SOUTH ATLANTIC COASTAL STUDY (SACS)

U.S. Virgin Islands Appendix

FINAL DRAFT

OCTOBER 2021

Table of Contents

Attachments

List of Tables

List of Figures

SECTION 1

Introduction

The South Atlantic Coastal Study (SACS) Main Report examines the SACS study area at a regional scale and describes the Coastal Storm Risk Management (CSRM) Framework (the Framework). The eight SACS state and territory appendices execute the Framework, considering specific conditions for each state or territory, including problems and opportunities, risk assessment, and comprehensive CSRM strategies to provide a more tailored analysis. This appendix provides details on the U.S. Virgin Islands.

The Framework is a three-tiered evaluation defined by different scales, objectives to address risk, and input from stakeholders. The Tier 1 and Tier 2 analysis are completed as part of the SACS while Tier 3 efforts would be completed as follow-on analyses, either by the U.S. Army Corps of Engineers (USACE) or other agencies and stakeholders. By completing a tiered analysis, assumptions and data requirements become more refined with each tier as described:

- Tier 1 presents a large-scale application of the Framework in the evaluation of exposure, hazards, vulnerability, and potential risk for the study area. For consistency across state and territory boundaries, national data sets were used to complete the Tier 1 analysis. The Main Report describes Tier 1 methods and general output. The U.S. Virgin Islands-specific Tier 1 information is provided in this appendix.
- The Tier 2 analysis for the U.S. Virgin Islands is provided in this appendix. Additional regional data sources are used to refine potential risk areas identified in Tier 1. Focus areas were selected from Tier 1 analysis data and stakeholder coordination. Detailed Focus Area Action Strategies (FAAS) were developed to serve as examples of how to develop strategies that lower risk in populated areas, areas of concentrated economic development, and areas with vulnerable environmental and cultural resources.
- Tier 3 (not completed by the SACS) would be a local-scale analysis incorporating in-depth analysis and benefit-cost evaluations of CSRM plans.

SACS Documentation

	Study Area	Analysis	Content
SACS Main Report	Full SACS Study Area	Tier 1	Large-scale application of CSRM Framework using national datasets
U.S. Virgin Islands Appendix	U.S. Virgin Islands	Tiers 1 and 2	Summary of U.S. Virgin Island-specific Tier 1 information, Tier 2 analysis to further refine high-risk location
Focus Area Action Strategy	Christian-sted or Charlotte Amalie	Tiers 1 and 2	Provides examples of how to develop strategies to lower risk in areas of public, economic, and environmental areas of concern

The purpose of this appendix is to provide U.S. Virgin Islands stakeholders with useful information and resources. The organization of this appendix and alignment with the CSRM Framework is shown in **Table 1-1**.

Table 1-1: Appendix Organization and Alignment with the Coastal Storm Risk Management Framework

Report Section	Content	CSRM Framework Step
Section 1: Introduction	Objective of the document and organization of the report	Step 1: Initiate Analysis
Section 2: Agency Coordination and Collaboration	Overview of the collaborative efforts of the SACS study including stakeholder engagement, workshops, informational sessions, and federal partners	
Section 3: Overview of Existing and Future Conditions	Provides geographic, climatic, and political context for the analysis and an overview of existing and expected future conditions	Step 2: Characterize Conditions
Section 4: Risk Assessment	Application of the Tier 1 Risk Assessment and development of the U. S. Virgin Islands-specific Tier 2 analysis used to identify high-risk areas	Step 3: Analyze Risk and Vulnerability
Section 5: Managing Risk	Overview of resources to support the U.S. Virgin Islands resiliency efforts, including federal directives, resources, and funding to help communities better leverage needed resources	Step 4: Identify Possible Solutions
Section 6: Institutional and Other Barriers	Identification of institutional and other barriers impeding further risk reduction efforts	
Section 7: Summary & Recommendations	Recommendations of actions to address the risks identified in Section 4	Step 5: Evaluate and compare solutions

SECTION 2

Agency Coordination and Collaboration

The study was conducted in coordination with other federal agencies and applicable state, local, and tribal officials to ensure that all information, observations, and recommendations are consistent with other plans to be developed.

On October 9, 2019, USACE Jacksonville District held an in-person visioning workshop in St. Thomas, U.S. Virgin Islands with 23 stakeholders from Virgin Islands Territorial Emergency Management Agency (VITEMA), Department of Planning and Natural Resources, Federal Emergency Management Agency (FEMA), University of the Virgin Islands, National Oceanic and Atmospheric Administration (NOAA), Bioimpact, Inc., Fletcher & Fischer P.L. Rising Tide Innovation Center, and Limetree Bay Terminals.

Participants were divided into breakout sessions focused on the following topics: (1) existing/future conditions, problems, and opportunities, (2) draft focus areas, (3) existing/planned risk reduction strategies and projects, (4) institutional and other barriers to reducing risk, and (5) National Fish and Wildlife Foundation (NFWF) Coastal Resilience Assessment. Stakeholders provided input via written questionnaires and facilitated discussion.

In summer and fall 2020, USACE held the Focus Area Visioning Meetings, a series of three virtual workshops, for each of the U.S. Virgin Islands focus areas. Like the visioning meeting, these were attended by representatives from federal agencies, territory agencies, the University of the Virgin Islands, and several other groups. Feedback received was used to inform the focus area action strategies for the U.S. Virgin Islands and summarized in Section 5.7 .

Throughout the development of the state/territory appendices and focus area action strategies, USACE held additional virtual workshops to engage specific subgroups of stakeholders, including two SACS Environmental Webinars, the SACS Cultural Stakeholder Webinar, and the SACS Military Installation Webinar.

The USACE Command Team and District Project Managers also held SACS Quarterly Update Webinars for stakeholders to provide information on various SACS products and answer stakeholder questions.

The USACE Jacksonville District team also engaged key stakeholders, such as the University of the Virgin Islands and the St. Croix Foundation, through one-on-one communication to gain insight on existing and planned projects in the area as well as potential partnership opportunities during the development of the focus area action strategies.

This page intentionally left blank.

SECTION 3

Overview of Existing and Future Conditions

3.1 Study Area

The U.S. Virgin Islands are an unincorporated territory of the United States and are located approximately 40 miles (64 kilometers) east of Puerto Rico. The territory is home to 106,405 people (U.S. Census Bureau 2011) and consists of approximately 135 square miles (350 square kilometers) of land, including St. Thomas, St. John, St. Croix, and many smaller islands (USACE 2011) (**Figure 3-1**).

The U.S. Virgin Islands are part of the Greater Antilles, a submarine mountain range in the Caribbean Sea. St. John and St. Thomas have steep and mountainous terrain with narrow populated areas along the coast, while St. Croix is mountainous in the northern portion of the island with rolling hills and flatter terrain in the south (Britannica 2020). All three of the main islands are surrounded by coral reefs (World Atlas 2021).

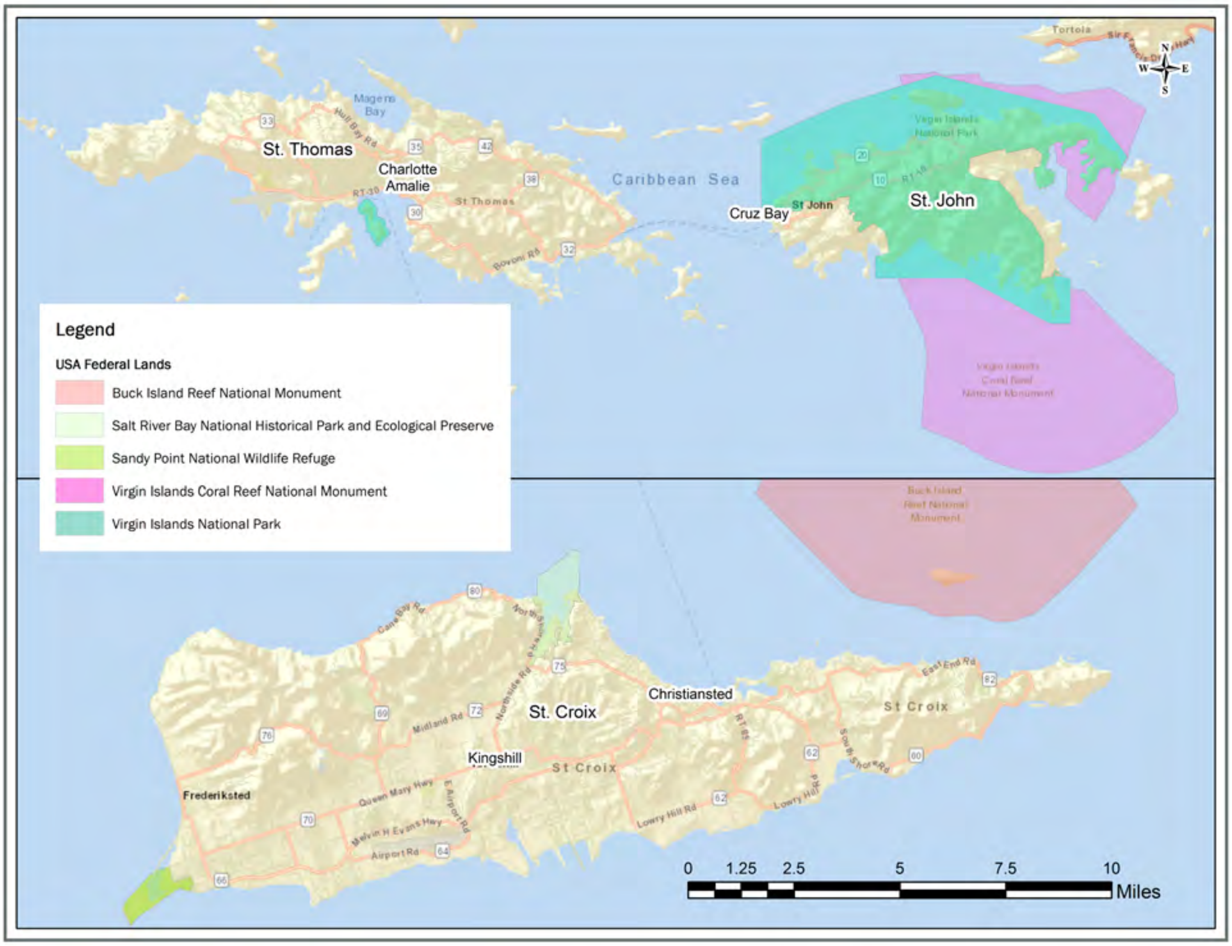


Figure 3-1: Study Area

3.1.1 Existing Conditions

The U.S. Virgin Islands rely heavily on tourism to support their economy (U.S. Virgin Islands Economic Development Authority 2020). Tourists, arriving primarily by cruise ship, are attracted to the beaches, coral reefs, and natural beauty of the volcanic islands. Cultural resources on the islands include unique colonial and precolonial building sites. Development on the islands is concentrated in the port towns of Frederiksted, Christiansted, and Charlotte Amalie.

The islands are still recovering from damage associated with two 2017 Category 5 hurricanes, Irma and Maria, which directly passed over the islands. Most of the infrastructure on the island was damaged and tourism still has not rebounded to pre-storm conditions.

Land elevations in the U.S. Virgin Islands generally increase quickly, moving inland from the coast, leaving a strip of coastal land with a significant amount of infrastructure and population left susceptible to coastal storm damages and sea level rise. Rainfall associated with coastal storms can result in significant inland flooding, which is exacerbated when inland water body surfaces are elevated by storm surge to the point where they meet the ocean.

Protecting the islands' surrounding natural resources is critical for infrastructure, shoreline stability, and tourism. As sea levels rise, so does the need for a well-implemented, consistent approach to coastal storm risk management (CSRM). The existing conditions are discussed herein including existing environmental conditions, shoreline conditions, populations, and supporting infrastructure within the study area.

3.1.2 Existing Environmental Resources

Larger wetland areas are more abundant along the flat coastal plains, estuaries, and coastlines of the U.S. Virgin Islands. In the drier, southwestern region of the Islands, sparsely vegetated coastal flats are flooded by high tides. Storm events exacerbate flooding in these areas. Vegetation communities found in these wetlands often consist of stunted black mangroves (*Avicennia germinans)* (USACE 2011).

Saltwater swamps dominated by mangroves occupy coastal fringes, tidal riverine areas, coastal basins, and overwash zones throughout the region. Mangle rojo or red mangrove (*Rhizophora mangle*) is more common in coastal and riverine situations, while mangle negro or black mangrove and mangle blanco or white mangrove (*Laguncularia racemosa*) dominate basin mangrove forests. In the U.S. Virgin Islands, mangroves are common along protected bays and in salt ponds (Adams and Hefner 1996).

Nearshore waters are NOAA-designated critical habitat for staghorn (*Acropora cervicornis*) and elkhorn (*Acropora palmata*) corals. Approximately 21,000 acres of coral reef habitat surround the islands, with the majority in the nearshore waters of St. Croix.

3.1.3 Existing Cultural Resources

Cultural remnants of human occupation are widely distributed throughout the U.S. Virgin Islands. These include artifacts from prehistoric and historic settlements and maritime commerce. These remnants serve as unique cultural resources that are important to maintain a sense of identity for locals and serve as valuable assets for the tourist economy.

Some prominent artifacts of early inhabitants include the Archaic site near Krum Bay, St. Thomas, and Late Ceramic Age prehistoric village sites, ball courts, petroglyphs, camp sites, burial sites, and submerged prehistoric sites located throughout each of the three islands (NPS 1988). The historical narrative of the U.S. Virgin Islands begins in 1493, when Europeans arrived at Salt River Bay, St. Croix during Christopher Columbus's second voyage to the New World. During the seventeenth century, Dutch, English, French, and the Knights of Malta attempted to colonize St. Croix. Because many of these early colonization efforts focused on Salt River Bay, 1,015 acres have been preserved to form the Salt River Bay National Historical Park and Ecological Preserve. Danish colonization was established on all three islands by 1733, and numerous remnants of early settlement as a Danish colony exist on all three islands, with historic portions of Christiansted and Ft. Christiansted in St. Croix serving as some of the best examples of eighteenth century Danish architecture in the U.S. Virgin Islands. Fort Christian in Charlotte Amalie, St. Thomas is another important historic military fortification, designated as a National Historic Landmark (The Virgin Islands Historic Preservation Office and University of Alabama Museums 2016).

Plantation-based agriculture with indentured servants dominated all three islands during the eighteenth and nineteenth centuries. Historic plantation-based archaeological sites are distributed throughout the U.S. Virgin Islands, and generally include domestic areas and an estate house, fields and production facilities, and slave quarters. Slave revolts and resistance are integral parts of the islands' history. Frederiksted, on the western end of St. Croix, has served as a benchmark for the emancipation movement in the islands. The town of Frederiksted is an established National Register of Historic Places historic district and a Historic and Architectural Control District. In addition to agriculture, trading and inter-island commerce was an important part of the islands' economy. Remains of the great coaling docks of St. Thomas and Hassel Island still exist today and are mostly owned by the U.S. National Park Service. As an important maritime center, there are over 400 recorded shipwrecks in and around the islands. While significant submerged resources are likely, looting, anchoring, storms, harbor development, and shoreline improvements have impacted the preservation of these resources (The Virgin Islands Historic Preservation Office and University of Alabama Museums 2016).

There are numerous buildings and sites on all three islands associated with the political development of the islands. These include the Government House in Charlotte Amalie, Emancipation Garden, and the Senate Building. In 1917, the United States purchased St. Thomas, St. John, and St. Croix from Denmark and shifted the island development. The military resources associated with World War I and World War II represent an important historical development. Sugar production ceased on the island in 1963, and the advent of post-World War II tourism and commercial expansion led to residential, industrial, and commercial development becoming part of the landscape, even in rural areas (The Virgin Islands Historic Preservation Office and University of Alabama Museums 2016).

3.2 Problems and Opportunities Overview

Identifying problems and opportunities is a key initial step in the planning process. Because each encompasses both current and future conditions, neither is meant to preclude the consideration of any alternatives for solving problems and achieving opportunities.

3.2.1 Problems

The following problems were identified as the most significant throughout the U.S. Virgin Islands. These problems will increase in both intensity and extent as sea levels rise in relation to the vulnerability and resiliency of the exposed population, infrastructure, and environmental and cultural resources.

- Lack of coordinated watershed-scale planning to address coastal storm risks and compound flooding risks limits the ability to improve community resilience.
- Coastal erosion and inundation, which is anticipated to worsen with sea level rise, causes damage to infrastructure and cultural resources, creates marine debris, and strains the local economy.

- Compound flooding risks are exacerbated by sea level rise and worsened by drainage systems that are outdated, insufficiently maintained, and inadequate to keep up with increasing flood levels and frequencies, thus resulting in increased risk to communities. Insufficient stormwater drainage systems contribute to water quality issues that degrade protective reef systems and reduce their ability to provide coastal storm risk reduction.
- Coastal erosion and sea level rise contribute to loss of natural habitats for coral reefs and mangroves, many of which provide CSRM benefits. Loss of these habitats exposes communities to increased erosion and coastal storm risk and may influence threatened or endangered species.
- Coastal storm events produce significant marine debris, contributing to environmental risk and impacting environmental and cultural resources.
- Lack of fundamental coastal engineering data (e.g., beach profile surveys or shoreline change estimates) in the U.S. Virgin Islands hinders the planning process.

3.2.2 Opportunities

Numerous opportunities exist to address coastal storm-related problems in the U.S. Virgin Islands. Encompassing current and future conditions, they include:

- Increase coordination, collaboration, communication, and engagement across constituents to support coastal storm risk management initiatives to streamline efforts and consolidate resources to build community resilience.
- Encourage federal and non-federal agencies to take a holistic system-based approach when responding to storm events and preparing for future sea level rise.
- Consider the full range of potential measures to address coastal storm risks.
- Incorporate long-term planning in future coastal storm risk management efforts.
- Improve ecosystem health of reefs and other natural protective features that provide coastal storm risk management benefits, support the economy (tourism), and conserve space to support mangrove migration.
- Uniformly and comprehensively consider economic, environmental, and social benefits in the evaluation of project alternatives. Opportunities exist to expand regional planning models and obtain necessary data to support alterative analyses that encompass the full range of potential benefits.
- Provide information to decision-makers and the public regarding coastal risk and resilience issues and encourage local leadership to become involved in building resilience against coastal storms.

- Demonstrate SACS tools (Measures and Costs Library [MCL] [USACE 2021d], Tier 2 Economic Risk Assessment, South Atlantic Coastal Study Environmental Technical Report, Tier 2 Environmental Resources Vulnerability and Risk Analysis/Priority Environmental Areas Identification [SACS Environmental Technical Report] [USACE 2021b], etc.) and emphasize how they can be applied by all stakeholders.

3.3 Political Boundaries

The U.S. Virgin Islands are a group of islands that are a self-governing commonwealth in association with the United States, making it an unincorporated U.S. territory with a nonvoting delegate to the U.S. House of Representatives. All persons born on the U.S. Virgin Islands are citizens of the United States and recognize their chief of state as the president of the United States of America. The local government (made up of three branches: executive, legislative, and judicial) is comprised of an elected governor and 15 elected senators. The District Court of the Virgin Islands operates under federal law and functions as a U.S. district court.

The U.S. Virgin Islands consists of two official districts: (1) St. Thomas and St. John, and (2) St. Croix. However, each of the three main islands is considered a county equivalent.

3.4 Planning Reaches

The planning reaches used in the SACS report for the U.S. Virgin Islands are shown in **Figure 3-2**. In other portions of the SACS study area, a detailed delineation process was used to determine planning reach boundaries. However, for the U.S. Virgin Islands, each of the three main islands is its own planning reach.

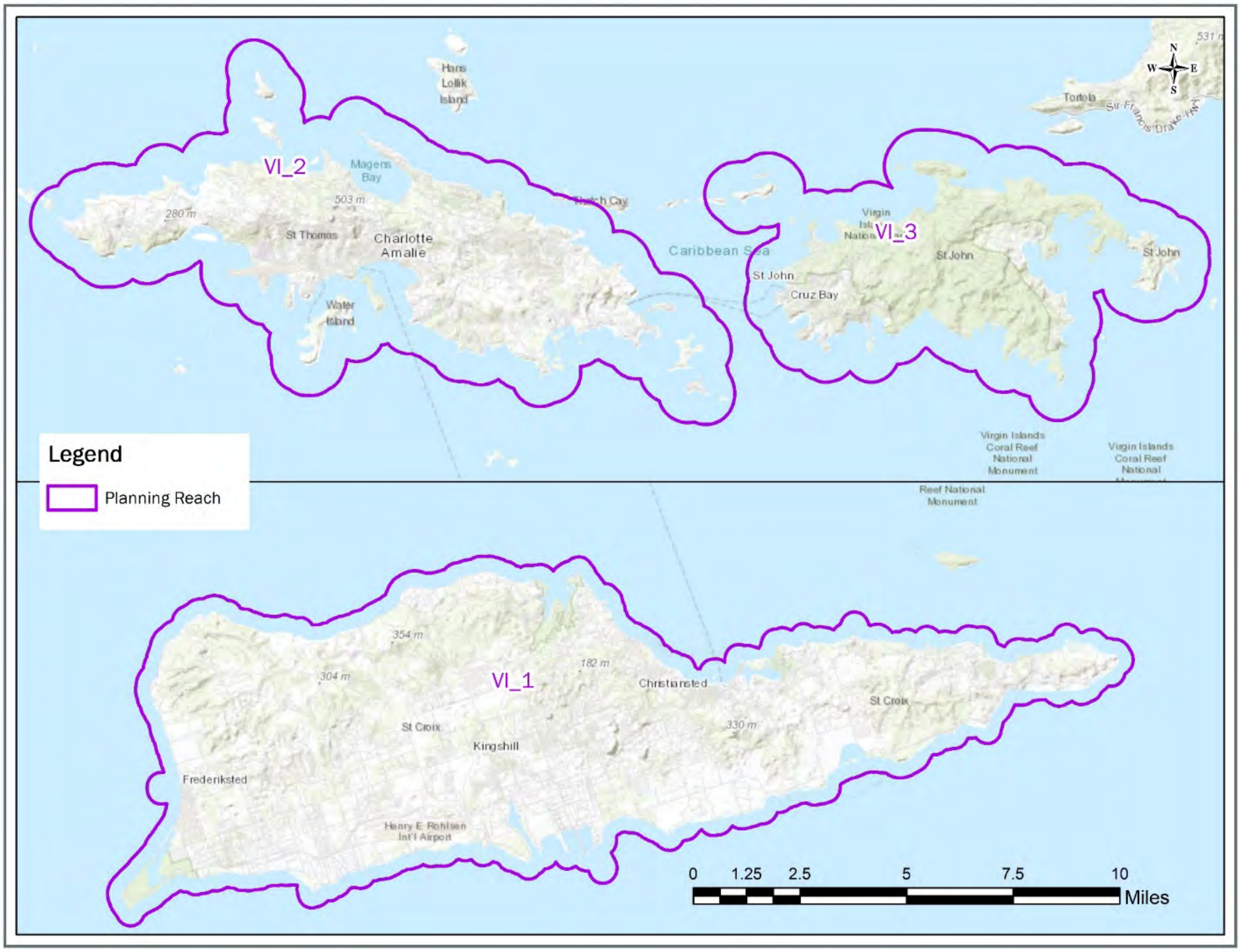


Figure 3-2: Planning Reaches in the U.S. Virgin Islands

3.5 Shoreline Characteristics

Based on the NOAA Environmental Sensitivity Index (ESI) guidelines, USACE developed a grouping of generalized shoreline types (as outlined in **Table 3-1**). Seven of the 11 USACE generalized shoreline types are found in the U.S. Virgin Islands.

Table 3-1: USACE Generalized Shoreline Types and National Oceanic and Atmospheric Administration Environmental Sensitivity Index Shoreline Types identified in the U.S. Virgin Islands (NOAA 2000)

USACE Generalized Shoreline Type	NOAA ESI Shoreline Types	Found in the U.S. Virgin Islands?
Coral Reefs and Hardbottom	Not an ESI Shoreline Type, but is Included as a Sensitive Shoreline Geographic Information System (GIS) Layer	Yes
Mangroves	10F/10D Mangroves	Yes
Man-Made Structures (Exposed)	1B Exposed, Solid Man-Made Structures and 6B Riprap	Yes

USACE Generalized Shoreline Type	NOAA ESI Shoreline Types	Found in the U.S. Virgin Islands?
Man-Made Structures (Sheltered)	8B Sheltered, Solid Man-Made Structures and 8C Sheltered Riprap.	Yes
Rocky Shores (Exposed)	1A Exposed rocky cliffs (PR/VI) 2A Exposed, Wave-Cut Platforms in bedrock (PR/VI). 6A Gravel Beaches, and Boulder Rubble	Yes
Rocky Shores (Sheltered)	8A Sheltered, Impermeable, Rocky Shores. Sheltered Scarps (Bedrock/Mud/Clay) and Sheltered, Rocky, Rubble Shores	No
Sandy Beaches (Exposed)	3A Fine to Medium Grained Sand Beaches, 4 Coarse Grained Sand Beaches, 5 Mixed Sand and Gravel Beaches, and 7 Exposed Tidal Flats	Yes
Sandy Beaches (Sheltered)	Sheltered Tidal Flats	No
Scarps and Steep Slopes	1A Exposed rocky cliffs (mainland). 2B: Exposed Scarps and Steep Slopes (Clay/Mud) 3B: Scarps and Steep Slopes (Sand)	No
Wetland/Marshes/Swamps (Exposed)	2A Exposed, Wave-Cut Platforms (Bedrock/Mud/Clay) and 2B Exposed Scarps and Steep Slopes (Clay), 7: Exposed Tidal Flats	No
Wetlands/Marshes/Swamps (Sheltered)	9A Sheltered Tidal Flats, 9B Vegetated Low Banks, 9C Hyper-Saline Tidal Flats, 10A Salt and Brackish Water Marshes, 10B Freshwater Marshes, 10C Swamps, and 10D Scrub and Shrub Wetlands	Yes

Table 3-2 provides the length and percentage for each type of shoreline per planning reach. All shorelines, including wetlands and mangroves along river floodplains, small cays and small islands were included. In addition to the combined 286 miles of shoreline, 21,241 acres of coral reef and hardbottom surround the U.S. Virgin Islands, with 13,444 acres around Planning Reach VI_1, 3,854 acres around Planning Reach VI_2, and 3,943 acres around Planning Reach VI_3. These coral reefs provide coastal storm risk management benefits to the nearby coastal communities. In Planning Reach VI_1, coral reefs protect an estimated 914 people and 274 buildings from the 1-percent annual exceedance probability (AEP). In Planning Reach VI_2, they protect an estimated 93 people and 24 buildings, and in Planning Reach VI_3, they protect 25 people and 15 buildings from the 1-percent AEP (Storlazzi et al. 2019).

Table 3-2: Shoreline Type Analysis

Metric	St. Croix (VI_1)		St. Thomas (VI_2)		St. John (VI_3)	
Length of Shoreline	98.4 miles (158.4 kilometers)		110.5 miles (177.8 kilometers)		76.8 miles (123.6 kilometers)	
Planning Reach Population	54,000		52,000		5,000	
Coral Reef and Hardbottom	13,400 acres (54 square kilometers)		3,850 acres (16 square kilometers)		3,940 acres (16 square kilometers)	
Shoreline Type	**Miles (Kilometers)**	**%**	**Miles (Kilometers)**	**%**	**Miles (Kilometers)**	**%**
Mangroves	19.4 (31.2)	19.7	15.4 (24.8)	13.9	14.3 (23.0)	18.6
Man-Made Structures (Exposed)	7.4 (11.9)	7.6	6.8 (10.9)	6.2	–	0.0
Man-Made Structures (Sheltered)	5.8 (9.3)	5.8	7.1 (11.4)	6.4	0.3 (0.5)	0.4
Rocky Shores (Exposed)	27.2 (43.8)	27.7	63.7 (102.5)	57.6	44.1 (71.0)	57.5
Sandy Beaches (Exposed)	37.6 (60.5)	38.2	17.5 (28.2)	15.8	18.1 (29.1)	23.6
Wetlands/Marshes/Swamps (Sheltered)	1.0 (1.6)	1.1	–	0.0	–	0.0

3.6 Overview of Storm History and Sea Level Rise Projections

3.6.1 Storm History

The U.S. Virgin Islands are in the path of tropical storms and hurricanes and, occasionally experience winds of extreme force. Nineteen storms have passed within 50 nautical miles of the centroid of the archipelago since 1899, as recorded by the National Hurricane Center (NHC) (NOAA 2019). Of those 19 storms, 14 made direct landfall on the U.S. Virgin Islands.

Table 3-3 provides a list of the historical coastal storms documented by NOAA within 50 nautical miles of the U.S. Virgin Islands. During intense storm activity, waves erode sediment from shorelines, beaches, and dune systems. Storm surge can flood coastal and inland properties. The higher the storm surge elevation, the greater the expectation for flooding (and subsequently more erosion, wave, and flood damage) to occur. Storm categories are reported as the maximum category while within the 50 nautical mile search area, however, active dates include the lifetime of the storm.

Table 3-3: Historical Hurricanes within 50 Nautical Miles of the U.S. Virgin Islands (NOAA 2019)

NAME	YEAR	CATEGORY	DATES ACTIVE
DORIAN[1]	2019	H1	Aug 24, 2019–Sep 9, 2019
MARIA[1]	2017	H5	Sep 16, 2017–Oct 2, 2017
IRMA[1]	2017	H5	Aug 30, 2017–Sep 13, 2017
OMAR[1]	2008	H2	Aug 19, 2000–Aug 24, 2000
DEBBY	2000	H1	Aug 19, 2000–Aug 24, 2000
JOSE	1999	H1	Oct 17, 1999–Oct 25, 1999
LENNY[1]	1999	H4	Nov 13, 1999–Nov 23, 1999
GEORGES[1]	1998	H3	Sep 15, 1998–Oct 1, 1998
BERTHA[1]	1996	H1	Jul 5, 1996–Jul 17, 1996
MARILYN[1]	1995	H2	Sep 12, 1995–Oct 1, 1995
HUGO[1]	1989	H3	Sep 10, 1989–Sep 25, 1989
BETSY	1956	H3	Aug 9, 1956–Aug 21, 1956
UNNAMED[1]	1933	H1	Jul 24, 1933–Aug 05, 1933
SAN CIPRIAN[1]	1932	H4	Sep 25, 1932–Oct 2, 1932
SAN NICOLÁS[1]	1931	H1	Sep 8, 1931–Sep 16, 1931
SAN FELIPE II[1]	1928	H5	Sep 6, 1928–Sep 21, 1928
UNNAMED[1]	1924	H2	Aug 26, 1924–Sep 6, 1924
SAN HIPÓLITO[1]	1916	H2	Aug 21, 1916–Aug 26, 1916
UNNAMED	1910	H2	Sep 5, 1910–Sep 15, 1910
SAN CIRIACO	1899	H4	Aug 3, 1899–Sep 4, 1899

[1] made landfall in U.S. Virgin Islands
H1 = Category 1 Hurricane
H2 = Category 2 Hurricane
H3 = Category 3 Hurricane
H4 = Category 4 Hurricane
H5 = Category 5 Hurricane

Particularly notable hurricanes include San Felipe II (1928), Hugo (1989), Irma (2017), and Maria (2017). These resulted in fatalities, loss of crops, property and infrastructure damage, and major economic impacts (National Weather Service n.d.; National Hurricane Center 1989; *Miami New Times* 2017; Humanity Road 2017a; *Boston Globe* 2017; Pasch et al. 2019).

3.6.2 Storm Surge

Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tide. Storm surge is produced by water being pushed toward the shore by the force of the winds moving cyclonically around the storm. In comparison to the water being forced toward the shore by wind, surge is minimally impacted by the low pressure associated with intense storms. Several factors can impact the complex phenomenon of maximum potential surge. These factors can include speed, size, storm intensity, angle of approach, pressure, shape, and coastal characteristics (i.e., the presence of bays and estuaries) (NOAA n.d.).

Width and slope of the continental shelf can also dictate storm surge potential, where a shallow slope will potentially create a greater storm surge than a steep one. For example, Louisiana has a wide and shallow continental shelf compared to Puerto Rico and U.S. Virgin Islands, which have a steeply sloped shelf. In this example, a Category 4 storm on the Louisiana coastline has the potential to produce a 20-foot (6.1 meter) storm surge, whereas storm surge for this same storm hitting Puerto Rico or U.S. Virgin Islands may only reach 9- to 12-feet (2.7 to 3.6 meters) (NOAA n.d.).

An estimate of storm surge elevations is required for a complete assessment of shoreline response and coastal storm risk. An increase in water depth may increase the potential for coastal flooding and allow larger waves (see Section 4.1.4.2 on waves) to attack the shore.

It is possible to classify and predict storm surge elevations for various storms via historical information and theoretical models. Coastal flood modeling was conducted as part of the CHS to evaluate coastal flood risks to existing and future conditions. The CHS modeling efforts are discussed further in Section 4.1.4.1. **Table 3-4** displays the CHS maximum inundation depths relative to mean sea level for a range of annual exceedance probability (AEP) storms based on existing conditions (USACE 2020b).

Table 3-4: Existing Conditions Coastal Hazards System Maximum Flood Depths by Planning Reach (USACE 2020b)

Planning Reach	10% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP
VI_1 (St Croix)	7.9 feet (2.4 m)	8.5 feet (2.6 m)	9.4 feet (2.9 m)	10.0 feet (3.0 m)	11.3 feet (3.4 m)
VI_2 (St. Thomas)	8.1 feet (2.5 m)	8.7 feet (2.6 m)	9.6 feet (2.9 m)	10.4 feet (3.2 m)	11.8 feet (3.6 m)
VI_3 (St. John)	8.1 feet (2.5 m)	8.7 feet (2.6 m)	9.7 feet (3.0 m)	10.5 feet (3.2 m)	12.1 feet (3.7 m)

While the CHS maximum flood depths are based on modeling, storm surge can also be assessed using historical flood depths. Some of the highest water levels ever recorded in the U.S. Virgin Islands occurred during Hurricane Maria. During Hurricane Maria, the measured storm surge at Lime Tree, St. Croix, U.S. Virgin Islands was recorded at 2.83 feet (0.86 meters), the highest water level measured at this gauge prior to damage to the gauge (NOAA 2020a). As shown in **Table 3-5**, the U.S. Virgin Islands Hurricane Risk and Resilience Task Force estimated an inundation level of 1.70 feet near Christiansted, St. Croix during Hurricane Irma and 2.80-foot inundation during Hurricane Maria.

Table 3-5: Measured Storm Surge: Hurricanes Irma and Maria (U.S. Virgin Islands Hurricane Recovery and Resilience Task Force 2018)

Storm	Island	Instrument and Identifier	Coordinates	Sustained (Miles Per Hour)	Gust (Miles Per Hour)	Storm Surge (Feet)	Estimated Inundation (Feet)
IRMA	St. Thomas	WeatherFlow Inc. site at Rupert Rock (XRUP)	18.33N 64.93W	83	132		
		Cyril E. King Airport (TIST)	18.33N 64.97W	59	87		
		WeatherFlow Inc. site at Buck Island (XBUK)	18.28N 64.90W	106	137		
		National Ocean Service (NOS) site at Charlotte Amalie, St. Thomas (CHAV3)	18.34N 64.92W	63	98	1.45	1.3
		WeatherFlow Inc. site at Savana Island (XSAV)	18.34N 65.08W	58	89		
	St. John	NOS site at Lameshur Bay, St. John (LAMV3)	18.32N 64.72W			1.62	1.2
	St. Croix	NOS site at Christiansted Harbor, St. Croix (CHSV3)	17.75N 64.70W	38	58	2.28	1.70
		Henry E. Rohlsen Airport (TISX)	17.68N 64.90W	38	63		
		NOS site at Limetree Bay, St. Croix (LTBV3)	17.70N 64.75W	49	61	0.60	0.50
		WeatherFlow Inc. site at Sandy Point National Wildlife Refuge, St. Croix (XCRX)	17.68N 64.90W	41	59		
MARIA	St. Thomas	WeatherFlow Inc. site at Rupert Rock, St. Thomas (XRUP)	18.33N 64.93W	45	64		
	St. John	NOS site at Lameshur Bay, St. John (LAMV3)	18.32N 64.72W			1.48	1.2
		Caribbean Coastal Ocean Observing System (CARICOOS) buoy south of St. John (41052)	18.25N 64.76W	47	64		
	St. Croix	NOS site at Christiansted Harbor, St. Croix (CHSV3)	17.75N 64.70W	49	75	2.27	2.00
		NOS site at Lime Tree Bay, St. Croix (LTBV3)	17.70N 64.75W	69*	102	2.85	2.80
		Christiansted, St. Croix (CVAV3)	17.74N 64.62W	99	136		
		WeatherFlow Inc. site at Sandy Point National Wildlife Refuge, St. Croix (XCRX)	17.68N 64.90W	107	137		

3.6.3 Sea Level Rise

The SACS addresses sea level change in accordance with the guidance document USACE Engineer Regulation (ER) 1100-2-8162, Incorporating Sea Level Change in Civil Works Programs (USACE 2019a).

The USACE Sea Level Change ER refers to "sea level change" (rather than sea level rise) because of its applicability throughout the nation, including locations where sea levels are falling are a result of land uplift. Within the entire SACS study area, sea levels are rising. Therefore, the SACS products refer to "sea level rise" to clearly communicate the sea level change trend occurring throughout the SACS study area. In accordance with ER 1100-2-8162, the SACS will not include projections of increased storm frequency or severity. The ER states, "At this time, no certain effects of climate change on tropical cyclone (TC) activity in terms of frequency, intensity, and rainfall across all global basins have been identified as changes to the variability of TC activity expected from natural causes [Knutson et al. 2010]….the current science related to climate effects on TC activity relevant to the United States (U.S.) has not reached the point of standard consensus necessary to inform a change in storm analysis baselines."

As described in the Main Report, sea level change was incorporated in the Tier 1 analysis in a manner consistent with the North Atlantic Coast Comprehensive Study (NACCS) and appropriate for a screening-level assessment. To simulate future flooding in Tier 1, three feet (0.9 meters) of sea level rise was added to the 1-percent and 10-percent AEP flood hazard layers, described in Section 4.1.1 . This value was based on compliant gauges throughout the study area. In Tier 2, two localized relative sea level rise estimates, based on U.S. Virgin Islands and Puerto Rico gauges (2.33 feet [0.71 meters] and 6.95 feet [2.12 meters]) for the 1-percent AEP event were applied for a territory-wide screening-level assessment of risk, described in Section 4.1.4 **.**

3.6.3.1 Relative Sea Level Change

Relative sea level change was calculated using the USACE Sea Level Change Curve Calculator (USACE 2019c). This calculator uses the methodology described in ER 1100-2-8162, *Incorporating Sea Level Changes in Civil Works Programs* (USACE 2019a).

Extreme water levels incorporated into the calculator are based on statistical probabilities using monthly recordings of historical extreme water level values. NOAA Technical Report NOS CO-OPS 067 – Extreme Water Levels of the United States 1893–2010 describes the methods and data used in the calculation of the exceedance probability levels using a generalized extreme value statistical function (NOAA 2013). The USACE method uses the same NOAA recorded monthly extreme values in a percentile statistical function. Both methods use data recorded and validated by NOAA at the long-term established tide gauges. The extreme values at the gauge can be significantly different than what may occur at other coastal locations because of differences in site characteristics and complex interactions of physical forces that vary between the locations. The level of confidence in the AEP decreases with longer return periods.

> Additional information is available at:
> https://tidesandcurrents.noaa.gov/

Relative sea level change refers to local elevation of the sea with respect to land, including the lowering or rising of land through geologic processes such as subsidence and glacial rebound. It is anticipated that sea level rise will accelerate within the next 100 years. To incorporate the direct and indirect physical effects of projected future sea level change on design, construction, operation, and maintenance of coastal projects, USACE provided guidance in EC 1100-2-8162 (USACE 2019a) which has been superseded by ER 1100-2-8162 and Engineer Technical Letter 1100-2-1 (USACE 2014b).

ER 1100-2-8162 provides both a methodology and a procedure for determining a range of future sea level change estimates. These estimates are referenced to the midpoint of the latest National Tidal Datum Epoch (1992). Refer to ER 1100-2-8162 for a detailed explanation of the procedure, equations employed, and variables included to account for the eustatic change as well as site-specific uplift or subsidence to develop corrected rates.

The U.S. Virgin Islands have two NOAA NOS gauges with time series water level data. One is located at Charlotte Amalie, St. Thomas and the other is located at Lime Tree Bay, St. Croix.

3.6.3.1.1 Charlotte Amalie

Based on historical sea level measurements taken from NOAA NOS Gauge No. 9751639, Charlotte Amalie, St. Thomas, U.S. Virgin Islands (**Figure 3-3**), the historical sea level rise rate was determined using updated sea level change (SLC) data (USACE 2019c). The relative sea level trend is 2.15 millimeters per year with a 95-percent confidence interval of ±0.61 millimeters per year based on monthly mean sea level data from 1975 to 2019, which is equivalent to a change of 0.71 feet (0.12 meters) in 100 years (**Figure 3-4**).

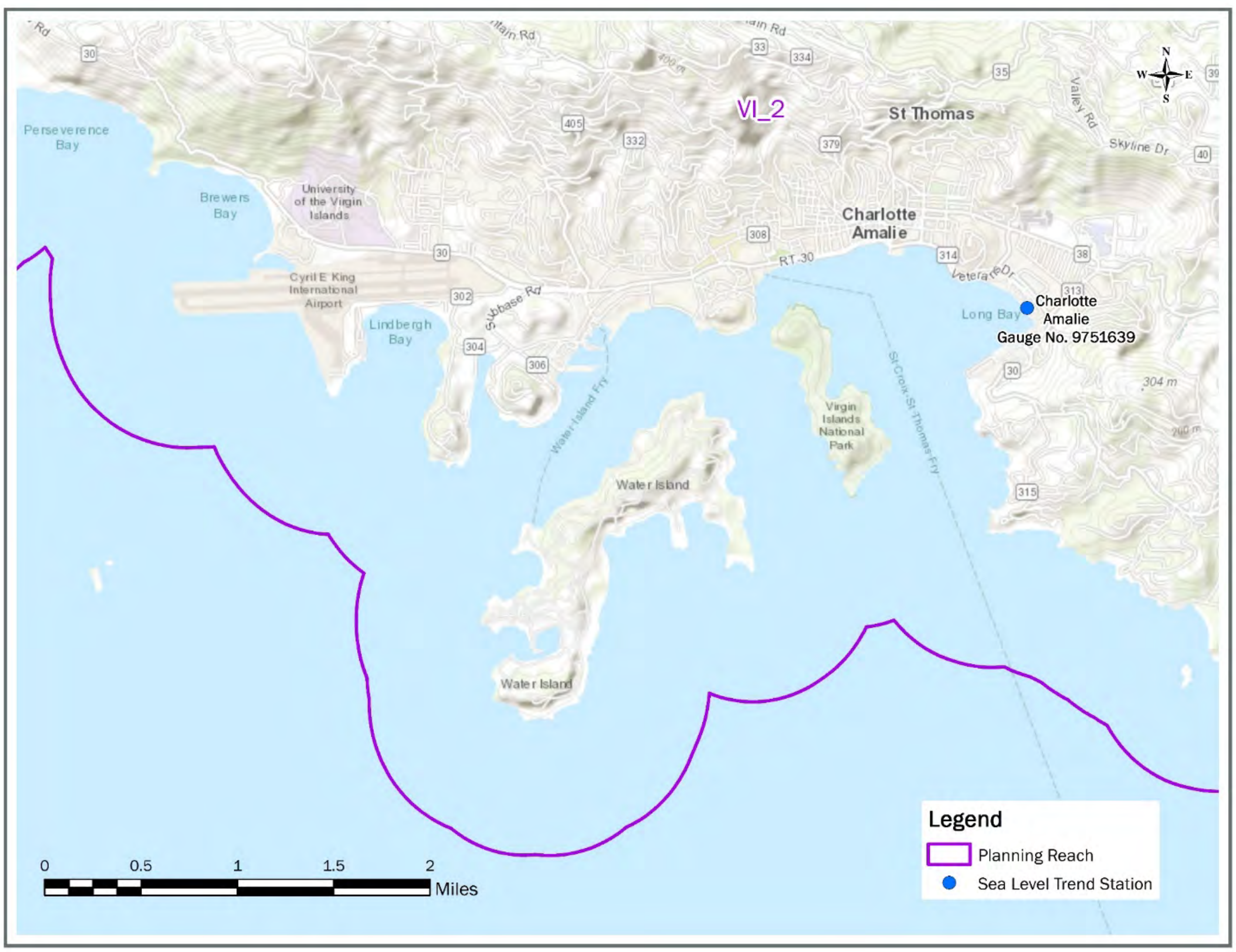


Figure 3-3: National Oceanic and Atmospheric Administration Gauge No. 9751639 Charlotte Amalie, St. Thomas, U.S. Virgin Islands (USACE 2019c)

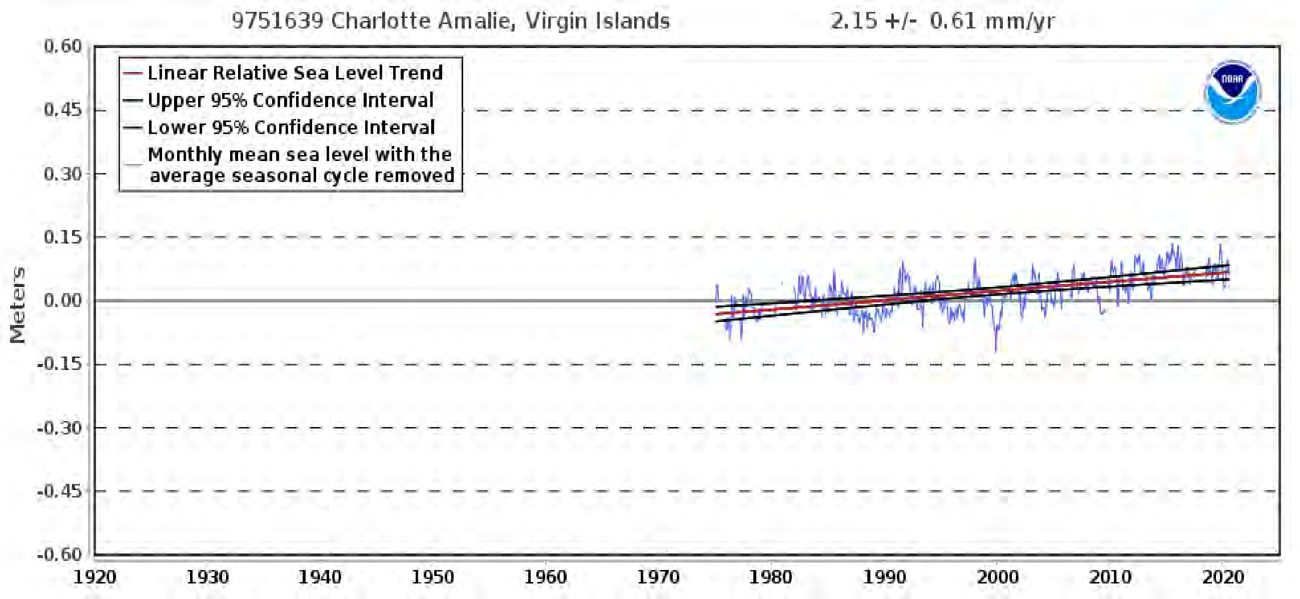


Figure 3-4: Historical Mean Sea Level Trend at National Oceanic and Atmospheric Administration Gauge No. 9751639 Charlotte Amalie, St. Thomas, U.S. Virgin Islands (NOAA 2020b)

Figure 3-5 shows the estimated relative sea level change projections to 2100 for three levels of projected future sea level change.

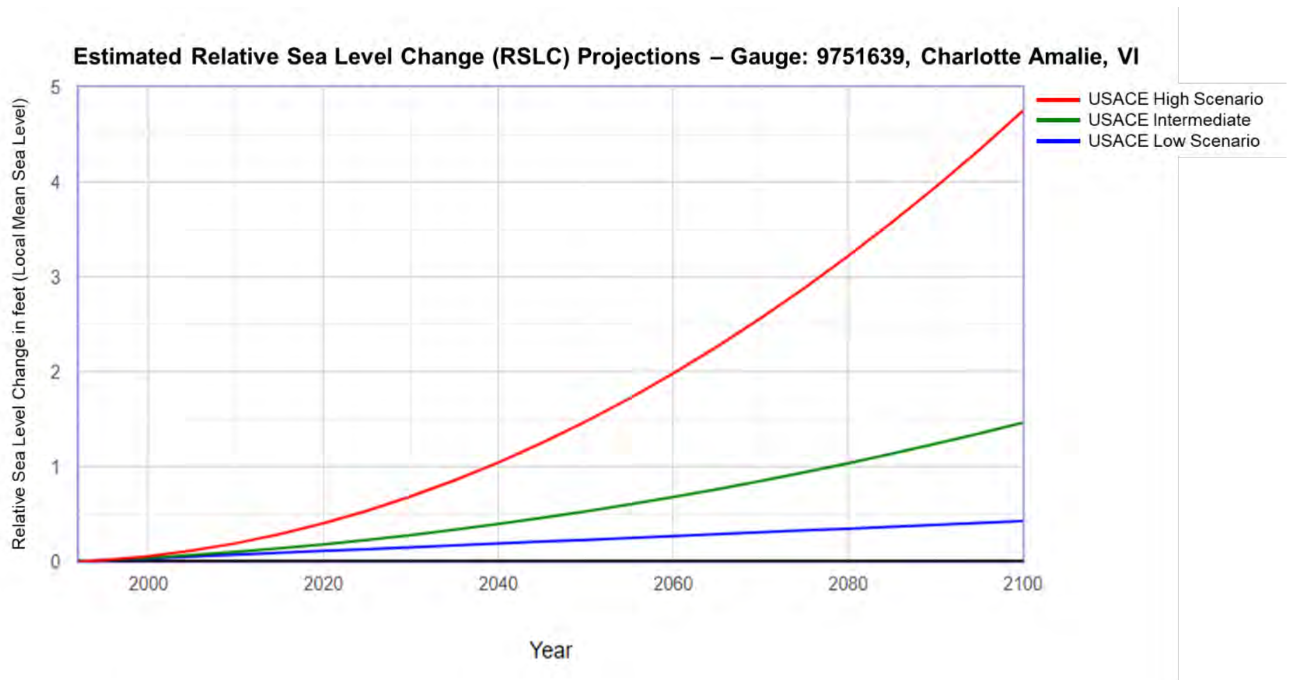
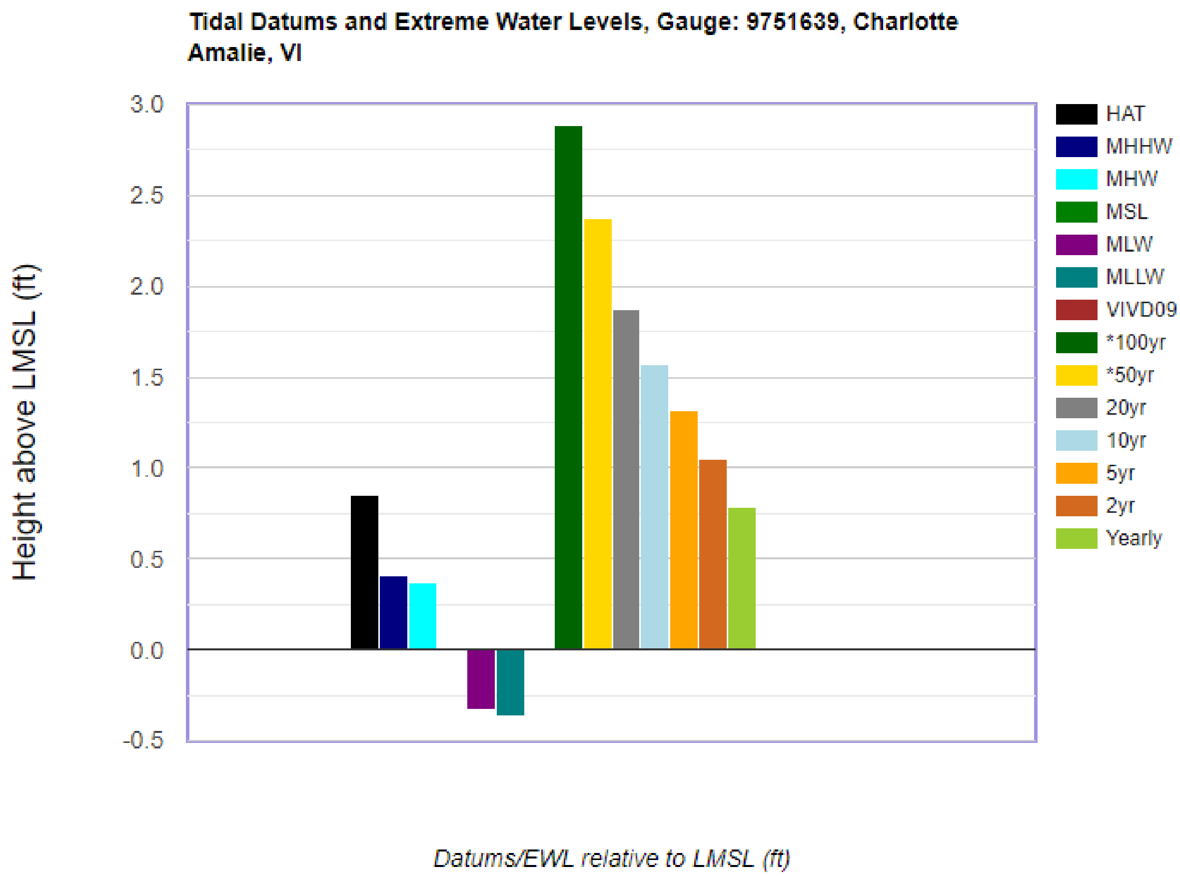


Figure 3-5: High, Intermediate, and Low Relative Sea Level Change Projections at Gauge No. 9751639 Charlotte Amalie, St. Thomas, U.S. Virgin Islands. All Values Are Expressed in Feet Relative to Local Mean Sea Level (USACE 2019c).

Tidal datums and extreme water levels for Gauge No. 9751639 Charlotte Amalie, St. Thomas, U.S. Virgin Islands are shown in **Figure 3-6.**



EWL – Extreme Water Level
HAT – Highest Astronomical Tide
LMSL – Local Mean Sea Level
MHHW – Mean Higher High Water
MHW – Mean High Water
MSL – Mean Sea Level
MLW – Mean Low Water
MLLW – Mean Lower Low Water

Figure 3-6: Tidal Datums and Extreme Water Levels for Gauge No. 9751639, Charlotte Amalie, St. Thomas, U.S. Virgin Islands. All Values are Expressed in Feet Relative to Local Mean Sea Level (USACE 2019c).

3.6.3.1.2 Lime Tree Bay

Based on historical sea level measurements taken from NOAA NOS Gauge No. 9751401, Lime Tree Bay, St. Croix, Virgin Islands, the historical sea level rise rate was determined using the updated published sea level change available through the USACE Climate Preparedness and Resilience Program. At NOAA Gauge No. 9751401, Lime Tree Bay, Virgin Islands **(Figure 3-7),** the relative sea level trend is 2.5 millimeters per year with a 95-percent confidence interval of ±0.71 millimeters per year based on monthly mean sea level data from 1977 to 2018, which is equivalent to a change of 0.82 feet (0.25 meter) in 100 years **(Figure 3-8).**

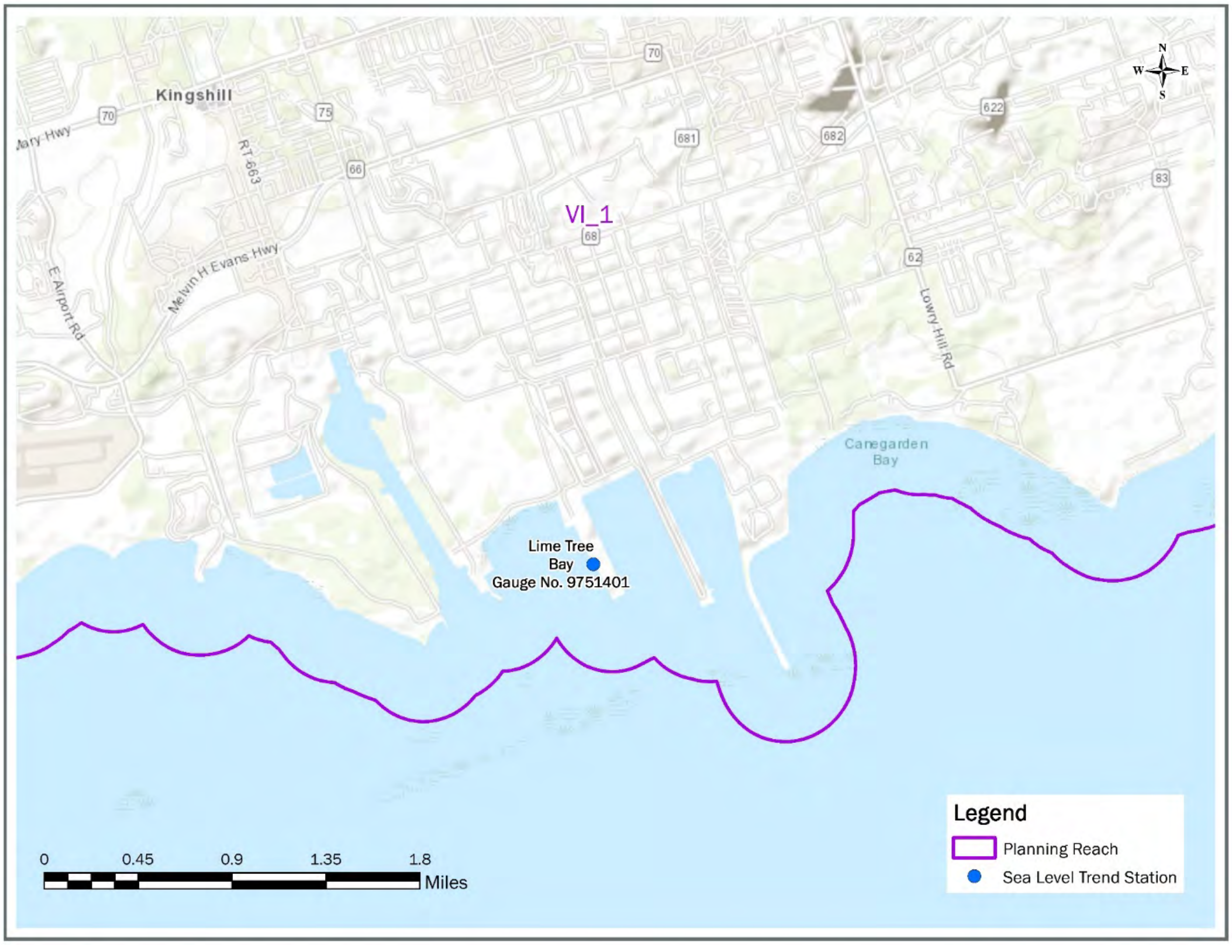


Figure 3-7: Gauge No. 9751401 at Lime Tree Bay, U.S. Virgin Islands; Gauge is noncompliant (USACE 2019c)

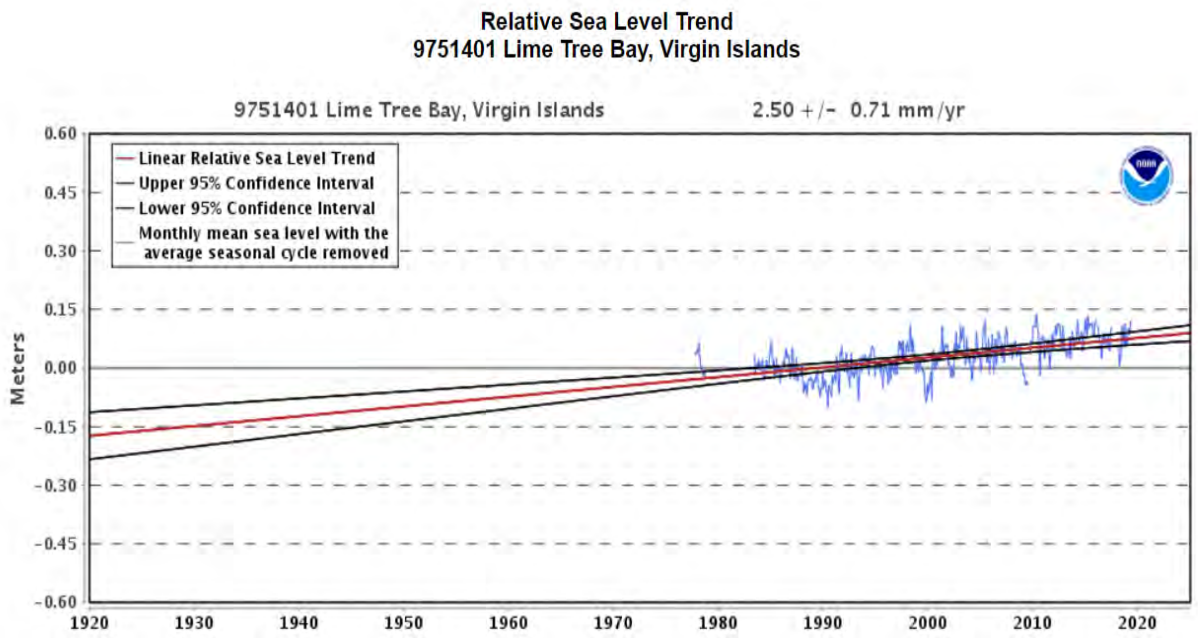


Figure 3-8: Historical Mean Sea Level Trend at National Oceanic and Atmospheric Administration Gauge No. 9751401 Lime Tree Bay, U.S. Virgin Islands (NOAA 2020b)

Figure 3-9 shows the estimated relative sea level change projections to 2100 for three levels of projected future sea level change. The total regional sea level rise predicted by the three scenarios (low, intermediate, and high) can have significant impacts, including overtopping of waterside structures, increased shoreline erosion, and flooding of low-lying areas.

Tidal datums and extreme water levels for Gauge No. 9751401, Lime Tree Bay, St. Croix, U.S. Virgin Islands are shown in **Figure 3-10.**

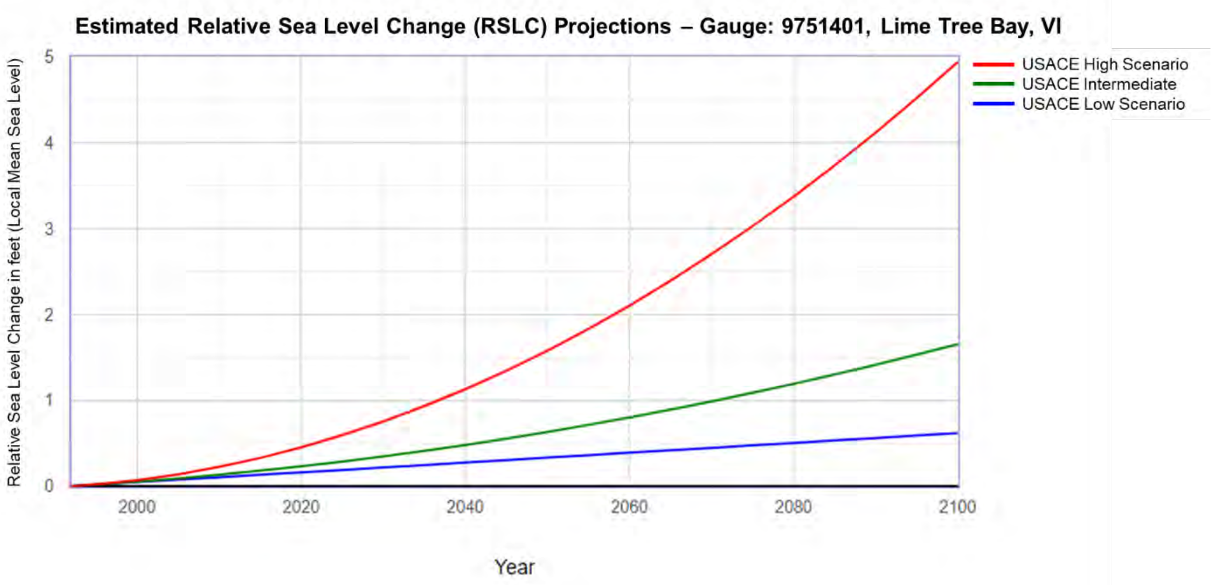
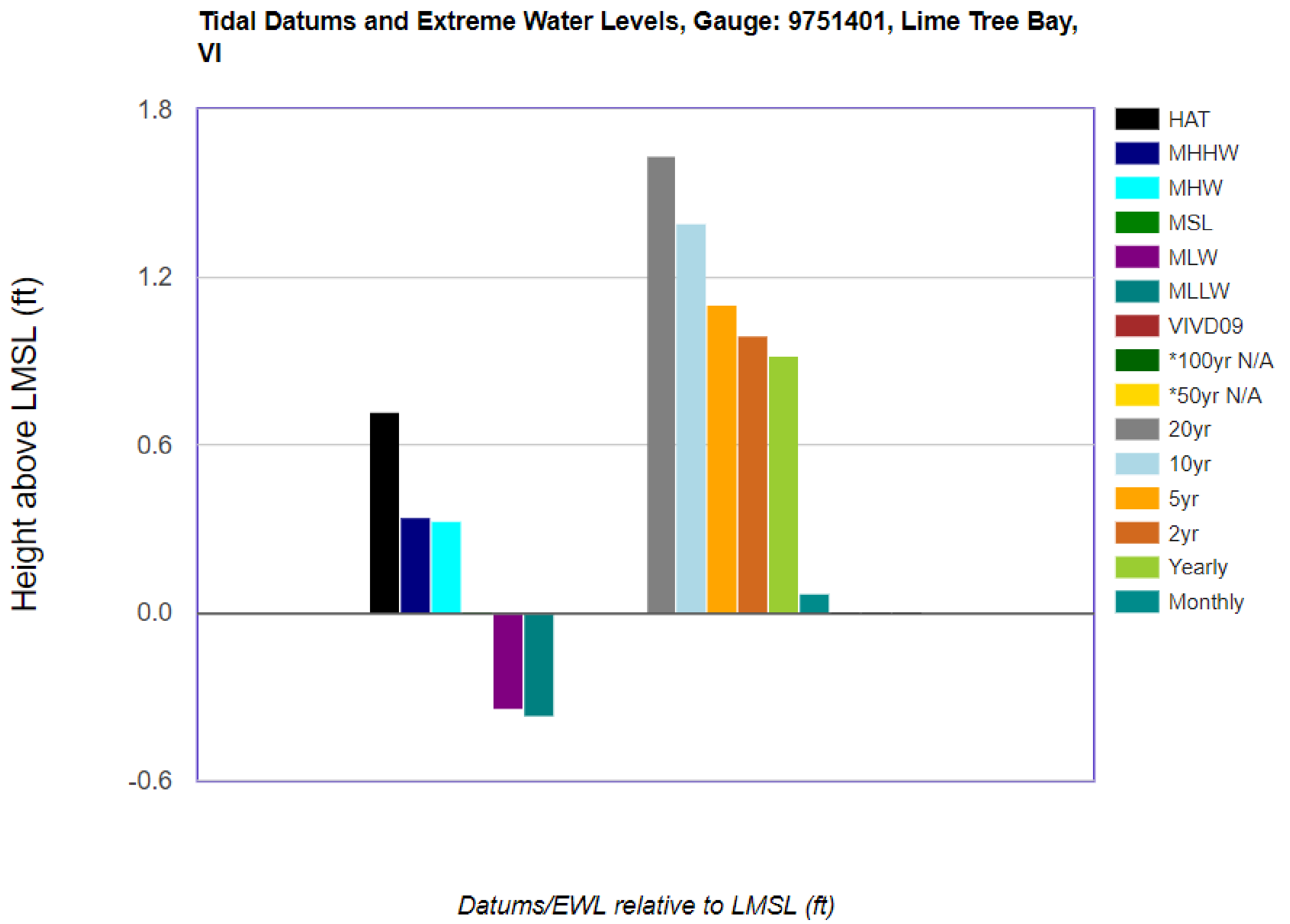


Figure 3-9: High, Intermediate, and Low Relative Sea Level Change Projections for Gauge No. 9751401, Lime Tree Bay, St. Croix, U.S. Virgin Islands. All Values are Expressed in Feet Relative to Local Mean Sea Level (USACE 2019c).



EWL – Extreme Water Level
HAT – Highest Astronomical Tide
LMSL – Local Mean Sea Level
MHHW – Mean Higher High Water
MHW – Mean High Water
MSL – Mean Sea Level
MLW – Mean Low Water
MLLW – Mean Lower Low Water

Figure 3-10: Tidal Datums and Extreme Water Levels for Gauge No. 9751401, Lime Tree Bay, St. Croix, U.S. Virgin Islands. All Values are expressed in Feet Relative to Local Mean Sea Level (USACE 2019c).

3.6.3.2 National Oceanic and Atmospheric Administration Sea Level Rise Viewer

The NOAA Sea Level Rise Viewer is a tool used to illustrate the inundation footprint caused by elevated mean sea level. Based on the USACE Sea Level Change Curve Calculator (USACE 2019c), the expected relative sea level change using the USACE High scenario will range from 6.58 feet (2.01 meters) at Charlotte Amalie to 6.81 feet (2.08 meters) at Lime Tree Bay (relative to mean sea level 1992). The NOAA Sea Level Rise Viewer tool was used at multiple locations across the territory of U.S. Virgin Islands to demonstrate the potential impacts of sea level change on coastal communities by applying seven feet (2.1 meters) of sea level rise. The results for Charlotte Amalie at St. Thomas are provided in **Figure 3-11**.

Impacts of sea level change can be viewed for other areas of the U.S. Virgin Islands using the NOAA Sea Level Rise Viewer at https://coast.noaa.gov/slr/.

Using the Sea Level Rise Viewer, other areas of the U.S. Virgin Islands most impacted by sea level rise will be Christiansted and Lime Tree Bay on St. Croix and Cruz Bay on St. John, as well as many of the beaches and coastal lagoons.

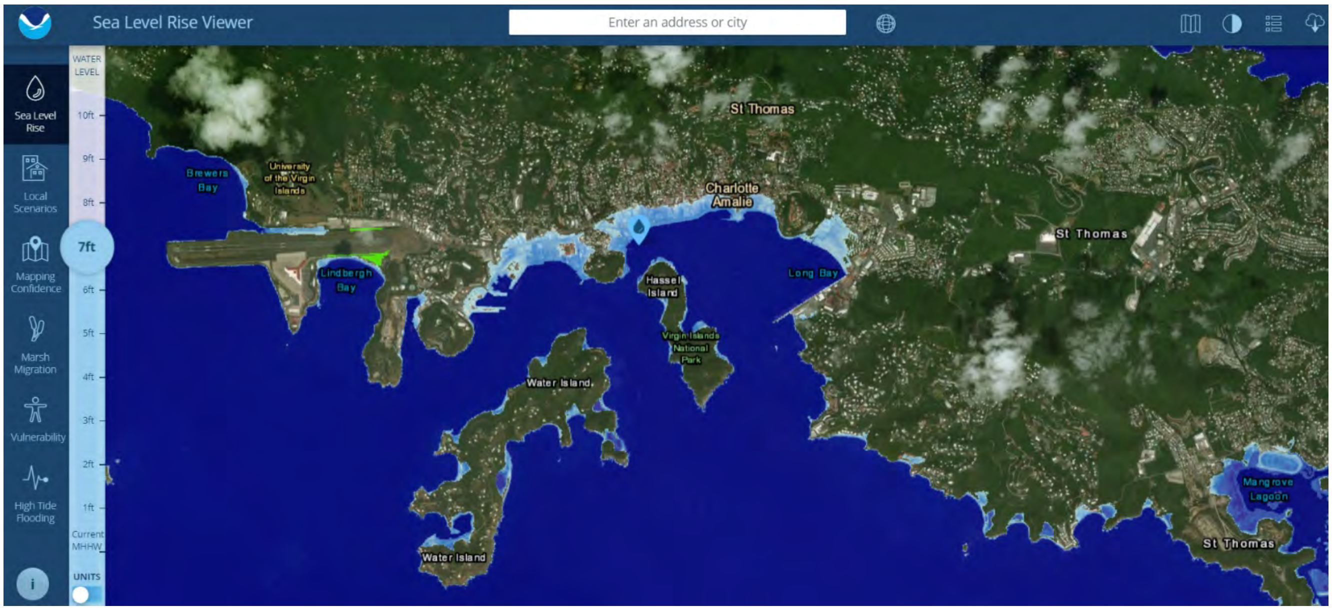


Figure 3-11. National Oceanic and Atmospheric Administration Sea Level Rise Viewer at Charlotte Amalie; Estimation of Seven Feet (2.1 meters) of Sea Level Rise Relative to Mean Higher High Water for Charlotte Amalie at St. Thomas (NOAA 2020c)

SECTION 4

Risk Assessment

This section describes the U.S. Virgin Islands-specific results from: (1) the Tier 1 Risk Assessment conducted consistently across the entire SACS study area and (2) the Tier 2 analysis, which represents a second pass through the Framework at a more refined analysis level. An overview of the methodology for each analysis is provided first, followed by the results organized by planning reach and a summary of the determined highest-risk locations.

4.1 Overview

The SACS refers to risk and vulnerability as defined in Engineering Regulation (ER) 1105-2-101. The ER clearly states that flood risk can be conceptualized as a function of the hazard, performance, exposure, vulnerability, and consequences, as depicted in **Figure 4-1**. As such, risk can be reduced by modifying these components (i.e., by reducing vulnerability or exposure).

The ER broadly defines risk as a situation or event in which something of value is at stake, and its gain or loss is uncertain. Risk is typically expressed as a combination of the likelihood and consequence of an event. Consequences are measured in terms of harm to people, cost, time, environment, property, and other metrics.

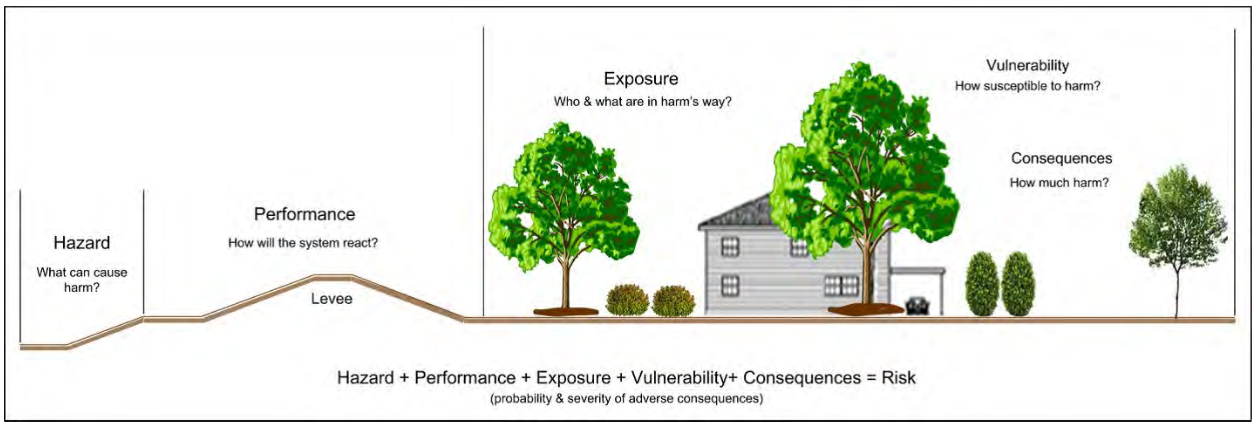


Figure 4-1. Risk Conceptualized (USACE 2017)

Definitions of risk components as utilized in the SACS include:

Hazard – In a general sense, hazard is anything that is a potential source of harm to a valued asset (human, animal, natural, economic, and social) (USACE 2014a).

Performance – System's reaction to the hazard, and its features and the capability to contain or manage the hazard for the full range of possible events. In the context of the SACS, performance can include multiple built or natural environments that contribute to how well the system reacts to a hazard.

Exposure – Describes who and what may be harmed by the flood hazard. Exposure incorporates a description of where the flooding occurs at a given frequency, and what assets exist in that area.

Vulnerability – Susceptibility of harm to human beings, property, and the environment when exposed to a hazard. Depth-damage functions, depth-mortality functions, and other similar relationships can be used to describe vulnerability.

Consequence – Harm that results from a single occurrence of the hazard. Consequences are measured in metrics such as economic damage, acreage of habitat lost, value of crops damaged, and lives lost.

Risk – Combination of likelihood and harm to people, property, infrastructure, and other assets.

This icon will serve as a guide through the Risk Assessment sub-sections. A red color indicates the risk component currently being assessed for a given Planning Reach.

4.1.1 Tier 1 Hazard

The Tier 1 products can be visualized through the interactive SACS Geoportal: https://data-sacs.opendata.arcgis.com/

The Tier 1 Risk Assessment provides a consistent regional assessment of coastal flood risk caused by storm surge and sea level rise for the study area scale. This is because, of all coastal storm hazards, storm surge inundation has the greatest potential to negatively impact populations and infrastructure. FEMA states, "Floods are the most common and costly hazard affecting communities and the hazard that is most predictable" (FEMA 2013).

Tier 1 flood risk hazards include the following water levels. Additional description is provided in the Geospatial Appendix.

- 10-percent AEP water levels from the U.S. Army Engineer Research and Development Center Coastal and Hydraulics Laboratory (ERDC/CHL)
- 1-percent AEP water levels, imported from the FEMA National Flood Hazard Layer (NFHL)
- Category 5 Maximum of Maximum (MOM) hazard from NOAA's Sea, Lake, and Overland Surges (SLOSH) model (Jelesnianski et al. 1992)

At the Tier 1 level, three feet (0.9 meters) of sea level rise was added to the 1-percent and 10-percent AEP flood hazard layers to simulate future flooding events. Three feet of sea level rise was not added to the Category 5 MOM because of the uncertainty of SLOSH modeling for such major events, as well as the extremely low probability of occurrence. The spatial extent of the 1-percent and 10- percent AEP events, plus three feet of sea level rise, fall within the bounds of spatial extent for the Category 5 MOM. Approximately three feet of sea level rise is projected to occur throughout the SACS study area by 2120. Three feet of sea level rise was chosen based on the USACE Intermediate Scenario projections for 2120 and USACE High Scenario projections for 2070, as shown in **Figure 4-2**, which displays regional average projections for compliant (record lengths of greater than 50 years) gauges basin-wide. Under the USACE Intermediate Scenario, the mean of the expected water surface elevation for compliant gauges throughout the study area in 2120 is 2.54 feet (0.77 meter) relative to the mean sea level (MSL) in 1992. Under the USACE High Scenario, the mean of the expected water surface elevation for compliant gauges in the study area in 2070 is 2.92 feet (0.89 meter) relative to the MSL in 1992.

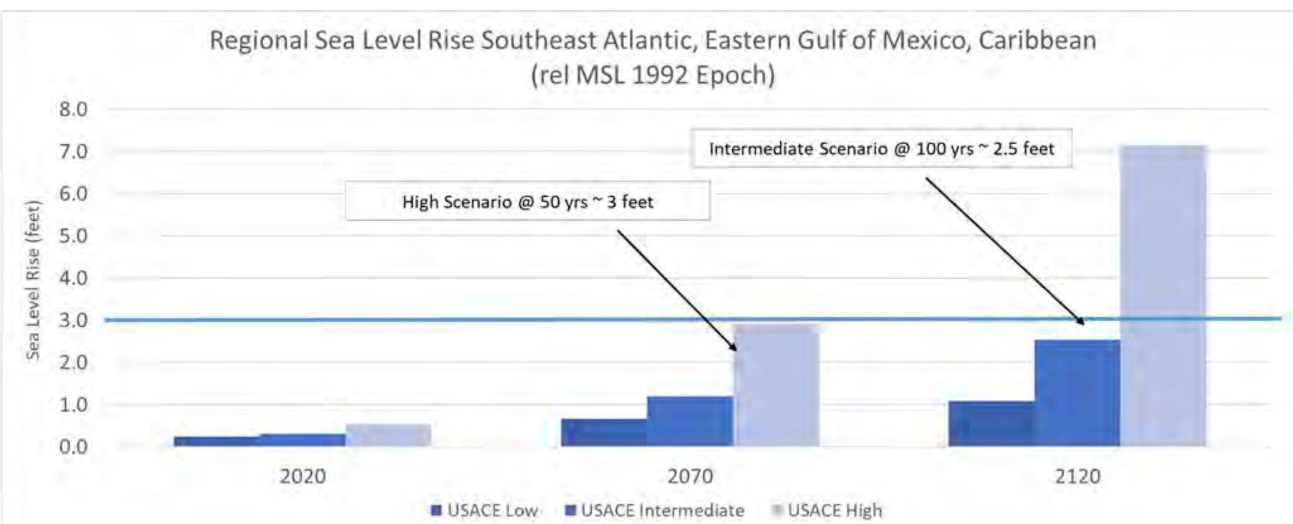


Figure 4-2. Regional Sea Level Rise in Southeast Atlantic, Eastern Gulf of Mexico, and the Caribbean for 2020, 2070, and 2120

4.1.2 Tier 1 Exposure

The term exposure describes who/what may be impacted by the flood hazard. Exposure incorporates a description of where the flooding occurs at a given frequency, and what exists in that area (USACE 2017b). On the Tier 1 scale, exposure was defined by the study area and not by individual hazard footprints. Although a myriad of factors or criteria can be used to identify exposure, the Tier 1 analysis focused on the following categories and criteria to define exposure indices:

- Population and Infrastructure Index: Population density includes the number of persons within an aerial extent across the study area. Infrastructure includes the roads and bridges, buildings, residential housing, hospitals, schools, fire departments, and other critical infrastructure that supports the population and communities. These factors were combined to reflect overall exposure of the built environment.

- Environmental and Cultural Resources Exposure Index: This exposure index captures important habitat and selected cultural resources that would be affected by storm surge.

- Social Vulnerability Exposure Index: Social vulnerability characterization includes certain segments of the population that may have more difficulty preparing for and responding to coastal flood events. Although this category is related to the vulnerability of the population within the study area, rather than actual exposure given the definition above, this category was maintained as an exposure index to maintain consistency with the NACCS.

The methodology and data used is described in the Main Report, Geoportal Tier 1 Risk Assessment Viewer Overview tab and the Geospatial Appendix.

As described in the Main Report, the three independent exposure indices were weighted and summed to develop one composite exposure index (CEI) to convey overall exposure.

- Weighting used in the NACCS methodology was 80/10/10 (80-percent population and infrastructure; 10-percent environmental, cultural, and habitat; and 10-percent social vulnerability).

- SACS weighting was modified from the NACCS to 60/30/10 (60-percent population and infrastructure; 30-percent environmental and cultural resources; and 10-percent social vulnerability).

This revised weighting better reflects the study authority and conditions in the study area for the following reasons:

- Decreasing the weight of the infrastructure/population exposure index to 60 percent to better reflect demographic differences in the coastal zone from the northeast (lower urban densities regionally/overall).

- Increasing the weight of the environmental and cultural resources exposure index to 30 percent to be consistent with authorizing language and better reflect the potential risk to vulnerable environmental resources that provide significant coastal storm risk reduction.

However, because the datasets used for social vulnerability for the SACS study area were not available for the U.S. Virgin Islands, the Tier 1 CEI did not include a social vulnerability index. Instead, the CEI was based on a 65 percent weighting for the population and infrastructure index and a 35 percent weighting for the environmental and cultural resources exposure index.

4.1.3 Tier 1 Vulnerability

Because the Tier 1 Risk Assessment relies on national-level data sets and a consistent approach, the broad assumption made regarding vulnerability is that any exposed resources impacted by the flood hazard are vulnerable. Essentially, if a resource gets wet from one of the hazards, it is vulnerable. While this is a broad assumption, it is relevant to the Tier 1 purpose—to broadly identify where coastal storm flood risk is likely and where the likelihood may increase with sea level rise.

4.1.4 Tier 2 Hazards

The Tier 2 analysis considers additional hazards and more localized hazard data and information relevant to the U.S. Virgin Islands. This analysis builds on the hazards evaluated as part of the Tier 1 analysis. Tier 2 hazards considered in this study include shoreline erosion, waves, coastal flooding caused by storm surge, and sea level rise. **Table 4-1** outlines the hazards considered in Tier 1 and Tier 2.

Table 4-1: Summary of Tier 2 Hazards

Hazards	Description of Hazard	Tier 1	Tier 2
Inundation	Inundation was assessed in Tier 1 but was reexamined using FEMA's FAST model to identify areas that were potentially missed in Tier 1.	X	X
Wave Attack	The impact of waves on shorelines that can be hazardous to both natural shorelines and engineered structures.		X
Erosion	Coastal erosion is hazardous to natural shorelines such as marshes and sandy beaches. Erosion can lead to increased vulnerability of cultural and environmental resources, and infrastructure.		X
Wind	High winds during hurricanes can damage both infrastructure, environmental resources such as mangroves, and cultural resources.		X
Compound Flooding	Compound flooding is combination of hazards that create a greater hazard. A combination of inundation, precipitation, nuisance flooding, and high groundwater table elevations can create greater flooding than storm surge alone.		X
Saltwater Inundation and Intrusion	Saltwater inundation and intrusion can damage and destroy environmental resources and freshwater sources.		X

Following the Framework, the Tier 2 analysis considers two additional relative, localized sea level rise values: 2.33 feet (0.71 meters) and 6.95 feet (2.12 meters). These values are based on relevant compliant gauges in Puerto Rico and the U.S. Virgin Islands. Sea level rise of 2.33 feet (0.71 meters) is based on the USACE Intermediate Scenario for 2120 and the USACE High Scenario for 2070, and sea level rise of 6.95 feet (2.12 meters) is based on the USACE High Scenario for 2120. The Tier 2

Economic Risk Assessment used 2.33 feet (0.71 meters) to provide a higher degree of resolution regarding economic risk to the U.S. Virgin Islands, while Coastal Hazards System data outputs for inundation and wave attack (described in further detail below) include both sea level rise values; 2.33 feet (0.71 meters) and 6.95 feet (2.12 meters).

4.1.4.1 Inundation

Inundation extents were analyzed in the Tier 1 Risk Assessment using the FEMA National Flood Hazard Layer (NFHL) 1-percent AEP, the ERDC/CHL 10-percent AEP, and the SLOSH Category 5 MOM modeled inundation (Jelesnianski et al. 1992), shown in **Table 4-2**. In the Tier 2 analysis, inundation hazards were further assessed by using FEMA's FAST model to develop a more refined understanding of the potential damages caused by inundation under existing and future conditions. The FAST model uses the same methodology as FEMA's Hazus Flood Model, in an open-source format that allows user-defined inputs. FAST estimates the impact of storm surge inundation by calculating expected damages for structures and contents, and the results can be spatially visualized. Depreciated losses were calculated by census block and by census place to identify additional potential high-risk areas not identified during the Tier 1 Risk Assessment.

The FAST analysis was completed for coastal U.S. Virgin Islands using inundation data from the CHS. Storm surge surface areas were created from CHS point data that represented the 10-, 4-, 2-, 1-, and 0.2-percent AEPs, and resulting depth grids were used in FAST to determine water levels at specific structure locations. To evaluate future conditions, 2.33 feet (0.71 meters) of sea level rise was added to these events. For more information regarding the application of the FAST model for the Tier 2 Risk Assessment, refer to the Tier 2 Economic Risk Assessment technical report.

FAST inundation damages were aggregated by census place and classified into low-, medium-, or high-risk categories based on the relative damage estimates. FAST results were compared to the Tier 1 Risk Assessment areas to analyze differences between Tier 1 and Tier 2.

The CHS (USACE 2020b) model, one of the products of the SACS study, provides a comprehensive coastal hazard dataset, which covers the territory of the U.S. Virgin Islands. The stillwater elevations developed as part of the CHS can be used to understand localized water surface elevations and associated potential inundation. There are over 14,800 virtual gauges around Puerto Rico and the U.S. Virgin Islands that have calculated a stillwater elevation for the 20-, 10-, 5-, 2-, 1-, 0.5-, 0.2-, 0.1-, 0.05-, 0.02-, and 0. 01-percent AEP water levels. **Table 4-2** is a sample of data available through the CHS web portal (USACE 2020b). Data from the CHS is in meters and relative to mean sea level. **Figure 4-3** through **Figure 4-5** illustrate the CHS modeled inundation under current conditions (**Figure 4-3**), with 2.33-feet (**Figure 4-4)** and 6.95-feet of sea level rise (**Figure 4-5**).

Table 4-2: Sample of Stillwater Elevations (SWL) from the Coastal Hazards System (meters, mean sea level) (USACE 2020b)

Virtual Gauge ID	Latitude (deg)	Longitude (deg)	Annual Exceedance Probability (SWL in m, MSL)										
			20%	10%	5%	2%	1%	0.5%	0.2%	0.1%	0.05%	0.02%	0.01%
625	17.8	-64.7	0.2	0.4	0.5	0.8	1.0	1.2	1.4	1.6	1.8	2.1	2.2
626	17.8	-64.7	0.3	0.4	0.6	0.9	1.0	1.2	1.5	1.6	1.6	2.1	2.2

Virtual Gauge ID	Latitude (deg)	Longitude (deg)	Annual Exceedance Probability (SWL in m, MSL)										
			20%	10%	5%	2%	1%	0.5%	0.2%	0.1%	0.05%	0.02%	0.01%
627	17.8	-64.7	0.2	0.4	0.5	0.8	1.0	1.1	1.4	1.6	1.8	2.0	2.1
628	17.8	-64.7	0.2	0.4	0.5	0.8	0.9	1.1	1.3	1.5	1.6	1.8	1.9
629	17.8	-64.7	0.2	0.4	0.5	0.8	0.9	1.1	1.3	1.4	1.6	1.8	1.8

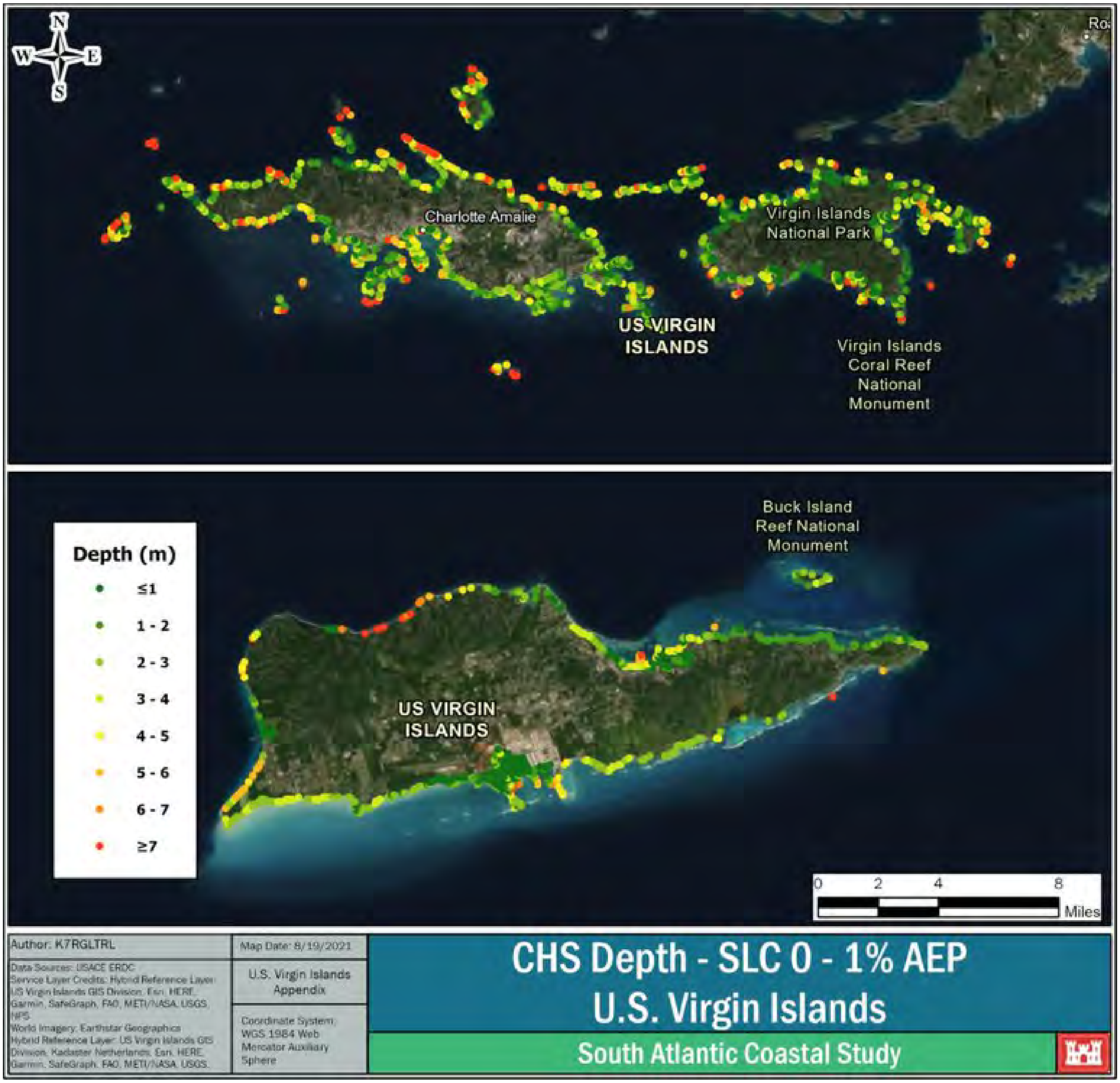


Figure 4-3: CHS Modeled Inundation Depth for the 1-Percent Annual Exceedance Probability Event in U.S. Virgin Islands

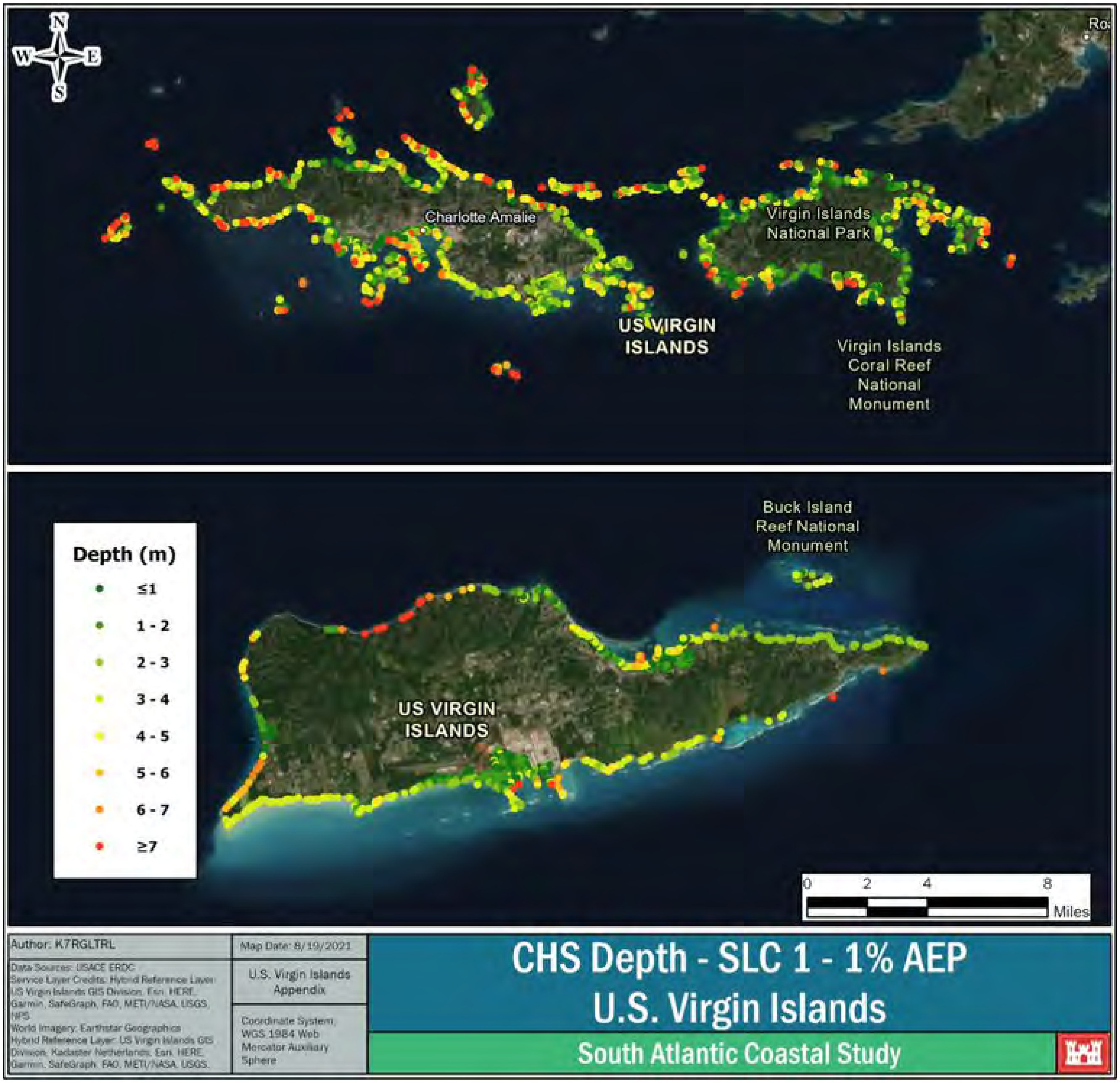


Figure 4-4: CHS Modeled Inundation Depth for the 1-Percent Annual Exceedance Probability Event with 2.33 feet of Sea Level Rise in U.S. Virgin Islands

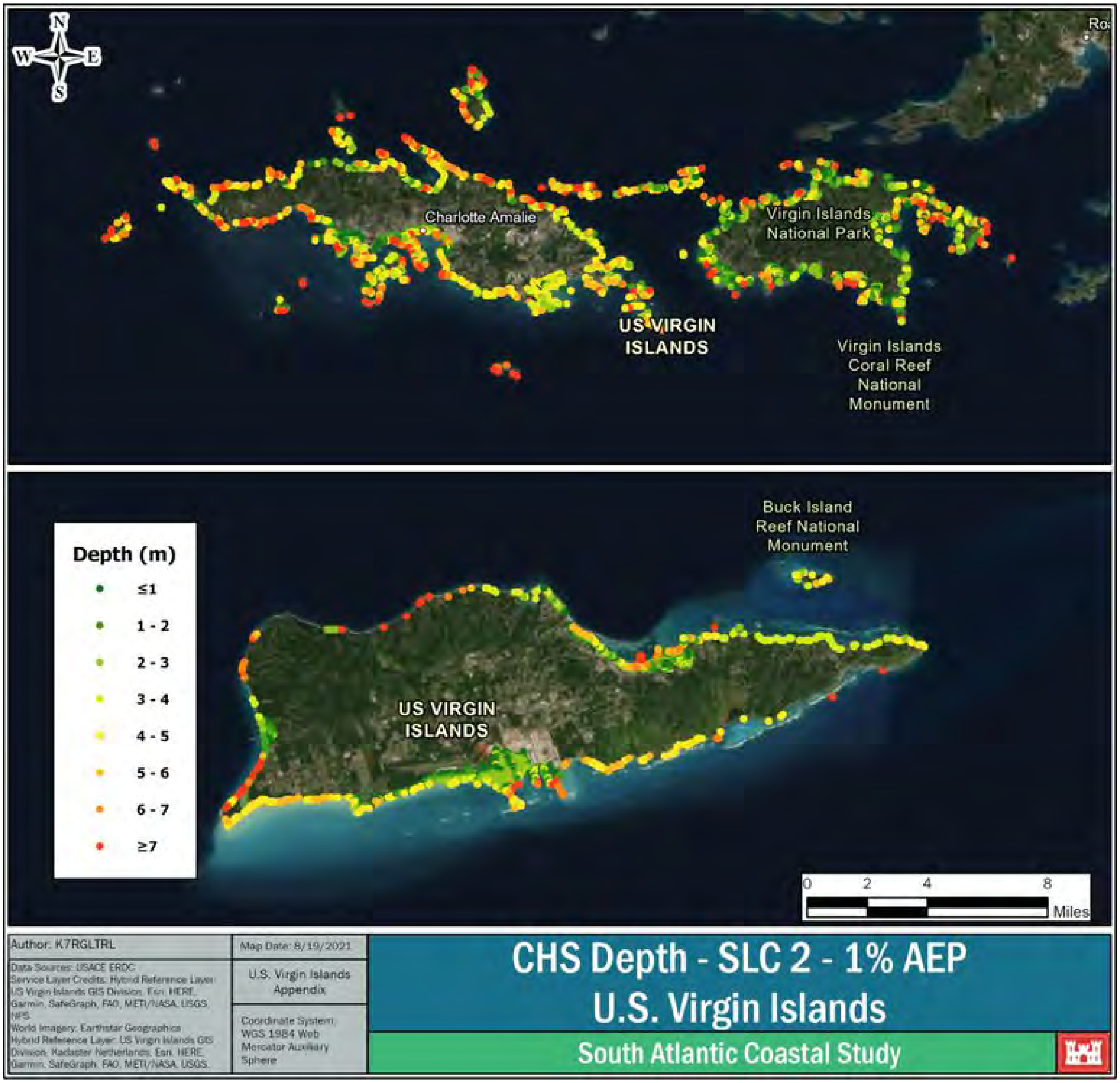


Figure 4-5: CHS Modeled Inundation Depth for the 1-Percent Annual Exceedance Probability Event with 6.95 feet of Sea Level Rise in U.S. Virgin Islands

4.1.4.2 Wave Attack

Coastal storms are generally accompanied by powerful and damaging waves. The repetitive pounding of waves on shorelines or structures can, over time, cause damage under normal wave conditions and is exacerbated during storm conditions when waves are larger and more frequent. Wave attack is a hazard for all coastal regions but has greater impacts in areas with prominent infrastructure and population, or cultural and environmental resource exposure in coastal areas. Waves can damage or destroy engineered structures, such as seawalls, revetments, or bulkheads, through direct wave impacts on a structure or by scouring and undermining the toe of the structure.

