roads during a storm to warn motorists of the depth of water on the road, and exploring the possibility of developing temporary auxiliary water storage basins to improve road drainage during major events. Emergency management during floods focuses largely on maintaining access to people on the island who need help, and in assisting property owners, guests, and workers in leaving the island. Effective communication of road conditions and expectations about an approaching storm are important. Assisting individuals with evacuation if necessary, availability of a high-freeboard rescue vehicle, use of high resolution GIS products in planning, improved traffic control during island closures, and advanced preparations for recovery activities are additional recommendations.

The third area is essential services: potable **water and wastewater services and electrical services.** The former are provided by the Kiawah Island Utility and electrical service is provided by Berkeley Electric Cooperative. Both appear to be well-managed and relatively prepared to withstand most expected flooding events. Susceptible stations for both systems can be raised incrementally and adaptively over time as dictated by flooding as it develops.

Fourth, there are steps property owners can take to **adapt their residences and landscapes** to more frequent flooding. The Committee met with three local architects, the Town's Building Official, and the Architectural Review Board's Director. Committee members reviewed the ARB Guidelines, and the Town's Flood Damage Prevention Ordinance. In addition to the list of recommendations for property owners, additional recommendations were made for how specific regulations of the governing bodies should be modified to assist in flooding mitigation and adaptation. Examples of recommendations range from adopting low impact development tools like pervious paving and rain gardens, to replacing loose mulch and flood intolerant plants, to increasing freeboard (the required height for the lowest floor of a building) requirements by ordinance, to wet floodproofing the first floor of a residence, to raising one's entire house above base flood elevation plus freeboard.

Fifth, Kiawah is fortunate in that it has a **beach** that accretes sand and that building construction has not generally been permitted to encroach on it or the dunes. As long as a plentiful supply of sand continues to move down the coast and as long as no anthropogenic structures create a barrier to dune building, natural processes should be able to maintain the beach and dune system despite rising sea levels. In most places on the island, experts recommend allowing the Kiawah beach and dune system to recover from storm erosion naturally rather than using artificial means such as sand fencing which can create other problems. Challenges may arise as the dune system moves landward with higher sea levels and encroaches on residences and public buildings. Such a barrier to beach movement may, in the future, lead to beach loss and require beach renourishment. The Town should plan in advance for access to beach compatible sand that might come from the uplands, nearshore, or offshore sources. The Committee recommends continuing to monitor the beach and its wildlife populations and to manage the beach as is currently done. All entities should discourage or prohibit the construction of buildings or recreational facilities seaward into the dune system. Construction into the dune system ensures not only infrastructure damage should a breach in the remaining dunes occur, but provides a highway for ocean water to flow onto other land-based properties and perhaps weaken the integrity of a considerable area

Sixth, the Committee wishes to stress that the preservation and, where necessary, the restoration of Kiawah's **salt marshes** is critical. Kiawah Island has more acres of salt marsh than dry land and five times more marsh front than beach. The salt marsh protects the land from erosion by reducing wave action and provides abundant wildlife, recreational, and aesthetic amenities. With rising sea levels, the marsh can grow vertically if it can accumulate sediments at a sufficient rate, it can migrate landward if paths are not obstructed by anthropogenic barriers, or it will drown and be converted to open water and mud flats. Experts fear that a large proportion of South Carolina marshes will be lost to sea level rise. Recommendations include working with neighborhoods and developing policies to protect migration routes for marshes and possibly supplying supplemental sediment for vertical growth. Living shoreline construction may be appropriate in some locations to protect marshes from sea level rise induced erosion.

Finally, Kiawah's terrestrial ecosystems depend on freshwater provided by precipitation. The **groundwater reservoir** for this water is the freshwater lens that floats on salt water underlying the island. Drought can reduce the recharge of this freshwater lens, reducing its volume and ability to hold back seawater. Sea level rise will also contract this lens by creating more pressure for saltwater infiltration. This could lead to changes in the island's vegetation assemblages. Kiawah's extensive irrigation supplements precipitation as a source of freshwater. The Committee suggests a hydrology study to map the freshwater lens and to monitor the groundwater table through the coming decades. As changes are detected, considerations should be given to a variety of actions for retaining freshwater on the island, such as low impact development practices and modifications to pond management.

In order to develop plans for mitigating flooding and adapting to sea level rise, it is essential that Kiawah Island residents, property owners, property managers, commercial interests, and governing bodies receive important, accurate, and useful information in a timely way. All these entities should work together to implement educational programs and avenues of communication for important information. For example, in addition to established programs like *Our World* and *Conservation Matters*, the Town and KICA should provide educational programs to help property owners learn of ways to protect their property from flooding, make informed decisions in the face of approaching storms, and implement low impact development practices. The Committee also recommends a number of readings that will help the Kiawah community to better understand the challenges and opportunities resulting from sea level rise in the coming decades.

In addressing the flooding challenges resulting from sea level rise and more intense rainfall events in the coming decades, it is essential that the Town, KICA, and the other decision-making entities work cooperatively and coordinate their efforts. Because the rate of sea level rise and its impacts on Kiawah are uncertain, the Committee recommends that these entities adopt an "adaptive management pathways" approach to addressing the issues that will confront the island. This approach identifies trigger points for when action needs to be taken and provides time to spread out implementation, allowing for capital development, community support, and new options to be developed. Planning for flooding and sea level rise should be recognized as important issues by incorporation into such documents as the Town's Comprehensive Plan and KICA's Strategic Plan. The Town and KICA, and perhaps other entities, should develop collaborative structures to ensure that these challenges are properly addressed over time. This may entail the creation of such things as a Resilience Specialist position, a Resilience Committee, ad hoc groups to establish trigger points and to periodically review progress, and collaboration by Kiawah representatives with Charleston County, the College of Charleston, a variety of state agencies, and public-private organizations like the Charleston Resilience Network. Sea level rise will affect everyone associated with Kiawah and success in dealing with it will require a broad cooperative and coordinated effort.

BACKGROUND

RECENT FLOODING EXPERIENCE

2015

This report may be particularly timely in light of Kiawah's recent experience with minor flooding. In early October 2015, the movement of very moist air over a stalled frontal boundary near the SC coast caused an extraordinary amount of rainfall in the state. The outer circulation of Hurricane Joaquin, situated well off the coast, added additional tropical moisture to the system. Kiawah experienced 16"-20" inches of rainfall over a four-day period, while Mount Pleasant received 27" (Di Liberto, 2015; National Weather Service, 2016). Runoff-swelled rivers, onshore winds, a perigee spring tide, and possibly Joaquin's slowing of the Gulf Stream created tides that exceeded Mean Higher High Water (MHHW) by 2.5 feet (Morrison, 2018; Murphy, 2016; NOAA-Tides and Currents, 2017). Widespread nuisance flooding occurred across Kiawah with approximately 42% of its land surface covered by water at some point (Appendix D). A dynamic tracking of Hurricane Joaquin can be viewed at https://www.nhc.noaa.gov/archive/2015 graphics/al11/loop.shtml.

2016

Hurricane Matthew was a Category 5 storm in the Caribbean but had dropped to Category 1 when it made landfall briefly on October 8th just south of McClellanville. Severe damage from winds and storm surge occurred just south of us on Hilton Head and Edisto islands. The storm tide at 3.5 feet above MHHW in Charleston was the highest since Hugo in 1989 and severe flooding was extensive (National Weather Service, 2017; NOAA-Tides and Currents, 2017). Rainfall on Kiawah was approximately 10 inches over a two-day period. Kiawah also experienced widespread flooding with approximately 65% of the island covered with some water and erosion to its dunes (Appendix D). Matthew's storm surge arrived at low tide. If it had been at high tide, the Charleston area might have experienced a storm tide of 9 feet above MHHW. A dynamic tracking of Hurricane Matthew can be viewed at https://www.nhc.noaa.gov/archive /2016/graphics/al14/loop_5W.shtml.

2017

The record storm surge of Matthew was exceeded the next year by Tropical Storm Irma, the third highest recorded for Charleston. Once a Category 4 storm when it hit southern Florida, it was a tropical storm and 200 miles inland when it damaged the South Carolina coast. Hilton Head, Edisto, and Folly Beach islands were again severely damaged by storm surge with major beach erosion (National Weather Service, 2018). Kiawah also suffered some beach erosion, but for the most part, its sand dunes stayed intact. The storm tide arrived at high tide and peaked at 4.15

feet above MHHW in Charleston. Kiawah's rainfall was approximately 6 inches over a two-day period. Flooding covered at least 73% of the island, prevented travel, and damaged some garages and first floor spaces (Appendix D). A dynamic tracking of Tropical Storm Irma can be viewed at https://www.nhc.noaa.gov/archive/2017/IRMA_graphics.php?product=5day_cone_with_line_and_wind.

SEA LEVEL BASICS

Historical Record

Throughout the history of the Earth, sea levels have risen and fallen by hundreds of feet. At the end of the last glacial maximum 20,000 years ago, the surface of the world ocean was about 350 feet below its present level because so much water was trapped in continental ice sheets. As the Earth warmed and the ice melted, sea level rose, sometimes as rapidly as several feet per century. Of course, during those times, human populations and permanent coastal developments were not an issue as they are today. During the 20th century, global sea level rose at an average rate of 6 inches per 100 years according to tide gauge data (Church and White, 2011). This value provides a modern benchmark for determining whether global sea level rise is currently accelerating as the Earth continues to warm.

Recent Observations

During the last 25 years, there has been an explosion of new, highly accurate observations that document what is happening now. These include satellite altimeter measurements of sea level, sub-surface ocean measurements of temperature and salinity, and satellite monitoring of glaciers and polar ice sheets. The combination of these new data has revealed not only the current rate of sea level rise, but also the relative contribution of ocean warming versus ice melt.

Satellite Altimetry

In 1992, the era of precise satellite altimetry was ushered in with the launch of Topex/Poseidon, a joint mission of the National Aeronautics and Space Administration (NASA) and the French Space Agency. With the National Oceanic and Atmospheric Administration (NOAA) as an operational partner, these observations were continued with the Jason satellites launched in 2001, 2008, and 2016. These microwave radar systems have provided a continuous record of global sea level (black curve in Figure 1) accurate to a fraction of an inch. The satellite data track very well with tide gauge data that was used historically to measure sea level. They reveal that the average global sea level rise during the last 25 years is 13 inches per 100 years – twice the 20th century rate.

Ocean Warming

In 2004, an array of approximately 4000 drifting floats known as Argo was deployed throughout the world oceans. These instruments spend most of their 5-year lifetimes at a depth of 2000 meters. But every 10 days, they rise to the surface and relay their positions and vertical profiles of ocean temperature and salinity before returning to depth. The Argo data document a significant warming of the global oceans, and as water warms it expands. As shown by the red curve in Fig. 1, these data indicate that one-third of current global sea level rise can be attributed to expansion due to ocean warming.

Melting of Glaciers and Polar Ice Sheets

As land-based ice melts, water flows into the oceans, and sea level rises. The increase in ocean mass produces changes in gravity which can be observed. In 2002, a satellite called GRACE (Gravity Recovery And Climate Experiment) was launched, and it operated until 2015. It consisted of two identical spacecraft, one trailing the other by 135 miles. By measuring slight changes in the distance between them, caused by changes in gravity, the mass of the oceans could be mapped as a function of time. These data (blue curve in Figure 1) indicate that two-thirds of current global sea level rise can be attributed to melting ice from glaciers and polar ice sheets. Together, warming and melting account for all of the observed global sea level rise over the last 25 years (green curve in Figure 1) (Leuliette and Nerem, 2016).

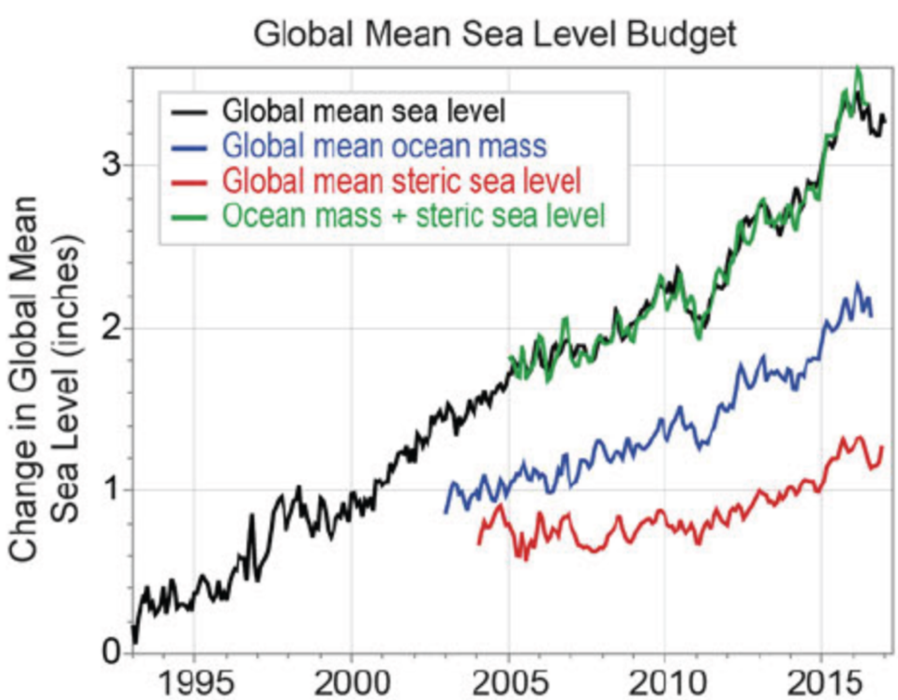

Figure 1. Black curve: Global sea level rise observed by satellite altimetry (13 inches per century). Red curve: Contribution from ocean warming (4 inches per century). Blue curve: Contribution from melting glaciers and polar ice sheets (9 inches per century). Green curve: combination of warming and melting, showing that these two factors fully explain recent global sea level rise. (Leuliette and Nerem, 2016).

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Predicting Future Sea Level

Figure 2 summarizes past sea level rise and shows predictions for the future. Tide gauge data collected during the 20th century give a global value of 6 inches per 100 years. Satellite altimetry indicates that in the past 25 years, the rate has doubled to 13 inches per century. In the future, it is likely that sea level rise will continue to accelerate, mostly due to increased melting of glacial and polar ice sheets in Greenland and Antarctica. It is difficult to capture all the factors contributing to ice melt. As a result, there is uncertainty over the exact rate of future sea level rise. This uncertainty led the 2017 U.S. National Climate Assessment to describe six sea level rise scenarios ranging from "low" to "extreme" (USGCRP, 2017.) In the "intermediate" scenario, global sea level with respect to 2000 is expected to rise 1.1 feet by 2050 and 3.3 feet by 2100. However, sea level rise is not uniform around the globe. There are regional variations in the rates of sea level, and many locations around the US, including the southeast Atlantic coast, are experiencing faster rates of sea level rise than the global mean. It is important to understand that while projections estimate sea level rise values associated with specific dates, it is a continuous process and impacts of varying degrees will be experienced prior to specified dates.

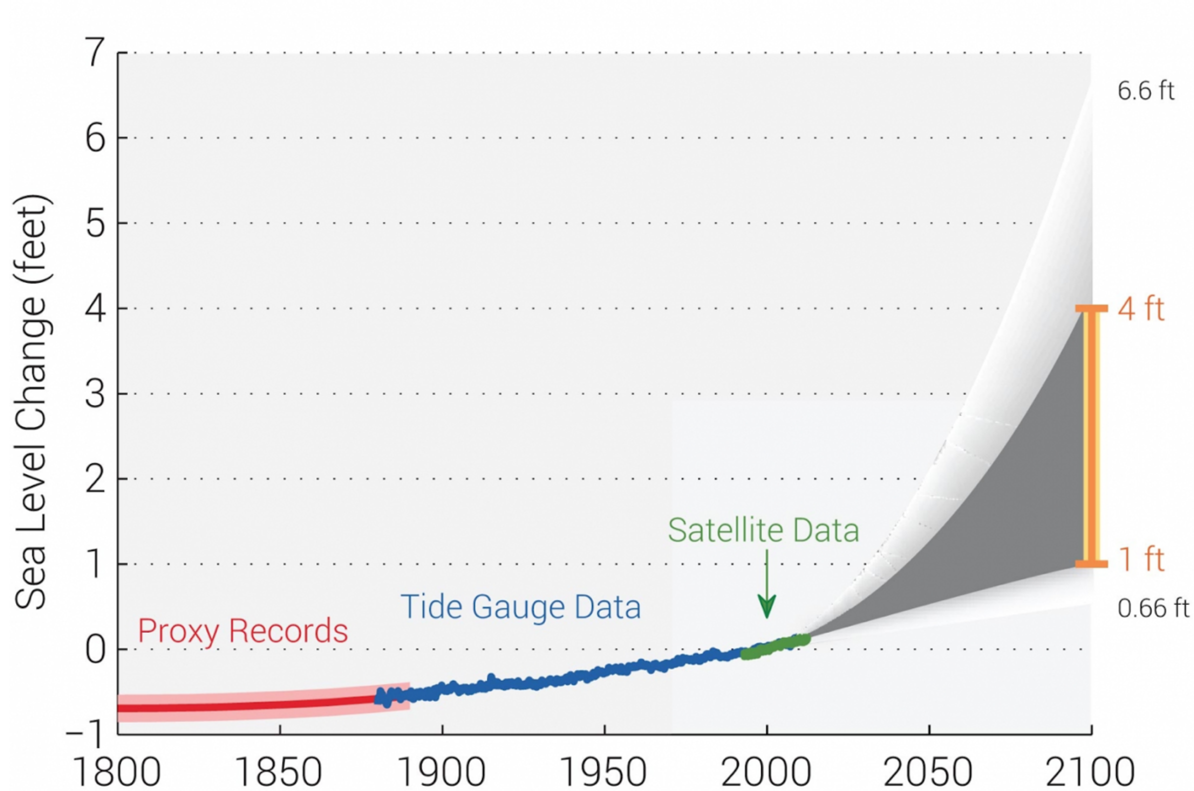

Figure 2. Estimated (proxy), observed (tide gauge and satellite), and possible future global sea level rise from 1800 to 2100, relative to the year 2000. The orange line shows the most likely range of sea level rise

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by 2100. The large projected range reflects uncertainty about how glaciers and ice sheets will react to the warming ocean (Parris et al., 2012).

<u>Charleston Sea Level</u>

Charleston's tide gauge at the Custom House pier on the Cooper River, maintained since 1921, shows that sea level has risen at an average rate of 13 inches per century through 2018 (Figure 3). This rate is higher than the global average for the 20th century mostly because of local subsidence -- the sinking of land due to a continuing response of the Earth's crust to the last period of glaciation, together with natural compaction of coastal soil. One estimate of the subsidence is 4 inches per century, obtained for the period 1996-2004 when NASA maintained a GPS station at the Charleston tide gauge (JPL, 2017). Although the long-term subsidence rate at Charleston is not well known, it is likely small enough to be only a minor factor in the context of global sea level change which is projected to rise by several feet by 2100.

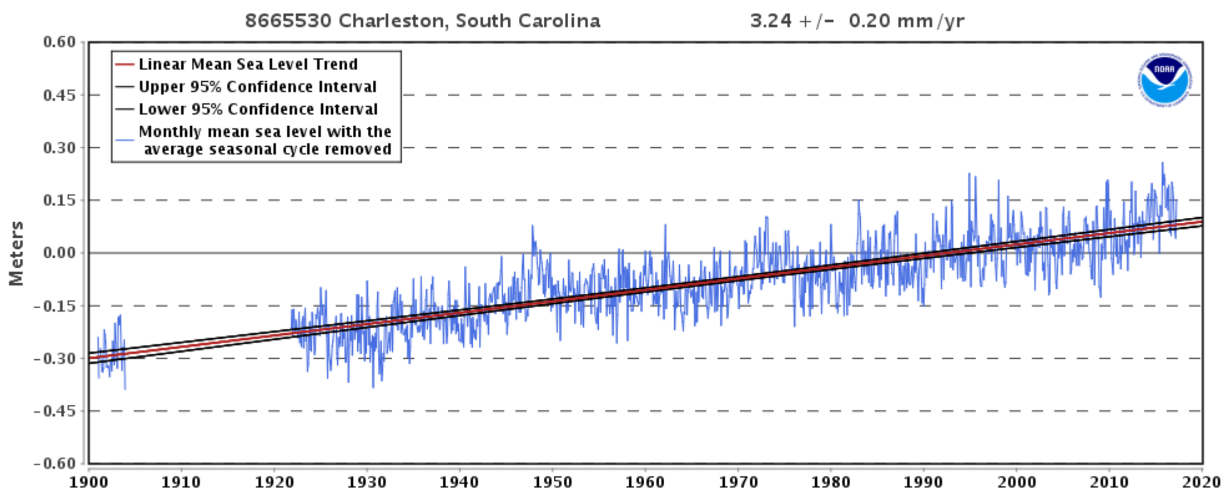

Figure 3. Monthly mean sea level measured by the NOAA tide gauge at Charleston, SC. The trend is 13 inches per century (NOAA-Tides and Currents, 2017).

Despite the nearly 100 years of water level data at Charleston, it is not possible to determine whether sea level rise is accelerating. The record contains too much "noise" -- inter-annual and inter-decadal sea level variations driven by changes in wind and ocean currents. In fact, a minimum of 50 years of data is necessary just to give a stable value of the rate of rise at any single tide gauge station (R. Cheney, personal communication). However, there is a different measure that can reveal what is happening over shorter time periods, namely the annual number of tidal flood days. The National Weather Service defines minor or "nuisance" flooding at the Charleston gauge as 1.25 feet above mean higher high water (MHHW) when storm drains overflow and roads are temporarily under water (Sweet and Mara, 2016). This level of flooding is occasionally caused by rain and wind, but in recent years, "sunny day" floods have become the more dominant problem.

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Sunny day flooding occurs during new or full moons when the monthly orbit of the moon aligns with the sun and the Earth. The combined gravitational pull of the sun and moon then exerts a greater force on the Earth's oceans, and the tides are higher than normal, creating "spring" tides (having nothing to do with the season - the water simply "springs" up). Several times a year, when the new or full moon is closest to the Earth (at its perigee), the gravitational force is even greater, and larger perigean spring tides result. These have come to be known as "king tides".

The problem for Charleston and other coastal cities is that the number of sunny day floods is increasing. In the 1970s there were only about 2 days each year with nuisance floods in Charleston, but their frequency has increased dramatically since 1990. In 2015, NOAA reported that Charleston had 38 days of sunny day flooding, and 50 days of sunny day flooding in 2016 (Behre, 2018; Morrison, 2018). It is predicted there could be 150-180 days per year of sunny day flooding by 2045 (City of Charleston, 2015; Runkle et al., 2017). Figure 4 shows the past record together with projections into the future.

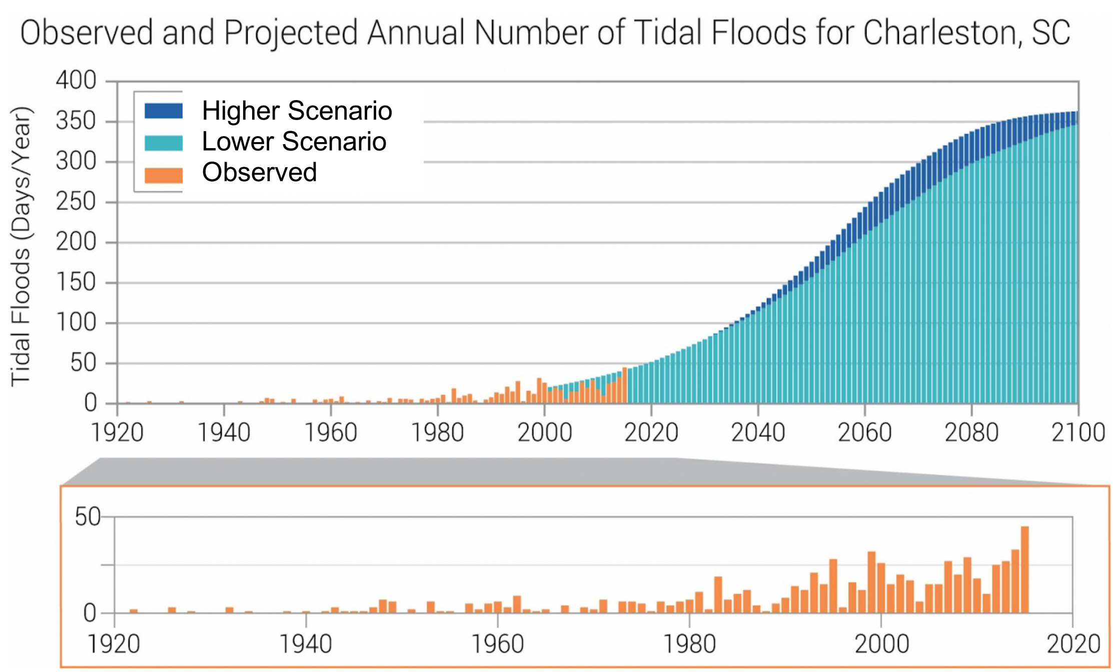

Figure 4. Number of tidal, "nuisance" flood days per year for the observed record (orange bars) and projections for two possible futures: lower scenario (light blue) and higher scenario (dark blue) per calendar year for Charleston, SC. (Melillo et al., 2014).

This increase in Charleston flooding frequency cannot be attributed solely to global sea level rise, which would only amount to about 3 inches between 1990 and 2016. Local fluctuations are also a factor. For example, the Charleston tide gauge record indicates that annual mean sea level increased 4.5 inches between 2011 and 2016. Researchers have attributed this rapid rise along the southeastern coast of the U.S. to three additional factors: a slowing of the Gulf Stream, shifts in the North Atlantic Oscillation, a major North Atlantic weather pattern that affects winds and currents, and the effects of El Niño climate cycles (Hu and Bates 2018; Morrison 2018; Sweet et al. 2017; Valle-Levinson et al. 2017). This was evidently enough to cause the abrupt increase in flooding days during the period. Still, over the longer term, global sea level rise will dominate, and coastal flooding will become more frequent.

Kiawah Island Sea Level

There is no tide gauge on Kiawah, but if there were, it would be virtually the same as Charleston's for monthly means and longer. This is because the tide, land subsidence, and sea level rise are all large-scale phenomena. Evidence of this is provided by the tide gauge record at Fort Pulaski, GA, maintained since 1935, which is virtually the same as Charleston's. But even though Kiawah is subject to the same sea level as nearby areas, the impact of sea level rise must be assessed separately for each coastal community based on its own unique beach dynamics, river/marsh conditions, and upland topography. We can consider each of these environments separately for Kiawah:

Beach

Kiawah's beaches and dunes are healthier than those of most barrier islands in South Carolina because the island continually accretes (gains) sand. The dominant longshore current is toward the southwest, so sand from Folly Island and sediment from the Stono River keep Kiawah's beach well supplied. Even if Folly Beach were to stop renourishing its beach or build a jetty to reduce its beach erosion, the Stono River would continue to deliver sand for decades (L. Sautter, personal communication; W. Doar, personal communication). Short term erosion is unavoidable, such as occurred during 2015-2017 owing to an unprecedented rain event, a hurricane, and a tropical storm. But in the long term, Kiawah's dunes should continue to build horizontally toward the ocean. Vertical growth is also critical to protect coastal structures, so it may sometimes be necessary to take proactive measures to promote dune development.

Kiawah River and Salt Marshes

The river side of Kiawah is dominated by *Spartina* salt marshes that can respond to increases in sea level in three ways (J. Leffler, personal communication). (1) If the sediment load of the water is sufficient, the marsh can accrete new sediment and rise with the rising sea levels. Usually sediment deposition comes from solids transported by rivers into the estuary. Since the Kiawah River does not drain any significant watersheds, it is questionable whether there will be sufficient sediments to grow the marshes in response to rising water. (2) The second scenario is for the salt marsh to migrate landward. Its ability to do so depends on the local geology, topography, hydrology, existing plant community, and most importantly human structures. This is the most likely scenario for Kiawah's salt marshes if their paths are not obstructed. However, hardened shorelines that protect homes and infrastructure will prevent the marshes from migrating. (3) This results in the third option, the drowning of the salt marshes in the rising waters and conversion to mudflats at low tide and open water at high tide, with long term consequences for the ecosystem and coastline protection.

Maritime Forest and Uplands

Kiawah is a relatively young island compared to other areas of the coast. The result is that Kiawah is relatively flat. Most of its roads meet the County minimum elevation of 2.4 feet above MHHW, and 73% of the island has an elevation of 4 feet or less above MHHW (see Appendix E). By comparison, Hilton Head Island is a much older island and its upland areas are more elevated than Kiawah's. Currently Kiawah does not suffer nearly as much from sunny day flooding as Charleston does. But the October 2015 rain event associated with Hurricane Joaquin and September 2017 storm surge during Tropical Storm Irma provided dramatic examples of what could be in store on a more regular basis if sea levels rise as expected in the future.

Figure 5. Tropical Storm Irma in September 2017 produced a 4-ft above MHHW storm surge. Because it coincided with high spring tide, many of Kiawah's streets flooded.

Predictions for Kiawah Island

In 2017 researchers from the Union of Concerned Scientists (UCS) published an analysis predicting how rising seas will impact coastal communities throughout the U.S. (Dahl et al, 2017). They first looked at tide gauge data for the period 1996-2015 (chosen to include the 18.6-year tidal cycle) to identify the water level that is exceeded 26 times per year. For Charleston, this turned out to be the same 1.25 feet above MHHW that the National Weather Service has defined as minor flooding. They then incorporated coastal digital elevation models (DEMs) derived from airborne LiDAR systems (Light Detection And Ranging). Using various scenarios for projected sea level rise, they determined when each coastal community begins to suffer from "chronic inundation", which they defined as 10% of the area being temporarily flooded at least 26 times per year.

The results were sobering. Coastal areas with known flooding problems fared the worst, such as Louisiana, Florida Keys, Maryland Eastern Shore, and New Jersey. But many other coastal communities also fared poorly, including those in South Carolina. Assuming an intermediate rate of sea level rise, Edisto and Kiawah-Seabrook may begin to suffer from chronic inundation by 2035. By 2060, the number of affected South Carolina communities grows to 12 and includes Johns Island, James Island, and Charleston. Looking ahead to 2100, virtually every South Carolina coastal community joins the list.

