CHAPTER ONE: INTRODUCTION

1.1 PROJECT PROFILE

The Portmore Hazard Risk Assessment Project is a joint project between the Mines and Geology Division (MGD) and the Office of Disaster Preparedness and Emergency Management (ODPEM). Funding for the project is undertaken by the United Nations Development Programme (UNDP) which seeks to include as part of its mandate, loss reduction strategies in disaster mitigation and management. The project began in July of the year 2006.

1.2 BACKGROUND

The history of Jamaica over the past 300 years has been subjected to geological, hydrological and atmospheric hazards, particularly along the southern coast of the island. Many storms which pass through the island frequently begin their entry along the south coast leaving behind severe damage and destruction to infrastructure.

The municipality of Portmore is situated on the south coast in the parish of St. Catherine (Figure1). It is situated approximately 15 miles south-west of the capital city of Kingston, comprising the communities of Old Portmore, Greater Portmore, Braeton and Hellshire. Regionally, it also forms a part of the Greater Kingston Metropolitan Area (KMA). Portmore is the fastest growing town in the country with respect to human settlement, having a population of 156,468 (2001 census data) and an annual growth rate of 4 percent since 1991. As such the need for a vulnerability assessment in this city is not only critical but also expedient.

Portmore was targeted for this assessment for the following reasons:

1. The current population of Portmore accounts for nearly 31 percent of the total population of St. Catherine and nearly 6 percent of that of Jamaica and with the current annual growth rate, its vulnerability and susceptibility to natural disasters has become a cause for concern.
2. Due to the number of residents and infrastructure in the Portmore economy, loss due to a natural disaster may be exorbitant.

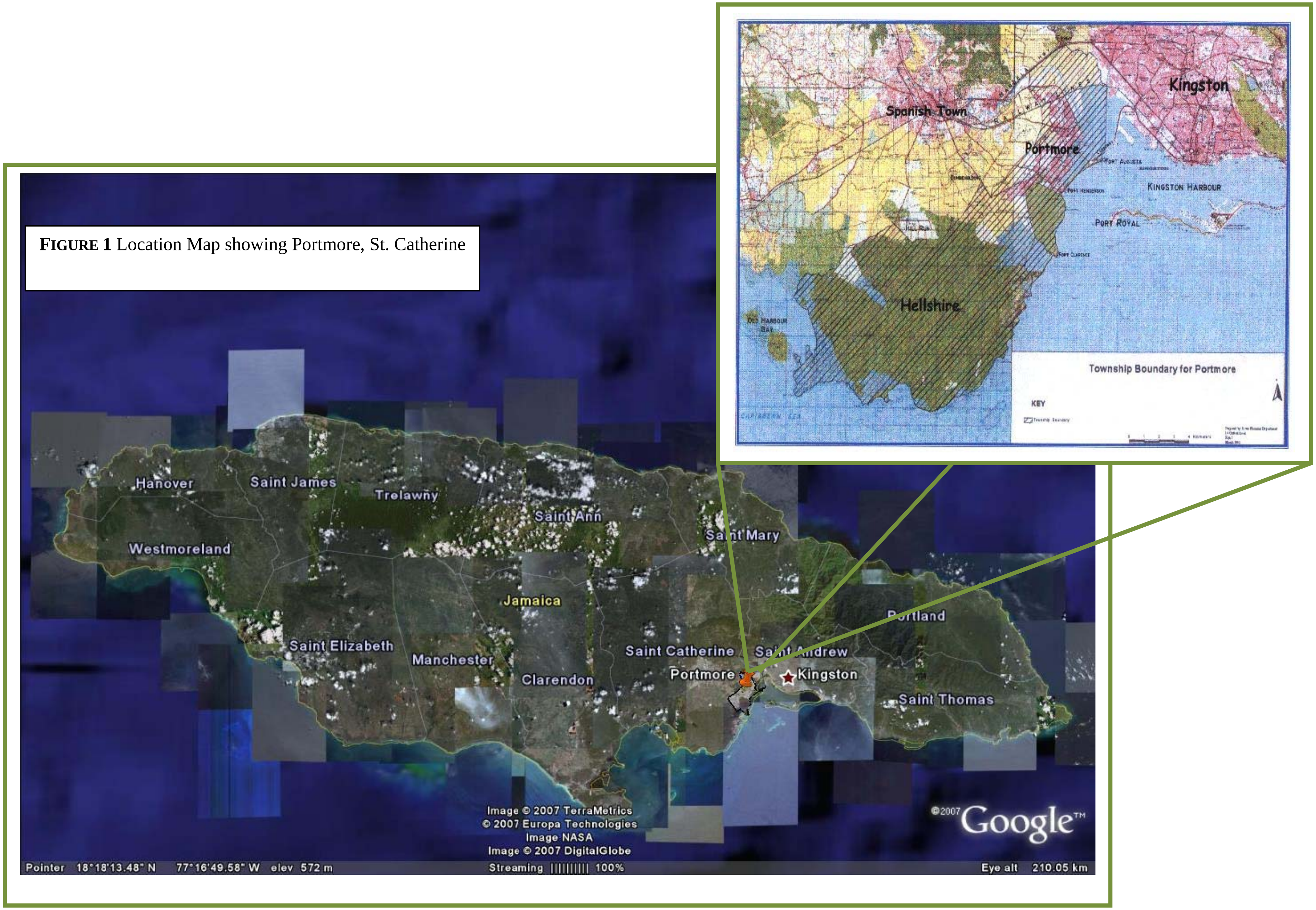


FIGURE 1 Location Map showing Portmore, St. Catherine

3. Portmore, which is located on the south coast of Jamaica, is one of the regions that are affected most frequently by hurricane. These hurricanes tend to approach the island from a southerly direction (Figure 2).
4. Portmore is also located in close proximity to the Blue Mountain – Wagwater fault system which is capable of generating earthquakes of significant magnitude (see section 3).
5. This area suffered in the past from natural disasters such as earthquake, hurricane and flooding, therefore, the probability of occurrence in the near future is high.

1.3 AIM

The Aim of the project is to:

1. Conduct a technical review of the major natural hazards/risks of Portmore to include floods, storm surge and earthquake.
2. Conduct comprehensive hazard/risk and vulnerability mapping for the community.
3. Determine the status of current evacuation routes and to recommend changes if necessary to improve/update the Portmore Evacuation Plan.

1.4 METHODOLOGY

1. An assessment of the level of major natural hazards in Portmore was conducted. This was accomplished by data gathering, literature review and aerial photographic interpretation.

2. Coastal and inland flood hazards were identified or confirmed through interviews and anecdotal evidence.

3. The vulnerability of communities in Portmore was determined by adapting the NOAA methodology for vulnerable communities.

4. Evacuation routes during emergency situations were identified and examined to further determine the vulnerability of this community.

5. Natural hazard and vulnerability maps for Portmore were created using Geographical Information System (GIS) - based programs and critical elements at risk were identified.

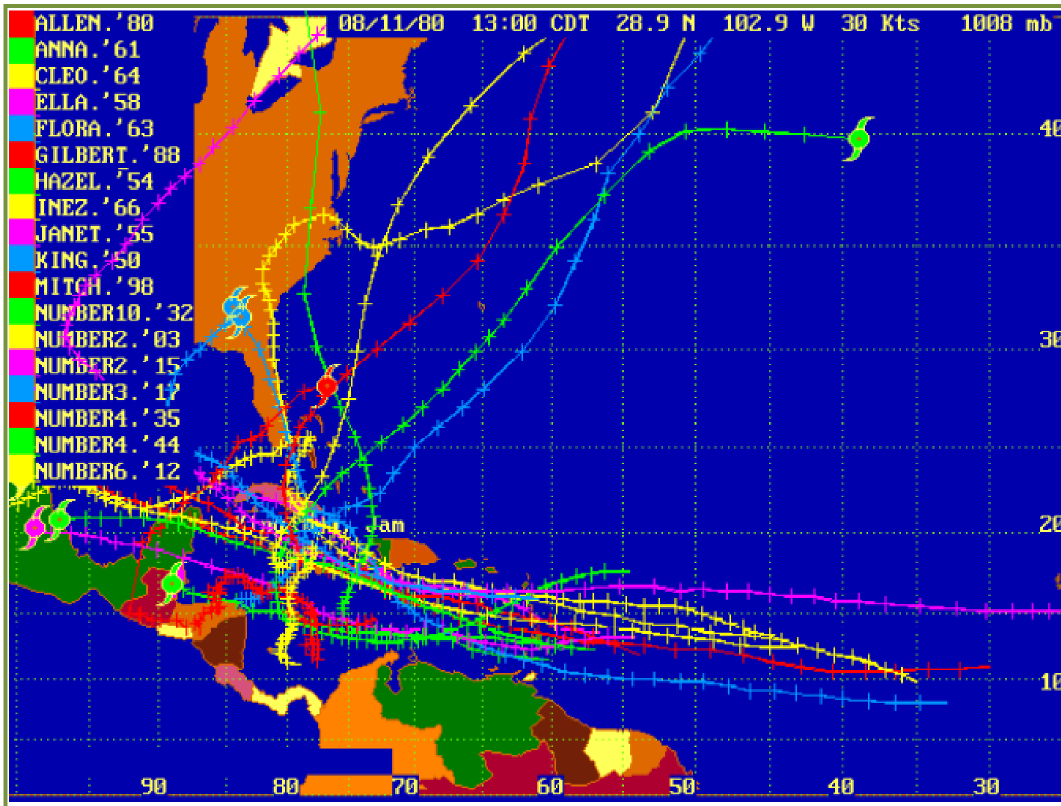


Figure 2 - Hurricane Tracks for Category III or Greater Storms

1.5. LIMITATIONS

This project was limited by several factors because of the lack of several data sets such as adequate flood data which include the depth and the extent of flood water and the exact location flood incidence. Several socio-economic data was not available such as income data, educational level of the residents. There was a lack of adequate information on the earthquake impact on Portmore buildings.

CHAPTER TWO: REGIONAL SETTINGS

Jamaica is located in the north Caribbean region between latitude 18 36’N 17 5’ S and longitude 76 15’ E 78 22’ W. Based on its location, the island is generally in the path of tropical storms and hurricanes. Geologically, it lies within the Caribbean Plate in a seismically active zone.

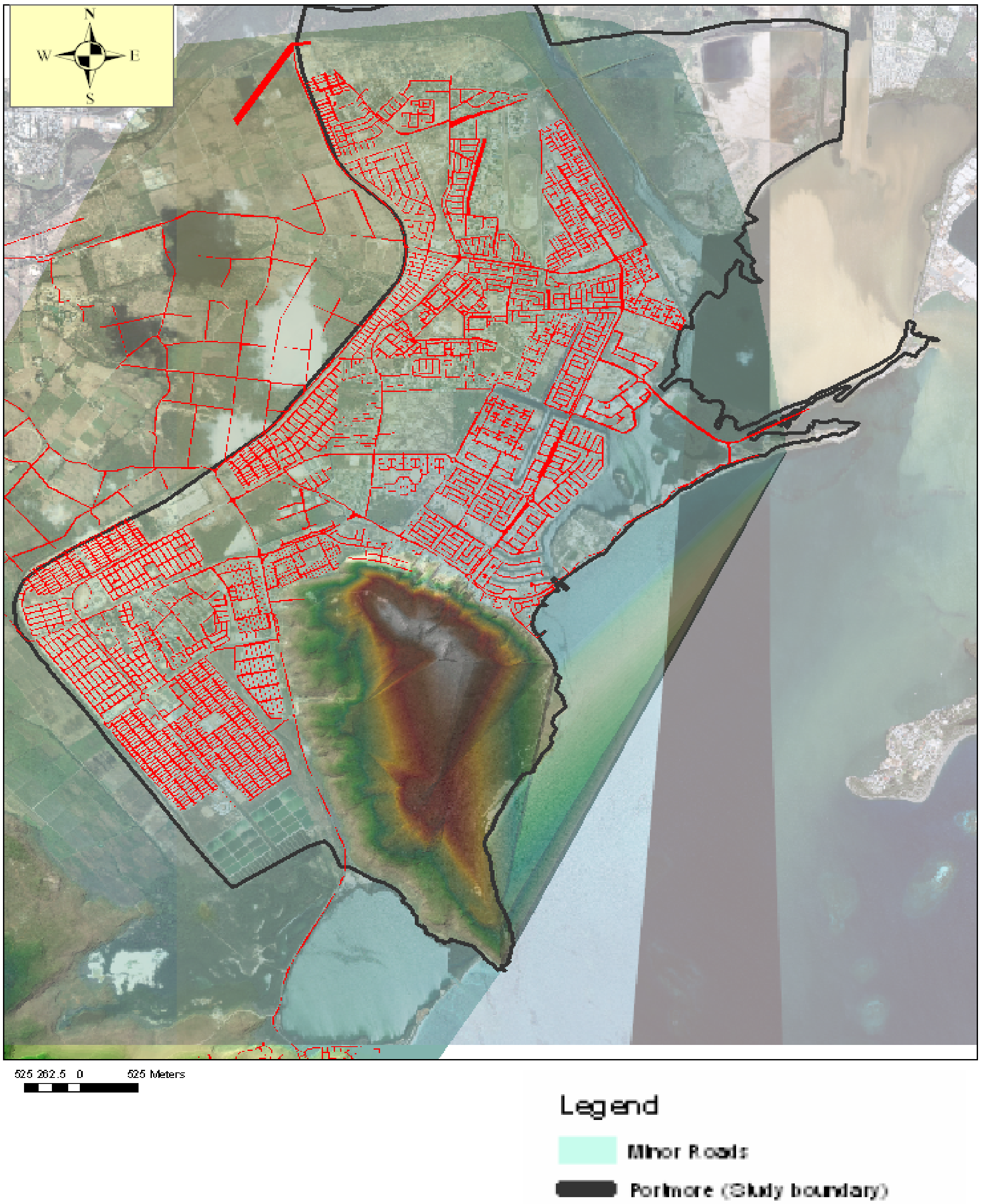
2.1 GEOGRAPHY OF PORTMORE

Portmore Municipality, also known as the Sunshine City, is located in the parish of St. Catherine. It encompasses the Hellshire Hills in the south, Port Henderson Hill in the east; the mangrove and saline wetland to the southeast and the alluvium areas in the center and west. The most densely populated areas in the Portmore Municipality are located on low lying areas of reclaimed land and alluvium of the younger member of the Liguanea Formation. The Port Henderson Hill and Hellshire Hills are elevated areas that rise above the gently sloping “Portmore Plains”. The Port Henderson Hill is the most prominent feature in this region with height over 680m above Mean Sea Level (amsl) while the surrounding plains have general elevation around 4m amsl.

Portmore is the fastest growing city in Jamaica in terms of population, with a population of 156, 468 (2001 census) which indicates an annual growth of 4 percent from 1991. Portmore, in addition with the rest of Kingston Metropolitan Area is one of the largest urban areas in the Caribbean with 26.25 percent of the country’s population. Portmore has one of the largest populations in Jamaica second only to Kingston.

The area of study for the Portmore Project is shown in Figure 3.

Figure 3 Map of Study Area for Portmore Project



2.2 THE GEOLOGY OF PORTMORE AND HELLSHIRE HILLS

2.2.1 Lithology

Portmore is situated on the younger alluvium member of the Liguanea Formation. The Liguanea Formation Plio-Pleistocene in age comprises of alternating layers of clayey grits, sands and silts and uncomfortably overlies the rocks of the White Limestone Group. The true thickness of the Liguanea Formation is general unknown. Port Henderson Hill, which is the most prominent feature in the Portmore Municipality, rises above the plains of Portmore and is predominantly comprised of limestone. The Port Henderson Hills contain the Lazaretto Inlier in which outcrops of metamorphic rocks of the Green Bay Formation (Cretaceous age) are exposed. The Port Henderson Hills also has minute outcropping of Grants Pen Clay Formation (Eocene age). The lithology of Port Henderson Hill includes limestones of the Troy Formation (Eocene), Newport Formation (lower Miocene) and August Town Formation (Upper Miocene). Hellshire Hills is comprised of rocks of the Newport Formation.

2.2.2 Structural Geology

Jamaica is located along the Northern Caribbean plate boundary zone which has strike-slip plate movement. It is the major exposed section of the Nicaraguan Rise, which exposure is due to transgression of the lateral strike-slip plate movement of the Caribbean plate. The location of island had led to the island being ripped with faults. There are two major faults systems a southeast-northwest trend (Montpelier-Newmarket and Blue Mountain/ Wagwater fault zones) and easterly-westerly trending (Duanvale, Rio Minho-Crawle River and Plantation River).

The Portmore Municipality is comprised of a synclinal basin that had been infilled by the Rio Cobre and the anticlinal hills of Port Henderson plus the elevated region of Hellshire Hills.

The Port Henderson Anticline is the most elevated structure in Portmore with a NW-SE trend. The anticline is bisected by the Rodney Fault with an estimated throw of 457 m. The Hellshire Hills are to the southwest of Port Henderson Hill and is separated by a NW-SE aligned syncline. Hellshire Hills are viewed as a broad domed structure. The folding and faulting of post Cretaceous rock post date the deposition of the August Town Formation (late Miocene) but predate that of the Liguanea Formation (Plio-Pleistocene).

2.2.3 Developmental History of Portmore

Portmore has grown from an agricultural dominated area (banana and sugar cane as the main crops) to the fastest growing urban area in Jamaica (Figure 4). Its development started as a result of the increased demand for housing in Kingston in the 1950s and 1960s. The Portmore Land Development Company Limited was created to oversee the development of housing projects. The first housing scheme in Portmore was called Independence City; this was followed by Edgewater villas.

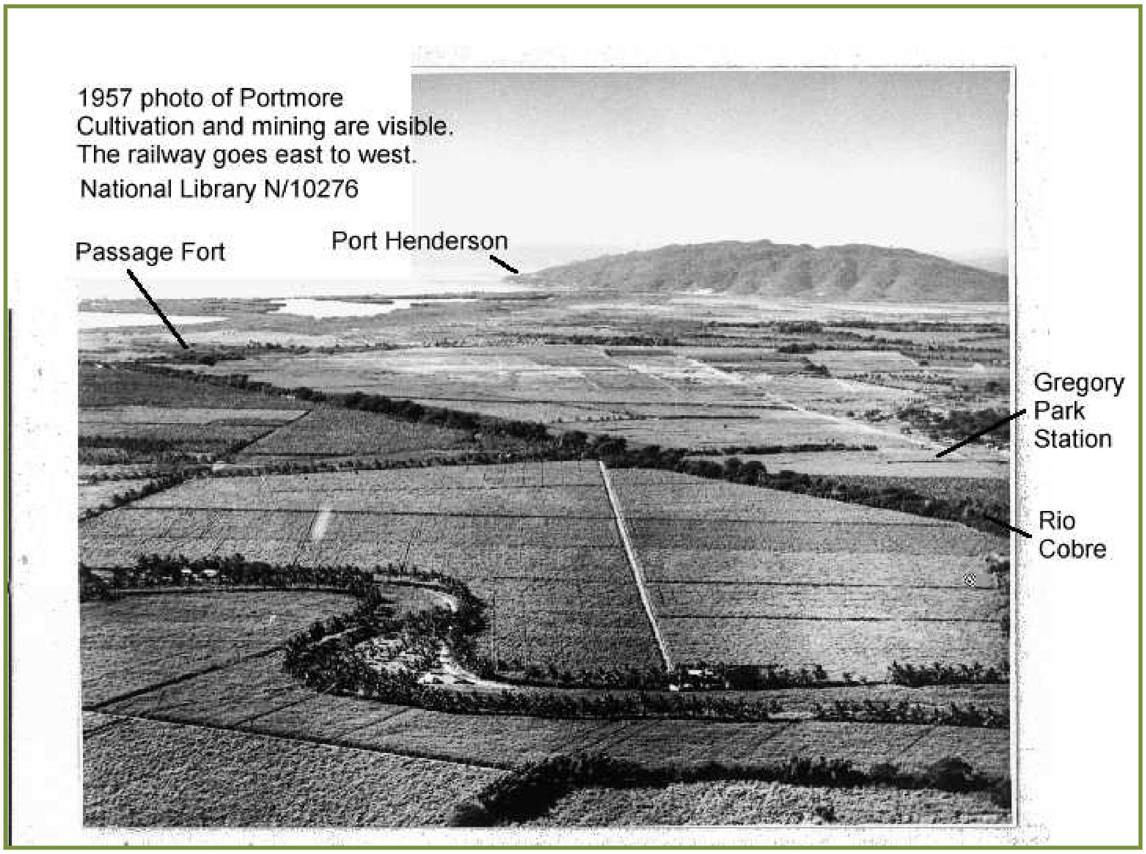


Figure 4 Map showing agricultural crops in Portmore - 1957 Source: Portmore info (www.portmore.info/)

Prior to its development, a number of engineering and ground improvement works were conducted to improve the land for housing construction. These included:

1) The construction of a 12 miles dyke structure to prevent flooding of the low lying area from the Rio Cobre, when in spate.

