Increasing Resilience of the Education System to Climate Change in Saint Lucia and Antigua and Barbuda

Rapid Climate Vulnerability Assessment for Twelve Schools in Saint Lucia

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Executive Summary

The vulnerability of Saint Lucia and Antigua & Barbuda to climate-related shocks is likely to increase unless their education sectors improve their capacity to anticipate, prepare, adapt and become more resilient to such events. Some of the public schools designated as emergency shelters in these two Small Island Development States (SIDS) are considered insufficient in terms of structural capacity to withstand a Category 5 Hurricane as well as ensuring minimum disruption to the populations' education system. Therefore, it is necessary to implement new approach to increase the resilience of those schools, particularly as they are often designated as emergency shelters for the communities, in which they are located.

As part of this project – Increasing Resilience of the Education System to Climate Change in Saint Lucia and Antigua and Barbuda, ECMC was required to perform a Rapid Climate Vulnerability Assessment of 12 schools and associated areas in Saint Lucia. The report provides a geospatial hazard assessment for each of the identified schools. The geographic coordinates of each school are provided together with a general description of the school plant, site plans and relative locations.

The twelve schools are located throughout Saint Lucia. Based on their geographic coordinates, the northernmost school is Corinth Secondary and Southernmost, Vieux Fort Primary. Ave Maria Infant and Primary schools are at the lowest elevation of 5.0 metres while Saltibus Combined is at the highest estimated to be at 278.0 metres.

ECMC's team of experts visited the selected schools and conducted in-depth site reconnaissance to obtain a clearer appreciation of the locations as well as the environmental and topographic conditions likely to contribute to the climate change impacts. To facilitate submission of the early Deliverables, a rapid condition assessment of the school plants was performed by the engineers on the reconnaissance team. At these visits, and as a means of stakeholder engagement, the schools' principals or their representatives were consulted to obtain information on priority issues and their assessment of adaptive capacities at a school, community, Ministry and national level.

Officials of the National Designated Entity of Saint Lucia – the Ministry of Education, Innovation, Gender Relations and Sustainable Development revealed that there are no mandated design standards for schools in the country. However, as part of the consultancy, the document "Guidelines for Locating and Designing of Disaster Resilient Schools for the Organization of Eastern Caribbean States" (OECS Schools Guidelines) had to be reviewed and a separate report prepared with reviewed criteria, cross-referenced with OECS Schools Guidelines. However, it was agreed with the Client that this report (Deliverable 2.2) be combined with this Rapid CVA Report. Whereas, the document suggests that schools are "specialized multi-functional facilities" which often operate as emergency shelters, and as such, must be designed to "accommodate a wide range of occupants", it was brief on the necessary guidelines.

On the issue of landslides, the OECS Schools Guidelines recommend the use of landslide hazard maps during the preliminary design phase of structures and that the exposure to landslides be considered in the design of roads and civil infrastructure used to access schools. On the issue of floods, which is one of the critical climatic hazards, the OECS Guidelines provide a list of reference documents, loads and return periods to be considered in the drainage design. Both fluvial and coastal flooding are discussed. As it specifically relates to designing for high winds, the OECS Schools Guidelines indicate that considerations should be given to designing schools in the OECS to resist high-speed wind loads due to the frequency and occurrence of intense hurricanes in the Islands. The document does not make any specific reference to design criteria and loads which need to be used. With reference to drought, the OECS Schools Guidelines document was silent.

Based on the review of the suggested OECS Schools Guidelines document, it is our view that, regarding the primary building code, designers should be referencing the OECS Building Code 7th Edition and that the ASCE/SEI 7-16 standard be used to guide the analysis and design of the structures at a minimum. ASCE 7-16 Chapter C1 notes that risk categories are used to relate the criteria for maximum environmental loads or distortions specified in the standard to the consequence of the loads being exceeded for the structure and its occupants. It is recommended that schools in Saint Lucia be classified as Risk Category III buildings and that schools that will be designated as emergency shelters should be classified as essential facilities.

As mandated by the Terms of Reference for the assignment, the relative vulnerability of the twelve schools was established using the five stipulated hazards, namely; Landslides; Fluvial flooding; Coastal flooding and sea level rise; Droughts; and Wind speed/Hurricanes. Hazard mapping was obtained from the Caribbean Handbook on Risk and Information Management (CHARIM) GeoNode[1] in the case of landslides and fluvial flooding. Hazard mapping for high winds and coastal flooding was obtained from the Department of Physical Planning. However, in the case of the drought hazard, there was a paucity of data that was further exacerbated by less than timely responses from the sole producer of water in Saint Lucia. In that regard, the consulting team decided to undertake a qualitative assessment based on information from senior officers of the Water and Sewerage Company Inc and the knowledge of the Senior Advisor on the team. The following hazard maps were produced as part of this Rapid CVA:

- National overview hazard maps for Wind, Drought, Flood, Landslide and general overview (Appendix A);
- Landslide hazard maps for each school (Appendix B);
- Flood hazard maps for each school (Appendix C);
- Wind hazard maps for north and south Saint Lucia (Appendix D).

Hazard risk scores were derived for each school and a summary table developed providing an overview of the hazard sensitivity associated with each school. The combined relative climate change vulnerability of each of the schools, resulted in an average score, giving rise to the eventual ranking of the schools.

The results indicate that Vieux Fort Primary School ranked number one as being the most susceptible to climate change impacts while Desruisseaux Combined and Corinth Secondary Schools ranked the least - number 11. Saltibus ranked as the second most susceptible followed by the Ave Maria and Balata Combined schools which jointly ranked the third most susceptible as indicated below.

Rank	Schools	Rank	Schools
1	Vieux-Fort Primary	7	Bexon Primary
	Saltibus Combined		Micoud Primary
3	Ave Maria Infant	9	Fond Assau Combined
	Ave Maria Primary		Vieux-Fort Infant
	Balata Combined	11	Corinth Secondary
6	Patience Combined		Desruisseaux Combined

[1] http://www.charim-geonode.net/ (accessed 14 October 2020)

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1 Introduction

1.1 Background

The vulnerability of Saint Lucia and Antigua & Barbuda to climate-related shocks is likely to increase unless their education sectors improve their capacity to anticipate, prepare, adapt and become more resilient to such events. Some of the public schools designated as emergency shelters in these two Small Island Development States (SIDS) are considered insufficient in terms of structural condition to withstand a Category 5 Hurricane as well as ensuring minimum disruption to the populations' education system. A new approach is also needed to increase the resilience of those schools as emergency shelters for the communities.

It is our understanding that the main aim of the Climate Technology Centre and Network (CTCN) technical assistance/consultancy assignment is to enable these two SIDS to strategically assess the climate risk and the related negative impacts to the educational system. The intention is to also appraise improvement measures that will allow both Governments to remove technology barriers and deploy specific adaptation technology solutions in preparation of a project proposal to be submitted to the Adaptation Fund.

1.2 Purpose of the Report

As part of the project 'Increasing resilience of the education system to climate change in Saint Lucia and Antigua & Barbuda' (CTCN request reference number: 2019000059), one of the key deliverables is to develop a rapid assessment of vulnerability for 12 specified schools in Saint Lucia. The locations of these schools are shown on a map of Saint Lucia presented in Figure 1.

This report forms part of Activity 2.1 (Carry out a rapid vulnerability assessment and school identification) and Activity 2.2 (Coordinate and agree with key stakeholders for data, criteria) in the aforementioned project. This report provides a geospatial hazard assessment for each of the 12 identified schools in Saint Lucia. The longitude and latitude of each school are provided in Table 1. This geospatial assessment will help contribute to the assessment by spatially identifying which schools are most vulnerable to climate change impacts.

The report also identifies vulnerable communities and other population vulnerabilities specific to the 12 school sites.

1.3 Sites Reconnaissance

As part of the rapid climate vulnerability assessment (CVA), the team of experts visited the sites of the selected schools and conducted in depth site reconnaissance so as to obtain a clear appreciation of the locations and the environmental and topographic conditions which would contribute to the climate change impacts. Population centres and concentrations in proximity to the schools and the communities being served by the schools were also noted.

Additionally, in order to perform a rapid assessment of the physical conditions to determine climate factors and impacts, a rapid condition assessment of the plant was performed by the engineers on the reconnaissance team. A montage of photographs of the schools (Photographs 1 to 12) is presented to provide a broader perspective of the CVA produced.

School Principals or their representatives were also engaged to obtain information on priority issues and their assessment of adaptive capacities at a school, community, Ministry and national level.

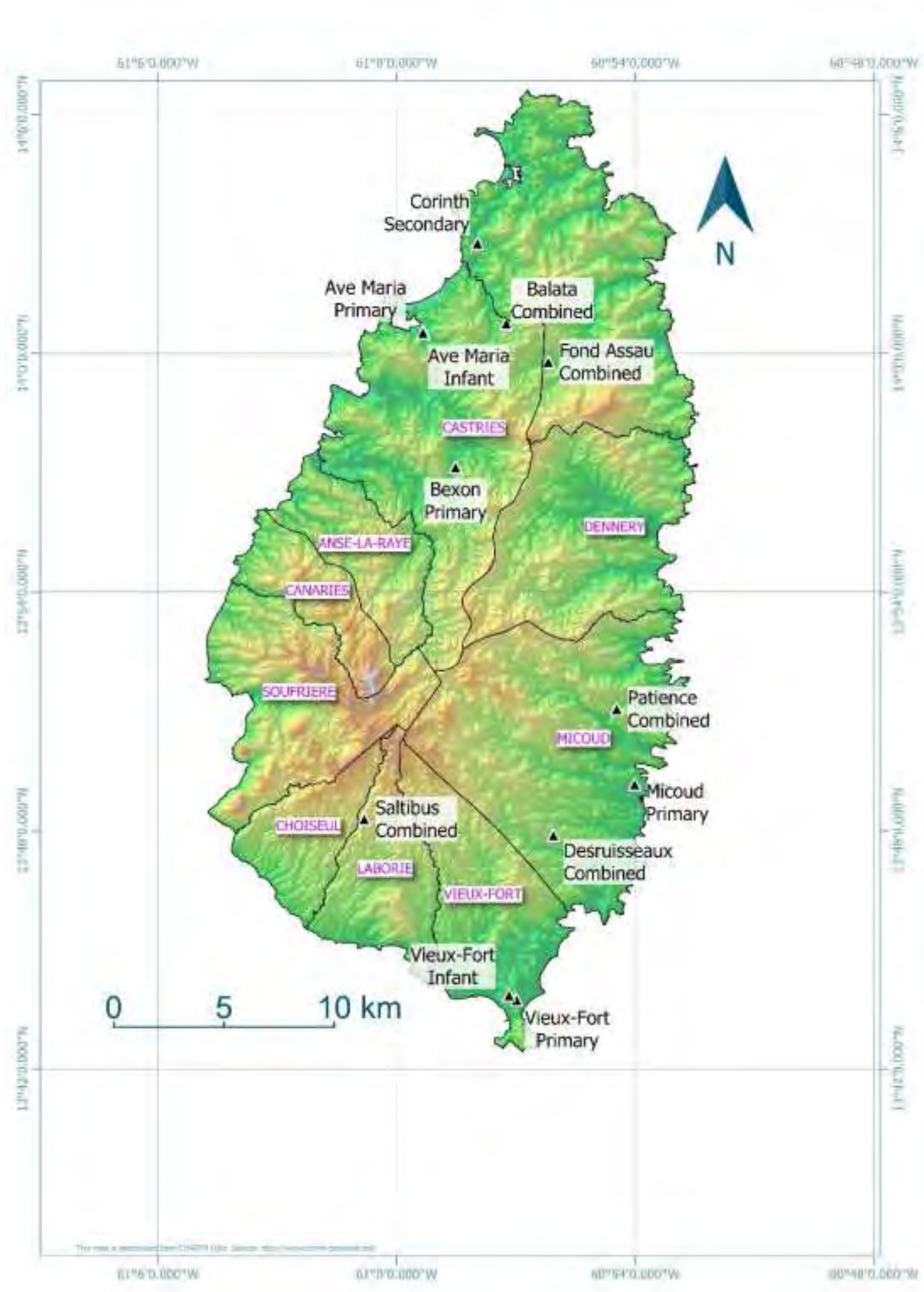

Figure 1 - Overview map of each of the 12 schools in Saint Lucia (note the Ave Maria schools are located very close together in Castries and appear as one point)

Source: HR Wallingford produced using data from ECMC Ltd and CHARIM GEONODE

Photo. 1 - Ave Maria Infant

Photo. 2 - Ave Maria Primary

Photo. 3 - Balata Combined

Photo. 4 - Bexon Primary

Photo. 5 - Corinth Secondary

Photo. 6 - Desruisseaux Combined

Photo. 7 - Fond Assau Combined

Photo. 8 - Micoud Primary

Photo. 9 - Patience Combined

Photo. 10 - Saltibus Combined

Photo. 11 -Vieux Fort Infant

Photo. 12 - Vieux Fort Primary

Understanding the vulnerability in a spatial context will enable the stakeholders to properly assess climate change vulnerability for every school on an individual basis. This tailored approach allows for individual improvement measures to be identified and prioritized on a case-by-case basis. Hazard maps assessing wind-speed, flood hazard, drought hazard and landslide vulnerability were produced both on an overview scale and individual school scale.

Table 1: Schools in Saint Lucia for which hazard maps were produced

School	Latitude	Longitude
Ave Maria Infant	14° 0'31.28"N	60°59'18.93"W
Ave Maria Primary	14° 0'31.72"N	60°59'20.00"W
Balata Combined	14° 0'45.28"N	60°57'14.30"W
Bexon Primary	13°57'8.60"N	60°58'30.85"W
Corinth Secondary	14° 2'46.30"N	60°57'57.71"W
Desruisseaux Combined	13°47'53.19"N	60°56'3.15"W
Fond Assau Combined	13°59'47.27"N	60°56'10.91"W
Micoud Primary	13°49'9.90"N	60°54'0.60"W
Patience Combined	13°51'3.47"N	60°54'27.74"W
Saltibus Combined	13°48'17.50"N	61° 0'48.48"W
Vieux-Fort Infant	13°43'51.76"N	60°57'10.26"W
Vieux-Fort Primary	13°43'44.77"N	60°56'58.91"W

1.4 Descriptions of Sites

The 12 school sites are located across Saint Lucia, from Corinth in the north (Gros Islet) to Vieux Fort at the southern tip of the Island. The schools and surrounding communities are located in areas varying from very flat to moderately sloping.