In a follow up study Dahl et al. (2018) released an economic impact analysis of projected nuisance flooding from rising sea levels on real estate values. Since long term home values have great significance not only for owners but for the tax base of the community, the authors cited a sea level rise scenario somewhat higher than the one previously used. By their published study, Kiawah-Seabrook may have 277 homes valued at $277 million suffering from chronic inundation by 2030 and 1,562 homes valued at $1.3 billion by 2045. However, if we use the intermediate scenario as we have throughout this Kiawah specific report, according to their calculations, by 2035 Kiawah-Seabrook may have 200 homes valued at $158 million faced with chronic inundation, and by 2060 that number could rise to 1,488 homes valued at $1.2 billion (Dahl, personal communication).

Members of the Committee met with the NOAA scientists who provided the inundation data that the UCS researchers employed, held telephone discussions with the lead author, and participated in a teleconference with several of the authors. Since the UCS researchers were looking at the entire U.S. coastline, the resolution of the mapping data they had to use is less than what we now have available for Kiawah (Appendix D). That could have led to some minor errors in accuracy. Their ranking of Kiawah-Seabrook as the most vulnerable of all South Carolina communities is misleading because they used US Census Bureau tracts to define communities. Since the Kiawah-Seabrook tract is totally composed of barrier islands, no upland on the mainland is included. This means that their percent inundation calculations are higher since there is no inland, higher land to offset the low coastal terrain. Despite these minor details, the Committee can find no fundamental errors in their analyses and conclusions.

There are a number of publicly available, online sea level viewers that enable users to create maps showing how the flooding may progress over time. The one with the most detail locally has been developed by the city of Charleston and can be accessed at http://gis.charleston-sc.gov/interactive/slr/ (City of Charleston, 2017). The baseline map shows the water line at MHHW. Sea level can then be added in 0.5-foot increments. To simulate the predicted extent of chronic flooding by 2060, add 3 feet to the MHHW level, 1.25 feet for the minor flood level plus 1.75 feet for sea level rise under the intermediate projection. The inundation maps found in Appendix D have been produced by Dr. Norman Levine and Lucas Hernandez of the College of Charleston and are the highest resolution, i.e. most detailed, maps available.

WEATHER TRENDS AND PROJECTIONS

Weather is always a complicated subject and is discussed further in Appendix E. We are relying on the very recently released *Fourth National Climate Assessment* because this is probably the most up-to-date, thoroughly reviewed, and authoritative publication on weather trends and projections (USCGRP 2017). Over the past century there has been a national upward trend in both temperature and precipitation, although significant differences exist among regions of the country. Charleston has seen increases in both temperature and precipitation for the period 1901-2015 (SCDNR-SCO 2018).

The Southeast is projected to warm over the coming decades, although less than other regions, while changes in annual precipitation are expected to be minor. However, expected changes in how this rain falls will increase the frequency of droughts followed by intense rainfall events. North Atlantic hurricanes are not expected to increase in number, but models and theory suggest that they will be larger and slower-moving with increases in associated precipitation (USCGRP 2017; Petersen, 2018).

SEA LEVEL RISE SCENARIOS

There is so much evidence that sea levels are rising, and will almost certainly accelerate in the coming decades, that the questions become, "how fast will oceans rise?", and by "how much?". Many factors come into play when trying to predict the future, how can one begin planning? The widely accepted approach is to consider a variety of scenarios and select ones to act upon by the amount of risk a community is willing to accept. Figure 6 depicts several global sea level rise scenarios derived from work of the U.S. Corps of Engineers and the National Oceanic and Atmospheric Administration and adopted by the City of Charleston (City of Charleston, 2015; Marcy and Jackson, 2016; Williams and Cabiness, 2017). The "high", "intermediate high",

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“intermediate”, “low” example NOAA scenarios are derived from a combination of emissions scenarios and assumptions about ocean warming and ice loss. “Scenarios are trajectories of environmental change for the purpose of risk and vulnerability assessment to inform the development of robust adaptation options. They are not predictions or projections of what will happen and are not formed under the assumption of reducing uncertainty” (Marcy and Jackson, 2016).

Our Committee reviewed several scenarios developed by different groups and feels comfortable in working from similar scenarios being used by the City of Charleston. We also have chosen to follow NOAA’s Intermediate High scenario. Lower ones either are just projections of current trends or do not consider the melting of land-based ice sheets. The Intermediate-High scenario model looks at the historical relationship between temperature and ice loss (Dahl, personal communication). It incorporates moderate melting ice but does not go as far as the High scenario that assumes massive ice melt. We also have chosen to consider 30-year time periods, the common length of a home mortgage, and the 50 year expected life of community infrastructure like roads, fire stations, or municipal buildings. Notice that there is a box around the point approximately 50 years out along the Intermediate High scenario. This brackets a sea level rise at that time of about 1.5-2.5 feet. The range acknowledges uncertainties in the future. A 1.5-foot increase can be used to plan for short-term, less vulnerable, lower risk investments, that can be changed as needed, such as a parking lot. The 2.5-foot increase can be used in planning for more critical, longer term, high risk investments that are difficult to change, such as emergency routes and public buildings.

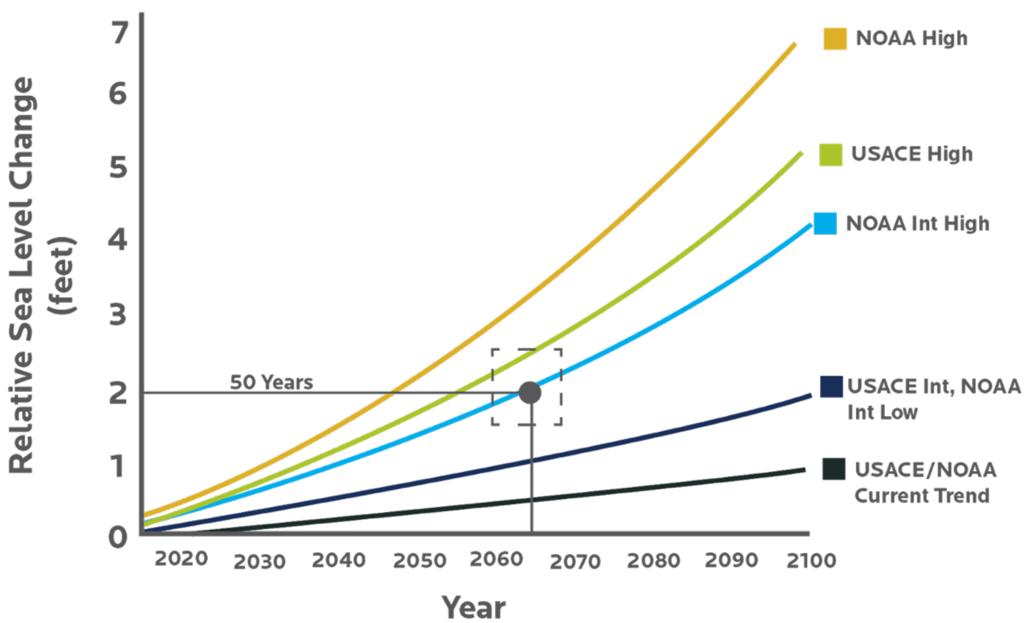

Figure 6. Possible sea level rise scenarios. The Committee chose to use the Intermediate High scenario for planning purposes. The bracketed box signifies a range of levels applicable to low risk versus high risk adaptation considerations (Marcy and Jackson, 2016; Williams and Cabiness, 2017).

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The choice of scenarios is something that should be reviewed every four years as new research is developed, and the choice for community planning adjusted as justified. For example, the National Climate Assessment that was just released in December 2017 has added another higher rate scenario based on observations that large ice sheets seem to be melting faster than previously anticipated. Other current research is seeking to explain why sea levels along the southeast coast are rising faster than the global average.

VERTICAL CONTROL DATUMS

When planning for flooding and sea level rise one spends a lot of time thinking about elevations. How high are the tides? A king tide? A storm surge? An inundation level? What is the elevation of the roads? Of Town Hall? Of the drain pipe to the river? Of my home's garage? What does the number on my home elevation certificate mean? All measurements of elevation must be referenced to some standard to permit comparisons. These standards are called datums. Unfortunately, there are a variety of different datums in use and all are involved in evaluating the impacts of sea level rise. For example, the elevation datum used to reference the height of your home is different from the datum used to reference a storm surge. In Appendix F we discuss the different datums, how each is used, and how to convert measurements from one to another.

Throughout this report, for clarity, the Committee has chosen to use one datum and to convert measurements referenced to a different standard to that chosen datum. We are referencing all elevations to the Mean Higher High Water (MHHW) datum based on the Charleston tide gauge station (Appendix F). MHHW is the average of all the higher of the two daily high tides over a period of 19 years. It is essentially the boundary of salt marsh where it meets dry land. This is the average range of our current high tides every day. Flooding occurs when the sea water rises above this boundary and spills out across the landscape either by unusually high king tides, a storm surge, or in the long run by sea level rise. It is therefore the most meaningful datum to use when planning pragmatically for flooding and is used as the reference for the inundation maps in Appendix D.

SCOPE OF THE REPORT

In the coming decades Kiawah Island will, as will all coastal communities, face existential challenges from sea level rise. But we don't have to wait that long. In the past three years we have experienced island-wide flooding from an extreme precipitation event and from storm surges. These episodes are likely to become more frequent. In studying actual and potential flooding on Kiawah, our Committee has focused on four phenomena:

1. **Tidal flooding** is sometimes referred to as nuisance flooding or sunny day flooding. According to the National Weather Service in Charleston, it occurs when unusually high tides exceed MHHW by 1.25 feet causing flooding even in the absence of any rainfall or storm event. In 2016 Charleston experienced 50 days of tidal flooding. Several factors mentioned earlier have contributed to the increase in tidal flooding along the Southeast coast beyond the longer-term effects of sea level rise.

2. **Storm Surge**, as the name implies, is an abnormal rise in seawater level during a storm, measured as the height of the water above the normal predicted astronomical tide. The surge is caused primarily by a storm's winds pushing water onshore. The amplitude of the storm surge at any given location depends on the orientation of the coast line with the storm track, the intensity, size, and speed of the storm, and the local bathymetry. The rise due to the low atmospheric pressure of the storm is generally minimal.

   Since wind generated waves ride on top of the storm surge, and are not included in the definition, the total instantaneous elevation may greatly exceed the predicted storm surge plus astronomic tide. It is potentially catastrophic, especially on low lying coasts with gently sloping offshore topography. In addition, extreme precipitation can add to the height of the water, especially in estuaries receiving floodwaters from rivers or the surrounding land. A **Storm Tide** is the total observed seawater level during a storm, resulting from the combination of the astronomical tide, the storm surge, wind-blown waves, and precipitation (Figure 7).

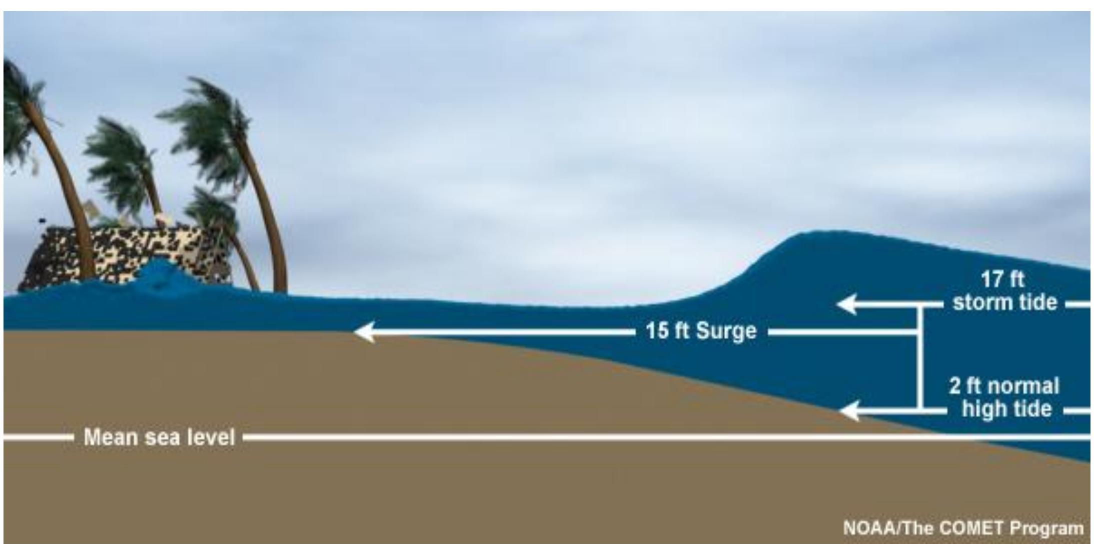

Figure 7. Total seawater height = Astronomical tide + Storm surge + Wind generated waves + Rainfall. (National Hurricane Center, 2018)

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3. **Extreme precipitation events** can be associated with tropical storms or may occur when other meteorological fronts come together and often stall or move slowly over an area. Warmer air masses, as are predicted in the coming decades, increase evapotranspiration and can hold greater volumes of water. Although droughts of various severity may result, when rain does come it is projected to more frequently be in the form of downpours, sometimes extreme. We experienced flooding from such an event in 2015.

4. **Sea level rise** is a documented phenomenon that physical laws project will accelerate in the coming decades, as was discussed earlier. Not only is it a challenge in its own right, but it will exacerbate all of the other phenomena. Normal tides and storm surges will start from a higher baseline. Higher water levels in the Kiawah River and the ocean means that precipitation stormwater will drain more slowly as the time period of daily lower tidal water decreases.

All four of these phenomena can also occur simultaneously. Heavy precipitation from a tropical storm is often accompanied by a storm surge causing flooding from both the sky and the ocean. Both phenomena can have much more severe impacts if they coincide with high spring tides. For example, Hurricane Matthew actually had a higher storm surge but arrived during a low tide while Tropical Storm Irma raised waters higher because it arrived on a high spring tide.

The Committee focused on these phenomena as it considered our vulnerabilities, possible ways of mitigating the impacts, and how to adapt to these realities. When considering how to mitigate and adapt to tropical storms, we restricted discussions to Category 1, 2, or 3 hurricanes. When it comes to a Category 4 and 5 storm making landfall at or immediately south of Kiawah, the only reasonable action is evacuation and picking up the pieces afterward. The destruction to Kiawah would be catastrophic and the Committee did not address issues associated with events of this magnitude.

It is widely acknowledged that there is a lot of uncertainty about the rate of sea level rise. Projections are just that. The rate could be slower or faster. The Committee believes that this report is only a first step and its assessments and recommendations should be revisited on a regular schedule. Kiawah’s approach should be a monitoring program of actual changes occurring on the island, and also a monitoring of new information and tools as they become available. With these in place, Kiawah can adjust the magnitude and rate of its mitigation and adaptation programs as warranted. Even with actions taken to prevent damage from flooding and sea level rise, adaptation will necessarily play an important role. Interruption of normal activities and damage from water events have been occurring and will continue to occur. Rapid draining of flooded areas and resilience to flood damage are key to quick recovery adaptations.

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The next section, “Assessments, Concerns, and Recommendations” is organized by topic in a standard format that is comprised of six parts:

1. **Significance** explains why the topic is important for property owners of Kiawah and the entities that represent them.
2. **Current Status on Kiawah** explores factual information about that topic and how it specifically applies to Kiawah.
3. **Concerns** describes the vulnerabilities that the Committee has identified concerning the topic and questions it has about how it might address issues of flooding and sea level rise.
4. **Recommendations** are suggestions, some general and some specific, from the Committee about how Kiawah could address the concerns raised about perceived vulnerabilities.
5. **Responsibilities and Partners** acknowledges that governance on Kiawah is split among several entities. The Committee makes suggestions about which entity must, should, or could take the lead in implementing some of the recommendations, and how different entities could work together to achieve common goals.
6. **Recommended Reading** or **Additional Information** is where the Committee lists additional resources not directly referenced in the text.

At the end of the report are a series of appendices. These contain a variety of information that is informative but was considered too detailed to place directly in the main body of the report because it would disrupt the flow for the reader. For example, of particular note, Appendix D presents map models depicting inundation of Kiawah Island twice daily at high tide under several sea level rise scenarios. The models also can be used to indicate inundation of the island as storm surges exceed MHHW. They were produced by Dr. Norman Levine and graduate student Lucas Hernandez at the College of Charleston under a grant to the Charleston Resilience Network from the South Carolina Sea Grant Consortium. The models project the land covered by water resulting from either tidal flooding, a storm surge, or from sea level rise, in one-foot intervals. Roads and buildings are shown, permitting one to assess some of the problems to expect given the current infrastructure and property structures. For reference, the storm surge from Irma was a little over 4 feet in Charleston harbor. According to these models, that 4-foot surge would be predicted to cover 73% of the island’s land surface.

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ASSESSMENTS, CONCERNS, AND RECOMMENDTIONS

STORMWATER AND NUISANCE FLOODING MANAGEMENT

Significance*:* Over the past three years Kiawah Island has experienced several major flooding events - some causing temporary, significant flooding, damage to homes, and disruption of services. In the coming decades we can anticipate more frequent and occasionally more severe flooding due to sea level rise and extreme precipitation events, including nuisance tidal flooding, storm surge, and combinations of these situations. It is important that we understand how well the island's current infrastructure and maintenance plans are responding to these challenges and identify changes that offer the best prospects for improving our stormwater management system.

Current Status: Compared to most other barrier islands, we are in a relatively good position to address these future challenges. There are two major components of Kiawah's Stormwater and Nuisance Flooding Management: (1) KICA's interconnected pond system, and (2) the island's terrain contours and drainage pipe system that carry water to the ponds or to the marsh.

The extensive pond system is the centerpiece of Kiawah's stormwater management system. It was developed for stormwater management related to rainfall events. The majority of the island's drainage system moves water into Kiawah's 125 ponds, most of which are interconnected by underground pipes. Water moves from pond to pond primarily by head pressure until it leaves the system through outfalls to the river or marsh. This network creates the potential for retaining a very significant amount of stormwater runoff. Kiawah's drainage system can accommodate 10 inches or more of rain falling within 24 hours, which is the equivalent of a 100-year storm, and is twice the capacity of typical storm system ponds in most developments. However, even this capacity can be stressed as observed during the 2015 storm associated with Hurricane Joaquin which dropped 18.25 inches of rain on Kiawah in a 4-day period (National Weather Service, 2016). The system's capacity was also strained because unusually high tides prevented the system from draining quickly.

It is important to understand that while the pond system is very effective in dealing with most precipitation events, no stormwater pond system can manage flooding from storm surges or increasingly frequent nuisance tidal flooding resulting from rising sea levels. No pond has the capacity to hold the ocean! Following a storm surge or tidal flooding, the critical requirement of a stormwater system is to drain the runoff quickly. In the future, higher tides will also decrease

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the effectiveness of the pond system by slowing the flow of water from the ponds into the outfalls and out to the estuary.

Kiawah Island has two major drainage basins and several smaller ones. Most of the ponds west of the Vanderhorst Gate flow into the river through the Beachwalker/Inlet Cove outfall. The other major basin drains much of the area between the Vanderhorst Gate and Canvasback Pond through an outfall at Canvasback Pond, near the fire station. Other smaller drainage basins include Rhett's Bluff, Egret Pond, The Preserve, and Ocean Park. The Sparrow Pond drainage basin now includes The Timbers. Some areas such as Inlet Cove have multiple small street drains that flow directly into the marsh. The two main pond systems have outfall control structures with manually operated gates and flap valves that are used to drain ponds before major storms. Lowering water levels creates capacity in the ponds for storm runoff and helps prevent saltwater intrusion into the ponds. Because the interconnected pond system is so large and has few outfalls (75% drains through two outfalls), it can take days to meaningfully lower water surface elevation. Water can only drain by gravity from the pond system through the outfalls when the tide is low enough. Normally, except at very high tides, this is not a problem. But as sea level rises in the future, the length of time daily when the tide is low enough for outfall drainage will decrease. It will therefore take longer for the pond system to drain.

KICA clears and maintains the pond piping and gates. New piping is often required to replace rusted out, disintegrating pipes. KICA is working with STANTEC, an engineering consulting firm, to improve the stormwater management system. Rain that falls at the Vanderhorst Gate travels three miles through ponds and pipes before reaching an outfall to the river. KICA identified a site for a new outfall which will reduce the distance, and thus the time required, for water to flow out of the main western basin of the stormwater system. Other new outfalls may be added later. KICA is designing an automatic control system to open and close gates and flap valves with the tides. The control operates remotely, has its own power system enabling it to operate when power is disrupted, and can be programmed a year in advance. The first automated control unit will be mounted on the Beachwalker/Inlet Cove outfall in 2019. It will enable KICA to exercise better control over the water levels in the ponds. KICA expects to add automatic controls to the Canvasback drainage basin next. In addition to being preprogrammed to open and close with tides, these automated outfall gates and flaps can be controlled remotely from off the island during major storms. This improves KICA's ability to move stormwater out of the drainage system at low tide and prevents recharge into the pond system during high tide. Written standard operating procedures to maximize the effectiveness of the system are being updated.

While the pond system has a large capacity to efficiently handle stormwater from rain events, there are some challenges getting runoff water into the ponds. Water from roads, homes, and

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yards is carried into the pond system by the contours in the island's terrain and by drainage pipes. On occasion, drainage pipes, swales, and ditches become clogged or filled with sand, pine straw, mulch, and yard debris. These clogs cause localized flooding, notably along Governor's Drive and the Parkway, both major thoroughfares. In some areas, private driveways or landscaping obstruct the flow of water through swales, thereby contributing to flooding.

Roadways are designed to drain water from the road and to minimize negative impacts on nearby property. The drainage infrastructure associated with KICA's roadways is an important part of Kiawah's island-wide drainage infrastructure. In many areas road flooding collects water that would otherwise flood private property. KICA works to maintain properly functioning drainage. Regular maintenance can minimize road flooding and enable rapid draining and recovery following a flood.

We are fortunate to have significant dune structure that usually prevents seawater from flowing inland from the beach side of the island. We are also fortunate to have wide, healthy marshes on the river side of the island that prevent shoreline erosion by absorbing a significant amount of incoming wave energy. However, with higher water from rising tides and storm surges, ocean water can enter the island. In 2017 Tropical Storm Irma water flowed onto the island from the river and marshes, damaging roads and filling ponds with overwash.

Concerns:

1) Over the long term as sea level rises, higher tides starting from a higher mean sea level will impede the ability of the island's gravity driven drainage system. Will elevation of pond piping be required in the future? If so, will drainage into the ponds over land and through drain pipes still function? Will the pond banks have to be extended outward in order to create sufficient water storage capacity for stormwater? Will higher pipes create an aesthetic problem? Will some pumps be required in the future to force water from the pond system out into the marshes and river?

2) Our pipes are old and deteriorating and require increased maintenance. Sand and debris blockage is an unending problem.

3) Some ponds need protection from overwash during storm surges and nuisance tidal flooding. This may require professionally engineered solutions such as the construction of berms or limited seawalls.

4) Will we devote adequate resources to maintain our stormwater system given the challenges the system faces?

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5) When road work is done are efforts made to maintain the original design of the roads, e.g. raised in the middle to drain to sides, or raised on sides to drain to center? Will we need some new concepts for roadway drainage maintenance in order to keep pace with long-term sea level rise?

6) Can we reduce clogged drains by finding substitutes for pine straw and loose mulch? How can we ensure KICA’s drainage easements and swales do not become blocked by landscaping and the careless or purposeful discard of yard wastes?

7) In those areas with storm drains that go directly from roads into the marsh, will higher tides and storm surges cause seawater to backflow through those pipes, flooding roadways and properties?

Recommendations:
1) Ensure that stormwater management planning addresses flooding problems resulting from extreme precipitation, tidal nuisance flooding, and storm surge, all of which will be exacerbated by sea level rise in the coming decades. Thoughtful planning which considers sea level rise can avoid costly retrofits. Concerns to consider include: composition, size, location, and elevation of pipes; number and location of outfalls; pond bank height; pond protection from storm surge; optimal depth and width of ponds for water storage; pumps for moving water through and out of the pond system.

2) Adapt our pond water-flow management, including outflow gates and valves. Identify the best strategies for current daily and major storm management. Develop incremental strategies to address sea level rise. Identify future tipping points as sea levels change and plan in advance for how those new conditions will be addressed.

3) Provide adequate resources for pond infrastructure maintenance and improvements, including inspections and regular preventive maintenance designed to clear pipes and outfalls of sand and other obstructions.

4) Support KICA’s plans to construct additional outfalls so ponds drain faster.

5) Support KICA plans to install automated flood gates and outfalls. Develop written standard operating procedures (SOP) to sync outfall gates and check valves to the tide cycle. The SOP should cover remote operations during major storms.

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6) Study high resolution flooding hazard maps provided by the College of Charleston to identify critical locations where marsh and river waters can breach and flow onto the island. Engage engineering professionals to develop strategies such as the construction of berms or seawalls to minimize or prevent these breaches. Relatively modest engineered solutions in critical areas may return significant benefits by preventing seawater damage to roads or overwash into ponds and by protecting adjacent neighborhoods.

7) Set priorities for near term and for 30-year and beyond timeframes and ensure the work is timely. Certain infrastructure will have to be adapted to sea level rise, but the rate of adaptation can be modified as the actual rate and effects of sea level rise become clearer.

8) Reduce clogging of drainage grates and pipes by identifying and utilizing aesthetically acceptable alternatives to pine straw and other loose mulch on slopes along roads, swales, ponds, and other parts of the drainage system.

9) Use a variety of efforts such as education, inspections, and rules enforcement to discourage contractors, landscapers and property owners from placing debris or other material in the ponds, swales, ditches, and drains.

10) Utilize detailed analyses of the College of Charleston mapping models at their highest resolution (1 m^2) when planning short-term and 30-year or more work on major roads and adjacent properties in order to anticipate and minimize drainage issues.

11) Explore the island for locations that could also serve as temporary runoff storage areas during heavy precipitation events, to reduce roadway flooding.

12) Encourage the use of Low Impact Development such as increased percentage of pervious surfaces, rain gardens, swales, and plantings, especially in large areas such as parking lots. Enforce such measures by codes or requirements.

13) Eliminate or minimize flooding on streets, particularly in major intersections by using regular maintenance and improvements. Explore selective recontouring to improve drainage in problem areas.

14) Organize neighborhood strategy groups to address local flooding caused by extreme weather events and sea level rise challenges. Provide education and technical advice for property owners about the logic and options to address problems.

15) Evaluate installing back-flow preventing check valves on drain pipes that carry runoff to the marsh in order to prevent high tides and storm surges from forcing water up through stormwater drains.

16) Ensure that Kiawah personnel have good ongoing access to College of Charleston mapping models and the skills to use the models for work on Kiawah.

17) Employ an Adaptive Management approach by thoroughly reviewing the functioning of the stormwater system on a regular basis and after every major storm event, and if necessary, modifying procedures accordingly.

Responsibilities and Partners:

- The Kiawah Island Community Association has primary responsibility for (a) the stormwater management system, including ponds, drains, and outfalls and (b) the roadways behind the main gate and certain other neighborhoods, including proper storm drains and pipes and drainage contouring along the roadways.
- The Town has responsibility for our new Town Hall and the private roads on that property, the roundabout, Beachwalker Drive, and the Parkway to the main gate along with their drainage systems.
- The Town has responsibility to promote good practices through education, by networking with other communities and government entities, and by developing ordinances where appropriate.
- The Architectural Review Board has responsibility to assist in accepting, promoting, and requiring designs that better address flooding issues.
- All property owners have responsibilities to increase the use of Low Impact Development including increased use of pervious surfaces in new construction, significant re-working of existing facilities and landscaping, and consciously working to reduce practices that worsen flooding.

What has been excluded from our considerations: Cassique is not included because it is not part of the Town or KICA. All other Town and KICA properties are included unless the infrastructure is maintained by a private entity. The Committee has not explored flooding adaptation and mitigation in those areas.

Recommended Readings:

Appendix G contains additional information on stormwater management.

ROADS INFRASTRUCTURE

Significance: Roads and bridges that dependably allow vehicular movement are essential for quality of life and for public safety. Whenever practical, considering the safety of first responders, emergency services must be able to reach residents, visitors, and workers in a timely manner. Island roads and bridges that maintain their reliability during storm events or quickly recover after the event are very valuable assets.

Current Status: KICA owns and maintains 60 miles of roads, almost all behind the main gate, but also including some regimes outside the gate such as Inlet Cove and RiverView. Other regimes may be added as development is completed. Kiawah Island Golf Resort owns Sanctuary Drive, the road leading to the Sanctuary. The Town is responsible for the Parkway from the Freshfields traffic circle to the main gate, including the bridge and causeway, and for Beachwalker Drive to the County park. Most side roads, driveways and parking lots are private, belonging to KICA, regimes, the Resort, the Developers, or others. As of January 1, 2017, KICA was no longer required to accept any roads and additional infrastructure from the Developer. Currently, KICA is developing an inspection process to review and evaluate roads and other infrastructure built by the Developer. As of January 1, 2017, any infrastructure built by the developer will be inspected by KICA before it is accepted.

The Kiawah Island Parkway was built in 1976. It and many of Kiawah's roads were designed by Thomas & Hutton Engineering. Charleston County Public Works reviewed and approved the design. At that time all County roads were required to be elevated, at a minimum, to 6.0 feet above the NGVD29 datum, sometimes referred to as MSL (see Appendix F). Since then, the County has raised the standard to 6.5 feet above NGVD29. These values translate to 2.4 feet and 2.9 feet above MHHW (Appendix F). Currently Kiawah has a few segments of roads below the original 6.0 feet County standard, and several additional areas below the 6.5 feet level. Normal, highest spring tides may be 1.9 feet above MHHW, so it will not require much sea level rise to cause frequent flooding problems. If, for example, over time there was two feet of sea level rise, Kiawah would experience regular nuisance flooding and would require a response, such as raising low spots in the road system by at least two feet, to keep the roads functioning as they do today during normal tide cycles. Any storm surge over 3 feet above MHHW currently causes road flooding in some areas. Sea level from tropical storm Irma in 2017, for instance, peaked at 4.15 feet above MHHW and approximately 73% of the island's land experienced flooding (see Appendix D). High resolution (1 m^2) College of Charleston mapping models are available to aid analyses of vulnerabilities to various flood events. These maps can show what happens to drainage in a particular area if the topography is modified. Thus, they can be a useful tool when evaluating proposed solutions to areas vulnerable to floods.

