

# **Barbados Country Paper on National Climate Change Issues**

**In Support of Component 4 of the  
Caribbean Planning for Adaptation to  
Climate Change: Formulation of a Policy  
Framework for Integrated (Adaptation)  
Planning and Management**

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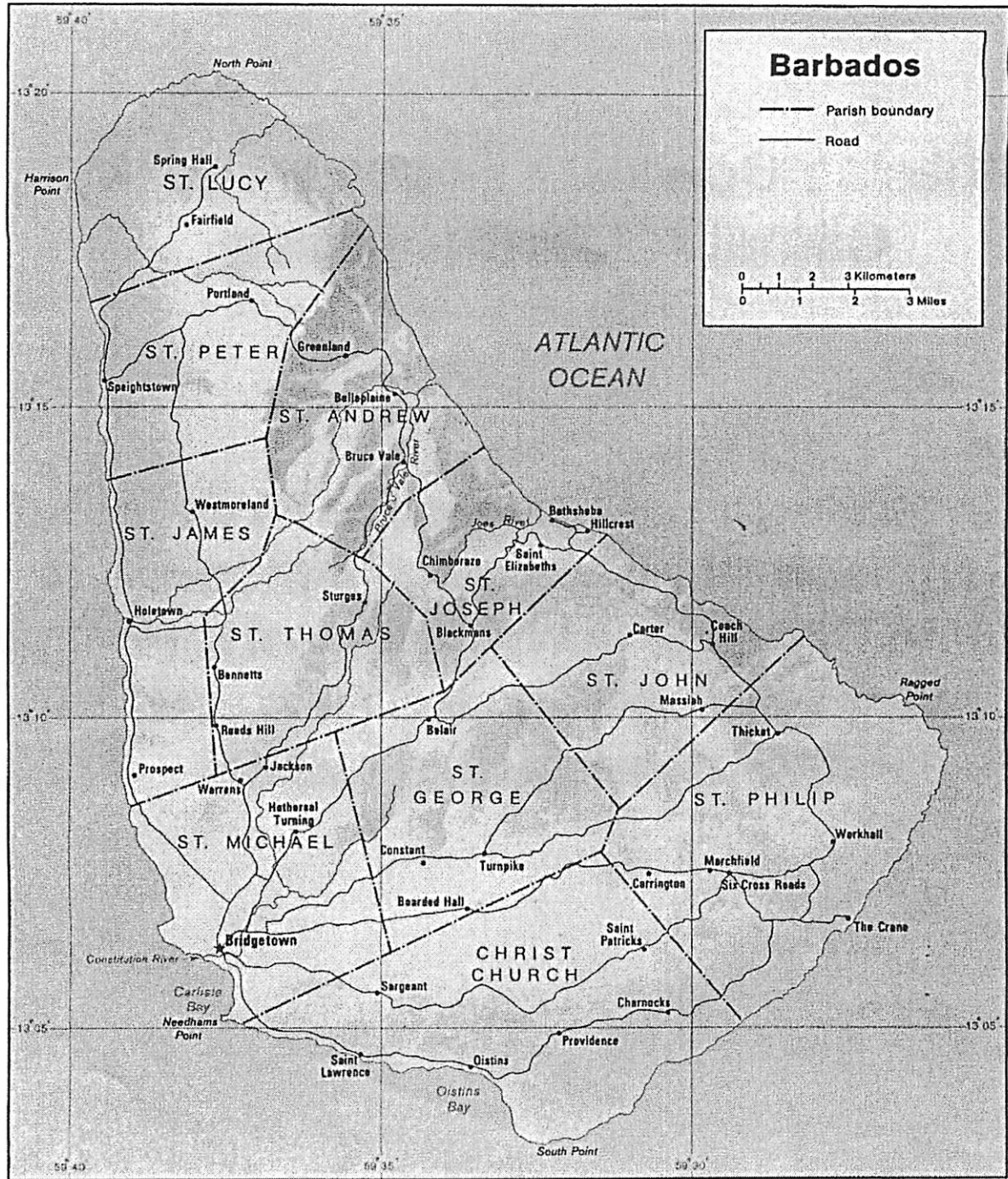
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MAP 1



**Barbados Country Paper on National Climate Change Issues**  
**In Support of Component 4 of the Caribbean Planning for Adaptation to Climate Change:**  
**Formulation of a Policy Framework for Integrated (Adaptation) Planning and**  
**Management**

## **1.0 INTRODUCTION**

Barbados, the most easterly of the islands of the Lesser Antilles, is a small island developing state of area 431 km<sup>2</sup>, located in the Atlantic Ocean, at 13° 4' north latitude and 59° 37' west longitude. It is bordered by the Caribbean Sea on the west coast and the Atlantic Ocean on the east, with a coastline of 97 km, and an exclusive economic zone of about 167, 000 km<sup>2</sup>. In 1997 the population of Barbados was recorded as 266,990, making it one of the ten most densely populated countries in the world. The population continues to grow at a rate of 0.4%. Map 2 in Appendix A shows the population density.

Before the 1970's, the economy was dependent on sugar cultivation for export. However since that time, the economic base has moved towards a service oriented economy, focussing on tourism, financial services, data processing and light manufacturing, such that agriculture now represents one of the lowest contributory sectors with respect to GDP. Most of the principally vital economic service sectors, unlike agriculture which is an inland activity, are concentrated within or proximal to the 2 km zone landward of the coastline, within the continuous urban corridor extending for the entire length of the south and west coasts.

Estimates of purchasing power parity, real growth rate and per capita GDP for 1996 stood at BDS \$ 2.65 billion, 3.5% and BDS\$ 10, 300, respectively.

## **1.1 Climate**

Barbados enjoys a tropical, oceanic climate with an average temperature of 26.8C. Since there are no drastic changes in either seasonal or daily temperatures, the weather seasons can be classified as either wet or dry. The wet season co-insides with the Atlantic hurricane season and runs from June to November, with the wettest month being October with an average rainfall of approximately of 170mm (6.65in). The dry season lasts from December to May with the driest month being February with an average rainfall of approximately 42mm (1.65in).