2) The reclamation of approximately 2,000 acres of land which was originally part of a wetland area. The urbanization of Portmore had led to a dramatic change in the land use pattern of Portmore as shown in Figure 5 which indicates land use in the 1960s’ versus the present day pattern.

CHAPTER 3: HAZARD ASSESSMENT OF PORTMORE

Residential and other occupied land in Portmore are located along the southern coast of Jamaica, on the Rio Cobre flood plain and on reclaimed land and as such are vulnerable to three main hazards. These are flooding, earthquakes and storm surges. The degree of hazards and the vulnerability of residential and commercial areas were assessed under this project.

3.1 EARTHQUAKE HAZARD ASSESSMENT

3.1.1 Definition of an Earthquake

An earthquake is the sudden motion or trembling in the earth caused by an abrupt release of slowly accumulating strain in the earths crust. This sudden release results in ground shaking, surface faulting, and/or ground failures. Earthquakes can be classified according to the intensity or magnitude of the seismic waves. The intensity of an earthquake is a subjective measurement of the effects of an earthquake and widely measured using the Modified Mercalli Scale which has twelve grades (see appendix). The magnitude of an earthquake is the size of the earthquake or the energy release from the earthquake. The magnitude is the quantitative measurement and the scale normally used is the Richter.

3.1.2 Earthquake Generation

Earthquakes are generally generated by rupturing of rocks along a fault plane. The fault planes are typically located near or along plate boundaries. The areas of greatest tectonic instability occurs at the perimeter of slowly moving plates because these locations are areas that are subjected to the greatest strains from plates moving in opposite direction at different speeds or similar direction at different velocities. The deformation along plate boundaries causes strain in the rocks thus a built-up in stored energy. When the stored energy of the rocks due to increases or sustained stress exceeds the strength of the rocks, rupture occurs to release the excess energy. The rocks on both sides of the fracture are snapped, releasing the stored energy and creating seismic waves that generates earthquakes.

3.1.3 History of Earthquakes in Jamaica

The island of Jamaica which is located within the Caribbean plate boundary zone has experienced many years of earthquake activity with at least 339 years of reliable documentation of felt earthquake. The following is a brief overview of significant earthquake activities in eastern Jamaica (table 1).

Historical Significant Earthquakes of Eastern Jamaica		
Date	**Intensity and/ or Magnitude**	**Area affected**
1667		Eastern Jamaica
March 1, 1688	VII	Port Royal
June 7, 1692	X	Entire Jamaica
September 3, 1771	VII	Port Royal, Kingston
January 14, 1907	IX, Ms 6.5	Kingston, Port Royal
August 3, 1914	VII	Eastern Jamaica
March 1 1957	MSK V[1]	Entire Jamaica
January 13, 1993	VII, Mw 5.5	Kingston, Port Royal, Portmore

Table 1 Source: Wiggin-Grandison, 2006

[1]MSK is an earthquake intensity scale that is equivalent to the Modified Mercalli Scale (Shepherd, 1971

3.1.4 Source Area for Earthquakes of significant magnitude

The source area for earthquake of significant magnitude may be divided into two groups the pre- and post-Woodford, 1993 earthquake. The location of earthquakes of significant magnitude has special bearing on the expectation of liquefaction-induced ground failure in Jamaica (Figure 5). There is a causal link with magnitude and distance of source from the area experiencing liquefaction.

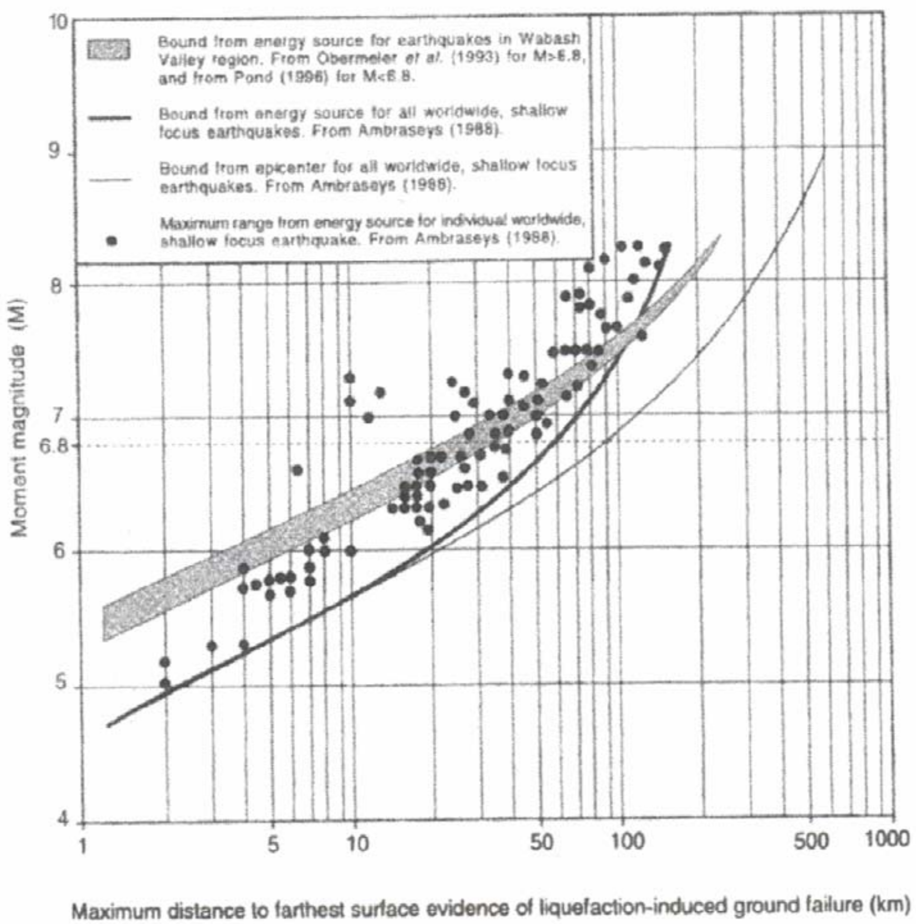


FIGURE 5: Liquefaction as a function of magnitude and distance (from Obermier and Pond, 1999)

3.1.4.1 Pre-Woodford, 1993 Earthquake Era

The early workers involved in seismic assessment for Jamaica were of the view that the location of sources for earthquakes of significant magnitude that had produced significant damage was located within the Bartlett Trough (Taber, 1970). The Bartlett Trough or the Cayman Trench is the major bathymetric feature in Caribbean region (KMA, 1999); it is a submarine trench on the floor of the western Caribbean Sea between Jamaica and the Cayman Islands. Shepherd (1971) had indicated that high magnitude shocks are very unlikely to occur inland because of the complexity the island's fault system which cuts up lengthy faults into smaller segments that in turn reduces the possibility of larger shocks being generated, as large shocks are generated by large source volume or long faults.

3.1.4.2 Post-Woodford, 1993 Earthquake Era

The location of 1993 earthquake of magnitude 5.5 with intensity of VII inland at Woodford, Portland (Figure 6) indicates that earthquake of significant magnitude can be generated inland (Wiggin-Grandison, 1994). The location of this earthquake on land had provided enough evidence to indicate that faults within the Blue Mountain/Wagwater Fault Zones are capable of generating earthquakes of significant magnitude which will have serious implication with regards to liquefaction and ground acceleration for the Liguanea - St Catherine Plains.

Obermeier and Pond (1999) indicated that there is a causal link between earthquake magnitude and the maximum hypocentral distance to the farthest surface evidence of liquefaction for a number of earthquakes (Fig 6). The location of the Woodford earthquake in close proximity to these alluvial plains also means that the amplification of the earthquake in the alluvium will be greater than one generated at the Bartlett Trough. Earthquakes that are generated in the Bartlett Trough or in the Oriente Fracture Zone will be dampened by the oceanic crust which separates Jamaica from the Oriente Fracture Zone, since oceanic crust is a poor propagating medium for high frequency shear waves (Mendi et al., 1997). This phenomenon was observed when an earthquake of magnitude

7 occurred on the Oriente Fracture Zone (Figure 7) about 200 Km north of Kingston produced intensity of only IV on the Liguanea Plain in 1992 (JSN bulletin, 1992).

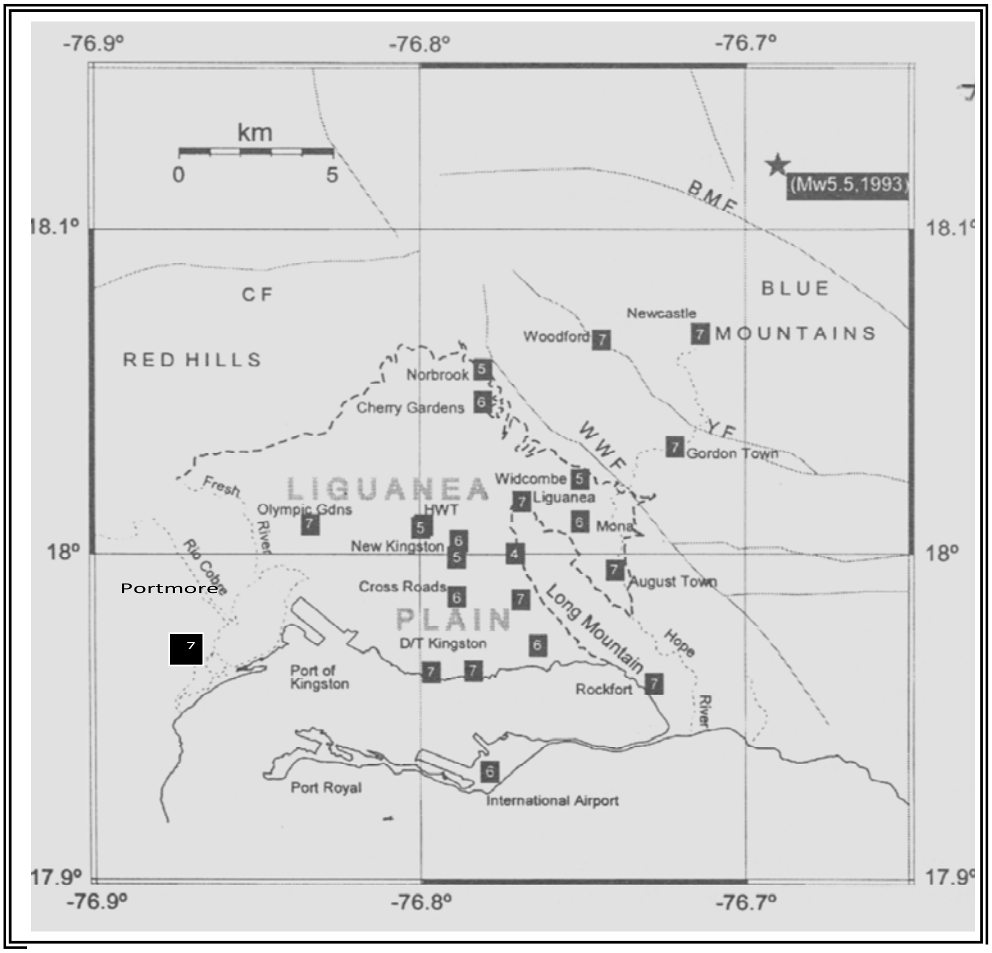


FIGURE 6: The intensity of the January 13, 1993 earthquake felt in Portmore, in relation to its surrounding communities on the Liguanea Plain. The epicenter is marked with a star.
Sources: Wiggin – Grandison, 2003, Phillip - Jordon, M. Phil Thesis, 1995

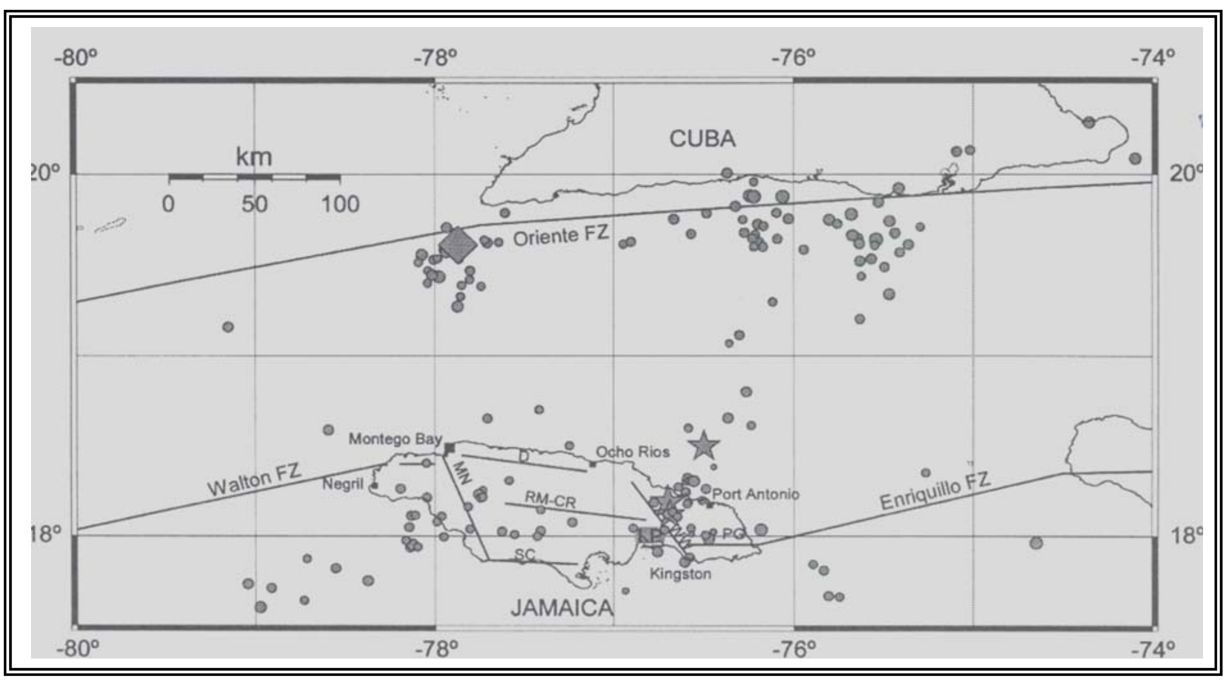


Figure 7: Geological Setting and seismicity (M.≥3.0) around Jamaica(LP)Liguanea Plain; FZ fracture/fault zone; MN = Montpelier –Newmarket; D = Daunvale: RM-CR=Rio Minho-Crawle River, SC= South Coast: WW= Wagwater, PG = Plantain garden; diameter of epicenters are scaled to magnitude;

3.1.5 Earthquake Hazard Mapping

In light of the known possibility of an earthquake of moderate to strong magnitude occurring in the Blue Mountain- Wagwater Fault system which is located in close proximity to Portmore Municipality situated on alluvium, this would provide contributory factors to seismic amplification. The Mexico City earthquake destruction (September 19- 21, 1985) is a testament of alluvium amplification of seismic waves even when they are generated from a source that is several kilometre away. Wiggins-Grandison (2003) had indicated that Kingston Metropolitan Area and by extension Portmore, faces an enhanced earthquake risk due to wave field excitation in the Liguanea alluvium. The presence of high water table and made ground (reclaimed land) in Portmore increases the possibility of liquefaction.

3.1.6 Portmore's Vulnerability to Earthquake

Portmore is essentially a residential city or dormitory city which means that the majority of the buildings in Portmore are residential. The houses in Portmore are 1-2 storey with a few commercial buildings up to three storey and as such are expected to experience a minimum intensity of VIII & IX for earthquakes of magnitude of 6 & 7 respectively (Table 2). The estimates by Shepherd (1977) was supported by Phillip-Jordon(1995) in her research indicated that the 1993 earthquake of magnitude 5.5 had produced an intensity of VII based on her assessment of the damage obtained from the Portmore residence from her field studies (Table 3). The similarity in intensities indicates that Portmore is very vulnerable to earthquake, with magnitude of 5 as the possible minimum magnitude that will result in intensities that could cause some damage.

Test Earthquake		Computed Mercalli Intensity			
No.	Magnitude	0.1 - 0.3 second	0.35 - 1.0 second	1.1-2.5 second	
1	7.5 Mb	VII	X	X	Maximum
		IV	VII	VIII	Mean Minimum
2	7.0 Mb	VIII	X	VIII	Maximum
		IV	VII	VI	Mean Minimum
3	6.0 Mb	IX	IX	VIII	Maximum
		IV	VII	VI	Mean Minimum
		1 - 3 storeys	3 - 10 storeys	High-rise buildings	

Table 2 Estimates of the Maximum and minimum Mercalli Intensities expected on the Liguanea – St. Catherine Plain, Jamaica

Source: Shepherd, 1977

Damage caused by Earthquake of January, 1993

N=348

Damage	Frequency
Cracks to walls, floors, roofs	176
Cracks to concrete fences, driveway	3
Damage to fittings, plumbing, and broken windows	4
Other damage	4
Don't know	1
No damage to building	160
Loss or damage of appliances, furniture, electronic equipment	6
Loss of ornaments, clocks, dishes	53
No damage to contents	289

'Other damage' included a wooden house in Naggo Head which had shifted off the large limestone boulders on which it stood. It had simply been pushed back into place.

TABLE 3: Damage Caused from Earthquake of January, 1993 Source: Phillip-Jordon, 1995

Pereira (1979) indicated that Kingston Metropolitan area, including Portmore historically experienced 8-15 events of intensity of IV or greater per century (Figure 8). The large number of events of intensity IV or greater may be due to the amplification of seismic waves by the alluvium deposits on which the Kingston Metropolitan Area and Portmore are situated, and the close proximity to the Blue Mountain\Wagwater Fault system.