The descriptions of the sites provide information on their relative locations within the communities, topography of the grounds, proximity to water courses, relative elevations and proximity to playgrounds and emergency services. In these descriptions, information on the type of community (rural, urban or sub-urban) is also provided. Information on the reported school occupation is also provided to provide an insight into the size of the school and its capacity as an emergency shelter.

1.4.1 *Ave Maria Infant and Ave Maria Primary*

Both of these schools are located within one fenced compound in the centre of Castries and three city blocks away from the Central Fire Station. The site is flat and occupies the major portion of a city block, on 3,000 m^2 of land. The location plan and aerial view of the school are presented in Figure 2.

The compound comprises six school buildings surrounding a playground, void of any vegetation. The property has exits on all the three streets which are contiguous to the northern, eastern and western boundaries. Both schools are identified as emergency shelters and are two of five schools which are considered as being located in the centre of Castries. The total population of the two Schools is 498 students.

Figure 2 - Location plan and aerial photo of Ave Maria Infant and Ave Maria Primary Schools

1.4.2 *Balata Combined*

The School is nestled within the Balata community, Quarter of Castries and in the central north of Saint Lucia. The location plan and aerial view of the school are presented in Figure 3. The compound is at the end of an ill-defined cul-de-sac, accessed by a narrow road with inadequate geometric design. The road reduces to a community footpath after passing the school, and there are no other vehicular accesses to the site. There is minimal space available for vehicular turning. A ravine flows to the western side of the school and is in close proximity to the school's north-western boundary. The compound is flat with school operations accommodated within an "L" shaped building with access to a playground on the opposite side of the access road. The school compound occupies circa 1,880 m^2. It is used as an emergency shelter and has a population of 378 students.

Figure 3 - Location plan and aerial photo of Balata Combined

1.4.3 *Bexon Primary*

The Bexon Primary school is located in the centre of the Island. It is considered to be between the Cul De Sac and Mabouya Valleys and sits within a low lying plain which is known to flood. Vehicular access is off an extended track which does not facilitate easy manoeuvrability of emergency and other vehicles. The location plan and aerial view of the school are presented in Figure 4. The pedestrian access across its eastern boundary crosses the Cul De Sac River off of the Castries-Vieux Fort Highway. The closest emergency vehicles (fire and ambulance) are located in the Castries and Dennery areas which are approximately 16 km to the north and south respectively. The school compound occupies 2,117 m^2. It is located near a community playground and is zoned as an emergency shelter. It has a population of 136 students.

Figure 4 - Location plan and aerial photo of Bexon Primary

1.4.4 *Corinth Secondary*

The Corinth Secondary School is located in the northern section of the Island and is accessed off a major secondary road which runs in an easterly direction from the Grand Riviere Junction off the Castries - Gros Islet Highway. The location plan and aerial view of the school are presented in Figure 5. It is within a densely populated residential area, which is quickly becoming sub-urban. It is one of the largest schools in the Gros Islet area and the compound occupies 8,130 m^2 of land adjacent to a community playground.

The La Brelotte River flows near its north-eastern boundary and the school site is known to have experienced issues with drainage and flooding of the northern side of the compound. Emergency services (police and fire) are available about 8 km to the north and the school is designated as an emergency shelter. It has a population of 706 students.

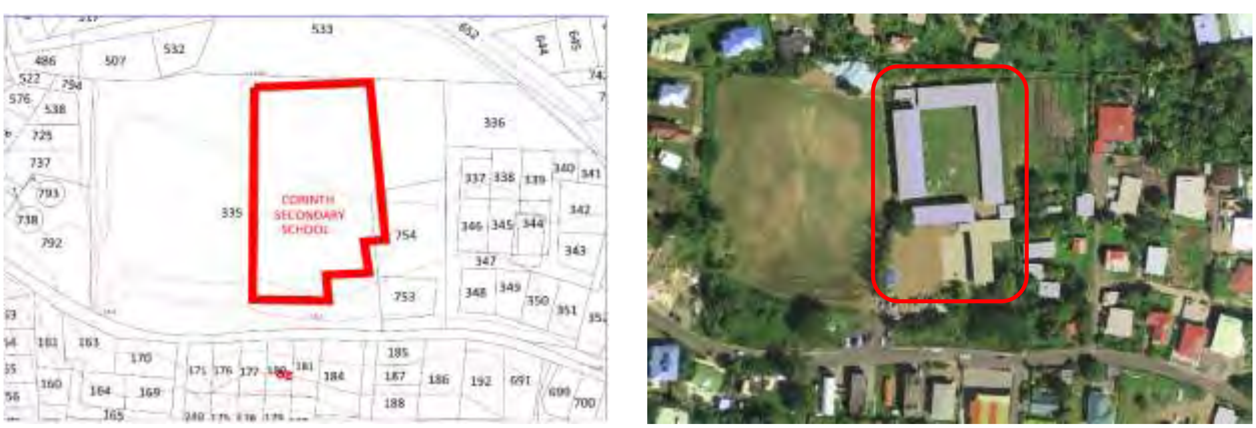

Figure 5 - Location plan and aerial photo of Corinth Secondary

1.4.5 Desruisseaux Combined

The Desruisseaux Combined school is located in the south of the island in the Quarter of Micoud. The location plan and aerial view of the school are presented in Figure 6. It is accessed directly off the Desruisseaux main road and is part of a Roman Catholic compound, with the Church and the playground, on the eastern boundary of the school. The site is generally gently sloping from south to north, at a high elevation of 133 m above sea level. The school compound occupies approximately 4,170 m^2 and is considered to be located within a mixed-use area in proximity to residential buildings and small community shops. The school is one of two in the Desruisseaux community and is a designated emergency shelter. It has a population of 230 pupils. The closest emergency services (fire services) are in Vieux Fort to the south and Micoud to the north.

Figure 6 - Location plan and aerial photo of Desruisseaux Combined

1.4.6 Fond Assau Combined

The school is located in the Babonneau community in the northeast of Saint Lucia and is considered to be within a rural agricultural setting. The location plan and aerial view of the school are presented in Figure 7. The property is accessed off the main Fond Assau road and is about 2 km downhill from the main Babonneau road. It is a sloping site which has been benched to place three main school blocks, one of which was constructed in recent years. The buildings enclose a paved playground and the entire compound measures about 3,932 m^2. It is zoned as an emergency shelter. Emergency services are available in the Babonneau area with a fire station less than 1,000 m uphill from the school. The school's population is 130 pupils.

Figure 7 - Location plan and aerial photo of Fond Assau Combined

1.4.7 Micoud Primary

The Micoud Primary School is located on the southeast of Saint Lucia and is accessed off the Castries – Vieux Fort Highway. The location plan and aerial view of the school are presented in Figure 8. However, the main access to the school is narrow and below standard, particularly as there are several institutional buildings in the immediate vicinity. There are four buildings within the compound, one of which was recently constructed. The site is close to a public playground but the buildings are configured in a manner which allows on-site open green areas. The compound is gently sloping from north to south and measures approximately 5,090 m^2. It is elevated without any ravines or watercourses in the immediate vicinity. There are emergency services (fire and ambulance services) in proximity to the school's compound along the nearby Highway. The school is on the outskirts of the main residential areas of the community and is identified as an emergency shelter in the Micoud area. It has a population of 385 students.

Figure 8 - Location plan and aerial photo of Micoud Primary

1.4.8 Patience Combined

Patience Combined is located in the District of Praslin, north of Micoud. The location plan and aerial view of the school are presented in Figure 9. It is east of the Castries – Vieux Fort Highway and is within a rural setting, with a view of the Atlantic coastline. It is accessed off a paved secondary road and comprises four buildings, one of which was built in recent years. The space enclosed by the buildings on the site's perimeter is paved and utilised as a playground. The compound measures 5,250 m^2. There is also a community recreational space contiguous with the eastern boundary of the school. Emergency services are not available in the Patience Community and the nearest would be in Micoud, 6 km to the south. The school is a designated emergency shelter. The school's population is 253 pupils.

Figure 9 - Location plan and aerial photo of Patience Combined

1.4.9 *Saltibus Combined*

The Saltibus Combined School is at an elevation of 282 m above sea level. It is located along an extended spur, which is circa 10 to 12 km off the Laborie to Choiseul Highway. The location plan and aerial view of the school are presented in Figure 10. The School appears to straddle the Laborie – Choiseul boundary. The immediate area is characterized by steep terrain and the only available access road to the school runs along the spur, where it ends some 12 to 13 km inland. The property area is 2,188 m^2. The school is not close to any emergency services, with the closest in Vieux Fort, some 20 km to the southeast. The school is adjacent to a community playground and is identified as an emergency shelter. It has a population of 106 students.

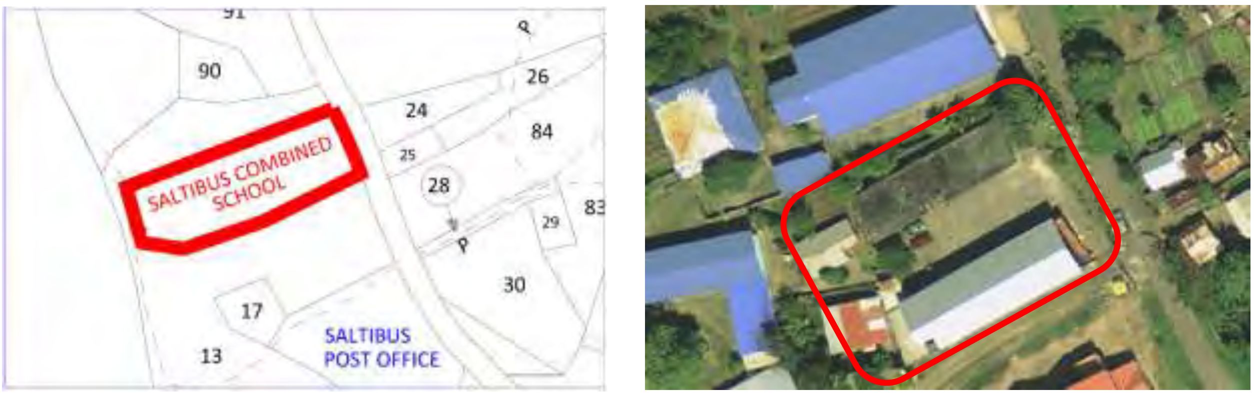

Figure 10 - Location plan and aerial photo of Saltibus Combined

1.4.10 *Vieux Fort Infant and Primary Schools*

The two Vieux Fort schools are located in the suburban locality of the town. The location plan and aerial views of the schools are presented in Figure 11. The Vieux Fort Infant School is accessed directly off Clarke Street which is the main road into the town centre. The Vieux Fort Primary School is further east, where the town urbanization appears to be expanding. Both schools are on extremely flat grounds but the primary school is much more exposed to the trade winds and coastal inundation.

The infant school occupies 2,922 m^2 of land and the primary school's compound is 7,120 m^2. Both schools are in close proximity to the emergency services and are designated as emergency shelters. The Infant school has a population of 167 students, and the primary school has 205 students. The Infant school's playground is limited to a space between the school building and the main road. There are two community playgrounds in proximity to the primary school.

Figure 11 - Location plan and aerial photos of Vieux Fort Infant and Primary schools

2 Relevant Design Standards for Schools

Information from the Ministry of Education, Innovation, Gender Relations and Sustainable Development revealed that there are no mandated design standards for schools in Saint Lucia. However, the Ministry of Education indicated that it is aware of the design standard "Guidelines for Locating and Designing of Disaster Resilient Schools for the Organization of Eastern Caribbean States" (OECS Schools Guidelines). This section reviews the OECS Schools Guidelines and presents other relevant design standards that should be considered in the design of schools.

2.1 OECS Schools Guidelines

The document was prepared on behalf of the OECS Commission and involved extensive stakeholder consultation with "National Focal Points in each of the OECS territories". The document further suggests that schools are "specialized multi-functional facilities" which often operate as emergency shelters, and as such, must be designed to "accommodate a wide range of occupants".

Box 1 presents the table of contents in the OECS Schools Guidelines. The "How to Use this Document" section states that "The main intention of these guidelines is to provide a starting point for the design phase of all school facilities in the OECS". The "How to Use this Document" section also suggests that it would be useful to other professionals in the construction industry as well as facility administrators and policy makers.

Box 1 - Table of Contents for Guidelines for Locating and Designing of Disaster Resilient Schools for the OECS

1.0 INTRODUCTION
- 1.1 How to Use this Document

2.0 GUIDELINES
- 2.1 Wind
- 2.2 Earthquake
- 2.3 Flood Risk
- 2.4 Road & Civil Infrastructure
- 2.5 Geologic & Geotechnical Factors
- 2.6 Tsunami
- 2.7 Volcanic Eruption
- 2.8 Planning & Architectural Design
- 2.9 Fire Safety
- 2.10 Security
- 2.11 Droughts & Grey Water Usage
- 2.12 Potable Water & Water Harvesting
- 2.13 Other Mechanical, Electrical & Plumbing Elements
- 2.14 Value Engineering
- 2.15 Facilities Operation & Maintenance Manuals

The document can be described as a set of guidelines relevant for the engineering design and construction of schools in the OECS as is suggested in the table of contents. The document essentially references a set of codes, standards, and technical papers which highlight the parameters which should be used in the design of disaster resilient schools. As shown in the table of contents, most of the climatic hazards being assessed in this rapid CVA are discussed except for sea level rise. It also provides resources for the design for non-climatic hazards that are faced by the OECS territories. The following sub-sections provide a summary of the information available in the document as it relates to four of the five climatic hazards being assessed in this rapid CVA.

2.1.1 *Landslides*

The OECS Schools Guidelines recommend the use of landslide hazard maps during the preliminary design phase of structures and that the exposure to landslides is considered in the design of roads and civil infrastructure used to access schools. It identifies the Caribbean Handbook on Risk Information Management (CHARIM), (2016) as a key resource for landslide hazard maps for some OECS territories and provides a minimum scope of a geotechnical investigation for landslide hazard and risk analysis.

2.1.2 Flooding

On the issue of floods, which is one of the critical climatic hazards, the said Guidelines provide a list of reference documents, loads and return periods to be considered in the drainage design. Both fluvial and coastal flooding are discussed. It addresses the design flood elevation level and equates it to the base flood level plus freeboard[2]. The flood base level has been recommended to be determined by using a return period of 1:100 years and for the freeboard to be 1.0 m, given the occurrence of climate change and its impact on the Islands. The basis for those values has not been provided, but most drainage standards would suggest the freeboard for varying uses. Nonetheless, it is important to note that allowance for climate change should be included in the drainage design and not by arbitrarily increasing the freeboard.

