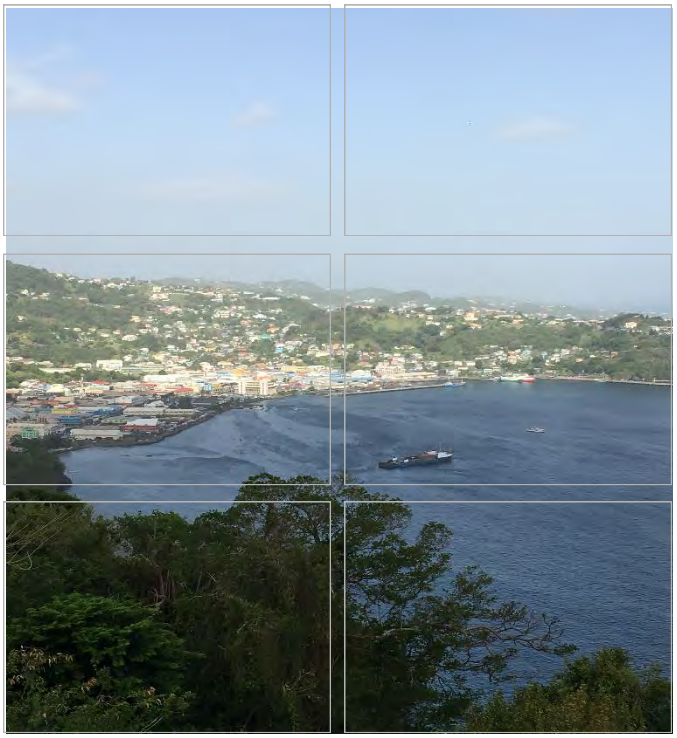

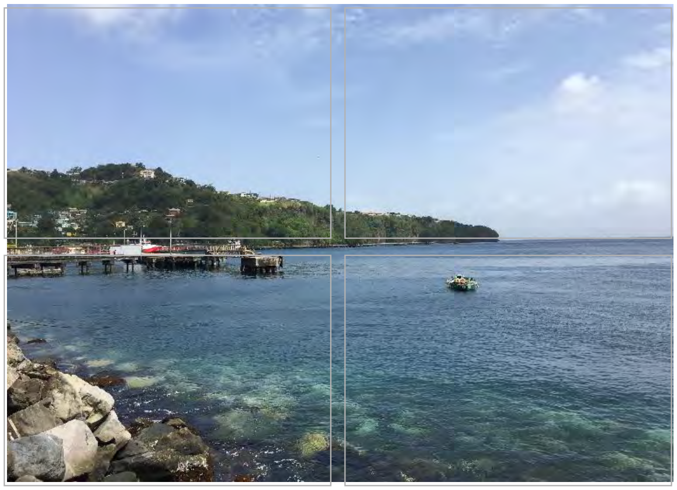

Prepared For:

HPC Hamburg Port Consulting GmbH
Container Terminal Altenwerder
Am Ballinkai 1
21129 Hamburg

Climate Risk & Vulnerability Assessment

Phase I – Port Kingstown Modernisation Programme

Final Report

4 December 2018

Environmental Resources Management
1776 I (Eye) St. NW Suite 200
Washington, DC 20006
www.erm.com

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FIRST INTERIM REPORT

Prepared for:

HPC Hamburg Port Consulting GmbH

Climate Risk & Vulnerability Assessment
Phase I – Port Kingstown Modernisation Programme

4 December 2018

Venkat S. Kolluru

Venkat Kolluru, *PhD*
Technical Director

William A. Schew, *PhD*
Project Manager

Environmental Resources Management
1776 I (Eye) St. NW Suite 200
Washington, DC 20006

http://www.erm.com

ABBREVIATIONS

Acronym	Meaning
AAL	Average Annual Loss
CATHALAC	Water Center for the Humid Tropics of Latin America and the Caribbean
CCCCC	Caribbean Community Climate Centre
CCCRA	CARIBSAVE Climate Risk Atlas
CCSIP	Caribbean Climate Smart Islands Program
CV	Coefficient of Variance
CZMAI	Coastal Zone Management Authority and Institute
ECA	Economics of Climate Adaptation
ECLAC	United Nations Economic Commission for Latin America and the Caribbean
ERM	Environmental Resources Management
GCM	Global Climate Models
GDP	Gross Domestic Product
GFDRR	Global Facility for Disaster Reduction and Recovery
GHG	Greenhouse gases
GOSVG	Government of Saint Vincent & the Grenadines
IDB	Inter-American Development Bank
IPCC	Intergovernmental Panel on Climate Change
MSUD	Millions of US Dollars
NA	Not Applicable
NASA	National Aeronautics and Space Administration
NCDA	Natural Capital Decision Analytics
NOAA	National Oceanic and Atmospheric Administration
PAHO	Pan American Health Organization
RCM	Regional Climate Models
RCP	Representative Concentration Pathways
SIDS	Small Island Developing State
SRES	Special Report on Emissions Scenario
SLR	Sea level rise
TDrp	Total Damage for the Return Period
TNC	Third National Communication
UN	United Nations
UNDP	United Nations Development Programme
UNISDR	United Nations Office for Disaster Risk Reduction
USD	US Dollars
USAID	United States Agency for International Development

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1.0 INTRODUCTION

1.1 BACKGROUND

In March 2016, the Government of St. Vincent and the Grenadines (GOSVG,) approved a Port Rationalisation Master Plan for SVG. The Port Rationalisation Master Plan (Master Plan) was developed to inform the St. Vincent and the Grenadines Port Authority's development of new physical port infrastructure in Kingstown on the island of Saint Vincent (the Study Area).[1] The Master Plan describes the most successful of five development alternatives, the so-called "development option C." In this option, the port development project (the Project) is planned to be executed in four main work packages as described below. The work packages will be carried out in a progressive manner within a 3-year implementation time frame.

- Work Package 1 – New Primary Cargo Port in Kingstown (the "Container Terminal")
- Work Package 2 – New Intra-Regional Cargo Terminal, Kingstown
- Work Package 3 – New Inter-Island Ferry Terminal, Kingstown
- Work Package 4 – Road improvement works in Kingstown

As part of this proposed development, a study is aimed at establishing a technically and economically viable, climate-resilient, socially inclusive, and gender-responsive framework for the development of the new cargo port facility in Kingstown.

This study includes undertaking a Climate Risk and Vulnerability Assessment (CRVA) to identify and evaluate the effects of projected climate change on the proposed project components, including the wider human and natural systems in which the port facilities have influence, and to identify resilience measures that should be included in the design.

ERM's approach involves the following six main tasks:

1. Data collection;
2. Stakeholder engagement;
3. Climate baseline development;
4. Selection of the General Circulation Model (GCM) and Regional Climate Model (RCM);
5. Assessment of climate change;
6. Hazard and risk assessment;
7. Climate Risk Vulnerability Assessment;
8. Socioeconomic analysis; and
9. CRVA reporting

---

[1] In this report, the main island will be referred to as "Saint Vincent" while the country will be referred to as SVG.

1.2 PROJECT DESCRIPTION

Work Package 1, the development of the new Container Terminal includes the following:

- Seaward reclamation of approximately 6.5 hectares of new port area adjacent to already reclaimed land, to provide for a double berth suitable for the projected design vessels with a length between 120 m length (Ro-ro vessel) and 192 m (Car Carrier). The Master Plan describes maximum draught to be –10 m; however, the current design for the container terminal foresees a draught of –12.5 m for safe vessel approach.
- A terminal with a sheet pile quay wall of 380 m length and rock revetments of 130 m length at both sides. Alternatively, the sides of the terminal will also be constructed of sheet piles. A final decision was still pending at the time of the assessment.
- A container storage yard and a Container Freight Station (CFS)
- Customs and Port Administration Building and adjacent car parking lot
- An area and transit shed for agricultural products and bananas, including a transit shed for the company "Geest"
- A break bulk and vehicle storage area
- An equipment maintenance area
- A truck parking lot, and
- A solid waste reception facility.

The terminal will be equipped with cargo handling facilities - reach stackers for handling of full containers, empty container handlers, and two mobile harbour cranes.

Further installations on the container terminal include:

- A storm water drainage system with oil separators to prevent run-off of contaminated water from the terminal to the sea in case of spillages
- A network for supplying drinking water and collection of waste water
- Electrical supply from the public network, supplemented by a back-up generator
- A firefighting system
- A security fence as required by the ISPS Code, and a sentry house at each gate

The Container Terminal will be constructed on reclaimed land. The required volume of filling material is estimated to be approximately 305,000 m^3. However, the Draft Geotechnical Report of this project (ARMANA 2013) discusses as an alternative to construct the berth on piles. This would drastically reduce the amount of filling material required, while at the same time having less impact on the marine environment, on current and sedimentation patterns. A final decision has not yet been made, but the sheet pile solution is likely to be preferred for financial reasons. For the purposes of this report, we assume the most likely construction alternative – sheet piling with fill.

1.3 OBJECTIVE AND SCOPE OF WORK

This study focuses on undertaking a baseline risk assessment and vulnerability analysis of Kingstown Port/Project Area, comprising a list of hydro-meteorological hazards, impact analysis and risk assessment. The analysis utilizes a common risk framework, where risk is a function of hazard, exposure and vulnerability. The results from this aspect of the study will assist decision makers:

- to better understand natural hazards;
- to identify which assets and areas are most exposed to natural hazards;
- to estimate the probabilistic damage and loss with no climate change under current conditions (baseline conditions);
- to understand the most serious potential consequences of future projected climate change (e.g., physical damage, economic loss, and loss of human life); and
- to improve decision-making for risk mitigation, in order to reduce infrastructure damages and human life losses.

1.4 LIMITATIONS AND EXCEPTIONS OF ASSESSMENT

1.4.1 Scope of Activity

The report is based upon the application of engineering principles and professional judgement to certain facts with resultant subjective interpretations. Professional judgements expressed herein are based on the currently available facts within the limits of the existing data, scope of work, budget and schedule. We make no warranties, express or implied, including, without limitation, warranties as to merchantability or fitness for a particular purpose. In addition, the information provided in this report is not to be construed as legal advice.

1.5 STRUCTURE OF REPORT

In this document, ERM presents the results of the hazard and risk assessment conducted for the area impacted by the proposed Container Terminal expansion. This study is comprised of the following remaining sections.

- **Section 2** – *Subject Area Description and Watershed Delineation*: describes the subject area and watershed;

- **Section 3** – *Socioeconomic Profile*: provides a summary of national, regional and local socioeconomic information;

- **Section 4** – *Natural Hazards*: provides a description of natural hazards that historically have affected SVG. This section also includes a list of non-climate stressors;

- **Section 5** – *Baseline Analytics* – establishes baseline conditions;

- **Section 6** – *Climate Change Projections* – provides a summary of regional climate changes projections;

- **Section** 7 – *Flooding Hazard Analysis*: presents the methods and results;
- **Section** 8 – *Asset Vulnerability to Climate Change*: identifies, quantifies, and prioritizes/ranks the vulnerable assets identified for the project area;
- **Section 9** – *Potential Adaptation Measures*: presents a preliminary list of potential adaptation measures for the project area.
- **Section 10** – *References*

2.0 SUBJECT AREA DESCRIPTION AND WATERSHED DELINEATION

Saint Vincent and the Grenadines (SVG,) is a Small Island Developing State (SIDS) in the southeastern Caribbean consisting of 32 islets and cays (**Figure 1**). It lies near the southern end of the eastern Caribbean. The country consists of thirty-four islands, islets and cays and is situated 13° north latitude, and 61° west longitude. It is approximately 150 kilometres west of Barbados, 40 kilometres southwest of St. Lucia, 110 kilometres north-northeast of Grenada, and 270 kilometres north of Trinidad and Tobago (GOSVG, 2010). It occupies a total land area of 359 km^2 and has a population of 110,225 (GOSVG, 2015).

Saint Vincent is the main island (345 km^2) with other, smaller islands comprising the Grenadines. The Grenadines cover a land area of approximately 50 km^2 and stretch a distance of 72 km to the southwest of the mainland, St. Vincent. The seven inhabited Grenadine islands are Bequia and Mustique in the Northern Grenadines; and Union, Canouan, Mayreau, Palm Island, and Petit St. Vincent in the Southern Grenadines. In addition there are a number of uninhabited islets and rocks, including the Tobago Cays, which are of environmental, historic and economic significance (GOSVG, 2010).

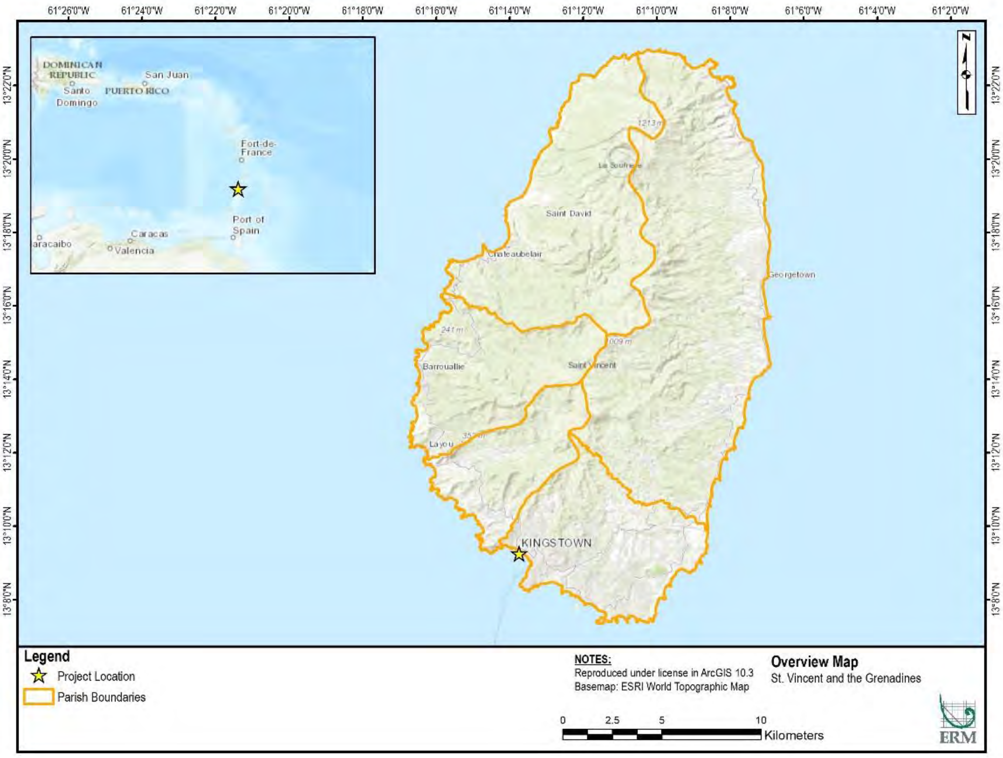


Figure 1: Overview Map of Saint Vincent and the Grenadines

The country's climate is tropical and the terrain of its islands are volcanic and mountainous. The main island of Saint Vincent is characterized by rugged, mountainous terrain with valleys that drain to the narrow coastal area, as well as wet upland forests, numerous rivers, and fertile soils (GOSVG, 2000). The islets and cays that form the Grenadines are smaller and less rugged than Saint Vincent; these islands are nearly entirely dependent on groundwater for their freshwater supply given a lack of rivers and lakes (GOSVG, 2000).

2.1 PROJECT SITE AND STUDY AREA DESCRIPTION

The proposed site for Container Terminal is located in Kingstown Bay in the Kingstown precinct, west of the existing cargo port, and against existing reclaimed foreshore lands occupied by a concentration of established warehousing and commercial properties (**Figure 2**). Seaward reclamation is required to provide approximately 6.5 hectares of port area that includes provision for double berth suitable for the projected design vessels.

Figure 2: Location of Proposed Container Terminal Expansion in Kingstown Bay

2.2 TOPOGRAPHY AND DRAINAGE

The islands of SVG are volcanic in origin and are characterized by a deeply dissected topography with a range of habitat components including marine, tropical and dry forest, urban and agricultural elements.

The main topographical feature of Saint Vincent is the rugged, thickly forested central mountain range that runs in a north–south direction. The highest point on the island, the La Soufrière stratovolcano, rises to 1,234 m. Other peaks range in height from 800 to 1,100 m. Highly dissected ridges and valleys, which extend to the coast, characterize the topography on the leeward side. The spurs are steep and the valleys deep and narrow. The windward side is dominated by more gently undulating foothills, shallow valleys and extensive coastal plains. There are many drainage systems of small streams and rivers. As such, the mainland is divided into numerous watershed areas (GOSVG, 2010).

The Kingstown area has two primary watersheds on the east and the west side of the proposed project area with multiple smaller watersheds that feed directly into the ocean (**Figure 3**). Many of the sub-watersheds do not have discernable rivers but may spill into the ocean through overland flow directed through numerous engineered stormwater structures (**Figure 4** through **Figure 7**).

Figure 3: The Kingstown Sub-watersheds

Figure 4: Example of Stormwater Conveyance in the Kingstown Port Area

Figure 5: Example of Stormwater Conveyance in the Kingstown Port Area

Figure 6: Example of Stormwater Conveyance in the Kingstown Port Area

Figure 7: Example of Stormwater Conveyance in the Kingstown Port Area

2.3 ELEVATION, SLOPE AND FLOW DIRECTION

Elevation of St. Vincent and the Grenadines range from 0 meters at the ocean to the high point of 1,234 meters located on La Soufrière mountain. Kingstown is located on the southern side of the island by the ocean and has a much lower elevation, ranging between 0 and 176 meters with an average of 40.6 meters (**Figure 8**). The proposed Container Terminal location is located by an alluvial plain on the shores of Kingstown. Kingstown is built on a relatively low lying part of the island in a small cove surrounded by steep cliffs to the east and west. Average slope within 1 kilometer of the proposed Container Terminal location is 27.5 (percent rise) and ranges between 0 and 361.6 percent rise (**Figure 9**).

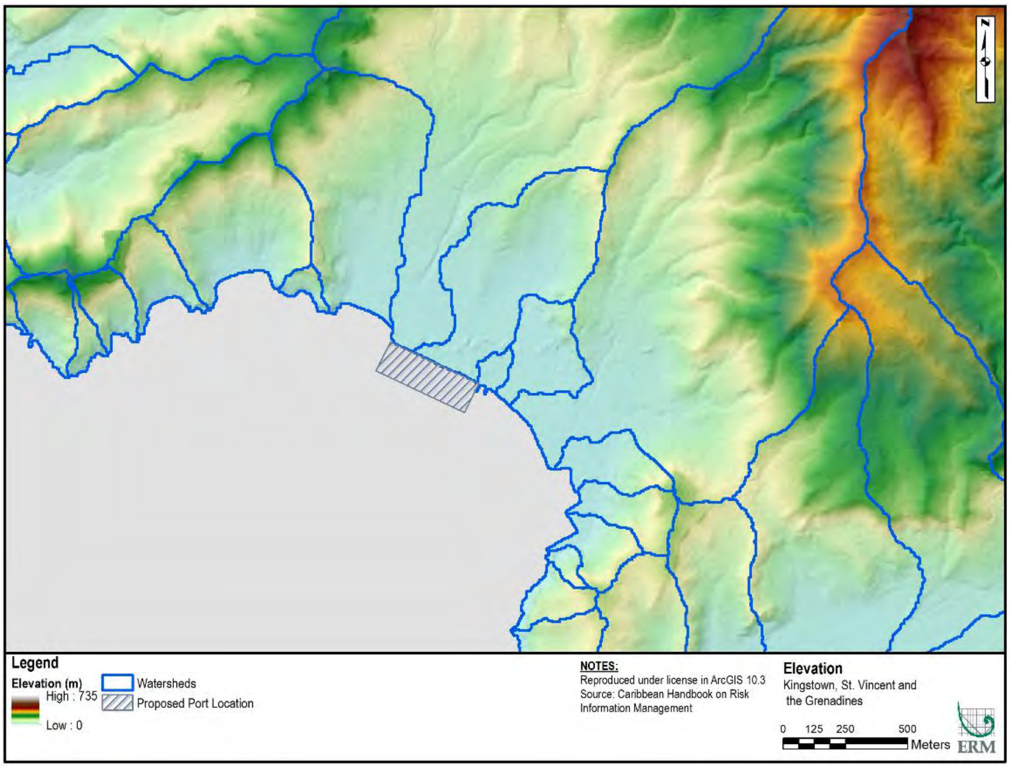


Figure 8: Elevation in the Kingstown Area

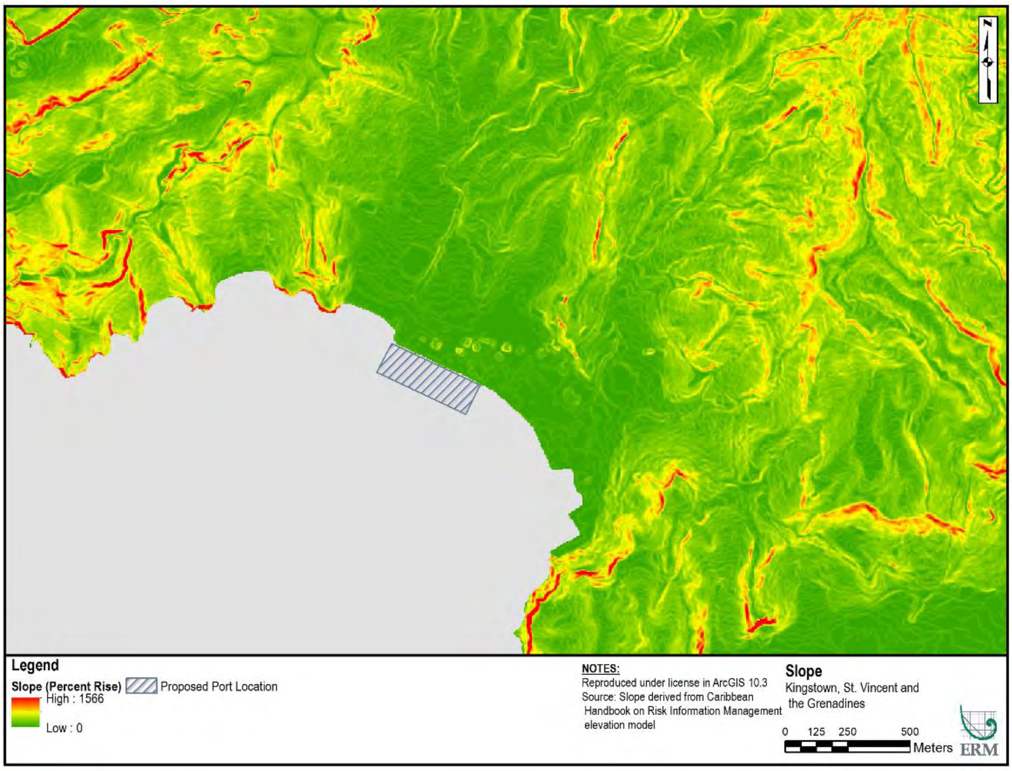


Figure 9: Slope of Land in the Kingstown Area

Kingstown sits in an alluvial plain with volcanic cliffs surrounding on three sides and water tends to drain down from the higher elevations from the east and west down into Kingstown. Smaller ridgelines within the major populated area divert water to two primary rivers (the North and South Rivers), which drain the major watersheds in the area (**Figure 10**).

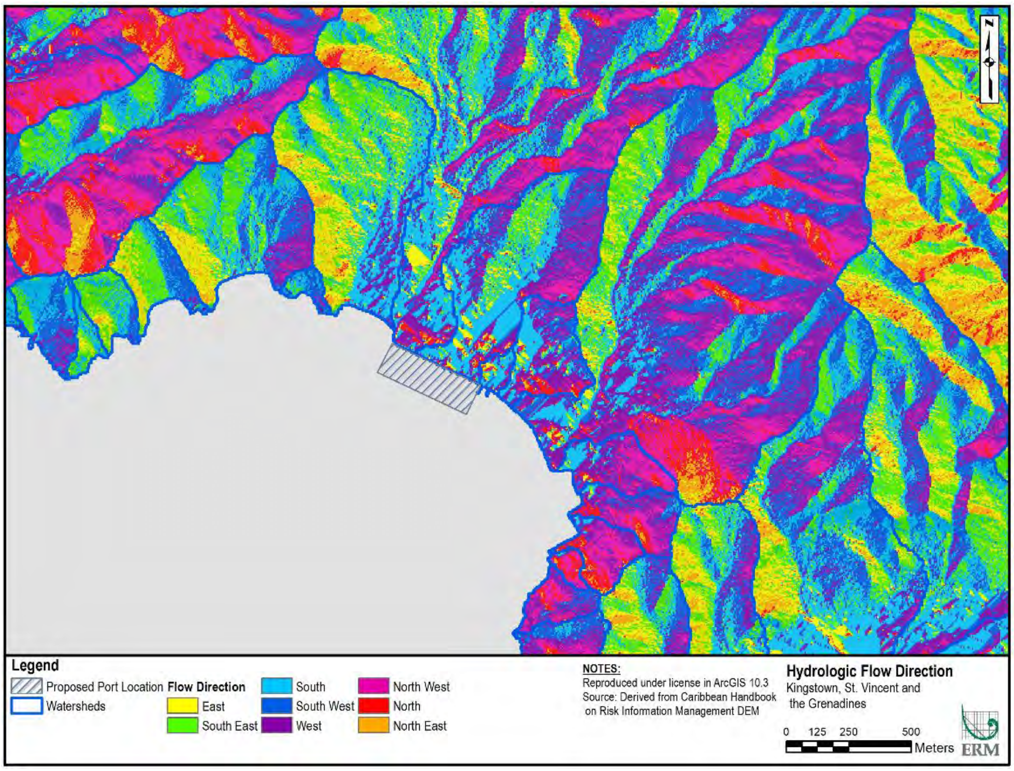


Figure 10: Hydrologic Flow in the Kingstown Area

2.4 LAND USE/LAND COVER

The country's climate is tropical and the terrain of its islands are volcanic and mountainous. The main island of Saint Vincent is characterized by rugged, mountainous terrain with valleys that drain to the narrow coastal area, as well as wet upland forests, numerous rivers, and fertile soils (GOSVG, 2000). The natural vegetation consists of species typical of tropical rainforest in the central mountains and wooded valleys. The coastal drier areas contain species reminiscent of scrub land.

Kingstown Parish on Saint Vincent is predominantly agricultural and forest with 31% of the land covered by pasture and herbaceous agriculture, 27% semi-deciduous forest, and 12% evergreen forest (**Figure 11**). Only 7% of the land is classified as buildings. The area within a 1-kilometer boundary of the proposed project location is much more urban than the rest of the parish (**Figure 12**) and is 26% buildings and 17% roads. However, even close to the city center, there is still a large amount of shrub land (15%), agriculture (25%), and semi-deciduous forest (13%).

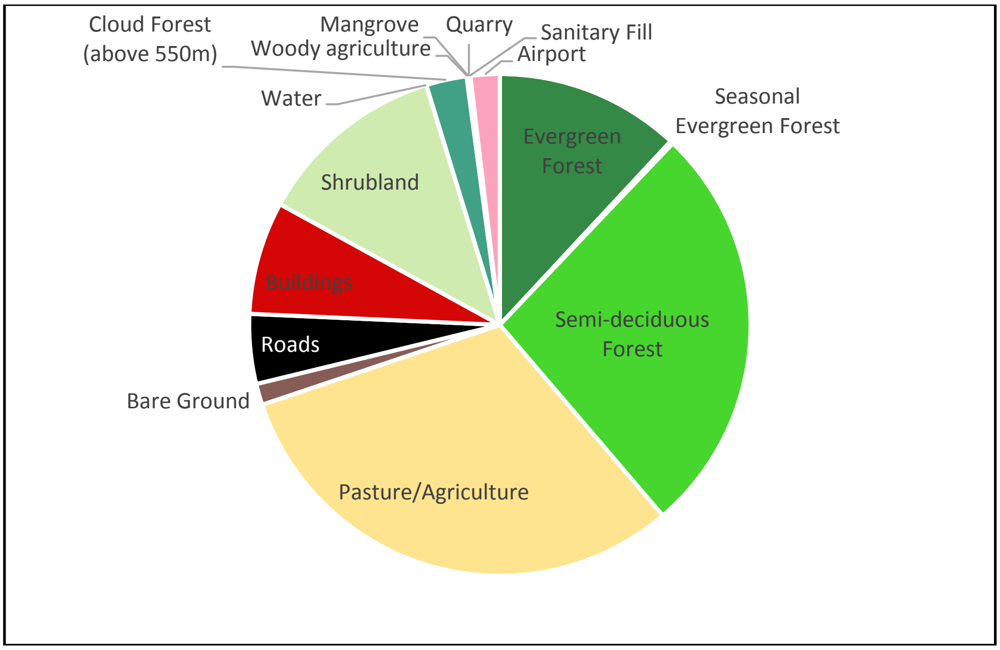


Figure 11: Land Cover for Kingstown Parish, Saint Vincent

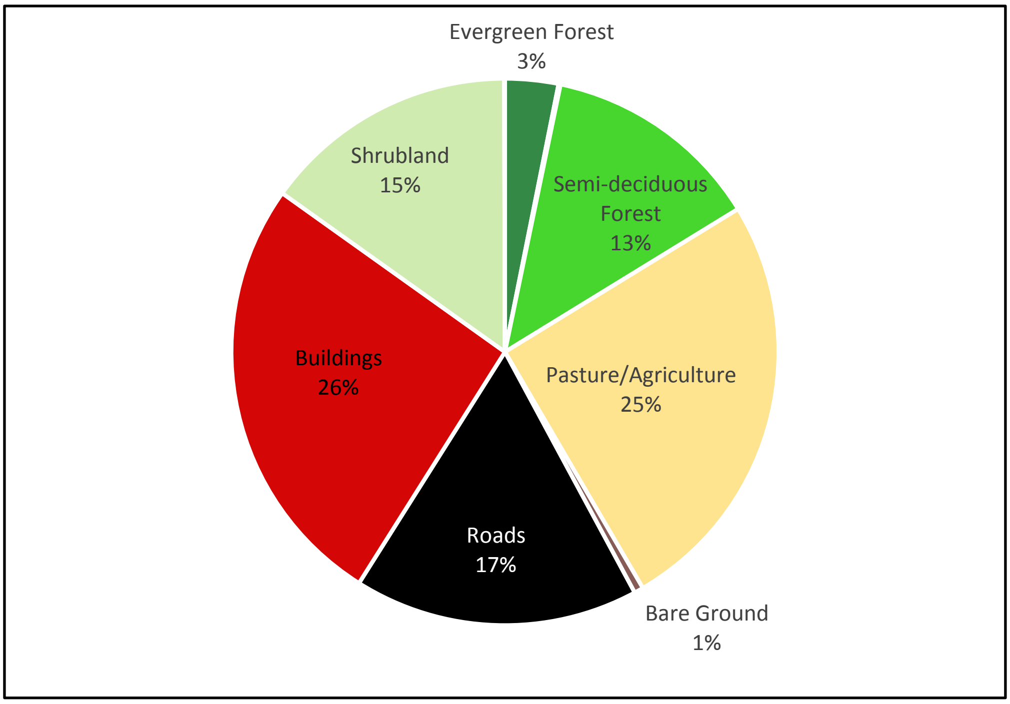


Figure 12: Proportion of Land Cover within 1 km of the Proposed Project Location

Most of the urban area in Kingstown is located directly along the port near the proposed project location (**Figure 13**). There are a total of 21,481 structures within the parish of Kingstown and 3,026 structures within 1-km of the proposed Container Terminal (**Figure 14**). Many of the structures near the proposed project location tend to be larger warehouses for industrial purposes. Many of the important assets by the port are for commercial or governmental use (**Figure 15**); however, this study did not have specific information about building type and did not analyze commercial and residential buildings. Smaller structures on the outskirts of Kingstown fall within some of the agricultural or forested areas and most likely are for residential use or micro-enterprises (**Figure 13** and **Figure 14**).

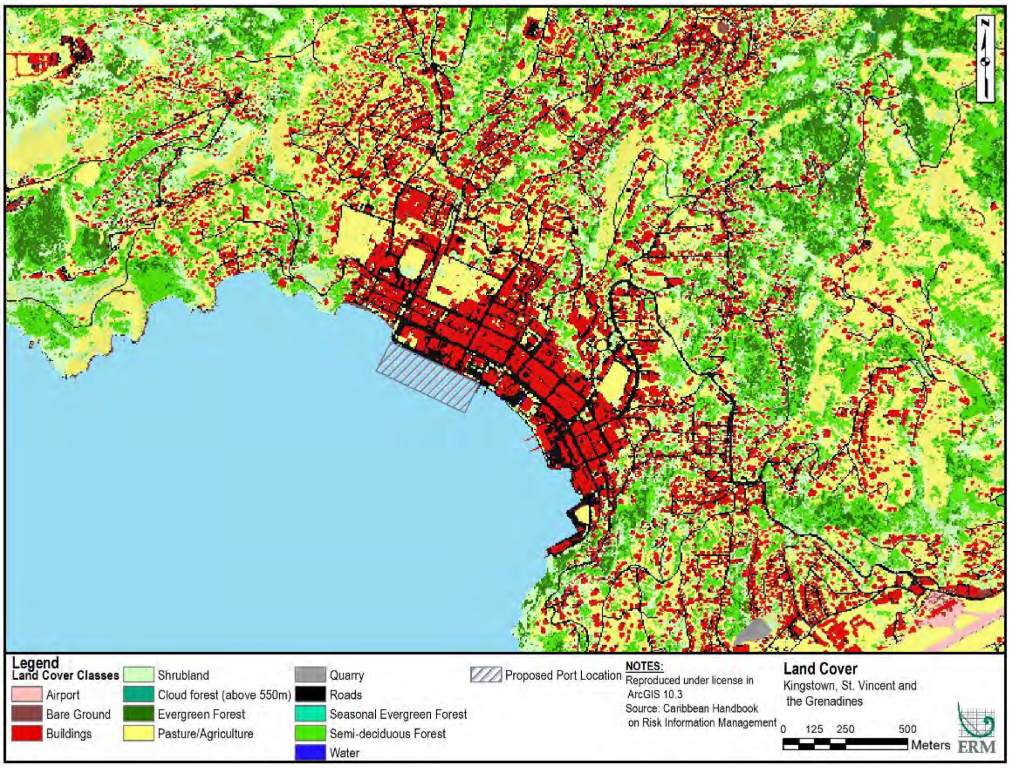


Figure 13: Land Cover in the Kingstown Area

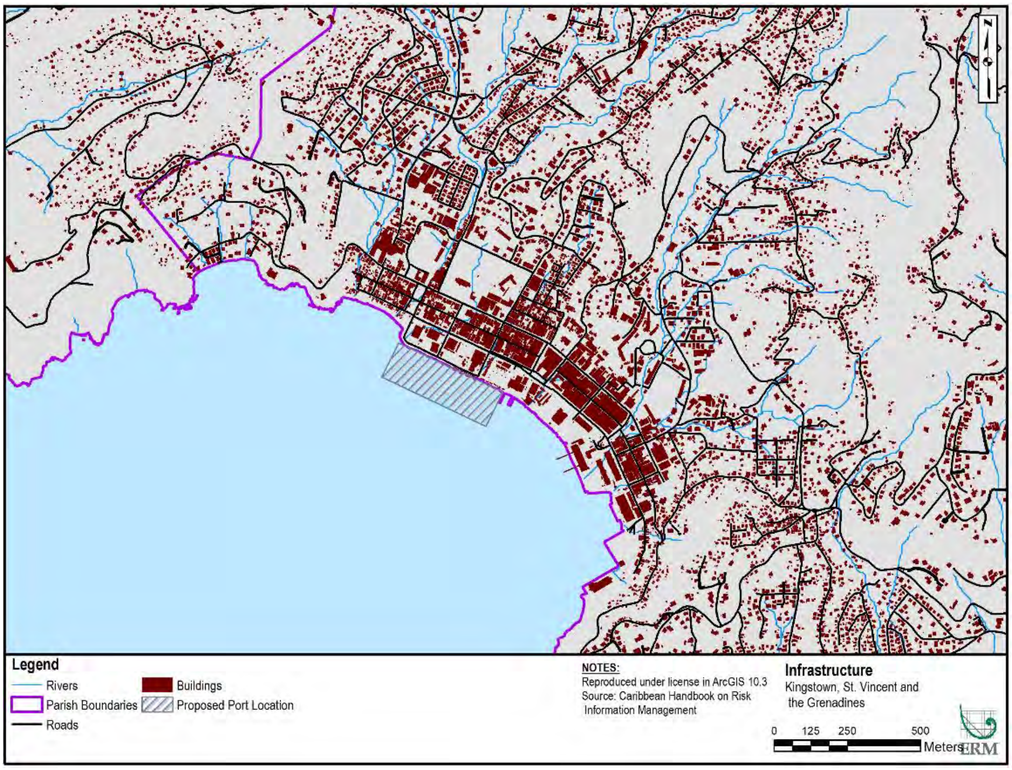


Figure 14: Buildings in the Kingstown Area

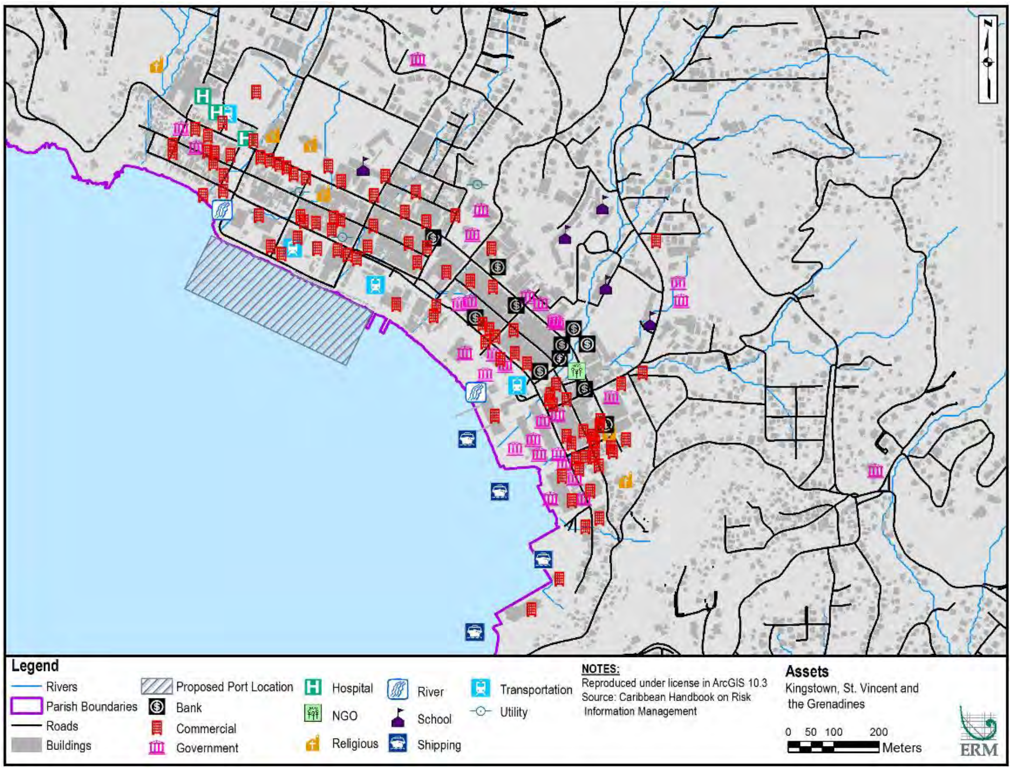


Figure 15: Asset Characterization in the Kingstown Area

2.5 GEOLOGY/SOIL

St. Vincent and the Grenadines is composed of 34 islands, islets and cays that extend from St Vincent, the largest island, southward toward Carriacou in the Grenadines of Grenada. The islands are part of the Windward Islands of the Lesser Antilles. The island arc is in a region of active volcano activity caused by subduction of the North American and/or South American Plate beneath the Caribbean Plate (Robertson, 2003). The island of Saint Vincent is relatively young (~ 3 million years old) and consists of a central axial range of mountains starting from La Soufrière (1,234 m), in the north, to Mount St Andrew (736 m) to the south. The geological history of the island consists of the development and northward migration of a series of volcanic centres (Robertson, 2002). Apart from recent alluvial deposits and beach sands are the only igneous rocks are found on the island. The main rock types exposed are sedimentary (impure limestone and coral) and igneous in origin.