Waves can also erode and thereby damage nonstructured shorelines such as beaches, dune systems, and marshes. The interaction of wave momentum with the land or built environment results in an uprush of water called wave run-up.

Wave run-up can result in wave hazards extending to higher elevations. In some cases, coastal features will be overtopped by waves and can damage the backside of dunes, structures, or other coastal features—which, in some cases, may lead to failure of coastal structures. Coastal ecosystems, such as dunes and marsh grasses, can also be damaged or destroyed by wave attack. The damage or loss of these ecosystems can leave inland areas more susceptible to additional erosion and wave attack.

As sea level rises, wave attack may be exacerbated. Wave heights are a direct function of water depth. As the water depth increases, larger waves can be supported. Areas of natural shorelines with enough room to migrate landward will be able to adapt to new coastal conditions under sea level rise. However, ecosystems with no room to migrate may be lost or damaged as sea levels rise. Areas with developed shorelines (e.g., seawalls, revetments) are likely to see increased nearshore water depths, resulting in higher wave heights under sea level rise conditions and higher potential damage. Structures that are built to withstand current conditions may not be stable under future sea level rise conditions and may need to be replaced or more frequently repaired.

Wave data (e.g., heights, periods, directions) is historically measured at offshore buoys. There is one buoy located near St. John. Hindcast models estimate wave conditions at discrete locations. The USACE Wave Information Study (WIS) is one example of a hindcast model dataset covering conditions for 1980 to 2014.

The CHS tool, one of the products of the SACS study, provides a comprehensive modeled coastal hazard dataset, which covers the territory of U.S. Virgin Islands. Wave height and wave period modeled data were reported for the 20-, 10-, 5-, 2-, 1-, 0.5-, 0.2-, 0.1-, 0.05-, 0.02-, and 0.01-percent AEPs. All wave height data from the CHS is reported in meters. **Table 4-3** displays samples of the wave height data around the U.S. Virgin Islands from the CHS (USACE 2020b).

Table 4-3: Sample of Wave Heights in Meters from the Coastal Hazards System (USACE 2020b)

Virtual Gauge ID	Latitude (deg)	Longitude (deg)	Annual Exceedance Probability (SWL in m, MSL)										
			20%	10%	5%	2%	1%	0.5%	0.2%	0.1%	0.05%	0.02%	0.01%
625	17.8	-64.7	0.2	0.4	0.5	0.8	1.0	1.2	1.4	1.6	1.8	2.1	2.2
626	17.8	-64.7	0.3	0.4	0.6	0.9	1.1	1.2	1.5	1.6	1.9	2.1	2.2
627	17.8	-64.7	0.2	0.4	0.5	0.8	1.0	1.1	1.4	1.6	1.8	2.0	2.1
628	17.8	-64.7	0.2	0.4	0.5	0.8	0.9	1.1	1.3	1.5	1.6	1.8	1.9
629	17.8	-64.7	0.2	0.4	0.5	0.8	0.9	1.1	1.3	1.4	1.6	1.8	1.8

4.1.4.3 Coastal Erosion

Coastal erosion hazards were evaluated as part of the Tier 2 analysis. A study by Luijendijk et al. (2018) summarizes historical (1984 to 2016) shoreline change rates for Puerto Rico, St. Thomas, and St. Croix. Negative historical shoreline change indicates areas of erosion hazard. Results of this study are provided in respective planning reach sections (Sections 4.2 through 4.4).

A United States Geological Survey (USGS) study on the coastal vulnerability of the Virgin Islands National Park found that most of the park is experiencing ± one meter of shoreline change per year, with a few small pockets of sandy areas experiencing erosion of greater than one meter per year (Pendleton et al. 2005).

As sea level rises and wave heights increase, coastal erosion will be exacerbated, threatening additional coastal infrastructure and environmental and cultural resources. As beaches erode, there is a subsequent increase in demand for sand sources to support beach nourishment efforts, which could strain the limited existing resources. An inventory of existing sand sources is available in the South Atlantic Division Sand Availability and Needs Determination Summary Report (SAND Report).

Marsh erosion occurs when waves impact the seaward marsh edge or when upstream dams cut off riverine sediment transport. Sea level rise is expected to increase marsh erosion by creating conditions where stronger waves can propagate onto tidal flats. Typically, a healthy marsh can recover eroded land by recolonizing bare tidal flats; however, consistent large waves can slow down or block this recovery by preventing seed establishment. The vegetation of a healthy marsh provides habitat for fish, shellfish, and crustaceans, and provide water quality benefits by filtering and absorbing pollutants. Like salt marshes, mangroves need to migrate with increased sea levels to avoid habitat loss. Salt marshes and mangroves provide CSRM benefits, such as absorbing wave energy and reducing coastal storm flooding (Narayan et al. 2017). Erosion of salt marshes will increase coastal hazard exposure to upland and adjacent areas.

4.1.4.4 Wind

Wind hazards, which were not evaluated as part of the Tier 1 Risk Assessment, are a significant coastal hazard. Hurricane Maria, which made landfall in St. Croix in September 2017, produced sustained wind speeds of up to 107 miles per hour (47.8 meters per second) and gusts up to 137 miles per hour (61.2 meters per second) in areas of St. Croix (Pasch et al. 2019). High winds, like those experienced during Hurricane Maria, can cause severe damage to the environment and infrastructure. High winds can destroy roofs, electrical infrastructure, and, if strong enough, entire buildings. Flying debris caused by high winds can also become a hazard. Ecosystems, such as mangroves, can be defoliated by wind, limiting the mangrove’s ability to provide wind shear reduction to adjacent areas.

Building codes require structures built on the U.S. Virgin Islands to follow the latest wind design criteria. **Table 4-4** describes some of the potential damages associated with tropical systems based on the Saffir-Simpson Scale for wind speeds.

Table 4-4: Damage Description Based on Wind Speeds

Tropical System Category Saffir Simpson Scale	Wind Speeds (Miles Per Hour)	Typical Damage Description
Tropical Depression	>39	Heavy rains and strong winds can cause minor flooding and property damage.
Tropical Storm	39–73	Minor damage will occur to many mobile homes. A few homes may receive mostly minor damage to roof shingles and siding.
Category 1 Hurricane	74–95	Damage is done primarily to shrubbery and trees, unanchored mobile homes are damaged, some signs are damaged, and no real damage is done to structures.
Category 2 Hurricane	96–110	Some trees are toppled, some roof coverings are damaged, and major damage is done to mobile homes.
Category 3 Hurricane	111–129	Large trees are toppled, some structural damage is done to roofs, mobile homes are destroyed, and structural damage is done to small homes and utility buildings.
Category 4 Hurricane	130–156	Extensive damage is done to roofs, windows, and doors; roof systems on small buildings completely fail; some curtain walls fail.
Category 5 Hurricane	>156	Roof damage is considerable and widespread, window and door damage are severe, there are extensive glass failures, and some complete buildings fail.

4.1.4.5 Compound Flooding

Compound flooding occurs when coastal flood hazards occur simultaneously with rainfall-runoff or fluvial flood hazards, resulting in potentially greater impacts, as shown in **Figure 4-6**. When these events co-occur, the potential for flooding in low-lying coastal areas is often much greater than from either flood hazard source alone. In the U.S. Virgin Islands, the steep terrain causes runoff to flow rapidly through the islands' numerous rivers or guts (main drainage channels for discharge of rainfall runoff events [Conservation Data Center 2010]), enhancing the effects from heavy precipitation events. While this can cause significant damage inland, the combination of this runoff with coastal flood hazards, including sea level rise and storm surge, creates an additional threat to the narrow, low-lying coastal areas of the islands (Silva-Araya et al. 2018). While the Tier 2 analysis does not consider compound flood hazards in detail, any areas near tidally influenced river mouths are subject to increased hazards from compound flooding.

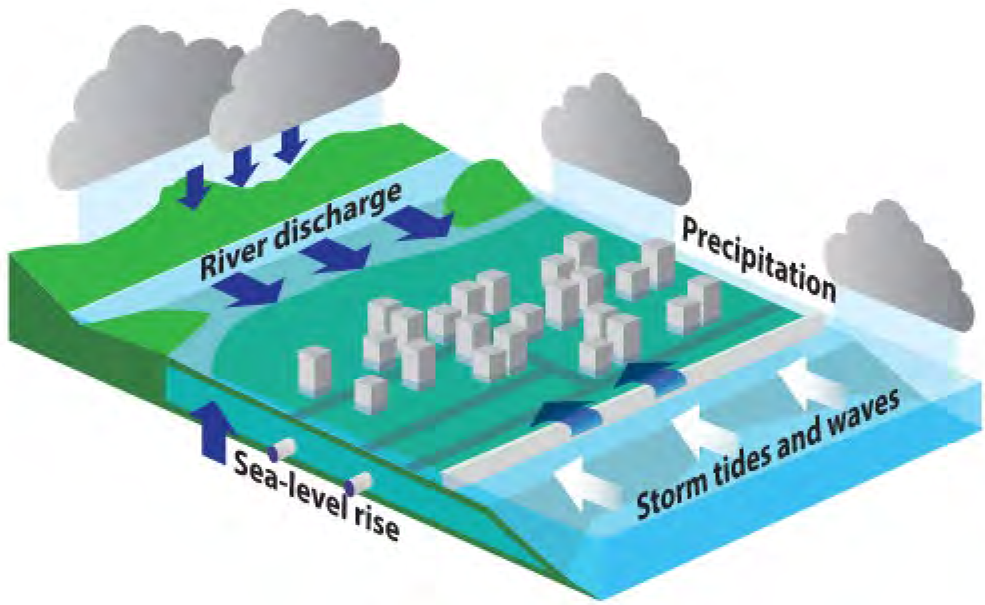


Figure 4-6. Types of Compound Flooding

To assess compound flooding in the U.S. Virgin Islands, an overlay of the Category 5 MOM modeled inundation extent and the NFWF flood-prone areas layer is provided in each planning reach section. The flood-prone areas layer is based on the FEMA 1-percent and 0.2% AEP flood zones as well as occasionally flooded soils (Dobson et al. 2020). While this overlay does not represent a detailed analysis of areas prone to compound flooding, it can highlight areas of the island that may be subject to this hazard. While the SACS does not have authority to address riverine flooding in detail, many stakeholders mentioned compound flooding as a concern in the U.S. Virgin Islands. Additional studies are needed to accurately assess compound flood hazards within the U.S. Virgin Islands.

4.1.4.6 Saltwater Intrusion

Sea level rise causes root zone salinization followed by saltwater inundation in tidal marshes and estuaries. Saltwater intrusion can affect environmental resources. As saltwater infiltrates the soil, plant growth of some species is halted, and they produce fewer seeds. The seeds that are produced have a harder time germinating and can result in a change in vegetation in an area as some species migrate or die off. Additionally, saltwater intrusion into freshwater aquifers can reduce freshwater water supplies and damage freshwater ecosystems. While saltwater intrusion was not considered in detail as part of the Tier 2 analysis, it is a hazard that will impact coastal and tidally influenced areas, especially under future sea level rise conditions.

4.1.5 Tier 2 Exposure

The Tier 1 exposure analysis incorporated regional datasets to determine who/what may be impacted. The Tier 2 analysis builds on the Tier 1 analysis at a refined scale through the incorporation of additional localized datasets and studies. The Tier 2 analysis evaluated three types of exposure data: (1) population and infrastructure, (2) environmental and cultural resources exposure, and (3) social vulnerability exposure.

4.1.5.1 Population and Infrastructure

Tier 2 infrastructure exposure builds on the Tier 1 population and infrastructure exposure analysis through inclusion of GIS point-based structure inventory data, developed by FEMA (FEMA n.d.), which includes the occupancy type, construction type, foundation type, and depreciated replacement value of the structure. This data is explored by planning reach in Sections 4.2 to 4.4 of this report.

Results of the 2010 Census reported a population of 106,405 in the U.S. Virgin Islands (U.S. Census Bureau 2011). The population has been declining, with projections showing continued decline over the coming decades. The current (August 2020) annual growth rate is -0.15 percent, with the annual growth rate estimated to be -0.95 percent by 2050 (World Population Review 2020). The largest city in the U.S. Virgin Islands is Charlotte Amalie on St. Thomas, which is the territory's capital (World Population Review 2020).

Estimates of the population subject to inundation were determined from the 2010 Census population of census estates that intersect with the Category 5 MOM inundation extent.

As of 2019, the U.S. Virgin Islands Code Title 12 § 910 requires coastal zone permits for any proposed development along the coastline. This law intends to both consolidate new development near existing development and discourage new development in flood-prone areas (Justia 2021).

4.1.5.2 Environmental and Cultural Resources

The U.S. Virgin Islands have a rich cultural history. The early residents of the islands included the Ciboney, Caribs, and Arawaks. The Spanish first visited the islands in 1493. Over the next few hundred years, England, Holland, Spain, and France all tried to gain control over the islands. In 1733, the Danish West Indian Company first joined the three islands together as one entity to create the Danish West Indies. After years under Danish control, the islands became U.S. territories in 1917 (VInow n.d.). Because of its location within the Caribbean, the U.S. Virgin Islands are subject to coastal hazards and many of its cultural resources are in hazardous locations. With sea level rise, these cultural resources will experience a heightened likelihood for flood inundation, potential damage from coastal erosion, and increased wave attack during major storms. Sections 4.2 to 4.4 highlight selected cultural resources in each planning reach and summarize their exposure to coastal hazards.

The U.S. Virgin Islands also contain numerous natural and environmentally sensitive areas. The NOAA Coastal Change Analysis Program (C-CAP) land cover classifications (NOAA 2015a.b.c.) (**Figure 4-7**), protected areas, mangrove habitats, and coral reef locations throughout the U.S. Virgin Islands were used to inform the environmental exposure analysis. More information on the Tier 2 environmental resources exposure analysis is available in the Environmental Technical Report.

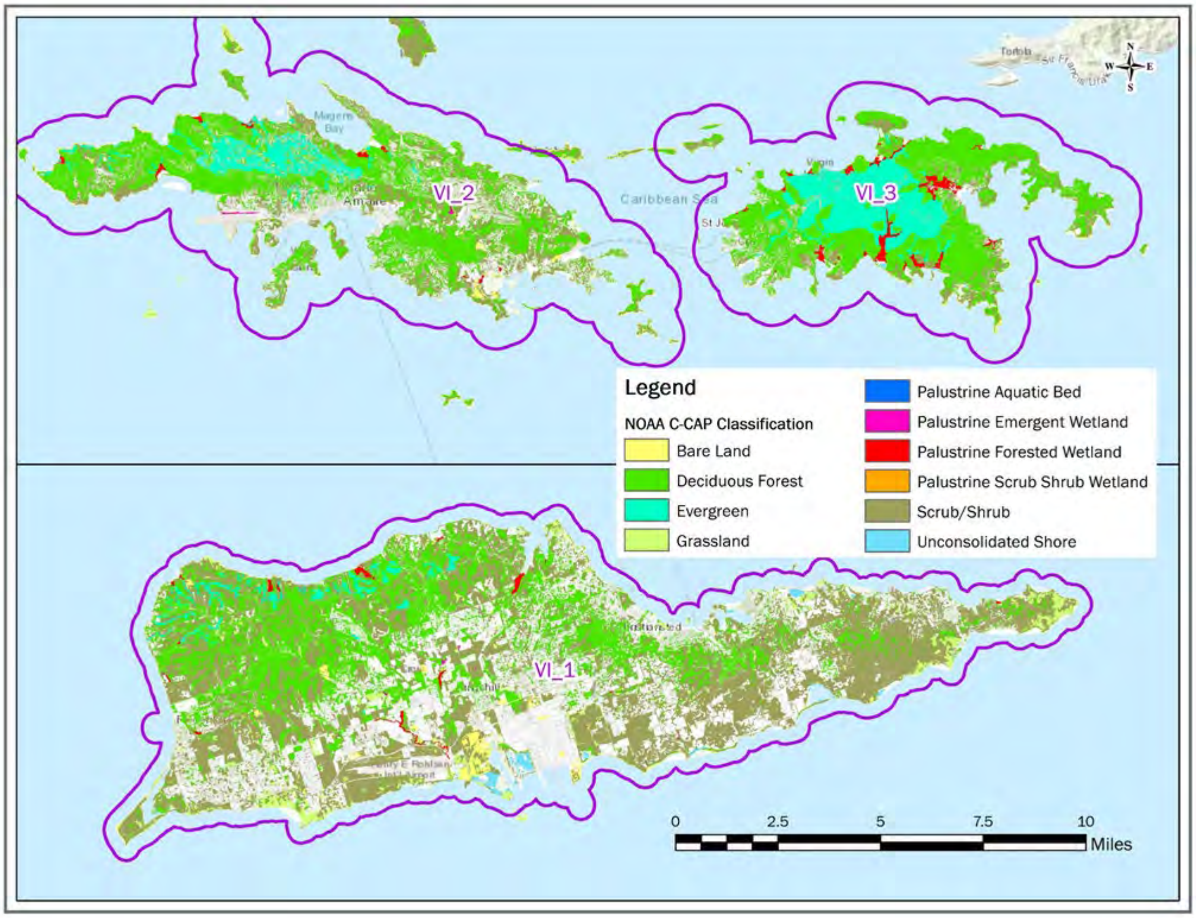


Figure 4-7: NOAA Coastal Change Analysis Program (C-CAP) Land Use Classifications (NOAA 2015a.b.c.)

4.1.5.3 Social Vulnerability

The Tier 1 Assessment for the U.S. Virgin Islands did not consider social vulnerability. Tier 2 uses 2010 Census data to examine social vulnerability by planning reach. Factors considered include percent of population under age 5, over age 65, with income below poverty level, without access to vehicle, and unemployment rate for each planning reach.

The U.S. Virgin Islands have a highly vulnerable population compared to the United States and Washington, DC, as highlighted in **Table 4-5** (Kaiser Family Foundation 2020). This vulnerability is exemplified by the percentage of the population living below the poverty level, which exceeds that of the United States by 8 percent, and an unemployment rate that is almost triple that of the United States. Based on the 2010 Census data (U.S. Census 2011), the majority (78 percent) of the territory's population identifies as Black or African American, while 16 percent identify as White. These factors are attributes of the U.S. Virgin Island's overall social vulnerability, which can influence the territory's resilience and ability to recover from coastal storms.

Table 4-5: Social Vulnerability Indicators for the U.S. Virgin Islands and the 50 States and Washington, DC based on the 2010 Census (Kaiser Family Foundation 2020)

Social Vulnerability Indicator	U.S. Virgin Islands	50 States and Washington, DC
Over age 65	18%	16%
Below poverty level	22%	14%
Unemployment rate	13%	5%
Median household income	$37,254	$57,617

NOAA and The Nature Conservancy (TNC) created a Social Sensitivity Index based on data from the 2010 Census to sensitivity to storm surge and climate change (Schill et al. 2014). The study assigned each census estate to a ranking of high, medium, or low based on the statistical distribution of the data. Data from this study is evaluated further in each planning reach. The study considered the following variables: total population, population under age 5, population over age 65, population living in group quarters, population living in institutional facilities, total households, total families with five or more children, grandparents living with their own grandchildren under age 18, total with disabilities, total housing units, no vehicle available, without telephone service available, and without internet service.

The Tier 2 analysis also considered social vulnerability data from the NFWF Coastal Resilience Evaluation and Siting Tool (Dobson et al. 2020) based on 2010 Census data (U.S. Census 2011). This dataset used a combination of percent low-income and percent minority by census estate to estimate social vulnerability.

Each planning reach section will provide in-depth detail about the social vulnerabilities unique to their area.

4.1.6 Tier 2 Vulnerability

Tier 2 Vulnerability is defined as the susceptibility to harm from a coastal event as well as the ability to recover and rebound after a coastal event. The Tier 2 analysis provides a more refined assessment of resource vulnerability than Tier 1.

The FAST model software used as part of the Tier 2 analysis considers infrastructure vulnerability using depth-damage functions to represent the performance of different types of infrastructure to flood hazards and to estimate the financial impact of flooding.

The Tier 2 Environmental Analysis used NOAA Coastal Change Analysis Program (C-CAP) land cover classifications to assess the vulnerability of natural resources in the U.S. Virgin Islands. Vulnerable natural resources areas are considered to be those natural areas or features that may be adversely affected by exposure to sea level rise or storm surge to the point of loss of habitat for endangered, threatened, and other important species, or of important protected/managed lands. A detailed summary of the natural resource area identification and environmental vulnerability scoring process is outlined in the Environmental Technical Report (USACE 2021b).

Exposed cultural resources were qualitatively assessed for vulnerability, with a focus on storm surge inundation, erosion, and wave attack hazards for each reach. Historic structures and archaeological sites located along coasts, bays, rivers, and in low-lying areas are potentially vulnerable to impacts from storm surge inundation, erosion, and wave attack. Storm surge inundation along the coast will flood historic properties and damage buildings. Damage may include structural damage and destruction of historic materials (e.g., furniture, textiles, archives). The aftermath of a storm can pose long-term issues, such as developing mold, mildew, and other potentially toxic residues. Erosion and wave attack pose threats to historic properties and terrestrial and submerged archaeological sites. Wave attack can cause substantial structural damage to historic properties. Inundation and erosion can eliminate surface evidence of archaeological sites, wear away site layers, and displace materials from various cultural layers, making recovery and interpretation challenging, if not impossible. Erosion threats to archaeological sites can extend along rivers where increased volume and energy can degrade site deposits. Strong currents cause hydrographic changes that can displace submerged cultural resources, including historic wrecks, as well as obscure or damage these resources because of storm debris. Currents and wind can uproot trees and other vegetation, which can disturb and destruct historic properties and archaeological sites.

4.1.7 Reporting Results: Planning Reaches and U.S. Census Bureau Geographic Types

In addition to planning peaches, several results from Tier 1 and Tier 2 analyses are reported by geographic types defined by the U.S. Census Bureau (**Figure 4-8**). The following description of these areas is excerpted from the University of Pittsburgh's research guide (Pitt n.d.). In the U.S. Virgin Islands, each of the three main islands is the equivalent of a county.

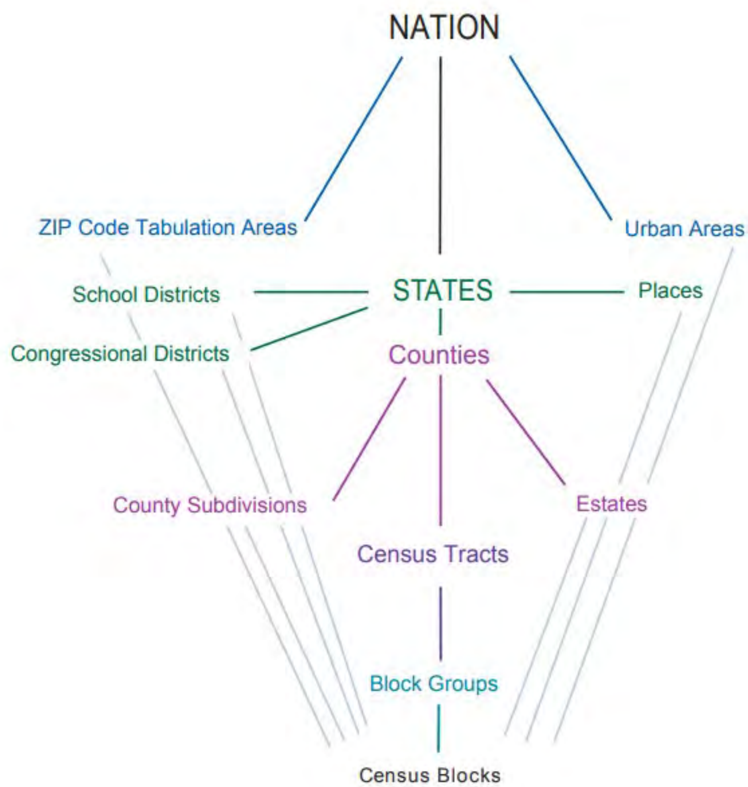


Figure 4-8: Relationships Among U.S. Census Bureau Geographic Entities in Island Areas (U.S. Census 2017)

- **Counties** and equivalent areas are the primary divisions of most of the 50 United States, Puerto Rico, and the U.S. Virgin Islands. They include counties in 48 states, parishes in Louisiana, boroughs and census areas in Alaska, municipalities in Puerto Rico, independent cities in Maryland, Missouri, Nevada, and Virginia, as well as other entities in the island areas.
- **Census places** are concentrations of population, such as cities that have legally prescribed boundaries, powers, and functions.
- **Census tracts** generally contain between 1,000 and 8,000 people, with an optimum size of 4,000 people. Census tract boundaries are delineated with the intention of being stable over many decades; therefore, they generally follow relatively permanent visible features. However, they may follow governmental unit boundaries and other invisible features in some instances. The boundary of a state or county is always a census tract boundary.

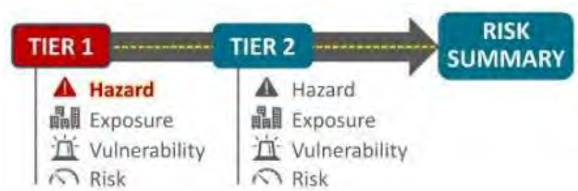
- **Census blocks** are statistical areas bounded by visible features, such as streets, roads, streams, and railroad tracks, and by nonvisible boundaries, such as selected property lines and city, township, school district, and county limits, and short line-of-sight extensions of streets and roads (Pitt n.d.).
- **Census estates** are specific to the U.S. Virgin Islands and are based on the boundaries of former plantations. They are smaller than county subdivisions and do not necessarily align with other census boundaries (U.S. Census 2012).

4.2 Planning Reach VI_1 (St. Croix) Risk Assessment

The U.S. Virgin Islands' Planning Reach 1 (VI_1) contains the island of St. Croix, as shown in **Figure 3-2**. St. Croix is the southernmost island of the U.S. Virgin Islands. It includes the coastal, historic districts of Christiansted and Frederiksted. Planning Reach VI_1 features sandy beaches, rolling hills and mountains, as well as historic sugar plantations, archeological sites, and the Salt River Bay National Historical Park and Ecological Preserve. The following sections walk through the Risk Assessment for Planning Reach VI_1. Various datasets are also available via the SACS Geoportal.

4.2.1 Planning Reach VI_1 (St. Croix) Tier 1

4.2.1.1 Planning Reach VI_1 Tier 1 Hazard



A description of the Tier 1 hazards is included in Section 4.1.1 and in the Main Report. **Figure 4-9** displays both existing and future flood hazards for St. Croix, U.S. Virgin Islands (Planning Reach VI_1). The 1-percent AEP water level is identified as a hazard to the back bay areas around the island. The probability of flooding increases to a 10-percent AEP event in the same places under the future scenario with 3 feet of sea level rise.

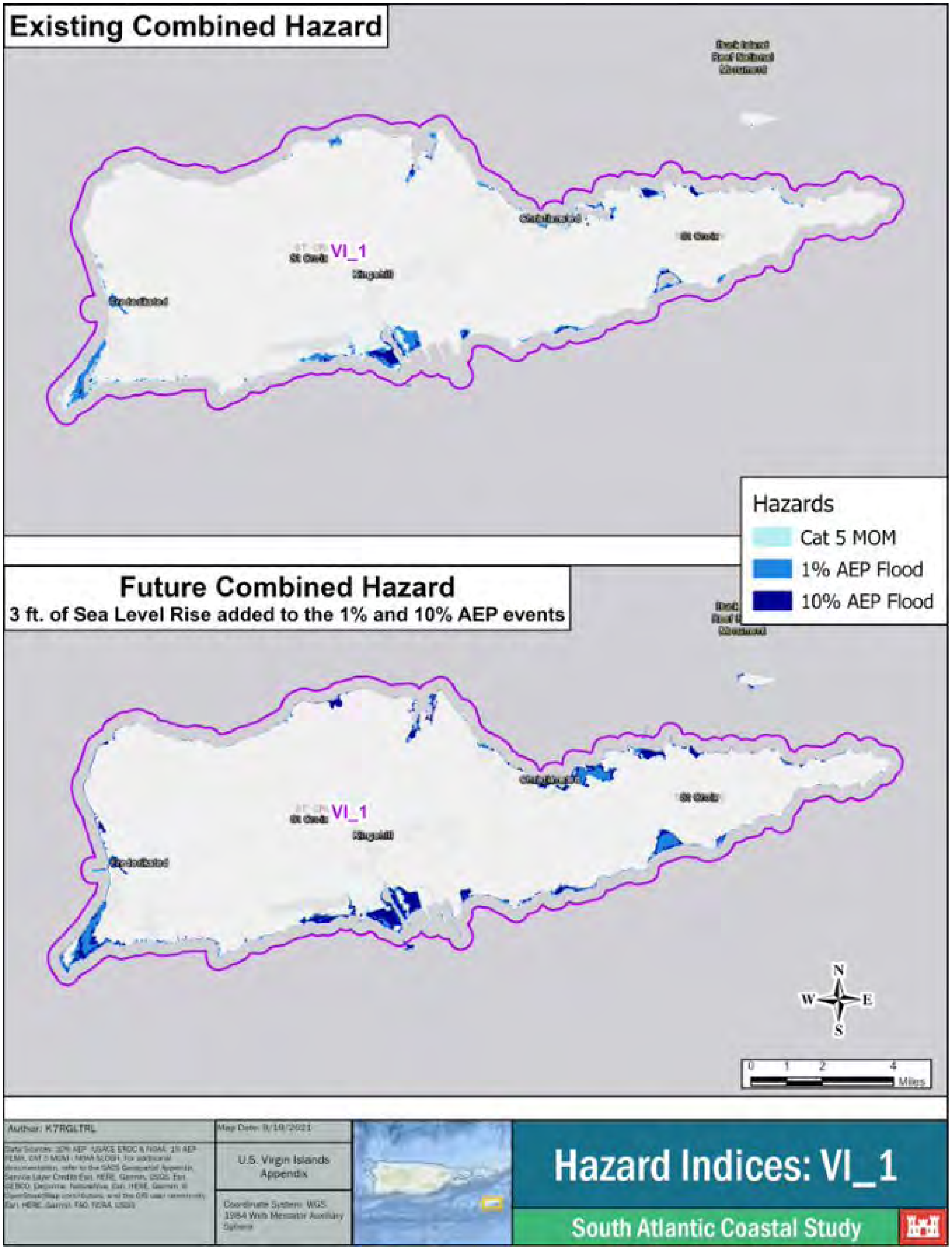
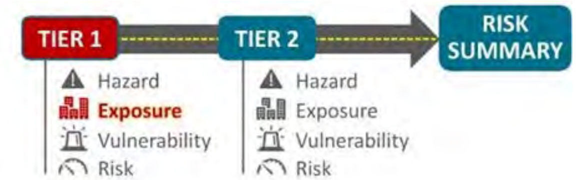


Figure 4-9: Existing and Future Flood Hazard for Planning Reach VI_1 from the 10-Percent Annual Exceedance Probability flood, the 1-Percent Annual Exceedance Probability Flood, and the Category 5 Maximum of Maximum Water Levels

4.2.1.2 Planning Reach VI_1 Tier 1 Exposure



Planning Reach VI_1 encompasses the island of St. Croix and includes the subdistricts of Anna's Hope Village, Christiansted, East End, Frederiksted, Northcentral, Northwest, Sion Farm, Southcentral, and Southwest. **Figure 4-10** shows the three individual Tier 1 exposure indices, as well as the CEI, composed of 65-percent population and infrastructure exposure and 35-percent environmental, cultural, and habitat exposure. Social vulnerability exposure data was not available for this planning reach. Areas colored red and amber indicate higher densities of populations, infrastructure, environmental and cultural resources, and habitat.

Population and Infrastructure

Based on the population and infrastructure exposure analysis, the town of Christiansted (on the north side of St. Croix) was identified as an area with a large population and critical infrastructure. The city of Frederiksted (on the far west side of the island) was identified as medium exposure owing to population and infrastructure. Additional areas to the north of Henry E. Rohlsen International Airport and west of the airport along Long Point Bay show medium population and infrastructure exposure.

Environmental and Cultural Resources

As shown in **Figure 4-10**, results of this analysis show that this planning reach contains several areas of high (orange and red) environmental and cultural resources exposure, including Coakley Bay, Chenay Bay, Beauregard Bay, a small area along the coast in Christiansted, Salt River Bay, Frederiksted, Sandy Point National Wildlife Refuge, Long Point Bay, Krause Point, and Great Pond Bay. These areas include important environmental and cultural resources that would be subject to coastal hazards. Predominant coastal resources within Planning Reach VI_1 include mangroves, multiple species of coral and sea grasses, as well as some riverine wetlands. St. Croix contains critical habitat for several species, including the St. Croix ground lizard (*Ameiva polops*), the leatherback sea turtle (*Dermochelys coriacea*), tropical lily thorn *(Catesbaea melanocarpa)* and Egger's century plant (a type of agave). Green Cay National Wildlife Refuge and Sandy Point National Wildlife Refuge are also located on St. Croix, along with several TNC preserves, and 13 Coastal Barrier Resources System areas. Inundation hazards are expected to increase with future sea level rise in areas where these resources exist.

This planning reach has many cultural resources located on the island of St. Croix, including the Frederiksted and Christiansted Historic Districts, historic properties listed on the National Register of Historic Places (NRHP), and archaeological sites. The possible Columbus landing site and large archaeological sites at Salt River, the colonial towns of Christiansted and Frederiksted, and coastal archaeological sites across the island are located within threatened coastal zones. Sea level rise will increase the hazards to the districts, structures, and archaeological sites located near the coast.

Social Vulnerability

The Tier 1 analysis for the U.S. Virgin Islands did not include social vulnerability data. The Tier 1 analysis used the Center for Disease Control's (CDC) 2016 Social Vulnerability Index dataset, which does not exist for the U.S. Virgin Islands; therefore, it could not be assessed. Other social vulnerability data will be included for the U.S. Virgin Islands in the Tier 2 analysis.

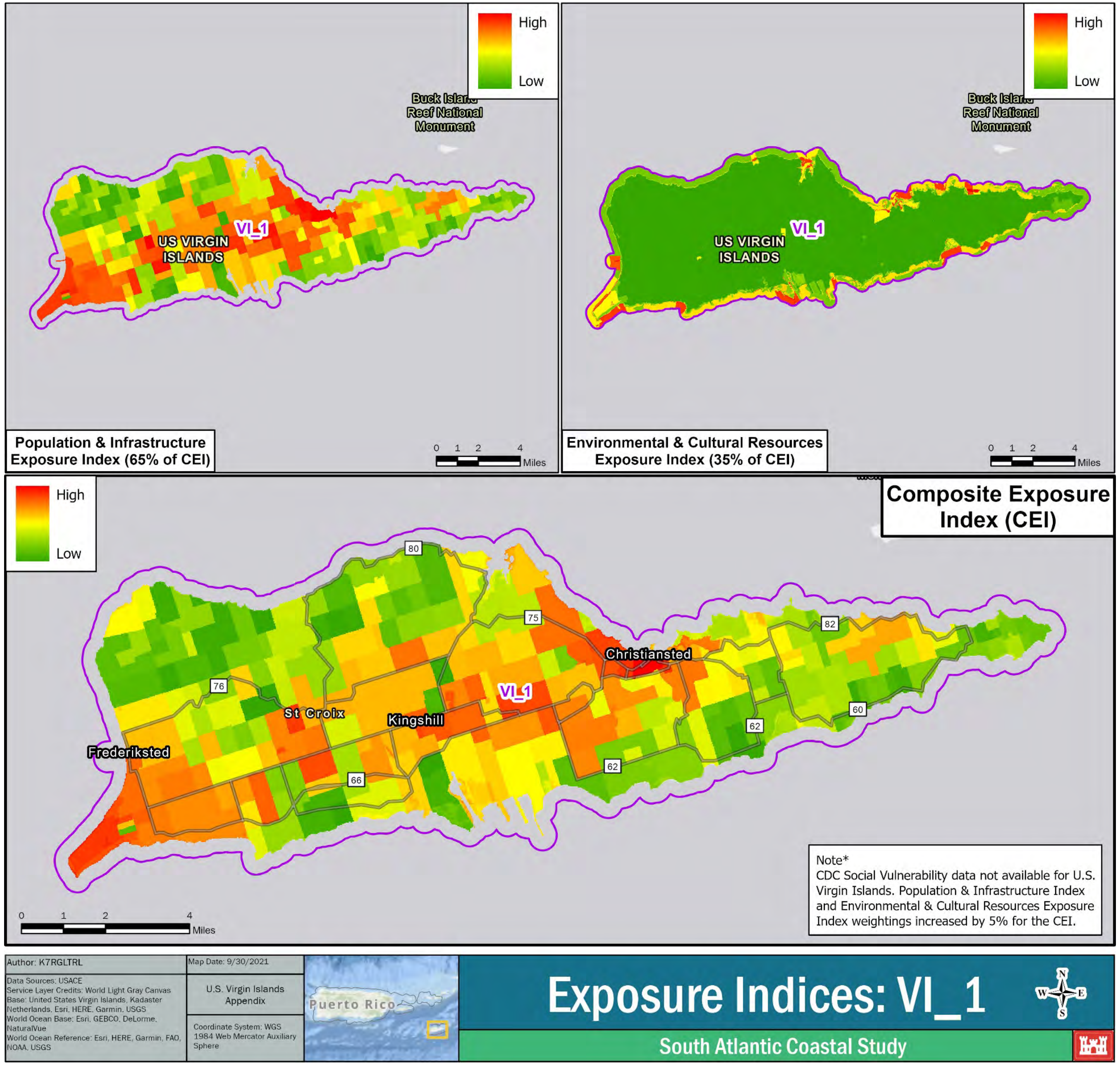
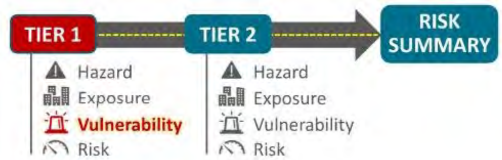


Figure 4-10: Exposure Indices for Planning Reach VI_1

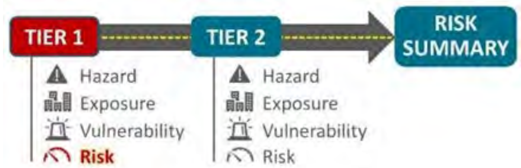
This page intentionally left blank.

4.2.1.3 Planning Reach VI_1 Tier 1 Vulnerability



As stated in Section 4.1.3 Tier 1 Vulnerability, if a resource is subject to a hazard it is considered vulnerable in the Tier 1 analysis.

4.2.1.4 Planning Reach VI_1 Tier 1 High-Risk Locations



The CEI and coastal flood inundation hazards were used to identify potential areas at risk. The Framework defines Tier 1 risk as a function of exposure and probability of hazard occurrence. The Geospatial Appendix describes how each of the inundation hazards (Category 5 MOM, 1-percent AEP flood, 10-percent AEP flood) and sea level rise were combined with the CEI to generate potential risk data presented in the Tier 1 Risk Assessment.

The Tier 1 Risk Assessment data are published as map services viewable in the SACS Risk Assessment Viewer.
https://sacs.maps.arcgis.com/apps/MapSeries/index.html?appid=c54beb5072a04632958f2373eb1151cf

Figure 4-11 displays both current and future potential risk for Planning Reach VI_1.

Most of the Planning Reach VI_1 coastline is classified as potential low risk or potential medium risk under existing conditions. Few areas are classified as potential medium-high risk or potential high risk, such as Altona Lagoon, Southgate Pond, Krause Point, and sections of Sandy Point National Wildlife Refuge. Under future conditions with sea level rise, many of these areas show increased potential risk. Because of sea level rise, areas around Christiansted show a significant change from potential low risk to potential high risk.

Tier 1 high-risk locations are those where potential medium-high (amber) and high (red) composite risk exists. U.S. Census Bureau census places were used to define the boundaries of high-risk locations. **Figure 4-11** displays both current and future potential risk for St. Croix (Planning Reach VI_1).

U.S. Census Bureau census places were used to define the boundaries of high-risk locations in the U.S. Virgin Islands. For a census place to be considered high risk, medium-high and/or high composite risk must cover at least 5 acres (0.02 square kilometer) and 0.5 percent of the total area.

Under existing conditions, no census places meet the criteria for a Tier 1 high-risk location. With sea level rise, Christiansted becomes high risk with 28.5 acres covered by medium-high and high risk, approximately nine percent of the total area of the census place.

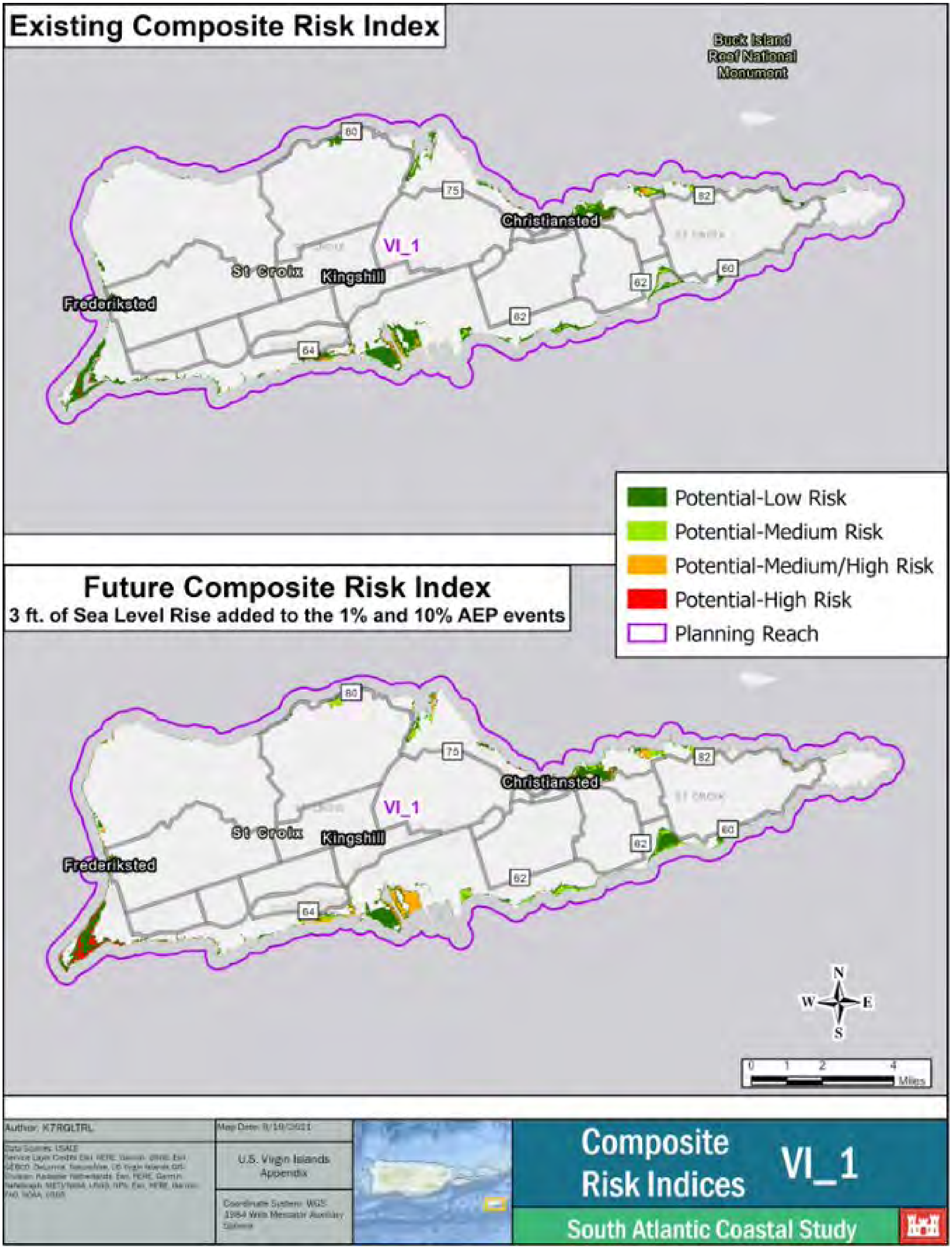


Figure 4-11: Existing Composite Risk Index and Future Composite Risk Index for Planning Reach VI_1

4.2.2 Planning Reach VI_1 (St. Croix) Tier 2

Tier 2 included additional and more localized hazard, vulnerability, and exposure information to refine the Tier 1 Risk Assessment.

4.2.2.1 Planning Reach VI_1 Tier 2 Hazard

This section highlights details of the Tier 2 hazards, or what may cause harm, for Planning Reach VI_1. An overview of each hazard is presented in Section 4.1.4 .

The Tier 2 hazards for Planning Reach VI_1 include the following:

Inundation

In Planning Reach VI_1, the extent of the inundation is confined by the mountainous terrain that abuts the coastline. Inundation depths from the Category 5 MOM hurricane (based on NOAA's SLOSH model [Jelesnianski et al. 1992]) are shown in **Figure 4-12.** The CHS stillwater data also provides information on inundation hazards for both existing and future conditions (USACE 2020b), where future conditions include 2.33 feet (0.71 meters) of sea level rise based on the USACE Intermediate Scenario and 6.95 feet of sea level rise based on the USACE High Scenario by 2120. **Table 4-5** shows the maximum inundation depth for the range of AEP storms for the planning reach under existing conditions and with 2.33 feet (0.71 meters) of sea level rise.

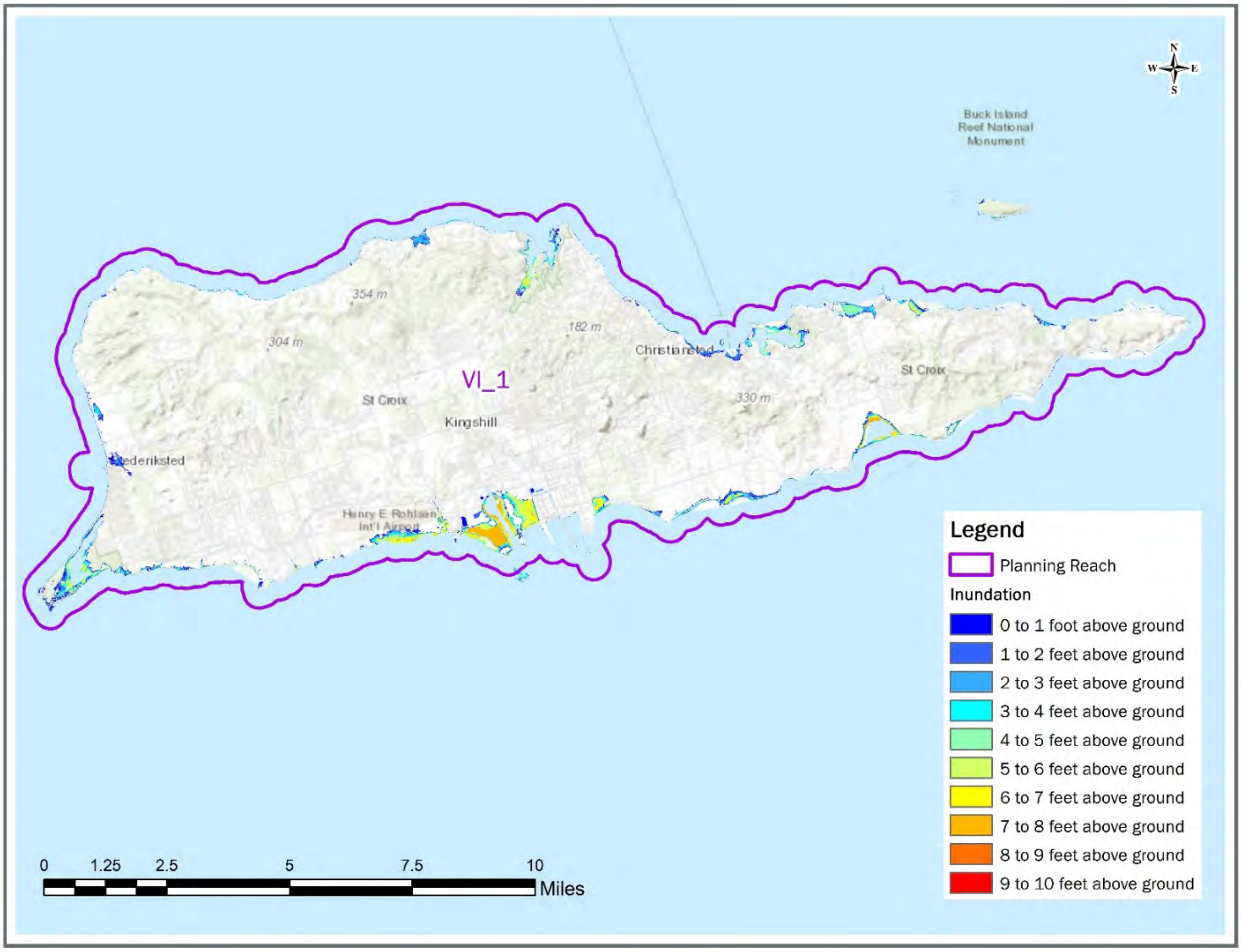


Figure 4-12: Inundation Depth from a Category 5 Maximum of Maximum Storm in Feet Above Ground Based on National Oceanic and Atmospheric Administration Sea, Lake, and Overland Surges from Hurricanes model (Jelesnianski et al. 1992) for Planning Reach VI_1

Table 4-5: Coastal Hazards System Maximum Flood Depths for Planning Reach VI_1 (USACE 2020b)

	10% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP
Existing Conditions	7.9 feet (2.4 meters)	8.5 feet (2.6 meters)	9.4 feet (2.9 meters)	10.0 feet (3.0 meters)	11.3 feet (3.4 meters)
Future Conditions	10.2 feet (3.1 meters)	10.7 feet (3.1 meters)	11.6 feet (3.5 meters)	12.2 feet (3.7 meters)	13.7 feet (4.2 meters)

Wave attack

Wave attack is prominent in St. Croix with the highest wave heights on the western and northern coasts. **Figure 4-13** displays the modeled wave heights for a 1-percent AEP event from the CHS (USACE 2020b). CHS modeling demonstrates offshore wave heights of over 26 feet (8 meters) during the 1-percent AEP event in the northwest corner of the island. Closer to the nearshore zone, wave heights are modeled to drop to 13 to 20 feet (4 to 6 meters) during the 1-percent AEP event. Wave heights are expected to increase around the island with sea level rise. By 2120, the northern coastline may experience wave height increases of over 1.6 feet (0.5 meters) based on the USACE Intermediate Scenario (**Figure 4-14**) and over 3.28 feet (1 meter) based on the USACE High Scenario.

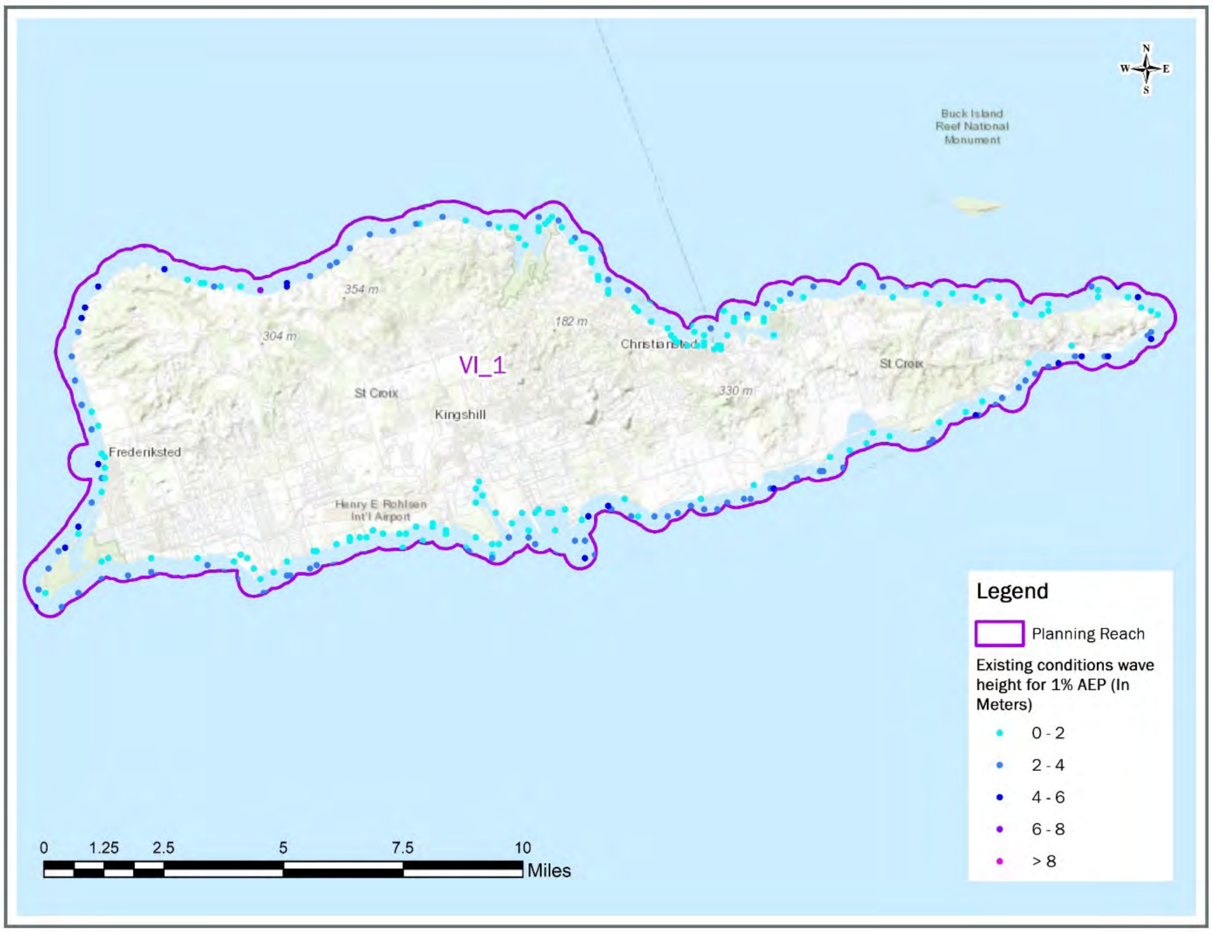


Figure 4-13: Modeled Wave Heights for the 1-percent Annual Exceedance Probability Event for Planning Reach VI_1 (USACE 2020b)

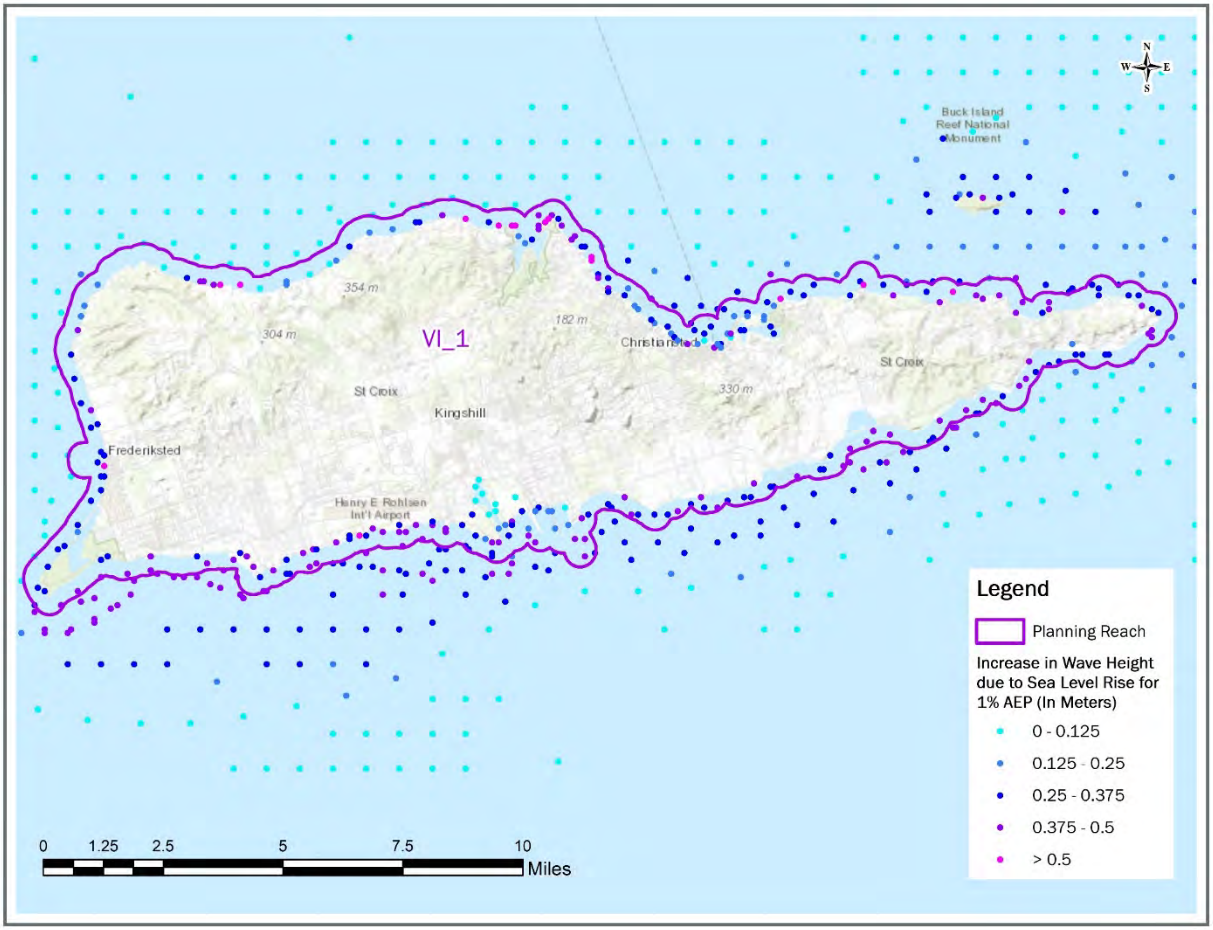


Figure 4-14: Increase in Modeled Wave Heights (Meters) for the 1-percent Annual Exceedance Probability Event for Planning Reach VI_1 with 2.33 Feet (0.71 Meter) of Sea Level Rise (USACE 2020b)

Coastal erosion

Coastal erosion is evaluated throughout Planning Reach VI_1. Most of the planning reach is stable or experiencing long-term shoreline erosion rates of less than 4.9 feet per year (1.5 meters per year). Hot spots, or areas of higher erosion, are located near Limetree Bay Terminals and along the western coast. **Figure 4-15** illustrates long-term shoreline change with erosion represented by negative shoreline change values.

Figure 4-15: Long-Term Shoreline Change for Planning Reach VI_1 (1984 to 2016) (Luijendijk et al. 2018)

Other hazards associated with coastal storms that may impact this Planning Reach but are not considered in detail as part of the Tier 2 analysis include:

Wind

Wind can cause devastation across the U.S. Virgin Islands during coastal events, such as direct wind damage to buildings, uprooting of trees that take down power lines, or the outgrowth of wind waves on top of storm surge.

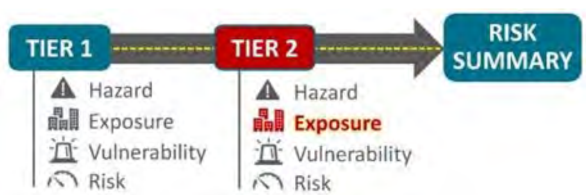
Compound flooding

Compound flooding is a hazard in Planning Reach VI_1, especially in low-lying areas along the coast and near the island's river mouths, such as Salt River Bay. **Figure 4-16** shows an overlay of the NFWF flood-prone areas layer (Dobson et al. 2020) with the Category 5 MOM modeled inundation extent. While this is not an analysis of compound flooding, it highlights areas that may experience flooding from riverine or coastal sources. Compound flooding damages may also increase in the future as sea levels rise. Additional studies are needed to better characterize the joint probability of riverine and coastal flooding.

Figure 4-16: Flood-Prone Areas and Category 5 Modeled Inundation for Planning Reach VI_1 (Dobson et al. 2020)

4.2.2.2 Planning Reach VI_1 Tier 2 Exposure

This section highlights details of the Tier 2 exposure—who/what may be impacted—for Planning Reach VI_1. An overview of each exposure element is presented in Section 4.1.5 .



Population and Infrastructure

The Tier 2 infrastructure exposure includes the estimate of potential losses (or the estimated exposure value) should infrastructure be flooded. In the Overview, Section 4.1.5 , background information is provided on Tier 2 exposure data sources. **Figure 4-17** displays FEMA structural exposure value data (FEMA n.d.) that is within the footprint of the Category 5 MOM event floodplain. Single-family homes make up the primary source of building exposure within the Category 5 MOM flood extents within Planning Reach VI_1.

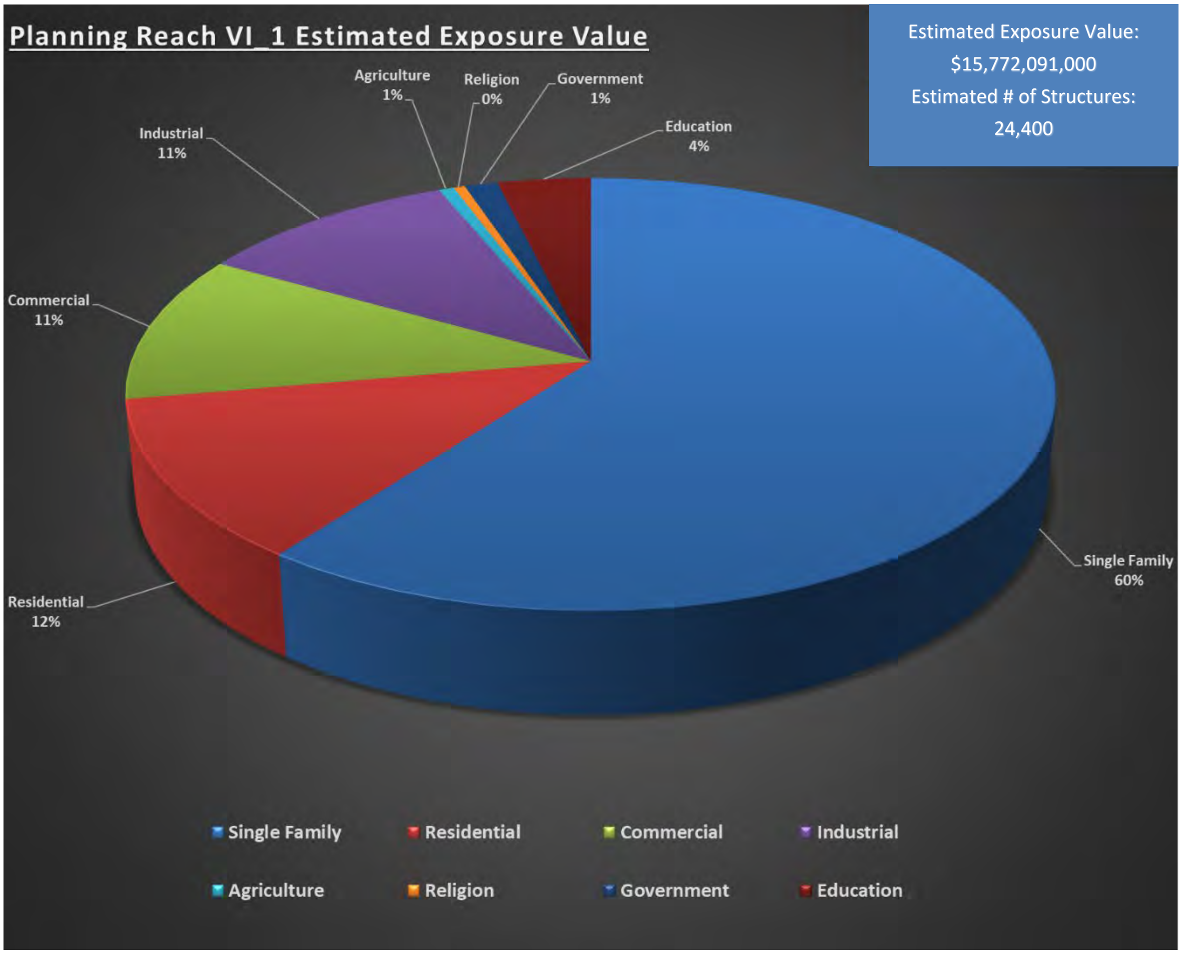


Figure 4-17: Planning Reach VI_1 Estimated Infrastructure Exposure (FEMA n.d.)

The total population of St. Croix (Planning Reach VI_1) is approximately 50,600 residents (U.S. Census 2011). Of that population, approximately 18,100 people live within census estates that are subject to flooding from the Category 5 MOM inundation extent (U.S. Census 2011). The population by estate and the Category 5 MOM modeled flooding extents are displayed in **Figure 4-18**. The total number of people on St. Croix often exceeds the resident population because of the significant tourism industry. St. Croix receives 163,100 air visitors and 79,600 cruise passengers annually, based on 2018 data (U.S. Virgin Islands Bureau of Economic Research 2018).

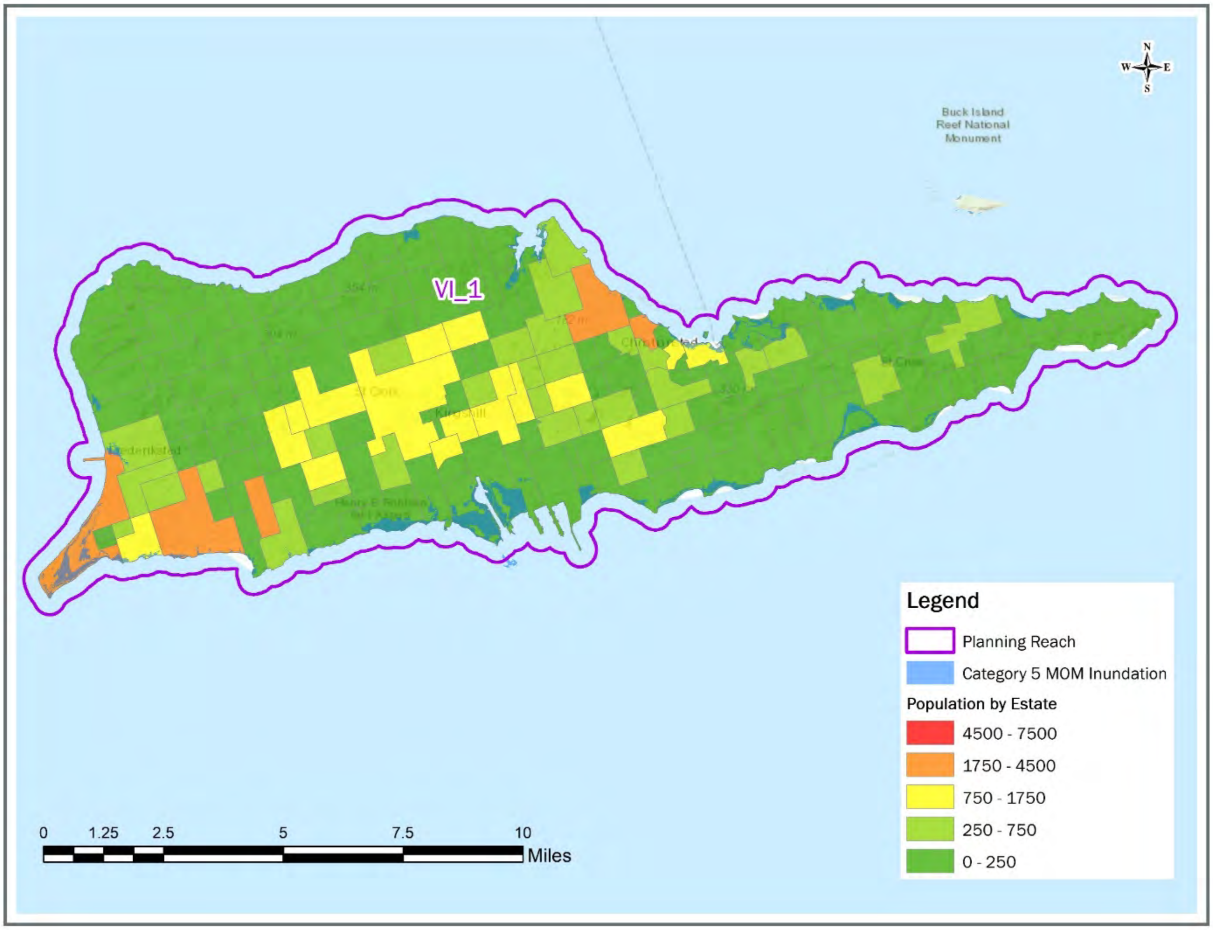


Figure 4-18: Population (U.S. Census 2011) of St. Croix (Planning Reach VI_1) and Category 5 Maximum of Maximum Storm Modeled Inundation Extent

Part of the Henry E. Rohlsen International Airport, a critical infrastructure element in Planning Reach VI_1, is subject to inundation from the Category 5 MOM under existing conditions. With 2.33 feet (0.7 meters) of sea level rise, additional portions of the airport will become exposed to the more frequent 10-percent AEP storm.

Environmental and Cultural Resources

The shoreline for Planning Reach VI_1 is 98 miles long with approximately 38-percent sandy beaches, 28-percent exposed rocky shores, and 20-percent mangroves. Mangrove forests make up nearly 20 miles of linear shoreline within St. Croix (Planning Reach VI_1). The largest mangrove habitats are located near Krause Lagoon, Great Pond, Altona Lagoon, and Salt River Bay. Based on the NOAA C-CAP classifications, Planning Reach VI_1 is predominantly scrub/shrub and deciduous forest, with some evergreen forest in the north and isolated areas of palustrine forested wetland across the island. Planning Reach VI_1 contains the Sandy Point National Wildlife Refuge, designated by U.S. Fish and Wildlife Service (USFWS) as critical habitat for the leatherback sea turtle. Several areas along the coast are designated by USFWS as critical habitat for the *Agave eggersiana*, the St. Croix ground lizard, and the *Catesbaea melanocarpa*. Nearshore waters are NOAA-designated critical habitat for staghorn (*Acropora cervicornis)* and elkhorn (*Acropora palmata)* corals. Approximately 13,444 acres of coral reefs surround the coast of Planning Reach VI_1 with the largest habitats along the southern and eastern shorelines.

There are approximately 30 NRHP-listed cultural resources within Planning Reach VI_1. Many additional unidentified or unlisted resources are likely also present within the reach. This assessment highlights a few resources identified within the NRHP or through literature review that are potentially exposed to Tier 2 hazards including Sandy Point National Wildlife Refuge, Salt River Bay National Historical Park and Ecological Preserve, Christiansted National Historic District, and Frederiksted Historic District.

Sandy Point National Wildlife Refuge is in the southwestern corner of St. Croix. The refuge preserves vital habitat for endangered and threatened species (USFWS 2017). The refuge also comprises a pre-Columbian former settlement or village. The area is of medium-high exposure in the Tier 1 Environmental and Cultural Resources Exposure Index. Coastal storms, storm surge events, hurricanes, and heavy precipitation are eroding the Sandy Point National Wildlife Refuge shoreline (O'Brian 2015). Historical shoreline change data indicate that erosion continues to occur in this refuge. CHS data indicate a rise of sea level causing increased wave heights under existing as well as future conditions.

Salt River Bay National Historical Park is in the north-central region of St. Croix. The 1,015-acre park contains prehistoric and colonial era ruins and archeological sites (NPS 2018b). The preserve also protects the Salt River watershed, mangrove forests, estuaries, and other marine environments and offshore coral reef ecosystems (Kendall et al. 2005). The park is located within an area ranked as high exposure in the Tier 1 Environmental and Cultural Resources Exposure Index. Shoreline change data (Luijendijk et al. 2018) show shoreline accretion; however according to CHS data, sea level rise is predicted to cause an increase in wave heights.

Christiansted National Historic District was developed on a former French settlement. The district includes Ft. Christiansvaern, the Old Danish Customs House, and many historic buildings along the waterfront (NPS 2020b, 2020e). The district is ranked as high exposure in the Tier 1 Environmental and Cultural Resources Exposure Index and is subject to inundation from the 1-percent AEP storm event. While the district's shoreline in this area is protected by man-made structures, which are (presumably) limiting the rate of coastal erosion, the waterfront is exposed to wave attack, which will worsen with sea level rise.

Frederiksted Historic District and Ft. Frederik are on the western side of St. Croix. The town and fort were built in the mid-1700's and were the focal point of several significant historic events. The district is in an area ranked as high exposure in the Tier 1 Environmental and Cultural Resources Exposure Index. The coastal portion of the district is protected by a man-made structure but is still exposed to future potential flooding, wave attack, and shoreline erosion.

Figure 4-19 displays the cultural resources within Planning Reach VI_1. Additional information is included within the SACS Tier 2 Cultural Resources Appendix.

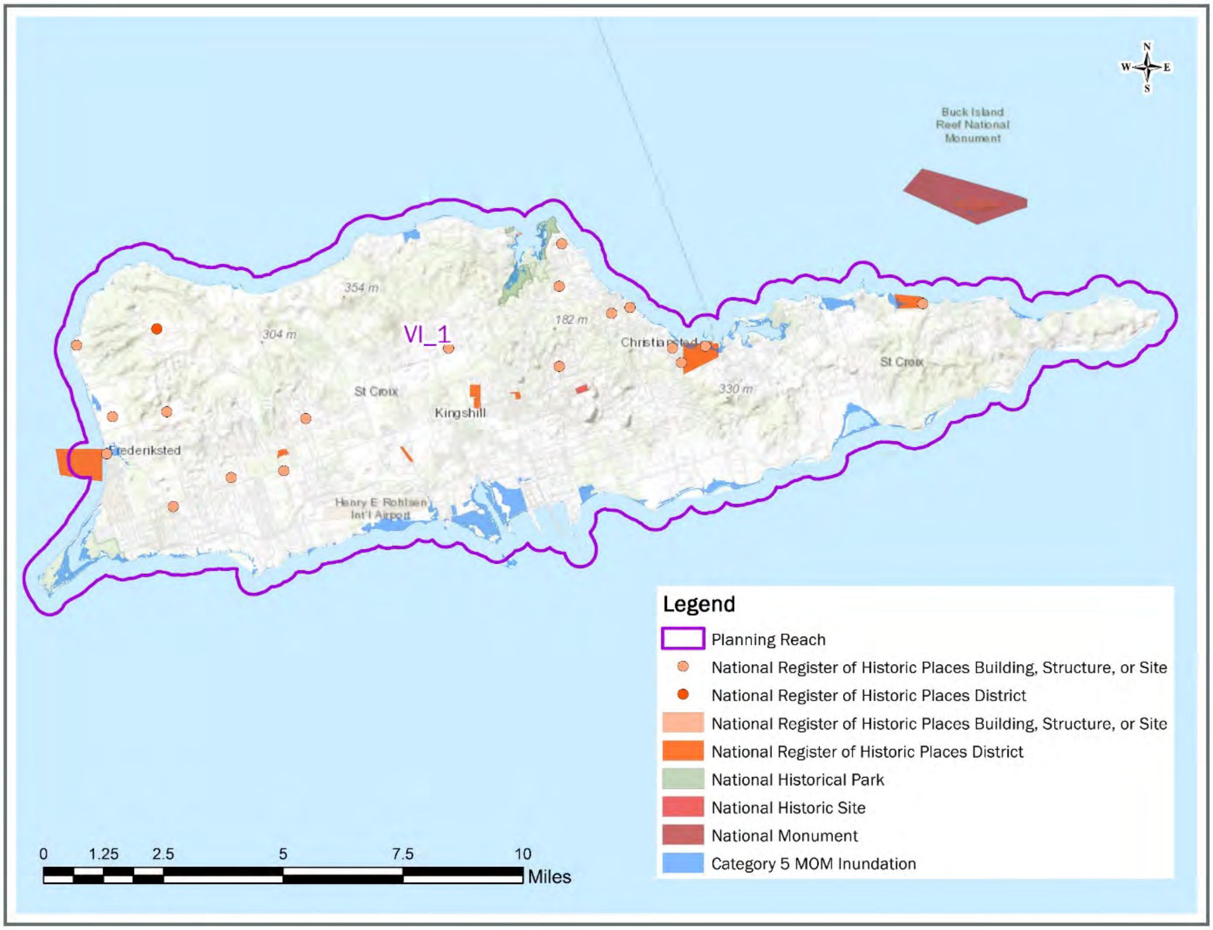


Figure 4-19: Cultural Resources in Planning Reach VI_1 (NPS 2014)

Social Vulnerability

As part of the Tier 2 analysis, 2010 Census data was used to examine social vulnerability for Planning Reach VI_1. **Table 4-6** displays factors that can contribute to social vulnerability, including percent of population under age 5, over age 65, with income below poverty level, without access to vehicle, and unemployment rate for the planning reach.

Table 4-6: 2010 Census Social Vulnerability Factors for Planning Reach VI_1 (U.S. Census 2011)

Planning Reach	Under Age 5	Over Age 65	Income Below Poverty Level	Occupied Households Without a Vehicle	Unemployment Rate
VI_1	7.5%	14%	25.8%	17.8%	6.4%

Figure 4-20 displays the NOAA and TNC Social Sensitivity Index based on data from the 2010 Census (Schill et al. 2014). Estate Two Brothers, Estate Whim, and Estate Fangselet have the highest social sensitivity within the planning reach, with index scores above 36.165700.

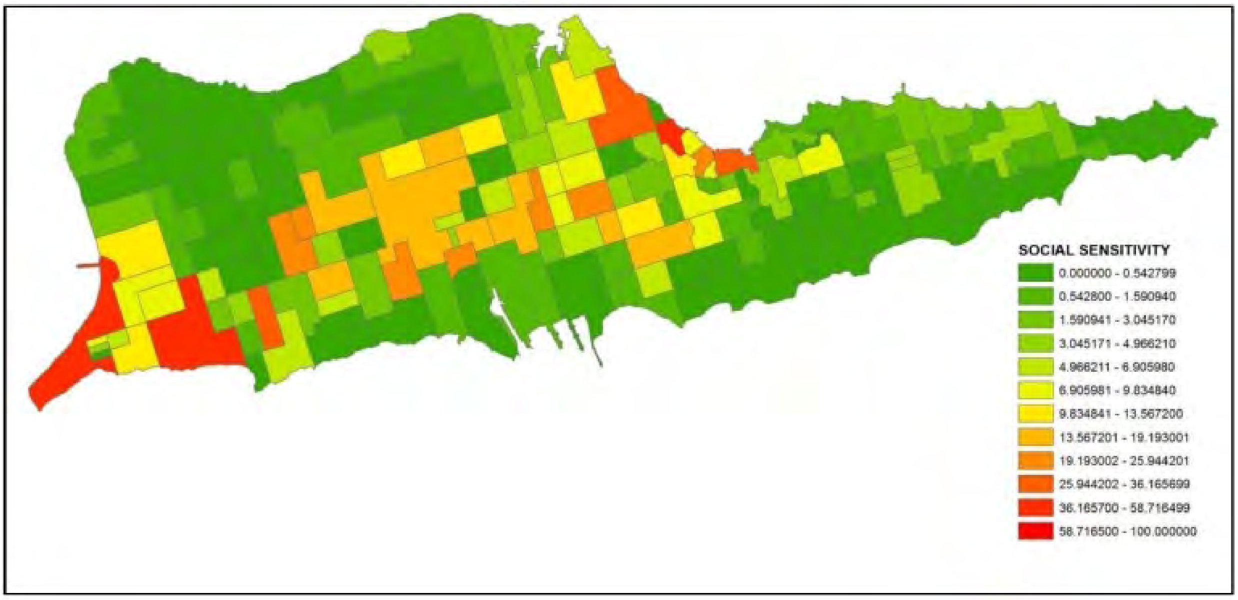


Figure 4-20: National Oceanic and Atmospheric Administration and The Nature Conservancy Social Sensitivity Index for Planning Reach VI_1 (Schill et al. 2014)

Figure 4-21 displays social vulnerability data from the Coastal Resilience Evaluation and Siting Tool (CREST) with the Category 5 MOM inundation extent to evaluate socially vulnerable populations subject to inundation (Dobson et al. 2020).

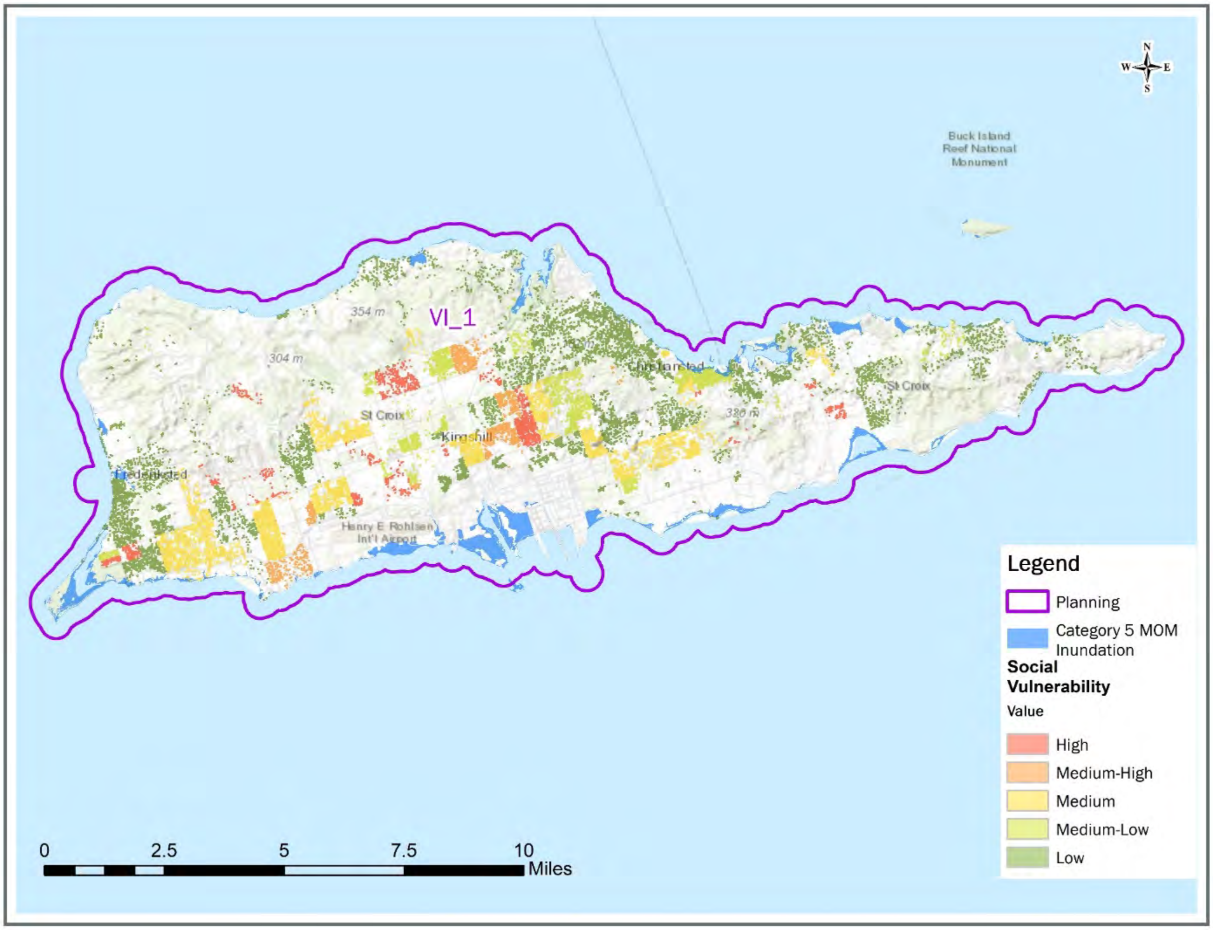


Figure 4-21: Coastal Resilience Evaluation and Siting Tool Socially Vulnerable Populations Subject to Inundation from Category 5 Maximum of Maximum for Planning Reach VI_1 (Dobson et al. 2020)

4.2.2.3 Planning Reach VI_1 Tier 2 Vulnerability

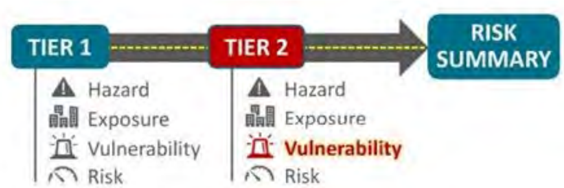


Figure 4-22 shows the environmental vulnerability in areas impacted by inundation from the Category 5 MOM event. Areas around Sandy Point National Wildlife Refuge, Krause Lagoon, Great Pond, and Altona Lagoon are shown as the most vulnerable environmentally sensitive locations, particularly the unconsolidated shores and deciduous forests. Additional information on the methodology and findings of the Tier 2 environmental resources analysis is included within the Environmental Technical Report (USACE 2021b).

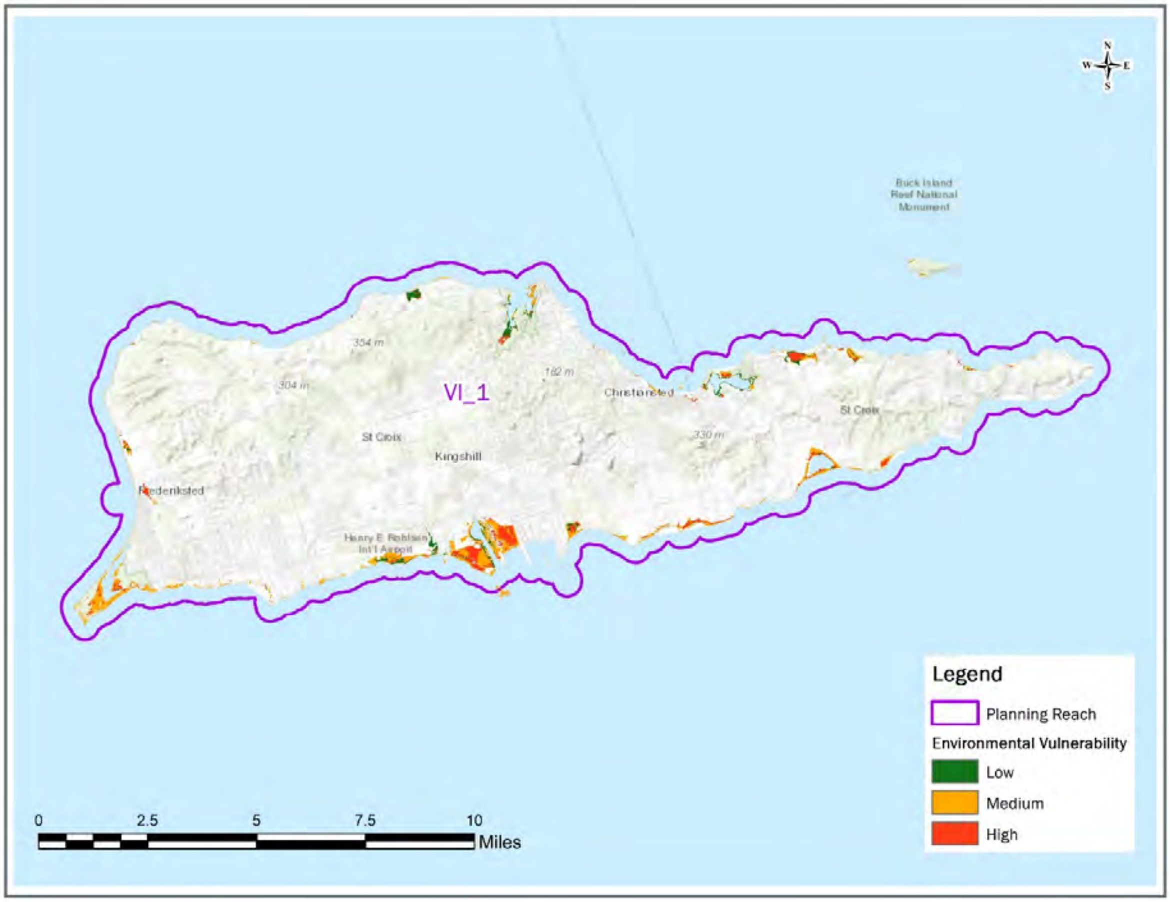


Figure 4-22: Environmental Vulnerability for Planning Reach VI_1 (USACE 2021b)

Cultural resource vulnerability was measured through qualitative assessment based on degree of exposure to coastal hazards and sea level rise, structural considerations, and the nature of the cultural resource. **Table 4-7** presents exposed cultural resources and the potential vulnerability to Tier 2 hazards. This is not an all-inclusive list.

Table 4-7: Planning Reach VI_1 Vulnerability of Exposed Cultural Resources to Tier 2 Hazards

Census Place/Estate	Exposed Cultural Resources	Tier 2 Hazards		
		Storm Surge Inundation	Erosion	Wave Attack
Christiansted	Christiansted National Historic District	Y	N	Y
Estate Coakley Bay	Coakley Bay Estate	Y	N	Y
Estate Two Brothers	Sandy Point National Wildlife Refuge	Y	Y	Y
Frederiksted; Estate Two Brothers	Frederiksted Historic District and Ft. Frederik	Y	N	Y
Estate Salt River; Estate Morning Star North; Estate Morning Star South; Estate St. John; Estate Judith's Fancy	Salt River Bay National Historical Park and Ecological Preserve	Y	N	Y

Within Planning Reach VI_1, historic districts and archeological sites are vulnerable to inundation, erosion, and wave attack. Storm surge inundation can flood historic properties and damage buildings, such as those located within the Christiansted Historic District and the Frederiksted Historical District. Damage may include structural damage and destruction of historic materials. Prehistoric, colonial, and archeological sites within the Salt River Bay National Historical Park and Ecological Preserve are vulnerable to damage and/or loss from inundation and wave attack. Inundation and erosion at archaeological sites located within Sandy Point National Wildlife Refuge could wear away site layers, resulting in the loss of both known and unknown artifacts.