2.1.3 Wind Speeds

As it specifically relates to designing for high winds, the OECS Schools Guidelines indicate that considerations should be given to designing schools in the OECS to resist high-speed wind loads due to the frequency and occurrence of intense hurricanes in the Islands. The document does not make any specific reference to design criteria and loads which need to be used. To provide a broad perspective of what the Guidelines offer, the following is instructive:

"Detailed studies and reports produced by various consultants and organisations have been referenced in order to outline the procedures presented here. In this document their findings will be utilized to provide preliminary guidelines for determining the design wind load for schools in the OECS territories".

2.1.4 Drought

In the case of droughts, the Guidelines point out that some OECS territories may be more affected by the hazard than others and discusses the situation in some of these territories. It does not provide any guidance on drought risk assessment but provides resources (references and recommendations) focused on mitigating against droughts by reducing the use of potable water and increasing the use of non-potable water.

2.2 OECS Building Code

The OECS Schools Guidelines briefly mentions the OECS Building Code 2015 as a key reference under the Planning and Architectural Design and Fire Safety sections of the document. However, the OECS Building Code 7th Edition (OECS-BC) published in 2016 must be a primary reference document in the design and retrofit of any school in Saint Lucia as it provides gravity and lateral (wind and seismic hazard values) loads. Importantly, the OECS-BC includes a factor for increasing the wind speeds to take climate change into account and provides the most up to date seismic hazard values for design of buildings. As the OECS-BC would need to be used in conjunction with a number of international codes and standards, it includes appendices listing applicable British and U.S. standards and codes as well as the names of U.S. agencies which would have relevant resource documents.

2.3 Relevant U.S. Standards and Codes

In 2000, the Council of Caribbean Engineering Organisations recommended that the International Building Code (IBC) should be adopted by the Eastern Caribbean. The premise was that application documents would be prepared for use with the IBC. An application document was prepared for wind

[2] It is described as a distance between the design water surface and the proposed elevation for the ground floor of the buildings.

design, it was to be used with Chapters 2 and 6 of the 2005 version of the American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures (ASCE 7-05), one of the referenced standards in the IBC. With regard to earthquake loads, a 2010 probabilistic seismic hazard assessment conducted under a joint collaboration project between the Seismic Research Centre at UWI, Trinidad and Tobago and the European Centre for Training and Research in Earthquake Engineering, Pavia Italy calculated spectral accelerations to allow the definition of seismic hazard in the region according to the IBC (2009)[3].

ASCE/SEI 7 has since been updated; in 2016, the name of the standard was changed to Minimum Design Loads and Associated Criteria for Buildings and Other Structures and significant changes were made that affect the wind and seismic design of buildings. However, in 2019, the Pan American Health Organization updated maps that show wind speeds on Caribbean islands and along the Caribbean coasts of Central and South America that can be used in conjunction with ASCE 7-16. In addition, Clarke (2019) published risk-targeted earthquake hazard values for several Caribbean Territories in accordance with ASCE 7-16.

There are other codes in the International Code Council suite of codes which would be applicable to the design and retrofit of schools. Other U.S. agencies which regularly produce applicable resource documents include FEMA and the National Earthquake Hazards Reduction Program. Box 2 provides a list of the relevant U.S standards and codes.

Box 2 - List of Relevant U.S. Standards and Codes

- International Building Code
- International Existing Building Code
- ICC Performance Code for Buildings and Other Facilities
- International Property Maintenance Code
- American Society of Civil Engineers Seismic Evaluation and Retrofit of Existing Buildings (ASCE 41)
- FEMA 389 Primer for Design Professionals Communicating with Owners and Managers of New Buildings on Earthquake Risk
- FEMA 424 Design Guide for Improving School Safety in Earthquakes, Floods, and High Winds
- FEMA 547 Techniques for the Seismic Rehabilitation of Existing Buildings
- FEMA P-1000, Safer, Stronger, Smarter: A Guide to Improving School Natural Hazard Safety
- FEMA P-1050, NEHRP Recommended Seismic Provisions for New Buildings and Other Structures
- National Earthquake Hazards Reduction Program Technical Briefs

2.4 Recommendations

Building codes and standards are dynamic documents and although they are not usually regulated or legal statutes in the OECS, designers of school buildings should make every effort to use updated versions of codes and standards. Current building codes are usually prescriptive and specify minimum design requirements to ensure the safety of users during defined events such as earthquakes or storms. However, buildings designed and built to code may not be fully functional after an event as evidenced by the major damage experienced by code-compliant buildings during recent natural disasters. FEMA P-424 argues that given the importance of schools that they “should be designed and constructed according to criteria that result in continued and uninterrupted functionality”. Therefore, if school buildings will also function as emergency shelters, they should be designed, constructed and maintained such that they experience minimal damage and can be immediately occupied following an event.

As to the primary building code, it is recommended that designers should be referencing the OECS Building Code 7th Edition and that the ASCE/SEI 7-16 standard is used to guide the analysis and design of the structures at a minimum. ASCE 7-16 Chapter C1 notes that risk categories are used to relate the

[3] The 2005 version of ASCE 7 was included as the referenced standard in the 2009 IBC.

criteria for maximum environmental loads or distortions specified in the standard to the consequence of the loads being exceeded for the structure and its occupants. It is recommended that schools in Saint Lucia are classified as Risk Category III buildings and that schools that will be designated as emergency shelters should be classified as essential facilities. In ASCE 7 terminology, Risk Category III buildings are those “that represent a substantial hazard to human life in the event of failure” and essential facilities are defined as “buildings and other structures that are intended to remain operational in the event of extreme environmental loading …”.

3 Hazard Exposure in Saint Lucia and Sensitivity of School Sites

Hazard maps were developed for the following climatic hazards:

- Landslides;
- Fluvial flooding;
- High winds;
- Droughts;
- Coastal flooding and sea level rise.

The data and methods used to develop these hazard maps are described below. Non-climatic hazards which the schools would be exposed to and which would need to be considered in the design of the facilities are also discussed.

3.1 Climatic Hazards

3.1.1 Landslides

Landslide susceptibility mapping was available through the Caribbean Handbook on Risk and Information Management (CHARIM) GeoNode[4]. The CHARIM project completed a national scale landslide susceptibility assessment for Saint Lucia in 2016 (Van Westen, 2016). This categorises landslide susceptibility into Low, Moderate and High categories, with accompanying recommendations for each class. These are shown in Box 3 below. The method report notes that this national assessment of hazard cannot be used for local or site-specific planning, but also indicates that in the absence of detailed site-specific recommendations, it represents the best available information for Saint Lucia despite its uncertainties. The report notes that the assessment does not include landslide run-out areas, and this should be a focus of future modelling work. Therefore, locations which are in the potential run out areas for landslides should be subject to more detailed investigations.

Recommendations from the CHARIM Landslide method report on planning considerations on landslide hazard for each of the three susceptibility classes.

[4] http://www.charim-geonode.net/ (accessed 14 October 2020)

Box 3 – Landslide susceptibility categories ***Source: CHARIM Landslide method report (Van Westen, 2016)***

- **Low susceptibility**: For planners there is no limitation with respect to expected landslide problems in the development of these areas. No special care should be taken by engineers with respect to planning and maintaining infrastructure in these areas with respect to landslides. Of course it is important to also check the other hazard maps for these areas. Of course it is important to also check the flood hazard maps for these areas, as areas that are flat and near a river or coast might be still flood prone.
- **Moderate susceptibility**: It is advised to carry out a more detailed landslide study for residential development and for critical infrastructure. There is no need to avoid these areas altogether, but care should be taken that landslides might occur. This class is actually the most problematic for use in spatial planning and planning/maintenance of infrastructure, as it is an intermediate class.
- **High susceptibility**: There are severe restrictions with respect to expected landslide problems in these areas. The best is to avoid these areas in the development of future residential areas or critical infrastructure whenever possible. Development plans should always incorporate a more detailed study of landslide hazard in these areas. Engineers should consider the high landslide hazard when designing or maintaining infrastructure. Further evaluations would have to be carried out before allowing new constructions – be that an expert inspection of the site, detailed slope stability evaluations – that may depend on the importance of the asset (e.g. a private building would be dealt with differently than a hospital)

The landslide susceptibility mapping was overlaid on the school locations to provide a national map and a local area map for each school. The landslide susceptibility was also extracted for each school and tabulated in the results section of this report.

3.1.2 Fluvial flooding

Fluvial flood hazard modelling was also carried out as part of the CHARIM project and is available on the CHARIM GeoNode. The modelling used a rainfall-runoff model, and a hydraulic flow routing model to predict the areas which are inundated for the 1 in 5, 1 in 10, 1 in 20 and 1 in 50-year return period storm events (Jetten, 2016). Given the uncertainties associated with these return periods, as well as the hydrological and hydraulic modelling, the mapping has simplified these to qualitative classifications, as set out in Table 2.

It should be noted that the flood hazard mapping covers the fluvial flood hazard only, no information was made available on pluvial flooding, and coastal flooding as a result of storm surge or sea level rise. In coastal or low-lying locations, there may be the potential for flooding from the sea or surface water runoff from intense rainfall which is not shown on the fluvial flood maps.

The national scale flood mapping was overlaid with the 12 school locations to produce maps of flood hazard nationally, and at each school location. The flood hazard was also extracted for each school and tabulated in the results section of this report. For those schools which are adjacent to modelled flood prone areas, it is suggested that local surveys should be used to confirm likely flood routes, as the Digital Terrain Model (DTM) used in the flood modelling was based on contour data of unknown origin and accuracy, which was gridded and resampled to 20 m horizontal resolution. This level of accuracy means that there is uncertainty in the DTM.

Table 2: Flood hazard susceptibility classes used in hazard maps

Class used in Map Legend	Return Period Associated with Classification
Very low flood hazard susceptibility	Predicted to flood less frequently than a 1 in 50-year return period storm event.
Low flood hazard susceptibility	Predicted to flood for events between 1:20 and 1 in 50- year return period.
Moderate flood hazard susceptibility	Predicted to flood for events between 1 in 10 and 1 in 20-year return period.
High flood hazard susceptibility	Predicted to flood for events between 1 in 5 and 1 in 10-year return period.
Very high flood hazard susceptibility	Predicted to flood for events of 1 in 5 years or more frequent.

3.1.3 Wind speeds

Hurricanes and storms form just off the coast of Africa during the hurricane season and usually pass over the Leeward and Windward Islands between Antigua in the north and Grenada in the south. Most times, the islands do not receive direct hits from the hurricanes and storms but are severely affected by the surge caused by storms which often create significant damage to the coastal regions; and heavy precipitation which often leads to flooding.

The Atlantic hurricane season runs from 1 June to 30 November. Around 97% of tropical activity occurs within these dates; however, hurricanes can occur outside these months (Destin, 2018). According to the National Hurricane Centre of the US National Oceanic and Atmospheric Administration (NOAA), tropical cyclones are classified as follows:

- Tropical depression: A tropical cyclone with maximum sustained winds of 38 miles per hour (mph) [61 kilometres per hour (km/h)] or less;
- Tropical storm: A tropical cyclone with maximum sustained winds of 39 to 73 mph (62 km/h to 118 km/h);
- Hurricane: A tropical cyclone with maximum sustained winds of 74 mph (119 km/h) or higher;
- Major hurricane: A tropical cyclone with maximum sustained winds of 111 mph (178 km/h) or higher; corresponding to a Category 3, 4 or 5 on the Saffir-Simpson Hurricane Wind Scale.

A "named storm" is the generic term for a tropical cyclone of at least tropical storm strength (Destin, 2018). Between the years 1851 and 2019, the following number of named storms and hurricanes have affected Saint Lucia i.e. passed within 69 nautical miles of the island:

- 52 named storms;
- 11 hurricanes;
- 1 major hurricane - Category 4.

According to NOAA's Atlantic Oceanographic and Meteorological Laboratory's Hurricane Research Division, the total number of named storms to have formed over the Atlantic Basin between the years 1851 and 2015 is 1,559; of these, 4.1% have affected Saint Lucia.

Based on information from Storm Carib – Caribbean Hurricane Network[5], Saint Lucia has only experienced two major hurricanes, since 1851; an un-named hurricane on August 19, 1891, with wind speeds of 127 mph and Hurricane Allen on August 4, 1980, with speeds of 132 mph. Figure 12 shows the tracks of the named storms to have affected or passed within 69 nautical miles of Saint Lucia from 1851 to 2019. Although Saint Lucia has been devasted by tropical storms, in 1995 and 2010, the impact was due to rainfall intensities and not wind speeds.

Tracks of the named storms to have affected or passed within 69 nautical miles of Saint Lucia – 1851 to 2019. In order to produce the maps required under the consultancy, ECMC obtained Adobe PDF and GIS shapefile format information of the 1 in 100-year 2-minute average wind speed for Saint Lucia, from the Ministry of Physical Development (Development Control Authority). This work was completed for the Government of Saint Lucia and Caribbean Disaster Emergency Response Agency (CDERA) collaboration through the Caribbean Hazard Mitigation Capacity Building Programme (Kinetic Analysis Corporation, 2006a).