The weathering of the volcanic rocks and the deposits of debris from volcanic eruptions has resulted in rather deep, fertile soils in many parts of Saint Vincent. The soils on the island are grouped into five categories, based on original material from which they were derived (Isaacs, 2013). These include yellow earth, recent volcanic ash soil, alluvial soil, aeoin soil and shallow clay soil, locally known as "shoal." The yellow earth, developed on original volcanic rocks, is sub-divided into high-level yellow earth and low-level yellow earth. The high-level yellow earth is believed to be the oldest soil type in St. Vincent, and is found in the north of the island close to the volcano. The low-level yellow earth occurs at elevations below 200 meters.

The soils surrounding Kingstown are predominantly clay loam that turn to sandy loam and sandy clay loam within the major populated areas (**Figure 16**). The geologic formations within the populated section of Kingstown and by the proposed

Container Terminal are alluvial deposits while the surrounding area is made of different volcanic formations.

Figure 16: Soil Map of the Kingstown Area

2.6 GROUNDWATER

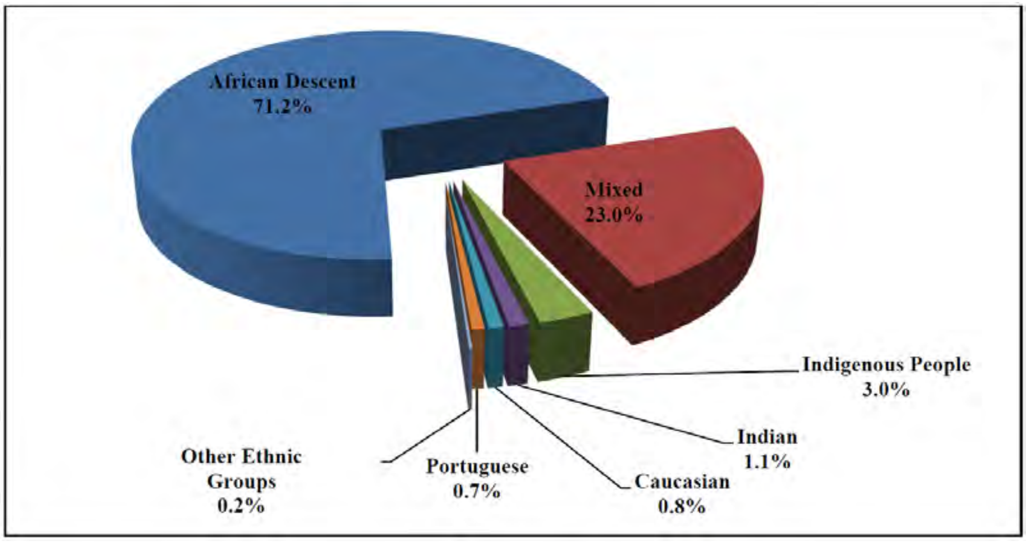
Although countries such as The Bahamas, Barbados, Jamaica, and most of the Grenadines rely heavily on groundwater resources as their source of water supplies, the island of Saint Vincent uses surface water for the majority of their freshwater supplies. In 2010, groundwater extraction was estimated to be only 0.01 km^3/year (Margat and van de Gun, 2013). This is low amount is likely because of inadequate groundwater supplies - a survey of SVG by the Survey British Geological Survey showed adequate groundwater resources were lacking in the island (BSG, 1991).

3.0 SOCIOECONOMIC INFORMATION

3.1 DEMOGRAPHIC INFORMATION

3.1.1 Population

St. Vincent and the Grenadines has a diverse ethnic population. Though the majority of the population is of African descent, the population is also comprised of Caribs/Amerindians, who are an indigenous group to the country, along with other minority ethnic groups (GOSVG, 2012). The largest ethnic group was African (71%), followed by those of mixed descent (23%), Carib Amerindian (3%), East Indian (1.1%), Portuguese (0.7%), and Caucasian (0.8%). **Figure 17** below illustrates this ethnic breakdown.



Source: 2012 Population and Housing Census Report (GOSVG,, 2012)

Figure 17: Percentage Population by Major Ethnic Group, 2012. (Source: SVG 2012)

According to the 2105 Population & Vital Statistics Report prepared Statistical Office, Economic Planning Division, Ministry of Finance & Economic Planning (GOSVG, 2015), the total population of SVG was 110,225 as of 2015 (see **Table 3-1** below).

Table 3-1: Population information for Saint Vincent and the Grenadines

Census Division	Total Mid-Year Population									
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Kingstown	13,913	13,924	13,935	13,947	13,958	13,969	12,909	12,919	12,930	12,940
Suburbs of Kingstown	13,080	13,090	13,101	13,111	13,122	13,132	13,812	13,823	13,834	13,845
Calliaqua	22,798	22,816	22,835	22,853	22,871	22,889	24,205	24,224	24,244	24,263
Marriaqua	8,287	8,294	8,301	8,307	8,314	8,321	7,798	7,804	7,810	7,817
Bridgetown	6,806	6,812	6,817	6,823	6,828	6,834	6,568	6,573	6,579	6,584
Colonarie	7,521	7,527	7,533	7,539	7,545	7,552	6,849	6,855	6,860	6,865
Georgetown	7,013	7,019	7,025	7,030	7,036	7,041	7,061	7,067	7,072	7,078
Sandy Bay	2,816	2,819	2,821	2,823	2,825	2,828	2,576	2,578	2,580	2,582
Layou	6,364	6,369	6,374	6,379	6,384	6,389	6,339	6,344	6,349	6,354
Barrouallie	5,485	5,490	5,494	5,498	5,503	5,507	5,884	5,889	5,893	5,898
Chateaubelair	6,106	6,111	6,115	6,120	6,125	6,130	5,756	5,761	5,765	5,770
Total (Mainland))	100,189	100,271	100,351	100,430	100,511	100,592	99,757	99,837	99,916	99,996
Northern Grenadines	5,670	5,674	5,679	5,684	5,688	5,693	6,184	6,189	6,194	6,199
Southern Grenadines	3,603	3,606	3,609	3,612	3,615	3,618	4,050	4,053	4,056	4,060
Total	109,462	109,551	109,639	109,726	109,814	109,903	109,991	110,079	110,166	110,255

Source: 2015 Population & Vital Statistics Report (GOSVG, 2015)

The majority of the population of SVG (91.3%) lived in private houses (GOSVG, 2012). Meanwhile, 6.4% of households lived in sections of private houses, 5.3% lived in flats/apartments during 2012, up from 2.2% in 2001. This type of dwelling (Flats/Apartment) was more prevalent in the census divisions of Kingstown, Suburbs of Kingstown and Calliaqua. Together, they accounted for 47.0% of the households living in this type of dwelling. The remaining households lived in Town Houses (0.4%), Double Houses/Duplexes (1.3%), Combined Business and Dwelling (1.3%), Barracks (0.03%), Group Dwellings (0.1%), Improvised Housing Units (0.02%), Other (0.2%), while 0.1% of households did not disclose their type of dwelling (GOSVG, 2012).

Saint Vincent and the Grenadines is comprised of 13 census divisions, 11 of which are on the main island. **Table 3-2** below presents the populations size, average household size, and population density for various census divisions within SVG (GOSVG, 2012).

Table 3-2: Population Density and Household Size for Saint Vincent and the Grenadines

Census Division	Area (Sq. Miles)	Population Size[1]	Population Density	Average Household Size[2]
Kingstown	1.9	12,940	6,811	3.0
Suburb of Kingstown	6.4	13,845	2,163	3.1
Calliaqua	11.8	24,263	2,056	2.8
Marriaqua	9.4	7,817	832	3.2
Bridgetown	7.2	6,584	914	3.1
Colonarie	13.4	6,865	512	3.2
Georgetown	22.2	7,078	319	3.2
Sandy Bay	5.3	2,582	487	3.9
Layou	11.1	6,354	572	2.9
Barrouallie	14.2	5,898	415	3.1
Chateaubelair	30.9	5,770	187	3.4
Northern Grenadines	9.0	6,199	689	2.3
Southern Grenadines	7.5	4,060	541	2.5
Total	**150.3**	**110,255**	**734**	**3.0**

Sources: [1] 2015 Population & Vital Statistics Report (GOSVG 2015)

[2] 2012 Population and Housing Census Report (GOSVG 2012)

Kingstown parish is the most densely populated parish in Saint Vincent with a mean population density of 830 ± 395 persons per square kilometer in 2015 (mean ± standard deviation). The area within a 1 km buffer of the proposed project location is the most densely populated area on the island with 1915 ± 269 persons per square kilometer (**Figure 18**). While average population density is expected to increase within Kingstown parish by 1.67% between 2015 and 2020, the population density for the area within 1 km of the proposed Container Terminal location is expected to decrease by 2.62% during that same time period (**Figure 19**).

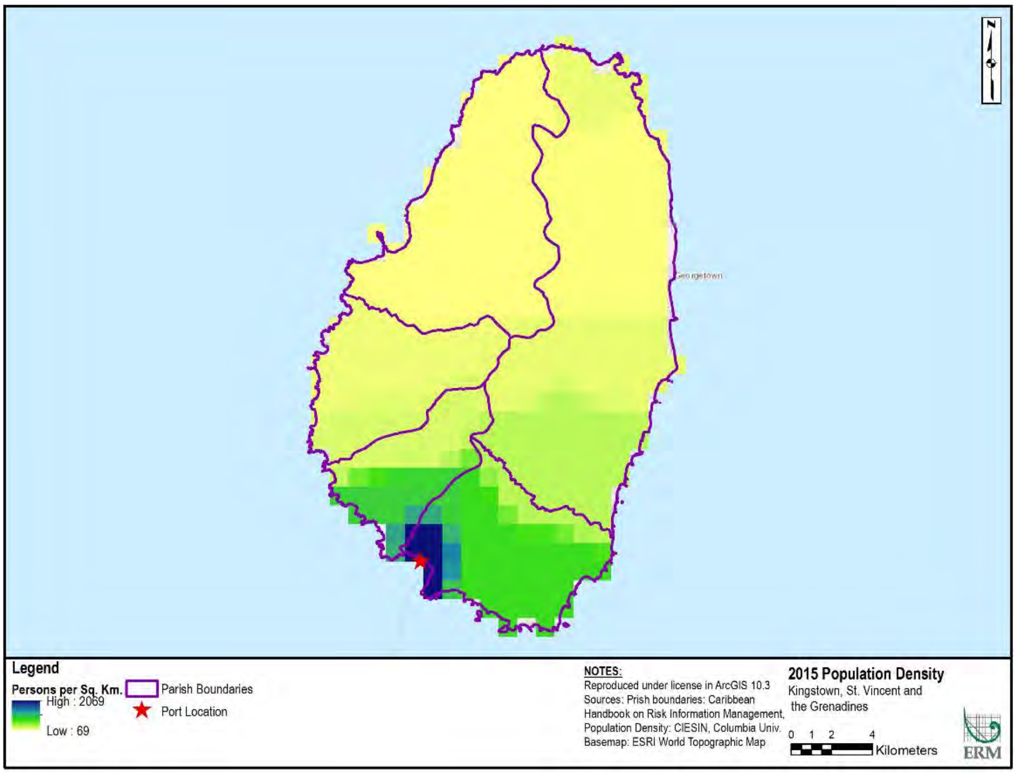


Figure 18: Population Density on Saint Vincent

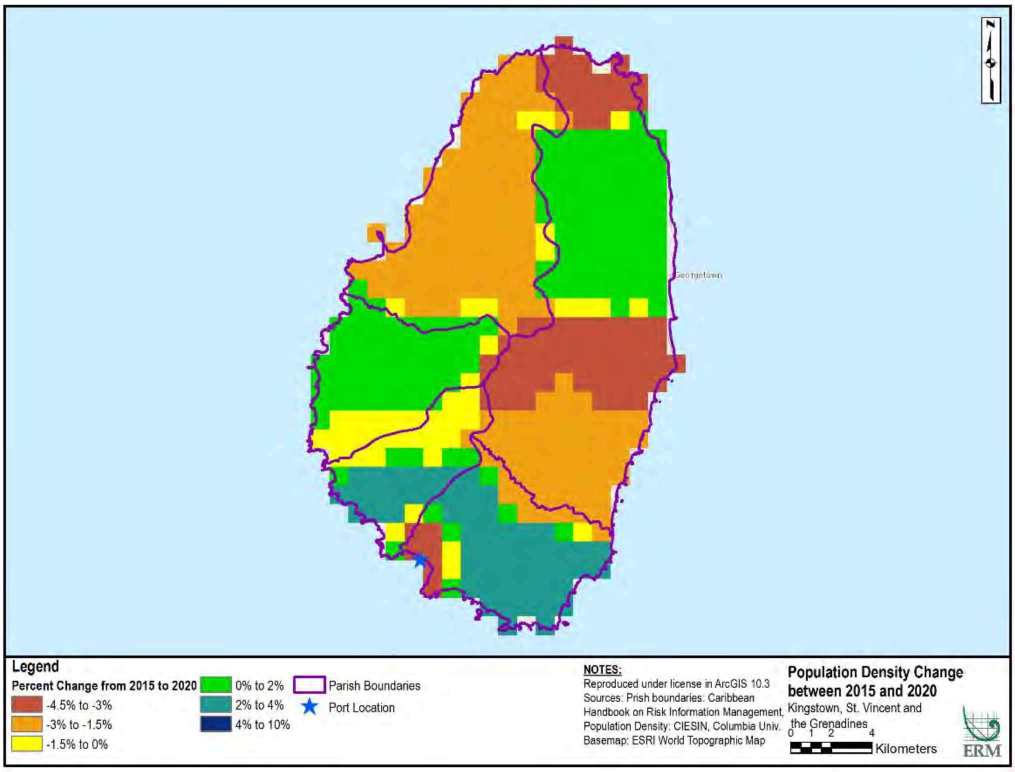
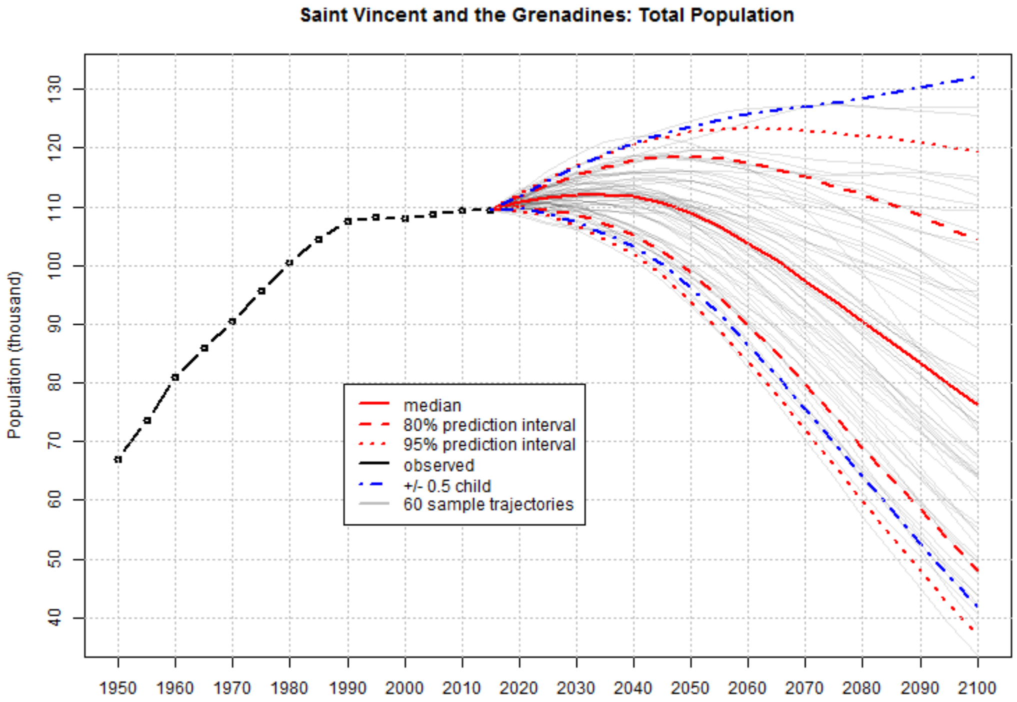


Figure 19: Projected Changes in Population Density on Saint Vincent

For SVG, the 2015 census reported an average annual growth rate of 0.1% per year (GOSVG, 2015). The United Nations (UN, 2017) predicts SVG's population to increase slightly through 2030 and degrease thereafter (**Figure 20**). By 2080, the UN expects SVG's population to decrease to approximately 90,000.



Source: United Nations, Department of Economic and Social Affairs, Population Division (2017).
World Population Prospects: The 2017 Revision. http://esa.un.org/unpd/wpp/

Figure 20: Saint Vincent and the Grenadines Population Growth 1950-2100

3.1.2 Livelihood

In 2012, there were 11,193 unemployed persons in SVG with an unemployment rate of 21.5% (GOSVG, 2012). Males accounted for 50.9% (5,693) of the unemployed and females, 49.1% (5,500). The majority of the unemployed were young: 15 – 19 years (14.1%), 20 – 24 years (22.8%) and 25 – 29 years (14.6%). Collectively, these three groups accounted for 51.5% of the unemployed population. The Calliaqua census division had the highest number of unemployed persons (2,441 or 20.0%). This was followed by Suburbs of Kingstown with 1,668 persons (14.9%) and Kingstown with 1,148 persons (10.3%). The Sandy Bay and Southern Grenadines census divisions had the lowest numbers of unemployed persons, with 196 (1.8%) and 283 (2.5%) individuals, respectively.

In 2012, there were 52,014 persons in the labour force (**Table 3-3,** below), representing an increase of 15.6% over 44,984 persons in 2001 (GOSVG, 2012). This overall increase was the net result of the 5,808 females and the 1,222 males who joined the labour force during the intercensal period. The 52,014 person labour force, in 2012, was male dominated. There were 29,383 (56.5%) males, compared with 22,631 (43.5%) females. The Calliaqua census division had the largest proportion with 23.1% of the economically active population. This was followed by Suburbs of Kingstown with 6,823 (13.1%) and Kingstown with 6,367 (12.2%). Sandy Bay, with 1,057 (2.0%) economically active persons, had the lowest supply of labour by census division.

Table 3-3: Working Age Population by Economic Activity and Census Division, 2012

Census Division	Work Age Population	Economically Active (Labour Force)			Persons not in Labour Force
		Employed	Unemployed	Total	
Kingstown	9,721	5,219	1,148	6,367	3,354
Suburbs of Kingstown	10,207	5,155	1,668	6,823	3,384
Calliaqua	18,407	9,762	2,241	12,003	6,404
Marriaqua	5,821	2,954	733	3,687	2,134
Bridgetown	4,935	2,307	645	2,952	1,983
Colonarie	5,124	2,146	813	2,959	2,165
Georgetown	5,172	2,291	830	3,121	2,051
Sandy Bay	1,874	861	196	1,057	817
Layou	4,791	2,172	751	2,923	1,868
Barrouallie	4,076	1,808	617	2,425	1,651
Chateaubelair	4,168	1,740	623	2,363	1,805
Northern Grenadines	4,851	2,470	645	3,115	1,736
Southern Grenadines	3,116	1,936	283	2,219	897
Total	82,263	40,821	11,193	52,014	30,249

Source: GOSVG, 2012.

In 2012, employed economically active persons (see **Table 3-4**) were employed primarily as Services and Sales Workers (26.0%), Craft and Related Trades Workers (13.4%) and Elementary Workers (13.4%). Services and Sales was the main occupation for each age group, with the exception of those 65 years and over, who were mainly engaged in the occupational group Skilled Agricultural, Forestry and Fishery (GOSVG, 2012). This was the fourth largest occupational group, representing 12.5% of employed persons. The other occupational groups: Professionals (11.1%), Technicians and Associate Professionals (7.1%), Clerical Support Workers (6.2%), Plant and Machine Operators, and Assemblers (5.0%), and Managers (4.0%), collectively accounted for 33.4% of the employed labour force.

Table 3-4: Currently Employed Population by Occupational Group, 2012

Occupational Group	Count			Percent (%)		
	Male	Female	Total	Male	Female	Total
Managers	968	661	1,629	4.1	3.9	4
Professionals	1,553	2,991	4,544	6.6	17.5	11.1
Technicians and associate professionals	1,436	1,470	2,906	6.1	8.6	7.1
Clerical support workers	606	1,905	2,511	2.6	11.1	6.2
Service and sales workers	4,442	6,188	10,630	18.8	36.1	26
Skilled agricultural, forestry and fishery workers	4,230	880	5,110	17.9	5.1	12.5
Craft and related trades workers	4,995	472	5,467	21.1	2.8	13.4
Plant and machine operators/assemblers	1,928	110	2,038	8.1	0.6	5
Elementary occupations	3,246	2,220	5,466	13.7	13	13.4
Not Stated	286	234	520	1.2	1.4	1.3
Total	23,690	17,131	40,821	100	100	100

Source: GOSVG. 2012.

3.2 ECONOMIC INFORMATION

Saint Vincent and the Grenadines is considered a low income country and in 2017, was 189th worldwide for its economy with a Gross Domestic Product (GDP) of USD$790 million reported in 2017 (WB, 2018). For 2017, the World Bank reports a per capita income of USD$7,185 for SVG. The inflation rate reported by the Department of Statistics of GOSVG is 2.2% for January 2017 to December 2017. The exchange rate in 2018, reported by World Bank, was USD$1 to EC$2.7.

While tourism is the lead sector in St. Vincent and the Grenadines (GOSVG, 2013), the economy of St. Vincent and the Grenadines historically has had the Agricultural Sector as one of its major pillars. In the 1980s and 1990s, banana and root crops exports were predominant resulting in Agriculture accounting for nineteen (19) % of annual GDP (FAO, 2011). In 1995, when World Trade Organization (WTO) trade rules were implemented, Saint Vincent and the Grenadines lost its banana preferential market status in Britain and the European Union (Wilson et al., 2009). This has led to a significant decline in banana exports and foreign exchange earnings. Beyond bananas, root crops (dasheens, eddoes, sweet potatoes, ginger, and yams), plantains, mangoes and coconuts are the main exported products. Arrowroot is the main processed output of the agricultural sector (WUSC Caribbean 2016).

Table 3-5 below provides a snapshot of the trade patterns for SVG in 2012 (IDB, 2013). More than one-half of all imports are energy-related. Fluctuations in international oil prices had a significant impact on the overall external current account for the island. Given the absence of a large manufacturing base, most machinery and equipment required for the production of goods and the provision of services are imported. The US is the country's largest trading partner, accounting for 33% of all imported goods, mostly consisting of consumer items (IDB, 2013). On the export side, the main commodity export category remains agricultural commodities, with alcoholic beverages also appearing in the top five export categories. More than one-third of these exports go to St. Lucia, with most of the remainder going to Trinidad and Tobago, Barbados and the UK.

Table 3-5: Trade Snapshot for Saint Vincent and the Grenadines, 2012

Top Imports	Value (USD$)
Mineral fuels, mineral oils and products of their distillation; bituminous substances; mineral waxes	114,989,177
Reactors, boilers, machinery and mechanical appliances; parts thereof	25,071,992
Electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles	25,027,192
Cereals/Grains	21,027,192
Meat and edible meat offal	20,023,676
Top Imports	**Value (USD$)**
Products of the milling industry; malt; starches; inulin; wheat gluten	11,647,684
Edible vegetables and certain roots and tubers	4,967,036
Beverages, spirits and vinegar	4,434,225
Cereals/Grains	4,383,287

Source: IDB 2013.

The industrial structure of St. Vincent and the Grenadines is dominated by services: in 2012 real-estate, renting and business activities; wholesale and retail trade; and transport, storage and communications together accounted for 48.1% of GDP (IDB, 2013). There is informal labour participation in the agricultural, construction and retail sectors. In 2010 around 80% of Vincentian businesses were informal, micro or small enterprises, and 60% of all employed persons were working in micro and small enterprises (IDB, 2013). Key industries, such as construction, wholesale and retail trade, and tourism, reported double-digit annual rates of decline in output in 2008-10, resulting in a significant deterioration in the local employment profile.

4.0 NATURAL HAZARDS

The United Nations International Strategy for Disaster Reduction (UNISDR) defines a natural hazard as a natural process or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage (UNISDR, 2007). Natural hazards can be divided into two main categories, fast-onset hazards such as storm surge, hurricanes and volcanic eruptions; and slow-onset hazards such as droughts. Communities worldwide are increasingly affected by natural hazards such as hurricanes, floods, droughts and wildfires. Disasters such as these, along with countless more frequent disasters of smaller magnitude, have been responsible for the loss of at least a million lives over the last decade, with recovery often taking years and financial losses estimated to be in the trillions of US dollars (UNISDR, 2013).

Saint Vincent and the Grenadines is exposed to a range of natural hazards such as hurricanes, storm surges, floods, landslides, volcanoes and coastal erosion with hazards stemming from weather related phenomena such as winds, rainfall, hurricane and drought representing the most significant risk (GOSVG, 2011). Human welfare, national economic well-being, property and natural resources are significantly affected by the significant and recurrent damages to national infrastructure caused by these hazards. 41.6% of the population is exposed to risk of mortality from 2 or more hazards (GFDRR, 2010). This section provides an overview of the main natural hazards that historically have affected SVG.

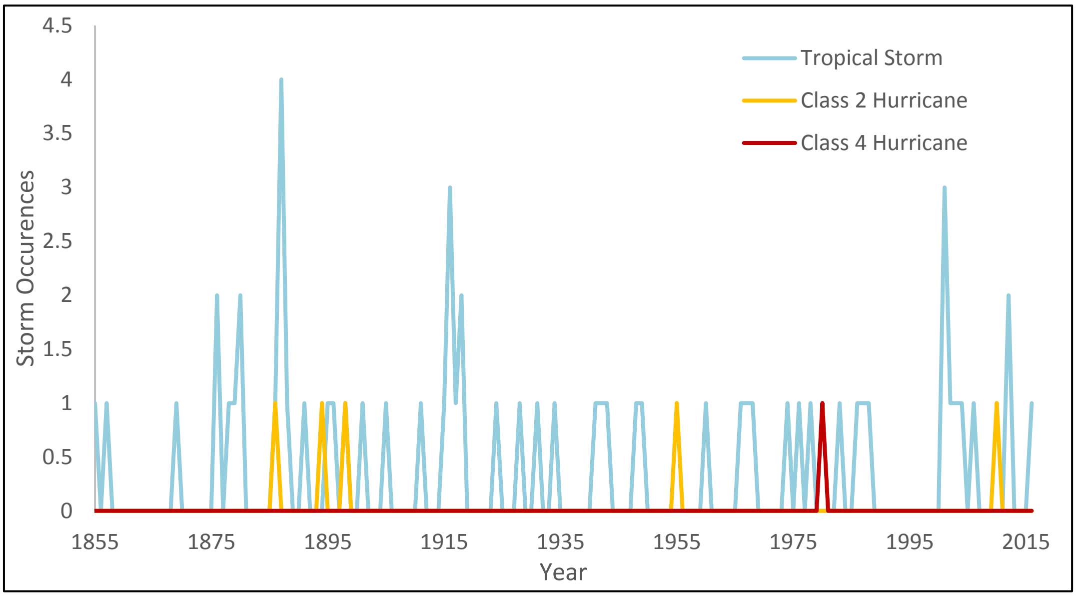
4.1 BASELINE NATURAL HAZARDS

4.1.1 Hurricanes

Tropical cyclones are rapidly rotating storm systems characterized by a low-pressure center and a spiral arrangement of thunderstorms. They usually bring strong winds and produce heavy rain. Depending on the storm intensity, tropical cyclones are classified as tropical depressions, tropical storms, and hurricanes. Storms in the hurricane category are particularly dangerous and have the potential of producing heavy coastal flooding. Hurricanes are further divided into five categories based on the maximum wind speed, central pressure, and resulting potential damages. The hurricane season in the Atlantic Ocean lasts between June 1 and November 30 and generally produces several hurricanes each year to necessitate warnings and alerts in SVG.

Historical data from the Eastern Caribbean sub-region indicates the regional probability of any category of hurricane in any given year is about 18 percent (World Bank, 2014a). It is widely acknowledged that natural events like hurricanes have the potential to cause major economic damage (an exogenous shock) - resulting in significant unforeseen public expenditures. For example, while not a direct hit, damages to SVG caused by Hurricane Ivan in 2004 were estimated at US $40 million or approximately 10 percent of GDP. This was compounded by GDP losses incurred in subsequent years owing to reduced agricultural productivity and impacts to the tourism sector World Bank, 2014a).

Since 1900, Saint Vincent has been hit by 8 storms, the strongest being Category 4 Hurricane Allen, which passed between Saint Lucia and Saint Vincent in 1980. Hurricane Hazel (Category 1), Tomas (Category 2) and Hurricane Lenny (Category 4) have also severely affected the country. There have been 65 storms that could have potentially affected Kingstown between 1855 and 2016 (**Figure 21**). Within the past 161 years there has been 1 major category 4 hurricane and 5 category 2 hurricanes to pass by St Vincent and the Grenadines. All remaining storms were either tropical storms or tropical depressions. In most cases Atlantic storms and hurricanes follow a west-northwest track as they approach the Windward Islands. In rare circumstances, such as Lenny (1999) and Omar (2008), they can develop west of the island in the Caribbean basin and move in an easterly direction and can cause damage to St Vincent's west coast. Such storms can also impact Kingstown Bay which, at the leeward side of the island, is usually protected by two promontories (Cane Garden Point and Old Woman Point) extending about 1.3 km out into the sea.



Source: NOAA National Hurricane Center

Figure 21: Occurrence of Hurricanes and Tropical Storms Affecting Saint Vincent and the Grenadines (1916 – 2016)

Return periods for tropical storms and hurricanes were calculated using the methods outlined by the National Oceanic and Atmospheric Administration (NOAA, 2018a). The probability of occurrence was calculated only using the most recent 100 years of data from 1916 to 2016. All storm paths that fell within a 50 nautical mile (58 mile) radius of Kingstown were used in this analysis. **Figure 22** below shows the trajectories of related weather systems during this period.

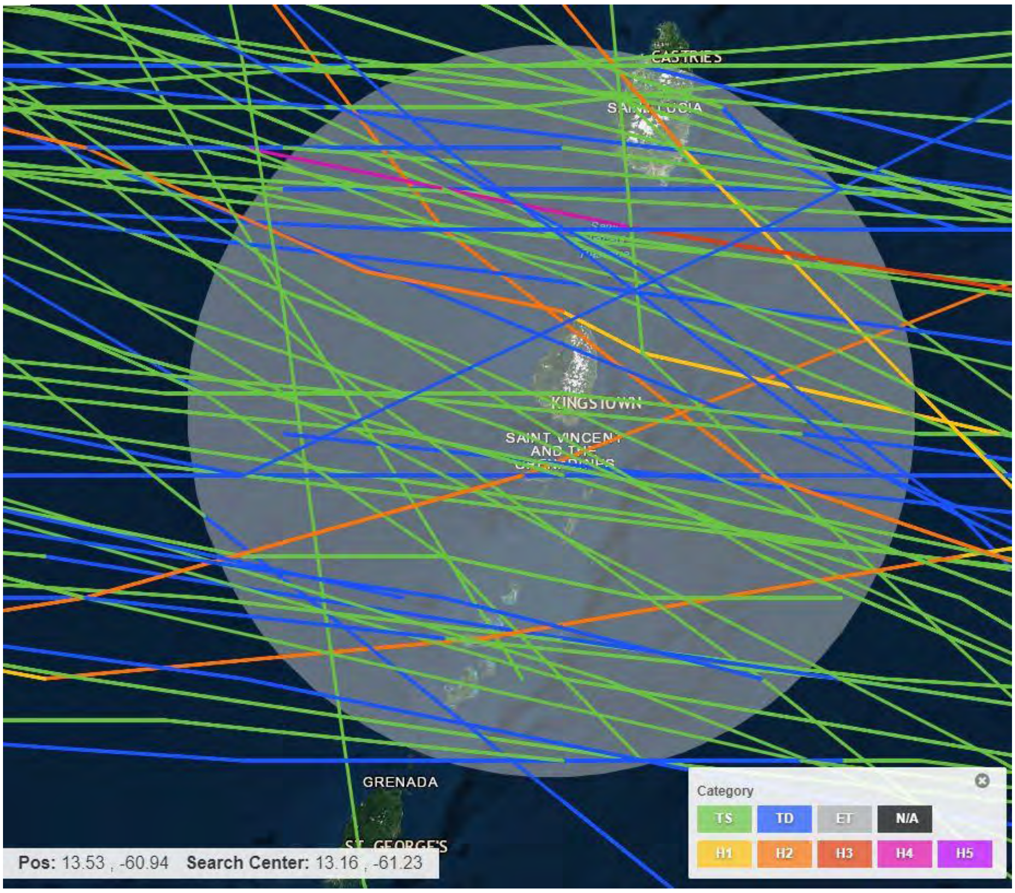


Figure 22: Trajectories of Hurricanes and Tropical Storms (1916 – 2016)

The average return period for a tropical storm was calculated to be 1.69 years while the return period for a hurricane was 33.33 years. Furthermore, class 2 hurricanes had a return period of 50 years while hurricane class 4 only had a return period of every 100 years due to the low number of historic occurrences. Therefore, there is a 59% annual probability that a tropical storm will affect Kingstown with only a 2% chance of a class 2 hurricane and a 1% chance of a class 4 hurricane.

4.1.2 Storm Surges

NOAA defines storm surge as an abnormal rise of water generated by a storm, over and above the predicted astronomical tides (NOAA, 2017a). Storm surge is the combination of wind setup and pressure setup during hurricanes and tropical storms. Wave setup is the increase in mean water level due to the presence of waves and is largest during tropical storms and hurricanes.

As part of the Caribbean Disaster Mitigation Project (CDMP), USAID and the Organization of American States (OAS) produced maximum likely estimates for surge, wave height and wind speeds across the Caribbean basin for 10-, 25-, 50- and 100-year return periods[2] by using the TAOS model. Estimates were made for each cell in approximately 1 km x 1 km grid, covering the entire Caribbean (CDMP, 2001).

Coastal flooding is a major concern on Saint Vincent, particularly relating to storm surge and high wave action. Flash flooding from mountain streams coupled with

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[2] A 100-year return recurrence interval or return period event can be described as an event having a 100-year recurrence interval or a probability of 1 in 100 chance that a particular event will occur during any year.

storm surge events present the greatest risk from flooding (GFDRR, 2010). Effects are generally limited to communities located in the coastal margins along stream passages. These are usually coastal fishing villages located where access to the sea is open, as much of the island's coast is marked by cliff formations. While bay and harbor areas are particularly at risk, storm surge and wave action pose a particular risk to the eastern side of St. Vincent where the coast is exposed to potentially very long fetch waves. The Windward Highway, a principal route linking the east and west sides of the island, was constructed very near the coastal margin and is vulnerable to wave action and storm surge.

4.1.3 Coastal Erosion

Storm episodes often cause extensive beach erosion that has severe economic impacts in many eastern Caribbean nations. In some areas of St. Vincent, for instance, an estimated 18-30 meters of beach were lost between 2005 and 2014 (World Bank, 2014b). A recent study by CARIBSAVE (2012a) completed a detailed coastal profile of five study sites throughout SVG. St. Vincent. One metre and two metre SLR scenarios and beach erosion scenarios of 50 m and 100 m, were used to assess the potential vulnerability of major tourism resources. Results of these surveys indicate that 1 m SLR places 10% of the major tourism properties at risk, along with 1% of road networks, 50% of airports and 67% of sea ports (CARIBSAVE, 2012a). With 2 m SLR, 24% of major tourism resorts will be impacted and 75% of airports. Critical beach assets will be affected much earlier than SLR-induced erosion damages to infrastructure. Once erosion damages infrastructure, the beach, which is a vital tourism asset, will have already essentially disappeared

With 100 m of erosion (resulting from approx. 1 m SLR), 76% of the major tourism resorts will be impacted and 47% of sea turtle nesting sites will be impacted (CARIBSAVE, 2012a). Engineered structures and natural environments (e.g., mangroves) can protect against some of these impacts to coastal regions, but the dynamics of these erosion processes will demand some adaptation of coastal infrastructure and settlements.