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Kiawah's roads have underdrains which lie about 2-3 feet deep. The underdrains are designed to keep the subgrade of the road dry. Generally, the underdrain is made of perforated pipes, gravel and filter paper. The underdrains have been breached in numerous places by utility companies installing underground utilities. As a result, the subgrade could be submerged in water too often. These wet conditions cause the subgrade, and eventually the road, to deteriorate more quickly. By forcing the water table upward, sea level rise will likely increase locations in which the underdrain system deteriorates under portions of the road system.

Any work on roadways is designed to have good drainage and to minimize negative impacts on nearby property. The drainage infrastructure associated with Kiawah's roadways is an important part of the island-wide stormwater management system, channeling water runoff from residences and yards into drains, swales, and ditches and moving it toward the pond system. Curbs may be either pitch curbs, which send water away from the curb, or catch curbs, which collect water and channel it to a drainage area. KICA conducts ongoing maintenance to keep roadway drainage in good condition and functioning well. This maintenance is key to minimizing road flooding during storm events and to draining rapidly during recovery.

Generally, Kiawah's roads are built at adequate elevation relative to MHHW today, with only a few areas below County standards. In most cases, improvements to prevent flooding will come from better drainage achieved by aggressive maintenance and targeted improvements. Once engineers review the roadways, and KICA assesses the results, they may find that some portions of the main roads may need to be elevated. Improving any drainage impact on adjacent properties will be a part of this process.

It is apparent from Kiawah's experience with recent storms that some sections of roads will have to be protected from nuisance flooding and storm surge. The Kiawah Island Parkway near Little Rabbit Island is an early candidate for action, and the Town has already contracted an engineering firm to study the situation.

Concerns:

1) An evaluation of the entire road system might identify more areas of the system that will be of concern as Kiawah prepares for 1.5 - 2.5 feet of sea level rise in the coming decades. The College of Charleston's high-resolution maps should be very helpful in identifying these areas.

2) Over the long term as sea level rises, if some of the drainage infrastructure associated with the roads and pond system cannot keep up with water volume, the roads themselves will become flooded. High capacity infrastructure maintained in good condition is important for the rapid removal of water from the roadways into island's drainage system.

3) Drainage pipes under roads, as with the rest of the drainage/pond system, are old and deteriorating, requiring increased maintenance. Collapsing pipes can lead to sinkholes and road closures.

4) Will KICA need some new concepts for roadway drainage maintenance in order to keep pace with long-term sea level rise?

5) In limited locations, some roads may need protection from storm surge over-wash, perhaps in the form of berms or hardened structures like sea walls.

6) If a section of road is raised, the drainage must also be reworked. Since all the drainage systems are interconnected, the elevation of roads requires extensive planning to minimize all negative impacts. Raising only the low portions of roads in limited areas is likely to require new storm drains, piping, and swales in more places than just the area where the road surface is raised.

7) Can a system be developed to warn residents, visitors, and others of water levels on specific roads both prior to a projected storm and in real time during a flooding event? This communication would permit advanced planning and would prevent people and vehicles from becoming stranded.

8) Storm flood models by the College of Charleston show that Kiawah's roads serve as a secondary or auxiliary pond system for storage and drainage of stormwater with moderate sea level rise and heavy flooding. This auxiliary function was actually seen during the 2015 floods on Kiawah. The extent and frequency of this road function will increase. One thing to pay attention to over time if roads are modified: Is the role of the road system changing?

Recommendations:

1) Plan for road improvements needed over the coming decades, not just short term. Such planning requires good stormwater management that must address extreme precipitation, tidal nuisance flooding, storm surge, and combinations of these.

2) Map the drainage patterns and flows of the island with the expectation that active management and optimization of drainage will be done on roadways across the island. Any designing for work on these major roads and adjacent properties could utilize College of Charleston's mapping models to anticipate and minimize drainage issues with various types and levels of water events.

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3) Provide adequate resources for road infrastructure maintenance and improvements. Set priorities for near term and for 30-year or more timeframe and ensure the work is timely.

4) The Town should improve the Kiawah Island Parkway between the round-a-bout and the Main Gate to permit vehicular travel when water levels are as high as experienced during the recent storm events, and in anticipation of nuisance flooding that accompanies 2.5 feet of sea level rise.

5) Identify areas where roads are susceptible to storm surge damage. Evaluate whether engineered modifications, possibly berms, sea walls or other forms of barriers, would be effective in protecting these vulnerable roads.

6) Identify specific low spots on Kiawah's roads, particularly along the main thoroughfares. If these areas are subject to flooding that interferes with traffic, identify practical solutions such as maintenance, drainage improvement, elevation or some other form of protection. Impacts on surrounding properties must be analyzed and mitigated.

7) Investigate using portions of leisure trails for limited emergency transport when roads are flooded. Many parts of the leisure trails are at higher elevations than roads and a combination pathway of roads and leisure trails may provide a makeshift roadway in dramatic circumstances.

8) Consider the recommendations in the Stormwater Management section regarding efforts to keep the drainage system unobstructed and operating effectively.

9) Using storm model projections and real-time measurements, develop a system to notify residents, visitors, and others of flood level categories expected or currently experienced throughout the island. Report categories so that people can evaluate their personal situation. For example, categories might include: "nuisance flooding, but can walk through it", "not passable to cars because of tailpipe coverage", "passable only to elevated vehicles". Develop a system before and during storms for placing water-depth-marking stakes along the Parkway and Governor's Drive so drivers can evaluate whether to drive through an area.

10) The Town or KICA should consider purchasing tail pipe adapters, high profile vehicles or small water craft to provide limited emergency access across the island when roads are flooded.

11) If roads are modified so that they cannot serve as auxiliary water storage and drainage basins, KICA and the Resort might consider allowing parts of the golf courses to serve that function. There

will be no golf on the island anyway until the excess water is drained and the island is back to normal operation.

Responsibilities and Partners:

- The Kiawah Island Community Association has primary responsibility for (a) the stormwater management system, including ponds, drains, and outfalls and (b) the roadways behind the main gate and certain other neighborhoods, including proper storm drains and pipes and drainage contouring along the roadways.
- The Town has responsibility for our new Town Hall and the private roads on that property, the roundabout, Beachwalker Drive, and the Parkway to the main gate along with their drainage systems.
- The Town has responsibility to promote good practices through education, by networking with other communities and support entities, and by developing ordinances where appropriate.
- The Architectural Review Board has responsibility to assist in accepting, promoting, and requiring designs that better address flooding issues.
- All property owners have responsibility to increase the use of Low Impact Development including increased use of pervious surfaces in their new construction and significant re-working of existing facilities.

What has been excluded from our considerations: Cassique is not included because it is not part of the Town or KICA. All other Town and KICA properties are included unless the infrastructure is maintained by a private entity. The Committee has not explored flooding adaptation and mitigation in those areas.

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EMERGENCY MANAGEMENT

Significance: The safety, security, and well-being of Kiawah residents, visitors, and workers must be of utmost concern to everyone. While emergency management is a broad topic, the Committee focused on the challenges raised by current levels of flooding and the expectation of more frequent events as sea level rise occurs.

Current Status: Successful emergency management is the coordinated effort of KICA, the Town, the Resort, and the Developer during the kind of flooding events that we experienced the last three years and that will likely increase in the future. Legally, only the Town can coordinate with County and State entities for pre-event planning and post-event recovery operations. That said, KICA's Security Department provides extensive experience and expertise in dealing with emergencies and is an important partner with the Town.

The Town is the legal entity ultimately responsible for emergency operations. The National Weather Service in Charleston will alert the Charleston County Emergency Management Division, which will then alert the Town of Kiawah Island. Town officials will then alert KICA, the Resort, the Developer, and all others who will be integral to preserving the safety of island residents and visitors. Only the Mayor can order an evacuation, and only the Mayor can reopen the island after a closure during and after a major storm. The Mayor may declare a State of Emergency before, or after a hurricane or other disaster. If such is declared, the Mayor becomes vested with broad powers which may be exercised at his discretion (Town of Kiawah Island, 2018).

The Town's Municipal Emergency Operations Center (MEOC) will be set up at Town Hall to coordinate storm related activities and to answer inquiries from residents, visitors, and commercial interests. It will be staffed until the alert is over or evacuation is underway. Information will be disseminated via the Town website (www.kiawahisland.org), email notifications, Residents Xchange, social media, and CodeRED, the Town's emergency notification system. The Town's MEOC will maintain contact with KICA, the Resort, the Developer, rental agencies, and commercial interests. These entities will be responsible for alerting their own employees and guests and keeping the MEOC informed (Town of Kiawah Island, 2018).

Getting off the island in the event of flooding is one thing but being able to traverse Johns Island and Rt. 17 under flooding conditions is also problematic. KICA has access to a live camera feed at the intersection of US 17 and Main Road to monitor conditions affecting access to Johns Island and expects a similar camera feed at the access point to James Island on Maybank Road. The cameras are dependent on electrical power and Comcast being operational. KICA can communicate this information through the avenues listed above. One should plan to evacuate well before flooding begins. When the island is under mandatory evacuation, key Town and KICA staff members are the last to leave. They block the inbound lane at the Main Gate before leaving. The waste treatment plant leaves 2 people on the island and the Resort leaves some staff at The Sanctuary unless a catastrophic storm is anticipated.

Concerns:

1) Despite the Town's existing multiple means of communicating with property owners, additional enhanced communication is advisable. If residents could have a better idea of what to expect from an approaching storm in terms of winds and flooding, and the timing of the arrival of those hazards, they could make more informed decisions about whether to evacuate.

2) A system to advise property owners of road conditions for flooding levels, locations, and timing before and during a storm event would enable drivers to make better decisions about traversing those roads.

3) Some residents who have special needs, especially medical, may need help evacuating. Information about who to call for assistance would be beneficial.

4) There may not be an evacuation, and flooding catches islanders by surprise, as happened with Tropical Storm Irma and the 2015 precipitation event. Should medical emergencies arise, first responders might not be able to reach the victim because of high water. When practical, emergency services need to be able to ingress and egress the island under flooding conditions.

5) During Tropical Storm Irma, the water level at the intersection of Beachwalker and the Parkway rose from a few inches to over a foot, making it impassable to normal vehicles, in a matter of minutes and took 24 hours to drain off after the event. That intersection at the Main Gate may not be the best location for blocking off the island and controlling access.

6) Recovery following a storm needs to be as rapid as possible with equipment and supplies in place prior to the storm's arrival.

Recommendations:

1) Develop a system that will provide information to residents and visitors alerting them about what to expect and when as a storm approaches. Provide information about who to contact, and how to contact, if they need help evacuating. Residents with special medical needs should be a particular focus.

2) The College of Charleston's models of expected flooding may be useful in planning ahead and alerting people about what to expect from an approaching storm event. Develop an easy to use version of these models that could be integrated with hourly reports from the National Weather Service.

3) Develop a Standard Operating Procedure for distributing water-level-marking stakes along the Parkway and Governor's Drive in advance of a major storm event so that drivers can read the water depth, avoid stalling out on these major roads, blocking traffic and, perhaps needing rescue. Emphasis should be on 6"-12" depth where there will be car passage problems due to exhaust pipes coverage. There should be alerts issued about the stakes as they are deployed.

4) Since the Town is responsible for ordering evacuations and island closures, it should subscribe to the Alastar service (a sharing system for public safety agencies, emergency managers, and first responders) for access to the live camera feed at the intersection of US 17 and Main Road and possibly other location, and communicate this information to property owners in real time during inclement weather.

5) Designate at least one emergency vehicle capable of reaching people in need for "ordinary" nuisance flooding.

6) Consider the acquisition of an additional higher-clearance vehicle that can carry some passengers who need evacuation through high water and a boat for rescues in even deeper water. These can also be used for assessing conditions during some storm events and during recovery. These could be stored at the new Town Hall for emergency use during storm events.

7) In order to ensure ingress and egress by first responders, professional engineers should be retained to proscribe modifications to specific sections of roads and drainage systems that present challenges during flooding events.

8) KICA should investigate the possibility of using certain sections of leisure trails to permit emergency vehicle access when roads in the vicinity are flooded.

9) As suggested by KICA's Security Department, moving Kiawah access control to the roundabout would provide a much better situation than the current location at the main gate. This requires coordination and agreement among the Town, KICA, Cassique, and Seabrook.

10) Ensure that there are enough drones and in ready-to-use condition that can be used to assess the island as the Town and KICA staffs undertake recovery operations.

11) KICA should maintain a few portable pumps in ready-to-use condition that can be deployed to relieve flooding in limited areas when clogged drains or other problems cause a temporary accumulation of water.

12) The Town, with support from KICA, should establish and ensure ongoing relationships with County and State Emergency Services entities to ensure that we can receive timely, specific assistance during times of crisis. Requests to access certain types of equipment and supplies should be made well in advance of a storm rather than afterward.

13) Designate a Town or KICA staff member to permanently represent Kiawah Island in such organizations as the Charleston Resilience Network and the Coastal South Carolina Community Rating System Users Group, attend most events, and appropriately disseminate all new information and tools that may become available through the Network.

Responsibilities and Partners:

- The Town is the legal entity that must take the lead in establishing relationships with County and State emergency services agencies. Only the Town can order evacuations, close the island, reopen the island, and declare a State of Emergency with the powers that entails.

- KICA is responsible for the majority of infrastructure on the island and offers considerable experience and expertise in many areas. It must be a full partner with the Town in planning for flooding emergencies, protecting life and property during the events, and in all recovery operations following flooding.

- The Town and KICA must work closely with the Resort, the Developer, rental agencies, and commercial businesses in planning for and managing flooding emergencies.

Recommended Readings:

- Town of Kiawah Island, 2018. *Emergency Preparedness Guide*. https://www.kiawahisland.org/wp-content/uploads/2017/11/2018-TOKI-Emergency-Preparedness-Guide.pdf

POTABLE WATER and WASTEWATER MANAGEMENT

Significance: Reliable supplies of high quality potable water and the efficient, unobtrusive handling of wastewater are essential for a vibrant residential and resort community. If the systems that handle either one are damaged or contaminated by floods or regular inundation from sea level rise, it would severely reduce the community's ability to recover quickly following the event or even to persist into the future.

Current Status: Both the potable water and wastewater systems are operated by the Kiawah Island Utility (KIU), which is now owned by SouthWest Water Company. The buildings at KIU's main property on Sora Rail sit on elevated cement pads on land at 9-11 feet above MHHW. A second pumping station on Governor's Drive is close to 5 feet above MHHW. It has high windows and metal storm door covers to protect equipment from flood waters. The Sora Rail facility has never flooded and is staffed 24/7 unless a Category 4 or 5 hurricane is approaching.

KIU has two water supply lines, one running along the Parkway and a new line that runs under the Kiawah River and comes onto the island at Marsh Island Drive. KIU has about 60 miles of water pipes on the island. KIU buys water from Johns Island Water Company which buys it from the Charleston Water Company. The source of the water is the Bushy Park Reservoir in Berkeley County and the Edisto River in Dorchester County. Both are reliable surface water sources. KIU has one 2,300-foot deep well that taps into the Middendorf aquifer. Besides supplying supplemental water for the golf courses, it serves as an emergency backup supply in the event that off-island delivery fails. Although the Middendorf aquifer is tapped by other communities, withdrawal rates are well managed by the partnership of those communities. Recharge rate is one year with the source coming from mid-state. There has been no evidence of saltwater intrusion or land subsidence caused by withdrawal. The Resort taps the Middendorf aquifer to water some of the golf courses.

KIU operates a secondary level sewage treatment plant that can treat up to 1.7 million gallons a day. Average flows are 500,000 gallons/day, but sometimes peak at 1.1 million gallons/day. KIU uses 52 sewage pumping stations, each with dual pumps, to move sewage to the treatment plant. There are about 60 miles of sewage pipe. They generally start at about 3 feet below ground level and drop to 8-10 feet in depth at which point pumps lift the sewage to the next pumping station. Each pumping station has audible and flashing light alarms to indicate problems. KIU can bypass individual stations if there is a problem and has three portable pumps as back-ups in an emergency.

All of KIU's treated liquid effluent goes to Cougar, Turtle Point, and the River Course golf courses. The nitrogen levels of the effluent are monitored and are always low. KIU has effluent storage ponds on its property capable of storing 14 million gallons until it can be transferred to the golf courses. KIU removes solids in drying beds where they are dewatered and then taken off Island by a third party to a disposal site in Dorchester County.

There are only a few septic systems on Kiawah, several on Eugenia and a few restrooms on the golf courses. The new Municipal Center is on a septic system. Depending on landscaping, prolonged heavy rains and flooding can saturate a drainfield and even fill the tank possibly causing backflow or rendering the system inoperable until water percolates out of the system.

Most of the water pipes and the sewage pipes are PVC and lie within the groundwater table. The pipes are totally separate with no chance of cross contamination. When a major storm is approaching, the sewage pumping stations and treatment facilities are pumped down so there is very little sewage in the system. KIU has never experienced any sewer overflows. The pumping station control panels are above ground and filled with sealant to prevent water from entering. When storms approach, KUI turns off power to the panels. Based on flooding from Tropical Storm Irma, 2 of KIU's 52 pumping station control panels were threatened. These are being raised. All other control panels can be raised incrementally as threats from rising sea level develop. If Berkeley Electric Cooperative power is off-line, KIU switches to in-house generators positioned on raised platforms in a raised building.

Flooding on the island can cover manholes, but the system is tight and it does not generally receive significant amounts of water infiltration. During Irma saltwater did enter the system and was pumped into the treatment plant, but the salinity was not high enough to disrupt the bacteria essential for secondary treatment. As flooding becomes more frequent, KIU can raise the height of the manholes as needed to prevent infiltration.

Concerns: KIU's infrastructure appears to be well engineered and professionally operated. Management seems to be taking flooding issues seriously and is well prepared for dealing with sea level rise issues for the long term. In general, the Committee has no serious concerns.

Recommendations:

1) KIU is owned by SouthWest Water Company. Maintain communications with KIU's leadership to ensure that it continues the current good practices and is willing to plan for adaptation to increased flooding. Ensure that any new owners in the future continue these practices.

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2) Buildings with septic systems should proactively make adjustments to reduce flooding problems. Stormwater runoff from impervious surfaces should be diverted away from the septic tank and drainfield. The ground can be slightly mounded over the drainfield to encourage runoff away from the system. Be sure that the septic tanks are pumped and inspected on a regular schedule and that a backflow protector is installed between the septic tank and the building.

Responsibilities and Partners: All entities that use the services of KIU should maintain close relations with its management to ensure close cooperation whenever a party must repair or expand infrastructure. Regulatory bodies need to work with KIU as it undertakes adaptations for managing more frequent flooding.

ELECTRICITY SERVICE

Significance: During both Hurricanes Matthew and Irma, Kiawah lost power to all or a significant portion of the properties. The loss of power can cause inconvenience to residents, loss of food in refrigerators and freezers, disruption of communication and information sources, and pose risks to individuals whose treatment requires constant power.

Current Status: The Committee met with seven managers and executives from Berkeley Electric Cooperative (BEC). BEC provides electricity to the individual residences, public services, and businesses on Kiawah. It buys power from Santee Electric. That power is delivered through a high voltage line that crosses the intracoastal waterway at the Limehouse Bridge on Main Road to substations at Seabrook and Legareville. Another loop for high voltage power is being constructed and soon will connect Wadmalaw to Seabrook and Kiawah for greater flexibility. BEC distributes electricity to customers through a network of switch gear stations, and transformers. The switch gear and transformers are spread throughout the island with the individual pieces becoming smaller as the distribution system gets closer to the ultimate customers.

Salt water is extremely destructive for electrical equipment. Inundation by salt water can cause the components of the distribution system to corrode and fail. The most vulnerable parts of the system are the above ground components such as switch gears that have parts that will be impaired by flooding. The power failure during Irma was caused by the loss of three switch gears on the island. BEC's policy is to take precautionary steps to protect the system from major damage by shutting down the power grid to the island prior to the arrival of a major storm. BEC is committed to bringing the network back on line immediately following a storm event.

BEC is not explicitly considering Sea Level Rise in their planning. Their focus has been on hardening the system in response to storms, including wind impacts and flooding. Once a specific location is impacted by a storm event, they concentrate on hardening that location. This adaptive management approach allows BEC to prioritize its investments to reduce the vulnerability of the network to future flooding. They have been placing some underground cables in conduits to protect them from salt water or using waterproof cabling. Switch gears in some vulnerable spots on the island have been replaced with units that can withstand being submerged. BEC has identified nine switch gear locations on Kiawah that need to be raised due to flood history or risk. The standard height of new pads beneath equipment is 15”. The previous standard was 5”, and when work is done to upgrade equipment the pad is often replaced and raised. Since funds are not available to harden the entire system for a major event that may never happen, BEC's strategy is to make investments as a need is identified and then include that in the regular budgeting and planning process.

Concerns: The Committee has very few concerns about BEC’s ability to provide electricity to Kiawah for future decades, but they are significant. The adaptive management approach to hardening their infrastructure on Kiawah seems pragmatic given that financial resources are limited on a year to year basis.

1) The major concern is that possibly large areas of Kiawah might not be prepared to withstand a major flooding event. It would be advantageous to identify areas of particular vulnerability and then work with BEC to prioritize upgrades for those areas.

2) If particularly vulnerable areas of the island’s electrical infrastructure are identified, BEC may not have the funding to harden those locations proactively.

3) Raising the height of switch gears and transformers is possible, but there is concern that the overall height of the equipment would not be aesthetically acceptable or that the ARB might not approve the actions.

Recommendations:

1) The more detailed GIS information developed by the College of Charleston should be shared with BEC to identify areas where electrical equipment could be exposed to flooding in storms or rain events as sea levels rise. This would enable BEC to be more proactive in planning investments.

2) Kiawah entities (the Town, KICA, the Resort, the Developer) may want to consider providing partnership funding for BEC to upgrade infrastructure in identifiable vulnerable areas.

3) Consideration should be given to the possibility of raising the height of critical switching stations to mitigate flooding risks.

4) ARB should work with BEC now to ensure that there is no delay in raising switch gear and transformer boxes when it becomes necessary.

5) Kiawah may want to evaluate the use of pump stations to reduce the risk to critical electrical equipment.

6) Actions that other coastal cities are taking to manage their electric service in anticipation of sea level rise and increased flooding should be researched and evaluated.

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Responsibilities and Partners:

- The Town should maintain open and frequent communication with BEC on sea level rise and flooding issues.
- The ARB may need to consider changes in the design of switching stations, including height, to improve resilience.
- The Town and KICA will need to evaluate the possible use of pump stations and to determine who would fund the stations.
- Property owners should be advised of BEC's policy to shut down power to the island prior to a major storm. Owners may decide to invest in a backup generator during these periods.

Additional Actions:

Kiawah Island residents and visitors increasingly rely on cell phones, social media, and email for information. During at least one prior storm, some equipment used by Comcast service was flooded, and it's entirely possible that local cell phone towers could be damaged or destroyed in a storm. This is one area of our local environment that the Committee did not examine. For now, the Committee would recommend that the individual, group, or office charged with responding to flooding and sea level rise on Kiawah Island investigate our digital environment and its strengths and weaknesses.

FLOODING ADAPTATIONS for RESIDENTIAL STRUCTURES

Significance: Over the past three years Kiawah Island residential property owners have witnessed several flooding events, and some have experienced direct damage to their homes. In the coming decades we can anticipate more frequent and occasionally more severe flooding due to extreme precipitation events, nuisance tidal flooding, storm surge, or combinations of these situations. It is important for property owners to be able to protect themselves and their residences as much as possible from these events.

Current Status: The Federal Emergency Management Agency (FEMA) develops maps that identify areas prone to flooding and delineates them into zones based on flood risk and source. Newly redrawn FEMA maps are now under review. These zones are the basis for setting flood insurance rates through the National Flood Insurance program (NFIP). Almost all residential properties on Kiawah lie within Zone AE (High Risk Area with Base Flood Elevations determined), with portions of some properties extending into Zone VE (High Risk and wave action hazard with Base Flood Elevations determined). Specific Base Flood Elevations (BFEs) are provided for each subdivision within these categories based on land topography and may vary by several feet across the island. Newly proposed FEMA flood maps for Kiawah are available at http://chascogis.maps.arcgis.com/apps/View/index.html?appid= 33df503a50284fcf8c4564930741a1b1.

All new residential construction must be built so that the first floor living space and all equipment supporting the residence (e.g. HVAC systems) is above the BFE for that location or is flood proofed to that elevation. In addition, the Town of Kiawah Island currently requires all new construction be built one foot higher than the BFE. While all newer homes are built to these standards, they often have an open area or non-living space, such as a garage, under the house. Older homes built prior to the FEMA standards may be elevated a few feet above grade, placing the living space below the BFE. Thus, dwellings on Kiawah fall into two main categories in regard to flood hazard.

1. Residences with first floor living space above the BFE for that location, including:
   - Single family homes generally behind the second gate or recently built, and
   - Free standing cottage regimes built on pilings, e.g. Inlet Cove, Sparrow Pond, Night Heron.
2. Residences with first floor living space below the BFE for that location, including:
   - Single family homes primarily in the West Beach area, and
   - Multifamily villa regimes, e.g. Parkside, Fairway Oaks, Turtle Cove, Tennis Club.

Concerns: There is potential for significant flood damage to residences in both categories. During the 2015, 2016, 2017 storms homeowners in the elevated homes category may have experienced

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more damage than those in the second category. The damage was largely due to items stored on ground level and to how the ground level of the home was enclosed. Flooding that encroaches on residences may result from very heavy precipitation or from salt water brought in by very high tides and by storm surges. Both types of events are projected to increase in the coming decades, and of course can occur simultaneously. Precipitation-induced flooding results when the storm water drainage system cannot move water away from residences and roads as quickly as the water is building up. Flooding from high tides and storm surges, on the other hand, cannot be removed simply by improved drainage, but must be prevented, or structures must be adapted to accommodate it.

Recommendations: In suggesting recommendations we recognize several different situations.

Precipitation-induced Flooding

1. Ensure that the ground around your residence slopes away from the house to prevent water from flowing under the dwelling.

2. Install downspouts connected to drain tile to carry water from the roof away from the foundation of the house or connect downspouts to cisterns to collect the water which can then be used later for irrigation.

3. Do not dump anything into storm drains, swales (roadside depressions designed to manage water runoff by directing it into drains, filter pollutants, and increase rainwater infiltration), ditches, streams, or lagoons. A single plastic bag, grass clippings, or shrubbery trimmings can clog the system and cause a backup, resulting in flooding a large area. Ensure that your landscape contractors abide by this regulation (Town Municipal Code, Section 15-213). If you see unauthorized dumping anywhere near ditches, streams, or lagoons, contact Town Hall (843) 768-9166.

4. If your property is adjacent to a storm drain, swale, ditch, stream, or lagoon, please proactively keep the banks and drain clear of debris. Join with your neighbors to "adopt a drain".

5. Install a rain garden or other low impact development landforms to better manage precipitation. A rain garden is a depressed area in the landscape that collects rain water from a roof, driveway or street and allows it to soak into the ground. Planted with grasses and flowering perennials, rain gardens can be a cost effective and attractive way to reduce

runoff from your property. Rain gardens can also help filter out pollutants in runoff and provide food and shelter for butterflies, song birds and other wildlife.

6. Install permeable surface driveways, walkways and patio pads to allow more precipitation to infiltrate the soil.

7. Do not block roadside swales by installing driveways, filling them with debris or taking any other actions to fill them. Filling or blocking swales can cause localized flooding.

8. Become better educated about managing precipitation runoff through Low Impact Development: http://www.scseagrant.org/pdf_files/LID-in-Coastal-SC-low-res.pdf.

9. Always check with Town Hall, KICA, and the Architectural Review Board before you build on, alter, remodel, re-grade or fill your property. Permits are required to ensure that you are in compliance with all applicable ordinances and regulations. If you have any questions regarding permits, please call the Town's Building Services Department at (843) 768-9166. If you see building or land alterations at a site without a permit sign posted, report it to the Town (843) 768-9166.

Residences Currently At or Above Base Flood Elevation plus Freeboard

1. Wet floodproof your home by ensuring that flood water vents are of sufficient size and fully open to allow water to flow beneath the structure as designed. Ensure that break-away walls will function as designed. Consider a new type of flood vent that automatically opens and closes with rising and falling water levels.

2. Consider installing a car ramp or lift in your garage that will elevate your vehicle a few extra feet in the event of a flood.

3. Move contents, electrical wiring, and ductwork from ground-level areas to higher floors if they are susceptible to damage by flood waters. Installation of an elevated racking system could be helpful.

4. Dry floodproof the area under the house with water-tight bolt-on panels. These may be expensive and must be installed and removed with changing conditions. Waterproof exterior walls and add watertight seals to doors.

5. Walls and other structures built under base flood elevation should be constructed of cement block, concrete, or other water-resistant material, never of sheetrock or other material susceptible to water damage.

6. Insure any yard or concrete pavement drains are free and unobstructed.

Residences Currently Below Base Flood Elevation

1. Consider raising your home to base flood elevation plus local freeboard height. While expensive, it may not be as cost-prohibitive as one might expect.

2. Ensure that flood water vents are of sufficient size to allow water to flow beneath the structure as designed.

3. Move contents, electrical wiring, and ductwork to higher floors if they are susceptible to damage by flood waters. Installation of an elevated racking system could be helpful.

4. Consider dry floodproofing the house by waterproofing exterior walls and the underside of the house and adding watertight seals to doors and windows. This option may be more expensive than raising the house.

5. Insure that any yard or concrete pavement drains are free and unobstructed.

General Recommendations

1. Because of the new FEMA base flood elevations, other local municipalities may increase their freeboard by an additional one to three feet. The Town should consider doing the same. Alternatively, the Town might require all new structures be built to a single elevation standard that exceeds all the BFEs found on the island on the new proposed FEMA maps.

2. The ARB should proactively work with homeowners, the Town, and other entities to help them identify and implement actions that will permit Kiawah property owners to adapt to changing weather and water conditions. The ARB has the responsibility to adapt their guidelines to encourage construction and renovation that allows structures to withstand or to recover more quickly from flooding.

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3. Organize with your neighbors and local officials to explore the construction of earthen berms to protect a neighborhood from tidal flooding, how to share the expense, and whether such actions would exacerbate flooding on neighboring properties.