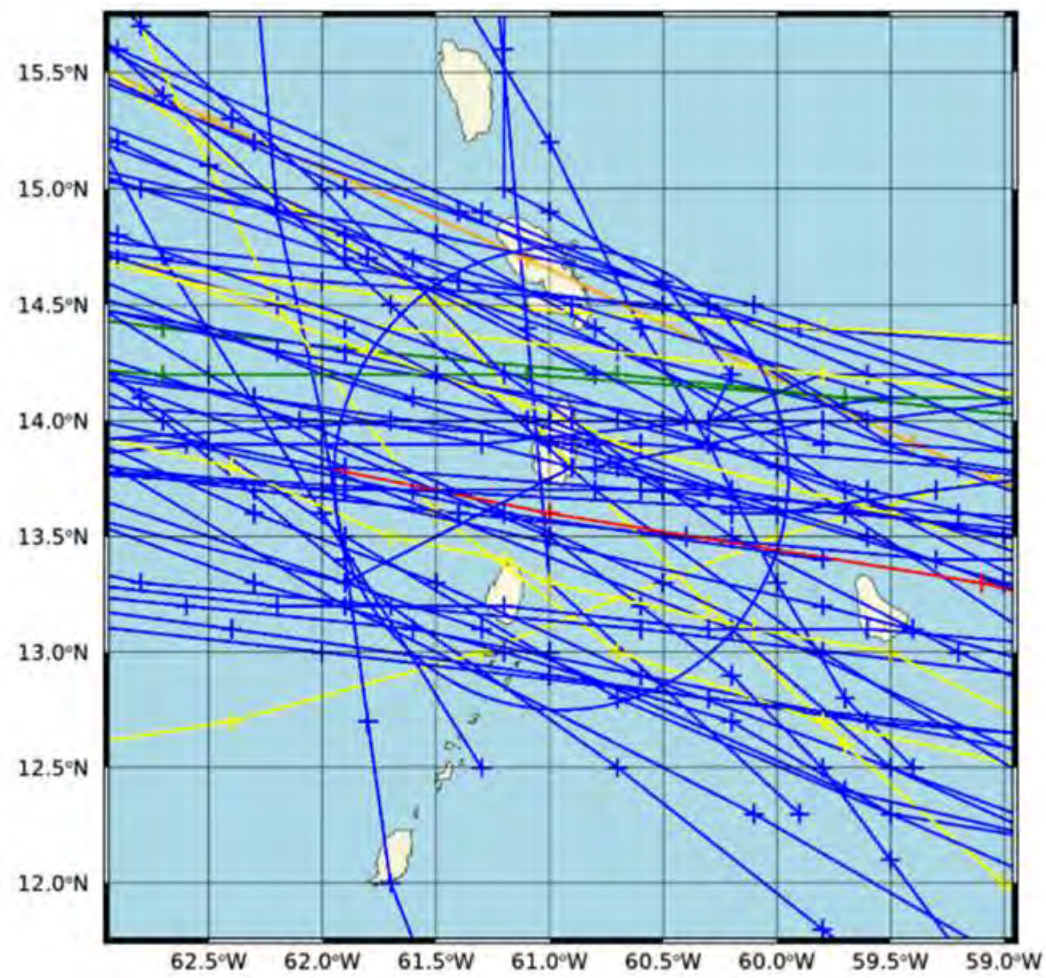

Figure 12 – Tracks of named storms to have affected or passed with 69 nautical miles of Saint Lucia – 1851 to 2019

[5] https://stormcarib.com/climatology/TLPC_all_isl.htm (Accessed January 2021)

The wind speed shapefile was overlaid on the school locations map to provide a national, plus maps for the north and south of the island. A map for each school was not produced due to the relatively coarse nature of the wind data. The wind speed was converted into a hazard rating based on the range of modelled wind speed values shown on the map (which ranged from 30-35 m/s up to 50-55 m/s). The wind speed rating is relative and should be used only to compare the schools, it does not imply that a school with a very low wind speed hazard rating is not exposed to some degree, as all buildings on a hurricane prone island such as Saint Lucia will be exposed to some degree.

While the information provided on the CDERA maps is useful, the return periods referenced are grossly inadequate, particularly as it relates to the design of critical facilities like emergency shelters for high wind speeds. Unfortunately, ECMC was unable to source information providing wind contour maps for Saint Lucia for the return periods as identified in Section 2 of this document. ASCE 7-16 recommends that Risk Category III structures are designed for wind speeds having a mean recurrence interval of 1700 years and Risk Category IV structures are designed for wind speeds having a mean recurrence interval of 3,000 years. The appropriate maps are shown in Figures 13 and 14[6].

[6] The wind speed maps were sourced from Mudd, L. et al, "Development of Design Wind Speed Maps for the Caribbean for Application with the Wind Load Provisions of ASCE 7-16 and Later", May 2019.

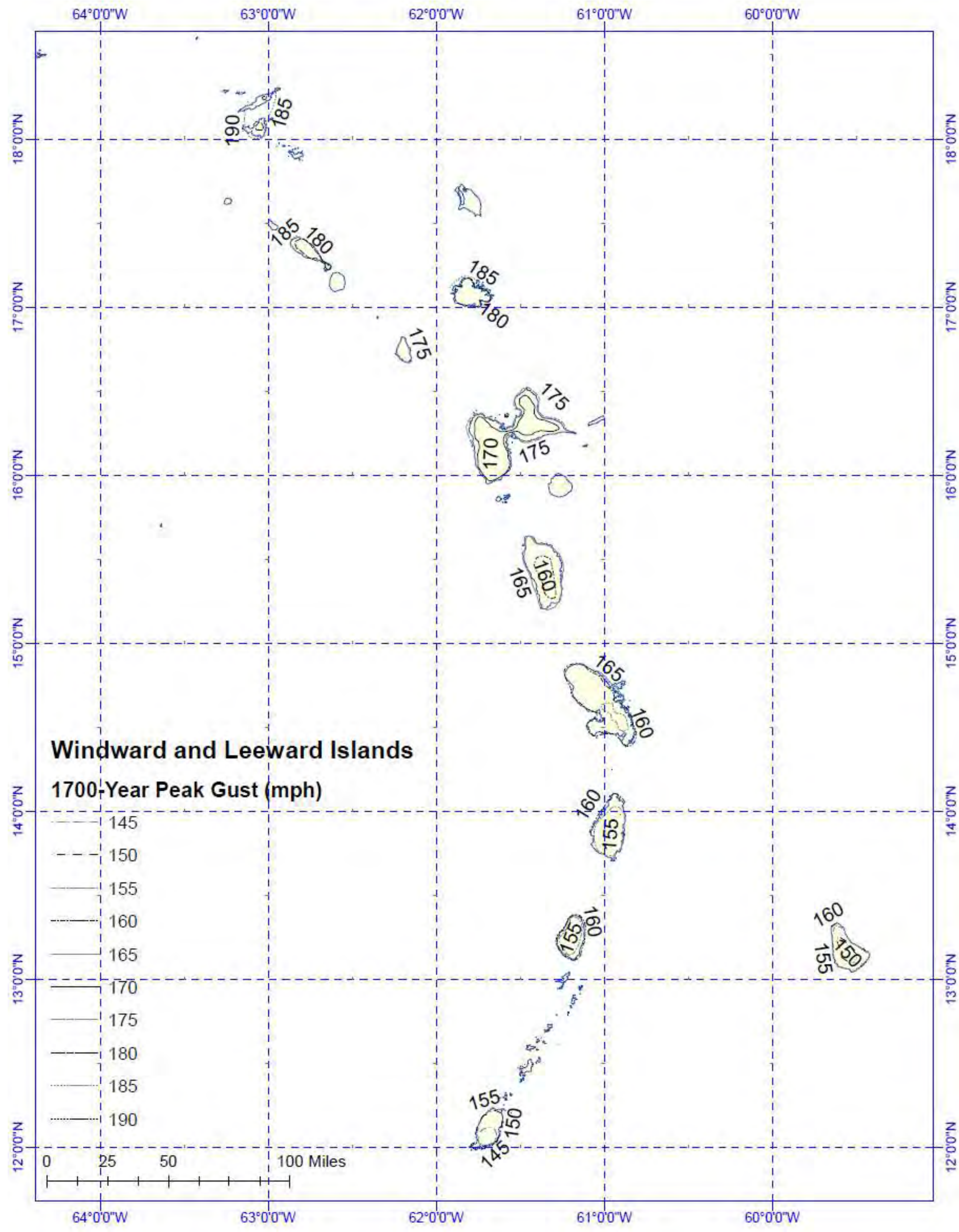

Figure 13 - Contours of predicted 1,700-year return period wind speeds (mph) at a height of 10 m above flat open terrain for Windward and Leeward Islands

Source: Mudd, L. et al (2019)

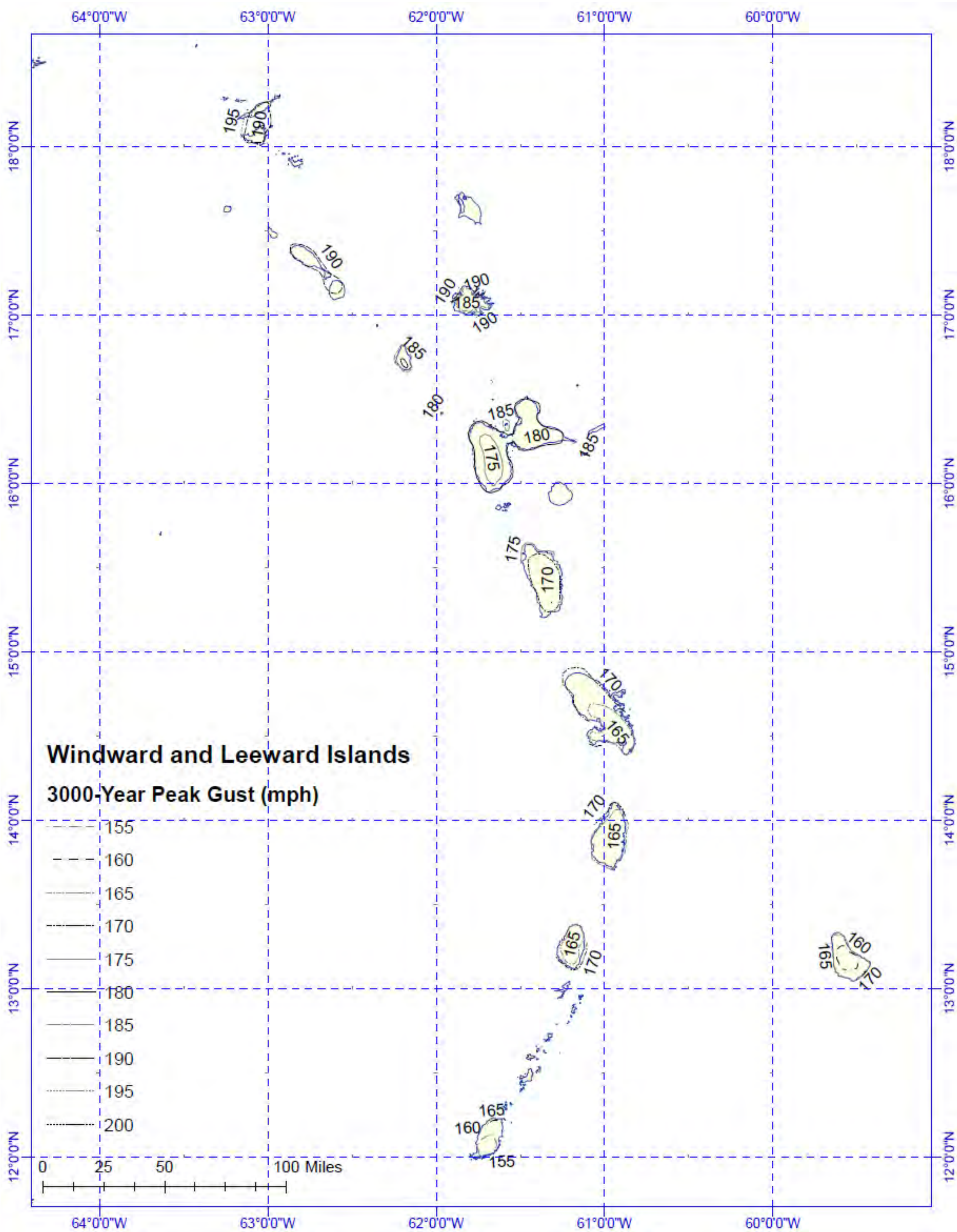

Figure 14 - Contours of predicted 3,000-year return period wind speeds (mph) at a height of 10 m above flat open terrain for Windward and Leeward Islands

Source: Mudd, L. et al (2019)

Figure 15 presents contours of predicted 3,000-year return period wind speeds (mph) at a height of 10 m above flat open terrain. The figure identifies 76 m/s (170 miles per hour) for coastal structures and 74 m/s (165 miles per hour) for the interior structures. However, using the contours, in Figures 13 and 14, Saint Lucia is zoned for the 76 m/s. Essentially, the schools can all be zoned as having the same exposure.

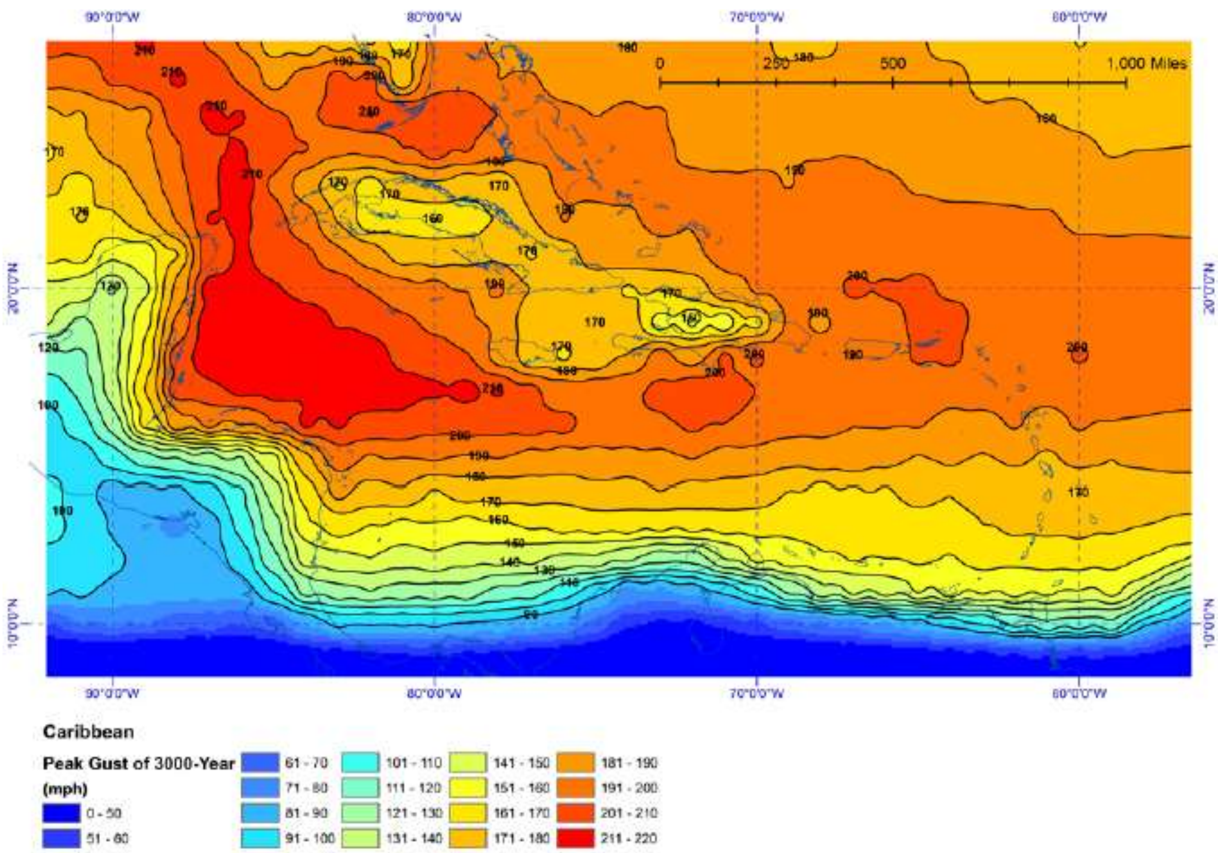

Figure 15 - Contours of predicted 3,000-year return period wind speeds (mph) at a height of 10 m above flat open terrain. Wind speeds are representative of a single point located at a distance of 1 km from coast in all wind directions

Source: Mudd, L. et al (2019)

3.1.4 Drought

For the purpose of this assignment drought risk for the schools was based on the likelihood of water scarcity affecting a school's water supply during the dry season or drought conditions. No modelling or mapping of the water supply system performance was available, and the Consultant therefore engaged with the water utility in Saint Lucia, Water and Sewerage Company (WASCO), to make a qualitative assessment of drought risk for each school based on WASCO's knowledge of the historical performance of the water supply systems for each school.