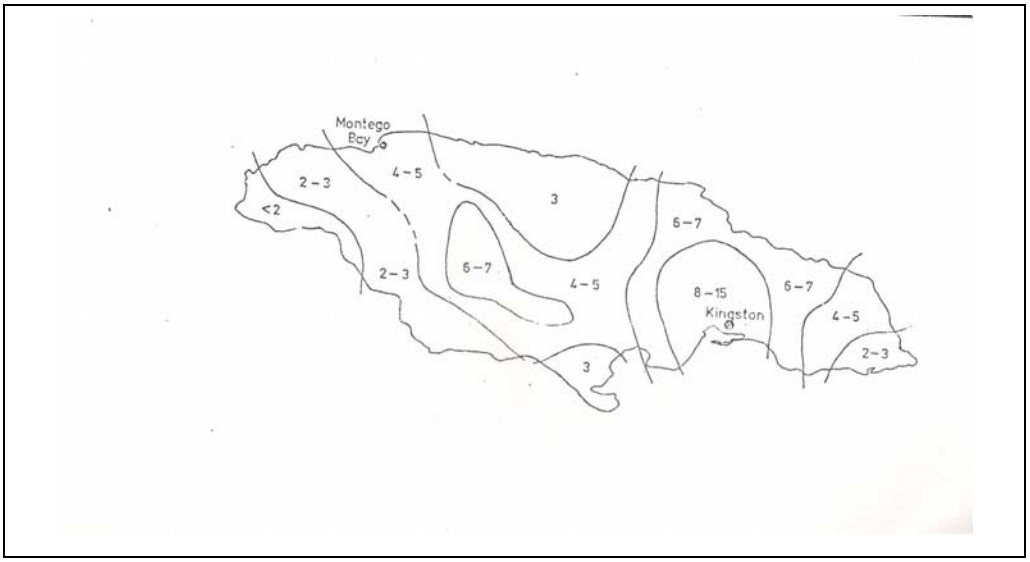
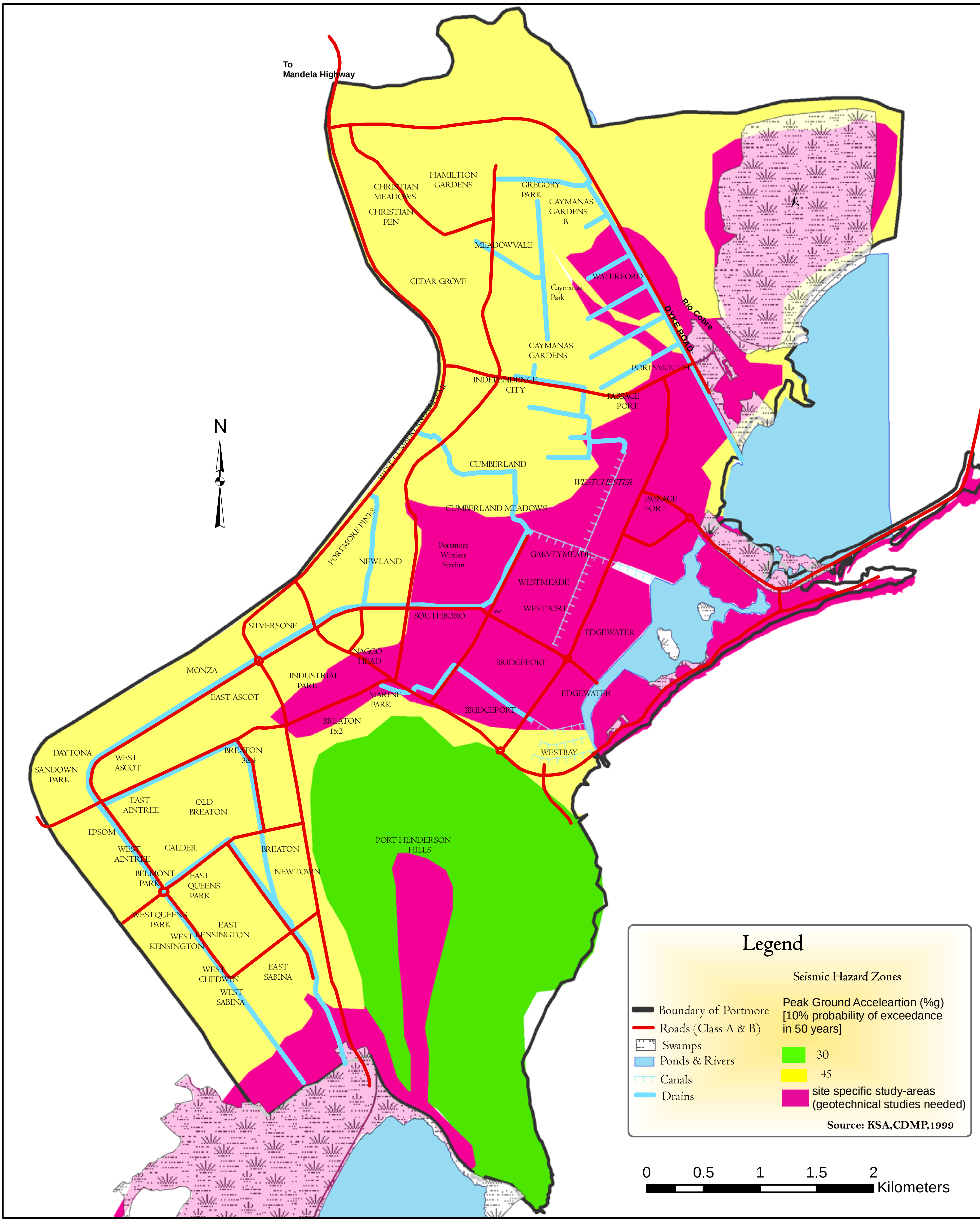


FIGURE 8: Number of events of Intensity VI or greater per century as determined for period 1879-1978.

Shepherd (1971) indicated that structures, 1- 3 storeys high, situated on the Liguanea Plain are affected significantly by earthquakes of magnitude 6 and over. The typical number of storeys of the building located in the Portmore region is 1-3 storey. Assuming that these 1-3 storey structures have shallow foundation rather than deep foundation, since it is more economical to have shallow foundation, these small structures will sustain extensive damage due to differential settling, especially in the Dawkins Pond and Great Salt Pond areas which are of reclaimed land. Liquefaction is stated to have occurred in the Great Salt Pond and Dawkins Pond areas (Shepherd, 1971) which means that it may occur again if the conditions are favorable.

Portmore residents, however, have not experienced or there is less evidence of damage from earthquake as in Kingston. It is clear that in some areas especially on reclaimed land that Portmore has similar seismic hazard conditions as that which is present in Kingston. The similar conditions were brought out in the Kingston Metropolitan Area (KMA) Seismic Hazard Assessment study which assessed the seismic hazard level for Kingston Metropolitan Area with the inclusion of Portmore (Figure 9).

FIGURE 9: Seismic Hazard Zones of Portmore



3.1.7 Interpretation of the Seismic Hazard Map

The seismic hazard map for Portmore has been adopted from the KMA Seismic Hazard Assessment Project. The seismic map divides Portmore into three zones that are based on ground acceleration. These zones are as follows:

- **ZONE OF GROUND ACCELERATION (% g) of 30**:- this represents seismic wave propagation in hard rock such as most of Port Henderson

- **ZONE OF GROUND ACCELERATION (%G) OF 45:-** this represent seismic wave propagation in alluvium deposits. The alluvium has higher ground acceleration than hard rocks since it is an amplifier of seismic wave that may have originated in the hard brittle rocks of the Blue Mountain region (see Post Woodford era for discussion on this phenomena).

- **ZONE OF SITE SPECIFIC ASSESSMENT: -** this zone corresponds with the area of reclaimed land, mangrove/salina and liquefaction. Areas of this zones may experience differential settling as material is water laden and not hard, compacted rocks.

The seismic hazard map of Portmore indicates that only about 10 percent of the area of Portmore has ground acceleration due to seismic activity at 30 % of gravity or less, while, 60 percentage of Portmore has ground acceleration due to seismic activity of 45 % of gravity, the remaining 30 % will require site specific assessment. Note that acceleration due to gravity is 9.8 ms^{-2}. This therefore suggests that Port Henderson Hills are less likely to sustain damage from an earthquake than east and northeast Portmore which is more at risk.

3.2 STORM SURGE HAZARD ASSESSMENT

3.2.1 Definition of Storm Surge

Storm surge is described as the rise in water level above normal of a body of water (lake or sea) which is associated with the passage of a low pressure system such as a hurricane which moves along or across a coast region (NOAA). As a depression passes over the sea, the water is subject to lower atmospheric pressure than its surroundings, causing the water level to rise and the surrounding water to fall (Figure 10); a fall in pressure of 1mbar will produce an increase in height of almost 1cm. Such rise in the sea surface can be compounded by high winds, setting up very long wave motion. This sea level rise can consist of three components, the first of which results from low barometric pressure, i.e. the so-called inverse barometer effect. The second component is wind set-up. The third component of the rise is due to coupled long waves where the peak of the wave coincides with the shoreline" called wave setup.

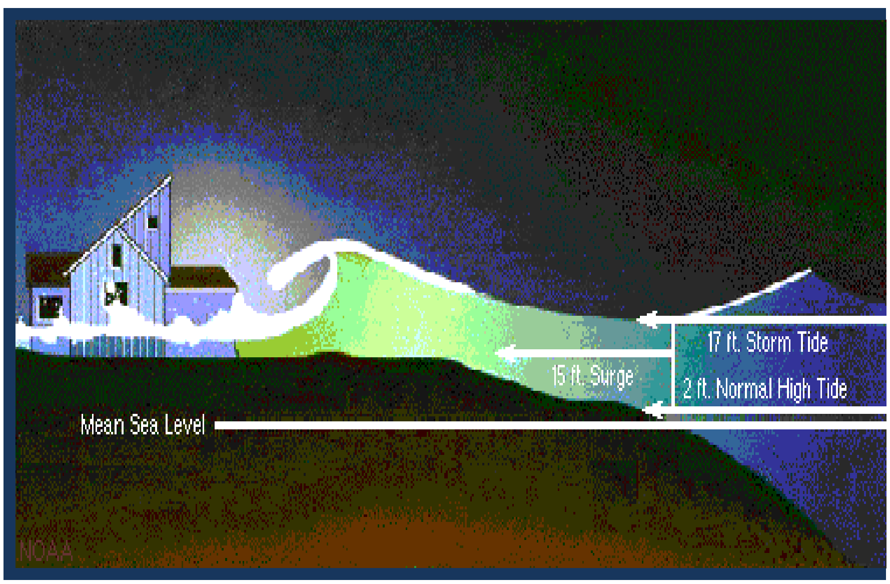


FIGURE 10: Schematic Diagram of a Storm Surge Source: NOAA

3.2.2 The Development of Storm Surge

Storm Surge is generated by a hurricane. The development of a storm surge is intertwined with the category of a hurricane and the velocity (forward speed and direction of a hurricane) of a hurricane along or across a coastal zone. The category and velocity of a hurricane are the two dynamic factors that influences storm surge while the other factors are static.

3.2.3 Factors that Influence the Height and Strength of a Storm Surge

There are several factors that will influence the size and strength of a storm surge. These factors include:

1. **THE INTENSITY OF THE HURRICANE**: The greater the wind speed, the higher the sea water will rise and waves that are associated with the surge will be taller (table 4)
2. **THE FORWARD SPEED OF THE HURRICANE:** The faster the hurricane moves across or near the coast, the quicker the surge will develop and the more powerful it will strike.
3. **THE ANGLE WHICH THE HURRICANE CROSSES THE COAST:** Generally, the more 'head-on' the angle of the hurricane movement the greater the surge. Other angles may lead to localized zones of enhancement of the surge.
4. **THE BATHYMETRY OF THE SEA FLOOR:** A shallow slope of the sea floor will allow greater surge to be built-up while a steep slope or if fringe reefs are present will not see as much surge inundation.
5. **LOCAL TOPOGRAPHY:** - bays, headlands and offshore islands may funnel and amplify the storm surge.

Category	Winds	Surge	Central Pressure
1 - Minimal	74 - 95 mph or 64 – 83 kts	4 - 5 feet	greater than 980 mb or 28.94 in
2 - Moderate	96 - 110 mph or 65 – 96 kts	6 - 8 feet	965 - 979 mb or 28.50 - 28.91 in
3 - Extensive	111 - 130 mph or 97 - 113 kts	9 - 12 feet	945 - 964 mb or 27.91 - 28.47 in
4 - Extreme	131 - 155 mph or 114 - 135 kts	13 - 18 feet	920 - 944 mb or 27.17 - 27.88 in
5 - Catastrophic	greater than 155 mph or 135 kts	greater than 18 feet	less than 920 mb or 27.17 in

TABLE 4: The effect of Hurricane intensity on the size of the surges generated. *Source: weather.com*

3.2.4 Storm Surge Analysis of Portmore

The municipality of Portmore has experienced numerous storm surges of various sizes. Three storm surge events that had been generated by the Hurricane of 1722, Hurricane Ivan, (2004) and Hurricane Dean, (2007) were examined.

Analysis of recent storm surges in Portmore was accomplished by mapping the areas that were affected by surges and measuring the distance of the run–up of the waves produced by a hurricane or tropical storm. For this project, waves generated by Hurricane Ivan and Dean were determined using ground truthing techniques. Ground-truthing techniques generally fall into two categories, observational and sampling techniques. In this case the observational technique was employed. This involved measuring the height of water marks left on buildings, extent of sand deposit and observing the destruction of buildings and moved objects such as vehicles, periphery walls and debris.

3.2.5. Storm Surge Mapping

3.2.5.1 Hurricane of 1722

The earliest recorded storm surge of significant magnitude was generated by a hurricane of category 4-5 in 1722. This hurricane had approached from the southeastern direction (Phillip-Jordon, 1995) and generated a storm surge of 5.49m in height at Port Royal and killed about 400 individuals (Atkins, 1735). The community of Queenstowne, which was situated at the present location of Passage Fort, was completely destroyed by the storm surge (see Figure 11).

The hurricane may have passed very close or across the island to have produced a run-up of this magnitude since similar hurricanes namely Hurricane Ivan and Dean have not generated a run up of that magnitude. Although Queenstowne was protected by the mangroves and other coastal barriers, these were not adequate to dampen the effects of this hurricane. Had the hurricane of 1722 traveled along a path similar to Hurricane Ivan and Dean, a similar run-up would have been generated as the 1722 hurricane especially with the removal or destruction of the mangroves resulting from to the urbanization of Portmore.

3.2.5.2 Hurricane Ivan

Hurricane Ivan had passed south of Jamaica with winds of a strong Category Four hurricane generated storm surge with height of 3.3m at Hellshire beach and 4m at Port Henderson-Fort Augusta, both in Portmore. The run-up of the surges for Hellshire and Port Henderson-Fort Augusta were 80m and 90m respectively. (See Plate 1, 2 and 3.)

Storm Surge in Portmore and Hellshire

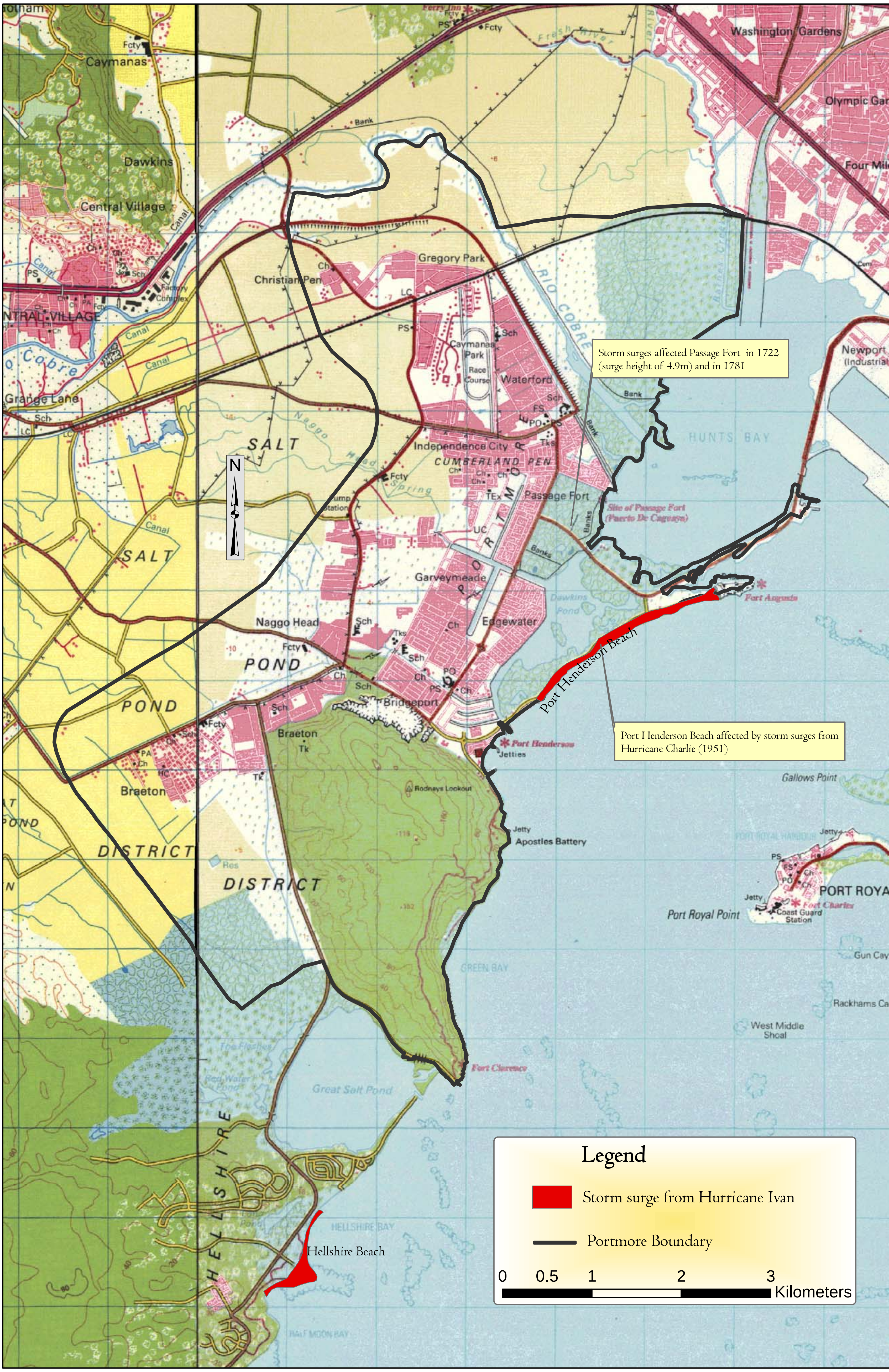


FIGURE 11: MAP SHOWING RUN – UP DISTANCE OF STORM SURGES PRODUCED BY HURRICANE IVAN

Sand deposited
by storm surge

Plate 1 Sand deposits extending to boundary fence of Port Henderson Beach, indicating run-up distance of approximately 90m. Hurricane Ivan

Plate 2 Sand covering entire width of road that leads to the Fort Augustus prison. The arrow indicates the run-up distance of approximately 90m.

Plate 3 Destruction of wooden structures at (built approximately 30 – 40m from the shore) along the Hellshire beach.