The island is affected by a number of weather systems during the year. During the wet months, most of the rainfall is derived from tropical waves moving across the Atlantic Ocean, along with the Inter-Tropical Convergence Zone ( I.T.C.Z.), which shifts northwards on occasions, especially during the passage of tropical waves. During the dryer months, upper level troughs and lows, and sometimes the tail end of cold fronts which survive after moving off the eastern seaboard of the United States of America, can contribute to the rainfall totals. In addition to the above, heavy showers

and thunderstorms sometimes develop, mostly over central and western areas, when strong daytime heating, along with light winds and an abundance of moisture are present (Map 3 in appendix A shows the distribution of mean annual rainfall for Barbados). This type of weather is more prevalent during the hurricane season and leads to flash flood conditions over low-lying areas, which can lead to minor infrastructural damage given this history. The last hurricane to have a major impact on Barbados was Hurricane Janet in 1955. Since then, several storms have threatened, but have all passed on a north easterly path away from the island. Therefore, only relatively mild disturbances in the weather are experienced in the form of high intensity rainfall and some low speed wind gusts. These disturbances are still enough to cause some flooding in low-lying coastal areas and minor infrastructural damage. This means that a large percentage of the population has no first hand knowledge of the severity of hurricanes and their direct impact on life or property. (Table 1 in appendix A lists the rainfall and wind events from 1990 to 1999 and below is a summary of wind and rain events from 1955 to 2000)

The predominant wind system affecting the island is the North East Trades; although the weather is influenced by such tropical systems as the Inter Tropical Convergence Zone (ITCZ), and tropical waves, depressions and storms which originate off the west coast of Africa. Much of Barbados' rainfall is derived from such systems. Additionally the island can experience effects from upper level troughs, cold fronts from the north, and the El Nino Southern Oscillation (ENSO).

## **1.2 Geology/Physical Characteristics**

Of the Lesser Antilles, Barbados is the only entirely non-volcanic, sedimentary rock island. The core rock of Barbados consists of sedimentary oceanic rock, and it is overlain by coral limestone (Map 4 in appendix A shows the geological the regions of Barbados). The island is low-lying, the highest point Mt. Hillaby, standing only 340m above sea level. Most of the land which lies within 2 km of the coastline is below the 20m contour line. The island is not prone to earthquakes and is currently emerging at rates which vary across the island: for example, at the South Coast rates of 0.22mm per year have been calculated; whilst similar numbers for the West Coast range from 0.3 to 0.44 mm per year. At the North, uplift is 0.18 mm per year; and the fastest rates of upliftment can be seen along the East Coast, which range from 0.43 mm per year to the South East, to 1.6 mm per year along the Scotland District area to the North of the East Coast.

From time series analyses, it has been determined that for the south coast, 12 beaches are accreting, 6 are stable and 1 is eroding; and for the west coast, 12 beaches are accreting, 25 are stable, and 13 are eroding.

As a limestone island Barbados' source of fresh water is from its underground aquifers but it is among 5 countries with most limited groundwater per capita and may be

threatened by salt water intrusion with SLR, and greater evapotranspiration during droughts and with higher temperatures. However, ground water is only recharged during 3 or 4 months of high rainfall, and higher rainfall intensities may augment this. Also, a wedge of salt water intrusion may at first force fresh water closer to the surface to be more accessible, but, more precise rain projections are needed and more water research is involved in proving that these positive effects will actually occur. (Map 5 in appendix A identifies the water zones for Barbados. The zones indicate the vulnerability of the ground water aquifers where zone 1 represents the most vulnerable and zone 5 represents the least vulnerable aquifers. On map 4 it can be seen that there are 4 major zone 1 aquifers along the west coast of the island that extend towards the coastline. These 4 aquifers are the most vulnerable to the effects of climate change).

### **1.3 Important Ecological/Biological Attributes**

#### **1.3.1 Terrestrial**

The remaining natural vegetation communities in Barbados are generalized according to

**vegetative type:**

- Pioneer and successional vegetation - vegetation colonizing “new” land (e.g beaches, recently denuded soil) or areas no longer under use for agriculture
- wetlands in low lying coastal areas
- woody vegetation - primarily as remnant forests
- beach and sand dune areas - found along the coastline not stabilized with vegetation

(Refer to Map 6 in appendix A which shows the distribution of the above mentioned vegetation communities in proportion to other land uses such as agriculture and development)

The natural vegetation communities which exist in Barbados today are an important component of human experience of the island. The forests and woodlands are important for their aesthetic value and non-commercial opportunities they provide for food, building materials and art supplies. Until very recently, the remaining vegetation was under the threat of total removal due to human activities.

The number of indigenous species remaining has fallen and the number of introduced species has risen. Those that are threatened most by sea-level rise fall within the 2 km coastal zone, the sand dunes/beaches and the wetlands, are also the most delicate and scarce of the vegetative types and therefore must be protected. The mangroves also act as an important habitat to a range of animal and plant species, from migratory birds

which nest in their branches, to various mosses, crustaceans, fish and amphibians which live amongst its roots.

Authentic natural wild life is a limited resource in Barbados today as is seen in tables 2 and 3 (Table 2 lists the non-indigenous terrestrial fauna present and breeding in Barbados. Table 3 lists the terrestrial fauna no longer present or no longer breeding in Barbados for which there is historical evidence) due mainly to the past actions of humans at clearing and degrading the natural vegetation communities. The greatest species diversity is observed in the wetlands and woodland areas and can be considered as significant habitat for indigenous birds and reptiles.

### **1.3.2 Aquatic and Marine**

Aquatic habitat is of limited distribution and scale in Barbados as a result of the activities of humans and they have not been well studied.

The marine environment surrounding Barbados is the best known feature of the island's natural heritage. There are coral reefs which protect the shorelines from the erosive forces of the sea and are critical ecosystems supporting fisheries. The sea grass beds which are found only at a few specific locations around the island along with the reefs, provide a continuous, near shore band of rich marine habitat for fish and reptiles around the entire island. The reefs are the habitat of many species of corals some of which are rare as well as home to various animal species. The sea grass beds are the nesting grounds for the sea egg which have become rare as a result of the removal and destruction of the beds and over exploitation by humans.

Ongoing damage to coral reefs and removal of sea grass beds, together with shoreline hardening and degradation of on-shore habitats for nesting reptiles have reduced the reproductive opportunities for populations of wildlife, particularly the endangered turtle species such as the Leatherback and Hawksbill which frequent the south and west coasts. (Map 7 identifies the turtle nesting sites along the coastline of Barbados. These sites are vulnerable to the consequences arising from climate change)

In 1995, the fishing industry was estimated to contribute some 1% of GDP, with some 2200 fishers being employed in the industry, of which 80% are full time. Target fisheries are largely pelagic and demersal today, nearshore coastal fisheries having declined significantly since the 1970's.