4.2.2.4 Planning Reach VI_1 Tier 2 High-Risk Locations

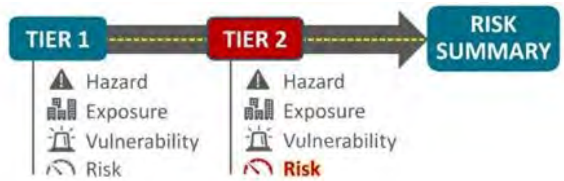


Figure 4-23 displays the expected annual damages (EAD) by census block based on the FAST modeling analysis for existing and future conditions for Planning Reach VI_1. Estate Mount Fancy and Christiansted have the highest current modeled EAD. Christiansted is expected to experience the largest increase in EAD as a result of sea level rise with $170,000 additional EAD.

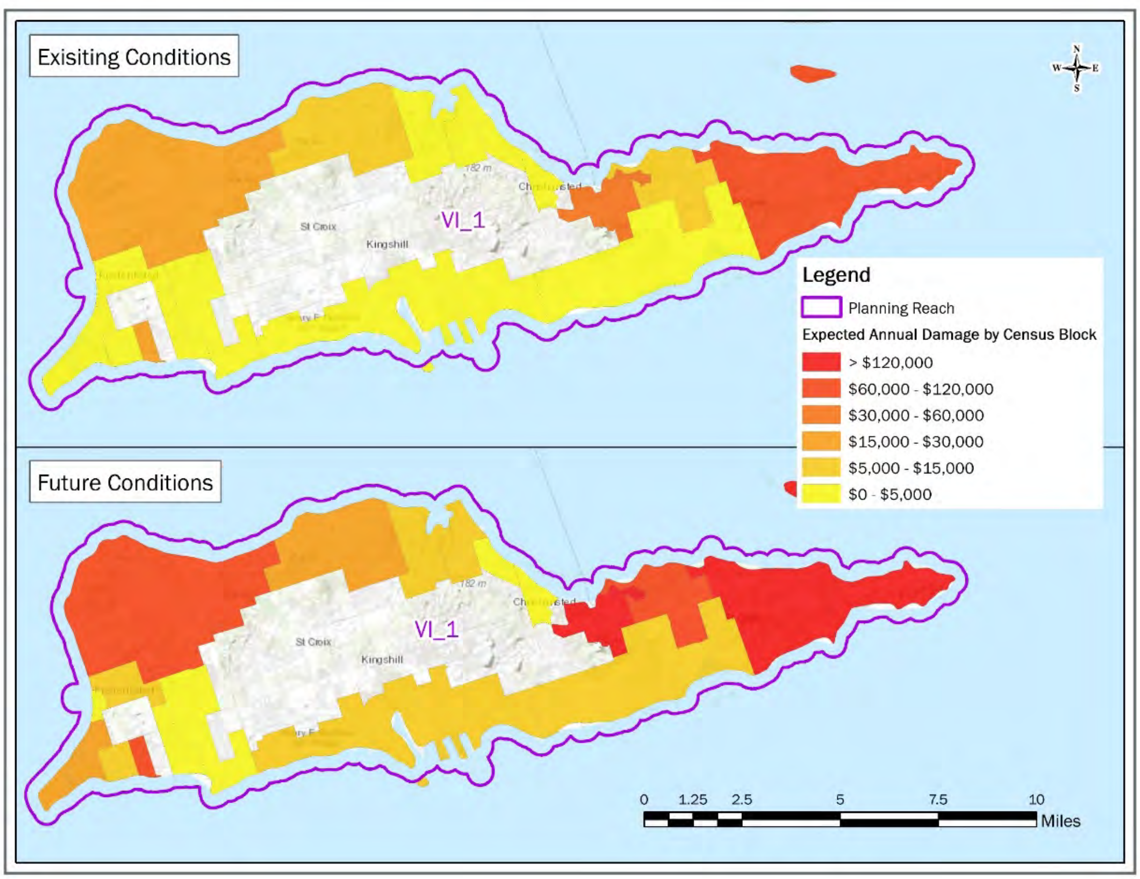


Figure 4-23: Expected Annual Damages (FY18) based on FEMA's Flood Assessment Structure Tool Results for Planning Reach VI_1

The environmental risk areas for Planning Reach VI_1 are shown in **Figure 4-24** and are summarized in **Table 4-9**. The Tier 2 environmental resources risk analysis was limited to the NOAA C-CAP classifications within the Category 5 MOM footprint. A detailed description of the Tier 2 environmental resource risk analysis is located in the Environmental Technical Report (USACE 2021b).

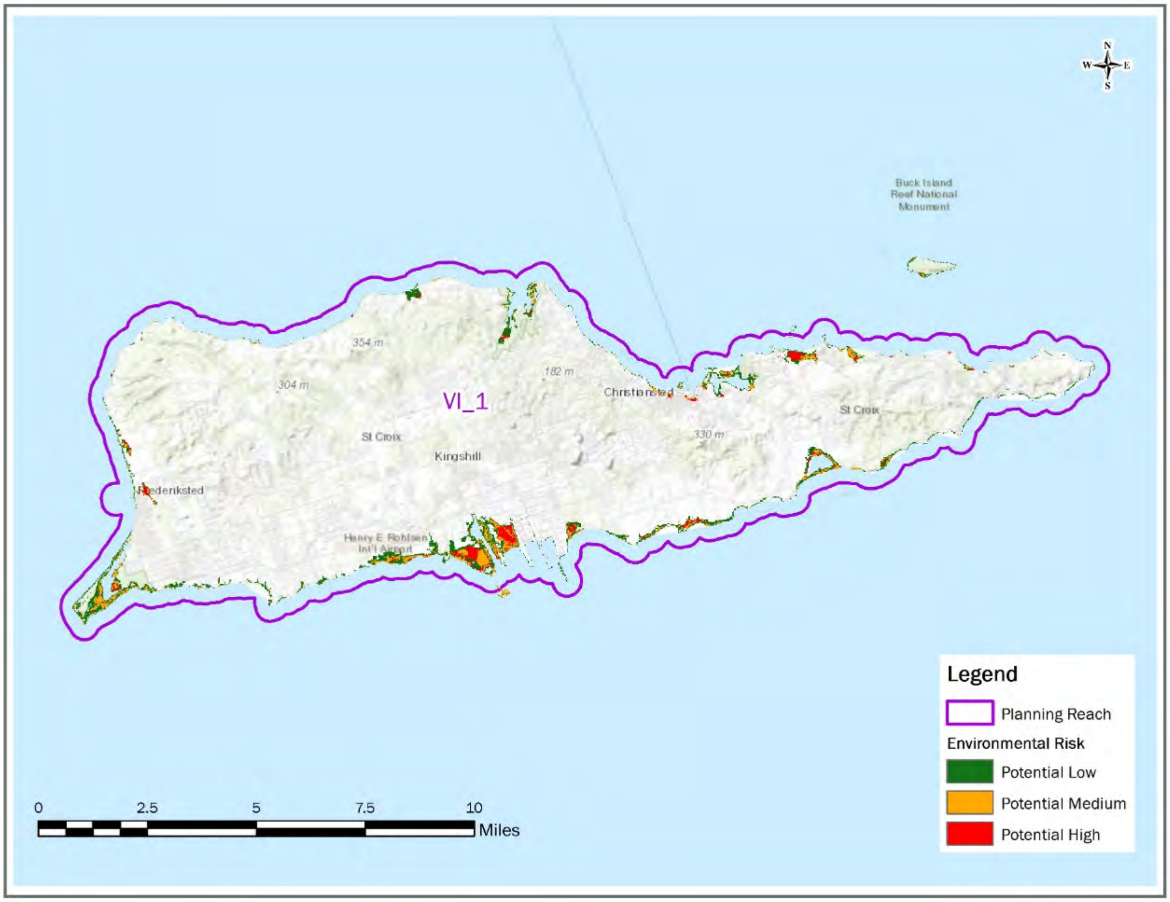


Figure 4-24: Tier 2 Environmental Resources Risk for Planning Reach VI_1 (USACE 2021b)

For Planning Reach VI_1, the largest high-risk environmental areas include Altona Lagoon and Krause Lagoon. For each planning reach, the Tier 2 environmental resources analysis identified Priority Environmental Areas (PEAs), defined as natural areas or features at medium to high risk to storm surge inundation and sea level rise. Priority biological resources are defined in the Final Planning Aid Report: *Biological Resources and Habitats Vulnerable to Sea Level Rise and Storm Activity in the Southeastern United States, including Puerto Rico and the U.S. Virgin Islands* (Planning Aid Report) (USFWS 2020a) as federally listed threatened and endangered species, waterbird nesting colonies, breeding, and wintering shorebirds, or other managed species. PEAs are considered high priorities for state and federal agencies and non-governmental organizations (e.g., USFWS critical habitats or national wildlife refuges, Audubon Important Bird Areas, state heritage preserves and wildlife management areas, and areas of national and state environmental significance). Stakeholders should consider these areas when looking for environmental resources to conserve and/or manage. USACE designation as a PEA does not create a special legal protection or status of the area and does not change how the area is regulated under federal and state laws. PEAs within VI_1 are demonstrated in **Figure 4-25** and include:

- Krause Lagoon
- Sandy Point National Wildlife Refuge
- Salt River Bay
- Altona Lagoon
- Southgate Pond
- Great Pond

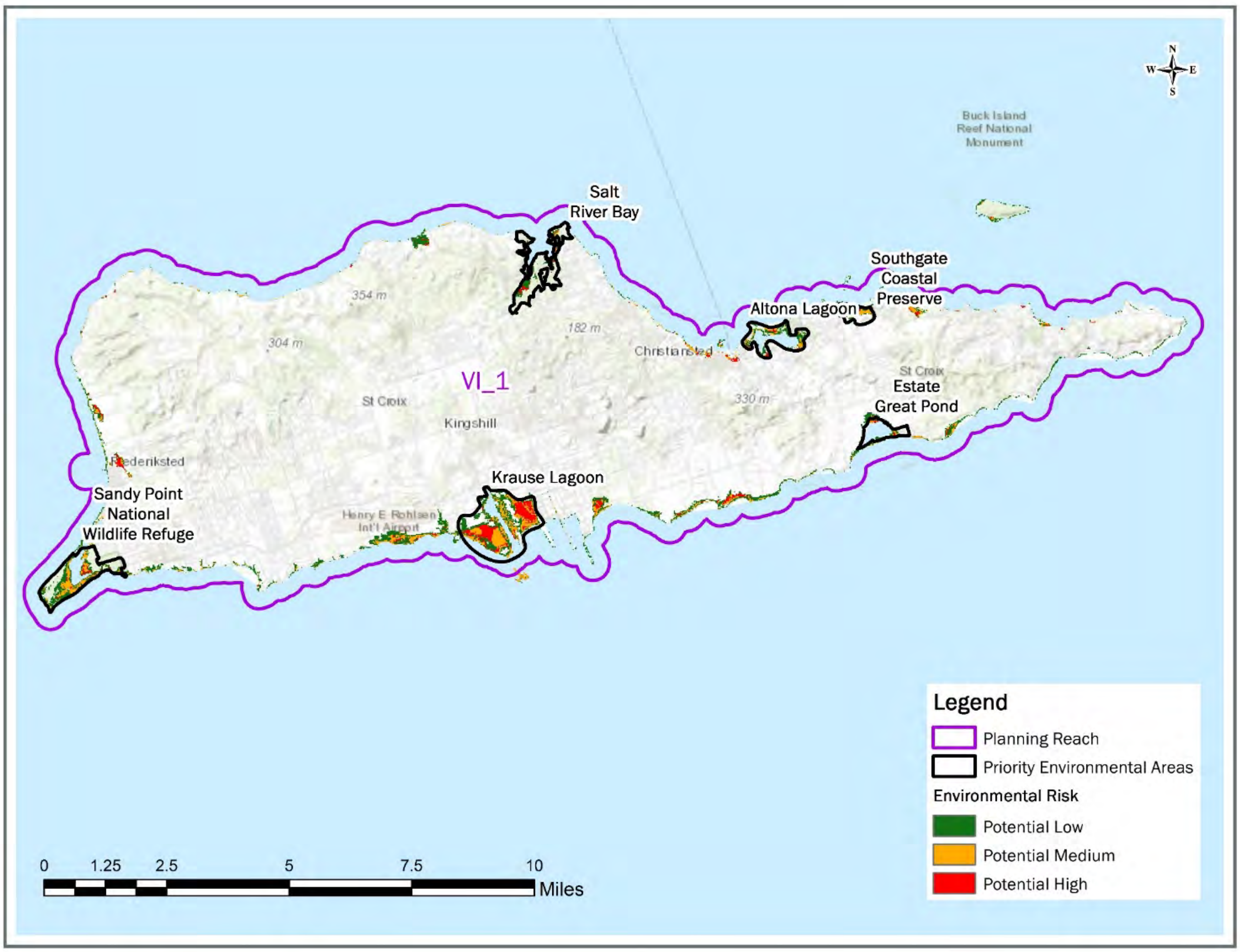


Figure 4-25: Priority Environmental Areas for VI_1

Detailed information about the methodology used and a detailed description of each PEA is located in the Environmental Technical Report (USACE 2021b). Additional environmental risks to Planning Reach VI_1 include those to coral reefs and SAV. These resources are not represented by the NOAA C-CAP classifications; however, they are susceptible to sea level rise, storm surge inundation, and wave damage. Risk to corals reefs and SAV is addressed in the Environmental Technical Report (USACE 2021b).

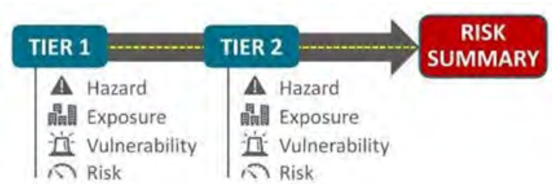
Risks to cultural resources were determined using the NRHP, relevant literature, and best professional judgment by reviewing the hazards of erosion, wave attack, and inundation. High-risk census places and census estates in Planning Reach VI_1 with cultural resources within the Category 5 MOM layer extent or areas with cultural resources at risk to wave attack and erosion were identified in **Table 4-9** (Summary of High-risk Locations).

Based on the qualitative risk assessment within the reach, historic districts, structures, and archeological sites are at risk of inundation, erosion, and wave attack. Historic districts and structures are at risk of foundational impacts as waters intrude. Without prevention or protection, these impacts can quickly lead to instability and, where impacts do not directly cause destruction, may necessitate demolition where public safety becomes a concern. Repairs and reactive measures are available but could be cost prohibitive.

Damage to archaeological sites, such as those located within Sandy Point National Wildlife Refuge and Salt River Bay National Historic Park and Ecological Preserve, can be even more harmful. There are no reconstructive measures that can be taken for these sites. Once they are lost, the areas can no longer be studied to understand the past.

4.2.3 Planning Reach VI_1 Summary and High-Risk Locations

High-risk locations were determined from the data presented in the hazard, exposure, and vulnerability sections above. No overall risk score was assigned to each location. Instead, the combined effect of all factors was qualitatively evaluated to determine the areas of highest risk.



Planning Reach VI_1 has areas with high populations, critical infrastructure, and social vulnerability, such as Christiansted and Frederiksted. Areas to the north and west of the airport are higher in population and contain critical infrastructure and cultural resources that are threatened by future sea level rise. Krause Lagoon and Altoona Lagoon are two of the highest-risk environmental areas within the reach—both are located in areas threatened by future sea level rise. Sea level rise is also expected to increase EAD in Christiansted and Estate Mount Fancy (the southeastern region of the U.S. Virgin Islands).

Table 4-9 displays the Planning Reach VI_1 high-risk locations identified through the Tier 1 and Tier 2 analyses. The table includes information on EAD, erosion risks, risks of increases in wave height, environmental risks, and locations where cultural resources are potentially at risk within each census place or census estate. The table highlights the estimated annualized inundation dollar damages for existing and future conditions and ranks them from low to high risk. These rankings were determined by USACE economists specifically for the U.S. Virgin Islands and are shown in Table 4-8. These are relative risks.

Table 4-8: Estimated Annualized Damage Range for Flood Assessment Structure Tool Ranking of Low to High for the U.S. Virgin Islands (FY18)

Risk Ranking	Lower Bound	Upper Bound
Low	$0	$1,878
Low-Med	$1,879	$5,326
Med	$5,327	$14,521
Med-High	$14,522	$48,834
High	$48,835	$1,265,777

Erosion risk was considered medium-high if long-term erosion rates were greater than 0.75 meters per year (2.5 feet per year) and high if greater than 1 meter per year (3.3 feet per year). Modeled wave height increases of greater than 0.5 meters (1.6 feet) for the 1-percent AEP event with sea level rise were considered significant. Social vulnerability was considered high if the estate scored above 36.165700 in the Social Sensitivity Index. The table notes whether environmental high-risk areas, priority environmental areas (PEAs), and cultural resources are present in each estate or census place.

Based on these factors, a few locations are particularly concerning. Christiansted was identified as high risk in the Tier 1 analysis under future conditions, medium-high risk for existing infrastructure risk in Tier 2, and high risk for future infrastructure risk in Tier 2. It also contains environmental high-risk areas and cultural resources. Christiansted was also selected as a focus area as part of the SACS. Estate Two Brothers is medium-high infrastructure risk in Tier 2, will likely see increased wave attack, and contains over 15 acres of environmental high-risk areas, including Sandy Point National Wildlife Refuge, a PEA.

Table 4-9: Summary of Tier 1 and Tier 2 Risk by Census Place and Census Estate for Planning Reach VI_1.

Planning Reach VI_1	Tier 1		Tier 2											
	Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)						At Risk Cultural Resources		At Risk Environmental Resources			
Census Place/Census Estate	Identified as Existing High Risk Location	Identified as Future High Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Tier 2 Historical Erosion Risk	Tier 2 Significant Increase in Future Wave Attack (>0.5 meters)	Identified as Area with Cultural Resource At Risk	Cultural Resource Name	Identified as Area with PEA or Resource At Risk	Tier 2 Environmental High Risk (acres)	Environmental Resource Name	Tier 2 Socially Vulnerable Areas
Christiansted		X	$32,000	Med-High	$371,000	High			X	Christiansted National Historic District	X	9.71		
Estate A Piece of Land											X	0.22		
Estate Altona			$0	Low	$26,000	Med-High					X	4.66	Altona Lagoon	
Estate Annaly								X						
Estate Anguilla							High				X	66.23	Krause Lagoon	
Estate Barren Spot 1											X	10.98		
Estate Bethlehem Middle Works											X	2.69		
Estate Blessing			$1,000	Low	$9,000	Med					X	58.91	Krause Lagoon	
Estate Boetzberg											X	0.59	Altona Lagoon	
Estate Cain Carlton			$0	Low	$4,000	Low-Med	High				X	0.43		
Estate Cane Bay											X	0.89		
Estate Cane Garden							Med-High							
Estate Coakley Bay			$0	Low	$3,000	Low-Med			X	Coakley Bay Estate	X	4.42		
Estate Cotton Garden											X	0.22		
Estate Concordia East								X						
Estate Envy								X						
Estate Cotton Valley			$3,000	Low-Med	$22,000	Med-High		X			X	0.22		
Estate Diamond Keturah											X	2.44		
Estate Fangselet			$0	Low	$4,000	Low-Med					X	0.67		X
Estate Fareham			$0	Low	$1,000	Low					X	0.21		
Estate Golden Rock			$0	Low	$1,000	Low					X	0.16		
Estate Granard			$1,000	Low	$10,000	Med					X	7.65		
Estate Great Pond			$0	Low	$1,000	Low					X	2.22	Great Pond	
Estate Green Cay			$1,000	Low	$5,000	Med		X			X	11.80	Southgate Pond	
Estate Hartman											X	11.76	Great Pond	
Estate Hope East											X	15.79	Krause Lagoon	
Estate Hannahs Rest			$1,000	Low	$6,000	Med								
Estate Judiths Fancy			$1,000	Low	$8,000	Med		X	X	Salt River Bay National Historical Park and Ecological Preserve	X	1.0	Salt River Bay	
Estate Kramers Park			$0	Low	$1,000	Low					X	0.22		
Estate La Grande Princess			$0	Low	$2,000	Low					X	0.22		

Planning Reach VI_1	Tier 1		Tier 2											
	Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)						At Risk Cultural Resources		At Risk Environmental Resources			
Census Place/Census Estate	Identified as Existing High Risk Location	Identified as Future High Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Tier 2 Historical Erosion Risk	Tier 2 Significant Increase in Future Wave Attack (>0.5 meters)	Identified as Area with Cultural Resource At Risk	Cultural Resource Name	Identified as Area with PEA or Resource At Risk	Tier 2 Environmental High Risk (acres)	Environmental Resource Name	Tier 2 Socially Vulnerable Areas
Estate La Grange			$0	Low	$11,000	Med					X	11.55		
Estate Little Princess North											X	0.22		
Estate Long Point											X	0.31		
Estate Mannings Bay			$0	Low	$0	Low	High				X	6.59		
Estate Montpellier East			$3,000	Low-Med	$7,000	Med			X	Salt River Bay National Historical Park and Ecological Preserve	X	5.54	Salt River Bay	
Estate Morning Star North									X	Salt River Bay National Historical Park and Ecological Preserve			Salt River Bay	
Estate Morning Star South									X	Salt River Bay National Historical Park and Ecological Preserve	X	4.18	Salt River Bay	
Estate Mount Fancy			$88,000	High	$258,000	High					X	2.44		
Estate North Grapetree Bay											X	0.58		
Estate North Slob			$1,000	Low	$11,000	Med					X	2.22		
Estate Northside							Med-High				X	2.00		
Estate Pearl											X	0.56		
Estate Prosperity West			$0	Low	$2,000	Low-Med					X	1.60		
Estate Protestant Cay			$0	Low	$2,000	Low					X	0.67		
Estate Roberts Hill			$8,000	Med	$50,000	High					X	0.35	Altona Lagoon	
Estate Rust Up Twist			$5,000	Med	$25,000	Med-High					X	4.21		
Estate Salt River			$0	Low	$7,000	Med		X	X	Salt River Bay National Historical Park and Ecological Preserve	X	0.29	Salt River Bay	
Estate Shoys			$0	Low	$10,000	Med		X			X	3.05	Altona Lagoon	
Estate Solitude East			$0	Low	$0	Low		X			X	0.30		
Estate South Grapetree Bay			$0	Low	$0	Low								
Estate Southgate			$0	Low	$3,000	Low-Med					X	20.80	Southgate Pond	

Planning Reach VI_1	Tier 1		Tier 2											
	Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)						At Risk Cultural Resources		At Risk Environmental Resources			
Census Place/Census Estate	**Identified as Existing High Risk Location**	**Identified as Future High Risk Location**	**Existing Economic Risk (EAD, FY18 dollars)**	**ERA Rating**	**Future Economic Risk (EAD, FY18 dollars)**	**ERA Rating**	**Tier 2 Historical Erosion Risk**	**Tier 2 Significant Increase in Future Wave Attack (>0.5 meters)**	**Identified as Area with Cultural Resource At Risk**	**Cultural Resource Name**	**Identified as Area with PEA or Resource At Risk**	**Tier 2 Environmental High Risk (acres)**	**Environmental Resource Name**	**Tier 2 Socially Vulnerable Areas**
Estate St. John									X	Salt River Bay National Historical Park and Ecological Preserve	X	0.22	Salt River Bay	
Estate Teague Bay			$0	Low	$1,000	Low					X	1.74		
Estate Two Brothers			$0	Low	$17,000	Med-High		X	X	Sandy Point National Wildlife Refuge; Frederiksted Historic District and Ft. Frederik	X	15.66	Sandy Point National Wildlife Refuge	X
Estate Wills Bay								X						
Estate Whim			$22,000	Med-High	$83,000	High	High							X
Estate William			$18,000	Med-High	$68,000	High					X	4.61		
Frederiksted			$0	Low	$2,000	Low-Med		X	X	Frederiksted Historic District and Ft. Frederik	X	0.23		

Note: Yellow highlight represents locations designated as high risk for entire territory.

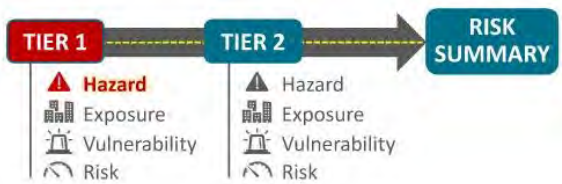
This page intentionally left blank.

4.3 Planning Reach VI_2 (St. Thomas) Risk Assessment

The U.S. Virgin Islands' Planning Reach VI_2 contains the island of St. Thomas, as shown in **Figure 3-2**. St. Thomas is the westernmost island of the U.S. Virgin Islands. It includes the capital of the U.S. Virgin Islands, Charlotte Amalie, as well as the Cyril E. King International Airport and a cruise port. Planning Reach VI_2 features sandy beaches and steep mountains, as well as several ecological preserves. The following sections walk through the Risk Assessment for Planning Reach VI_2.

4.3.1 Planning Reach VI_2 (St. Thomas) Tier 1

4.3.1.1 Planning Reach VI_2 Tier 1 Hazard



A description of the Tier 1 hazards is included in Section 4.1.1 and in the Main Report. **Figure 4-26** displays both existing and future flood hazards for St. Thomas, U.S. Virgin Islands (Planning Reach VI_2). The 1-percent AEP water level hazard extends to the back bay areas around the island. Specifically, the coastline of Charlotte Amalie susceptible to flooding from the 1-percent AEP flood event under current conditions. Mangrove Lagoon and Magens Bay are subject to flooding from both the 1-percent and 10-percent AEP flood events under current conditions. Low-lying areas along the northeast coast near Smith Bay are also subject to inundation from both the 1-percent AEP water levels and the 10-percent AEP water levels. Under future conditions, these areas show increased flooding potential to the 10-percent AEP flood event.

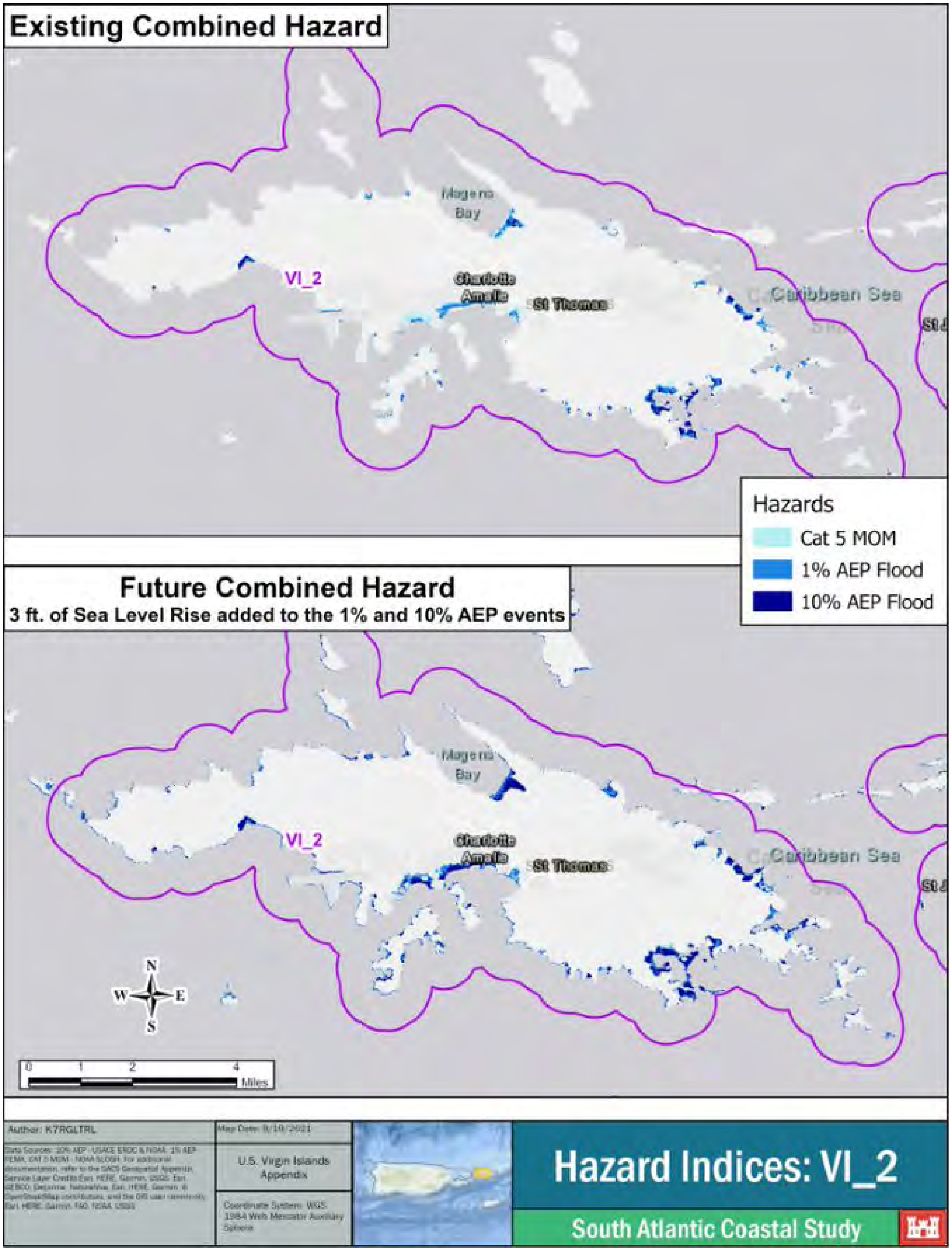
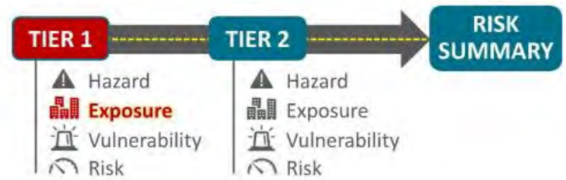


Figure 4-26: Existing and Future Flood Hazards for Planning Reach VI_2 from the 10-Percent Annual Exceedance Probability Flood, the 1-Percent Annual Exceedance Probability Flood, and the Category 5 Maximum of Maximum Water Levels

4.3.1.2 Planning Reach VI_2 Tier 1 Exposure



Planning Reach VI_2 encompasses the island of St. Thomas and includes the subdistricts/cities of Charlotte Amalie, Charlotte Amalie West, Charlotte Amalie East, Anna's Retreat, and Estate Bovoni. **Figure 4-27** shows the individual Tier 1 exposure indices as well as the CEI, composed of 65-percent population and infrastructure exposure, and 35-percent environmental and cultural resources exposure. Social vulnerability exposure data were not available for this planning reach. Areas colored red and amber indicate higher densities of populations, infrastructure, environmental and cultural resources, and habitat.

Population and Infrastructure

Based on the population and infrastructure exposure analysis, significant portions of the island have high population and infrastructure exposure. Charlotte Amalie and the surrounding area, which is the capital of the U.S. Virgin Islands and serves as a cruise ship port for St. Thomas Island, was identified as an area of high exposure. The southwest portion of St. Thomas Island (consisting of Cyril E. King International Airport, the University of the Virgin Islands – St. Thomas, and Water Island) was also identified as medium-high exposure for critical island infrastructure and dense populations.

Environmental and Cultural Resources

As shown in **Figure 4-27**, results of this analysis show that this planning reach contains several areas of high (orange and red) environmental and cultural resources exposure, including Perseverance Bay, Hassel Island, areas off the coast of Water Island, the coast of Charlotte Amalie, off the coast of Bovoni Cay, Great Bay, Smith Bay, and an area near Magens Bay. These areas include important environmental and cultural resources that are more susceptible to coastal hazards. Predominant coastal resources within Planning Reach VI_2 include mangroves, seagrasses, and multiple species of coral. St. Thomas also contains the Water Islands Coastal Preserve, the Magens Bay Watershed Preserve, and Little St. Thomas Preserve, all of which are TNC-designated lands. A total of nine Coastal Barrier Resources System areas are also located within Planning Reach VI_2. Inundation hazards in these areas are anticipated to increase with future sea level rise.

There are many cultural resources located across St. Thomas, including many historic structures concentrated in the two NRHP historic districts in and around Charlotte Amalie. Around the periphery of the island, within the coastal zone, there are NRHP-listed sites associated with historic estates and the historical inhabitants of the island. Many of these resources are in areas highly susceptible to coastal erosion and storm damage. Sea level rise will increase the threat to the cultural resources, particularly the colonial town of Charlotte Amalie.

Social Vulnerability

The Tier 1 analysis for the U.S. Virgin Islands did not include social vulnerability data. The Tier 1 analysis used the CDC's 2016 Social Vulnerability Index dataset. This dataset does not exist for the U.S. Virgin Islands; therefore, it could not be assessed. Other social vulnerability data will be included for the U.S. Virgin Islands in the Tier 2 analysis.

This page intentionally left blank.

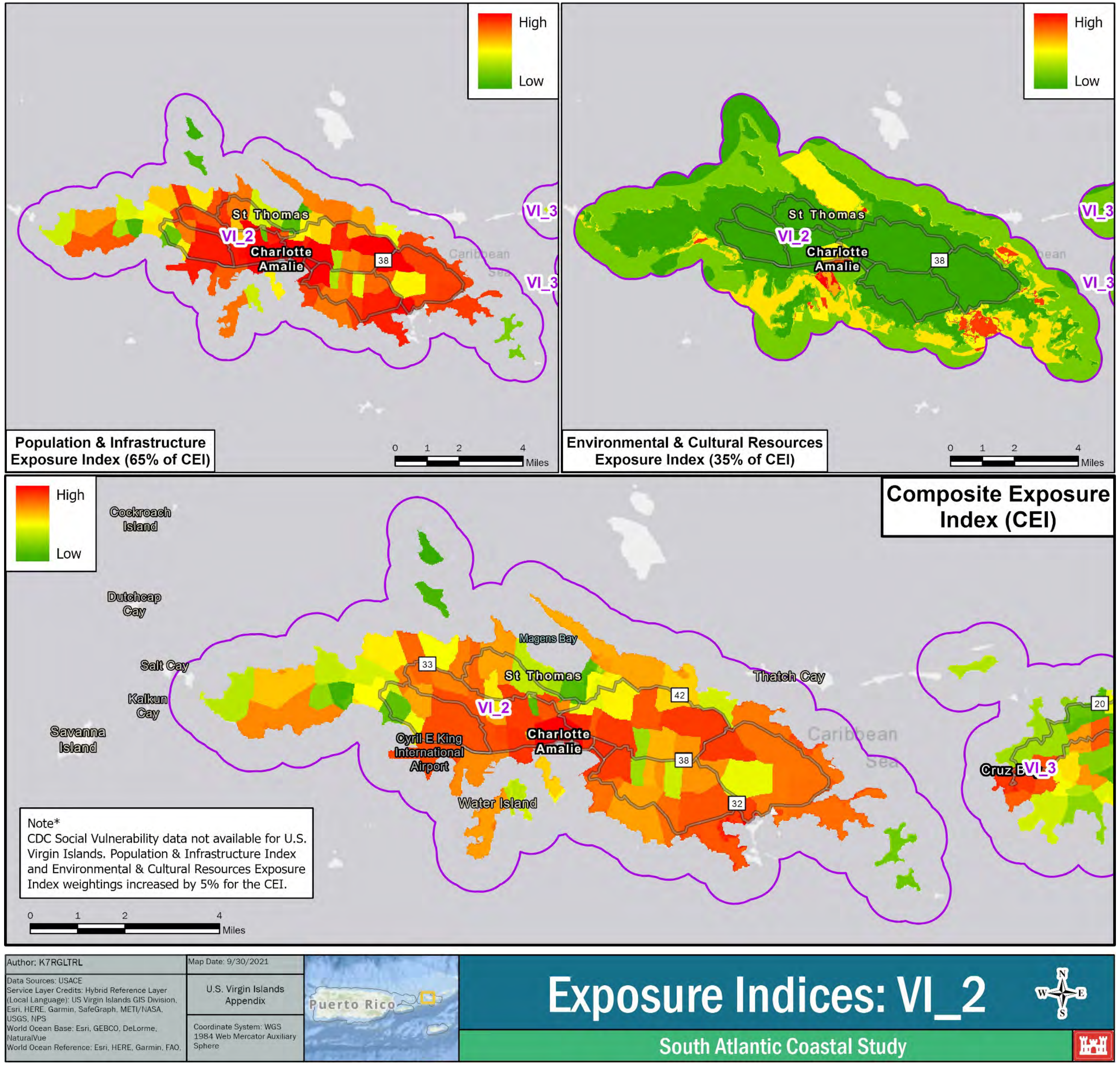
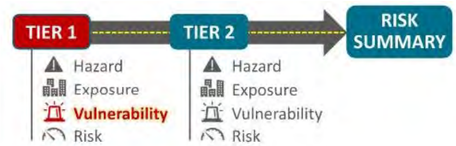


Figure 4-27: Exposure Indices for Planning Reach VI_2.

This page intentionally left blank.

4.3.1.3 Planning Reach VI_2 Tier 1 Vulnerability



As stated in Section 4.1.3 **,** Tier 1 Vulnerability, if a resource is subject to a hazard, it is considered vulnerable in the Tier 1 analysis.

4.3.1.4 Planning Reach VI_2 Tier 1 High-Risk Locations

The CEI and coastal flood inundation hazards were used to identify potential areas at risk. The Framework defines risk as a function of exposure and probability of hazard occurrence. The Geospatial Appendix describes how each of the inundation hazards (Category 5 MOM, 1-percent AEP flood, and 10-percent AEP flood) and sea level rise were combined with the CEI to generate potential risk data presented in the Tier 1 Risk Assessment.

Figure 4-28 displays both current and future potential risk for Planning Reach VI_2. Tier 1 high-risk locations are those where potential medium-high (amber) and high (red) composite risk exists. U.S. Census Bureau census places were used to define the boundaries of high-risk locations.

Much of Planning Reach VI_2, under existing conditions, is classified as potential low risk. A few areas are classified as potential medium-high risk or potential high risk, such as Mangrove Lagoon, Brenner Bay, and Smith Bay. Under future conditions and increasing sea level rise, many of these areas show increased potential risk. Areas around Charlotte Amalie show a significant change from potential low risk to potential high risk with sea level rise.

U.S. Census Bureau census places were used to define the boundaries of high-risk locations. Medium-high and/or high composite risk needs to cover at least 5 acres (0.02 square kilometers) and 0.5 percent of the total area of a census place for it to be considered high risk.

Tier 1 high-risk locations for Planning Reach VI_2 are summarized by the acres covered by medium-high and high risk for each census place in **Figure 4-29** and the percentage of the entire census place area covered by medium-high and high risk acreage in **Figure 4-30.** Red Hook is considered high risk under existing and future conditions. Charlotte Amalie and Charlotte Amalie West are not considered high risk under existing conditions but are considered high risk with regard to sea level rise. Risk areas in Charlotte Amalie increase by over 50 acres with the addition of sea level rise, Charlotte Amalie West increases by 26 acres, and Red Hook increases by nearly 15 acres.

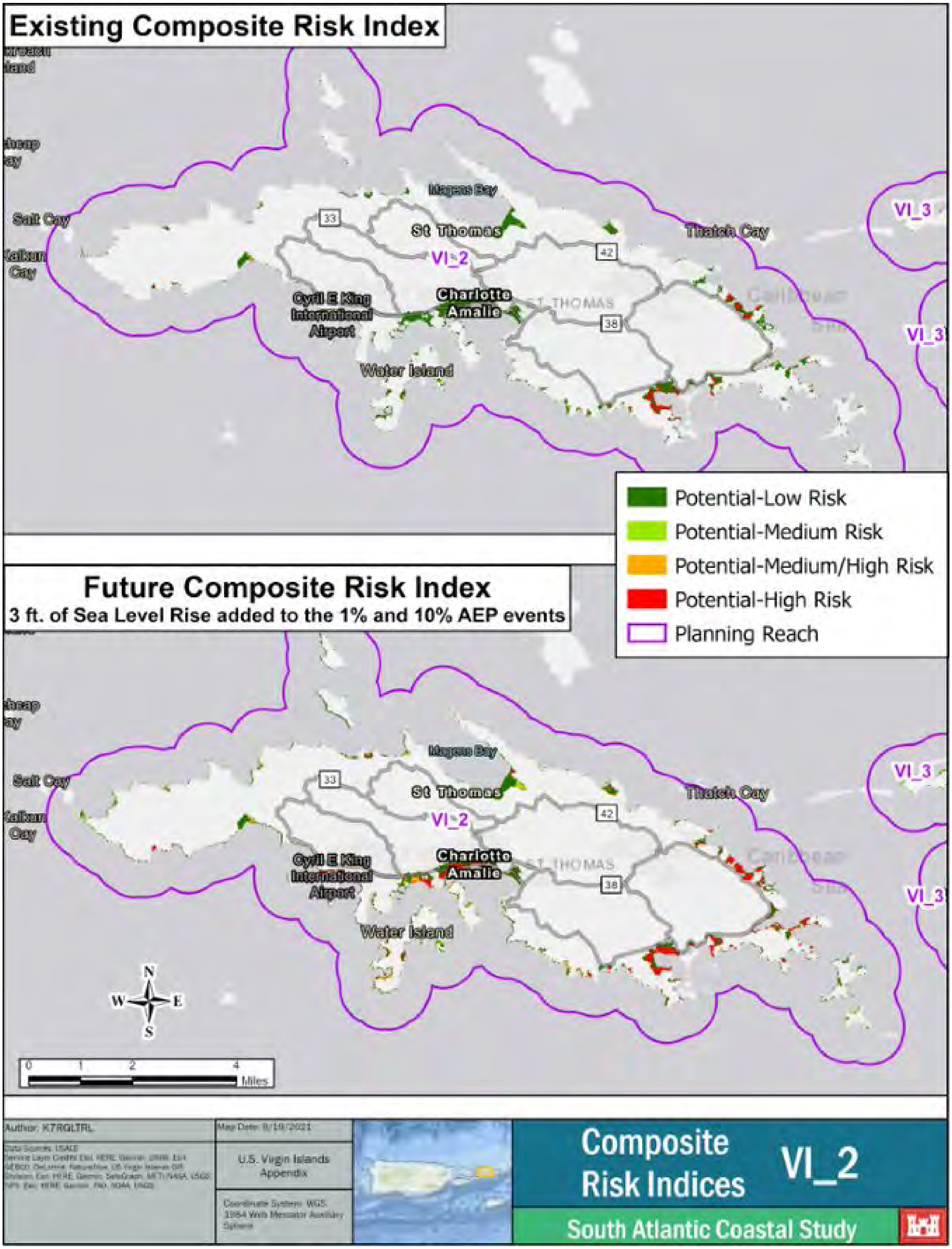


Figure 4-28: Existing Composite Risk Index and Future Composite Risk Index for Planning Reach VI_2

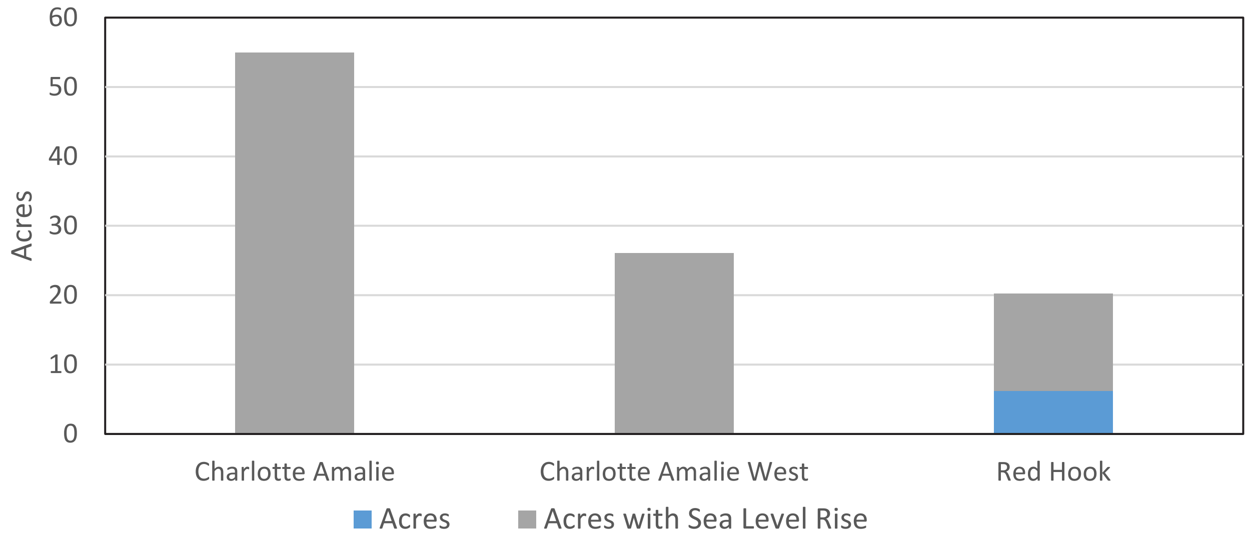


Figure 4-29: Acres of Land Identified as Existing and Future Medium-high and High-Risk per Census Place in VI_2

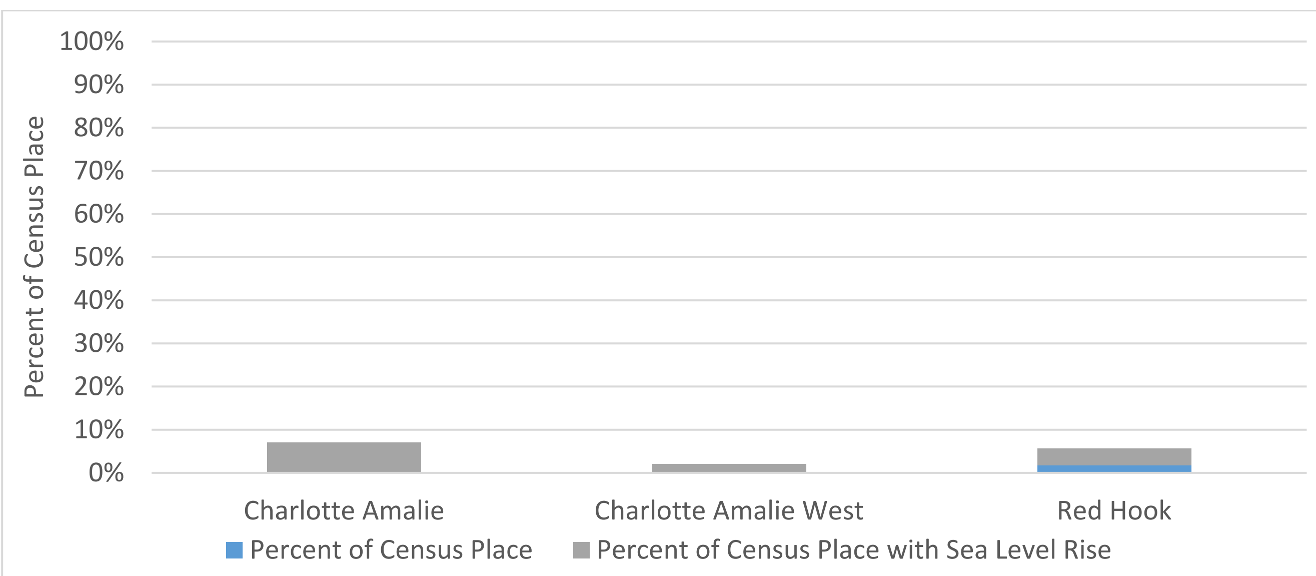


Figure 4-30: Percentage of Entire Census Place Area Covered by Medium-high-risk and High-Risk Acreage (Existing and Future Conditions)

4.3.2 Planning Reach VI_2 (St. Thomas) Tier 2

Tier 2 included additional and more localized hazard, vulnerability, and exposure information to refine the Tier 1 Risk Assessment.

4.3.2.1 Planning Reach VI_2 Tier 2 Hazard

This section highlights details of the Tier 2 hazards, or what may cause harm, for U.S. Virgin Islands' Planning Reach VI_2. An overview of each hazard is presented in Section 4.1.4.

The Tier 2 hazards for the Planning Reach VI_2 (St. Thomas) include the following:

Inundation

The Tier 2 analysis considered inundation depths as well as extent from coastal storm flooding. Inundation depths from the NOAA SLOSH model (Jelesnianski et al. 1992) for a Category 5 MOM hurricane are shown in **Figure 4-31. Table 4-10** shows the CHS maximum inundation depths in Planning Reach VI_2 for the range of AEP storms for both existing and future conditions (USACE 2020b), where future conditions include 2.33 feet (0.71 meters) of sea level rise by 2120 based on the USACE Intermediate scenario. Areas of significant inundation depths include Mangrove Lagoon (subject to up to nine feet [2.7 meters] of inundation), Charlotte Amalie (up to five feet [1.5 meters] of inundation) and Magens Bay (up to six feet [1.8 meters] of inundation) during a Category 5 MOM hurricane.

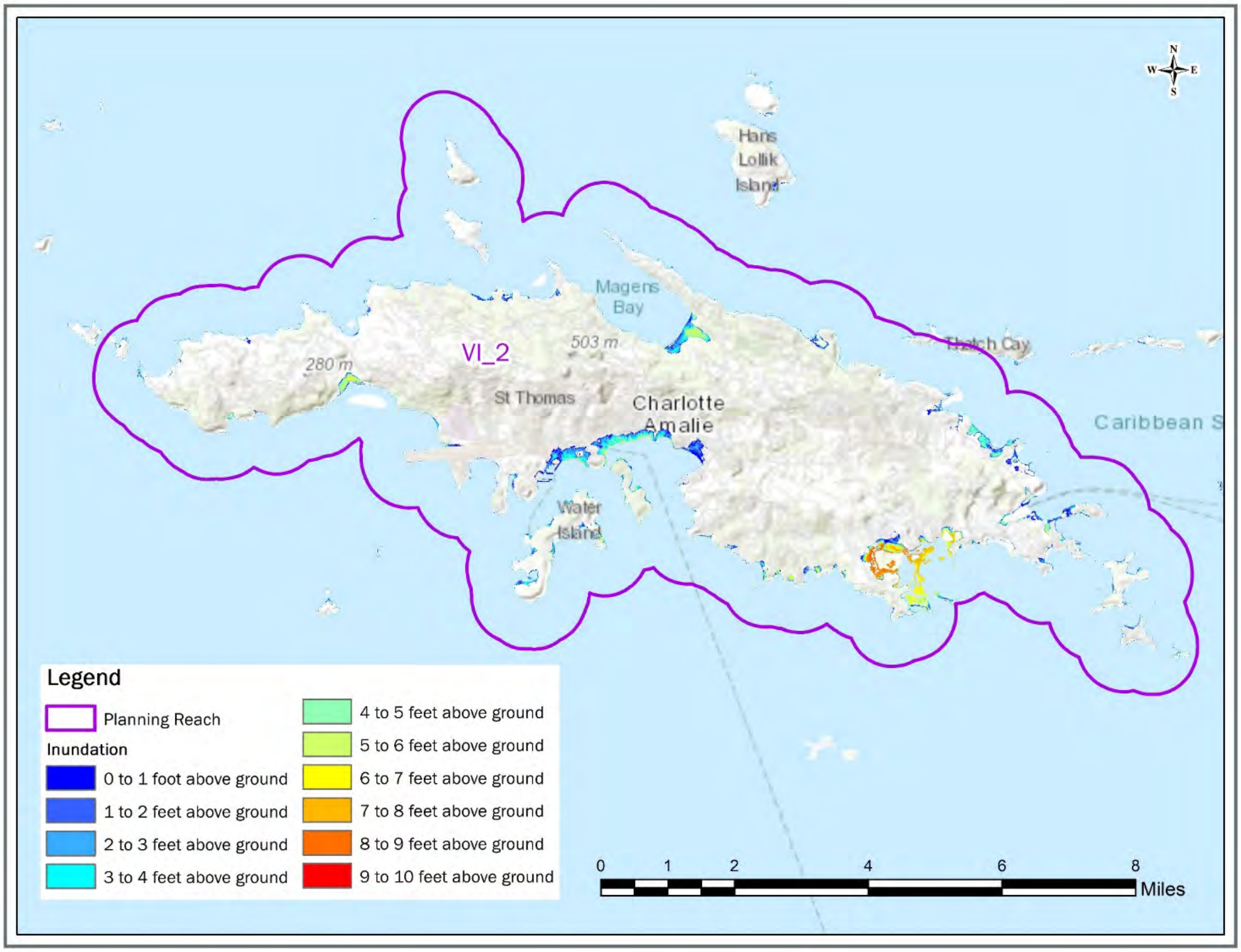


Figure 4-31: Inundation Depth from a Category 5 Maximum of Maximum Storm in Feet Above Ground, Based on National Oceanic and Atmospheric Administration's Sea, Lake, and Overland Surges from Hurricanes Model (Jelesnianski et al. 1992) for Planning Reach VI_2

Table 4-10: Coastal Hazards System Maximum Flood Depths for Planning Reach VI_2 (USACE 2020b)

	10 Percent AEP	5 Percent AEP	2 Percent AEP	1 Percent AEP	0.2 Percent AEP
Existing Conditions	8.1 ft (2.5 m)	8.7 ft (2.6 m)	9. 6 ft (2.9 m)	10.4 ft (3.2 m)	11.8 ft (3.6 m)
Future Conditions	10.4 ft (3.2 m)	11.0 ft (3.3 m)	11.9 ft (3.6 m)	12.6 ft (3.9 m)	14.1 ft (4.3 m)

Wave Attack

Wave attack is prominent in St. Thomas, with the highest wave heights occurring on the western coast. **Figure 4-32** displays the modeled wave heights for the 1-percent AEP event from the CHS (USACE 2020b). CHS modeling demonstrates offshore wave heights of 20 to 26 feet (6 to 8 meters) during the 1-percent AEP in the northwest corner of the island. Along the shoreline, wave heights drop to 13 to 20 feet (4 to 6 meters) during the 1-percent AEP event. Wave heights are expected to increase around the island with sea level rise **(Figure 4-33)**. CHS modeling demonstrates wave height increases of over 1.6 feet (0.5 meters) in some locations based on the USACE Intermediate scenario and over 3.3 feet (1 meter) based on the USACE High scenario.

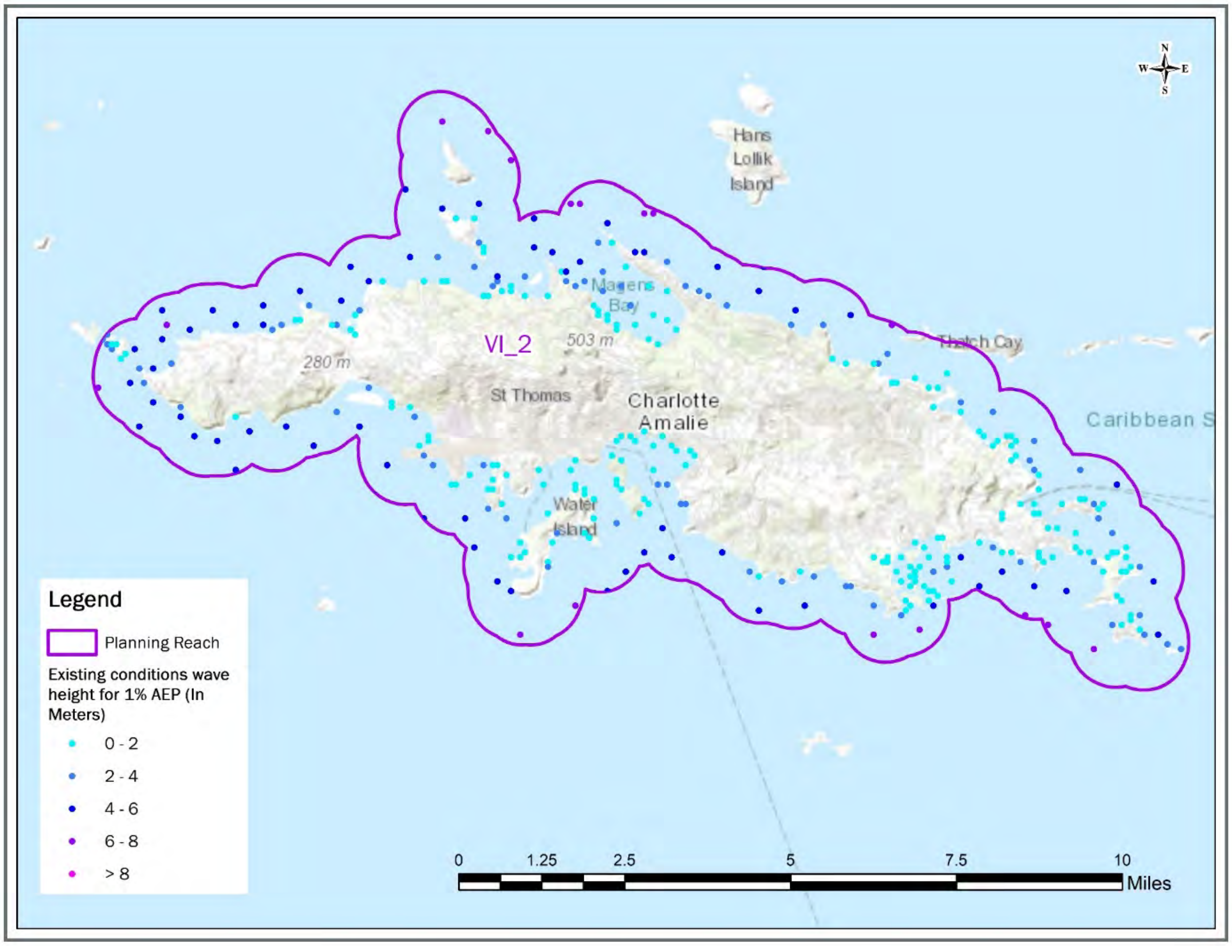


Figure 4-32: Existing Conditions Wave Heights for the 1-Percent Annual Exceedance Probability Event for Planning Reach VI_2 (USACE 2020b)

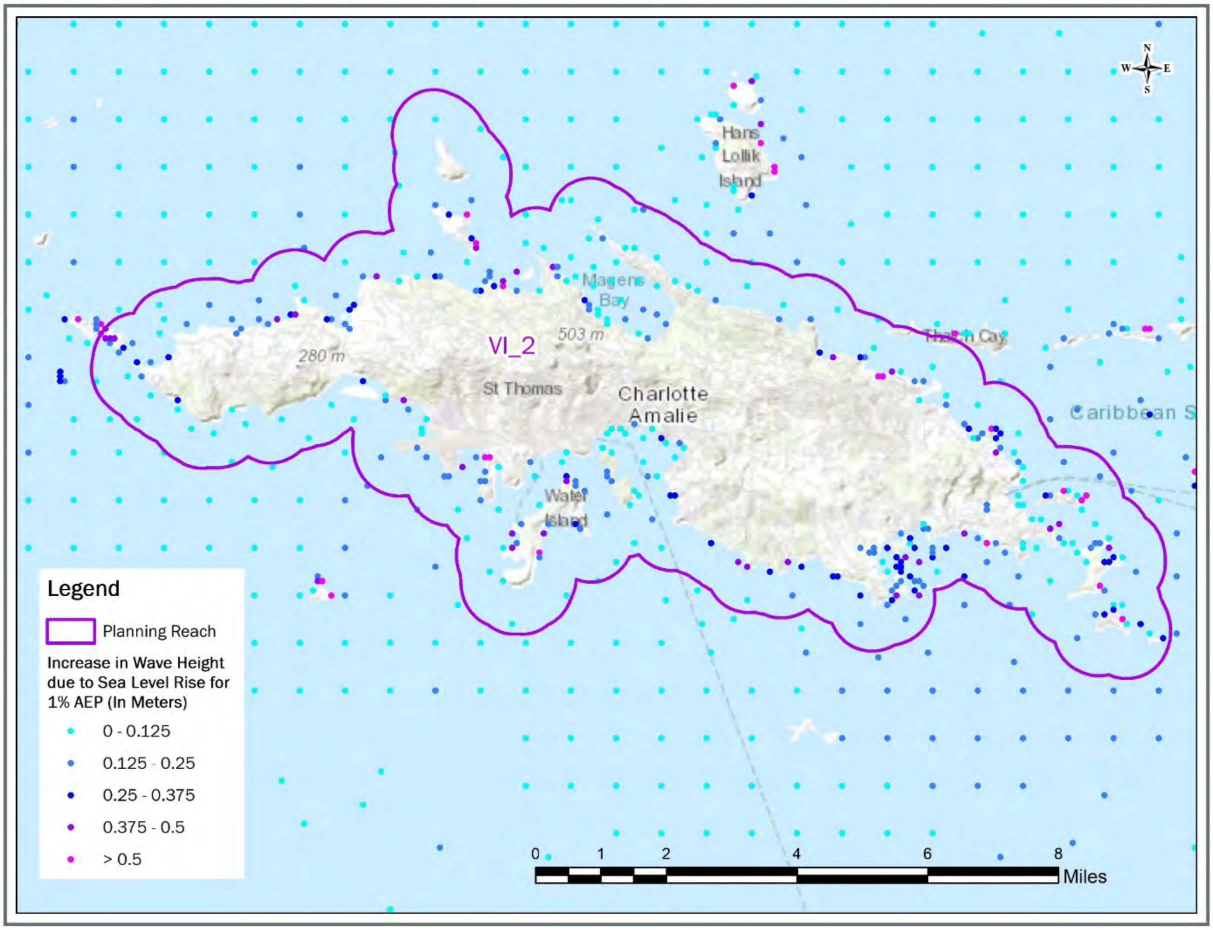


Figure 4-33: Increased Wave Heights for the 1-Percent Annual Exceedance Probability Event for Planning Reach VI_2 with 2.33 Feet of Sea Level Rise (USACE 2020b)

Coastal erosion

Coastal erosion is evaluated throughout Planning Reach VI_2. Most of the northern coast is stable or accreting, while most of the southern coast is eroding. Areas of high erosion are located in Charlotte Amalie, Charlotte Amalie West, and along the eastern coast. **Figure 4-34** illustrates long-term shoreline change with erosion represented by negative values.

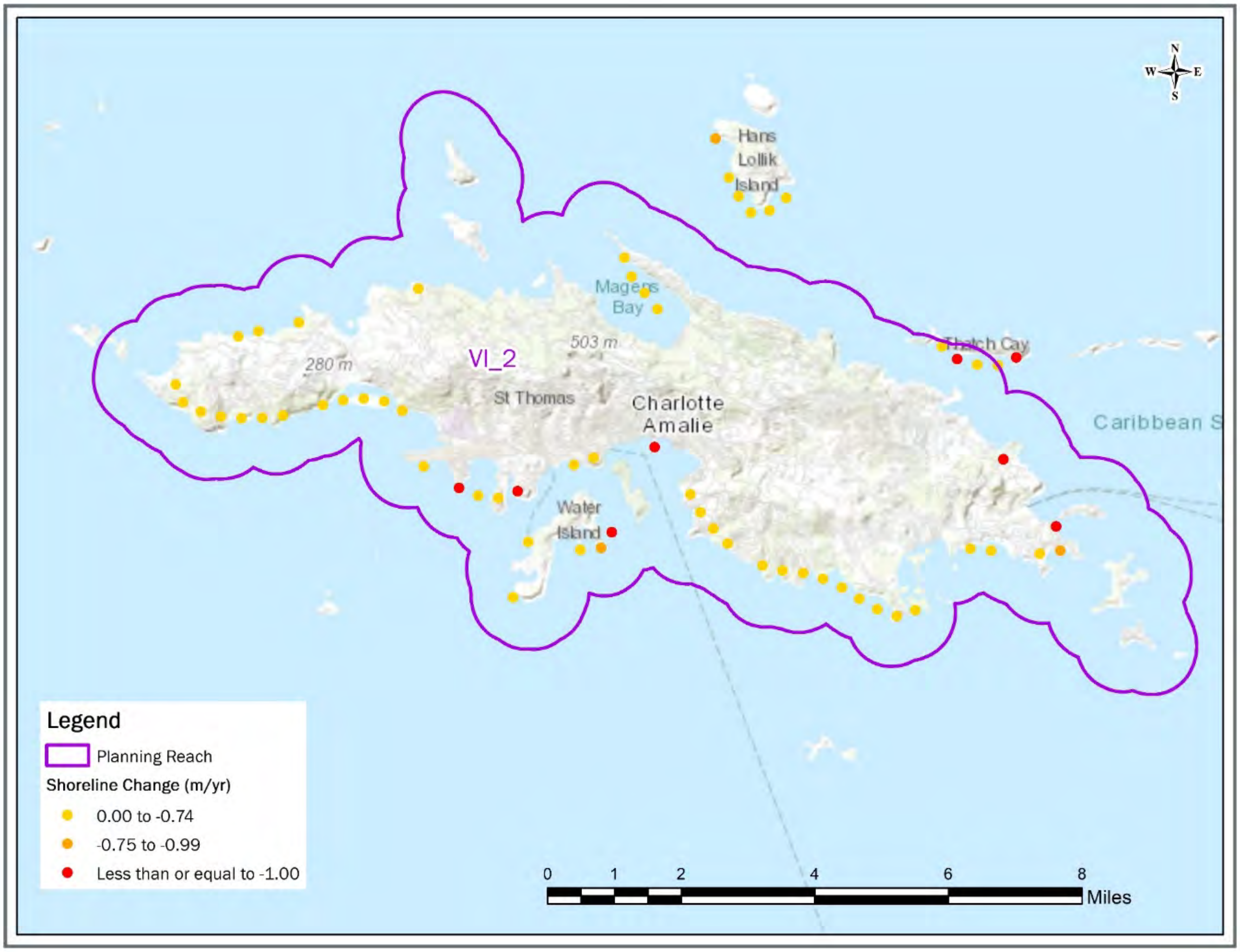


Figure 4-34: Long-Term Shoreline Change for Planning Reach VI_2 (1984 to 2016) (Luijendijk et al. 2018)

Other hazards associated with coastal storms that may impact this planning reach but are not considered in detail as part of the Tier 2 analysis include:

Wind

Wind during coastal events can cause devastation across the U.S. Virgin Islands, from direct wind damage to buildings, uprooting trees that take down power lines, or outgrowth of wind waves on top of storm surge.

Compound flooding

Compound flooding is a hazard in Planning Reach VI_2, especially in low-lying areas along the coast and near the island's river mouths, such as Turpentine Run. **Figure 4-35** shows an overlay of the NFWF flood-prone areas layer (Dobson et al. 2020) with the Category 5 hurricane SLOSH modeled inundation extent (Jelesnianski et al. 1992). While this is not an analysis of compound flooding, it highlights areas that may experience flooding from riverine or coastal sources, with the potential for compound flooding in areas where the two flooding sources converge. Compound flooding damages may also increase in the future as sea levels rise. Additional studies are needed to better characterize and understand the compound flooding risks.

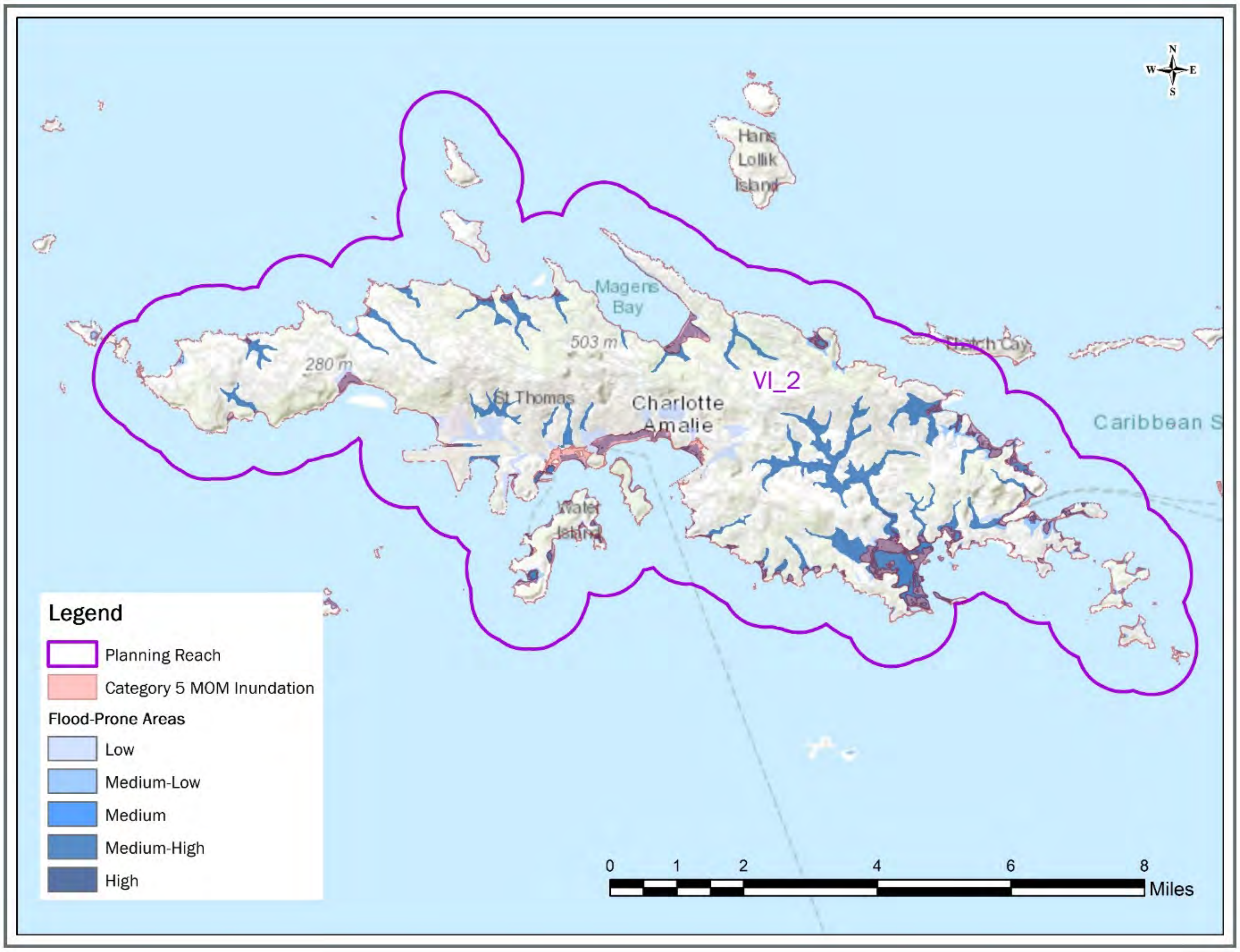
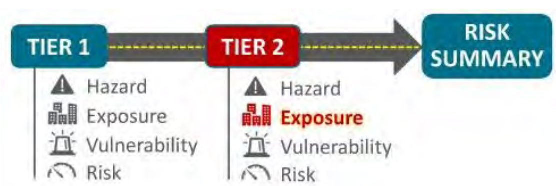


Figure 4-35: Flood-Prone Areas and Category 5 Modeled Inundation for Planning Reach VI_2 (Dobson et al. 2020)

4.3.2.2 Planning Reach VI_2 Tier 2 Exposure

This section highlights details of the Tier 2 exposure—who/what may be impacted—for the Planning Reach VI_2. An overview of each exposure element is presented in Section 4.1.5.



Population and Infrastructure

The Tier 2 infrastructure exposure includes the estimate of potential losses (or the estimated exposure value) if infrastructure is flooded. Background information is provided on Tier 2 exposure data sources in Section 4.1.5. **Figure 4-36** displays infrastructure data from a GIS point-based structure inventory (FEMA n.d.) that is within the footprint of the Category 5 MOM floodplain. Single-family homes make up the primary source of building exposure within the coastal Category 5 MOM flood extents within Planning Reach VI_2.

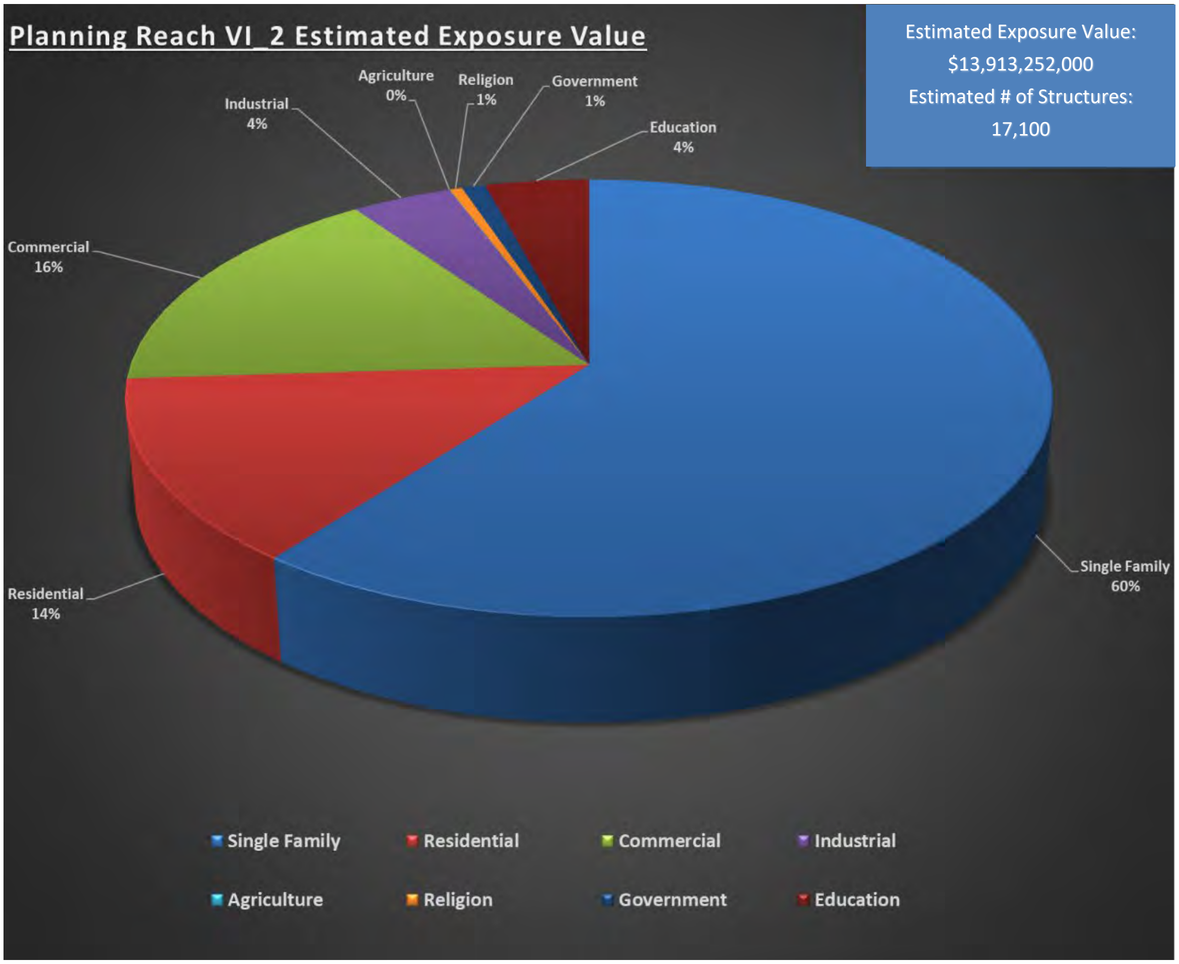


Figure 4-36: Planning Reach VI_2 Estimated Infrastructure Exposure (FY18) (FEMA n.d.)

The total population of St. Thomas (Planning Reach VI_2) is approximately 51,600 residents. Of that population, approximately 37,800 people (73 percent) live within census estates that are subject to flooding from the Category 5 MOM inundation extent (U.S. Census 2011). The population by estate and the Category 5 MOM modeled flooding extents are displayed in **Figure 4-37**. The total number of people on St. Thomas often exceeds the resident population because of the significant tourism industry. The St. Thomas/St. John district receives 328,000 air visitors and 1,366,400 cruise passengers annually, based on 2018 data (U.S. Virgin Islands Bureau of Economic Research 2018). These visitors are attracted to the area's, "powdery beaches and sun-drenched weather" (Visit St. Thomas.com 2018).

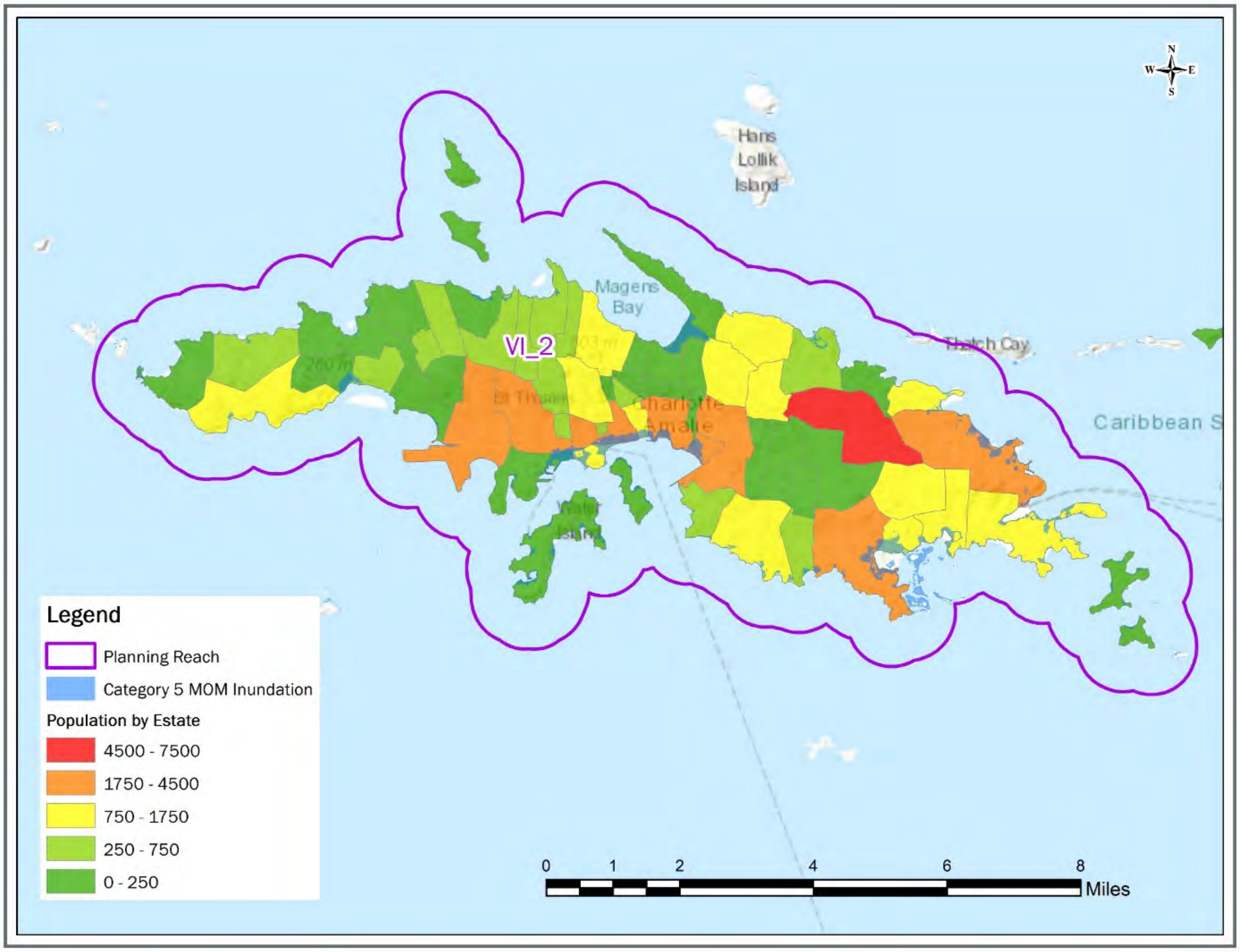


Figure 4-37-: Population (U.S. Census 2011) of St. Thomas (Planning Reach VI_2) and Category 5 Maximum of Maximum Storm Modeled Inundation Extent

Environmental and Cultural Resources

The shoreline for Planning Reach VI_2 is 111 miles long, containing approximately 58-percent rocky shores, 16-percent sandy beaches, and 14-percent mangroves (NOAA 2000). Mangrove forests make up 15 miles of linear shoreline within St. Thomas (Planning Reach VI_2). The largest mangrove habitats are in Mangrove Lagoon, Magens Bay, and Perseverance Bay. Approximately 3,854 acres of coral reefs surround the coast of Planning Reach VI_2, with the largest habitats located along the northern shoreline.

Based on the NOAA C-CAP classifications, Planning Reach VI_2 is predominantly deciduous forest, evergreen forest, and scrub/shrub with isolated areas of palustrine forested wetland across the island. Nearshore waters are NOAA-designated critical habitat for staghorn and elkhorn corals.

There are approximately 17 NRHP-listed cultural resources within Planning Reach VI_2. Many additional unidentified or unlisted resources are likely also present within the reach. This assessment highlights a few resources identified within the NRHP or through literature review that are potentially exposed to Tier 2 hazards, including the Charlotte Amalie Historic District, Hassel Island Historic District, historic sugar plantations, and Magens Bay Archeological District.

Charlotte Amalie Historic District includes the first European settlement on St. Thomas and is now the capital and largest town of the U.S. Virgin Islands. Ft. Christian is also located within the historic district and is the oldest remaining structure in the U.S. Virgin Islands, built between 1672 and 1680 (NPS 2020a, 2020e). The Charlotte Amalie Historic District is ranked as high exposure in the Tier 1 Environmental and Cultural Resources Exposure Index and is within the Charlotte Amalie Focus Area. A combination of seawalls and riprap line the coast of the district, which may have prevented substantial shoreline retreat (Luijendijk et al. 2018). Portions of the district currently experience flooding and are expected to experience exacerbated flooding under future sea level rise conditions.

Hassel Island is a small island just south of the harbor of Charlotte Amalie. The island contains ruins of English fortifications from the early and mid-1800's. A section of Hassel Island is designated as part of the Virgin Islands National Park (NPS 2020g). The Hassel Island Historic District is ranked as high in the Tier 1 Environmental and Cultural Resources Exposure Index and is within the Charlotte Amalie Focus Area. Low-lying portions of the island are subject to up to four feet of inundation from a Category 5 MOM hurricane. Though rocky shores and man-made structures have likely prevented significant coastal erosion, the island may experience an increase in wave height above existing conditions over the next 50 to 100 years.

St. Thomas contains the ruins of historic sugar plantations, many of which are subject to coastal hazards. The Estate Brewers Bay is within an area ranked as medium-high exposure in the Tier 1 Environmental and Cultural Resources Exposure Index. With sea level rise, this portion of the coast may experience an increase in inundation and wave heights that may also accelerate possible damage to the ruins.

Magens Bay is located on the northern side of the island and is a popular tourist attraction due to its white sandy beach. Magens Bay is ranked medium-high exposure in the Tier 1 Environmental and Cultural Resources Exposure Index. The bay is subject to inundation hazards and shoreline erosion.

Figure 4-38 shows the location of cultural resources in Planning Reach VI_2. Additional information is included within the Tier 2 Cultural Resources Appendix.

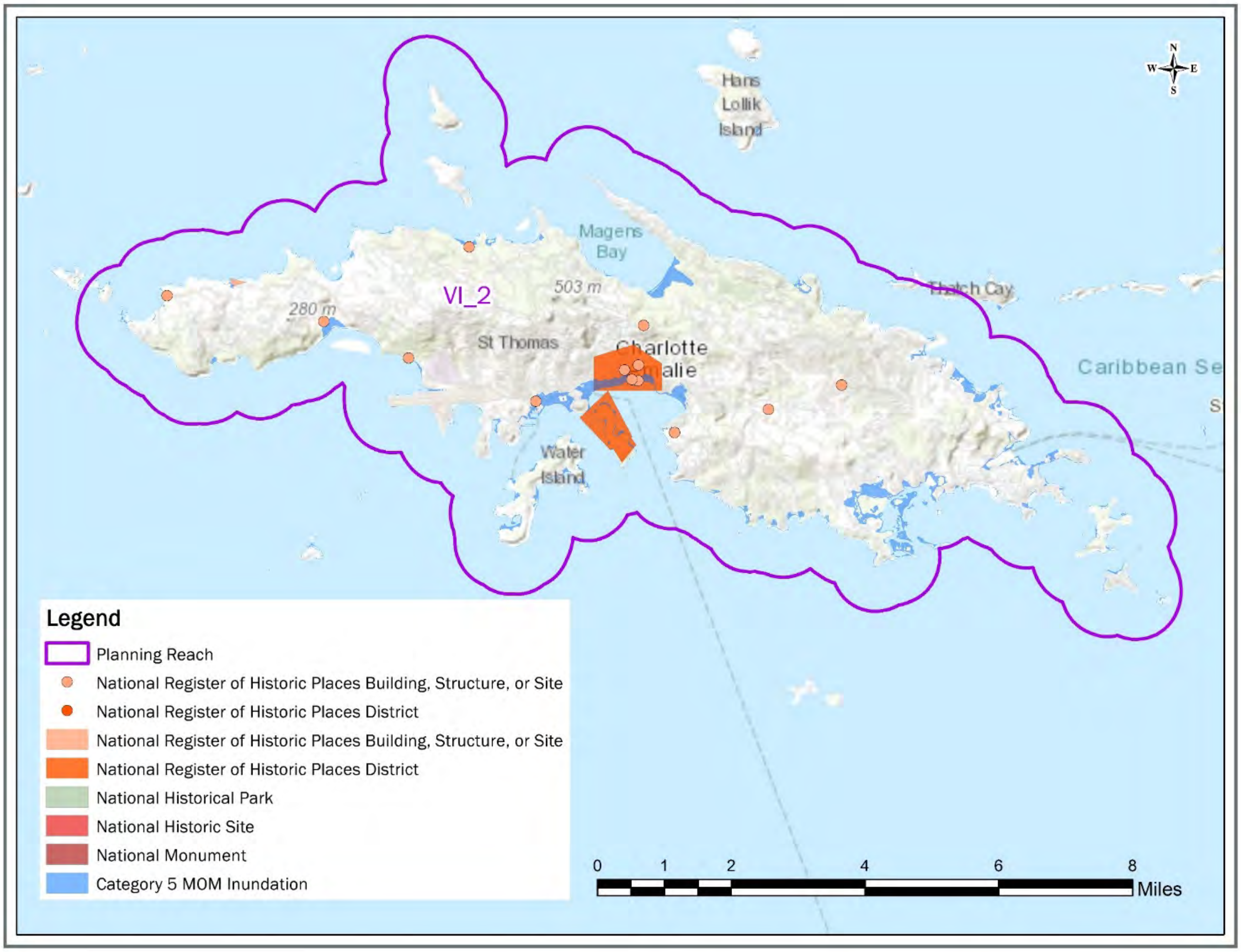


Figure 4-38: Cultural Resources in Planning Reach VI_2 (NPS 2014)

Social Vulnerability

As part of the Tier 2 analysis, 2010 Census data was used to examine social vulnerability for Planning Reach VI_2. **Table 4-11** displays factors that can contribute to social vulnerability, including percent of population under age 5, over age 65, with income below poverty level, without access to vehicle, and unemployment rate for the planning reach.

Table 4-11: 2010 Census Social Vulnerability Factors for Planning Reach VI_2 (U.S. Census 2011)

Planning Reach	Under Age 5	Over Age 65	Income Below Poverty Level	Occupied Households Without a Vehicle	Unemployment Rate
VI_2	6.8%	13.2%	19.2%	23.2%	5.3%

Figure 4-39 displays the NOAA and TNC Social Sensitivity Index based on data from the 2010 Census (Schill et al. 2014). Estate Contant (within Charlotte Amalie West), Estate Demarara (within Charlotte Amalie), Estate Kings Quarter (within Charlotte Amalie), Estate Thomas, and Estate Annas Retreat have the highest social sensitivity within the planning reach with index scores above 36.165700.

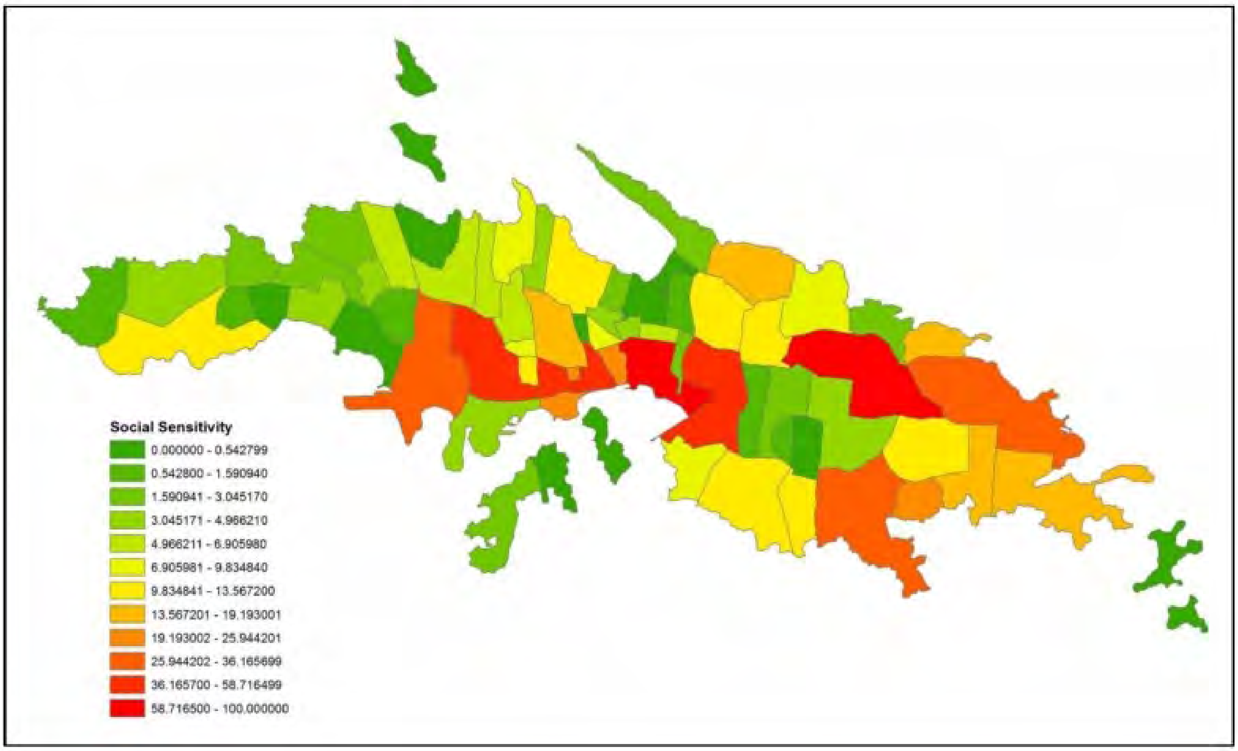


Figure 4-39: National Oceanic and Atmospheric Administration and The Nature Conservancy Social Sensitivity Index for Planning Reach VI_2 (Schill et al. 2014)

Figure 4-40 displays social vulnerability data from the CREST overlain with the Category 5 MOM inundation extent to evaluate socially vulnerable populations subject to inundation (Dobson et al. 2020).

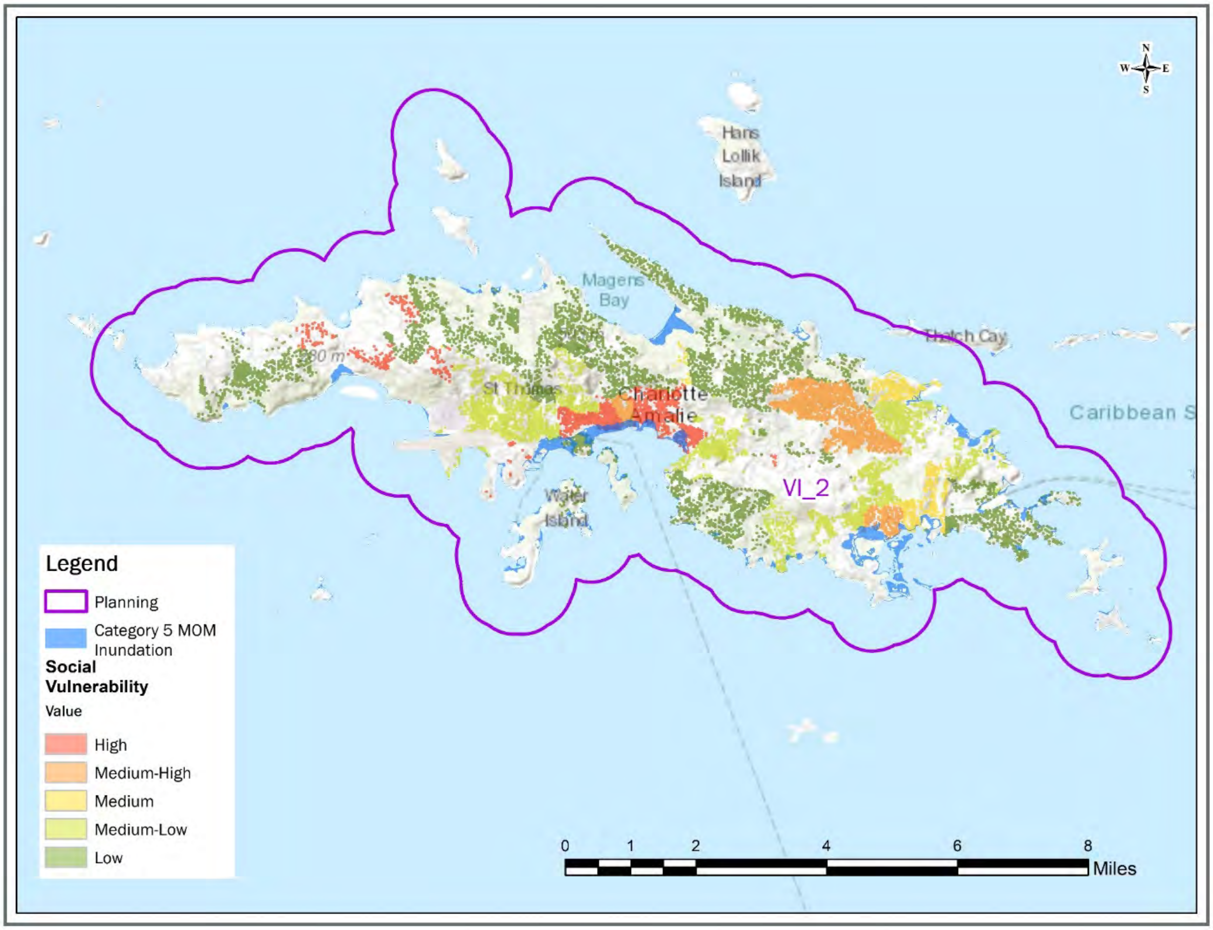


Figure 4-40: Coastal Resilience Evaluation and Siting Tool Socially Vulnerable Populations Subject to Inundation from Category 5 Maximum of Maximum for Planning Reach VI_2 (Dobson et al. 2020).

4.3.2.3 Planning Reach VI_2 Tier 2 Vulnerability

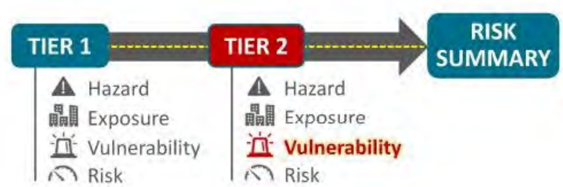


Figure 4-41 shows the environmental vulnerability in areas impacted by inundation from the Category 5 MOM event. Areas around Magens Bay, Mangrove Lagoon, Smith Bay, and Perseverance Bay are shown as the most vulnerable and environmentally sensitive locations, particularly palustrine forested wetlands, unconsolidated shores, and deciduous forests. Additional information on the methodology and findings of the Tier 2 environmental resources analysis is included within the Environmental Technical Report (USACE 2021b).