3.2.5.3. Hurricane Dean

Hurricane Dean came in close proximity to Jamaica on August 19, 2007, with the eye of the hurricane passing 80 kilometres south of Kingston. It was characterized as a strong Category Four Hurricane (Saffir-Simpson Scale) with wind speeds averaging 225 kilometres per hour and inverse barometre pressure of approximately 920 millibars. Following a path similar to that of Hurricane Ivan, it generated storm surges that affected the southern coast.

3.2.5.3.1 Hurricane Dean Storm Surge Impacts

The storm surge run-up distance, for the area of the Fort Augustus Prison was 90 m to 101 m as shown in Plate 4.

Plate 4. Impacts of storm surge activity on Fort Augustus Prison Showing the walls of the prison inundated by water from storm surge. *Source: MGD, 2007*

The run-up distance along Port Henderson road was approximately 54m (MGD, 2007), while along Rodney's Arm and Forum Beach areas the run-up distance, estimated from sand and debris deposits on land in addition to the location of the boats was measured as 250m. (see plate 5).

Along the shoreline however, a number of wooden buildings that served as homes or stalls for the fishing village were completely destroyed (Plate 6). Waves also brought a ferry boat from the Kingston Harbour unto the shore along the beach. (see Plate 7 (MGD, 2007).

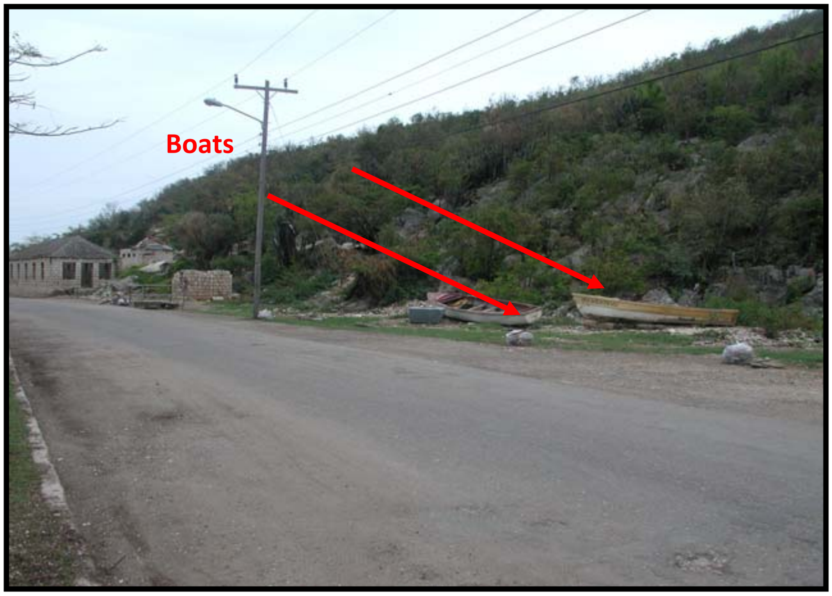


Plate 5. Impacts of storm surge activity on the Rodney's Arm area. Boats brought by waves from coastal area to land *Source: MGD, 2007*

Plate 6. Impacts of storm surge activity on Forum Beach.
A. Wooden shacks of fishing village destroyed. B. Ferry carried from Kingston Harbour unto beach area behind Forum Hotel. Source*: Marine Geology Unit, University of the West Indies, Mona*

For the Hellshire beach the total run-up distance measured in the eastern section is approximately 383 metres, MGD, 2007

The storm surge generated by Hurricane Dean resulted in damage and destruction to many of the coastal area in the Portmore Municipality with a few effects highlighted above. The surge height for the most part was not well preserved, however the damage (see plate 7) and the approximate run-up were ascertained from assessment carried out by Mines and Geology Division.

Plate 7. Impacts of storm surge activity on Hellshire Beach.
A. Concrete structure of fishing village destroyed Wall destroyed by waves. B. Wooden shacks of fishing village destroyed

3.2.5.4 Interpretation of Storm Surge Map

The Storm Surge Map for Hurricane Ivan (figure 11) highlights areas of the Portmore Municipality that was affected, in particular:

PORT HENDERSON AREA: - Fort Augustus Prison and buildings located along the Port Henderson Road suffered effects of coastal flooding from storm surges of maximum height of 4m and total distance covered (maximum run-up) by the surge about 90m (See plate 1- 3). Most of the well constructed (concrete and blocks as building materials) residential and commercial buildings were moderately damaged. Flooding and the deposition of sand and debris were as a result of the surge. Water storage facilities were also affected by storm waters. Wooden constructed structures were most severely affected, along with sea walls, boundary walls, retaining walls, electricity poles and a few fishing boats (See Appendix). The damage was estimated at $13,325,000 {US$190,357 (MGD, 2004)}.

HELLSHIRE BEACH AREA: - this area experienced storm surge with height 3.3m with a maximum run up distance of 80m. Fishing stalls (both wooden and concrete) as well as retaining walls and groins sustained severe damages or were totally destroyed. Damage was estimated at $2,072,000 {US$29,600 (MGD, 2004)}.

3.3 FLOOD HAZARD ASSESSMENT

3.3.1. Definition of Flood

A flood is a natural phenomenon in which areas of land that are normally dry have experienced temporary inundation due to excessive rainfall or wave action. There are several different types of floods; these include riverine, flash, urban, and coastal flooding.

Types of flooding:

- **Riverine Flooding:** This type of flooding is normally caused by prolonged rainfall from events such as hurricane and stationary wave. The prolonged period of rainfall results in overflowing of the river banks and water flows in areas outside of the river channel. Some floods develop slowly, sometimes over a period of days.

- **Flash Flood:** This type of flooding develops quickly, sometimes in just a few minutes and without any visible signs of rain. Flash floods often have a dangerous wall of roaring water that carries rocks, mud, and other debris and can sweep away objects in its path., such as when a levee is breached.

- **Urban Flooding:** this type of flooding is as a result of the paved streets which promote surface runoff since the asphalt is generally impermeable. The drainage systems are also incapable of carrying the volume of run-off that is associated with the period of heavy rainfall.

- **Coastal Flooding:** are caused by winds generated from tropical storms and hurricanes that can drive sea water inland and cause significant flooding.

3.3.2. History of Flooding in Portmore

Portmore Municipality is located on a coastal flood plain that has a history of riverine, urban and coastal flooding (see Table 5). Coastal flooding is usually a result of storm surges and was included in the previous section. This section examines both riverine and urban flooding. The flooding in Portmore can be divided into pre-dyke and post-dyke periods.

Pre-Dyke Period

The pre-dyke period is dominated by riverine flooding. This flooding is due to the overflowing of the Rio Cobre onto its flood plain on which the Portmore Municipality is situated.

Post-Dyke Period

The Rio Cobre when in spate would (before the construction of the Dyke) overflow onto its flood plain. Without the construction of the dyke, flooding would be a costly hazard, if Portmore was to be developed. Reduction of this hazard was very critical in the development of Portmore, thus the Rio Cobre dyke was constructed to prevent riverine flooding onto the urbanizing Portmore. The post-dyke period is dominated by urban flooding (Fig. 15). The urban flooding that occurs at present in Portmore is a result of inadequate drainage system (plate 8 and 9), poor maintenance of these drains, (plate 10) and back-flows into the drains.

Table 5: History of Flood Incidences in Portmore

Type of Flooding	Year/ Month/Day	Area Flooded	Cause	Damage	Source of Data and Storm System
Riverine	1933/8	Passage Fort	Over bank flooding of Rio Cobre		Phillip-Jordon M.phil Thesis
	1933/10	Passage Fort			
	1963	Gregory Park	Over bank flooding of Rio Cobre	Damage to roads and culvert in Gregory Park (?400 in cost)	
	1969/5	Gregory Park	Over bank flooding of Rio Cobre	Old railway bridge wash away	
Urban	1978/3	Causeway	Low level of the Causeway		
	1979	Braeton, Westport	Inadequate drainage system resulting in the back up of sewage		
	1979	New Braeton	Hurricane Frederic	Road damage	
	1986	Caymanas Gardens, Braeton, Portsmouth, Independence City, Westchester, Passage Fort	Poor drainage network		
		Causeway		Road surface damages	
	1993/ 2	Caymanas Gardens, Independence city			
	1993/5	Passage drive in Passage Fort Independence city, Westchester	Inadequate and block drains		

	1993/5	Southborough	Southborough drains have their capacities overwhelm (draining Southborough and Naggo head)		
		Gregory Park	Block drains and roads acting as drains		
		Waterford, Naggo Head, Newland	Inadequate drains		
		Bridgeport: Kent Avenue	Bridgeview scheme development had altered underground drainage system		
		Westmeade	Streets acting as drains		
	1993/ 11/23	Waterford, Braeton	Block drains		Gleaner Archive
	1997/6/5	Bridgeport, Gregory Park, Waterford, Caymanas Gardens, Portsmouth, Germaine Road (Naggo Head)	Block drains and gullies		
	1998/4/27	Waterford, Bridgeport, Garveymeade, Coronada (Gregory Park)			
	1998/9/13-14	Waterford, Passagefort drive	Canal flood		
		Gregory Park, Watson Grove, Caymanas Gardens	Block drains		
	1999/9/20-25	West Sabina, Marlin Avenue (Braeton)	Block drains		
	2001/10	Caymanas Gardens (Site D)			ODPEM
	2001/11	Caymanas Gardens, Bridgeport, Hamilton Gardens, Gregory Park, Greater Portmore, Waterford, Independence City, Westchester	Block drains		Gleaner website Hurricane Michelle

	2002/9	West Chedwin, Old Braeton (Hellshire Drive), Silverstone, East Sabina, Waterford (Caberet Way ,Souvenier Way,Fray Close, Craig Way), Braeton Phase 1, Garveymeade (Canal Drive), Naggo Head, Bridgeport (Anderson Avenue)	Block drains		ODPEM Tropical Storm Lili
	2003/5	Garveymeade, West Sabina, East Sabina, Braeton Phase 1 (Dolphin Way, 16Marlin Way, 508 Marlene Avenue), Old Breaton			Portmore Website, ODPEM
	2004/3	Passage Fort (Panny Way Lane), Braeton Phase 1			ODPEM
	2004/9	Westmeade, Bridgeport (Savoy Avenue, Ventura Road)		Flooded roads	ODPEM Hurricane Ivan
	2005/7/10	Braeton, Newtown			
	2005/10	Edgewater, Bridgeport, Waterford, Christian Gardens, Braeton, Old Braeton, Portmore Gardens, Passage Fort, Garveymeade, Portsmouth, 2 North, 2 East, 2West, Westchester, 6 West	Block drains in most cases by garbage, in 2 east vegetation overgrowth in drains due to sewage from nearby treatment plant		ODPEM Hurricane Wilma
	2005/7/7	Bridgeport, Waterford, Silverstone, Greater Portmore, West Cumberland Waterford, Bridgeport, Keystone, Southboro, 2 East, Braeton Phase 1, Portsmouth, Gregory Park (Cedar Manor), Passage Fort (Halland Drive), 8 West (Greater Portmore), Braeton Newtown (Walkway Tree)	Canal Between Portsmouth and Dike Road overflows it banks, Inadequate drainage (Breaton Phase 1), blocked drains	Dike road	ODPEM, PMC Hurricane Dennis

3.3.3. Flood Hazard Mapping

The analysis of the historical flood data for Portmore is very critical in the generation of the flood hazard map. The flood data from the pre-dyke or riverine period was not used in the generation of the flood hazard map, as Portmore's susceptibility to riverine flooding is low, due to the efficiency of the dyke. Flood flow analysis indicates that the Rio Cobre River is contained within the dyke with a return period of 1 in 100 years (Rio Cobre Flood Plain Mapping Project: Water Resources Authority).

The flood hazard map was generated by using the historical data from the post-dyke or urban flooding period along with field research. The flood data gathered was used to create the flood hazard map (see figure13).

3.3.3.1. The Rational for Flood Hazard Map using Urban Flooding

The historical flood data presented indicates that the main type of flooding that Portmore experiences since the creation of the Rio Cobre Dyke in the late 1960s, is urban flooding, thus, the creation of flood hazard map for urban flooding was undertaken. Discussion with the Water Resources Authority (WRA) gave us insight on several methods for flood mapping, and along with literature review, the following method were looked at:

- Rainfall Intensity Duration Curve Method
- Rational Method
- Hec-2 Model commonly used in riverine flooding
- Using anecdotal evidence through interviews and field observation along with historical location of flooding

The above methods were carefully examined in order to ascertain which method may best be used in urban flood mapping. As stated above, flooding in Portmore (post-Portmore Dyke

Construction) appears to be the result of undersized drains, blocked drains and intrusion of flood water into drains because of high water table as well as back flows into the drainage system caused by wastewater overflows; however, individual models presented were not flexible to deal with the varying causes of flood hazards. The models either dealt with the sizing of drains to accommodate expected run-off levels in drains, or with anticipated levels of flooding assuming unhindered flows from a riverine system. Therefore, the decision was taken to use anecdotal evidence by conducting detailed interviews with Portmore Municipality, Local Parish Councillors, Presidents of Citizens Associations and long-standing members of communities as well as collecting field evidence of flooding where these can be identified. The data obtained from the Portmore citizens and field mapping were used along with historical flood data to provide the base data for the creation of the urban flood map. This base data was grouped into different zones by the Geostatistical Analyst Extension of ArcGIS, thus creating the urban flood map base on historical flood data.

3.3.4 Results of Flood Mapping In Portmore

3.3.4.1 Waterford Division

The Waterford Division is divided into nine blocks. The blocks are separated by lateral drains that drain into the Waterford canal/storm drain. Within each block there are numerous covered drains which are connected to the lateral drains. The lateral drains are open paved drains that normally contain several centimeters of stagnant water. During periods of high rainfall, the Waterford canal has large volumes of water flowing through it, resulting in the lateral drains experiencing backflow during these periods. This backflow is due to the volume of water flowing through the Waterford canal that serves the Waterford and Gregory Park Divisions.

The gentle gradient of the Portmore plains exacerbates the backflow problem as storm water cannot flow through the canal at any substantial rate to reduce the backflow. The Portsmouth segment of the Waterford canal is unpaved and poorly maintained. The presence of plants and weeds (vegetation overgrowth) within the canal has significantly reduced the rate of the storm water flow leading to flooding in the area. This segment of the Waterford canal was reported to be an area that has caused flooding of the adjoining communities in the 1990s.

Most houses along the lateral drains are located approximately two to three metres from the lateral drain walls while a few are located a few centimetres from the wall of the lateral drains. Houses in blocks 3, 4, 5 and 7 (especially those close to the drain) flood frequently. The Waterford canal is poorly maintained with overgrowth of trees along the bank that has the potential to undermine the walls of the canal.

3.3.4.2 Westchester Community

The canal that drains Westchester area is poorly maintained. Garbage has been dumped into the canal, significantly reducing the surface area for the drainage of the canal, thus causes a rise in the water level, therefore increasing the risk of flooding within the surrounding areas. The water in the upper section of the canal is stagnant which makes it a health hazard as it allows the development of organisms that are harmful to citizens.

3.3.4.3 East & West Sabina Community

The canal that runs through Sabina divides the community into East and West Sabina. The canal for the most part is an earth drain and is poorly maintained. This canal drains all of Greater Portmore. West Sabina has experienced more flooding episodes than East Sabina and this may be due to the presence of a second canal to the eastern part of East Sabina which facilitates in the removal of storm water. During periods of heavy rainfall, both the canal and the nearby waste water sewage treatment ponds are overwhelmed. The volume of water coupled with the low gradient of the area results in the backflow of both sewage and drainage. Flood waters occasionally enter the residents’ homes and may attain up to 1m in height. The poor maintenance of the canal has led to an increase in the likelihood of flooding in the general area.

The swales (small earth drain) are used as areas for parking and gardens by some of residents. The use of swales for gardening and parking area has changed its dimension of the (width of 1 m by depth of 0.6 m) and so its function is reduced.

A number of schools used as shelter during disasters are located in Sabina and are inappropriate for that purpose since the schools are flooded frequently and are located in close proximity to the canal.

3.3.4.4 Gregory Park Division

The drainage network within the Caymanas Garden D (Gregory Park Division) is inadequate as shown in Plate 8 where the section of the drain that cut across the road results in flooding of the main access point for this community. The drain at this point cannot handle the volume of run-off that flow through this drain.

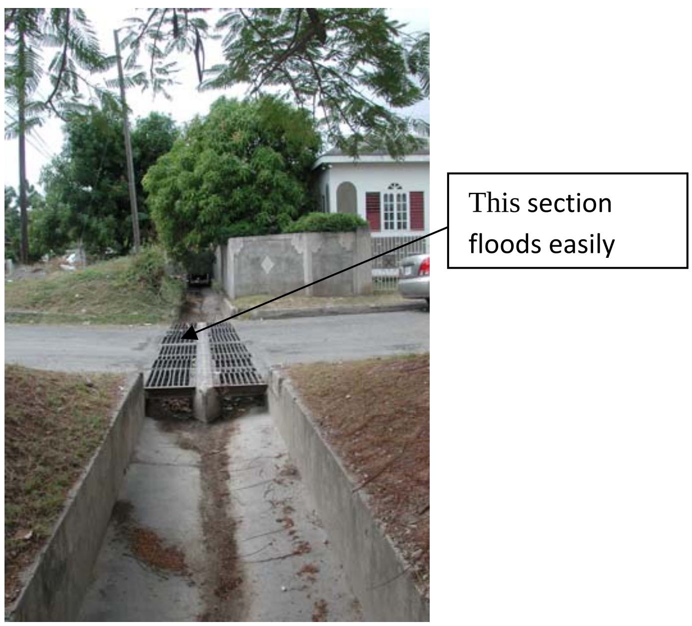


Plate 8: Showing a section of the drain that floods whenever there is significant rainfall

The Caymanas Garden D drains are poorly maintained (Plate 9) which increase the potential for flooding within this area. Some of the residents have modified their homes to reduce the possibility of flood water getting into their homes as shown in Plate 10.

Plate 9: Showing poor maintenance of drains with in Caymanas Gardens D Scale: 175 cm

Plate 10: House near the drains in Caymanas Gardens D

The Drains along Gregory Park Main Road is poorly maintained (Plate 11a &b), also the surface of the road is raised higher than surrounding homes along the road which results in surface run-off from the road flooding the surrounding homes and businesses along the road. The Gregory Park Main Road which flood easily is the main exit route for the communities of Christian Meadows and Gregory Park. This poses a problem when evacuation becomes necessary.

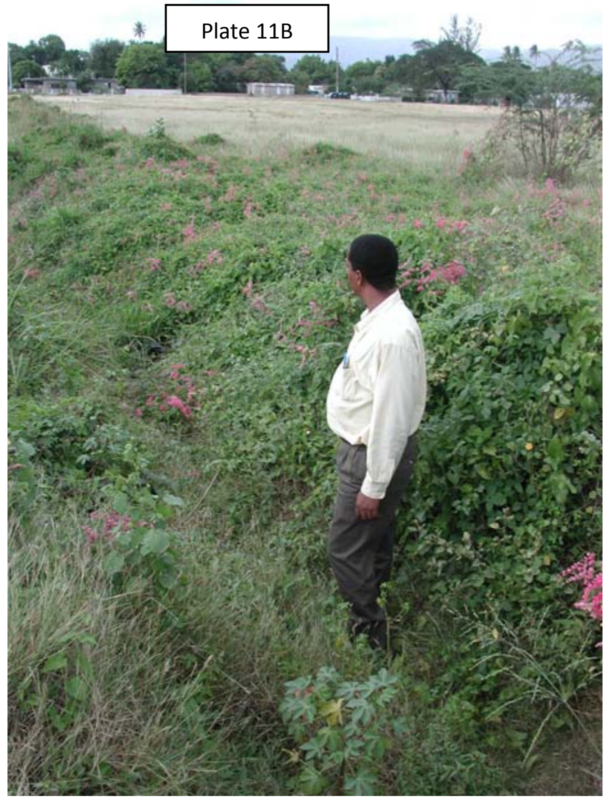


Plate 11 A& B: Showing poorly maintained drains along Gregory Park Main Road

3.3.4.5 Garveymeade Community

The drains within this community are covered, however, if the drains are not properly maintained, flooding will occur since the area has a high surface runoff (Plate 12).