There are 26 coastal landing sites around the entire island coastline, classified as primary (include a harbour/jetty and market complex), secondary (characterized by sheds and concrete slabs for cutting fish), and tertiary (beach and bay areas with no physical infrastructure, where boats are moored, beached and fish landed) sites. There are 3 primary sites at Oistins to the south, Bridgetown at the south west coast, adjacent to the Deep Water Harbour, and Speightstown to the north west. Existing primary sites have already reached their capacity with respect to the size and number of vessels they can accommodate; and available beach space for the beaching of vessels is fast diminishing with the intense competition between other coastal user groups, often associated with tourism.

## 1.4 Socio-Economic Profile

Criteria	1990	1991	1992	1993	1994	1995	1996	1997	1998
Population ('000)	260.8	262.5	263.1	263.9	264.3	264.4	264.6	266.1	266.8
GDP (US \$)	1483	1446	1354	1396	1460	1574	1689	1804	1962
GDP per capita ( '000 US \$)	5.8	5.6	5.2	5.3	5.6	6	6.4	6.8	7.4
Share of industry in GDP (percentage)	8.7	8.6	8.1	7.9	7.7	7.3	6.7	6.8	6.7
Share of services in GDP (percentage)	85.9	85.8	86	86.3	87.2	86.4	86.6	87.9	89.3
Share of agriculture in GDP (percentage)	5.4	5.6	5.6	5.8	5.1	6.3	6.7	5.2	4
Urban population as percentage of total population	45	45	46	46	47	47		48	48
Life expectancy at birth (years)	75.1		75.6	75.7	75.9	76		76.4	

**Table 4**

The Barbadian economy has continued to grow since 1992. Its growth is led by the non-traded sectors with tourism and construction sectors being the main engines of growth. In 1998 the tourism sector grew by 6.5% compared with a moderate 2% in 1997. The value of real GDP for 1998 was estimated at \$957.4 million. The value of output in tourism for 1998 was estimated at \$143.9 million. Construction activity was very strong in 1998 concentrated in the private sector although Government projects such as the South Coast Sewerage, road construction and repairs also contributed to the strong growth. Figure 1 below shows the 3 major sectors of the Barbados' economy and their percentage share in the Gross Domestic Product (GDP).

Sector	Share in GDP ( % )
Services	85.9
Industry	8.7
Agriculture	5.4

**Figure 5**

The tourism industry is the single largest revenue earner for Barbados, employing some 25% of the labour force. There are approximately 6000 hotel rooms distributed across 135 hotel properties, all except 12 of which are located wither on or proximal to the beach. In 1997 tourism contributed some 12% of GDP with 472,290 shore stays and



517,888 visitors being recorded. In that same year tourists spent US\$ 750.5 million.

The tourism and construction sectors both have special relevance to climate change issues as the center of these activities is concentrated within the 2 km coastal zone.

Agriculture is confined for the most part, to those portions of the island which are inland to the coastal urban corridor. 50% of the island's land area is described as arable; although significant portions are not currently under production. Approximately 67% of cultivated land was dedicated to sugar cane, with pastures on approximately 9%, and the remainder being dedicated to cut flowers, vegetables, fruit, and cotton. Today, sugar contributes less than 1% of the GDP, and the area of land under cultivation has fallen of its peak cultivation levels. Non sugar agriculture is now contributing just over 5% of GDP, and the island is becoming increasingly dependent on imported foods.

In more recent times, there has been increased pressure to subdivide agricultural lands for golf tourism, resort and residential development.

The USA market is the primary supplier of imported goods to Barbados, accounting for approximately 41% of total imports in 1998. The other major suppliers are the UK, Canada, Japan, and CARICOM countries. The Caribbean region continues to be the primary purchasers of Barbadian products. Exports to CARICOM countries as a share of the total, amounted to 41.5% in 1998, while the remainder of the exports were distributed among the UK, Canada, Germany, USA and Japan. The major export is sugar, followed by manufactured goods.

### **Location of population centres**

The major population centres. With the exception of Warrens and Six Roads developments, located towards the central and eastern inland portions of the island, respectively, all of the principal urban settlement, including that of the capital, Bridgetown, are located within the coastal urban corridor. Over 60% of the island's total population is located in the three coastal parishes of St. James (to the west; contains the 2 large urban settlement nodes of Holetown and Speightstown), St. Michael (to the south west; contains the capital Bridgetown), and Christ Church (to the south; contains the Oistins urban settlement node). Approximately 25% of the island's population lives within 2 km of the coast, concentrated within a continuous linear coastal urban corridor, extending for the entire length of the west and south coasts as seen on map 8 in appendix A. Since the 1990s there has been increasing pressure for residential housing development, and the coastal urban corridor has expanded significantly along the south coast, with a change of land use from agricultural lands to subdivisions for residential purposes.

The distribution of residential housing mirrors that of the population distribution, along the west and south coast coastal urban corridor. Apart from a few enclaves, coastal property tends to be high income, high value real estate. The majority of homes in Barbados as a whole are owner occupied, although coastal properties have a lower incidence of owner occupation.

The construction of the traditional, wooden “chattel house” has been on the decline, going from being 72.5% of all houses built in 1970, to 39.98% in 1990. Barbadians have over the years seen to the conversion of their homes from wood to concrete. In 1990, 35.47% of all homes were concrete, and 21.3% of houses were a mix of concrete and wood. However, despite these apparent improvements, there are several fundamental issues of housing quality and design as pertains to resistance to natural hazards, which have yet to be addressed nationally. About 45% of all houses were built over 20 years ago.

Also of note is the existence of settlements in flood plains and coastal water courses. Around the capital of Bridgetown, for example, there exists much low income, ‘slum’ housing, which sits on what is essentially low gradient coastal land which forms part of the Constitution River catchment.

### **Industry**

Almost two thirds of industrial facilities are located in St. Michael, within the Greater Bridgetown area. Christ Church holds one fifth of the total, the remaining establishments being scattered about the island. Of the registered business establishments in the manufacturing and quarrying sector, 56% are characterised as small, employing less than 10% of the labour force; and of these, only 7% employ 100 persons or more. Food and beverage manufacturing, metal and machinery, and construction sectors predominate.

The Barbados Industrial Development Corporation (BIDC) is a government agency that develops industrial estates, renting industrial space at subsidized levels. The BIDC owns 10 industrial estates, three of which are located within the coastal urban corridor.

There are also several private industrial areas across the island, several located throughout the Greater Bridgetown area within the urban corridor.

### **Infrastructure**

There are several water supply wells and mains along the south and west coasts. In addition the Barbados Light & Power, the sole producer of the island’s electricity, has its facilities on two sites, both of which are located near to the shoreline, on either side of Bridgetown.