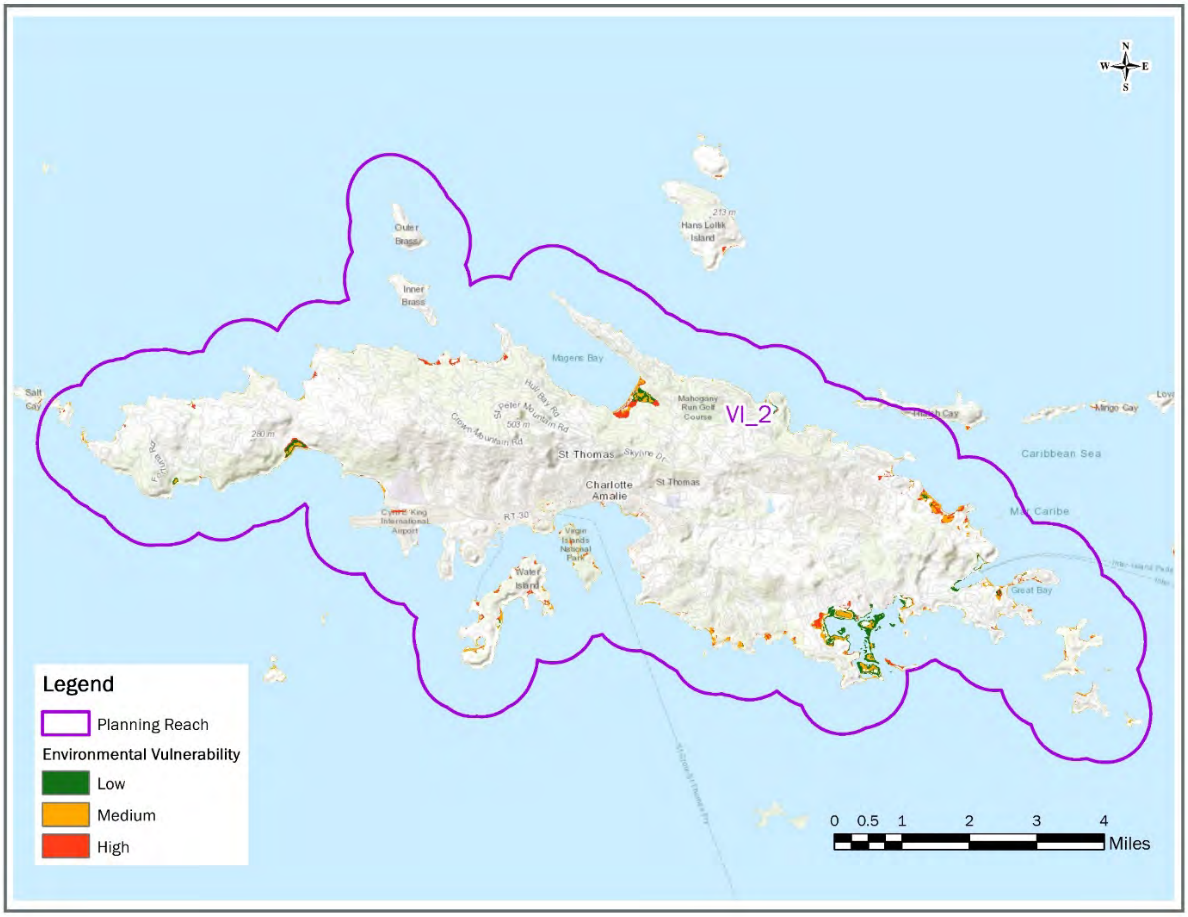


Figure 4-41: Environmental Vulnerability for Planning Reach VI_2 (USACE 2021b)

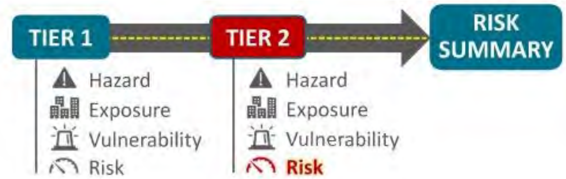
Cultural resource vulnerability was measured through qualitative assessment based on degree of exposure to coastal hazards and sea level rise, structural considerations, and the nature of the cultural resource. **Table 4-12** presents exposed cultural resources and the potential vulnerability to Tier 2 hazards. This is not an all-inclusive list.

Table 4-12: Planning Reach VI_2 Vulnerability of Exposed Cultural Resources to Tier 2 Hazards

Census Place/Estate	Exposed Cultural Resources	Tier 2 Hazards		
		Storm Surge Inundation	Erosion	Wave Attack
Estate Demarara; Estate Queens Quarter; Estate Kings Quarter	Charlotte Amalie Historic District	Y	N	Y
Estate Hassel Island	Hassel Island Historic District	Y	N	Y
Estate Bordeaux	Bordeaux (Plantation)	Y	Y	Y
Charlotte Amalie West; Estate Niesky	Estate Niesky (Plantation)	Y	N	N
Estate Magens Bay	Magens Bay Archeological District	Y	N	Y
Estate John Brewers Bay	Estate Brewers Bay (Plantation)	Y	N	Y

Within Planning Reach VI_2, historic districts, structures, and archeological sites are vulnerable to inundation, erosion, and wave attack. Storm surge inundation can flood historic properties and damage buildings, such as those located within the Charlotte Amalie Historic District. Damage may include structural damage and destruction of historic materials. Ruins and archeological sites at Estate Brewers Bay and within the Magens Bay Archeological District are vulnerable to damage and/or loss from inundation and wave attack.

4.3.2.4 Planning Reach VI_2 Tier 2 High-Risk Locations



The high-risk locations were determined from multiple evaluations of the data presented in the Hazard, Exposure, and Vulnerability sections. No single data set criterion was used to define what is high risk; rather, an integration of all the factors was used to assess the combined effect to determine the areas of highest risk in each planning reach.

Figure 4-42 displays the EAD in dollars by census block based on the FAST model analysis for existing and future conditions for Planning Reach VI_2. Charlotte Amalie and Red Hook have the highest current modeled EAD. Charlotte Amalie is expected to experience the largest increase in EAD as a result of sea level rise, with $838,000 additional expected damages.

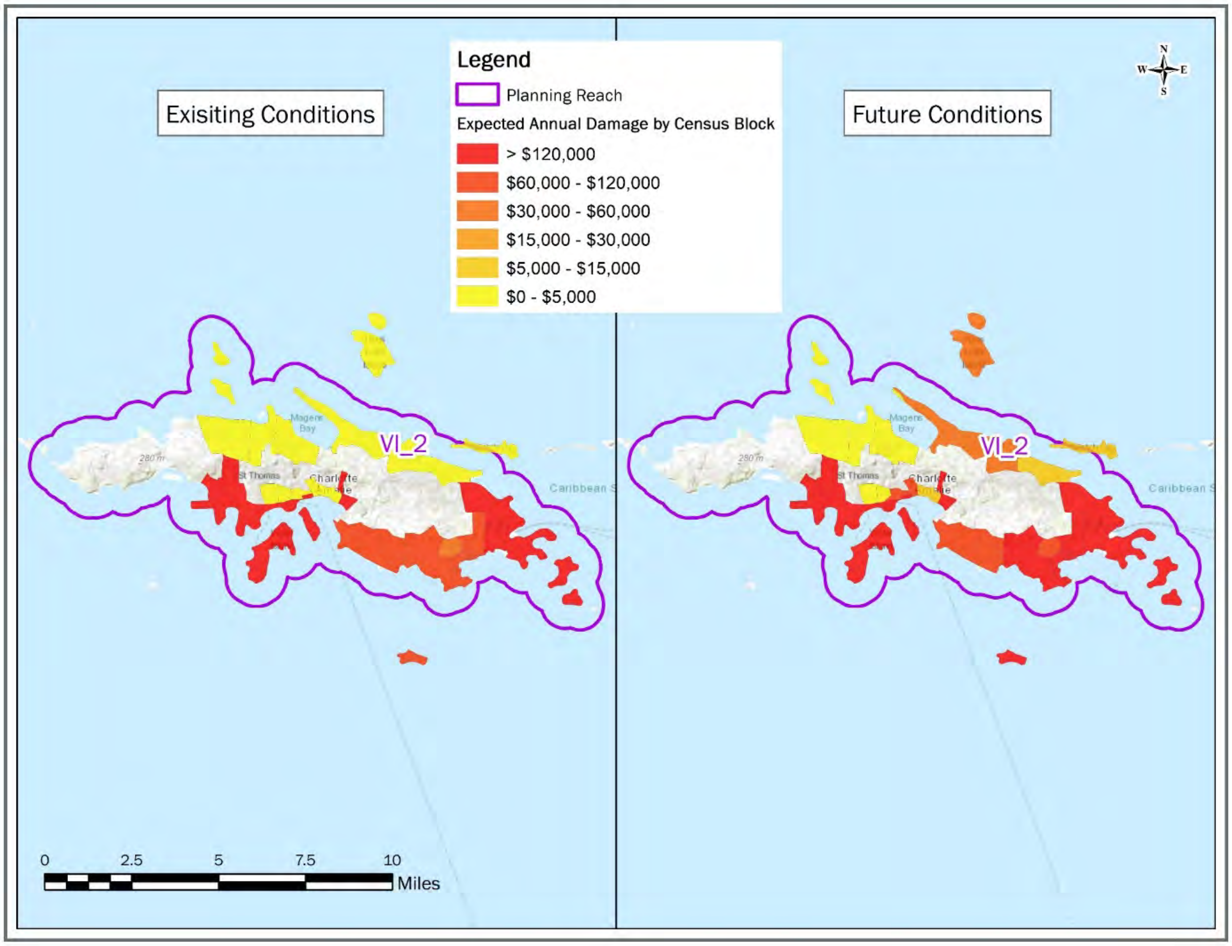


Figure 4-42: Modeled Expected Annual Infrastructure Damages for Planning Reach VI_2

The environmental risk areas for Planning Reach VI_2 are shown in **Figure 4-43** and summarized in **Table 4-13**. The Tier 2 environmental resources risk analysis was limited to the NOAA C-CAP classifications within the Category 5 MOM footprint. A detailed description of the Tier 2 environmental resources risk analysis is located in the Environmental Technical Report (USACE 2021b).

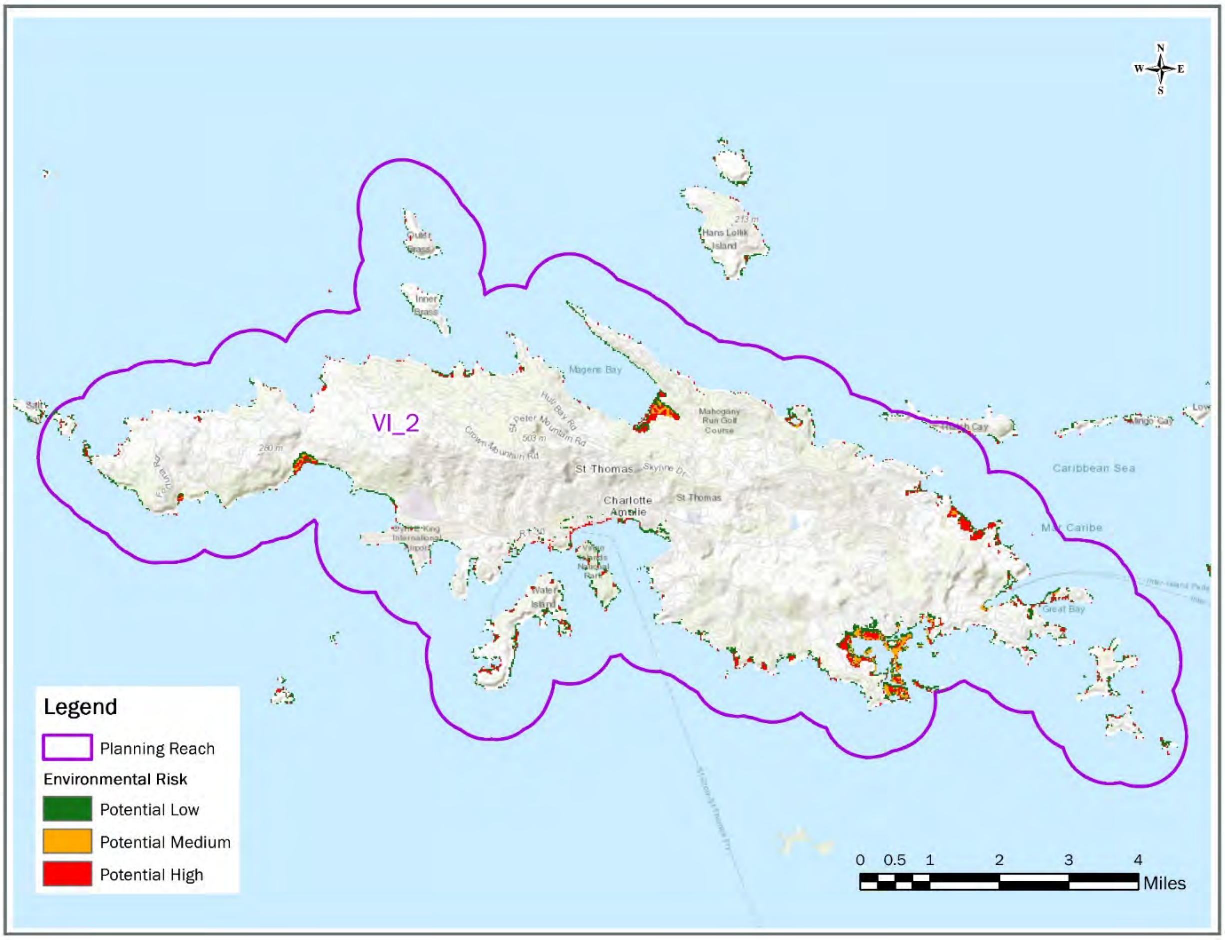


Figure 4-43: Tier 2 Environmental Resources Risk for Planning Reach VI_2 (USACE 2021b)

For Planning Reach VI_2, the largest high-risk environmental areas, also designated as PEAs, include Magens Bay, Smith Bay, Mangrove Lagoon, and Perseverance Bay as shown in **Figure 4-44**.

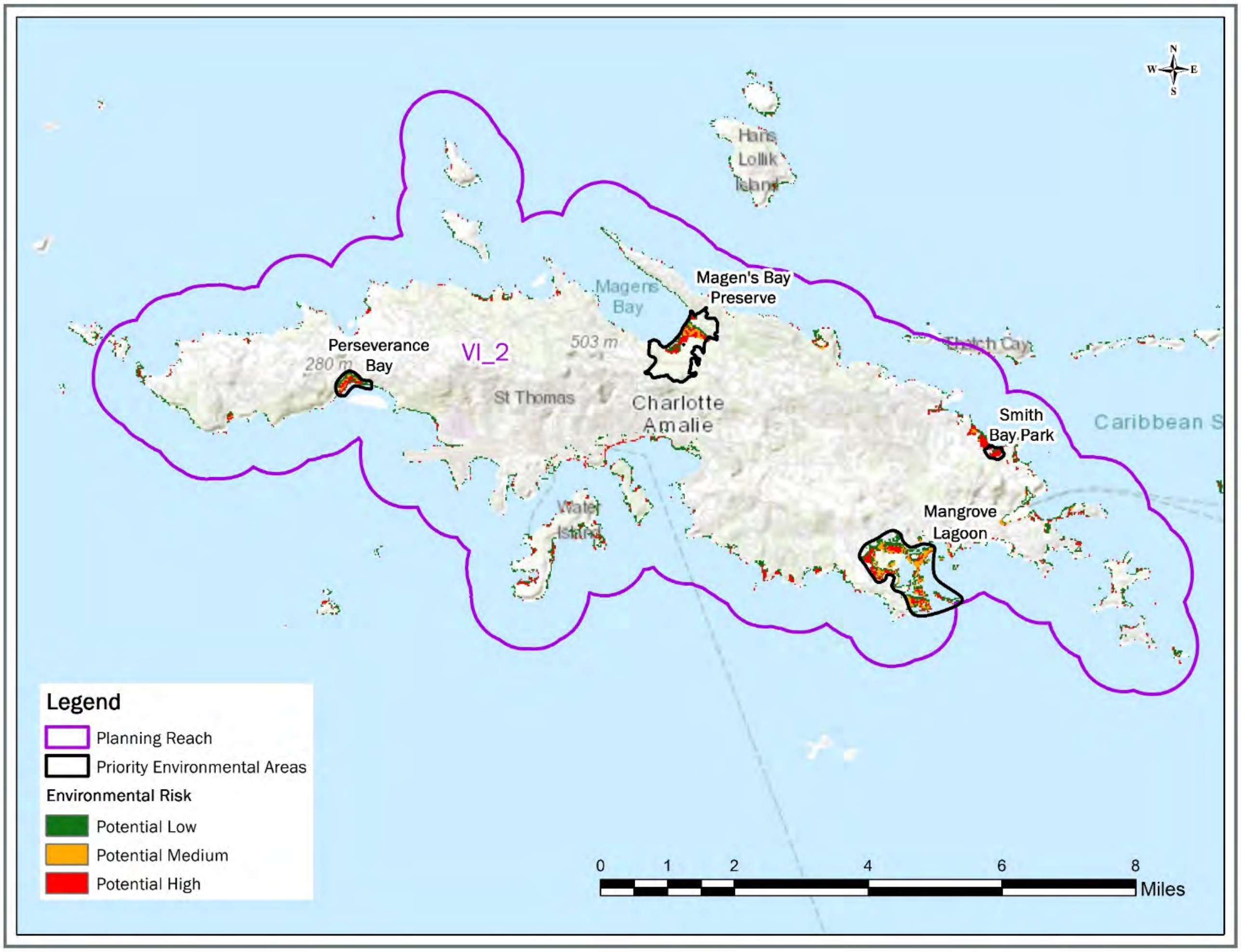


Figure 4-44: Priority Environmental Areas for VI_2

More information on the methodology used and a detailed description of each PEA is located in the Environmental Technical Report (USACE 2021b).

Additional environmental risks to Planning Reach VI_2 include those to coral reefs and SAV. These resources are not represented by the NOAA C-CAP classifications; however, they are susceptible to sea level rise, storm surge inundation, and wave damage. Risk to corals reefs and SAV is addressed in the Environmental Technical Report (USACE 2021b).

Risks to cultural resources were determined using the NRHP, relevant literature, and best professional judgment by reviewing the hazards of erosion, wave attack, and inundation. Census places and census estates in Planning Reach VI_2 with cultural resources within the Category 5 MOM layer extent were identified in **Table 4-13**, along with additional cultural resources that are at risk from wave attack and erosion.

Based on the qualitative risk assessment within the reach, historic districts, structures, and archeological sites are at risk of inundation, erosion, and wave attack. Historic districts and structures are at risk of foundational impacts as waters intrude. Without prevention or protection, these impacts can quickly lead to instability and, where impacts do not directly cause destruction, may necessitate demolition where public safety becomes a concern. Repairs and reactive measures are available but could be cost prohibitive.

Damage to archaeological sites, such as those located within the Magens Bay Archeological District, can be even more harmful. There are no reconstructive measures that can be taken for these sites. Once they are lost, the areas can no longer be studied to understand the past.

4.3.3 Planning Reach VI_2 Summary and High-Risk Locations

High-risk locations were determined from the data presented in the aforementioned hazard, exposure, and vulnerability sections. An overall risk score was not assigned to each location. Instead, the combined effect of all factors was qualitatively evaluated to determine the areas of highest risk.

Charlotte Amalie and its surrounding area, as well as the southwest portion of St. Thomas, were identified as high and medium-high exposure, respectively. These areas contain dense populations, critical island infrastructure, numerous historic structures, and two NRHP districts. Many of these resources are susceptible to coastal erosion and storm damage—and sea level rise is increasing the threat to these resources. Charlotte Amalie and Red Hook have the highest EAD, and Charlotte Amalie is expected to experience the largest increase to EAD as a result of sea level rise. The largest high-risk environmental areas in this planning reach include Magens Bay, Smith Bay, Mangrove Lagoon, and Perseverance Bay.

Table 4-13 displays the Planning Reach VI_2 high-risk locations identified through the Tier 1 and Tier 2 analyses. The table includes information on EAD, erosion risks, risks of increases in wave height, environmental risks, and locations where cultural resources are potentially at risk within each census place or census estate. The table highlights the estimated annualized inundation dollar damages for existing and future conditions and ranks them from low to high risk. These rankings were determined by USACE economists specifically for the U.S. Virgin Islands and are shown in **Table 4-8**.

Table 4-15 depicts if there is a significant increase in damages between the Tier 1 and Tier 2 analyses. The presence of high-risk environmental areas within each census place or estate, as well as the presence of PEAs and cultural resources, are highlighted in **Table 4-15**. Areas with medium-high or high historical erosion rates are identified in **Table 4-13**. Areas of historical erosion rates greater than -0.75 to -1.0 meters per year (2.5 feet per year) were noted as medium-high erosion risk, and areas with historical erosion rates greater than 1 meter per year (3.3 feet per year) were noted as high erosion risk. Modeled wave height increases of greater than 0.5 meters (1.6 feet) for the 1-percent AEP with sea level rise were considered significant and are noted in **Table 4-13**. Social vulnerability was considered high if the estate scored above 36.165700 in the Social Sensitivity Index.

Charlotte Amalie and Charlotte Amalie West were identified as future risk locations in the Tier 1 analysis, have high current and future EAD, have high erosion risk, contain areas of high environmental risk, have at-risk cultural resources, and are socially vulnerable areas. Charlotte Amalie West is also expected to experience an increase in future wave attack. These two locations together were selected as a combined focus area in the SACS.

Estate Nazareth has high potential for infrastructure damages, as well as high erosion risk, potential for increased wave attack with sea level rise, and the presence of high-risk environmental areas.

Estate Smith Bay has high potential for infrastructure damages, potential increase in future wave attack, high environmental risk, and includes a PEA.

Red Hook has high potential for infrastructure damages and increased future wave attack and contains areas of high environmental risk.

Table 4-13: Summary of Tier 1 and Tier 2 Risk by Census Place and Census Estate for Planning Reach VI_2.

Planning Reach VI_2	Tier 1		Tier 2											
	Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)						At Risk Cultural Resources		At Risk Environmental Resources			
Census Place/Census Estate	Identified as Existing High Risk Location	Identified as Future High Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Tier 2 Historical Erosion Risk	Tier 2 Significant Increase in Future Wave Attack (>0.5 meters)	Identified as Area with Cultural Resource At Risk	Cultural Resource Name	Identified as Area with PEA of Resource At Risk	Tier 2 Environmental High Risk (acres)	Environmental Resource Name	Tier 2 Socially Vulnerable Areas
Charlotte Amalie		X	$428,000	High	$1,266,000	High	High		X	Charlotte Amalie Historic District	X	12.09		X
Charlotte Amalie West		X	$177,000	High	$485,000	High	High	X	X	Estate Niesky	X	7.19		X
Estate Anna's Retreat														X
Estate Bakkero			$6,000	Med	$9,000	Med					X	1.45		
Estate Bolongo			$18,000	Med-High	$28,000	Med-High					X	0.22		
Estate Bonne Esperance											X	0.52	Perseverance Bay	
Estate Bonne Resolution											X	3.20		
Estate Bordeaux									X	Bordeaux	X	0.52		
Estate Bovoni			$24,000	Med-High	$31,000	Med-High					X	28.90	Mangrove Lagoon	
Estate Canaan and Sherpenjewel											X	0.16	Magens Bay	
Estate Caret Bay			$0	Low	$2,000	Low-Med					X	0.77		
Estate Demarara									X	Charlotte Amalie Historic District	X	2.13		X
Estate Dorothea			$0	Low	$2,000	Low-Med		X			X	2.63		
Estate Eastern Water Island			$111,000	High	$121,000	High	High				X	8.43		
Estate Fortuna											X	3.81		
Estate Frenchman Bay			$39,000	Med-High	$39,000	Med-High					X	11.44		
Estate Frydendal			$0	Low	$6,000	Med		X			X	3.00		
Estate Frydenhoj			$120,000	High	$621,000	High					X	7.30		
Estate Great St. James Island								X			X	6.18		
Estate Hassel Island			$25,000	Med-High	$32,000	Med-High			X	Hassel Island Historic District	X	5.42		
Estate Herleins Kob											X	4.45	Magens Bay	
Estate Hope											X	1.35		
Estate Hull			$3,000	Low-Med	$4,000	Low-Med					X	2.97		
Estate Inner Brass Island								X			X	0.25		
Estate John Brewers Bay									X	Estate Brewers Bay	X	1.30		
Estate Kings Quarter			$20,000	Med-High	$22,000	Med-High			X	Charlotte Amalie Historic District	X	2.60		X
Estate Lerkenlund			$0	Low	$0	Low					X	0.88		
Estate Little St. James Island								X			X	3.11		
Estate Little St. Thomas											X	5.26		
Estate Lovenlund											X	1.23		

Planning Reach VI_2	Tier 1		Tier 2											
	Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)						At Risk Cultural Resources		At Risk Environmental Resources			
Census Place/Census Estate	Identified as Existing High Risk Location	Identified as Future High Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Tier 2 Historical Erosion Risk	Tier 2 Significant Increase in Future Wave Attack (>0.5 meters)	Identified as Area with Cultural Resource At Risk	Cultural Resource Name	Identified as Area with PEA of Resource At Risk	Tier 2 Environmental High Risk (acres)	Environmental Resource Name	Tier 2 Socially Vulnerable Areas
Estate Magens Bay			$4,000	Low-Med	$34,000	Med-High			X	Magens Bay Archeological District	X	20.91	Magens Bay	
Estate Mandal											X	5.67		
Estate Nadir			$56,000	High	$87,000	High					X	11.24	Mangrove Lagoon	
Estate Nazareth			$132,000	High	$299,000	High	High	X			X	18.43		
Estate Neltjeberg								X			X	3.61		
Estate Niesky			$0	Low	$11,000	Med	High	X	X	Estate Niesky	X	3.15		
Estate Outer Brass Island											X	1.68		
Estate Perseverance											X	8.13	Perseverance Bay	
Estate Peterborg			$0	Low	$1,000	Low					X	4.58	Magens Bay	
Estate Queens Quarter									X	Charlotte Amalie Historic District	X	0.66		
Estate Santa Maria											X	0.86		
Estate Smith Bay			$13,000	Med	$60,000	High	High	X			X	45.73	Smith Bay	
Estate Sorgenfri											X	3.65		
Estate Tabor and Harmony											X	0.80		
Estate Western Water Island			$44,000	Med-High	$45,000	Med-High		X			X	15.51		
Estate Zufriedenheit											X	5.35	Magens Bay	
Red Hook	X	X	$341,000	High	$553,000	High		X			X	7.78		

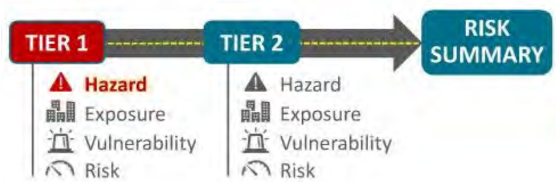
Note: Yellow highlight represents locations designated as high risk for entire territory.

4.4 Planning Reach VI_3 (St. John) Risk Assessment

Planning Reach VI_3 contains the island of St. John, as shown in **Figure 3-2**. St. John is located to the east of St. Thomas and north of St. Croix. Two-thirds of the island is designated as a national park. Planning Reach VI_3 features narrow, sandy beaches and steep mountainous terrain. Cruz Bay, located on the western side of the island, is the most populated area with restaurants, shops, and access to the ferry to St. Thomas. The following sections walk through the Risk Assessment for Planning Reach VI_3. Various datasets are also available via the SACS Geoportal.

4.4.1 Planning Reach VI_3 (St. John) Tier 1

4.4.1.1 Planning Reach VI_3 Tier 1 Hazard



A description of the Tier 1 hazards is included in Section 4.1.1 and in the Main Report. **Figure 4-45** displays both existing and future flood hazards for St. John, U.S. Virgin Islands (Planning Reach VI_3). The 1-percent AEP water level is identified as a flood hazard to the bay areas around the island, such as Cruz Bay, Fish Bay, Coral Harbor, and Maho Bay. Chocolate Hole and portions of Fish Bay, Europa Bay, and Leinster Bay are also subject to flooding from the 10-percent AEP flood events under current conditions. Under future conditions, these areas show an increased flood hazard for the 10-percent AEP flood event.

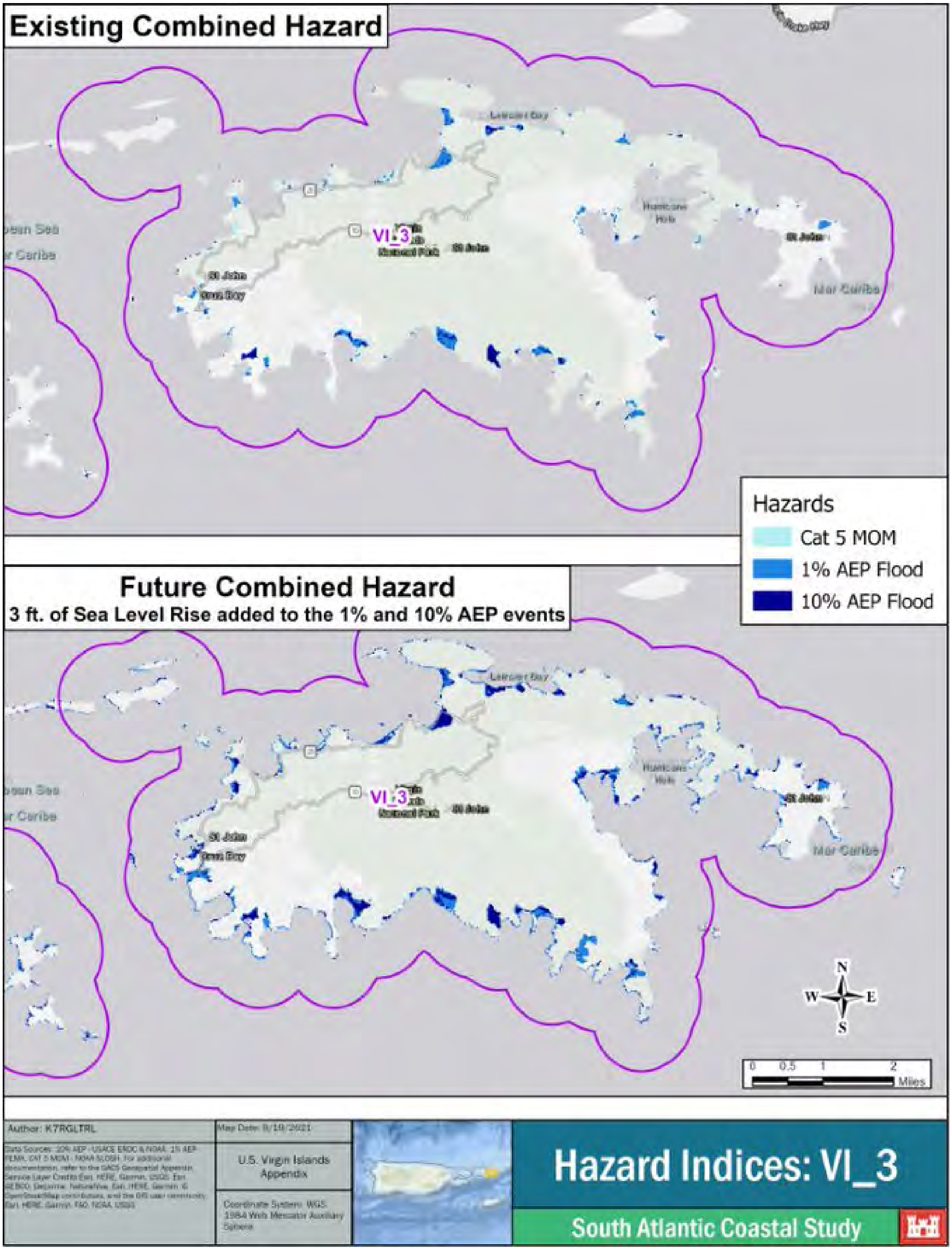
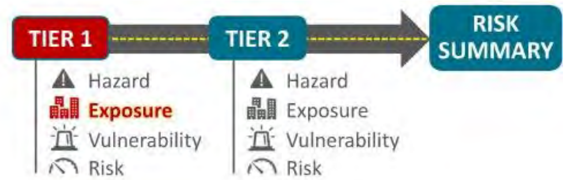


Figure 4-45: Existing and Future Flood Hazards for Planning Reach VI_3 from the 10-Percent Annual Exceedance Probability Flood, the 1-Percent Annual Exceedance Probability Flood, and the Category 5 Maximum of Maximum Water Levels

4.4.1.2 Planning Reach VI_3 Tier 1 Exposure



Planning Reach VI_3 encompasses the island of St. John and includes the subdistricts of Cruz Bay, Coral Bay, Central, and East End. **Figure 4-46** shows the three individual Tier 1 exposure indices as well as the CEI, composed of 65-percent population and infrastructure exposure, and 35-percent environmental, cultural, and habitat exposure. Social vulnerability exposure data were not available for this planning reach. Areas colored red and amber indicate higher densities of populations, infrastructure, environmental and cultural resources, and habitat.

Population and Infrastructure

Based on the population and infrastructure exposure analysis, Cruz Bay was identified as an area with a large population and critical infrastructure. Along the southeast corner of the island, an area of medium-high exposure was identified near Johnson Bay. Areas around Coral Harbor were also identified as medium exposure. The rest of the island consists largely of Virgin Island National Park, where population and infrastructure are minimal.

Environmental and Cultural Resources

As shown in **Figure 4-46**, results of this analysis show that this planning reach contains several areas of high (orange and red) environmental and cultural resources exposure, including Fish Bay, Reef Bay, Great and Little Lameshur Bays, Europa Bay, Salt Pond Bay, east of Coral Harbor, Brown Bay, Leinster Bay, Maho Bay, Cinnamon Bay, and Hawknest Bay. These areas include important environmental and cultural resources. Predominant coastal resources within Planning Reach VI_3 include mangroves, seagrasses, and multiple species of coral. St. John also contains freshwater forest/shrub and riverine wetlands, as well as 14 coastal barrier resources system areas. Most of the island is designated as the Virgin Islands National Park.

There are many cultural resources located throughout St. John, including historic estates and clusters of archaeological sites documented in areas subject to coastal flood hazard. The NRHP-listed historic districts and archaeological sites are located on or very near the coast, frequently where past inhabitants could access the water on this island with narrow drainages and steep slopes. The same particulars that provide access to water also expose the cultural resources to erosion and storm damage. The Virgin Islands Coral Reef National Monument is also located within this planning reach. The hazards to cultural resources will increase in relation to sea level rise.

Social Vulnerability

The Tier 1 analysis for the U.S. Virgin Islands did not include social vulnerability data. The Tier 1 analysis used the CDC's 2016 Social Vulnerability Index dataset. This dataset does not exist for the U.S. Virgin Islands; therefore, it could not be assessed. Other social vulnerability data will be included for the U.S. Virgin Islands in the Tier 2 analysis.

This page intentionally left blank.

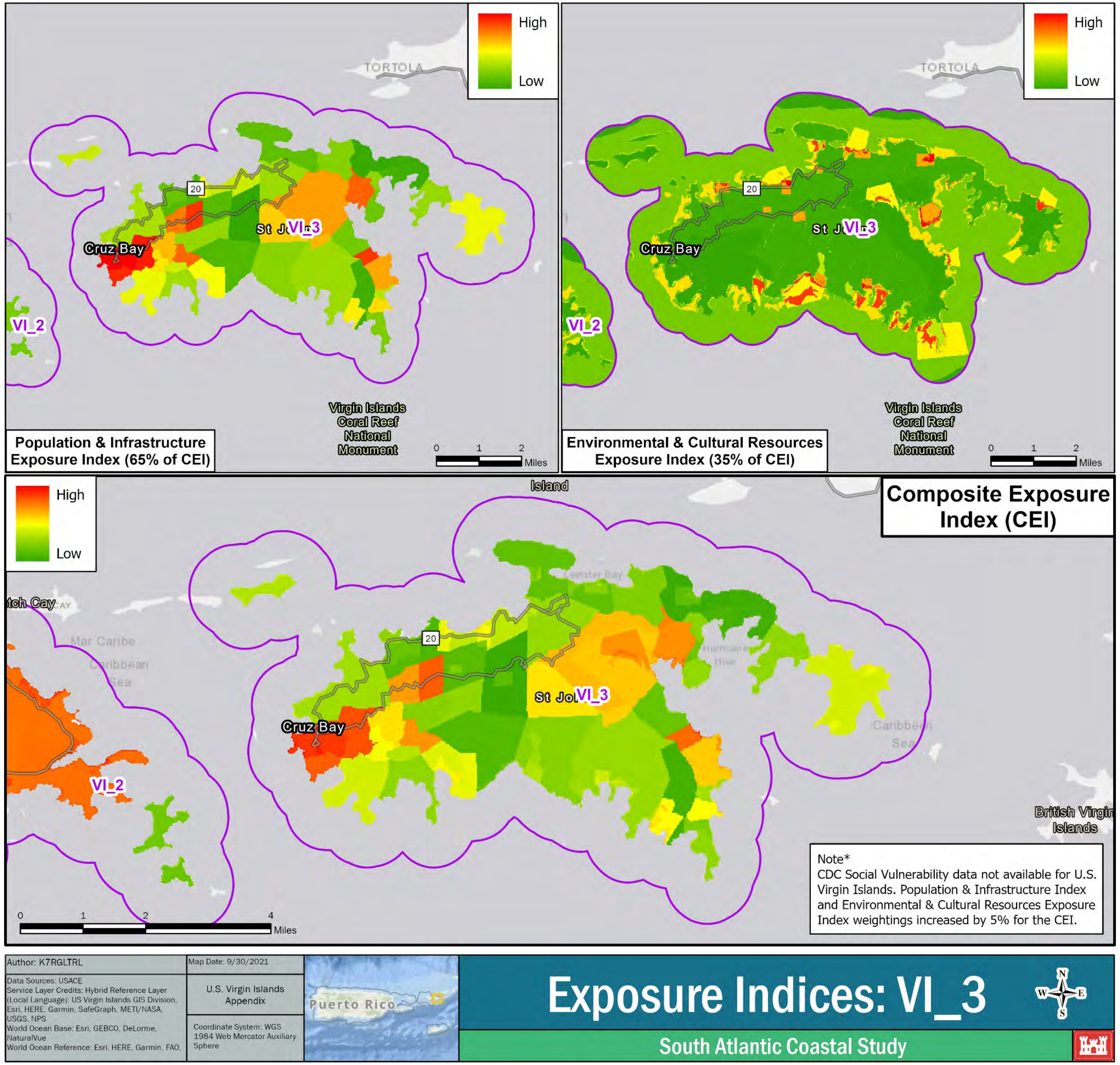
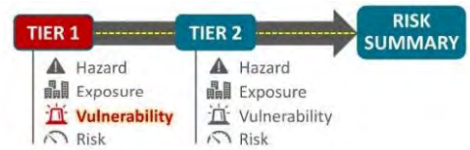


Figure 4-46: Exposure Indices for Planning Reach VI_3

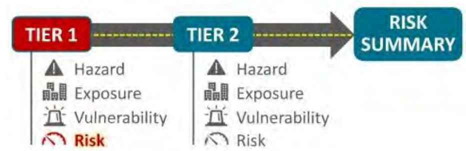
This page intentionally left blank.

4.4.1.3 Planning Reach VI_3 Tier 1 Vulnerability



As stated in Section 4.1.3**,** Tier 1 Vulnerability, if a resource is subject to a hazard it is considered vulnerable in the Tier 1 analysis.

4.4.1.4 Planning Reach VI_3 Tier 1 High-Risk Locations



The CEI and coastal flood inundation hazards were used to identify potential areas at risk. The Framework defines risk as a function of exposure and probability of hazard occurrence. The Geospatial Appendix describes how each of the inundation hazards (Category 5 MOM, 1-percent AEP flood, and 10-percent AEP flood) and sea level rise were combined with the CEI to generate potential risk data presented in the Tier 1 Risk Assessment.

Figure 4-47 displays both current and future potential risk for Planning Reach VI_3. Tier 1 high-risk locations are those where potential medium-high risk (amber) and high (red) composite risk exists. U.S. Census Bureau census places were used to define the boundaries of high-risk locations. Medium-high and/or high composite risk needs to cover at least 5 acres and 0.5 percent of the total area of a census place for it to be considered high-risk in the U.S. Virgin Islands. The Tier 1 high-risk locations for Planning Reach VI_3 are Coral Bay and Cruz Bay.

Much of Planning Reach VI_3, under existing conditions, is classified as potential low risk. A few areas are classified as potential medium-high risk or potential high risk, such as Fish Bay, Coral Harbor, and a few areas near Cruz Bay. Under future conditions, along with sea level rise, many of these areas show increased potential risk. Cruz Bay shows a significant increase as a potential high-risk area.

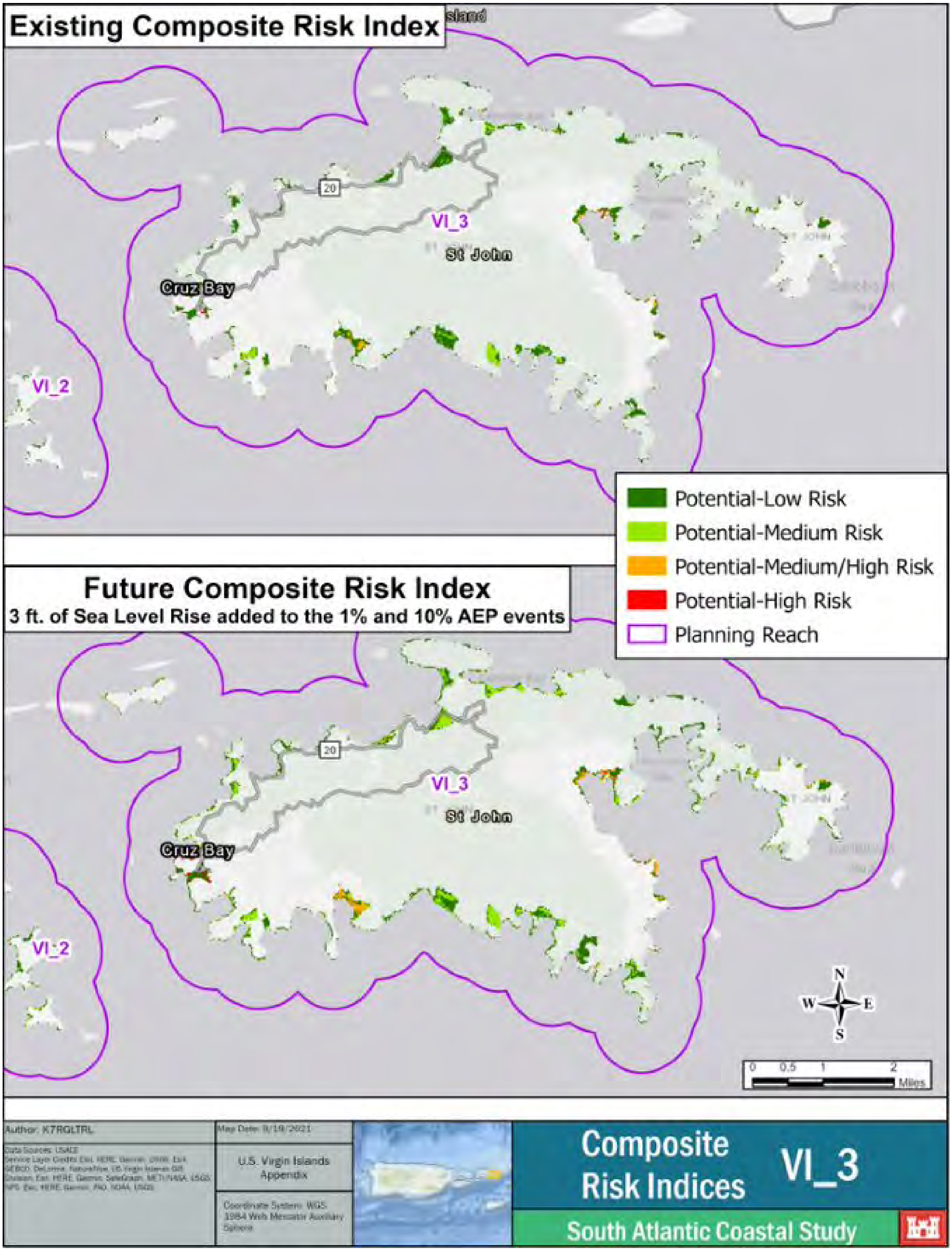


Figure 4-47: Existing Composite Risk Index and Future Composite Risk Index for Planning Reach VI_3

U.S. Census Bureau census places were used to define the boundaries of high-risk locations. Medium-high and/or high composite risk needs to cover at least 5 acres (0.02 square kilometers) and 0.5 percent of the total area of a census place for it to be considered high risk.

Tier 1 high-risk locations for Planning Reach VI_3 are summarized by the acres covered by medium-high and high risk for each census place in **Figure 4-48** and by the percentage of the entire census place area covered by medium-high and high risk acreage in **Figure 4-49.** Coral Bay and Cruz Bay are considered high risk under existing and future conditions. Areas of medium-high and/or high risk in Cruz Bay increases by nearly 25 acres with sea level rise.

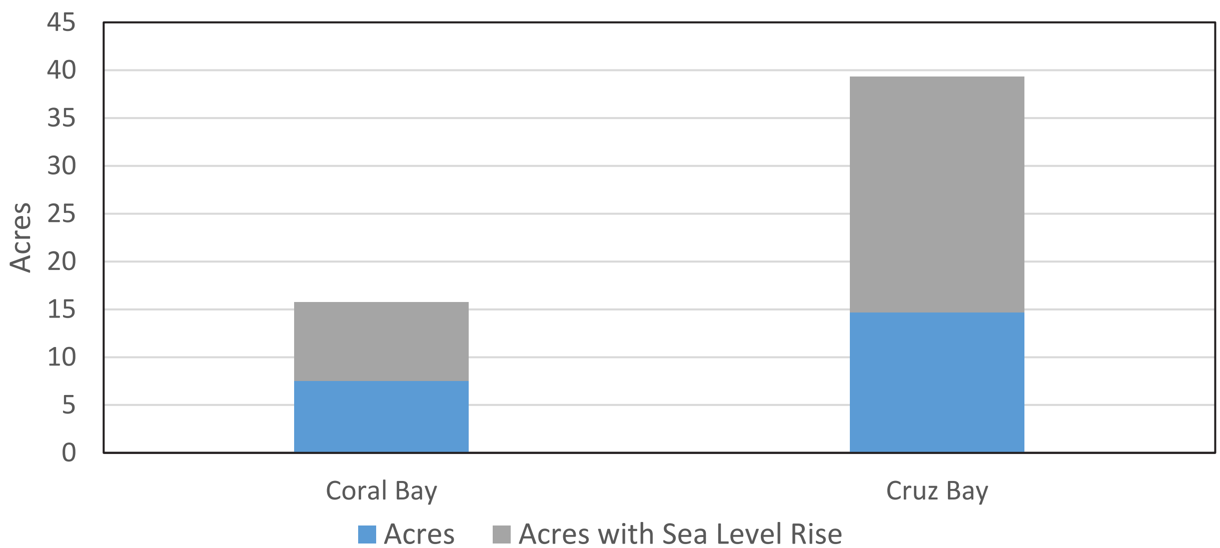


Figure 4-48: Acres of Land Identified as Existing and Future Medium-High and High-Risk per Census Place in VI_3

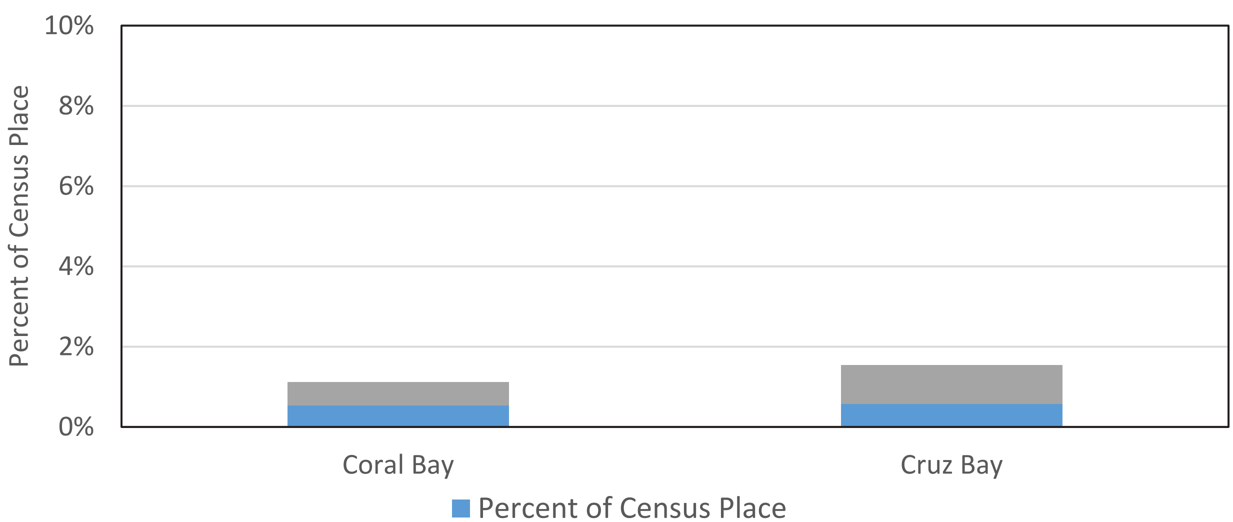
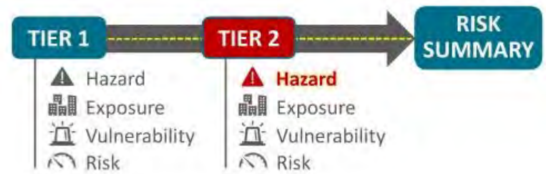


Figure 4-49: Percentage of Entire Census Place Area Covered by Medium-High-Risk and High-Risk Acreage (Existing and Future Conditions)

4.4.2 Planning Reach VI_3 (St. John) Tier 2

The Tier 2 analysis included additional and more localized hazard, vulnerability, and exposure information to refine the Tier 1 Risk Assessment.



4.4.2.1 Planning Reach VI_3 Tier 2 Hazard

This section highlights details of the Tier 2 hazards, or what may cause harm, to the Planning Reach VI_3. An overview of each hazard is presented in Section 4.1.4.

The Tier 2 hazards for Planning Reach VI_3 (St. John) include the following:

Inundation

The Tier 2 analysis considered inundation depths and extent. Inundation depths from the NOAA SLOSH model (Jelesnianski et al. 1992) for a Category 5 MOM hurricane are shown in **Figure 4-50. Table 4-14** shows the CHS maximum inundation depths in Planning Reach VI_3 for the range of AEP storms for both existing and future conditions (USACE 2020b), where future conditions include 2.33 feet (0.71 meters) of sea level rise based on the USACE Intermediate scenario and 6.95 feet (2.12 meters) based on the USACE High scenario. Areas of significant inundation depth include Coral Bay (subject to 6 to 7 feet [1.8 to 2.1 meters] of inundation), Europa Bay (subject to 5 to 6 feet [1.5 to 1.8 meters] of inundation) and Fish Bay (subject to 5 to 6 feet [1.5 to 1.8 meters] of inundation).

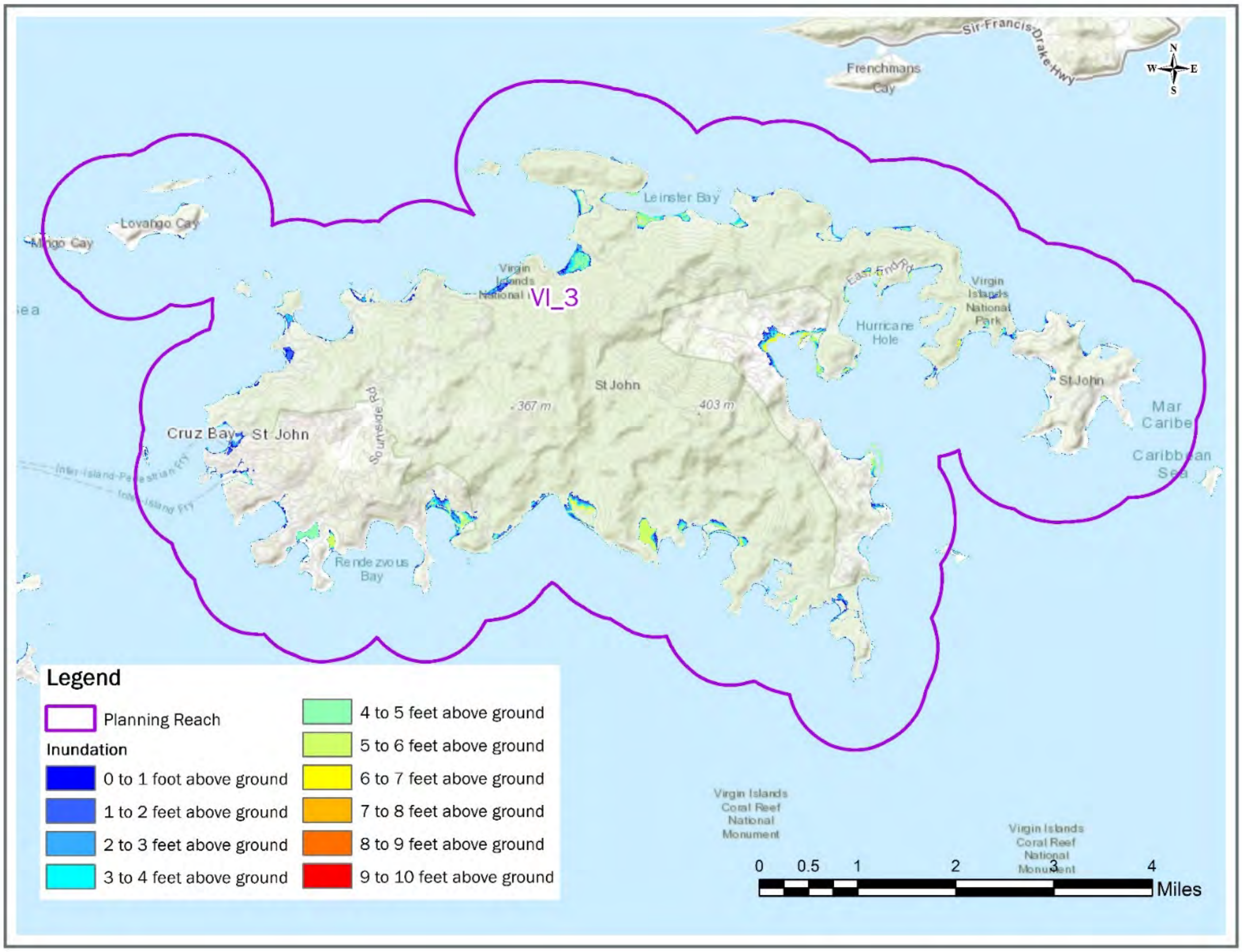


Figure 4-50: Inundation Depth from a Category 5 Maximum of Maximum Storm in Feet Above Ground Based on National Oceanic and Atmospheric Administration's Sea, Lake, and Overland Surges from Hurricanes Model (Jelesnianski et al. 1992) for Planning Reach VI_3

Table 4-14: Coastal Hazards System Maximum Flood Depths for Planning Reach VI_3 (USACE 2020b)

	10% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP
Existing Conditions	8.1 feet (2.5 meters)	8.7 feet (2.6 meters)	9.7 feet (3.0 meters)	10.5 feet (3.2 meters)	12.1 feet (3.7 meters)
Future Conditions	10.4 feet (3.2 meters)	11.0 feet (3.3 meters)	12.0 feet (3.7 meters)	12.78 feet (3.9 meters)	14.4 feet (4.4 meters)

Wave Attack

Wave attack is prominent in St. John, with the highest wave heights occurring along the southern coast. **Figure 4-51** displays the modeled wave heights for a 1-percent AEP event from the CHS (USACE 2020b). CHS modeling demonstrates offshore wave heights of 20 to 26 feet (6 to 8 meters) from the 1-percent AEP event in the northwest corner of the island. Along the shoreline, wave heights drop to

13 to 20 feet (4 to 6 meters) during the 1-percent AEP event. With 2.33 feet (0.71 meters) of sea level rise, wave heights from the 1-percent AEP event were modeled to increase by 0.8 to 1.6 feet (0.25 to 0.5 meters) in many locations around the island (**Figure 4-52**). With 6.95 feet (2.12 meters) of sea level rise, wave heights may increase by over 3.3 feet (1 meter) by 2120.

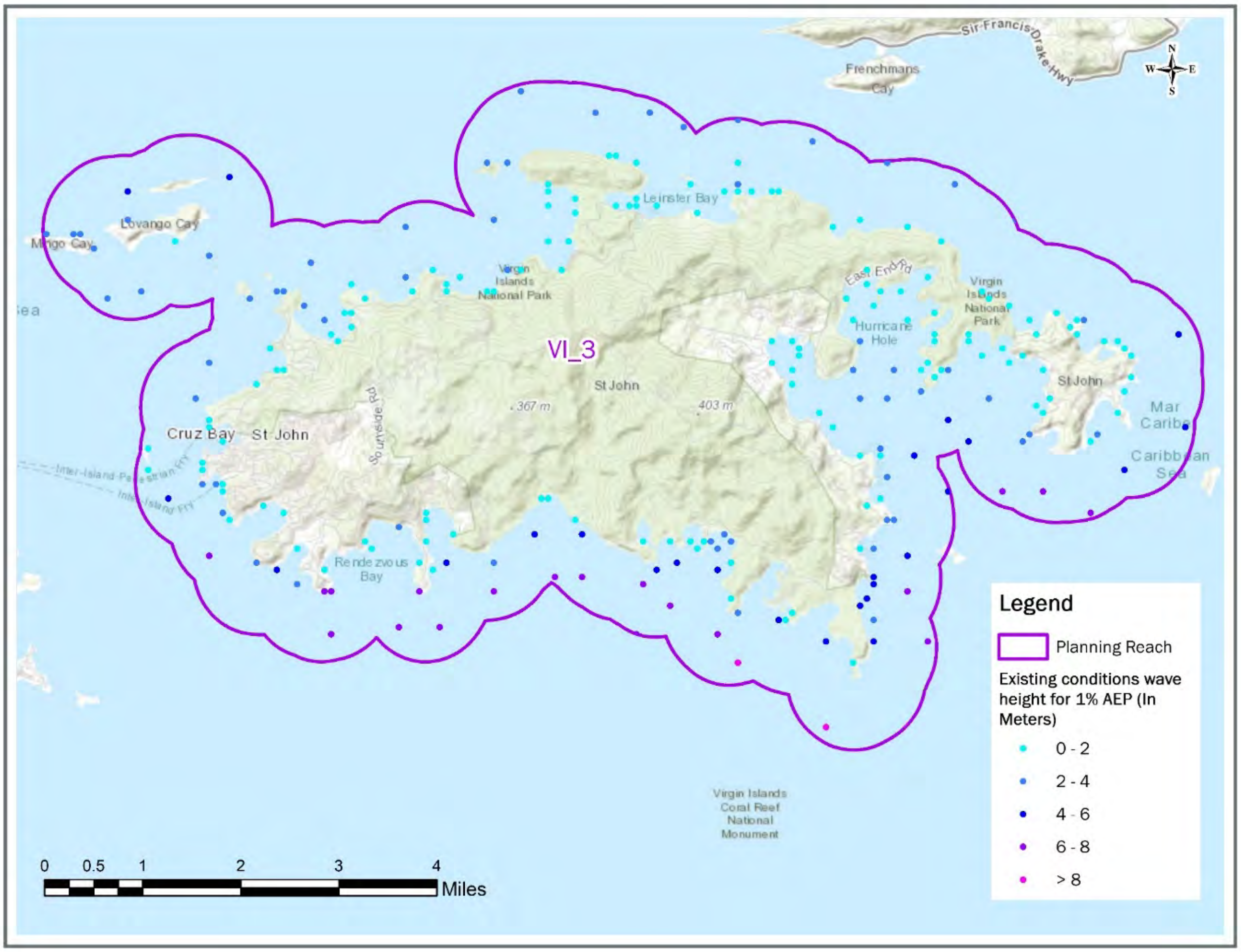


Figure 4-51: Existing Conditions Wave Heights During the 1-Percent Annual Exceedance Probability Event for Planning Reach VI_3 (USACE 2020b)

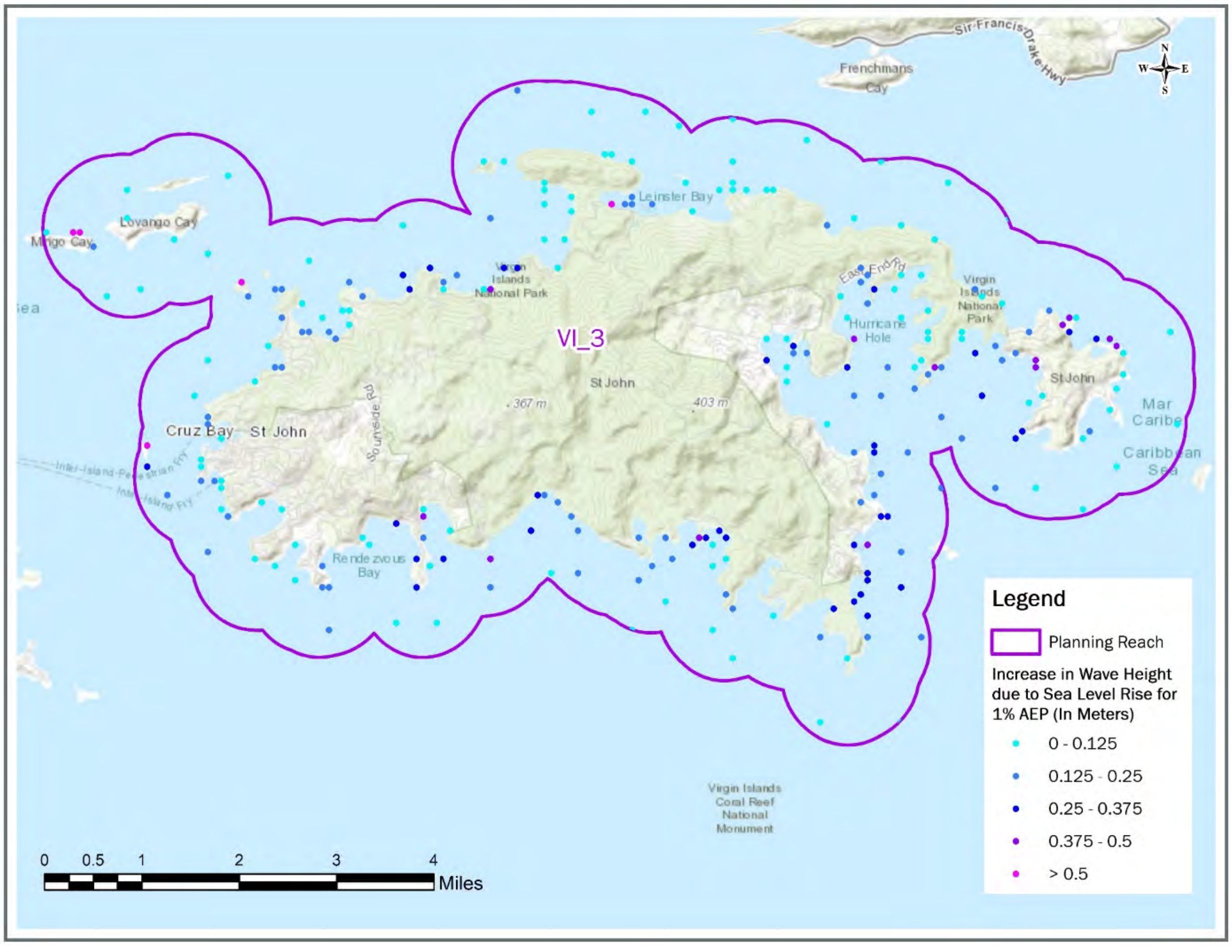


Figure 4-52: Increased Wave Heights for the 1-Percent Annual Exceedance Probability Event for Planning Reach VI_3 with 2.33 Feet of Sea Level Rise (USACE 2020b)

Coastal Erosion

For Planning Reach VI_3, coastal erosion was evaluated within the Virgin Islands National Park using data from a USGS study on coastal vulnerability to sea level rise (Pendleton et al. 2005). Shoreline change rates for most of the National Park are between -1 meter per year and +1 meter per year (-3.3 feet per year and +3.3 feet per year), where negative values represent erosion and positive values represent accretion (**Figure 4-53**). Areas of significant erosion are in Leinster Bay (<-2 meters per year [-6.7 feet per year]) and Coral Bay (between -2 and -1 meters per year [-6.7 feet to -3.3 feet per year]). Coastal erosion data are not available for areas of Planning Reach VI_3 outside of the national park.

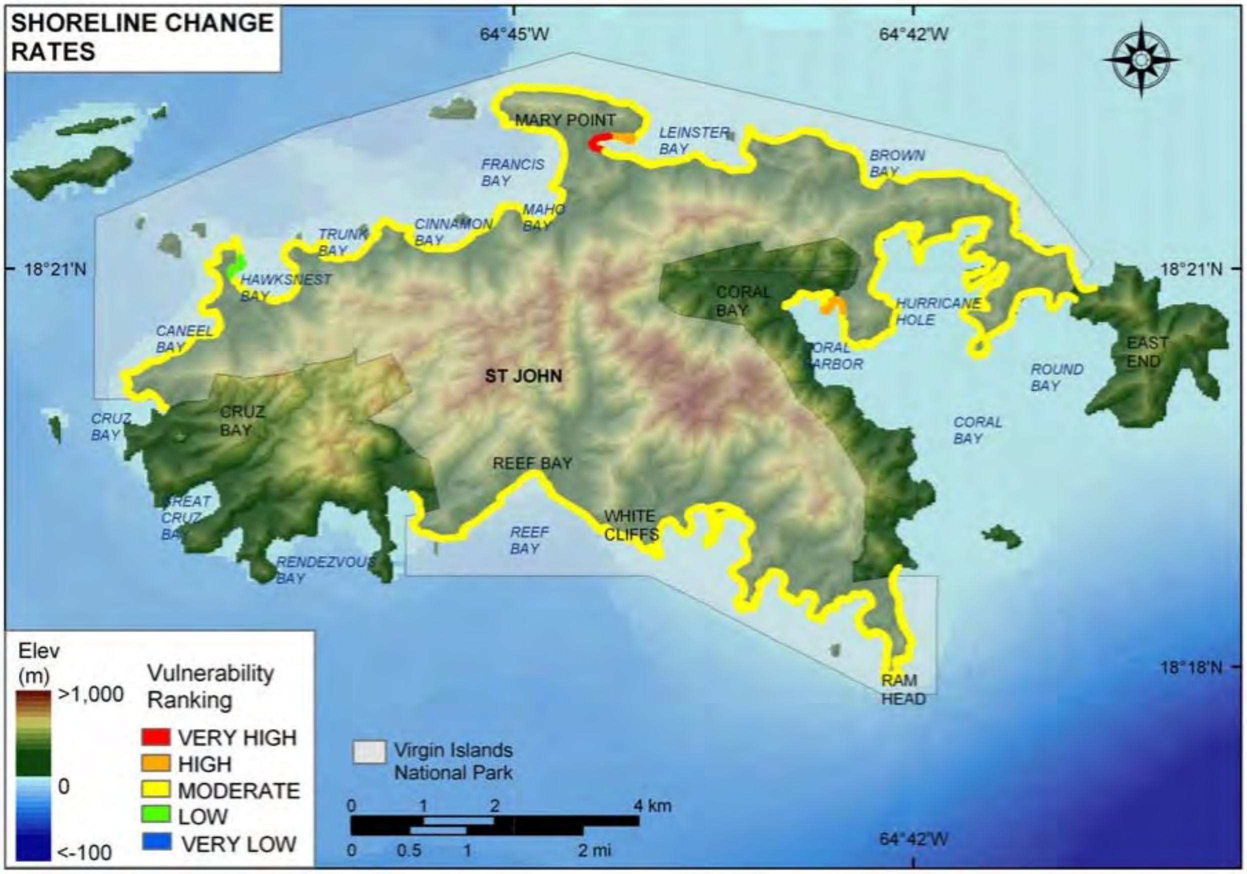


Figure 4-53: Shoreline Change Rates for Planning Reach VI_3 (Pendleton et al. 2005)

Other hazards associated with coastal storms are present for this planning reach but are not considered for this analysis.

Wind

Wind during coastal events can cause devastation across the U.S. Virgin Islands, from direct wind damage to buildings, uprooting trees that take down power lines, or outgrowth of wind waves on top of storm surge.

Compound flooding

Compound flooding is a hazard in Planning Reach VI_3, especially in low-lying areas along the coast and near the island's river mouths. **Figure 4-54** shows an overlay of the NFWF flood-prone areas layer (Dobson et al. 2020) with the Category 5 hurricane SLOSH modeled inundation extent (Jelesnianski et al. 1992). While this is not an analysis of compound flooding, it highlights areas that may experience flooding from riverine or coastal sources, with the potential for compound flooding in areas where the two flooding sources converge. Compound flooding damages may also increase in the future as sea levels rise. Additional studies are needed to better characterize and understand the compound flooding risks.

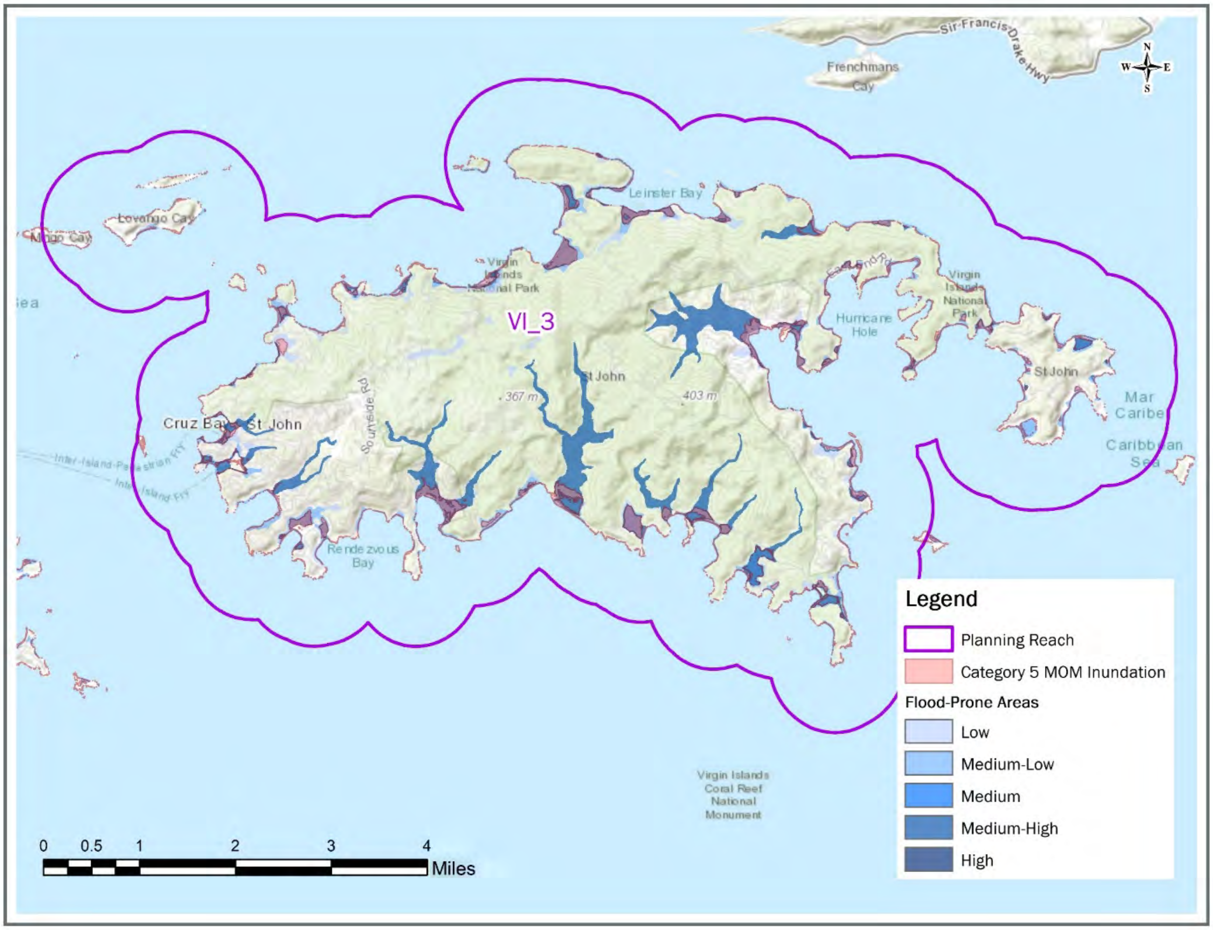
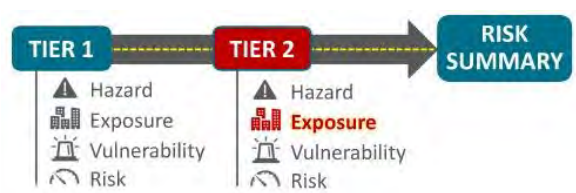


Figure 4-54: Flood-Prone Areas and Category 5 Modeled Inundation for Planning Reach VI_3 (Dobson et al. 2020)

4.4.2.2 Planning Reach VI_3 Tier 2 Exposure

This section highlights details of the Tier 2 exposure—who or what may be in harm's way—for Planning Reach VI_3. An overview of each exposure element is presented in Section 4.1.5 .



Population and Infrastructure

The Tier 2 infrastructure exposure includes the estimate of potential losses (or the estimated exposure value) if infrastructure is flooded. Background information is provided on Tier 2 exposure data sources in Section 4.1.5 . **Figure 4-55** displays infrastructure data from a FEMA GIS point-based structure inventory (FEMA n.d.) that is within the footprint of the Category 5 MOM floodplain. Single-family homes make up the primary source of building exposure within the coastal Category 5 MOM flood extents within Planning Reach VI_3.

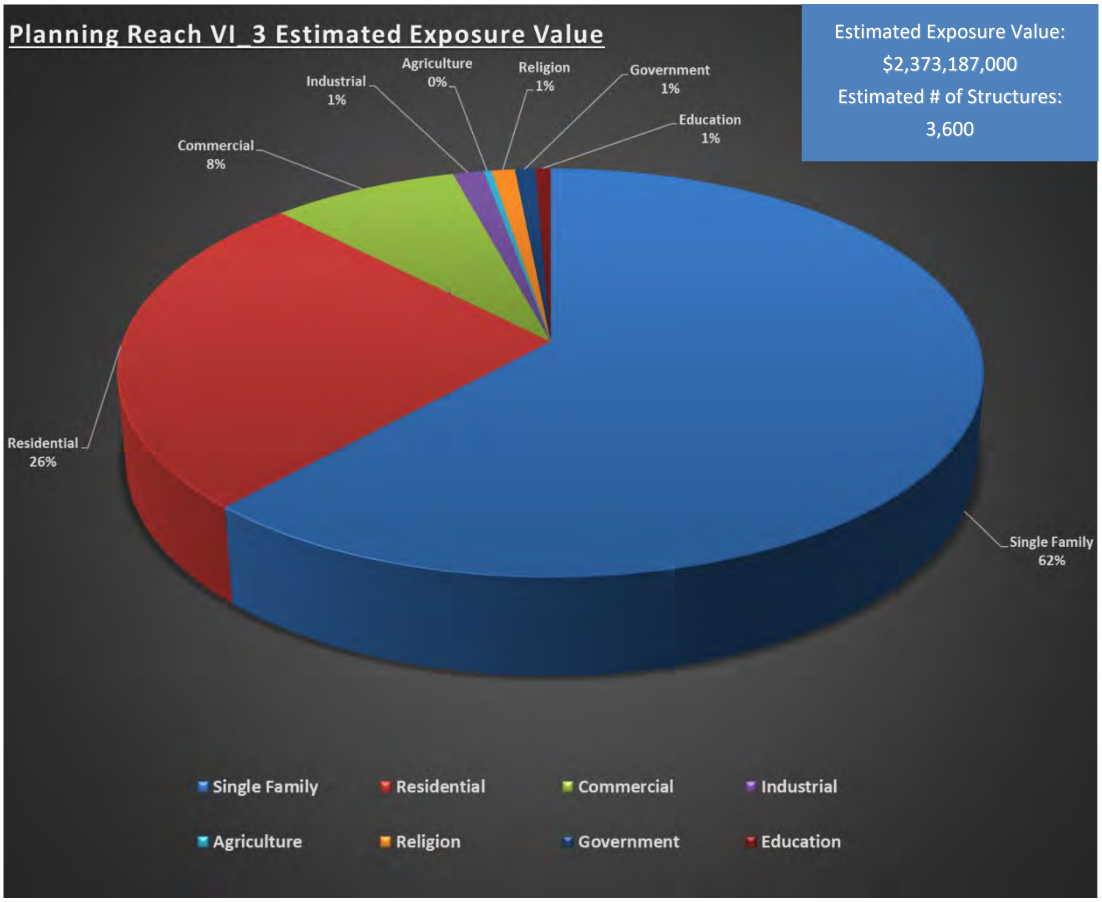


Figure 4-55: Planning Reach VI_3 Estimated Infrastructure Exposure (FEMA n.d.)

The total population of St. John (Planning Reach VI_3) is approximately 4,200 residents. Of that population, approximately 2,600 people (63 percent) live within census estates that are subject to flooding from the Category 5 MOM inundation extent (U.S. Census 2011). The population by estate and the Category 5 MOM modeled flooding extents are displayed in **Figure 4-56**. The total number of people on St. John often exceeds the resident population because of the significant tourism industry. The St. Thomas/St. John district receives 328,000 air visitors and 1,366,400 cruise passengers annually, based on 2018 data (U.S. Virgin Islands Bureau of Economic Research 2018).

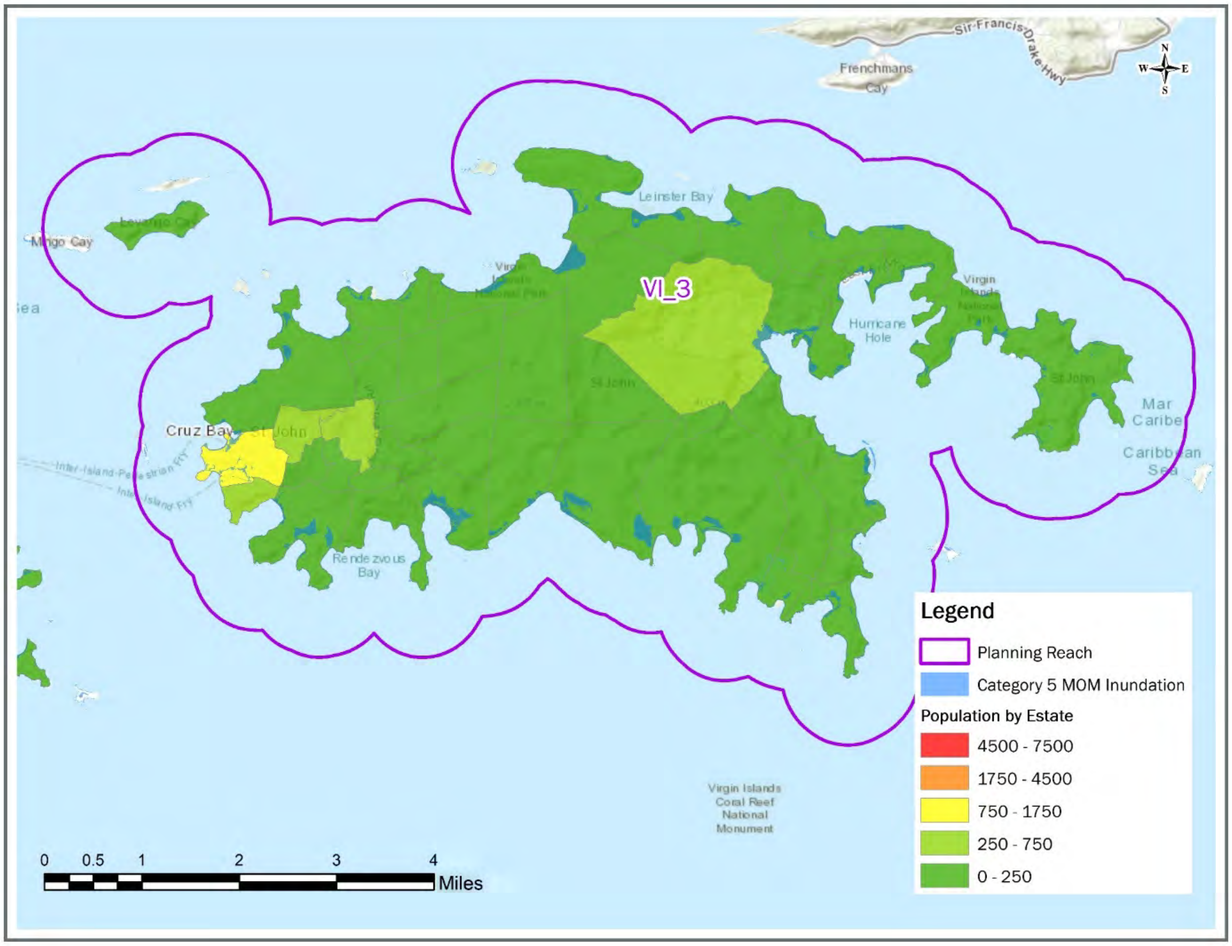


Figure 4-56: Population (U.S. Census 2011) of St. John (Planning Reach VI_3) and Category 5 Maximum of Maximum Storm Modeled Inundation Extent

Environmental and Cultural Resources

The shoreline for Planning Reach VI_3 is 77 miles long with approximately 58-percent exposed rocky shores, 24-percent sandy beaches, and 19-percent mangroves (NOAA 2000). Mangrove forests entail up to 14 miles of linear shoreline within St. John (Planning Reach VI_3). The largest mangrove habitats are located near Leinster Bay and Reef Bay. Based on the NOAA C-CAP classifications, Planning Reach VI_3 is predominantly deciduous and evergreen forest, with isolated areas of palustrine forested wetland across the island. Approximately 3,943 acres of coral reefs surround the coast of Planning Reach VI_3, with the largest habitats along the northwestern and eastern shorelines. Nearshore waters are NOAA-designated critical habitat for staghorn and elkhorn corals. Planning Reach VI_3 also contains the Virgin Islands National Park, which USFWS has proposed naming critical habitat along the southeast and northeast coasts to protect the Marron bacora, a rare plant only found on St. John.

There are approximately 22 NRHP-listed cultural resources within Planning Reach VI_3. Many additional unidentified or unlisted resources are likely also present within the reach. This assessment highlights a few resources identified within the NRHP or through literature review that are potentially exposed to Tier 2 hazards, including Virgin Islands National Park, Dennis Bay Historic District, Reef Bay Great House Historic District, Cinnamon Bay Plantation, Cruz Bay Historic District, and Lameshur Plantation.

Covering the majority of St. John, the Virgin Islands National Park contains an abundance of archeological sites from past civilizations (NPS 2018c). Many locations within the park are a part of the island's sugar production industry, including Dennis Bay Historic District, Cinnamon Bay Plantation, Mary Point Estate, and Reef Bay Great House Historic District. The Dennis Bay Historic District, Reef Bay Great House Historic District, and Cinnamon Bay Plantation are all ranked as high exposure in the Tier 1 Environmental and Cultural Resources Exposure Index. Many of these sites are located along sandy beaches within the park and are subject to inundation from storm surge or potential damage from wave attack.

Cruz Bay is the location of the main port and area of commerce on the island of Saint John. The Cruz Bay Historic District was listed on the National Register of Historic Places in 2016. The Town of Cruz Bay was originally designed in 1766 (U.S. Department of the Interior 2016). Cruz Bay ranked as medium to medium-high exposure in the Tier 1 Environmental and Cultural Resources Exposure Index. Portions of the district are subject to inundation under existing conditions, and areas of inundation are expected to increase with projected sea level rise. A significant portion of the district is protected from damaging wave hazards because of the sheltered nature of the bay. However, modeling shows some areas will experience wave height increases based on future sea level rise estimates.

Lameshur Plantation, which was originally built for sugar production, consists of ruins along the shoreline of Little Lameshur Bay and along the nearby hillside (NPS 2020h). The Lameshur Plantation is ranked as high in the Tier 1 Environmental and Cultural Resources Exposure Index. Areas of the plantation that are closer to the shore are subject to inundation under existing conditions, and exposure to coastal hazards are expected to increase with sea level rise.

Figure 4-57 shows cultural resources in Planning Reach VI_3. Additional information is included within the Tier 2 Cultural Resources Appendix.

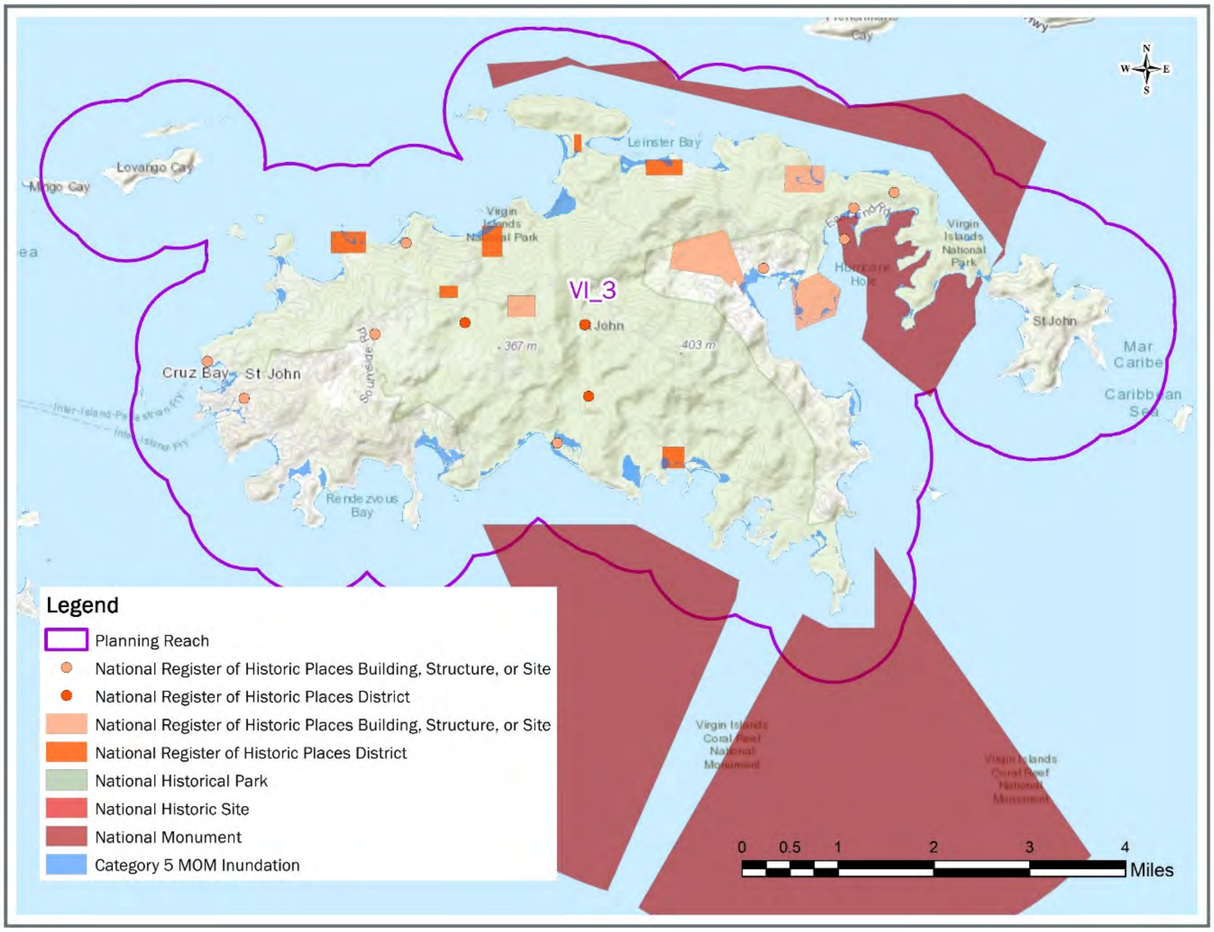


Figure 4-57: Cultural Resources in Planning Reach VI_3 (NPS 2014)

Social Vulnerability

The Tier 2 social vulnerability exposure analysis uses 2010 Census data to examine social vulnerability for Planning Reach VI_3. **Table 4-15** displays factors that can contribute to social vulnerability, including percent of population under age 5, over age 65, with income below poverty level, without access to vehicle, and unemployment rate for the planning reach.

Table 4-15: 2010 Census Social Vulnerability Factors for Planning Reach VI_3 (U.S. Census 2011)

Planning Reach	Under Age 5	Over Age 65	Income Below Poverty Level	Occupied Households Without a Vehicle	Unemployment Rate
VI_3	5.4%	11.8%	15.0%	19.9%	3.0%

Figure 4-58 displays the NOAA and TNC Social Sensitivity Index based on data from the 2010 Census (Schill et al. 2014). Though Estate Enighed (located within Cruz Bay) has the highest social sensitivity within the planning reach, no areas within the planning reach scored high on the Social Sensitivity Index.

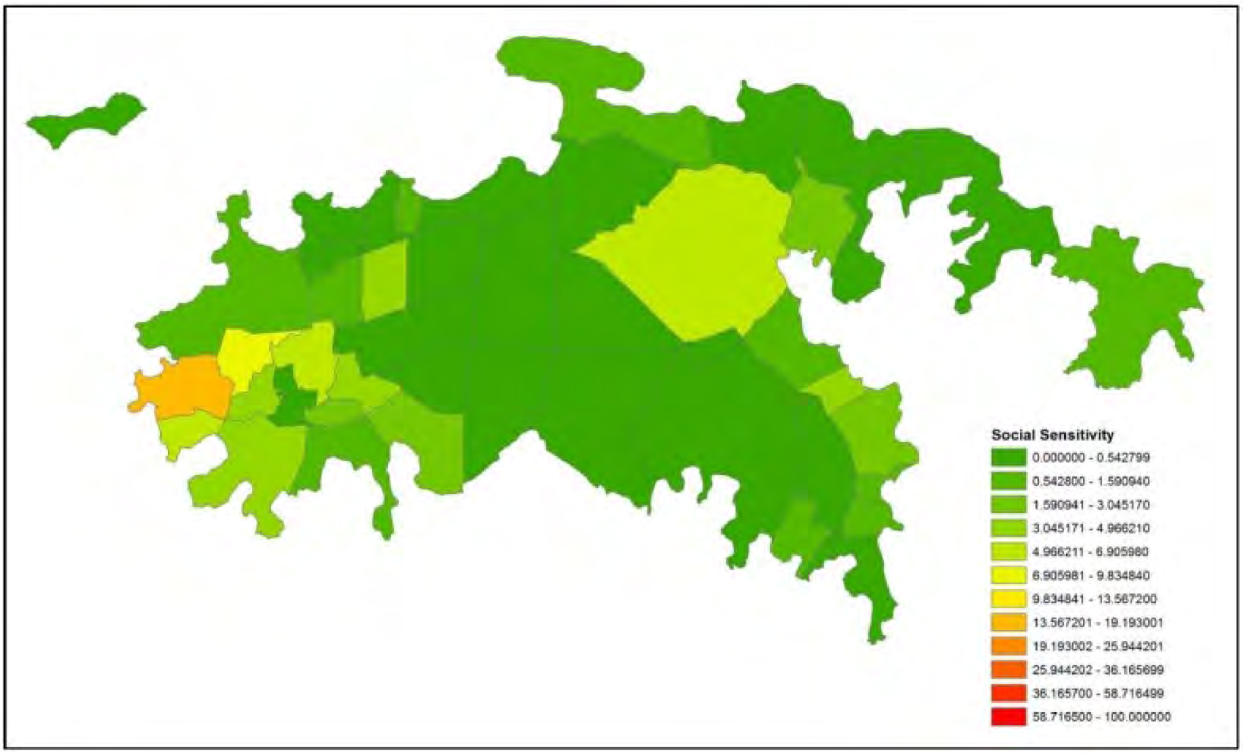


Figure 4-58: National Oceanic and Atmospheric Administration and The Nature Conservancy Social Sensitivity Index for Planning Reach VI_3 (Schill et al. 2014)

Figure 4-59 displays social vulnerability data from the CREST overlain with the Category 5 MOM inundation extent to evaluate socially vulnerable populations subject to inundation (Dobson et al. 2020).

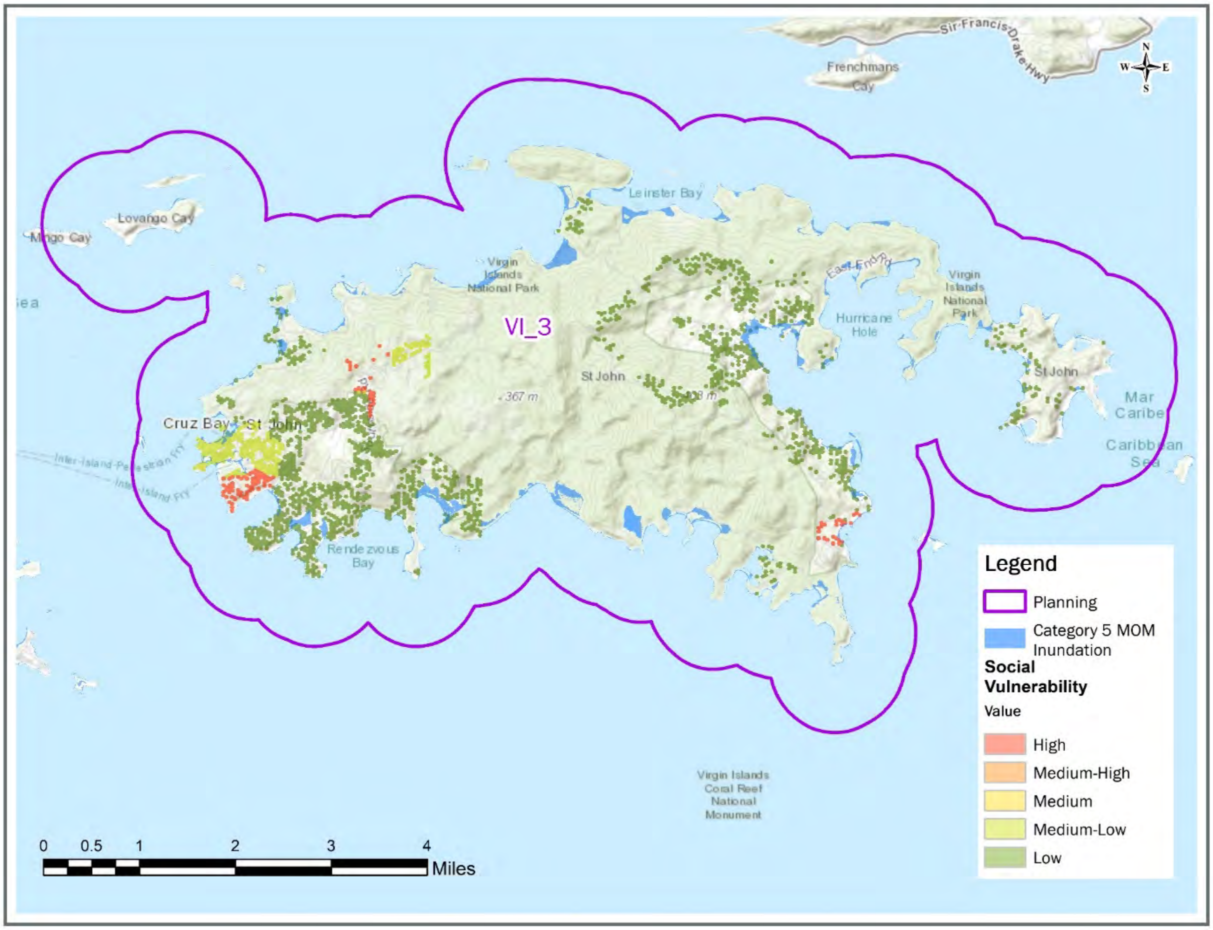


Figure 4-59: Coastal Resilience Evaluation and Siting Tool Socially Vulnerable Populations and Inundation from Category 5 Maximum of Maximum for Planning Reach VI_3 (Dobson et al. 2020)

4.4.2.3 Planning Reach VI_3 Tier 2 Vulnerability

This section highlights details of the Tier 2 vulnerability—susceptibility of harm when exposed to a hazard—for Planning Reach VI_3. **Figure 4-60** shows the environmental vulnerability in areas impacted by inundation from the Category 5 MOM event. Areas around Fish Bay, Reef Bay, Coral Bay, and Maho Bay are shown as the most vulnerable environmentally sensitive locations, particularly unconsolidated shores, palustrine forested wetlands, deciduous forests. Additional information on the methodology and findings of the Tier 2 environmental resources analysis is included within the Environmental Technical Report (USACE 2021b).