Plate 12: Flood Rains May 24, 2003 in Garveymeade Source: Portmore Website, 2006.

3.3.4.6 Washington Mews

This community is a linear settlement with one access road, which runs adjacent to an unpaved storm water gully. The gully has been poorly maintained and whenever there is substantial amount of rainfall the community experiences flooding.

3.3.4.7 Epsom

Epsom is located within the Greater Portmore region with its characteristic network of swales and drains. The swales may be seen as first order streams that transport storm water into the larger drains. The swales in their design may be deemed by community members as unimportant and so in some areas the dimensions of the swales are changed to facilitate expansion of boundaries and gardens. The dimension changes and the poor maintenance of the swales and drains have increased the possibility of flooding in this community

3.3.4.8 Naggo Head Division

Several communities within the Naggo Head Division have experienced flooding. The main causes for flooding in this area are poorly maintained drains and inadequate sizing of drains. The areas that experience flooding are West Cumberland, Southboro, Portmore Lane, Naggo Head and roads such as Marinda Way, Germain Road and Veneto Way

3.3.4.9 Christian Gardens

Flooding occurs in Christian Gardens whenever there is substantial amount of rainfall because the drains are inadequately sized (Plate13)

PLATE 13: The Flooding Potential of Christian Gardens. This shows the amount of water settling and rising after thirty minutes of rainfall. The dimension of the drains is 0.61 m in depth by width of 1.2 m. There is a high potential for flooding with Christian Gardens

3.3.5 FLOOD HAZARD MAP

3.3.5.1 Methodology for Creation of Flood Map

The creation of the flood hazard map for Portmore was undertaken in three phases:

1. **Phase One: Data Collection and Corrections**
   - Urban flood data for Portmore was collected from various sources such as interviews, literature review and placed into the flood database.
   - The flood data was checked for errors and necessary corrections were made.
2. **Phase Two: Generation of Flood Hazard Map**
   - Flood incidences were grouped into zones based on the communities within Portmore.
   - By using Geostatistical Analyst Extension of ArcGIS the flood zones for Portmore were created.
3. **Phase Three: Correction and Modification of the Flood zones**
   - The Geostatistical Analyst generates zones based on the number of points and the nearest points (flood incidence in this case), after which correction of flood zones was done based on acquired field experience.
   - Due to the shape of Portmore and the limited flood incidence in some of the communities, modification of the generated image was undertaken to include all of the communities based on field knowledge.

3.3.6. Flood Map Analysis

The flood hazard zonation map was generated by using data obtained from historical flood events and field survey. The flood map is shown below (Figure 12).

Flood Hazard of Portmore

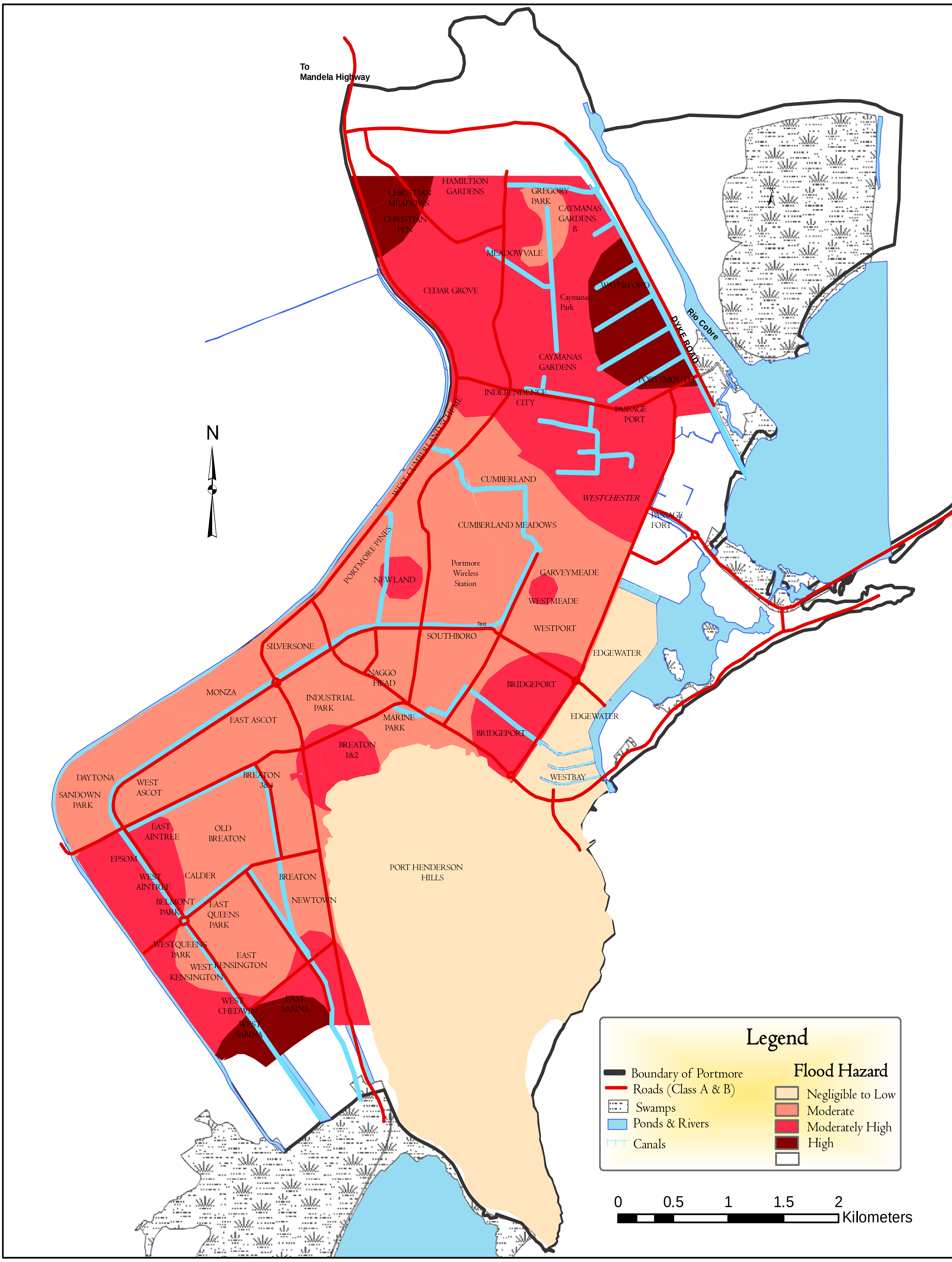


FIGURE 12: Flood Hazard potential of communities in Portmore

3.3.6.1. Flood Hazard Map

The flood map was generated after an analysis of flood hazard in the study area, and the application of field survey information. Four categories of flood hazard were established.

- ***AREAS OF VERY HIGH FLOOD HAZARD***: they are located in areas where there are highest incidences of flood based on historical data and field survey. The drainage network is unable to adequately handle the volume of surface runoff. The gradient of the drains and the 'Portmore Plain' exacerbates the flood problem since any overland flow tends to stagnate or drain slowly away.

- ***AREAS OF MODERATELY HIGH FLOOD HAZARD:*** These areas show the second highest level of flood incidences. These areas will flood easily when there is a continual, intermittent to heavy rainfall. As in the case of the very high flood potential storm-water infrastructure is unable to handle the volume of run – off.

- ***AREAS OF MEDIUM FLOOD HAZARD:*** locations show low flood incidences and will flood when there is extended period of rainfall or a strong storm system to cause flood

- ***AREAS OF VERY-LOW TO NEGLIGIBLE FLOOD HAZARD****:* Low-lying areas that have lowest flood incidences (probable good drainage system) and hilly areas where flooding is minimal to negligible.

CHAPTER 4 – VULNERABILITY ASSESSMENT

4.1. DEFINITION OF VULNERABILITY

Vulnerability is the “susceptibility to degradation or damage from adverse factors or influences” (Regional Vulnerability Assessment of United States Environmental Protection Agency).

Cutter (1993) defines Vulnerability *as the likelihood that an individual or group will be exposed to and adversely affected by a hazard. It is the interaction of the hazards of place (risk and migration) with the social profile of communities.* Barroca et.al indicates that “*Vulnerability is a complex notion defining for each hazard the resulting impacts”* (Barroca et.al, 2006).

4.2. VULNERABILITY ASSESSMENT OF PORTMORE

The concept of vulnerability assessment is an evolving one especially as it is being included more often in hazard assessment as policy makers are becoming more proactive. There are several methods for conducting a vulnerability assessment. The method used in this assessment has been obtained from the NOAA Vulnerability Assessment Tool (VAT) and University of South Carolina ‘Handbook for conducting a GIS-Based Hazard Assessment at the County level’.

4.3. METHODOLOGY

The following activities were conducted in order to carry out vulnerability assessment in Portmore:

1) Hazard identification & analysis
2) Vulnerability analysis which included
    (a) Societal analysis
    (b) Built Environment Analysis
    (c) Critical Facilities Analysis

4.4. VULNERABILITY ASSESSMENT FOR THE HAZARD

4.4.1. Hazard Identification & Analysis

In order to carry a vulnerability assessment, it was first necessary to determine the hazard that Portmore would be vulnerable to. As outlined previously, this analysis included a review of the physical characteristics of Portmore (i.e. topography, geology, and drainage), review of the data on historical hurricanes, storm surges and flooding, anecdotal reports and documentation from community residents and fieldwork to confirm and identify the hazards. The hazards that were identified were flooding, storm surges and earthquakes.

The vulnerability analysis sought to answer 'What' and 'where' are the aspects of Portmore that are exposed to damage and economic loss from the impact of flooding, storm surges and earthquakes, along with the 'How' and 'Why' are these areas vulnerable. These questions were answered by conducting a societal analysis, built environmental analysis and critical facility analysis.

4.4.2 Societal Analysis

There are three main steps in the societal analysis determination: vulnerable group identification; data acquisition; and the calculation of the social vulnerability score.

<u>Step 1: The vulnerability group identification</u>

i. <u>The number of people less than 18 years of age and four and under (young people)</u>

   This is a useful variable as it an indicator of where the dependent population are located especially the four and under group. This population group will need assistance during a hazard event and this group will have less ability to recover quickly after the event (Figures 13 & 14).

ii. Number of people over 65 years of age

This group is similar to the less than 18 group in that this is a dependent population with restricted mobility that will require preferential assistance in the event of an earthquake, flood or storm surge (figure 15).

iii. Number of Females

Research has indicated that there is a correlation between this variable and a lack of resources and influences and when combined with the young people variable can further indicate the most vulnerable areas (Figure 16).

iv. Total Population

The total Population map gives the distribution of the Portmore residents. It may be used, along with the other vulnerable group, to aid in the efficient targeting and evacuation of the residents if the need arises (Figure 17).

Step 2: Data Acquisition

The enumeration boundaries and demographic data used in the societal analysis were obtained from the Statistical Institute of Jamaica (STATIN).

Step 3: Calculation of the Societal Vulnerability Score

By creating a score for vulnerability, it can be represented spatially and analysed using GIS software such as ArcGIS. Those societal vulnerable groups/variable that have been identified will then have their percentage determined by dividing the number for each variable in each enumeration district by the total number of the variable for the entire city and scaled for final vulnerability summation.

The following steps were used to calculate the societal vulnerability score with example of the number of people over 65 years of age

Step 1: Calculate the percentage (X) of the elderly in each enumeration district

X = # of people over 65 (elderly) in Enumeration District

# of people over 65 (elderly) in the City

Step 2: Calculate the elderly score by dividing X by the maximum X since it places all the variables in the same scale

$$\text{Elderly Score} = \frac{\mathbf{X}}{\text{Maximum } \mathbf{X}}$$

The score for each variable is ranked from 0 = lowest and 1 = highest
The calculation for the variables and the societal vulnerability is located in the Appendix

Step 3: Mapping the Societal Vulnerability

1. The societal vulnerability variable score is analyzed using ArcGIS and grouped into four classes then displayed (Figures 13 - 17).

2. The individual societal vulnerability groups' scores are combined by using the ArcGIS map calculator to give an overall societal vulnerable score (Figure 18).

The combination of the individual societal groups to give the spatial distribution of overall societal vulnerability score is necessary, as it gives general as well as specific information of areas that will need to be carefully monitored.

The communities with the highest societal vulnerability scores in Portmore are Gregory Park, Westchester, Newlands and Independence City/Passage Fort. Newland and sections of Gregory Park are comprised of informal settlement

Step 4: Hazard Zones and Societal Vulnerability Intersection

The summation of the social variables to create an overall societal vulnerability score for each enumeration district and combination of the hazard zones will give the vulnerability of the area or vulnerability of places (Cutter et al, 2000) to that hazard (Figures 19 -20)

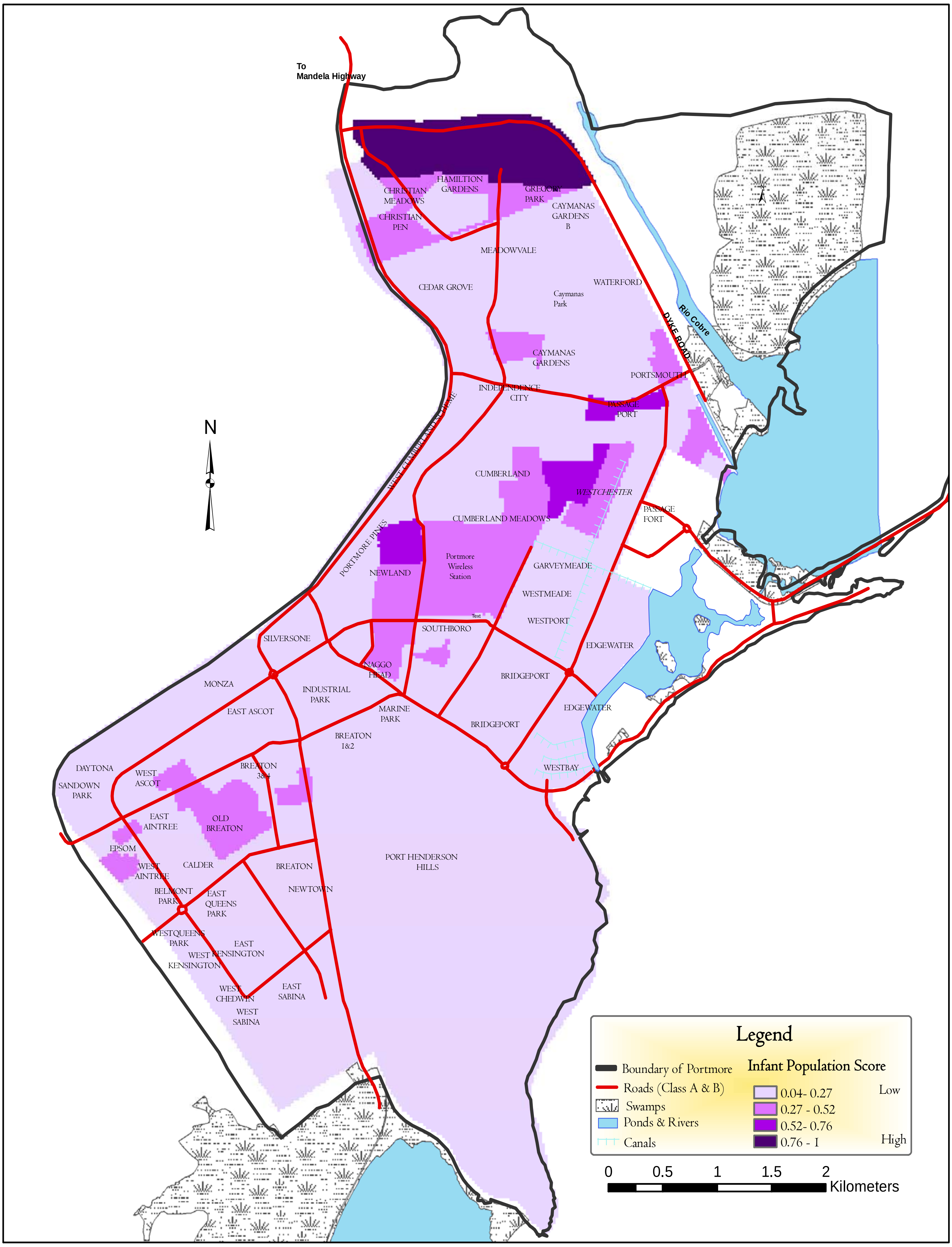
The examination of the vulnerability of places in Portmore to the various hazards using GIS has given a spatial arrangement (Figure 19 - 20) of the vulnerability. This spatial arrangement of the place vulnerability may be used by planners and emergency management groups to adequately plan and implement site specific emergency plan. This will ensure that plans are easy to implement without overlooking some critical elements of the communities.

The most vulnerable places with respect to flood hazard are shown in Figure 19. These are Waterford, Caymanas Gardens, Independence City and Westchester.

The most vulnerable areas with respect to seismic hazard are shown in Figure 20. These are Newlands, Westchester, Cumberland, Gregory Park, Parts of Passage Fort and Independence City, and Caymanas Gardens. With respect to storm surges, Port Henderson is the most vulnerable.

The societal vulnerable groups' maps are compiled together to give the overall societal vulnerable score. It also gives direct spatial distribution of each vulnerable element. This spatial distribution may be used in the evacuation process as it will aid in providing direct visual assistance of the key areas that should be targeted. The maps also indicate areas that may be given lower societal score, although it may have a relatively high score for a specific vulnerable group. Each of the maps indicates that several communities show a high level of the vulnerable groups.