4.1.4 Flash Flood Susceptibility

The low lying areas in the Kingstown port area are highly susceptible to flash flooding from storms or heavy rain. Specifically, the land area directly adjacent to the proposed Container Terminal location is extremely susceptible to flooding (**Figure 23**). Within the 1-kilometer boundary from the proposed Container Terminal location, 565 out of the total 3,026 buildings that fall within a very high susceptible area for flash flooding. In addition, there are 74 buildings that fall within the high susceptibility range, 93 in the moderate, and 105 in a low susceptibility zone. These results suggest that flash flooding may be the most common physical risk to structures in Kingstown.

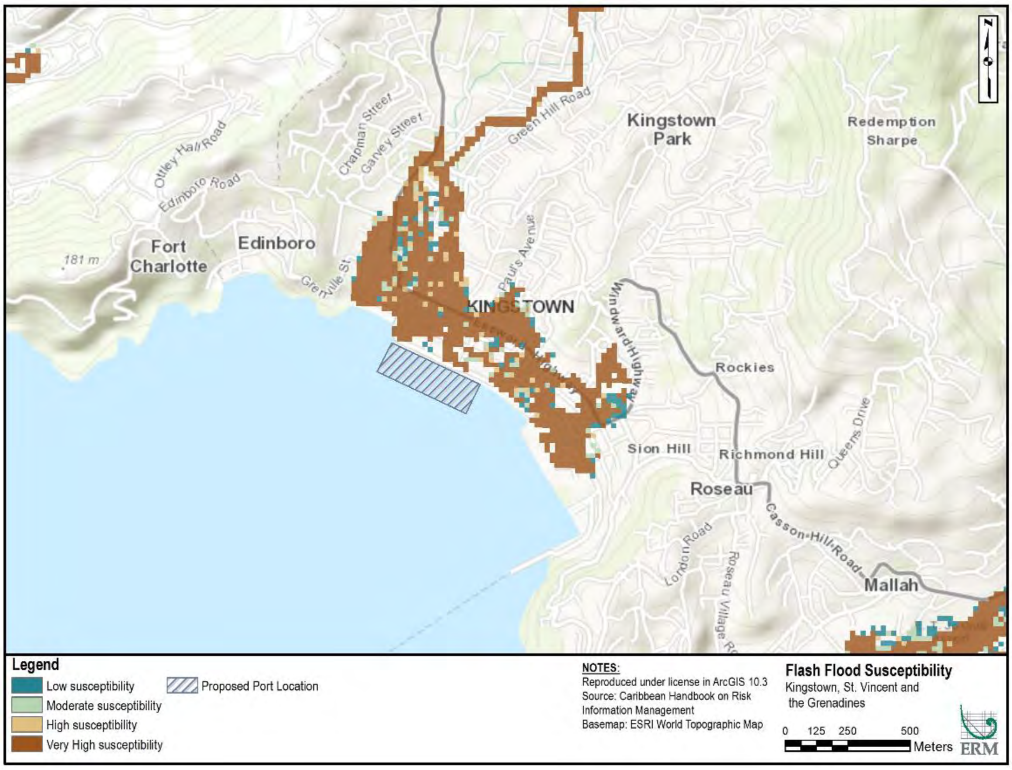

Figure 23: Flash Flood Susceptibility in the Study Area

4.1.5 Landslides

Flooding and landslides associated with persistent rain and severe storms are common in the Caribbean. Like other islands of volcanic origin in the Caribbean, SVG is vulnerable to landslides resulting from the combination of its volcanic geomorphology and steep terrain (GFDRR, 2010). Road cuts and building constructions on steep slopes contribute to landslide potential; there is little flat land available for construction. Structures built without adequate design or quality control are at greatest risk. Landslides are usually associated with periods of prolonged rainfall as occurs during the rainy season from May to November.

Severe rains and high winds due to a low level trough system caused floods and landslides in SVG, Saint Lucia and Dominica from 23-25 December 2013. Saint Vincent and the Grenadines reported nine deaths and over five hundred persons affected, of which 237 were provided with emergency shelter. According to preliminary reports from initial assessments 30 homes were destroyed and a further 135 damaged. Assessments are on-going and these numbers are expected to increase. The Government declared a level two disaster. A level two disaster is declared when the damage is severe and for which local resources and response capacity are limited and specialized external assistance is requested. In Saint Lucia, six people were killed, and Dominica reported 185 people affected. (CDEMA, 2014). As recently as 2016, heavy rains provoked numerous landslides in SVG, resulting in 1 death and the activation of search and rescue operations.

The majority of the land area proximal to the project area has a low level of landslide susceptibility (**Figure 24**). There have been eleven landslides documented close to the population center of Kingstown, and only four have been within 1 kilometer of the proposed Container Terminal location. All of the previous landslides have occurred on the outskirts of the major population center along the steep cliffs to the west of east of the proposed Container Terminal location. There have been no reported landslide incidences within the major populated area.

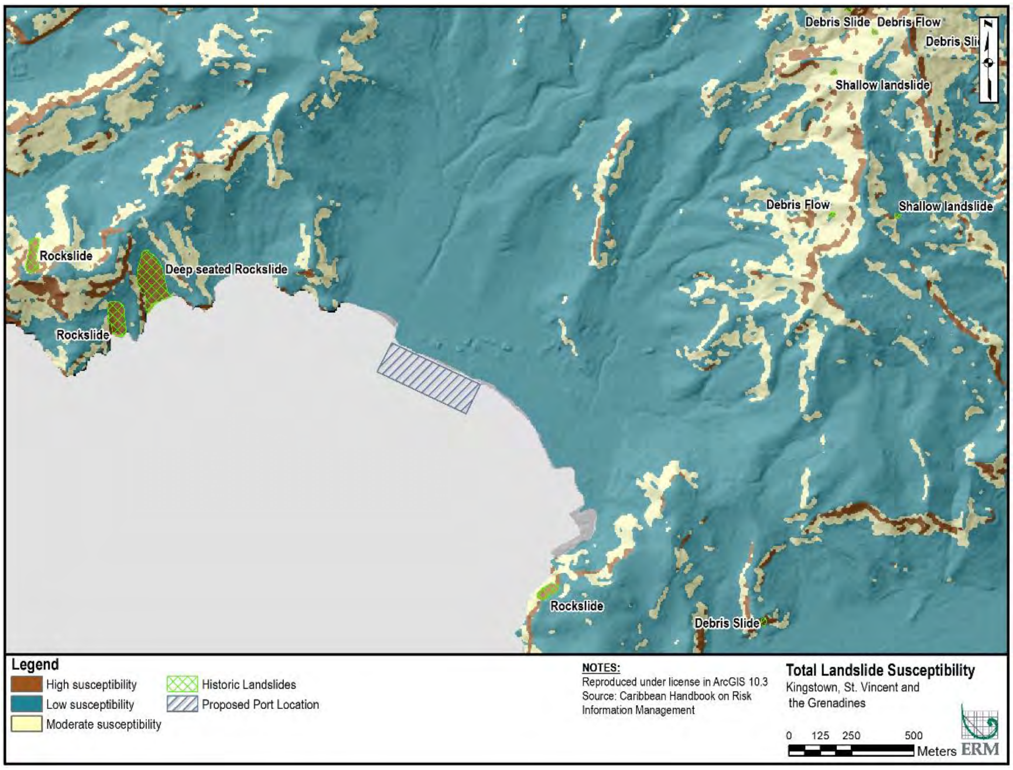

Figure 24: Landslide Susceptibility within a 1-kilometer Boundary of the Project Area.

Total landslide susceptibility is an approximation of the combined shallow landslide and rockslide susceptibility. Shallow landslides historically have occurred in the high slope hills further northeast from the proposed Container Terminal location. Similar to the total landslide susceptibility, there is a low likelihood of shallow landslides occurring within a 1-km boundary of the proposed Container Terminal location (**Figure 25**).

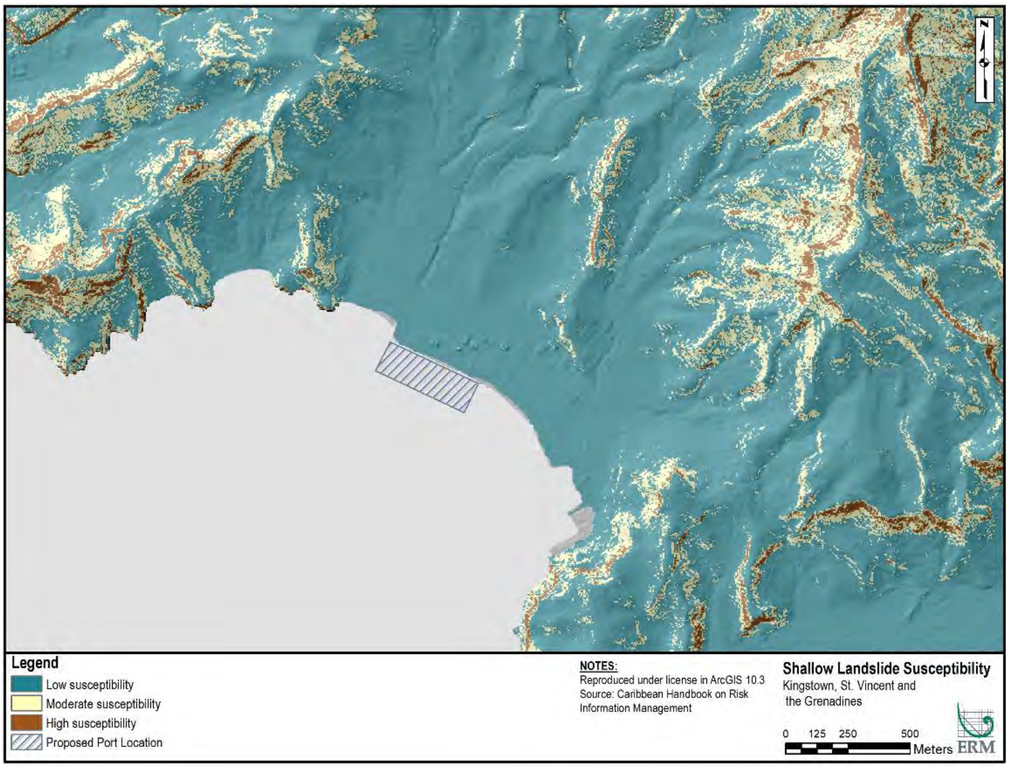

Figure 25: Shallow Landslide Susceptibility within a 1-kilometer Boundary of the Project Area.

Of all landslide types, rockslides have the highest probability of occurring near the project area. All of the landslides that have occurred within 1-kilometer of the project area have been rockslides. However, many of those occurrences have been isolated to the steep slopes on the outskirts of the major populated area in Kingstown. Most of the high slope areas around the city have a high susceptibility, but the major populated area still has a low susceptibility of rockslide occurrence. Rockslides overall susceptibility within 1-kilometer of the port is still much higher relative to shallow landslides with 22% proportion of land area covered by land that is highly susceptible to rockslide incidences (**Figure 26**).

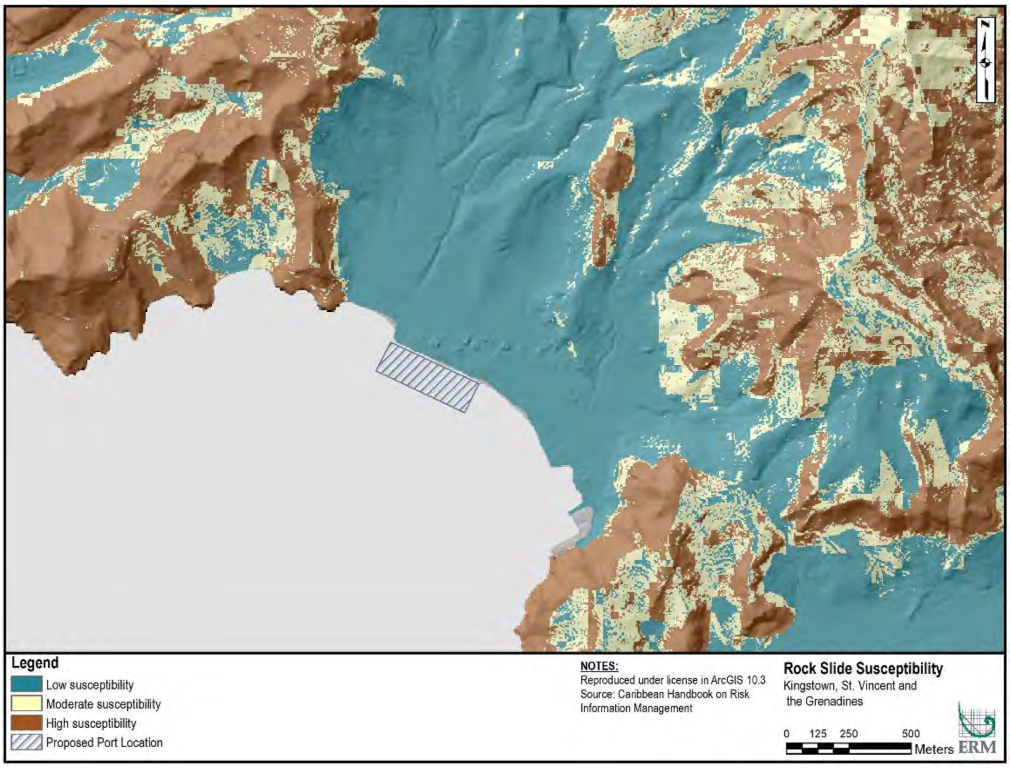

Figure 26: Rockslides Susceptibility within a 1-kilometer Boundary of the Project Area.

4.1.6 Volcanic Eruptions

The Caribbean has several volcanoes distributed all over the region. Those that been recorded as having erupted are classified as active volcanoes. The others are classified as inactive. Presently, the most active is the Soufriere Hills Volcano in Montserrat.

Overall, the country is exposed to low-to-moderate seismic risk - seismic zone 2 on a 0-4 scale[3] (GFDRR, 2010). Its location along the eastern margin of the Caribbean plate exposes the islands to seismic and/or tectonic activity. SVG is particularly vulnerable to shallow seismic activity from one of the more active volcanoes in the eastern Caribbean, La Soufrière, located on the northern portion of Saint Vincent. La Soufriere rises to 1,234 meters and has erupted in historical times. La Soufrière erupted violently in 1718, 1812, 1902, 1971, and 1979. The eruption of 6 May 1902 killed 1,680 people. The last recorded eruption was in April 1979; due to advance warning there were no fatalities (OSU, 2018). Direct impacts are generally limited to the island of Saint Vincent; however, potential ash fall can threaten the neighboring islands. In addition to La the underwater volcano *Kick 'em Jenny* offshore of Grenada, constitutes permanent threats to SVG.

4.1.7 Earthquakes

Earthquakes are common in the Caribbean, particularly in the southeastern Caribbean, which is an area of frequent strong seismicity. Shallow (0-70 km) and intermediate (70-200 km) depth earth quakes of the region have been recorded at teleseimic distances since the early decades of this century, and extensive local

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[3] SEOC (Structural Engineers Association of California) zone system. Zone 2 corresponds to a Z factor of 0.500 as defined under CUBiC 1985.

networks have been maintained in the Lesser Antilles since the 1950s, and in Martinique, Guadeloupe, and Venezuela from even earlier (Russo, et al., 1992).

As shown in **Figure 27**, most of the Caribbean countries lie close to the boundary of the Caribbean Plate, making most of the region susceptible to damaging levels of earthquake shaking (CCRIF, 2013). **Figure 28** shows the epicentral location of earthquakes of magnitude 6.0 and above occurring in the region since 1530.

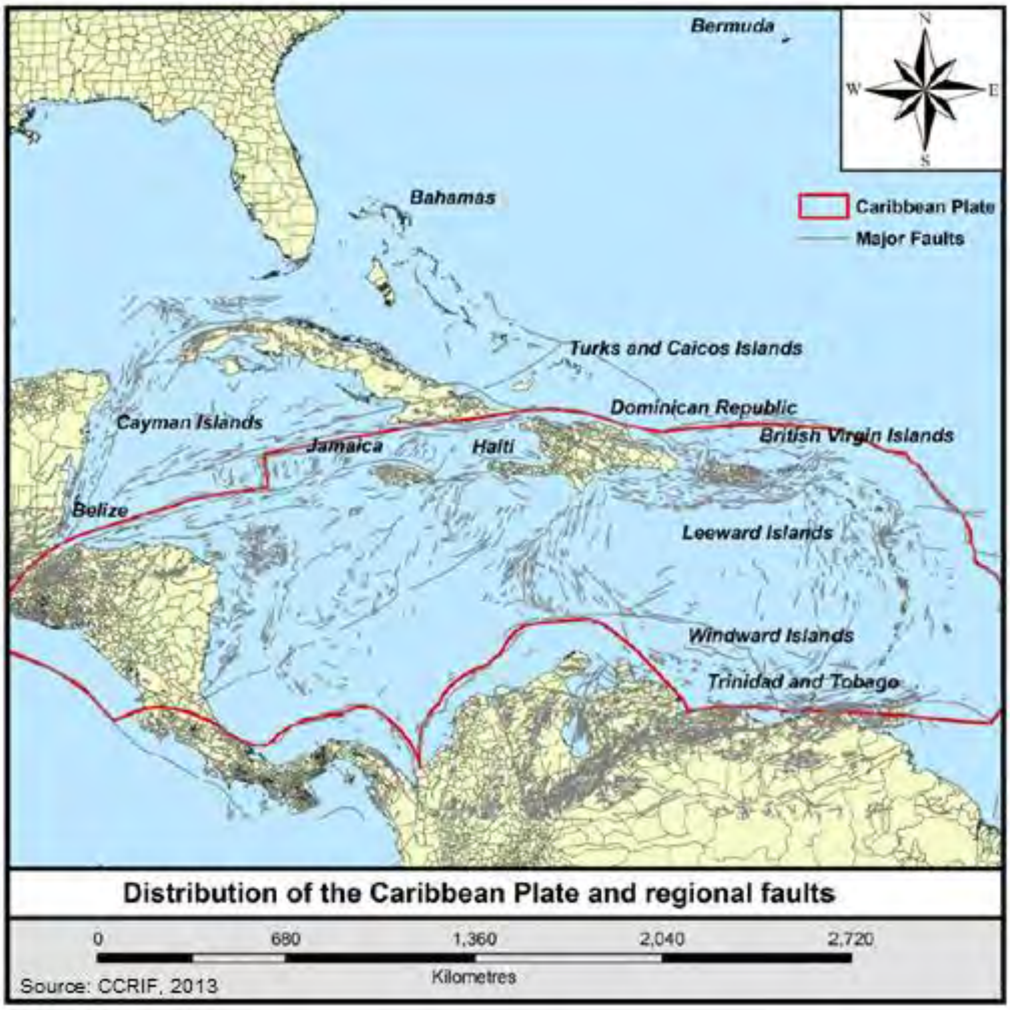
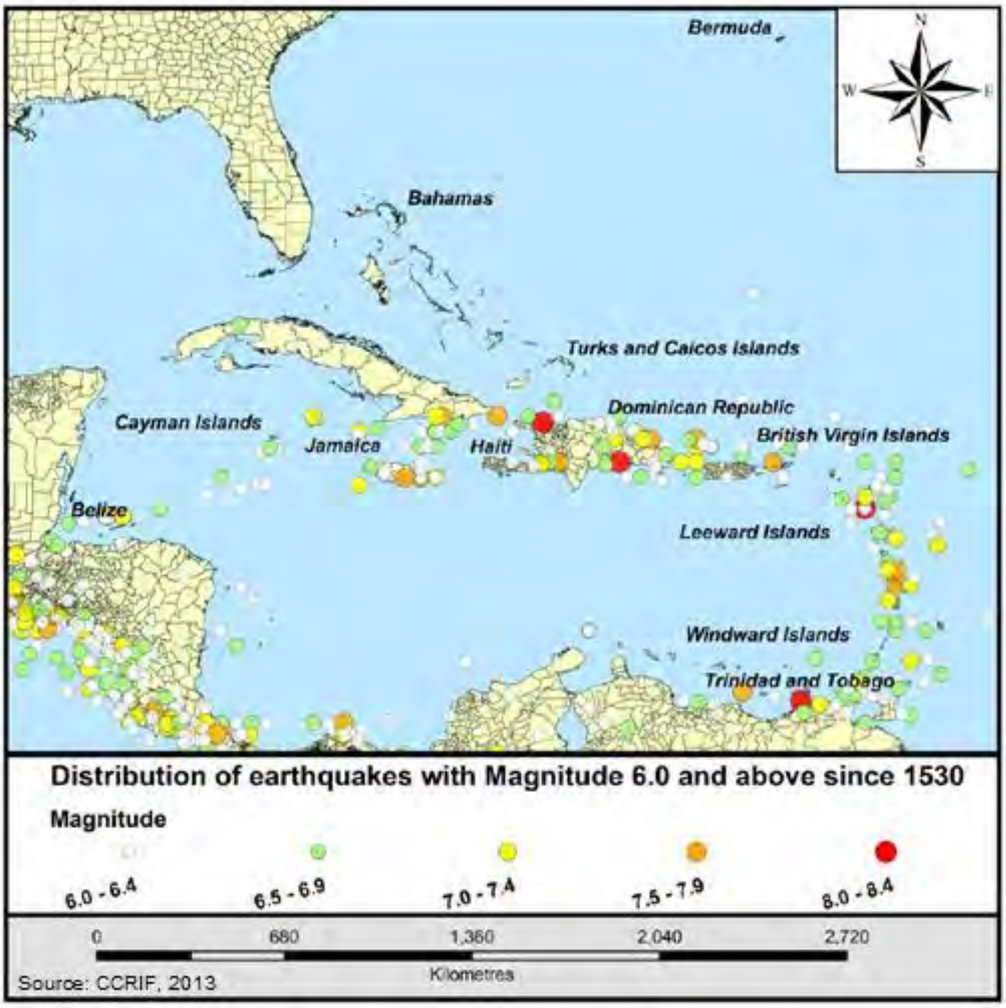


Figure 27: Caribbean Plate and regional faults.



Source: CCRIF, 2013

Figure 28: Earthquakes of magnitude 6.0 or greater since 1530.

One of the most destructive quakes in the Caribbean occurred in 1692 when a 7.5-magnitude quake dismantled the city of Port Royal, Jamaica. Much of the city was submerged under water, and thousands of people lost their lives. The last recorded earthquake in SVG, which occurred on 2 October 2017, was a magnitude 4.3 (Earthquake Track, 2018).

4.1.8 Tsunamis

Although tsunamis are rare in the Caribbean, earthquakes are not. More than a dozen earthquakes of magnitude 7.0 or greater have occurred in the Caribbean in the past 500 years. Several of these have generated tsunamis, with the most recent occurring in 1946 following a magnitude-8.1 earthquake off the northeast coast of the Dominican Republic. The most recent tsunami to hit SVG occurred in 1868 when a tsunami hit Bequia, destroying 2 homes in Admiralty Bay (O'Loughlin & Lander, 2003).

In SVG, the tsunami hazard is classified as *medium* (GFDRR, 2018), indicating that there is more than a 10% chance of a potentially-damaging tsunami occurring in the next 50 years. The areas at risk of tsunami will increase as global mean sea level rises. According to the IPCC (2013), global mean sea level rise depends on a variety of factors, and estimates for 2100 range from ~20 cm to nearly 1 m. However, regional changes in sea level are difficult to predict.

4.2 NATURAL DISASTER RESPONSE

Saint Vincent and the Grenadines is among the most disaster-prone countries in the world, regularly suffering disasters related to natural events such as earthquakes, hurricanes, landslide, rain and drought (GOSVG, 2011). These events have caused significant damages to national infrastructure including housing, road networks, schools, hospitals and utilities such as phone lines, water and electricity. This significantly affects human welfare, national economic activities, property, and natural resources. The effects of climate change are already evident in many parts of the country with rising sea levels and storm activity continuing to impact on exposed coastlines and development. The situation is only expected to worsen because SVG is highly vulnerable to the effects of global warming and climate change.

4.3 NATIONAL DISASTER MANAGEMENT FRAMEWORK

The national structure for Disaster Risk Management and relief coordination in SVG involves numerous key entities. The role of these entities is discussed below.

4.3.1 The National Emergency Council

The National Emergency Council (NEC) sits at the highest level of the network of disaster coordination structures created by the National Emergency and Disaster Management Act (IFRC, 2017). The NEC is a high-level, multi-sector governance authority that is at the helm of disaster management. The NEC is chaired by the Prime Minister and includes several other Ministers of Government, as well as Permanent Secretaries, state officials and functionaries, private sector CEOs and NGO representatives. The NEC provides governance oversight to the National Emergency Management Organisation (NEMO), and guides policy for all aspects of disaster management.

4.3.2 The National Emergency Management Organisation

The NEMO was launched in 2002 and is the core administrative, coordinating body within the network of management and governance systems. The NEMO is an executive body having core staff and year-round functionality in comprehensive disaster management. The NEMO's mandate and functions are defined under SVG's National Disaster Plan and includes the following six categories of activities (IFRC, 2017):

Training: Identifying skills necessary to implement a national disaster management programme and sourcing appropriate trainers.

Informing: Developing and disseminating information packages to help individuals, government entities and private sector to better cope with emergencies. n Warning: Analyzing and forecasting potential hazards.

Coordinating: Coordinating disaster preparedness, response and rehabilitation and enabling resources to be effectively applied during and after a disaster.

Warehousing: Providing and maintaining extraordinary resources and stocks to meet emergency needs.

Evaluating: Conducting annual performance reviews and designing performance improvement measures.

In addition to coordinating the disaster management activities of state entities, the NEMO has a number of memorandum of understandings with charitable, religious, private sector and volunteer organisations, and uses this modality to integrate non-state actors into disaster management while maintaining predictability and reliability of services (IFRC, 2017).

4.3.3 The National Emergency Executive Committee and Sub-Committees

The National Emergency Executive Committee (NEEC), which is chaired by the Director of NEMO, is tasked with the implementation of disaster prevention, preparedness, response and recovery at varying levels. The NEEC implements the plans and policies of the NEC. While it is a voluntary structure, it is comprised primarily by state entities that support to disaster management. Reporting to the NEEC are a total of ten sub-committees covering each of the following issues:

- Public education, training and information
- Damage and needs assessment
- Transport and road clearance
- Emergency shelters and shelter management
- Emergency supplies
- Health services
- Emergency telecommunications
- Search and rescue (land and sea)
- Rehabilitation and reconstruction
- Voluntary services

4.3.4 District Disaster Management Committees

Each district disaster management committee covers a specific geographic area, and develops disaster management plans for that area. Their existence is critical within the SVG territory, which is comprised of 32 islands, islets and cays, with differing disaster profiles, evacuation schemes, localized resources etc. (IFRC, 2017). Each district is required to have disaster alert and response mechanisms that can – if required – function independently. Each committee is led by a district coordinator, and reports to the NEEC.

4.3.5 National Emergency Operations Centre

During a disaster alert or disaster, the National Emergency Operations Centre (NEOC) is convened and becomes the hub of communications and coordinated activities (IFRC, 2017). It that operates primarily during an alert or disaster and manages initial relief coordination. The NEOC, therefore, includes executive personnel from the state entities that drive disaster response, relief and recovery, and can also have the support and input of non-state disaster relief actors, as well as the media.

5.0 BASELINE ANALYTICS

A first step in designing effective adaptation strategies is to clearly establish the baseline conditions. The current baseline is defined by historic climate conditions and the prevailing conditions at the time of the assessment. The following sections provide an evaluation of baseline climatological conditions.

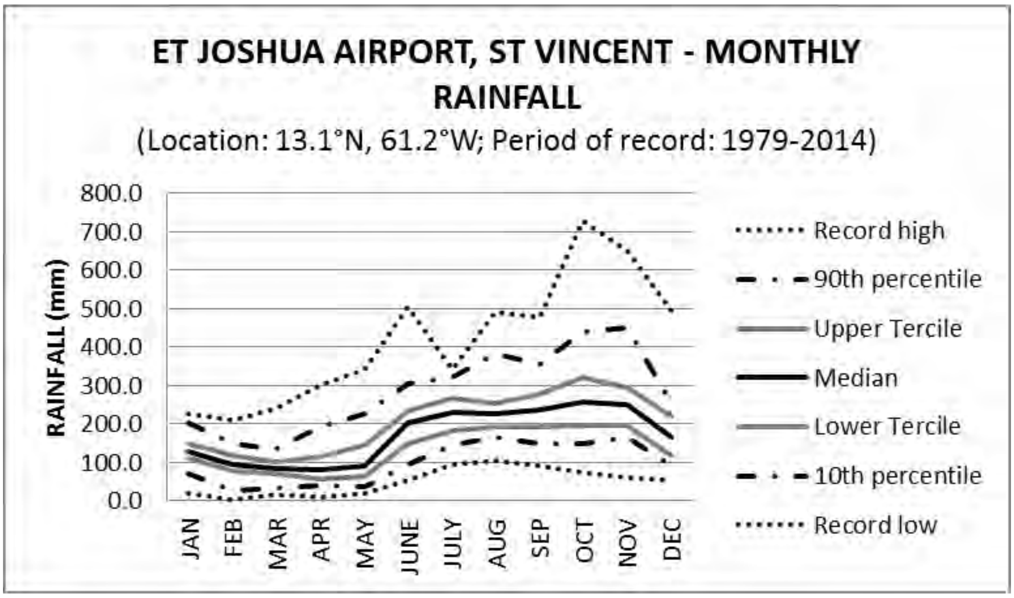
5.1 CLIMATOLOGY

5.1.1 Air Temperature

Baseline air temperature at the weather station at E.T. Joshua Airport, measured daily from 1999 - 2016, ranged from 18.5 °C to 33.5 °C. The average minimum temperature was 24.7 °C and the average maximum temperature was 30.4 °C. Throughout the year, the average minimum temperature varies by only 1.6 °C. Likewise, the average maximum temperature varies by only 1.6 °C.

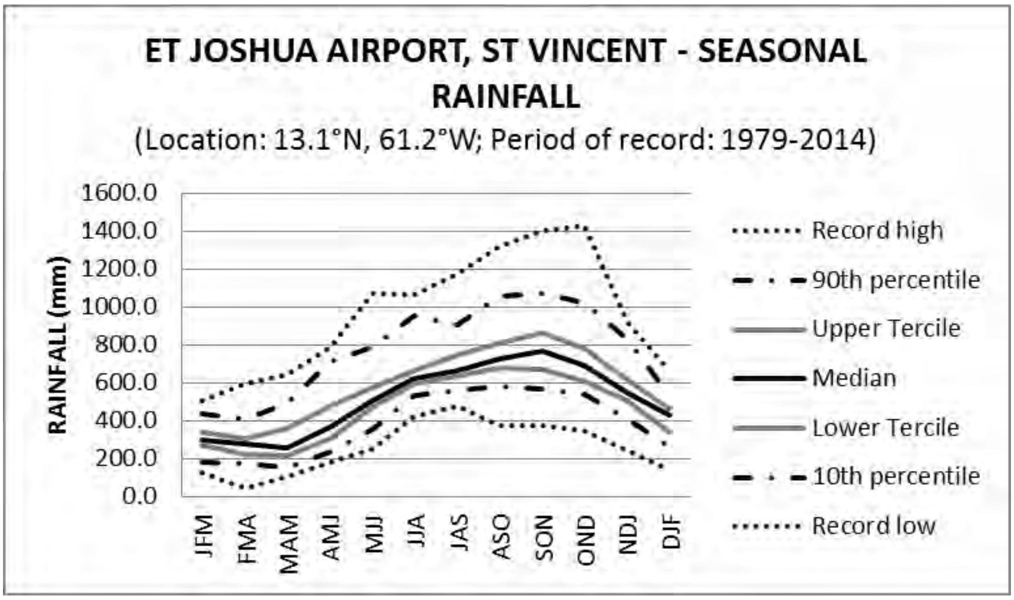
5.1.2 Precipitation

Baseline daily precipitation data were taken from the weather station at E.T. Joshua Airport for the period of record spanning 1979 – 2014 (CIMH, 2018). During this period, the average annual rainfall was 2187.1 mm. The wettest year on record was 2011, with 3424.7 mm of rain. The wettest month on record was October 1998 with 727.9 mm of rainfall (Figure 29). The wettest month on average is also October with 283 mm of rainfall. The peak wet season is September, October, November with an average rainfall of 803.1 mm (Figure 30). The driest year on record was 1997 with 1594.1 mm of rainfall. The driest month on average is March with 86.4 mm of rainfall (Figure 29). The driest month on record was February 2010 with only 2.7 mm of rainfall. The peak dry season on average is February, March, April with 279.8 mm of rainfall (Figure 30). The driest 3-month period on record was February, March, April 1987 with only 44.7 mm of rainfall.



Source: CIMH, 2018.

Figure 29: Monthly Rainfall at E.T. Joshua Airport.



Source: CIMH, 2018.

Figure 30: Seasonal Rainfall at E.T. Joshua Airport.

5.1.3 Wind

Wind at E.T. Joshua Airport for the period 1997–2018 was mostly north and easterly, off the Atlantic (**Figure 31**), largely coming from the Northeast Trade Winds and the Intertropical Convergence Zone.

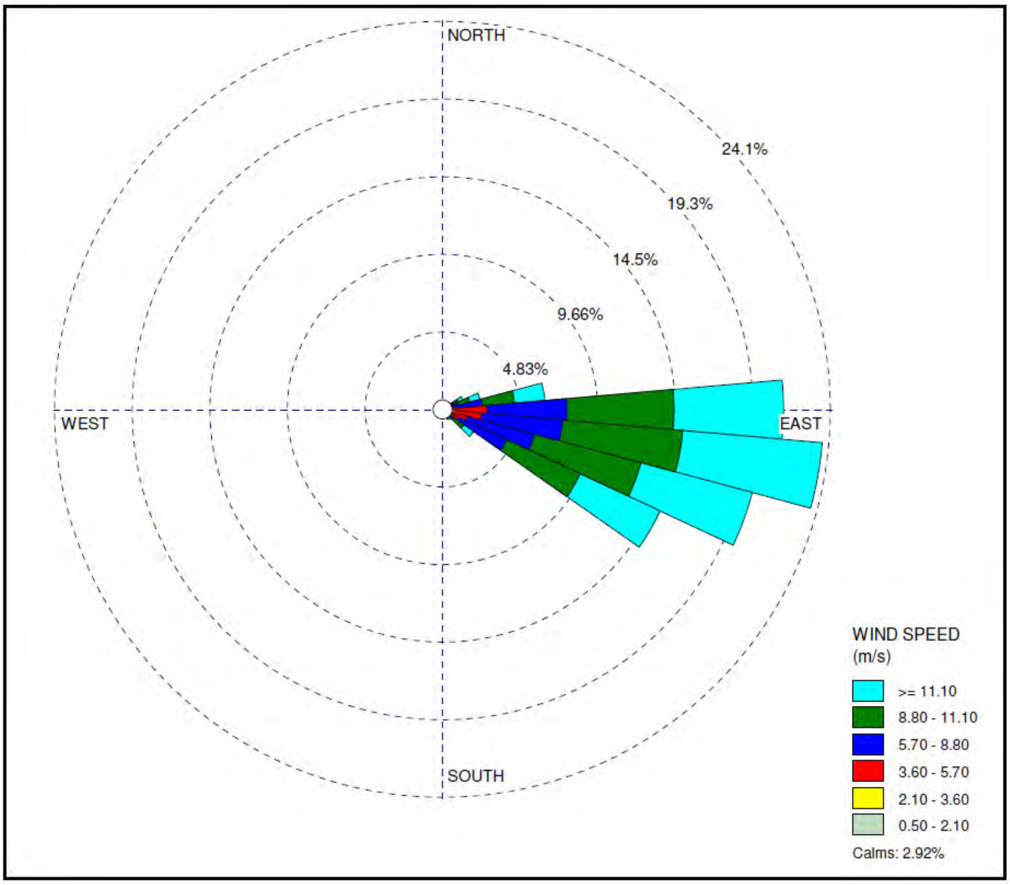


Figure 31: Wind Rose for E.T. Joshua Airport.

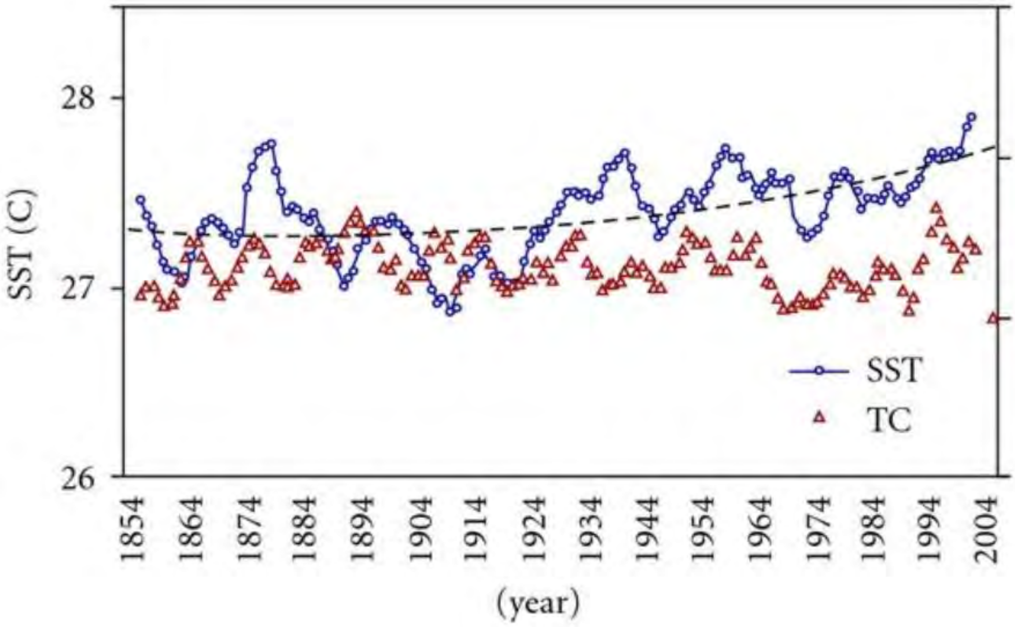
5.2 COASTAL OCEANOGRAPHY

5.2.1 Sea Temperature

The average temperature of the Caribbean Sea is 27°C (Spalding et al., 2001). Persistent subtropical trade winds, year-round sunshine, and consistent water exchanges result in little seasonal variation – no more than 3°C (Spalding et al., 2001, Jury 2011). The surface warm layer is >100 m deep and the upper 1200 m is stratified (Murphy et al., 1999 and Andrade and Barton, 2000).