4. Everyone should ensure their neighborhood street and any yard drains are functioning as designed.

5. The Town or KICA should Identify parking areas that residents can use in anticipation of a flood event.

6. Obtain a copy of FEMA P-312, Homeowner's Guide to Retrofitting 3rd Edition (2014) at https://www.fema.gov/media-library/assets/documents/480#

6. The Town and the ARB might consider lowering the coverage area on lots to minimize impervious surfaces, thus improving a lot's ability to absorb water.

7. Establish and provide a menu of property owner options which allows property owners to select changes they make to their property. The menu option could include:
   a. Elevate the house
   b. Guidelines for filling lots
   c. Information on how to tear down, fill and rebuild the home
   d. Programs which allow homeowners to sacrifice their property to aid in the island's overall ability to adapt to sea level rise.

8. The Town should investigate the selective and proper use of living shorelines such as oyster reefs and natural fiber logs (e.g. Coir logs®) to protect marsh edge properties in areas where appropriate.

Responsibilities and Partners:

- The Town is responsible for establishing and enforcing building codes and ordinances prohibiting dumping of trash or other materials into the stormwater management system.
- The ARB is responsible for approving all exterior building modifications and landscaping.
- KICA is responsible for maintenance and modification to the stormwater management system.

Additional Information and Recommended Readings:

The Committee was assisted in preparing this section by three local architects who work extensively on Kiawah:

- Charles L. Hudson, Jr. AIA, NOMA, Owner of Hudson Designs, Inc.
- Mark Permar, Founding Principal of Permar, Inc.
- Tyler Smyth, AIA, LEED AP – Tyler Smyth Architects, LLC
- FEMA's Homeowner's Guide to Retrofitting 3rd Edition (2014) at https://www.fema.gov/media-library/assets/documents/480#
- Low Impact Development for Coastal South Carolina (2014) at http://www.scseagrant.org/pdf_files/LID-in-Coastal-SC-low-res.pdf
- Newly proposed FEMA flood maps for Kiawah are available at http://chascogis.maps.arcgis.com/apps/View/index.html?appid=33df503a50284fcf8c4564930741a1b1

LANDSCAPING ADAPTATION

Significance: Kiawah Island has witnessed significant flooding events over the past three years with major periods of saltwater intrusion and standing freshwater, and there is the anticipation that these will occur more frequently. In addition to flooding and the movement of pollutants from roofs and paved surfaces into the environment, homeowners lost many landscaping plants due to standing water and high salt levels. To this end, residents and other entities on the island should consider landscaping adaptations that will minimize the impacts of these events.

Current Status: Currently on Kiawah many older homes, villa regimes and other properties do not utilize landscaping options that have the potential to reduce damage from saltwater intrusion and standing water. Many island neighborhoods have aging landscapes with little understory and/or plantings of nonnative, invasive, or exotic species. Landscapers, builders, architects and others may not realize landscape options can help reduce or eliminate some of the problems that arise with flooding from major rain events, nuisance flooding, or storm surge.

Concerns: Saltwater intrusion and standing water from flooding may kill landscaped plantings, often at considerable expense to homeowners. Runoff from roofs, driveways, and roads during major rains not only exacerbate flooding problems, but carry a variety of anthropogenic pollutants into marshes, ponds, and natural environments. Poorly designed lot topography can also cause serious problems for neighboring properties and along roads during rains and flooding.

Recommendations:

1) Organize a committee of knowledgeable experts and stakeholders from various entities on Kiawah to develop a database of salt/flood tolerant plants with an emphasis on native species that can be used on the island. This committee should gather information on each species/subspecies/cultivar including but not limited to information on shade/sun tolerance and soil preference. The database should be easy to find on a website and easy to use.

2) Develop "showcase" landscapes that demonstrate plantings for different habitats, perhaps in areas around the new Town Hall.

3) Discourage the use of non-natives, exotic and invasive species with information available on these species for property owners, landscapers and other groups. Included in this list should be plant species that are not salt, flood, and deer tolerant and do not survive well on Kiawah.

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4) Encourage habitats for wildlife on the island.

5) Provide information about local horticulturists, retailers, and others who sell or supply the plant species that are recommended for Kiawah.

6) Provide information about plants and landscapes that protect marsh and pond borders. Also provide information about what plants NOT to use in these areas.

7) Provide information about the positive effects of reducing runoff and flooding by the use of Low Impact Development practices, including pervious driveways, walkways, and parking lots along with the benefits of rain gardens, rain barrels, and cisterns.

8) Discourage the use of mulch and pine straw on slopes near roads to prevent the washing of this material into roads and especially into drains. Encourage the use of appropriate ground-covering plants as road borders instead of mulch.

9) Develop and provide pre-approved landscape plans that meet the criteria mentioned above.

10) Encourage the use of well-adapted grass species on the island and discourage the use of grasses that require watering, trimming, fertilizers, pesticides and herbicides.

11) Develop ways to educate and encourage property owners, landscape architects, and landscaping companies, and all island entities to "buy in" to the recommendations listed in this report.

Responsibilities and Partners:

- The Town's Environmental Committee Chair, Jim Jordan, has taken the initiative to establish a "Landscaping Work Group" to address most of the recommendations mentioned in this report. This committee of experts from Kiawah is in the process of developing its mission and goals. Members of this committee include representatives from KICA, the Town, the Conservancy, the ARB, and the Resort.

- All island entities, the Town, the Resort, the Conservancy, the Developer, and KICA play a role in development and education, but the Conservancy and the Resort's Nature Center could lead efforts.

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Recommended Reading:

- Ellis, K., C. Berg, D. Caraco, S. Drescher, G. Hoffmann, B. Keppler, M. LaRocco, and A. Turner. 2014. *Low Impact Development in Coastal South Carolina: A Planning and Design Guide.* ACE Basin and North Inlet – Winyah Bay National Estuarine Research Reserves, 462 pp. http://www.scseagrant.org/pdf_files/LID-in-Coastal-SC-low-res.pdf

- Clemson Extension*, Exotic Invasive Plant Species of South Carolina*: https://www.se-eppc.org/southcarolina/Publications/InvasivePlantsBooklet.pdf

- Clemson Extension, *Salt Tolerant Plants for the South Carolina Coast*: https://www.clemson.edu/extension/hgic/plants/other/ landscaping/hgic1730.html

- Kiawah Conservancy: https://kiawahconservancy.org/habitat

- Kiawah Island Architectural Review Board, *Enhance Value with Smart, Sustainable Design*: http://arb.kiawahisland.com/wp-content/uploads/2015/09/kp_14_5452 insights_ARB.pdf

- Spring Island Native Plant Project: http://npp.springislandtrust.org/plant-database-a-more/frontpage.html

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<u>RULES and REGULATIONS</u>

<u>Significance</u>: Kiawah Island developed with an emphasis on living with nature and respecting the island's environment. The rules, regulations and guidelines that govern development protect the natural environment, influence what the island looks like and govern how property owners develop and maintain their homes, yards, businesses, golf courses and the like. It's important for the islands' various regulatory regimes to encourage practices which protect and adapt the island to rising water levels.

<u>Current Status</u>: Construction projects on Kiawah Island are subject to regulation and review by the Town of Kiawah Island, the Architectural Review Board (ARB, which is controlled by Kiawah Partners), the Kiawah Island Community Association (KICA), and authorities of the U.S. Government, the State of South Carolina, and Charleston County. These organizations oversee lot coverage, fill, drainage, roof heights, site grading, and landscaping to name a few currently regulated activities. Typically, the state's DHEC-Office of Ocean and Coastal Resource Management (OCRM) regulates construction in areas near water and marshes. In addition to these oversight bodies, the Kiawah Island Golf Resort (KIGR) and the Kiawah Island Partners (KP) have separate development agreements with the Town. Typically, the development agreements require compliance with all federal, state and local laws.

Generally, the regulations focus on construction and become more restrictive as the organization promulgating the rules gets closer to Kiawah. As such, the ARB's regulations are often the most restrictive. The Town monitors state and local requirements. The ARB and KICA monitor covenant violations. OCRM conducts periodic reviews of the ocean, river and marsh fronts.

The Town, the ARB, and to a lesser extent, KICA, each review plans for new construction and renovations. Each of these organizations relies upon the homeowner and the homeowner's contracted professionals to ensure that construction complies with all current regulations. KICA reviews plans to ensure projects respect KICA's common area drainage and stormwater management systems. This section will focus on the areas most likely to be influenced by sea level rise.

<u>Elevations</u>: FEMA produces Flood Insurance Rate Maps (FIRMs) that typically show flood risk zones, floodways, and base flood elevations. The Town and the ARB use the base flood elevation shown in these FIRMs to establish the lowest elevation at which the first floor of any structure constructed on Kiawah must be built. In most cases, the lowest permitted first floor elevation is one foot above the base elevation (the height above the flood elevation at which the first floor of a structure is located is called "freeboard"). In 2017, FEMA published new FIRMs for Kiawah. These new FIRMs changed the base flood elevation for portions of Kiawah. In many locations, the

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base flood elevation decreased. The Town plans to adopt FEMA's base flood elevations and is considering increasing the freeboard by an additional one to three feet. This is in the range of other local municipalities' plans. Currently, the Town's reference datum is NGVD29; the Town expects to adopt NAVD88 when FEMA's new flood elevation maps are adopted. In addition to FEMA's and the Town's elevation requirements, the ARB regulates roof height and pitch. Height and pitch restrictions vary according to neighborhood as the ARB strives to ensure new construction or renovations are consistent with a neighborhood's character.

Fill and Lot Grades: The Town monitors fill and grading during initial construction. It does not regulate natural fill resulting from tide, wind or surges, nor do they monitor changes in lot elevation after a construction or landscaping project is completed. If a structure is torn down, the Town requires the lot to be regraded to the original natural elevations. The ARB discourages excessive fill and encourages site plans that integrate the building with the existing terrain and minimize disruption of the natural topography.

Erosion Control on Water and Marsh Edges: OCRM and the Army Corps of Engineers (ACOE) control development along the ocean, dunes, marsh and river edges and other natural waterways. Marshes and marsh edges are either state property or privately owned through King's Grants. Bulkheads, docks, walkways, fill and any other changes to the natural landscape in these areas require permits by the relevant state and federal agencies and normally the Town and the ARB. Erosion control measures such as installing oyster beds, Coir logs®, or fill is the purview of OCRM and ACOE, and no control measures may be undertaken unless the property owners receive a permit. The ARB, OCRM, and ACOE must approve all installation and improvement of docks and bulkheads. The ARB encourages fabrication with natural and blending materials, although there are exceptions. It is open to reviewing alternative, environmentally friendly solutions, e.g. "Envirolok" and planted banks, as long as they are allowed by OCRM and the ACOE, and are natural in appearance.

Stormwater Management: Stormwater drainage is addressed during site planning and development review. The ARB relies upon the site contractor, architect and landscaping professionals to comply with all regulations. In 2014, KICA engineers began to review plans ensuring that new construction respects the community's drainage easements and rights of way. KICA's engineers may comment on other drainage issues associated with the construction, however, the ARB controls those decisions. If needed, homeowners are required to clear blocked drainage ditches, install swales, regrade or take other actions in order to manage runoff properly. On developed lots, KICA engineers work with property owners to identify and correct obstructions to the community drainage and stormwater management system.

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<u>Concerns</u>:

1) Have the Island's governing bodies kept their rules/regulations/ordinances/standards up-to-date considering the recent flooding occurrences on Kiawah and the expectation of further sea level rise? Are they staying current with low-impact development ideas that may be useful on Kiawah?

2) Could current rules/regulations/ordinances/standards that were written before sea level rise considerations interfere with property owners' efforts to adapt to rising waters?

<u>Recommendations</u>:

1. Kiawah's regulating entities, property owners and developers should review *Low Impact Development in Coastal South Carolina: A Planning and Design Guide* referenced below to identify and adopt new practices to improve stormwater management on existing and new developments.

2. The language in the ARB guidelines should be modified to strongly encourage the use of pervious surfaces. Further, lower lot coverage could be achieved by changes including reducing requirements for large walkways, parking pads and driveways.

3. The ARB should waive review fees for improvements associated with adapting a property for sea level rise.

4. The ARB should proactively work with homeowners, the Town, and other entities to help them identify and implement actions that will permit Kiawah property owners to adapt to changing weather and water conditions. The ARB has the responsibility to adapt their guidelines to encourage construction and renovation that allows structures to withstand or to recover more quickly from flooding.

5. As the Town's regulations on freeboard and FEMA base level flood elevations develop, ARB regulations on roof height and roof pitches should accommodate homes built higher off the ground and existing homes that may be raised because of potential flooding.

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6. The KICA should schedule neighborhood property drainage and grading reviews, beyond initial lot construction reviews, to proactively address issues before they cause flooding. It is imperative that neighborhoods and property owners understand the relevance of these reviews and the importance of correcting any problems. To solidify the importance of proper maintenance, KICA should formalize its water management education procedures. KICA should work with neighborhoods and property owners to correct drainage issues such as drainage ditches filled with landscaping material or correct lots whose grade creates runoff problems.

7. The Town should update its building and flood management codes to include proactive flood management regulations. This should include: adopting NAVD88 instead of NGVD29, additional freeboard requirements that the Town is considering, and strengthening the penalties for drainage and grading violations.

Responsibilities and Partners:

- The ARB has the responsibility to adapt their guidelines to encourage construction and renovation that allows structures to withstand or to recover more quickly from flooding.
- KICA and the Town have the responsibility to maintain and improve the roads, drainage system, leisure trails, community centers and other communal assets so they can accommodate and recover quickly from flooding. If penalties are assessed for damage caused by improper drainage, grading or other infractions, the dollars collected could go to the entity that is responsible for correcting the damage.
- The Town should review and update all their building and flood management codes so they reflect the most current practices associated with managing sea level rise.

Recommended Reading:

- Designing with Nature, Architectural Review Board Standards and Guidelines, http://arb.kiawahisland.com/wp-content/uploads/2017/12/kiawah_dwn_r12-4-2017.pdf

- Ellis, K., C. Berg, D. Caraco, S. Drescher, G. Hoffmann, B. Keppler, M. LaRocco, and A. Turner. 2014. *Low Impact Development in Coastal South Carolina: A Planning and Design Guide.* ACE Basin and North Inlet – Winyah Bay National Estuarine Research Reserves, 462 pp. http://www.scseagrant.org/pdf_files/LID-in-Coastal-SC-low-res.pdf

- Town of Kiawah Island Flood Damage Prevention Ordinance, https://s3-us-west-2.amazonaws.com/kiawah-island/wp-content/uploads/2016/10/13172653/flood-prevention-ordinance-Est2013-11.pdf

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BEACH ENVIRONMENT

Significance: Some call the beach Kiawah's crown jewel. Despite all of its other amenities, the beach epitomizes the character of Kiawah, and has ultimately been its primary reason for development. Residents and visitors alike enjoy the beach and its wildlife in many ways, and property values are directly linked to the quality of the beach environment. Maintaining a healthy and beautiful beach must be a priority for every property owner, governing body, and commercial entity associated with the island.

Current Status: The 2017 Beach Monitoring Program Report, which is prepared annually for the Town by Coastal Science and Engineering (CSE), stated that "Kiawah Island is one of the healthiest barrier islands in South Carolina. The addition of sand generated from the Stono Inlet has led to stable dunes spanning the beachfront with only minor localized erosion in specific hotspots as sand migrates downcoast from Stono Inlet. The foresight of the island's developers to properly study the processes controlling the morphology of the island make Kiawah Island an excellent example of beachfront development and a premier community along the South Carolina coast." A major strength and somewhat unique feature of Kiawah compared to other locations is that residential construction into the primary and secondary dunes is prohibited for the majority of the island. In conclusion, the CSE report said that "Kiawah Island is one of healthiest barrier islands in South Carolina."

The health of our beach is one reason we have suffered relatively minor damage during three recent storms, The 2015 historic rain event, Hurricane Matthew (2016), and Tropical Storm Irma (2017). Each storm caused some beach erosion. Hurricane Matthew caused severe dune loss ranging from ~15 feet to 40 feet along most of the residential area, and even higher loss rates were observed west of Beachwalker Park. The storm resulted in damaged dune walkovers, but no significant property damage. While many communities along South Carolina's coast experienced significant property damage and sand overwash onto public roads, Kiawah was able to withstand significant dune recession without damage to homes or roads.

By February 2017, the entire island showed significant recovery of the dry-sand berm and some dune growth. However, in September 2017 Tropical Storm Irma resulted in another 10–20 feet of dune loss beyond what was lost with Hurricane Matthew, even though overall sand volume loss was lower. With the additional dune loss, some areas along the golf courses were within DHEC-OCRM's definition of an emergency condition, and other areas had insufficient setbacks from the high-tide line. The Town conducted a dune restoration project along these areas after securing state and federal authorization.

An important characteristic of Kiawah's beach dynamics is that it is accretional. The 1975 environmental study conducted for the island's original developers reported that Kiawah is one of the few islands on the South Carolina coast that is prograding, with an annual seaward growth of tens of feet (Chamberlain et al. 1975). Much of the island was deposited in the last 3,000-4,000 years (Hayes et al. 2008). This growth was largely due to material that migrated from Morris and Folly Islands and the Stono Inlet. The buildup was not even, though. Sand deposited on the shore blew landward, creating Kiawah's characteristic low elevation topography with a series of former beach ridges and swales from the beachfront to the marsh side on the Kiawah River.

Significant sea level rise occurs over decades while natural beach modification processes occur over years. Hayes and Michel (2008) state that, "The theory that a rising sea level is the major cause of beach erosion worldwide prevails in both scientific and popular literature. A careful analysis of beach erosion in a number of settings casts doubt on this assumption, particularly with regard to the problems of concern in the near future. In fact, we think that, in most cases, man's impact on sediment supplies and unwise construction practices cause most beach erosion problems. However, opinions of the experts differ markedly on this topic." They also cite a colleague, C.J. Galvin, who believes that "…sea-level change has negligible effect on shore erosion, compared with fluctuations in long-shore sand transport."

Should the transport of sand down the coast be disrupted or slowed in the coming decades, for whatever reason, Kiawah would then need to consider beach renourishment, similar to a number of our neighboring communities. High quality offshore sand to conduct such beach rebuilding, however, is limited. Should that process ever be required, Kiawah would find itself in competition with other communities for the sand that is available.

The Town contracts annually with CSE for an assessment of beach health that includes recommendations for actions. These annual beach reports maintain that, except for the eastern and western ends of the island, Kiawah Island has been stable over a long period of time. The Town should continue to monitor the health of the beach in its entirety on an annual basis. Overall, the consensus is that Kiawah's beach should be able to maintain its basic morphological characteristics in the face of rising sea levels, assuming the rates of sand accretion keeps pace with the erosional effects of sea level rise.

Nesting sea turtles require a beach where they can easily crawl to sandy areas that will not be flooded by high tides. Sharp dune escarpments from an eroding beach degrade their nesting habitat. Shorebirds must be able to find an abundance of food organisms in the intertidal sands and the mud flats at the ends of the island. Fortunately, the invertebrates that comprise their diets can recover rapidly from major erosional events and can easily colonize new areas as sea levels rise. In the long run we should be able to retain turtle nesting and shorebird habitats, albeit with temporary and episodic interruptions from storm events, as long as we do not put up hard structures to protect the dunes or private property or engage in major anthropogenic beach modifications.

The natural shape of our dunes is key to good protection of our uplands and buildings. The most important factor is the volume of sand in the dunes with adequate height and a broad shape. Height is important to block wave action, but width and overall volume are needed to avoid a breach. Wind and water will cause the beach to adjust, but breaches lead to flooding behind the dunes and movement of sand inland. Natural processes on Kiawah should be sufficient to build large volume dunes even as sea levels rise. In our current situation, and for the foreseeable future, hard structures, including sand fences, are unnecessary to protect the dunes and property and would lead to a less environmentally friendly contour of the beach.

Figure 8. Kiawah Island at the east end of the island, where changes to the beach contours occur regularly.

Concerns: As Hayes and Michel (2008) acknowledge, and our consultants confirm, there is uncertainty about the effect of sea level rise and attendant higher tides on the morphology of the beach. As long as a plentiful supply of sand continues to move down the coast and as long as no anthropogenic structures create a barrier to dune building, natural processes should be able to maintain the beach and dune system despite rising sea levels.

1) If sea levels rise and storms breach the dunes, how much damage might occur to human infrastructure before years of dune building can restore the protective barrier? What happens if multiple storms come over several years, not providing time for dunes to rebuild naturally?

2) Are structures and facilities built out into the current dunes particularly vulnerable to breaches of the smaller volume of dunes remaining in front of them? Do they provide an avenue for seawater to flow into the island in the event of a breach?

3) Will the positioning of homes and other structures that today are well back from the beach hinder the volume building of new dunes as sea levels continue to push the MHHW line further landward? What impact will the building of new dunes have on these structures?

4) Who should pay for erosional or dune loss problems incurred by private property owners, especially if they built seaward of the set-back line established in 1974 by the consultants for the original developer (Hayes and Michel, 2008)?

5) Since Kiawah is a private island, government funding is not available for beach renourishment if it ever becomes necessary. How will it be paid for? Will the Town be in a position to secure a source of high quality sand in competition with its neighbors?

6) If sea levels rise 2.5 feet in the next 50 years, there will be a dynamic, shifting beach and dune system. Will habitats for nesting sea turtles and feeding shorebirds remain viable during this process?

7) If sand accretion does not keep pace with anticipated sea level rise during the next 30-50 year period, will some renourishment of the beach be needed, particularly in the eastern and western areas where the dune system is not as robust?

Recommendations:

1) Continue to contract for regular beach management reports, watching for beach erosion that can be attributed to sea level changes. Regularly assess the recovery of the dune area through photographs or dune-line GPS surveys.

2) Continue to repair our dunes as needed after major storms using the sand scraping technique. Be prudent in the use of sand fences or hard structures to “protect the beach” as they alter the contour of the beach, making it steeper. The key to good protection from the dunes is volume with sufficient height and a broad shape, the natural shape of our dunes.

3) One of the most effective and aesthetically pleasing ways to build and stabilize a sand dune is to cover it with vegetation. The foliage helps increase the size of the dune by trapping wind-blown sand. Plant roots also contribute as they bind sand particles to the dune. Consider efforts by KICA, the Town and ARB to establish, restore and maintain good protective vegetation of the dunes.

4) All entities should discourage or prohibit the construction of buildings or recreational facilities seaward into the dune system. Construction into the dune system ensures not only infrastructure damage should a breach in the dunes occur, but provides a highway for ocean water to flow onto other land-based properties.

5) Even though we currently have an accreting beach, at some point in the future we may need to import sand. However, there is a shortage of suitable sand on the east coast, and sand mining in both state and federal waters requires permits. Therefore, the Town should be aware of regional sources of sand, rules for their access and use, and methods for better harvesting sand.

6) As long as dunes exist along all of Kiawah, CSE recommends allowing the beach and dune system to recover from storm erosion naturally rather than installing sand fencing. Placing fencing in eroded areas may promote dune growth in locations where it would not form naturally, or it may restrict sand from building the more landward dune features. One large, wide dune offers more protection than a small series of low foredunes. If sand fencing is installed, it should be set as close to the primary dune as possible. This will reduce the chance that the fencing could be eroded in the future, and it increases the recreational area of the beach.

7) If small, localized dune restoration is deemed necessary at times, upland sand can be used for minor nourishment, although it is relatively expensive.

8) Continue to support monitoring shorebird and sea turtle populations both on Kiawah and along the eastern seaboard as an indicator of the health of our beach environment.

9) Make full use of the College of Charleston inundation mapping model to understand the risk to the beach from sea level rise and the consequent higher tide levels that will result. This tool can help Kiawah better assess the timing of risks, the extent of the risks, and possible mitigation.

10) Continue to update the Town's Local Comprehensive Beach Management Plan on 5-year cycle, in coordination with S.C. DHEC Ocean and Coastal Resource Management.

11) Ensure that all new construction is prohibited in the primary and secondary dunes.

Responsibilities and Partners:

- Under state law, the Town of Kiawah Island has legal responsibility for managing the beach and for developing and implementing a Local Comprehensive Beach Management Plan in coordination with S.C. DHEC OCRM. To that end, the Town employs Coastal Science and Engineering (CSE) to produce an annual report on the health of the beach with recommendations for action when appropriate.
- Since KICA owns the primary and secondary dunes along most of the island, it should ensure that new construction does not impinge on this protective area.
- The ARB and the Resort should support a policy that the entire area of primary and secondary dunes is a no-build area.
- KICA, the Town and ARB should support polices to establish, restore and maintain good protective vegetation of the dunes.

Recommended Readings:

- Hayes, M.O. and J. Michel, 2008. “Kiawah Island”, pp. 200-211. In *A Coast for All Seasons: A Naturalist’s Guide to the Coast of South Carolina*. Pandion Books, Columbia, SC, 285 pp.

- How to Build a Dune (DHEC) http://www.scdhec.gov/environment/docs/dunes_howto.pdf

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SALT MARSH ENVIRONMENT

Significance: Salt marshes are one of the most productive ecosystems in the world. They provide essential food, refuge, and nursery habitats for more than 75% of fisheries species, including shrimp, blue crabs and many finfish. They also provide important protection for shorelines from erosion by buffering wave action and trapping sediments. Salt marshes reduce flooding by slowing and absorbing rainwater and protect water quality by filtering runoff and metabolizing excess nutrients (NOAA-NOS, 2017). Knutson et al. (1982) and Williams and Cabiness (2017), speaking for the City of Charleston, stated that 15 feet of marsh can absorb 50% of incoming wave energy. Marsh vegetation can raise land elevation by trapping sediment and adding organic matter. Numerous species of birds such as herons, egrets, terns, ospreys, and clapper rails feed on the invertebrates and fish found in the marsh. The diamondback terrapin makes its home here and raccoons, mink, and other mammals forage in this complex ecosystem. Not only do salt marshes provide summer and wintering habitat for numerous native species, they are also very important as critical stop-over locations for migrating bird species.

Current Status: Kiawah has about 50 miles of marsh front compared to ten miles of beach (J. Jordan, personal communication). There are actually more acres of salt marsh (4,517 acres) surrounding Kiawah than dry land (4,302 acres). The critical area, is defined as the coastal waters, tidelands (salt marshes), and beach/dune systems in SC, is owned by the state, except in the case where a King's Grant documenting ownership going back to colonial times has been established . Any construction that infringes on these public lands such as salt marshes requires permitting from SCDHEC-OCRM and ACOE.

In some areas of the country such as Louisiana, land subsidence and the extensive transecting of salt marshes by canals is causing rapid erosion and loss. Dr. William Doar, Senior Coastal Geologist for the South Carolina Geological Survey, has monitored salt marsh elevation levels for 20 years. During that time he has noted no salt marsh land subsidence. South Carolina marshes generally experience less human intervention than such places as Louisiana and are not eroding as rapidly. Currently studies in South Carolina indicate that while some areas of marsh are accumulating sediment and have grown vertically at the same rate as sea level rise over the past century, other areas are not accreting sediment fast enough to keep up with sea level rise (W. Doar, personal communication). Researchers monitoring Cape Romain see small marsh platform "islands" disintegrating and they also believe they are seeing grass losses. Research is showing that across the state we are losing salt marsh acreage to seawater (W. Doar, personal communication). Thirty years ago, Kana et al. (1986) predicted that 50%-90% of the salt marshes in the Charleston area would be lost to sea level rise of by the end of the 21st century, even assuming no anthropogenic hardening of the shoreline. With rising sea levels, marshes will move into the uplands as seawater inundates the grasses for longer periods of time, as long as the migration route is not blocked by hardened structures like revetments or bulkheads.

Although salt marsh grasses are bathed twice daily by saltwater, they also require some freshwater around their roots. This freshwater can come from rainfall or from groundwater percolating out from the upland. On occasions when South Carolina and Georgia have experienced prolonged droughts, areas of marsh “die-back” have occurred. The grass dies and the area becomes barren. Such blighted areas usually recover following the end of the drought, but sometimes significant erosion occurs or the barren area converts to mud flats.

In areas all along the U.S. coast where salt marshes are eroding and collapsing into the water due to higher water or increased wave activity, various public and private entities are constructing “living shorelines” to slow the trend. Living shorelines are more natural approaches to stabilizing a shore than hardened structures like a concrete wall. Although a variety of materials can be used under different site-specific circumstances and locations, the most common approach for South Carolina is the construction of oyster reefs. Our waters have an abundance of oyster spat, larval oysters dispersed by the currents, but limited hard substrate which the spat require for attachment and growth. Often mesh bags of oyster shells are placed in front of a shoreline to form a sill. Oyster spat attach to these shells and grow into a reef. This reef breaks the wave energy and stabilizes the marsh shoreline. Often greenhouse-raised *Spartina* grasses will be planted behind the reef to speed the development of a stable shoreline. The South Carolina Department of Natural Resources’ SCORE program has run a citizen-volunteer program building such reefs for many years and the local office of The Nature Conservancy also operates a similar program. Depending on the amount of wave energy and the firmness of the bottom at a site, other approaches to oyster reef construction may include blowing loose oyster shell from a barge, concrete blocks known as “oyster castles”, or wire mesh coated with concrete. Oyster reef living shorelines not only stabilize a shoreline but provide habitat and food for a diversity of fauna and flora. Because the oyster community is composed of living organisms, as sea level rises, the reef also grows vertically, easily keeping pace with the higher waters. In addition, non-oyster-based living shorelines like the use of natural fiber structures such as Coir logs® can be used.

Living shorelines have been discussed as a way to protect Kiawah’s saltmarsh shoreline. The Kiawah River has extensive, healthy, naturally-occurring oyster beds, which already help to protect the marshes from wave action erosion. As sea level rises, these reefs should grow vertically as well. As a result, the challenge facing our marshes is probably not from wave induced erosion, but rather from insufficient accreting sediment for vertical growth or from barriers preventing inland migration. Thus, construction of new living shorelines may provide benefits only in limited locations along Kiawah.

The health of salt marshes can be harmed by rapid stormwater runoff from impervious surfaces because it carries nutrients, chemicals like gasoline and oil, pathogens like fecal bacteria, and sediments. Watersheds with greater than 10% impervious surface levels have increased chemicals, nutrients, and fecal bacteria in tidal creeks. Salt marsh tidal creek biotic health is impaired when the amount of impervious surface within a watershed exceeds 20-30% (Sanger and Parker 2016). Low Impact Development practices and vegetative buffers along the edge of the marsh filter large amounts of runoff through soils and vegetation to capture pollutants.