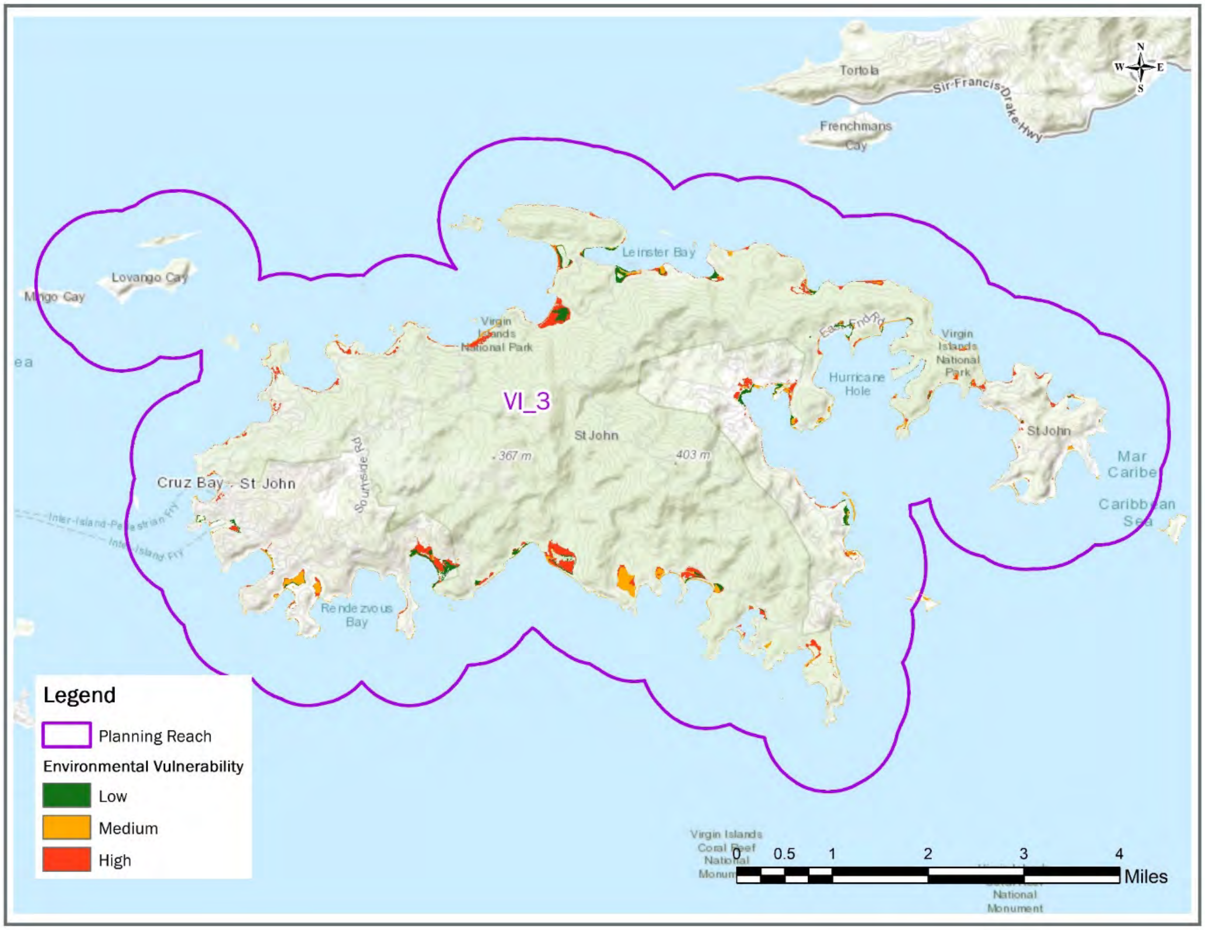


Figure 4-60: Environmental Vulnerability for Planning Reach VI_3 (USACE 2021b)

Cultural resource vulnerability was measured through qualitative assessment based on degree of exposure to coastal hazards and sea level rise, structural considerations, and the nature of the cultural resource. **Table 4-16** presents exposed cultural resources and the potential vulnerability to Tier 2 hazards. This is not an all-inclusive list.

Table 4-16: Planning Reach VI_3 Vulnerability of Exposed Cultural Resources to Tier 2 Hazards

Census Place/Estate	Exposed Cultural Resources	Tier 2 Hazards		
		Storm Surge Inundation	Erosion	Wave Attack
Cruz Bay	Cruz Bay Town Historic District	Y	N/A	Y
Estate Reef Bay	Reef Bay Great House Historic District	Y	N/A	Y
Estate Great Cinnamon Bay	Cinnamon Bay Plantation	Y	N/A	Y
Estate Dennis Bay	Dennis Bay Historic District	Y	N/A	Y
Estate Lameshur	Lameshur Plantation	Y	N/A	Y

Within Planning Reach VI_3, historic districts, structures, and archeological sites are vulnerable to inundation and wave attack. Detailed erosion hazard information is not available for this reach. Storm surge inundation can flood historic properties and damage buildings, such as those located within the Cruz Bay Historic District. Damage may include structural damage and destruction of historic materials. Ruins of sugar plantations and archeological sites within the Virgin Islands National Park are vulnerable to damage and/or loss from inundation and wave attack.

4.4.2.4 Planning Reach VI_3 Tier 2 High-Risk Locations

The high-risk locations were determined from multiple evaluations of the data presented in the Hazard, Exposure, and Vulnerability sections. No single data set criterion was used to define what is high risk; rather, an integration of all the factors was used to assess the combined effect to determine the areas of highest risk for each planning reach.

Figure 4-61 displays the EAD in dollars by census block based on the FAST model analysis for existing and future conditions for Planning Reach VI_3. The highest EAD for existing conditions are concentrated in the center of the island in the planning reach's largest census block. However, EAD for Cruz Bay and the eastern coast of the island are predicted to increase significantly with sea level rise.

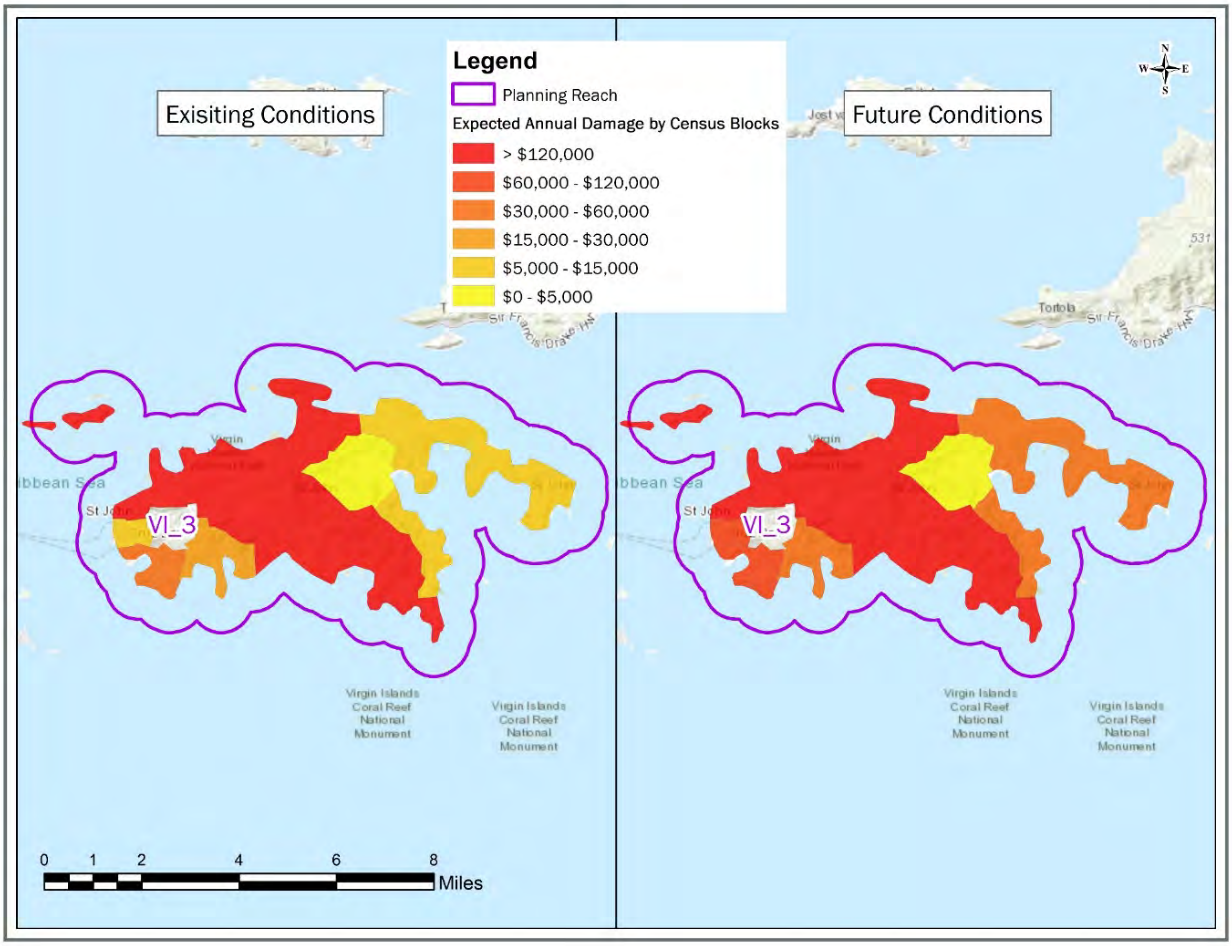


Figure 4-61: Expected Annual Damages in Dollars Based on Flood Assessment Structure Tool Results for Planning Reach VI_3

The environmental risk areas for Planning Reach VI_3 are shown in **Figure 4-62** and summarized in **Table 4-17**. The Tier 2 environmental resources risk analysis was limited to the NOAA C-CAP classifications within the Category 5 MOM footprint. A detailed description of the Tier 2 environmental resources risk analysis is located in the Environmental Technical Report (USACE 2021b).

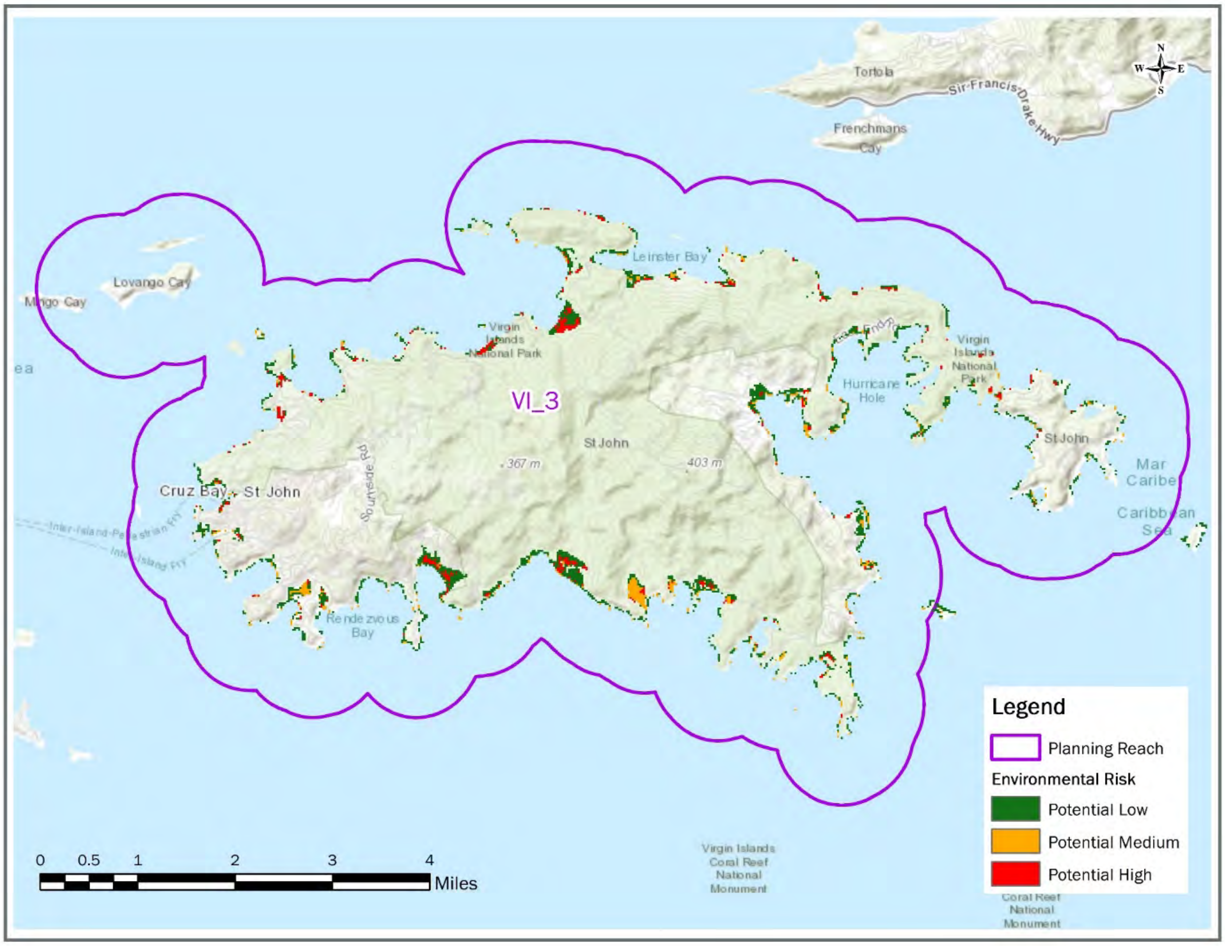


Figure 4-62: Tier 2 Environmental Resources Risk for Planning Reach VI_3 (USACE 2021b)

For Planning Reach VI_3, the largest high-risk environmental areas, also designated as PEAs, include Fish Bay, Reef Bay, and Maho Bay and are shown in **Figure 4-63**.

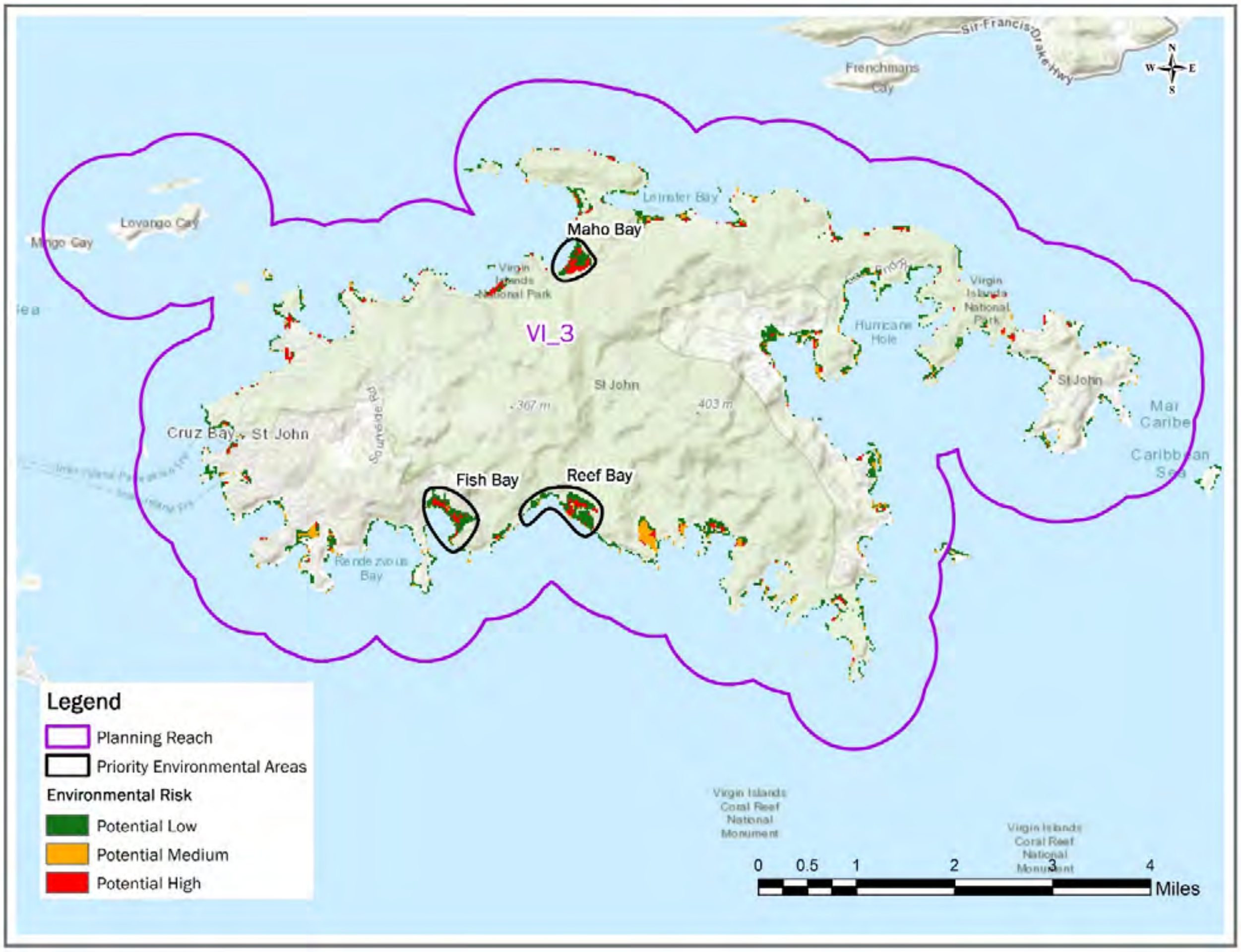


Figure 4-63: Priority Environmental Areas for VI_3

More information on the methodology used to identify the PEAs and a detailed description of each PEA is located in the Environmental Technical Report (USACE 2021b).

Additional environmental risks to Planning Reach VI_3 include those to coral reefs and SAV. These resources are not represented by the NOAA C-CAP classifications; however, they are susceptible to sea level rise, storm surge inundation, and wave damage. Risk to corals reefs and SAV is addressed in the Environmental Technical Report (USACE 2021b).

Risks to cultural resources were determined using the NRHP, relevant literature, and best professional judgment by reviewing wave attack and inundation hazards. Census places and census estates in Planning Reach VI_3 with cultural resources within the Category 5 MOM layer extent were identified in **Table 4-17** to be considered for the overall risk, along with additional cultural resources that are at risk from the hazards of wave attack.

Based on the qualitative risk assessment within the reach, historic districts, structures, and archeological sites are at risk of inundation and wave attack. Historic districts and structures are at risk of foundational impacts as waters intrude. Without prevention or protection, these impacts can quickly lead to instability and, where impacts do not directly cause destruction, may necessitate demolition where public safety becomes a concern. Repairs and reactive measures are available but could be cost prohibitive.

Damage to archaeological sites, such as those located within the Virgin Islands National Park, can be even more harmful. There are no reconstructive measures that can be taken for these sites. Once they are lost, the areas can no longer be studied to understand the past.

4.4.3 Planning Reach VI_3 Summary and High-Risk Locations

High-risk locations were determined from the data presented in the aforementioned hazard, exposure, and vulnerability sections. No overall risk score was assigned to each location. Instead, the combined effect of all factors was qualitatively evaluated to determine the areas of highest risk.

Planning Reach VI_3 contains large areas of high population and critical infrastructure, including Cruz Bay, Johnson Bay, and Coral Harbor. These areas are of particular interest as they have the highest exposure ratings and are anticipated to be most impacted by sea level rise. Additionally, cultural resources located within this planning reach are clustered along the coast, where hazards are expected to increase in relation to sea level rise. In Cruz Bay, the EAD is predicted to increase significantly with sea level rise. Fish Bay, Reef Bay, and Maho Bay are the largest high-risk environmental areas located within this planning reach.

Table 4-17 displays the Planning Reach VI_3 high-risk locations identified through the Tier 1 and Tier 2 analyses. The table includes information on EAD, erosion risks, risks of increases in wave height, environmental risks, and locations where cultural resources are potentially at risk within each census place or census estate. The table highlights the estimated annualized inundation dollar damages for existing and future conditions and ranks them from low to high risk. These rankings were determined by USACE economists specifically for the U.S. Virgin Islands and are shown in **Table 4-8** in Section 4.2.3.

Erosion risk was considered medium-high if long-term erosion rates were greater than 0.75 meters per year (2.5 feet per year) and high if greater than 1 meter per year (3.3 feet per year). Modeled wave height increases of greater than 0.5 meters (1.6 feet) for the 1-percent AEP event with sea level rise were considered significant. Social vulnerability was considered high if the estate scored above 36.165700 in the Social Sensitivity Index. The table notes whether environmental high-risk areas, PEAs, and cultural resources are present in each estate or census place.

Cruz Bay is the most densely populated area of the island and was identified as a high-risk location for both existing and future conditions in the Tier 1 analysis, and a high-risk location for existing and future infrastructure in Tier 2. It was also modeled to experience increased wave attack with sea level rise. While it is the most socially vulnerable location in the planning reach, it does not meet the threshold for high social sensitivity.

Estate Great Cinnamon Bay ranked as medium-high for both existing and future Tier 2 infrastructure risk. It also contains a cultural resource and 8.81 acres of environmental high-risk areas, including Maho Bay, which is a PEA.

Table 4-17: Summary of Tier 1 and Tier 2 Risk by Census Place and Census Estate for Planning Reach VI_3.

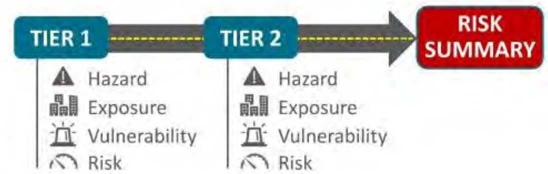
Planning Reach VI_3	Tier 1		Tier 2											
	Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)						At Risk Cultural Resources		At Risk Environmental Resources			
Census Place/Census Estate	Identified as Existing High Risk Location	Identified as Future High Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Tier 2 Historical Erosion Risk	Tier 2 Significant Increase in Future Wave Attack (> 0.5 meters)	Identified as Area with Cultural Resource At Risk	Cultural Resource Name	Identified as Area with PEA or Resource	Tier 2 Environmental High Risk (acres)	Environmental Resource Name	Tier 2 Socially Vulnerable Areas
Coral Bay	X	X	$2,000	Low-Med	$25,000	Med-High						5.94		
Cruz Bay	X	X	$73,000	High	$225,000	High		X (Offshore)	X	Cruz Bay Town Historic District		18.39		
Estate Annaberg							High	X				8.72		
Estate Browns Bay												3.10		
Estate Caneel Bay			$0	Low	$8,000	Med		X (Offshore)				9.68		
Estate Carolina												1.77		
Estate Chocolate Hole and Great Cruz Bay									X	Cruz Bay Town Historic District		3.09		
Estate Dennis Bay									X	Dennis Bay Historic District		1.94		
Estate Emmaus							Med-High					2.15		
Estate Enighed									X	Cruz Bay Town Historic District		3.68		
Estate Fish Bay									X	Cruz Bay Town Historic District	X	9.75	Fish Bay	
Estate Fortberg												1.47		
Estate Great Cinnamon Bay			$19,000	Med-High	$42,000	Med-High			X	Cinnamon Bay Plantation	X	8.81	Maho Bay	
Estate Hansen Bay			$8,000	Med	$19,000	Med-High						4.74		
Estate Haulover												3.60		
Estate Hawksnest			$0	Low	$3,000	Low-Med						0.22		
Estate Hermitage												0.44		
Estate Johns Folly			$0	Low	$5,000	Low-Med						0.20		
Estate Lameshur			$241,000	High	$241,000	High			X	Lameshur Plantation		5.46		
Estate Leinster Bay												3.31		
Estate Maho Bay			$0	Low	$3,000	Low-Med					X	10.13	Maho Bay	
Estate Mandal												0.44		
Estate Molendal and Little Reef Bay											X	1.12	Reef Bay	
Estate Mount Pleasant and Retreat												2.44		
Estate Number 1 of Trunk Bay			$0	Low	$5,000	Low-Med						1.30		
Estate Parcel of Concordia			$0	Low	$0	Low						3.32		
Estate Peter Bay			$0	Low	$0	Low						0.22		

Planning Reach VI_3	Tier 1		Tier 2											
	Tier 1 Risk Assessment		Tier 2 Economic Risk Assessment (ERA)						At Risk Cultural Resources		At Risk Environmental Resources			
Census Place/Census Estate	Identified as Existing High Risk Location	Identified as Future High Risk Location	Existing Economic Risk (EAD, FY18 dollars)	ERA Rating	Future Economic Risk (EAD, FY18 dollars)	ERA Rating	Tier 2 Historical Erosion Risk	Tier 2 Significant Increase in Future Wave Attack (> 0.5 meters)	Identified as Area with Cultural Resource At Risk	Cultural Resource Name	Identified as Area with PEA or Resource	Tier 2 Environmental High Risk (acres)	Environmental Resource Name	Tier 2 Socially Vulnerable Areas
Estate Reef Bay			$0	Low	$0	Low			X	Reef Bay Great House Historic District	X	11.00	Reef Bay	
Estate St. Quaco and Zimmerman			$0	Low	$2,000	Low-Med						2.42		
Estate Zootenvaal												0.44		

Note: Yellow highlight represents locations designated as high risk for entire territory.

4.5 Summary of U.S. Virgin Islands High-Risk Locations

The following section summarizes overall risk by planning reach, Tier 2 Economic Risk Assessment results by census place/municipality, and the process, criteria, and results of selecting overall "high-risk locations" for the U.S. Virgin Islands.



4.5.1 Summary of Risk Assessment by Planning Reach

Table 4-18 displays a summary of risk by planning reach, including the total number of census places and estates that were identified as high-risk locations in the Tier 1 Risk Assessment and the sum of EAD to infrastructure for existing and future conditions. The table also summarizes the percentage of locations with high erosion risk, locations modeled to experience significant increases in wave attack with sea level rise, locations with high environmental risk, locations with cultural resources identified, and locations with high social vulnerability.

Based on this evaluation, Planning Reach VI_2 (St. Thomas) is at the greatest total risk to coastal hazards. Planning Reach VI_2 has the highest current and future EAD risk (**Figure 4-64**). Of the coastal locations evaluated in Planning Reach VI_2, 14 percent are subject to high erosion hazards, 28 percent are modeled to experience increase wave attack with 2.33 feet (0.71 meters) of sea level rise, 42 percent contain an area of high environmental risk, 19 percent contain cultural resources, and 9 percent include areas of high social vulnerability.

As the largest planning reach, Planning Reach VI_1 (St. Croix) has high total counts for several of the risk factors, including increased wave attack, environmental risk, and cultural resources. In addition, future EAD risk to infrastructure is greater than $1,000,000 (FY18).

This page intentionally left blank.

Table 4-18: Summary of Risk Assessment Totals by Planning Reach

Planning Reach	Total Census Places/Estates Identified	Number of Tier 1 Existing Condition High Risk Locations	Number of Tier 1 Future Condition High Risk Location	Total Tier 2 Annualized Infrastructure Damage Estimate Existing Conditions (FY18)	Total Tier 2 Annualized Infrastructure Damage Estimate Future Conditions (FY18)	Estates with Erosion Risk	Number of Estates with Increase in Future Wave attack	Estates with Tier 2 Environmental High Risk (> 5 acres)	Estates with Tier 2 PEAs	Number of Estates with Cultural Resources Identified	Number of Estates with High Social Vulnerability
VI_1	59	0 (0%)	1 (2%)	$185,000	$1,031,000	6 (10%)	12 (20%)	13 (22%)	18 (30%)	16 (27%)	3 (5%)
VI_2	43	1 (2%)	3 (7%)	$1,561,000	$3,758,000	6 (14%)	12 (28%)	18 (42%)	10 (23%)	8 (19%)	4 (9%)
VI_3	22	2 (9%)	2 (9%)	$343,000	$578,000	2 (9%)	5 (23%)	9 (41%)	5 (23%)	14 (64%)	0 (0%)

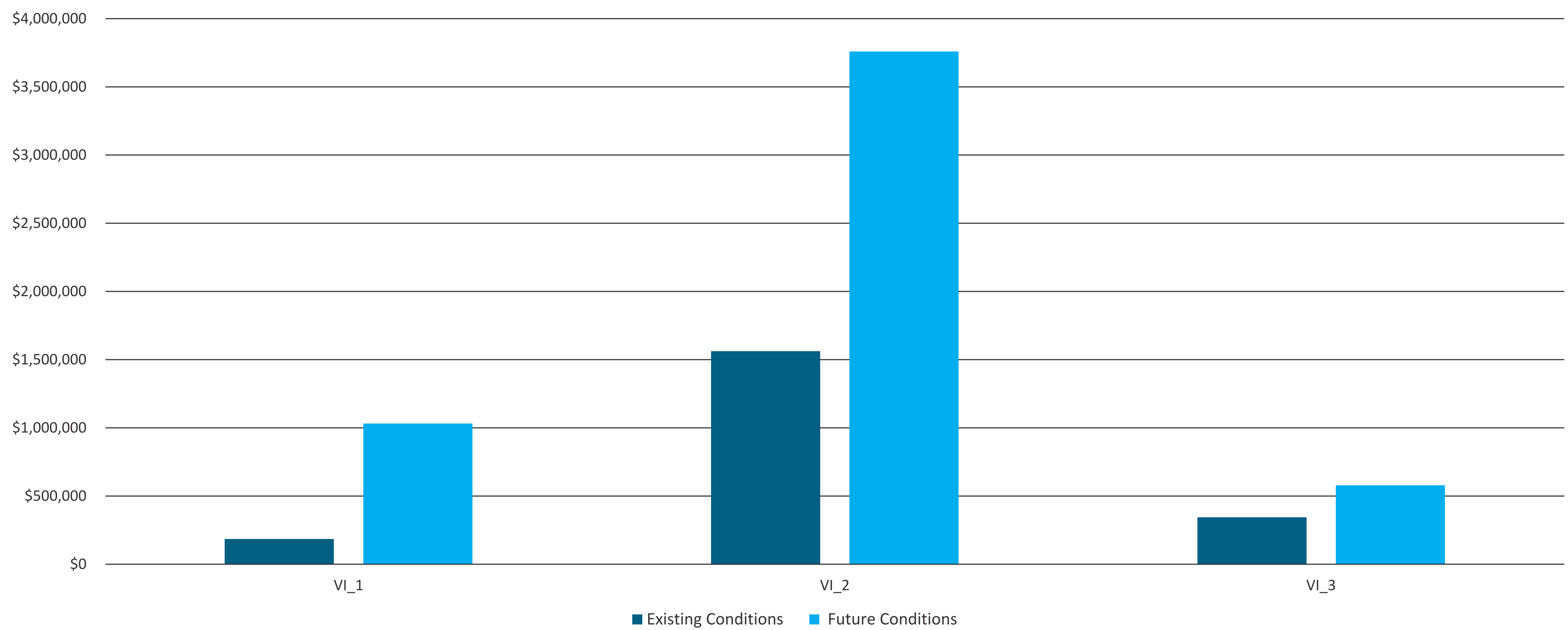


Figure 4-64: Tier 2 Annualized Infrastructure Damages (FY18) by Planning Reach

This page intentionally left blank.

4.5.2 Tier 2 Economic Risk Assessment by Census Place/Estate

Results of the Tier 2 FAST analysis by census place/estate are presented for all of the U.S. Virgin Islands. To define economic "high-risk locations" across the SACS study area, the FAST ranges of medium, medium-high, and high are all considered above the threshold for "high-risk locations." For the U.S. Virgin Islands, that equates to any annualized damages over $5,327,000 (FY18).

Across all three planning reaches, the locations with the greatest current risk to infrastructure are Charlotte Amalie (Planning Reach VI_2), Red Hook (Planning Reach VI_2), and Estate Lameshur (Planning Reach V1_3). Locations with the greatest future risk to infrastructure are Charlotte Amalie (Planning Reach VI_2), Estate Frydenhoj (Planning Reach VI_2), and Red Hook (Planning Reach VI_2). **Figure 4-65** displays the 20 census places/estates with the highest EAD.

This page intentionally left blank.

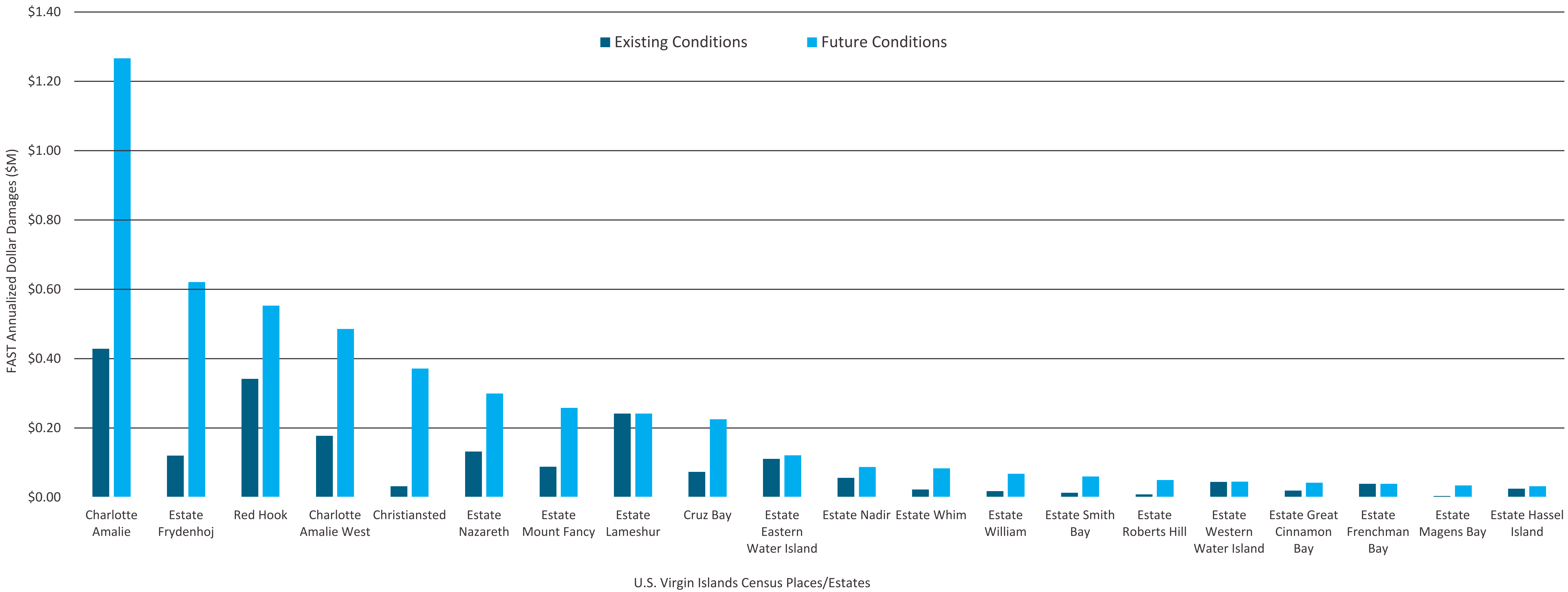


Figure 4-65: Summary of Flood Assessment Structure Tool Estimated Annualized Damages (FY18) by Census Place/Estate for Existing and Future Conditions

This page intentionally left blank.

4.5.3 U.S. Virgin Islands High-Risk Locations

U.S. Virgin Island “high-risk locations” were identified through an assessment of the Summary of High-risk Locations in Planning Reach VI_1, Summary of High-risk Locations in Planning Reach VI_2, and Summary of High-risk Locations in Planning Reach VI_3 tables located at the end of each planning reach section. The U.S. Virgin Islands “high-risk locations” were based on the combination of eight criteria: (1) Tier 1 existing/future high risk, (2) medium-high/high existing or future infrastructure risk, (3) medium-high or high erosion risk, (4) future wave height increases of more than 1.6 feet (0.5 meter), (5) over 5 acres of high environmental risk, (6) the presence of PEAs, (7) the presence of identified at-risk cultural resources, and (8) high social vulnerability scores. The census places/estates identified as “high-risk locations” for U.S. Virgin Islands met the criteria for risk in at least four of these eight criteria. This process identified 9 total “high-risk locations” within the U.S. Virgin Islands (**Table 4-19**).

This page intentionally left blank.

Table 4-19: SACS-Identified High-Risk Locations for the U.S. Virgin Islands

Census Place/Municipality	Tier 1 Existing/Future High Risk	Tier 2 Annualized Infrastructure Damage Estimate Existing Conditions (FY18)	Tier 2 Annualized Infrastructure Damage Estimate Future Conditions (FY18)	Tier 2 Historical Erosion Risk[1]	Tier 2 Significant Increase in Future Wave Attack (>0.75 meters)	Tier 2 Environmental High Risk (acres)	Tier 2 Priority Environmental Areas	Tier 2 Cultural Resources Identified	Tier 2 Socially Vulnerable Areas
Christiansted	X	$32,000	$371,000			9.71		X	
Estate Two Brothers		$0	$17,000		X	15.66	Sandy Point National Wildlife Refuge	X	X
Charlotte Amalie	X	$428,000	$1,266,000	High		12.09		X	X
Charlotte Amalie West	X	$177,000	$485,000	High	X	7.19		X	X
Estate Nazareth		$132,000	$299,000	High	X	18.43			
Estate Smith Bay		$13,000	$60,000	High	X	45.73	Smith Bay		
Red Hook	X	$341,000	$553,000		X	7.78			
Cruz Bay	X	$73,000	$225,000		X (Offshore)	18.39		X	
Estate Great Cinnamon Bay		$19,000	$42,000			8.81	Maho Bay	X	

[1]High: >-1 meters per year; Med-High: .75 to -1 meters per year

This page intentionally left blank.

SECTION 5

Managing Risk

This section identifies opportunities to enhance resiliency, increase sustainability, and lower coastal storm risks from coastal hazards in populated areas, areas of concentrated economic development, and areas with vulnerable environmental and cultural resources.

5.1 Coastal Program Guide – U.S. Virgin Islands

The SACS Coastal Program Guide (USACE 2021a) provides broad information on federal directives, resources, and funding opportunities to help communities better leverage resources needed on a disaster-wide, state-/territory-wide, or community-wide basis. Many states/territories have additional resources available for local projects. Resources specific to the U.S. Virgin Islands are described below and can also be found in the SACS Coastal Program Guide.

VITEMA: VITEMA has locations in St. Thomas, St. Croix, and St. John. VITEMA developed the Virgin Islands Territorial Emergency Operations Plan (VITEMA 2016) to provide guidelines on how different levels of government can work together to support disaster response within the U.S. Virgin Islands. VITEMA also manages an emergency alert system and provides disaster preparedness guidance for the public.

Southeast and Caribbean Disaster Resilience Partnership (SCDRP): SCDRP is a network of public, private, and nonprofit organizations that share experience, expertise, and resources regarding disaster resilience and recovery planning. SCDRP offers a platform for regional collaboration and learning as well as funded on-the-ground training, planning, and research in the southeastern states and territories. SCDRP brings together professionals engaged in a variety of disaster recovery capacities from across the Southeast to share best practices and innovate for a more resilient future. Recovery planning also allows communities to predetermine priorities for recovery, such as which infrastructure to repair first or whether to incorporate resilience measures into rebuilding, to reduce the number of difficult decisions to be made in the aftermath of a disaster (Southeast Coastal Ocean Observing Regional Association 2020).

CARICOOS, NOAA: This program brings together coastal ocean data and forecasts from a variety of sources, including satellites, ocean instruments, and numerical models, to give the user an integrated view of past, present, and forecasted ocean conditions in the U.S. Caribbean region through a user-friendly website (CARICOOS 2020).

University of Puerto Rico Sea Grant College Program: The University of Puerto Rico's Sea Grants College Program is an educational, research, and service program focused on "conservation and sustainable use of coastal and marine resources" within the Caribbean, including the U.S. Virgin Islands (Sea Grant Puerto Rico 2020).

Citizen Corps: The Homeland Security's Citizen Corps program allows citizens to get involved in emergency response and recovery. The program offers trainings, community exercises, and volunteer support for local first responders (FEMA 2020a).

Guidance on Partnering with USACE, USACE Institute for Water Resources: This document provides guidance for communities, local governments, states, tribes, and nongovernmental organizations for partnering with the USACE to examine water resource problems and defining practical solutions through a wide variety of technology transfer mechanisms (USACE 2019b).

U.S. Virgin Islands Coastal Resilience Tool: The U.S. Virgin Islands Coastal Resilience Tool is a decision support tool developed by TNC that provides local, state, and national planners with a step-by-step process to guide decisions to reduce the ecological and socioeconomic risks of coastal hazards in the U.S. Virgin Islands (TNC 2016).

U.S. Virgin Islands Coastal Resilience Assessment: This document was developed to support effective decision-making to help build resilience for communities facing flood-related threats. The GIS-based Coastal Resilience Assessment identifies areas in the U.S. Virgin Islands where the implementation of natural and nature-based features (NNBF) may maximize dual benefits for human community resilience and for fish and wildlife (Dobson et al. 2020).

U.S. Virgin Islands Hurricane Recovery and Resilience Task Force: The U.S. Virgin Islands Hurricane Recovery and Resilience Task Force was developed to guide the recovery from the 2017 hurricane season to make the U.S. Virgin Islands more resilient. The task force was built from a multidisciplinary team of local officials, community members, business, and environmental experts, and thought leaders around the U.S. As part of this effort, the task force published a report to help guide reconstruction efforts. The report includes over 200 recommendations on the long-term recovery to improve critical infrastructure and public services and to make businesses more resilient to future storms and natural disasters (U.S. Virgin Islands Hurricane Recovery and Resilience Task Force 2018).

U.S. Virgin Islands Silver Jackets: The U.S. Virgin Islands Silver Jackets are an interagency team dedicated to improving the quality of life, infrastructure, and the environment by making the U.S. Virgin Islands more resilient to natural disasters (Silver Jackets n.d.).

In addition to the programs listed above, many federal agencies have jurisdictions in the U.S. Virgin Islands that provide funding, guidance documents, and other resources to local government agencies, organizations, and the public. These include the FEMA Caribbean Office, and the U.S. Small-Business Administration Puerto Rico and U.S. Virgin Islands District Office. For more information, refer to the SACS Coastal Program Guide (USACE 2021a).

5.2 Hurricane Evacuation Planning

Hurricanes are low-frequency, high-consequence events. Recent hurricanes prove that locations far inland are not safe from intense storms and considerable damage can still occur. The goal of hurricane evacuation planning is to provide a 24-hour warning for residents to evacuate before the onset of tropical storm force winds.

USACE's National Planning Center of Expertise for Coastal Storm Risk Management National Hurricane Program Office, the Jacksonville District, and Dewberry were in the process of supporting the VITEMA Hurricane Evacuation Study (HES). However, efforts to complete the HES stalled after Hurricane Maria.

Hurricane evacuation planning involves complex decision-making and a variety of factors. A detailed HES consists of multiple analyses: hazard, vulnerability, behavior, shelter, and transportation.

- **Hazard Analysis:** Quantifies the wind speeds and stillwater surge heights that could be produced by a combination of hurricane intensities, approach speeds, approach directions, and tracks considered to have a reasonable meteorological probability of occurrence within the study area. The NHC uses the SLOSH numerical model (Jelesnianski et al. 1992), but there are new models currently being developed at the NHC.

- **Vulnerability Analysis:** Identifies the areas, populations, and facilities that are potentially vulnerable to flooding and extraordinary wind damage under a variety of hurricane threats. Inundation maps are used to determine which surge-vulnerable areas may need to be evacuated in response to a particular coastal storm threat. The vulnerable population is composed of all persons residing within the area subject to storm surge and all residents of mobile homes because of their greater vulnerability to strong winds associated with hurricanes. Evacuation zones are established during the vulnerability analysis by local officials with coordination with NHC partners.

- **Behavior Analysis:** Forecasts the public's response to hurricane threats. This data includes the percentage of vulnerable and nonvulnerable population likely to evacuate, when the evacuating population will leave in relation to an evacuation order or advisory, the probable destinations of the evacuees, the percentage of available vehicles, the evacuation response of tourists, and the percentage of evacuees who would require public assistance for emergency transportation. This information is used to make shelter and transportation decisions. This is typically done by collecting survey data through phone calls or interviews, but new approaches such as collecting cell phone data are being used.

- **Shelter Analysis:** Estimates the number of evacuees who will seek public shelter and the number of shelter spaces available. This information is used in determining evacuation clearance times in the transportation analysis. The shelter analysis should address shelter locations, capacities, demand, and potential vulnerability.

- **Transportation Analysis:** Calculates the clearance times needed to conduct a safe and timely evacuation for a range of hurricane threats. The transportation analysis defines the evacuation roadway network and evaluates traffic control measures for improving traffic flow and avoiding bottlenecks during the evacuation. The hazard, vulnerability, behavioral, and shelter analyses are all used to calculate the clearance times for the transportation analysis.

- **VITEMA HES:** Currently includes a behavioral analysis (2014), shelter analysis (2015), and a vulnerability analysis (2018).

An HES is comprehensive in scope and multiregional in perspective. Traffic and sheltering concerns can affect locations far removed from the evacuation area. This is especially true for the U.S. Virgin Islands because residents may be required to leave the island or territory. An HES encourages collaboration between local emergency management officials, territory emergency management officials, local National Weather Service officials, the NHC, the media, and other agencies such as American Red Cross. The result should be a prepared government and informed public.

Hurricane forecasting is not an exact science. Decision-makers and the public should be aware that hurricane intensities and tracks can change at any time. Because of the uncertainties, a worst-case approach is taken for wind and surge hazards in evacuation studies.

HURREVAC, short for hurricane evacuation, is a web-based tool used by emergency management officials to translate forecast data to chart the progress of a storm. HURREVAC provides a real-time analysis of potential consequence of current storms to help emergency management officials make the difficult decision of when to issue evacuation orders based on clearance times from the onset of tropical storm force winds. The clearance time developed in the transportation analysis is the time is takes for every person to evacuate safely before the arrival of tropical storm-force winds. HURREVAC provides earliest likely and most reasonable arrival time of tropical storm-force winds, thus giving a range of times for emergency managers to plan and make decisions. Wind arrival times are also predicted through HURREVAC.

HURREVAC can also predict the MOM of the hurricane and the Maximum Envelope of Water for multiple scenarios of the approaching storm based on hurricane category and direction of approach. These factors greatly influence the consequences of a hurricane event and the amount of storm surge communities can expect.

5.3 Existing Coastal Storm Risk Management Projects and Programs

Existing federal and non-federal CSRM projects can act as a building block for future projects and partnerships. An inventory of existing projects can also highlight gaps where coastal risk is high and CSRM projects are needed. **Table 5-1** summarizes current (as of September 2020) federal and non-federal efforts to support coastal storm risk reduction within the U.S. Virgin Islands.

The U.S. Virgin Islands currently have no active federal USACE CSRM projects, highlighting an opportunity for greater federal focus on coastal risk management in the territory. The U.S. Virgin Islands have considerable risk to coastal storms but have not received the same level of attention as other regions. This may be due, in part, to challenges in justifying economic benefits in some areas with fewer economic drivers for CSRM, but where social vulnerabilities may exist. USACE identified four accounts to facilitate evaluation of potential projects—National Economic Development (NED), Environmental Quality (EQ), Regional Economic Development (RED) and Other Social Effects (OSE). The evaluation of RED and OSE benefits have historically been discretionary. The ability to qualitatively or quantitatively evaluate RED and OSE may have been limited by data and tool availability. Recent guidance has required a comprehensive benefit evaluation for all decision documents (i.e., feasibility studies and post-authorization change reports), including considerations for RED and OSE in addition to NED and EQ. This shift in benefit quantification may support the implementation of future CRSM projects within the U.S. Virgin Islands. However, there are other initiatives by federal and non-federal agencies that support CSRM. **Table 5-1** summarizes these initiatives.

Table 5-1: Summary of Existing/Ongoing Federal and Non-federal Efforts to Support Coastal Storm Risk Reduction within the U.S. Virgin Islands

Project	Planning Reach	Project Area	Agency/Organization	Comments
Estate La Grange	VI_1	St. Croix	USACE/U.S. Virgin Islands Department of Public Works	Potential Continuing Authorities Program Section 205 (USACE 2020c)
Renovation of Alexander Theater	VI_1	St. Croix	FEMA/St. Croix Foundation	Renovation of historic theater to include a safe room capable of withstanding hurricane force winds (FEMA 2020b).
Bulkhead Rebuild in Christiansted	VI_1	St. Croix	NOAA/NPS/ BioImpact, Inc.	From 2019 Field Workshop
Retaining Wall in Frederiksted	VI_1	St. Croix	VITEMA	From 2019 Field Workshop
Great Pond Mangrove Restoration	VI_1	St. Croix	U.S. Virgin Islands Department of Planning and Natural Resources (DPNR)/NFWF	From 2019 Field Workshop
Department of Interior Roads (Christiansted) – Queen Street, Hill Street, Smith Street, East Street, Strand Street, West Street, Prince Street	VI_1	St. Croix	U.S. Virgin Islands Department of Public Works	From communication with the U.S. Virgin Islands Office of Disaster Recovery
Department of Interior Roads (Frederiksted) – Queen Cross Street, Hospital Street, New Street, Hill Street, Customs Street, Lagoon Street, Market Street, King Street	VI_1	St. Croix	U.S. Virgin Islands Department of Public Works	From communication with the U.S. Virgin Islands Office of Disaster Recovery
Northside Road	VI_1	St. Croix	U.S. Virgin Islands Department of Public Works	From communication with the U.S. Virgin Islands Office of Disaster Recovery
Dredging Projects – Gallows Bay	VI_1	St. Croix	Virgin Islands Port Authority	From communication with the U.S. Virgin Islands Office of Disaster Recovery
Gallows Bay Drainage	VI_1	St. Croix	U.S. Virgin Islands Department of Public Works	From communication with the U.S. Virgin Islands Office of Disaster Recovery
Queen Mary Highway	VI_1	St. Croix	U.S. Virgin Islands Department of Public Works	From communication with the U.S. Virgin Islands Office of Disaster Recovery

Project	Planning Reach	Project Area	Agency/Organization	Comments
Beach Nourishment and Dune Design Project at Ritz-Carlton Hotel	VI_2	St. Thomas	BioImpact, Inc	From 2019 Field Workshop
Waste Management Facility Elevation at Lindbergh Bay Park	VI_2	St. Thomas	Waste Management Authority	From Focus Area Strategy Development Webinar
Dredging Projects - Charlotte Amalie	VI_2	St. Thomas	Virgin Islands Port Authority	From communication with the U.S. Virgin Islands Office of Disaster Recovery
Savan Gut Phase II	VI_2	St. Thomas	USACE/U.S. Virgin Islands Department of Public Works	Feasibility Study (USACE 2020d)
Turpentine Run	VI_2	St. Thomas	USACE/U.S. Virgin Islands Department of Public Works	Feasibility Study (USACE n.d.)
Veteran's Drive	VI_2	St. Thomas	U.S. Virgin Islands Department of Public Works	Improvements to seawall and drainage systems. From Focus Area Strategy Development Webinar.
Charlotte Amalie Harbor Maintenance	VI_2	St. Thomas	USACE	Permit pending as of July 2020. Potential RSM source. Estimated 60,000 cubic yards of beach quality sand per SAND Report. From 2019 Field Workshop.
Crown Bay Dredging Project	VI_2	St. Thomas	Virgin Islands Port Authority/NOAA/ BioImpact/DPNR	From 2019 Field Workshop
Centerline Road	VI_3	St. John	U.S. Virgin Islands Department of Public Works	From communication with the U.S. Virgin Islands Office of Disaster Recovery
Watershed Management Plans	VI_1, VI_2	St. Croix, St. Thomas	DPNR/FEMA	From Focus Area Strategy Development Webinar
Mangrove Planting	VI_1, VI_2	St. Croix, St. Thomas	BioImpact, Inc	From 2019 Field Workshop
Hazard Mitigation Plan Update	VI_1, VI_2, VI_3	Territory-wide	VITEMA/University of the Virgin Islands	From personal stakeholder correspondence
Coastal Vulnerability Index Update	VI_1, V_2, VI_3	Territory-wide	DPNR/University of the Virgin Islands /USGS	From personal stakeholder correspondence
Outfall Inundation and Impacts from Sea Level Rise	VI_1, V_2, VI_3	Territory-wide	University of the Virgin Islands	From personal stakeholder correspondence
Shoreline Development/Setback Study	VI_1, VI_2, VI_3	Territory-wide	University of the Virgin Islands/DPNR	From personal stakeholder correspondence
Building Code Improvements and National Flood Insurance Code Compliance	VI_1, VI_2, VI_3	Territory-wide	FEMA/VITEMA	From 2019 Field Workshop

Project	Planning Reach	Project Area	Agency/Organization	Comments
Marine Debris Action Plan	VI_1, VI_2, VI_3	Territory-wide	University of the Virgin Islands/NOAA/DPNR	$100,000 award to reduce marine debris from mangrove habitats. From 2019 Field Workshop.
Tsunami Warning System	VI_1, VI_2, VI_3	Territory-wide	VITEMA	From communication with the U.S. Virgin Islands Office of Disaster Recovery
U.S. Virgin Islands Hurricane Recovery and Resilience Task Force	VI_1, VI_2, VI_3	Territory-wide	Governor's Office/Multi-Agency Collaboration	2018 report on the impacts from the 2017 hurricanes and provides recommendations for recovery/resilience (the U.S. Virgin Islands Hurricane Recovery and Resilience Task Force 2018)

Several additional initiatives may be planned, contracted, or in progress as funded by the FEMA Public Assistance Program. These types of projects include transportation, housing, utility, and infrastructure projects, as well as others (U.S. Virgin Islands Office of Disaster Recovery 2019).

Other Notable Initiatives

The St. Croix Foundation for Community Development signed the Climate Strong Islands Declaration, joining island communities from across the world to increase awareness of the growing challenges island nations face (The Ocean Foundation 2020).

While there are no federal feasibility-level CSRM projects in the U.S. Virgin Islands, opportunities exist to evaluate possible projects beyond the NED to support the development of more CSRM studies.

5.4 Regional Sediment Management Strategies

Regional Sediment Management (RSM) is a systematic approach to managing sediments in a manner that maximizes natural and economic efficiencies to contribute to sustainable water resource projects, environments, and communities. Economic value is demonstrated by integrating CSRM and navigation projects, such as when a navigation project uses the CSRM project as a dredged material placement area or when a CSRM project uses a navigation project's channel(s) as a sediment source. Benefits can include reduced lifecycle costs, improved stakeholder communication and partnerships, and more robust project systems.

RSM methodologies, tools, and processes are outlined in the *Regional Sediment Management Tools and Technologies Volume I Coastal* (USACE 2018). The several phases of implementing RSM include:

1. Understand the Region – Develop an understanding of sediment processes and morphology, ecological conditions, ongoing projects and activities, knowledge gaps, potential partnerships, and sediment-related challenges.

2. RSM Strategies Project Scale – Understand how projects work within the existing system and how they might change with RSM practices.

3. Regional RSM Strategy – Integrate the project-scale strategies into the regional strategy.

4. Take Action – After projects are developed and implemented, monitor the project, and adaptively manage to ensure it is performing as expected.

Table 5-2 is pulled from the 2020 RSM Optimization Update, which depicts the general data inputs used to define RSM opportunities and quantify RSM values (USACE 2020a). Routine navigation and CSRM placement strategies, lessons learned, and costs are summarized in the 2020 RSM Optimization Update for all projects throughout the South Atlantic Division.

Table 5-2: List of Data Inputs for Optimization Template to Define RSM Opportunities and Quantify Value of Implemented RSM Projects and Potential RSM Opportunities

Project	Cost Engineering	Environmental/Permitting
Project Name	Cost Per Cubic Yard (dredge and place)	Shovel Ready?
Type of Material and Location	Mobilization/Demobilization Costs	Time to Shovel Ready
Dredge/Nourish Interval	Total Contract Costs	Cost to Shovel Ready
Most Recent Year of Activity	Dredge Type	Dredging Windows/Restrictions
Borrow/Placement Options	Cost Assumptions	Year Permitted
		Year Permit Expires

Currently there are no federal navigation and CRSM projects coupled within the U.S. Virgin Islands. However, potential opportunities may exist to keep sediment in the active coastal system.

5.4.1 Opportunities for Action

Opportunities may exist for the beneficial use of dredged material, such as the Charlotte Amalie Harbor Maintenance Project. These opportunities can include coastal wetland creation and restoration, hard bottom habitat creation, and filling relict dredge holes. To encourage beneficial use, Congress passed Section 1122 of the WRDA 2016, consisting of 10 pilot projects for the beneficial use of dredged material.

The 2020 RSM Optimization Update (USACE 2020a) outlines implemented RSM strategies and opportunities for RSM within each district. While this report did not highlight any strategies in the U.S. Virgin Islands, the SAND Report provided the following information about sediment sources and sand needs within the territory (USACE 2020e).

In St. Thomas, the SAND Report highlighted potential nourishment needs at Bluebeard's Castle Resort, Marriott's Frenchman Cove, Secret Harbour Beach Resort, The Ritz-Carlton, and Wyndham Margaritaville. One potential sediment source is the Charlotte Amalie Harbor Maintenance project with an estimated 60,000 cubic yards of beach-quality sand that could be placed on a nearby beach

(USACE 2020e). USACE had insufficient data to estimate sand volumes in RSM sources for St. John. The SAND Report cited Westin St. John Resort on Great Cruz Bay as the island's only proposed beach nourishment project (USACE 2020e). No information was provided for St. Croix.

The Virgin Islands Port Authority is currently the lead agency for a proposed $6 million dredging project in Gallows Bay, St. Croix, with an estimated completion date in 2021. The Virgin Islands Port Authority evaluated potential disposal sites based on location, physical features, capacity, and environmental and regulatory constraints, and identified the following potential disposal sites:

- Yabucoa Ocean Dredged Material Disposal Site
- Red Mud Pile Cap
- Public Works Department Veterans Drive Project
- Former dredge hole in Lindberg Bay
- St. Croix Quarry Site

Several of these sites, such as the Public Works Department Veterans Drive Project and dredge hole in Lindberg Bay (both of which are in the Charlotte Amalie Focus Area), offer potential CSRM benefits in the systems where sand is placed. Maintaining an active sediment system increases the resiliency of coastal communities where coastal storms, sea level rise, subsidence, and erosion threaten their long-term sustainability.

5.5 Coastal Storm Risk Management Measures and Costs

A management measure is a feature or activity at a site that addresses one or more of the planning objectives (**Figure 5-1**). A wide variety of measures may be considered in CSRM project planning. Measures considered as part of the SACS are:

1. No Action: USACE is required to consider "No Action" as one of the alternatives to comply with the requirements of the National Environmental Policy Act (NEPA). "No Action" assumes that no project would be implemented by the federal government or by local interests. "No Action," which is synonymous with the "Without Project Condition," forms the basis from which all other alternative plans are measured.

2. Nonstructural: Various nonstructural alternatives, including buyouts/relocations, elevating structures, dry and wet flood proofing, land conservation, and risk analyses are all considered viable nonstructural measures for CSRM. Other policy-related nonstructural measures may also be important in achieving CSRM.

3. Structural: Measures such as beach nourishment, breakwaters, groins, seawalls, ringwalls, and dikes are structural measures for CSRM. Construction of a structural feature serves to prevent waters from reaching residential property, businesses, and roads.

4. Natural and Nature-Based Features (NNBF): NNBF refers to the intentional use of natural and engineered features to produce engineering functions in combination with ecosystem services and social benefits. Natural coastal features take a variety of forms, including reefs (e.g., coral and oyster), barrier islands, tidal flats, wetlands, and mangroves.

5. Additional Measures to Complete Alternatives: Feasibility-level analysis may identify measures that might be required to generate a "complete" alternative. These may also include elements of an overall project in which USACE does not have authority to become a cost-sharing participant. Additionally, ecosystem restoration opportunities may provide dual storm damage reduction services.

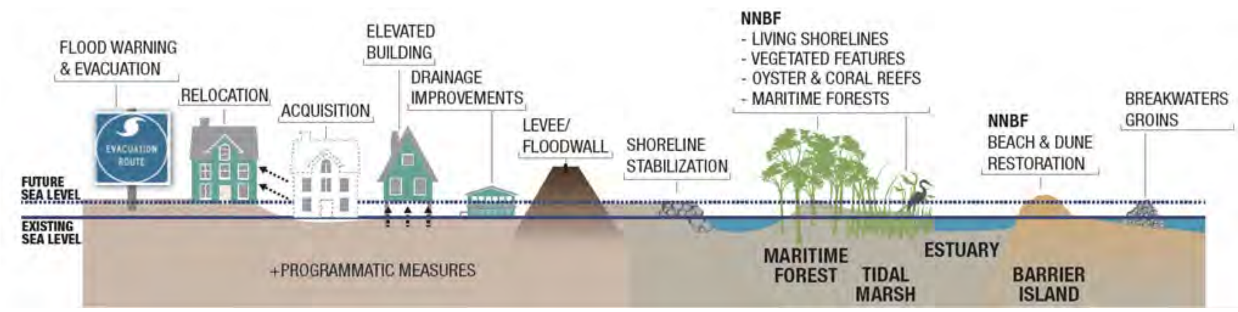


Figure 5-1: Potential Measures to Improve Resilience and Sustainability in the Coastal Environment (USACE 2015)

The MCL tool provides a suite of specific coastal storm risk management options that exemplify the categories outlined above. It provides users with the associated costs of these measures, considering the risk management category, risk management function, shoreline applicability, regional location, cost components, and uncertainty. Measures range from NNBF, such as living shorelines and wetland restorations, to harder techniques, such as revetments or bulkheads. **Figure 5-2** provides visual depictions of the range of options.

Figure 5-2: Gradient of Green/Softer Techniques to Gray/Harder Techniques for Coastal Storm Risk Management Measures (NOAA 2015d)

The MCL provides approximate order of magnitude (ROM) cost data specific to each planning reach within the SACS area. The following tables display ROM cost ranges based on unit inputs specific to Planning Reach VI_1. **Table 5-3** displays structural CSRM measures, **Table 5-4** displays NNBF, and **Table 5-5** displays nonstructural physical measures (which are also included in the MCL but without cost information). Examples of nonstructural nonphysical measures are flood warning systems, flood insurance, floodplain mapping, flood emergency preparedness plans, land use regulations, zoning, evacuation plans, risk communication, risk analysis, and land conservation. The MCL tool allows users to enter specific project parameters to calculate ROM cost ranges based on the scope of the potential project. More information regarding the MCL tool is detailed in Section 5.8.

Table 5-3: Structural Coastal Storm Risk Management Measures from the SACS Measures and Costs Library and Associated Annual Cost/Unit (based on Planning Reach VI_1)

Measure	Annual Mobilization and Demobilization Cost Range	Annual Construction Cost Per Unit Range (Dollars Per Unit)
Groins	$5,556–$14,816	$64–$359 ($/Linear Foot [LF])
Seawall	$25,929–$40,745	$456–$1,062 ($/LF)
Revetment	$6,667–$15,928	$175–$538 ($/LF)
Bulkhead	$6,667–$7,779	$66–$173 ($/LF)
Breakwaters	$14,816–$44,449	$204–$873 ($/LF)
Floodwalls	$20,743–$20,743	$227–$366 ($/LF)
Deployable Floodwalls	$704–$889	$106–$130 ($/LF)
Levees/Dikes	$9,631–$12,224	$76–$205 ($/LF)
Surge Barriers	$74,082–$6,945,172	$6,714–$10,563 ($/LF)
Beach Nourishment (Initial Construction)	$92,602–$222,246	$31–$174 ($/LF)
Beach Nourishment (Renourishment)	$92,602–$222,246	$16–$80 ($/LF)
Nearshore Nourishment	$16,668–$16,668	$4–$12 ($/LF)
Road Elevation	$370–$5,556	$280–$515 ($/LF)
Ringwalls	$370–$5,556	$76–$90 ($/LF)

Table 5-4: Natural and Nature-Based Coastal Storm Risk Management Measures from the SACS Measures and Costs Library (based on Planning Reach VI_1)

Measure	Annual Mobilization and Demobilization Cost Range	Annual Construction Cost Per Unit Range (Dollars Per Unit)
Barrier Island	$166,684–$385,226	$8,560–$41,899 ($/acre [AC])
Tidal Flats	$14,816–$18,520	$4–$9 ($/square foot [SF])
Wetland	$14,816–$55,561	$7,334–$47,265 ($/AC)
Maritime Forest	$370–$3,704	$77–$414 ($/AC)
Wet Pine Savannah	$370–$3,704	$77–$414 ($/AC)
Mangroves	$370–$5,556	$70–$114 ($/LF)
SAV	$3,704–$11,112	$6,408–$21,687 ($/AC)
Living Shoreline Vegetation	$370–$5,556	$1–$83 ($/LF)
Living Shoreline Reefs	$9,260–$44,449	$227–$715 ($/LF)
Living Shoreline Sills	$9,260–$44,449	$67–$316 ($/LF)
Coral Reef Breakwater	$14,816–$44,449	$262–$989 ($/LF)
Oyster Reef Breakwater	$3,704–$11,112	$36–$151 ($/LF)

Table 5-5: Nonstructural Physical Coastal Storm Risk Management Measures from the SACS Measures and Costs Library (based on Planning Reach VI_1)

Measure	Annual Mobilization and Demobilization Cost Range	Annual Construction Cost Per Unit Range (Dollars Per Unit)
Buyout and Acquisition	N/A	$12,968–$35,539 ($/Asset)
Building Elevation	N/A	$3,962–$14,676 ($/Asset)
Dry Flood Proofing	N/A	$1,250–$4,033 ($/Asset)
Wet Flood Proofing	N/A	$327–$634 ($/Asset)
Relocation	N/A	$6,217–$15,089 ($/LF)

CSRM projects can combine multiple measures to achieve desired risk reduction. The location of each measure type must match the shoreline type, coastal conditions, and hazard being mitigated. Examples of the application of the MCL can be found in the SACS Focus Area Action Strategy (FAAS) reports.

5.6 Focus Area Selection

The SACS focus areas were selected based on Tier 1 high-risk areas and stakeholder feedback. They were developed to serve as examples of how to develop action strategies to manage coastal storm risks in populated areas, areas of concentrated economic development, and areas with vulnerable environmental and cultural resources. Each district developed draft focus areas and presented these to stakeholders during the 2019 field workshops. Based on stakeholder feedback from these workshops, the district teams identified 21 final focus areas within the SACS study area, selecting at least one per state/territory, with U.S. Virgin Islands focus areas shown in **Figure 5-3**. Focus area selection was dependent on multiple factors, including diversity of focus areas, particularly a variety of high-risk areas ranging from areas of high-risks to population and infrastructure to areas with high cultural and environmental resources, and/or a combination thereof.

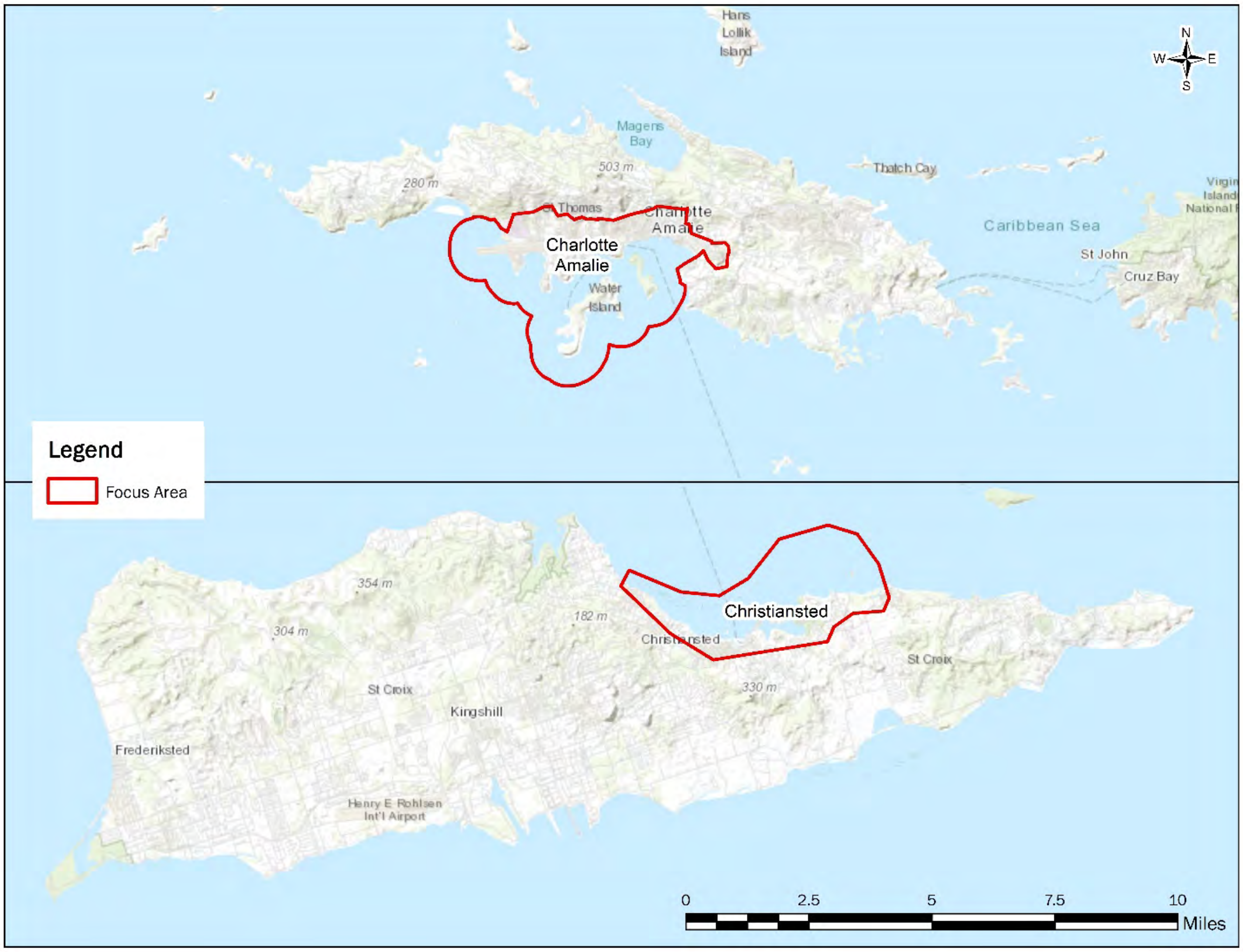


Figure 5-3: SACS U.S. Virgin Islands Focus Areas

The South Atlantic Jacksonville District team presented five draft focus areas to stakeholders at the 2019 U.S. Virgin Islands field workshop. Based on this feedback and additional analysis by the SAJ District team, two focus areas were selected for the U.S. Virgin Islands: Charlotte Amalie in St. Thomas (**Figure 5-3** top) and Christiansted in St. Croix (**Figure 5-3** bottom).

Stakeholders were engaged throughout the Focus Area Action Strategy analysis, such as the University of the Virgin Islands and the Department of Planning and Natural Resources, to maximize local knowledge in the area and promote collaboration toward achieving coastal storm risk resilience. The focus area action strategies (detailed in Section 5.7) use a “watershed approach” to address problems (Watershed Planning Guidance: PB 2019-01, EC 1105-2-411). This watershed approach to CSRM implemented at these focus areas could be applied to other areas throughout the territories.

5.7 Focus Area Action Strategies

The FAAS were developed to identify action strategies to reduce risk to coastal storms and increase resilience in the U.S. Virgin Islands. SACS key products and analyses were leveraged to understand existing and future conditions and quantify existing and potential risks. Stakeholders were engaged throughout the process to provide feedback on problems and opportunities, identify specific institutional and other barriers, and identify and prioritize potential action strategies to improve resilience. While these FAAS were developed specifically for the Christiansted and Charlotte Amalie areas, they can serve as examples of how to develop action strategies for other high-risk locations within the territory.

In both of these focus areas, opportunities were identified for additional outreach and collaboration, specifically targeting the communication of the economic implications of coastal storm risk to the U.S. Virgin Islands. For USACE to increase participation in supporting CSRM in these focus areas and throughout the U.S. Virgin Islands, opportunities exist to look beyond the NED account justification for projects and consider OSE, RED, and EQ accounts.

Section 5.7.1 and Section 5.7.2 summarize the findings of the FAAS reports.

5.7.1 Christiansted Focus Area Action Strategy

The Christiansted Focus Area (**Figure 5-4**) is located on the northern coast of St. Croix and was selected based on its cultural and environmental significance, dense population, and its current and future risk to coastal hazards, based on the Tier 1 analysis. The focus area includes offshore coral reef habitat and the Christiansted Historic District, as well as two PEAs (Altona Lagoon and Southgate Pond).

Figure 5-4: Christiansted Focus Area Boundary

Based on stakeholder feedback from the Christiansted Focus Area Action Strategy workshops and questionnaires, the project team developed the following shared vision for the area:

"The Christiansted Focus Area Action Strategy is a collaborative effort that leverages local capacity to plan and implement cohesive CSRM strategies along the northern shoreline on the island of St. Croix. The FAAS vision is to provide a common understanding of risk from coastal storms and sea level rise to support and protect resilient communities, native habitats and wildlife, culturally significant areas, existing infrastructure and natural features."

The key problems reported for this focus area include lack of coordinated watershed-scale planning to address coastal storm risks and compound flooding and lack of engagement at all levels of government to support efforts, coastal erosion and inundation causing damage to infrastructure and cultural resources, loss of NNBF such as coral reef systems due to anthropogenic activities, mangrove loss and loss of habitat for migratory birds and other threatened and endangered species, marine debris, and compound flood risks, which are exacerbated by storm surge inundation and sea level rise. Through coordination with stakeholders, USACE developed several potential actions to address these problems, which include the following themes:

- Community Engagement, Communication, and Policy Improvements
- Shoreline Erosion
- Environmental Resources
- Downtown Flooding

Recommendations based on this FAAS can be found in the Christiansted FAAS report and are incorporated in SECTION 7 of this appendix.

5.7.2 Charlotte Amalie Focus Area Action Strategy

The Charlotte Amalie Focus Area (**Figure 5-5**) is located on the southern coast of St. Thomas and was selected based on its significant population, critical infrastructure, cultural significance as the capital of the Virgin Islands, and its current and future risk to coastal hazards. The boundaries of the focus area were delineated specifically to include the Cyril E. King Airport to the west of Charlotte Amalie, Water and Hassel Islands to the south, and the Charlotte Amalie/Ft. Christian Historic District.

Figure 5-5: Charlotte Amalie Focus Area Boundary

Based on stakeholder feedback from the Charlotte Amalie Focus Area Action Strategy workshops and questionnaires, the project team developed the following shared vision for the area:

"The Charlotte Amalie Focus Area vision is to utilize local knowledge along with the tools provided through the SACS and partners to provide a common understanding of risk from coastal storms and sea level rise to support resilient communities and habitats. This collaborative effort will leverage stakeholders' actions to plan and implement cohesive coastal risk management strategies to protect and strengthen culturally significant areas, existing infrastructure, and natural features in Charlotte Amalie."

The key problems reported for this focus area include lack of coordinated watershed-scale planning to address coastal storm risks and compound flooding and lack of engagement at all levels of government to support efforts, coastal erosion and inundation causing damage to infrastructure and cultural resources, loss of NNBF such as coral reef systems due to anthropogenic activities, mangrove loss and loss of habitat for migratory birds and other threatened and endangered species, marine debris, and compound flood risks, which are exacerbated by storm surge inundation and sea level rise. Through coordination with stakeholders, USACE developed several potential actions to address these problems, which include the following themes:

- Policy Improvements and Community Engagement
- Shoreline Erosion and Inundation Along Lindbergh Bay and Airport Road
- Environmental Resources
- Flood Risks along Veterans Drive

Recommendations based on this Focus Area Action Strategy can be found in the Charlotte Amalie FAAS report, and are incorporated in Section 7.2 of this appendix.

5.8 Strategies to Address Remaining High-Risk Areas

This section documents strategies to address the residual risks not addressed in the FAAS documents. The FAAS are intended to serve as strategy development examples of how to leverage SACS tools to manage coastal storm risks in other high-risk areas within the SACS area of responsibility.

Table 5-6 identifies the high-risk locations from each U.S. Virgin Islands planning reach that was not chosen as a focus area but that may be candidates for a similar action strategy analysis. These locations were identified through the Tier 1 and Tier 2 Summary of High-risk Locations tables (**Table 4-9**, **Table 4-13**, and **Table 4-17**) located at the end of each Planning Reach section. The high-risk summary tables were based on the Tier 1 Risk Assessment, the Tier 2 Economic Risk Assessment, historical erosion risk, potential increase in wave attack with sea level rise, social vulnerability, and locations containing valuable environmental or cultural resources at risk from coastal storms as sea levels rise. The Xs in the columns indicate the identified risk for each place listed in the table. The threshold values used to identify the risk for each column are detailed in Sections 4.2.3 , 4.3.3 , and 4.4.3. The locations identified as high-risk met the criteria for risk in at least four of the eight columns in the table.

This page intentionally left blank.

Table 5-6: Additional High-Risk Locations Not Addressed in the Focus Area Action Strategies

Location	Planning Reach	Tier 1 Risk Assessment	Tier 2 Economic Risk Assessment	Erosion Risk	Future Wave Attack	Environmental Risk	Priority Environmental Area	Cultural Resources	Social Vulnerability
Estate Two Brothers	VI_1		X		X	X	X	X	X
Estate Nazareth	VI_2		X	X	X	X			
Estate Smith Bay	VI_2		X	X	X	X	X		
Red Hook	VI_2	X	X		X	X			
Cruz Bay	VI_3	X	X		X	X		X	
Estate Great Cinnamon Bay	VI_3		X			X	X	X	

This page intentionally left blank.

The following steps can be taken to apply the FAAS methodology to the remaining high-risk areas within the U.S. Virgin Islands.

1. **Identify the problem**

    - Section 3.2 identifies problems and opportunities that the territory currently faces. Many of these problems will worsen as sea levels rise. Understanding the most important problems for the area will help refine the action strategy development. When identifying the problem, it is important to specify who/what is impacted, the spatial extent of the impact, and the primary drivers of the impact. Identifying corresponding opportunities while addressing the problem is also included during this first step.

2. **Utilize exposure, hazard, and risk tools**

    - The Geoportal has several data layers that can be utilized to assess potential risk to populations, infrastructure, environmental, and cultural resources from coastal storms hazards. The data layers in the geoportal include both products developed during the SACS, as well as products developed by other agencies/stakeholders.

    After identifying the problem and assessing potential exposure, hazards, and risk, an array of alternatives can be developed to mitigate risks. Section 5.5 details alternative measures consisting of nonstructural, structural, and NNBF. Measures can be assessed based on shoreline types, exposure to resources at risk, and extent of residual risk in the future condition.

    Wave Energy Analysis: Wave energy can be used to identify measures to address coastal risk. Exposed shorelines have high and mixed wave energy environments while sheltered shorelines have low wave energy environments. Shorelines with high-wave energy are more suitable for structural measures, such as beach nourishment, floodwalls, and revetments. Shorelines with low-wave energy are more suitable for NNBF, including mangroves, wetlands, or living shorelines. Nonstructural measures are also applicable to both high- and low-wave energy environments, depending upon the objectives of the projects.

    Sand Availability and Needs Determination: Data from the SAND Report can be used when evaluating high-risk locations. If erosion and wave attack are causing damage to infrastructure or loss of habitat along exposed sandy beach shorelines, then implementing beach and dune nourishment and creating a more robust berm and dune system can help to mitigate these risks. The SAND Needs layer identifies areas that need future beach nourishment projects. Alternatives can include beach nourishment, dune enhancement, and accompanying RSM strategies. At this time, there are no SAND Borrow Areas identified within the U.S. Virgin Islands. However, potential sand resources include local navigation channels or upland mines.

    Conservation and/or Restoration: There are several datasets that can be used to identify land conservation and restoration opportunities. Opportunities include reducing the loss of important habitat (thereby maintaining natural storm damage reduction benefits) and improving future development planning. The SACS Environmental Analysis Web Application was created to identify the environmental resources potentially at risk from inundation in the future condition with 2.33 feet (0.71 meter) of sea level rise. The methodology for the environmental analysis is documented in the Environmental Technical Report (USACE 2021b).

MCL: The MCL contains a repository of potential structural, nonstructural, and NNBF measures that could be considered for CSRM. While there may be other potential measures not included in the MCL, the MCL provides several measures to consider. Using the shoreline and SAND analyses listed above, an array of alternative measures can be developed to address the problems identified. The MCL can help develop measures by considering the risk management function, regional location, and cost components (cost will be discussed in Step 4). An array of alternatives could include a no action alternative, a nonstructural alternative, a structural alternative, and an NNBF alternative. These different types of measures can be combined to create a final array of alternatives.

3. **Evaluate and compare alternatives**

- When evaluating alternatives, it is important to determine whether the measure addresses the problem while meeting the objectives of the project. Measures are often combined (nonstructural, structural, and NNBF) to meet the most objectives.
- *Tier 2 Economic Risk Assessment Dashboard:* This dashboard was created using FEMA's FAST to estimate annualized damages to structures and contents from coastal storm inundation. EAD were computed for the existing conditions as well as for future conditions while also considering additional inundation from 2.33 feet (0.71 meter) of sea level rise. **Figure 5-6** demonstrates the output from the Tier 2 Economic Risk Assessment Dashboard, which can provide EAD data for user-selected census blocks. This information can be used to evaluate the economic inundation risk to content and structures, which may be compared to the cost of implementing a risk management measure (using the MCL) for a high-level BOM benefit-cost analysis.

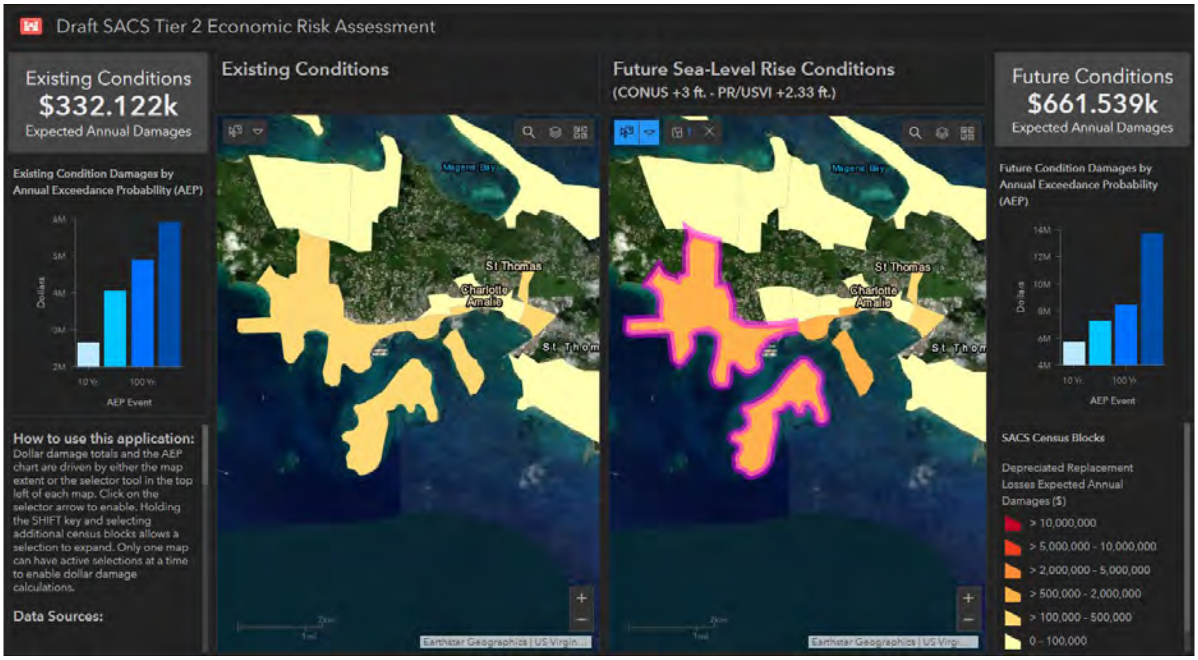


Figure 5-6: Tier 2 Economic Risk Assessment Dashboard Depicting Expected Annual Damages

- ***MCL:*** MCL consists of two components. The first component was discussed in Step 3 when creating an array of alternatives utilizing nonstructural, structural, and NNBF measures. The second component of the MCL is ROM costs that are developed per unit for all structural and NNBF measures as well as some nonstructural measures. MCL will output an annual cost range based on the input size of the measure and a 50-year period of analysis. **Table 5-7** exemplifies the use of the MCL tool to compute the annualized costs for a deployable floodwall and surge barrier.

Table 5-7: Annualized Cost Output Based on Measurements Input

	Measure Code	Measure Group Name	Measure Unit	ROM Cost Range Based on User Input	
				Annual Cost Low	Annual Cost High
Structural Measures	S-1	Groins	$/LF	$0	$0
	S-2	Seawall	$/LF	$0	$0
	S-3	Revetment	$/LF	$0	$0
	S-4	Bulkhead	$/LF	$0	$0
	S-5	Breakwaters	$/LF	$0	$0
	S-6	Floodwalls	$/LF	$0	$0
	S-7	Deployable Floodwalls	$/LF	$12,359	$40,208
	S-8	Levees / Dikes	$/LF	$0	$0
	S-9	Surge Barrier	$/LF	$3,273,394	4,773,699
	S-10	Beach Nourishment	$/LF	$0	$0
	S-11	Nearshore Nourishment	$/LF	$0	$0

4. Develop an action strategy

- The final step is to develop an action strategy based on the previous four steps. **Table 5-8** presents an example of an action strategy table that summarizes potential CSRM actions. The columns in the table address many of the topics discussed in the first four steps of the process. An action strategy should consider prioritization and the time frame of actions with identified lead stakeholders. The actions are identified as needed, planned, or ongoing, based on stakeholder input and knowledge.

Table 5-8: Action Strategy Table Example

Category	Status	Measure/ Action Type	Description/ Purpose	Lead Stakeholder(s)	Time Frame[1]	Priority
Structural	Ongoing	Coastal Storm Risk Management	Rehabilitation and mitigation of dilapidated underground water and sewer lines along Watergut Street	Utilities and Federal Partners	Mid	High
Structural	Ongoing	Bulkhead	Rebuild damaged bulkhead in front of Ft. Christiansvaern	NPS, NOAA, BioImpact, Inc.	Short	*Unspecified*
Nonstructural	Ongoing	Study	Long-term shoreline erosion study	University of the Virgin Islands, DPNR	Short	*Unspecified*
Natural and Nature-Based Feature	Ongoing	Study	Coral reef monitoring program	U.S. Virgin Islands	Long	Medium

[1]Time Frame: short = < 2 years, mid = 2–10 years, long = >10 years

5.8.1 Identification of Further Study Efforts

An action strategy to address coastal storm risks may include follow-on studies or designs. USACE has several authorities to support smaller studies. The USACE Small Projects Program consists of several programs and authorities, including the Continuing Authorities Program, Planning Assistance to States, and Flood Plain Management System.

The Continuing Authorities Program consists of nine legislative authorities under which the Secretary of the Army (acting through the Chief of Engineers) is authorized to plan, design, and implement certain types of water resources projects without additional project-specific congressional authorization. **Table 5-9** lists and describes the purpose of the nine Continuing Authorities Program Authorities, including federal and non-federal cost-sharing information and federal financial contribution limits, or federal project limits.

Table 5-9: Summary of Continuing Authorities Program and Specific Requirements

Authority	Purpose	Feasibility Cost Share Federal/Non Federal	Implementation Cost Share Federal/Non Federal	Federal Project Limit
Section 14, 1946 Flood Control Act, as amended	Emergency Stream Bank and Shoreline Protection	100%/0% for initial $100,000; 50%/50% remaining cost	65%/35%	$5,000,000
Section 103, 1962 River and Harbors Act, as amended	Hurricane and Storm Damage Reduction (Beach Erosion)	100%/0% for initial $100,000; 50%/50% remaining cost	65%/35%	$5,000,000
Section 107, 1960 River and Harbor Act, as amended	Navigation Improvements	100%/0% for initial $100,000; 50%/50% remaining cost	Varies, based on depth	$10,000,000
Section 111, 1968 River and Harbor Act, as amended	Mitigation to Shore Damage Attributable to Navigation Works	100%/0% for initial $100,00; 50%/50% remaining cost	Shared in same proportion as project causing damage	$10,000,000
Section 204, 1992 WRDA, as amended	RSM	100%/0%	65%/35%	$10,000,000
Section 205, 1948 Flood Control Act, as amended	Flood Damage Reduction	100%/0% for initial $100,000; 50%/50% remaining cost	65%/35%	$12,000,000
Section 206, 1996 WRDA, as amended	Aquatic Ecosystem Restoration	100%/0% for initial $100,000; 50%/50% remaining cost	65%/35%	$10,000,000
Section 208, 1954 Flood Control Act, as amended	Snagging and Clearing for Flood Damage Reduction	100%/0% for initial $100,000; 50%/50% remaining cost	65%/35%	$500,000
Section 1135, 1986 WRDA Act, as amended	Project Modifications for Improvements to the Environment	100%/0% for initial $100,000; 50%/50% remaining cost	75%/25%	$10,000,000

This page intentionally left blank.

SECTION 6

Institutional and Other Barriers

The SACS Institutional and Other Barriers Report (USACE 2021c) summarizes the institutional and other barriers identified by stakeholders throughout the development of the SACS study. The following sections provide a high-level summary of this report.

6.1 Barriers to Implementing Regional Sediment Management

Section 1204 of WRDA 2016 specifically directs that the SACS will, "conduct a comprehensive analysis of current hurricane and storm damage reduction measures with an emphasis on RSM practices to sustainably maintain or enhance current levels of storm protection." Districts and regional stakeholders have noted that financial, institutional, and other barriers often prevent implementation of RSM strategies. For the U.S. Virgin Islands, the lack of data related to potential sediment sources and shoreline position present additional barriers.

6.2 Other Barrier Categories

Section 1204 of WRDA 2016 directs that the SACS, "identify… institutional and other barriers to providing protection to the vulnerable coastal populations." Modeled after the NACCS Institutional and Other Barriers Report, the SACS *Institutional and Other Barriers Report* (USACE 2021c) summarized stakeholder input from fall 2019 field workshops into six themes:

- Theme 1: Risk and Resilience Standards
- Theme 2: Risk Communication
- Theme 3: Risk Management
- Theme 4: Science, Engineering, and Technology
- Theme 5: Leadership and Institutional Coordination
- Theme 6: Local Planning and Financing

Feedback was then categorized further into subthemes based on specific key barriers provided within each theme. Subthemes unique to the SACS were created to identify additional trends in the feedback and capture differences between the two studies. **Figure 6-1** shows the distribution of barriers across the six themes based on U.S. Virgin Islands stakeholder feedback. Stakeholders mentioned risk management barriers most often, followed by risk communication and leadership/institutional coordination barriers.

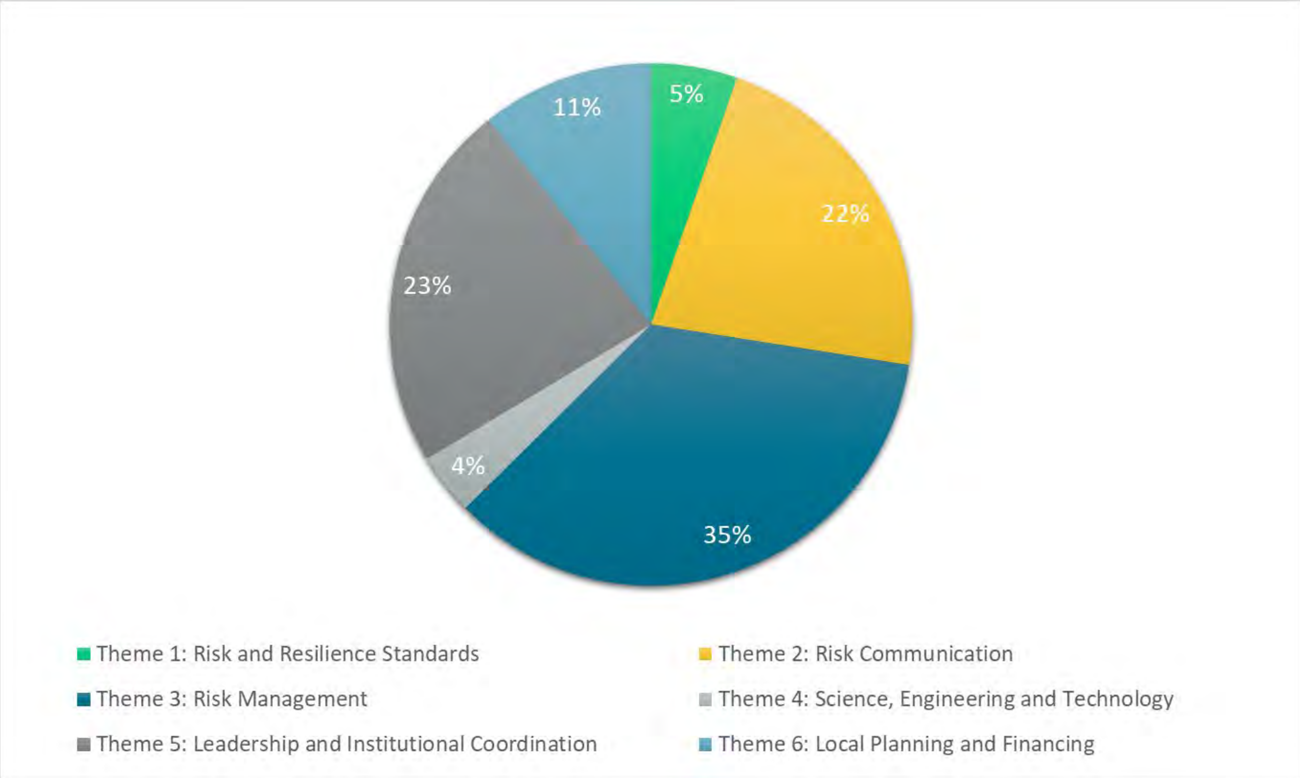


Figure 6-1: Barriers Identified by Theme in the U.S. Virgin Islands

Across all themes, the U.S. Virgin Islands stakeholders mentioned the following barriers most frequently:

- Limited staff capacity and expertise, particularly at the local level
- Limited coordination and leadership at all levels
- Limited education in environmental science, ecology, climate change, and the cost of inaction
- Lack of funding
- Relaxed or limited enforcement of existing regulations

Stakeholders also mentioned that the territorial status of the U.S. Virgin Islands presented additional barriers to managing coastal risk. The lack of data for the territories also emerged as a barrier throughout the development of this analysis. For example, the U.S. Virgin Islands were not included in the creation of the EPA Integrated Climate and Land Use Scenarios (ICLUS) dataset, which was used in the Tier 2 analysis for other regions of the SACS area. The absence of data in the U.S. Virgin Islands inhibits the use of the Social Vulnerability Exposure Index tool to understand Other Social Effects from potential USACE projects. Similarly, lack of input data hinders the use of the Regional Economic System model to understand Regional Economic Development benefits sourced from potential projects in the U.S. Virgin Islands. In addition, limited fundamental coastal engineering data, such as beach profile surveys or shoreline change estimates, reduce the ability to accurately characterize hazards on the U.S. Virgin Islands.