Each school was scored 1 (very low drought hazard) to 5 (very high drought hazard), based on the criteria below:

- 1 = very low (low flows resulting in demand restrictions have never been experienced in this system);
- 2 = low (low flows result in demand restrictions implemented less than once in 5 years);
- 3 = medium (low flows result in demand restrictions implemented once every 1 to 5 years);
- 4 = high (low flows result in demand restrictions implemented typically once per dry season on average);
- 5 = very high (low flows result in demand restrictions implemented multiple times each dry season).

Table 3 presents the scoring of the drought hazard for each school with a justification for each scoring. A thematic map was then created at national level showing the drought score for each school.

Table 3: Summary of Drought Impacts, Based on Consultation Between WASCO and ECMC

School	Supplying Intake	Historical Drought Impacts	Notable Periods of Demand Restrictions Due to Drought	Other Notes
Ave Maria Infant	JC Dam & Millet	1	The Ave Maria School has a very consistent water supply annually even during the dry season.	This facility is located near the city centre which is served by the most dependable water system island wide.
Ave Maria Primary	JC Dam & Millet	1	The Ave Maria School has a very consistent water supply annually even during the dry season.	This facility is located near the city centre which is served by the most dependable water system island wide.
Balata Combined	John Compton Dam, Millet, Vanard	2	This institution suffered from acute water issues during the dry season, however, the situation has improved significantly. The institution presently is only affected during prolonged drought periods, for example, this year during the dry season.	The community was transferred from the Marquis, Talvern System to the John Compton Dam to improve the potable water supply. Historically the community was at the far end of the Marquis, Talvern water supply system experiencing low flows and inadequate supply. The situation is now improved.
Bexon Primary	John Compton Dam, Millet, Vanard	1	The school has a very consistent water supply annually even during the dry season.	This institution is located near the main potable water transmission line.
Corinth Secondary	JC Dam & Millet	1	This educational institution has a reliable and constant supply of water during the dry season. During the 2010 and 2020 droughts, this area was not adversely affected.	This institution is located near the main potable water transmission line supplying water to the north, thus the effect of drought on the water supply is minimal to none.
Desruisseaux Combined	Desruisseaux	2	The Desruisseaux Combined School, as the rest of the community had acute water supply issues historically throughout the year, up until 2018. However, at present, the institution has only been affected during prolonged drought periods for example this year.	The water supply to the community was augmented, thus reducing the vulnerability to drought.
Fond Assau Combined	Marquis, Talvern	3	During the dry season, water rationing schedules are enforced to ensure that water is equitably distributed. However, in extreme drought periods trucking of water is required to this area for the last 3 to 4 months for example in 2010 and 2020.	Owing to low flows from the river sources during the dry season, potable water supply is diminished resulting in water shortages to the community.

School	Supplying Intake	Historical Drought Impacts	Notable Periods of Demand Restrictions Due to Drought	Other Notes
Micoud Primary	Micoud	2	This educational institution has suffered from water supply issues during extended drought periods as in 2010 and 2020.	The school is located approximately 100 metre from the utility's water storage facility and within the 24-hour service area of the community treatment plant. Water problems are only serious if drought conditions persist over six months.
Patience Combined	Patience	3	There are water shortages every dry season for the past 10 years. Water is trucked in for 2 to 3 months per year has become the norm. The situation got to its worst in 2010 and then in 2020.	There are serious water storage issues in this area and during the dry season, the lack of storage amplifies the problem.
Saltibus Combined	Upper Saltibus	4	To sustain operations, water must be trucked to this institution 4 to 5 month a year during the dry season. This has been ongoing for the last 10 years.	The water system in this community cannot normally meet the needs of the residents and dry season further exacerbates this situation.
Vieux-Fort Infant	Beausejour	1	The school has a very consistent water supply annually even during the dry season.	This community is ideally located both geographically and topographically in relation to the water treatment plant and storage facilities. Therefore, the facility has a constant supply of water annually, although areas in higher elevations from the same community suffer from water supply issues during the dry season due to low flows from the river sources.
Vieux-Fort Primary	Beausejour	3	This facility has suffered from water shortages every dry season over the past 10 years, with the situation being at its worst in 2010 and 2020. Water rationing regimes are employed every dry season to mitigate this issue.	This system has been over expanded and supply does not equate demand. This situation worsens during the dry season when water flows from the river source drop significantly.

Source: Ranking completed by WASCO and ECMC Ltd

3.1.5 *Coastal flooding and sea level rise*

The elevations of the schools were extracted from a DTM from the CHARIM GeoNode[7]. It is unclear how this DTM was generated, but the metadata appears to indicate it was created from a contour dataset, which was itself created from a DTM derived from photogrammetry conducted by Fugro[8]. Given the uncertain provenance of this dataset, it is difficult to comment on its likely vertical accuracy. There is an urgent need to create a more accurate DTM for Saint Lucia, based on for example Light Detection and Ranging (LiDAR) data.

The hazard from sea level rise and coastal flooding has been determined by combining a school's elevation with a 4 m storm surge and a maximum anticipated sea level rise (SLR) of 1.1 m. This sea level rise is derived from the latest IPCC report on sea level rise (Oppenheimer et al, 2019, see Technical Summary p55-56). The anticipated 4 m storm surge was derived from local mapping outputs provided by the Department of Physical Planning (Ministry of Agriculture, Fisheries, Physical Planning, Natural Resources and Co-operatives) for each of the schools studied. The product of anticipated sea level rise (1.1 m) and a 4 m storm surge was calculated (i.e. 5.1 m). If the elevation of the school was lower than this value it was deemed to be impacted by sea level rise and coastal flood hazard. If the elevation of the school was above 5.1 m it was ascertained to have no impact.

A 1 in 100-year coastal flood hazard map showing coastal storm surge and predicted wave height (Kinetic Analysis Corporation, 2006b) shown in Figure 17 was also used. Although the resolution of the map is rather low it indicates storm surge conditions of between 1 m and 3 m for the 1 in 100-year return period event. The largest storm surge heights are associated with the eastern side of the island, notably the southeast, of relevance to the Vieux Fort area. For the purposes of this assessment, the 4 m storm surge was used to provide some additional conservatism in the results given the uncertainty over the data sources and DTM.

Table 4 summarises the school elevations from the DTM against the 1 in 100-year coastal flood levels, the 4 m surge scenario and the 4 m plus 1.1 m SLR scenario. It indicates that under the 4 m scenario, only the Vieux Fort Primary School is exposed to coastal flooding. When 1.1 m SLR is included, both Ave Maria Infant and Primary schools are exposed.

It is recommended that the ground level and floor levels for the Ave Maria Infant and Primary, and both Vieux Fort schools are surveyed to validate the levels extracted from the DTM, if the surveyed levels are lower than those from the DTM then these schools will be at greater risk than predicted in this report. The ground levels of the other schools are 15 m or higher and are therefore not considered to be at risk from coastal flooding unless there are gross errors in the DTM.

Detailed modelling of storm surge under present and future sea levels is recommended, based on a suitably accurate Digital Terrain Model (DTM), for example, based on LiDAR data. This detailed modelling would provide more confidence in assessing the risks posed to coastal developments from storm surge and sea level rise.

[7] http://www.charim-geonode.net/layers/geonode:dem accessed 14 October 2020

[8] http://charim-geonode.net/layers/geonode:contours - as the source used to create the contours and DTM based on photogrammetry. https://www.fugro.com/ . However, no report from Fugro or further information is available on the CHARIM geonode, so we mentioned this in the report as being an source of uncertainty.

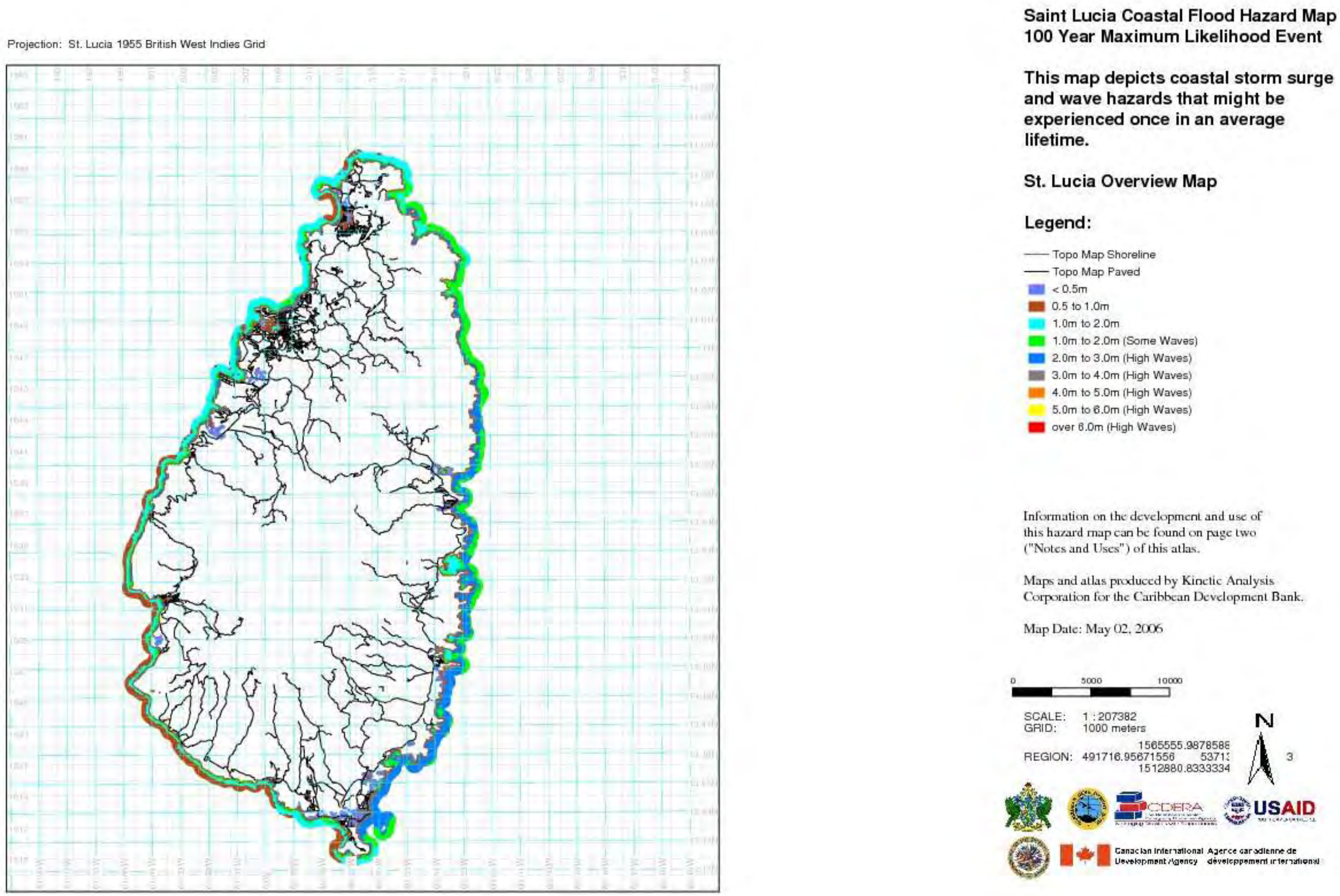

Figure 16 - 2.1: 1 in 100-year coastal flood hazard map

Source: Kinetic Analysis Corporation. 2006b

Table 4: Summary of School Elevation and Coastal Flooding Predictions Including Sea Level Rise (SLR)

School	Elevation from Geonode DTM (m)	1 in 100-year Coastal Flood Level (m)	School Impacted by a 4 m Storm Surge	School Impacted by a 4 m Storm Surge Plus 1.1 m Sea Level Rise
Ave Maria Infant	5	1-2m	Not impacted	Impacted
Ave Maria Primary	5	1-2m	Not impacted	Impacted
Balata Combined	35	No hazard	Not impacted	Not impacted
Bexon Primary	22	No hazard.	Not impacted	Not impacted
Corinth Secondary	15	1-2m	Not impacted	Not impacted
Desruisseaux Combined	135	No hazard.	Not impacted	Not impacted
Fond Assau Combined	63	No hazard.	Not impacted	Not impacted
Micoud Primary	24	2-3m	Not impacted	Not impacted
Patience Combined	88	No hazard.	Not impacted	Not impacted
Saltibus Combined	278	No hazard.	Not impacted	Not impacted
Vieux-Fort Infant	11	2-3m	Not impacted	Not impacted
Vieux-Fort Primary	4	2-3m	Impacted	Impacted

***Source**: Data from Department of Physical Planning - GOSL (4m storm surge scenario), CHARIM Geonode (DTM), Oppenheimer et al 2019 (1.1m SLR scenario, and Kinetic Analysis Corporation. 2006b (1 in 100-year flood level). Schools with 'no hazard' are inland.*

3.2 Non-Climatic Hazards Assessment

3.2.1 Earthquakes

The Eastern Caribbean is an island arc system formed at a convergent plate boundary referred to as a subduction zone. The North America Plate is subducting beneath the Caribbean plate resulting in geohazards such as earthquakes and volcanoes. Subduction zones are associated with the largest earthquakes because of the greater width of rupture zone at these larger boundaries. Common effects of earthquakes include ground shaking, surface rupture, tsunami run-up, liquefaction, and landslides. Of these effects, earthquake-induced ground shaking causes the most damage to the built environment and is the hazard addressed by building codes.

Based on ground motion hazard maps[9] available through the Seismic Research Centre of the University of the West Indies (UWI SRC), Saint Lucia's seismic hazard can be considered to be high when using ASCE 7's classifications. Maps for the Eastern Caribbean with spectral accelerations at 0.2 seconds and 1.0 second for a return period of 2475 years[10] are presented in Figures 18 and 19. The OECS-BC indicates that the 0.2 seconds spectral acceleration is 1.183 g[11] and the 1.0 second spectral acceleration is 0.383 g. Thus, all of the schools' sites would be exposed to seismic ground shaking.