Concerns: Local experts on salt marsh research expect to see significant loss of marsh in South Carolina as sea levels rise and cause more erosion (R. Van Dolah, personal communication). Van Dolah reported that research at the Belle Baruch Marine Institute in Georgetown suggests the marshes in the North Inlet estuary will be unlikely to survive by the end of this century (Morris, 2016). Van Dolah's own review of the SLAMM (Sea Level Affecting Marshes Model; Warren Pinnacle Consulting, Inc., Waitsfield, VT) model also suggests that that there will be large areas of salt marsh loss all along the South Carolina coast. Other studies have concluded that accelerated sea level rise may cause most habitats of middle and high marshes to drown, resulting in mud flats (W. Doar, personal communication; Tibbetts, 2007). He also noted that as sea levels rise, *Spartina*, marsh grass, will naturally migrate into higher elevations of the uplands, but only if there are gradual slopes to follow.

Our concerns are based on the fact that salt marshes can respond only in three ways under the stress of sea level rise:

1) If enough sediment is available in the water column, marshes can trap the sediment and grow vertically as the water rises. Although turbid, the Kiawah River does not receive outside sediment from an upland river, and most sand from the Stono Inlet is transported down the beach side of the island. So the sediment present is largely just being moved around, with little new sediment coming into the system. This is of concern because it raises doubts that our marshes will be able to grow vertically as water rises.

2) Where there are gradual slopes from the present marsh into the uplands, salt marshes will migrate landward as sea levels rise. This is likely the natural scenario for a low topography barrier island like Kiawah. Unfortunately, most of the shoreline adjoining the marshes is high value real estate populated with existing or future homes. As sea levels rise in the coming decades, there will be great pressure to protect properties with hardened structures. This will prevent marshes from moving horizontally over major portions of Kiawah's shoreline.

3) If salt marshes cannot grow vertically because of insufficient sediment and cannot move horizontally because of barriers in one form or another, they will drown as sea levels rise. The

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result will be open water at high tide and mud flats at low tide. While mud flats are productive in their own right, they do not provide the same habitats, productivity, and ecosystem services as salt marshes.

An additional concern is whether Kiawah's salt marshes are being harmed by pollutants in stormwater runoff especially when runoff is diverted directly into the marsh rather than passing through the pond system?

Recommendations: There are limits on recommended actions that we can take that will effectively deal with the challenges of sea level rise to our vast marsh system. Estuaries are always dynamic and to some extent unpredictable.

1) Develop a program that helps property owners to consider alternatives to the construction of hard barriers to protect the salt marsh adjacent to their property from rising sea levels. Although permits from SCDHEC-OCRM and the ACOE are required, a permitting process by the Town and the ARB should consider all alternatives and favor more natural approaches if possible. The use of sea walls or hard structures for preventing upland erosion and marsh incursion should be considered as a last resort. The consequences for neighboring properties and infrastructure of constructing these barriers must be addressed. SCDHEC-OCRM, SCDNR, FWS – Bears Bluff Laboratory, and The Nature Conservancy are good local resources for nature-based solutions.

2) The Conservancy and other land-owning entities should consider acquiring or protecting strategic properties that will provide future salt marsh migration routes. The Conservancy could explore the legal and practical possibility of acquiring tax-reducing easements on portions of properties along the edge of salt marshes that will permit some future inland migration. The College of Charleston inundation mapping models will be helpful to establish priority locations.

3) Analyze the College of Charleston inundation mapping models to understand the timing and extent of the risks to salt marshes and to help evaluate mitigation strategies.

4) Monitor the health of Kiawah's salt marshes on a regular schedule, especially indicator species such as the saltmarsh sparrow.

5) Monitor the development of state guidelines and new techniques for constructing living shorelines in appropriate situations. Evaluate how these may be applied to different locations and situations around Kiawah, e.g. the Parkway between the bridge and main gate, Rhett's

Bluff causeway, or private marsh edge lots. Living shorelines might prove useful in both protecting areas of salt marsh and in mitigating flooding and storm surge.

6) Organize and work with neighborhoods to develop coordinated efforts to address questions such as adding fill to lots equal to the rate of sea level rise particularly on marsh edge properties. Assist these neighborhoods in the evaluation of land elevation and construction of living shorelines that can be done selectively over the years at the timing chosen by property owners. Provide a menu of useful ideas and possible incentives for cooperative, coordinated actions.
7) Support Low Impact Development practices and required vegetative buffers to reduce pollutants from entering the salt marshes through stormwater runoff.

Responsibilities and Partners:

- Establish the Town as having primary responsibility for the marsh, similar to its beach responsibilities. The Town should work with the state and federal agencies that have jurisdiction over salt marshes, stay up to date on regulations and techniques for property protection and marsh health, provide guidance to property owners, and ensure compliance with ordinances related to salt marsh protection.
- The Conservancy should explore its role in acting now to protect the marsh ecosystem from future stresses resulting from sea level rise decades in the future.
- The ARB, KICA, and the Developer should review, adopt, and enforce policies aimed at the long-term protection of Kiawah's salt marsh ecosystem.

Recommended Reading:

- Dynamics of the Salt Marsh, http://www.dnr.sc.gov/marine/pub/seascience/dynamic.html

- Marshes to Mudflats – Effects of Sea-Level Rise on Tidal Marshes along a Latitudinal Gradient in the Pacific North, https://pubs.usgs.gov/of/2015/1204/ofr20151204.pdf

- Seabrook, C., 2012. *The World of the Salt Marsh*. University of Georgia Press, Athens, GA. 367 pp.

- The **Sea Level Affecting Marshes Model** (SLAMM) simulates the dominant processes involved in wetland conversions and shoreline modifications during long-term sea level rise. Map distributions of wetlands are predicted under conditions of accelerated sea level rise, and results are summarized in tabular and graphical form. The newest versions of SLAMM include a Roads module to investigate the inundation frequency of road infrastructure and a

stochastic uncertainty analysis module for assessing the effects of input data uncertainty on model predictions. The uncertainty analysis module can be used to produce confidence intervals for model predictions and likelihood maps."
http://warrenpinnacle.com/prof/SLAMM/index.html

- South Carolina Department of Natural Resources SCORE program for constructing Living Shorelines. http://score.dnr.sc.gov/deep.php?subject=2

- DHEC Living Shorelines Working Group. http://www.scdhec.gov/HomeAndEnvironment/Water/CoastalManagement/LivingShorelines/

- *Guide to the Salt Marshes and Tidal Creeks of the Southeastern United States*. www.saltmarshguide.org

- Rising Tide: Will Climate Change Drown Coastal Wetlands? http://www.scseagrant.org/pdf_files/ch_winter_07.pdf

TERRESTRIAL ECOSYSTEMS and GROUNDWATER

Significance: Essential to the character of Kiawah for aesthetics, recreation, and comfortable residential living are its diverse and flourishing terrestrial ecosystems, which also provide habitats for the island's abundant wildlife. Sea level rise impacts on beaches and salt marshes are easier to visualize, but might it also threaten the maritime forests of Kiawah?

Current Status: Barrier island vegetation communities are primarily distributed based on the depth to the freshwater table. This zone of non-permanently saturated soil is called the vadose zone and sits atop the freshwater aquifer. The viability of maritime forests on barrier islands is highly dependent on vadose zone thickness and groundwater salinity in the underlying, shallow aquifer (Masterson et al. 2014).

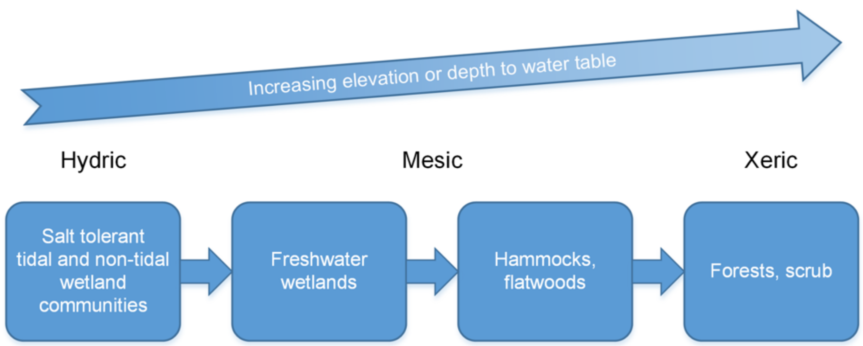

Figure 9. Distribution of plant communities and the wildlife associated with them is largely dependent on the depth of the groundwater relative to the surface. (From Foster et al. 2017)

Freshwater availability on a barrier island is typically a function of precipitation falling on the island less the amount lost to the atmosphere by evaporation and transpiration through plants. As rainfall percolates down through the soil, it accumulates in a shallow, surficial aquifer generally within 50 feet of the surface. Seawater surrounding an island infiltrates beneath the surface of the island. The surficial freshwater aquifer floats on top of the subsurface seawater because it is less salty and thus less dense. This floating body of freshwater is called a freshwater lens because it is generally convex, i.e. thicker in the middle and narrower towards the edges of the island. The actual shape, however, is influenced by the geomorphology of the island. In some instances, the boundary between the freshwater lens and the underlying seawater is fairly sharp, but in other cases there is a broad zone of brackish water mixing.

Drought can reduce the recharge of the groundwater, reducing the thickness of the freshwater lens and raising the water table since there is less freshwater volume to hold back the seawater. Similarly, sea level rise also will reduce the thickness of the freshwater lens by creating more head pressure for the infiltration of seawater under the island. Saltwater infiltration will likely

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increase the salinity of the lens, as well. This will impact the distribution and health of terrestrial vegetation. Sea level rise will turn some marginal brackish areas to salt, and some freshwater areas will become brackish. Masterson et al. (2014) modeled the effect of sea level rise on the hydrology of a barrier island. They found that a sea level rise of only 8 inches led to substantial changes in the depth of the water table and the extent of saltwater, both of which influenced the establishment, distribution and succession of vegetation assemblages and habitat suitability in barrier islands ecosystems. In low lying areas, groundwater was forced to the surface creating new freshwater wetlands, and overall there was thinning of the underlying freshwater lens. On Kiawah, rising groundwater might increase the horizontal and vertical dimensions of many ponds.

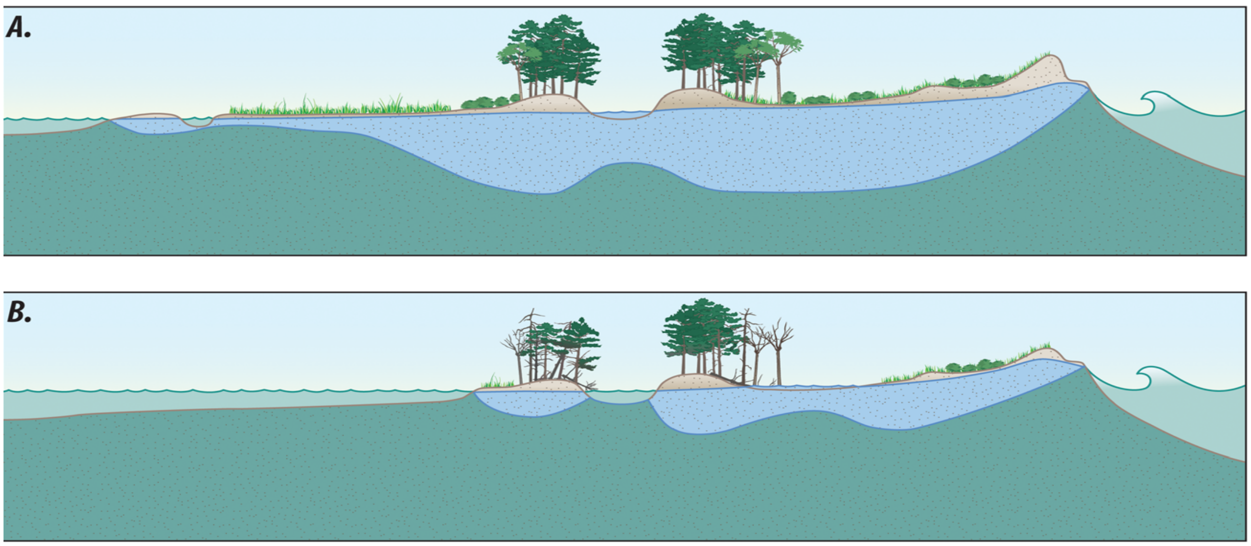

Figure 10. Sea-level rise can affect groundwater flow in barrier island aquifers by decreasing the vadose zone (shown in brown) and the freshwater lens thickness (shown in blue) as the water table rises in response to increases in sea level from current (A.) to future conditions (B.). These hydrologic responses are key determinants in the establishment, distribution and succession of vegetation assemblages and habitat suitability in barrier island systems. (From Masterson et al. 2014)

Rising sea levels and higher storm surges may cause the death of trees and shrubs along the edges of islands as they frequently become inundated with salty seawater. "Ghost forests" of dead and dying trees can be seen in many areas along the Southeast coast (Drouin 2016). Examples can be seen on Kiawah in The Preserve and in other locations throughout the Low Country. This phenomenon will expand with higher sea levels. With the death of pines and other maritime forest plants, new, more salt tolerant plants can move in, including undesirable invasives such as *Phragmites*. In most locations the freshwater lens extends to the edge of the island and freshwater flows underground into the saltmarsh. It may be possible to maintain good tree canopy along the marsh edge if the freshwater flow irrigates the tree roots (Callahan, personal communication). Droughts could disrupt this flow, and of course long-term sea level rise may stop this outward flow of freshwater.

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One of the important factors for maintaining the integrity of the groundwater lens is the input of freshwater through precipitation. Based on rainfall amounts for the last three years provided by KICA's Lakes Management Department, Kiawah averaged 47.95 inches per year. This converts to approximately 5,601 million gallons of water falling on Kiawah annually. Irrigation water provided by the Kiawah Island Utility for KICA, the Resort, some regimes, and a few homeowners, but not including the majority of private homeowner irrigation, amounted to approximately 587 million gallons in 2017. This adds an additional 10% of freshwater to Kiawah's groundwater, which is not insignificant, especially during periods of drought. Additional irrigation from the Resort's very deep wells (2,500-foot Middendorf aquifer) and homeowners' irrigation increase this contribution. Irrigation water percolates through the vadose zone to the freshwater lens, while considerable amounts of precipitation run off through the stormwater system and out into the marshes. Thus, the contribution from irrigation may be significantly higher than the calculated 10%. These supplements from irrigation may be important in increasing the resilience of Kiawah's groundwater resources.

Concerns: The health and viability of Kiawah's maritime forests and other terrestrial environments depend upon the depth of the vadose zone above the freshwater lens and the salinity of the water in the surficial aquifer.

1) With rising sea levels, will the vadose zone be reduced and groundwater salinity increased, with direct consequences for vegetation across the island?

2) Will sea level rise and storm surges claim more areas on the periphery of the island, turning them into "ghost forests" or making the environments favorable for less desirable species?

3) Will warmer temperatures and more frequent droughts negatively impact Kiawah's groundwater by increasing evaporation and the volume of water available to percolate to the freshwater lens?

4) How will the wildlife that inhabit the terrestrial environments be impacted by these possible changes?

Recommendations:

1) Contract for a mapping of the depth and distribution of Kiawah's freshwater lens and a study of how annual and seasonal rainfall, as well as irrigation, affects groundwater and

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the vadose zone. This will help us to better understand the hydrological conditions that support our terrestrial communities.

2) Establish a monitoring program for the depth of the freshwater table and how it is changing over time. Develop a similar program to monitor the maritime forest in critical locations identified by the mapping program. If negative trends are detected, develop appropriate responses.

3) Review the relationship between the groundwater table and the pond system. Consider how lowering the pond system affects movement of groundwater and its ability to prevent saltwater intrusion.

4) Retain as much freshwater as practical. Model the best places to accumulate water along the edges of the island in order to slow or minimize saltwater intrusion. Rain gardens, ponds, or irrigation can all contribute to this goal.

5) Maintain functioning check valves on outfalls to the pond system. A pond that has been drained without a good check valve is an easy entry channel for saltwater.

6) During storms, consider allowing ponds to remain filled since a full pond is a good defense against saltwater intrusion from higher sea levels.

7) Homeowners could consider installing 500-gallon underground rainwater cisterns to help with yard flooding and for irrigation. Cost for the cistern and installation is approximately $700. The additional water could percolate into the soil rather than runoff into the stormwater system and would help maintain the surficial aquifer as a defense against saltwater intrusion.

Responsibilities and Partners:

- Since the groundwater is interconnected with the pond system, KICA should take the lead in conducting a monitoring program of Kiawah's freshwater lens and in managing the surficial aquifer.
- The Town or the Conservancy could assist KICA by contracting for the initial mapping and modeling of the lens including the effects of precipitation and irrigation in maintaining it.
- The Conservancy could conduct periodic evaluations of the health of the maritime forest in relation to the depth of the vadose zone across the island.

Additional Information:

- Carolinas Integrated Sciences and Assessments (CISA), in association with the University of South Carolina; http://www.cisa.sc.edu/

- Department of Geology and Environmental Geosciences, College of Charleston; http://geology.cofc.edu/

- Charleston Resilience Network; http://www.charlestonresilience.net/

- Nemours Wildlife Foundation, Dr. Ernie Wiggers, director; coastal impoundment management and development, research, and education; http://www.nemourswildlifefoundation.org/

EDUCATION for SEA LEVEL RISE ADAPTATION

Significance: The Environmental Protection Agency, the National Oceanic and Atmospheric Administration, and other governmental agencies, have published information in the past few years reporting that there is a measurable increase in global temperature and this increase is accompanied by an increase in global sea level along with increasingly severe storms and rain events.

Locally, sea level has increased, and we are experiencing an increase in the number of days each year of tidal flooding. We have also had several significant storms in the past three years:

- The extreme rain event of 2015 produced many inches of rain and significant flooding.
- Hurricane Matthew (2016) fortunately did relatively little damage but flooding was an issue. A mandatory evacuation of Kiawah was ordered.
- For Tropical Storm Irma (2017) there was no mandatory evacuation of Kiawah Island, but a large portion of the island suffered significant flooding.

Most scientific studies done in recent years make it clear there has been and will continue to be a rise in local sea level and an increase in the number and severity of storms that will lead to more damage through water and wind. The City of Charleston and surrounding communities such as Beaufort and Folly Beach have been developing plans to ameliorate damage from storms and flooding, and this report represents the efforts of Kiawah Island to do the same.

Property owners need and deserve timely, understandable, and accurate information on sea level rise, the consequences of that change, and the current status of storm and flooding preparation. To plan their lives, they also need information on plans for changes to be made in the next 3-5 years and over the next few decades. They also need to know the communication channels, trust those sources, and how to access them in the event of an emergency or to access relevant information.

Current Status: To this point the main ways property owners have been educated on the general topic of sea level rise, climate issues, and hurricanes and other storms have been through the following:

- The Town of Kiawah Island through its publications and emergency warning system.
- The Kiawah Island Community Association, through its publications, the *Our World* seminar series, and its safety division.
- The Kiawah Conservancy through the *Naturally Kiawah* magazine and periodic lecture programs, *Conservation Matters*.
- The *Post & Courier, which* has published numerous articles on climate change, sea level rise,

flooding events, and the city's effort on lessening the damage from flooding.

<u>Concerns</u>: Most importantly, we need to be sure that Kiawah Island residents, property owners, and governing entities receive important, accurate, and useful information in a timely way.

<u>Recommendations</u>:

1) In the near future bring a series of speakers to the island on the issues surrounding sea level rise and its consequences. The Town Environmental Committee could take the lead in organizing this with KICA (through the *Our World* program) and the Kiawah Conservancy (and its *Conservation Matters* programs). A list of possible speakers can be assembled and at least one or two talks should be sponsored each fall and spring. Some of these talks can be by those who operate the Island's infrastructure, e.g. stormwater ponds, the water and sewage plants, the roads.

2) Assemble a database of the most relevant and accurate articles and make it available through the Town, KICA, and the Conservancy websites.

3) Inform residents of exact locations where the island is most vulnerable to street flooding that could impede vehicles leaving the island, could prevent them from entering or leaving a part of the island, or that impede emergency vehicles.

4) Residents should understand what level of storm activity (e.g., rain intensity, storm surge, tidal action) would lead to specific actions from the Town and KICA.

5) Educate island residents on what the Town and KICA do to prepare for a storm or large rain event so residents better understand how the island systems function.

6) Help residents appreciate what would be required to recover from an event and how long it might take, hours, days, or weeks.

7) Educate property owners about the vulnerability of their property to minor flooding so they can better recognize whether they might experience localized flooding during a king tide or significant rain event. This would enable them to make decisions and take actions to protect personal property in garages or decide to sand bag garage doors, for example. This would also be useful for the many non-resident property owners who could benefit from knowing whether they should have local contractors or representatives take protective measures for their homes.

8) Publicize the National Weather Service – Charleston's website that provides current flood predictions: https://www.weather.gov/chs/products.

9) If a storm appears to be headed to our vicinity, provide residents with reliable and accurate information about what the impact may be so they can make proper judgements about leaving the island, protecting their property, and, if they leave, when it is appropriate to return. Commercial interests such as the Resort and rental companies also need this information so they can make decisions about their operations and guests.

10) Develop a communication plan for weather-related emergencies. Most residents have cell phone and internet service, but not everyone does. This would apply to information and instructions before, during, and after a storm. There should also be a way for non-resident property owners to get timely, useful information.

11) The ARB should work with architects, builders, and landscape designers to develop recommendations for construction that would lessen damage in the event a home is partially flooded.

12) Coordinate efforts by the Town, KICA, and the Conservancy to develop landscaping plans that better allow rain to permeate the ground and discourage or even eliminate the use of pine straw on slopes because it easily washes off and clogs drainage systems. Encourage the use of permeable materials for driveways and parking lots.

13) Have the Town Environmental Committee work with KICA and the Conservancy to develop lists of landscaping materials that can withstand a saltier environment. Then implement a proactive program to educate property owners and HOA boards and provide consulting support to help them adopt the recommendations.

Responsibilities and Partners: The Town and KICA are the logical parties to be most responsible for implementing an education program, but with significant assistance from the Conservancy and the ARB. How these parties can best organize will have to be worked out, but the following seems logical at this point:

- Communications: Town, KICA, and the Conservancy
- Educational Programs: Town Environmental Committee, KICA *Our World* program, and the Conservancy.
- Landscape Recommendations: Town Environmental Committee, KICA, ARB, and the Conservancy.
- Architectural and Building Recommendations: Town, ARB, and KICA

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Recommended Readings: The following are documents that provide general information that the Committee has found particularly useful.

- Burkett, V. and M. Davidson (eds.), 2012. *Coastal Impacts, Adaptation, and Vulnerabilities: A Technical Input to the 2013 National Climate Assessment*. Island Press, Washington, DC. 185 pp.

- Charleston Resilience Network. http://www.charlestonresilience.net/

- Charleston Sea Level Rise Viewer. City of Charleston with assistance from NOAA. Works in 6-inch increments. http://gis.charleston-sc.gov/interactive/slr/

- "Climate Change: How Do We Know?" 2018. NASA's Jet Propulsion Laboratory. https://climate.nasa.gov/evidence/

- "Climate Change 2014, Synthesis Report". 2014. Intergovernmental Panel on Climate Change. http://www.ipcc.ch/report/ar5/syr/

- "Climate Change: Global Sea Level," an overall review of sea level rise in 2017 from NOAA, https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level

- "Climate Science Special Report, Fourth National Climate Assessment (NCA), Vol. 1". 2017. https://science2017.globalchange.gov/

- "Global Sea Level Rise Scenarios for the United States National Climate Assessment," (NOAA) https://scenarios.globalchange.gov/sites/default/files/NOAA_SLR_r3_0.pdf

- Goodell, J. 2017. *The Water Will Come — Rising Seas, Sinking Cities, and the Remaking of the Civilized World*, Little, Brown and Company.

- "Mapping Coastal Inundation Primer," (NOAA) https://coast.noaa.gov/data/digitalcoast/pdf / coastal-inundation-guidebook.pdf"

- Military Expert Panel Report, 2018. *Sea Level Rise and the U.S. Military's Mission*. 2nd edition. The Center for Climate and Security. https:/climateandsecurity.files.wordpress.com/2018

/02/military-expert-panel-report_sea-level-rise-and-the-us-militarys-mission_2nd-edition_02_2018.pdf

- National Weather Service – Charleston' Severe Weather updates and predictions. https://www.weather.gov/chs/products

- Pilkey, O.H., L. Pilkey-Jarvis, and K.C. Pilkey, 2016. *Retreat from a Rising Sea: Hard Choices in the Era of Climate Change*. Columbia University Press, New York. 214 pp.

- "Primer on Sea Level Rise and Future Flooding," http://www.charlestonresilience.net/wp-content/uploads/2017/03/flooding_primer_marcy.pdf

- "Responding to the Threat of Sea Level Rise," National Academy of Sciences, https://www.nap.edu/catalog/24847/responding-to-the-threat-of-sea-level-rise-proceedings-of

- SCDHEC's Coastal Hazard Vulnerability Assessment Tool. https://gis.dhec.sc.gov/hva/

- SCDHEC's King Tides Initiative for the South Carolina coast, https://mycoast.org/sc

- South Carolina Department of Natural Resources, 2013. *Climate Change Impacts to Natural Resources in South Carolina*. 101 pp. http://www.dnr.sc.gov/pubs/CCINatResReport.pdf

- Spanger-Siegfried, E., M.F. Fitzpatrick, and K. Dahl. 2014. Encroaching tides: How sea level rise and tidal flooding threaten U.S. East and Gulf Coast communities over the next 30 years. Cambridge, MA: Union of Concerned Scientists. https://www.ucsusa.org/global_ warming/impacts/effects-of-tidal-flooding-and-sea-level-rise-east-coast-gulf-of-mexico#.W1ow5thKhBy

- Tibbetts, J.H., 2007. Rising tide: Will climate change drown coastal wetlands? http://www.scseagrant.org/pdf_files/ch_winter_07.pdf

- Town of Kiawah Island Emergency Preparedness Guide. https://s3-us-west-2.amazonaws.com/kiawah-island/wp-content/uploads/2017/06/16140132/2017-Emergency-Preparedness-Guide.pdf

- "Underwater: Rising Seas, Chronic Floods, and the Implications for U.S. Coastal Real Estate," Union of Concerned Scientists, https://www.ucsusa.org

- "U.S. Climate Resilience Toolkit," (NOAA) https://toolkit.climate.gov

- "When Rising Seas Hit Home," Union of Concerned Scientists, https://www.ucsusa.org/sites/default/files/attach/2017/07/when-rising-seas-hit-home-full-report.pdf

A PATH FORWARD

This report has tried to capture an understanding of how sea level rise and extreme precipitation events will lead to more frequent flooding of Kiawah in the decades ahead. It has also suggested a diversity of recommendations which may help the island adapt to the changes and to become more resilient. While sea level rise is real and will almost certainly accelerate in the coming decades, the rate of change is uncertain. The Committee has adopted an intermediate rate scenario, similar to that the City of Charleston and many other communities are using, of 1.5 to 2.5 feet of sea level rise in 30 to 50 years. Given this time frame, it is not necessary to implement every recommendation immediately, nor practical to do so.

Working cooperatively, it would be prudent for the Town, KICA, and other entities to adopt an adaptive management "pathways" approach to addressing flooding and sea level rise issues (CoastAdapt, 2017; OneSF, 2015; Stephens et al., 2017). Some decisions and actions need to be taken now and others can be postponed to different times in the future. A pathways approach allows decision-makers to plan for, prioritize, and stagger investments in adaptation options. Identifying trigger points and thresholds helps them to know when to take action and when to revisit decisions or prior actions. This adaptive management approach does not lock a community into one path for decades with investments that might waste resources and prove to be futile. It allows decision-makers to learn from past actions and to incorporate new information that may become available in the future.

As an example, suppose a section of road is deemed susceptible to flooding because during Tropical Storm Irma it was impassable with 18 inches of water. That was a rare occurrence, so immediate action may not be justified. A threshold could be set that a foot of water on that road three times a year is unacceptable. The trigger point for action might be the occurrence of a few inches of nuisance flooding six times annually. Immediate action might have led to elevating the road at considerable expense. Waiting perhaps a decade or more until the trigger point is reached might permit the development of new technologies, such as a "retractable floating wall" that could be installed at a fraction of the cost and that effectively protects the road from ever reaching the undesirable threshold. The elevation of the road at that later trigger point time still remained an option.

Adaptive management pathways provide an approach for addressing sea level rise, with implementation spread out over time, allowing for capital development, community support, and new options to develop. Regular monitoring of actions already taken as well as actual changes as trigger points are approached allows decision-makers to establish and re-establish schedules and to take advantage of new options that may develop without shutting off alternative pathways. Figure 11 illustrates how this process might work.

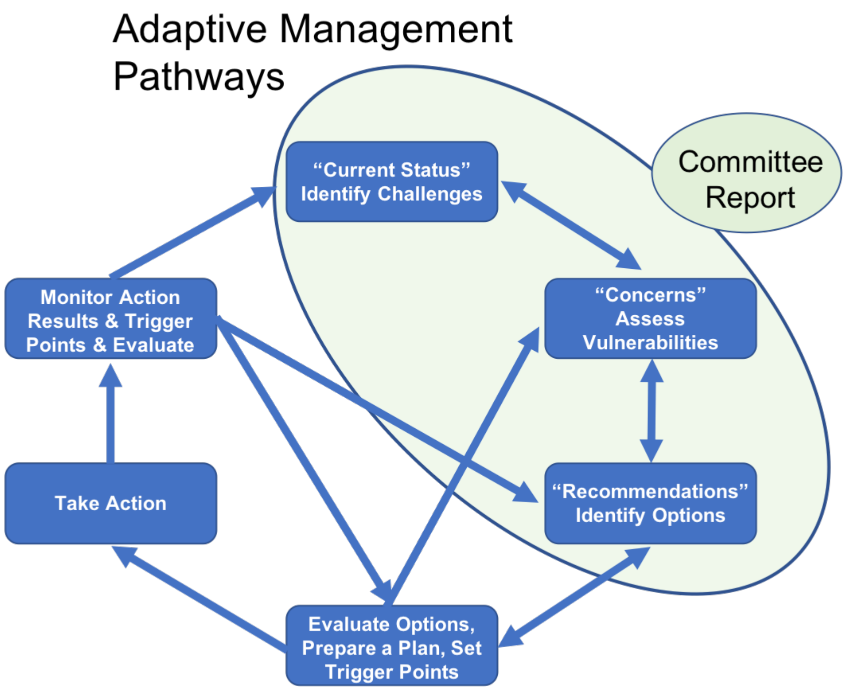

Figure 11. Because of the uncertainty of the rate of sea level rise, the Committee recommends an approach in which trigger points and thresholds are used for planning adaptation actions over a time frame appropriate for the environmental changes as they occur. The Committee has started this process with activities identified in the diagram. Decision makers can develop plans for actions in the future to be implemented as identified trigger points are reached. This requires regular monitoring and re-evaluation of options and plans. (Modified from CoastAdapt, 2017).