The historical Caribbean-area surface temperatures are illustrated in **Figure 32**. Sea surface temperatures (SST) exhibit quasi-decadal oscillations and a cool period in the early 20th century (Jury, 2011). There is a positive trend with a 40% fit suggesting acceleration of warming in the late 20th and early 21st century.

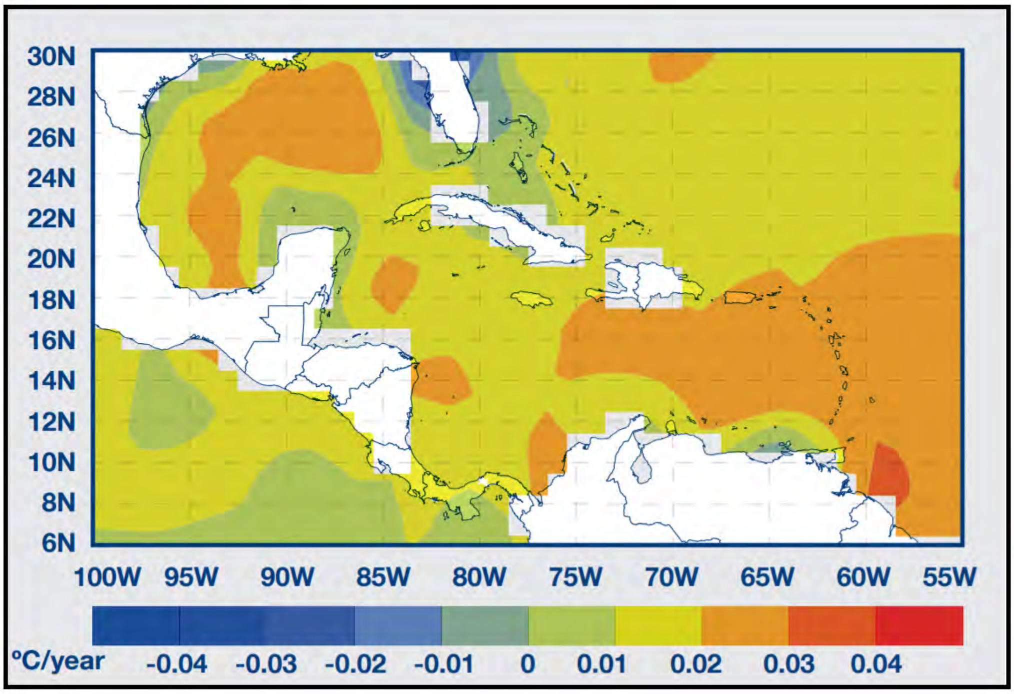
Source: Jury, 2011



Source: Jury, 2011

Figure 32: Caribbean area-averaged 5-year smoothed time series for SST and tropical cyclones (TC).

Glenn, et al. (2015) showed a sea surface temperature (SST) warming trend for the Caribbean and surrounding region over the period 1982–2012. Using an optimum interpolated SST product, a 30 year climatological analysis was generated to observe annual, monthly, and seasonal trends. Results show SSTs increasing annually for the region. For the two Caribbean rainy seasons, the Early Rainfall Season and the Late Rainfall Season, estimated increases of 0.0161 °C yr^{-1} and 0.0209 °C yr^{-1} were observed. This pattern is also borne out with more recent data indicating that SSTs around SVG have increased 0.02 – 0.03 °C during the period 1982 – 2016 (**Figure 33**; CMEP, 2017).



Source: CMEP, 2017. Data from NOAA Optimum Interpolation SST Dataset.

Figure 33: Detected Sea Surface Temperature Trends (Per Degree Celsius Per Year) for the Intra-Americas Region Over the Period 1982–2016.

5.2.2 Waves

Generally, hurricanes and other storms follow a west-northwest track as they approach SVG. In these cases, the Project Area is fairly protected from wave action. However, on the rare occasion that storms develop in the Caribbean basin, leeward side of the island, including the Project Area, are vulnerable to wave action. For example, on the north leeward side of the island, waves from hurricane Lennie destroyed ten (10) meters of coastal forest that stood for over fifty years (GOSVG, 2001). The same storm destroyed the coastal access road 15 m inland at Richmond and swept away a small coastal village in Rose Bank. Discussions with local authorities also revealed that the cruise ship berth adjacent to the proposed Container Terminal also received damage from waves generated by Hurricane Lenny.

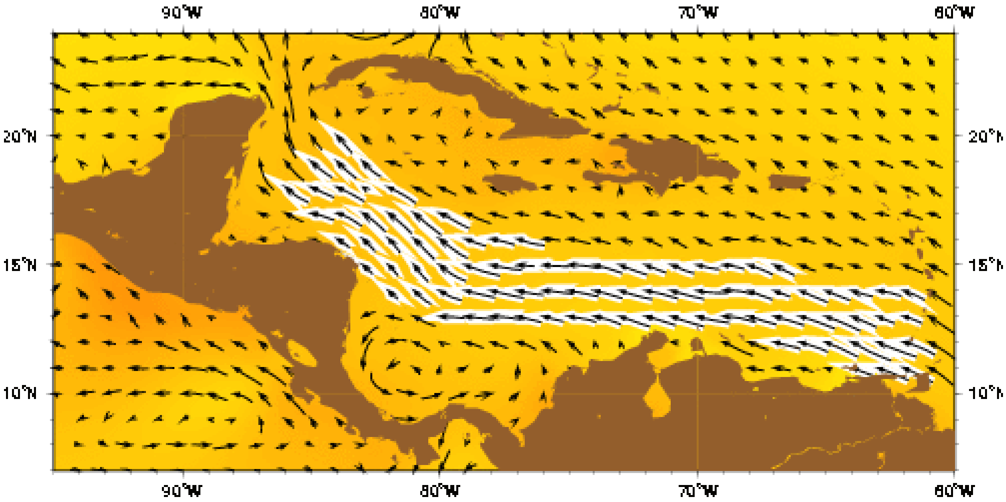
5.2.3 Currents

The Caribbean is a semi-enclosed sea adjacent to Central and South America. The closely spaced chain of islands, banks, and sills of the Antilles Islands Arc separate the Caribbean from the Atlantic Ocean and act as a sieve for the inflow of Atlantic water (Murphy et al. 1999; Andrade and Barton 2000). The Caribbean Sea is highly stratified in the upper 1200 m of the water column; weakly stratified between 1200 and 2000 m; and nearly homogeneous below 2000 m. This water structure is directly related to the sill depths of the Antilles Islands arc, because they impede the flow of deep water into the Caribbean (Gordon 1967). In total, the Caribbean Sea spans over 3500 km of longitude and about 2500 km of latitude (Andrade and Barton 2000).

Water flows into the Caribbean Sea mostly through the Grenada, St. Vincent, and St. Lucia Passages in the southeast (Johns et al., 2002, Gordon, 1967, and Wust, 1964; see

Source: RSMAS, 2018

Figure 34). The water then continues westward as the Caribbean Current, the main surface circulation in the Caribbean Sea (Wust 1964; Gordon 1967; Roemich 1981; Hernandez-Guerra and Joyce 2000). The strongest flow in the Caribbean belongs to the Caribbean Current (Gordon 1967; Kinder 1983). In this area, the highest surface velocities can reach 70 cm s-1 along the coasts of Venezuela and the Netherland Antilles (Fratantoni 2001). There are also strong (60 cm*s^{-1}) currents along the Panamanian and Colombian coasts, but there is little flow over the Central American Rise, since most of the northwestward flow gets channeled through a trough southwest of Jamaica. The flow turns sharply westward as it crosses the Cayman Basin, and it enters the Gulf of Mexico as a narrow boundary current that hugs the Yucatan Peninsula (Fratantoni 2001). This Yucatan Current flows into the Gulf of Mexico through the Yucatan Channel. It eventually becomes the Loop Current. The Loop Current then becomes the Florida Current as it exits the Gulf of Mexico through the Straits of Florida (Molinari and Morrison 1988).



Source: RSMAS, 2018

Figure 34: The Caribbean current as represented by the Mariano Global Surface Velocity Analysis (MGSVA).

5.3 NON-CLIMATE STRESSORS

5.3.1 Water Resources

It is generally believed that the supply (surface water from rivers and springs) on Saint Vincent is more than enough to meet developmental needs. However, studies have shown a slow but steady decline in flow volume of many rivers in Saint Vincent (ECLAC, 2011). The major rivers on the mainland are the Richmond, Cumberland, Buccament, Yambou and Colonarie, all originating at high elevations in the centre of the island and flowing in steep river valleys to the coast. The higher rainfall in these upper catchments and the likelihood of these streams being fed by base-flow from coarse, weathered rock debris beneath, may explain not only the greater flow rates of these streams but also their perennial nature. Some of the smaller rivers, particularly on the west coast, are intermittent. More noticeable than the decline in quantity is the deterioration in quality of surface water (ECLAC, 2011). There has been increased stress to aquatic life occasioned by the reduction in stream flow, and the change/loss of flora and fauna associated with the change of land use. The competing water demands does not limit irrigation activities in St. Vincent. However, if the observed decline in stream volume should continue or escalate or if climate change should result in decrease precipitation or drought then the irrigation process can be seriously impeded. The current decrease in forest cover and the accompanying soil erosion has reduced soil percolation. This will reduce soil water retention and increase irrigation demands with decreasing water resource (ECLAC, 2011).

5.3.2 Groundwater

As noted in Section 2.6, the island of Saint Vincent uses surface water for the majority of their freshwater supplies, rather than groundwater. In 2010, groundwater extraction was estimated to be only 0.01 km^3/year (Margat and van de Gun, 2013). A survey of SVG by the Survey British Geological Survey showed adequate groundwater resources lacking (BSG, 1991).

6.0 CLIMATE CHANGE PROJECTIONS

Anthropogenic activities are the primary sources of greenhouse gas (GHG) emissions that contribute to the warming of the earth's atmosphere and lead to climate change and SLR. GHG and climate variability result in SLR, more frequent and extreme weather events, coastal erosion, ocean acidification, coral bleaching, and changing precipitation patterns, all of which have potentially damaging ecological and socioeconomic impacts. This is particularly true for small and developing countries with long coastlines, and countries whose inhabitants live in the narrow coastal belt, which are expected to be among the most vulnerable to climate change (CCCCC and MFFSD, 2014). SVG is, therefore, at high risk of severe climate change impact.

6.1 GCM AND RCM

In this section, the future climate change variables projected for SVG and recognized by the GOSVG were taken from the *CARIWIG Portal* system (Newcastle University, 2012) associated with and reported in The CARIBSAVE Climate Change Risk Atlas (CCCRA; CARIBSAVE, 2012a). CARIWIG is a tool used to generate a suite of climate variable projections including temperature and precipitation based on the use of different Special Report on Emissions Scenarios (SRES). IPCC has replaced these SRES with new scenarios called Representative Concentration Pathways (RCP) and RCP 6.0 is nearly identical to A1B. This tool uses ECHAM5- and HADCM3Q0-conditioned PRECIS Regional Climate Model (RCM) projections to generate climate change projections for SVG. The climate change projections assumed an A1B emissions scenario as defined by the IPCC. CARIWIG does not provide details about why the A1B emissions scenario was used. The A1B scenario describes a future world of very rapid economic growth, global population that peaks in the middle of the century, and the rapid introduction of new, more efficient technologies that nevertheless do not rely too heavily on any one source of energy.

6.2 CLIMATOLOGY

6.2.1 Air temperature

Table 6-1 presents the range of air temperature projections for Saint Vincent and the Grenadines reported in the CCCRA for Saint Vincent and the Grenadines (CARIBSAVE, 2012a). These projections are based on a GCM ensemble of 15 models for three IPCC standard scenarios – A2 (a high emissions scenario), A1B (a medium high emissions scenario), and B1 (a low emissions scenario). The A2 scenario is most similar to RCP 8.5, while A1B is similar to RCP 6.0 and B1 is similar to RCP 4.5. These projections were not used in the risk matrix put together by ERM, which used higher resolution PRECIS RCM projected data in its analysis, but they provide a generalized idea of future climate change in Saint Vincent and the Grenadines.

Mean annual temperature is projected to increase by 0.15 °C per decade over the next century. GCMs project maximum temperature changes of up to 4 °C by the end of the century under the A2 scenario, with a median temperatures projected to increase by up to 1 °C by the 2030s, 1.8 °C by the 2060s, and 2°C by the 2090s (SNCCC, 2015).

Table 6-1: Projected Country-scale Air Temperature Changes for Saint Vincent

		Projected Changes by the 2020s (°C)			Projected Changes by the 2050s (°C)			Projected Changes by the 2080s (°C)		
Season/Scenario		Min	Median	Max	Min	Median	Max	Min	Median	Max
Annual	A2	0.4	0.7	0.9	1.1	1.4	2	1.9	2.5	3.4
	A1B	0.3	0.7	1.1	1	1.4	2	1.3	2.1	2.9
	B1	0.3	0.7	0.9	0.6	1.1	1.3	0.9	1.5	2
DJF	A2	0.4	0.7	0.8	1.1	1.4	2	1.8	2.5	3.5
	A1B	0.3	0.7	1.1	1	1.4	2	1.3	2.2	2.9
	B1	0.4	0.7	0.9	0.5	1.1	1.3	0.9	1.5	2
MAM	A2	0.3	0.7	0.9	0.9	1.3	1.8	1.7	2.3	3.3
	A1B	0.3	0.7	1.1	1	1.4	1.9	1.2	2.1	2.6
	B1	0.3	0.6	0.9	0.6	1	1.2	0.7	1.4	1.9
JJA	A2	0.3	0.8	0.8	1.1	1.4	1.9	1.9	2.5	3.2
	A1B	0.3	0.7	1.1	1	1.4	1.9	1.3	2.1	3
	B1	0.3	0.7	0.9	0.7	1.1	1.3	1	1.5	2.1
SON	A2	0.5	0.8	0.9	1.1	1.5	2.2	2	2.6	3.6
	A1B	0.3	0.7	1.2	1.2	1.5	2.2	1.5	2.1	3
	B1	0.4	0.8	1	0.8	1.2	1.4	1.1	1.5	2

Source: CCCRA, 2012

6.2.2 Precipitation

Table 6-2 presents the range of precipitation projections for Saint Vincent and the Grenadines reported in the CCCRA for Saint Vincent and the Grenadines (CARIBSAVE, 2012A). These projections are based on a GCM ensemble of 15 models for three IPCC standard scenarios – A2 (a high emissions scenario), A1B (a medium high emissions scenario), and B1 (a low emissions scenario). The A2 scenario is most similar to RCP 8.5, while A1B is similar to RCP 6.0 and B1 is similar to RCP 4.5. These projections were *not* used in the risk matrix put together by ERM, which used higher resolution PRECIS RCM projected data in its analysis, but they provide a generalized idea of future climate change in Saint Vincent and the Grenadines.

Mean annual rainfall projections from different GCMs are broadly consistent in indicating decreasing trends in all seasons in rainfall for SVG, which is consistent with climate projection-adjusted data generated using the change factors projected by the PRECIS RCM. Precipitation has exhibited a decreasing trend over the period of historical record. The observed trend in annual rainfall in the period between 1960 and 2006 is -7.7 mm per decade with strongest decreasing trends seen in the wet season, such that June-July-August (JJA) precipitation decreases by 12 mm per decade and September-October-November (SON) precipitation decreases by 12.4 mm per decade (CCCRA, 2015).

GCM projections of future rainfall for SVG ranged from -34 to +6 mm per month by 2080 across the 3 scenarios compared in the CCCRA for SVG. Most projections tend to show a decrease in future precipitation.

Table 6-2: Projected Country-scale Precipitation Changes for Saint Vincent

		Projected Changes by the 2020s (mm/month)			Projected Changes by the 2050s (mm/month)			Projected Changes by the 2080s (mm/month)		
Season/Scenario		Min	Median	Max	Min	Median	Max	Min	Median	Max
Annual	A2	-17	-3	6	-23	-7	5	-34	-14	2
	A1B	-10	-4	9	-20	-7	4	-33	-8	1
	B1	-12	-2	11	-22	-4	3	-26	-4	6
DJF	A2	-2	0	9	-8	-2	0	-9	-4	1
	A1B	-5	0	4	-7	-3	7	-8	-5	1
	B1	-7	0	13	-6	-2	5	-6	-1	4
MAM	A2	-17	0	10	-14	-1	18	-20	-2	8
	A1B	-6	0	5	-14	0	7	-19	0	5
	B1	-8	0	9	-14	0	2	-14	0	5
JJA	A2	-46	-7	10	-53	-18	6	-69	-28	8
	A1B	-30	-6	7	-44	-16	4	-68	-22	8
	B1	-34	-8	26	-50	-12	16	-61	-15	17
SON	A2	-22	-3	17	-36	-6	11	-58	-11	0
	A1B	-30	-3	26	-32	-7	16	-58	-13	5
	B1	-22	-2	10	-35	-2	14	-43	-6	5

Source: CCCRA, 2012

6.2.3 Wind

Wind speed over SVG typically show a very small increase in GCM projections across the A2, A1B, and B1 scenarios. Mean change in windspeed by the 2080s ranges from -0.2 and +0.5 m/s by the 2080s across the three emission scenarios, and both increases and decreases are seen in all seasons across the 15 model ensemble (CARIBSAVE, 2012a). However, RCM projections based on the HadCM3 GCM project a relatively large increase in JJA (+1.2 m/s) and SON (+1.2 m/s) wind speed by the 2080s for the SRES A2 scenario.

6.3 SEA LEVEL RISE

The sea level has risen in the Caribbean at about 3.1 mm per year from 1950 to 2000 (Church, White, Coleman, Lambeck, & Mitrovica, 2004). Global SLR is anticipated to increase as much as 1.5 m to 2 m above present levels in the 21st century (Rahmstorf, 2007; Vermeer & Rahmstorf, 2009; Grinsted, Moore, & Jevrejeva, 2009). SLR has direct effects on freshwater discharge and groundwater salinization among small islands like Saint Vincent. The SLR projections for SVG for RCP 8.5 generated from *CLIMsystems* indicates that sea level will rise by 15 cm by 2025, 37 cm by 2050, and 111 cm by 2100, which could lead to a significant loss of beach area for Saint Vincent. The RCP 8.5 scenario describes a world in which emissions continue to rise throughout the 21st century and is the "*worst-case*" of the four RCP scenarios described by the IPCC (2013). These SLR values were used for ERM's risk assessment.

Other projections for the Caribbean have estimated a range of values. For example *The BahamasSimCLIM* system indicate that sea level will rise 9.0 cm, 20 cm, and near 70 cm by 2030, 2050 and 2100, respectively. Taylor (2016) shows that for the east side of the Bahamas, projected mean SLR for RCP 8.5 is 11, 18, 33 and 72 cm and maximum is 21, 31, 54 and 112 cm for 2025, 2035, 2055 and 2100, respectively.

These levels of SLR would result in severe economic impacts for SVG. For example, CARIBSAVE (2012a) estimates that 1 meter of SLR would place 10% of major tourism properties at risk, along with 1% of road networks, 50% of airports, and 67% of sea ports. 1 meter of SLR would also result in approximately 100 meters of erosion, which in turn would result in negative impacts to 76% of the major tourism resorts and 47% of sea turtle nesting sites. 2 meters of SLR would place 24% of major tourism properties at risk, along with 75% of airports.

7.0 FLOOD HAZARD ANALYSIS

7.1 HISTORICAL FLOODS

Extreme vulnerability to natural disasters and the impacts of climate variability are of grave concern in SVG. Hurricanes and extreme weather caused by low-level troughs have caused major flooding throughout Saint Vincent. In the last 10 years, three major low-level trough systems have severely impacted the island. These are described briefly below.

A low pressure tropical trough brought heavy rainfalls to the Eastern Caribbean on 24 December 2013, severely affecting the islands of St Vincent and the Grenadines, and St Lucia. The sustained torrential rains caused severe flooding, landslides, and damage to infrastructures including health facilities, homes, roads and bridges. The rainfall totaled 310 mm in a 2-3 hour period. This resulted in 11 deaths, and 3 persons never unaccounted for. A national level 2 disaster was declared in accordance with the national Emergency and Disaster Management Act 2006 for 12 main areas on St. Vincent. Damage and losses were calculated at US$108.4 million or 15% of the country's Gross Domestic Product. It was estimated that 97% of the damage was sustained in critical infrastructure, including the Milton Cato Memorial Hospital, the main hospital in the country. The final disaster assessment concluded: 77 homes were completely destroyed or severely damaged; approximately another 300 homes were damaged; and 500 people were displaced and housed in temporary shelters.

From September through November 2016, Saint Vincent and the Grenadines (SVG) experienced a series of significant rainfall events beginning with the passage of Hurricane Mathew in September 2016 and culminating with the passage of two trough systems on November 9 and November 28, 2016. Due to the consistent rainfall over the period, ground conditions were largely saturated which set the stage for intense flash flooding associated with the two troughs. Sandy Bay in the north-eastern area of St. Vincent was the most severely affected community; however, the villages of Magum, Orange Hill, Overland, London, Point, Owia and Fancy in the north-east and Spring Village, Coulls Hill, Troumaca, Rose Bank, Sharpes, Fitz Hughes and Chateaubelair in the northwest of St. Vincent were also impacted. Some people suffered losses to their subsistence crops and livestock, and a they are experiencing severe psychosocial effects, access to water and sanitation issues, and financial challenges as a direct consequence of the flooding. The flooding destroyed 15 houses, severely damaged 20 houses and partially damaged more than 50 (IFRC, 2016). A single death was reported from Bequia (GOSVG, 2016).

7.2 MODELLING METHODOLOGY

7.2.1 Selection of Models

Identification and assessment of flood risk requires modelling of inundation that allows risk managers to make informed decisions on how to manage the risk. The main factors that affect flooding in the Study Area are ocean water levels (which are dependent on the tide and storm surge), wave heights in Kingstown Bay, and watershed runoff (overland flow) into the Study Area.

To evaluate coastal and inland floods in the Kingstown Port area of Saint Vincent, ERM used FLO-2D[4], which is an effective model for evaluating flood hazards. FLO-2D is a flood routing model that simulates channel flow, unconfined overland flow, and street flow over complex topography. The model routes flood hydrographs and rainfall runoff with many rural and urban detail features including street flow, levees and walls, and hydraulic structures. This software is approved by the United States Federal Emergency Management Agency (FEMA) for Flood Insurance Studies.

FLO-2D models two dimensional overland flow across a floodplain by conducting volume conservation. Flow within stream channels is modeled as one-dimensional. The model is set up with uniform, square grid elements. Inflow to the model occurs at inflow nodes with a specified hydrograph. Velocities and flow rates are computed for each grid element based on inflow water surface elevation, ground surface elevation, and Manning's roughness coefficient. The transfer of water mass between grid elements occurs in the eight compass directions: E, S, W, N, NE, SE, SW, and NW.

7.2.2 Modeled Scenarios

Four main scenarios were simulated to evaluate different coastal and inland flooding hazard in SVG. These scenarios present the following characteristics:

- **Baseline**: This scenario considers the existing land use and climatological conditions
- **Climate Change (2025)**: This scenario uses the existing land use and climate change projections for the study area for the year 2025
- **Climate Change (2050)**: This scenario uses the existing land use and climate change projections for the study area for the year 2050
- **Climate Change (2100)**: This scenario uses the existing land use and climate change projections for the study area

These scenarios were evaluated for four different return periods (10-, 25-, 50- and 100-year return periods).

7.3 DEVELOPMENT OF BASELINE AND CLIMATE CHANGE SCENARIOS

The rainfall intensity and storm surge are the primary factors that are used to develop baseline scenarios using extreme event analysis.

7.3.1 Baseline Precipitation Analysis

The rainfall information was obtained by developing Intensity-Duration-Frequency (IDF) curves using historic multiyear data from the E.T. Joshua Airport in the Study Area. The 24-hour maximum precipitation values computed for the airport for 10-, 25-, 50-, and 100-year return periods using Generalized Extreme Value (GEV) distributions are presented in **Table 7-1** below.

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[4] FLO-2D is a bi-dimensional flood model developed by FLO-2D Software, Inc., Arizona, USA. www.flo-2d.com

Table 7-1: 24-hour Maximum Precipitation Computed for E.T Joshua Airport Using GEV Method

Return Period (years)	24-hour Precipitation Maximum (mm)
10	167.3
25	203.3
50	230.0
100	256.6

IDF curves (**Figure 35** below) were developed using the projections listed in **Table 7-1** above.

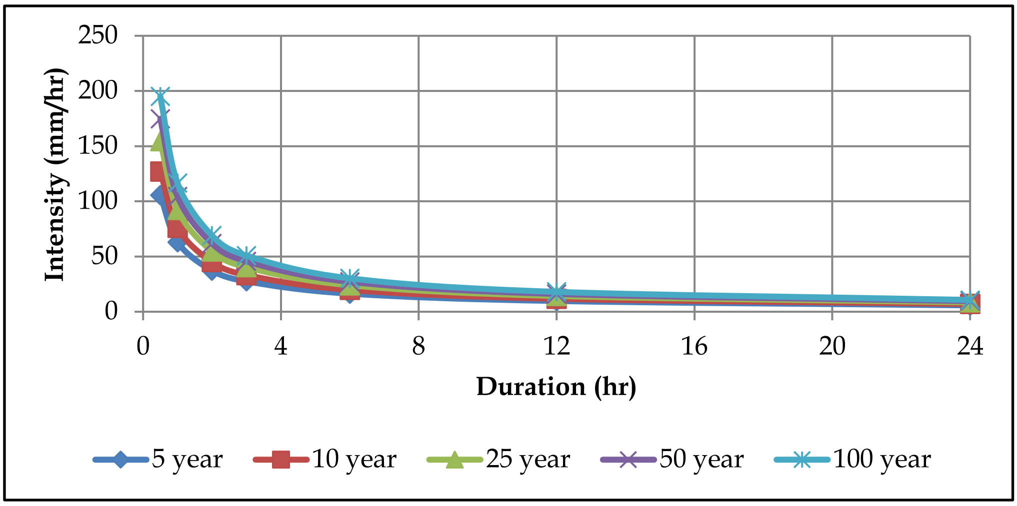


Figure 35: IDF Curves for E.T. Joshua Airport.

7.3.2 Climate Change Precipitation Analysis

The seasonally varying extreme precipitation data for the SRES Scenario A2 (Equivalent to RCP 8.5) was computed from RCM models ECHAM4 and HadAM3 are presented in **Table 7-2**. The monthly climate change projection of extreme precipitation was used along with synthetic time-series precipitation data obtained from KNN weather generator to develop IDF curves for future years of 2025, 2050 and 2100. Extreme precipitation in this study refers to maximum percent change in rainfall intensity based on 1-day rainfall total from an ensemble of GCM projections.

Table 7-2: Percent Change in Precipitation for Climate Change SRES Scenario A2 (~RCP 8.5)

Month	Climate Change 2050	Climate Change 2100
January	2	3
February	2	3
March	8	8
April	8	8
May	8	8
June	3	6
July	3	6
August	3	6
September	6	3
October	6	3
November	6	3
December	2	3

Table 7-3: Percent Change in Precipitation for Climate Change SRES A1B Scenario

Month	Climate Change 2025	Climate Change 2050	Climate Change 2100
January	14	-6	-17
February	14	-6	-17
March	-18	-35	-51
April	-18	-35	-51
May	-18	-35	-51
June	-6	-12	-22
July	-6	-12	-22
August	-6	-12	-22
September	-9	-12	-10
October	-9	-12	-10
November	-9	-12	-10
December	14	-6	-17

Year 2025

The IDF curves computed for the year 2025 using the climate change projections listed in **Table 7-4** and **Figure 36.**

Table 7-4: 24-hour Maximum Precipitation Computed for Year 2025

Return Period (years)	24-hour Precipitation Maximum (mm)
10	155.2
25	188.0
50	212.3
100	236.4

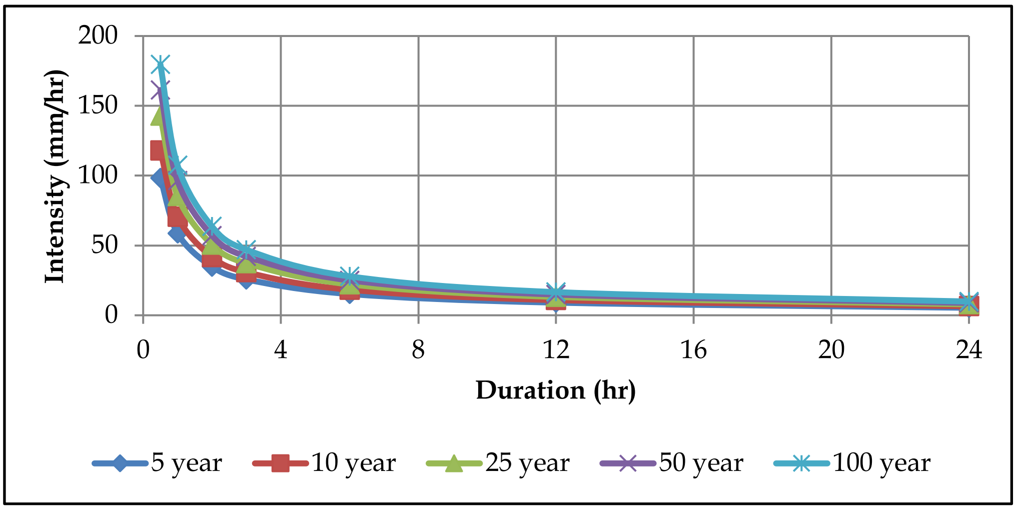


Figure 36: Year 2025 IDF Curves for E.T. Joshua Airport.

Year 2050

The IDF curves computed for the year 2050 using the climate change projections listed in **Table 7-5** and **Figure 37** below.

Table 7-5: 24-hour Maximum Precipitation Computed for Year 2050

Return Period (years)	24-hour Precipitation Maximum (mm)
10	146.1
25	177.7
50	201.2
100	224.5

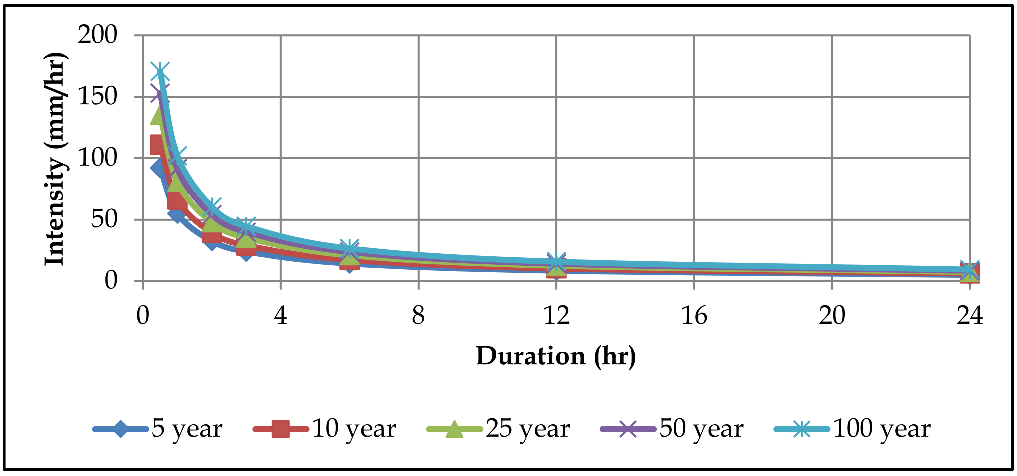


Figure 37: Year 2050 IDF Curves for E.T. Joshua Airport.

Year 2100

The IDF curves computed for the year 2100 using the climate change projections listed in **Table 7-6** and **Figure 38** below.

Table 7-6: 24-hour Maximum Precipitation Computed for Year 2100

Return Period (years)	24-hour Precipitation Maximum (mm)
10	140.5
25	170.7
50	193.1
100	215.4

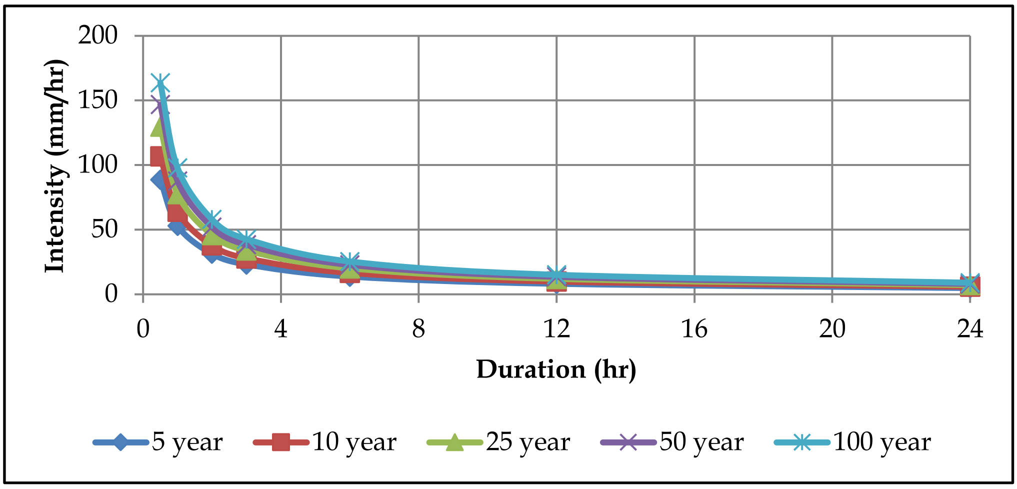
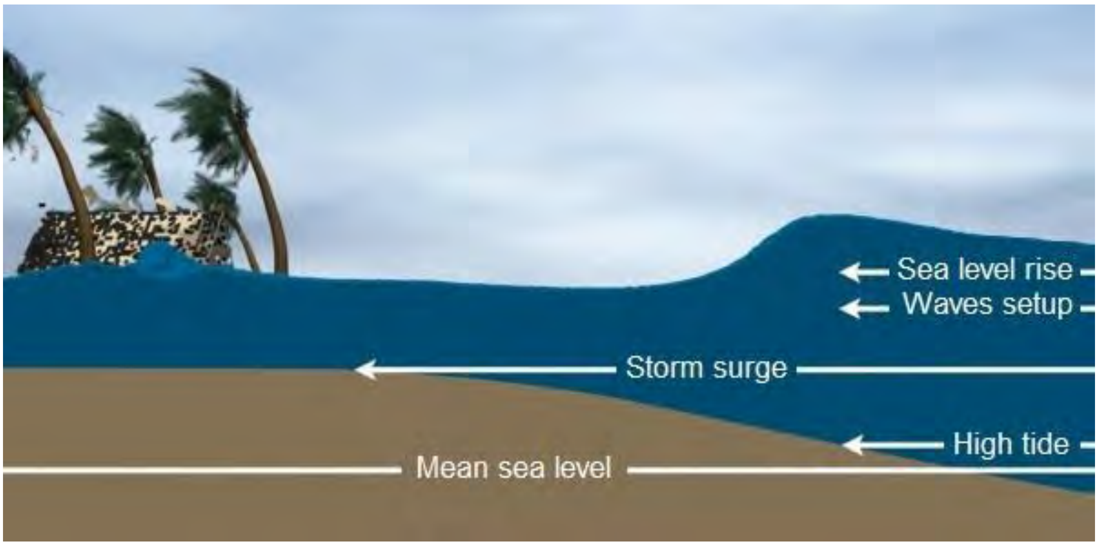


Figure 38: Year 2100 IDF Curves for E.T. Joshua Airport.

7.3.3 Baseline Storm Surge

Coastal flooding occurs mostly because of the storm surge created by hurricanes and its effects on inland rivers and stormwater systems. Storm surge is the combination of wind setup and pressure setup during hurricanes and tropical storms. The processes contributing to the total storm surge are shown in **Figure 39.** High tides depend on the combined effects of the gravitational forces exerted by the Moon and the Sun and the rotation of the Earth. Wave setup is the increase in mean water level due to the presence of waves. Wave setup is largest during tropical storms and hurricanes.



Source: Adapted from NOAA, 2015

Figure 39: Processes Contributing to Storm Surge.

The total storm surge resulting from the combination of storm surge, high tides, wave setup and sea level rise due to climate changes is provided in **Table 7-7**, below.

Table 7-7: Calculated Storm Surge for the Port of Kingstown

Return Period	Wind Speed (m/s)[a]	Surge (m)[b]	Waves (m)[c]	Total Surge (m)[d]
10-year	25	0.1	3.2	3.3
25-year	33.5	0.2	4.2	4.4
50-year	38.5	0.3	4.8	5.1
100-year	44	0.4	5.5	5.9

[a] Represents sustained 1-minute winds at 10 m above the surface, and include both surface friction and topographic effects at a resolution of 30 arc-seconds.

[b] Includes astronomical tide and setups from pressure, wind and wave, but not wave runup

[c] Waves are the heights of wave crests above the storm surge level in open water. Shoreline effects do not appear at this resolution

[d] Total Surge = Surge + Waves

7.3.4 Climate Change Storm Surge

For climate change scenarios, the following storm surges presented in **Table 7-8** were used in this analysis.

Table 7-8: Storm Surge Adjusted to RPC 8.5 Scenarios for 2025, 2050, and 2100

Return Period	Total Coastal Flood Wave Peak (m)			
	Baseline	Climate Change		
		2025	2050	2100
10-year	3.3	3.45	3.67	4.42
25-year	4.4	4.55	4.77	5.52
50-year	5.1	5.25	5.47	6.22
100-year	5.9	6.05	6.27	7.02

7.4 FLOOD MODELLING OF THE STUDY AREA USING FLO-2D

Coastal flooding occurs when the sea water level rises during tropical storms and hurricanes have the potential to severely impact low-lying coastal settlements such as cities, villages and infrastructures. The United States National Oceanic and Atmospheric Administration (NOAA) identifies the rise in sea water level during storm conditions as storm surge, which is defined as an abnormal rise of water generated by a storm, over and above the predicted astronomical high tide (NOAA, 2015a). The raised sea water can inundate the coastal land via two major paths:

- Direct inundation, where the sea level exceeds the elevation of the land; or
- Overtopping of a barrier, where the sea level overtops or breaches a natural or artificial barrier.

Coastal flooding is largely a naturally occurring event. However, human influence on the coastal environment can facilitate the sea level rise and exacerbate the damage. For example, extraction of water from groundwater reservoirs in the coastal zone can enhance subsidence and increase the risk of flooding.