Additional barriers identified by stakeholders as part of the focus area action strategy development process echoed the need for updated regulations, particularly regarding building setbacks, and the need for enforcement of those regulations. The lack of understanding of resilient building best practices among local contractors emerged as a barrier. The need for more robust coastal storm risk representation and modeling of joint probability risks was also noted. Stakeholders also emphasized a lack of political support for CSRM and the need for engagement of local civic employees in these efforts. Communication of economic implications of coastal storm risks was also identified as an opportunity to increase awareness of the importance of coastal storm risks in supporting the economic sustainability of the territory.

This page intentionally left blank.

.

SECTION 7

Summary & Recommendations

In 2017, the U.S. Virgin Islands suffered severe damage from Hurricanes Irma and Maria, two major back-to-back hurricanes. While hurricanes and coastal hazards have historically been a threat to the islands, these two storm events highlighted the increased need for action to address the islands' vulnerabilities, reduce existing coastal risks, and prepare for the future hazards. This section provides a summary of some of the key findings from the SACS pertaining to the U.S. Virgin Islands, followed by recommendations to manage coastal storm risk, which include identified follow-on studies.

7.1 Summary

The U.S. Virgin Islands faces significant CSRM challenges today and these will only worsen as sea levels rise. The territory has old and inadequate drainage systems that can no longer control the increased flood hazards. Much of the islands' infrastructure is in vulnerable low-lying areas, has already been damaged in previous storms, and requires significant maintenance. The territory is losing natural habitats, such as coral reefs, mangroves, wetlands, and sea grasses. A struggling economy and a lack of coordinated planning strain the territory's ability to rebuild, recover and prepare for the changing future.

In addition to the challenges above, the U.S. Virgin Islands has higher poverty rates, lower median income, and a higher unemployment rate compared to the continental United States. These social vulnerabilities result in a population less resilient to coastal hazards than many other regions of the SACS area of responsibility. While many efforts are currently underway, more can be done to support vulnerable populations by managing coastal storm risks. More specifically, opportunities exist for USACE to engage with local stakeholders and support future studies that will provide benefits not just for economic development but through addressing the other social impacts of coastal storms. To increase USACE engagement in the U.S. Virgin Islands, USACE may leverage OSE, RED, and EQ benefits to illustrate and justify project needs.

The SACS effort identified nine high-risk locations within the U.S. Virgin Islands based on the Tier 1 and Tier 2 analyses. The high-risk locations were based on medium-high/high infrastructure risk, medium-high or high erosion risk, future wave height increases of over 1.6 feet (0.5 meters) and over five acres of areas classified as high environmental risk. The presence of PEAs and cultural resources at risk were also considered in the selection of the high-risk locations, shown in **Figure 7-1*.*** Section 5.8 outlines the general steps to address high-risk areas used in the development of the U.S. Virgin Islands Appendix and the FAAS, which can be applied to other high-risk locations.

Coastal storm risks pose significant economic, environmental, cultural, and social challenges in the U.S. Virgin Islands. Fifty-five percent of the population of the U.S. Virgin Islands live in census estates subject to flooding from the Category 5 MOM (U.S. Census Bureau 2010). Under current conditions, the territory is expected to experience $2,089,000 in annualized structure and content damages (FY18) from coastal storms. With sea level rise, future EAD will more than double, totaling $5,367,000 (FY18). The added high social vulnerability of the territory impedes the ability for the population to recover from coastal storm events. Of the eight most socially vulnerable census estates identified within the CREST social vulnerability data, three are subject to coastal hazards (Dobson et al. 2020). Without significant environmental protection, more than 4,000 acres of environmental resources in the U.S. Virgin Islands may be lost to sea level rise and coastal storms, with over 800 acres classified as high environmental risk (USACE 2021b). Coastal hazards also threaten the historical and cultural character of the U.S. Virgin Islands, with 22 NRHP-listed cultural resources subject to flooding from the 1-percent AEP storm by 2120 (NPS 2014). Sea level rise is also expected to increase wave attack and coastal erosion, putting additional cultural and environmental resources and infrastructure at risk.

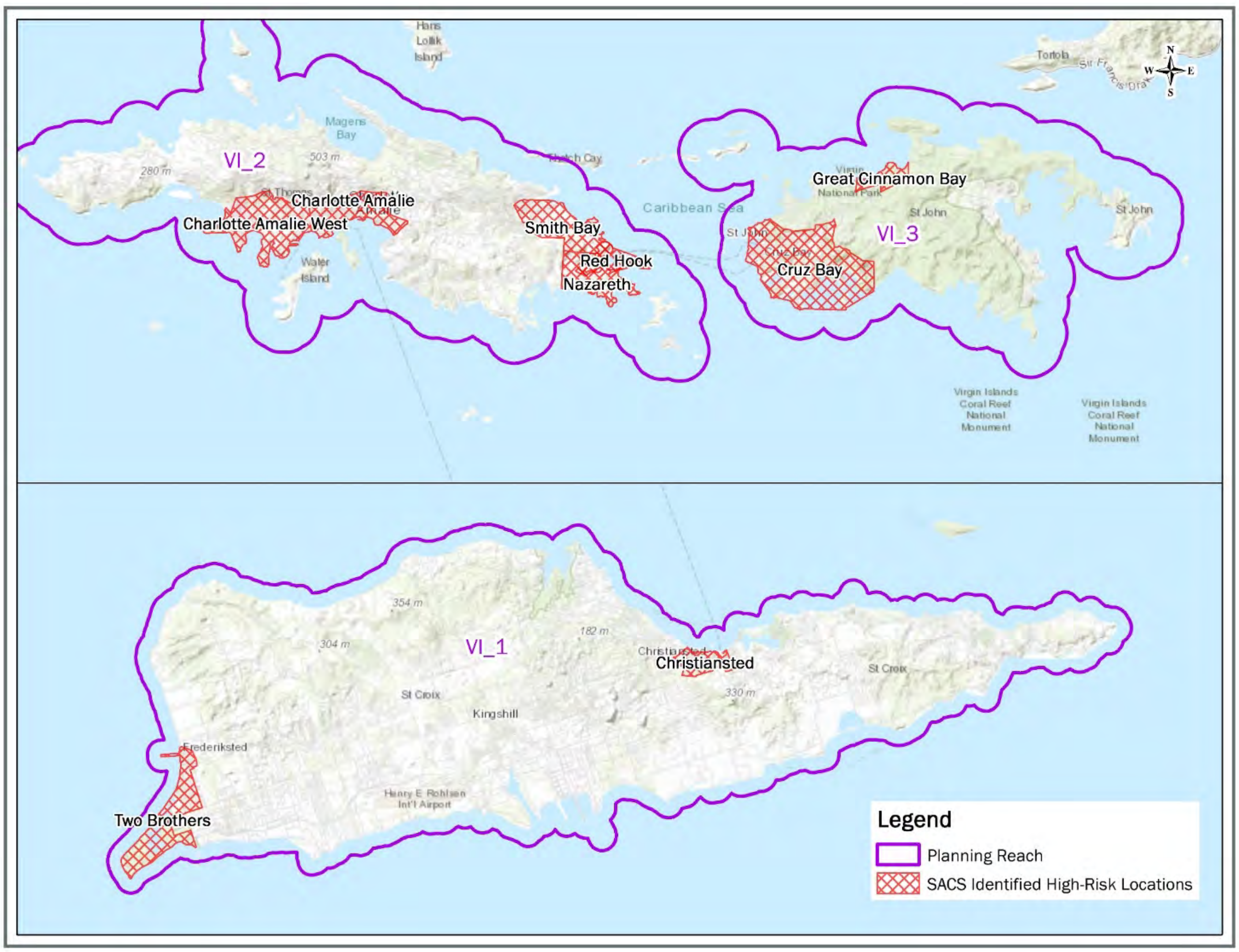


Figure 7-1: SACS-Identified High-Risk Locations in the U.S. Virgin Islands

Institutional and other types of barriers can slow or prevent the successful implementation of any potential action strategy. U.S. Virgin Islands stakeholders identified the lack of funding, shortages of qualified staff at the local level, and limited coordination and leadership across all levels of government as major barriers to risk reduction. Stakeholders identified opportunities to build local expertise through an increased focus on public education in science, ecology, climate change, and engineering/construction. Additionally, communicating the cost of inaction and the link between coastal storm risks and the overall economic sustainability of the territory was identified as a way to increase engagement in CSRM.

Relaxed enforcement of existing regulations also emerged as a barrier. While enforcement is an issue in the continental United States, it is a particular challenge for the U.S. Virgin Islands. Stakeholders noted that there is minimal oversight of private construction projects, relaxed adherence to the latest building codes, and minimal recourse for lack of compliance. CSRM policies cannot be successful without appropriate application.

The SACS also determined that the lack of data regarding potential sediment sources serves as a barrier to implementing RSM within the territory. Throughout the SACS effort, the lack of data for the U.S. Virgin Islands acted as barrier to understanding coastal risk. Several datasets exist for the continental United States that are not currently available for the U.S. Virgin Islands, such as the ICLUS dataset, making the characterization of hazards, exposure, and risks a challenge.

The U.S. Virgin Islands have a highly vulnerable population compared to the United States and Washington, DC (Kaiser Family Foundation 2020). This vulnerability is exemplified by the percentage of the population living below the poverty level, which exceeds that of the United States by eight percent, and an unemployment rate that is almost triple that of the United States. Based on the 2010 Census data (U.S. Census 2011), the majority (78 percent) of the territory's population identifies as Black or African American, while 16 percent identify as White. These factors are attributes of the U.S. Virgin Island's overall social vulnerability. A lack of resources can inhibit socially vulnerable coastal communities from becoming more resilient to coastal storms. USACE has opportunities to support these communities by considering other social effects and environmental quality benefits to justify CSRM projects in the communities that need it most.

In addition to the challenges above, the U.S. Virgin Islands has higher poverty rates, lower median income, and a higher unemployment rate compared to the continental United States. These social vulnerabilities result in a population less resilient to coastal hazards than many other regions of the SACS area of responsibility. While many efforts are currently underway, more can be done to support vulnerable populations by reducing coastal storm risks. More specifically, opportunities exist for USACE to engage with local stakeholders and support future studies that will provide benefits not just for economic development but through addressing the other social impacts of coastal storms. To increase USACE engagement in the U.S. Virgin Islands, USACE may leverage OSE, RED, and EQ benefits to illustrate and justify project needs

7.2 Recommendations

The following recommendations (**Table 7-1**) result from the analyses detailed within this appendix and from coordination with stakeholders throughout the U.S. Virgin Islands. As part of the Tier 2 analysis, efforts were made to develop specific and detailed recommendations to address coastal storm risk within the selected focus areas as described in each FAAS. Importantly, several recommendations initially developed for focus areas are also applicable throughout all coastal areas of USVI. Other high-risk areas not located within a focus area may also have had recommendations developed.

All recommendations for the U.S. Virgin Islands are shown in **Table 7-1** and represent important components of an overall regional strategy for the full SACS study area. As described in the Main Report, the SACS regional strategy focuses on maintaining and adapting projects and programs that are successfully addressing coastal risk while advancing emerging methods. The regional strategy also emphasizes the importance of advancing coordination and collaboration on complex issues, such as land use and development practices, to manage increased coastal storm risk as a result of sea level rise throughout the SACS study area. Recommendations are made for either multiagency action, USACE action, or consideration by the United States Congress (Congress) to advance specific actions resulting from analyses presented in this report and from coordination with stakeholders.

Recommendations are organized into six categories, as shown in **Figure 7-2,** and three implementation time frames (near-, mid-, and long-term). Implementation timing is influenced by the degree of stakeholder collaboration needed, technical complexity of the recommendation, current momentum toward implementation, and other factors needed to implement the recommendation. Implementation time frames include:

- **Near-Term Implementation (<5 years):** These recommendations are generally less complex and have significant stakeholder momentum toward implementation. The recommendations generally maintain and adapt actions that are recognized to successfully manage coastal storm risk.
- **Mid-Term Implementation (5–10 years):** These recommendations may be more technically complex and/or require additional stakeholder coordination and collaboration for implementation. They advance ongoing and emerging efforts to address coastal storm risk.

Figure 7-2: Recommendation Categories

- **Long-Term Implementation (>10 years):** These recommendations typically require significant stakeholder coordination and—from technical, political, or social perspectives—may be the most challenging to implement on a regional scale. Importantly, coordination and collaboration on these recommendations should not be delayed. The long-term time frame is reflective of the time to implementation based on lead time needed to advance these recommendations, which include complex issues such as land use, zoning, and building codes.

Based on its shoreline length relative to other states and territories in the SACS study area, 2 priority recommendations were made for the U.S. Virgin Islands. Priority recommendations can manage a significant amount of risk and have a high implementation potential based on stakeholder interest and other factors.

This page intentionally left blank.

Table 7-1: Recommendations for the U.S. Virgin Islands (Priority Recommendations in Yellow)

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description
Address Barriers Preventing Comprehensive Risk Management	Near-Term (<5 years)	Multi-Agency Action	Use of risk assessment tools and collaboration for coastal resilience needs	The Tier 2 Economic Risk Assessment highlights the potential future cost of inaction for the territory. The risk assessment tools, in concert with other SACS key products, should be leveraged to help provide data and foster additional collaboration around co-benefits and coastal resilience needs. For example, economic development plans such as Vision 2040 can be enriched by the analyses already compiled as part of SACS. USACE can continue to participate in these collaborative efforts, particularly through the Silver Jackets program, and provide support, where appropriate.
Address Barriers Preventing Comprehensive Risk Management	Near-Term (<5 years)	USACE	Improve methodology for quantification of OSE, EQ and RED benefits during feasibility phase to assist USACE teams during plan formulation	The socially vulnerable communities within SAD that are also vulnerable to coastal storm damages and sea level rise have a difficult time justifying plan selection upon NED benefits alone. In light of the 5 JAN 21 ASA Policy Directive, develop a more streamlined and enterprise-wide acceptable way to quantify and evaluate these benefit categories during feasibility. In future project planning, the four planning benefit accounts for project justification and evaluation of alternatives should be evaluated. The OSE account can be evaluated using census data or the USACE Institute of Water Resources SV-X tool for larger-scale projects. To determine the maximum benefit from the RED account, the existing RECONS model database needs to be updated to include data for Puerto Rico. Leveraging and expanding tools to support a comprehensive evaluation of benefits will help overcome existing institutional barriers limiting communities within the focus area from justifying projects that support community resilience. Expansion of the RECONS model would help support the computation of regional economic development benefits for potential projects.
Address Barriers Preventing Comprehensive Risk Management	Mid-Term (5-10 years)	Multi-Agency Action	Community engagement efforts	Without the support of the community and political representatives, resiliency and risk management efforts are not likely to be prioritized and progressed. While these issues are critical, communities in the focus area face several competing priorities. Stakeholders in the U.S. Virgin Islands focus on economic development; opportunities exist to highlight the interconnectivity between local economy, environmental habitats, and resiliency to stakeholders and local agencies. Community engagement efforts are needed to bring public awareness to the economic savings afforded by flood mitigation and habitat protection efforts because economic costs will incur if these kinds of measures are not soon implemented.

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description
Address Barriers Preventing Comprehensive Risk Management	Mid-Term (5-10 years)	Multi-Agency Action	Identify and conserve parcels of land to accommodate mangrove migration	A mangrove migration study was identified as a potential study opportunity to address the loss of NNBF. There are several stakeholders currently invested in studying and protecting mangroves around Altona Lagoon. Potential non-federal sponsors could be identified to support a Planning Assistance to States or Continuing Authorities Program Section 206 study to support this effort going forward.
Address Barriers Preventing Comprehensive Risk Management	Long-Term (>10 years)	Multi-Agency Action	Coastal hazard modeling guidance	Traditional coastal hazard assessments employ hydrodynamic or coupled hydrodynamic and spectral wave models to assess the hazard to storm surge inundation. While this approach is widely accepted throughout the CONUS, in many island environments storm surge is not the leading driver dictating the coastal hazard. Due to the unique geographic setting and surrounding bathymetry of Puerto Rico and the USVI the true hazard is largely a result of wave impacts and specifically wave runup effects. In these locations the traditional hazard modeling approach needs to be enhanced to include wave runup modeling. The recommendation is to work with other agencies (USGS, NOAA, academia, etc.) to develop a framework for identifying the appropriate models and steps to do a complete hazard assessment in these regions.
Address Barriers Preventing Comprehensive Risk Management	Long-Term (>10 years)	Multi-Agency Action	Develop a concentrated, joint stakeholder effort to provide data consistent with that available for the continental United States	Data available for Puerto Rico and the U.S. Virgin Islands is inconsistent with similar data available for the continental United States, making consistent evaluation difficult and creating the potential to omit information critical to decision-making, especially those data related to infrastructure, social vulnerability, and benefits of tourism to regional and national economies. For instance, the lack of standardized social vulnerability data in U.S. Virgin Islands, such as the Centers for Disease Control and Prevention's Social Vulnerability Index, inhibits the use of the Social Vulnerability Index-Explorer tool to understand other social effects from potential USACE projects
Address Barriers Preventing Comprehensive Risk Management	Long-Term (>10 years)	Multi-Agency Action	Establishment and enforcement of updated regulatory set-back	Lack of standards and too many exemptions allowing construction in high-risk locations. Support ongoing efforts to develop unique and location appropriate setbacks, as well as defining the coastline as the baseline for the setbacks.
Regional Sediment Management Practices	Mid-Term (5-10 years)	USACE	RSM Opportunities on St. Croix	The dredged material from the dredging of Gallows Bay should be assessed for regional sediment management beneficial reuse opportunities, and potential use for living shorelines or support of other CSRM activities to address problems with shoreline erosion.

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description
Study Efforts (Activities under CAP)	Near-Term (<5 years)	USACE	Protection of Airport Road	Mitigating erosion and inundation risks to Airport Road, an emergency evacuation route, is necessary to protect residents and tourists on the island. Coastal erosion and inundation of the only evacuation route to the airport on the island was noted as a significant problem within the Charlotte Amalie focus area. USACE may be able to support these efforts through the Continuing Authorities Program Section 14 – Emergency Streambank and Shoreline Protection or Section 103- Beach Erosion and Hurricane and Storm Damage Reduction authority, pending interest from a non-federal sponsor. While some potential actions to manage coastal storm risks to Airport Road may exceed the CAP federal funding limit of $10 million, additional funding sources, such as the Federal Highway Authority could be considered. Non-federal cost sharing waivers are also available for CAP studies and projects in the U.S. Virgin Islands (Department of the Army 2017). The waiver amount is currently (2021) $512,000, but this amount will vary based on inflation.
Study Efforts (follow-on USACE feasibility study)	Mid-Term (5-10 years)	Congress	Creation of a comprehensive coastal improvements plan	Analysis of comprehensive improvements or modifications to existing improvements in the U.S. Virgin Islands focused on hurricane and storm damage reduction, prevention of saltwater intrusion, preservation of fish and wildlife, and prevention of erosion
Study Efforts (follow-on USACE feasibility study)	Mid-Term (5-10 years)	USACE	Christiansted Comprehensive Flood Protection	An opportunity for a comprehensive study of CSRM opportunities in downtown Christiansted was identified to conduct a more detailed and holistic assessment of potential CSRM opportunities. Non-federal sponsors would be needed for USACE engagement in this type of study. Continued collaboration to discuss these opportunities and identify potential partnerships is recommended.
Study Efforts (Multi-agency partnership/ activities)	Long-Term (>10 years)	Multi-Agency Action	Protect and Restore Coral Reefs	Offshore natural protective features, such as the coral reefs in Christiansted Harbor, provide wave attenuation and coastal storm risk reduction benefits to the shorelines behind them. Maintaining a healthy offshore reef system would help reduce shoreline erosion risks. Poor water quality influenced by compound flooding coupled with inadequate waste management systems threaten these reef systems. Future opportunities may exist to protect and restore coral reefs in Christiansted Harbor once water quality concerns are addressed.

This page intentionally left blank.

SECTION 8

References

Adams, D. B., and J.M. Hefner. 1996. U.S. Virgin Islands wetland resources. *National water summary on wetland resources*. Water Supply Paper 2425, 333-338. Washington, DC: U.S. Geological Survey.

Boston Globe. 2017. "St. John resident says there were 'houses flying away' when Irma hit." Accessed 2020, https://www.bostonglobe.com/metro/2017/09/08/john-resident-says-there-were-houses-flying-away-when-hurricane-irma-hit/iOCRjkFW2xiKgBfs4vM6YO/story.html#:~:text=John%20resident%20says%20there%20were%20'houses%20flying%20away'%20when%20Irma%20hit,-John's%20Caneel%20Bay&text=Jack%20Harrington%20could%20barely%20get,John%20without%20choking%20up.

Britannica. 2020. "United States Virgin Islands." Accessed June 2020, https://www.britannica.com/place/United-States-Virgin-Islands.

Caribbean Integrated Ocean Observing System (CARICOOS). 2020. "CARICOOS." https://www.caricoos.org/?locale=en#.

Conservation Data Center. 2010. "Wetlands of the U.S. Virgin Islands." Division of Environmental Protection, Department of Planning & Natural Resources. U.S. Virgin Islands. Accessed 2020, http://ess-caribbean.com/wp-content/uploads/2017/06/Wetlands-of-the-U.S.-Virgin-Islands-2010.pdf.

Dobson, J.G., I.P. Johnson, and K.A. Rhodes. 2020. *U.S. Virgin Islands Coastal Resilience Assessment*. Asheville, NC: UNC Asheville National Environmental Modeling and Analysis Center. Prepared for the National Fish and Wildlife Foundation. https://www.nfwf.org/sites/default/files/2020-08/us-virgin-islands-coastal-resilience-assessment.pdf.

Department of the Army Office. 2017. *Implementation Guidance for Section 1119 of the Water Resources Development Act (WRDA) 2016, Indian Tribes.* Department of Defense.

Federal Emergency Management Agency. 2020a. "Citizen Corps Partner Programs." Accessed November 20, 2020, https://www.ready.gov/citizen-corps-partner-programs

———. 2020b. *Hazard Mitigation Assistance Mitigation Action Portfolio*. Accessed November 20, 2020, https://www.fema.gov/sites/default/files/2020-08/fema_mitigation-action-portfolio-support-document_08-01-2020_0.pdf.

———. 2013. "Flood Risks Nationwide." https://www.fema.gov/media-library-data/1381427654930-ab448ad691a3a8bc93f59c8f3b63fc49/FS_FloodRisksNationwide_092013.pdf.

———. 2007. *Flood Insurance Study U.S. Virgin Islands*. https://map1.msc.fema.gov/data/78/S/PDF/780000V000A.pdf?LOC=e3ae79aa7cbf44681bd1d7d8d5bebe4a.

———. n.d. GIS point-based structure data. Unpublished GIS data.

Humanity Road. 2017a. *Hurricane Maria Situation Report 1*. Accessed November 25, 2020, Hurricane Maria Situation Report 1 (September 20, 2017) - Dominica | ReliefWeb.

Jelesnianski, C. P., J. Chen, and W.A. Shaffer. 1992. *SLOSH: SEA, Lake, and Overland Surges from Hurricanes*. NOAA Tech. Rep. NWS 48, 71. https://slosh.nws.noaa.gov/sloshPub/pubs/SLOSH_TR48.pdf.

Justia. 2021. "2019 US Virgin Islands Code Title 12 – Conservation Chapter 21 - Virgin Islands Coastal Zone Management § 906. Specific policies applicable to the first tier of the coastal zone." Accessed September 1, 2021. https://law.justia.com/codes/virgin-islands/2019/title-12/chapter-21/906/.

Kaiser Family Foundation. 2020. "U.S. Virgin Islands: Fast Facts." Accessed November 11, 2020, https://www.kff.org/racial-equity-and-health-policy/fact-sheet/u-s-virgin-islands-fast-facts/

Kendall, M.S., L.T. Takata, O. Jensen, Z. Hillis-Starr, and M.E. Monaco. 2005. *An Ecological Characterization of Salt River Bay National Historical Park and Ecological Preserve, U.S. Virgin Islands.* NOAA Technical Memorandum NOS NCCOS 14, 116. Accessed November 20, 2020, https://pdfs.semanticscholar.org/aef6/3c88cdb2cf497fbc5e395b5fa6b8cfb9252f.pdf

Luijendijk, A., G. Hagenaars, R. Ranasinghe, F. Baart, G. Donchyts, and S. Aarninkhof. 2018. "The State of the World's Beaches." *Scientific Reports* 8, no. 6641. https://www.nature.com/articles/s41598-018-24630-6.

Miami New Times. 2017. "Irmageddon: Thousands of Miamians Just Had Their First Taste of Hurricane Misery." Accessed 2020, https://www.miaminewtimes.com/news/irma-miamians-just-had-their-first-taste-of-hurricane-misery-9668516

Narayan et al. 2017. "The Value of Coastal Wetlands for Flood Damage Reduction in the Northeastern USA." *Scientific Reports* 7, no. 9465. doi.org/10.1038/s41598-017-09269-z.

National Hurricane Center. 1989. "Preliminary Report, Hurricane Hugo, 10-22 September 1989." Accessed April 23, 2021, https://www.weather.gov/media/ilm/climate/Hugo/NHC_report_Hugo.pdf

National Oceanic and Atmospheric Administration (NOAA). 2020a. "Highest Storm Water Levels – Tides and Currents." Accessed 2020, https://tidesandcurrents.noaa.gov/quicklook_highest_storm.html.

———. 2020b. "Sea Level Trends – NOAA Tides and Currents." Accessed 2020, https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=9751639.

———. 2020c. “Sea Level Rise Viewer.” Accessed 2020, https://coast.noaa.gov/slr/#.

———. 2019. “Historical Hurricane Tracks.” Accessed August 16, 2019, https://coast.noaa.gov/hurricanes/#map=4/32/-80.

———. 2015a. *C-CAP Land Cover, United States Virgin Islands, St. Croix, 2012*. NOAA National Centers for Environmental Information. https://www.fisheries.noaa.gov/inport/item/48361.

———. 2015b. *C-CAP Land Cover, United States Virgin Islands, St. John, 2012*. NOAA National Centers for Environmental Information. https://www.fisheries.noaa.gov/inport/item/48363.

———. 2015c. *C-CAP Land Cover, United States Virgin Islands, St. Thomas, 2012*. NOAA National Centers for Environmental Information. https://www.fisheries.noaa.gov/inport/item/48365.

———. 2015d. *Guidance for Considering the Use of Living Shorelines*. https://cdn.coastalscience.noaa.gov/projects-attachments/311/noaa_guidance_for_considering_the_use_of_living_shorelines_2015.pdf.

———. 2013. *NOAA Technical Report NOS CO-OPS 067 – Extreme Water Levels of the United States 1893–2010*. Silver Spring, Maryland: NOAA.

———. 2000. *Environmental Sensitivity Index data for the Virgin Islands*. Accessed June 15, 2020, https://response.restoration.noaa.gov/esi_download#VirginIslands.

———. n.d. “Storm Surge Overview.” Accessed April 26, 2021, https://www.nhc.noaa.gov/surge/?text.

National Parks Service (NPS). 1988. *The Historic Resources of the U.S. Virgin Islands*. Prepared by the Cultural Resource Group Caribbean Strategy National Park Service. Accessed July 29, 2021, http://npshistory.com/publications/viis/historic-resources.pdf.

———. 2020a. “Charlotte Amalia Historic District.” Accessed July 21, 2020, https://www.nps.gov/nr/travel/prvi/pr30.htm.

———. 2020b. “Christiansted Historic District/Christiansted National Historic Site.” Accessed July 20, 2020, https://www.nps.gov/nr/travel/prvi/pr45.htm.

———. 2020e. “Fort Christian.” Accessed July 21, 2020, https://www.nps.gov/nr/travel/prvi/pr29.htm.

———. 2020g. **“**Hassel Island Historic District.” Accessed July 21, 2020, https://www.nps.gov/nr/travel/prvi/pr31.htm.

———. 2020h. “Lameshur Plantation.” Accessed July 21, 2020, https://www.nps.gov/nr/travel/prvi/pr38.htm.

———. 2018b. “Salt River Bay National Historic Park and Ecological Preserve.” Accessed July 20, 2020, https://www.nps.gov/places/salt-river-bay-nhp.htm.

———. 2018c. “Virgin Islands History & Culture.” Accessed July 21, 2020, https://www.nps.gov/viis/learn/historyculture/index.htm.

———. 2014. National Register of Historic Places Geospatial Dataset. National Parks Service. Accessed July 21, 2020, https://irma.nps.gov/DataStore/Reference/Profile/2210280

National Weather Service. n.d. Memorial Web Page for the 1928 Okeechobee Hurricane.” Accessed April 23, 2021, https://www.weather.gov/mfl/okeechobee#:~:text=More%20than%20300%20persons%20were,residents%20of%20Florida's%20east%20coast.

The Nature Conservancy (TNC). 2016. “Coastal Resilience U.S. Virgin Islands.” Accessed November 20, 2020, https://maps.coastalresilience.org/usvi/.

O’Brian, Bill. 2015. “A Race Against Time at Sandy Point Refuge.” National Wildlife Refuge System. Accessed July 21, 2020, https://www.fws.gov/refuges/RefugeUpdate/JulAug_2015/race-against-time.html.

The Ocean Foundation. 2020. “The Climate Strong Islands Declaration.” Accessed November 20, 2020, https://oceanfdn.org/the-climate-strong-islands-declaration/.

Pasch, R.J., A. B. Penny, and R. Berg. 2019. *National Hurricane Center Tropical Cyclone Report: Hurricane Maria*. https://www.nhc.noaa.gov/data/tcr/AL152017_Maria.pdf.

Pendleton, E. A., E. Thieler, and S. J. Williams. 2005. “Coastal Vulnerability Assessment of Virgin Islands National Park (VIIS) to Sea level Rise.” U.S. Geological Survey. https://pubs.er.usgs.gov/publication/ofr20041398.

Schill, S., J. Brown, A. Justiniano, and A.M. Hoffman. 2014. *U.S. Virgin Islands Climate Change Ecosystem-Based Adaptation Promoting Resilient Coastal and Marine Communities*. National Oceanic and Atmospheric Administration and The Nature Conservancy. https://maps.coastalresilience.org/usvi/#

Sea Grant Puerto Rico. 2020. “About the Sea Grant Program.” Accessed November 20, 2020, https://seagrantpr.org/about-the-sea-grant-program/

Silva-Araya, W.F., F.L. Santiago-Collazo, J. Gonzalez-Lopez, and J. Maldonado-Maldonado. 2018. “Dynamic Modeling of Surface Runoff and Storm Surge During Hurricane and Tropical Storm Events.” *Hydrology*, 5(1):13. doi.org/10.3390/hydrology5010013.

Silver Jackets. n.d. “U.S. Virgin Islands.” Accessed November 20, 2020, https://silverjackets.nfrmp.us/State-Teams/US-Virgin-Islands.

Southeast Coastal Ocean Observing Regional Association. 2020. "Southeast & Caribbean Disaster Resilience Partnership." Accessed November 20, 2020, https://www.sdrp.secoora.org/.

Storlazzi, C.D., B.G. Reguero, A.D. Cole, E. Lowe, J.B. Shope, A.E. Gibbs, B.A. Nickel, R.T. McCall, A.R. van Dongeren, and M.W. Beck. 2019. *Rigorously valuing the role of U.S. coral reefs in coastal hazard risk reduction: U.S. Geological Survey Open-File Report 2019–1027*, p. 42. https://doi.org/10.3133/ofr20191027

University of Pittsburgh (Pitt). n.d. "Research Guide: Understanding Census Geography." Accessed June 15, 2020. https://pitt.libguides.com/uscensus/understandinggeography.

U.S. Army Corps of Engineers (USACE). 2021a. *South Atlantic Coastal Study Coastal Program Guide*. Charleston, VA: U.S. Army Corps of Engineers.

———. 2021b. *South Atlantic Coastal Study Environmental Technical Report, Environmental Resources Vulnerability and Risk Analysis/Priority Environmental Areas.* Charleston, VA: U.S. Army Corps of Engineers.

———. 2021c. *South Atlantic Coastal Study (SACS) Institutional and Other Barriers Report*. Charleston, VA: U.S. Army Corps of Engineers.

———. 2021d. South Atlantic Coastal Study (SACS) *Measures and Cost Library*. Charleston, VA: U.S. Army Corps of Engineers.

———. 2020a. *2020 Regional Sediment Management Optimization Update*. Charleston, South Carolina: U.S. Army Corps of Engineers.

———. 2020b. *Coastal Hazards System.*

———. 2020c. *Estate La Grange VI (205)*, accessed November 2020, https://www.saj.usace.army.mil/About/Congressional-Fact-Sheets-2020/Estate-La-Grange-VI-205/.

———. 2020d. *Northeast Florida RSM: A Guide to Using Dredged Material for Estuarine Restoration*.

———. 2020e. *South Atlantic Division Sand Availability and Needs Determination (SAND Report)*. Jacksonville, Florida: U.S. Army Corps of Engineers.

———. 2019a. *Incorporating Sea Level Change in Civil Works Programs*. Washington, D.C.: Department of the Army. https://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1100-2-8162.pdf.

———. 2019b. Institute of Water Resources. *Partnering with the U.S. Army Corps of Engineers, A Guide for Communities, Local Governments, States, Tribes, and Non-Governmental Organizations*. Alexandria, VA: U.S. Army Corps of Engineers. Accessed July 29, 2021, https://www.iwr.usace.army.mil/Media/News-Stories/Article/1976109/new-usace-report-partnering-with-the-us-army-corps-of-engineers-a-guide-for-com/.

———. 2019c. “Sea level Curve Calculator (Version 2019.21).” Accessed October 19, 2020, http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html.

———. 2018. Regional Sediment Management Tools and Technologies Volume I Coastal. Vicksburg, Mississippi: U.S. Army Corps of Engineers.

———. 2017. *Planning: Risk Assessment for Flood Risk Management Studies*. ER 1105-2-101. July 17, 2017. Accessed on April 21, 2021, https://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1105-2-101.pdf.

———. 2014a. *Engineering and Design; Safety of Dams – Policy and Procedures*. ER 1110-2-1156. Accessed April 10, 2021, https://www.publications.usace.army.mil/Portals/76/Publications/EngineerRegulations/ER_1110-2-1156.pdf.

———. 2014b. *Procedures to Evaluate Sea Level Change: Impacts, Responses, and Adaptation*. Washington, D.C.: Department of the Army. Engineer Technical Letter (ETL) 1100-2-1

———. 2015. *North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk. Main Report*. Accessed April 26, 2021, https://www.nad.usace.army.mil/Portals/40/docs/NACCS/NACCS_main_report.pdf.

———. 2013a. Civil Works Directorate. *Coastal Risk Reduction and Resilience: Using a Full Array of Measures*. Washington D.C.: US Army Corps of Engineers, Directorate of Civil Works

———. 2011. *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Caribbean Islands Region* (Version 2.0). ed. J. S. Wakeley, R. W. Lichvar, C. V. Noble, and J. F. Berkowitz. ERDC/EL TR-11-4. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

———. n.d. “Turpentine Run CAP Conversion project.” Accessed November 20, 2020, https://www.saj.usace.army.mil/Missions/Continuing-Authorities-Program/Section-205-Flood-Damage-Reduction/Turpentine-Run/igphoto/2002288482/.

U.S. Census Bureau. 2017. “Hierarchy Diagrams.” Accessed October 2020, https://www.census.gov/programs-surveys/geography/guidance/hierarchy.html.

———. 2012. Shapefile for United States Virgin Islands by Census Estates. https://catalog.data.gov/dataset/tiger-line-shapefile-2017-state-united-states-virgin-islands-current-estate-state-based-shapefi

———. 2011. “U.S. Census Bureau “U.S. Census Bureau Releases 2010 Census Population Counts for the U.S. Virgin Islands.” Accessed on April 22, 2021, https://www.census.gov/newsroom/releases/archives/2010_census/cb11-cn180.html.

U.S. Department of the Interior. 2016. "Cruz Bay Town Historic District National Register of Historic Places Listing". Accessed July 23, 2020, https://www.nps.gov/nr/feature/places/pdfs/16000699.pdf

U.S. Fish and Wildlife Service (USFWS). 2020a. "Endangered and Threatened Wildlife and Plants; Endangered Species Status for Marron Bacora and Designation of Critical Habitat." 85 FR 52516. Accessed November 20, 2020, https://www.federalregister.gov/documents/2020/08/26/2020-17091/endangered-and-threatened-wildlife-and-plants-endangered-species-status-for-marron-bacora-and.

———. 2017. "Sandy Point National Wildlife Refuge." Accessed July 21, 2020, https://www.fws.gov/refuge/Sandy_Point/about.html.

U.S. Virgin Islands Bureau of Economic Research. 2018. *U.S. Virgin Islands Annual Tourism Indictors*. Accessed October 13, 2020, http://usviber.org/wp-content/uploads/2016/11/TOUR18-2.pdf.

U.S. Virgin Islands Economic Development Authority. 2020. "Vision 2040 U.S. Virgin Islands 20 Year Economic Plan." Accessed November 2020, https://www.usvieda.org/vision2040.

———. n.d. "Tourism and Hospitality." Accessed April 22, 2021, https://www.usvieda.org/relocate-business/key-industries/tourism-hospitality.

U.S. Virgin Islands Hurricane Recovery and Resilience Task Force. 2018. "U.S. Virgin Islands Hurricane Recovery and Resilience Task Force." Accessed November 20, 2020, https://www.usvihurricanetaskforce.org/.

U.S. Virgin Islands Office of Disaster Recovery. 2019. "FEMA-PA Search by Applicant." Accessed November 2020, http://www.usviodr.com/fema-pa-search-by-applicant/

VInow. n.d. "Virgin Islands History." Accessed July 24, 2020, https://www.vinow.com/general_usvi/history/.

The Virgin Islands State Historic Preservation Office and University of Alabama Museums. 2016. *The U.S. Virgin Islands Historic Preservation Plan: Historic Preservation in the U.S. Virgin Islands: Preserving our Past for our Future For 2016-2021*. Accessed June 2021, http://oar.museums.ua.edu/wp-content/uploads/sites/6/2016/09/PreservationPlan2016-2021.pdf.

Visit St. Thomas.com. 2018. "Relax in St. Thomas." Accessed June 2021, https://visitstthomas.com/.

World Atlas. 2021. "Maps of U.S. Virgin Islands." Accessed July 30, 2021, https://www.worldatlas.com/maps/us-virgin-islands.

World Population Review. 2020. "United States Virgin Islands Population 2020 (Live)." https://worldpopulationreview.com/countries/united-states-virgin-islands-population

This page intentionally left blank.

SOUTH ATLANTIC COASTAL STUDY (SACS)

Charlotte Amalie Focus Area Action Strategy

FINAL DRAFT REPORT

OCTOBER 2021

Table of Contents

List of Tables

List of Figures

This page intentionally left blank.

1. Introduction

This Focus Area Action Strategy (FAAS) identifies action strategies to reduce risk to coastal storms and increase resilience in the Charlotte Amalie area of St. Thomas in the U.S. Virgin Islands. The South Atlantic Coastal Study (SACS) key products and analyses were leveraged to assess existing and future conditions and quantify existing and potential risks. Agency stakeholders were engaged throughout the development of the Charlotte Amalie FAAS to elicit feedback on problems and opportunities, identify and prioritize specific institutional and other barriers, and identify potential action strategies to improve resilience. Participating agency stakeholders in this FAAS included representatives from University of the Virgin Islands (UVI), Coral Bay Community Council, U.S. Virgin Islands Department of Planning and Natural Resources (DPNR), Bioimpacts, Inc., Federal Emergency Management Agency (FEMA), U.S. Department of the Interior (DOI), U.S. Virgin Islands Office of the Lieutenant Governor, U.S. Fish and Wildlife Service (FWS), U.S. Department of Agriculture (USDA), National Oceanic and Atmospheric Administration (NOAA), Virgin Islands Territorial Emergency Management Agency (VITEMA), Virgin Islands Port Authority (VIPA), Virgin Islands Public Finance Authority (VIPFA), and Ocean and the Coastal Observing Virgin Islands (OCOVI). While this FAAS was developed for the Charlotte Amalie area, it can serve as a model for developing action strategies in other high-risk locations.

The FAAS was developed according to the Coastal Storm Risk Management (CSRM) Framework, an iterative process with three tiers of analysis that gains resolution each time it is implemented. Under the Tier 1 regional analysis, national data sets were utilized to assess potential risk across the entire SACS study area, as documented in the SACS Main Report. For the Tier 2 analysis, more refined data and analyses unique to each individual state or territory were incorporated. The Tier 2 analysis for Charlotte Amalie is documented within the U.S. Virgin Islands Appendix. The FAAS is a third iteration of the SACS study framework, incorporating data and knowledge unique to the local area to identify risks to coastal storm events and develop potential strategies to address the risks.

This FAAS is carried out as part of SACS, which was authorized by Section 1204 of the Water Resources Development Act of 2016 (WRDA 2016) as described in the Main Report.

1.1 Study Area

The Charlotte Amalie Focus Area is on the island of St. Thomas, within Planning Reach VI 2, as identified in the U.S. Virgin Islands Appendix. The focus area includes the subdistricts of Charlotte Amalie (the capital of the U.S. Virgin Islands), Hassel Island, and Water Island, as well as the Cyril E. King International Airport and a cruise port (**Figure 1**)**.** The northern boundary of the focus area follows the sub-district boundary of Charlotte Amalie and the southern boundary extends a half mile offshore of St. Thomas, Hassel Island, and Water Island. The focus area is 10.5 square miles (27.1 square kilometers), and includes the census estates Agnes Fancy, Annas Fancy, Contant, Demerara, Eastern Water Island, Hassel Island, Honduras, John Brewers Bay, Kings Quarter, Lindbergh Bay, Lower John Dunko, Nisky, Queens Quarter, Ross, Solberg, Thomas, and Western Water Island. **Figure 2** displays the names and locations of the census estates within the focus area.

Focus areas were selected based on Tier 1 high-risk areas, stakeholder feedback and ensuring a range of environments and risk factors were represented across all 21 focus areas selected within the SACS. Draft focus areas were presented to stakeholders at the 2019 U.S. Virgin Islands Field Workshop. Based on provided feedback and additional analysis, two focus areas were selected for the U.S. Virgin Islands: Charlotte Amalie and Christiansted.

Figure 1: Charlotte Amalie Focus Area Boundary

Figure 2: Census Estates within the Charlotte Amalie Focus Area Boundary

1.2 Prior Reports and Efforts by Stakeholders within the Focus Area

Prior and ongoing stakeholder efforts within the Charlotte Amalie Focus Area to address coastal storm risks and impacts from sea level rise include:

- The Federal Emergency Management Agency (FEMA) awarded funding to the Virgin Islands Department of Public Works to address waterfront drainage improvement project along Veterans Drive (Route 30). Phase I of the project was completed and Phase II is underway.
- University of the Virgin Islands (UVI) has ongoing efforts to study and assess compound flooding
- USACE has a planned drainage improvement project adjacent to Veterans Drive.
- UVI has an ongoing base knowledge study in St. Thomas Harbor, which evaluates the effects of sedimentation from cruise ships on the habitat.

- UVI, the National Oceanic and Atmospheric Administration (NOAA), and the Department of Planning and Natural Resources (DPNR) are conducting a territory-wide Marine Debris Action Plan.
- DPNR of the U.S. Virgin Islands is developing watershed studies for three watersheds on St. Thomas:
  - Cyril E. King, where the island’s international airport is located on the southwest
  - Adjacent watershed of St. Thomas Harbor, where the capital city Charlotte Amalie and the historic and commercial waterfront are located
  - Bolongo Bay sub-basin of the Frenchman’s Bay watershed on the southeast of the island
- FEMA is bringing the U.S. Virgin Islands into compliance with the National Flood Insurance Program (NFIP) by enforcing updated building codes.
- Virgin Islands Port Authority is planning dredging projects in Charlotte Amalie Harbor and Crown Bay.
- Virgin Islands Territorial Emergency Management Agency (VITEMA) is working on the Hazard Mitigation Plan Update, including a focus on coastal hazards
- VITEMA is developing a territory-wide Tsunami Warning System.
- The U.S. Virgin Islands government is developing updated comprehensive island-wide land use plans for each island.
- The U.S. Virgin Islands Hurricane Recovery and Resilience Task Force compiled a report on the impacts from the 2017 hurricanes. Recommendations were provided for recovery and resilience across the islands.
- St. Croix Foundation signed the Climate Strong Islands Declaration, joining island communities around the world to increase awareness of the growing challenges island nations face.
- With funding from the U.S. Economic Development Authority, the U.S. Virgin Islands Economic Development Authority is developing Vision 2040, a 20-year economic plan for the territory.

1.3 Shared Vision

The shared vision statement was developed and edited using input from key stakeholders in the focus area. The overall goal of this Charlotte Amalie FAAS is to incrementally contribute to the shared vision statement developed for this watershed study.

> "The Charlotte Amalie Focus Area vision is to utilize local knowledge along with the tools provided through the SACS and partners to provide a common understanding of risk from coastal storms and sea level rise to support resilient communities and habitats. This collaborative effort will leverage stakeholders' actions to plan and implement cohesive coastal risk management strategies to protect and strengthen culturally significant areas, existing infrastructure, and natural features in Charlotte Amalie."

2. Problems and Opportunities

Identifying problems and opportunities is a key initial step in the planning process. The problems and opportunities statements encompass both current and future conditions and are not meant to preclude the consideration of any alternatives to solve the problems and achieve the opportunities.

2.1 Problems

The following problems were identified as the most significant throughout the focus area and may not be exhaustive of all problems. These problems will increase in both intensity and extent as sea levels rise depending on the vulnerability and resiliency of the exposed population, infrastructure, and environmental and cultural resources.

- Lack of coordinated watershed-scale planning to address coastal storm risks and compound flood risks, limiting ability to improve community resilience
- Coastal erosion and inundation causing damage to existing roads and critical infrastructure, including the only evacuation route to the airport on the island
- Loss of natural habitats for coral reefs and mangroves, many of which provide CSRM benefits
- Compound flood risks are exacerbated by storm surge inundation and sea level rise, while drainage systems are outdated, insufficiently maintained, and inadequate to keep up with increasing flood levels and frequencies. These flood events contribute to water quality issues that influence environmental resources.
- Significant marine debris resultant of coastal storm events contributes to environmental risk and impacts environmental and cultural resources.

2.1.1 Institutional and Other Barriers

As described in the *SACS Institutional and Other Barriers Report* (USACE 2021c), "Institutional and other barriers" impede the attainment of SACS goals and limit the ability to provide comprehensive CSRM. Several barriers were identified within the Charlotte Amalie Focus Area by agency stakeholders:

- *Lack of data:* Local datasets are critical for adhering to guidance supplementing ER 1105-2-100 (Department of the Army Office of the Assistant Secretary 2020), which requires comprehensive consideration of regional economic, environmental, and social project benefits.
    - Absence of data for the U.S. Virgin Islands inhibits the use of the USACE Regional Economic System (RECONS) model for understanding Regional Economic Development (RED) benefits from potential projects.
    - Lack of social vulnerability data for the U.S. Virgin Islands inhibits the use of the Social Vulnerability Exposure Index tool for understanding Other Social Effects (OSE) from potential USACE projects.
    - Lack of fundamental coastal engineering data (e.g., beach profile surveys or shoreline change estimates) inhibits accuracy when characterizing hazards.
- *Limited comprehensive land use planning and political commitment:* There is a lack of climate change adaptation planning within the territory.
- *Insufficient capacity at the local level to address risks*: Local government agencies are often short-staffed or in need specific technical subject matter expertise related to coastal risk reduction. Institutional knowledge of local flood problems is declining.
- *Limited coordination and leadership:* Lack of communication between agencies leads to inconsistencies, missed chances for collaboration on projects within the same location, and reduced opportunities to enhance risk reduction efforts.
- *Need for increased community engagement:* Additional public engagement and communication regarding level of risk, consequences, and mitigation opportunities is needed to increase public involvement and support of coastal risk reduction measures.
- *Relaxed enforcement of existing regulations:* Frequent exceptions to permitting requirements and relaxed enforcement of setback requirements have allowed continued development in areas subject to coastal storm hazards.
- *Insufficient funding:* There is a lack of funding for coastal storm risk reduction, specifically for proactive projects such as risk reduction studies and coastal habitat restoration and conservation.

2.2 Opportunities

While there are several coastal storm-related problems in the focus area, numerous opportunities exist to address them as exemplified by ongoing efforts within the U.S. Virgin Islands. Stakeholders identified several opportunities that include conditions, resources, and factors to contribute favorably to the Charlotte Amalie Focus Area, including:

- Encourage federal and non-federal agencies to take a holistic system-based approach when responding to storm events and preparing for future sea level rise.
- Provide information to decision-makers and the public regarding coastal risk and resilience issues and encourage local leadership to become involved in building resilience to coastal storms.
- Consider the full range of potential measures to address coastal storm risks.
- Incorporate long-term planning in future coastal storm risk management efforts.
- Apply an equal and comprehensive evaluation of economic, environmental, and social benefits in the evaluation of project alternatives. Opportunities exist to expand regional planning models and obtain necessary data to support alternative analyses that encompass the full range of potential benefits.
- Demonstrate the SACS tools (Measures and Costs Library [MCL] [USACE 2021d], Tier 2 Economic Risk Assessment, Priority Environmental Area [PEA] Analysis) and emphasize how they can be applied by all stakeholders.

3. Objectives and Constraints

Planning objectives describe the desired outcome of the planning process. Objectives are designed to solve problems and seize opportunities identified within the planning process. Constraints are conditions that limit the planning process. The final strategy formulated during this study is intended to meet the planning process objectives while reasonably working within the constraints.

3.1 Objectives

The overall objectives developed for the focus area concentrated on reducing coastal storm risk to environmental and cultural resources and infrastructure. Because of factor variability, specific metrics were not developed to measure project success. More specific performance metrics should be developed in Tier 3 follow-on efforts. Objectives and goals of the FAAS are included in this section.

Objective:

- Reduce coastal storm risk and erosion hazards to critical infrastructure and population within the Charlotte Amalie focus area.

Goals:

- Present the data on existing risk to coastal storm events and projected future risks considering sea level rise to motivate long-term policy change.
- Identify potential federal involvement in specific actions identified by stakeholders.
- Highlight the importance of preserving the natural features currently protecting the coastline.
- Incorporate social vulnerability when considering potential measures in the FAAS.

3.2 Constraints

A constraint limits action during a planning process. To the maximum extent practicable, the SACS analysis will minimize information, observations, and recommendations that may be inconsistent with coastal risk reduction plans developed by other federal and applicable territory and local agencies and tribes within the study area.

4. Existing and Future Conditions

The Charlotte Amalie Focus Area predominately includes developed shoreline of exposed and sheltered manmade structures (10.4 miles [16.7 kilometers]) with increased density around the commercial district and St. Thomas Harbor. There are extensive exposed rocky shores (11.5 miles [18.5 kilometers]) and some sandy beaches near the Cyril E. King International Airport and around Water Island and Hassel Island. Shoreline types are shown in **Figure 3**. Offshore, outside of St. Thomas Harbor boundary, is a substantial stretch of coral reef and seagrass habitat. Near Water Island, there are a few pockets of mangroves.

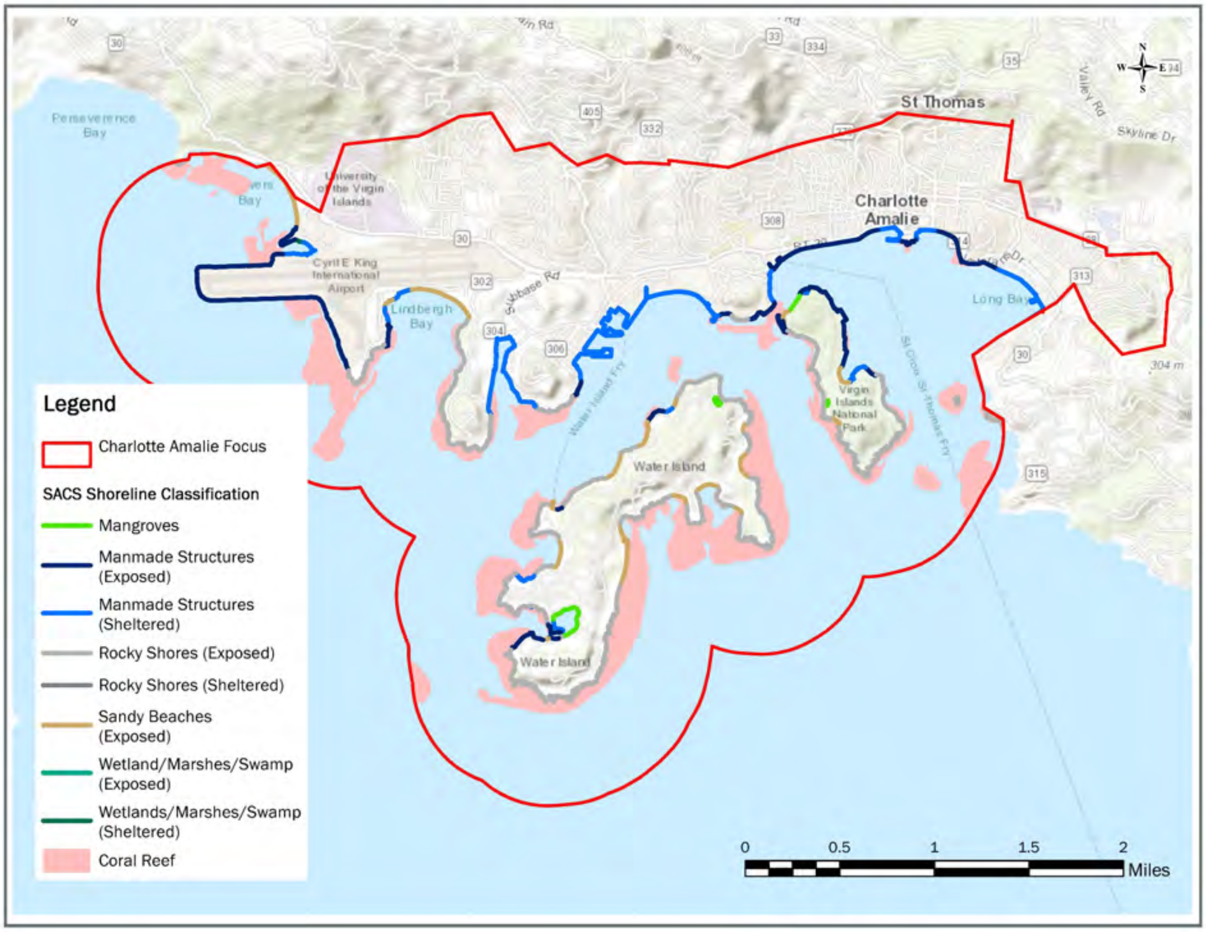


Figure 3: Shoreline Types and Coral Reef Locations within the Charlotte Amalie Focus Area

Tourism is an important component of the Charlotte Amalie economy. At the base of St. Thomas Harbor is the Charlotte Amalie historic district and Ft. Christian. The Hassel Island Historic District, located on Hassel Island, and Ft. Segarra, an underground Word War II fort located on Water Island, are significant cultural resources within the focus area. An archival collection is housed at the UVI campus on St. Thomas. Significant transportation infrastructure, including the busiest cruise ship port in the Caribbean, are located on the southside of St. Thomas Harbor in Havensight. The Cyril E. King International Airport is located in Charlotte Amalie West.

Charlotte Amalie was severely impacted by Hurricanes Irma and Maria in 2017. Veterans Drive (Route 30), along the coastline of St. Thomas Harbor, is consistently affected by flooding, where coastal inundation and inland flooding are compounded because of insufficient drainage capacity following precipitation events. Airport Road, an evacuation route, is affected by coastal inundation and is subject to shoreline erosion. During localized storms, safety may be found by moving inland and upland; when larger storms affect a broader area, evacuation can mean leaving the island, making access to airports more critical. Protection of natural resources is critical to reducing coastal storm risks to infrastructure, shoreline stability, and tourism. As sea level rises, there is an increased need for a well-implemented consistent approach to CSRM to protect infrastructure.

Risk is broadly defined as a situation or event where something of value is at stake and its gain or loss is uncertain. Risk is typically expressed as a combination of the likelihood and consequence of an event. Consequences are measured in terms of harm to people, cost, time, the environment, property damage, and other metrics. **Figure 4** illustrates the components that make up risk: hazards, system performance, exposure, vulnerability, and consequences. The following sections outline the components of the risk assessment conducted based on SACS Tier 1 and Tier 2 analyses for the Charlotte Amalie Focus Area.

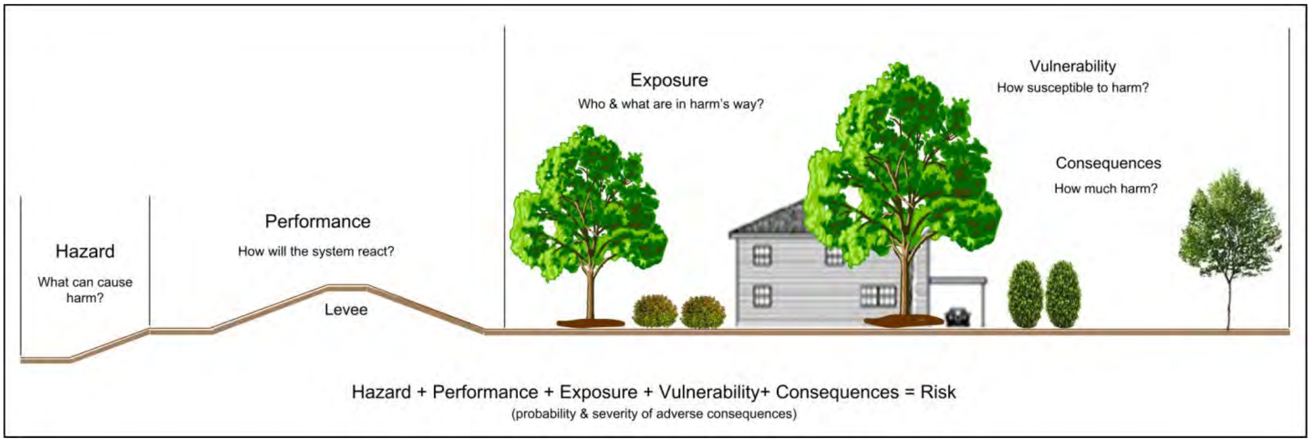


Figure 4: Risk Conceptualized

4.1 Hazards

Coastal storm hazards in the Charlotte Amalie Focus Area include storm surge inundation, wave attack, erosion, wind, and compound flooding. Inundation extents were assessed in triplicate via:

- NOAA's Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model Category 5 Maximum of Maximum (Category 5 MOM) event results
- FEMA National Flood Hazard Layer (NFHL) 1-percent annual exceedance probability (AEP) flood event
- U.S. Army Engineer Research and Development Center Coastal and Hydraulics Laboratory (ERDC/CHL) 10-percent AEP flood event

Figure 5 indicates the extent of coastal flood inundation based on current conditions and future conditions with 3 feet (0.9 meters) of sea level rise. The modeled Category 5 MOM event data indicates that probable depths of coastal inundation range from 0 to 3 feet (0 to 0.9 meters) in Charlotte Amalie West and 3 to 7 feet (0.9 to 2.1 meters) along the shoreline of Coral Bay, St. Thomas Harbor, Water Island, and Hassel Island (**Figure 6**). The SACS Coastal Hazards System (CHS) provides modeled wave height on a regional scale for a range of AEP events. The existing wave height for Charlotte Amalie for the 1-percent AEP event is estimated to range from 0 to 6.6 feet (0 to 2.0 meters) along the shoreline north of Water and Hassel Islands, and 6.6 to 19.7 feet (2.0 to 6.0 meters) along the southern shoreline of Water and Hassel Islands (**Figure 7**). Erosion hazard was assessed based on historical shoreline change rate data, which was estimated from freely available optical satellite imagery (Luijendijk et al. 2018) since local shoreline survey information is unavailable in this region. **Figure 8** displays the observed long-term shoreline change (erosion and accretion) in the Charlotte Amalie Focus Area. The data indicated erosion rates of around 3.3 feet (1 meter) per year in St. Thomas Harbor, along Lindbergh Bay, and along the eastern side of Water Island.

The inundation and wave hazard data developed from the Tier 1 and Tier 2 analyses are based on regional models. The models selected provide a regional view of the hazard but may not capture the high-resolution details of the focus area. While these results provide an initial assessment, opportunities exist to conduct more refined characterizations of the hazards.

Wind hazard has the potential to significantly damage infrastructure within the Charlotte Amalie Focus Area. Compound flooding is a hazard to the focus area when coastal flood hazards occur simultaneously with rainfall/runoff hazards, resulting in potentially greater flood impacts. Further description of the hazards assessed in the U.S. Virgin Islands is included in Sections 3.1.1 and 3.1.4 of the U.S. Virgin Islands Appendix.

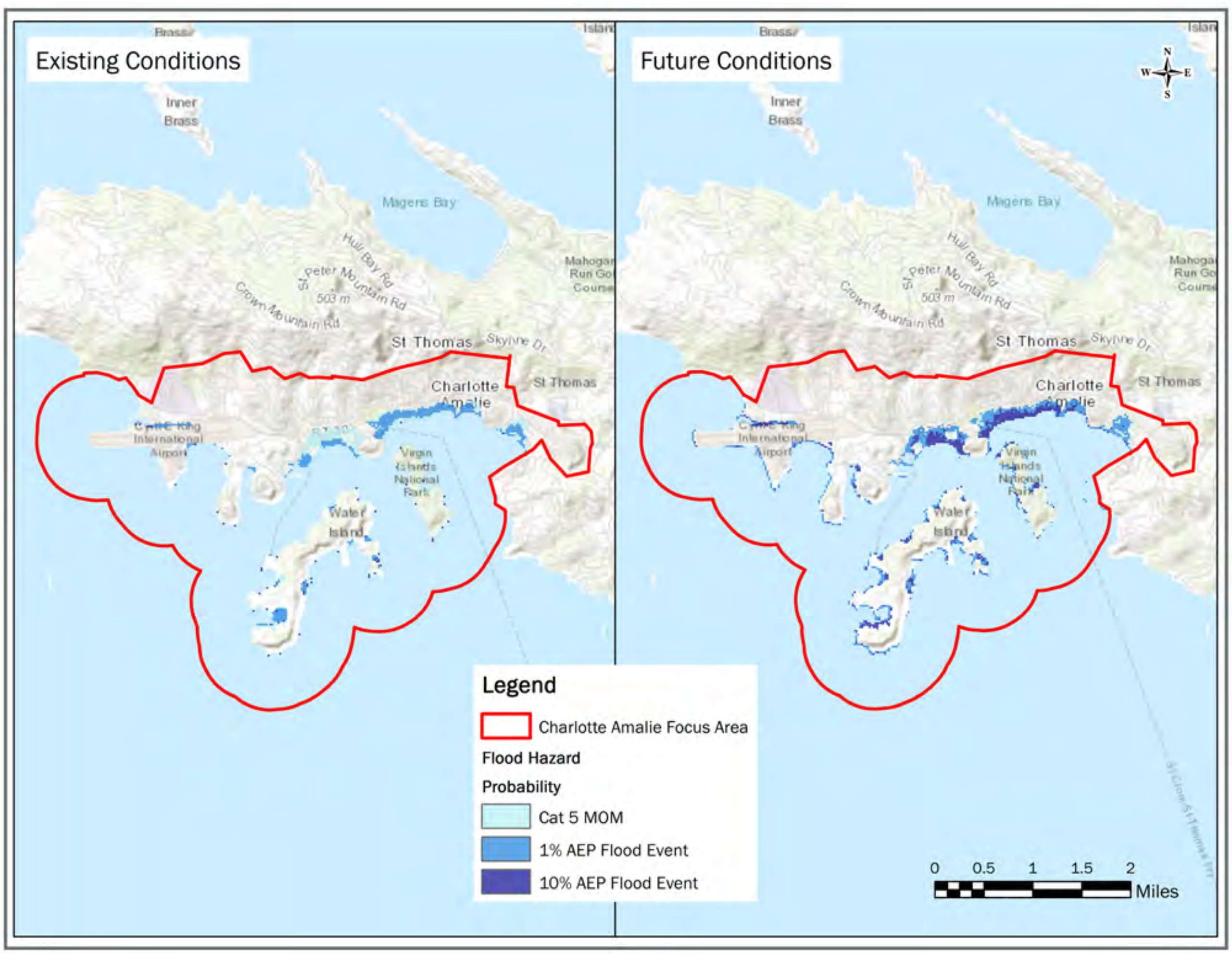


Figure 5: Existing and Future Flood Hazard for the Charlotte Amalie Focus Area from the 10-percent Annual Exceedance Probability Flood, the 1-percent Annual Exceedance Probability Flood, and the Category 5 Maximum of Maximum Event Water Levels

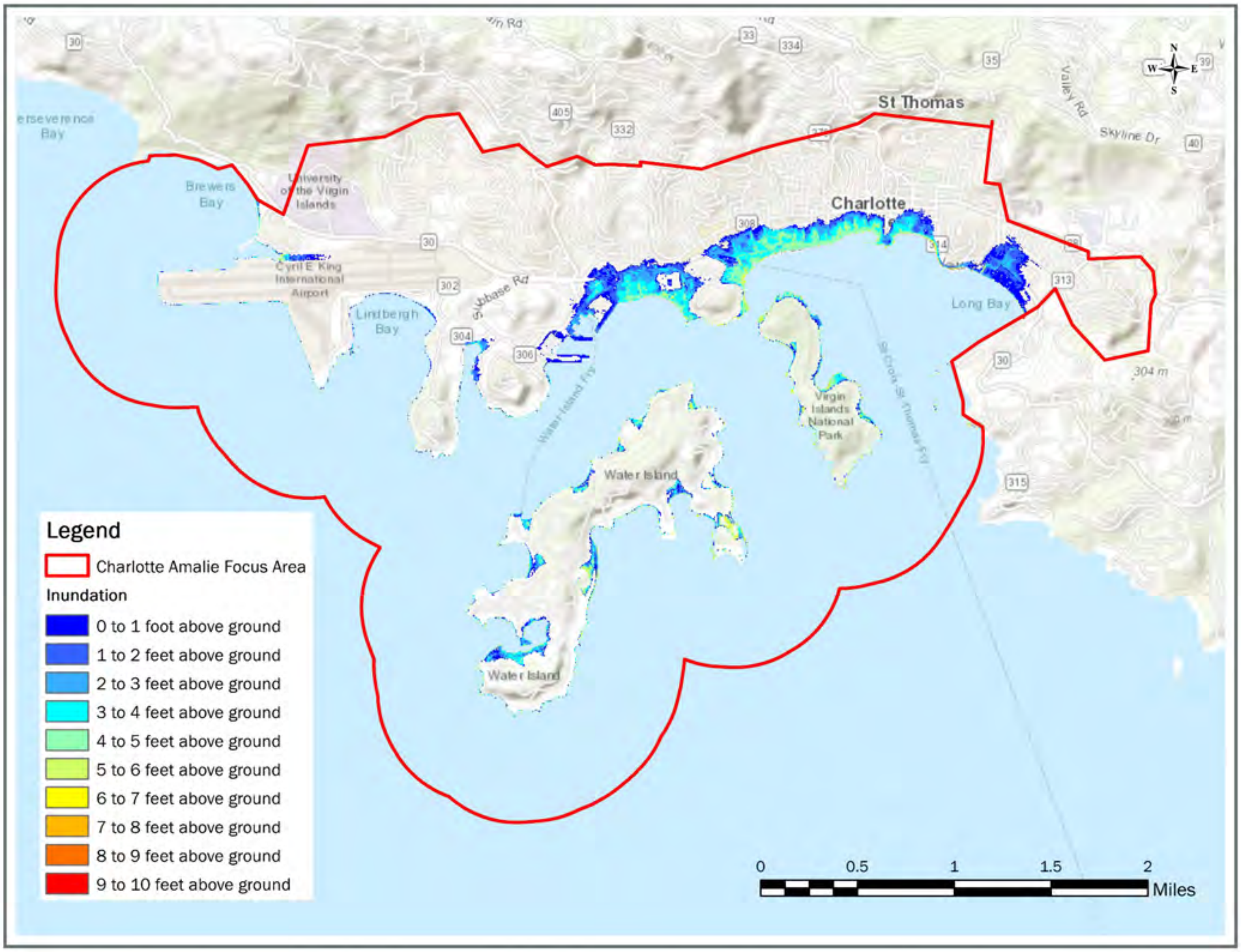


Figure 6: Inundation Depths in Feet from Category 5 Maximum of Maximum for the Charlotte Amalie Focus Area

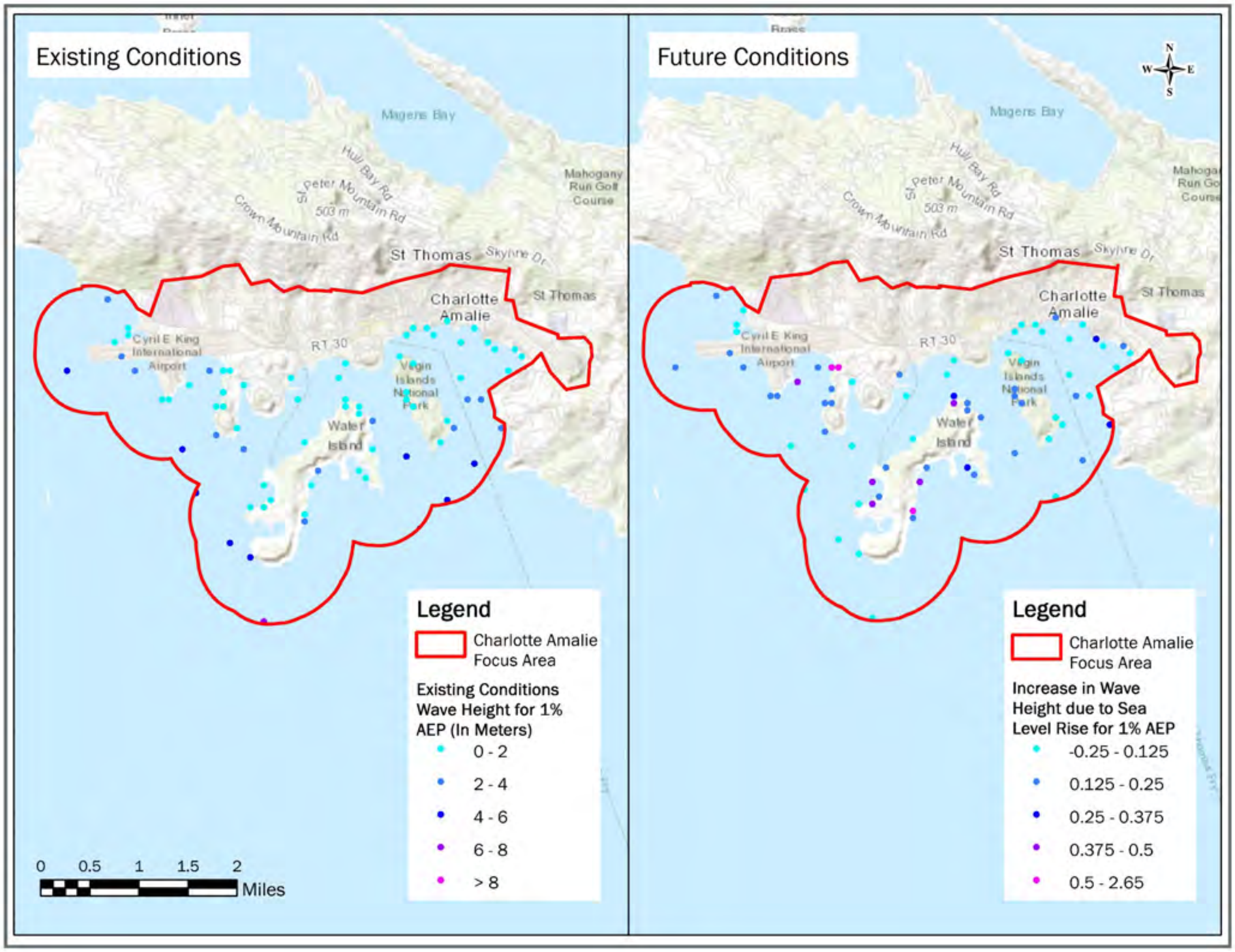


Figure 7: Existing Wave Height and Increased Wave Height due to Sea Level Rise for 1-percent Annual Exceedance Probability and for the Charlotte Amalie Focus Area (USACE 2020a)

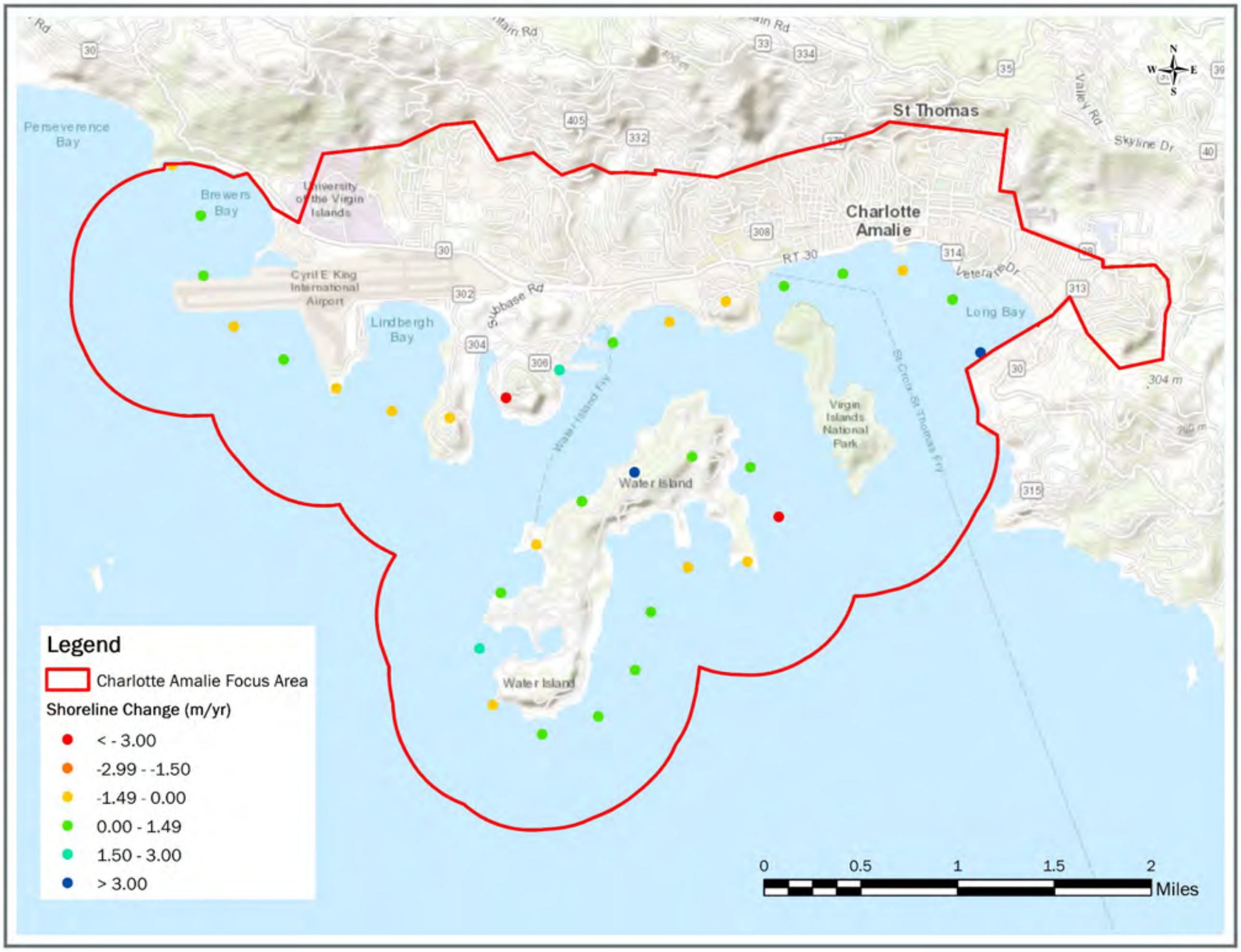


Figure 8: Long-Term Shoreline Change (erosion and accretion) (1984–2016) (Luijendijk et al. 2018)

4.1.1 Sea Level Rise Effect on Hazards

For the Tier 1 analysis of inundation, 3 feet (0.9 meters) of sea level rise was consistently assumed across the SACS area for the 10-percent and 1-percent AEP, while the Category 5 MOM results remained the same. In some of the more refined Tier 2 analyses, 2.33 feet (0.71 meters) and 6.95 feet (2.12 meters) were applied within the U.S. Virgin Islands. The values represent the average projected sea level rise in 100 years (2120) at compliant gauges within Puerto Rico and the U.S. Virgin Islands using the USACE Intermediate and High Scenarios, respectively. Sea level rise will have a negative impact on the coastal hazards mentioned above. As shown in **Figure 5**, the inundation extents for the Charlotte Amalie Focus Area do not shift inland because the Category 5 MOM holds constant. However, the probability of flooding in several areas increases to a 10-percent AEP with sea level rise. Given the modeled water depth increase, wave action and coastal erosion are also expected to be exacerbated with sea level rise.

4.2 System Performance

Performance is a system's reaction to a hazard. System performance refers to a system's features and the ability to contain/manage the flood hazard for all possible events.

Although the offshore habitats of coral reef and seagrass provide a natural barrier from wave energy, the coastline shows evidence of frequent wave energy and inundation. Without these natural protective features, risk to areas currently protected by these coastal features is likely to increase. The health and longevity of these offshore natural features impact the entire system performance in responding to coastal risks.

Airport Road is an emergency evacuation route and the vehicular access to the Cyril E. King International Airport, which runs parallel to a portion of the coastline of Lindbergh Bay. In the 1930s, Lindbergh Bay was dredged, creating a 35-foot dredge hole that may have created conditions that allow larger waves to propagate through the bay (The Saint Croix Source, 2009). Wave action and recurrent inundation along the evacuation route threaten its reliability as a passage to safety in the event of a coastal storm. The risk to this piece of infrastructure has implications on the health and safety of residents of the entire island.

Veterans Drive (Route 30) runs parallel to the coastline throughout the southeastern portion of the Charlotte Amalie Focus Area. Veterans Drive is subject to frequent coastal inundation. Existing inland drainage infrastructure conveying precipitation runoff to the harbor is outdated and compound flooding from coastal inundation and rainfall runoff overwhelms the system and causes flooding in low-lying inland areas. The shoreline is primarily armored with man-made structures with heavily developed neighborhoods abutting the roadway. The Department of Public Works and USACE have drainage improvement and seawall hardening projects along the coastline and adjacent to Veterans Drive. The heavily developed shoreline in this area and the compound flood risks present unique challenges to the area.

4.3 Exposure

Exposure considers who and what may be harmed by a hazard. The Tier 1 analysis used a composite exposure index (CEI) based on 65-percent population and infrastructure exposure and 35-percent environmental, cultural, and habitat exposure. **Figure 9** illustrates the CEI for the Charlotte Amalie Focus Area. The following sections summarize the exposure identified in the Charlotte Amalie Focus Area. Additional details can be found in the Tier 2 section of the U.S. Virgin Islands Appendix.

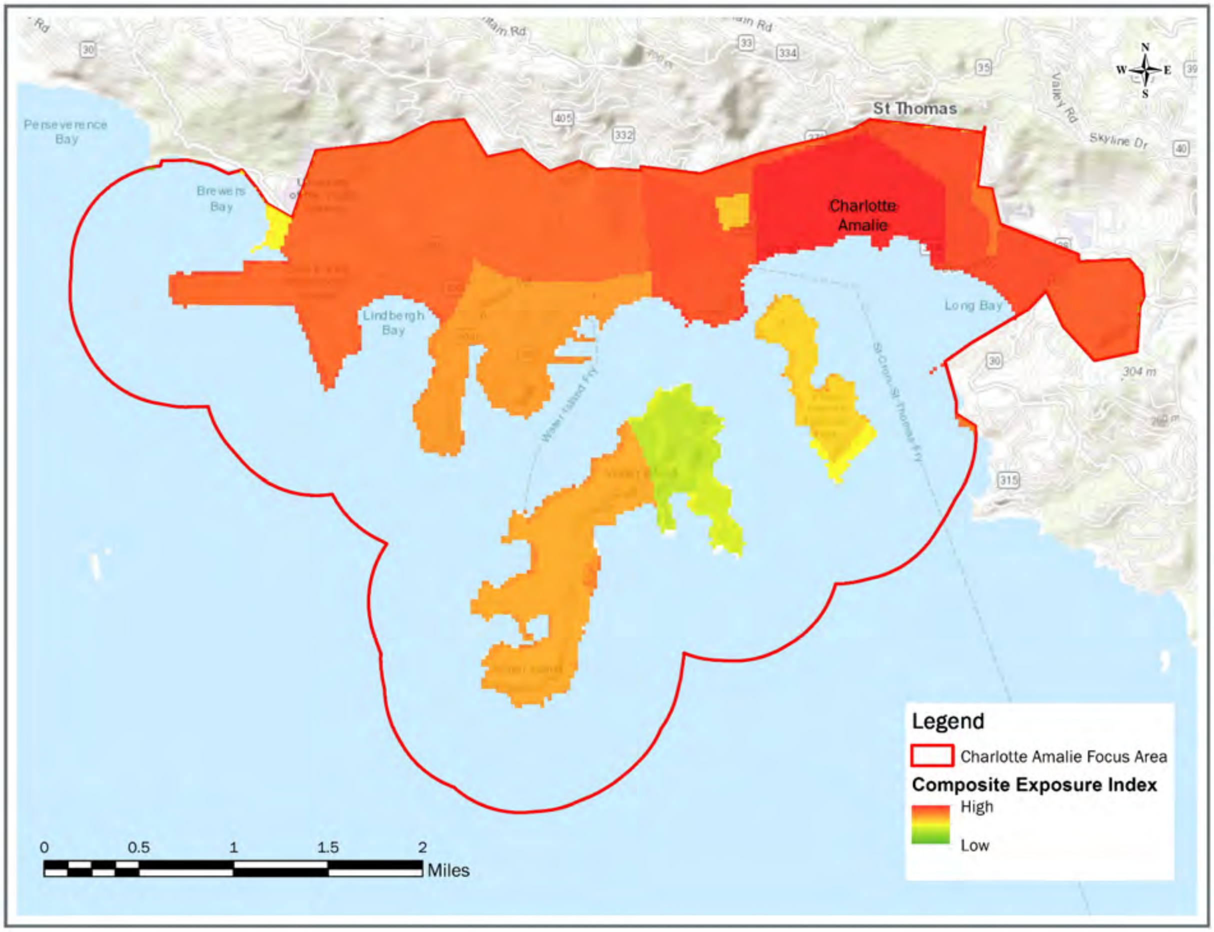


Figure 9: Exposure Index for Charlotte Amalie Focus Area

4.3.1 Exposed Population

The Charlotte Amalie Focus Area has a population of approximately 17,134 (U.S. Census 2010). The U.S. Census growth rates show a declining population in the U.S. Virgin Islands overall, with the growth rate estimated to be -0.95 percent by 2050. In addition to residents, the U.S. Virgin Islands Economic Development Authority (2020) estimates over two million tourists visit U.S. Virgin Islands each year, with most passengers arriving by cruise ship at Havensight Dock in St. Thomas Harbor. The U.S. Virgin Islands Bureau of Economic Research compiles monthly statistics on the number of arrivals, form of arrival, and departure and destination points. In 2016, over 2.5 million tourists visited the U.S. Virgin Islands, with approximately 800,000 air arrivals and 1.7 million cruise passenger arrivals (U.S. Virgin Islands Bureau of Economic Research 2017). Given the density of cruise ship docks, hotels, and tourist attractions located in Charlotte Amalie, many tourists likely reside within or near the focus area.

4.3.2 Exposed Infrastructure

The Tier 2 infrastructure exposure was assessed for Planning Reach VI_2. Section 3.3.1.3 of the U.S. Virgin Islands Appendix summarizes infrastructure exposure for the planning reach.

4.3.2.1 Residential

Residential structures are present throughout the focus area boundary. The structure types include multi-story apartment buildings and single-story, single-family residences.

4.3.2.2 Commercial

Commercial structures within the focus area are predominately located within the historic district and Havensight Dock along St. Thomas Harbor. Most of the commercial structures are tied to the tourism economy, including Vendor's Market, stores, urban malls, hotels, restaurants, and bars.

4.3.2.3 Public

There are several government offices located within the Charlotte Amalie Focus Area, including the Superior Courts and District Courts of the Virgin Islands, the Legislature of the Virgin Islands, the Virgin Islands Department of Education, the Virgin Islands Department of Labor, U.S. Customs and Border Protection Area Port of St. Thomas, U.S. Virgin Islands Bureau of Motor Vehicles, U.S. Virgin Islands Water and Power Authority, and Virgin Islands Port Authority. The UVI St. Thomas campus is located on the western side of the focus area.

4.3.2.4 Transportation

The busiest cruise ship port in the Caribbean is Charlotte Amalie and the focus area contains numerous other key transportation links. The Havensight district, located on the southwest portion of the focus area, has ferry routes to St. Croix and St. John's Islands, the Yacht Haven Grande pier, and an aerial tramway system. The Charlotte Amalie ferry pier is located within the historic district, while the Charlotte Amalie Harbor Seaplane Base and the Blyden ferry pier are located on the western side of St. Thomas Harbor. Crown Bay hosts the Crown Bay Marina and the Water Island ferry route.

Route 30 is the major road through the focus area, generally following the coastline from Havensight through the historic district and Frenchtown, then westward toward Cyril E. King International Airport.

4.3.3 Exposed Environmental and Cultural Resources

The Charlotte Amalie Focus Area contains several areas of significant environmental and cultural resources. The environmental and cultural resources are outlined in the Tier 2 section of the U.S. Virgin Islands Appendix and the South Atlantic Coastal Study Environmental Technical Report, Tier 2 Environmental Resources Vulnerability and Risk Analysis/Priority Environmental Areas Identification (Environmental Technical Report) (USACE 2021b), and the Tier 2 Cultural Resources Appendix.

4.3.3.1 Environmental Resources

Coral reefs and seagrass beds containing multiple species are present within the focus area (**Figure 10**). Coral reefs are more densely populated around the southern and westerns sides of Water and Hassel Islands, as well as along the southern points of Krum Bay and Lindbergh Bay near the Cyril E. King International Airport. Seagrass habitat surrounds Hassel Island and expands west between St. Thomas and Water Island. Mangroves are present in small pockets on the southeastern portion of Water Island. Adjacent to the northern side of the airport is a significant area of palustrine wetlands, which are limited throughout the U.S. Virgin Islands. Hassel Island is part of the U.S. Virgin Islands National Park land and is identified as a natural protected area (Gould et al. 2013). Both Hassel Island and its neighboring Water Island contain estuarine shrub/scrub wetlands, deciduous forests, and sandy beaches. These resources provide habitat for waterfowl, sea turtles, and other aquatic wildlife (U.S. Virgin Islands-DPP 2010). Environmental resources are scarce within St. Thomas Harbor because of the deep waters and high cruise ship traffic. Figure 10 shows the environmental resources along with environmental risk (discussed further in Section 4.6.2) present within the focus area.

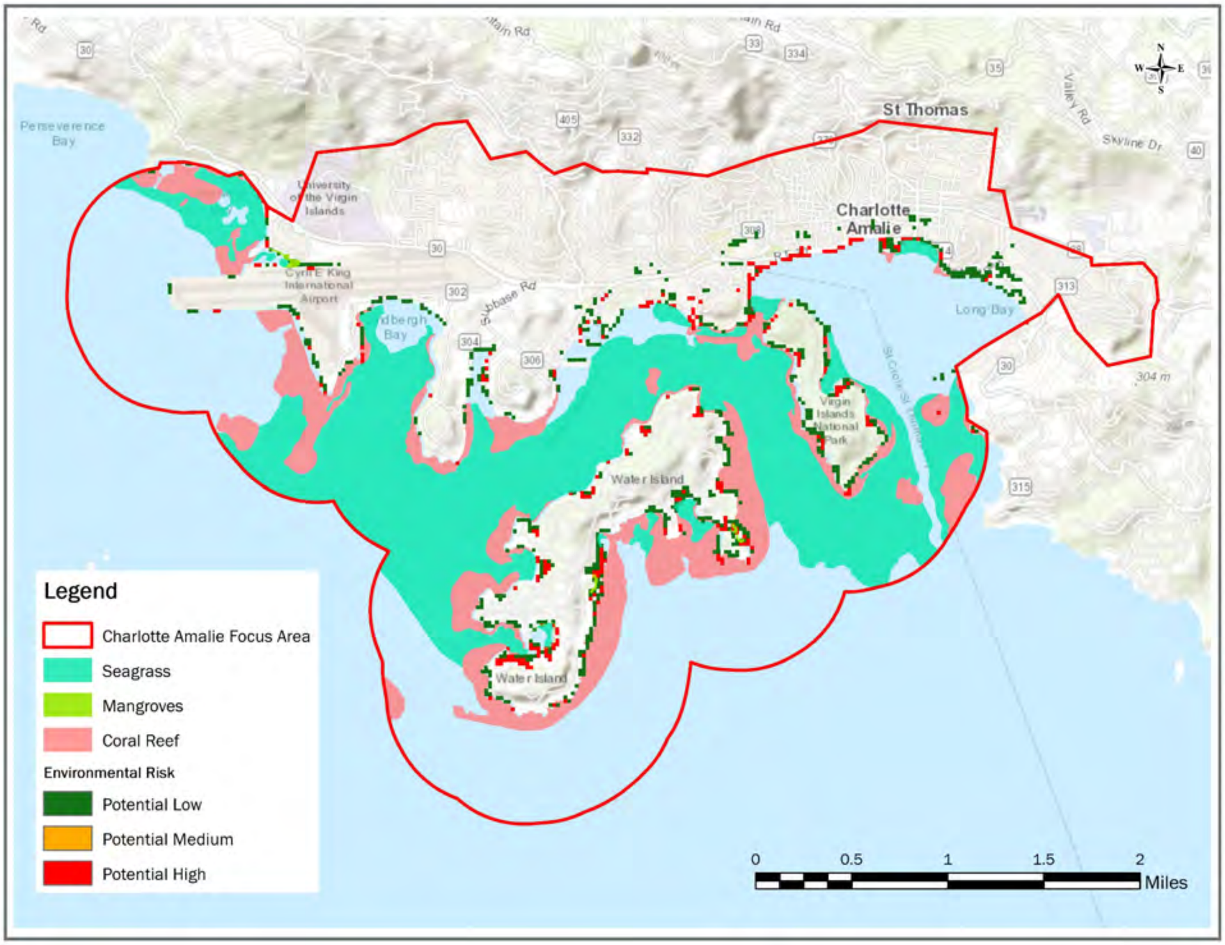


Figure 10: Environmental Resources and Risk within the Charlotte Amalie Focus Area

4.3.3.2 Cultural Resources

The cultural resources present within the Charlotte Amalie Focus Area are abundant and diverse (**Figure 11**). The focus area contains several cultural resources listed within the National Register of Historic Places (NRHP), all of which are exposed to Tier 2 hazards. Located at the base of St. Thomas Harbor, the Charlotte Amalie historic district includes Danish colonial architecture, and Ft. Christian, which is the oldest standing structure in the U.S. Virgin Islands, built between 1672 and 1680 (NPS 2020). The Hassel Island historic district located on Hassel Island is another cultural resource within the focus area. The Charlotte Amalie historic district and Hassel Island historic district are exposed to both storm surge inundation and wave attack. Ft. Segarra, an underground World War II fort located on Water Island and an archival collection housed at UVI's St. Thomas campus were identified as cultural resources within the focus area. Offshore, there are numerous shipwrecks that surround St. Thomas Island. Although not a comprehensive list of all cultural resources within the Charlotte Amalie focus area, these sites are highlighted due to their potential exposure to Tier 2 hazards.

Coastal erosion poses a physical threat to both recorded and unrecorded archaeological resources across this region. In addition, changes in the biological communities, such as the loss of protective coral reefs and seagrasses, may lead to new threats to archaeological resources.

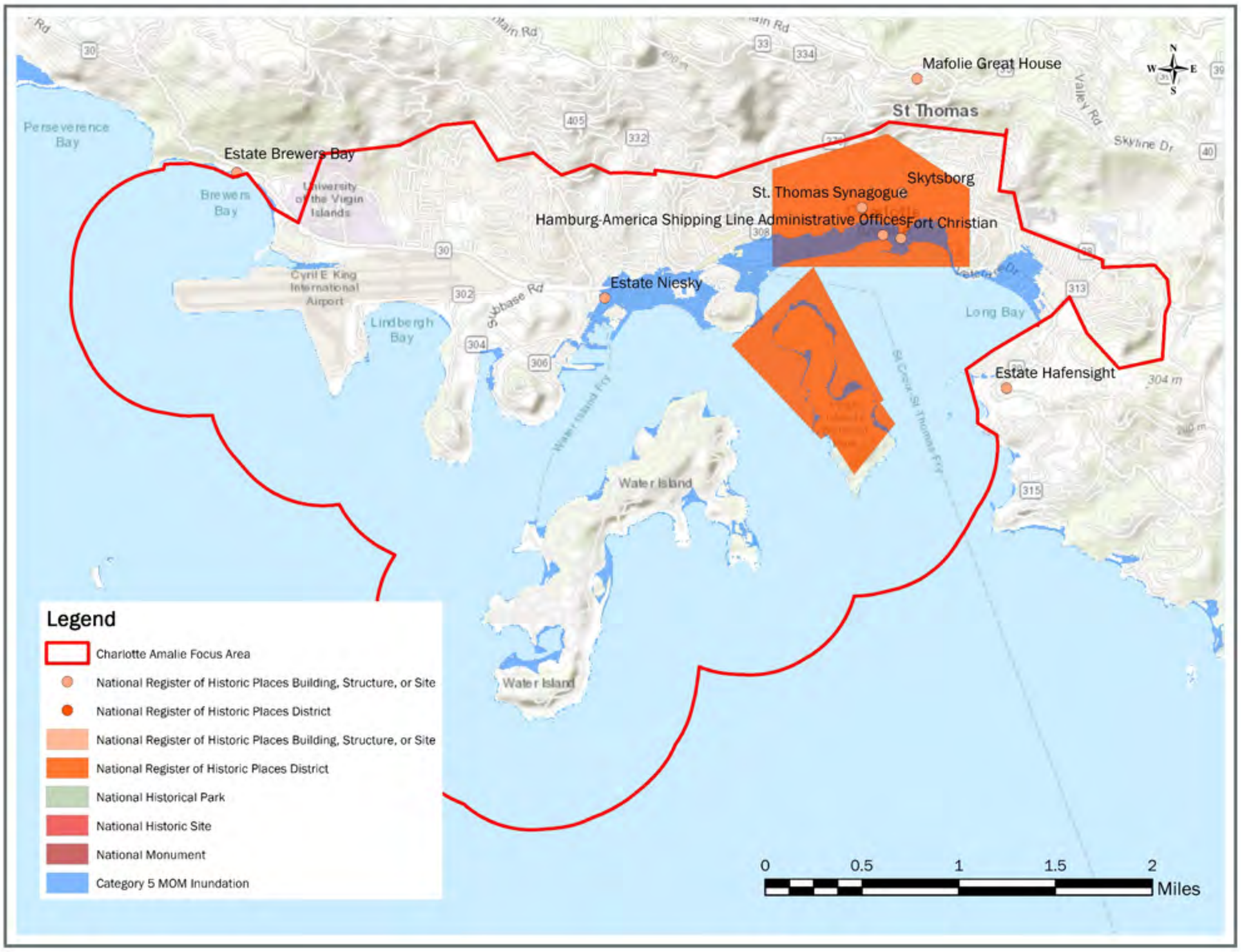


Figure 11: Cultural Resources in Charlotte Amalie (NPS 2014)

4.3.3.3 Environmental and Cultural Resource Uncertainty

Uncertainty needs to be considered when evaluating the potential effects of coastal storms and sea level rise to vulnerable environmental and cultural resources. Without protective measures, natural habitats and resources will become more susceptible to increased wave attack, inundation, and erosion. Many of the cultural resources present are in areas highly susceptible to coastal erosion and storm damage. Sea level rise will increase the threat to the cultural resources, particularly within the colonial town of Charlotte Amalie.