The Committee concludes this report with the following recommendations:

1) The long-term challenges posed for a barrier island by sea level rise are serious and Kiawah's decision-makers should embrace the opportunity to develop policies and actions that will permit Kiawah to adapt and remain a resilient and vibrant community. Hopefully this report is a starting point.

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2) The Town and KICA, and perhaps the other major interests, should appoint a small group of professionals such as the Town's Wildlife Biologist, KICA's Director of Major Repairs, and a few others with relevant expertise to recommend a range of "trigger points" for action. This will be essential to the decision-makers for long term adaptation and resilience planning.

3) In order to ensure that the flooding and sea level rise issues receive the necessary planning and implementation attention, the Town and KICA need some structure

- to assist in policy and planning development,
- to provide GIS analysis, data and technical support,
- to provide educational and problem-solving, technical support for the community at large,
- to foster communication and cooperation among the major decision-making entities,
- to coordinate research and monitoring studies related to sea level rise on the island and disseminate the results,
- to monitor trigger points, project progress, and new data as it appears in the literature, and
- to represent Kiawah in county, state, and regional groups such as the Charleston Resilience Network and SCDHEC-OCRM's Coastal South Carolina Community Ratings System Users Group.

The Town and other Kiawah entities should work together to hire a Resilience Specialist, or to develop a Resilience Committee consisting of appointed representatives from the major decision-making bodies, but at least the KICA and the Town. This will likely require new resources rather than just expanding the job description of a current employee. If a Resilience Specialist position is created, joint funding could be considered.

4) The Town and KICA should establish a procedure whereby every four years (maybe following the publication of the new National Climate Assessment) a small appointed "external" group reviews the recent literature, the progress made regarding projects on Kiawah, and any monitored changes on the island relevant to sea level rise issues. The group would then modify the recommendations in this report, make new ones as appropriate, and present its findings to the decision-making bodies.

5) The Town should recognize the importance of sea level rise planning by incorporating it into the next revision of the Town's Comprehensive Plan. As an example, the following is extracted from Beaufort County's 2010 Comprehensive Plan:

*"**Recommendation 5- 20: Climate Change and Rising Sea- Level***

1. *Beaufort County should anticipate and plan for the impacts of climate change and sea level rise.*
    - *Anticipate Sea Level Rise. Work with the U.S. Geological Survey and other monitoring agencies to track inlet and ocean levels; utilize estimates for mean sea level rise to map potential areas subject to future inundation; and work with FEMA to amend flood maps for any areas subject to increased flooding from a rise in sea level.*

- *Plan for Sea Level Rise. The potential impacts of sea level rise on low-lying areas should be a consideration in future land use planning, site plan review, and the location of future roads and other public facilities.*
- *Disclosure: Consider requiring a disclosure statement when development and building permits are issued on low-lying property acknowledging that the County is not committed to stabilizing property or maintaining private roads and causeways by constructing seawalls, levees or other devices."*

6) Similarly, KICA should recognize the importance of sea level rise planning by incorporating it into its Strategic Plan.

7) In order to successfully address issues of flooding and sea level rise, all governing bodies, service providers, and commercial property managers, as well as individual property owners should work together. Throughout this report the responsibilities of the governing bodies have been identified and recommendations often aimed at one entity or another. But successful planning for mitigation and adaptation to these challenges will require that all these entities cooperate on developing solutions and coordinate in implementing the appropriate actions. In addition to the governing bodies and the service utilities included in this report, the property management companies should be included at some point. Because the property managers deal with so many renters and property owners, they need to be kept informed about what is being done and why, so that they can present a consistent, positive message about Kiawah's proactive programs to address sea level rise. Kiawah also can benefit greatly through collaboration with Charleston County, the College of Charleston, a variety of state agencies, and public-private organizations like the Charleston Resilience Network. Sea level rise will affect everyone associated with Kiawah and success in dealing with it will require a broad, cooperative and coordinated effort.

APPENDIX A - DEFINITIONS

Altimetry - a technique for measuring height. Satellite altimetry measures the time taken by a radar pulse to travel from the satellite antenna to the surface and back to the satellite receiver. Combined with precise satellite location data, altimetry measurements yield sea surface heights.

Astronomical tide - The tide levels that result from gravitational effects of the Earth, Sun and Moon, without any atmospheric influences like wind or low pressure systems.

Base flood elevation - The computed elevation to which floodwater is anticipated to rise during the base flood. The base flood elevation is the regulatory requirement for the elevation or floodproofing of structures. The relationship between the BFE and a structure's elevation determines the flood insurance premium.

Barrier Island - a coastal landform and a type of dune system that are exceptionally flat or lumpy areas of sand that form by wave and tidal action parallel to the mainland coast. The amount of vegetation determines the height and evolution of the island.

Evapotranspiration - the process of transferring water from the earth to the atmosphere by direct evaporation from physical surfaces and by water movement through plants and its evaporation from aerial parts, such as leaves, stems and flowers.

FEMA Base Flood - The flood having a 1% chance of being equaled or exceeded in any given year. Also referred to as the 100-year flood. The base flood is used by the National Flood Insurance Program as the basis for mapping, insurance rating, and regulating new construction.

FEMA Zone A - The Special Flood Hazard Area shown on a community's Flood Insurance Rate Map. Areas with a 1% annual chance of flooding and a 26% chance of flooding over the life of a 30-year mortgage.

FEMA Zone V - The Special Flood Hazard Area subject to coastal high hazard flooding. Coastal areas with a 1% or greater annual chance of flooding and an additional hazard associated with storm waves. These areas have a 26% chance of flooding over the life of a 30-year mortgage.

FEMA Zone X - Areas outside of the Special Flood Hazard Area with moderate (between 0.2% and 1%) risk of annual flooding, or minimal (less than 0.2%) annual risk of flooding.

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Freeboard - the required height for the lowest floor of a building proscribed by a jurisdiction above the base flood elevation.

Freshwater lens - A convex-shaped layer of fresh groundwater that floats above the denser saltwater, usually found on small islands. This aquifer of fresh water is recharged through precipitation that infiltrates the top layer of soil and percolates downwards until it reaches the saturated zone.

GIS - A geographic information system (GIS) is a system designed to capture, store, manipulate, analyze, manage, and present spatial or geographic data.

Global Sea Level Rate - The worldwide change of sea level elevation with time. The changes are primarily due to glacial melting or formation and thermal expansion or contraction of seawater.

High Water (HW) - The maximum height reached by a rising tide. The high water is due to the periodic tidal forces and the effects of meteorological, hydrologic, and/or oceanographic conditions.

King Tide - A non-scientific term used to describe the highest seasonal tides that occur each year. For example, in Charleston, the average high tide range is about 5.5 ft., whereas during a King Tide event the high tide range may reach 7 ft. or higher. These tides occur naturally and are typically caused when a spring tide takes place when the moon is closest to Earth during the 28-day elliptical orbit. Over time, the frequency and effect of King Tide events may increase due to gradual mean sea level rise. Also known as perigean spring tides.

LIDAR - *Light Detection and Ranging*; a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system— generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.

Mean Higher High Water (MHHW) - A tidal datum. The average of the higher high water height of each tidal day observed over the National Tidal Datum Epoch.

Mean Lower Low Water (MLLW) - A tidal datum. The average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch.

Mean Sea Level (MSL) - A tidal datum. The arithmetic mean of hourly heights observed over the National Tidal Datum Epoch.

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National Geodetic Vertical Datum of 1929 (NGVD 29) - an orthometric, unchanging, vertical control datum established for surveying elevation in the United States. NGVD 29 is often incorrectly referred to as Mean Sea Level because it was originally based on mean sea level measured at 26 tide gauges in the U.S. and Canada. It never accurately describe mean sea level for any specific location. For a variety of reasons, its use was abandoned by the National Geodetic Survey in 1993 in favor of the NAVD88 orthometric datum, although it is still widely used by contractors and surveyors.

National Tidal Datum Epoch - The specific l9-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.

Neap Tide - A tide in which the difference between high and low tide is the least. Neap tides occur twice a month when the sun and moon are at right angles to the Earth. When this is the case, their total gravitational pull on the Earth's water is weakened because it comes from two different directions.

North American Vertical Datum of 1988 (NAVD 88) - an orthometric, unchanging vertical control datum established in 1991 for surveying elevation in the United States. All surveying or mapping activities performed or financed by the federal government are referenced to NAVD88. Today, most elevation data are derived from LIDAR data and are referenced to NAVD88 before producing products such as Digital Elevation Models (DEMs), which are used for modeling and mapping flooding.

Nuisance flooding - Minor, recurrent flooding that takes place at high tide not necessarily linked to storms or heavy rain. See **Tidal flooding**.

Perigean Tides -Tides of increased range occurring monthly as the result of the moon being in perigee.

Perigee - The point in the orbit of the moon nearest to the Earth.

Rain garden - native shrubs, perennials, and flowers planted in a small depression, generally formed on a natural slope. It is designed to temporarily hold rainwater runoff that flows from roofs, driveways, patios or lawns, and allow it to soak into the ground.

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Relative Sea Level Change - A local change in mean sea level relative to a network of bench marks on the land adjacent to the tide gauge station. A change in relative mean sea level may be composed of both an absolute water level change and vertical land movement.

Sea Level Rise Adaptation - The process of adjusting to actual or expected sea level rise.

Sea level rise – An increase in the global average sea level relative to land due to increased water volume of the ocean over a period long enough to average out transients such as waves, tides, and storms. Sea level rise is usually attributed to thermal expansion of the water in the oceans and by melting of ice sheets and glaciers on land. Sea level rise at specific locations may be more or less than the global average. Local factors might include bathymetry, subsidence of the land, tides, major currents, and storm frequency.

Spring Tide - A tide of increased range occurring semimonthly as the result of the Moon being new or full, and hence, aligned with the sun. The combined gravitational pull of the sun and moon increases tidal amplitude.

Steric Sea Level Change - Variation in water levels caused by changes in density driven by temperature and salinity fluctuations.

Storm Surge - The abnormal rise in seawater level during a storm, measured as the height of the water above the normal predicted astronomical tide. The surge is caused primarily by a storm's winds pushing water onshore. The amplitude of the storm surge at any given location depends on the orientation of the coast line with the storm track; the intensity, size, and speed of the storm; and the local bathymetry. Since wind generated waves ride on top of the storm surge (and are not included in the definition), the total instantaneous elevation may greatly exceed the predicted storm surge plus astronomic tide. It is potentially catastrophic, especially on low lying coasts with gently sloping offshore topography.

Storm Tide - The total observed seawater level during a storm, resulting from the combination of storm surge and the astronomical tide.

Subsidence - The sinking or lowering of land due to a continuing response of the Earth's crust to the last period of glaciation, natural soil compaction, or human activity such as aquifer withdrawal.

Surficial aquifer - Shallow underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials like gravel, sand, or silt typically less than 50 feet thick. They commonly consist of unconsolidated sand enclosed by layers of limestone, sandstone or clay and are replenished by precipitation.

Swale - A low tract of land or gully, often grassed, that is designed as an infiltration basin to manage water runoff, filter pollutants, and increase rainwater infiltration.

Tidal flooding - Also known as **sunny day flooding, blue sky flooding,** or **nuisance flooding** is the temporary inundation of low-lying areas, especially streets, during exceptionally high tide events, such as spring tides. It is not necessarily linked to heavy rain.

Tide - The periodic rise and fall of a body of water resulting from gravitational interactions between the sun, moon, and earth.

Vadose zone - the undersaturated portion of the subsurface that lies above the groundwater table.

APPENDIX B – RESOURCE INDIVIDUALS CONSULTED

The Committee members acknowledge and sincerely thank the following individuals for sharing their time, knowledge, and excellent advice with us.

- Beaufort County Planning Department: Amanda Flake, Natural Resources Planner; Robert Merchant, AICP, Assistant Community Development Director; Heather Spade, Community Development Assistant
- Berkeley Electric Cooperative: Tim Motley, VP Operations; Mark Gowdy, VP Economic Development and Public Relations; Tony Vincent, Public Relations; Tom Harvey, Manager Distribution Operations; Scott Bennet, Superintendent Johns Island; Chris Rutledge, Superintendent System Management; Jeff Coleman, Manager System Dispatch
- Billy Brooks, GIS Special Analyst, National Oceanic and Atmospheric Administration, Office of Coastal Management
- Burger, Daniel, Director of the Coastal Services Division of the S.C. Department of Health and Environmental Control, Office of Ocean and Coastal Resource Management and Chair of the Charleston Resilience Network
- Dr. Timothy Callahan, Professor of Hydrology, Chair of the Department of Geology and Environmental Geosciences, College of Charleston
- Dr. Kristina Dahl, Erika Spanger-Siegfried, Dr. Astrid Caldas, Shana Udvardy - Union of Concerned Scientists and authors of *Effective Inundation of Continental United States Communities with 21st century Sea Level Rise*, *When Rising Seas Hit Home*, and *Underwater: Rising Seas, Chronic Floods, and the Implications for US Coastal Real Estate*.
- Michael Delgado, Climate Impact Lab and the Rhodium Group, Inc.
- Becky Dennis, Director of Operations, Kiawah Island Utility
- Dr. William Doar, Senior Coastal Geologist, South Carolina Geological Survey, South Carolina Department of Natural Resources
- Tony Elder, Director of Security, Kiawah Island Community Association
- Dr. Elizabeth Fly, former Coastal Climate and Resilience Specialist, South Carolina Sea Grant Consortium; currently Marine Conservation Director, South Carolina Chapter of The Nature Conservancy
- Matt Hamilton, National Oceanic and Atmospheric Administration, Office of Coastal Management
- Lucas Hernandez, Graduate Student, Department of Geology and Environmental Geosciences, College of Charleston
- Steve Hirsch, Director of Engineering, Seabrook Island Property Owners Association
- Charles L. Hudson, Jr. AIA, NOMA, Architect and Principal of Hudson Designs, Inc.
- Colleen Jolley, Folly Beach Municipal Clerk/Clerk of Council

- Dr. Norman Levine, Associate Professor of Environmental GeoScience, College of Charleston and Director of Santee Cooper GIS Laboratory and Lowcountry Hazards Center
- Doug Marcy, National Oceanic and Atmospheric Administration, Office of Coastal Management
- Mark Permar, Architect and Founding Principal of Permar, Inc.
- Joshua Robinson, civil/environmental engineer and Principal of Robinson Design Engineers
- Dr. Denise Sanger, Associate Scientist and Environmental Section Manager, Marine Resources Research Institute, South Carolina Department of Natural Resources
- Dr. Leslie Sautter, Associate Professor of Marine Geology, College of Charleston
- Tyler Smyth, AIA, LEED AP, Architect and Principal of Tyler Smyth Architects, LLC
- Steven Traynum, Coastal Physical Scientist, Coastal Science and Engineering
- Dr. Robert Van Dolah, Director Emeritus, Marine Resources Research Institute, South Carolina Department of Natural Resources
- Weston & Sampson: Frank Ricciardi, Vice President, EG&E Program Manager; Julie Easton, Lead Resiliency Engineer.
- Mark Wilbert, Chief Resilience Officer and Emergency Management Director, City of Charleston
- Carolee Williams, AICP, former Special Projects Manager, Planning, Preservation, and Sustainability Office, City of Charleston; currently Lowcountry Field Director, Conservation Voters of South Carolina

APPENDIX C – REFERENCES CITED

Arnott, S.A., 2012. Sixty years of water temperature data from Charleston Harbor. The Climate Connection Workshop Series: Climate Variability and Impacts to South Carolina's Natural Resources. http://www.dnr.sc.gov/ccworkshops/pdf/CCWSSept13Arnott.pdf

Behre, R. 2018. Sunny day flooding could soon be history in Charleston as new valves hold back highest tides. Post & Courier, February 9, 2018. https://www.postandcourier.com/news/sunny-day-flooding-could-soon-be-history-in-charleston-as/article_850e70f2-0d21-11e8-a0fe-9ba6c603a928.html

Chamberlain, W.D., W.M. Campbell, and J.M. Dean, 1975. *Environmental Inventory of Kiawah Island*. Environmental research Center, Inc., Columbia, SC. Document reviewed by Environmental Science Committee of the Kiawah Island Conservancy, 2014. *A Review of the 1975 Report on the Environment of Kiawah Island.* https://view.joomag.com/reports-and-studies-2014-review-1975-environment-of-kiawah-report/0873545001414426408?short.

Cheney, Robert, retired Chief of NOAA's Laboratory for Satellite Altimetry.

Church, J.A. and N.J. White, 2011. Sea-level rise from the late 19th to the early 21st century. Surveys in Geophysics 32: 585-602. http://dx.doi.org/10.1007/s10712-011-9119-1.

City of Charleston, 2015. Sea Level Rise Strategy, accessed July 7, 2017 at http://www.charleston-sc.gov/DocumentCenter/View/10089/.

City of Charleston, 2017. Charleston Area Sea Level Rise Viewer. http://gis.charleston-sc.gov/interactive/slr/

CoastAdapt, 2017. What is a pathways approach to adaptation? The National Climate Change Adaptation Research Facility, Southport, Australia. https://coastadapt.com.au/pathways -approach

Dahl, Kristina, PhD., senior climate scientist for the Climate & Energy program at the Union of Concerned Scientists.

Dahl, K.A., E. Spanger-Siegfried, A. Caldas, and S. Udvardy, 2017. Effective inundation of continental United States communities with 21st century sea level rise. *Elem Sci Anth* 5: 37, doi: https://doi.org/10.1525/elementa.234.

Dahl, K.A., R. Cleetus, E. Spanger-Siegfried, S. Udvardy, A. Caldas, P. Worth, 2018. Underwater: rising seas, chronic floods, and the implications for US coastal real estate. https://www.ucsusa.org/sites/default/files/attach/2018/06/underwater-analysis-full-report.pdf

Di Liberto, T., 2015. Thousand-year Deluge in South Carolina. NOAA. https://www.climate.gov/news-features/event-tracker/thousand-year-deluge-south-carolina

Doar, William, PhD., 2018. Senior Coastal Geologist, South Carolina Geological Survey, South Carolina Department of Natural Resources.

Drouin, R. 2016. How rising seas are killing southern U.S. woodlands. Yale Environment 360, November 1, 2016. https://e360.yale.edu/features/ghost_forest_rising_sea_levels__killing_coastal_woodlands.

Foster, T.E., E.D. Stolen, C.R. Hall, R. Schaub, B.W. Duncan, D.K. Hunt DK, and J.H. Drese, 2017. Modeling vegetation community responses to sea-level rise on Barrier Island systems: A case study on the Cape Canaveral Barrier Island complex, Florida, USA. PLoS ONE 12(8): e0182605. https://doi.org/ 10.1371/journal.pone.0182605.

Hayes, M.O. and J. Michel, 2008. "Kiawah Island", pp. 200-211. In *A Coast for All Seasons: A Naturalist's Guide to the Coast of South Carolina*. Pandion Books, Columbia, SC, 285 pp.

Hu, A. and S.C. Bates, 2018. Internal climate variability and projected future regional steric and dynamic sea level rise. Nature Communications 9: 1068. https://www.nature.com/articles/s41467-018-03474-8#Fig2

Ingram, K., K. Dow, L. Carter, and J. Anderson, Eds., 2013. *Climate of the Southeast United States: Variability, Change, Impacts, and Vulnerability*. Island Press, 341 pp.

IPCC, 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II, and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. R.K. Pachauri and L.A. Meyers, eds. IPCC, Geneva, Switzerland. 151 pp.

JPL, 2017. GPS Time Series interactive web-site, Jet Propulsion Laboratory, California Institute of Technology, under contract to NASA. http://sideshow.jpl.nasa.gov/mbh/series.html, Last accessed July 2017.

Kana, T.W., B.J. Baca, and M.L. Williams, 1986. Potential Impacts of Sea Level Rise on Wetlands around Charleston, South Carolina. EPA-230-10-85-014. U.S. Environmental Protection Agency, Washington, DC. 65 pp. https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=2000917L.TXT

Knutson, P. L., R. A. Brochu, W. N. Seelig, and M. Inskeep. 1982. Wave dampening in Spartina alterniflora marshes. Wetlands 2:87-104.

Kunkel, K.E, L.E. Stevens, S.E. Stevens, L. Sun, E. Janssen, D. Wuebbles, C.E. Konrad II, C.M. Fuhrman, B.D. Keim, M.C. Kruk, A. Billet, H. Needham, M. Schafer, and J.G. Dobson, 2013.

Regional Climate Trends and Scenarios for the U.S. National Climate Assessment. Part 2. Climate of the Southeast U.S., NOAA Technical Report NESDIS 142-2, 94 pp.

Leffler John, Ph.D., retired Research Coordinator, ACE Basin National Estuarine Research Reserve.

Leuliette, E.W. and R.S. Nerem, 2016: Contributions of Greenland and Antarctica to global and regional sea level change. Oceanography 29: 154-159.

Marcy, D. and R. Jackson, 2016. Primer on Sea Level Rise and Future Flooding. NOAA Office for Coastal Management. http://www.charlestonresilience.net/wp-content/uploads/2017/03/flooding_primer_marcy.pdf

Masterson, J.P., M.N. Fienen, E.R. Thieler, D.B. Gesch, B.T. Gutierrez, and N.G. Plant, 2014. Effects of sea-level rise on barrier island groundwater system dynamics – ecohydrological implications. Ecohydrology 7. doi: 10.1002/eco.1442.

Melillo, J.M., T.C. Richmond, and G.W. Yohe, Eds., 2014. *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program, 841 pp. doi:10.7930/J0Z31WJ2.

Mizell, H., M. Malsick, and I. Abramyan, 2014. South Carolina's climate report card: understanding South Carolina's climate trends and variability. Journal of South Carolina Water Resources 1(1): 4-9.

Morris, J., 2016. The marsh is chasing the ocean…And losing the race. https://www.baruch.sc.edu/sites/baruch.sc.edu/files/attachments/LTREB%20research%20article.pdf

Morrison, J., 2018. Flooding Hot Spots: Why Seas Are Rising Faster on the U.S. East Coast. Yale Environment 360, April 24, 2018. https://e360.yale.edu/features/flooding-hot-spots-why-seas-are-rising-faster-on-the-u.s.-east-coast.

Murphy, J.D., 2016. The Historic South Carolina Floods of October 1–5, 2015. National Weather Service. https://www.weather.gov/media/publications/assessments/SCFlooding_072216_Signed_Final.pdf

National Hurricane Center. 2018. Storm Surge Overview. https://www.nhc.noaa.gov/surge/

National Weather Service, 2016. Historic Flooding - October 1-5, 2015. https://www.weather.gov/chs/HistoricFlooding-Oct2015

National Weather Service, 2017. Hurricane Matthew in the Carolinas: October 8, 2016. https://www.weather.gov/ilm/Matthew

National Weather Service, 2018. Tropical Storm Irma-September 10-11, 2017. https://www.weather.gov/chs/TropicalStormIrma-Sep2017

NOAA-Digital Coast, 2017. National Oceanic and Atmospheric Administration, Office for Coastal Management, accessed July 8, 2017at https://coast.noaa.gov/slr/#/layer/slr/0/-8914129.10960793/3844296.974658797/13/satellite/none/0.8/2050/interHigh/midAccretion/.

NOAA-NCEI, 2017. National Oceanic and Atmospheric Administration, National Centers for Environmental Information, accessed July 7, 2017 at https://www.ncdc.noaa.gov/cdo-web/datatools/normals/.

NOAA-NOS, 2017. What is a Salt Marsh? National Ocean Service website. https://oceanservice.noaa.gov/facts/saltmarsh.html. 10/10/17.

NOAA-Tides and Currents, 2017. *Mean Sea Level Trend 8665530 Charleston, South Carolina*, accessed July 7, 2017 at https://tidesandcurrents.noaa.gov/sltrends/ sltrends_station.shtml?stnid=8665530/.

OneSF, 2015. Guidance for Incorporating Sea Level Rise into Capital Planning in San Francisco: Assessing Vulnerability and Risk to Support Adaptation to Support Adaptation. Prepared by the City and County of San Francisco Sea Level Rise Committee. http://onesanfrancisco.org/sites/default/files/inline-files/Guidance-for-Incorporating-Sea-Level-Rise-into-Capital-Planning1.pdf

Parris, A., P. Bromirski, V. Burkett, D. Cayan, M. Culver, J. Hall, R. Horton, K. Knuuti, R. Moss, J. Obeysekera, A. Sallenger, and J. Weiss. 2012. *Global Sea Level Rise Scenarios for the US National Climate Assessment*. NOAA Tech Memo OAR CPO-1. 37 pp.

Perry, B. (ed.) 2012. *Climate Change Impacts to Natural Resources in South Carolina*, South Carolina Department of Natural Resources, 101 pp., accessed July 7, 2017 at http:www.dnr.sc.gov/.

Petersen, B. 2017. *Downtown Charleston broke record for flooded days last year; Rain, floods continue to swamp Lowcountry*. The Post and Courier, June 2017.

Petersen, B. 2018. Slower but stronger hurricanes may be the dangerous norm. The Post and Courier, July 1, 2018.

Runkle, J., K. Kunkel, L. Stevens, R. Frankson, B. Stewart, and W. Sweet, 2017. *South Carolina State Summary*. NOAA Technical report NESDIS 149-SC, 4 pp. https://statesummaries.ncics.org/sc/.

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Sanger, D. and C. Parker, 2016. *Guide to the Salt Marshes and Tidal Creeks of the Southeastern United States.* South Carolina Department of Natural Resources, Columbia, SC. 103 pp.

Sautter, Leslie, Ph.D., Associate Professor of Geology, College of Charleston.

SCDNR=SCO, 2018. South Carolina State Climatology Office. Accessed June 16, 2018. http://www.dnr.sc.gov/climate/sco/Publications/2015TP_Trends/2015TP_main.php

Spanger-Siegfried, E., K. Dahl, A. Caldas,S. Udvardy, R. Cleetus, P. Worth, and N. Hernandez-Hammer, 2017. *Hard choices ahead for hundreds of US coastal communities*. Union of Concerned Scientists, www.ucsusa.org/RisingSeasHitHome/.

Stephens, S.A., R.G. Bell. and J. Lawrence, 2017. Applying principles of uncertainty within coastal hazard assessments to better support coastal adaptation. *J. Mar. Sci. Eng.* 5, 40; doi:10.3390/jmse5030040

Sweet, W.V. and J.J. Marra, 2016. *2015 State of U.S. "Nuisance" Tidal Flooding*. National Oceanic and Atmospheric Administration's Center for Operational Oceanographic Products and Services and National Centers for Environmental Information. https://www.ncdc.noaa.gov/monitoring-content/sotc/national/2016/may/sweet-marra-nuisance-flooding-2015.pdf

Sweet, W.V., J. J. Marra and G. Dusek, 2017: 2016 State of U.S. High Tide Flooding and a 2017 Outlook. Supplement to *State of the Climate: National Overview for May 2017.* https://www.ncdc.noaa.gov/monitoring-content/sotc/national/2017/may/2016_StateofHighTideFlooding.pd

Tibbetts, J.H., 2007. Rising tide: Will climate change drown coastal wetlands? http://www.scseagrant.org/pdf_files/ch_winter_07.pdf

Town of Kiawah Island, 2018. *Emergency Preparedness Guide*. https://www.kiawahisland.org/wp-content/uploads/2017/11/2018-TOKI-Emergency-Preparedness-Guide.pdf

Traynum, Steven, M.S., 2018. Coastal Physical Scientist, Coastal Science and Engineering

USGCRP, 2017. *Climate Science Special Report: Fourth National Climate Assessment, Volume I.* D.J. Wuebbles, D.W. Fahaey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock, eds. U.S. Global Change Research Program, Washington, DC, USA. 4700pp. doi: 10.7930/J0J964J6.

Valle-Levinson, A., A. Dutton, and J.B. Martin, 2017. Spatial and temporal variability of sea level rise hot spots over the eastern United States. Geophysical Research Letters 44(15):7876-7882.

Van Dolah, Robert, 2018. Director Emeritus, Marine Resources Research Institute, South Carolina Department of Natural Resources

Williams, C. and L. Cabiness, 2017. *Sea Level Rise Strategy - A Guiding Principle*. http://nafsma.org/sites/default/files/shared-files/2017_AM_Sea_Level_Rise_Carolee_Williams_Laura_Cabiness.pdf

APPENDIX D – KIAWAH ISLAND INUNDATION MAPS

The following maps were developed specifically for Kiawah Island by Dr. Norman Levine and graduate student, Lucas Hernandez, of the College of Charleston's Department of Geology and Environmental Geosciences.

The mapping technique employed is called a "single-value surface model" or commonly called a "bathtub model." It uses two variables, the water elevation surface, and the elevation of the land. Water surface elevation or inundation level can be measured by a tide gauge station (Charleston Harbor) and extrapolated to nearby locations. The land elevation is depicted through a digital elevation model (DEM) derived from recent LiDAR data, among the most accurate of remote sensing elevation techniques. The map models depicted here have a horizontal resolution of about 16 feet (5 meters) x 16 feet (5 meters) and vertical error of 6 inches (15 cm). These maps use the Mean Higher High Water (MHHW) datum derived from the Charleston Harbor tide gauge station as a reference point to begin adding increments of storm surge or sea level rise. This modelling shows how the addition of water beyond the average highest high tide will move onto the island and settle into its lowest areas of elevation. Under sea level rise, the maps show areas that would be inundated twice daily at high tide. The inundation maps derived from these models do not account for flooding resulting from precipitation, clogged drainage systems, or local variations in sea level height resulting from winds, currents, and bathymetry. Therefore, the maps would underestimate water depth if heavy precipitation was experienced simultaneously with a storm surge. Since the following maps are products of a modeling process in which the data and the model have some inherent error, they may overestimate or underestimate the percent of land inundation, but still provide a reasonable estimate.