7.4.1 Analysis of Model Results – Without Port Expansion

7.4.2 Flood Hazard – Baseline

10-year Return Period

For the 10-year return period, the majority of the area between Lower Middle Street and Kingstown Bay (including Rose Place) has a high hazard as does the area between Middle Street and Kingstown Bay that extends from Hillsboro Street to beyond the Kingstown Ferry terminal and SVG Cruise Ship Terminal (**Figure 40**). High flood hazard is also observed north of Lower Middle Street almost to the southwest end of Level Garden as is the area bounded by Paul's Avenue to the west, Edgemont Street to the east, Middle Street to the south and the area just north of Halifax Street. The total area experiencing high flood hazard is 58.6 acres.

Medium hazard is seen in localized areas between Lower Middle Street and Grenville Street, areas along Paul's Avenue, and the area between Middle Street and Granby Street. The total area experiencing medium flood risk is 23.2 acres.

Isolated pockets of low hazard tend to be limited to areas farther than 300 m inland from the shoreline and along drainage routes. The total area experiencing low flood risk is 8.9 acres.

Although the majority of the Project Area exhibits high or medium flood hazard, there are small areas within 300 m of the coastline that are not susceptible to flooding (non-colored areas) for a 10-year return period (**Figure 40**). These include the Quality Paints & Supplies, New Central Market, the Kingstown Fish Market, The GOSVG Administrative Complex, the Geest banana shed, the Queen's Warehouse, the Customs & Excise Warehouse, and the Massy Stores Supermarket, among these areas. Construction details of these buildings are not known; however, it is likely that they will likely experience 1st flooring given the high flood hazard conditions surrounding them for this scenario.

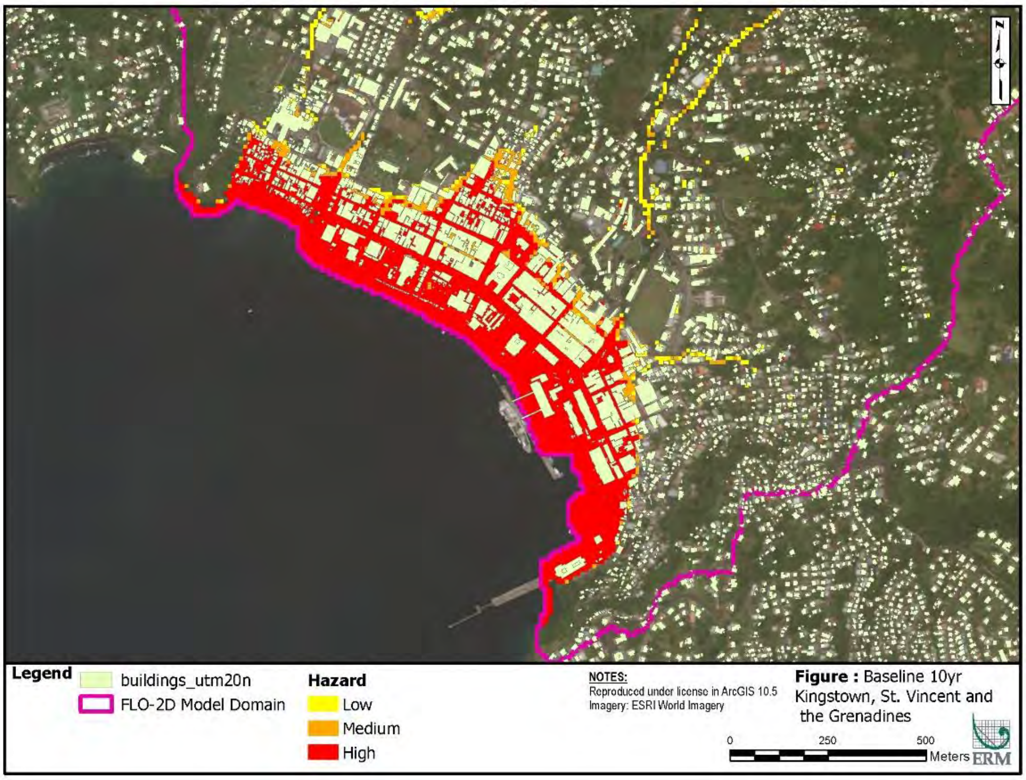


Figure 40: Flood Hazard Assessment: Baseline: 10-year Return Period.

25-year Return Period

Under this scenario, the area of high flood hazard moves inland and encompasses the majority of areas considered to have a medium flood hazard under the 10-year return period scenario (**Figure 41**). The total area identified with a high hazard is 72.2 acres. The total area identified with a medium hazard is 22.3 acres and 15.1 acres experience a low hazard.

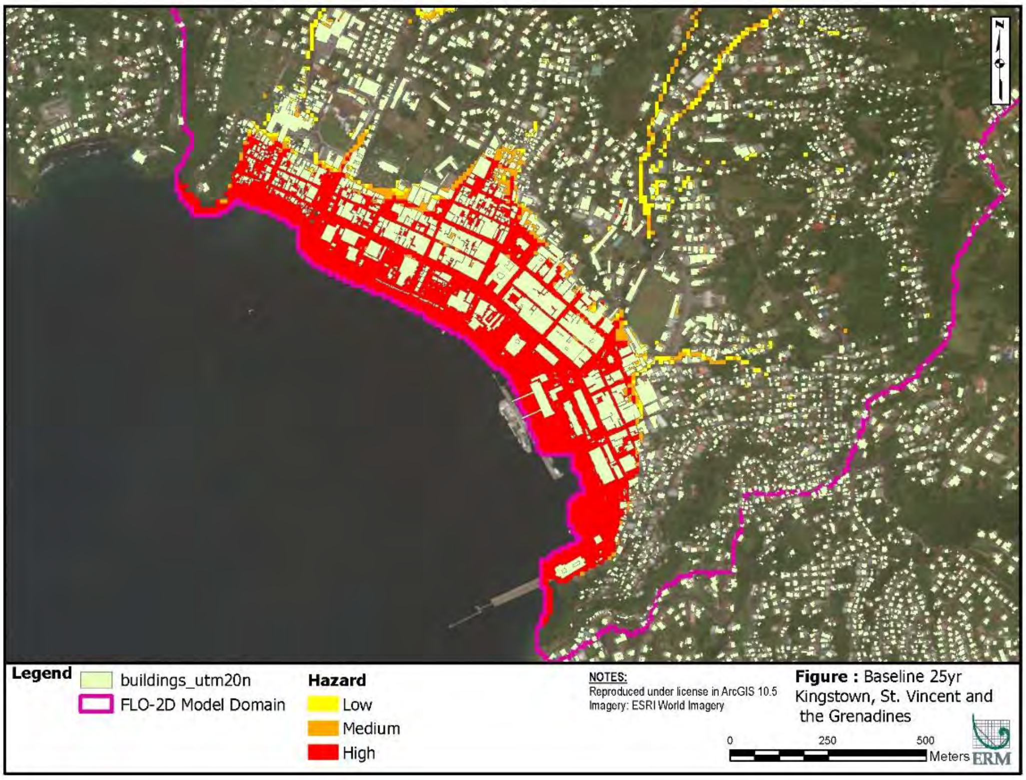


Figure 41: Flood Hazard Assessment: Baseline: 25-year Return Period.

50-year Return Period

Under the 50-year return period scenario, the area of high flood hazard continues to move inland and encompasses the many areas that had a medium flood hazard under the 25-year return period scenario (**Figure 42**). The total area identified with a high hazard is 78.3 acres. The total area identified with a medium hazard is 26.1 acres and 21.9 acres experience a low hazard.

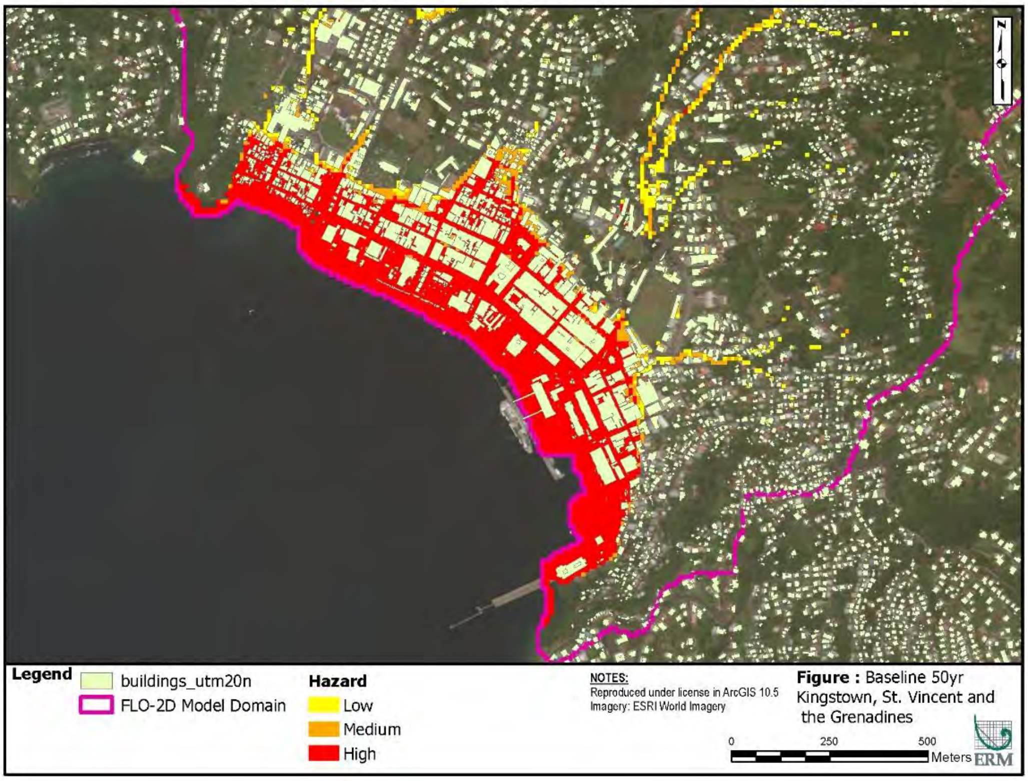


Figure 42: Flood Hazard Assessment: Baseline: 50-year Return Period.

100-year Return Period

Under the 100-year return period scenario, the area of high flood hazard continues to move inland and encompasses the many areas considered to have a medium flood hazard under the 50-year return period scenario (**Figure 43)**. The total area identified with a high hazard is 85.2 acres. The total area identified with a medium hazard is 29.9 acres and 25.7 acres experience a low hazard.

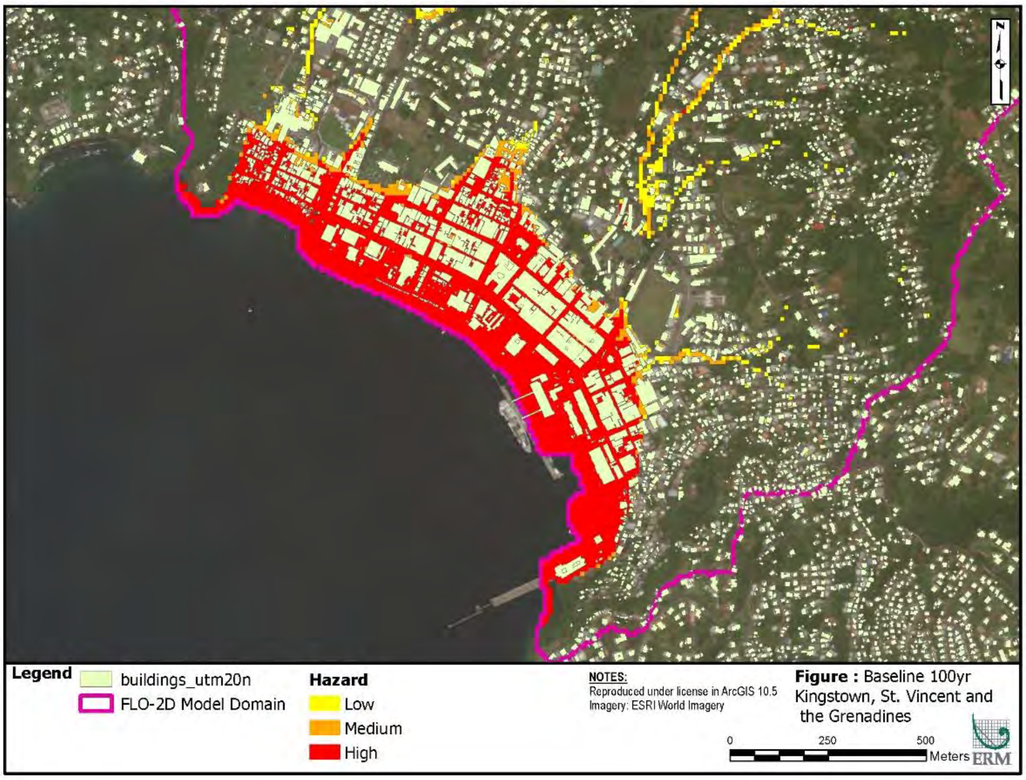


Figure 43: Flood Hazard Assessment: Baseline: 100-year Return Period.

7.4.3 *Flood Hazard – Climate Change*

A flood hazard assessment was conducted for the Kingstown Port area under climate change scenarios for 2025, 2050, and 2100 with 10-, 25, 50, and 100-year return periods. To illustrate the potential effects of climate change, the years 2050 and 2100 with a 100-year return period are presented below.

Year 2050, 100-year Return Period

Based on climate change projections for 2050 and a 100-year return period, the majority of the Kingstown port area will experience a high flood hazard (**Figure 44**). The total area identified with a high hazard is 86.8 acres, which is an increase of ~6 acres more than the high risk area identified for the baseline 100-year return period. The total area identified with a medium hazard is 22.3 acres, which is ~3 acres less than the medium risk area identified for the baseline 100-year return period.

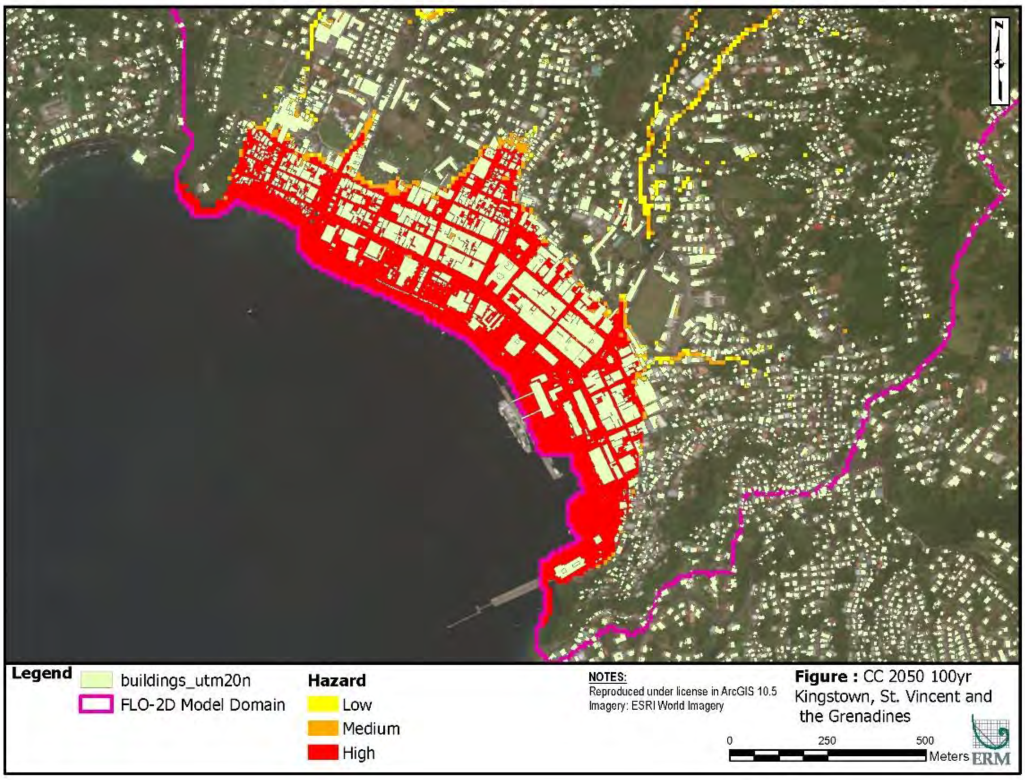


Figure 44: Flood Hazard Assessment: 2050, 100-year Return Period.

Year 2100, 100-year Return Period

The area of flooding for the year 2100 and a 100-year return period (129.3 acres) was virtually the same as the total area of flooding for the year 2050 and a 100-year return period (128.7 acres; **Figure 45**). However, the total area of high flood hazard increased slightly (92.0 aces vs. 86.8 acres), while the total area experiencing low (16.3 acres vs. 19.6 acres) and medium flood hazard (21.0 acres vs 22.3 acres) declined slightly.

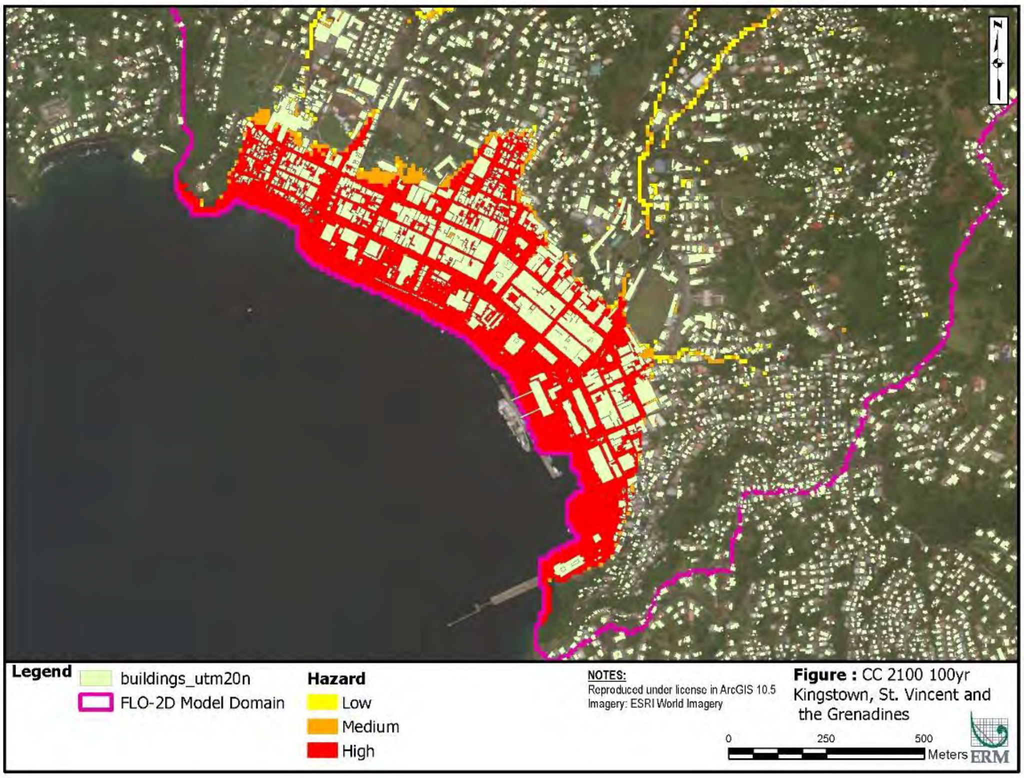


Figure 45: Flood Hazard Assessment: 2100, 100-year Return Period.

7.4.4 Flood Depth – Baseline

An assessment of flooding depth was conducted for the Kingstown Port area for 10-, 25, 50, and 100-year return periods. Under baseline conditions, the majority of downtown Kingstown is expected to flood to a maximum depth of 0.1 m – 3.0 m for the 10-year return period (**Figure 46**). Low lying areas along the shoreline will experience a maximum depth 4.1 m – 5.0 m. As expected, as the return period increases, the flood depth increases. For 25- and 50-year return periods, maximum flood levels of 4.1 m – 6.0 m are limited to the shoreline, with the majority of downtown Kingstown experiencing maximum depths of 3.1 m – 4.0 m. For the 100-year return period areas generally between the shoreline and Lower Middle, Grenville, Halifax and Granby Streets experience a maximum depth range of 3.1 m – 5.0 m. In addition, Rose Place, the current port, the Ferry Terminal and the SVG Cruise Terminal area experience flood depths of 5.1 m – 6.0 m.

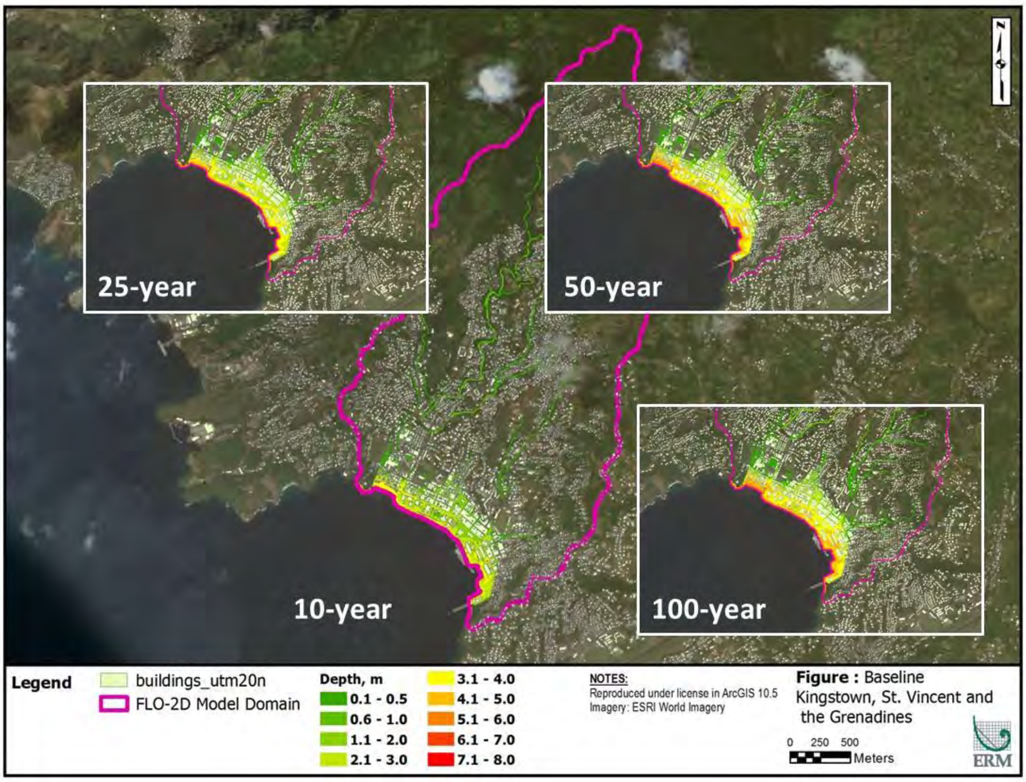


Figure 46: Flood Depth Assessment: Baseline – All Return Periods.

Timing of Flooding

Although expected maximum depth of flooding is an important aspect to review, the timing of flooding and eventual water recession is also important to consider. As a worst case example, the timing of flooding and water recession was evaluated for the baseline condition and a 100-year return period **(Figure 47, Figure 48**, and **Figure 49**). These figures depict the maximum flood depth on an hourly basis from the onset of the storm surge. By the end of hour 1, low lying areas along the shoreline are inundated to a maximum depth of 0.6 m – 1.0 m (**Figure 47**). By hour 4, the majority of downtown Kingstown is inundated. The impacts of the storm surge and overland flow reach a peak by hour 6 resulting in the majority of downtown Kingstown being flood to with depth of 0.1 m – 3.0 m, and areas immediately adjacent to the bay being flooded to a maximum of 3.1 m – 4.1 m (**Figure 48**). The ebbing of the flood waters occurs faster than flooding; by hour 8, water has receded from the majority of downtown Kingstown, leaving mostly areas of minor maximum flooding (0.1 m – 0.5 m), with smaller areas of moderate maximum flooding (1.1 m – 3.0 m) that include Rose Place and the eastern end of Lower Middle Street **(Figure 48**). This remnant flooding is due to upland runoff within the watershed.

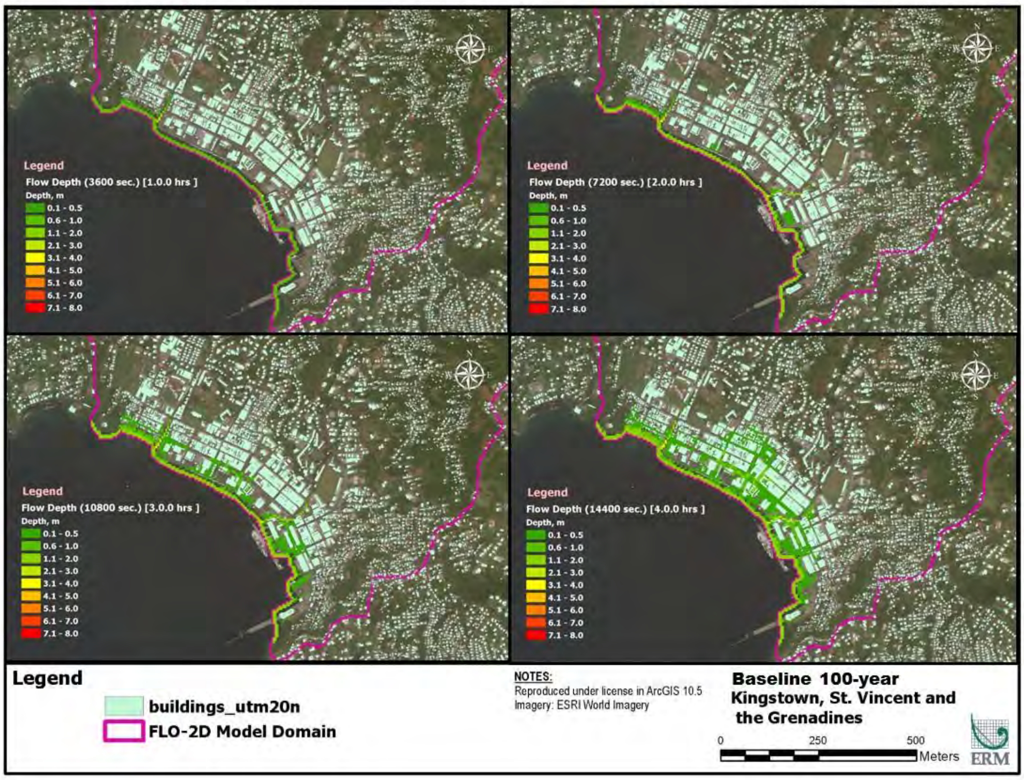


Figure 47: Hourly Maximum Depth from Onset of Storm Surge (Hr 1 – Hr 4)

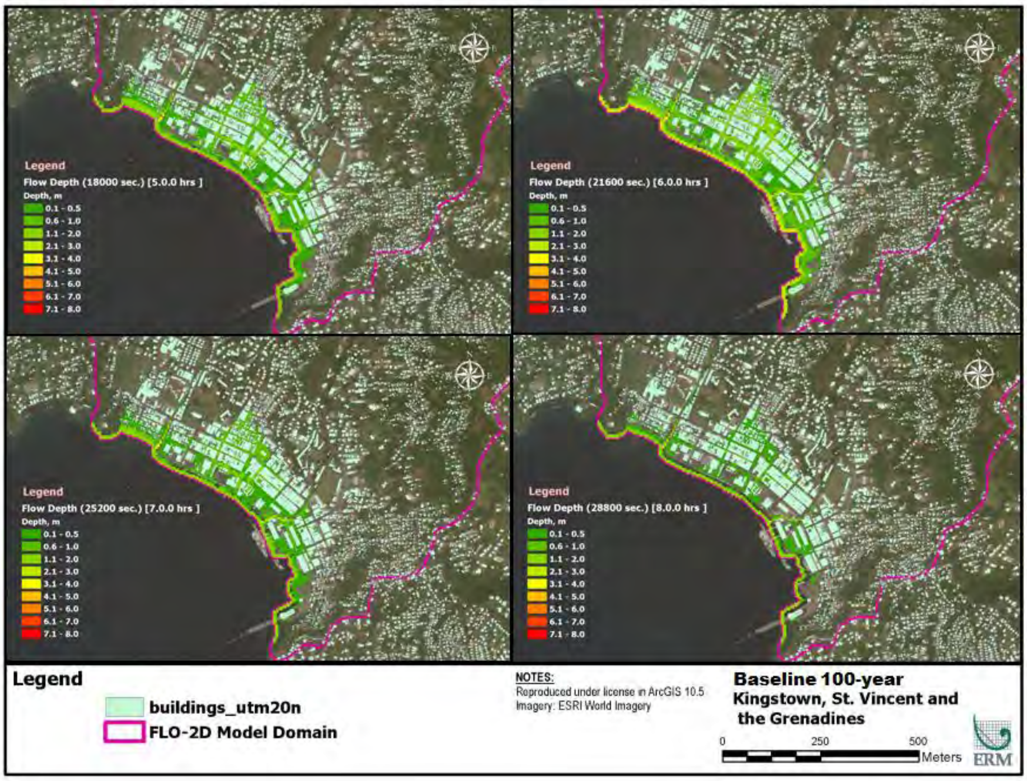


Figure 48: Hourly Maximum Depth from Onset of Storm Surge (Hr 5 – Hr 8)

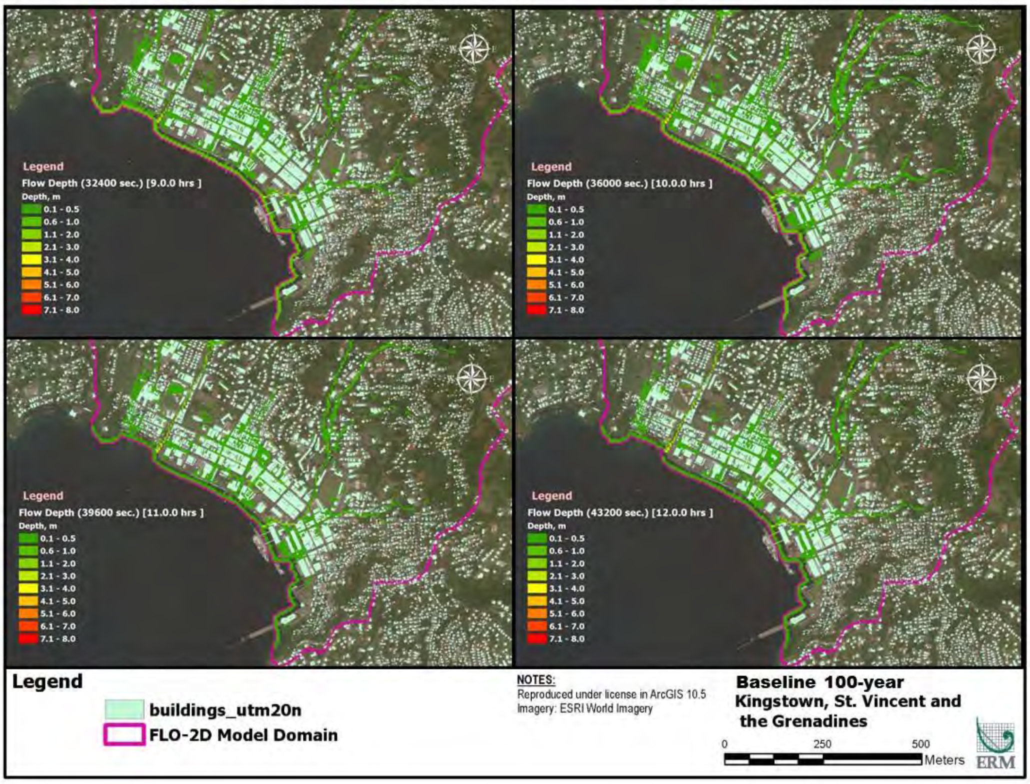


Figure 49: Hourly Maximum Depth from Onset of Storm Surge (Hr 9 – Hr 12)

7.4.5 Flood Depth – Climate Change

An assessment of flood depth was conducted for the Kingstown Port area under climate change scenarios for 2025, 2050, and 2100 with 10-, 25, 50, and 100-year return periods.. To illustrate the potential effects of climate change, the years 2025, 2050 and 2100 with a 100-year return period are presented below in **Figure 50**, **Figure 51**, and **Figure 52**.

Year 2025

For the 2025 climate change scenario and a 10-year return period (**Figure 50**), the area of experiencing moderate maximum flood depths (3.1 m – 5.0 m) was approximately three times Baseline and included a significant portion of Rose Place as well as the current port, the Ferry Terminal and the SVG Cruise Terminal area. For the 25-year return period, the area experiencing moderate maximum flood depths was approximately twice that of Baseline and extended a maximum of ~07.5 km inland to Level Garden Street. For the 50-year return period, there was a slight increase in the area experiencing severe maximum flood levels (5.1 m – 8.1 m) with most of the increase occurring in the current port, the Ferry Terminal and the SVG Cruise Terminal areas. Maximum flood depths for the the year 2025 and 100-year return period were virtually identical to the Baseline 100-year return period.

Year 2050

For the 2050 climate change scenario and a 10-year return period (**Figure 51**), the area of experiencing moderate maximum flood depths (3.1 m – 5.0 m) was approximately three times Baseline and included a significant portion of Rose Place as well as the current port, the Ferry Terminal and the SVG Cruise Terminal area.

The pattern and depths of maximum flooding for the 25-year return period were very similar to that seen for the Year 2025 with the same return period. For the 50-year return period, the area of severe flooding increased beyond that seen in the 2025 climate change scenario, particularly in Rose Place, the Ferry Terminal and the SVG Cruise Terminal. The maximum flood depths for the the year 2050 with a 100-year return period were virtually identical to the Baseline 2025 climate change scenarios with the same return period.

Year 2100

For the 2100 climate change scenario and a 10-year return period (**Figure 51**), the area of experiencing moderate maximum flood depths (3.1 m – 5.0 m) was approximately two times that seen for the year 2050 with the same return period. For the 25-year return period, there is a significant increase in the area experiencing severe flooding, including Rose Place, the Kingstown Fish Market area, and the areas adjacent to the current port, the Ferry Terminal and the SVG Cruise Terminal. For the 50-year return period, the area of high maximum flood depths increased, with most areas within 200 m – 300 m of the shoreline experiencing a maximum flood depth of 5.1 m – 6.0 m. For the 100-year return period, the majority of downtown Kingstown also experiences maximum flood depths of 5.1 m – 6.0 m.

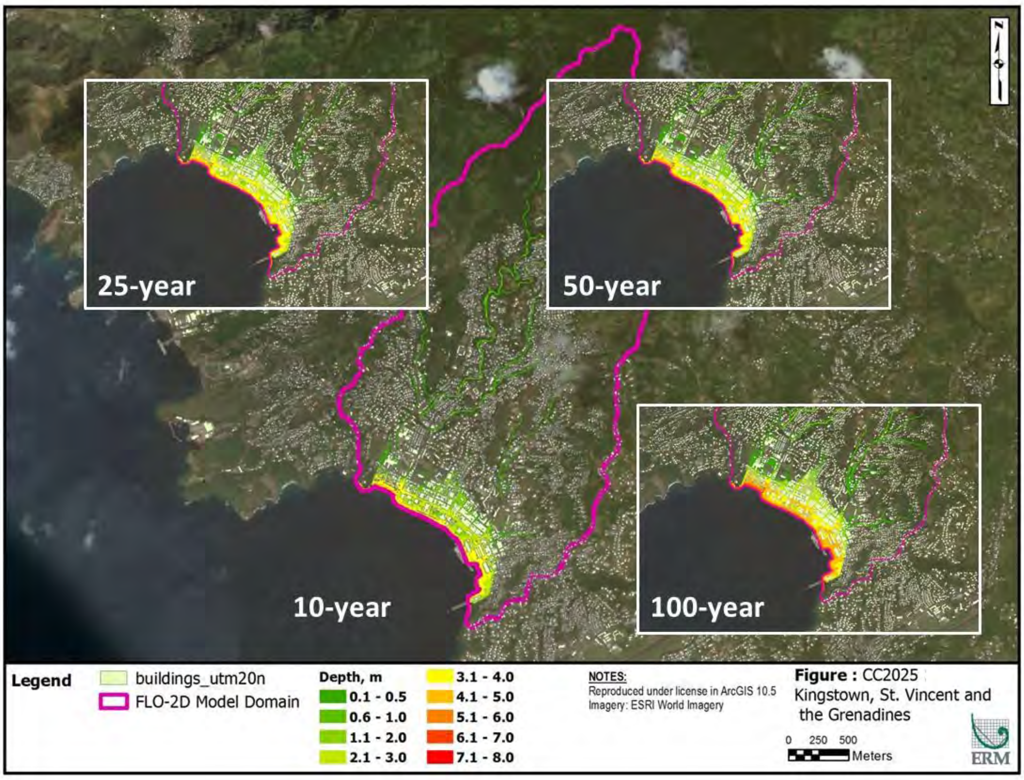


Figure 50: Flood Inundation Assessment: Year 2025 – All Return Periods

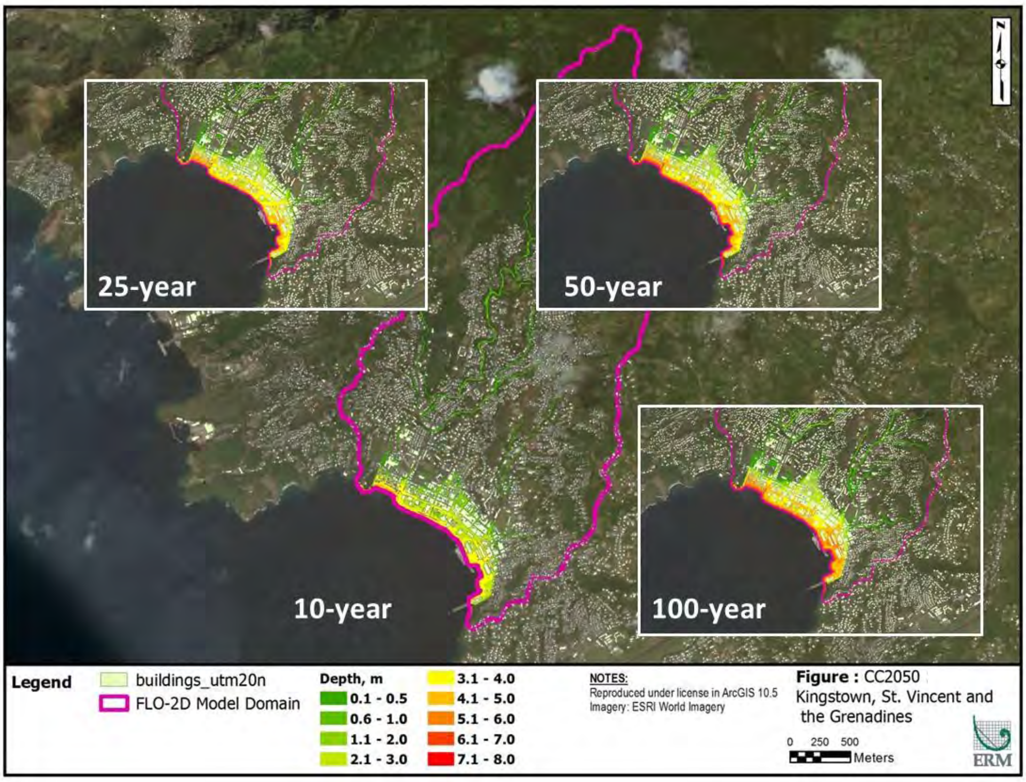


Figure 51: Flood Inundation Assessment: Year 2050 – All Return Periods

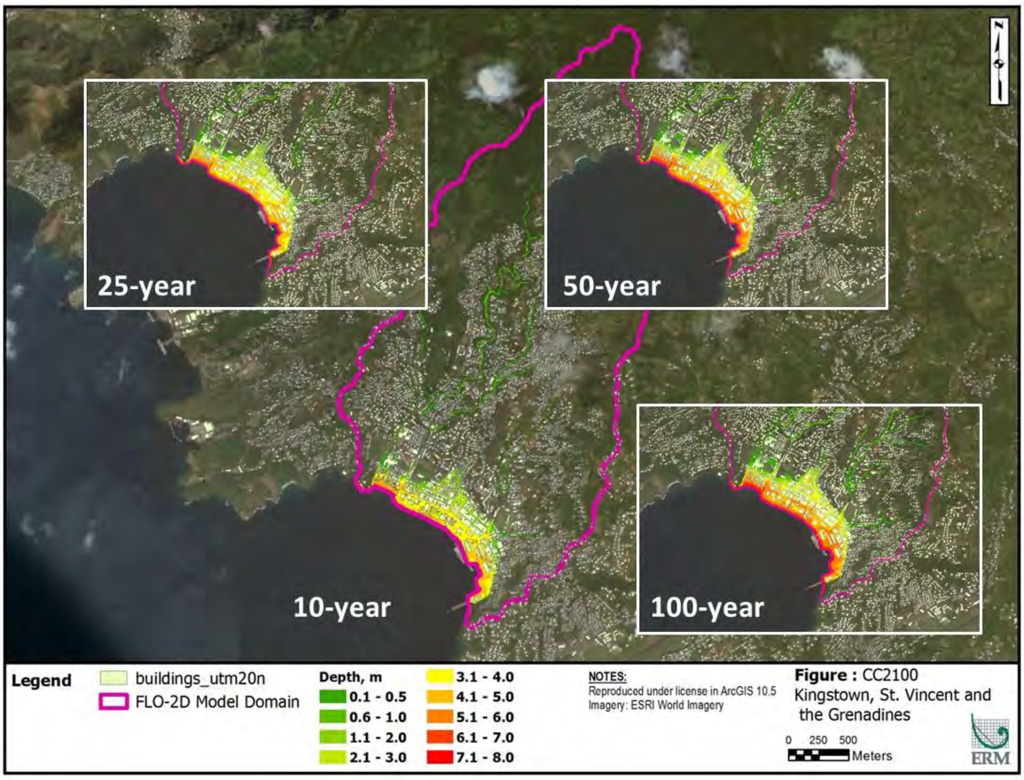


Figure 52: Flood Inundation Assessment: Year 2100 – All Return Periods.