[9] The seismic hazard maps were computed using a probabilistic seismic hazard analysis for the Eastern Caribbean and can be used with the International Building Code and ASCE 7. (Bozzoni et. al, 2011).

[10] A probability of exceedance of 2 percent in 50 years.

[11] The acceleration due to gravity is 9.806 metres per second squared

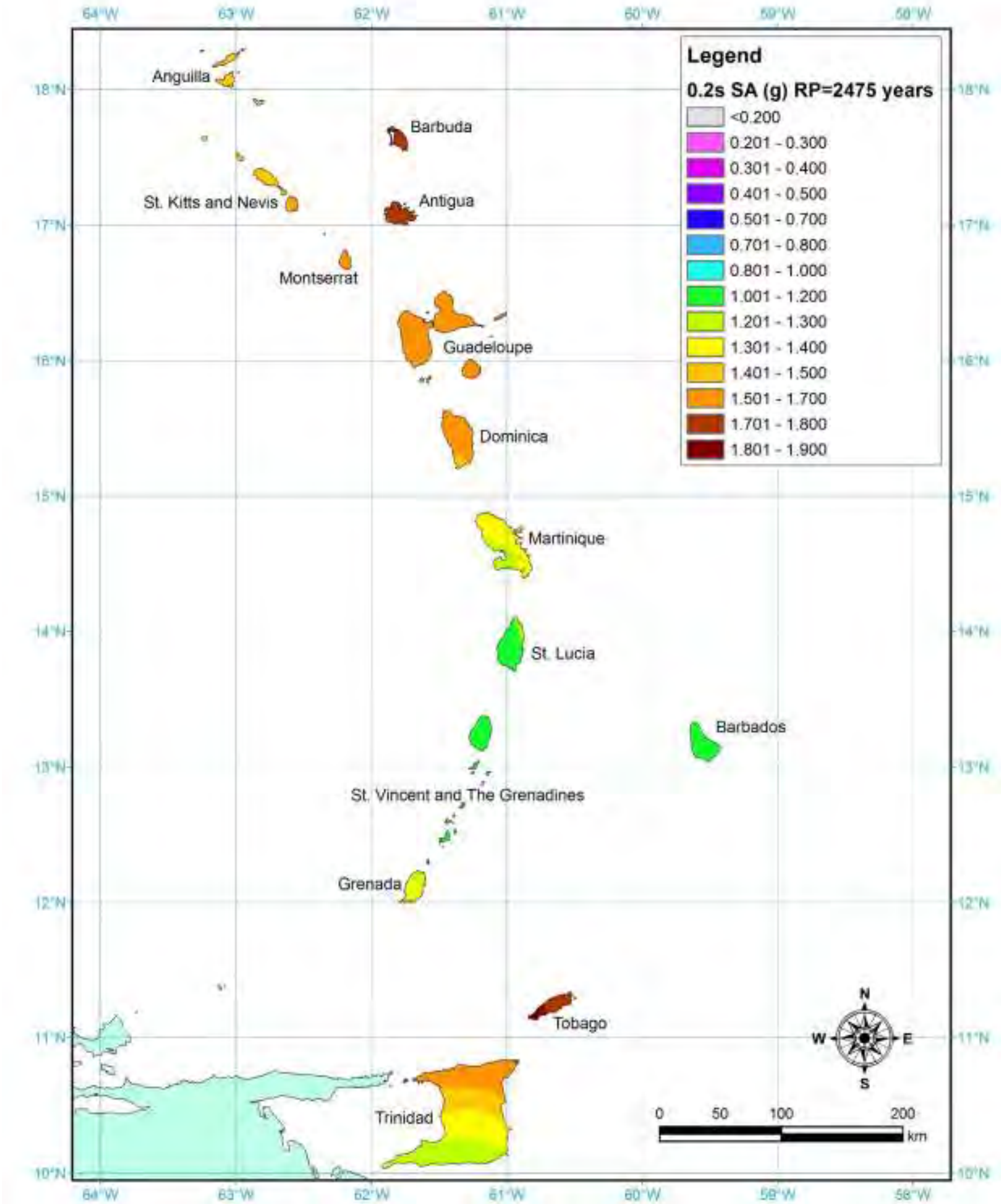

Figure 17 - Eastern Caribbean Seismic Hazard Map - 0.2 s Spectral Accelerations for 2,475-year return period

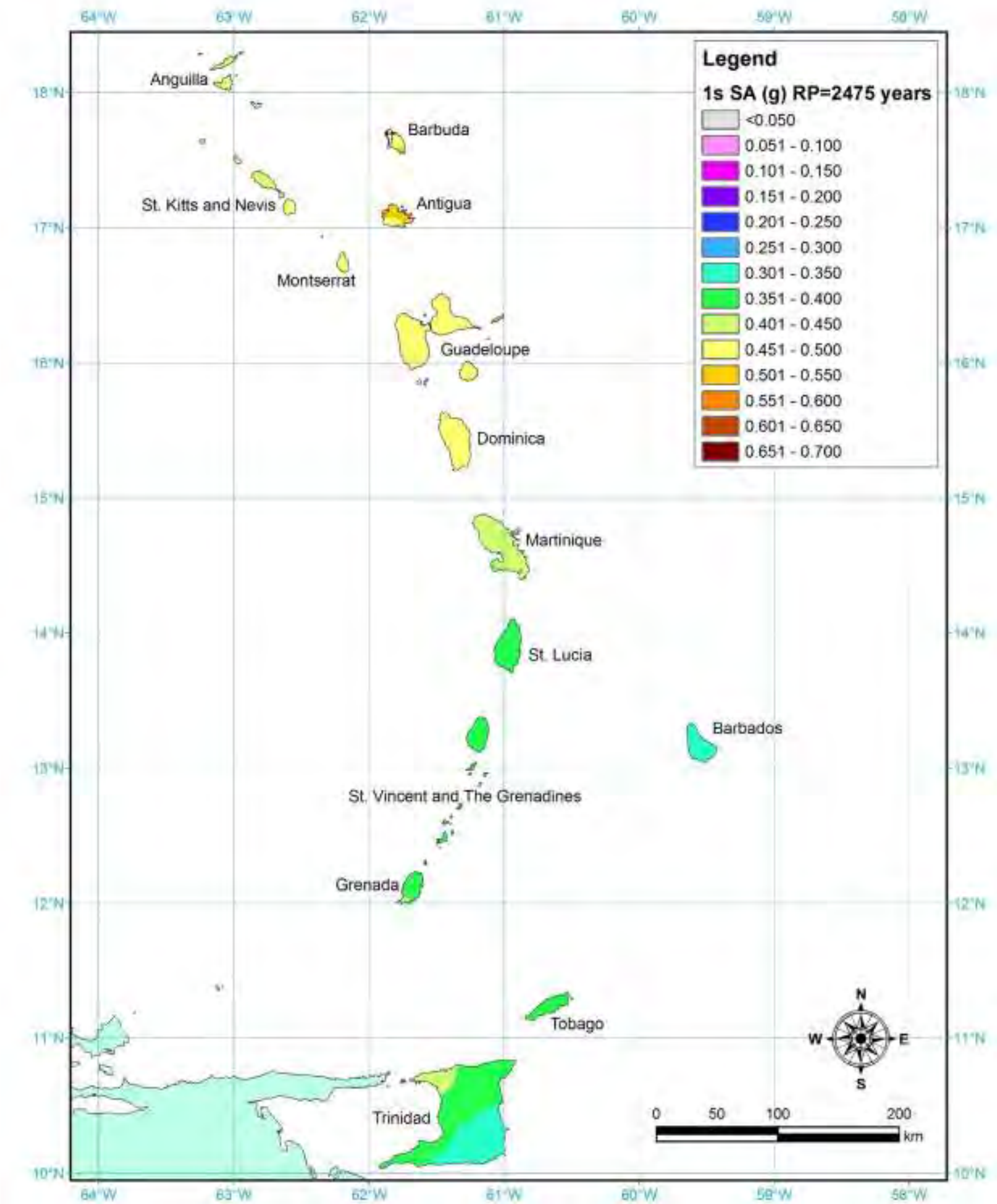

Figure 18 - Eastern Caribbean Seismic Hazard Map - 1.0 s Spectral Acceleration for 2,475-year return period

It should be noted that the focus of the building codes is ensuring life safety. Therefore, as noted in Section 2, a performance-based design approach would need to be considered to prevent loss of life, allow continued operations after the design level seismic event and minimize economic losses.

3.2.2 *Fire*

There have not been many reports of fires at the schools which are identified under this consultancy. However, safety officers with the Ministry of Education have expressed concerns about the issue of fire safety. Consequently, structure fire has been identified as one of the secondary hazards assessed under this CVA.

As indicated in the description of the schools' sites, emergency services such as firefighting tenders are not always available in the community in which the school is located. In some cases, the nearest fire station is over 20 km away. Therefore, the structures are at risk of significant damage if a significant fire occurs and the requisite firefighting capacity does not exist on the site.

At the schools, fires could be ignited by a number of causes, such as faulty electrical wiring, cooking and although rarely, burning of debris and cut trees. In some cases, fires may also be ignited intentionally. While some of the schools have properly designed firefighting resources comprising water tanks, hose reels and pumps, this was not evident in most. Fire detection systems were not evident in all the schools. Furthermore, most of the schools did not have auxiliary power which could be used in situations where there are electrical outages.

3.2.3 *Pandemics*

Disease and illnesses have always plagued humanity. With the shift to agrarian community practices, the scale and spread of diseases increased dramatically. As trade practices evolved, human and animal interactions increased, as did the spread of diseases such as malaria, tuberculosis, leprosy, influenza and smallpox. As civilization continued to advance with larger cities, increased trade and increased contact between different populations of people, animals, and ecosystems, the likelihood of pandemics has also increased (LePan, N., 2020). Over the last century, several pandemics have occurred, including (Balita-Centeno, 2020):

a. The Spanish Flu of 1918 is considered the deadliest in history, infecting 1/3 of the world's population and killing 20 to 50 million people worldwide. It came in three waves. The first wave hit in the spring of 1918. The second wave that appeared in the fall of the same year was deadlier. It killed people within hours or a few days after the onset of symptoms. The third wave that came the following year was just as deadly and added more to the death toll.

b. The 1968 flu pandemic caused by the influenza H3N2 virus was not as deadly but was highly contagious. It spread throughout southeast Asia within two weeks of its emergence in Hong Kong in July 1968. By December, the virus had spread to the United States and Europe. It killed an estimated one million people.

c. The first case of acquired immunodeficiency syndrome (AIDS) was reported in 1981. Since then, HIV (Human Immunodeficiency Virus), a sexually transmitted disease, has spread globally, infecting more than 65 million people according to the Centre for Disease Control and Prevention. While there is no known cure, treatments that keep the virus under control allow people to live longer.

d. Severe Acute Respiratory Syndrome (SARS) was first reported in Guangdong, China in 2003. After a few months, it spread throughout countries in North and South America, Europe, and Asia, infecting 8,098 people and killing 774 people. The disease caused high fever, body aches, and dry cough which then led to pneumonia in some cases.

e. A new coronavirus named SARS-CoV-2 is believed to have originated in Wuhan, China. The virus spread to every part of the world within months since it emerged in late 2019. The virus causes a disease referred to as Coronavirus disease (COVID-19).

   By December 2020, SARS-CoV-2 had infected more than 72 million people and killed more than 1.6 million worldwide. In Saint Lucia, by December 31, 2020, 353 cases and 5 deaths had been recorded (https://www.worldometers.info/coronavirus/).

Rising global connections and interactions are a driving force behind pandemics. Macro trends such as urbanization, greater pressure on the environment and increased air travel are having a profound impact on the spread of infectious disease (LePan, N., 2020). The potential for future pandemics is vast, as numerous unidentified viruses with the capacity to infect people are believed to exist in mammals and birds. Any of these could cause the next pandemic, spreading disease potentially even more disruptive and lethal than COVID-19. Some of the world's leading scientists have warned that future pandemics are likely to be more frequent, spread more rapidly, kill more people and inflict even worse economic damage if humanity fails to fundamentally change how it is damaging the environment and exploiting wildlife (Dalton, J., 2020).

Children play an important role in the community spread of infectious diseases. Their many contacts at school increase their risk of infection, making schools an important source of transmission to households, from where further spread is possible (Gemmetto et al, 2014). Since the outbreak of the COVID-19 pandemic in March 2020, national protocols in force in Saint Lucia have required schools to close at times or to operate a shift system with smaller classes at other times. School closure is a mitigation strategy often used for epidemics, especially novel pandemics for which pharmaceutical interventions, such as vaccines, are not readily available and delaying disease spread is a priority. However, the measure has significant and wide-reaching socio-economic costs as parents may need to take time off work to care for their children (Gemmetto et al, 2014). This may also have adverse implications for the availability of public health staff. The children themselves are often adversely affected as the quality of learning may deteriorate and other benefits of attendance such as school feeding and socialisation are lost. This is particularly so for vulnerable children in the community (USAID, 2020). These impacts significantly reduce the benefits of school closure, and research has been conducted to show that using targeted closure strategies at the class or grade level that are reactively triggered when symptomatic cases are detected can be effective (Gemmetto et al, 2014).

The Centre for Disease Control (CDC) recommends a layered strategy to reduce exposures in schools to SARS-CoV-2. While every consideration need not be applied, multiple mitigation strategies should be implemented as appropriate, to improve effectiveness. These strategies include ventilation, social distancing, wearing of face masks and hand hygiene (CDC, 2020). It is noted that in Saint Lucian schools which do not experience winter conditions, classrooms tend to be relatively open, typically with natural cross ventilation. This could be enhanced with the use of fans strategically located.

4 Summary of Hazard Sensitivity Analysis

Most schools are exposed to high wind and drought events as it is possible for these to affect any location to a greater or lesser extent. However, many schools and/or their accesses are in locations that significantly increase their sensitivity to certain types of hazards, such as:

- fluvial flooding,
- landslides,
- storm surge and seal level rise.

Some schools may have relatively high sensitivities to more than one hazard. It is possible for some hazard events to occur simultaneously e.g. flooding and storm surge.

The scoring system for each hazard is provided in Table 5 and Table 6 provides a summary of the hazards associated with each school. Where a school area intersects more than one hazard class, the upper hazard class has been selected for the summary table, to provide some measure of conservatism in respect of the hazard modelling and mapping uncertainties. Additionally, when a school is within 100 m of a higher band of hazard class, the upper band is selected to account for mapping and modelling uncertainties in the interest of conservatism. These have also been derived by taking into account comments from Senior Advisor on this Consultancy on the current exposure of the school (see comments in Table 6).