The two coastal highways, Highway 1 which runs from Bridgetown north along the west coast, and Highway 7, which runs in the opposite direction from Bridgetown along the south coast, are the connective vein within the coastal urban corridor. These highways are both barely above sea level, running essentially along the back beach routings.

Ground water is the major source (98.6%) for public and private water supplies. Within the coastal zones of the west and south coasts, there are a number of wells and pumping stations, utilised to provide potable water to the surrounding areas both for domestic

purposes and agriculture. There are many water mains located proximally to the erosion prone shoreline, close to the mean high water mark. The new desalination plant has been constructed in an area at Spring Garden along the south west coast, which is especially vulnerable to storm induced erosion.

Related to the water mains issue, is the positioning of the sewerage mains with back beach routings, particularly on narrower beaches along the coast. Currently, the South and West Coast Sewerage Projects are on-going, with new mains being laid beneath the coastal highways.

Government headquarters is located along the south west coast of the island only a few feet away from the shoreline.

## 2.0 KEY ISSUES WITH RESPECT TO CLIMATE CHANGE

At present, with an increase in global temperatures, the key changes in climate and natural processes expected in the Caribbean are:-

- ▶ **sea level rise;**
- ▶ **increase in the frequency and intensity of storms and hurricanes;**
- ▶ **decreased annual rainfall, with a resultant decrease aquifer recharge**

<b>FUTURE CLIMATE SCENARIOS</b>				
<b>PROPOSED BARBADOS COMMON ASSUMPTIONS</b>				
	<b>Present</b>	<b>2020s</b>	<b>2050s</b>	<b>2080s</b>
CO <sub>2</sub> concentrations (ppmv)	368	441	565	731
Temperature °C (including sulphate aerosol effect)	0	0.8	1.5	2.5
Annual precipitation change (%) (UKMO Model)	0	-2%	-5%	-10%
Sea level rise (cm)	0	10	26	44

- Also:
- a) convective precipitation intensities +1 mm on rain days.
  - b) Longer, more intense, droughts, especially in El Niño years.
  - c) No change in hurricane frequency, but strongest storms more intense.

If one is to rank the three expected environmental changes for Barbados, the implications of sea level rise must be ranked as most crucial, since sea level rise can

directly exacerbate the impacts of the other factors listed; although the converse is not true. For example, for an island like Barbados, with groundwater acting as the only source of freshwater as the island, decreased rainfall means low aquifer recharge, and increased chance of saline

intrusion. Increase in sea level therefore acts to move saline intrusion farther inland. Also, as aforementioned, whilst Barbados tends not to be hit directly by storms and hurricanes, damage from storm surge and excessive rain and flooding is not unheard of from passing systems; and these storm related impacts are grossly amplified by sea level rise.

In light of this, the critical issues/factors for Barbados in need of urgent address are :

- **intensification of human settlement in the 2km coastal zone**
- **Concentration of tourism related infrastructure in the 2km coastal zone**
- **Uncontrolled and ill-conceived coastal development schemes**
- **poorly maintained drainage infrastructure in the high density coastal population centres.**
- **severe weather events which are economically damaging to the economy**
- **mismanagement of coastal and marine resources including wetlands, sand dunes and beaches, coral reefs, and sea grass beds.**
- **diminishing ground water resources.**

Anticipated global climate change and subsequent sea level rise, alterations to sea surface temperature and wind/ocean patterns, and an increase in severe weather events will seriously compound the above mentioned problems.

### **Linkages**

As Barbados is low-lying, flat and densely populated along the south and west coasts, a policy is needed to restrict the size of houses per plot of land depending upon the size and location of the plot, so as to reduce the paved/concrete area that would create surface runoff, hence, exacerbating the problem of coastal flooding.

A similar policy is needed to cater to the tourism infrastructure as the yearly meteorological reports predict increasing numbers and intensities of tropical disturbances. A policy that will restrict the amount and types of tourism related infrastructure along the coastline through building codes, as well as encouraging development set back regulations more than 200 metre from the shoreline (which is the current legal distance) is needed. This policy will serve to help to reduce damage and prevent the coastal tourism developments from millions of dollars in damage in the event of a major tropical storm.

As Barbados is only 166 square miles it therefore takes no longer than 15 to 20 minutes driving from the centre of the island to the nearest beach. There is also an extensive

road network with more than adequate signage that runs throughout the entire island. Thus, a policy with added incentives is needed to encourage tourism development away from the coastline to help reduce the “concrete jungle” effect already being experienced along the west and parts of the south coast. Barbados can begin to establish an eco-tourism market which will serve to diversify the tourism industry and its related activities. Tourist resorts can be inland, away from the overpopulated coasts, away from the flood prone areas whilst still being in close enough proximity with easy access to any of the beaches.

As reduced rainfall is predicted, doubled with the fact that Barbados has been listed among the top 5 water scare countries in the world by the UN, the government should move to implement a policy which encourages the augmentation of water resources from non-traditional sources such as desalination; particularly with recent moves towards development of golf courses for tourism purposes.

In an island like Barbados, with groundwater acting as the only source of freshwater available to the island, decreased rainfall means low aquifer recharge, and increased chance of saline intrusion. Hotels and businesses should be encouraged to reduce water use with the addition of water saving mechanisms in the bathrooms and/or water collection and storage tanks as are found at Coconut Court Hotel and Caribbean Home Insurance.

## **2.1 Impacts of *potential changes* in Sea-Level, Hurricane Characteristics, Storm Surge, Rainfall Patterns and Temperature:**

### **General Sea Level Rise (SLR) Induced Impacts**

Based on known mean rates of tectonic uplift, derived from geological evidence for Barbados, as well as global and regional projections, a medium sea level rise scenario of 5 mm per year is considered to be the current best estimate.

The principal SLR impacts expected are :-

- (i) Coastal Erosion;**
- (ii) Inundation; and**
- (iii) Saltwater intrusion into coastal aquifers (salinisation)**

These impacts can be described in a general manner.

#### **2.1.1 (i) Expected Erosion Impacts**

##### **Beach and shoreline stability**

Given the fact that many of the island’s beaches are narrow (averaging 12-15 m wide), and of gentle gradient (generally less than 10°), sea level rise is expected to bring about

significant shoreline/beach loss. The rate of such loss will be influenced locally by such factors as nearshore bathymetry, incident wave energy, amplitude spectra, wave approach direction, physio-chemical, geologic and morphologic properties of shoreline materials, sediment transport pathways, sediment sources and production rates.