7.4.6 Analysis of Model Results – With Port Expansion

7.4.7 Flood Hazard – Baseline

10-year Return Period

Under 10-year return period baseline conditions the Container Terminal experiences a medium flood hazard whereas the surrounding area experience a high flood hazard. The total area of flooding increased from 90.8 acres without the Container Terminal to 114.5 acres with the terminal constructed (**Figure 53**).

Small areas of improvement in Kingstown were see under the Container Terminal scenario. Some areas directly on Lower Middle Street actually saw an improvement with flood hazard changing from *high* to *medium*.

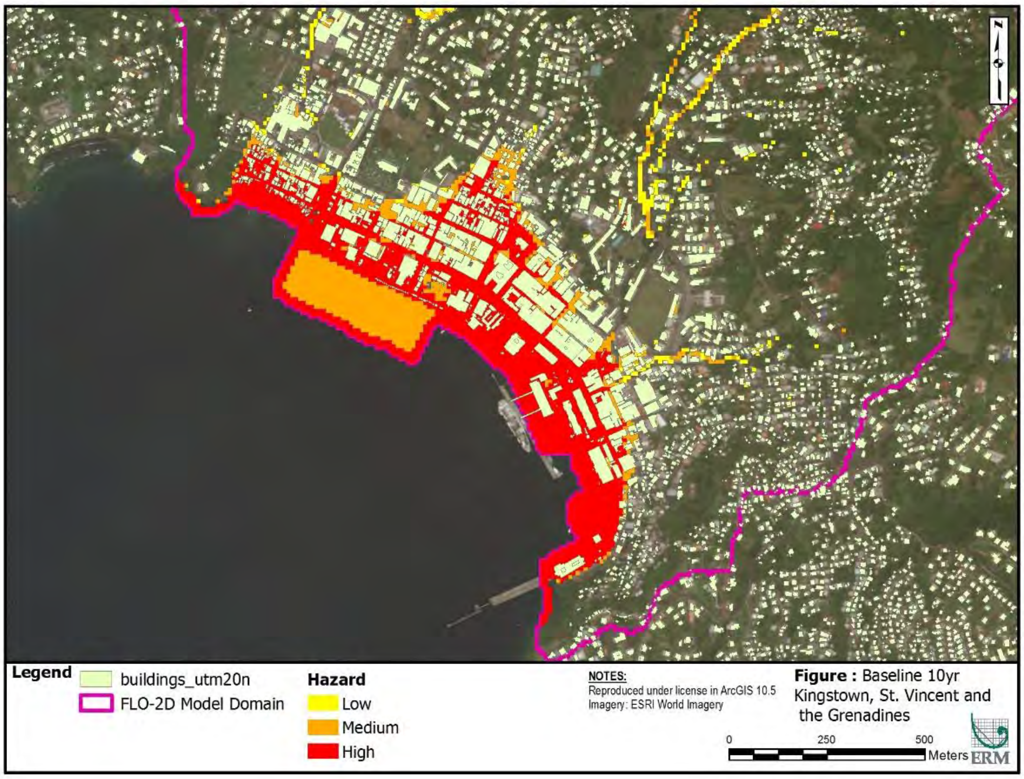


Figure 53: Flood Hazard Assessment with Container Terminal: Baseline: 10-year Return Period.

25-year Return Period

Under 25-year return period for baseline conditions, the Container Terminal area, like other the adjacent areas of Kingstown shows a high flood hazard. With the Container Terminal in place, the total area of flooding in Kingstown increased from 109.6 acres to 140 acres (**Figure 54**).

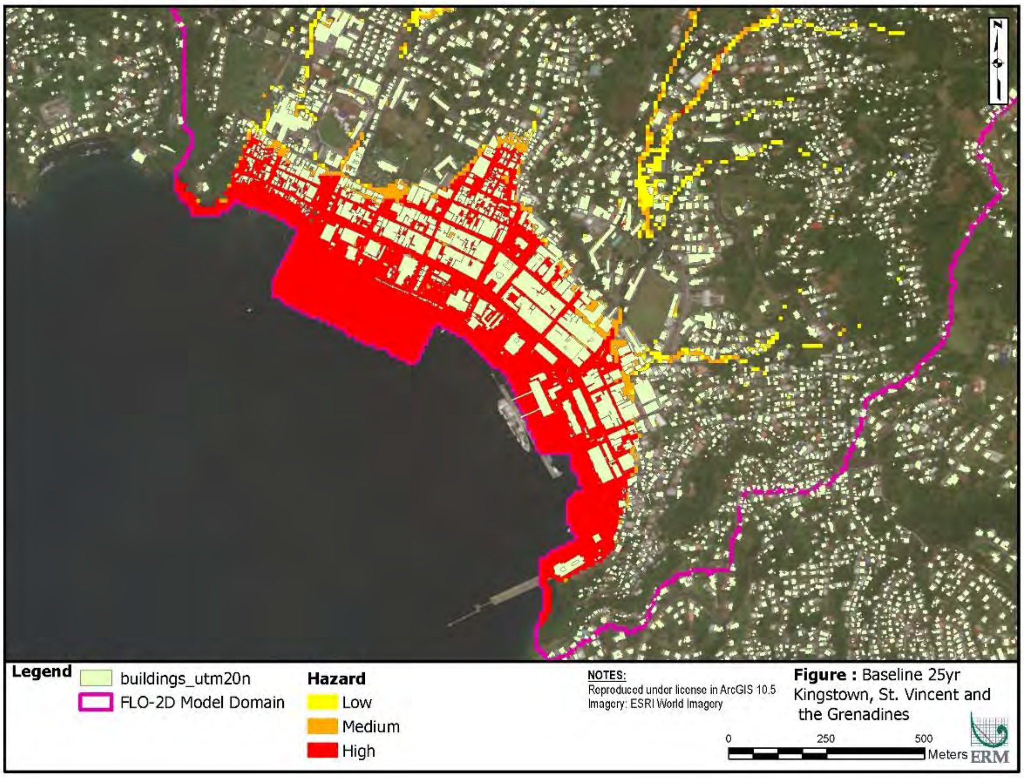


Figure 54: Flood Hazard Assessment with Container Terminal: Baseline: 25-year Return Period.

<u>50-year Return Period</u>

Under 50-year return period for baseline conditions, the Container Terminal area, like other the adjacent areas of Kingstown shows a high flood hazard. With the Container Terminal in place, the total area of flooding in Kingstown increased from 126.3 acres to 154.7 acres (**Figure 55**).

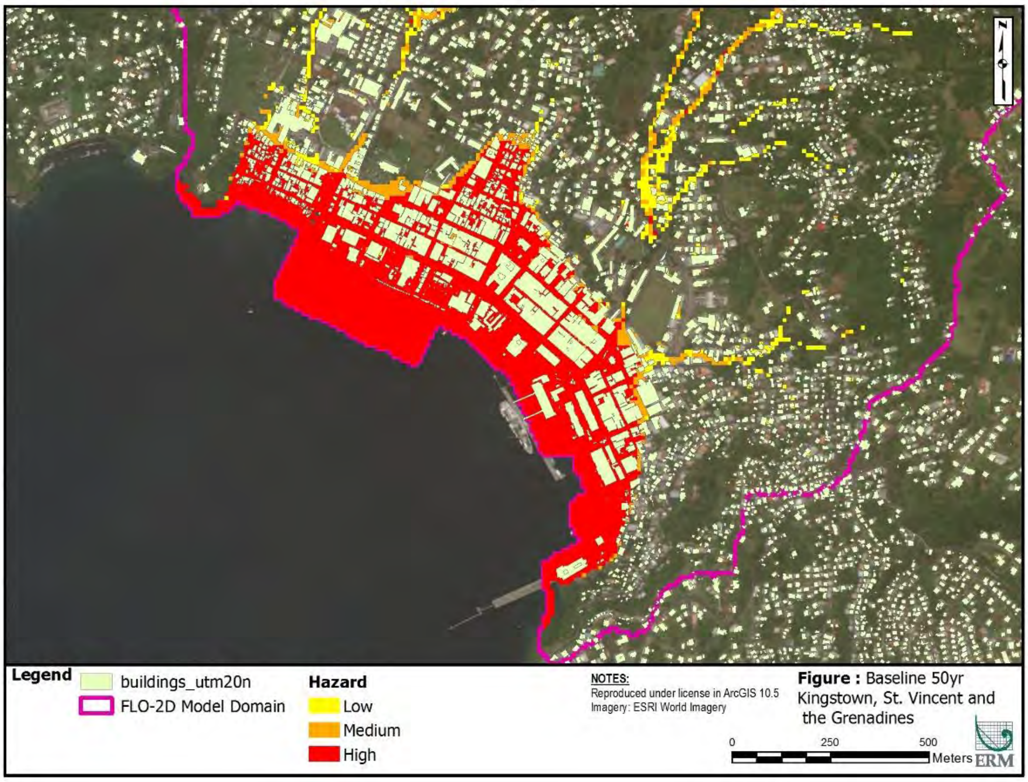


Figure 55: Flood Hazard Assessment with Container Terminal: Baseline: 50-year Return Period.

100-year Return Period

Under 100-year return period for baseline conditions, the Container Terminal area, like other the adjacent areas of Kingstown shows a high flood hazard. With the Container Terminal in place, the total area of flooding in Kingstown increased from 137.3 acres to 167.6 acres (**Figure 56**).

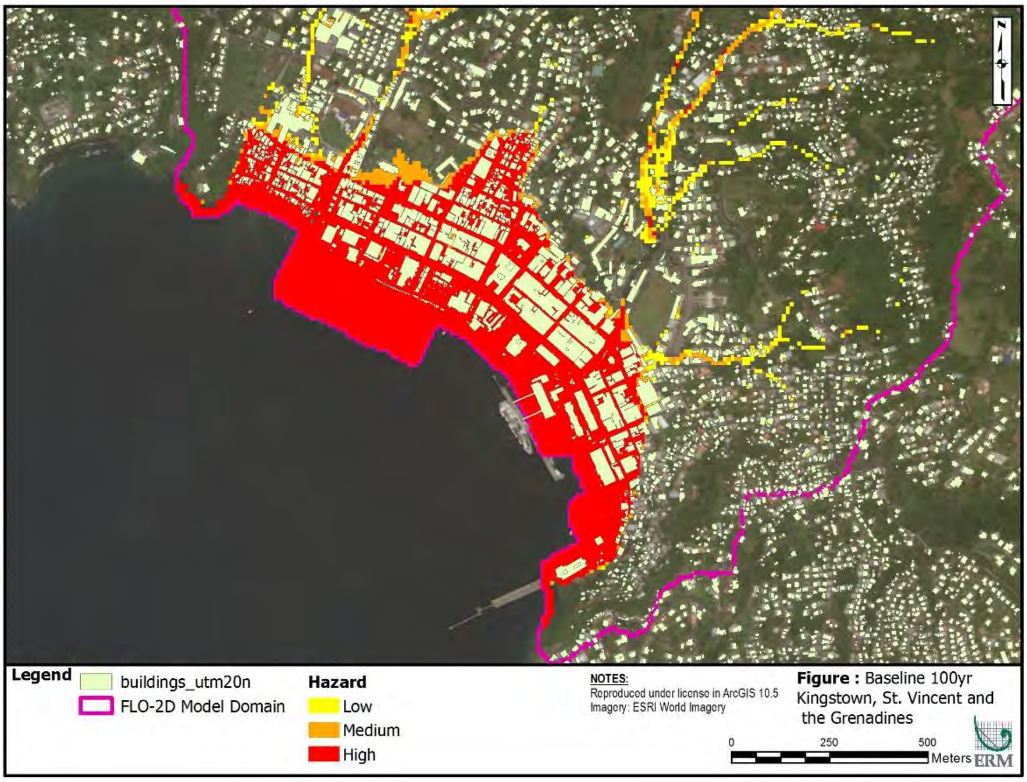


Figure 56: Flood Hazard Assessment with Container Terminal: Baseline: 100-year Return Period.

7.4.8 Flood Hazard – Climate Change

A flood hazard assessment was conducted for the Kingstown Port area with the Container Terminal constructed under climate change scenarios for 2025, 2050, and 2100 with 10-, 25, 50, and 100-year return periods.

Year 2025

Based on climate change projections for 2025, the Container Terminal area experiences medium flood hazard for the 10-year return period (**Figure 59**), however, that risk increases to *high* for the 25-year return period and greater (**Figure 58**). As with baseline conditions, the total area of flooding increased due to the Container Terminal construction.

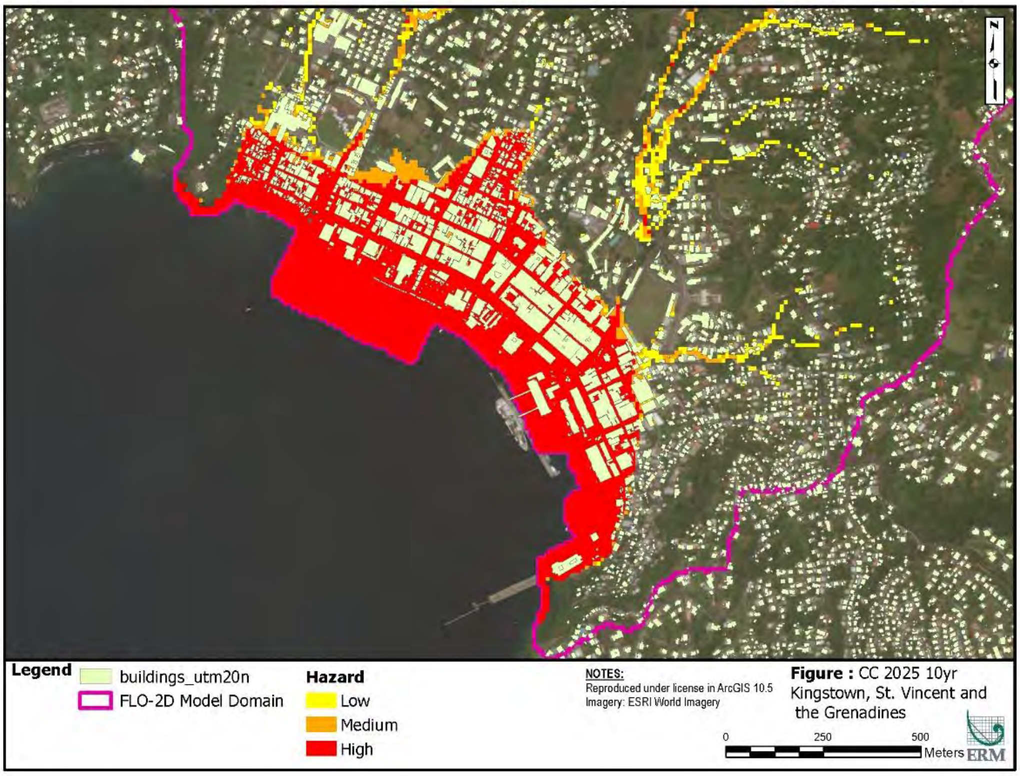


Figure 57: Flood Hazard Assessment: 2025, 10-year Return Period with the Container Terminal Built.

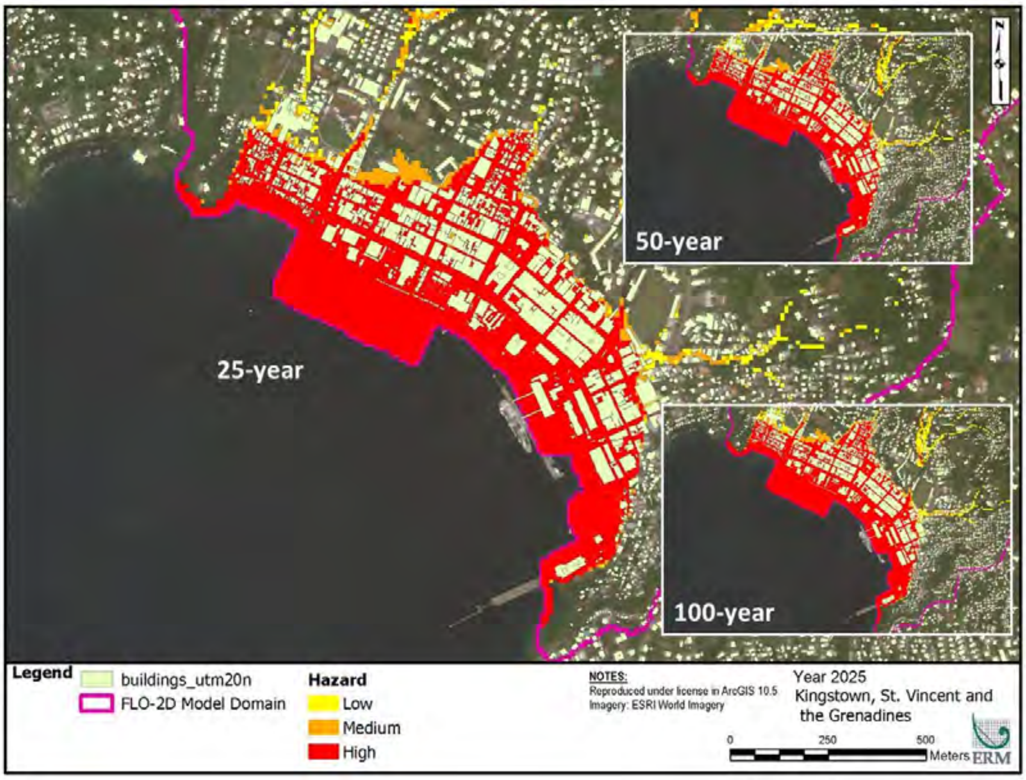


Figure 58: Flood Hazard Assessment: 2025, 25-, 50- and 100-year Return Periods with the Container Terminal Built.

Year 2050

Based on climate change projections for 2050, the Container Terminal area experiences medium flood hazard for the 10-year return period (**Figure 59**); however, that risk increases to *high* for the 25-year return period and greater (**Figure 60**). As with baseline conditions, the total area of flooding increased due to the Container Terminal construction.

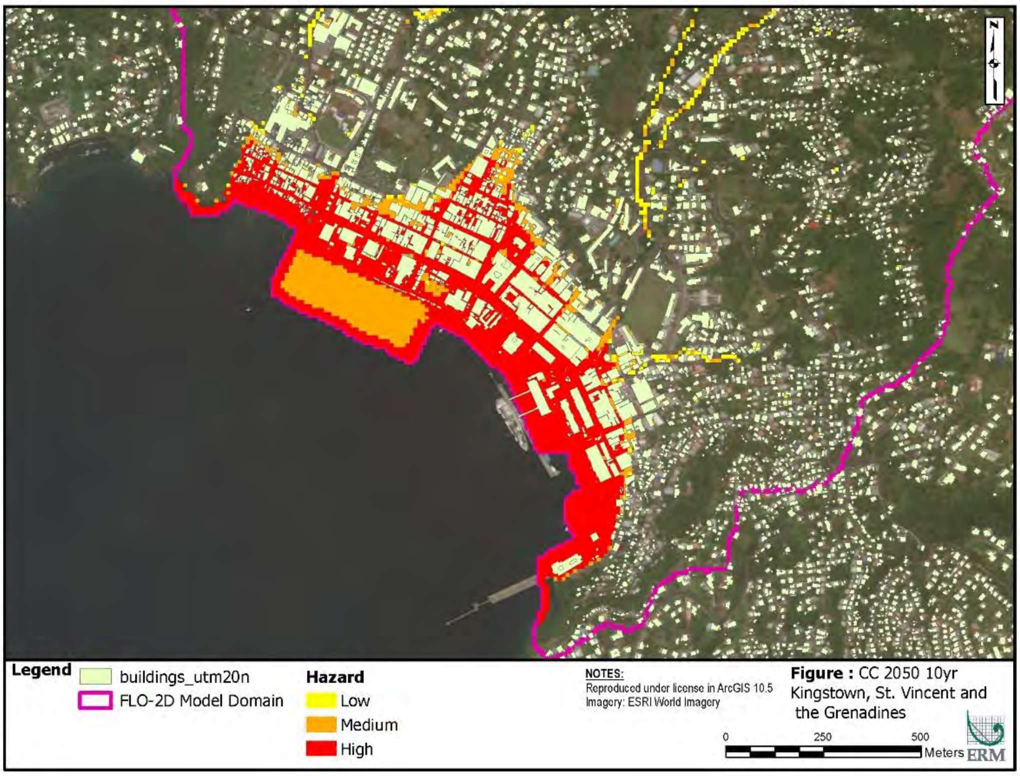


Figure 59: Flood Hazard Assessment: 2050, 10-year Return Period

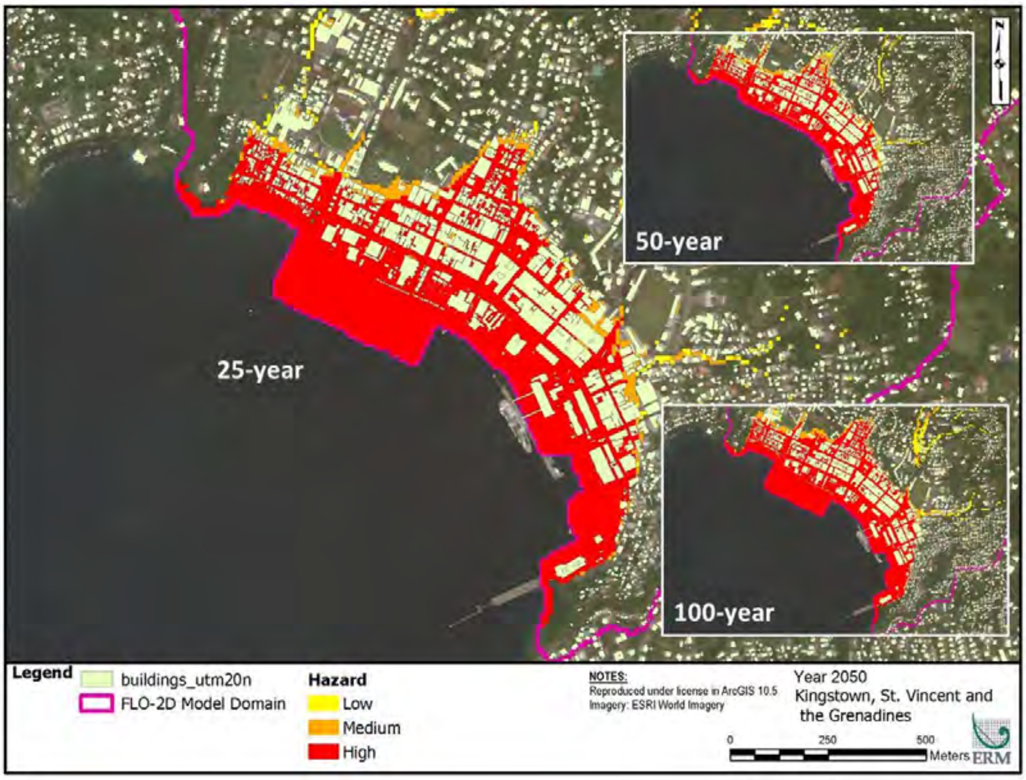


Figure 60: Flood Hazard Assessment: 2050, 25-, 50- and 100-year Return Periods

Year 2100

Based on climate change projections for 2100, the Container Terminal area experiences high flood hazard for *all return periods* (**Figure 61**). As with baseline conditions, the total area of flooding increased due to the Container Terminal construction.

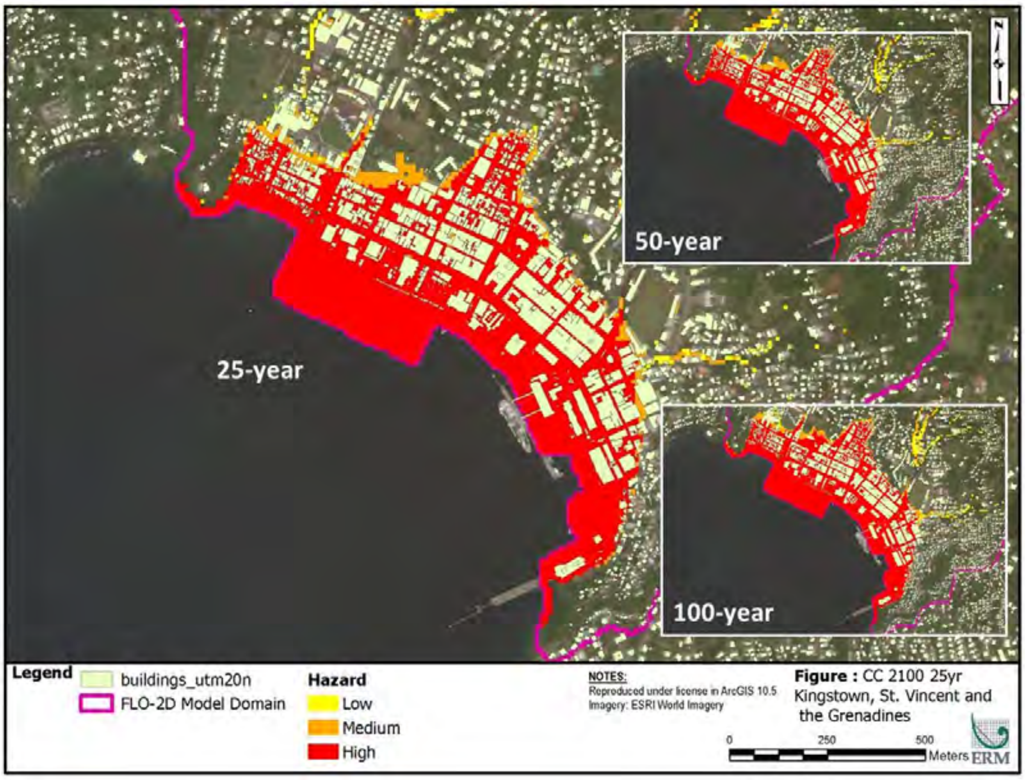


Figure 61: Flood Hazard Assessment: 2100, All Return Periods

7.4.9 Flood Depth – Baseline

10-year Return Period

Under Baseline conditions the Container Terminal experiences maximum depths of 0.1 m – 0.5 m (**Figure 62**). The maximum flood depths in Kingstown were mostly identical to the maximum flood depths for the current Baseline (**Figure 46**), however, the maximum flood depth in Rose Place increased slightly.

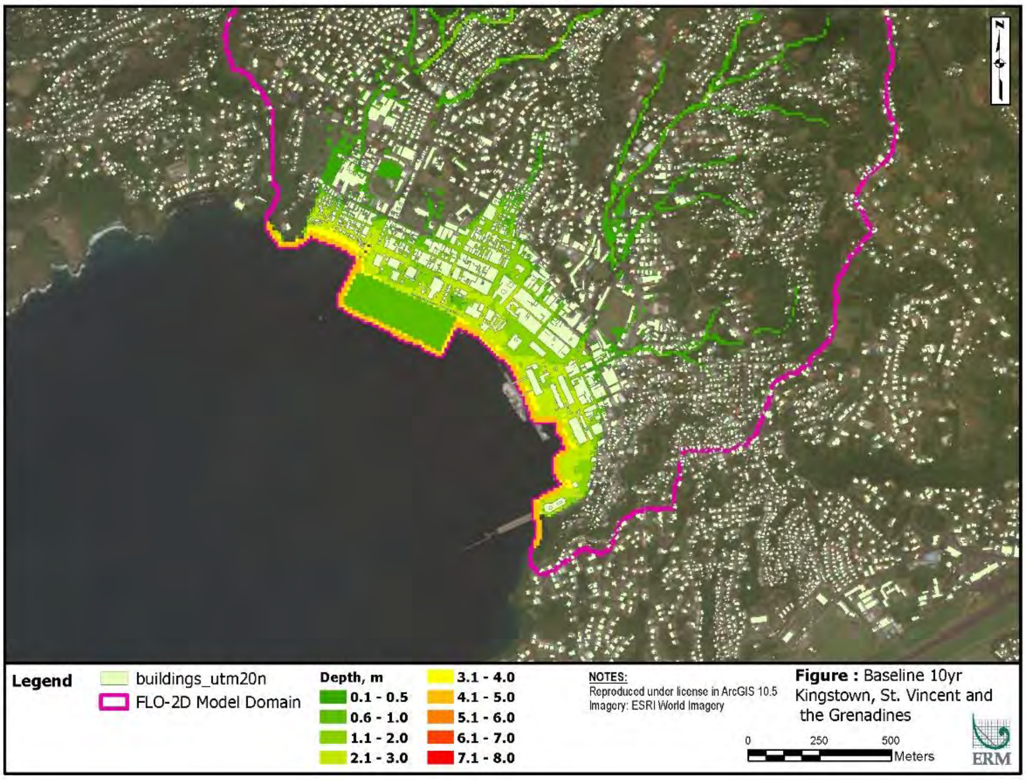


Figure 62: Flood Depth Assessment: Baseline – 10-year Return Period

<u>*25-year Return Period*</u>

Under Baseline conditions the Container Terminal experiences maximum depths of 1.1 m – 2.0 m (**Figure 63**). The maximum flood depths in Kingstown were mostly identical to the maximum flood depths for the current Baseline (**Figure 46**); however, there was a slight increase in the maximum flood depths along the immediate coastline.

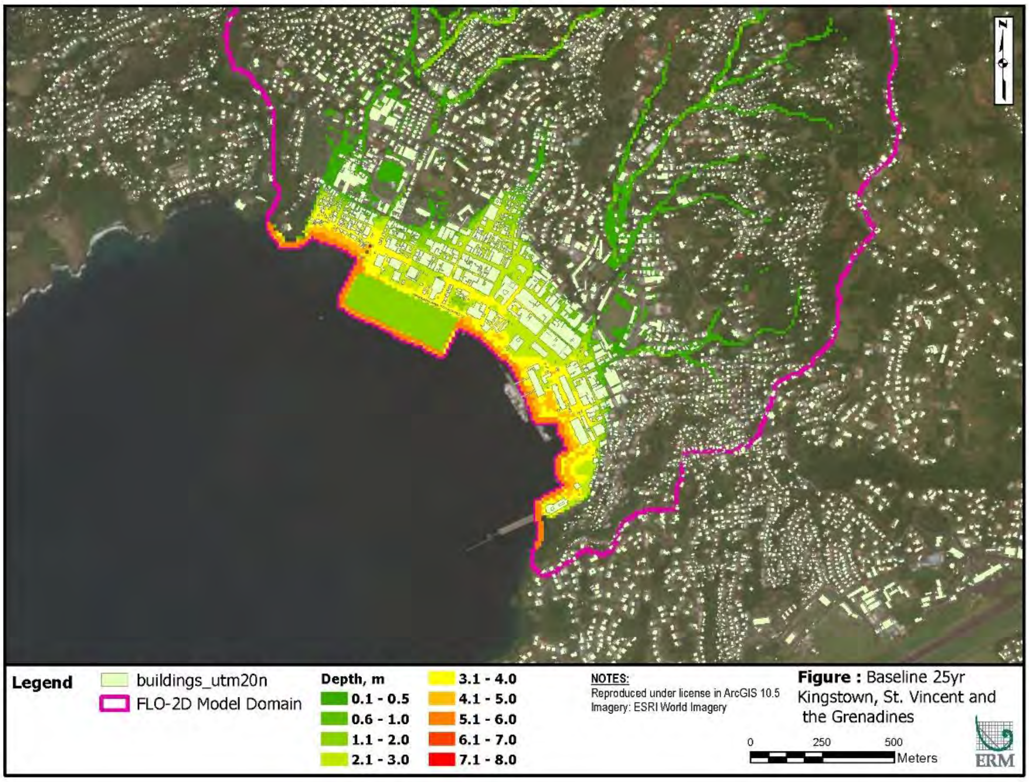


Figure 63: Flood Depth Assessment: Baseline – 25-year Return Period

50-year Return Period

Under Baseline conditions the Container Terminal experiences maximum depths of 2.1 m – 3.0 m (**Figure 64**). The maximum flood depths in Kingstown were mostly identical to the maximum flood depths for the current Baseline (**Figure 46**); however, there was a slight increase in the maximum flood depths along the immediate coastline, particularly in and around Rose Place.

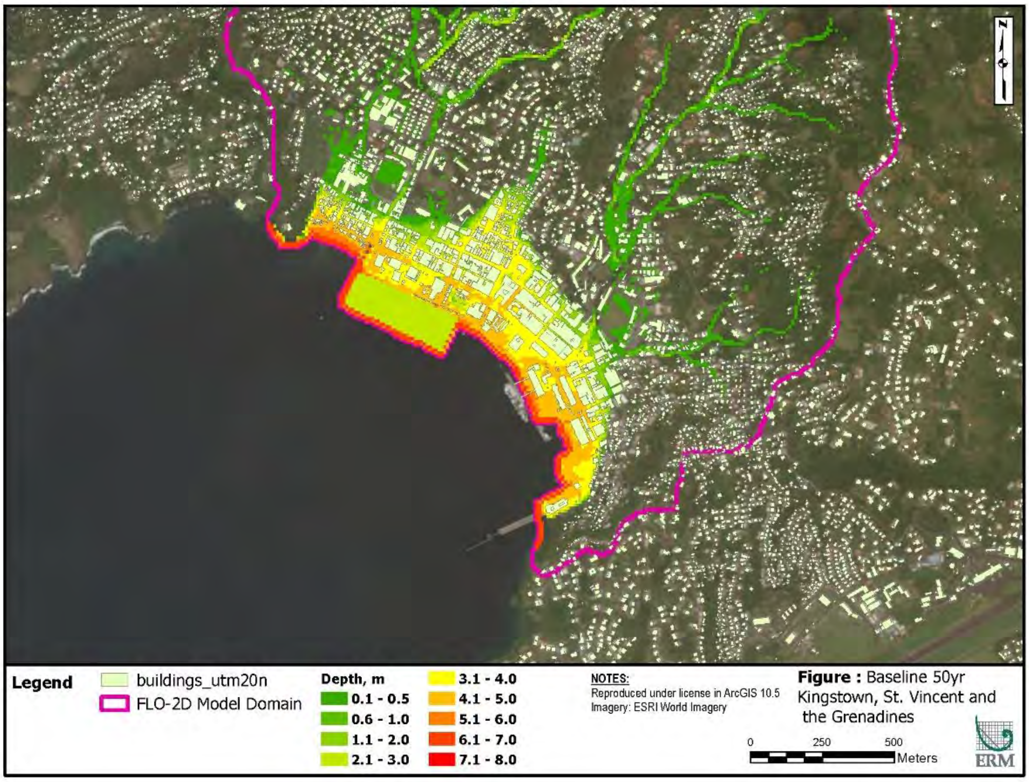


Figure 64: Flood Depth Assessment: Baseline – 50-year Return Period

100-year Return Period

Under Baseline conditions the Container Terminal experiences maximum depths of 3.1 – 4.0 m (**Figure 65**). The maximum flood depths in Kingstown were mostly identical to the maximum flood depths for the current Baseline (**Figure 46**); however, there was a slight increase in the maximum flood depths along the immediate coastline, particularly in and around Rose Place.