FIGURE 13: Infant Population Score of Portmore



Young Population Score of Portmore

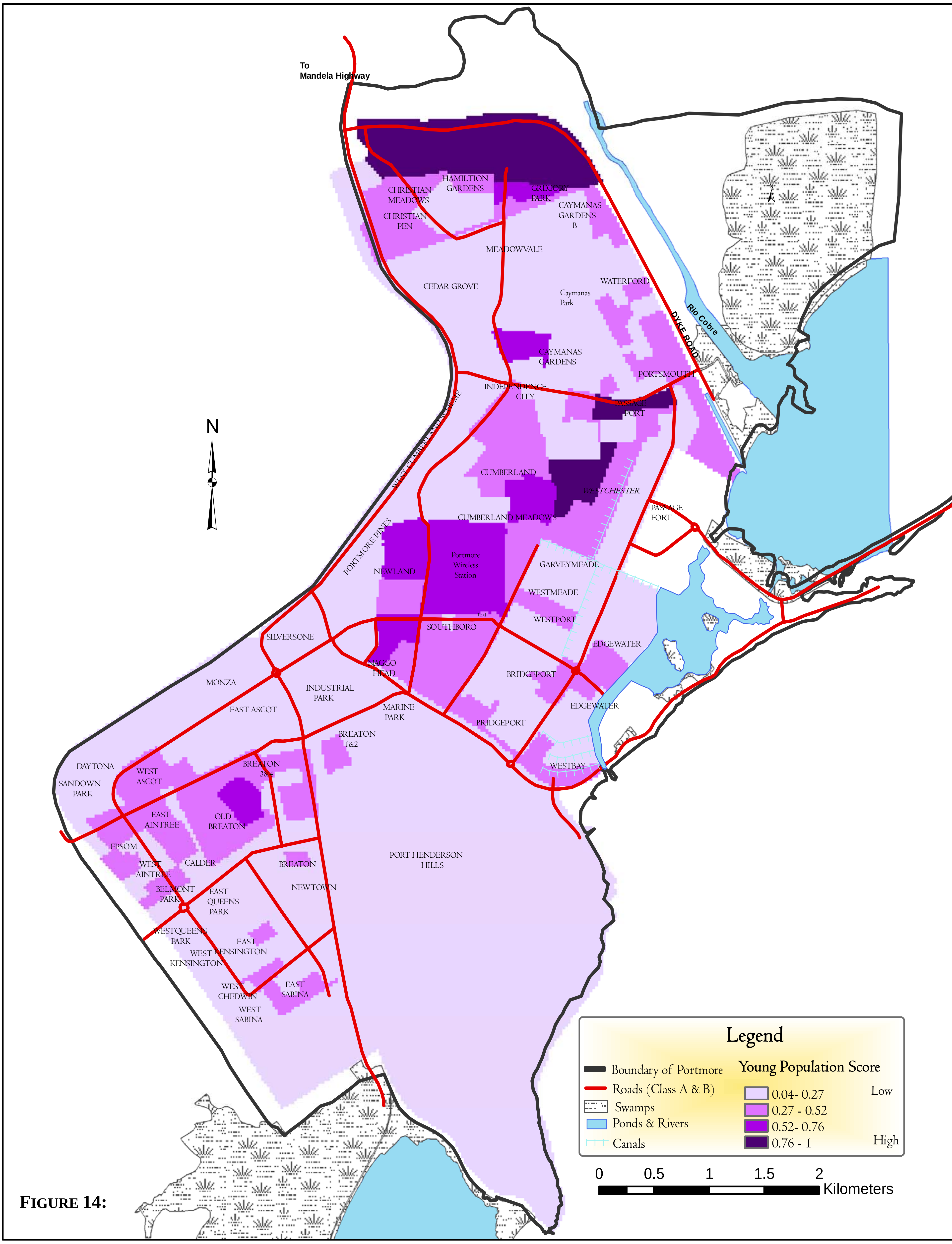


FIGURE 14:

Elderly Population Score of Portmore

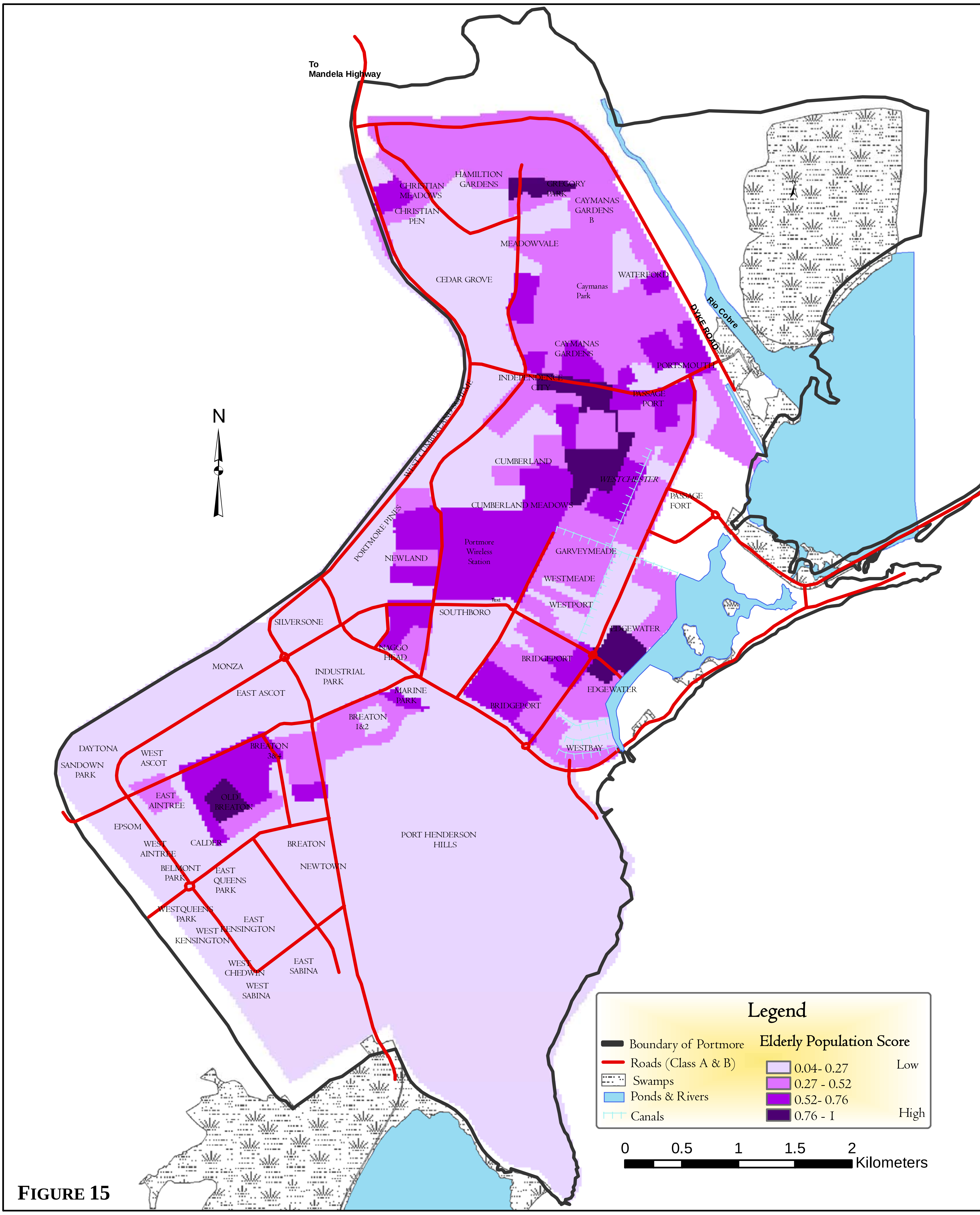


FIGURE 15

Female Population Score of Portmore

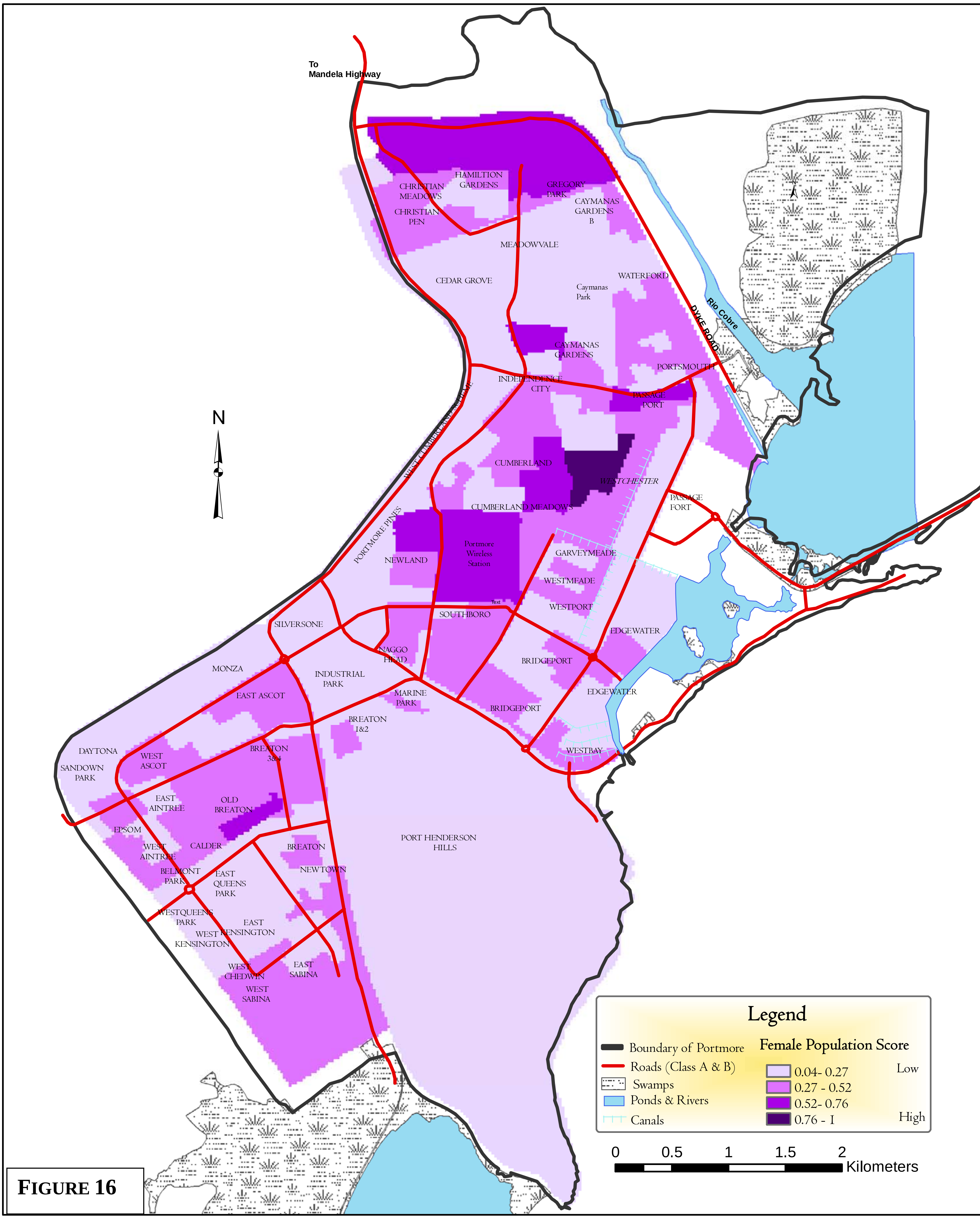


FIGURE 16

Total Population Score of Portmore

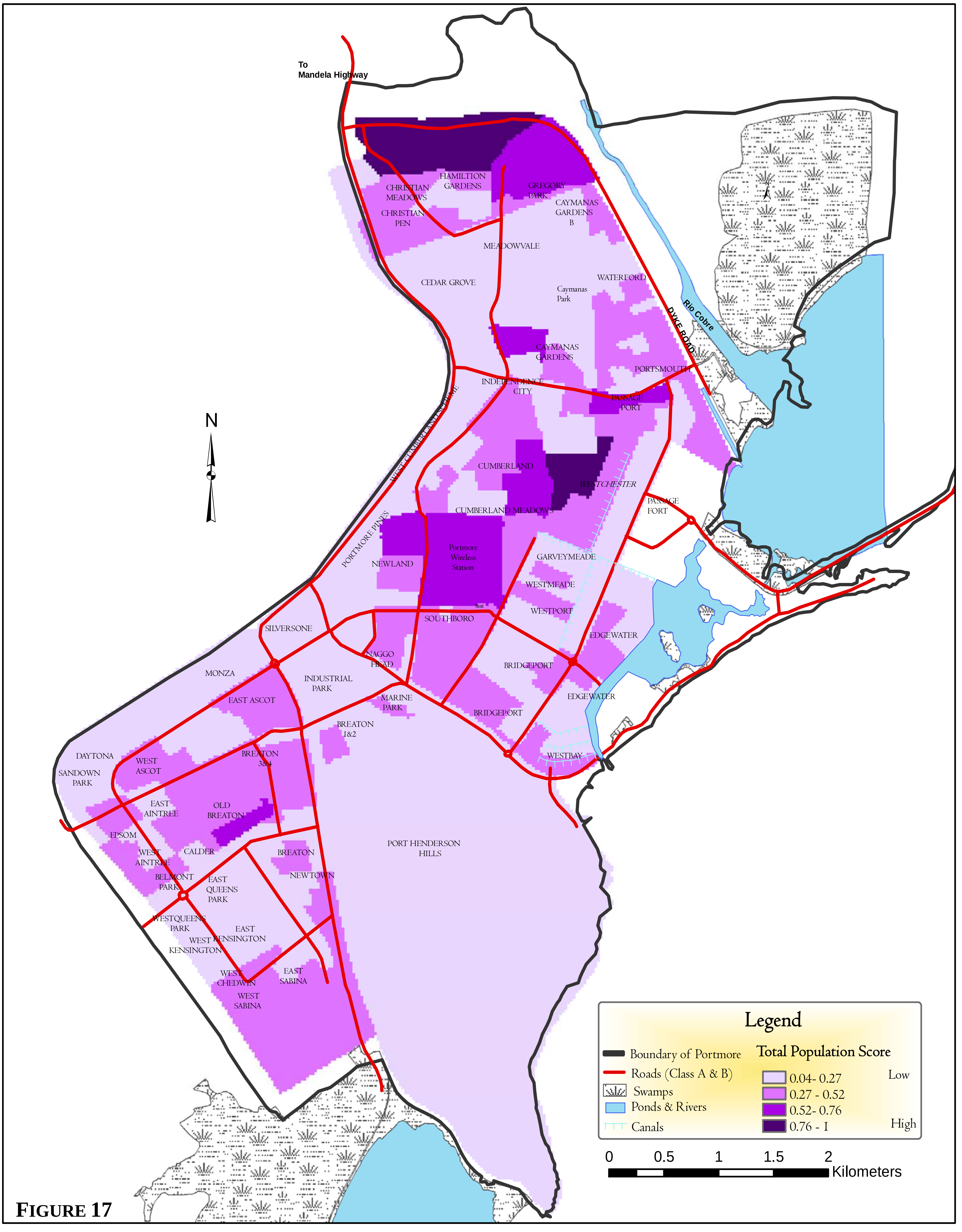


FIGURE 17

Figure 18: Societal Vulnerability of Portmore

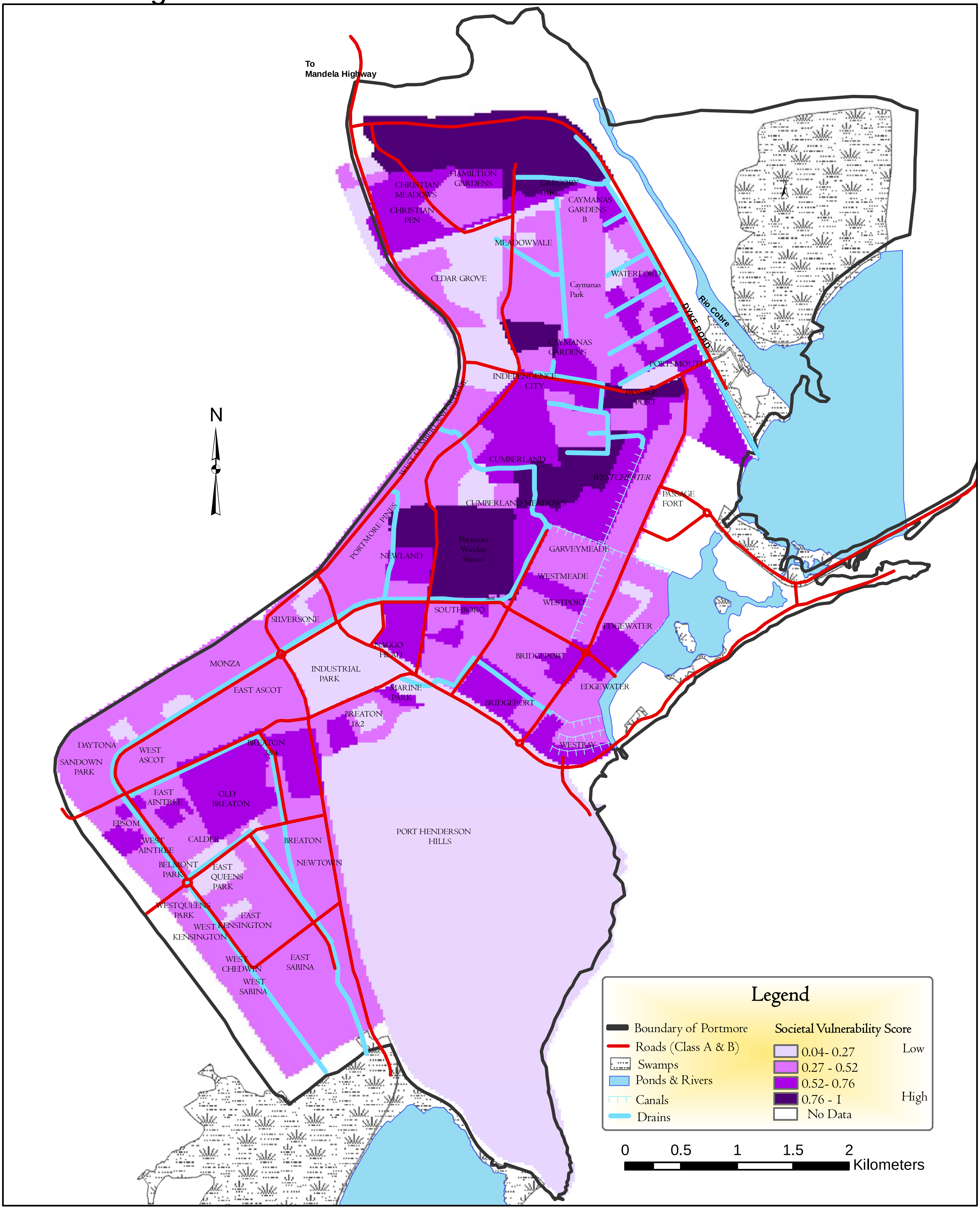
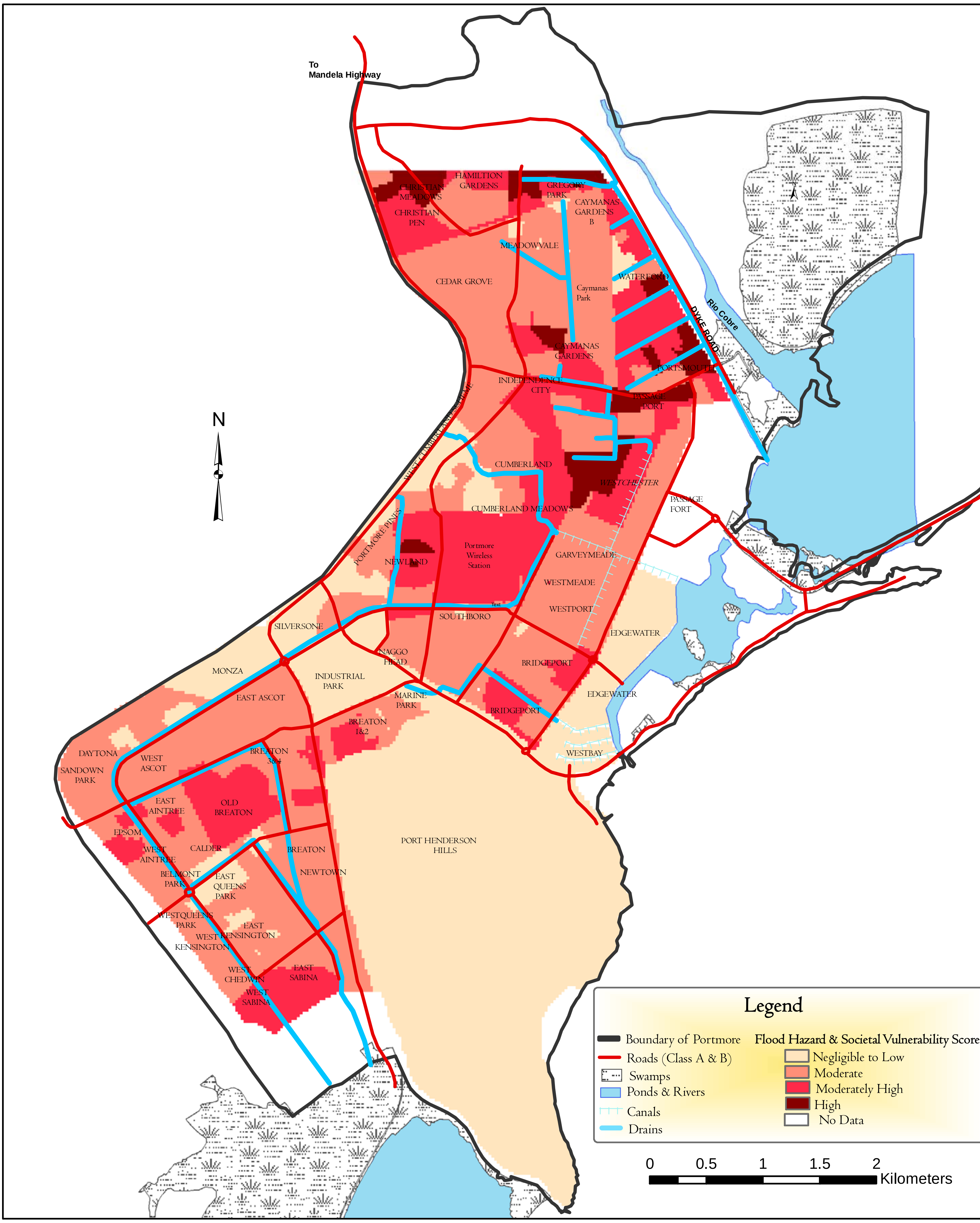