Another major concerning factor is profile steepening, where underwater portions of the beach in the nearshore erode more quickly than the visible portion. This is of special significance since a steeper gradient of the beach permits greater wave height during storm events, removing the historical coastal protection that flat beach profiles provided. It should be noted, however, that the rate of cliff or beach erosion will not necessarily be identical to the rate of shoreline retreat, since beach propagation can occur simultaneously due to other depositional and nourishment processes

As the sea erodes the coastline removing valuable beach sand and soil, the roots of mangroves become exposed. If the roots are not firmly secured in the ground the trees lose their stability and grow at an angle to the ground, often falling over completely. This destroys the habitat of the dependant wildlife. The two major wetland locations in Barbados at present are situated approximately 250 metres inland and one of the wetland areas is protected by sand dunes. If the dunes are eroded the wetlands themselves become vulnerable to the erosive forces of the sea. This erosive effect will have similar consequences on any other coastal vegetation

### **Fisheries**

SLR induced erosion is expected to exacerbate the loss of already limited shoreline space for vessel haul up, as well as to damage the fisheries infrastructure significantly.

### **Agriculture**

Agricultural activities are concentrated mostly in the central parts of the island and therefore are not likely to be affected by the erosional effects of sea level rise.

### **Settlement**

Given the characteristics of the urban coastal corridor in Barbados, SLR erosion is predicted to have a large negative impact on human settlement and associated infrastructure.

### **Infrastructure**

The damage to infrastructure associated with SLR induced erosion would cripple the island since most trafficked highways would be dramatically affected. These major road systems provides Barbados with access to the hospitals, police, post offices, fire services and many other public services.

## **Tourism**

SLR induced erosion is expected to have wide scale, major impacts, both in terms of beach area loss, degradation of beach quality and ultimately depreciation of recreational value. This too will result in reduced visitor arrivals, shorter stay over, and a fall in repeat visits. And as tourism is one of the island's principal economic pillars, major economic losses might be expected.

The major source of beachfront erosion is caused by the passage of deep surface lows as they cross the Atlantic Ocean. These can occur at any time of the year and are a major threat to the low-lying areas on the west coasts, where most of the tourism is located.

## **Water supply**

Given the location of coastal wells and mains, SLR induced erosion is expected to significantly impact water supply in the urban corridor. Erosion is also expected to damage mains, which will have implications for fresh water quality, coastal water quality, as well as human and environmental health

## **Health**

In those areas where sewerage mains are located proximal to the shoreline, SLR induced erosion and inundation will likely damage mains, increasing the chance of the flourishing and transmission of water borne pathogens, increasing the chance of the outbreak of disease. In addition, vector borne diseases like dengue fever, which are temperature, rainfall and humidity sensitive, could increase in areas where inundation and decreased offshore flow occur.

### **2.2.9. Other Implications**

SLR related damage will increase the cost of sea defense works, engineering design and construction of protective structural solutions, as well as insurance premiums on coastal properties.

## **2.1.1 (ii) Expected Inundation Impacts**

The definition of inundation is given as "flooding, by the rise and spread of water, over a land surface that is not normally submerged".

It was recognised that sea-level rise would be the most serious problem when superimposed on high tides, storm and wave set up in severe storms. A large part of highly developed area of the south and west coast could be inundated in severe storms.

## **Beach and shoreline stability**

At the coast, a rise in sea level means that waves, which are limited by available water depth, can be of greater height and magnitude, resulting also in a reduction in the freeboard of coastal defences. This combination of factors means higher overtopping rates, and increased flooding of coastal property. The northwest, west and southwest

coasts of Barbados are characteristically low lying and sandy, and so are especially vulnerable to erosion. The east and southeast coasts, however, are generally cliffed with few 'pocket beaches', and so are potentially more resilient to the effects of sea level rise.

In 1994, Delcan International generated design water levels for the south and west coasts, for a 1 in 50 and a 1 in 100 year return storm event. Their analyses included water level considerations due to sea level rise, tide, beach crest elevation, wave setup, runup/surfbeat, inverse barometric rise, and suggested freeboard. Model runs were executed on a coastal reach by reach basis, and expected inundation/flooding elevations developed. A list of the critical infrastructure expected to be affected (see Appendix 1) and a coastal inundation map 3 were generated from the modelling exercise.

### **Marine ecosystems**

On most of the south coast, extensive flooding is predicted, up to and inland of the main coastal highway (Highway 7). For example, the area around Graeme Hall the island's last swamp, is extensively flooded up to 1km inland.

### **Settlement**

Towards the southwest, where the capital of Bridgetown is located, a flood zone of approximately 150 m wide is predicted; and as one moves farther up the west coast, the flood zone is expected to widen to some 300 m, before narrowing once again to about 150 m wide as one approaches the northernmost parts of the west coast.

Major impact from inundation is also expected as a high percentage of residential and commercial development are also concentrated in the 1 in 50 and 1 in 100 year event inundation zones.

### **Tourism**

A higher incidence of marine flooding on the sand terrace and coastal plain would place infrastructure and property at risk. Given the largely coastal nature of Barbados' tourism (more than 70% of tourist accommodation is less than 250m from the high water mark), the overall industry would be seriously dislocated.

### **Agriculture**

Marine inundation is not predicted to have a large impact on the agricultural sector, as most farm plots are located in the central area of the island.

### **Water supply**

SLR inundation will only present a significant threat to water supply if inundation precipitates excessive shoreline erosion.

### **Fisheries**

SLR induced inundation is also capable of significant damage to primary and secondary landing sites, although fisheries activity is unlikely to cease under such scenarios.



### **Infrastructure, Public Services, and Health**

Both SLR induced and inundation have great capacity for loss of industrial and economic activity, due primarily to damage of associated infrastructure. For example, industrial areas along the Spring Garden Highway (Highway 1), around the Greater Bridgetown area, include paint manufacturing, a rum refinery, a fuel storage and processing facility, a flour mill, and desalination plant, all well within the inundation and erosion zone. Leakage of chemicals from these facilities has great implications for environmental and human health.

In the Greater Bridgetown area, within the 1 in 100 year event inundation zone, one finds the Government Headquarters, two hospitals, the Coastal Zone Management Unit, the Ministry of Health, the Coast Guard Headquarters, the Barbados Port Authority, and the General Post Office. On the west coast, the Holetown Police Station sits right on the beach, as does the Weston Fire Station.

Associated with the flash flooding, is damage to roads and the erosion of soil from agricultural land. SLR induced inundation would cripple the island since most trafficked highways would be dramatically affected. These major road systems provides Barbados with access to the hospitals, police, post offices, fire services and many other public services. SLR induced erosion and inundation would cripple the island since most trafficked highways would be dramatically affected. These major road systems provides Barbados with access to the hospitals, police, post offices, fire services and many other public services.