Accordingly, in the map outputs listed in the appendices, a school may not intersect the hazard boundary highlighted in Table 6. However, the interpretation of the maps using knowledge of the local situation and the limitations of the data enabled a more appropriate hazard scoring mechanism to be used. Both the maps and Table 6 should be used in conjunction with each other. Table 6 also provides an average hazard score for each school, and a ranking of the schools based on the average hazard score. The ranking has been colour coded into three classes, the top four most exposed schools, the central four schools and the four least exposed schools.

The following appendices provide hazard maps for the Schools:

- Appendix A – National overview hazard maps for Wind, Drought, Flood, Landslide and general overview;
- Appendix B – Landslide hazard maps for each school;
- Appendix C – Flood hazard maps for each school;
- Appendix D – Wind hazard maps for north and south Saint Lucia.

An assessment of sensitivities to particular hazards will identify specific areas to be strengthened as a priority in each school.

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Table 5: Hazard Scoring Criteria

Score	Landslide	Fluvial Flooding	Wind Speed	Drought	Sea Level Rise/Coastal Hazards
1	No or low susceptibility	Very low or no flood hazard susceptibility (Predicted to flood less frequently than a 1 in 50-year return period storm event)	Very low wind hazard susceptibility (between 30-35 m/s wind speed; 100-year maximum likelihood event).	Very low (low flows resulting in demand restrictions have never been experienced in this system).	No impact – combined 1.1 m Sea Level Rise and a 4 m storm surge will have no impact due to high elevation of school above sea-level.
2	Low to moderate susceptibility	Low flood hazard susceptibility (Predicted to flood for events between 1:20 and 1 in 50 year-return period).	Low wind speed hazard susceptibility (between 35 to 40 m/s; 1 in 100-year maximum likelihood event).	Low (low flows result in demand restrictions implemented less than once in 5 years).	
3	Moderate susceptibility	Moderate flood hazard susceptibility (Predicted to flood for events between 1:10 and 1:20 year return period	Moderate wind speed hazard (between 40 to 45 m/s; 1 in 100-year maximum likelihood event).	Medium (low flows result in demand restrictions implemented once every 1 to 5 years).	Future impact only – combined 1.1 m Sea Level Rise and a 4 m storm surge will have an impact due to low elevation of school above sea-level.
4	Moderate to high susceptibility	High flood hazard susceptibility (Predicted to flood for events between 1:5 and 1:10 year return period)	High wind speed hazard (between 45 to 50 m/s; 1 in 100-year maximum likelihood event).	High (low flows result in demand restrictions implemented typically once per dry season on average).	
5	High susceptibility	Very high flood hazard susceptibility (Predicted to flood for events of 1:5 years or more frequent).	Very high wind speed hazard (50-55 m/s; 1 in 100-year maximum likelihood event).	Very high (low flows result in demand restrictions implemented multiple times each dry season).	High impact – a 4 m storm surge will have an impact due to low elevation of school above sea-level.

Table 6: Summary of Hazard Sensitivity Associated with Each School

School	Landslide	Fluvial Flooding	Wind Speed	Drought	Sea Level Rise	Average Score	School Average Hazard Rank	Comments (provided by ECMC based on local knowledge)
Ave Maria Infant	1	5	3	1	3	2.6	3	In centre of Castries which is known to flood. Located in fairly open country
Ave Maria Primary	1	5	3	1	3	2.6	3	In centre of Castries which is known to flood, located in a fairly open area
Balata Combined	3	3	2	2	1	2.6	3	Very inland and near a river
Bexon Primary	3	3	1	1	1	2.2	7	Known to be in a flood plain. The hill to the east can be a concern
Corinth Secondary	1	5	3	1	1	1.8	11	In a low-lying area, near a river, and is known to have drainage issues. Located in open country
Desruisseaux Combined	1	1	4	2	1	1.8	11	In the South, elevated and exposed. Water shortage is a known concern
Fond Assau Combined	1	1	4	3	1	2	9	Within an agricultural zone and on the upper slopes of a narrow valley
Micoud Primary	3	1	4	2	1	2.2	7	In the southeast and elevated topography. Supply of water is known to be an issue
Patience Combined	3	1	4	3	1	2.4	6	In the southeast and elevated topography. Supply of water is known to be an issue
Saltibus Combined	5	1	4	4	1	3	2	At a high elevation, with the Saltibus River being a water source
Vieux-Fort Infant	1	1	4	1	1	2	9	In the south of the island which is extremely flat and known to have water problems
Vieux-Fort Primary	1	1	4	3	5	3.6	1	In the south of the Island which is extremely flat and known to have water supply problems

5 Adaptive Capacity Assessment

There are varying definitions of adaptive capacity. One is the ability of a system to evolve to accommodate climate change or to cope with an expanded range of vulnerabilities. Another is the degree to which a system can currently cope and accommodate change caused by exposure to a climate hazard within existing resources and constraints. Low adaptive capacity enhances vulnerability and reduces resilience to climate change. Adaptive capacity of SIDS is generally low due to their physical size, limited access to capital and technology, shortage of human resource skills and limited access to resources for construction. SIDS adaptation costs are high relative to GDP. Saint Lucia, like most SIDS, is reliant on the international community to obtain the financial and technological resources necessary to achieve a resilient and sustainable low-carbon economy. Notably, too, a high adaptive capacity may not translate into effective adaptation if there is no commitment to sustained action.

The quality of the physical plant is quite variable from school to school. Generally, the more aged the structure, the greater the sensitivity to high wind speeds and other hazards. Wind speeds used for design have increased over time, making the older schools under-designed for cyclonic events unless they have been retrofitted to respond to updated design criteria. Similarly, drainage capacities may have been designed for peak flows that are now too low due to increased development of surroundings combined with higher rainfall intensities attributed to climate change. The materials in place in older schools are more likely to have reached or exceeded their design lives and therefore to be of significantly lower strength now than at the time of their installation.

Hazard vulnerability of some schools may be increased in locations where access/egress options available are limited, increasing the risk of isolation during or after an extreme event. Opportunities to develop additional access/egress routes may be limited in some locations due to terrain or constraints imposed by adjacent existing development.

Some schools have water storage on site, some of which are harvested rainwater storage. Some have limited water storage capacity overall, while others do not have any rainwater storage. Some schools do not have roof guttering, which makes it relatively more expensive to invest in rainwater harvesting. Current applications of harvested rainwater vary from irrigation of the school's market garden only to those that also include flushing of toilets. In most instances, storage capacity of harvested rainwater could be increased and optimised to better use this resource, particularly in schools with chronic public water supply issues. Schools, like most (if not all) public buildings, are not insured.

During the reconnaissance site visits and subsequent stakeholder discussions, the consulting team structured their interviews to deliberately gather information on the existing adaptive management capabilities within the school and the immediate community to reduce the impact of climate-induced hazards. The discussions also allowed the schools' principals to advance opinions and suggestions for improving adaptive capacity.

Measures to increase the adaptive capacity of schools will require closer examination of features at the Ministry and school levels, such as infrastructure, technology, resources for emergency management, capability/skills of staff and students, knowledge and information dissemination, evacuation plans, and leadership. Features at the household level include parents' participation in school disaster preparedness and response protocols; sharing of responsibilities among adults in the household; provision of shelter and protection, and meeting basic needs. Features at the community/district level include socio-economic and environmental conditions (poverty, level of educational attainment, functional literacy); infrastructure (mass transit, roads and bridges, utilities); voluntary support (school-based groups) and institutional support (community-based groups, private sector, public sector agencies, corporate partners). These features need to be examined in the context of the school's specific hazard exposures to identify the gaps and most effective approaches to enhance adaptive capacity. A gender sensitive and responsive approach is fundamental to guarantee gender equity as an outcome of enhanced adaptive capacity.

The Ministry of Education manages and maintains all public-school plant in Saint Lucia. Some conclusions based on a review of available information and stakeholder feedback are that:

1. The annual budget made available to schools for a day to day routine maintenance is too low, with a fixed amount of $6,000.00 per year provided to every school. There is no consideration of school age, vulnerabilities, size, population, community shelter requirements, etc. in determining this amount. Most schools are forced to seek out sponsorship from the corporate sector and support from parents and the community to supplement these funds and undertake basic maintenance activities.
2. The schools report maintenance requirements classified as significant to the Ministry; however, these issues may not be attended to for extended periods. Reasons for the delay or lack of attention to maintenance requests likely include one or more of the following:
    a. perceived priority and importance levels;
    b. funding constraints;
    c. human resource availability.
3. Maintenance of current school emergency management plans and routine engagement of the school population in emergency drills do not appear to be a strict requirement of the Ministry. Some schools engaged indicated one or more of the following:
    a. their emergency management committee within the school was not operational;
    b. their emergency management plans were not up to date;
    c. they had not conducted emergency drills with the school population in the recent past.

In relation to the schools functioning as emergency shelters:

1. Some school personnel consulted were not aware if the school was designated as an emergency shelter. This has implications for preparedness of the broader community pre-and post-hazard events.
2. Most schools, even if designated as emergency Shelters, do not have any shelter supplies on compound.
3. Despite being designated emergency shelters, many schools do not have a direct relationship with the National Emergency Management Organization (NEMO) or the District Disaster Committees (DDC) in their area.

The extent of community-level support across schools is highly variable. Some schools reported having highly engaged and active parent-teacher associations (PTA) and/or neighbours, while others reported very little community and/or PTA support. This spirit of volunteerism and ownership has implications for a school's recovery capacity in the aftermath of a disaster. Level of support may be influenced by factors such as:

1. limited means or interest of a parent body derived mainly from depressed neighbourhood(s);
2. distant relationship between school senior management and adjacent community; and
3. an inactive PTA.

To facilitate an evaluation of adaptive capacity at each of the schools, qualitative definitions have been developed:

1. Low Adaptive Capacity – The school and/or community do not possess the ability to influence the impact of hazards with current resources available.
2. Medium Adaptive Capacity – The school's operations can be adjusted to reduce impact with current resources but the facility will still be adversely be affected.
3. High Adaptive Capacity – The school has the resources and redundancy to continue operating without being adversely affected by hazards.

The analysis assumes that the adaptive capacity of the Ministry is constant and does not vary from school to school. Closer examination of the quality of Ministry resources available at a district level could warrant a review of this assumption. The following indicators are considered in the assessment of adaptive capacity in Table 7 below:

- Quality of physical plant - a function of school age and sufficiency of available maintenance budget among other things.
- Adequacy of surrounding infrastructure (roads, drainage, redundancy of access, proximity of emergency services).
- Availability of community support (PTA, corporate entities).
- Ability to continue operations in drought conditions for relatively longer periods (based on availability of public supply, on site potable water storage capacity, and capacity to harvest and store rainwater).
- Emergency response capacity (currency and adequacy of the emergency response plan for relevant hazards; drills, engagement with national/community disaster managers; proximity of emergency services).

Significant improvements can be made to adaptive capacities at both the national - Ministry of Education and NEMO - and school levels, thereby further reducing vulnerability of the education system. At the national level, the support for maintenance required at schools should be improved in terms of level of resources made available, management of maintenance works and response time. Communication between schools' management and the Ministry of Education should be improved. This may require strengthening or restructuring of the Building Unit within the Ministry. For example:

- Standards for typical maintenance works should be developed and used both to specify requisite works and to verify that works completed are compliant with the requisite standards.
- Contractors should be pre-qualified to ensure that they have the capacity to properly undertake the contracted works.
- Managers of the schools should be more involved in scoping the required maintenance works to better ensure that the planned works will resolve the issues faced.
- Third-party service providers require better supervision. Managers of the schools should be aware of what third-party service providers have been contracted to do and should be consulted before final payments are made, to ensure that the issues have been satisfactorily addressed.

Table 7: Schools Adaptive Capacity

School	Quality of Physical Plant	Adequacy of surrounding Infrastructure	Community Support	Ability to continue operations in drought conditions	Emergency Response Capacity	Overall Ranking	Overall Adaptive Capacity
Ave Maria Infant	Medium	High	Medium	High	High	4	**High**
Ave Maria Primary	Medium	High	Medium	High	High	4	**High**
Balata Combined	Low	Low	Low	Medium	Medium	2	**Low**
Bexon Primary	Low	Low	Low	High	Medium	2	**Low**
Corinth Secondary	High	High	High	High	High	5	**High**
Desruisseaux Combined	Low	Medium	Medium	Medium	Medium	3	**Medium**
Fond Assau Combined	High	Medium	Low	Medium	High	3	**Medium**
Micoud Primary	Medium	Low	Low	Medium	High	3	**Medium**
Patience Combined	Medium	Medium	Low	Medium	Medium	3	**Medium**
Saltibus Combined	Medium	Low	Medium	Low	Low	2	**Low**
Vieux-Fort Infant	Low	Medium	Medium	Low	High	3	**Medium**
Vieux-Fort Primary	Low	Medium	Medium	Low	High	3	**Medium**

Quantifying the ranking: - High =5, Medium = 3, Low = 1
Overall Adaptive Capacity – Average of all five parameters: - High = 4.0 to 5.0; Medium = < 4.0 and ≥ 2.5 and Low: < 2.5

The capacity to harvest, store and optimally use rainwater should be enhanced in most schools, to facilitate continued school (or emergency shelter) operation through drought conditions or service interruptions that may be triggered by adverse weather or other events. A formula to determine requirements based on school population/shelter capacity and other relevant factors could be derived.

Caretakers employed at the schools should be trained and assessed by the Ministry in job requirements that are designed to increase school resilience, such as proper maintenance of drains and guttering, identification of signs of early deterioration of school plant to be dealt with before they escalate, management of water storage, management of vegetation to reduce erosion and landslide risk, etc. Some of these requirements will apply to all schools, while others will be site specific.

Requirements for maintenance of emergency response plans and emergency drills should be more structured. This will likely require a higher level of training, monitoring, engagement and support by the Ministry. Performance appraisals of Principals and other responsible staff could include consideration of the extent to which these requirements have been met.

There should be greater collaboration with and support from NEMO at a national level and DDCs at a district level, to ensure schools are adequately prepared to meet community emergency shelter responsibilities. All programmes developed to improve resilience through building adaptive capacity need to be sustained, in recognition of the fact that staff changes, people need to be continuously motivated and informed, and the guidance itself is likely to be amended over time as knowledge grows.

6 Vulnerability Assessment

For Saint Lucia's schools to become more resilient to climate change, an appreciation of the potential impacts and associated implications in the short, medium and long term is required, both within the individual schools and at the policy making levels of government. Physical improvements planned through this and similar programmes can go a long way toward reducing vulnerability of schools by lowering their sensitivity to the various hazards.