Dr. Levine and Mr. Hernandez are currently developing Kiawah maps with 3 feet (1 meter) x 3 feet (1 meter) horizontal resolution that will provide more specific location detail. Additionally, the team plans to gather rainfall and drainage data from Kiawah Island to include in future maps and to further understand the unique hydrology and coastal resilience on Kiawah Island. These maps will be valuable to better understand how and where flood waters move across the land surfaces. They may also provide data to determine possible modifications to roads or drainage systems to alleviate flood waters. By developing a model of the roads across Kiawah, the resultant maps can help identify the lowest sections that are most susceptible to flooding and the role that roads may have in the mitigation of flood waters in the future.

The first map depicts Kiawah under normal conditions at MHHW. Notice that the ponds, marshes, marsh creeks, and a significant portion of the beach are under up to 12 inches of water. The water depths are not accurate since LiDAR does not penetrate the water surface of the ponds and tidal

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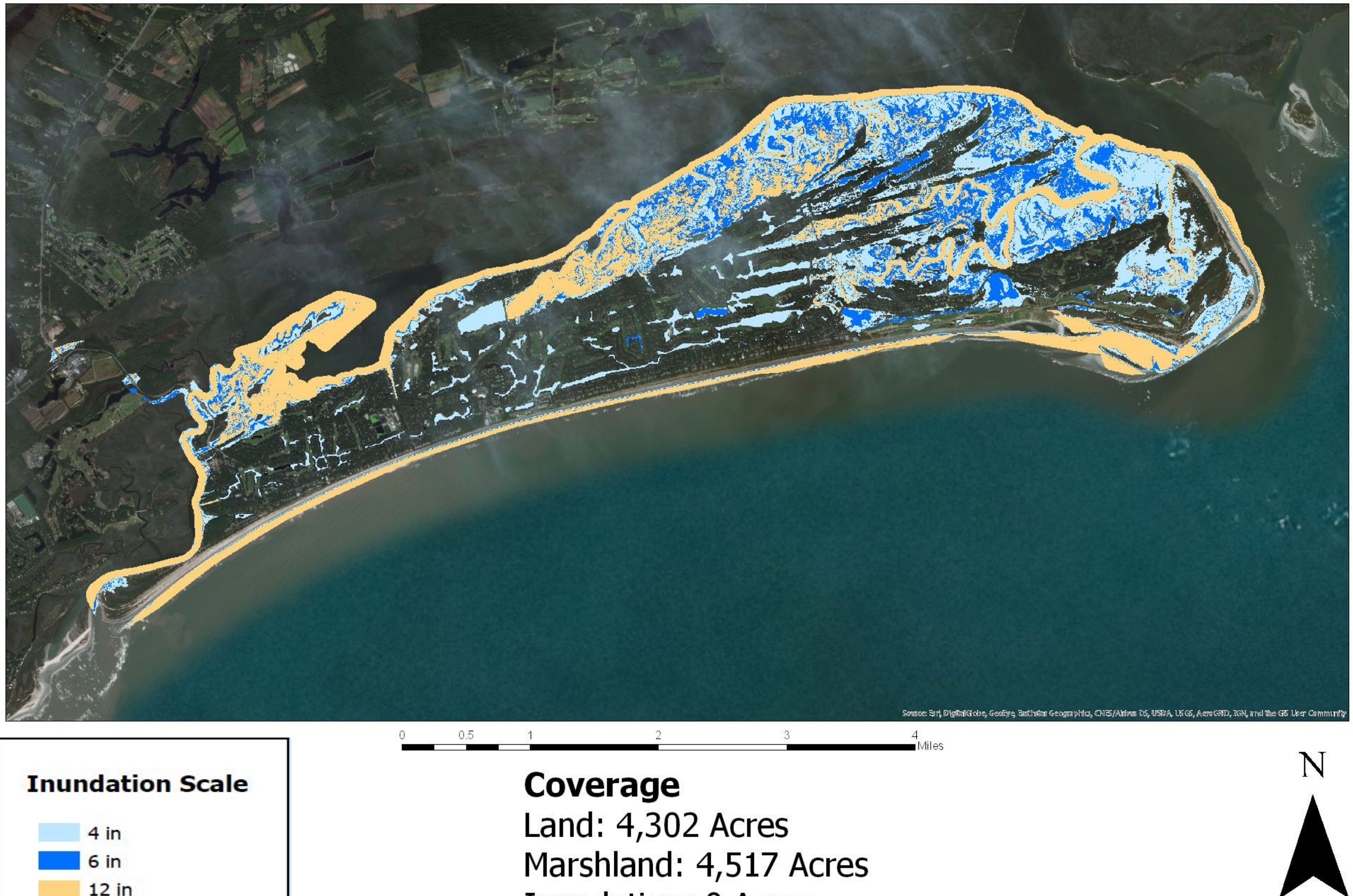
creeks when the tide is out. Use this first map as a reference for where water usually is found at high tide. The maps that follow project what will be covered by water if sea levels exceed MHHW. Note that the ponds, marshes, marsh creeks, and the beach all show increasingly deep water as well as what then inundates normally dry land.

Kiawah Island at Mean Higher High Water



Inundation Scale

- 4 in
- 6 in
- 12 in
- 18 in
- 24 in
- 36 in

Coverage

Land: 4,302 Acres
Marshland: 4,517 Acres
Inundation: 0 Acres
Percent Land Not Inundated: 100%

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Kiawah Island One Foot Storm Surge or Sea Level Rise

Inundation Scale

- 4 in
- 6 in
- 12 in
- 18 in
- 24 in
- 36 in

N

Coverage
Land: 3,709 Acres
Marshland: 4,517 Acres
Inundation: 592 Acres
Percent Land Not Inundated: 86%

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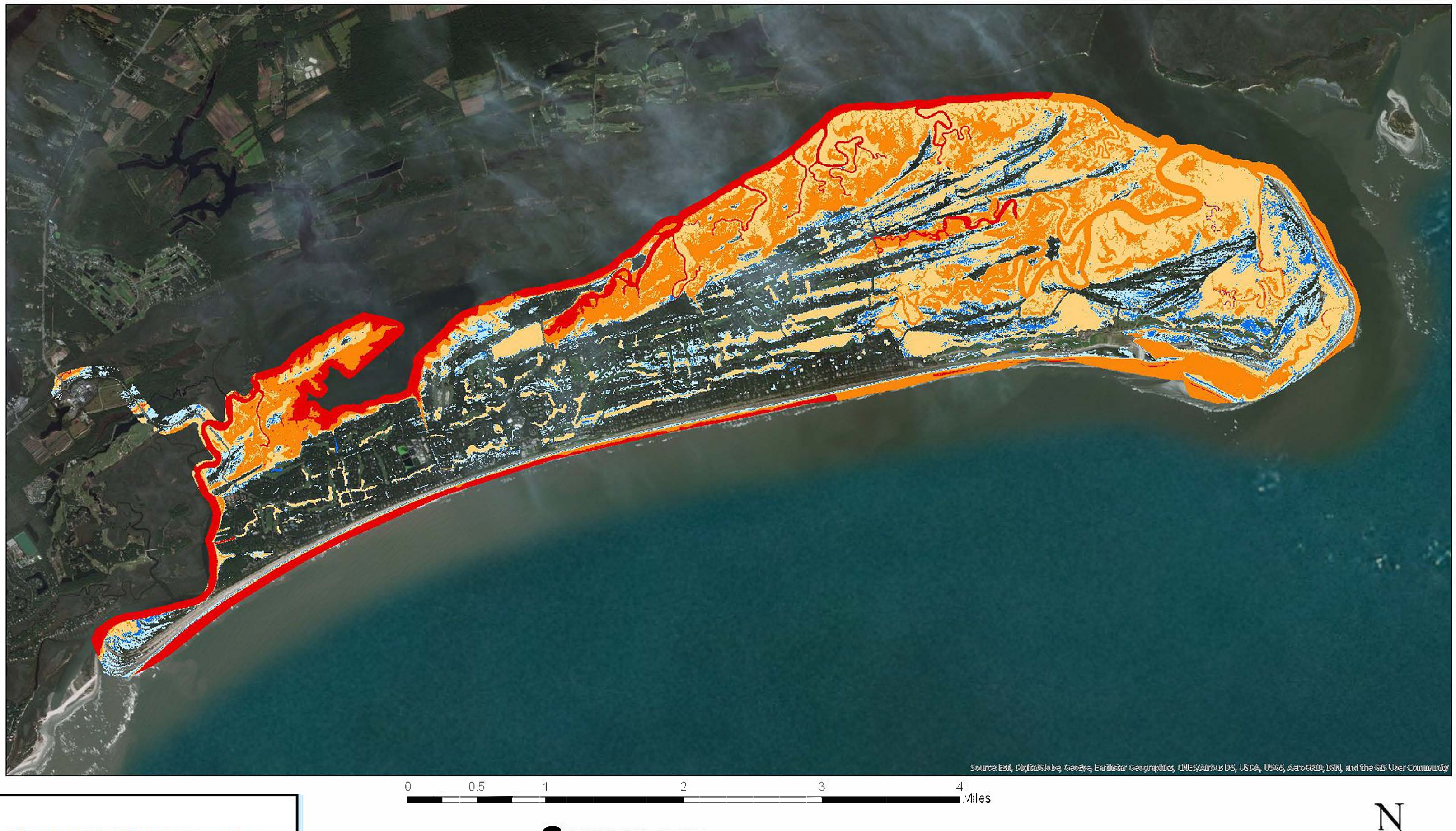
Kiawah Island Two Foot Storm Surge or Sea Level Rise



Inundation Scale

- 4 in
- 6 in
- 12 in
- 18 in
- 24 in
- 36 in

Coverage

Land: 3,102 Acres

Marshland: 4,517 Acres

Inundation: 1,199 Acres

Percent Land Not Inundated: 72%

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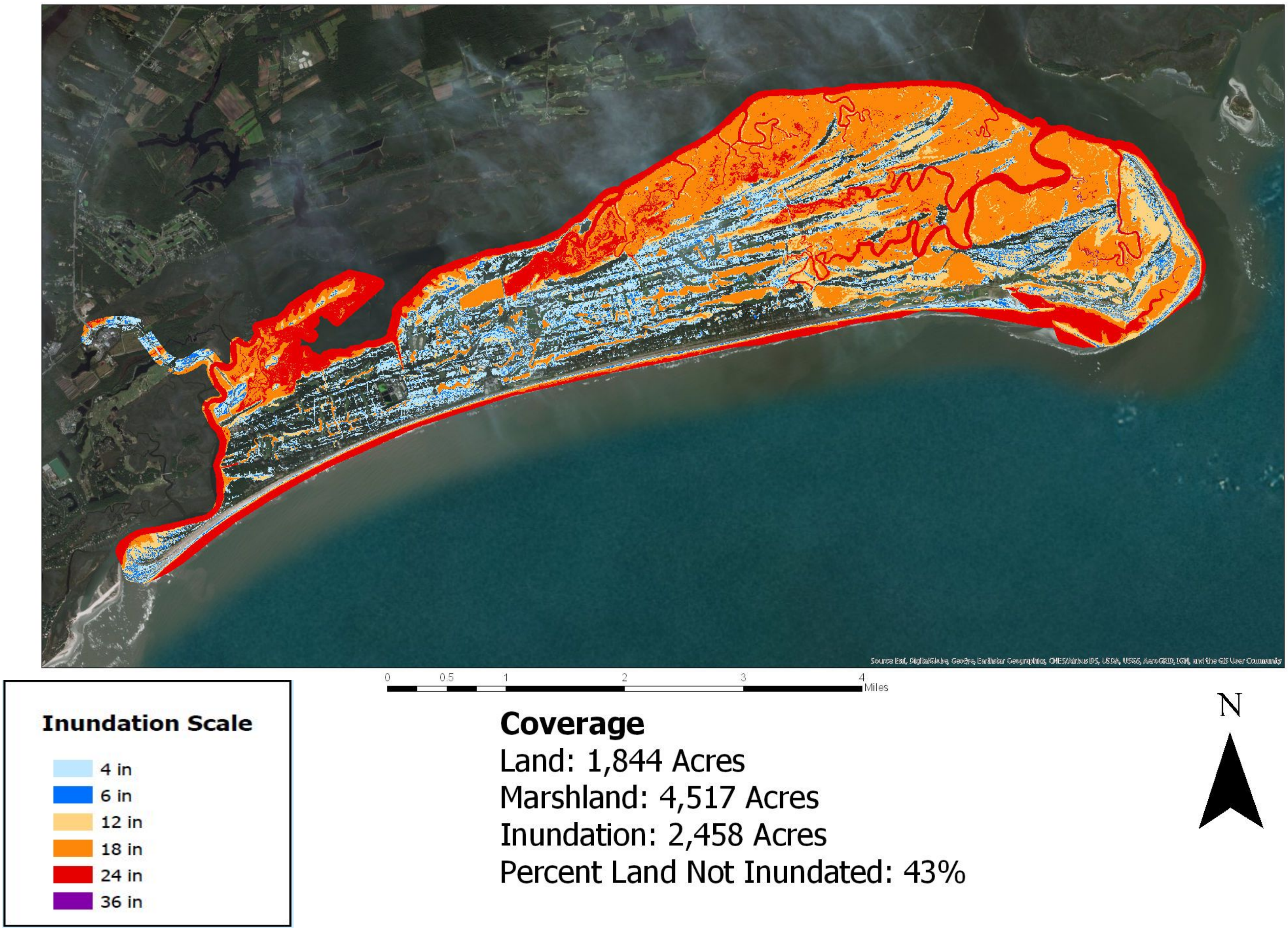
Kiawah Island Three Foot Storm Surge or Sea Level Rise



Coverage
Land: 1,844 Acres
Marshland: 4,517 Acres
Inundation: 2,458 Acres
Percent Land Not Inundated: 43%

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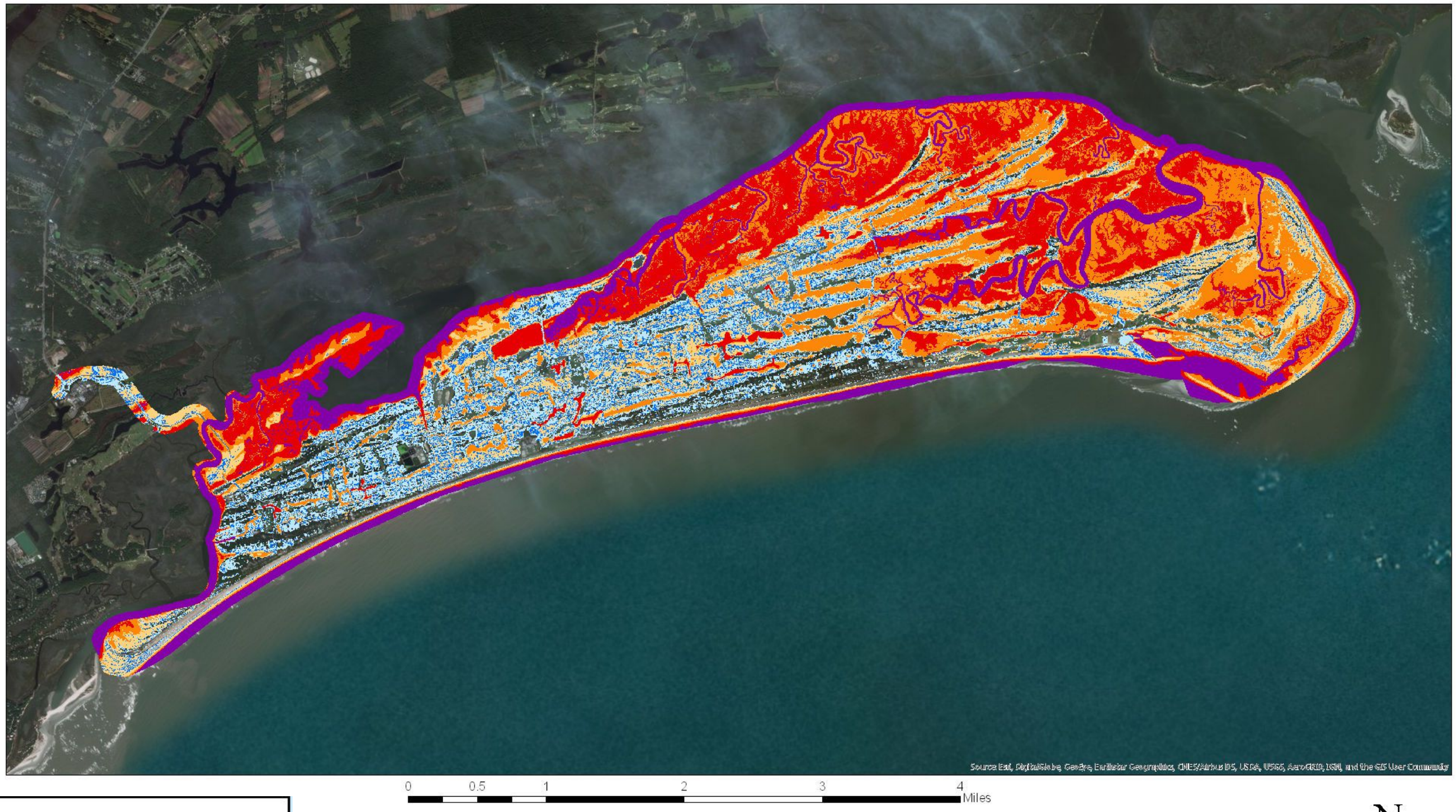
Kiawah Island Four Foot Storm Surge or Sea Level Rise



Inundation Scale

- 4 in
- 6 in
- 12 in
- 18 in
- 24 in
- 36 in

Coverage

Land: 1,181 Acres
Marshland: 4,517 Acres
Inundation: 3,121 Acres
Percent Land Not Inundated: 27%

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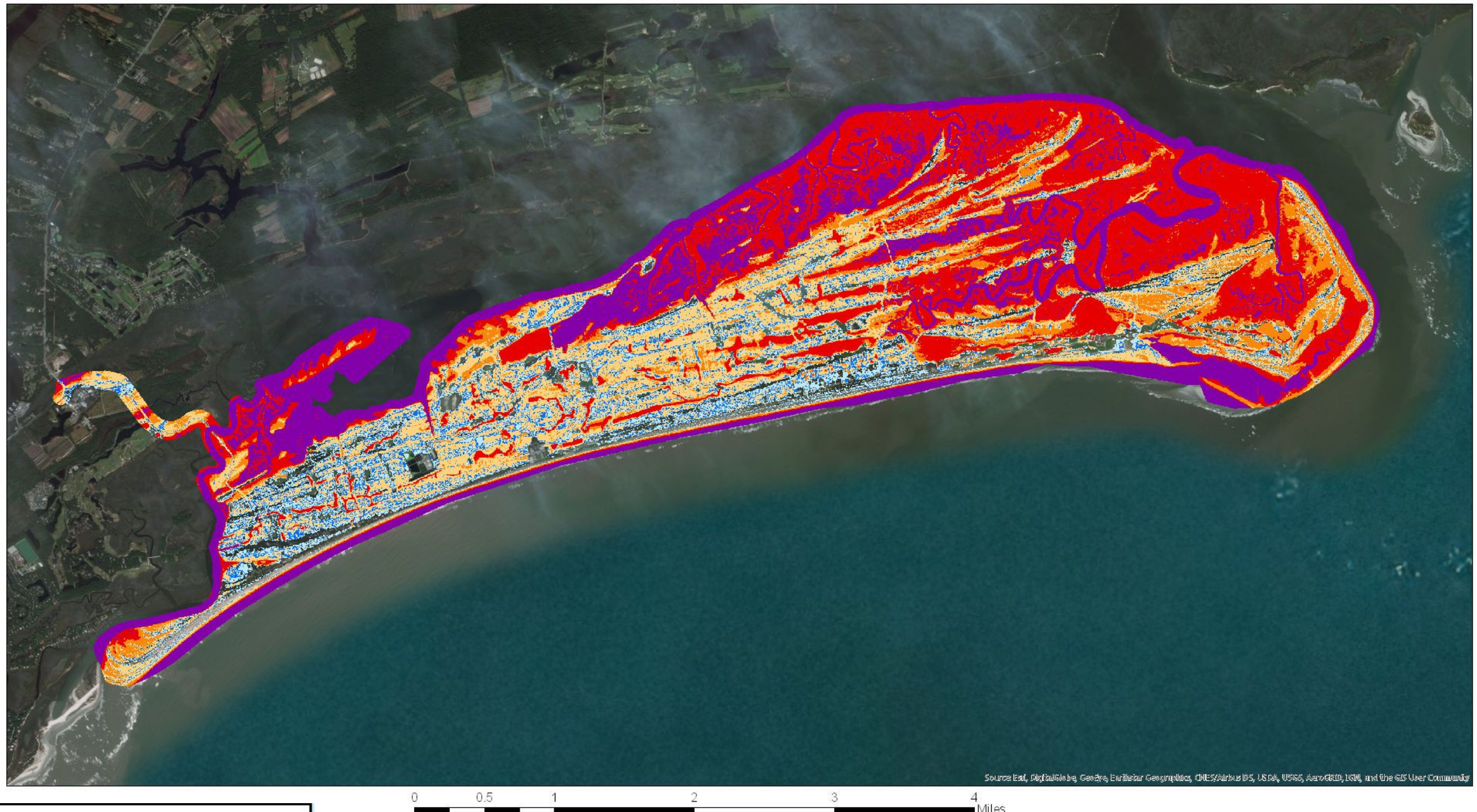
Kiawah Island Five Foot Storm Surge or Sea Level Rise



Inundation Scale

- 4 in
- 6 in
- 12 in
- 18 in
- 24 in
- 36 in

Coverage

Land: 689 Acres
Marshland: 4,517 Acres
Inundation: 3,621 Acres
Percent Land Not Inundated: 16%

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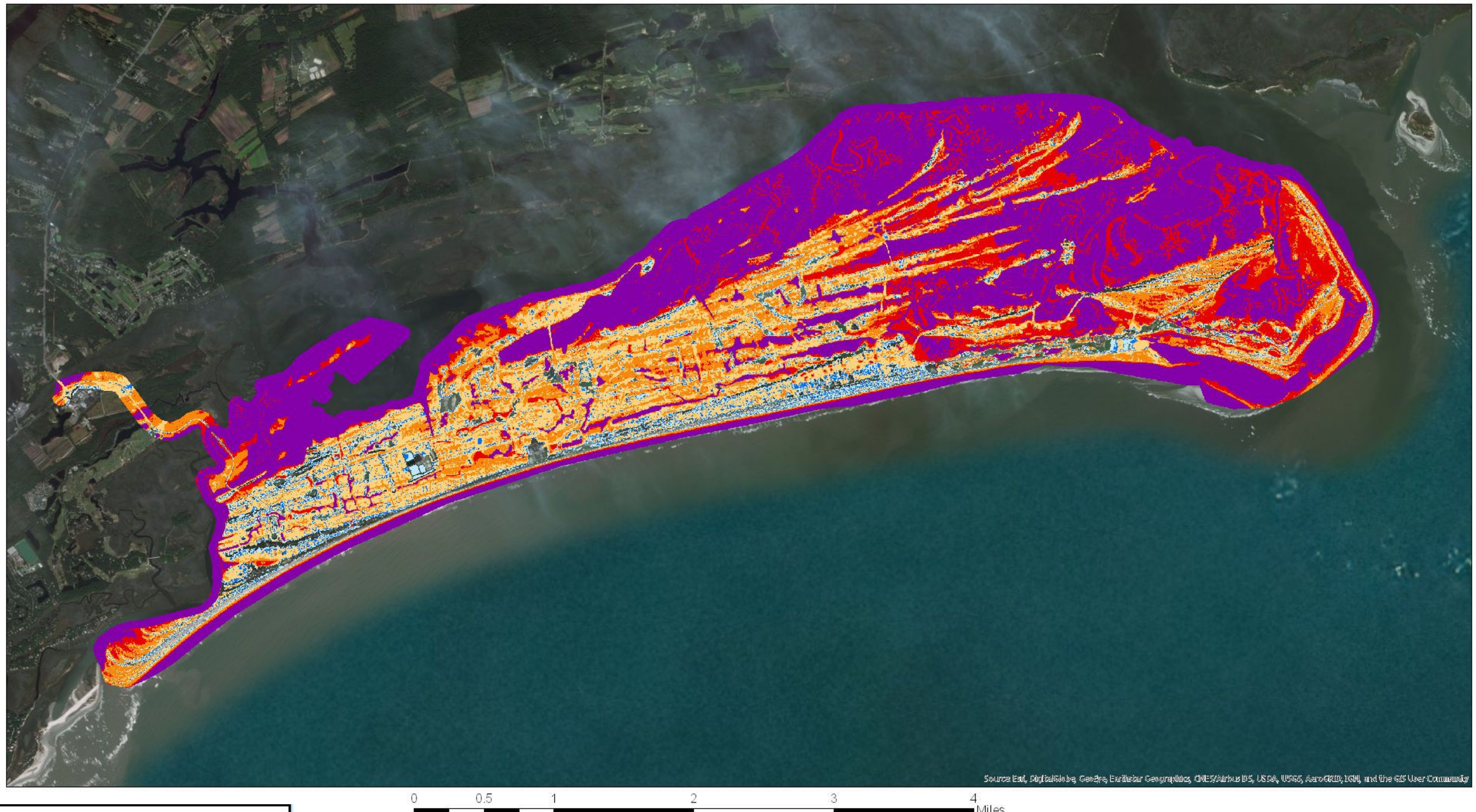
Kiawah Island Six Foot Storm Surge or Sea Level Rise



Inundation Scale

- 4 in
- 6 in
- 12 in
- 18 in
- 24 in
- 36 in

Coverage

Land: 414 Acres
Marshland: 4,517 Acres
Inundation: 3,888 Acres
Percent Land Not Inundated: 10%

N

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Kiawah Island Seven Foot Storm Surge or Sea Level Rise

Inundation Scale

- 4 in
- 6 in
- 12 in
- 18 in
- 24 in
- 36 in

Coverage

Land: 261 Acres
Marshland: 4,517 Acres
Inundation: 4,041 Acres
Percent Land Not Inundated: 6%

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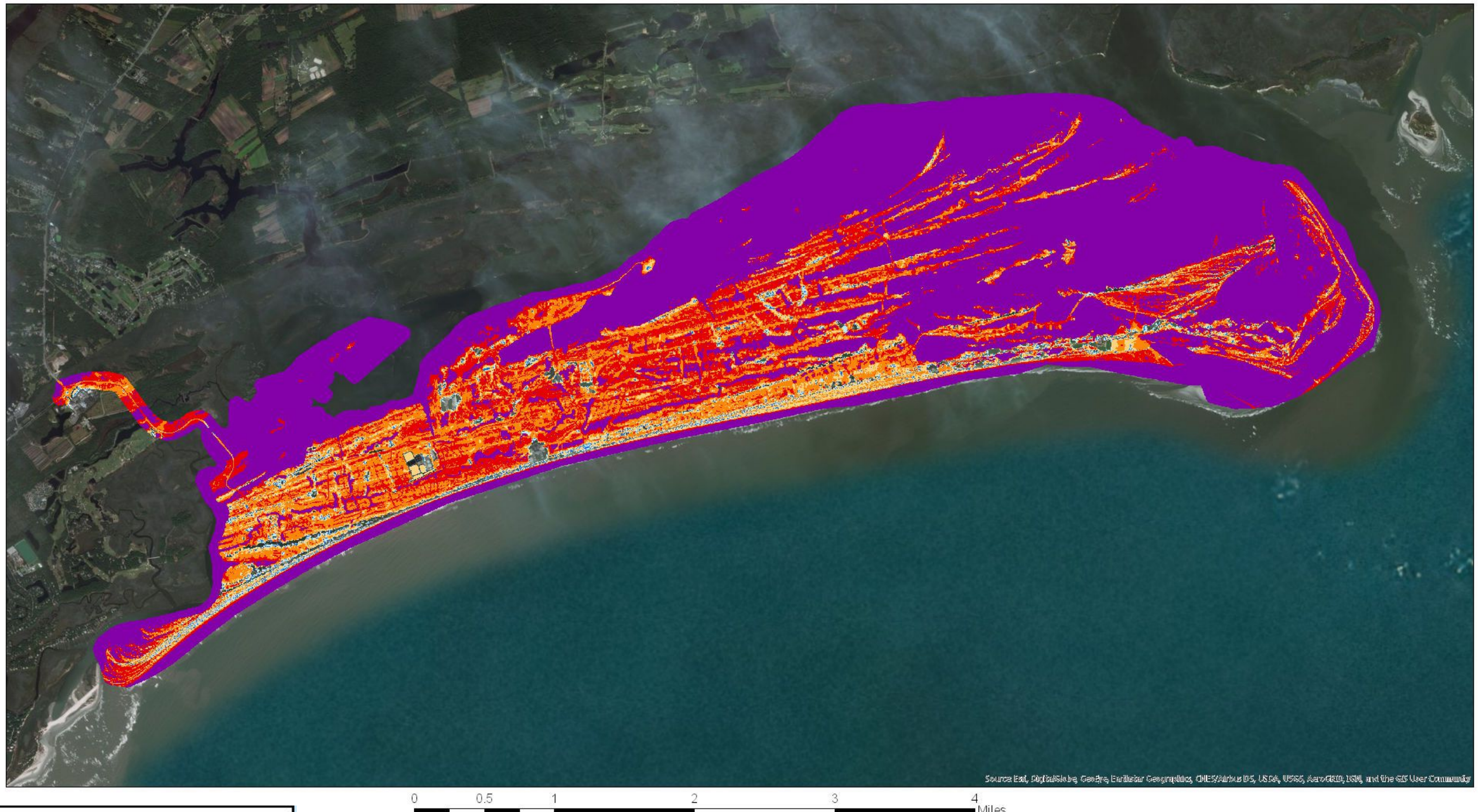
Kiawah Island Eight Foot Storm Surge or Sea Level Rise



Inundation Scale

- 4 in
- 6 in
- 12 in
- 18 in
- 24 in
- 36 in

Coverage

Land: 166 Acres
Marshland: 4,517 Acres
Inundation: 4,135 Acres
Percent Land Not Inundated: 4%

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APPENDIX E – WEATHER TRENDS and PROJECTIONS

Weather trends and projections are important because they directly influence the amounts and timing of precipitation that is an important contributing factor to local flooding. Temperature and precipitation trends vary widely throughout the United States. For the contiguous US mainland, the annual average temperature increased by 1.8°F between 1895–2016 (USCGRP, 2017). Surface and satellite data are consistent in their depiction of rapid warming since 1979. The number of high temperature records set in the past two decades far exceeds the number of low temperature records (USCGRP, 2017). Rising temperatures have been less in the Southeast than other areas of the country. Focusing on South Carolina, analyses by the South Carolina State Climatology Office from 1901-2010 found only slight trends in temperature. (Mizell et al. 2014). They detected a decreasing temperature trend from the late 1950s through the 1960s with a steady temperature increase since the 1970s.