FIGURE 19: Flood Hazard and Societal Vulnerability of Portmore



Seismic Hazard and Societal Vulnerability Score of Portmore

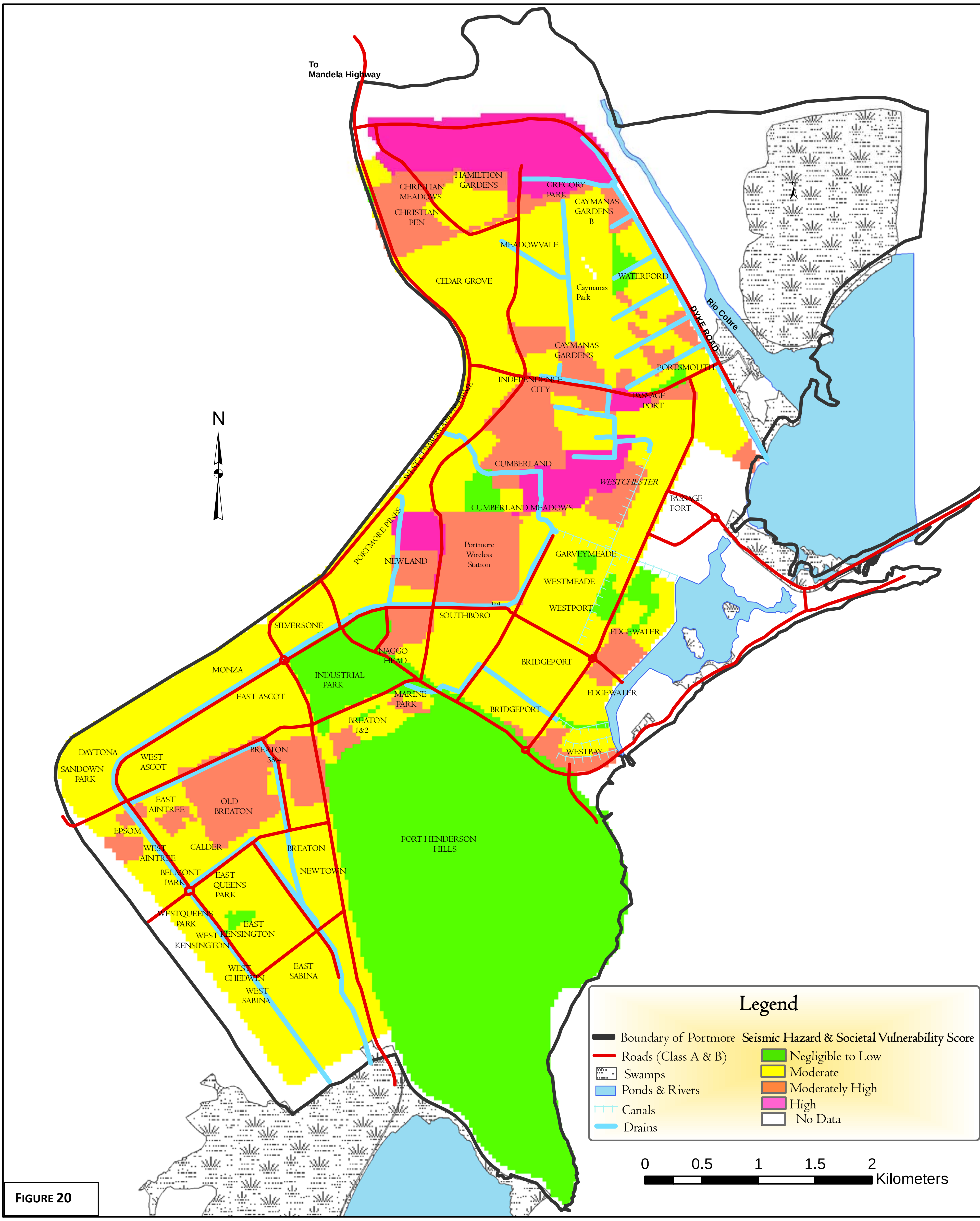


FIGURE 20

4.4.2.1. Built Environment Analysis

The built environment analysis includes an assessment of the vulnerability of all the buildings and structures that are not considered to be in the critical facilities analysis. The built environment includes a variety of structures such as businesses, single- and multi-family dwellings, and other man-made facilities. The built environment is susceptible to damage and/or destruction of the structures themselves, as well as damage or loss of contents (i.e., personal possessions and inventory of goods).

The built environment is divided into two groups that are most prevalent in Portmore namely:

1. Residential
2. Commercial

METHODOLOGY

i. The built environment (residential and commercial) was digitized from IKONOS images using the ArcGIS software in combination with the enumeration districts.

ii. The built environment was then combined with the flood and earthquake hazard maps in order to ascertain the vulnerable sectors of the built environment.

iii. Lastly, the built environment was analyzed with the seismic hazard map (Figures 20 - 21)

Residential Seismic Hazard Vulnerability (Portmore)

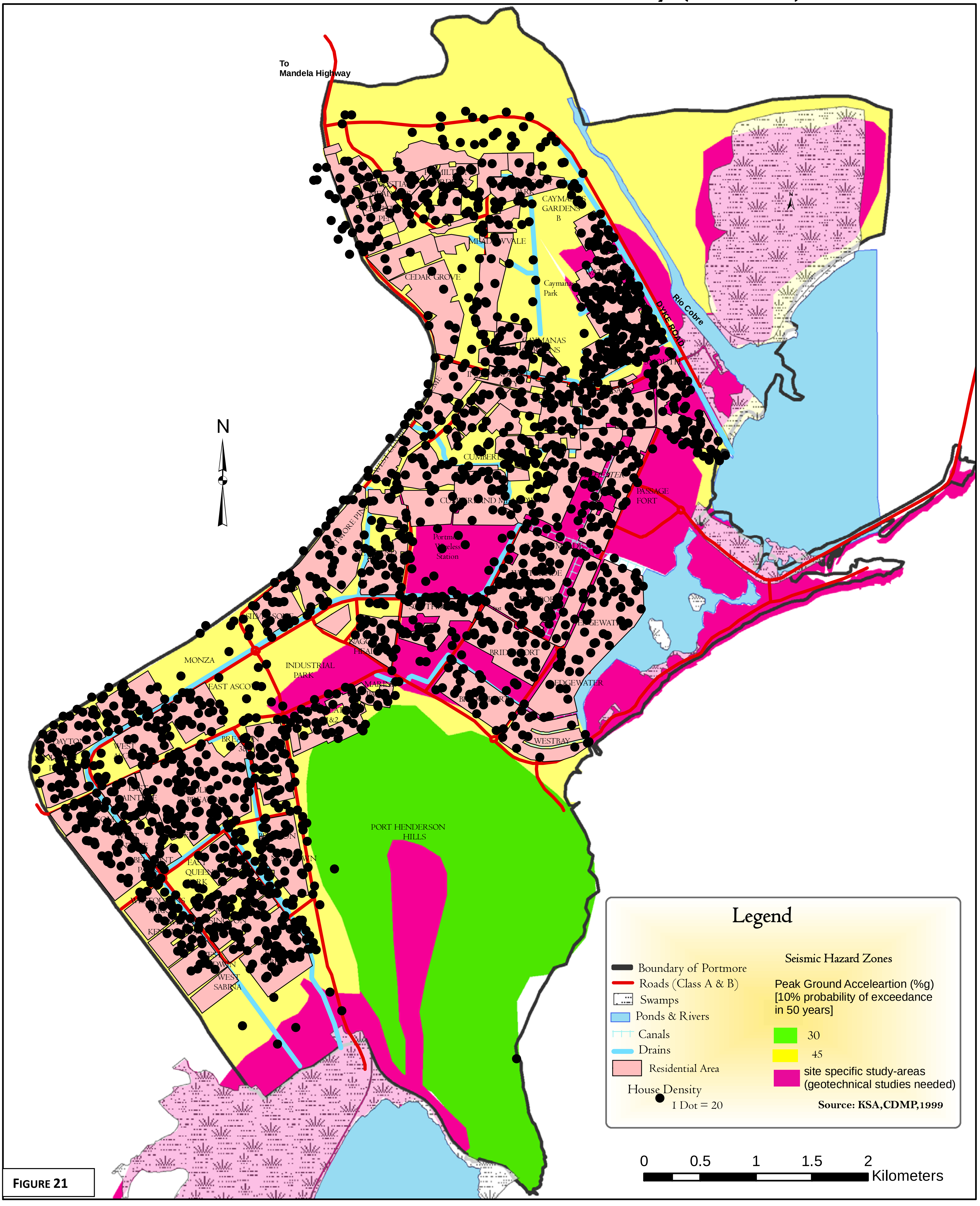


FIGURE 21

Analysis of Results

The Residential Built Environment

Residential built environment is calculated in view of these assumptions:

1) One household contains four individuals
2) Additions to houses are not considered but are noted and discussed.
3) The houses are primarily constructed of the same material (pre-fabricated) except in the informal settlement and other areas

The residential built environment is represented as dot density to ascertain the spatial distribution of the households. The dot density is overlain unto the seismic zones.

The households are grouped into their respective communities (figure 21). From the analysis, the following built environment for these communities are located within the seismic zone for which site specific assessment will be required (Table 6):

Community	Population	Number of Homes
Edgewater	4428	700
Waterford	18111	3725
Westchester	4907	1140
Portsmouth	6416	1000
Bridgeport	6688	1140
Southborough	4129	900
Garvey Meade	3369	842
Passage Fort	7378	1200

Table 6 Number of Houses with the seismic vulnerable zone that require site specific assessment

The ranking of vulnerability of these communities within this seismic zone will be based on the number of homes. The assumptions are:

- The greater the number of houses within a community, the higher the possibility of at least one of these houses being damaged, assuming all are in the same seismic zone
- The larger the development, the greater the number of houses that will be affected.

RESULTS

By taking this assumption into consideration, Waterford community would be considered the most vulnerable built environment while Edgewater is the least.

The informal settlement along Port Henderson Road and Forum beach are fishing villages, although the most vulnerable communities were not included here but will be looked at in the commercial built environment.

Commercial Activity Seismic Hazard (Portmore)

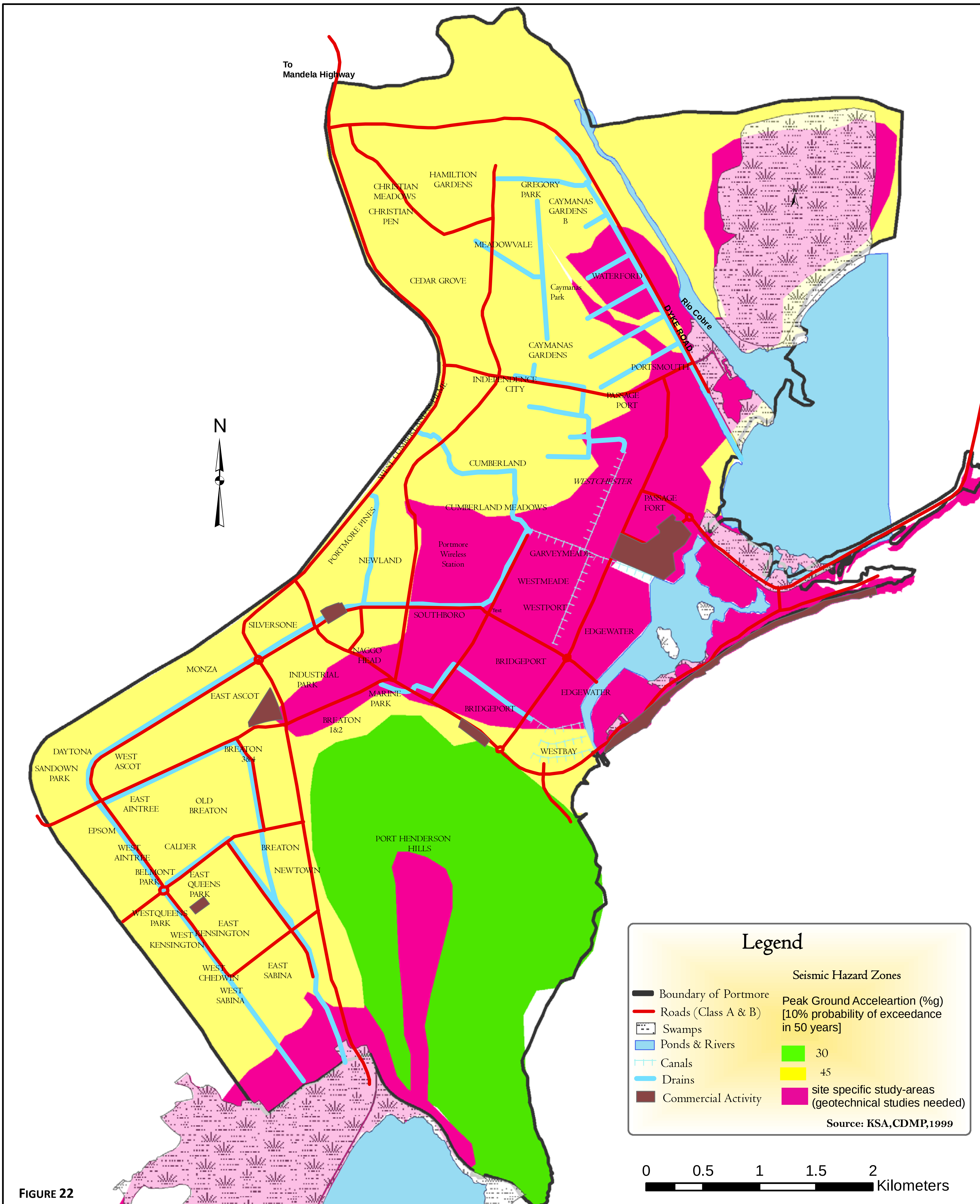


FIGURE 22

Commercial Built Environment Analysis

The commercial built environment assessment for the hazards required the use of the following data:

1) The seismic hazard map was overlain by the extracted commercial entities to ascertain the level of seismic vulnerability for the commercial areas.
    - No assessment was made on the commercial structures, however, the assumption that in the informal areas the structures will not be seismically sound, while the developed commercial areas the structures are more likely to be engineered and therefore less vulnerable to seismic hazard.

2) The informal commercial entities were mapped along with the developed commercial entities and colour coded to separate the different structure with respect to seismic soundness.

From the analysis, the following built environment for the commercial areas are located with the seismic zone that will require site specific assessment:

- The informal commercial areas/ fishing villages along Port Henderson Road and Forum Beach are the most seismically vulnerable built environment.

- The most vulnerable developed commercial areas are: the Portmore Mall, Port Henderson Commercial Area and Industrial Park.

4.4.2.2 Critical Facilities Analysis

Within the study area, there are several key individual facilities, lifeline or resources which are critical to the effective functioning of that community. These facilities normally play a critical and important role in disaster response and recovery. It must be ensured, that during and after a natural hazardous event, these facilities are protected to ensure that service interruption is reduced or eliminated. Critical facilities include: police; fire and rescue departments; emergency operation centers; transportation routes; bridges; utilities; essential governmental facilities; schools; hospitals; etc. As such, it is therefore necessary to identify which critical facilities are generally vulnerable to hazards due to either direct location or in close proximity to high-risk areas

METHODOLOGY

i. The location of the critical facilities are obtained from the National Land Agency and digitized from Ikonos images and 1: 4000 maps of Portmore.

ii. The critical facilities are combined with the hazard maps.

iii. The critical facilities are given hazard index to indicate their level of vulnerability.

The critical facilities are overlain on both the hazard societal vulnerability maps: seismic societal vulnerability and the flood societal vulnerability maps; these are examined in section 4.4.1. This combination of critical facilities and the hazard societal maps generates critical hazard societal maps which gives a representation of the final segment of the vulnerability analysis. The critical hazard societal vulnerability maps also give a spatial representation of the critical facilities with respect to their interaction with the hazard and societal vulnerable elements. The critical facilities are colour-coded based on their location, when they have been overlain on the hazard societal maps.

4.4.2.3 Results

The hazard societal vulnerability maps have indicated that several critical facilities and shelters are located within zones of high and moderately high vulnerability thus highlighting the possibility of reduction in the operational function of these critical facilities and shelters.
The number of critical facilities that are located within each zone are tabulated below
(Tables 7a & 7b).