Vulnerability of all schools should be assessed in a structured way, and measures to upgrade to requisite standards for increased resilience identified and prioritized. A detailed risk assessment of vulnerable assets will guide development of appropriate adaptations and of an implementation plan that prioritises recommended interventions based on asset importance and vulnerability. It is also important to increase adaptive capacity within each school and of the education system as a whole as recommended in the foregoing section, to further reduce hazard vulnerability.

The table below presents an assessment of the vulnerability of each school to the hazards under consideration. This combines information on sensitivity to these hazards at each location with knowledge of the adaptive capacities of the schools and the Ministry of Education.

Table 8: Summary of Vulnerability Assessment

Schools	Landslide	Fluvial Flooding	Wind Speed	Drought	Sea Level Rise/Coastal Hazards
Ave Maria Infant	NA	High	Medium	High	High
Ave Maria Primary	NA	High	Medium	High	High
Balata Combined	Low	Medium	High	Medium	NA
Bexon Primary	Low	High	High	Medium	NA
Corinth Secondary	NA	Medium	High	High	NA
Desruisseaux Combined	Medium	NA	Medium	High	NA
Fond Assau Combined	Low	NA	Medium	Medium	NA
Micoud Primary	NA	NA	Medium	Medium	NA
Patience Combined	Medium	Low	Medium	Medium	NA
Saltibus Combined	High	NA	Medium	High	NA
Vieux-Fort Infant	NA	High	High	High	High
Vieux-Fort Primary	NA	High	High	High	High

6.1 Conclusions of Hazard Vulnerability Assessment

This study presents a rapid assessment of natural hazard vulnerability for 12 schools in Saint Lucia for landslides, fluvial flooding, drought, wind speed and sea level rise. Maps at national and school levels have been prepared which provide information on the specific hazard exposures at, and in the vicinity of the schools. A summary table synthesising the hazard exposure for each school has been prepared. It is anticipated that this information will support planners in the identification and prioritisation of measures to reduce the exposure of these schools to natural hazards to an acceptable level. The acceptable level of exposure should be determined by planners (for example linking flood zones to adaptation measures).

The results show that the hazard profile of each school is distinct, based on its location and provide a basis for prioritising those schools for which further detailed investigation of hazard exposure and development of mitigation measures where appropriate. An average hazard score for each school has been used to rank the schools from most to least exposed across all the hazards considered in this study. Whilst this aggregate ranking is useful as an overview it is important to note that each school is unique in terms of hazard impacts and mitigation measures required.

6.2 Hazard Vulnerability Ranking

The 12 schools are ranked for hazard vulnerability below (from most to least exposed):

- Vieux-Fort Primary (1)
- Saltibus Combined (2)
- Ave Maria Infant (3)
- Ave Maria Primary (3)
- Balata Combined (3)
- Patience Combined (6)
- Bexon Primary (7)
- Micoud Primary (7)
- Fond Assau Combined (9)
- Vieux-Fort Infant (9)
- Corinth Secondary (11)
- Desruisseaux Combined (11)

Focussing on the most vulnerable schools, Vieux Fort Primary is the top-ranked school due to its exposure to fluvial and coastal flooding and sea level rise, high wind speeds and drought conditions. Salitbus is the second-ranked school due to its exposure to landslides, wind speed and drought. The Ave Maria Schools, jointly ranked third, are exposed to fluvial, and to a lesser extent coastal flooding and sea-level rise, and moderately to high wind speeds. The Balata school is also ranked third due to its exposure to fluvial flooding and landslides to a lesser extent. It should be noted that the Vieux Fort Infant school ranks ninth despite its proximity to the top-ranking Vieux Fort Primary school. This ranking is because the infant school appears to be at a higher elevation (10 metres above sea level, compared to 4 metres for the Primary school), reducing its exposure to fluvial and coastal flooding. However, this should be verified by a site visit, if the DEM used in the coastal and fluvial flood modelling is inaccurate, and the school is lower than estimated here, it may have a similar exposure to the coastal and fluvial flood hazards.

6.3 Next Steps in Addressing the Specific Hazard Vulnerabilities

6.3.1 *Landslide*

The Saltibus school is most exposed to landslides. It is recommended that a further detailed landslide risk investigation is conducted for this school, in order to determine if specific measures are required to reduce landslide risk. The school is in a mountainous region and sits on a ridge with steep slopes on either side. Access to the school via incoming roads may also be vulnerable to landslide hazards. Therefore, further assessment of the landslide risk for commuting routes to this school is recommended to further understand the potential for disruption to access for staff and pupils.

Patience, Balata, Micoud and Bexon schools are rated as medium landslide risk. It is recommended to undertake site visits to these schools with competent professionals to validate this risk rating, especially noting that the landslide hazard mapping does not include run out areas, and therefore, schools that are downslope of high hazard zones may be underestimated in the datasets.

6.3.2 *Fluvial flooding*

The Ave Maria schools, Balata, Bexon and Vieux Fort Primary schools are located in the highest flood hazard zones. Ave Maria schools sit within an urban floodplain in Castries, while Balata and Bexon are located in valley bottom locations adjacent to rivers. The Vieux Fort Primary school is located in a low-lying area which has been known to flood in the recent past (UNCTAD, 2017 and GOSL and World Bank, 2014).

A more detailed investigation of the flood hazard (based on flooding history and inspection of the local topography) is recommended for these schools. The purpose of the investigations is to validate the hazard rating and understand local flood ponding and routing areas so as to design appropriate flood mitigation solutions. Site specific flood modelling would be useful if sufficiently accurate ground modelling is available, for example, based on LiDAR data.

In addition, the Corinth Secondary and Vieux Fort Infant schools although at a medium hazard category should be inspected as recommended above. Based on the flood mapping and elevation contour data, there is some uncertainty in the flood hazard zones. The Corinth Secondary school sits within a valley bottom and it is possible that local flood flow routes in the flood hazard modelling may not be correctly represented. The Vieux Fort Infant school is shown to be on a slightly more elevated ground than the Primary school, but this should be verified given uncertainties in the accuracy of the elevation model used in the flooding hazard data.

6.3.3 *Wind speeds*

The following schools are the most exposed to high wind speeds: Desruisseaux Combined, Fond Assau Combined, Micoud Primary, Patience Combined, Saltibus Combined, Vieux-Fort Infant, Vieux-Fort Primary. The remaining schools are located in more sheltered positions with lower hazard scores. None of the schools fall into the maximum wind speed hazard category which occupies the mountainous centre of the island.

It is recommended that any specific additional wind hazard mitigation measures are considered for the schools listed above as a priority, if such measures are considered appropriate above and beyond the design standard wind speeds used for general development planning control in Saint Lucia.

6.3.4 *Drought*

The Saltibus school is the highest ranked for drought risk, and the supporting notes indicate that water trucking is required for four to five months of the year. As such, this school is highest priority for drought mitigation measures, if the existing approach of water trucking is considered too unreliable, unsustainable or unsafe to be acceptable in the long term. Ideally, the water supply system for the entire community, not only the school should be prioritised for upgrade, but if this is not feasible then appropriate measures should be introduced to ensure a reliable supply of potable water for the school throughout the year. Fond Assau, Patience, and Vieux-Fort Primary are also exposed to drought to a lesser degree. In these instances, it is recommended that more detailed investigations of the feasibility of drought mitigation measures are recommended.

It is unclear why the Vieux Fort Primary School is significantly more exposed to drought than the Vieux Fort Infant school when they are only 400 m apart, at similar elevations and presumably share the same water distribution network. In the qualitative assessment of drought risk, WASCO indicated that the Infant school is closer to the treatment works, whereas the Primary School is served by a network which has been over-expanded. It is recommended that this explanation is verified, before prioritizing one school over the other for provision of drought mitigation measures.

6.3.5 *Coastal flooding and sea level rise*

Vieux Fort Primary is the most exposed school to coastal flooding and sea level rise. This exposure rating is due to its low-lying position adjacent to the exposed south-eastern coast of the island, and the area is known to have flooded in the past on several occasions (UNCTAD, 2017), although it is unclear whether this flooding was coastal or fluvial or both. Based on the school's elevation of 4 m, it would be vulnerable to a 4 m storm surge, and this vulnerability would increase as sea level rise is superimposed.

More detailed coastal inundation modelling and mapping is recommended for the Vieux Fort area, noting that this would also need to consider fluvial flood hazards. Validation of the school elevation using survey data is also recommended in order to confirm the hazard rating, which is based on an elevation of 4 m.

The Vieux Fort Infant school is not considered to be exposed as it is on slightly more elevated ground than the Primary school, but this should be verified given uncertainties in the accuracy of the elevation model used in the flooding hazard data.

The Ave Maria schools in Castries are also exposed, although to a lesser degree, being on the less exposed west coast. The school elevations based on the DEM used in this study are 5 m above mean sea level, therefore a 4 m storm surge combined with a 1.1 m sea level rise would be required to pose a risk to the schools. This is considered relatively unlikely although it remains a possibility. It is recommended that the school elevations are confirmed using survey data to check whether they are more or less exposed than predicted on the basis of a 5 m elevation.

The remaining schools are not considered to be at risk from coastal flooding and sea level rise, as the school at the next lowest elevation is Bexon at around 20 m above sea level.

6.4 Limitations of the Data and Methods

The data sources used to make this assessment are national scale hazard maps (with the exception of drought which was based on detailed local knowledge from the water utility company, WASCO). Uncertainties in the input data in the hazard models mean that the local detail of hazard locations (such as flood hazard outlines or landslide outlines) may be subject to some uncertainty. Furthermore, the landslide hazard mapping does not include landslide run out zones which represent a source of hazard. Therefore, it is recommended that the hazard ratings are validated based on site inspections, especially in the case of landslides and flooding. For example, the Corinth school is shown at only marginal risk of flooding on the hazard maps, but local inaccuracies in the DTM may affect local modelled flow routes. This validation may result in adjustment of the hazard scores and further supplementary notes.

It should also be noted that for wind speed, the hazard ratings are based on relative hazards between the schools. This means that a school with a low wind speed rating is merely low relative to the other schools, and should still be subject to national wind speed design standards, while those with a higher rating may merit additional detailed consideration of wind risk mitigation measures.

The exposure of schools to coastal flooding and sea level rise has been based on the elevation of the school derived from the DTM used in this study, not surveyed site levels. Therefore, for the schools at low elevations (suggested less than 15 m above sea level), the levels should be checked against surveyed levels to validate the exposure of the schools.

As a general recommendation on the assessment of hazards:

- The wind speed and coastal inundation maps which were used in this study should be sourced from their authors in digital format and uploaded to the CHARIM online database. This would allow future assessments to use a more accurate and easily computer readable datasets for these types of assessments.
- The landslide hazard mapping should be extended to include landslide run out areas as well as the slopes themselves.
- WASCO should prepare drought hazard maps for each water supply system (and ideally different parts of the network in each system) categorising the drought hazard to water supply across the island. This would aid future assessments by providing an understanding of the reliability of piped water supplies. It is noted that Vieux Fort Infant school is rated very low for drought hazard, while the nearby Vieux Fort Primary is rated medium, indicating the influence of the local distribution system on levels of service during periods of drought.
- The validation of the hazard exposure based on site visits should be used as a basis for further improvements to the hazard mapping if it is deemed inaccurate in certain areas.

Appendix A - National Overview Hazard Maps

Table A.1: Summary of National Hazard Maps

Hazard	Map file name
N/A	*fwm8628_schoolSites_overview_20201012.pdf*
Wind	*fwm8628_windHazard_overview_20201109.pdf*
Drought	*fwm8628_droughtHazard_overview_20201012.pdf*
Flood	*fwm8628_floodHazard_overview_20201109.pdf*
Landslide	*fwm8628_landslideHazard_overview_20201012.pdf*

Appendix B - Landslide Hazard Maps for Each School

Table B.1: Summary of landslide hazard maps

School	Map file name
Ave Maria Infant	*fwm8628_landslideHazard_aveMaria_20201012.pdf*
Ave Maria Primary	*fwm8628_landslideHazard_aveMaria_20201012.pdf*
Balata Combined	*fwm8628_landslideHazard_balataSchool_20201012.pdf*
Bexon Primary	*fwm8628_landslideHazard_bexon_20201012.pdf*
Corinth Secondary	*fwm8628_landslideHazard_corinthSecondary_20201012.pdf*
Desruisseaux Combined	*fwm8628_landslideHazard_desruisseauxCombined_20201012.pdf*
Fond Assau Combined	*fwm8628_landslideHazard_fondAssau_20201012.pdf*
Micoud Primary	*fwm8628_landslideHazard_micoudPrimary_20201012.pdf*
Patience Combined	*fwm8628_landslideHazard_patienceCombined_20201012.pdf*
Saltibus Combined	*fwm8628_landslideHazard_saltibusCombined_20201012.pdf*
Vieux-Fort Infant	*fwm8628_landslideHazard_vieuxFort_20201012.pdf*
Vieux-Fort Primary	*fwm8628_landslideHazard_vieuxFort_20201012.pdf*

Appendix C - Flood Hazard Maps for Each School

Table C.1: Summary of fluvial flood hazard maps

School	Map file name
Ave Maria Infant	*fwm8628_floodHazard_aveMariaSchool_20201109.pdf*
Ave Maria Primary	*fwm8628_floodHazard_aveMariaSchool_20201109.pdf*
Balata Combined	*fwm8628_floodHazard_balataSchool_20201109.pdf*
Bexon Primary	*fwm8628_floodHazard_bexonSchool_20201109.pdf*
Corinth Secondary	*fwm8628_floodHazard_corinthSchool_20201109.pdf*
Desruisseaux Combined	*fwm8628_floodHazard_desruisseauxSchool_20201109.pdf*
Fond Assau Combined	*fwm8628_floodHazard_fondAssauSchool_20201109.pdf*
Micoud Primary	*fwm8628_floodHazard_micoudSchool_20201109.pdf*
Patience Combined	*fwm8628_floodHazard_patienceSchool_20201109.pdf*
Saltibus Combined	*fwm8628_floodHazard_saltibusSchool_20201109.pdf*
Vieux-Fort Infant	*fwm8628_floodHazard_vieuxFortSchool_20201109.pdf*
Vieux-Fort Primary	*fwm8628_floodHazard_vieuxFortSchool_20201109.pdf*

Appendix D - Wind hazard maps for north and south Saint Lucia

Table D.1: Summary of wind hazard maps

Map region	Map file name
Northern Regional Overview	*fwm8628_windHazard_20201109_northern.pdf*
Southern Regional Overview	*fwm8+628_windHazard_20201109_southern.pdf*