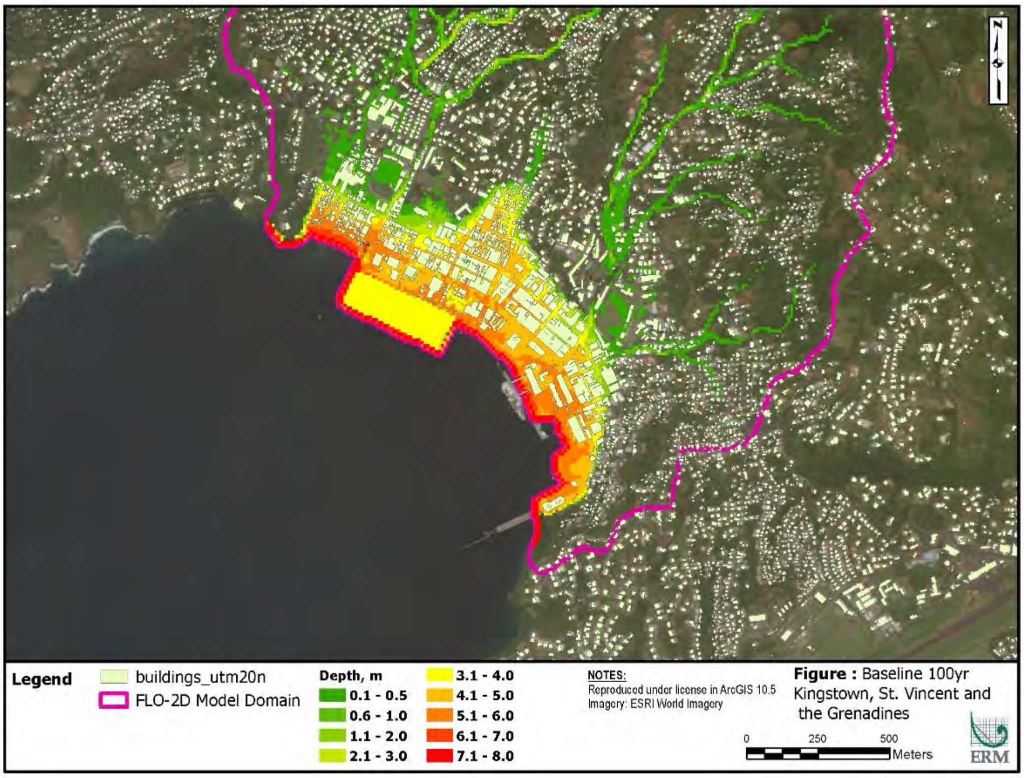
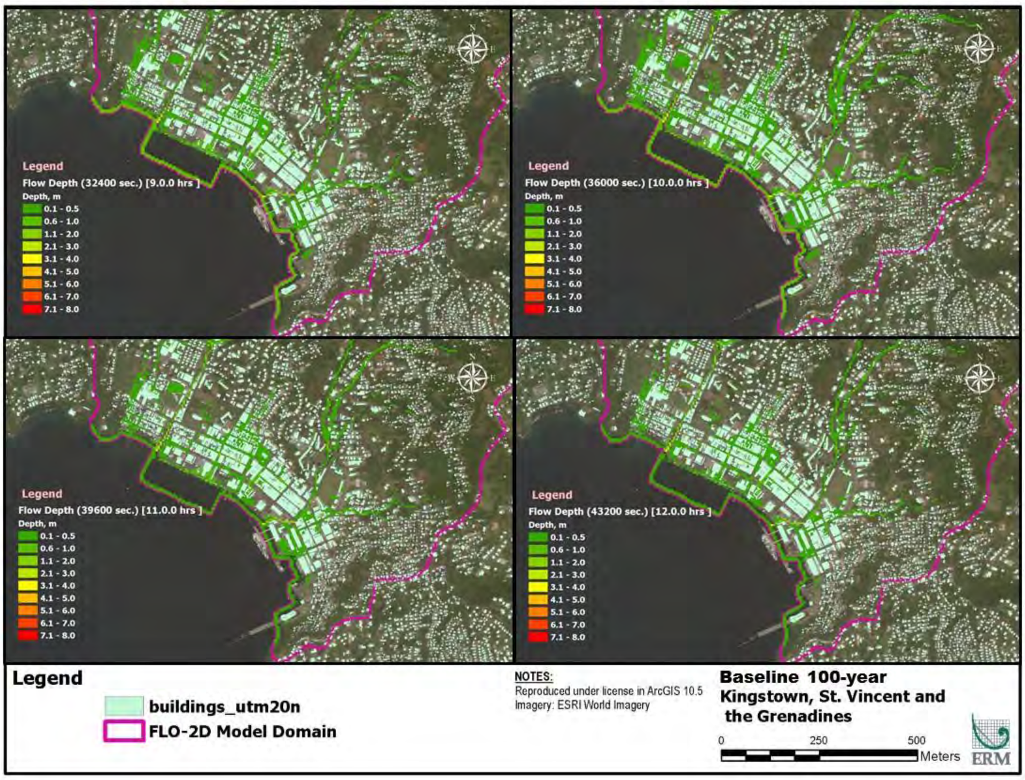


Figure 65: Flood Depth Assessment: Baseline – 100-year Return Period

Timing of Flooding

Although expected maximum depth of flooding is an important aspect to review, the timing of flooding and eventual water recession is also important to consider. As a worst case example, the timing of flooding and water recession was evaluated for the baseline condition and a 100-year return period **(Figure 66, Figure 67**, and **Figure 68**). These figures depict the maximum flood depth on an hourly basis from the onset of the storm surge. By the end of hour 1, low lying areas along the immediate shoreline are inundated to a maximum depth of 0.6 m – 1.0 m with a small area at the mouth if the North River at a maximum of 2.1 m – 3.0 m (**Figure 66**). The Container Terminal itself, however, is not inundated through hour 3. By hour 4, the Container Terminal begins to be inundated with a maximum depth of 0.1 m – 0.5 m as is the majority of downtown Kingstown. By hour 6 the majority of downtown Kingstown being flood to a maximum depth of 1.1 m – 3.0 m and areas immediately adjacent to the bay are flooded to a maximum of 3.1 m – 4.0 m (**Figure 67**). It should be noted, however, that in this analysis, because water depth is being predicted at 1 hour increments, the overall maximum depth, which is short in duration, was missed.



The ebbing of the flood waters occurs more quickly than flooding; by hour 8, water has receded from the Container Terminal and from the majority of downtown Kingstown, leaving mostly areas clear with only a small area minor maximum flooding (0.1 m – 0.5 m) inland, small areas of moderate maximum flooding (1.1 m – 2.0 m) along the shoreline. Much of the remnant flooding inland is due to upland runoff within the watershed. By hour 10, the majority of flooding is minor and a result of runoff.

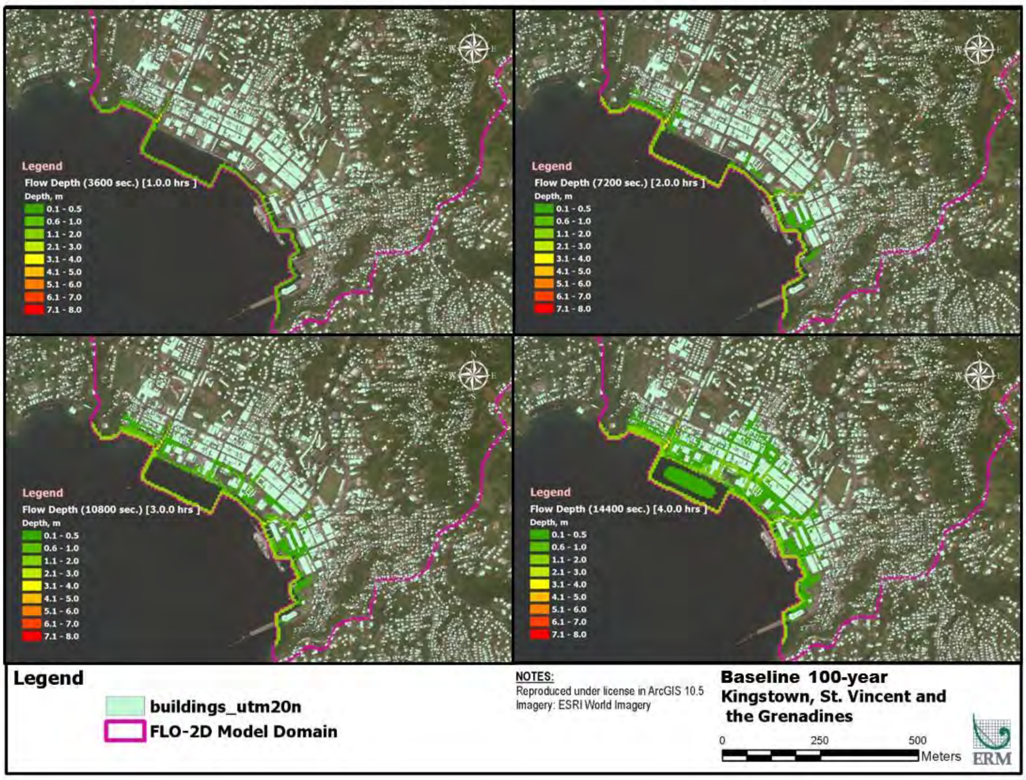


Figure 66: Hourly Maximum Depth from Onset of Storm Surge (Hr 1 – Hr 4)

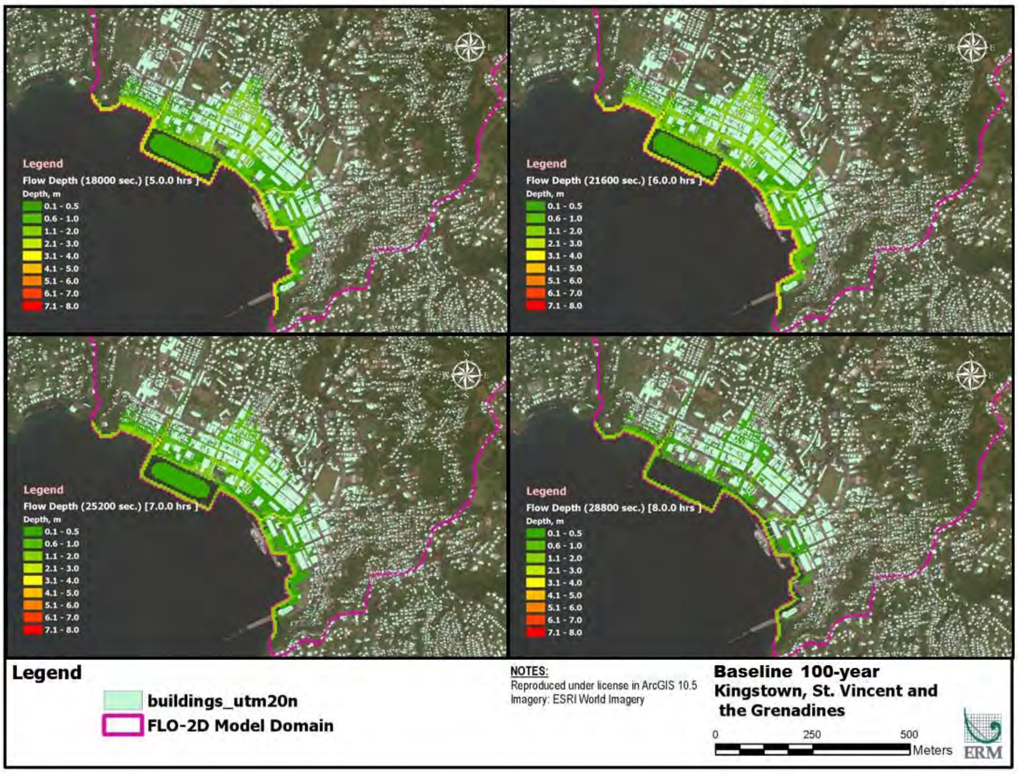


Figure 67: Hourly Maximum Depth from Onset of Storm Surge (Hr 5 – Hr 8)

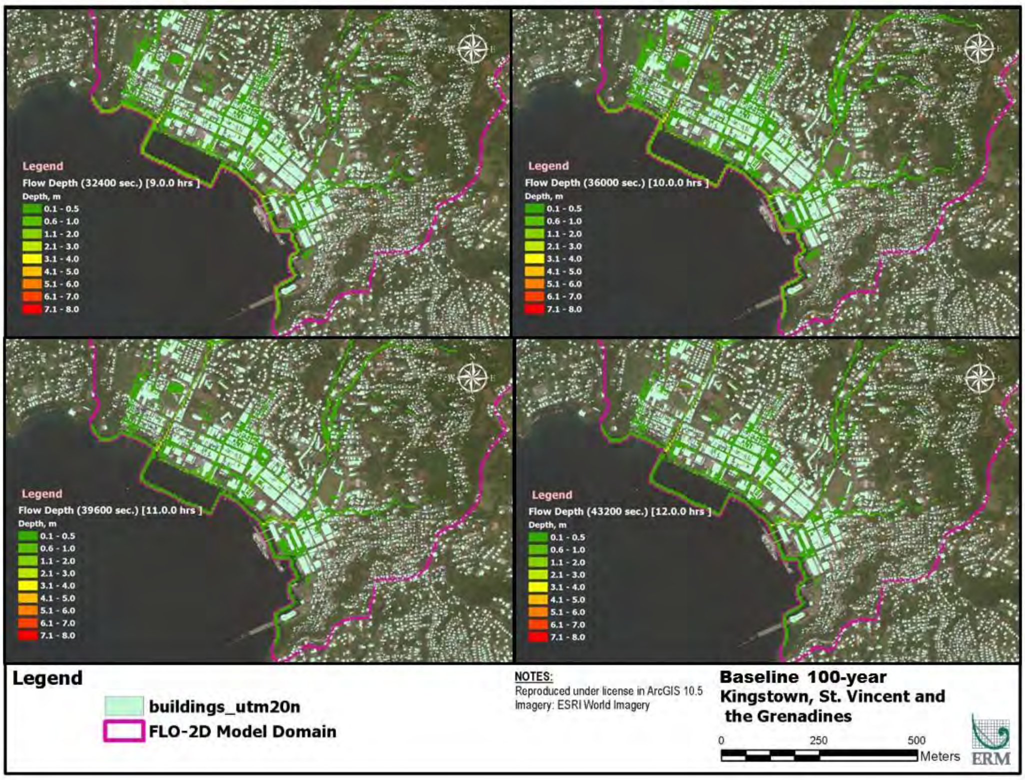


Figure 68: Hourly Maximum Depth from Onset of Storm Surge (Hr 9 – Hr 12)

7.4.10 Flood Depth – Climate Change

An assessment of flood depth was conducted for the Kingstown Port area with the Container Terminal constructed under climate change scenarios for 2025, 2050, and 2100 with 10-, 25, 50, and 100-year return periods. To illustrate the potential effects of climate change, the years 2025, 2050 and 2100 with a 100-year return period are presented below in **Figure 69**, **Figure 70**, and **Figure 71**.

Year 2025

For the 2025 climate change scenario and a 10-year return period (**Figure 69**), the Container Terminal experiences maximum flood depth of 0.6 m – 2.0 m. The majority of Kingstown also experiences maximum flood depth of 1.1 m – 3.0 m, however, areas immediately adjacent to the shoreline (e.g., the fishing boat area in Rose Place, the current port, the Ferry Terminal and the SVG Cruise Terminal area) experience maximum depths of 4.1 m – 5.0 m. For the 25-year return period, the Container Terminal experiences maximum flood depths of mostly 1.1 m – 3.0 m, while the majority of Kingstown experiences maximum flood depths of 3.1 m – 4.0 m. Shoreline areas experience major flooding with maximum depths of 5.1 m – 6.0 m. For the 50-year return period, maximum flood depths at the Container Terminal remained at 2.1 m – 3.0 m. Elsewhere, there was a slight increase in the area experiencing moderate to severe maximum flood levels (5.1 m – 8.0 m) with most of the increase occurring in the current port, the Ferry Terminal and the SVG Cruise Terminal areas. For the 100-year return period, maximum flood depths at the Container Terminal were 3.1 m – 4.0 m. Maximum flood depths elsewhere for 100-year return period were virtually identical to the Baseline 100-year return period.

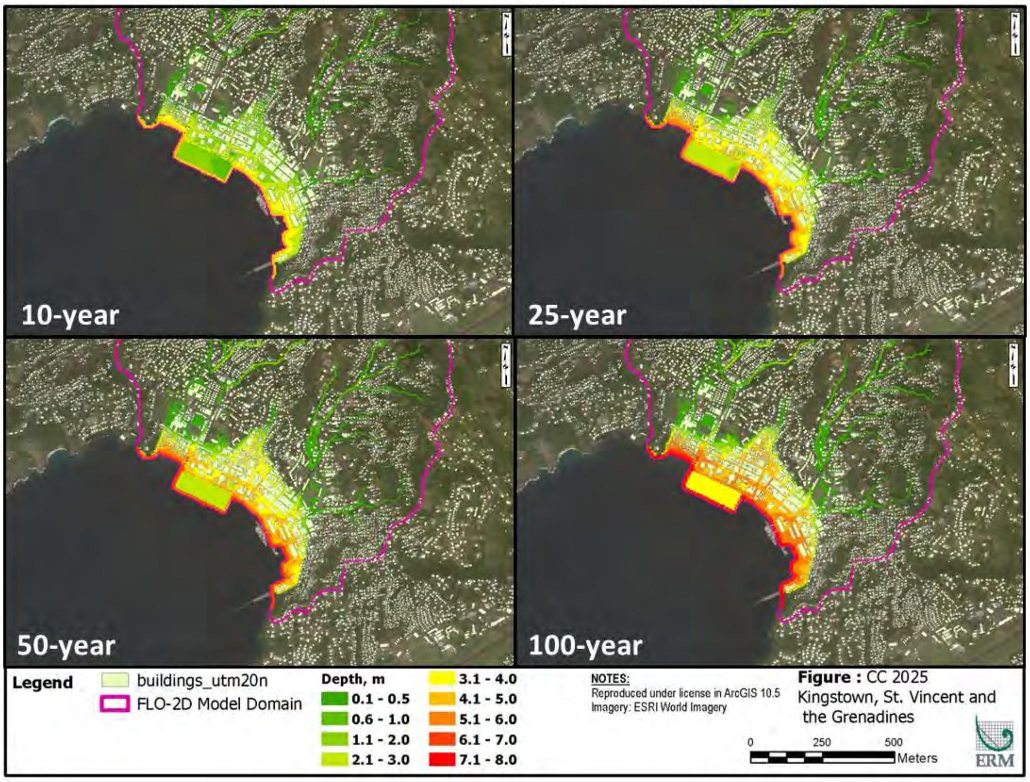


Figure 69: Flood Inundation Assessment: Year 2025 – All Return Periods

Year 2050

For the 2050 climate change scenario and a 10-year return period (**Figure 70**), the Container Terminal experiences maximum flood depths of 1.1 m – 2.0 m. The area containing Rose Place, immediately adjacent to the Container Terminal experiences moderate maximum flood depths (4.1 m – 5.0 m), as does the current port, the Ferry Terminal and the SVG Cruise Terminal area. For the 25-year return period, the Container Terminal experiences maximum flood depths of 2.1 m – 3.0 m. The majority of Kingstown experiences maximum flood depths of 3.1 m – 5.0 m. Areas directly along the shoreline experience severe flooding with maximum depths of 5.1 m – 6.0 m. This includes Rose Place, the current port, the Ferry Terminal and the SVG Cruise Terminal. For the 50-year return period, most of the Container Terminal experiences maximum flood depths of 2.1 m – 3.0 m, however, the area immediately adjacent to the mouth of the North River experiences maximum flood depths of 3.1 m – 4.0 m. In Kingstown, severe flooding with maximum depths of 6.1 m – 7.0 m occurs in areas adjacent to the shoreline, including Rose Place, the current port, the Ferry Terminal and the SVG Cruise Terminal. For the 100-year return period, the maximum flood depths at the Container Terminal were 3.1 m – 4.0 m. The maximum flood depths in Kingstown for a 100-year return period were generally about 1 m higher than the maximum flood depths without the Container Terminal constructed.

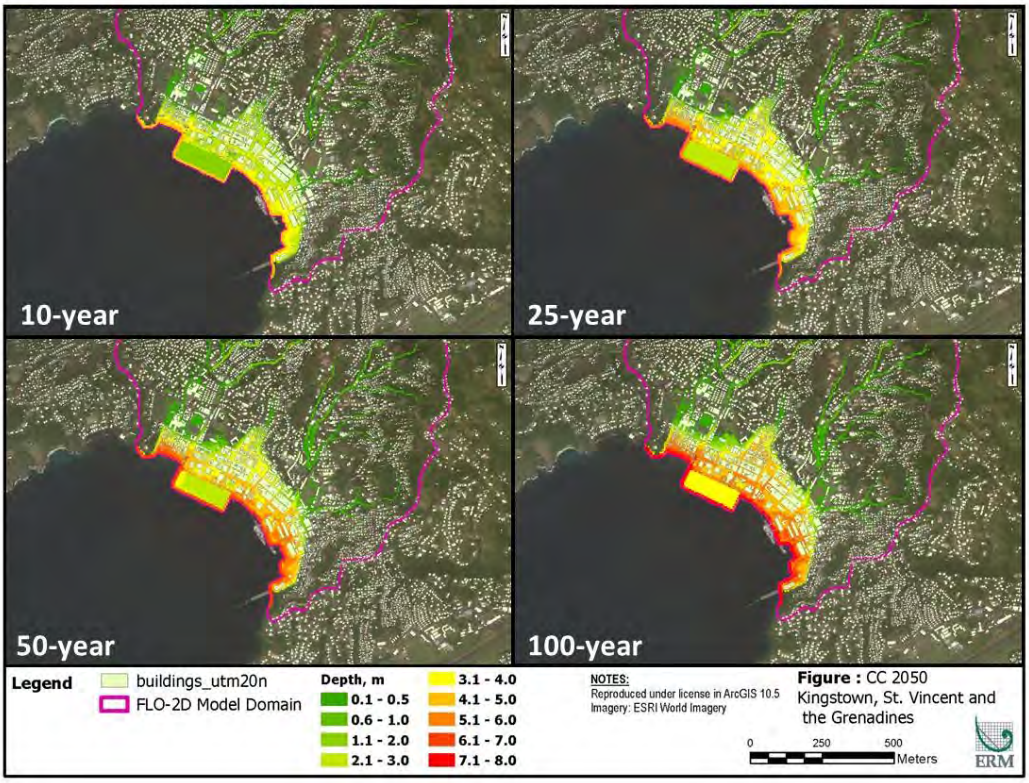


Figure 70: Flood Inundation Assessment: Year 2050 – All Return Periods

Year 2100

For the 2100 climate change scenario and a 10-year return period (**Figure 71**), the Container Terminal experiences maximum flood depths of 1.1 m – 2.0 m. as was seen in the 2050 climate change scenario. Flooding in Kingstown was also similar to that seen for the year 2050; however, there were small increases in the area of moderate flooding seen along the immediate coastline. For the 25-year return period, maximum flood depths at the Container Terminal remained at 3.1 m – 4.0 m, occurring adjacent to the mouth of the North River. For the 50-year return period, the entire Container Terminal experiences maximum flood depths of 3.1 m – 4.0 m and the majority of downtown Kingstown experiences maximum flood depths of 4.1 m – 6.0 m.

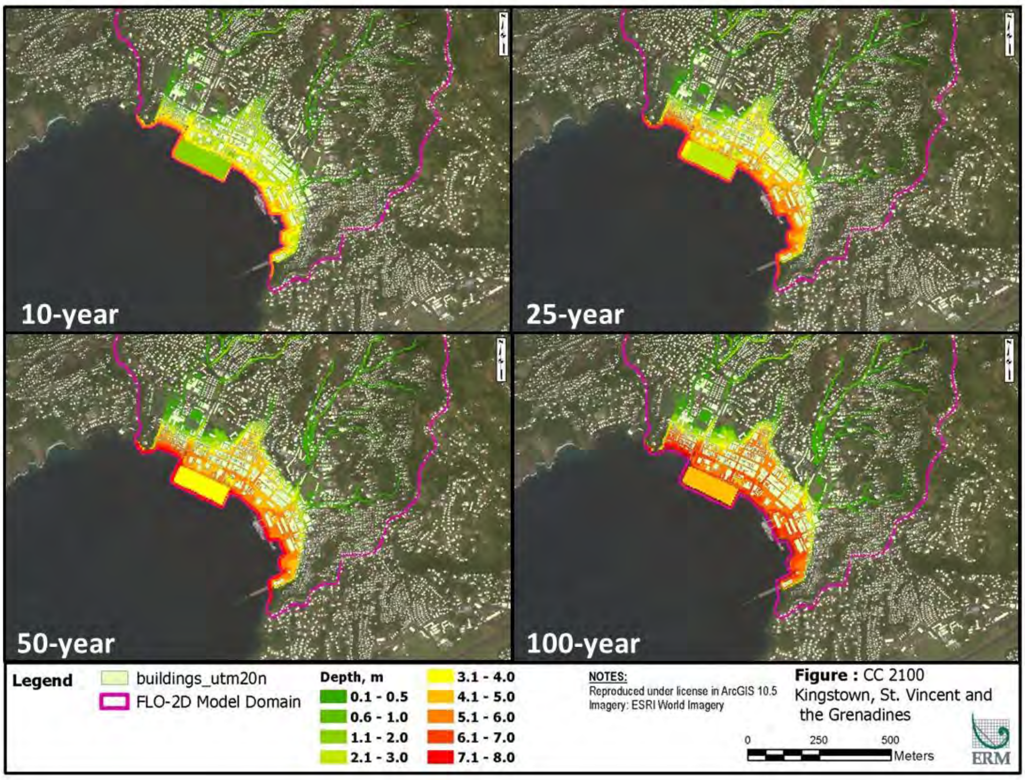


Figure 71: Flood Inundation Assessment: Year 2100 – All Return Periods

8.0 ASSETS VULNERABILITY TO CLIMATE HAZARDS

The UNSDR (2016) defines vulnerability as the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard, in this case a natural hazard. Vulnerability aspects are associated to different physical, socioeconomic and environmental factors such as poor design and construction of buildings, inappropriate protection of assets, lack of public information and awareness. In common use, vulnerability includes characteristics of the element of interest like community, system or asset and exposure of the element.

8.1 NON-PROJECT ASSETS

In this section, the main assets of interest are identified for the Kingstown port area. This list was prepared based on available data related to natural hazards and their impacts on the island; previous vulnerability reports conducted for the island; disaster reports; hazard maps prepared for the island (see Section 7); and a site visit conducted by ERM's team in June 2018. The asset map developed for the study area is shown below in **Figure 72**.

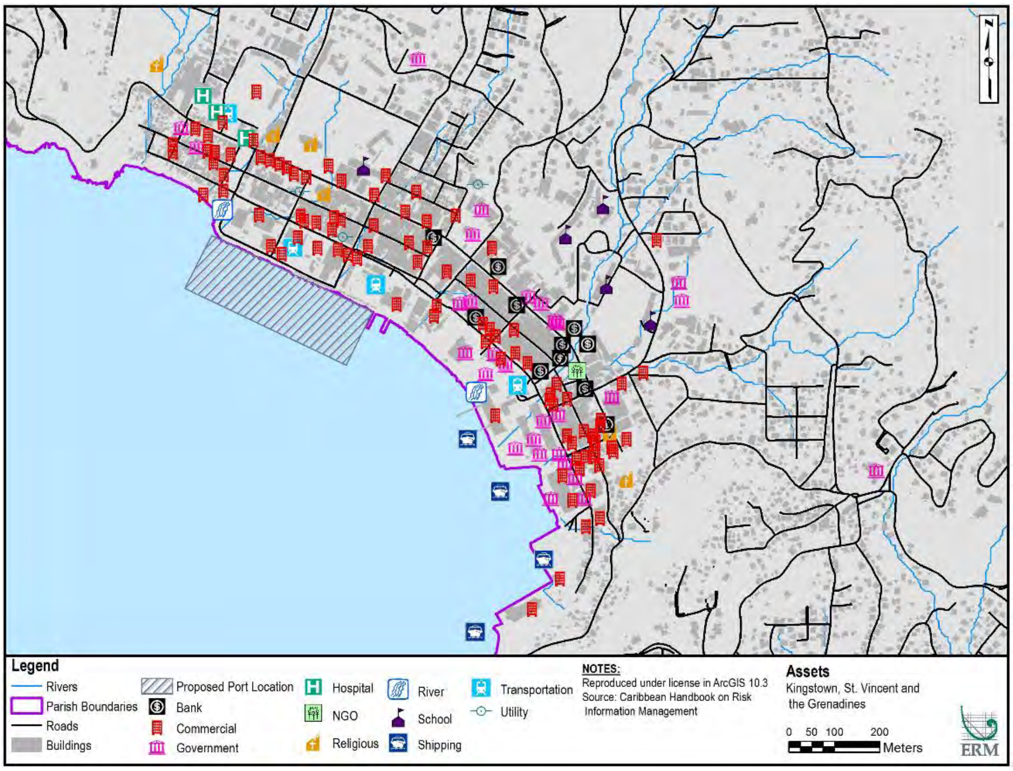


Figure 72: Asset Map for the Downtown Kingstown Area

A qualitative vulnerability assessment was performed by overlaying the asset map on various hazard maps developed in Section 7. As an example, the asset map was overlaid on worst case flood scenario (100 year climate + inland flooding) in **Figure 56** to identify the hazard intensity and also associated area impacted by it. **Table 8-1** shows vulnerability qualitative rates assigned for twenty-six different assets/asset types in Kingstown using asset and hazard maps. This table also considers properties of exposed assets, sensitivity and adaptive capacity as low, medium or high used to categorize asset's vulnerability qualitatively.

The list of assets shown in **Table 8-1** includes the main elements found in Saint Vincent that have historically been affected by natural hazards based on previous studies. According to CARIBSAVE (2012) and CZMAI (2014), climate change is projected to be a progressive process and therefore vulnerability will arise at different times and spatial scales affecting communities and sectors in distinct ways. As described previously, the main natural hazards that have historically affected Saint Vincent are hurricanes and storm surges and, therefore, combined inland and coastal flooding and coastal erosion. Vulnerability results shown in **Table 8-1** served to define risk from climate impacts and prepare a preliminary list of potential adaptation measures (see Section 9).

Table 8-1: Vulnerability of Assets in the Kingstown Port Area

Key Asset or Resource	Weather or Climate Threat	Potential or Historical Consequences	Climate Stressors and Trend	Potential effects	Additional Impact Related to Port Expansion	Sensitivity Level	Adaptive Capacity Level	Vulnerability Level
Storm Shelters (e.g. Gospel Hall Church, Sion Hill Government School)	Hurricane/tropical storm winds, heavy precipitation	Hurricane winds may lead to structural damage; heavy precipitation may lead to local flooding	Heavier precipitation events and stronger hurricane winds	Insufficient support during major storm events	None	Low	High	**Low**
Government Buildings (e.g., Administrative Complex, Passport & Immigration Department, Port Authority)	Hurricane/tropical storm winds, heavy precipitation, rising sea level, storm surge	Hurricane winds may lead to structural damage; heavy precipitation may lead to local inland flooding	Heaver precipitation events and stronger hurricane winds	Insufficient civil services	None	Medium	High	**High**
Schools (e.g. St. Vincent Grammar School, Kingstown Technical Institute)	Hurricanes, winds, heavy precipitation	Hurricane winds may lead to structural damage; heavy precipitation may lead to local inland flooding	Heavy precipitation events and stronger hurricane winds	Insufficient educational services	None	Medium	High	**High**
Sewage Pump Station on Bay Street	Rising sea level, storm surge	Coastal flooding associated with storm surge may reduce its operational capacity (e.g. damage electrical components) or lead to release of fuel and environmental contamination	Rising sea level, higher storm surge, stronger hurricane winds, and heavy precipitation events	Damage of equipment due to flooding. And power outages due to lack of fuel could lead to inability to pump sewage.	None	High	Low	**High**
Transportation Hubs (e.g. Leeward Bus Terminal, Little Tokyo Bus Station	Hurricane/tropical storm winds, heavy precipitation, rising sea level, storm surge	Hurricane winds and combined coastal and inland flooding due to storm surge may compromise structural integrity of the facility	Rising sea level, higher storm surge, stronger hurricane winds, and heavy precipitation events	Limited access to transportation and insufficient civil services	None	High	High	**High**

Key Asset or Resource	Weather or Climate Threat	Potential or Historical Consequences	Climate Stressors and Trend	Potential effects	Additional Impact Related to Port Expansion	Sensitivity Level	Adaptive Capacity Level	Vulnerability Level
Cemeteries (e.g., Kingstown Cemetery)	Heavy precipitation	Heavy precipitation may oversaturate the soil and lead to instability of the area and displacement of burial sites	Heavy precipitation events	Potential for displacement of burial sites	None	Low	Low	**Low**
Vinlec Kingstown Power Substation	Hurricane/tropical storm winds, heavy precipitation, rising sea level, storm surge	Coastal flooding due to rising sea level may impact long-term operation capacity of the facility; storm surge may impact immediate operation and consequently the power supply on the island; storm surge may damage electrical components with salt water	Rising sea level, higher storm surge, stronger hurricane winds, and heavy precipitation events	Poor or lacking electrical energy service	None	High	Medium	**High**
Rose Place	Hurricane/tropical storm winds, heavy precipitation, flooding, rising sea level, storm surge	Sensitive to storm surge, coastal flooding, and associated erosion	Rising sea level, higher storm surge, stronger hurricane winds, and heavy precipitation	Reduction of tourism sector	None	High	Medium	**High**
Milton Cato Memorial Hospital	Hurricanes winds, heavy precipitation	Hurricane winds may impact structural integrity and accessibility of this community resource ultimately preventing access to long-term and intensive medical care	Heavy precipitation events and stronger hurricane winds	Potentially limits of access to medical care	None	Medium	Medium	**Medium**
Clinic	Hurricanes winds, heavy precipitation	Hurricane winds may impact structural integrity and accessibility of this community resource ultimately preventing access to long-term and intensive medical care	Heavy precipitation events and stronger hurricane winds	Potentially limits of access to medical care	None	Medium	Medium	**Medium**
Kingstown Clinic	Hurricanes, winds, heavy precipitation	Hurricane winds may impact structural integrity and accessibility, ultimately preventing access to medical care	Heavy precipitation events and stronger hurricane winds	Potentially limits of access to medical care	None	Medium	Medium	**Medium**
Kingstown Public Library	Hurricanes winds, heavy precipitation	Hurricane winds may impact structural integrity and accessibility of this community resource	Heavy precipitation events and stronger hurricane winds	Insufficient civil services	None	Low	Medium	**Medium**

Key Asset or Resource	Weather or Climate Threat	Potential or Historical Consequences	Climate Stressors and Trend	Potential effects	Additional Impact Related to Port Expansion	Sensitivity Level	Adaptive Capacity Level	Vulnerability Level
Docks (e.g., Port of Kingstown Deep Water Berth, Schooner Berth, Kingstown Ferry Terminal, SVG Cruise Terminal)	Rising sea level, storm surge, hurricanes winds, heavy precipitation	Sensitive to storm surge and rising sea levels which may impact structural integrity and accessibility	Rising sea level, higher storm surge, stronger hurricane winds, and heavy precipitation events	Limited access to shipping and transportation	None	High	Medium	**High**
Fuel Stations (e.g. Banfield and Rubis gas stations)	Hurricanes, winds, heavy precipitation, inland flooding	Sensitive to storm surge and rising sea levels; release of refuse may contaminate local areas	Rising sea level, higher storm surge, stronger hurricane winds, and heavy precipitation events	Insufficient fuel to meet demand.	None	High	High	**High**
Commercial businesses (e.g., Massey Store Supermarket, Coreas Food Mart, Vee Jay's Restaurant & Bar, Jax Enterprises	Hurricane/tropical storm winds, heavy precipitation, rising sea level, storm surge	Sensitive to coastal flooding where located near the coast and structural damage from hurricane winds	Rising sea level, higher storm surge, stronger hurricane winds, and heavy precipitation events	Lack of goods, including food and necessities may not be available.	None	Medium	Medium	**Medium**
Housing (residential and hotels	Hurricane/tropical storm winds, heavy precipitation, rising sea level, storm surge	Sensitive to coastal flooding where located near the coast and structural damage from hurricane winds	Rising sea level, higher storm surge, stronger hurricane winds, and heavy precipitation events	Lack of sufficient housing and general prevalence of dilapidated properties may reduce the appeal of the island to tourists and the local population.	None	Medium	Medium	**Medium**

8.2 VULNERABILITY OF CONTAINER TERMINAL ASSETS

As described in Section 1.2, the proposed Container Terminal will include specific assets/areas for multiple uses and operations. These include:

- Gates and guard houses
- Solid waste facility
- Container freight station/warehouse
- Customs and Port administrative building
- An area and transit shed for agricultural products and bananas, including a transit shed for the company, "Geest"
- Maintenance yard
- Car and light vehicle parking
- Truck parking
- General cargo, break bulk and roll-on/roll-off vehicle storage area
- Reefer stack area
- Full container stack areas
- Empty container stack area
- Main quay and apron area

As described in Section 7.4.6, all assets within the container terminal are vulnerable to flooding under baseline conditions for all return periods. In addition to the assets themselves, the navigation berthing, connecting roads, vehicle movement and Container Terminal workers are all at risk for all return periods. Under climate change scenarios, asset vulnerability and the corresponding risks to navigation and ship berthing, logistics, and Container Terminal workers increase, as expected.

8.3 ECONOMIC AND POPULATION RISK

Risk is defined as the combination of the probability of an event and its negative consequences (UN, 2014b). The components of risks for the Study Area, people and environment are:

- Exposure (probability and intensity of natural disasters and the number of people exposed or threatened by these disasters); and
- Vulnerability (considering susceptibility, coping capacity, and adaptive capacity).