1. Seismic Hazard Societal Vulnerability

Critical Facilities	Zones			
	High	Moderately High	Medium	Low
Church	3	10	16	1
School	1	17	35	1
Community Centre			2	
Police			3	1
Fire Station		1		
Health Centre	1	1	3	1
Medical Centre			8	
Post Office		1	2	

Table 7A: showing the number of critical facilities per hazard zones for seismic hazard

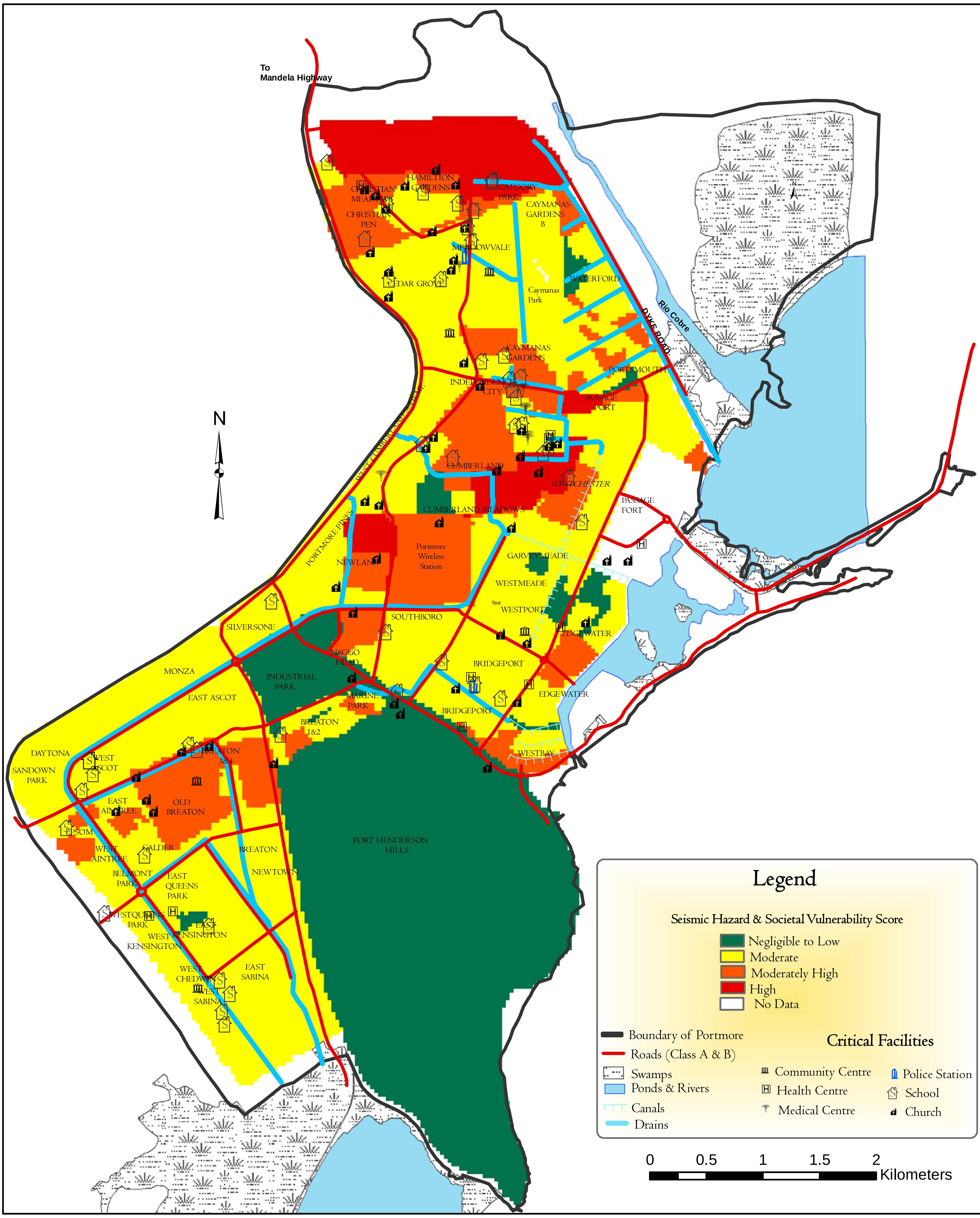
2. FLOOD HAZARD SOCIETAL VULNERABILITY

Critical Facilities	Zones			
	High	Moderately High	Medium	Low
Church	4	7	15	4
School	3	21	23	4
Community Centre				1
Police	1	1	1	
Fire Station		1		
Health Centre	2	2	2	
Medical Centre		1	6	1
Post Office		1	2	

Table 7B The number of critical facilities per hazard zones for Flood hazard

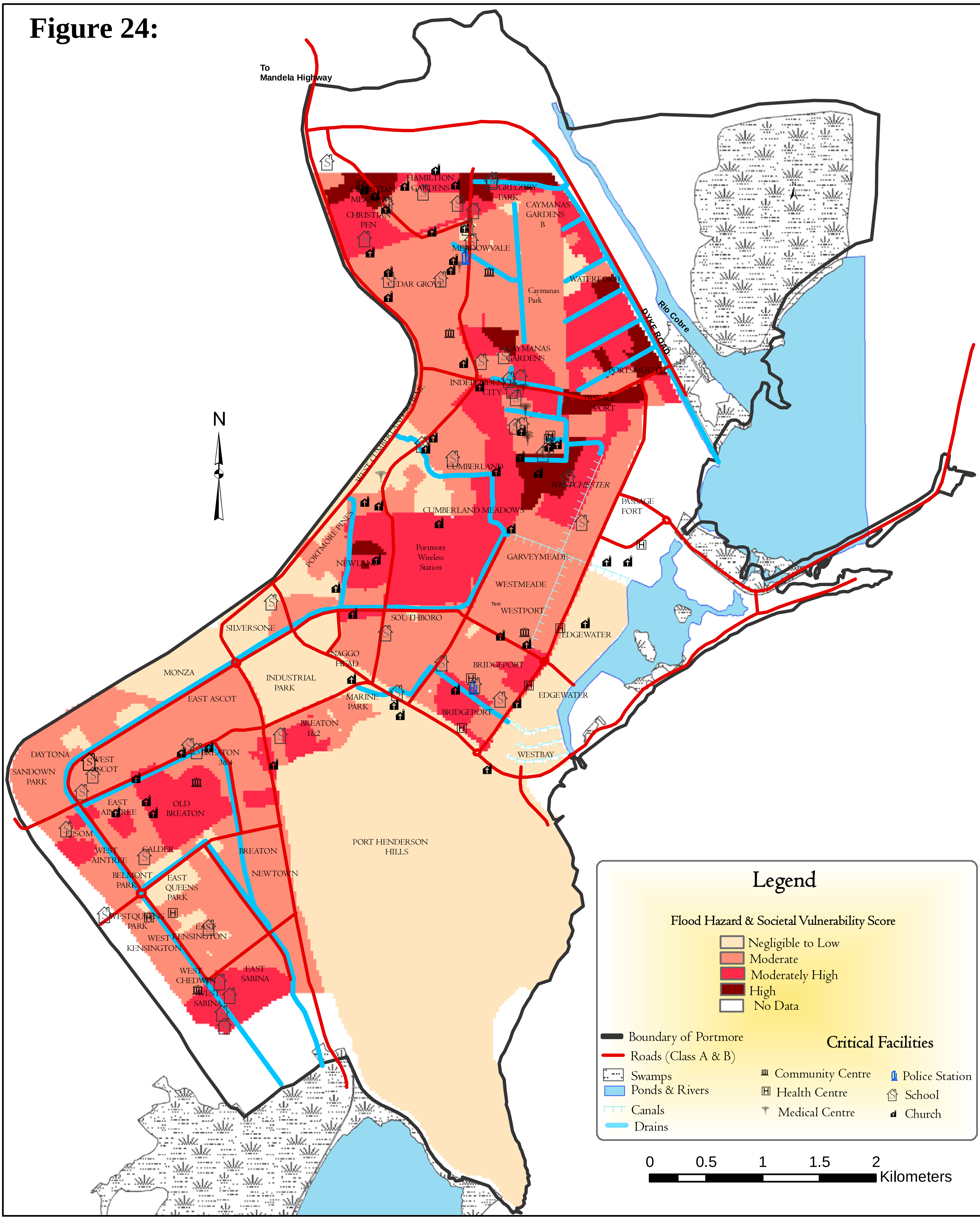
Due to inadequate data, some of the critical facilities fall within areas of no or very limited flood hazard data, seismic hazard data and societal data thus are given no colour code.

Figure 23: Seismic Societal Vulnerability Map with Critical Facilites



Flood Societal Vulnerability Map with Critical Facilites

Figure 24:



CHAPTER 5: EVACUATION PLAN REVIEW

5.1. OVERVIEW

The Portmore Evacuation Plan was developed with the aim of providing the Emergency Management Committee of Portmore with the necessary arrangement that would enable the adequate management of the effects of disastrous meteorological events such as hurricanes, tropical storm, flooding, storm surges, wind destruction, and tropical depressions. The plan also seeks to provide the Emergency Management Committee with evacuation procedures that could be used to improve the efficiency of evacuation process of the residents of the city. This plan was finalized in 2000.

5.2. CONSIDERATION FOR EVACUATION

The Portmore Evacuation Plan, however, in light of new information garnered from the analysis of urban flood data, in conjunction with socio-economic data for Portmore as well as data that indicated the high flooding potential of several evacuation routes, a review of the evacuation plan was undertaken.

This project has reviewed the evacuation plan and several recommendations are made to improve the effectiveness of the plan. These recommendations have taken into consideration the findings of this project. The recommendations for the Portmore Evacuation Plan are minimal as the plan for the most part is adequate. This project shows that the Bernard Lodge Road, Lakes Pen Road, Dunbeholden Road and Gregory Park Main Road, which are flood prone areas should not be considered as evacuation routes during emergencies.

This project also conducted vulnerability assessment which included the examination of several societal vulnerable elements. Consideration of these societal vulnerable elements or groups will also aid the Emergency Management Committee in planning as they indicate key areas that should be given special attention during the evacuation process. The vulnerable groups should be given special attention in the evacuation process as these groups will be among the most dependent and in need of assistance during a natural hazard incident.

Children are one of the vulnerable groups and are represented within this project with scores; the closer the score is to number 1 the greater the children population. The children's group is divided into the infants and the young people vulnerable score map which indicate the following communities are to be given special attention: Gregory Park, Newlands, Westchester, Naggo's Head, Independence City, Caymanas Gardens and Old Braeton (Figure 13 & 14). The other vulnerable group is the elderly population which is taken to be adults 65 and over. The elderly population is also scored in similar manner as all the societal vulnerable elements. The elderly population vulnerability score indicates that the following communities should be given special attention, which include all the communities listed above for the children vulnerability score along with Edgewater (Figure 15).

The map below (Figure 24) shows the urban flood map for Portmore with shelters included. It indicates that two of the shelters are located within high flood prone areas. The shelters are Waterford Comprehensive High School and the Greater Portmore High School. There should be a reconsideration of these buildings as shelters.

Flood Hazard Map with Shelters

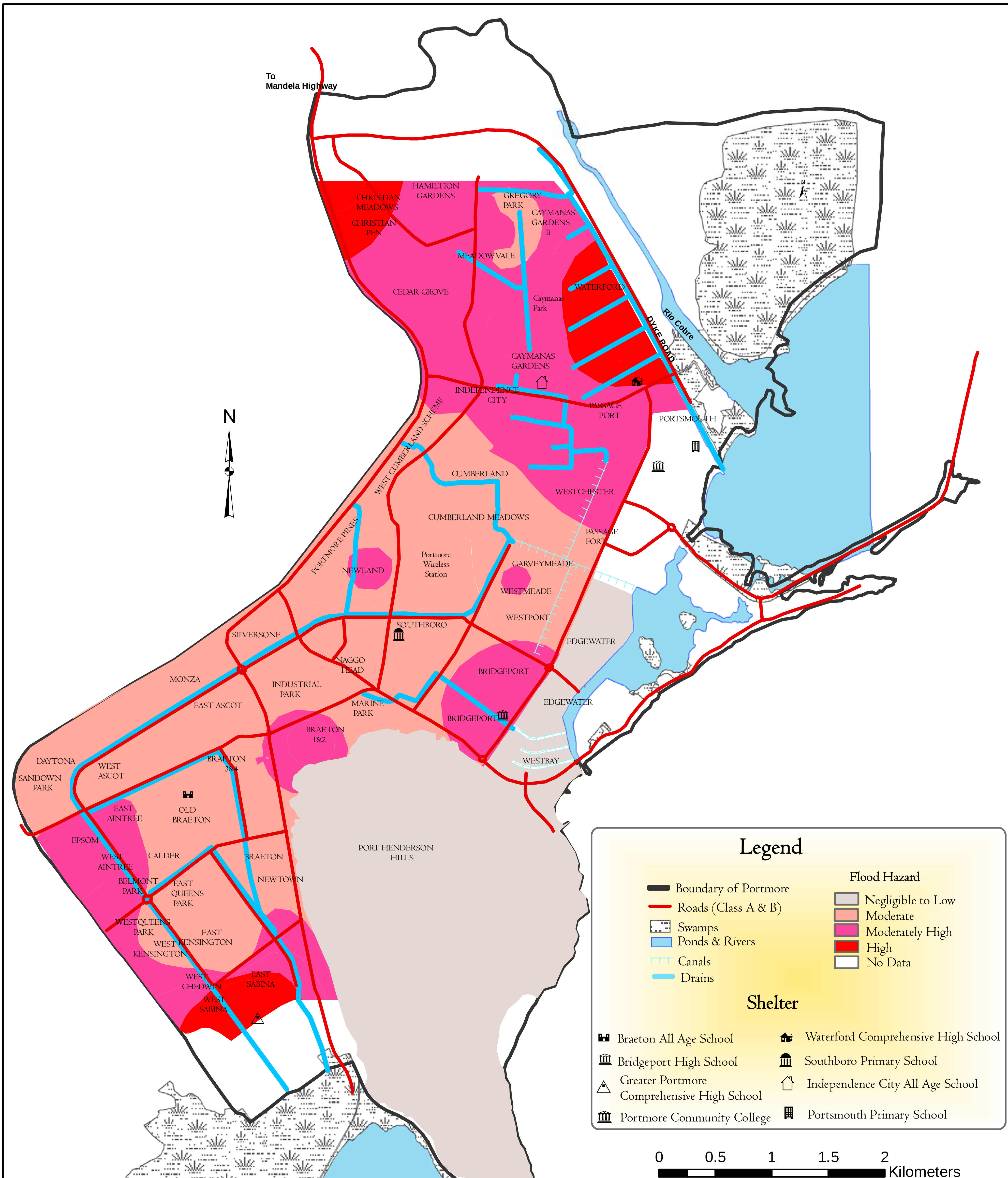


Figure 25

CHAPTER 6: DISCUSSION AND RECOMMENDATION

6.1 FLOOD AND HAZARD VULNERABILITY

The flood hazard zonation map was generated using data from historical flood events and conducting flood hazard assessment of the study area. In technical terms, the methodology adopted is not the most scientific, but based on the varied circumstances which have contributed to flooding in Portmore, the methodology used in the study provides reasonably reliable results which can be used to determine the flood vulnerability of communities. From the analysis, the communities most vulnerable are Waterford, Caymanas Gardens, Independence City and Westchester.

6.2 SEISMIC HAZARD VULNERABILITY

Due to the absence of relevant data pertaining to the type and quality of construction to adequately assess vulnerability in the built environment, there is a strong reliance on the number of houses within a given community. Larger communities are given higher scores, depending on their location in the seismic hazard zone.

Waterford is considered to be the most vulnerable built environment with respect to seismic hazard. Given Waterford's vulnerability, this community should be treated as a priority in the management of disaster risks.

6.3 SOCIETAL VULNERABILITY

With respect to societal vulnerable groups, the analysis shows that the communities of Independence City, Westchester and sections of Gregory Park Division are most vulnerable, particularly for the elderly and infant groups. Evacuation Plans and procedures for Portmore should be geared towards giving higher levels of priority to these areas.

6.4 COASTAL VULNERABILITY

The commercial areas on the coastline of Portmore are found to be both vulnerable to seismic hazard and coastal flooding. These areas include, but not limited to the informal commercial areas/ fishing villages along Port Henderson Road and Forum Beach and the formal commercial entities on the Port Henderson Road. These fishing villages were severely damaged by Hurricanes Ivan and Dean in September 2004 and August 2007 respectively. However, there is a visible residential component to the commercial activities, which further increases vulnerability of the community. Immediate intervention in these communities is desirable to limit the growth of residences and to allow for the necessary setback from the shoreline in keeping with current planning guidelines.

6.5 EVACUATION ROUTES

The level of vulnerability of Portmore residents and infrastructure to natural hazards in the study is influenced by the level of the hazards present and its interaction with the socio- economic level of the Portmore residents. This is compounded by the fact that although Portmore has five exit routes, three are highly prone to flooding; Bernard Lodge Main Road, Lake Pen Road and Dunbeholden Road which should not be used as evacuation route when there is flooding in Portmore. The fourth exit route is the Portmore Causeway Bridge which is vulnerable to storm surges; however the level of vulnerability is reduced due to the improvement of the bridge under the Highway 2000 project. The final exit route, the Mandela Highway, is also prone to flooding especially the section of the dual carriageway leading from Ferry toward Kingston.

This project recommends that the Portmore Causeway is used as the first exit option for those communities that are closest to it and in high flood hazard zone. The section of Mandela Highway leading to Spanish Town should be utilized as the last exit route in the event of a hurricane or an unstable weather system with flood generated precipitation.

6.6 SHELTERS

The Waterford Comprehensive and Greater Portmore High Schools are two of the shelters located within the high flood prone area. The project recommends that the Greater Portmore High School should no longer be used as a shelter because of the areas' vulnerability to flooding.

6.7 DRAIN MAINTENANCE

In light of these findings, it is very critical that storm drains and other infrastructure are properly maintained and education of the residents on the susceptibility and vulnerability of their community be conducted and building codes are strictly adhered to**.**

CHAPTER 7: CONCLUSIONS

As one of the fastest growing urban communities in Jamaica, it is important that Portmore's vulnerability to natural hazards be assessed. This project has presented a natural hazard and vulnerability study of Portmore, which included an examination of the various forces that are intertwined with the hazards as well as an assessment of the major hazards affecting Portmore. The interactions of the hazards and the various forces (socio-economic variables, built environments, critical facilities) have been examined using GIS which allows spatial analysis to be carried out.

The hazards that have been examined are earthquakes, storm surges, and inland flooding. In examination of these three hazards, the various data sets of the hazards were analyzed in GIS to determine the areas that are affected by these hazards. The socio economic and built environment variables were examined similar to the hazards using GIS and combined with the dataset from the hazard analysis to determine the vulnerability of the communities within Portmore. The critical facilities are next overlain to determine the areas and the lifelines that are vulnerable to these hazards.

The examination of the hazards and subsequent vulnerability assessment in GIS, it has been determined that several communities in Portmore are very vulnerable to natural hazards, in particular urban flooding, storm surge and earthquakes.

The new information that this project has produced was used in the review of the excavation plan of Portmore. The new information has indicated that several roads that are used as evacuation route are not suitable since those roads are flood prone. These include the Bernard Lodge Main Road, Lakes Pen Road, Dunbeholden Road and Gregory Park Road. The Portmore causeway is recommended to be used as the first exit option, particularly for communities that are in close proximity to it, while Mandela Highway leading to Spanish Town should also be utilized as an exit option.

It is very important that the residents are made aware of these hazards that are present and how their actions can either reduced or increase their vulnerability to these hazards.

APPENDICES

Interview Questions

1. Where in your community does flooding occur?

2. How often (frequency) of flooding within your community?

3. What are the extent of the flood waters/ height of flood waters?

4. What are the main causes of flooding within the community?

5. How effective are the drains within the community?

PORTMORE FLOOD MAP