There has been a national average increase of 4% in annual precipitation since 1901 mostly a result of large increases in the fall season (USCGRP, 2017). However, this increase is not evenly distributed. Annual precipitation has decreased in much of the West, Southwest, and Southeast while increasing in most of the Northern and Southern Plains, Midwest, and Northeast (USCGRP, 2017). In South Carolina as a whole there was a decreasing precipitation trend during the 1950s, an increasing trend during the 1960s, with a decreasing trend over the past decade. (Mizell et al., 2014). However, examination of just the Charleston City weather station shows that there has been an upward trend in both temperature and precipitation (Table 1). Since 1950, mean annual water temperature of Charleston Harbor has increased about 2 ^{o}F (Arnott, 2012).

Weather Trends for Charleston City, 1901 - 2015					
	Winter	Spring	Summer	Fall	Annual
Maximum Temperature (^{o}F)	+3.21	+2.51	+2.44	+3.16	+2.83
Minimum Temperature (^{o}F)	+0.43	+1.07	+1.22	+1.38	+1.03
Average Temperature (^{o}F)	+1.82	+1.79	+1.83	+2.27	+1.93
Precipitation (inches)	+0.24	+1.86	+0.61	+3.75	+5.47

Table 1. Weather trends for Charleston City, 1901 – 2015 (SCDNR-SCO, 2018).

Projections for future weather patterns vary greatly depending on location, season, and scenario. The U.S. Global Change Research Program, incorporating contributions of thirteen federal agencies, projects that the annual average temperature over the contiguous United States will increase about 2.5°F for the period 2021–2050 relative to 1976–2005, with much larger rises projected by late century, 2071–2100. Cold waves are projected to become less intense while heat waves will become more intense. The number of days below freezing is projected to decline while the number above 90°F will rise. The Southeast should have slightly less warming because of cooling from evapotranspiration, and less warming is projected along the coasts due to maritime influences, although increases are still substantial. For the continental U.S. future changes in seasonal average precipitation will include a mix of increases, decreases, or little change, depending on location and season. Overall average precipitation changes for the Southeast are expected to be minor and not distinguishable from natural variation (USGCRP, 2017)

While total rainfall in the Southeast may not change in the coming decades, droughts may become more frequent. Soil moisture is a function of both precipitation and evapotranspiration. Because potential evapotranspiration increases with temperature, we can anticipate periods of depleted surface (top 4 inches) soil moisture, drier soils, and less runoff even in regions and seasons where precipitation is projected to increase (USCGRP, 2017).

Extreme precipitation events, one of the controlling factors in flood statistics, have increased in most parts of the United States in both intensity and frequency since 1901, although there are important regional differences in trends. A U.S. index of extreme precipitation is the number of 2-day events with a precipitation total exceeding the largest 2-day amount that is expected to occur, on average only once every 5 years, as calculated over the period 1901-2016 (Figure 12). The number of events has been well above average for the last three decades. For the Southeast this index has increased 58% (USCGRP, 2017).

Percent Change in the Number of 5-year, 2-Day Events (1901-2016)

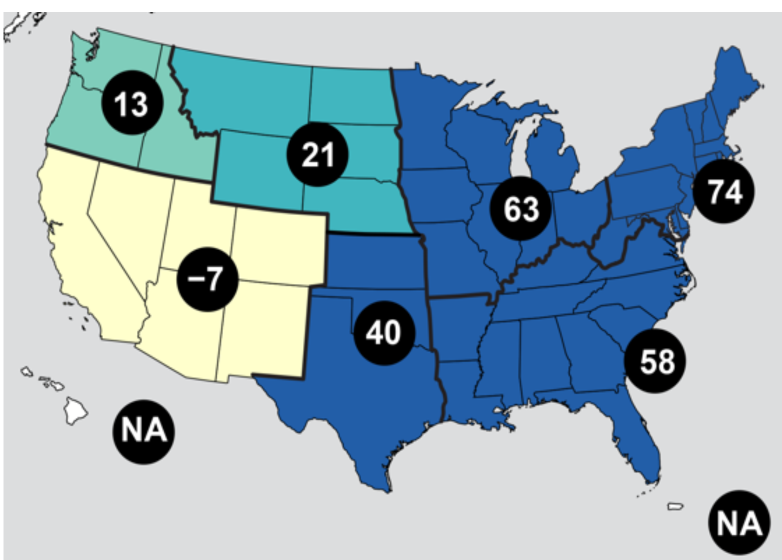

Figure 12. Observed change in heavy precipitation 1901-2016. The numbers represent the percent change in the number of 2-day events with a precipitation total exceeding the largest 2-day amount that is expected to occur, on average only once every 5 years (USCGRP, 2017).

Extreme precipitation events occur when the air is nearly completely saturated. Because atmospheric water vapor will increase with rising temperatures, precipitation extremes will increase in frequency and intensity in the future throughout the continental U.S. As seen in Figure 13, the Southeast is projected to see 12% increase in extreme precipitation events by mid-century and a 21% increase by the end of the century (USCGRP, 2017). Thus, projections suggest that even if annual precipitation does not change significantly, we will experience both periods of drought and extreme precipitation events.

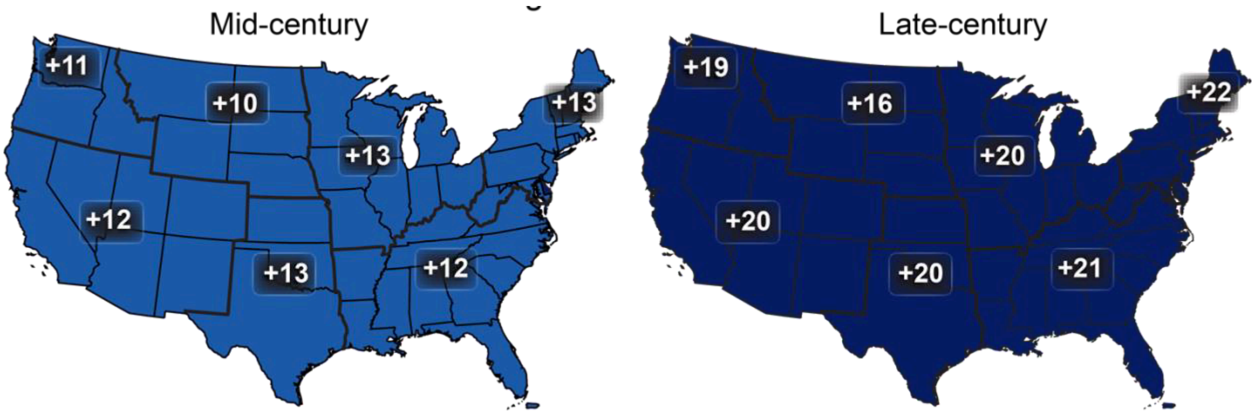

Figure 13. Projected percent changes in extreme precipitation by mid-century and the end of the century (USCGRP, 2017).

Since hurricanes are responsible for many of the most extreme precipitation events in the southeastern United States, as well as storm surge flooding, any increase in tropical storm activity is of concern. Data are insufficient to show a statistically significant trend in the intensity, frequency, or landfall of North Atlantic hurricanes. Both theory and numerical modeling simulations suggest an increase in hurricane intensity in a warmer world, i.e. more Category 4 and 5 storms, slower moving storms, and increases in precipitation rates. It is projected that the global frequency of hurricanes will either decrease or remain essentially the same (USCGRP, 2017; Petersen, 2018).

APPENDIX F – HOW ELEVATIONS ARE REFERENCED

This report addresses flooding issues on Kiawah that may result from extreme precipitation events, storm surges, and rising sea levels. In doing so, we must talk about the height of seawater during these situations, as well as the elevations of infrastructure such as roads and homes. This can be very confusing because all elevation measurements must be referenced to some standard, and different reference standards, or datums, are used by different parties to describe the measurements that they report.

There are two types of datums commonly used to describe elevations: geodetic datums and tidal datums. Geodetic datums are fixed and unchanging with time. Surveyors use them to calibrate their instruments and standardize their measurements. The National Geodetic Survey's (NGS) small metal plaques that you've seen set in the ground provide such a standard. Those that indicate elevation are called "benchmarks". One such geodetic benchmark is situated next to the Kiawah River Bridge.

Tidal datums are based on empirical measurements of the tides at National Oceanic and Atmospheric Administration (NOAA) tide stations situated all along the coast. Tidal datums vary from station to station and can change over time. They are derived by carefully measuring the water level every six minutes and averaging all those water levels at a specific station over a 19-year period called an "epoch" (National Tidal Datum Epoch). An epoch is used because complex astronomic relationships create a general tidal periodicity over that time frame. The current epoch for which tidal datums were measured is 1983-2001. Tidal datums are usually recalculated for a new epoch every 20-25 years.

The most important tidal and geodetic datums relevant to this report are

MHHW (Mean Higher High Water) – At Kiawah we have two high tides daily with one always a bit higher than the other. This tidal datum is the average of the daily higher high tides at a given station, over the 19-year epoch. It generally defines the landward boundary of a salt marsh, that is, the area that is normally flooded on daily high tides. The National Weather Service (NWS) uses MHHW to define nuisance flooding. For Charleston, nuisance flooding occurs when the tide is 1.25 feet above MHHW. It is important to understand that this datum is an average, so that under normal circumstances, high tides will exceed this level frequently. A brief survey of monthly high tides at the Charleston gauge station showed that at least one tide per month, unrelated to a named storm, exceeded MHHW by 0.6 to 1.9 feet over a 13-month period in 2016-2017. Since this datum is the most relevant to understand flooding, the Committee chose to use it as our standard reference throughout this report.

MSL (Mean Sea Level) – the average of hourly water levels measured continuously at a given station over the 19-year epoch. Although many infrastructure elevations are referred to as height above MSL, they are really being measured relative to a geodetic datum, probably NGVD29, which is not equivalent to MSL. The tidal datum MSL is specific for a given tide gauge station and changes from epoch to epoch, especially considering rising sea levels.

MLLW (Mean Lower Low Water) - the average height of the lower of the two daily low tides recorded at a given tide station each day over the 19-year epoch. NOAA tide charts reference tides to this datum because the depth of water in an area at the lowest tide is important for navigational purposes. This is widely used as an unstated reference in the popular media. For example, the newspaper might report a "king tide" as 7 feet. For Charleston, that translates into only 1.24 feet above MHHW, a level that may or may not lead to some nuisance flooding.

NGVD29 (National Geodetic Vertical Datum of 1929) – This is a fixed geodetic datum widely used for surveying of infrastructure. It is sometimes incorrectly referred to as Mean Sea Level because it started out being named the Sea Level Datum of 1929 and was based on the 1929 average sea level at 26 tide gauges in the U.S. and Canada. As survey technologies became more accurate, it was recognized that tide gauge stations all had different MSL elevations relative to each other, so it was renamed NGVD29 in 1973. The relationship between this geodetic datum and local mean sea level is not consistent from one location to another in either time or space. Today's MSL in Charleston, for example is almost a foot higher than it was in 1929. For this reason, the NGVD29 should not be confused with MSL and should not be called MSL. For a variety of reasons associated with advances in technology, NGVD 29 is no longer supported by the National Geodetic Survey and has been replaced by the NAVD88 geodetic datum for all federal or federally funded programs.

NAVD88 (North American Vertical Datum of 1988) – the current unchanging geodetic datum used to reference elevation measurements. Established in 1991, it is the new standard reference for measuring infrastructure, flood maps, and inundation today and is more accurate than the previously used NGVD29 datum. It also should not be confused with MSL and should not be used as MSL. Since most flooding and sea level rise inundation models are based on LiDAR measurements, those data are converted to NAVD88 referenced elevations. All federal and federally-funded programs now require use of NAVD88 as the datum for referencing elevations. FEMA is requiring a gradual, systematic conversion from NGVD29 elevations to NAVD88 elevations.

For a specific location, all of these tidal and geodetic datums can be converted from one to another. The following table displays tidal and geodetic datums from the Charleston tide gauge station with a NAVD88 to NGVD29 conversion for Charleston and the surrounding area. The National Weather Service calculated the Minor Flood Threshold for Charleston as 1.25 feet above MHHW.

Geodetic and Tidal Datum Conversions for the Charleston Tide Station and Surrounding Area (feet)

		In Reference to					
		Minor Flood Threshold	MHHW	NAVD88	MSL	NGVD29	MLLW
Elevation of	Minimum 6.0' Road Elevation	1.15	2.40	5.02	5.24	6.00	8.16
	Minor Flood Threshold	0.00	1.25	3.87	4.09	4.85	7.01
	MHHW	-1.25	0.00	2.62	2.84	3.60	5.76
	NAVD88	-3.87	-2.62	0.00	0.22	0.98	3.14
	MSL	-4.09	-2.84	-0.22	0.00	0.76	2.92
	NGVD29	-4.85	-3.60	-0.98	-0.76	0.00	2.16
	MLLW	-7.01	-5.76	-2.16	-2.92	-2.16	0.00

Table 2. Elevations referenced to a specific datum can be converted to a different reference datum. See explanation below.

How to use this table

The table should be read by finding the datum of interest in the left-hand column and reading across the row to the datum to which you wish to reference it. For example, the elevation of "MHHW" in reference to "MLLW" is 5.76 feet higher than "MLLW". The elevation of "MHHW" in reference to "Minor Flood Threshold" is -1.25 feet lower than "Minor Flood Threshold".

As a practical example, each home on Kiawah has an Elevation Certificate, required for the FEMA National Flood Insurance Program. It contains a number of height measurements, all relative to

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NGVD29. The table above enables these heights to be converted to other, more meaningful references.

For example, suppose the certificate shows a garage height of 7 feet and bottom floor height of 13 feet relative to NGVD29. To convert these to Mean Higher High Water (MHHW), the table indicates that 3.6 feet must be subtracted. The garage and bottom floor are therefore 3.4 feet and 9.4 feet above MHHW, respectively.

These converted elevations can then be viewed in the context of meteorological events. On September 11, 2017, Tropical Storm Irma arrived at Kiawah at high tide, and its easterly winds produced a storm surge of approximately 4 feet relative to MHHW. For the property described here, the garage would have flooded to a depth of 0.6 feet, while the bottom floor was still 5.4 feet above the water.

For the same tropical storm, consider Kiawah's older roads, sections of which are elevated 6.0 feet relative to NGVD29, or 2.4 feet relative to MHHW (after subtracting 3.6 feet). Irma's 4-foot storm surge therefore could have resulted in roads being flooded with 1.6 feet of water, as occurred in some areas. This is a simplified example. Tropical storm flooding is a function of wind direction, the distance over water that the wind blows in a single direction, land topography, ocean bathymetry, localized rain, and drainage, so not all areas of Kiawah would be inundated to the same degree.

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APPENDIX G – ADDITIONAL INFORMATION about STORMWATER MANAGEMENT

Pond System Overview (provided by Will Connor, Director of Major Repairs for KICA)

Kiawah Island's 125 ponds are mostly interconnected, and the normal water levels are mostly at the same elevation. Pond height is about 0.4 feet above MHHW. Pond depth is typically 3 to 5 feet. Because the pipes connecting the ponds are all submerged, flow through the pond system to the river is controlled by small changes in head pressure from one pond to the next.

The drainage system can accommodate 10 inches or more of rainfall within 24 hours. Kiawah's drainage system has twice the capacity of typical storm system ponds. If rain falls at the V-gate, it has three miles to travel before flowing to the river through outlets on Beachwalker Drive. Storm surge can fill the ponds immediately causing road washouts due to rushing water and flooding. During tropical storm Irma, the storm surge peaked at 4.1 feet above MHHW and flowed over the roads and filled the ponds.

The 2015 historic rainfall and the 2017 tropical storm Irma's storm surge each occurred around high tides. High tides make it harder to drain the ponds as the outfalls allow water to flow into the island from the ocean and river. KICA could have drained more water from the storm water system in October 2015 had staff been able to open and close the gates every six hours. However, KICA does not have enough manpower to open and close the manual, spinning-wheel gates. No KICA staff remains on island during major storm events.

There are two major drainage basins controlling 75% of the island's water flow to rivers and marshes and several smaller ones. The westernmost main drainage basin flows out the Beachwalker outfall on Beachwalker Drive through Inlet Cove. The other major basin, largely serving the area behind the V-gate to Canvasback Pond, drains at Canvasback Pond, near Flyway and Governor's Drive by the fire station. Other drainage basins include Rhett's Bluff, Egret Pond, The Preserve, and Ocean Park. Sparrow Pond drainage basin includes The Timbers. Some areas like Inlet Cove have multiple drainage pipes directly to the river. With 75% of the island's water drainage through two outfalls, pond levels do not drop quickly. It takes days to meaningfully lower water surface elevations.

One of KICA's consultants is STANTEC. As a result of their hydrology study, KICA adopted a computer model and written Standard Operating Procedures for manipulating pond levels based on the forecasted magnitudes of approaching storms. The computer program can model how the storm drainage system might respond to various conditions, or can analyze what happened during a storm for future storm preparation. The model produces a guide which suggests when and how to lower pond water levels ahead of a storm in order to minimize prospective flooding. The program also estimates how many tide cycles the stormwater system needs to drain each basin.

STANTEC suggested adding a new outlet for the western drainage basin in order to reduce the distance water must travel to flow out of the system. KICA put this new outlet into the 2018 budget for design and planning and may build it in 2019.

Gates: Currently drainage gates are opened and closed by manually-operated spinning-wheels. KICA is designing an automatic control (WAAOCS) which will operate remotely and can be programmed to open and close gates and flap valves with the tides. The control unit will have its own generator allowing it to operate when the power goes out. This first control unit will be mounted on the Beachwalker/Inlet Cove outlet. The Canvasback drainage basin is slated to be the next automatic control installation. Once installed, the Lakes department will be in charge of operating the gates.

Drainage Pipes and Pond Flushing: Drainage pipes are placed so the top of the pipe is approximately one foot below the ponds' water surface when ponds are at normal levels. Flap valves normally remain partially open allowing some pond and sea water exchange. The amount of water flowing from the river into the ponds depends upon the height of individual tides. During high spring tides, KICA personnel close the gates to prevent too much water from flowing in. Rain can produce flooding during high tide periods.

The largest pipes are 54 inches in diameter, so the bottom of the pipe is below MSL. The ARB currently does not typically approve visible pipes. A decision to raise the pipes would be a substantial project requiring digging up golf courses, roads and yards to replace old pipes with new ones at higher elevations.

Many of the old, and often failing, metal pipes are impeded by sediment sandbars in the ponds. Frequently, the sandbar is so large it stands above the top of the pipe. Removing sand from the ponds requires an OCRM permit because ponds contain brackish water. (OCRM requires permits for digging in areas of salt and brackish water.) Permits take about 6 months to process, so KICA has proactively applied for permits to dig 1/3 of the ponds on the island. Mr. Connor estimates KICA will continue to replace metal pipes for the next 15 years. All of the pipes under Turtle Point and Cougar Point golf courses need to be replaced.

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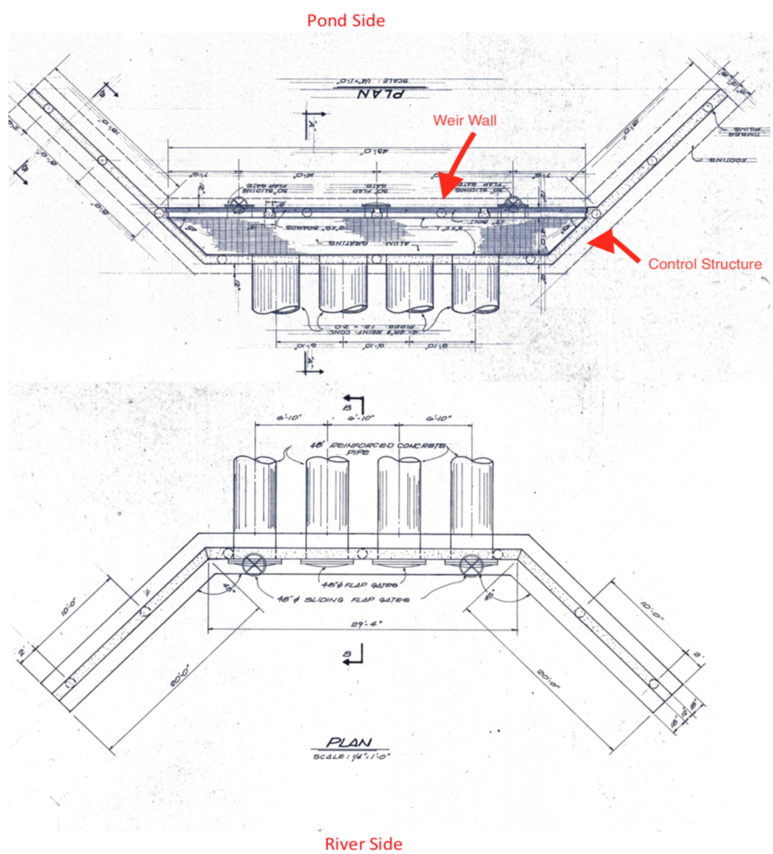
Outfall Weir System Description and Operation:

Normally, KICA personnel leave creek-side gates and flap valves partially open so seawater will flow over the weir and into the ponds. Typically, this overflow happens at high tide, when water levels are 0.24 - 0.74 feet over MHHW. The aim of encouraging the overflow is to manage water quality. When KICA staff want to reduce the amount of water in the stormwater system, they close the creek-side gates and flap valves and open valves and gates on the pond side of the weir. This configuration allows water to flow out of the pond into the creek. To prevent or minimize seawater from storm surges and exceptionally high tides from entering the pond system, the creek-side gates and flap valves are closed. During heavy precipitation, the creek-side gates and flap valves are left open allowing water from the pond to flow over the weir, through the creek-side flap valves, and into the creek, away from the island when the tide cycle water level is low enough.

Outfall Gates



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Mid-Tide; 3' to go until high tide

Beachwalker Drive outfall on May 18, 2018 at 9:15 AM. The tide is mid-tide and rising. High tide will raise the water about three more feet. The stain marks for high tide can be seen on the outfall wall.

APPENDIX H – SEA LEVEL RISE SUBCOMMITTEE MEMBERSHIP

Robert Cheney - MS in Physical Oceanography. During his 30-year career as a researcher with the US Navy, NASA, and NOAA, Mr. Cheney developed methods for measuring sea level using satellite radar altimetry. He was Principal Investigator for a series of NASA satellite missions beginning with TOPEX/Poseidon in 1992 and served as Chief of NOAA's Laboratory for Satellite Altimetry.

Jim Chitwood - Ph.D. in Chemistry (University of California - Berkeley) and Advanced Management Program (Harvard). He had a career of more than 30 years at Eastman Chemical Company starting in research and ending as a Senior VP at various times responsible for the company's specialty businesses, strategic planning, technology, and operations outside the US. He has served on various nonprofit boards (both in and outside the US). At Kiawah, he has been a Conservancy trustee for 6 years and leader of the Science Committee, active on various KICA committees, and a member of the Town Environmental Committee for more than 10 years.

William Connor – Bachelor's and Master's degrees in Civil Engineering from Clemson University. Mr. Connor worked as a Nuclear Engineer at the Charleston Naval Shipyard, and was Vice President of Engineering for George A.Z. Johnson, Inc. Engineering and Surveying in Charleston where he supervised many projects involving stormwater drainage and routing, roads, detention/retention ponds, potable water, sanitary sewer, wetland permitting, and many other areas. He was Principal Engineer and Owner of Connor Engineering, Inc. for 21 years where he continued to supervise design, permitting, and construction oversight of a diversity of commercial sites, subdivisions, governmental, and institutional projects. Mr. Connor came to work for KICA in 2012 as Director of Major Repairs and Replacements where his job is to maintain all of KICA's physical assets including the roads and stormwater pond system.

Jane Ellis - Ph.D. in Plant Physiology, Clemson University. She is an Emerita Professor of Biology (Presbyterian College) and has taught plant physiology, plant taxonomy, medical botany, and other courses. Dr. Ellis has supervised undergraduate research, wrote, received and reviewed grants; and authored and co-authored research articles for a variety of journals. Through the years she has been either a visiting professor or an adjunct at Clemson University and College of Charleston. She is a past president of the South Carolina Academy of Science and served the American Society of Plant Biologists (ASPB) in a number of leadership positions. Dr. Ellis has been an invited speaker and/or invited participant at conferences nationally and internationally. In 2008, she was awarded a grant to study at Oxford University and was named an Oxford Scholar. Currently she is chair of the Environmental Science Advisory Committee of the Kiawah Conservancy, on the Conservancy Board of Trustees, and is a member of TOKI Environmental Committee.

Jim Jordan - BS in Biology, Furman University; MS in Wildlife Ecology and Management, University of Georgia. A native of Columbia, SC, Jim has been the Wildlife Biologist for the Town of Kiawah Island since 2000. His work at Kiawah involves nuisance wildlife management, invasive plant control, beach management, wildlife population surveys, community outreach, and wildlife research. Over the last 20 years, Jim has conducted and/or coordinated a variety of research projects on Kiawah Island, focusing primarily on white-tailed deer ecology and fawn survival, bobcat ecology and habitat use, songbird migration and banding, and alligator behavior and habitat use.

Jack Kotz - John (Jack) Kotz. Ph.D. in chemistry, Cornell University (1963). Taught and did research for 40 years, first at Kansas State University and then at the State University of New York (SUNY). He was a National Institutes of Health Postdoctoral Research Fellow (Manchester, England), a Fulbright Lecturer and Researcher (Lisbon, Portugal), and a visiting professor in South Africa and New Zealand. Among other honors he received the national award in college chemistry education from the Chemical Manufacturers Association (1992) and retired as a SUNY Distinguished Teaching Professor in 2005. He has coauthored 15 books on basic and advanced chemistry as well as a number of refereed research and review articles. He taught undergraduate and graduate courses in chemistry as well as courses on the social and political implications of science, including climate change. He has given over 50 invited lectures on chemistry and chemical education at universities and conferences in the U.S. and abroad. He served 6 years on the board of the Kiawah Conservancy and chaired the Science Committee.

John Leffler - PhD in Zoology/Ecology, University of Georgia. As a Professor of Environmental Science, Dr. Leffler taught a variety of ecology, natural resource, biology, and biostatistics course for nearly 30 years. He led a quality of life study for a 15 county/city region of western Virginia and conducted funded research in areas of environmental toxicology, water pollution, and endangered species. Upon moving to South Carolina, Dr. Leffler worked 10 years for the SC Department of Natural Resources as a Marine Scientist managing research programs in seafood health, aquaculture, wild crustaceans, and sea level rise impacts on the marshes of the ACE Basin as well as serving as an adjunct graduate faculty member at the College of Charleston. He also served 20 years as the business manager for a small incorporated veterinary practice.

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Diana Mezzanotte - Bachelor of Business Administration - Accounting, St. Mary's College, Notre Dame, IN. CPA Emeritus, South Carolina. Ms. Mezzanotte started her career in public accounting with Arthur Andersen, moving to E. I du Pont where she worked as an internal auditor, accounting and IT supervisor, and manufacturing manager. Certified Mediator - four years. Pro bono mediation with the Better Business Bureau of Richmond, VA. KICA Finance Committee. Town of Kiawah Island Town Council. Chair of Arts & Cultural Events Council. Chair/Liaison Town Environmental Committee. Our Lady of Mercy Board of Directors.

David Pumphrey - B.A. in Economics, Duke University; M.A. in Economics from George Mason University. Mr. Pumphrey has been a full-time resident of Kiawah for four years. His career has focused on domestic and international energy economics and policy issues. He was a Senior Fellow and Co-Director of the Energy and National Security Program of the Center for Strategic and International Studies (CSIS) where his research focused on global energy issues, US energy security and climate change. For 35 years he served as an energy policy official with the United States Federal Government where the scope of his work covered energy market analysis, energy and climate change policy, and trade relations with key countries.

Lynette Schroeder - MBA, University of Virginia, A.B. University of Chicago, Ms. Schroeder worked in investment management as a portfolio manager. She ran several funds focused on international investments. At Kiawah Ms. Schroeder serves as a member of The Town's Environmental Committee, on Turtle Patrol and as a volunteer at Barrier Island Free Medical Clinic.

James V. Sullivan - B.S. in Chemical Engineering from Northeastern University. Jim worked over 40 years in the International Chemicals and Performance Materials industry with Dupont, Celanese, Hoechst AG, and 3M Corporations. His career included assignments in manufacturing, sales, product management, international business development and global business management. Jim bought his first Kiawah property in 1978 and moved here permanently in 2010. He has been a lifelong supporter of environmental and conservation non-profits, currently serving on the Kiawah Nature Conservancy board and the Town Environmental Committee. While living 14 years in Bedminster, New Jersey, he served on the town's planning board, town committee and as mayor.

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Ex-Officio:

Matt Hill – Represents the Kiawah Island Community Association. He has a BS in Marine Biology from the College of Charleston and has lived in Charleston his entire life. Mr. Hill worked in the wildlife and fisheries biology management field including positions with the SC Department of Natural Resources, US Fish and Wildlife Service, and the US Forest Service. For the past four years he has worked for as the Lakes Management Supervisor and Biologist.

Sara Senst – Represents the Architectural Review Board of which she is the Director. Ms. Senst, AIA, holds a Bachelor of Architecture degree from the University of North Carolina at Charlotte and studied abroad in Denmark. She has experience in master planning as well as residential and commercial architecture, holding architectural licenses in South Carolina and Connecticut, and has worked on a variety of projects throughout the Low Country. Prior to her move to Charleston in 2016, she was the Interim Director of Planning and Design at Fairfield University and designed and managed award-winning projects around the country with the architectural firm Shope Reno Wharton Associates.

The Committee thanks **Bruce Spicher**, Town of Kiawah Island Development Services Director, for his advice and generous technical assistance throughout the development of this report.