4.4 Vulnerability

Vulnerability is defined as the susceptibility of harm to people, infrastructure, and the natural environment from a hazardous event. The following subsections summarize components that increase the vulnerability within the Charlotte Amalie Focus Area.

4.4.1 Infrastructure and Economy

There are numerous colonial structures within the Charlotte Amalie and Hassel Island historic districts that are in areas subject to storm damage. Older structures may be more vulnerable, as they were designed to historical conditions without consideration of current or future coastal storm risks, and many assets likely at elevations subject to hazard. The local economy is largely driven by tourism, making it vulnerable when tourism is prevented or diminished from destruction caused by natural hazards. The ability to pay for structure and infrastructure restoration will be further threatened with reduced operating periods and therefore reduced revenue.

4.4.2 Population

The vulnerability of the focus area's population compared to the U.S. Virgin Islands and the United States is shown in **Table 1**. Over 46 percent of the focus area's population is without a vehicle, leaving residents dependent upon public transportation (or other means) to reach the airport to evacuate the island and/or to move inland and upland to seek shelter prior to a storm. Additionally, with nearly one quarter of the population living in poverty, funds to rebuild and recover are limited, as is the ability to apply for outside assistance, which often requires internet access. These vulnerabilities make preparation for and recovery from coastal storms more challenging.

Table 1: Census Data Used to Determine the Social Vulnerability of the Area (U.S. Census 2010)

Category	Focus Area 2010 Data	U.S. Virgin Islands 2010 Data	United States 2010 Data
Total population	18,464	106,405	308,745,538
Persons under age 5	7.00%	7.00%	6.50%
Persons over age 65	12.60%	13.50%	13.00%
Persons identifying as Hispanic or Latino	17.10%	17.40%	16.40%
Persons with a disability and under age 65	6.00%	5.40%	7.20%
Households without a vehicle	46.60%	20.60%	9.10%
Persons unemployed	16.80%	17.30%	11.00%
Median household income (poverty threshold for 2010 is $18,310 for a family of three)	$36,080	$37,254	$50,046
Persons living in poverty	25.70%	22.20%	15.30%

The Tier 2 analysis considered social vulnerability data from the NOAA and the Nature Conservancy (TNC) (Schill et al. 2014). A Social Sensitivity Index was created based on 2010 Census data for a suite of variables to rank communities based on their sensitivity to storm surge and climate change. This index was mapped, scaled, and assigned a category of high, medium, or low based on the statistical distribution of the range of values that were calculated. The study considered the following variables:

total population, population under age 5, population over age 65, population living in group quarters, population living in institutional facilities, total households, total families with five or more children, grandparents living with their own grandchildren under age 18, total with disabilities, total housing units, no vehicle available, without telephone service, and without internet service. This data indicated that Estate Contant (within Charlotte Amalie West), Estate Demerara, and Estate Kings Quarter (within Charlotte Amalie) have high social sensitivity scores. Indices on social sensitivity, adaptive capacity, and exposure were combined to construct a Socioeconomic Vulnerability Index. Scores within the Charlotte Amalie Focus Area were some of the highest in the U.S. Virgin Islands. **Figure 12** displays the Vulnerability Index data for St. Thomas including the Charlotte Amalie Focus Area.

The National Fish and Wildlife Foundation's Coastal Resilience Evaluation and Siting Tool (CREST) also considered variables from the 2010 Census data and ranked areas according to guidance from the U.S. Environmental Protection Agency (EPA) environmental justice screening and mapping tool (Dobson 2010). **Figure 13** depicts some areas along the coastline within the Category 5 MOM with a relatively low vulnerability; however, toward downtown Charlotte Amalie there is a medium-high and high social vulnerability. More information on social vulnerability can be found in the U.S. Virgin Islands Appendix.

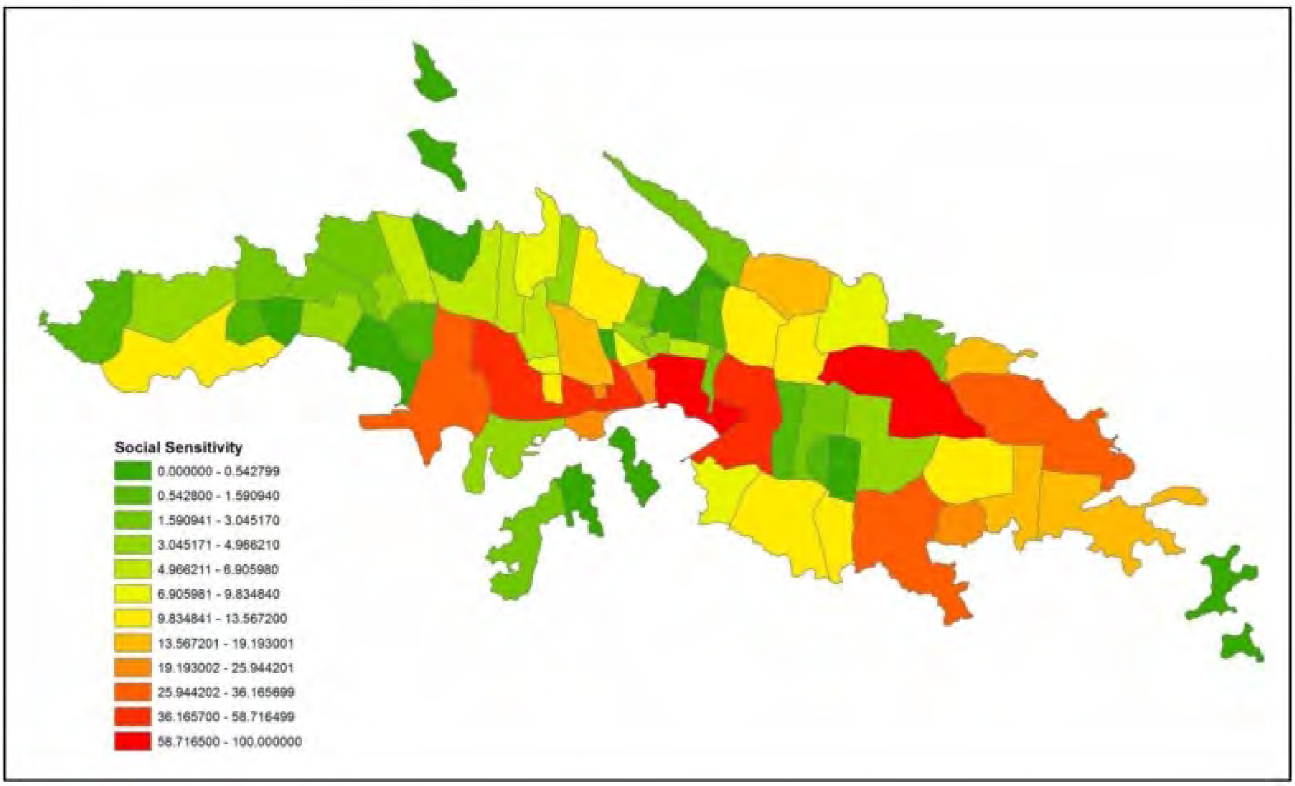


Figure 12: National Oceanic and Atmospheric Administration and The Nature Conservancy Social Sensitivity Index for Charlotte Amalie Focus Area (Schill et al. 2014)

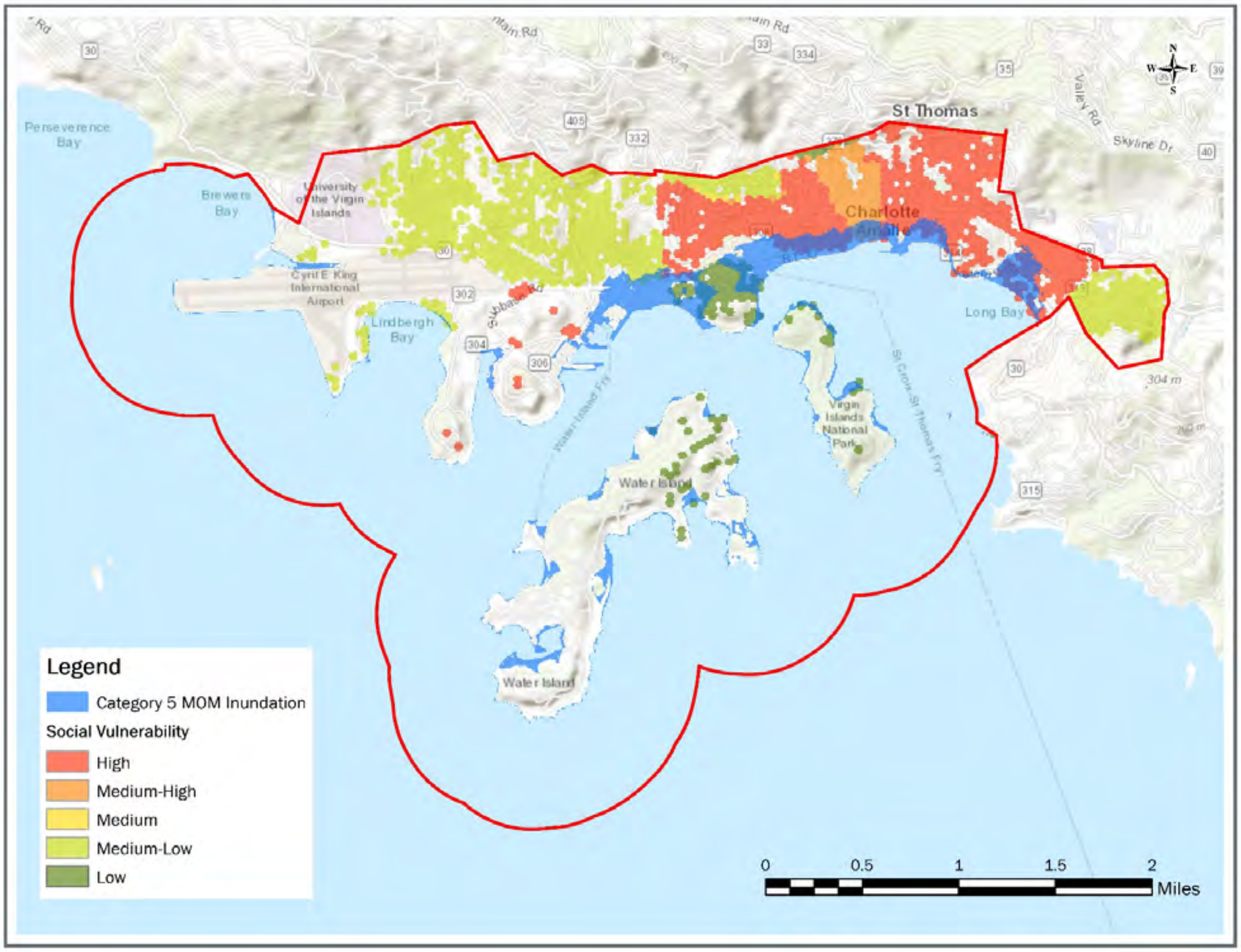


Figure 13: Coastal Resilience Evaluation and Siting Tool Socially Vulnerable Populations Subject to Inundation from Category 5 Maximum of Maximum for Charlotte Amalie Focus Area (Dobson 2010)

4.4.3 Environmental and Cultural Resources

Within the focus area, coral reef and seagrass habitat, palustrine wetlands, and sandy beaches are vulnerable natural habitats. The coral reef is vulnerable to physical and chemical degradation. Coral can be physically impacted by strong and/or frequent storm events. Sea level rise may lead to increased sedimentation that can decrease or eliminate coral production. Chemical degradation can be caused by harbor pollution and ocean acidification. Degradation of the coral health from these stressors increases the coral's vulnerability to coastal storms.

Seagrass habitat is vulnerable to physical impacts from storm events and to increased sedimentation caused by sea level rise. As sea levels and temperatures rise, carbon-storing seagrass will diminish because of altered environmental conditions. Palustrine wetlands are very limited throughout the U.S. Virgin Islands. Located adjacent to the airport, the area is under threat from pollution from commercial development.

Exposed cultural resources were qualitatively assessed for vulnerability based on degree of exposure to coastal hazards and sea level rise, structural considerations, and the nature of the cultural resource. **Table 2** presents exposed cultural resources and the potential vulnerability to Tier 2 hazards. Within the Charlotte Amalie focus area historic districts, archeological sites, sites located along coasts, bays, and in low-lying areas are potentially vulnerable to impacts from storm surge inundation and wave attack. Storm surge inundation along the coast will flood historic properties and damage buildings. Damage may include structural damage and destruction of historic materials (e.g., furniture, textiles, archives). The aftermath of a storm can pose long-term issues, such as the development of mold, mildew, and other potentially toxic residues. Wave attack can cause substantial structural damage to historic properties.

Table 2: Vulnerability of Exposed Cultural Resources to Tier 2 Hazards in the Charlotte Amalie Focus Area

Census Place/Estate	Exposed Cultural Resources	Tier 2 Hazards		
		Storm Surge Inundation	Erosion	Wave Attack
Estate Demarara; Estate Queens Quarter; Estate Kings Quarter	Charlotte Amalie Historic District	Y	N	Y
Estate Hassel Island	Hassel Island Historic District	Y	N	Y
Charlotte Amalie West; Estate Niesky	Estate Niesky (Plantation)	Y	N	N

4.5 Consequences

Consequences are the potential impacts or harm that could result if/when the exposed elements described in the previous section are subject to hazards. In Charlotte Amalie, the consequences of a coastal hazard event would have negative impacts to the commercial and historic district. Damages to historic buildings and infrastructure could potentially cost more than repairs to newer buildings or be considered an invaluable loss. Damages to historic structures or artifacts would also have a negative impact on the tourism economy. Increased costs for repairs and reduced revenues from long periods of closure due to recovery operations will threaten businesses. Socially vulnerable populations whose livelihood is based in tourism would be significantly affected by a coastal hazard event.

Loss of environmental habitat, such as coral reef and seagrass, would reduce available habitat that many species depend on. This would impact the area’s biodiversity and have a negative impact on tourism operations. Degradation of the coral reefs and seagrasses would also decrease the amount of natural protection to coastal storms and result in greater risk to the shoreline during coastal storm events.

4.6 Risk Assessment

The Tier 1 Risk Assessment combined the probability of inundation hazard (**Figure 5**) with the CEI (**Figure 9**) to produce a composite risk assessment. **Figure 14** displays current and future composite risk with 3.0 feet (or 0.9 meters) of sea level rise for the Charlotte Amalie Focus Area. The Tier 1 Risk Assessment demonstrates under existing conditions, most of the Charlotte Amalie Focus Area is classified as potential low risk. However, under future conditions with sea level rise, the downtown

Charlotte Amalie historic district and Crown Bay demonstrate significant change from potential low risk to potential high risk.

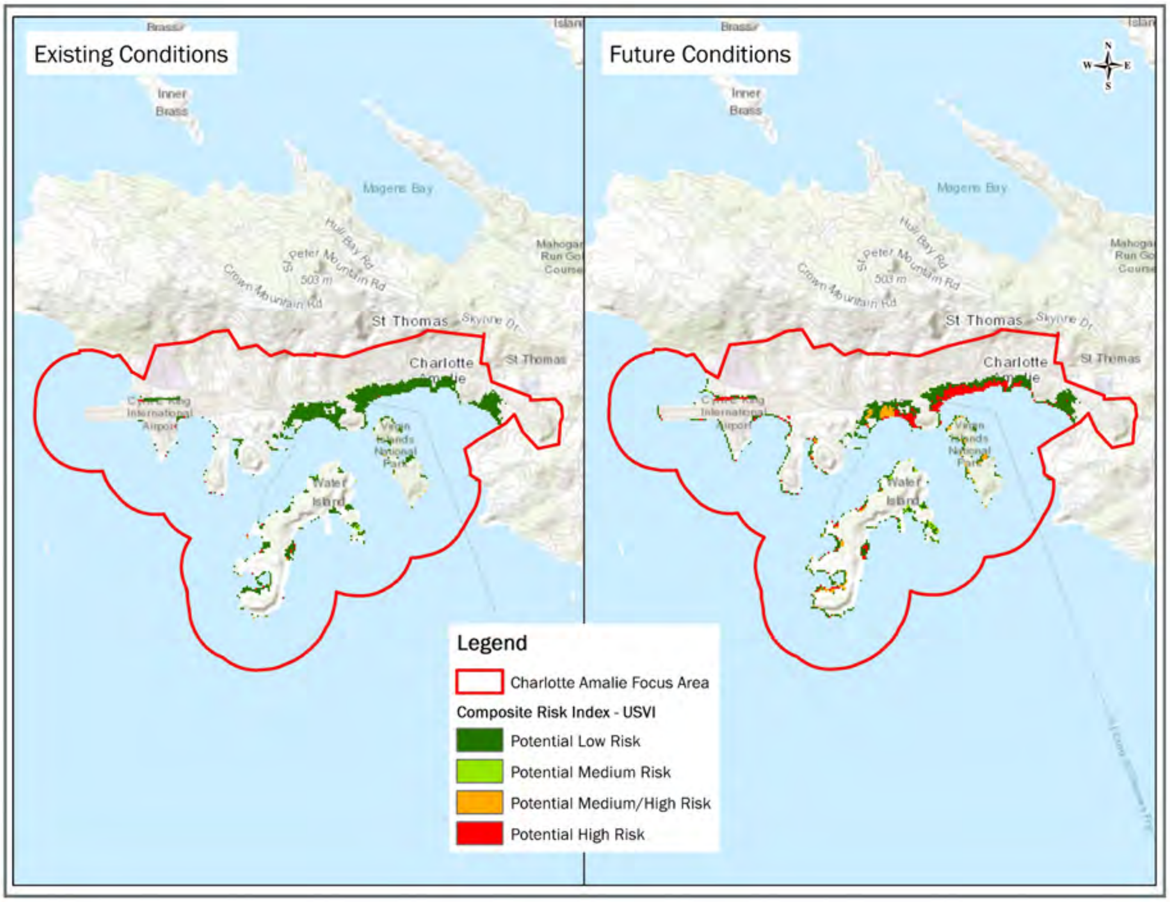


Figure 14: Existing and Future Composite Risk Index for the Charlotte Amalie Focus Area

The Tier 2 Risk Assessment incorporated additional detail and more localized hazard, vulnerability, and exposure information to refine the Tier 1 Risk Assessment.

Important coastal cultural resources were identified based on their potential exposure to coastal hazards. Portions of the Charlotte Amalie historic district and the Hassel Island historic district are located within the Category 5 MOM inundation area. Coastal erosion poses a threat to both recorded and unrecorded archaeological resources across this region. Coastal storm impacts to cultural resources within Charlotte Amalie are expected to increase in relation to sea level rise. More detail is provided within the Tier 2 Cultural Resources Appendix.

4.6.1 Erosion and Wave Attack Risk Assessment

Wave attack can increase the extent and severity of erosion damages along the coast, consequently causing direct damage to infrastructure and both environmental and cultural resources. As summarized in the U.S. Virgin Islands Appendix, areas predicted to experience increases in future wave heights for the 1-percent AEP event greater than 0.75 meters were classified as significant risk, as shown in **Figure 7.** Based on this classification, there are no areas within Charlotte Amalie at high risk to increased future wave heights.

Historical erosion rates were classified as medium-high risk (-0.75 meter per year to -1 meter per year) and high risk (> -1 meter per year), as discussed in the U.S. Virgin Islands Appendix, to identify areas most at risk to erosion hazards under historical conditions. These thresholds were applied to the shoreline change data for Charlotte Amalie and are shown **Figure 8**. Red Point near Cyril E. King Airport, Regis Point, portions of Veteran's Drive, and the eastern coast of Water Island were identified as medium-high and high risk for erosion. Stakeholders identified coastal erosion and inundation as a significant problem along Airport Road, the only evacuation route to the airport. As stated, as a key problem within the focus area with potential loss or reduction in natural offshore barriers, risks to these areas with high historical erosion rates are likely to increase, further threatening infrastructure, and cultural and environmental resources.

4.6.2 Tier 2 Economic Risk Assessment

The Tier 2 Economic Risk Assessment used FEMA's Flood Assessment Structure Tool (FAST) to estimate current and future potential annual damages from coastal hazards. **Figure 15** demonstrates that expected annual damages increase significantly under future conditions with sea level rise. The Tier 2 Economic Risk Assessment FAST results are available for use through an interactive web map. When all the census places within the Charlotte Amalie Focus Area boundary are selected (though some census places cross over the focus area boundary), the analysis estimates $805,000 in annual damages under existing conditions and $1.98 million in annual damages under future conditions with sea level rise.

Table 3 contains the estimated damages from hazard events based on the event's AEP. For example, for the 1-percent AEP event, estimated damages under existing conditions are $10.5 million, and under future conditions, estimated damages are $35.3 million. These damage estimates include damages to physical structures and infrastructure caused by coastal inundation. These estimates do not include damages from flooding from inland runoff or compound flooding. The estimates also do not consider economic losses resulting from temporary or permanent business closures following a natural hazard event or impacts to the local economy from lost or reduced tourism revenue. If inland flooding and impacts to tourism and business operations were considered in the analysis, the estimated damages under both existing and future conditions would be significantly higher. The financial consequences of future risk from coastal inundation are significant.

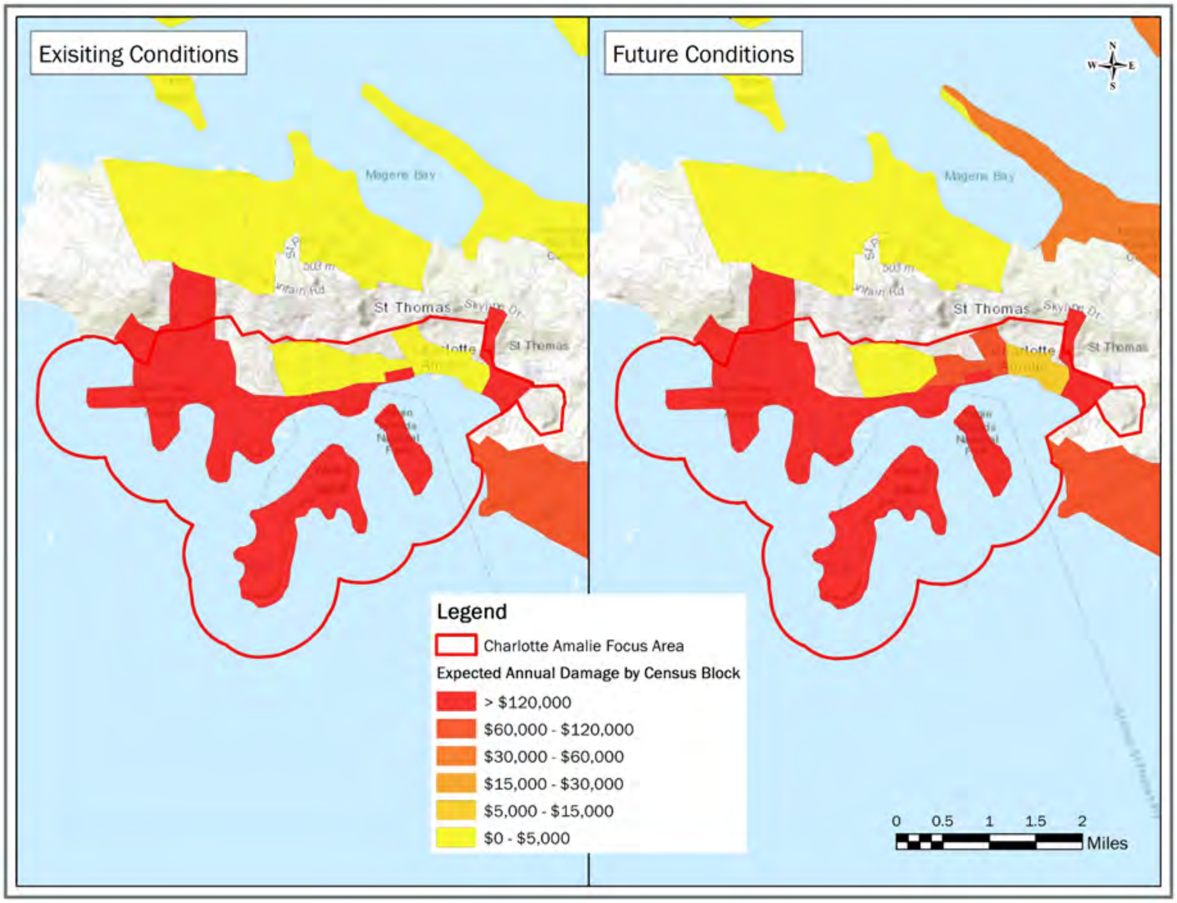


Figure 15: Expected Annual Damages in Dollars Based on FEMA's Flood Assessment Structure Tool Results for the Charlotte Amalie Focus Area

Table 3: Damages under Existing and Future Conditions by Annual Exceedance Probability in the Charlotte Amalie Focus Area

AEP Event	Annualized Damages under Existing Conditions (FY20)	Annualized Damages under Future Conditions (FY20)
10%	$6,700,000	$12,100,000
2%	$9,000,000	$25,300,000
1%	$10,500,000	$35,300,000
0.2%	$17,700,000	$66,700,000

4.6.3 Environmental and Cultural Risk Assessment

A detailed description of the environmental risk assessment is provided in the *South Atlantic Coastal Study Environmental Technical Report, Environmental Resources Vulnerability and Risk Analysis/Priority Environmental Areas* (Environmental Technical Report) (USACE 2021b). **Figure 16** displays the analysis results. The environmental risk ranges from low to high throughout the entire focus area. The eastern side of the St. Thomas Harbor has a low environmental risk, while Charlotte Amalie historic district on the western side of the harbor is high environmental risk.

Risk to cultural resources was identified based on their potential exposure to inundation from the Category 5 MOM and vulnerability to coastal hazards including storm surge inundation, erosion, and wave attack. Without prevention or protection, these impacts can quickly lead to instability and, where impacts do not directly cause destruction, may necessitate demolition where public safety becomes a concern. Repairs and reactive measures are available but could be cost prohibitive.

Damage to archaeological sites can be even more harmful. There are no reconstructive measures that can be taken for these sites. Once they are lost, the areas can no longer be studied to understand the past. More detail is provided within the SACS Tier 2 Cultural Resources Report Appendix.

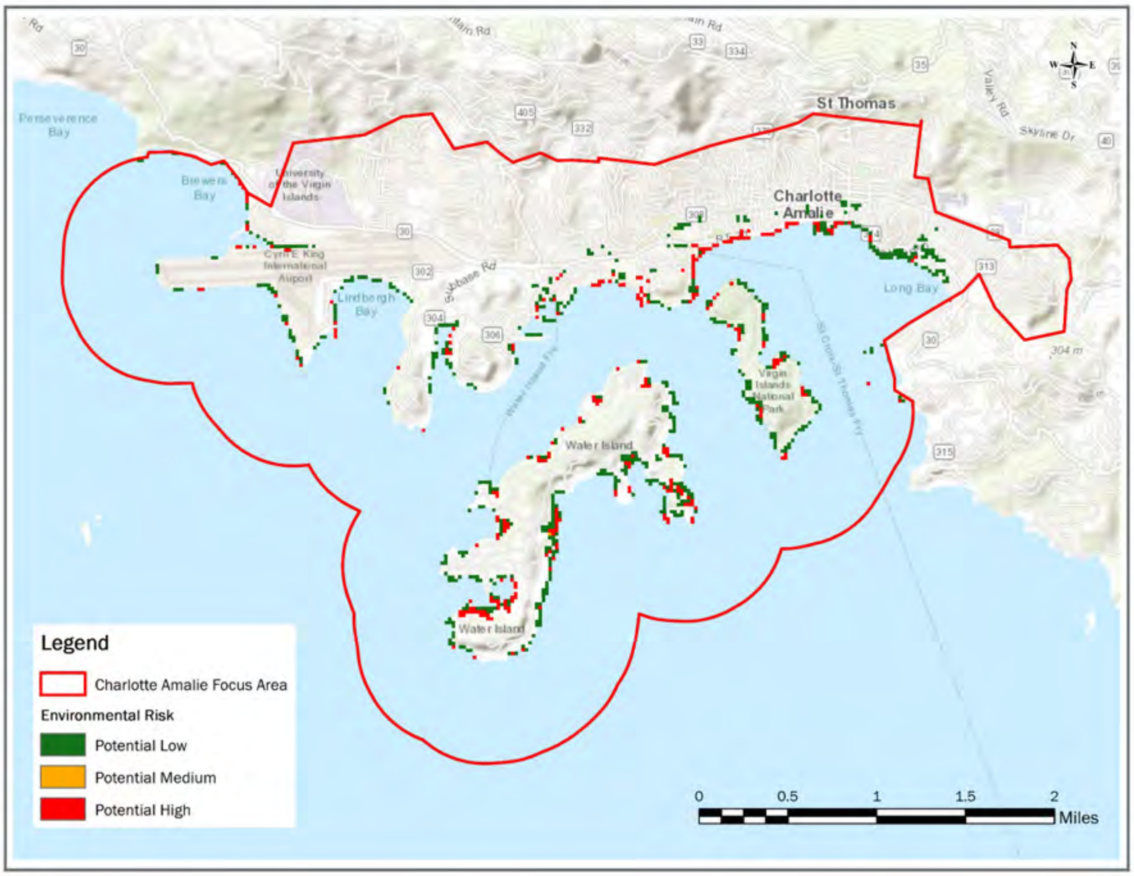


Figure 16: Environmental Risk for the Charlotte Amalie Focus Area

No SACS PEAs were identified for the Charlotte Amalie Focus Area. However, Hassel Island and areas of Water Island were designated as protected natural areas (Gould et al. 2013). Hassel Island is part of the U.S. Virgin Islands National Park. Hassel Island and Water Island contain estuarine shrub/scrub wetlands, deciduous forests, and sandy beaches. These environmental resources provide habitat for waterfowl, sea turtles, and other aquatic wildlife. Habitats on these islands are vulnerable to conversion of estuarine systems to marine open waters and forest composition alteration from inundation.

5. Action Strategy Development

To address coastal storm risks, agency stakeholders participated in the Focus Area Visioning Meetings, a series of interactive webinars to identify completed, ongoing, and needed actions within the focus area. Suggested actions compiled during the sessions were organized into a table and grouped according to recurrent themes. This grouping process produced a collection of themes to evaluate and compare. The following sections describe the process and outcomes of identifying and screening the measures.

5.1 Identify Possible Solutions

Actions were identified by agency stakeholders during the Field Workshop held in Charlotte Amalie in October 2019, the Focus Area Strategy Development Webinar in September 2020, and through additional follow-on conversations. The actions gathered were summarized (**Table 4**) and classified as nonstructural, structural, or NNBF. Nonstructural measures are identified as modifications in public policy, management practices, regulatory policy, and pricing policy; typically, USACE includes structure acquisitions, relocations, floodproofing, and flood-risk related warning systems planning and policy as nonstructural measures. Structural measures are designed to decrease coastal inundation and erosion risks such as levees, storm surge barriers, seawalls, revetments groins and breakwaters. Natural and nature-based features can attenuate waves and reduce risk to coastlines and improve ecosystem services such as dunes, vegetated features, mangroves, coral reefs, barrier islands, and shoreline forests (USACE 2013). For each action, the status, time frame, priority, and potential lead stakeholder were identified.

Table 4: Actions Identified for the Charlotte Amalie Focus Area

Category	Status	Measure/ Action Type	Description/Purpose	Potential Stakeholder(s)	Time Frame[1]	Priority
Nonstructural	Ongoing	Regulatory	Implement code compliance initiatives to improve structure performance during flood events	FEMA	Mid	*Unspecified*
Nonstructural	Ongoing	Plan	Develop detailed action plan to address marine debris	NOAA	*Unspecified*	*Unspecified*
Nonstructural	Ongoing	Plan	Update FEMA Hazard Mitigation Plan	FEMA	Short	High
Nonstructural	Ongoing	Plan	Conduct a watershed management plan assessment that quantitatively and qualitatively addresses the rate of change of the landscape (development and permeability, green infrastructure)	DPNR and FEMA	Mid	High

Category	Status	Measure/ Action Type	Description/Purpose	Potential Stakeholder(s)	Time Frame[1]	Priority
Nonstructural	Ongoing	Habitat Protection	There are endangered coral hot spots with the harbor and ongoing artificial reef projects	DPNR and Department of Fish and Wildlife (DFW)	*Unspecified*	*Unspecified*
Nonstructural	Ongoing	Study	Conduct a base knowledge study evaluating the effects of sedimentation from cruise ships on the habitat	University of the Virgin Islands and DFW	*Unspecified*	*Unspecified*
Nonstructural	Needed	Regulatory	Understand existing setbacks and develop a defined coastline for construction setbacks (updating reference coastline)	UVI and DPNR	*Unspecified*	High
Nonstructural	Needed	Regulatory	Enhance coastal zone policy enforcement	*Unspecified*	*Unspecified*	High
Nonstructural	Needed	Community Engagement	Implement community engagement and capacity building initiatives	*Unspecified*	*Unspecified*	High
Nonstructural	Needed	Modeling and Analysis	Expand the use of the Social Vulnerability Exposure Index and RECONS modeling tools to apply to the U.S. Virgin Islands to help USACE consider all benefits when evaluating projects in the territory	USACE	*Unspecified*	*Unspecified*
Nonstructural	Needed	Plan	Identify emergency evacuation routes and vulnerabilities within each route. Engage and coordinate with stakeholders to reduce impacts.	*Unspecified*	*Unspecified*	*Unspecified*
Structural	Needed	Erosion Control	Mitigate shoreline erosion in Lindbergh Bay and along Airport Road	*Unspecified*	*Unspecified*	High
Structural	Ongoing	Coastal Storm Risk Management	Elevate the waste management facility located in Lindbergh Bay Park	Waste Management Authority	Short	High
Structural	Ongoing	Coastal Storm Risk Management	Make drainage improvements to mitigate flooding across the island	FEMA	Mid	High

Category	Status	Measure/ Action Type	Description/Purpose	Potential Stakeholder(s)	Time Frame[1]	Priority
Structural	Ongoing	Coastal Storm Risk Management	Improve stormwater management systems	Department of Public Works	Mid	High
Structural	Planned	Coastal Storm Risk Management	Install a new box culvert and replace the bridge adjacent to Veterans Drive	USACE	Mid	Medium
Structural	Needed	Coastal Storm Risk Management	Improve drainage to mitigate flooding along Airport Road	*Unspecified*	*Unspecified*	High
Structural	Needed	Coastal Storm Risk Management	Improve stormwater drainage and reduce wave action along the harbor and Long Bay area	*Unspecified*	*Unspecified*	*Unspecified*
NNBF	Planned	Study	Conduct a survey of natural resources (seagrass)	DPNR and DFW	Mid	*Unspecified*
NNBF	Needed	Coastal Storm Risk Management	Incorporate NNBF along Veterans Drive for flood reduction, beautification, and reduction of overtopping	*Unspecified*	*Unspecified*	*Unspecified*

[1]For Time Frame: Short = <2 years; Mid = 2–10 years; Long = >10 years

5.2 Evaluation and Comparison of Solutions

Current and potential actions were collected, evaluated, grouped, and refined into five action themes: shoreline erosion and inundation along Lindbergh Bay and Airport Road, environmental resources, flood risks along Veterans Drive, policy improvements, and community outreach. These categories were presented to agency stakeholders during the Focus Area Wrap-up Webinar in November 2020 to elicit additional feedback, to identify missed actions or opportunities, and to identify stakeholders that could act as potential sponsors or partners in proposed actions.

5.2.1 Policy Improvements and Community Engagement

Policy improvements were identified as a foundational action to manage coastal storm risks in the Charlotte Amalie Focus Area and throughout the U.S. Virgin Islands. Without policies in place to support CSRM principles, and the engagement of civic employees and citizens to support those policies, all other strategies are likely to be unsuccessful. The policy improvement measures include four actions: (1) an ongoing FEMA effort for building code improvements and NFIP compliance, (2) an ongoing NOAA effort to develop a marine debris action plan, (3) a needed effort to develop a defined coastline as a basis for construction setbacks, from which setbacks will be developed based on morphologic conditions and landscape features, and (4) a need for enhanced coastal zone policy enforcement.

Community outreach was identified as another foundational action to support successful CSRM in Charlotte Amalie and across the U.S. Virgin Islands. Cooperation and coordination are an integral component of the other identified CSRM strategies. Opportunities exist to improve risk communication and outreach, especially when conveying risk in economic terms, which can be more impactful for decision-makers. The FAST analysis summarized in Section 4.6.1 provides an example of how coastal storm risks can be quantified and communicated. Expansion of the hazard analysis to include compound flood risks and stormwater flooding would show increased consequences. The modeled hazard data from the SACS analyses were based on regional models. More appropriate models may exist and could be coupled with developed models to capture conditions specific to the U.S. Virgin Islands and the Charlotte Amalie Focus Area. Opportunities exist to improve the understanding of hazards in this area with more refined models. The overarching community outreach plan for Charlotte Amalie includes three identified actions: (1) an ongoing update of the Virgin Islands Hazard Mitigation Plan, (2) the identified need for increased community engagement and capacity building initiatives, and (3) refined hazard modeling to improve accuracy of hazard data and risk communication.

5.2.2 Shoreline Erosion and Inundation Along Lindbergh Bay and Airport Road

Airport Road is an emergency evacuation route and the vehicular access to the Cyril E. King International Airport, which runs parallel to a portion of the coastline of Lindbergh Bay. In the 1930s, Lindbergh Bay was dredged, creating a 35-foot dredge hole that may have created conditions that allow larger waves to propagate through the bay. As shown in **Figure 17**, Airport Road adjacent to Lindbergh Bay experiences 0 to 3 feet (0 to 0.9 meters) of flooding during the Category 5 MOM event. Expected sea level rise will impact Airport Road by causing more frequent flooding during all AEP events. Additionally, as demonstrated in **Figure 7**, wave heights are anticipated to increase up to 8.7 feet (2.7 meters) in the Lindbergh Bay area, further exacerbating the already eroding coastline and likely to cause increased flood depths. **Figure 18** shows shoreline changes in recent history.

DPNR of the U.S. Virgin Islands was awarded FEMA funding to conduct a watershed management studies project. Three watersheds are being analyzed on St. Thomas as part of the study, one of which includes Lindbergh Bay. This effort will quantitatively and qualitatively address the rate of change of the landscape (development and permeability, green infrastructure); develop comprehensive watershed management plans; and support the development of mitigation projects for stormwater management.

Several potential measures were identified through collaboration with agency stakeholders to address coastal storm risks along Airport Road adjacent to Lindbergh Bay, including road elevation, shoreline stabilization (e.g., a revetment), or filling of the dredge hole. The USACE could potentially support these types of actions through the Continuing Authorities Program Section 14: Protection of Public Infrastructure, Section 103: Hurricane and Storm Damage Reduction, or Section 205: Flood Damage Reduction Projects.

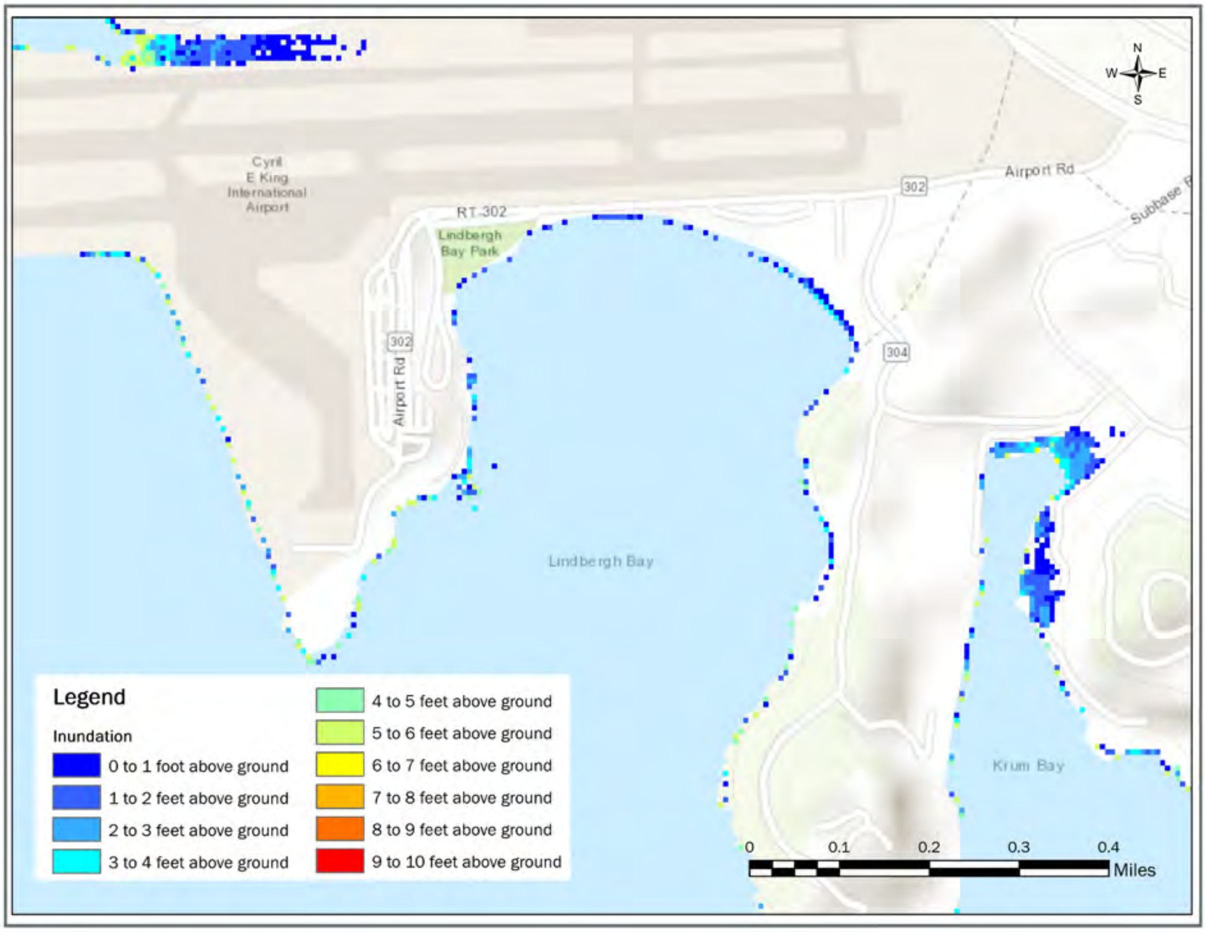


Figure 17: Inundation Depths in Feet from Category 5 Maximum of Maximum Along Lindbergh Bay and Airport Road

Figure 18: Comparison of Historic Aerial Imagery of Airport Road Abutting Lindbergh Bay (Google Earth Pro 2020 and Google Earth Pro 2006)

The MCL (USACE 2021d) was used to derive reconnaissance-level cost estimates for the identified road elevation and revetment measures, and the USACE Dredge Material Management Plan for the San Juan Harbor Puerto Rico Navigation Improvements Study (USACE 2017) was used to develop a cost estimate for filling the dredge hole. Cost estimates were developed to manage risks along 900 linear feet (270 meters) of Airport Road. Road elevation was considered a viable mitigation action to protect the road from increased wave action and erosion, and to maintain accessibility of the road as an evacuation route during a flood event. Development of revetment measures was identified as a mitigation action to harden the shoreline to reduce the impacts of wave action and erosion. Filling the dredge hole with sediment was another potential mitigation action identified as an erosion control measure. **Table 5** displays the range of rough order of magnitude costs for each identified mitigation measure. Additional rough order of magnitude costs for filling the dredge hole were based on a $600,000 additional mobilization and $4.7 per cubic yard ($3.6 per cubic meter) on top of the dredge base costs. These estimates are based the USACE Dredge Material Management Plan for the San Juan Harbor Puerto Rico Navigation Improvements Study (USACE 2017). Filling the hole will require approximately 105,000 to 142,000 cubic yards (80,300 to 108,600 cubic meters) of material to match surrounding elevations. To refine the estimate on costs to fill the dredge hole, several hydrographic surveys and/or sediment transport models would be needed to determine the sediment movement within the bay and the volume of material needed to stabilize the shoreline. The cost estimate would vary significantly for this effort because of the source of the dredging material. One potential source could be the ongoing effort by Virgin Islands Port Authority to dredge the West Indian Company Limited (WICO) cruise ship dock and channel to accommodate larger ships.

According to the South Atlantic Division Sand Availability and Needs Determination Summary Report (SAND Report) (USACE 2020b), the project should remove an estimated 60,000 cubic yards (45,900 cubic meters) of beach-quality sand and 195,000 cubic yards (149,100 cubic meters) of material that could be used to fill the Lindbergh Bay dredge hole approximately 4 miles (6.5 kilometers) away. With the dredge pipeline in place, the option to lay the beach-quality sand on the dry beach should be further explored. Another potential sand source is Gallows Bay, off the coast of St. Croix (within the Christiansted focus area), where dredging is planned. Such beneficial use of the dredged material provides opportunities to keep sediment within the littoral system.

Table 5: Planning Level Cost Estimates for Measures along Airport Road

Mitigation Action	Road Elevation (MCL)		Revetment (MCL)		Fill Dredge Hole (USACE Study)	
Order of Magnitude	Low Estimate	High Estimate	Low Estimate	High Estimate	Low Estimate	High Estimate
Base Cost Estimate	$6,819,000	$12,668,000	$4,439,000	$13,507,000	$14,275,000	$37,950,000
Additional Costs	$0	$0	$0	$0	$1,100,000	$1,270,000
Total Cost Estimate	$6,819,000	$12,668,000	$4,439,000	$13,507,000	$15,375,000	$39,217,000

Providing an evacuation route that can function during and after a storm event will protect residents and tourists on the island by providing access to the Cyril E. King International Airport. An accessible evacuation route provides the opportunity for people to travel on and off the island and for resources and supplies to efficiently be delivered and distributed, which are critical to emergency and recovery efforts.

5.2.3 Environmental Resources

To manage and support environmental resources within the focus area, ongoing efforts include work by DPNR and DFW to survey seagrasses and to create artificial reef projects for habitat restoration in St. Thomas Harbor. UVI has an ongoing study evaluating cruise ship sedimentation and its effects on habitat along the St. Croix–St. Thomas ferry route.

Coral reefs serve as natural, sustainable offshore barriers that reduce wave energy and onshore impact. Environmental habitats also provide opportunities for fish and marine life to flourish, which is critical for the tourism industry and local economy. Focusing on the restoration of existing environmental habitats and expansion of environmental resources within the focus area will provide additional beneficial aquatic habitat that will reduce onshore storm impacts and support the local economy. A study by NOAA published in 2016 indicates that approximately 60 percent of the total gross domestic product in the U.S. Virgin Islands comes from ocean-related tourism (NOAA 2016). Supporting the resilience of marine habitats is likely to produce economic co-benefits in the territory.

5.2.4 Flood Risks along Veterans Drive

Veterans Drive (Route 30) runs parallel to the coastline throughout the southeastern portion of the Charlotte Amalie Focus Area. Veterans Drive is continually affected by compound flooding from both coastal and inland flooding caused by insufficient drainage capacity following precipitation events.

The shoreline is primarily armored with man-made structures with heavily developed neighborhoods abutting the roadway. As discussed in Section 1.2, there is an ongoing Department of Public Works Veterans Drive expansion project and a USACE stormwater improvement project along the St. Thomas Harbor. The Department of Public Works project includes the addition of two lanes and a pedestrian boardwalk along the harbor, which will be supported by a new seawall, as well as improvements to the stormwater drainage system. The USACE has an ongoing flood risk management project located on the northern side of Veterans Drive. The heavily developed shoreline in this area and the compound flood risks present somewhat unique challenges in this area. Collaboration with practitioners from other locations with similar characteristics subject to coastal storm risks may foster best practices and lessons learned to effectively manage risks in ways that incorporate NNBF to the greatest extent possible to maximize co-benefits.

5.3 Focus Area Action Strategy

Potential measures—based on findings from the SACS analyses and multiple rounds of workshops and collaboration with agency stakeholders—were compiled to address risk from coastal storm events in Charlotte Amalie. Some actions were already implemented, and other actions will be needed going forward. Funding opportunities to support many of these actions can be found in the SACS Coastal Program Guide (USACE 2021a). Lead stakeholders were identified for most actions. Actions were organized into themes: shoreline erosion and inundation along Lindbergh Bay and Airport Road, environmental resources, flood risks along Veterans Drive, policy improvements, and community outreach. **Table 6** contains the actions grouped by theme. Together, these actions form one cohesive FAAS, working to incrementally achieve the shared vision. The implementation of this action strategy will reduce Charlotte Amalie's risk to coastal hazards and increase the region's resilience against future hazard conditions with increased sea level rise.

Table 6: Charlotte Amalie Focus Area Action Strategy

Theme	Key Actions	Status	Priority	Time Frame	Identified Potential Stakeholder(s)
Policy Improvements, Communication, and Community Engagement	Implement code compliance initiatives to improve structure performance during flood events	Ongoing	High	Medium	FEMA
	Develop a detailed action plan to address marine debris	Ongoing	Mid	Short	NOAA
	Develop a defined coastal construction setback (updating reference coastline)	Needed	High	Long	*Unspecified*
	Expand the use of the Social Vulnerability Exposure Index and RECONS modeling tools to apply to U.S. Virgin Islands to help USACE consider all benefits when evaluating projects in the territory	Needed	High	Medium	USACE
	Enhance coastal zone policy enforcement	Needed	High	Medium	*Unspecified*
	Implement community engagement, coordination, and capacity building initiatives	Needed	High	Short	*Unspecified*

Theme	Key Actions	Status	Priority	Time Frame	Identified Potential Stakeholder(s)
	Refine modeling using modeling techniques and software most appropriate for the territories with appropriate level of resolution	Needed	Mid	Medium	*Unspecified*
Shoreline Erosion and Inundation along Airport Road and Lindbergh Bay	Update FEMA Hazard Mitigation Plan	Ongoing	High	Short	FEMA
	Develop a watershed management plan assessment that quantitatively and qualitatively addresses the rate of change of the landscape (development and permeability, green infrastructure)	Ongoing	High	Mid	DPNR and FEMA
	Identify emergency evacuation routes and vulnerabilities within each route. Engage and coordinate with stakeholders to reduce impacts.	Needed	High	Mid	*Unspecified*
	Address shoreline erosion in Lindbergh Bay along Airport Road through filling the dredge hole, developing a revetment along the shoreline, or elevating Airport Road	Needed	High	Mid	*Unspecified*
	Improve drainage to mitigate flooding along Airport Road	Needed	High	Mid	*Unspecified*
	Elevate the waste management facility located in Lindbergh Bay Park	Ongoing	High	Short	Waste Management Authority
Natural Resources	Implement artificial coral reef projects	Ongoing	High	Mid	DPNR and DFW
	Conduct a survey of natural resources (seagrass)	Planned	Mid	Mid	DPNR and DFW
	Perform a base knowledge study evaluating the effects of sedimentation from cruise ships on the habitat	Ongoing	Mid	Short	University of the Virgin Islands and DFW
	Improve stormwater drainage and reduce wave attack along the harbor and Long Bay area	Needed	High	Mid	*Unspecified*
Flood Risks along Veterans Drive	Improve drainage to mitigate flooding along Veterans Drive	Ongoing	High	Mid	FEMA
	Installation of new box culvert and bridge replacement	Planned	Mid	Mid	USACE
	Improve stormwater management system	Ongoing	High	Long	Department of Public Works

6. Recommendations

The Focus Area Action Strategy was developed to advance the shared vision and manage increased coastal storm risk as a result of sea level rise in the Charlotte Amalie Focus Area as shown in **Figure 19**. The shared vision is the overarching goal of the FAAS, broadly representing problems and opportunities stakeholders wish to address in the focus area. Resultingly, FAAS goals and objectives support the shared vision. SACS key products and other stakeholders' shared tools and data were used to support FAAS goals and objectives by assessing risk and identifying ongoing, planned, and needed actions to communicate and address the risk.

Figure 19: Focus Area Action Strategy Supports the Focus Area's Shared Vision

Recommendations are made for either multi-agency action, USACE action, or consideration by the United States Congress (Congress) to advance specific actions resulting from analyses presented in this report and coordination with stakeholders throughout the focus area. Recommendations are organized into six categories, as shown **Figure 20,** and three implementation timeframes (near-, mid-, and long-term). Implementation timing is influenced by the degree of stakeholder collaboration needed, technical complexity of the recommendation, current momentum toward implementation, and other factors needed to implement the recommendation. Implementation timeframes include:

Figure 20: Recommendation Categories

- **Near-Term Implementation (<5 years):** These recommendations are generally less complex and have significant stakeholder momentum toward implementation. The recommendations generally maintain and adapt actions that are recognized to successfully manage coastal storm risk.

- **Mid-Term Implementation (5-10 years):** These recommendations may be more technically complex and/or require additional stakeholder coordination and collaboration for implementation. They advance emerging efforts to address coastal storm risk.

- **Long-Term Implementation (>10 years):** These recommendations typically require significant stakeholder coordination before implementation and may be the most challenging to implement on regional scales from technical, political, or social perspectives. Importantly, coordination and collaboration on these recommendations should not be delayed. The long-term timeframe is reflective of the time to implementation based on immediate action to advance these recommendations which include complex issues such as land-use, zoning, and building codes.

Table 7 provides the recommendations for the Charlotte Amalie focus area.

Table 7: Recommendations for the Charlotte Amalie Focus Area

Authority Category	Implementation	Recommendation		
Address Barriers Preventing Comprehensive Risk Management	Near-Term (<5 years)	Multi-Agency Action	Use of risk assessment tools and collaboration for coastal resilience needs	The Tier 2 Economic Risk Assessment highlights the potential future cost of inaction for the territory. The risk assessment tools, in concert with other SACS key products, should be leveraged to help provide data and foster additional collaboration around co-benefits and coastal resilience needs. For example, economic development plans such as Vision 2040 can be enriched by the analyses already compiled as part of SACS. USACE can continue to participate in these collaborative efforts, particularly through the Silver Jackets program, and provide support, where appropriate.
Study Efforts (Activities under CAP)	Near-Term (<5 years)	USACE	Protection of Airport Road	Mitigating erosion and inundation risks to Airport Road, an emergency evacuation route, is necessary to protect residents and tourists on the island. Coastal erosion and inundation of the only evacuation route to the airport on the island was noted as a significant problem within the Charlotte Amalie focus area. USACE may be able to support these efforts through the Continuing Authorities Program Section 14 – Emergency Streambank and Shoreline Protection or Section 103- Beach Erosion and Hurricane and Storm Damage Reduction authority, pending interest from a non-federal sponsor. While some potential actions to manage coastal storm risks to Airport Road may exceed the CAP federal funding limit of $10 million, additional funding sources, such as the Federal Highway Authority could be considered. Non-federal cost sharing waivers are also available for CAP studies and projects in the U.S. Virgin Islands (Department of the Army 2017). The waiver amount is currently (2021) $512,000, but this amount will vary based on inflation.

7. References

Department of the Army Office of the Assistant Secretary Civil Works. April 3, 2020. *Comprehensive Documentation of Benefits in Feasibility Studies*. Department of Defense.

Department of the Army Office. May 11, 2017. *Implementation Guidance for Section 1119 of the Water Resources Development Act (WRDA) 2016, Indian Tribes.* Department of Defense.

Dobson, J.G., I.P. Johnson, and K.A. Rhodes. 2020. *U.S. Virgin Islands Coastal Resilience Assessment*. Asheville, North Carolina: UNC Asheville National Environmental Modeling and Analysis Center. Prepared for the National Fish and Wildlife Foundation. Accessed March 30, 2021, https://www.nfwf.org/sites/default/files/2020-08/us-virgin-islands-coastal-resilience-assessment.pdf.

Google Earth Pro version 7.3.3.7786. 2020. *Airport Road Abutting Lindbergh Bay*. 18˚20'10.16"N 64˚58'02.22"W, Eye alt 1096 feet. Accessed December 2020.

Google Earth Pro version 7.3.3.7786. 2006. *Airport Road Abutting Lindbergh Bay*. 18˚20'10.16"N 64˚58'02.22"W, Eye alt 1096 feet. Accessed December 2020.

Gould, W.A., M.C. Solórzano, G.S. Potts, M Quiñones, J. Castro-Prieto, and L.D. Yntema. 2013. *U.S. Virgin Islands Gap Analysis Project – Final Report.* Río Piedras: USGS, Moscow ID and the USDA FS International Institute of Tropical Forestry. Accessed March 30, 2021, https://www.sciencebase.gov/catalog/item/560eba73e4b0ba4884c5ebf2.

Luijendijk, A, G. Hagenaars, R. Ranasinghe, F. Baart, G. Donchyts, and S. Aarninkhof, S. 2018. "The State of the World's Beaches." Scientific Reports, Vol. 8, Spring: 6641. Accessed March 30, 2021, https://doi.org/10.1038/s41598-018-24630-6

National Oceanic and Atmospheric Administration. 2016. *Report Summary: U.S. Virgin Islands' Ocean Economy Data*. Accessed December 15, 2020, https://coast.noaa.gov/data/digitalcoast/pdf/econ-report-summary-usvi.pdf.

National Park Service (NPS). 2014. National Register of Historic Places Geospatial Dataset. National Parks Service. Accessed July 21, 2020, https://irma.nps.gov/DataStore/Reference/Profile/2210280.

National Park Service (NPS). 2020. "Charlotte Amalia Historic District." Accessed July 21, 2020, https://www.nps.gov/nr/travel/prvi/pr30.htm.

Schill, S, J. Brown, A. Justiniano, and A.M. Hoffman. 2014. *U.S. Virgin Islands Climate Change Ecosystem-Based Adaptation Promoting Resilient Coastal and Marine Communities.* Washington, D.C.: National Oceanic and Atmospheric Administration and The Nature Conservancy. Accessed March 30, 2021, https://www.ncei.noaa.gov/data/oceans/coris/library/NOAA/CRCP/other/grants/NA09NOS4190173/USVI/USVI_TNC_USVI_EBA_Guidance.pdf.

The St. Croix Source US Virgin Islands. 2009. “Lindbergh Bay Backers Urge CZM to Back Off Plan to Dump Sediment.” Accessed December 4, 2020. https://stcroixsource.com/2009/04/08/lindbergh-bay-backers-urge-czm-back-plan-dump-sediment/.

U.S. Army Corps of Engineers (USACE). 2021a. *Coastal Program Guide.* Charleston, VA: U.S. Army Corps of Engineers.

———. 2021b. *South Atlantic Coastal Study Environmental Technical Report, Tier 2 Environmental Resources Vulnerability and Risk Analysis/Priority Environmental Areas Identification.* Charleston, VA: U.S. Army Corps of Engineers.

———. 2021c. *South Atlantic Coastal Study (SACS) Institutional and Other Barriers Report.* Charleston, VA: U.S. Army Corps of Engineers.

———. 2021d. *South Atlantic Coastal Study (SACS) Measures and Cost Library.* Charleston, VA: U.S. Army Corps of Engineers.

———. 2020a. *Coastal Hazards System.*

———. 2020b. *Sand Availability and Needs Determination (SAND) Summary Report*. Accessed December 2020. https://www.sad.usace.army.mil/Portals/60/siteimages/SACS/508%20SAND_FINAL_Report_15Sep_CC.pdf?ver=0m6wxMybXbFmX_UJdid1kg%3d%3d.

———. 2019. “Continuing Authorities Program.” Accessed December 12, 2020, https://www.nae.usace.army.mil/Missions/Public-Services/Continuing-Authorities-Program/Section-206/.

———. 2017. Preliminary Assessment – Dredged Material Management Plan. Accessed January 2021, https://usace.contentdm.oclc.org/digital/api/collection/p16021coll7/id/4603/download.

U.S. Department of Commerce, Census Bureau. 2010. “US Decennial Census.” Accessed January 2021, https://www.census.gov/programs-surveys/decennial-census/data/datasets.2010.html.

U.S. Virgin Islands Bureau of Economic Research. 2017. *U.S. Virgin Islands Tourism Indicator: December & Annual 2016 Review*. Accessed March 30, 2021, http://www.usviber.org/wp-content/uploads/2016/11/Tourism-Indicator-Annual-2016-December-9-6-17.pdf.

U.S. Virgin Islands Economic Development Authority. 2020. “Strong Opportunities for Tourism Investment.” Accessed December 11, 2020, https://www.usvieda.org/relocate-business/key-industries/tourism-hospitality.

SOUTH ATLANTIC COASTAL STUDY (SACS)

Christiansted Focus Area Action Strategy

FINAL DRAFT REPORT

OCTOBER 2021

Table of Contents

List of Tables

List of Figures

This page intentionally left blank.

1. Introduction

This Focus Area Action Strategy (FAAS) identifies action strategies to reduce risk to coastal storms and increase resilience in the Christiansted area of St. Croix in the U.S. Virgin Islands. The South Atlantic Coastal Study (SACS) key products and analyses were leveraged to assess existing and future conditions and quantify existing and potential risks. Agency stakeholders were engaged throughout the development of the Christiansted FAAS to elicit feedback on problems and opportunities, identify and prioritize specific institutional and other barriers, and identify potential action strategies to improve resilience. Participating agency stakeholders in this FAAS included representatives from University of the Virgin Islands (UVI), St. Croix Foundation, St. Croix Environmental Association, Coral Bay Community Council, U.S. Virgin Islands Department of Planning and Natural Resources (DPNR), Virgin Islands Territorial Emergency Management Agency (VITEMA), U.S. Virgin Island Office of the Lieutenant Governor, Bioimpact, Inc., U.S. Fish and Wildlife Service, U.S. Department of Agriculture (USDA), National Oceanic and Atmospheric Administration (NOAA), Virgin Islands Port Authority (VIPA), and the Federal Emergency Management Agency (FEMA). While this FAAS was developed for Christiansted, it can serve as a model for developing action strategies in other high-risk locations.

The FAAS was developed according to the Coastal Storm Risk Management (CSRM) Framework, an iterative process with three tiers of analysis that gains resolution each time it is implemented. Under the Tier 1 regional analysis, national data sets were utilized to assess potential risk across the entire SACS study area, as documented in the SACS Main Report. For the Tier 2 analysis, more refined data and analyses unique to each individual state or territory were incorporated. The Tier 2 analysis for Christiansted is documented within the U.S. Virgin Islands Appendix. The FAAS is a third iteration of the SACS study framework, incorporating data and knowledge unique to the local area to identify risks to coastal storm events and develop potential strategies to address the risks.

This FAAS is carried out as part of SACS, which was authorized by Section 1204 of the Water Resources Development Act of 2016 (WRDA 2016) as described in the Main Report.

1.1 Study Area

The Christiansted Focus Area is on the island of St. Croix, within Planning Reach VI_1, as identified in the U.S. Virgin Islands Appendix. The focus area comprises coastal areas within the subdistricts of Sion Farm, Christiansted, and East End (**Figure 1**). The southern boundary of the focus area extends inland to capture the Category 5 Hurricane Maximum of Maximum (Category 5 MOM) hurricane inundation extent. The northern boundary extends offshore and includes coral reef habitat. The boundary extends west along the shoreline to include Pelican Cove and east to include Chenay Bay. The focus area encompasses two SACS Priority Environmental Areas (PEAs): Altona Lagoon and Southgate Pond. Both areas contain salt ponds, salt flats and mangroves and provide habitat for waterfowl and other aquatic wildlife. The focus area is 7 square miles (18 square kilometers) and includes the census estates of La Grande Princess, Little Princess North, Golden Rock, Fangselet, Richmond, Friedensthal, East Street, Altona, Mount Welcome, Shoys, Roberts Hill, Boetzberg, Mount Pleasant East 1, South Gate, St. Peters, Protestant Cay, and Green Cay. **Figure 2** displays the names and locations of the census estates within the focus area.

Focus areas were selected based on Tier 1 high-risk areas, stakeholder feedback and ensuring a range of environments and risk factors were represented across all 21 focus areas selected within the SACS. Five draft focus areas were presented to stakeholders at the 2019 U.S. Virgin Islands Field Workshop. Based on provided feedback and additional analysis, two focus areas were selected for the U.S. Virgin Islands: Charlotte Amalie and Christiansted.

Figure 1: Christiansted Focus Area Boundary

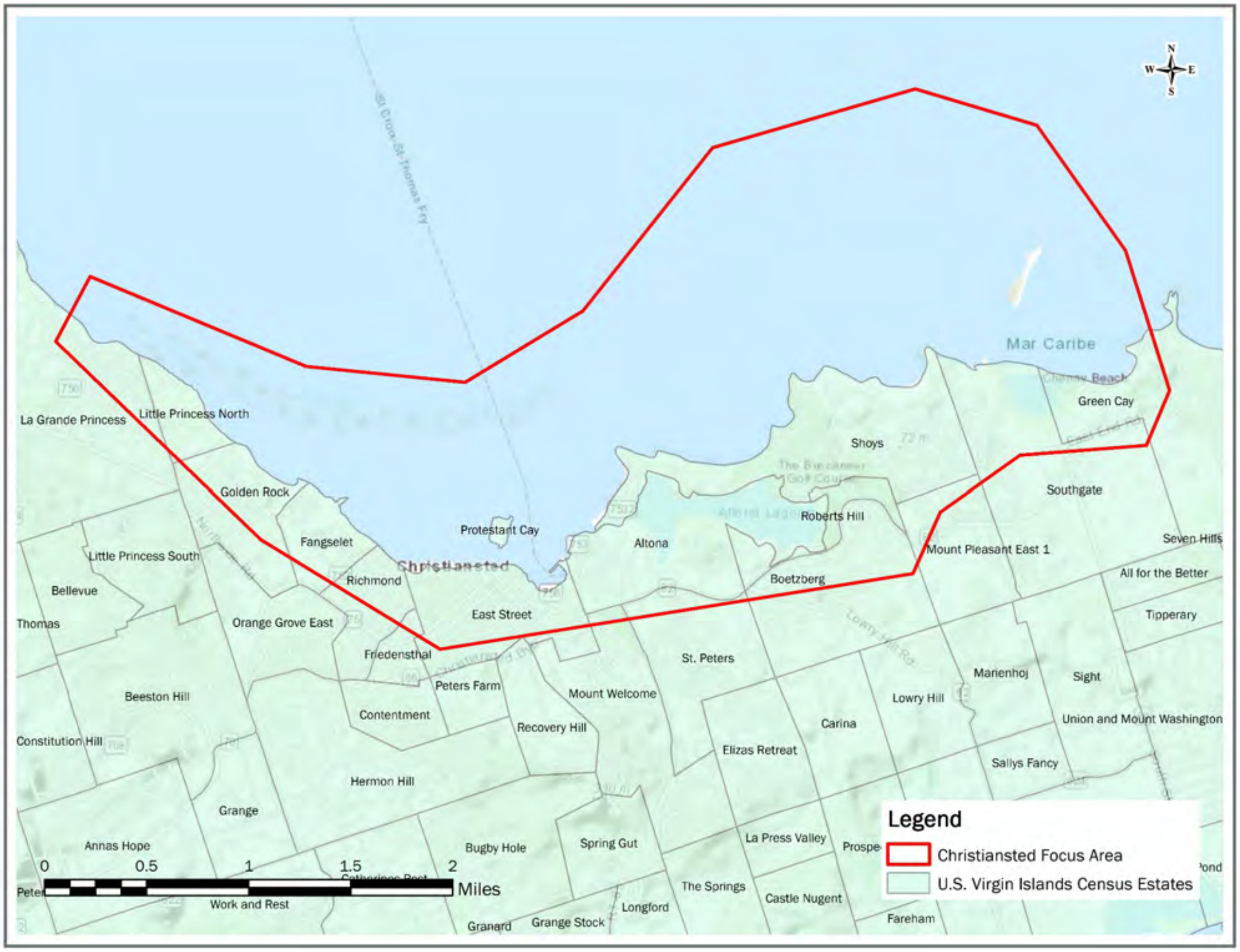


Figure 2: Census Estates within the Christiansted Focus Area Boundary

1.2 Prior Reports and Efforts by Stakeholders within the Focus Area

Prior and ongoing stakeholder efforts within the Christiansted Focus Area to address coastal storm risks and impacts from sea level rise include:

- FEMA awarded funding to the Virgin Islands Department of Public Works to address repetitive flooding issues in Gallows Bay as part of the Gallows Bay Culvert Mitigation Project (VI Free Press 2020).
- FEMA is bringing the U.S. Virgin Islands into compliance with the National Flood Insurance Program by enforcing updated building codes.
- St. Croix Foundation received FEMA funding to renovate the Alexander Theater to include a hurricane shelter (FEMA Hazard Mitigation Assistance 2020).

- NOAA is collaborating with the U.S. National Park Service to rebuild the damaged bulkhead in front of Ft. Christiansvaern.
- NOAA, with support from DPNR, is maintaining boat ramps in the focus area and controlling marine debris through the Marine Debris Removal Program.
- Virgin Islands Waste Management Authority was awarded a FEMA Pre-Disaster Mitigation Grant to replace and relocate a coastal interceptor to reduce the risk of sewage contamination into nearby coastal waters (FEMA 2015).
- VITEMA is working on the Hazard Mitigation Plan Update to include heightened focus on coastal hazards.
- VITEMA is developing a territory-wide Tsunami Warning System.
- DPNR (with support from FEMA) is developing watershed management plans for St. Croix.
- DPNR, UVI, and the U.S. Geological Survey (USGS) are partnering to develop a Coastal Vulnerability Index Update.
- UVI and DPNR are conducting a long-term shoreline erosion study to inform efforts for updating and enforcing regulatory coastal setbacks.
- UVI, NOAA, and DPNR are conducting a territory-wide Marine Debris Action Plan. This includes a $100,000 award to remove marine debris from mangrove habitats.
- The U.S. Virgin Islands Hurricane Recovery and Resilience Task Force compiled a report on the impacts from the 2017 hurricanes. Recommendations were provided for recovery and resilience across the islands.
- St. Croix Foundation signed the Climate Strong Islands Declaration, joining island communities across the United States and around the world to increase awareness of the growing challenges island nations face.
- With funding from the U.S. Economic Development Authority, the U.S. Virgin Islands Economic Development Authority is developing Vision 2040, a 20-year economic plan for the territory.
- VIPA plans to dredge Gallows Bay with support from U.S. Department of Housing and Urban Development (HUD) Community Development Block Grant – Disaster Recovery (CDBG-DR) Funds.

1.3 Shared Vision

The shared vision statement was developed and edited using input from key stakeholders in the focus area. The overall goal of this Christiansted FAAS is to incrementally contribute to the shared vision statement developed for this watershed study:

> "The Christiansted FAAS is a collaborative effort that leverages local capacity to plan and implement cohesive CSRM strategies along the northern shoreline on the island of St. Croix. The FAAS vision is to provide a common understanding of risk from coastal storms and sea level rise to support and protect resilient communities, native habitats and wildlife, culturally significant areas, existing infrastructure, and natural features."

2. Problems and Opportunities

Identifying problems and opportunities is a key initial step in the planning process. The problems and opportunities statements encompass both current and future conditions and are not meant to preclude the consideration of any alternatives to solve the problems and achieve the opportunities.

2.1 Problems

The following problems were identified as the most significant throughout the focus area and may not be exhaustive of all problems. These problems will increase in both intensity and extent as sea levels rise depending on the vulnerability and resiliency of the exposed population, infrastructure, and environmental and cultural resources.

- There is a lack of coordinated watershed-scale planning to address coastal storm risks and compound flood risks, and lack of engagement at all levels of government to support CSRM efforts, limiting the ability to improve community resilience.
- Coastal erosion and inundation are damaging infrastructure, including cultural resources.
- Loss of natural features, such as the offshore coral reef systems, due to anthropogenic activities, poor water quality, and wave attack from coastal storms. These features provide natural storm protection, and without them, communities face increased coastal storm risks and impacts from sea level rise.
- Coastal erosion and sea level rise may cause mangrove loss, as well as habitat loss for migratory birds and other threatened or endangered species.
- Coastal storm events produce significant marine debris, contributing to environmental risk and impacting environmental and cultural resources.

- Compound flood risks are exacerbated by storm surge inundation and sea level rise, while drainage systems are outdated, insufficiently maintained, and inadequate to keep up with increasing flood levels and frequencies, resulting in increased risk to communities. Insufficient stormwater drainage systems contribute to water quality issues that degrade protective reef systems, reducing their ability to reduce coastal storm risk.

2.1.1 Institutional and Other Barriers

As described in the *SACS Institutional and Other Barriers Report* (USACE 2021c), “Institutional and other barriers” impede the attainment of SACS goals and limit the ability to provide comprehensive CSRM. Several barriers were identified within the Christiansted Focus Area by agency stakeholders:

- *Relaxed enforcement of existing regulations:* Frequent exceptions to permitting requirements and relaxed enforcement of setback requirements have allowed continued development in areas subject to coastal storm hazards*.*

- *Limited funding or inefficient use of funds*: There is a lack of funding in general for coastal storm risk reduction, and specifically for vulnerable groups who cannot meet federal cost share requirements.

- *Data needs:* Local datasets are critical to adhere to guidance supporting Engineer Regulation (ER) 1105-2-100 (Department of the Army Office of the Assistant Secretary 2020), which requires comprehensive consideration of regional economic, environmental, and social project benefits.

  - The absence of data in the U.S. Virgin Islands inhibits the use of the USACE Regional Economic System (RECONS) model to understand Regional Economic Development (RED) benefits from potential projects.

  - The lack of social vulnerability data in the U.S. Virgin Islands inhibits the use of the Social Vulnerability Exposure Index tool to understand Other Social Effects (OSE) from potential USACE projects.

  - The lack of fundamental coastal engineering data, such as beach profile surveys or shoreline change estimates, inhibits the ability to accurately characterize hazards.

- *Limited comprehensive land use planning and political commitment:* There is a lack of climate change adaptation planning within the territory.

- *Limited coordination and leadership:* Lack of coordination among agencies, including local government, inhibits consistency and collaboration on projects within the same location.

- *Limited community engagement:* Lack of public engagement and communication regarding level of risk, mitigation opportunities, and proposed projects could limit public involvement and support of coastal risk reduction measures.

- *Limited communication:* Lack of communication between decision makers and boots on the ground could decrease the success of risk reduction measures and ensure that policies align with community needs.

2.2 Opportunities

While there are several coastal storm-related problems in the focus area, numerous opportunities exist to address them as exemplified by ongoing efforts within the U.S. Virgin Islands. Stakeholders identified several opportunities that include conditions, resources, and factors to contribute favorably to the Christiansted Focus Area, including:

- Increase coordination, collaboration, communication, and engagement across constituents to support CSRM initiatives, streamlining efforts and consolidating resources to build community resilience.
- Encourage federal and non-federal agencies to take a holistic system-based approach when responding to and planning for future storm events and preparing for future sea level rise.
- Consider the full range of potential measures to address coastal storm risks.
- Consider economic, environmental, and social benefits equally and comprehensively when evaluating project alternatives. Opportunities exist to expand regional planning models and obtain necessary data to support alterative analyses that encompass the full range of potential benefits to encourage justifying and selecting projects that reduce coastal storm risks and provide economic, social, and environmental benefits.
- Improve ecosystem health of reefs and other natural protective features that provide CSRM benefits, supporting the economy (tourism) and conserving space to support mangrove migration.
- Demonstrate the SACS tools (e.g., Measures and Cost Library [MCL] [USACE 2021d], Tier 2 Economic Risk Assessment, PEA analysis) and emphasize how they can be applied by all stakeholders.

3. Objectives and Constraints

Planning objectives are statements that describe the desired results of the planning process by solving the problems and taking advantage of the opportunities identified within the planning process. Constraints are conditions that limit the planning process. The final strategy formulated during this study is intended to meet the planning process objectives while working within the constraints.

3.1 Objectives

Overall objectives were developed for the focus area, generally focused on reducing coastal storm risk to environmental and cultural resources, and infrastructure. Because of the variability of factors, specific metrics were not developed to measure project success. More specific performance metrics should be developed in Tier 3 follow-on efforts. Objectives and goals of the FAAS are included in this section.

Objectives:

- Reduce coastal storm risk—which has increased because of sea level rise—to populations, economic centers, infrastructure, and environmental and cultural resources.
- Reduce storm surge inundation risk to public, private, and critical infrastructure.

Goals:

- Identify opportunities to reduce risk from coastal storm inundation, sea level rise, and erosion.
- Present the data on existing risk to coastal storm events and projected future risks considering sea level rise to motivate long-term policy change.
- Identify potential federal involvement in specific actions identified by stakeholders.
- Highlight the importance of preserving the natural features currently protecting the coastline.
- Incorporate social vulnerability in the consideration of potential measures in the FAAS.

3.2 Constraints

A constraint may limit the planning process. To the maximum extent practicable, the SACS analysis will minimize information, observations, and recommendations that may be inconsistent with coastal risk reduction plans developed by other federal and applicable territory and local agencies and tribes within the study area.

4. Existing and Future Conditions

The Christiansted Harbor is low-lying, with elevations rising steeply toward the inland mountainous terrain. The coastline is primarily exposed sandy beaches with developed shorelines around the commercial district, and some areas of rocky shorelines. Shoreline types are shown in **Figure 3**. Offshore is a substantial stretch of coral reef and seagrass habitat. Mangroves surround the shoreline lagoons and ponds.

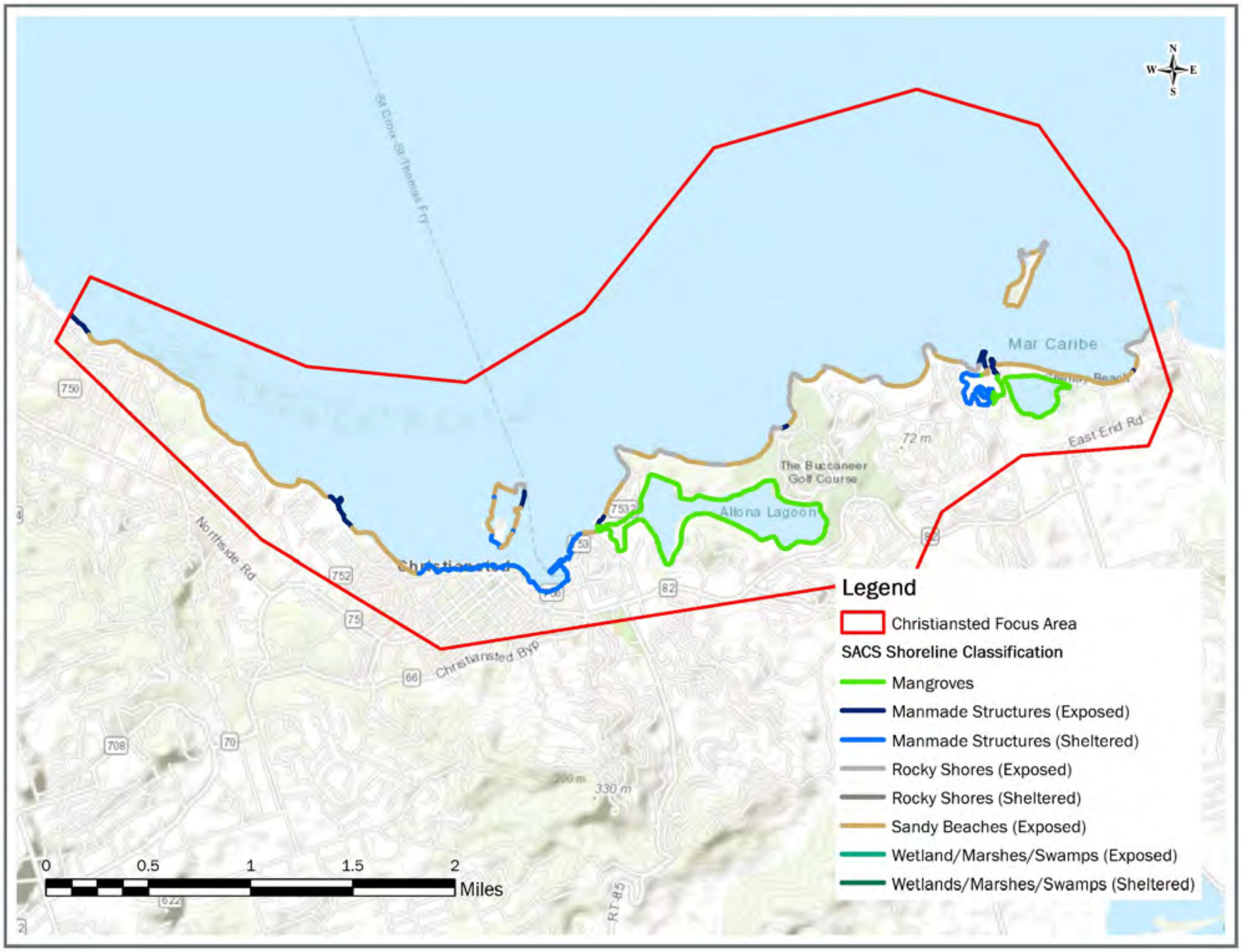


Figure 3: Shoreline Types within the Christiansted Focus Area

Tourism is an important component of the Christiansted economy. At the base of the harbor is the historic district, including Ft. Christiansvaern and the commercial district. Significant transportation infrastructure located in the harbor includes a seaplane base and the Gallows Bay Dock ferry terminal that hosts the principal ferry service to St. Thomas.

Christiansted was severely impacted by Hurricanes Irma and Maria in 2017. The harbor area is regularly affected by compound flooding, where coastal flooding is compounded by precipitation-based flooding caused by insufficient drainage capacity. Protection of the harbor's natural resources is critical to infrastructure, shoreline stability, and tourism. As sea level rises, there is an increased need for a well-implemented consistent approach to CSRM.

Risk is broadly defined as a situation or event where something of value is at stake and its gain or loss is uncertain. Risk is typically expressed as a combination of the likelihood and consequence of an event. Consequences are measured in terms of harm to people, cost, time, the environment, property damage, and other metrics. **Figure 4** illustrates the components that make up risk: hazards, system performance, exposure, vulnerability, and consequences. The following sections outline the components of the risk assessment conducted using Tier 1 and Tier 2 analyses data for the Christiansted Focus Area.

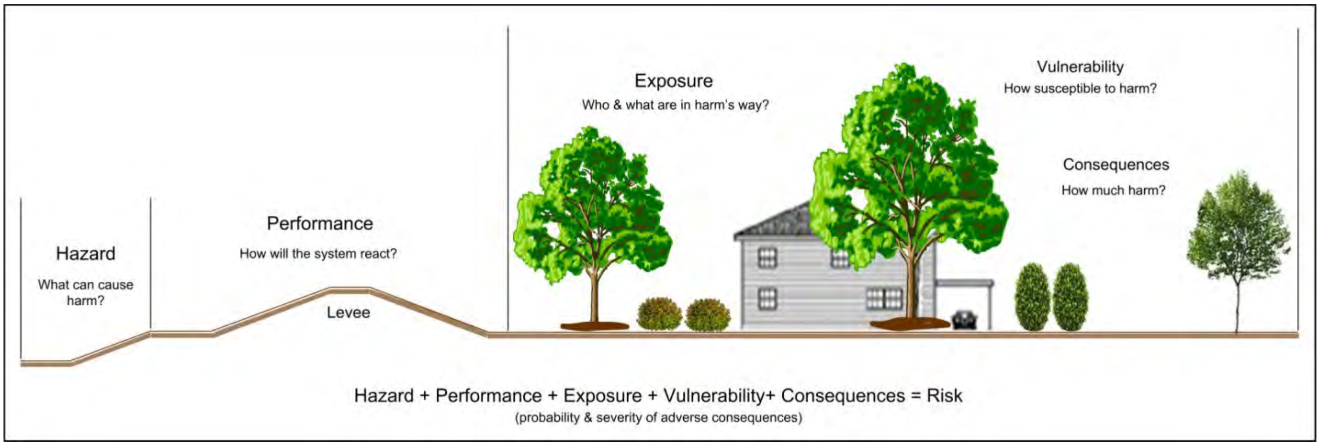


Figure 4: Risk Conceptualized

4.1 Hazards

Coastal storm hazards in the Christiansted Focus Area include storm surge inundation, wave attack, erosion, wind, and compound flooding. Inundation extents were assessed using NOAA's Sea, Lake and Overland Surges from Hurricanes (SLOSH) model Category 5 MOM event results: the FEMA National Flood Hazard Layer (NFHL) 1-percent annual exceedance probability (AEP) flood event, and the USACE Engineering Research and Development Center Coastal and Hydraulics Laboratory (ERDC/CHL) 10-percent AEP flood event. **Figure 5** indicates the extent of coastal flood inundation based on current and future conditions with 3 feet (0.9 meters) of sea level rise. Modeled inundation depths from the Category 5 MOM event range from 0 to 3 feet (0 to 0.9 meters). The SACS Coastal Hazards System (CHS) provides modeled wave heights for a range of AEPs. Modeled wave heights for the Christiansted Harbor for the 1-percent AEP event is estimated between 0 and 6.6 feet (0 to 2 meters) along the shoreline and 6.6 to 13.1 feet (2 to 4 meters) offshore. Because the CHS modeling was conducted at a regional scale, the modeling did not fully capture the impact of the coral reef on the wave conditions within Christiansted Harbor. Erosion hazard was assessed based on historical shoreline change rate data that was estimated from freely available optical satellite imagery (Luijendijk et al. 2018) since local shoreline survey information is unavailable in this region. **Figure 6** displays the observed long-term shoreline change (erosion and accretion) in the Christiansted Focus area. The data indicates erosion rates of 0 to 4.8 feet (0 to 1.49 meters) per year along the eastern side of the focus area boundary, particularly on the coastal side of Altona Lagoon.

The inundation and wave hazard data developed from the Tier 1 and Tier 2 analyses are based on regional models. The selected models provide a regional view of the hazard but may not capture the high-resolution details of the focus area. While these results provide an initial assessment, opportunities exist to conduct more refined characterizations of the hazards.

Wind hazard has the potential to damage infrastructure and mangrove habitat, both abundant in the Christiansted Focus Area. Compound flooding is a hazard to the focus area when a coastal flood hazard occurs simultaneously with rainfall/runoff hazards, resulting in potentially greater flood impacts. While wind and compound flood hazards exist within the focus area, they are outside of the scope of this study. Further description of the hazards assessed in the U.S. Virgin Islands is included in Sections 3.1.1 and 3.1.4 of the U.S. Virgin Islands Appendix.

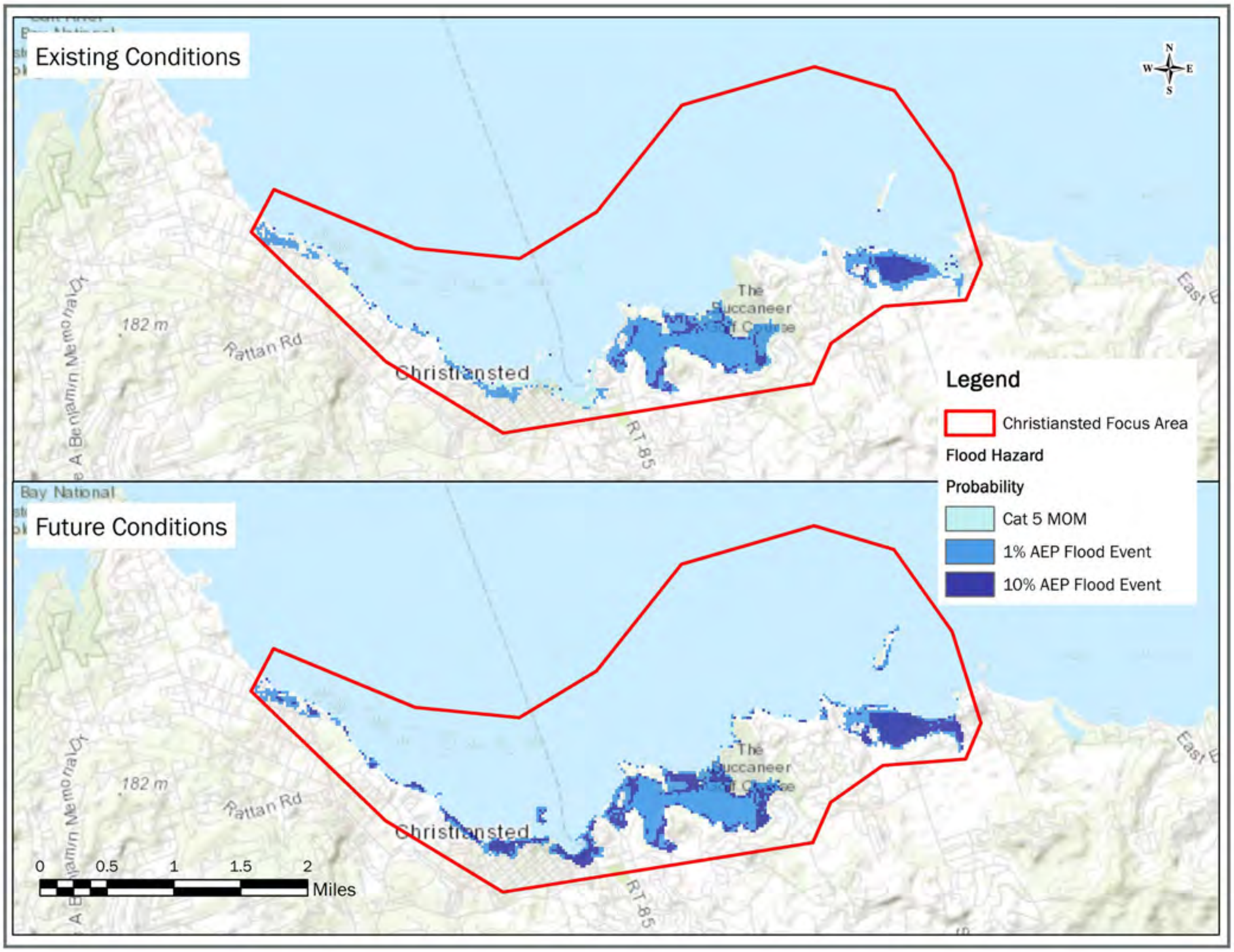


Figure 5: Existing and Future Flood Hazard for Christiansted Focus Area from the 10-percent Annual Exceedance Probability Flood, the 1-percent Annual Exceedance Probability Flood, and the Category 5 Maximum of Maximum Event Water Levels

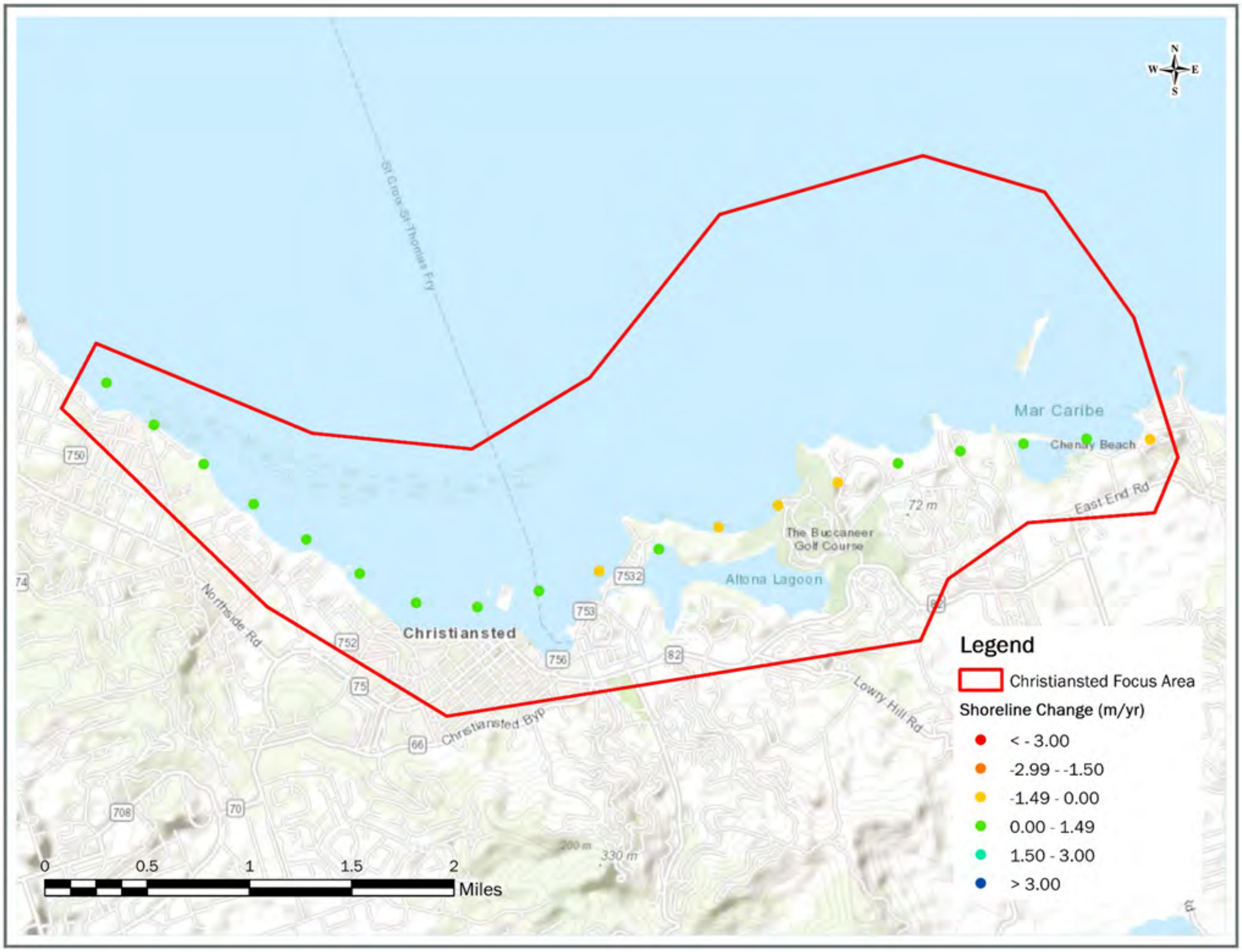


Figure 6: Long-Term Shoreline Change (erosion and accretion) (1984–2016) (Luijendijk et al. 2018)

4.1.1 Sea Level Rise Effect on Hazards

For the Tier 1 analysis, 3 feet (0.9 meters) of sea level rise was consistently assumed across the SACS area for the 10-percent and 1-percent AEP events, while the Category 5 MOM results remained the same. In some of the more refined Tier 2 analyses, two localized relative estimates of 2.33 feet (0.71 meters) and 6.95 feet (2.12 meters) were applied within the U.S. Virgin Islands. The values represent the average projected sea level rise in 100 years (2120) at compliant gauges within Puerto Rico and the U.S. Virgin Islands using the USACE Intermediate and High Scenarios, respectively. Sea level rise will exacerbate coastal hazards. As shown in **Figure 5**, the inundation extent for the Christiansted Focus Area does not shift inland because the Category 5 MOM was held constant under existing and future conditions. However, the probability of flooding increases to a 10-percent AEP with sea level rise. Given the modeled water depth increase, wave attack and coastal erosion are also expected to be exacerbated. **Figure 7** demonstrates the estimated increase in wave height in the Christiansted Focus Area. Wave heights along the boardwalk are estimated to increase 1.2 to 1.6 feet (0.375 to 0.5 meters) under future conditions.