The damage associated with SLR, induced erosion and inundation would cripple the island since the very seat of government, hospitals, the sea port, police and fire services and the most trafficked highways would be dramatically affected.

#### **2.1.1 (iii) Expected Salinisation Impact**

Barbados a low coral island, without large natural bodies of freshwater (eg. lakes and rivers) is completely dependent of its ground water supplies for domestic, agricultural, and industrial purposes extracted from freshwater aquifers to meet these water supply needs. All models for low limestone islands (eg. Barbados, Antigua, Bahamas) and coral atolls show that a 1m rise in sea level would lead to salt water intrusion into the fresh water lens. Barbados is listed among the top 5 water scarce countries in the world by the UN. Salinisation of the island's fresh water lenses ( in addition to the threat already posed by over pumping) would therefore seriously affect the availability of potable water.

Within the coastal zones of the west and south coasts, there a number of wells and pumping stations, utilised to provide potable water to the surrounding areas both for domestic purposes and agriculture. In recent times some of the wells located within the west coast have become increasingly saline, largely because of excessive rates of abstraction which in turn result from increased demand for freshwater and reduced

aquifer recharge rates. A rise in sea level will cause further salinisation with the intrusion of salt water into the coastal wells of the west coast, and a further diminishment in the amount of freshwater available for domestic and economic activity.

### **Coastal Ecosystems**

The mangroves wetlands are delicately balanced by specific concentrations of brackish water and therefore would be adversely affected by the introduction of extreme saline conditions as well as the habitat it supports

## **2.1.2 Hurricane Characteristics and storm surge; the expected Impacts on Coastal Assets/Economic Activities**

### **Tourism**

The fact that over 90% of all hotels are either on or proximal to the beach, it also means that the island's hotels are almost exclusively sitting within the 1 in 500 and 1 in 100 year storm inundation zones, and are therefore at risk for major structural damage. This translates to a large potential for facility closure and revenue loss.

### **Settlement**

In extreme events such as hurricanes, Barbados' vulnerability to the negative impacts of sea-level could be expected to increase. Model simulations suggest that if a hurricane (category 3 and above) should make direct landfall, coinciding with an astronomical high tide, a 2m wave generated by the system could reach at least 80m inland on parts of the west coast. With in the sea-level rise factor added to the equation, the threat to life and property would be exacerbated.

### **Infrastructure and Utilities**

On occasion, the strong downdrafts from thunderstorm activity can lead to minor structural damage to some buildings. This damage is normally in the form of a few downed trees and electricity poles along with damage to rooftops. Therefore in a hurricane situation we might expect significant loss of services, given the over ground placement of electric wires, as well as the vulnerability of the coastally situated water mains and industrial areas

## **2.1.3 TEMPERATURE and RAINFALL**

Global warming in of itself has potential implications for tourism, in that many of Barbados' tourists visit to escape the cold north, and so warmer, milder winters could remove some of the incentive of the traditional winter visitor to escape to warmer climes. Reduced rainfall, and hence availability of freshwater presents a crisis to any tourism industry. But the import of this climate change issue is being further aggravated in Barbados with the move towards water intensive golf course tourism, without

consideration of the augmentation of water resources (eg. by desalinisation, importation or increased conservation).

## **Health**

Higher temperatures could cause a higher incidence of heat waves and consequently related illness, especially cardio-respiratory illnesses. Global shifts in temperature regimes could bring an increase in the frequency and intensity of extreme events such as hurricanes and floods, and with that more deaths, injury, and infectious diseases would occur, especially in the tropics. Vector borne diseases like malaria, dengue and yellow fever are sensitive to changes in climatic factors such as temperature, rainfall and humidity. Projected climate change effects could potentially result in more efficient transmission of such vector-borne diseases. Mathematical models project the possibility of an additional 50-80 million cases of malaria worldwide with a temperature increase of 3°C. (Martens et al., 1995). There might also be microorganism proliferation in water bodies in tropical regions resulting in an increase in water and food-borne infectious diseases eg. algal blooms and ciguatera, which are associated with biotoxin contamination of fish and shellfish could become more frequent, and lead to higher incidences of cholera.

In addition, decreased rainfall which leads to water scarcity, can greatly affect sanitation processes.

## **Coral Reefs**

It is not expected that sea level rise will have a major impact on coral growth, as present upward growth rates can keep paces with projected increases. However, most species of corals live at or near their threshold of tolerance for temperature (25 -29 degrees). These organisms can be so temperature-sensitive that increases as small as 1-2 degrees above seasonal maxima can cause bleaching to occur (loss of pigmented algae yields paling in colour). Increases in temperature as a result of greenhouse gas emissions will cause a higher incidence of coral bleaching. Widespread bleaching and mortality occurred in the Caribbean following strong El Nino events (causing higher than normal sea surface temperatures) in 1982, 1987 and 1993. El Nino Southern Oscillation (ENSO) is only a periodically occurring phenomenon: elevated sea surface temperatures will be a permanent feature of the climate if excessive greenhouse gas emissions continue. Hence, more frequent episodes of bleaching are likely, unless the corals can adapt.

## **Fisheries**

Higher water temperatures would affect pelagic larvae, any damage to reefs could affect fish health, abundance and migratory patterns could be affected. Social and economic impact on fishing communities could be serious.

## **Infrastructure**

Increased rain intensity would increase flash flood frequencies. In 1998 for example, 15 such events occurred. In one event 5-9 inches of rain in 12 hours occurred causing

some structural damage

**Agriculture**

Decreased levels of rainfall will obviously have implications for crop growth rates and yields.