In the Study Area, baseline physical configuration and hydrological and meteorological conditions provided the information to establish baseline hazard and associated risks. Relevant climate change projections, which alter the existing dynamic system, were used to predict future changes that could lead to changes in the baseline hazard and risk profiles. By using all the data collected, generated and analyzed in previous sections, ERM evaluated the damages to assets associated to floods within the Study Area using the following methodology:

- Development of flooding hazard maps (water depth and velocity);

- Assessment of vulnerability (exposed building characteristics and population) using land use/cover, spatial economic and population databases;
- Estimates of economic and population risk and development of associated maps;

Land costs were used to create the economic-based risk maps based on existing land used data and costs obtained from the Saint Vincent real estate websites while population-based risk maps were created by using population density for Saint Vincent from 2012 demography data.

When risks were estimated, we evaluated at the maximum elevation and momentum in the study region due to the impact of maximum flooding at various return periods for baseline and future scenarios for the combined impact of storm surge and inland flooding due to rainfall. This was done by summing the maximum impact at each grid cell from all the simulations described in the previous sections and appendices. Though combined flood inundation maps were not included in the report, they were created as interim results to develop economic and population risk maps.

8.3.1 Economic Risk

The inventory of exposed assets involves understanding the distribution of people, buildings, and infrastructure that may be affected by floods. Exposed assets are buildings and infrastructure that are susceptible to damage given some hazard. Assets can be agriculture, residential, commercial, and industrial buildings, institutions such as hospitals and schools, or infrastructure such as roads and bridges, electrical systems, and telecommunication systems.

Land production value was calculated for agricultural and forestry sectors of SVG. While other land uses other than forest or agricultural land may also produce annual economic value, agriculture and forest products are the most common exports of St. Vincent. Economic estimates of production value for the year 2015 from agricultural land was quantified using data from the Food and Agricultural Organization of the United Nations (FAO) data repository. Specifically, the export value and hectares harvested for each crop in SVG was collected from FAO and used to calculate the US$ per square meter. The agricultural land proximal to the proposed Container Terminal location in Kingstown is predominantly pasture or cultivated herbaceous crops. Therefore, land production value was only calculated using non-woody herbaceous crops and excluded other crops such as bananas, coconuts, or cocoa (

Table 8-2). A weighted average of the USD$ per square meter weighted by the area harvested was calculated for all herbaceous crops and used as the estimate for agricultural land production value. Final agricultural production value for land near the Container Terminal location in Kingstown was estimated to be equal to $USD0.765/m^2.

Table 8-2: Export Value and Area Harvested of Herbaceous Crops From SVG for 2015.

Crop	USD ($Millions)	Area Harvested (Ha)
Carrots and Turnips	1.3	67
Cassava	1.4	104
Chilies and Peppers, Green	0.7	58
Maize	1.1	32
Pigeon Peas	1.1	28
Pumpkins, Squash and Gourds	0.5	30
Roots and Tubers	11.0	661
Spices	2.9	56
Sweet Potatoes	3.0	2342
Yams	4.5	215

Forestry products export value was derived between the years 2005 and 2009 as outlined in the Country Programme Framework (CPF) 2012-2015 For St. Vincent and the Grenadines Agricultural Sector (The government of St. Vincent and the Grenadines and the Food and Agricultural Organization of the United Nations, 2011; **Table 8-3)**. The Eastern Caribbean dollar was transformed to United States Dollar using a 0.37 exchange rate. As forest harvest area is generally not known or recorded, the total land used for forest products per year was estimated using the forest change dataset from World Resources Institutes Global Forest Watch. Forest clearing from St. Vincent and the Grenadines is common for subsistence farming and total forest change per year may not indicate the true area used for timber extraction. In this report, we assume that all cleared forestland held economic value and the timber was sold for full market price within the five year analysis period. The average annual forest value between 2005 and 2009 was calculated to be $USD1.38/m^2. Future value of annual forest production for the year 2015 was calculated to be $USD1.46/m^2 using annual inflation rates from the World Bank Group[v]

Table 8-3: Export Value, Area Harvested, and Value Per Square Meter for Forestry Land Products Between 2005 and 2009.

Year	USD ($ Thousand)	*Area Harvested (HA)*	$USD/m^2
2005	333	16.6	2.01
2006	336.7	10.5	3.21
2007	344.1	23.2	1.48
2008	336.7	41.9	0.80
2009	329.3	29.9	1.10

Land Value Estimates

Property value on Saint Vincent was estimated using the most recent property sale prices from Remax.com[vi]. Specifically, land value containing buildings was

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[v] https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?end=2016&locations=VC&start=2004

[vi] https://www.remax-caribbeanislands.com/st-vincent-and-the-grenadines/page/4/sortby/Most-recent

estimated to be US$540.26/m^2 based on estimated values from 26 residential properties and 5 commercial properties.

Land values of properties that do not have buildings were assumed to vary based on the relative slope of the area. Specifically, locations with higher slopes would be less desirable for agricultural or development purposes than flat areas. A linear interpolation of land area was calculated based on maximum and minimum slope in St Vincent and the Grenadines (maximum: 1566.29 [percent rise]; minimum: 0) and the maximum and minimum land value from 17 vacant lots (maximum: $USD100.42/m^2; minimum: $USD2.23/m^2). Specifically, land value was calculated using the following equation:

Land Value = (Slope * -0.063) +100.42

Economic value of the decommissioned E.T. Joshua Airport just southeast of the port location was not estimated, as there are tentative plans to demolish the structure to make way for New Kingstown development.

Total combined land and production value within 1-kilometer of the proposed Container Terminal location is estimated to be $USD200m with an average value of $USD214/m^2. Specifically, there is an estimated $USD570,000/year potential production value from the land within 1-kilometer of the proposed Container Terminal due to the abundance of agricultural and forestland on the outskirts of the populated areas. The total land value of $USD199,800 makes up the majority of the estimated value within Kingstown. Most of the land value is concentrated near the proposed Container Terminal location due to the high abundance of commercial and residential structures in the area. The higher elevation areas surrounding Kingstown have a lower average land value due to high slopes and potentially lower quality of land.

Information on commercial and residential buildings was not available for Kingstown, and therefore this report does not differentiate residential or commercial land values. It is possible, that land value for commercial areas close to the waterfront in Kingstown have a higher land value than estimated in this analysis. Additionally, commercial buildings may have variable production values which were not analyzed in this report.

Economic Risk Factors

Landslides

Both shallow landslide and rockslide vulnerability were derived directly from data provided by the Caribbean Handbook on Risk Information Management where landslide susceptibility was classified as low, medium, or high. Areas with low susceptibility generally refer to locations where less than 0.01% of the area experienced a landslide in the past 30 years and only have a 4% chance of new landslides occurring in the future. Moderate susceptibility zones are locations where up to 0.35% of the land area experienced landslides in the past and where there is a 10% chance of landslide occurrences in the future. High susceptibility areas are zones where about 6% of the land area has experienced landslides and there is an 86% chance they will occur in the future.

A normative value was applied to each qualitative susceptibility ranking as a proxy for an environmental vulnerability index (EVI). The EVI is the proportion of total land and production value at risk due to landslides. High susceptibility areas were given an EVI of 1, moderate were estimated to be 0.66, and low was 0.33.

Economic risk factor was calculated using the EVI transformed shallow landslide and rockslide susceptibility data along with the total land value data. The economic risk factor (ERF) is an estimate of the dollar value per square meter at risk of being lost due to landslides. Specifically, the ERF was calculated using the following equation:

ERF = EVI * Land and Production Value ($USD)

Average shallow landslide ERF was $USD74.2/m^2 within 1-km of the proposed Container Terminal location with a total potential loss value of $USD69,104,465. Buildings in generally have a much higher ERF that most other land classes in the city. Even though most of the area proximal to the Container Terminal has a low susceptibility to shallow landslides, the high land and production value of structures results in relatively high economic risk. The ERF of land surrounding the Container Terminal is significantly less than most other areas within Kingstown as most of the land is low lying and has a low susceptibility to shallow landslides. The hills surrounding Kingstown port also have relatively low ERF with the exception of the highest slope areas that are more susceptible to landslides.

Average rockslide ERF was higher than the shallow landslides at $USD99/m^2. Similarly, the total potential loss due to rockslides was estimated at $USD90,984,068. It is likely that the higher relative loss within 1-km of the proposed Container Terminal location is due to the high susceptibility areas along the slopes of Kingstown port. While many of the buildings and land value proximal to the Container Terminal location have low susceptibility and relatively similar ERF profile to that of shallow landslides, the surrounding hillside is much more susceptible to rockslides and has a higher potential ERF.

Flash Floods

Flash floods susceptibility estimates were calculated by the Caribbean Handbook on Risk Information Management into four discrete classes: low, moderate, high, and very high susceptibility. Flash flood susceptibility was measured by the return period of a given flood. Specifically, low susceptibility floods were had a return period of 50 years which equated to a probability of 0.02% per year. A summary of the return period and annual probability of occurrence can be found in **Table 8-4**.

Table 8-4: Return Period and Annual Probability for Flash Flood Susceptibility Classifications[vii]

CHRIM Classification	Return (years)	Annual Probability
Low	50	2%

[vii] Flash flood data and classifications were derived from the Caribbean Handbook on Risk Information Management (CHARIM) website: http://www.charim.net/

Moderate	20	5%
High	10	10%
Very High	5	20%

The ERF equation outlined in the Landslides section of this report was used to calculate the flash floods ERF. Specifically, the annual probability of occurrence was used as the EVI for flash floods.

Average annual estimated potential loss due to flash floods in Kingstown Port was estimated to be $USD9.2/m^2 with a total potential loss of $USD8,548,393. Flash floods have a much lower economic risk than either rockslides or shallow landslides as most of the risk is isolated directly near the proposed Container Terminal location and along major rivers. Similar to landslides, the highest potential loss is from buildings while land has a significantly lower potential loss. However, most of the area that is susceptible to flash floods is located within the dense urban and commercial area near the proposed Container Terminal location.

Combined Coastal and Inland Flooding

The land cost in $USD/m^2 for the study region is shown in **Figure 73**.

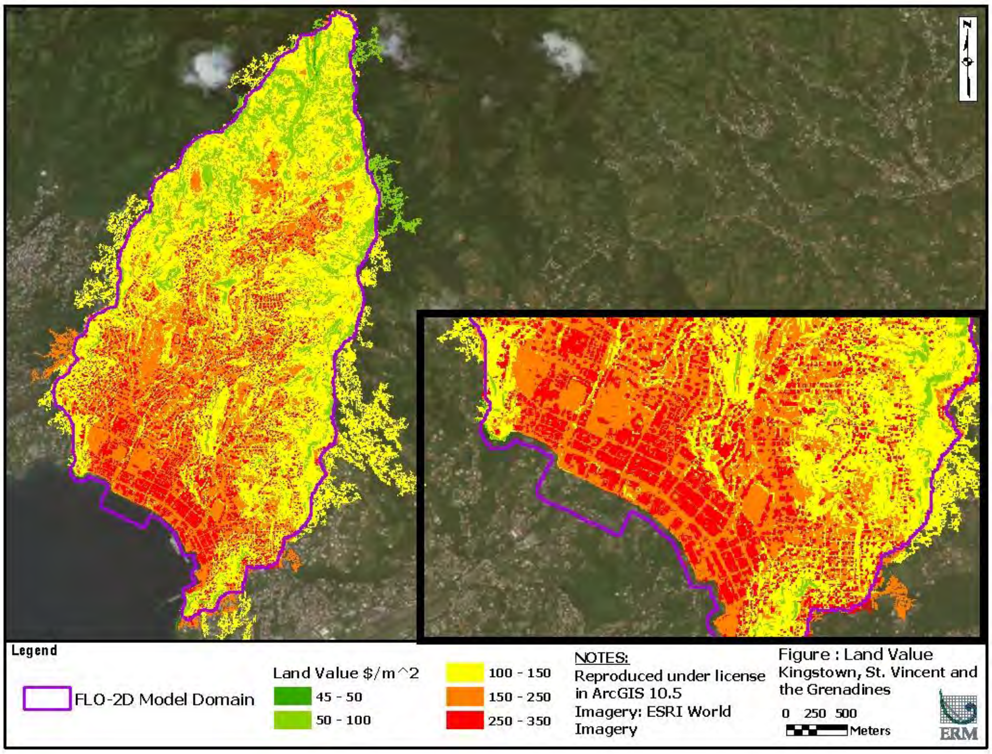


Figure 73: Land Use Property Values ($USD) Estimated for the Study Region

The vulnerability index were calculated based on the global damage functions reported in Huizinga (2007) and is shown in **Table 8-5**.

Table 8-5: Economic Vulnerability Index by Land Use and Hazard

Land Code	Land Classification Name	Hazard Low	 Medium	 High
1	Evergreen Forest	0.1	0.25	0.5
2	Seasonal Evergreen Forest	0.1	0.25	0.5
3	Semi-deciduous Forest	0.1	0.25	0.5
4	Pasture, cultivated land, and herbaceous agriculture	0.3	0.6	0.9
5	Bare Ground	0.1	0.3	0.6
6	Roads and other built-up structures	0.2	0.5	0.8
7	Buildings	0.2	0.5	0.8
8	Drought deciduous, coastal evergreen, and mixed forest shrubland	0.2	0.5	0.8
9	Water	0.2	0.45	0.9
10	Elfin, Evergreen and Sierra Palm tall cloud forest (above 550m)	0.1	0.25	0.5
12	Montane non-forested vegetation (e.g. high altitude pastures)	0.1	0.25	0.5

As an example, economic risk map for baseline at 100-year return period without the Container Terminal is shown in **Figure 74**. Similar maps were created for all baseline and climate change with and without port scenarios.

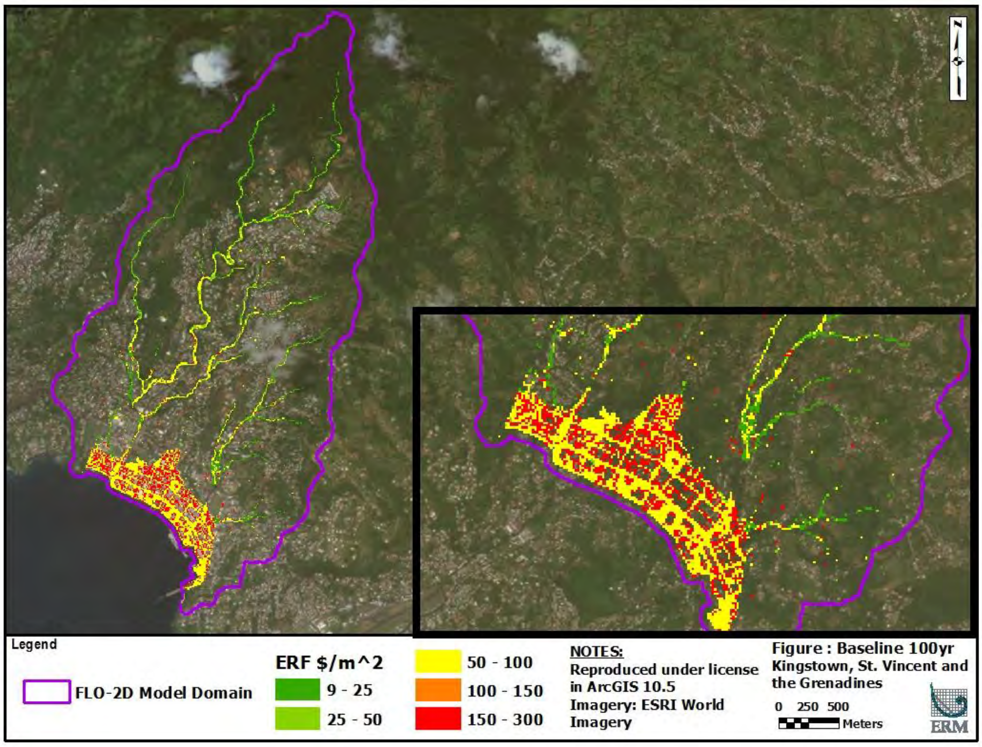


Figure 74: Economic-based Risk Map of the Study Area for the Baseline 100-year Return Period without the Container Terminal

Average annual losses (AAL) were calculated using standard formulas. Under baseline conditions, for each land classification(LC) the value per square meter (Vp) is multiplied by the percent loss (EVI) that is expected to occur for each return period (i.e., 10-, 25-, 50-, 100-years) and by the total square meters(Sm) in that land classification. This calculation represents the total damage for the return period.

(TDrp = LC x Vp x EVI X Sm). The total damage is divided by the number of years in the return period, which is the AAL for that return period and land classification (AALrp = TDrp/rp). Summing up these values for all land classifications yields the AAL. The calculation is performed separately for the baseline scenario with and without the Container Terminal.

The same set of calculations are performed under the climate change scenario, although with additional steps to allow the AAL to vary by year over the study period. For example, the model provides data for calculating the AAL for three discrete years, 2025, 2050, and 2100. To calculate the AAL for each intervening year, we assume the AAL changes linearly by year from 2018 to 2024, from 2025 to 2049, from 2050 to 2099. 2100 has a separate AAL. Then the AALs for each year are averaged for the entire study period. This calculation provides the climate change AAL with the Container Terminal and the climate change AAL without the Port.

Based on the above calculations, AALs for baseline scenario with and without the Container Terminal are $USD7,806,865 and $USD7,831,805, respectively. Similarly, AALs due to climate change with and without the Container Terminal are $USD7,733,072 and $USD7,763,712, respectively. These results clearly show that with the Container Terminal the total damages gets reduced due to the fact that it acts like a flood protection wall resulting in less flooding. Similarly due to climate change, the annual total estimated damage losses decreases for both scenarios due to the decrease in precipitation.

8.3.2 Population Risk

Population based risk refers to impact on human health which is quantified using the spatial distribution of population density in the Study Area. Estimated probable losses were determined from the exposed assets and flood hazards. Estimations were made for either the economic losses from property damage or for the risks posed to human health. Exposed assets are based on the distribution of properties and populations, as described in earlier sections. Information on the geographical distribution of population density was analyzed with geographic information systems (GIS). Population density data was obtained from NASA Socioeconomic Data and Applications Center (SEDAC)[viii]. The geospatial dataset has a resolution of 1 km at the equator available for the year 2015. Population Risk Factor (PRF) was calculated using the following equation:

Population Risk = PVI * Population Density (# people/m^2)

Where PVI refers to Population Vulnerability Index (PVI) and population density was obtained from SEDAC data shown in Figure 18. PVI was assigned based on hazard ratings. The index ranges from 0 to 1 where 0 indicates that danger to persons is very low or non-existent, and 1 indicates a high or very high danger to persons, as provided in **Table 8-6**.

[viii] Center for International Earth Science Information Network (CIESIN), Columbia University. 2017. Documentation for the Gridded Population of the World, Version 4 (GPWv4), Revision 10 Data Sets. Palisades NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H4B56GPT Accessed September 2018.

Table 8-6: Population vulnerability index (PVI) by hazard

Hazard	PVI
None	0
Low	0.25
Medium	0.50
High	1.0

The population risk map for baseline at 100-year return period with and without the Container Terminal is shown in **Figure 75** and **Figure 76**, respectively, for base case. Similar results are shown for climate change 2100 scenario with and without the Container Terminal in **Figure 77** and **Figure 78**, respectively.

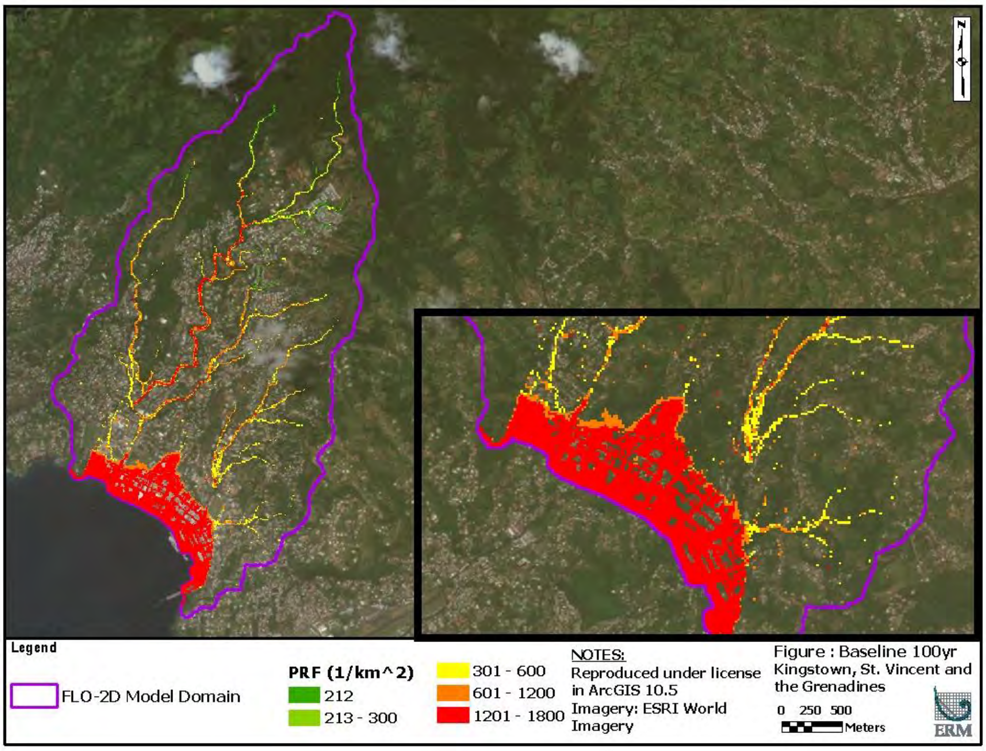


Figure 75: Population-based risk map of the study area for the baseline scenario at 100-year return period without port.

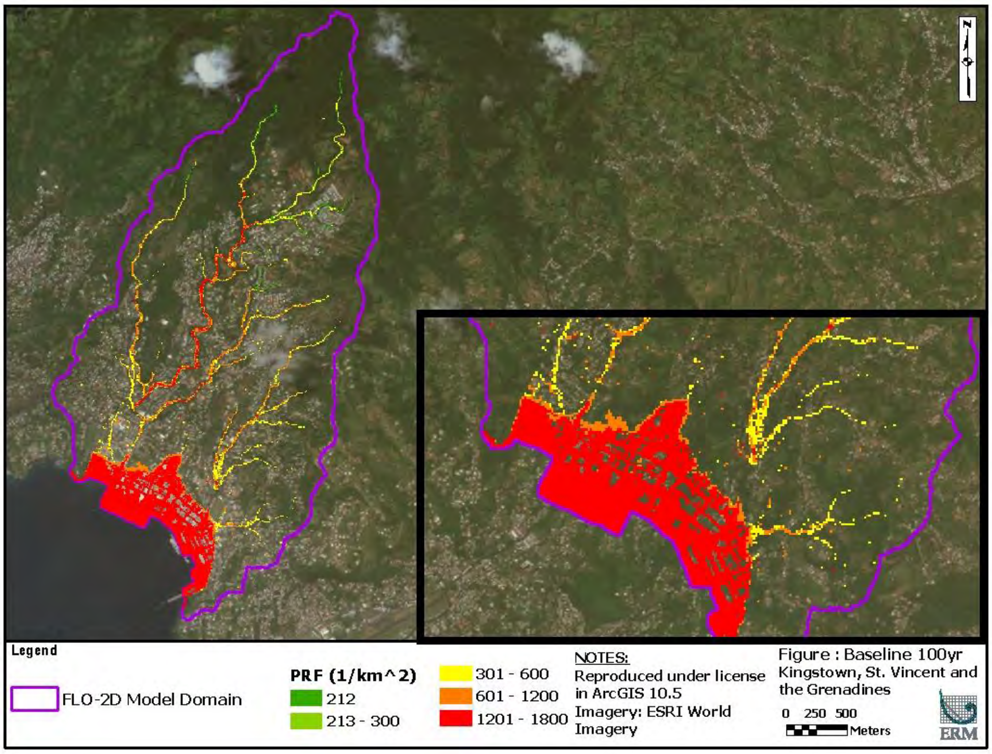


Figure 76: Population-Based Risk Map of the Study Area for the Baseline Scenario for a 100-Year Return Period with the Container Terminal.

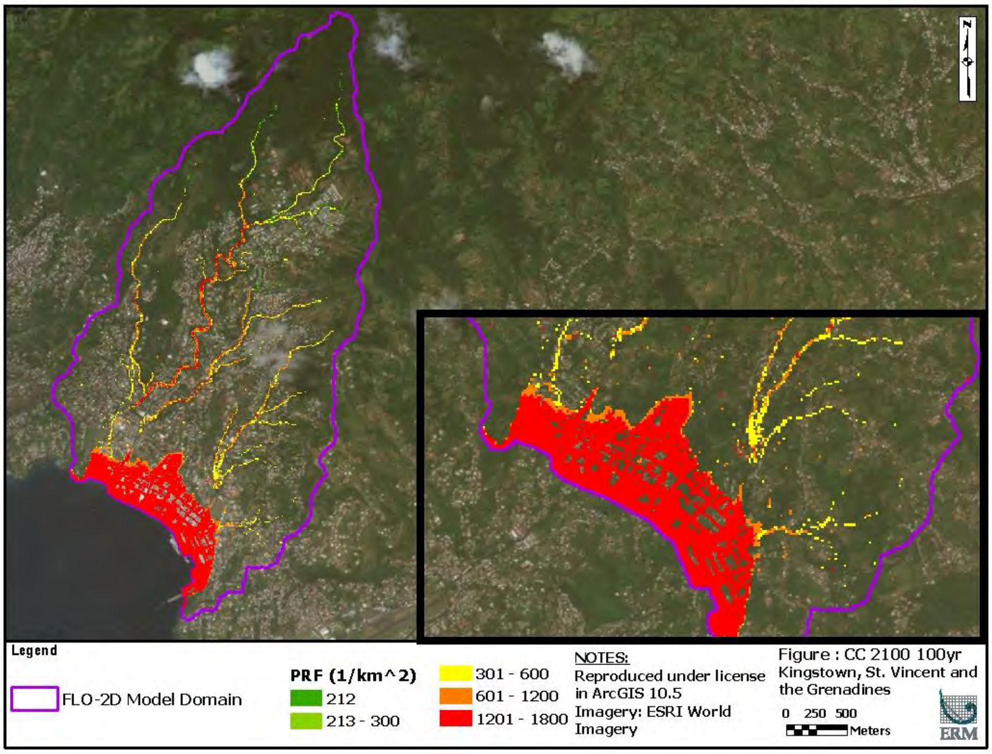


Figure 77: Population-Based Risk Map of the Study Area for the Climate Change 2100 Scenario for a 100-Year Return Period without the Container Terminal

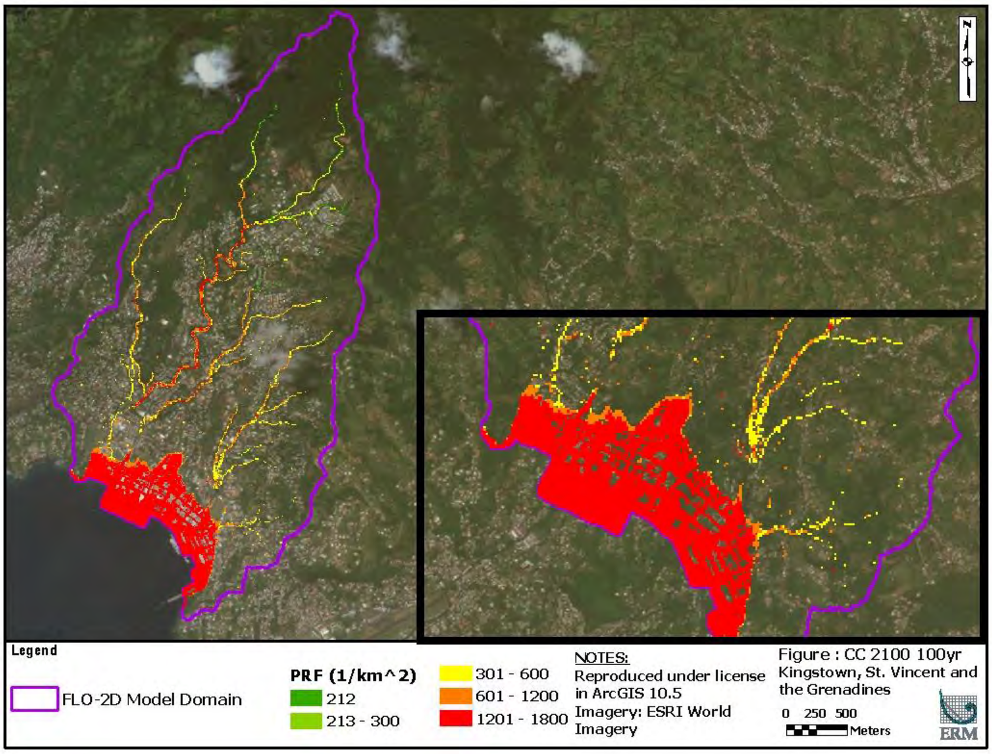


Figure 78: Population-Based Risk Map of the Study Region for the Climate Change 2100 Scenario for a 100-Year Return Period with the Container Terminal

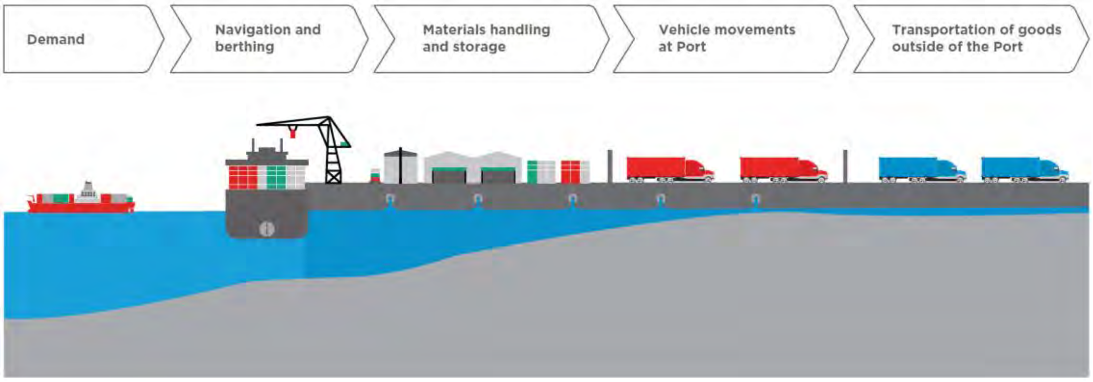
These results clearly show that high population risk exists for areas immediately adjacent to the coastal region for all the scenarios with a small reduction in the risk for climate change scenarios due to the projected decrease in precipitation due to climate change. The population risk maps are useful in preparing the disaster risk management for the study region.

9.0 POTENTIAL ADAPTATION MEASURES

The results from this hazard and risk assessment were assessed to determine the range of adaptation responses that may be relevant to the planned Container Terminal and the surrounding area of Kingstown. This section includes a list of preliminary adaptation measures by considering outcomes from this hazard and risk assessment. These measures were developed based on ERM's expertise and experience with similar issues in the region, interviews with local stakeholders, and information obtained from regional organizations (e.g., the Caribbean Community Climate Change Centre).
Various areas of port operations that can be affected by climate change (see Source: IDB 2015.

Figure 79). These include:

- Trade levels and patterns and the consequent demand for port's services.
- Navigation in and out of ports and ship berthing
- Goods handling and storage inside ports.
- Movements of goods, vehicles and people inside ports.
- Inland transportation beyond ports' fence lines.



Source: IDB 2015.

Figure 79: Conceptual Model of Container Terminal Operations That Can Be affected by Climate Change

9.1 CURRENT VULNERABILITIES AND FUTURE RISKS

As described previously in Section 1.2, the proposed Container Terminal will consist of several buildings, parking lots, storage areas, a Container Freight Station, equipment maintenance area, and a solid waste reception facility. The terminal also will be equipped with cargo handling facilities - reach stackers and two mobile harbour cranes. Further installations on the container terminal include:

- A storm water drainage system with oil separators to prevent run-off of contaminated water from the terminal to the sea in case of spillages
- A network for supplying drinking water and collection of waste water
- Electrical supply from the public network, supplemented by a back-up generator
- A firefighting system

- A security fence and a sentry house at each gate

Some current vulnerabilities to these assets are presented in **Table 9-1**.

Table 9-1: Climate Risks for the proposed Container Terminal

Climate Variable	Risks
Increased rainfall intensity	• Extreme land-side flooding could lead to terminal being cut off land-side transportation avenues • Damage to land-side support buildings
Increased intensity of storms	• Closure of linked modes of transportation
Increased intensity of storm surge	• Increased wave action at land/sea interface affecting loading and unloading operations • Increased toppling rates of containers • Increased flood depths at Container Terminal • Increased flood depths land-side
High wind speeds	• Damage to navigation and communication equipment • Delays/stoppage of loading/unloading operations
Heat	• Higher energy consumption of refrigerated containers • Higher deterioration rates of pavements and roadways

Table 9-2 summarizes some of the vulnerabilities of assets identified at the proposed Container Terminal. It identifies assets perceived to have significant or moderate vulnerability.

Table 9-2: Operational Assets Vulnerable to Climate Change

Climate Variable	Asset Vulnerability		
	Interface	Significant	Moderate
Flash Floods	Land	• Roadways • Power supply (Kingstown substation)	• Trucks • Storage buildings
Storm Surge	Sea/Land	Harbour cranes • Customs and Port Administrative buildings • Transit shed • Storage areas • Backup generator	• Reach stackers • Empty container handlers
	Land	• Harbour cranes • Stacked containers • Roadways • Power supply (Kingstown substation) • Administration buildings • Warehouses	• Trucks • Storage buildings
High Speed Winds	Sea/Land	• Harbour cranes • Stacked containers	• Backup power supply • Reach stackers • Empty container handlers • Storage areas • Transit shed

9.2 RECOMMENDED ADAPTATIONS

The recommended preliminary adaptations are aimed at minimizing the risk level and increase resilience against natural hazards and its projected exacerbation due to climate change. The measures related to construction of the proposed Container Terminal fall into two main categories of consideration: 1) enabling studies, and 2) adaptation and design opportunities.

9.2.1 Enabling Studies

This study has identified a number of data gaps in the understanding and knowledge of the island and the associated natural processes and dynamics that contribute to the Container Terminal's vulnerability. A number of enabling studies are, therefore, recommended to facilitate better understanding and suitably informed decision making for adaptation measures. These comprise:

- *Ground truthing of the high resolution DEM used in this study is proposed* – Ground truthing along the coastal region of the study area will provide a better estimation of flood inundation depth and hazards. Once this has been obtained, aspects of the flood analysis and modelling contained in this report could be re-run and a more precise determination of priority assets could be undertaken.
- *North River Monitoring Study* - Stakeholders have indicated flooding impacts from the North River are a major concern. A hydrographic study of the North River would assist in a better understanding of the flooding potential of the river. The collected data will provide the opportunity to understand the river dynamics at the mouth of the river adjacent to the proposed Container Terminal. This information can be applied to develop appropriate mitigation measures.
- *Wave force evaluation* – The increase in hydrodynamic forces on the terminal foundation structures from SLR and other climate change impacts should be considered for the Container Terminal design and other civil construction purposes.
- *Revisit SVG's Comprehensive Disaster Management Plan* – The results of this study should be used to enhance SVG's Comprehensive Disaster Management Plan by accounting for the impact of the Container Terminal due to climate change.

9.2.2 Adaptation and Design Opportunities

The following adaptation and design opportunities are made based on an understanding and knowledge of the island, natural processes and physical dynamics, and expected changes in these processes and dynamics due to climate change that will likely contribute to the Container Terminal's vulnerability. Opportunities that were identified from this study cover technological, design, engineering, maintenance, and planning are summarized in Table 9-3 below.

Table 9-3: Recommended Adaptation Actions

Action Area	Action	Reason for Action
Technological	Targeted investment in harbor cranes that operate safely under stronger wind gust	Increased frequency of extreme weather events. Currently, the probability of a hurricane hitting SVG is 18% and expected to increase. RCM projections indicate an increase in JJA (+1.2 m/s) and SON (+1.2 m/s) wind speed by the 2080s for the SRES A2 scenario.
	Invest in appropriate climate control systems to meet the demands of temperature changes.	Mean annual temperature is projected to increase by 0.15 °C per decade. GCMs project maximum temperature changes of up to 4 °C by the end of the century under the A2 scenario, with a median temperatures projected to increase by up to 1 °C by the 2030s, 1.8 °C by the 2060s, and 2°C by the 2090s.
Design	Ensure that climate change is accounted for in the design specifications for the Container Terminal elevations.	• The SLR projections indicates sea level Rise of 15 cm by 2025, 37 cm by 2050, and 111 cm by 2100. • Storm surge is expected to increase significantly by 2100 (RCP8.5 scenario). Storm surge associated with a 100-year return period is expected to be 6.05 m in 2025, 6.27 m in 2050, and 7.02 m in 2100. • The expected maximum flood depths for the year 2100 with a 100-year return period is 3.1 m – 5.0 m.
	Incorporate future climate change projections into the design of administration buildings, security systems, and storage areas and facilities.	
	Incorporate climate change projections into the design of the the Container Terminal's stormwater management system.	
	Reassess the current stormwater management system in Kingstown and undertake steps to better convey stormwater to Kingstown Bay and to expedite the ebbing of water following storm surges.	
	The roadways in and out of the Container Terminal should be be designed to respond to flooding conditions.	
Engineering	The patterns of flooding as well as the magnitude of flooding documented in this study can be used to reassess the current stormwater management system in Kingstown and undertake steps to better convey stormwater to Kingstown Bay and to expedite the ebbing of water following storm surges.	See above.
	The flood hazard and flood depth analysis indicates the potential for the landside of the Container Terminal to experience severe flood hazards and significant flood depths even without climate change effects. Invest on improving the existing roads and infrastructure supporting Container Terminal to better convey flood waters to Kingstown Bay.	
Planning	Install automated monitoring system for monitoring hydro-meteorological stations – Monitoring of the the hydro-meteorological stations should be automated so that data can quickly be updated and the early warning system becomes more effective.	Worker safety

Action Area	Action	Reason for Action
Planning	Establishment emergency routes with sufficient and proper signage. Such improvements will efficiently direct the public as well as Container Terminal worker and customers to the shelters or to the evacuation points as appropriate.	Worker Safety

The range of adaptation measures described above must consider economic and time resources, technical knowledge, adaptive capacity, land availability for displaced people among the main factor. Traditionally, all these preliminary adaptation measures will be complemented with measures that local key stakeholders and can be used with the Natural Capital Decision Analytics (NCDA) Tool to select interventions that can be implemented for the sustainable management of the Container Terminal and the surrounding area.

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