Increased depth and extent of coastal inundation with sea level rise could cause temporary or permanent saltwater intrusion into freshwater habitats. Saltwater intrusion will negatively affect freshwater species in the area, such as mangrove habitat.

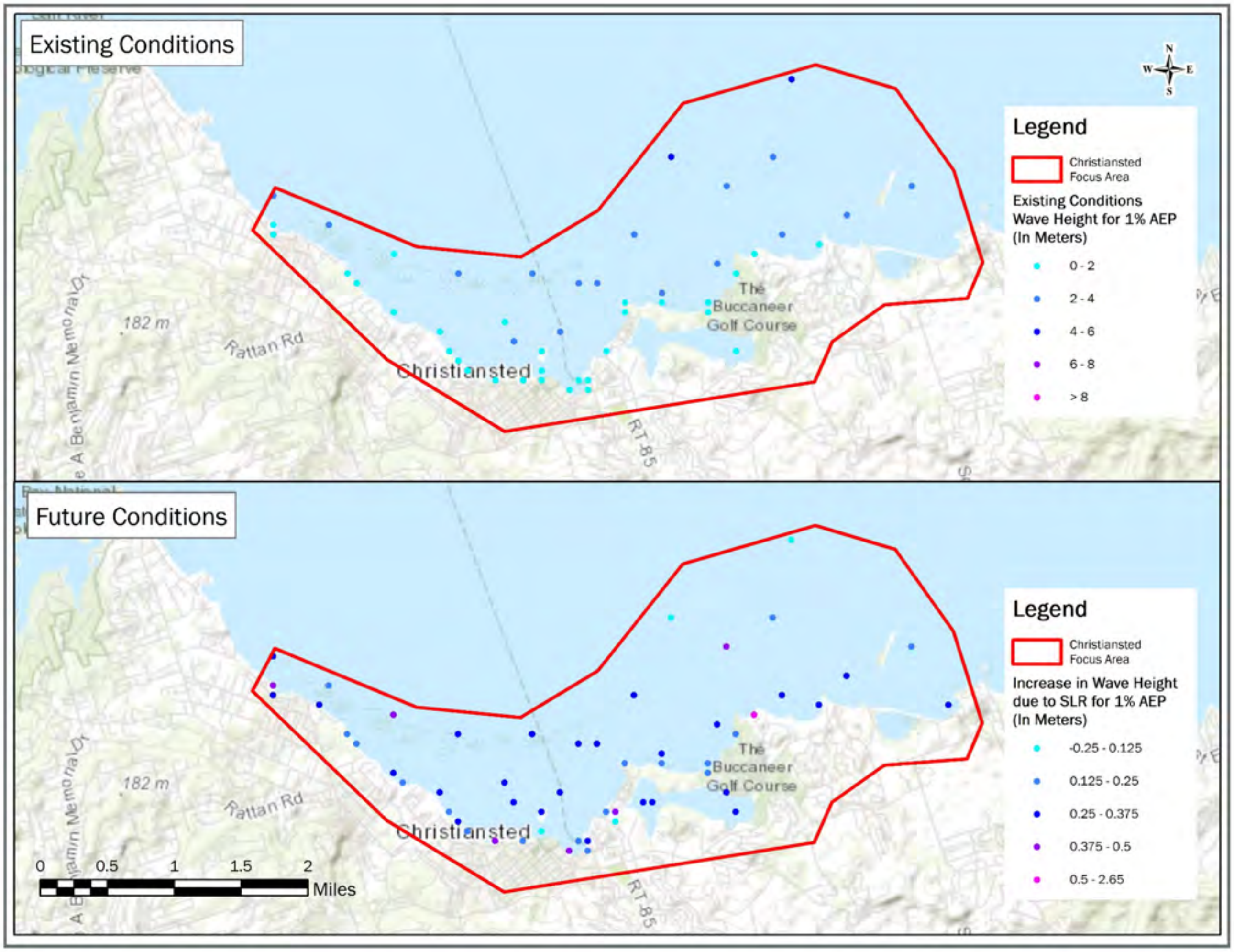


Figure 7: Wave Heights in Existing Conditions and Modeled Increase in Wave Height Under Future Conditions with 2.33 feet (0.71 meters) of Sea Level Rise for the 1-Percent Annual Exceedance Probability Event (USACE 2020)

4.2 System Performance

Performance is a system's reaction to a hazard. System performance refers to a system's features and the ability to contain/manage the hazard for all possible events. Christiansted's system performance is characterized by a mix of natural and man-made features. The offshore border of the Christiansted Harbor is composed of coral reef that nearly extends around the entire island. An extensive seagrass habitat is between the reef and the shore. These natural features help to attenuate wave energy and likely reduce the amount of erosion that would otherwise occur in this area. Water quality issues associated with discharge and runoff from development, particularly during compound flooding, threaten these offshore protective features. A break in the reef on the eastern side of the bay provides a natural channel through which the St. Croix–St. Thomas Ferry traverses through to the ferry terminal, located at the base of Gallows Bay. The harbor coastline shows evidence of erosion and saltwater inundation further inland.

The Christiansted Harbor shoreline is predominately exposed sandy beaches and rocky bluffs. The base of the harbor borders the downtown commercial area. Along this stretch, the shoreline is predominately man-made structures, including a wooden boardwalk that provides a walking path along the harbor front and a cement bulkhead that protects the historic Ft. Christiansvaern. Protestant Cay is a small island that sits at the base of the harbor and likely provides additional wave attenuation for the shoreline directly behind it. The Ft. Christiansvaern bulkhead is currently undergoing repairs from damages caused by recent hurricane events and years of erosion. There are also plans to dredge Gallows Bay. The dredged material deposition site has not yet been selected but will be one of five sites within the U.S. Virgin Islands. Some of these proposed deposition sites offer CSRM benefits.

There are several guts (ephemeral natural or man-made streams) that drain into the Christiansted Harbor. Two primary streams, Lower Water Gut and Spring Gut, convey stormwater drainage from higher elevations down to the mouth of the harbor. Guts require annual cleaning and maintenance and can cause stormwater flooding in downtown areas during heavy precipitation events. In past storm events, the inland stormwater flooding combines with the overland coastal inundation flooding to create compound flooding. This compound flooding is exacerbated by outdated water and sewer infrastructure. Flooded wastewater systems contaminate the floodwater, intensifying clean up processes, causing health hazards, and straining environmental resources.

Just east of the harbor is Altona Lagoon. Altona Lagoon is an enclosed embayment with a single point of connection to the sea, maintained as a permanent connection by a concrete structure. Fresh water enters the lagoon from several guts and as sheet flow from the surrounding hills. The lagoon is surrounded by mangrove habitat. East of Altona Lagoon is Southgate Pond. Southgate Pond is a wetland comprised of open water, mud flats, and submerged aquatic grasses. Southgate Pond is also bordered by mangrove habitat. Both Altona Lagoon and Southgate Pond are sensitive ecological areas that provide habitat to a variety of wildlife, notably fish and bird species. Water pollution and decline of mangrove habitat threaten these areas. Saltwater intrusion is causing mangrove habitat to retreat inland.

4.3 Exposure

Exposure considers who and what that harmed by a hazard. The Tier 1 analysis used a composite exposure index (CEI) based on 65-percent population and infrastructure exposure and 35-percent environmental, cultural, and habitat exposure. **Figure 8** illustrates the CEI for the Christiansted Focus Area. The following sections summarize the exposure identified in the Christiansted Focus Area. Additional details can be found in the Tier 2 Exposure section of the U.S. Virgin Islands Appendix (Section 3.2.2.2).

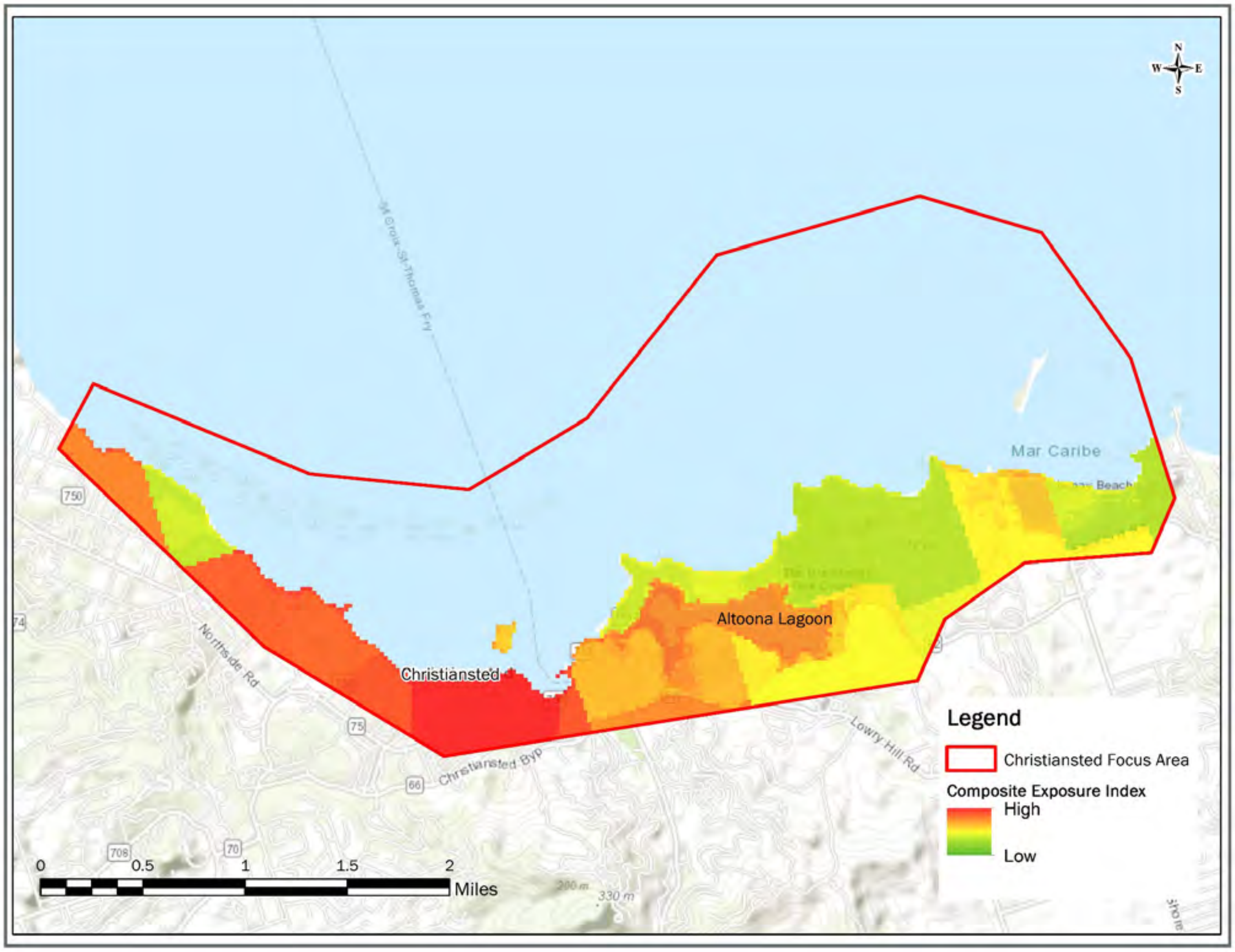


Figure 8: Exposure Index for Christiansted Focus Area

4.3.1 Exposed Population

According to U.S. Census 2010 data, approximately 4,600 people reside within the Christiansted Focus Area boundary. Census growth rates show a declining population in the U.S. Virgin Islands overall, with the growth rate estimated to be -0.95 percent by 2050. In addition to residents, the U.S. Virgin Islands Economic Development Authority estimates approximately two million tourists visit the U.S. Virgin Islands each year (U.S. Virgin Islands Economic Development Authority 2020). The U.S. Virgin Islands Bureau of Economic Research compiles monthly statistics on the number of arrivals, form of arrival, and departure and destination points. Data from 2016 indicates most visitors arrive via cruise ship into St. Thomas or St. John. St. Croix had approximately 300,000 visitors in 2016. These estimates do not indicate whether visitors that initially arrived in St. Thomas or St. John then visited St Croix. Given the density of hotels and tourist attractions located in downtown Christiansted, many St. Croix tourists likely temporarily reside within or near the focus area.

4.3.2 Exposed Infrastructure

The Tier 2 infrastructure exposure was assessed for Planning Reach VI_1. Section 3.2.2.2 of the U.S. Virgin Islands Appendix summarizes the infrastructure exposure for the planning reach.

4.3.2.1 Residential

Most of the residential structures within the focus area boundary are located along the western side of the harbor. This area contains a mix of multistory apartment buildings and single-story, single-family residences. The eastern side of the focus area contains residential structures with larger lot sizes and less density than the residential areas along the western shore. Some residential structures are also located throughout the commercial district.

4.3.2.2 Commercial

Commercial structures within the focus area are predominantly located within the historic district at the base of the harbor. Most of the commercial structures are tied to the tourism economy, including hotels, restaurants, and bars.

4.3.2.3 Public

There are several government offices located within the focus area, including post offices, the U.S. Virgin Islands Department of Property and Procurement, and the U.S. Virgin Islands Department of Health. There is also a primary school and a power substation located along the western shore of the harbor.

4.3.2.4 Transportation

The primary ferry service to St. Thomas uses the ferry terminal at the base of Gallows Bay. To the west of Gallows Bay is a seaplane base. The harbor hosts several commercial piers for private boat docking, as does the Southgate Pond marina on eastern side of the focus area. The main road entering the focus area—the Christiansted Bypass—forms the southern edge of the commercial district, skirting around the steep mountainous terrain to the south.

4.3.3 Exposed Environmental and Cultural Resources

The Christiansted Focus Area contains several areas of environmental and cultural resources. The environmental and cultural resources are outlined in the Tier 2 section of the U.S. Virgin Islands Appendix and the South Atlantic Coastal Study Environmental Technical Report, Tier 2 Environmental Resources Vulnerability and Risk Analysis/Priority Environmental Areas Identification (Environmental Technical Report) (USACE 2021b), and the Tier 2 Cultural Resources Appendix.

4.3.3.1 Environmental Resources

The northern border of Christiansted Harbor is an expanse of coral reef that surrounds a majority of St. Croix. The coral reef comprises linear reef, spur and groove reef, and areas of colonized bedrock and pavement. Seagrass habitat is located between the coral reef and the harbor coastline. Mangrove habitat borders the two bodies of brackish water near the shoreline: the Altona Lagoon and the Southgate Pond. Altona Lagoon and Southgate Pond are considered PEAs. These areas provide habitat for waterfowl and other aquatic wildlife. **Figure 9** shows the environmental resources in the focus area.

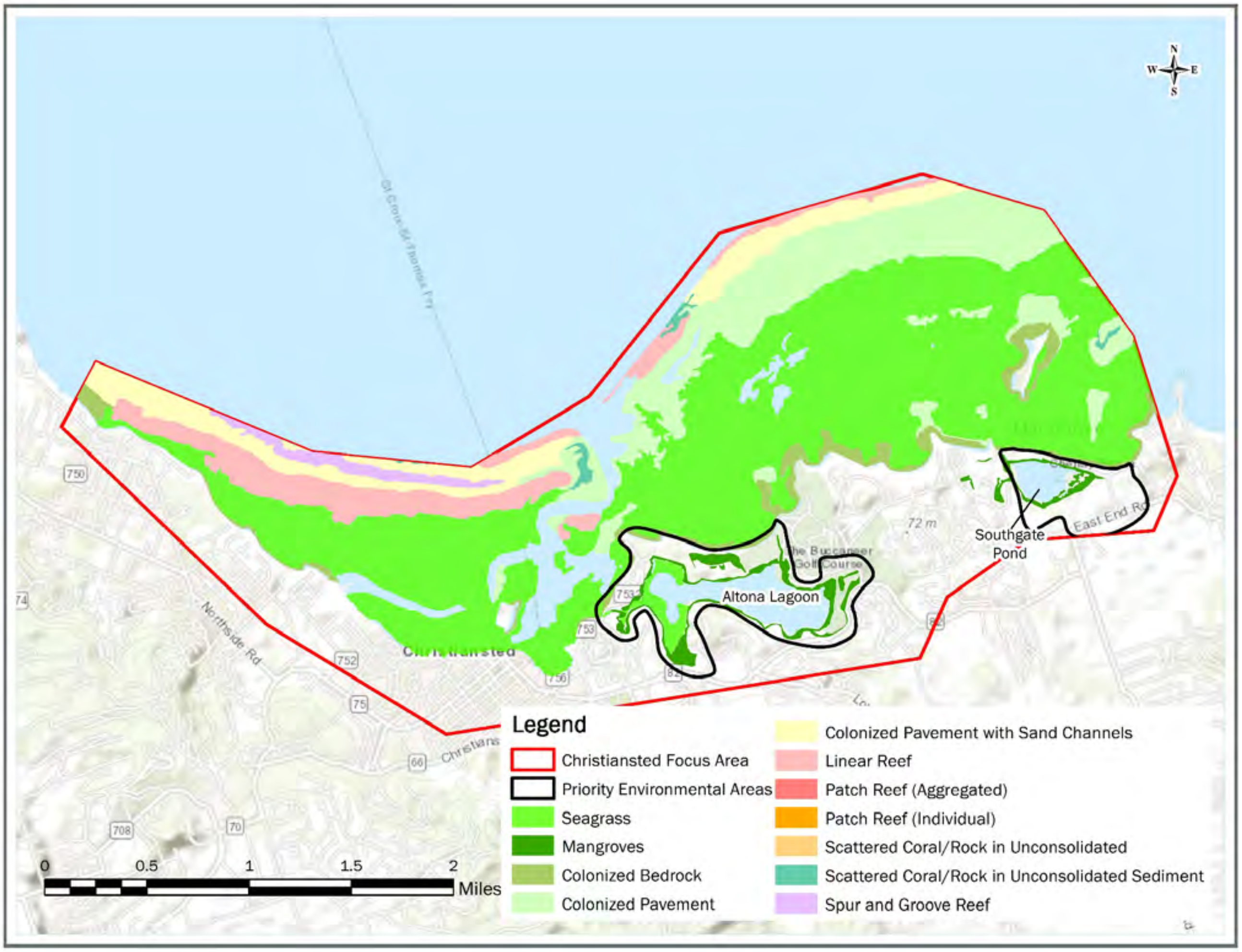


Figure 9: Environmental Resources

4.3.3.2 Cultural Resources

The U.S. National Register of Historic Places (NHRP) lists 25 historic places in Christiansted (U.S. National Park Service 2021). Many additional unidentified or unlisted resources are likely also present within the focus area. This assessment highlights a few resources identified within the NRHP or through literature review that are potentially exposed to hazards. Ft. Christiansvaern and the adjacent historic district comprise several cultural resources in the focus area including the Old Danish Customs House, historic buildings along the waterfront, and (outside of the historic district) the historic Estate Little Princess. Because of its low elevation and proximity to the shoreline, areas of the district could potentially experience 1 to 5 feet (0.3 to 1.5 meters) of inundation during a Category 5 MOM hurricane. **Figure 10** shows the cultural resources in the focus area.

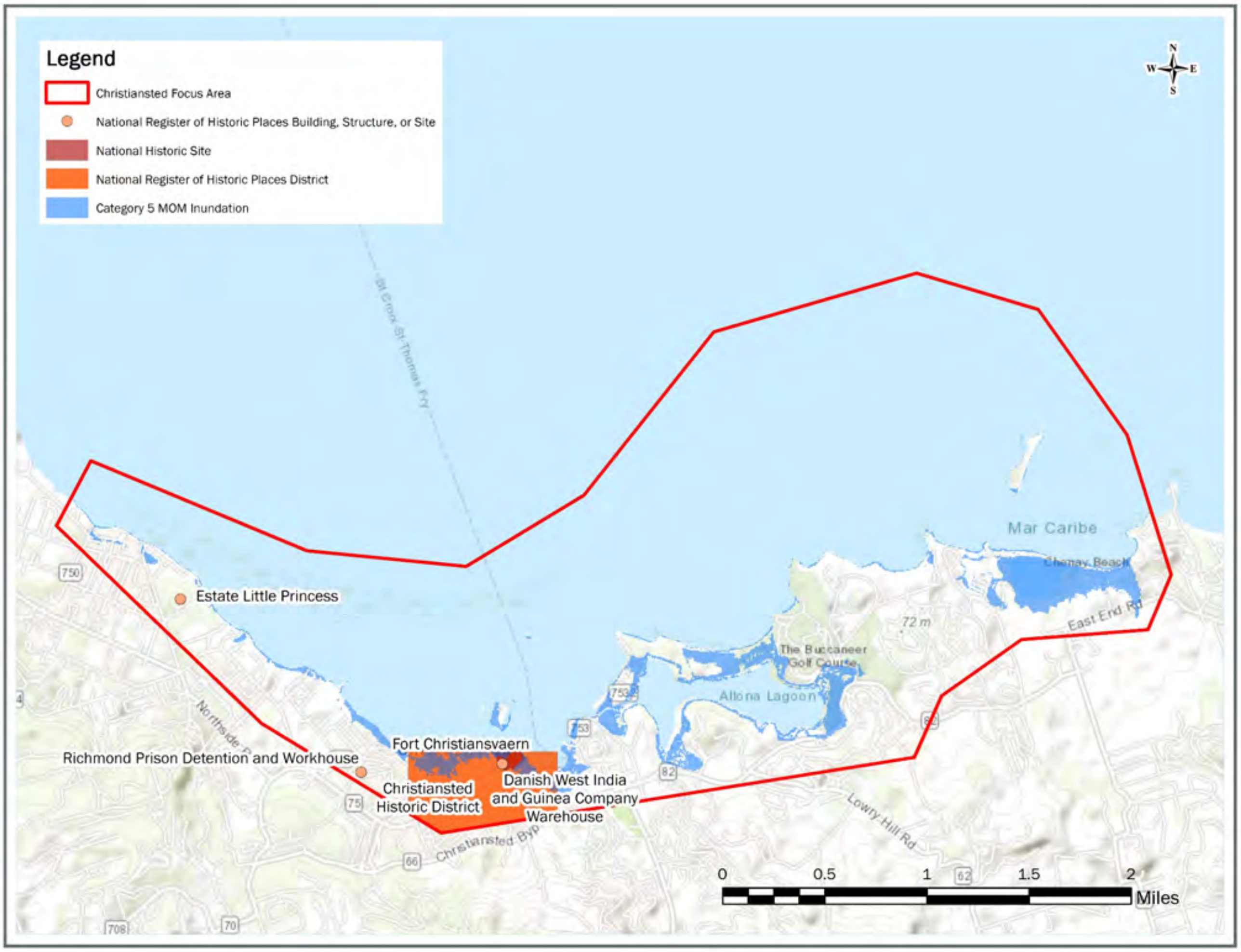


Figure 10: Cultural Resources

4.3.3.3 Environmental and Cultural Resource Uncertainty

Uncertainty needs to be considered when evaluating storm paths, intensity, and the potential effects of coastal storms and sea level rise on vulnerable environmental and cultural resources. Without protective measures, habitats with limited tolerance to salinity may migrate inland, be displaced by other habitat types, or be lost because of inundation or erosion. Cultural resources may be subjected to increased erosive forces, increased saline conditions, and potential inundation from coastal storm hazards and sea level rise.

4.4 Vulnerability

Much of the area within the Christiansted Focus Area boundary is low-lying, making it especially vulnerable to coastal hazards. The following subsections summarize components that increase the vulnerability of the area.

4.4.1 Infrastructure and Economy

Given the historic designation of the downtown Christiansted commercial area, much of the infrastructure is more than 100 years old, making it more vulnerable to storm damage. The local economy is largely driven by tourism, making the local economy vulnerable when tourism is prevented or diminished. The tourism economy will be especially vulnerable to natural hazard events and their impacts because damages to buildings and infrastructure may require costly repairs and further delay the opening of closed businesses, and staff who rely on tourism will look for other work while tourist operations are closed. The ability to pay for physical damages will be further threatened by reduced operating periods and therefore reduced revenue.

4.4.2 Population

The vulnerability of the population can be gathered from census data for the focus area compared to the U.S. Virgin Islands and the United States, as shown in **Table 1**. The data highlights vulnerabilities of the focus area's population impacting their ability to prepare for, and recover from, a coastal storm. Over 39 percent of the population in the focus area is without a vehicle, leaving them dependent on public transportation or other people to evacuate inland or upland prior to a localized storm where evacuation to other areas on the island may be appropriate. Additionally, with nearly half the population living below the poverty line, funds to rebuild and recover are more limited as is the ability to apply for assistance, which often requires access to an internet connection.

Table 1: Census Data Used to Determine the Social Vulnerability of the Area (U.S. Census 2010)

Category	Focus Area 2010 Data	U.S. Virgin Islands 2010 Data	United States 2010 Data
Total population	4,602	106,405	308,745,538
Persons under age 5	10.80%	7.00%	6.50%
Persons over age 65	10.70%	13.50%	13.00%
Persons identifying as Hispanic or Latino	33.30%	17.40%	16.40%
Persons with a disability and under age 65	8.70%	5.40%	7.20%
Households without a vehicle	39.30%	20.60%	9.10%
Persons unemployed	15.90%	17.30%	11.00%
Median household income (poverty threshold for 2010 is $18,310 for family of three)	$41,117	$37,254	$50,046
Persons living in poverty	44.70%	22.20%	15.30%

The Tier 2 analysis considered social vulnerability data from two sources. The Nature Conservancy's (TNC) Social Sensitivity Index (Schill et al. 2014) used 2010 Census data for a suite of variables to rank communities based on their sensitivity to storm surge and climate change. This index was mapped, scaled, and assigned a category of high, medium, or low based on the statistical distribution of the range of values calculated. Indices on social sensitivity, adaptive capacity, and exposure were combined to construct a socioeconomic Vulnerability Index. The Vulnerability Index data indicated that Estate East Street and Estate Fanselet are the most socially vulnerable in the focus area.

The National Fish and Wildlife Foundation's Coastal Resilience Evaluation and Siting Tool (CREST) also considered variables from the 2010 Census data and ranked areas according to guidance from the U.S. Environmental Protection Agency (EPA) environmental justice screening and mapping tool. The findings indicated medium social vulnerability clustered in Estate Fanselet (to the northwest of downtown area) and medium-low social vulnerability in the downtown area. More information on social vulnerability can be found in the U.S. Virgin Islands Appendix. **Figure 11** displays the social vulnerability data for the Christiansted Focus Area (Dobson et al. 2020).

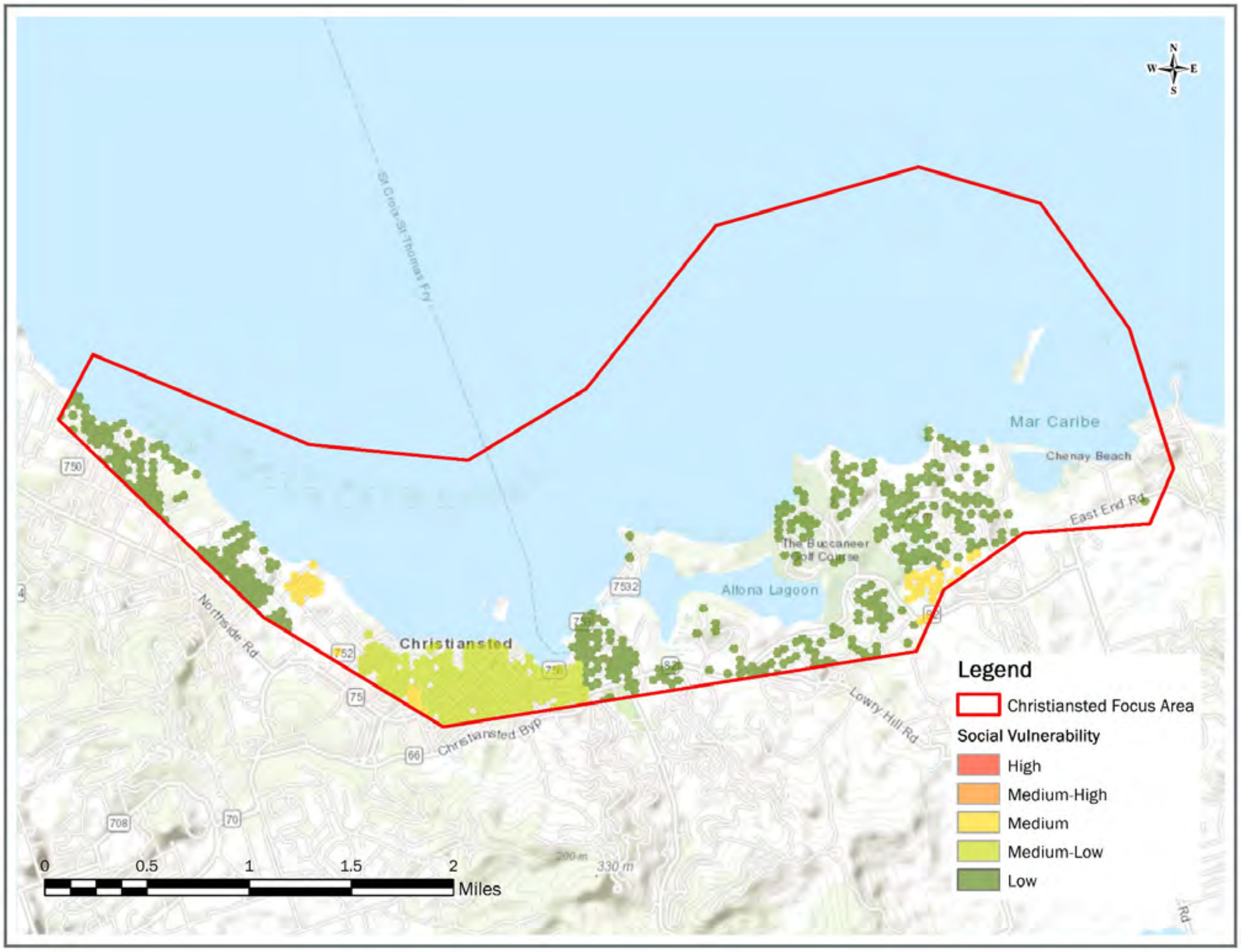


Figure 11: Social Vulnerability Index for Christiansted Focus Area (Dobson et al. 2020)

4.4.3 Environmental Resources

Within the focus area, coral reef and mangrove habitat are considered vulnerable natural habitats. The coral reef is vulnerable to physical and chemical degradation. Coral can be physically impacted by strong and/or frequent storm events. Additionally, sea level rise may lead to increases in sedimentation that can smother coral. Chemical degradation can be caused by harbor pollution and ocean acidification. Degradation of the coral health from these stressors increases the coral's vulnerability to coastal storms.

Mangrove habitat is also vulnerable to physical impacts from strong and/or frequent storm events and to increased sedimentation caused by sea level rise. As sea levels rise, mangrove habitat will migrate inland to maintain their preferred environmental conditions, such as depth and frequency of inundation and salinity. If the mangrove habitat does not have space to migrate or cannot migrate quickly enough, the habitat will decrease, and its vulnerability will increase.

4.4.4 Cultural Resources

Exposed cultural resources were qualitatively assessed for vulnerability based on degree of exposure to coastal hazards and sea level rise, structural considerations, and the nature of the cultural resource. **Table 2** presents exposed cultural resources and the potential vulnerability to Tier 2 hazards. This is not an all-inclusive list.

Table 2: Vulnerability of Exposed Cultural Resources to Tier 2 Hazards in Christiansted

Exposed Cultural Resources	Tier 2 Hazards		
	Storm Surge Inundation	Erosion	Wave Attack
Christiansted National Historic District	Y	N	Y
Fort Christiansvaern	Y	Y	Y
Old Danish Customs House	Y	N	N
Danish West India and Guinea Company Warehouse	Y	N	N

Within Christiansted, historic districts and sites are vulnerable to inundation, erosion, and wave attack. Storm surge inundation can flood historic properties and damage buildings, such as those located within the Christiansted Historic District. Damage may include structural damage and destruction of historic materials.

4.5 Consequences

Consequences are the potential impacts or harm that could result if/when the exposed elements described in the previous section are subjected to inundation or other coastal hazards. For Christiansted, the consequences of a coastal storm event include impacts to the commercial and historic district and to sensitive environmental areas. Damages to the historic buildings and infrastructure could potentially cost more than repairs to newer buildings and could be considered an invaluable loss. Damages to historic structures or artifacts would also have a negative impact on the tourism economy. Increased costs for repairs and reduced revenues from long periods of closure due to recovery operations will threaten the existence of many businesses. Socially vulnerable populations whose livelihood is based in tourism would be significantly affected by a coastal storm event.

Environmental consequences consider the amount of habitat that would be damaged or destroyed by a coastal storm event. Damage to the coral reef would reduce available coral habitat on which many species depend. This would impact the area’s biodiversity and have a negative impact on tourism operations. Coral reef degradation could decrease the amount of natural protection provided and potentially result in greater risk to the shoreline during coastal storm events. Exacerbated erosion of beaches and dunes could increase the potential for storm damage to the upland development and infrastructure.

The Altona Lagoon area and Southgate Pond are considered PEAs. Potential consequences to these sensitive areas include habitat loss from conversion of estuarine systems to marine open waters, forest composition alteration, and erosion to beaches and dunes. Habitat loss in these areas would be detrimental to the species that require specific environmental conditions and could have unforeseen ecological impacts. Loss of mangrove habitat would also constitute the removal of a natural barrier to storm effects, potentially increasing shoreline vulnerability to erosion and damages from coastal storms and wave attack.

4.6 Risk Assessment

The Tier 1 Risk Assessment combined the probability of inundation hazard (**Figure 5**) with the CEI (**Figure 8**) to produce a composite risk assessment. **Figure 12** displays current and future risk with 3.0 feet (or 0.9 meters) of sea level rise for the Christiansted Focus Area. The Tier 1 Risk Assessment demonstrates that, under existing conditions, most of the Christiansted Focus Area is classified as potential low risk. Some areas, such as Southgate Pond, are classified as potential medium/high risk or potential high risk. However, under future conditions with sea level rise, most of the area around the base of the Christiansted Harbor, including the boardwalk area, shows a significant change from potential low risk to potential high risk.

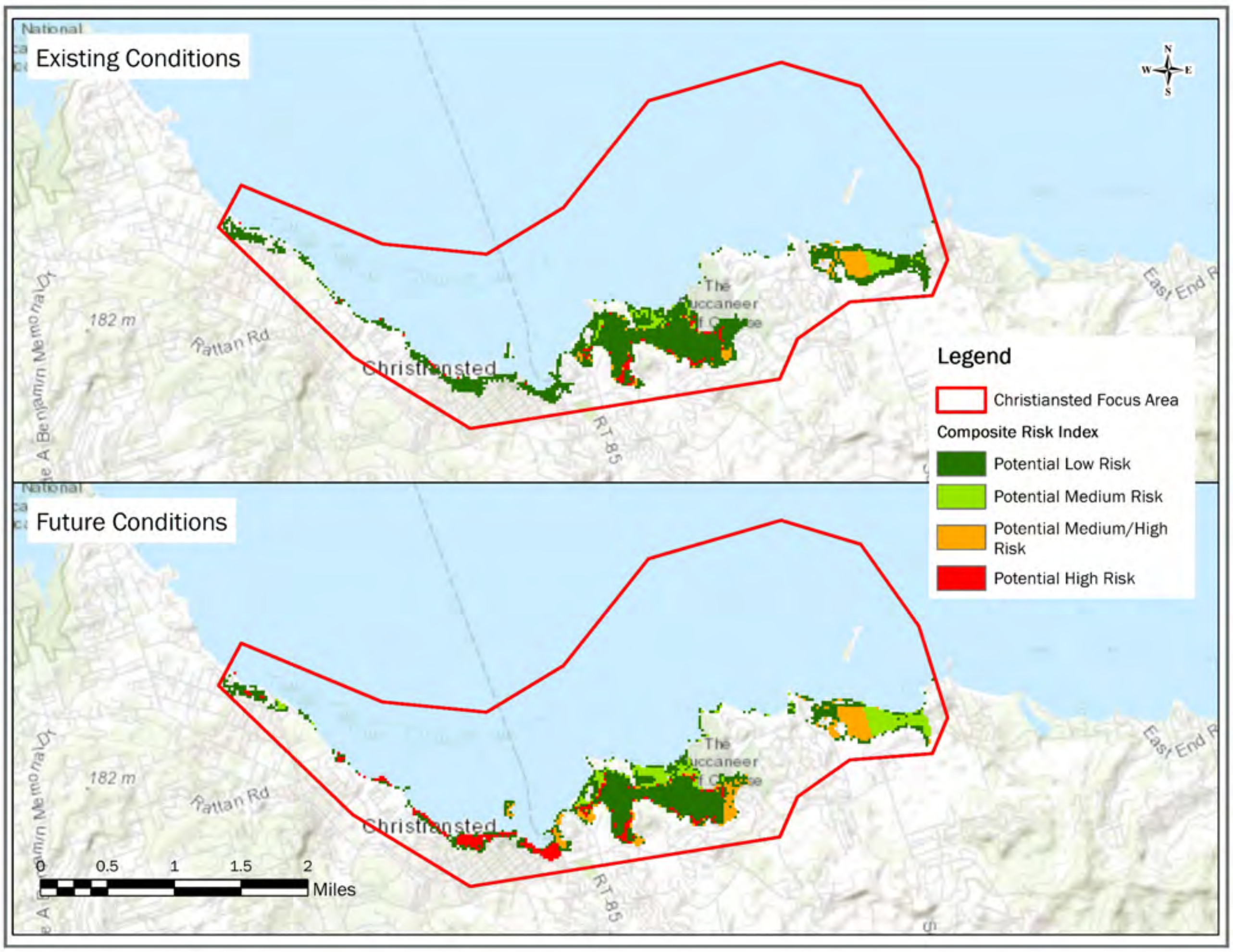


Figure 12: Existing and Future Composite Risk Index for Christiansted

The Tier 2 Risk Assessment incorporated additional detail and more localized hazard, vulnerability, and exposure information to refine the Tier 1 Risk Assessment.

Important coastal cultural resources were identified as potentially exposed to coastal hazards. Ft. Christiansvaern and the adjacent historic district comprise several cultural resources in the focus area. Because of its low elevation and proximity to the shoreline, areas of the historic district could potentially experience 1 to 5 feet (0.3 to 1.5 meters) of inundation during a Category 5 MOM hurricane. Coastal storm impacts to cultural resources within the focus area are expected to increase with sea level rise. More detail is provided within the Tier 2 Cultural Resources Appendix.

4.6.1 Erosion and Wave Attack Risk Assessment

Wave attack can directly damage infrastructure and environmental and cultural resources and can increase the extent and severity of erosion damages along the coast. As summarized in the U.S. Virgin Islands Appendix, areas predicted to experience increases in future wave heights greater than 0.75 meters for the 1-percent AEP event were classified as significant risk, as shown in **Figure 7** in Section 4.1. The area north of the Buccaneer Golf Course is at high risk of future increased wave heights and corresponding damages.

Historical erosion rates were classified as medium-high risk (-0.75 meter per year to -1 meter per year) and high risk (>-1 meter per year), as discussed in the U.S. Virgin Island Appendix, to identify areas most at risk to erosion hazards under historical conditions. These thresholds were applied to the shoreline change data for Christiansted and are shown in **Figure 6** in Section 4.1. Although no medium-high or high erosion areas were identified within the focus area based on the satellite analysis, more robust datasets would need to be collected to fully understand the scope of erosion issues. Erosion was identified as a key problem, particularly along Buccaneer Beach and Altoona Lagoon, a key environmental resource, discussed further in Section 4.6.3. Erosion rates are likely to increase with sea level rise and the potential loss or reduction in natural offshore barriers, further threatening infrastructure and cultural and environmental resources.

4.6.2 Tier 2 Economic Risk Assessment

The Tier 2 Economic Risk Assessment used FEMA's Flood Assessment Structure Tool (FAST) to estimate current and future potential annual damages from coastal hazards. **Figure 13** demonstrates that expected annual damages increase significantly under future conditions with sea level rise. The Tier 2 Economic Risk Assessment FAST results are available for use through an interactive web map. When all the census places within the Christiansted Focus Area boundary are selected, the analysis estimates $40,000 in annual damages under existing conditions and $466,000 in annual damages under future conditions with sea level rise. **Table 3** contains the estimated damages from hazard events based on the event's AEP. For example, for the 1-percent AEP event, estimated damages under existing conditions are $1.1 million, and under future conditions, estimated damages are $11.3 million.

These damage estimates include damages to physical structures and infrastructure caused by coastal inundation. These estimates do not include damages from flooding due to inland runoff or compound flooding. The estimates also do not consider economic losses resulting from temporary or permanent business closures following a storm event or impacts to the local economy from lost or reduced tourism revenue. If inland flooding and impacts to tourism and business operations were considered in the analysis, the estimated damages under both existing and future conditions would likely be significantly higher. These damage estimates should give pause to local stakeholders including residents, business owners, and the government agencies that support these entities. The financial consequences of future risk from coastal inundation are significant. Measures to address future risk should be considered in the near term, while the costs to do so are still feasible.

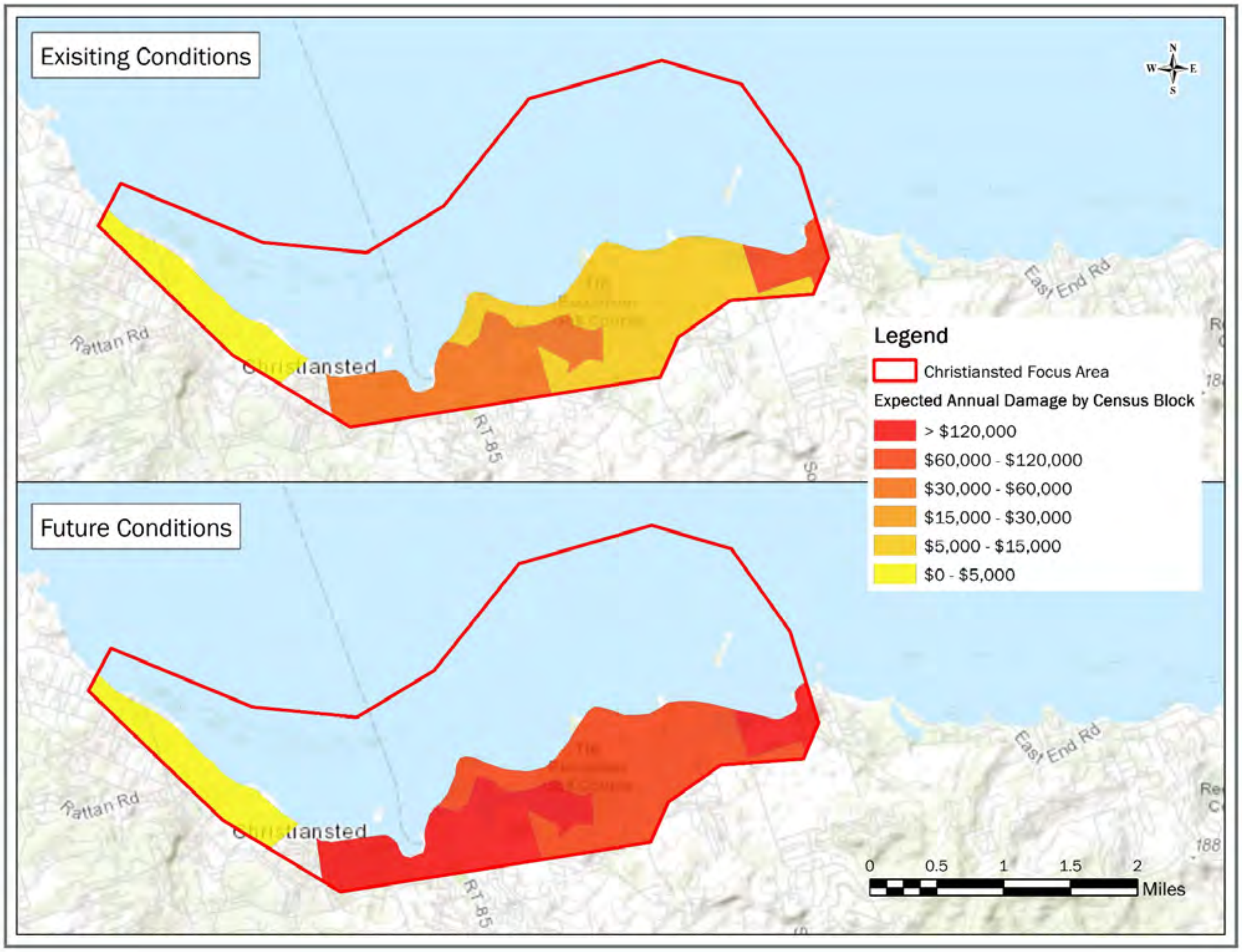


Figure 13: Expected Annual Damages in Dollars Based on the Federal Emergency Management Agency's Flood Assessment Structure Tool Results

Table 3: Damages Under Existing and Future Conditions by Annual Exceedance Probability Event

AEP Event	Annualized Damages under Existing Conditions (FY18)	Annualized Damages under Future Conditions with Sea Level Rise (FY18)
10% (10-year)	$0	$1,000,000
2% (50-year)	$407,000	$6,600,000
1% (100-year)	$1,100,000	$11,300,000
0.2% (500-year)	$5,700,000	$26,800,000

4.6.3 Environmental Risk Assessment

The Tier 2 Environmental Risk Assessment summarized in the Environmental Technical Report (USACE 2021b) identified areas of risk to environmental features. **Figure 14** displays the analysis results. The Altona Lagoon PEA has areas of low to high environmental risk while Southgate Pond PEA is considered vulnerable and at high risk. Areas just east of the pond are ranked as medium risk.

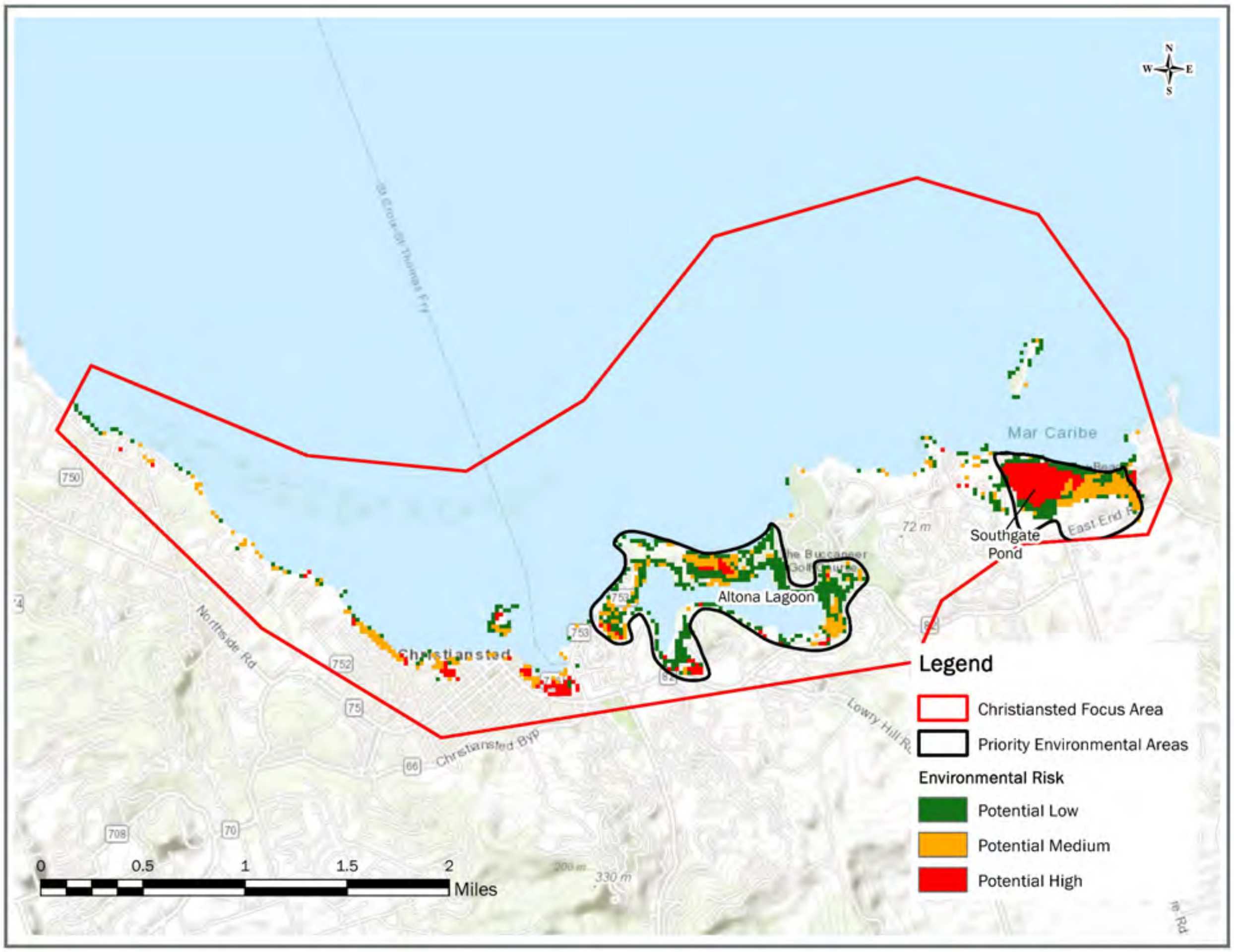


Figure 14: Environmental Risk for Christiansted

Altona Lagoon contains a variety of ecosystems including salt ponds, salt flats, mangroves beaches, dunes, shrub/scrub, and grasslands. Southgate Pond contains estuarine habitats, salt ponds and flats, mangroves, beaches, dunes, and grasslands. Risks posed to these areas include conversion from estuarine to saltwater ecosystems and erosion to beaches and dunes. Southgate Pond has a high inundation risk as well. These risks pose a threat to the waterfowl and aquatic life that live within these areas. More details are included in the Environmental Technical Report (USACE 2021b).

4.6.4 Cultural Risk Assessment

Risk to cultural resources was identified based on their potential exposure to inundation from the Category 5 MOM and vulnerability to coastal hazards including storm surge inundation, erosion, and wave attack. Without prevention or protection, coastal storm impacts can quickly lead to instability and, where impacts do not directly cause destruction, may necessitate demolition where public safety becomes a concern. Repairs and reactive measures are available but could be cost prohibitive.

Damage to archaeological sites can be even more harmful. There are no reconstructive measures that can be taken for these sites. Once they are lost, the areas can no longer be studied to understand the past. More detail is provided within the SACS Tier 2 Cultural Resources Report Appendix.

5. Action Strategy Development

To address coastal storm risks, agency stakeholders participated in the Focus Area Visioning Meetings, a series of interactive webinars to identify completed, ongoing, and needed actions to address coastal storm risks within the focus area. Suggested actions compiled during the sessions were organized into a table and grouped according to prominent themes. This grouping process produced an array of actions to evaluate and compare. The following sections describe the process and outcomes of identifying and screening the measures.

5.1 Identify Possible Solutions

Actions were identified by agency stakeholders during the Field Workshop held in Charlotte Amalie in October 2019, the Focus Area Strategy Development Webinar in September 2020, and through additional correspondence. The actions gathered were summarized in a table and identified as nonstructural, structural, or NNBF. Nonstructural measures are identified as modifications in public policy, management practices, regulatory policy, and pricing policy; typically, USACE includes structure acquisitions, relocations, floodproofing, and flood-risk related warning systems planning and policy as nonstructural measures. Structural measures are designed to decrease coastal inundation and erosion risks such as levees, storm surge barriers, seawalls, revetments groins and breakwaters. Natural and nature-based features can attenuate waves and reduce risk to coastlines and improve ecosystem services such as dunes, vegetated features, mangroves, coral reefs, barrier islands, and shoreline forests (USACE 2013). For each action, the status, time frame, priority, and potential lead stakeholder were identified (**Table 4**).

Table 4: Actions Identified for the Christiansted Focus Area

Category	Status	Measure/ Action Type	Description/ Purpose	Potential Stakeholder(s)	Time Frame[1]	Priority
Structural	Ongoing	Bulkhead	Fortify bulkhead along seaplane base	Virgin Islands Port Authority, Dept Public Works	*Unspecified*	*Unspecified*
Structural	Ongoing	CSRM	Rehabilitate and mitigate dilapidated underground water and sewer lines along Watergut Street	Utilities and Federal Partners	Mid	High

Category	Status	Measure/ Action Type	Description/ Purpose	Potential Stakeholder(s)	Time Frame[1]	Priority
Structural	Ongoing	Bulkhead	Rebuild damaged bulkhead in front of Ft. Christiansvaern	U.S. National Park Service, NOAA, BioImpact	Short	*Unspecified*
Structural	Ongoing	Erosion Mitigation	Stabilize eroding shoreline along Buccaneer Beach	*Unspecified*	*Unspecified*	*Unspecified*
Structural	Ongoing	Waste Management	Implement a coastal interceptor at Sugar Beach	Virgin Islands Waste Management	*Unspecified*	*Unspecified*
Structural	Ongoing	CSRM	Improve drainage to mitigate flooding of streets and buildings	FEMA	Mid	*Unspecified*
Structural	Ongoing	CSRM	Upgrade and mitigate water utility systems to prevent overflow flooding and control stormwater runoff	USACE, FEMA, DPNR Coastal Zone Management	*Unspecified*	*Unspecified*
Structural	Planned	CSRM	Identify locations in downtown area where storm water connects to sanitary sewers	Public Works and Waste Management Authority	Mid	*Unspecified*
Structural	Planned	Dredging	Dredge Gallows Bay	Virgin Islands Port Authority	Short	*Unspecified*
Structural	Planned	CSRM	Improve culvert and channel at Herman Hill	HUD (CDBG-DR), FEMA	*Unspecified*	*Unspecified*
Structural	Needed	Erosion Mitigation	Relocate Buccaneer Hotel structures behind appropriate setback. Add green infrastructure to prevent erosion	DPNR Coastal Zone Management	Mid	Medium
Nonstructural	Ongoing	Study	Conduct a long-term shoreline erosion study	UVI, DPNR	Short	*Unspecified*
Nonstructural	Ongoing	Study	Track impacts to mangroves since 2017 storms	USGS	*Unspecified*	*Unspecified*
Nonstructural	Ongoing	Plan	Implement Marine Debris Action Plan	NOAA	*Unspecified*	*Unspecified*
Nonstructural	Ongoing	Habitat Protection	Protect fish habitats and encourage fish population growth offshore	DPNR Division of Fish and Wildlife	Long	*Unspecified*
Nonstructural	Ongoing	Regulatory	Implement code compliance initiatives to improve structure performance during flood events	FEMA	Mid	*Unspecified*

Category	Status	Measure/ Action Type	Description/ Purpose	Potential Stakeholder(s)	Time Frame[1]	Priority
Nonstructural	Ongoing	Plan	Update the FEMA Hazard Mitigation Plan	FEMA	Short	*Unspecified*
Nonstructural	Planned	CSRM	Remove debris from Lower Water Gut to restore functionality	*Unspecified*	*Unspecified*	*Unspecified*
Nonstructural	Needed	Community Engagement	Conduct community engagement and capacity building initiatives	*Unspecified*	*Unspecified*	*Unspecified*
Nonstructural	Needed	Regulatory	Establish shoreline setbacks and enforce them	*Unspecified*	*Unspecified*	*Unspecified*
Nonstructural	Needed	Habitat Protection	Identify and preserve land for future mangrove retreat	DPNR Division of Fish and Wildlife	*Unspecified*	*Unspecified*
Nonstructural	Needed	Modeling	Expand applicability of social vulnerability index and regional economic modeling software to support comprehensive benefit evaluation for USACE studies in the territory	*USACE*	*Unspecified*	*Unspecified*
Nonstructural	Needed	Modeling	Develop an improved hazard characterization using more refined models with best practices and area-appropriate tools	*Unspecified*	*Unspecified*	*Unspecified*
NNBF	Ongoing	Study	Conduct a coral reef monitoring program	UVI	Long	Medium
NNBF	Ongoing	Habitat Protection	Maintain a land-based coral nursery	TNC, DPNR Coastal Zone Management, UVI	Long	*Unspecified*
NNBF	Needed	Erosion Mitigation	Plant native vegetation to reduce shoreline erosion	*Unspecified*	*Unspecified*	*Unspecified*

[1] Time Frame: Short = <2 years, Mid = 2–10 years, Long = >10 years

5.2 Evaluation and Comparison of Solutions

Ongoing, planned, and needed actions were collected, evaluated, grouped, and refined into four themes: community engagement and policy improvements, shoreline erosion, environmental resources, and downtown flooding. These themes were presented to the agency stakeholders during the Focus Area Wrap-up Webinar in November 2020 to elicit additional feedback, to identify missed actions or opportunities, and to identify stakeholders that could act as potential sponsors or partners in proposed actions.

5.2.1 Community Engagement, Communication, and Policy Improvements

The community engagement theme includes the following actions: (1) the ongoing update of the Virgin Islands Hazard Mitigation Plan, (2) the identified need for increased community engagement and capacity building initiatives, (3) the expansion of benefit analysis tools for USACE project evaluation, and (4) improved computation and communication of risks using regionally appropriate modeling tools. This theme is considered an overarching theme that is fundamental for the success of the other three themes described in further detail in later subsections. The updated Hazard Mitigation Plan will identify the same hazards described in the FAAS and will likely reference ongoing, planned, and needed actions mentioned in the following strategies. Similarly, the identified need for additional community outreach and education is an integral component across the other three themes. Opportunities exist for improved risk communication and outreach, especially when conveying risk in economic terms, which can be more impactful for decision-makers. The Tier 2 Economic Risk Assessment summarized in Section 4.6.1 provides an example of how coastal storm risks can be quantified and communicated. The risks computed as part of the SACS are based on regional modeling of coastal storm hazards. With more appropriate modeling tools for the territories and more refined data, the characterization of the hazards, and the associated economic risks associated with those hazards, can be better resolved.

Stakeholders identified a need for increased public education on the coastal hazards that threaten the Christiansted Focus Area. Additional community outreach efforts will facilitate the identification and collaboration of key stakeholders to implement the needed actions described in the following three themes.

Additionally, opportunities exist to communicate the benefits of coastal storm risk measures with regard to reducing social vulnerabilities and bolstering the regional economy. Modeling tools exist to support the evaluation of these benefits leveraged by USACE as part of the planning process. However, these tools are currently not designed to run in the U.S. Virgin Islands. Expansion of the geographic coverage of these tools would help communicate project benefits and help justify investments in CSRM projects with federal dollars.

5.2.2 Shoreline Erosion

Coastal erosion was identified as a problem in the Christiansted Focus Area. Offshore coral reef and sea grass habitats provide CSRM benefits, attenuating wave energy, thereby reducing coastal erosion to the shorelines behind them. These natural systems are threatened by water quality issues, partially driven by stormwater runoff and compound flooding. Ongoing efforts to maintain and improve the health of the reef are discussed in Section 5.2.3. While reef restoration was identified as a potential solution to provide additional CSRM benefits, these efforts should only be undertaken once water quality can support the environmental resources.

Several ongoing efforts were identified under the theme of coastal erosion. Efforts are underway to repair and enhance previously damaged shoreline areas. There are plans to fortify the bulkhead in front of the seaplane base. The U.S. National Park Service, in partnership with NOAA, is currently repairing and fortifying the bulkhead in front of Ft. Christiansvaern, which was previously deteriorating and substantially damaged by Hurricane Maria. There are also plans for shoreline assessment and stabilization along Buccaneer Beach. A long-term shoreline erosion study is being conducted by the UVI in partnership with the DPNR. The results of this study could help to inform other erosion mitigation efforts such as establishing coastal setbacks that vary by location and topography.

There are also plans to dredge Gallows Bay. The Virgin Islands Port Authority expects the dredging to cost about $6 million and to take approximately 9 months to complete. The project is expected to complete in 2021. The dredged material will be relocated to another area that would benefit from it. The location for dredged material placement has not been confirmed but includes one of the five sources based on criteria including location, physical features, capacity, and environmental and regulatory constraints: Yabucoa Ocean Dredged Material Disposal Site, Red Mud Pile Cap, the Department of Public Works Veterans Drive project, former dredge hole in Lindberg Bay, or the St. Croix Quarry Site. While the exact location for the placement of dredged material has yet to be confirmed, opportunities exist to beneficially reuse the material at a designated site that meets qualifying criteria and aligns with SACS goals and intent for the FAAS.

There were three needed efforts identified under the theme of shoreline erosion: (1) relocate private structures that were built too close to the bluff and are at risk of failure, (2) update and enforce shoreline setbacks, and (3) reduce erosion and protect from storm surge with additional native shoreline vegetation.

During discussions with webinar participants, it was recommended that revisions to shoreline setbacks be informed by results of the ongoing long-term shoreline erosion study. The intent would be to develop coastal construction setback guidance and/or regulation unique for each region or shoreline type that would be informed by the long-term shoreline erosion study as opposed to a blanket island- or territory-wide regulation that may not be appropriate in all areas. Sea level rise projections should also be considered as part of a comprehensive development of construction setbacks. The CHS provides data that could be leveraged to incorporate estimated effects of sea level rise. The CHS includes data on wave height and impacts from sea level rise. This data could demonstrate where the largest increases in wave height are anticipated to identify areas of likely increased erosion and avoid development near those coastlines.

The SACS MCL (USACE 2021d) provides planning-level cost estimates for planting native shoreline vegetation. The MCL measure of Living Shoreline Vegetation was used, which consists of planting existing slopes with hardy native vegetation to stabilize the shoreline. This measure may include vegetation types associated with dune enhancement and tidal and forest wetland restoration but can also incorporate additional shrub and herbaceous species. This measure often includes earthwork to generate milder slopes along existing shorelines but typically does not consist of bringing in fill to construct new land.

Participants in the Focus Area Strategy Development Webinar identified the sandy beaches along the western shores of the focus area as opportunities for living shorelines. The area identified is approximately 1.8 miles [2.9 kilometers], or 9,900 linear feet [3,020 meters].

Table 5 displays the results derived from the MCL for the low and high-cost estimates for implementing 9,900 linear feet [3,020 meters] of Living Shoreline Vegetation. The MCL also generates the estimated equivalent annual cost for implementing this measure. Equivalent annual cost is calculated based on the total investment cost considered over the lifespan of the project (how long the measure will be effective for) plus the expected maintenance costs. This equivalent annual cost can be compared to the estimated damages derived from FEMA's FAST (Section 4.6.1) to conduct a preliminary cost-benefit analysis. If the results do not demonstrate cost effectiveness, it may be beneficial to evaluate shorter stretches of shoreline for which implementing Living Shoreline Vegetation would be most effective at reducing risk.

The construction costs for Living Shoreline Vegetation from the MCL include mobilization and demobilization to the site ($10,000 for the low estimate and $150,000 for the high estimate), as well as contingency (20 percent of the measure cost for the low estimate and 40 percent for the high estimate), engineering and design (10 percent for both estimates), supervision and administration (12 percent for both estimates), and monitoring and adaptive management (3 percent for the low estimate and 4 percent for the high estimate) (USACE 2021d).

Table 5: Planning Level Cost Estimate for Living Shoreline Vegetation along Western Shoreline of the Christiansted Focus Area (9,900 Linear Feet [3,020 meters])

Construction Cost (FY20)		Equivalent Annual Cost (FY20)	
Low Estimate	**High Estimate**	**Low Estimate**	**High Estimate**
$230,000	$22,262,000	$9,000	$825,000

As noted in previous sections, the hazard data developed in the SACS Tier 1 analysis was conducted on a regional scale and may not have captured localized nuances along the Christiansted shoreline, such as the effect of coral reef on reducing wave height and coastal erosion. If future conditions with sea level rise exacerbate the degradation of the reef, the sandy shores along the Christiansted Harbor are likely to experience a significant increase in risk from coastal hazards. Under future conditions, Living Shoreline Vegetation and other erosion mitigation measures may alleviate the impact of coastal hazards, though additional erosion measures may be necessary to reduce the impact of coastal hazards from reaching further inland. The planned dredging of Gallows Bay may provide an opportunity for beneficial reuse of dredged material within living shorelines or other CSRM activities.

Planting native vegetation along the shoreline would provide several benefits. A living shoreline can help prevent or slow shoreline erosion by reducing wave energy (Manis et al. 2015; Systems Approach to Geomorphic Engineering 2015). In this way, the shoreline vegetation can act as an additional natural barrier, providing enhanced protection to inland areas from coastal inundation and wave attack.

Findings from the ongoing shoreline assessment study by UVI and DPRN can inform efforts to update and enforce setbacks, which will benefit the focus area by preventing future development from encroaching the coastline and potentially exacerbating erosion. The actions within this theme would also positively impact socially vulnerable areas, which were identified in the downtown Christiansted area and the area to its northwest.

5.2.3 Environmental Resources

Habitat loss for migratory birds and other threatened and endangered species is a problem within the Christiansted Focus Area. Given the abundance and importance of the natural resources in the focus area, the second theme denotes the ongoing and needed actions related to protecting the environmental resources within the focus area. Ongoing efforts identified under this theme include actions related to monitoring and preserving existing environmental resources. UVI is currently monitoring the coral reefs and TNC has established a coral nursery at their offices in Estate Little Princess. There are also ongoing efforts related to mangrove and fish habitat monitoring and protection efforts. NOAA’s marine debris removal program is being used to remove old vessels and other marine pollution.

Needed efforts identified under this theme include coral rehabilitation and the identification and preservation of land for mangrove habitat migration under future sea level rise conditions. Coral reef restoration along Long Reef in Christiansted Harbor was discussed with UVI stakeholders. Because of existing water quality concerns in Christiansted Harbor (partially attributable to consequences of compound flood risks, and wastewater system capacity) and the shallow bathymetry in an area of high wave activity, rehabilitation was not considered a viable strategy at this time.

As part of a preliminary assessment to support identification of mangrove migration areas, geospatial data layers from the CREST (Dobson et al. 2020) were compiled and analyzed to identify potential areas for conservation and preservation. This preliminary assessment considered areas that are adjacent to existing mangrove habitat, areas within the floodway, areas expected to be inundated by 1 foot of sea level rise in future conditions, and areas of low slope. **Figure 15** illustrates the areas that met the selection criteria for consideration as conservation and preservation land. Darker shades of pink on **Figure 15** indicate areas preferred for mangrove migration per the analysis criteria.

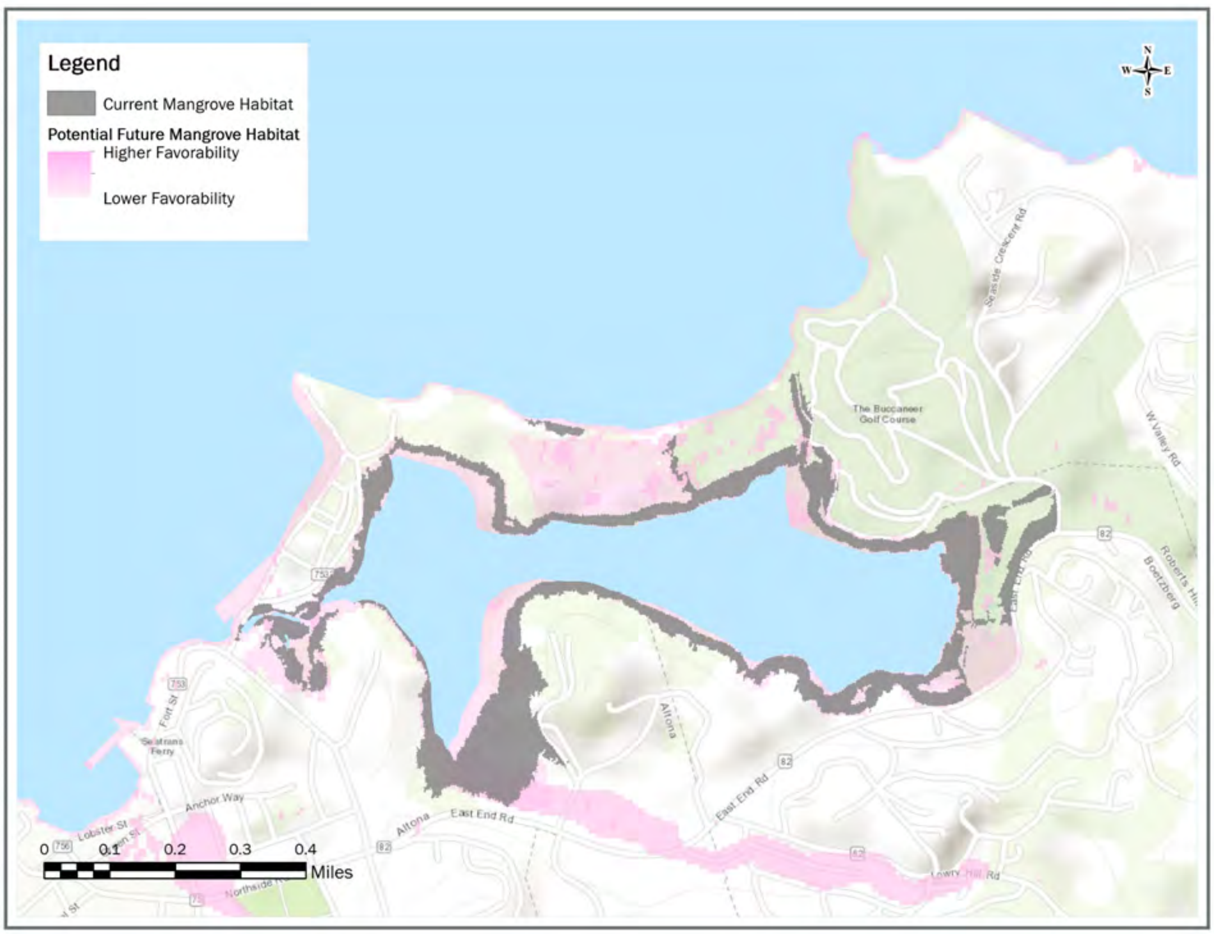


Figure 15: Potential Habitat for Mangrove Migration around Altona Lagoon

These results are intended to be preliminary to demonstrate that a more targeted assessment would be beneficial. A study to further investigate areas favorable for mangrove migration could potentially qualify for funding through the USACE Planning Assistance to States or under the Continuing Authorities Program Section 206 authority. These programs and other funding opportunities are outlined in the SACS Coastal Program Guide (USACE 2021a). Planning Assistance to States studies typically range between $100,000 and $200,000. These costs would cover the study but not include any implementation activities, developing designs, or construction. Continuing Authorities Program Section 206 projects must demonstrate cost effectiveness and be less than $10 million in total cost. The feasibility study is cost shared at 50-percent federal and 50-percent non-federal after the first $100,000 in study costs. Design and construction are cost shared at 65-percent federal and 35-percent non-federal (USACE 2019).

During discussions with agency stakeholders, several entities were identified as potential sponsors or coordinating partners. It was noted that the U.S. Department of Agriculture plans to include areas within the Christiansted Focus Area in future soil sampling evaluations. DPNR’s Coastal Zone Management Program recently identified mangrove policy and management as a priority for the agency. It was also noted that a local division of the U.S. Fish and Wildlife service is planning measures to reintroduce the St. Croix ground lizard to the Altona Lagoon. This process would involve studies of the existing habitat that could leverage the proposed mangrove migration study.

The PEA analysis identified Altona Lagoon as a high-risk PEA. The mangrove migration study would be a proactive step to protect the mangrove habitat. In a no-action scenario, valuable mangrove habitat may be lost. The mangrove habitat is crucial for a variety of species. Loss of the habitat would reduce biodiversity, potentially impact tourism, and potentially expose inland areas to a greater risk to coastal hazards. Identification and conservation of mangrove migration areas would help preserve this vital habitat.

The ongoing efforts identified under this theme will have a positive impact through preserving environmental resources. Besides their intrinsic benefits, environmental resources support the tourism economy and provide protection from coastal hazards. Preserving these areas directly improves the resilience of the focus area.

5.2.4 Downtown Flooding

The downtown area of Christiansted is the main commercial area within the focus area, which encompasses the historic district. This area is at risk to coastal flooding. Through stakeholder discussions, it was noted that this area is also subject to flooding from overwhelmed stormwater infrastructure, much of which is considerably outdated. This stormwater flooding is compounded by coastal inundation, thus intensifying the problem.

Ongoing efforts to address these problems include stormwater improvements, upgrading waterlines and wastewater systems, utility enhancement and protection measures (such as hardening electrical lines), and updating building codes.

Planned efforts include removing debris from guts—the ephemeral streams in the U.S. Virgin Islands that typically flow only after rainfall (Reiblich 2016)—widening culverts and upgrading drainage channels. The SACS data demonstrates that there is significant risk under current conditions and that future sea level rise conditions will increase damages exponentially. Because of the complexities of the compound flood risks and dense historic development, a more detailed study to better characterize risks and evaluate alternatives is recommended.

Because the downtown area is low-lying, historic, and the local economy is heavily based on tourism, any large-scale structural measures may not be feasible physically or socially. During the Focus Area Strategy Development Webinar, stakeholders expressed concern that the placement of a large-scale structural measure would likely impact the viewshed of the water or historic structures, which is an essential draw for customers to the many shops and restaurants in the downtown area. While a large-scale measure to mitigate coastal inundation may not be feasible, there are opportunities to implement structural measures to mitigate flooding caused by stormwater runoff. Given the array of current and planned actions to address stormwater flooding being conducted by several agencies, coordination will be needed to determine gaps in flood protection and where additional measures would add value.

One potential measure could be the installation of small flood walls along existing guts to reduce stormwater flooding. An example of this could be a flood barrier along the gut at the end of Watergut Street that meets the ocean just to the east of the seaplane base. A flood barrier along either side could help to divert stormwater flow into the ocean and reduce overflow into the surrounding neighborhood. This type of measure, along with ongoing and planned stormwater system mitigation measures, could alleviate the compound flooding in the downtown area.

Given the physical, economical, and cultural constraints in downtown Christiansted, measures to address coastal inundation risk may need to be considered on a structure-by-structure basis. Potential measures for buildings include wet floodproofing, dry floodproofing, elevations, and buyout/acquisition. Descriptions and historical considerations for implementing measures are:

- *Wet Floodproofing* – Floodwater can enter the structure. Vulnerable items (e.g., utilities, appliances, and furnaces) are waterproofed, elevated, or relocated to higher locations (e.g., the second floor, where available). Allowing floodwater to enter the structure equalizes the hydrostatic forces inside and outside of the structure, reducing the risk of structural damage.

- *Dry Floodproofing* – Includes actions designed to prevent floodwater from entering a building. This measure involves sealing building walls with waterproofing compounds, impermeable sheeting, or other materials to prevent the entry of floodwaters into damageable structures. Dry floodproofing is applicable only in shallow, low-velocity flooding areas.

- *Elevation* – Involves raising structures in place so that the structure sees a reduction in frequency and/or depth of flooding during high-water events. Because most of the structures in the downtown area have slab-on-grade foundations, it will not be feasible to elevate them by constructing new, higher foundations. The other options for elevation include elevating the interior structure and abandoning the first story.

    - *Elevate the Interior Structure* – Actions that involve removing the historic building's first or ground floor level and replacing it with a new floor plate at a level above the flood risk. This treatment allows the exterior of the structure to remain generally unchanged but requires an adequate ceiling height to accommodate the change.

- *Abandon the First Story* – Actions that modify a multi-story building to relocate all living spaces to upper floors above the flood risk level. The abandoned floor will require wet or dry floodproofing.

- *Buyout/Acquisition* – Involves purchase and elimination of flood-damageable structures, allowing for inhabitants to relocate away from flood hazards.

These measures could be complemented by nonphysical nonstructural measures such as temporary flood protective measures, flood warning systems, flood insurance, flood emergency preparedness plans, evacuation plans, and risk communication.

5.2.4.1 Planning-Level Cost Estimates

The MCL (USACE 2021d) was used to determine planning-level cost estimates for the potential CSRM measures that could be applied to downtown Christiansted. This exercise considered structural and nonstructural measures.

For structural measures, a floodwall along an existing gut was considered. Along Watergut Street there is a gut that daylights beginning at King Cross Street to the ocean boardwalk where it goes under the boardwalk to empty into the ocean on the eastern side of the seaplane base. The distance from King Cross street to the boardwalk is approximately 152 feet (46 meters). To approximate the cost of a flood barrier that would be placed on either side of the existing gut, a floodwall of twice this length (304 feet [93 meters]) was costed using the MCL. Site-specific soil conditions, water depths, currents, waves, as well as other physical, environmental, and economic factors will typically dictate the applicability and type of floodwall. For the purposes of this preliminary assessment, a concrete T-wall is assumed. The MCL floodwall cost estimate represents a coastal floodwall 12 feet in height (3.7 meters), which is likely overestimating the costs needed for flood barriers at the Watergut gut, which would be shorter and likely have shallower foundations. **Table 6** demonstrates the MCL low and high rough order of magnitude cost estimates for the Watergut Street floodwall span of 304 feet (93 meters) in length (152 feet [46 meters] on each side).

Table 6: Planning-Level Cost Estimate for Potential Structural Measure (304 feet)

Measure Name	Construction Cost (FY20)	
	Low Estimate	High Estimate
Floodwall	$2,423,000	$3,566,000

For nonstructural measures, wet floodproofing, dry floodproofing, elevations, and buyout/acquisition were considered. The MCL building elevation cost estimates are based on elevating foundations of residential, wood frame structures. These elevation cost estimates do not accurately reflect the costs needed to elevate structures in downtown Christiansted, which would require elevating the interior structure or abandoning the first story because of the foundation types and cultural significance of the buildings. Similarly, the MCL buyout and acquisition estimates are based on single-family residential structures and do not account for commercial structures. More information is needed to determine the costs associated with commercial buyouts, especially for historic buildings. Because the MCL elevation and acquisition cost estimates would not accurately reflect costs required to implement these measures in Christiansted, they were excluded from the analysis.

The MCL was used to compare costs of wet floodproofing and dry floodproofing. For each of these measures, the MCL calculates costs based on the number of assets to which the measure will be applied. Two hundred buildings were identified within the focus area that are subject to coastal flooding from the modeled Category 5 MOM event. Each structure will require an assessment and evaluation of the potential for wet or dry floodproofing as well as the anticipated costs. For this preliminary analysis, generalized assumptions were made to assess many structures at once. This preliminary cost gives a ballpark estimate of the anticipated costs to mitigate all the downtown area structures. **Table 7** demonstrates the MCL low and high-cost estimates for each of the measures for the 200 assets.

Table 7: Planning-Level Cost Estimates for Potential Nonstructural Measures (200 Assets)

Measure Name	Construction Cost (FY20)	
	Low Estimate	High Estimate
Wet Floodproofing	$1,918,000	$2,781,000
Dry Floodproofing	$7,229,000	$20,044,000

Wet floodproofing cost estimates are based on single-family residential structures. Actual wet floodproofing costs for the area would likely be higher because of the high number of commercial structures. Cost components include the total size of the asset, the length of the asset's perimeter, the height of the protected area (2.5 feet [0.8 meters] for the low estimate and 3 feet [0.9 meters] for the high estimate) and the height to which utilities are raised (2.5 feet [0.8 meters] for the low estimate and 3 feet [0.9 meters] for the high estimate). High and low values for asset size and perimeter are based on the FAST data set. Dry floodproofing estimates are based on single-family residential structures. Cost components include the asset perimeter, the height of the protected area (2.5 feet [0.8 meters] for the low estimate and 3 feet [0.9 meters] for the high estimate), and the width of pedestrian doors (3 feet [0.9 meters] for the low estimate and 13 feet [4.0 meters] for the high estimate).

Further investigation is needed to identify the best strategy to mitigate coastal inundation flooding in this area. A comprehensive study for coastal flood protection of the downtown area could potentially qualify for Planning Assistance to States funding. Comprehensive planning activities through the Planning Assistance to States program are cost-shared (50 percent) with the study partner.

5.2.4.2 Impacts of Sea Level Rise and Climate Change

Flood barriers installed along existing guts will help to reduce flooding to the downtown area from heavy rainfall events but will not address coastal flood inundation risk, which is anticipated to become more frequent in future conditions with sea level rise. Any flood barrier measures should consider the flood frequency and extent of coastal inundation under future conditions before installing something that would quickly become obsolete. Nonstructural measures will need to be assessed on a structure-by-structure basis, given the projected increased frequency of flooding in the downtown area. For example, for residential structures where residents evacuate before every flood event, it may be more efficient and cost effective to consider acquisition of the structure and relocation of the residents. For commercial structures, wet floodproofing may be a viable option if the business can move assets to higher floors and quickly reopen following an event. For structures located close to the shoreline, the anticipated increase in wave heights and erosion rates will also need to be considered.

5.2.4.3 Potential Benefits and Impacts

The downtown area of Christiansted contains the historic and commercial district. The continued operation of the businesses in this area is vital to the local economy. From a business operations standpoint, it is beneficial for structures to remain near the ferry terminal and the boardwalk where there is heavy foot traffic. Many of the downtown structures are historic, which affects the physical and regulatory feasibility of implementing proposed measures.

Flood barriers along guts would help reduce stormwater flooding but would not reduce, and could potentially exacerbate, coastal inundation flooding. Floodwalls tend to trap rainfall runoff associated with storms on the landward side, creating a residual flooding risk. Given the unique context of the area, flood barriers may be more expensive and difficult to implement (public buy-in and environmental concerns) than measures like stormwater system improvements.

Both wet and dry floodproofing could adversely affect the character of the historic district and historic integrity of structures. U.S. National Park Service guidance on modifying historic structures, *Standards for Treatment of Historic Properties* (U.S. National Park Service 2017), includes considerations for increased resilience while maintaining historic qualities. Methods of minimizing the impact of flood proofing to cultural resources have been successful elsewhere by ensuring consistency of materials, appearances, and elevations with the historic character of an area. The cultural value of historic districts and structures do not preclude floodproofing but do add additional considerations. Though there may be impacts to cultural resources, the modification to add sustainability and resilience to cultural resources can outweigh the adverse effects if completed with sensitivity and in consultation with stakeholders.

For older, commercial structures, wet floodproofing may be the most suitable option because it allows the structure to remain intact at the current location. Dry floodproofing may be appropriate for structures further inland, or in areas where there is shallow, low-velocity flooding. Elevating structures may be preferred for businesses or residents that want to remain in the area. However, given the age of many of the structures, the costs required to safely elevate may outweigh the potential benefits. From a CSRM perspective, the most effective mitigation measure would be to acquire structures and enable inhabitants to relocate away from flood risk, yet it may not be popular or economically viable. Also, businesses that rely on local tourism may be unable to operate successfully further from the waterfront commercial area.

Given physical constraints and inherent advantages and disadvantages for each measure, it is likely that the most effective strategy will be a combination of measures to protect the at-risk structures. A combination of measures should be developed to consider the costs as well as physical, social, and economic factors. A comprehensive CSRM study for the Christiansted downtown area is recommended to further refine the characterization of existing and future hazards and evaluate potential measures in more detail. In addition to considering mitigation activities to the structures in the focus area, the planned and ongoing actions under this strategy address the flood risk to infrastructure (e.g., electric, potable water, sewer, and stormwater systems). Upgrades and improvements to the municipal infrastructure and drainage systems will positively impact the downtown area. As Christiansted resolves challenges with stormwater runoff and outdated utility infrastructure, attention should be directed toward the coastal inundation hazard and the long-term strategies needed to protect people and infrastructure from future coastal flooding.

5.3 Focus Area Action Strategy

Potential measures—based on findings from the SACS analyses and multiple rounds of workshops and collaboration with agency stakeholders—were compiled to address risk from coastal storm events in Christiansted. Some actions are already being implemented and other actions will be needed going forward. Lead stakeholders were identified for most actions. Actions were organized into themes: community engagement, communication, and policy improvements, shoreline erosion, environmental resources, and downtown flooding (**Table 8**). Priority and suggested sequence (scale of 1 through 3) were assigned to each action in the strategy. Together, these actions form one cohesive FAAS. The implementation of this action strategy will reduce Christiansted's risk to coastal hazards and increase the region's resilience against future storm events with increased sea level rise.

Table 8: Christiansted Focus Area Action Strategy

Theme	Key Actions	Status	Suggested Priority	Time Frame	Identified Potential Stakeholders
Community Engagement, Communication, and Policy Improvements	Update the FEMA Hazard Mitigation Plan	Ongoing	High	Short	FEMA
	Expand application of regional economic development and social vulnerability index models for USACE to perform a comprehensive benefit analysis when exploring project alternatives and opportunities	Needed	High	Mid	USACE
	Conduct more refined modeling using regionally appropriate tools to better understand and communicate hazards and their corresponding risks and consequences	Needed	Medium	Mid	*Undetermined*
	Conduct community engagement and capacity building initiatives	Needed	High	Short	*Undetermined*
Shoreline Erosion	Fortify bulkhead along seaplane base	Ongoing	High	Short	Virgin Islands Port Authority, Department of Public Works
	Rebuild damaged bulkhead in front of Ft. Christiansvaern	Ongoing	High	Short	U.S. National Park Service, NOAA, BioImpact
	Stabilize eroding shoreline along Buccaneer Beach	Ongoing	High	Short	*Undetermined*
	Conduct a long-term shoreline erosion study	Ongoing	Medium	Short	UVI, DPNR

Theme	Key Actions	Status	Suggested Priority	Time Frame	Identified Potential Stakeholders
	Relocate Buccaneer Hotel structures behind appropriate setback. Add measures to prevent erosion.	Needed	Medium	Mid	*Undetermined*
	Establish shoreline setbacks and enforce them	Needed	High	Mid	*Undetermined*
	Beneficial Reuse of Dredged Material from Gallows Bay	Planned	High	Short	Virgin Islands Port Authority
	Plant native vegetation to reduce shoreline erosion	Needed	Medium	Short	*Undetermined*
Environmental Resources	Track impacts to mangroves since 2017 storms	Ongoing	Medium	Short	USGS
	Protect fish habitats and encourage fish population growth offshore	Ongoing	High	Long	DPNR Division of Fish and Wildlife
	Conduct a coral reef monitoring program	Ongoing	Medium	Long	UVI
	Maintain a land-based coral nursery	Ongoing	High	Long	TNC, DPNR Coastal Zone Management, UVI
	Identify and preserve land for future mangrove retreat	Needed	Medium	Long	*Undetermined*
Downtown Flooding	Rehabilitate and mitigate dilapidated underground water and sewer lines along Watergut St.	Ongoing	High	Mid	Utilities and Federal Partners
	Drainage improvements to mitigate flooding of streets and buildings	Ongoing	High	Mid	FEMA
	Upgrade and mitigate water utility systems to prevent flooding and control stormwater runoff	Ongoing	High	Mid	USACE, FEMA, DPNR Coastal Zone Management
	Code compliance initiatives to improve structure performance during flood events	Ongoing	Medium	Short	FEMA
	Identify locations in downtown area where storm water connects to sanitary sewers	Planned	Medium	Mid	Public Works and Waste Management Authority
	Culvert and channel improvements at Herman Hill	Planned	Medium	Mid	HUD (CDBG-DR), FEMA
	Remove debris from Lower Water Gut to restore functionality	Planned	Medium	Short	*Unspecified*
	Conduct downtown Christiansted comprehensive flood study	Needed	High	Mid	USACE with unspecified non-federal sponsor

6. Recommendations

The Focus Area Action Strategy was developed to advance the shared vision and manage increased coastal storm risk as a result of sea level rise in the Christiansted Focus Area as shown in **Figure 16**. The shared vision is the overarching goal of the FAAS, broadly representing problems and opportunities stakeholders wish to address in the focus area. Resultingly, FAAS goals and objectives support the shared vision. SACS key products and other stakeholders' shared tools and data were used to support FAAS goals and objectives by assessing risk and identifying ongoing, planned, and needed actions to communicate and address the risk.

Figure 16: Focus Area Action Strategy Supports the Focus Area's Shared Vision

Recommendations are made for either multi-agency action, USACE action, or consideration by the United States Congress (Congress) to advance specific actions resulting from analyses presented in this report and coordination with stakeholders throughout the focus area. Recommendations are organized into six categories, as shown **Figure 17,** and three implementation timeframes (near-, mid-, and long-term). Implementation timing is influenced by the degree of stakeholder collaboration needed, technical complexity of the recommendation, current momentum toward implementation, and other factors needed to implement the recommendation. Implementation timeframes include:

Figure 17: Recommendation Categories

- **Near-Term Implementation (<5 years):** These recommendations are generally less complex and have significant stakeholder momentum toward implementation. The recommendations generally maintain and adapt actions that are recognized to successfully manage coastal storm risk.

- **Mid-Term Implementation (5-10 years):** These recommendations may be more technically complex and/or require additional stakeholder coordination and collaboration for implementation. They advance emerging efforts to address coastal storm risk.

- **Long-Term Implementation (>10 years):** These recommendations typically require significant stakeholder coordination before implementation and may be the most challenging to implement on regional scales from technical, political, or social perspectives. Importantly, coordination and collaboration on these recommendations should not be delayed. The long-term timeframe is reflective of the time to implementation based on immediate action to advance these recommendations which include complex issues such as land-use, zoning, and building codes.

Table 9 provides the recommendations for the Christiansted focus area.

Table 9: Recommendations for the Christiansted Focus Area

Authority Category	Implementation Timing	Recommendation For	Recommendation	Description
Address Barriers Preventing Comprehensive Risk Management	Near-Term (<5 years)	Multi-Agency Action	Use of risk assessment tools and collaboration for coastal resilience needs	The Tier 2 Economic Risk Assessment highlights the potential future cost of inaction for the territory. The risk assessment tools, in concert with other SACS key products, should be leveraged to help provide data and foster additional collaboration around co-benefits and coastal resilience needs. For example, economic development plans such as Vision 2040 can be enriched by the analyses already compiled as part of SACS. USACE can continue to participate in these collaborative efforts, particularly through the Silver Jackets program, and provide support, where appropriate.
Address Barriers Preventing Comprehensive Risk Management	Mid-Term (5-10 years)	Multi-Agency Action	Identify and conserve parcels of land to accommodate mangrove migration	A mangrove migration study was identified as a potential study opportunity to address the loss of NNBF. There are several stakeholders currently invested in studying and protecting mangroves around Altona Lagoon. Potential non-federal sponsors could be identified to support a Planning Assistance to States or Continuing Authorities Program Section 206 study to support this effort going forward.
Study Efforts (follow-on USACE feasibility study)	Mid-Term (5-10 years)	USACE	Christiansted Comprehensive Flood Protection	An opportunity for a comprehensive study of CSRM opportunities in downtown Christiansted was identified to conduct a more detailed and holistic assessment of potential CSRM opportunities. Non-federal sponsors would be needed for USACE engagement in this type of study. Continued collaboration to discuss these opportunities and identify potential partnerships is recommended.
Study Efforts (Multi-agency partnership/ activities)	Long-Term (>10 years)	Multi-Agency Action	Protect and Restore Coral Reefs	Offshore natural protective features, such as the coral reefs in Christiansted Harbor, provide wave attenuation and coastal storm risk reduction benefits to the shorelines behind them. Maintaining a healthy offshore reef system would help reduce shoreline erosion risks. Poor water quality influenced by compound flooding coupled with inadequate waste management systems threaten these reef systems. Future opportunities may exist to protect and restore coral reefs in Christiansted Harbor once water quality concerns are addressed.

7. References

Department of the Army Office of the Assistant Secretary Civil Works. April 3, 2020. *Comprehensive Documentation of Benefits in Feasibility Studies*. Department of Defense.

Dobson, J.G., I.P. Johnson, and K.A. Rhodes. 2020. *U.S. Virgin Islands Coastal Resilience Assessment*. Asheville, North Carolina: UNC Asheville National Environmental Modeling and Analysis Center. Prepared for the National Fish and Wildlife Foundation. https://www.nfwf.org/sites/default/files/2020-08/us-virgin-islands-coastal-resilience-assessment.pdf.

FEMA. 2020. *Hazard Mitigation Assistance Mitigation Action Portfolio*. Accessed November 20, 2020, https://www.fema.gov/sites/default/files/2020-08/fema_mitigation-action-portfolio-support-document_08-01-2020_0.pdf.

———. 2015. “Finding of No Significant Impact St. Croix Coastal Interceptor Relocation Project.” Accessed 2020, https://www.fema.gov/media-library-data/1439468258144-2c13d4f88752edb4fa7d00e260c76acd/St-Croix-Coastal-Interceptor-FONSI.pdf.

Luijendijk, A, G. Hagenaars, R. Ranasinghe, F. Baart, G. Donchyts, and S. Aarninkhof, S. 2018. “The State of the World’s Beaches.” *Scientific Reports*, 8(6641). https://doi.org/10.1038/s41598-018-24630-6.

Manis, J.E., S. Garvis, S. Jachec, and L.J. Walters. 2015. "Wave Attenuation Experiments Over Living Shorelines Over Time." *Journal of Coastal Conservation*, 19(1). https://link.springer.com/article/10.1007/s11852-014-0349-5.

Reiblich, J., and T. Ankerson. 2016. “Got Guts? The Iconic Streams of the U.S. Virgin Islands and the Law’s Ephemeral Edge.” University of Florida Law Faculty Publications. https://scholarship.law.ufl.edu/cgi/viewcontent.cgi?article=1801&context=facultypub.

Schill, S, J. Brown, A. Justiniano, and A.M. Hoffman. 2014. *U.S. Virgin Islands Climate Change Ecosystem-Based Adaptation Promoting Resilient Coastal and Marine Communities*. National Oceanic and Atmospheric Administration and The Nature Conservancy. https://www.ncei.noaa.gov/data/oceans/coris/library/NOAA/CRCP/other/grants/NA09NOS4190173/USVI/USVI_TNC_USVI_EBA_Guidance.pdf.

Systems Approach to Geomorphic Engineering (SAGE). 2015. *Natural and Structural Measures for Shoreline Stabilization*. https://coast.noaa.gov/data/digitalcoast/pdf/living-shoreline.pdf.

The Nature Conservancy. 2021. “Coastal Resilience: U.S. Virgin Islands.” Accessed January 26, 2021. https://maps.coastalresilience.org/usvi/.

USACE. 2021a. *Coastal Program Guide.* Charleston, VA: U.S. Army Corps of Engineers.

———. 2021b. *Environmental Technical Report, Environmental Resources Vulnerability and Risk Analysis/Priority Environmental Areas Identification*. Charleston, VA: U.S. Army Corps of Engineers.

———. 2021c. *South Atlantic Coastal Study (SACS) Institutional and Other Barriers Report.* Charleston, VA: U.S. Army Corps of Engineers.

———*. 2021d. South Atlantic Coastal Study (SACS) Measures and Cost Library. Charleston, VA: U.S. Army Corps of Engineers.*

———. 2020. *Coastal Hazards System.*

———. 2019. "Continuing Authorities Program*."* Accessed December 12, 2020, https://www.nae.usace.army.mil/Missions/Public-Services/Continuing-Authorities-Program/Section-206/.

U.S. Department of Commerce, Census Bureau. 2010. "US Decennial Census." Accessed January 2021, https://www.census.gov/programs-surveys/decennial-census/data/data sets.2010.html.

U.S. National Park Service. 2021. "National Register Listed 20210617." Accessed July 21, 2021, https://www.nps.gov/subjects/nationalregister/database-research.htm.

———. 2017. *The Secretary of the Interior's Standards for Treatment of Historic Properties*. Accessed November 20, 2019, https://www.nps.gov/tps/standards/treatment-guidelines-2017.pdf.

U.S. Virgin Islands Economic Development Authority. 2020. "Strong Opportunities for Tourism Investment". Accessed December 11, 2020, https://www.usvieda.org/relocate-business/key-industries/tourism-hospitality.

Virgin Islands Free Press. 2020. "DPW Uses $1.1 Million to Fix Flooding Problem in Gallows Bay." Accessed December 10, 2020, https://vifreepress.com/2020/05/dpw-uses-1-1-million-to-fix-flooding-problem-in-gallows-bay/.