ISSUES	RANK	REASON
Tourism	1	<ul style="list-style-type: none"> <li>-The single largest revenue earner for the island</li> <li>-employing 25% of the labour force.</li> <li>-Of 135 hotel properties all except 12 are located in close proximity to the beach</li> </ul>
Settlement	2	<ul style="list-style-type: none"> <li>-25% of the island's population lives within 2.0km of the coast.</li> <li>-Increasing pressure for residential housing developments along the coast</li> </ul>
Water Resources	3	<ul style="list-style-type: none"> <li>-Along the coastal zones there a number of wells and pumping stations, utilised to provide potable water to the surrounding areas both for domestic and agriculture purposes</li> <li>-Ground water is the major source (98.6%) for public and private water supplies</li> </ul>
Human Health	4	<ul style="list-style-type: none"> <li>-increasing the chance of the flourishing and transmission of water borne pathogens.</li> <li>-increasing the chance of vector borne diseases like dengue fever</li> <li>-injury and death resulting from violent storms and hurricanes</li> </ul>
Marine ecosystems	5	<ul style="list-style-type: none"> <li>-resource economic valuations have been conducted for the reefs of the west and south coasts which are estimated to be worth \$ US 1156, 800, 035.</li> </ul>
Fisheries	6	<ul style="list-style-type: none"> <li>-26 coastal landing sites around the island</li> <li>-1% of GDP</li> <li>-2200 fishers employed</li> </ul>
Public Utilities	7	<ul style="list-style-type: none"> <li>-location of coastal wells, mainsand power generation plants, SLR is expected to significantly impact water and electricity supply in the urban corridor</li> </ul>
Infrastructure	8	<ul style="list-style-type: none"> <li>-SLR activity can lead to major structural damage to some buildings</li> </ul>
Industry	9	<ul style="list-style-type: none"> <li>-contributes 6.7% of GDP</li> </ul>
Agriculture	10	<ul style="list-style-type: none"> <li>-largely confined to the central areas of the island</li> <li>-only contributes 4.0% of GDP</li> </ul>

<b>Socio-Economic Sector</b>	<b>Biophysical Impact</b>		
	<b>Erosion</b>	<b>Inundation</b>	<b>Salinization</b>
<b>Tourism</b>	1	1	1
<b>Settlement</b>	1	1	1
<b>Human Health</b>	2	1	1
<b>Water Resources</b>	2	3	1
<b>Marine ecosystems</b>	2	2	2
<b>Fisheries</b>	2	2	3
<b>Public Utilities</b>	2	1	2
<b>Infrastructure</b>	1	1	3
<b>Industry</b>	2	1	2
<b>Agriculture</b>	3	3	2
<b><i>Economic Impacts</i></b>	1	1	1

1=Major Impact  
 2=Significant Impact  
 3=Minor/Negligible Impact

### **3.0 INSTITUTIONAL AND LEGAL ARRANGEMENTS FOR RESPONDING TO ISSUES**

There are approximately 37 main pieces of legislation in Barbados which deal with environmental (62% of the total), land use (27% of the total) and building issues (1% of the total). There is some overlap between the various categories of statutes, but fragmentation of approach is problematic.

In Barbados, the majority of the statutes were enacted in the early 1970's. Only 10 of the 37 statutes were enacted after 1992, the year of the United Conference on Environment and Development which began the global environment movement, when countries were encouraged to establish ministries of environment, with supporting legislation. Of the post-1992 legislation, 6 statutes are environmental in scope, the remaining four addressing land use matters. Hence the majority of Barbados' relevant statutes are outdated.

Due to a lack of resources (financial, human, technological), the modernisation of environmental laws and the appropriate strengthening of institutional capacity has not occurred in Barbados. Hence while one would expect a positive relationship between the enactment of environmental, land use and building laws, and economic development, this has not been observed in Barbados. The urbanisation of the coastal corridor over the last 30 years has resulted in an increase of land use and resource utilisation conflicts, pollution and population density, increasing the stress on coastal resources. However, the environmental, land use and building laws have not kept pace with the new challenges posed by the urbanisation process, and many of the relevant laws are quite ineffective.

#### **3.1. Relevance to the Coastal Zone**

The coastal zone or coastal area of Barbados is defined within the Coastal Zone Management Act (CZMA) as all those areas in which coastal resources are located. Coastal resources in turn are defined as "the land, water and living resources associated with the shoreline marine areas of Barbados, including beaches, shorecliffs, coral reefs, coral rubble, algal beds, sea grass beds, sand dunes, wetlands and other ecosystems found along the shore together with the flora and fauna found in these areas". Despite the apparently narrow geographical area inferred by this definition, the CZMA coastal management area is in actuality a much wider geographic area, as ordered by the Minister. To date no official coastal zone management area has been designated pursuant to the Act. Much of the literature follows the national Physical Development Plan (PDP), which describes the coastal zone management area as coinciding with the coastal urban corridor.

Generally all 37 pieces of environmental, land use and building legislation which exist in Barbados, while not exclusive to the coastal zone of the island, they are applicable to varying degrees to coastal zone management. The list of existing legislation is appended at Appendix 2, complete with a brief description of each statute.

## 3.2 Weaknesses

In discussing the weakness of Barbados' legal framework in managing the coastal zone, one can categorise weaknesses as either **substantiative** (gaps, omissions), or **procedural** (institutional weaknesses, fragmentation, overlaps).

### 3.2.1. Substantiative Weaknesses

#### 3.2.1.1. Environmental legislation

There is little or no comprehensive law to address environmental issues in Barbados. The Coastal Zone Management Act (1998) , although it seeks the more effective management of coastal resources and related matters, currently provides for the *drafting* of a coastal zone management plan comprising policies strategies and standards. This work is on-going.

#### ***Gaps/Omissions***

Gaps in environmental legislation identified in the literature, leave the following issues unaddressed :-

- implementation of multilateral environmental agreements (CITES, Climate Change, Basel Convention, Vienna Convention & Montreal Protocol, etc)
- protection and enhancement of ambient environmental conditions;
- prohibition and regulation of discharges to the environment\*;
- regulation of waste management and waste disposal operations\* ;
- control of nuisances such as dust, noise, vibrations\*;
- integrated environmental management\*;
- enforcement procedures.

Those gaps asterisked (\*) represent those where some attempts have been made to begin addressing the situation. The Marine Pollution Act, for example seeks to prevent, reduce and control pollution of the marine environment of Barbados, whatever the source; but there are no regulations under this act at the moment. The Ministry of Health Sewerage and Solid Waste Project Unit is currently working both on the infrastructure and regulation associated with sanitation and waste disposal. The Ministry of Health, Environmental Engineering Division has been identified to take the lead on air quality guidelines.

The Ministry of Environment, in its Environmental Management & Land Use Planning for Sustainable Development (EMLUP) study (completed in 1999), included the drafting of both comprehensive environmental legislation to address environmental issues, as well as institutional strengthening guidelines to permit the Ministry to carry out the duties proposed in the draft Environmental Management Act. However due to the long delays associated with comments required from other ministries and the evaluation of the



economic implication of the institutional strengthening process, the environmental management process has been effectively stalled.

### **3.2.1.2. Land Use legislation**

The Town Planning & Country Planning Act (TCPA) provides the legal framework for the physical land use planning system. However, this land use planning system emerged in the 1950s when the island's economy was moving away from the sugar monoculture to tourism, industry and services; and so does not take environmental or climate change issues into consideration.

This Act provides for three key management functions:

- (i) A national Physical Development Plan (PDP) system;
- (ii) A Development Control System; and
- (iii) An Enforcement System.

The first national Physical Development Plan for Barbados was approved in 1976 and amended in 1988. Government is currently finalising the 1998 PDP amendments. The TCPA mandates a review of a development plan every five years after it comes into operation. The PDP is Barbados' single most important policy document as it patterns land use and physical development, though with a flexible approach, where land uses are assessed according to the expected external impacts likely to be generated.

The development control system is used to determine the issue of and permitting of land development proposals. Under the TCPA, development has a wide scope including building, mining, engineering and other operations, in, on, over, or under any land; the making of material change in the use of buildings or other land or the subdivision of land. Development also extend to the sea bed within the 12 nautical mile territorial sea of the island. The Development Order (1972) allows for certain classes of permitted development that do not require formal planning permission.

The act provided for a variety of enforcement actions including the serving of enforcement notices, stop notices, penalties (including fines and imprisonment).

### ***Gaps/Omissions***

Some of the gaps identified in the literature include :-

- lack of Environmental Impact Assessment guidelines (EIA);
- lack of preparation of plans at the intermediate and local level;
- lack of genuine participation by the public within the planning process;
- inadequate protection of natural areas;
- lack of national parks legislation; and
- weak enforcement provisions.

### **3.2.1.3. Building Legislation**

There are no statutes covering building codes and national standards for the design and construction of buildings, not even for the mitigation of effects from natural disaster and emergencies.

### **3.2.2. Procedural Weaknesses**

There is significant fragmentation, duplication and overlap of jurisdiction and general institutional weakness within the existing environmental, land use and building laws.

#### **3.2.2.1 Environmental Legislation**

At the moment, environmental management is fragmented between various ministries, such that environmental issues are either addressed in an ad hoc manner, or not at all. The Ministry of Environment, Energy & Natural Resources currently acts as the institutional focal point for comprehensive environmental management. However, as aforementioned, with the delays attendant to the draft Environmental Management Act and the institutional strengthening of the Ministry, this agency is unable to effectively coordinate national environmental policy.

An example of fragmentation can be seen within the issue of hazardous chemicals and substances management, which currently involves the Ministry of Environment Energy & Natural Resources, the Ministry of Agriculture, two divisions of the Ministry of Health, Ministry of Labour, and Customs & Excise. The Ministry of Environment, Energy & Natural Resources has drafted a comprehensive management structure, but again its implementation has been delayed.

Fragmentation, outdated legislation and under-utilisation of provisions can be also be observed within the areas of water resource protection, surface water management, and conservation of natural heritage resources, flora and fauna.

#### **3.2.2.2. Land Use Legislation**

The weaknesses identified in the literature are:-

- the need to strengthen the mandatory consultation process by including critical agencies such as the Coastal Zone Management Unit;
- provide for greater public participation in the planning process by increasing access to information and general transparency of processes.

### **3.2.2.3. Building Legislation**

With respect to procedural weaknesses, there must first be the establishment of an institutional focal point to coordinate the implementation of building design standards.

### **3.2.2.4 Other (Draft) Policy, Standards & Institutional Arrangements**

It would be an incomplete analysis of the legal framework without acknowledging non-legislated practices and relevant draft legislation, since informal cross-sectoral consultations significantly buttress the fragmented legal framework available to monitor Climate Change issues in Barbados.

The current TCPA, mandates, for example, consultations with the Environmental Engineering Division (EED) of the Ministry of Health (for matters pertaining to sewerage and waste water disposal), the Barbados Water Authority (BWA), and the Ministry of Agriculture (MAR) (where there is subdivision of agricultural lands). The most recent revision of the TCPA however, formally proposes the addition of other critical agencies in the process, such as the Coastal Zone Management Unit (CZMU), although this in effect simply regularises consultative practices of the last decade and a half or so. It is currently common practice for the Town & Country Planning Office (TCPO) to form an ad hoc Environmental Impact Assessment Committee (including such agencies as Coastal Zone Management Unit (CZMU), Environment Unit (EU), Barbados Water Authority (BWA), Ministry of Public Works & Transport (MPT), Ministry of Agriculture (MAR)) to better access the range of technical expertise across the Government in guiding the physical development process. The Government of Barbados is currently moving towards regularising this process with the passing of draft EIA Guidelines to formally trigger the EIA process.

Also, the Ministry of Public Works and Transport (MPT) is in the process of drafting an amended Building Code with some input from the Barbados National Standards Institute (BNSI), CZMU and Central Emergency Relief Organisation (CERO). The amendments are geared to addressing (hurricane) wind resistance in structures on land, but Coastal Engineering Design Criteria have to date not been included in the draft Building Code, thereby leaving it largely unable to adapt to such SLR induced impacts as flooding and coastal erosion.

Another significant piece of draft legislation is the so-called Accretion Bill (or Draft Beach Accretion Act 2000), which seeks to make all land accreted subsequent to the enforcement of this Act, property of the Crown. As such, the Crown alone will be given exclusive authority to construct, or approve the private construction, of any structures specifically designed to cause the accretion or to prevent erosion of land. When completed and brought into force, this will be a flexible piece of legislation to address SLR-induced impacts of erosion and flooding in particular. Such compulsory acquisition of land will also assist in better delimitation and development of vulnerable, unstable coastal areas.

### **3.3 Adequacy of the Present Legal Framework to deal with the Sea Level Rise**

Section 2 of this report examined the key issues with respect to climate change. It was acknowledged that sea level rise, and the attendant impacts of erosion, inundation and salinization of freshwater resources, were of the greatest import to the island of Barbados. The matrix below, adapted from the literature, seeks to highlight what legal framework is in place, whether what is in place is adequate, as well as to highlight what is needed.

In adapting to climate change, countries have a choice of strategies:-

**Strategy A:** Prevention of Loss, Tolerating Loss (Enhancing the Resilience of Natural Systems), Spreading Sharing of Loss

**Strategy B:** Changing Use or Activity (involves a switch of activity or resource to adjust to the consequences of climate change)

**Strategy C:** Relocation/Retreat

**Strategy D:** Restoration (following damage or modification of systems due to climate change).

In Barbados, there is limited area for retreat (Strategy C), so Strategies A and B, and, where cost allows, Strategy D, will largely be pursued. Legally, the response to impacts is either to prevent or reduce effects; and so the matrix highlights how the present legislative framework prevents or reduces the SLR induced impacts. Oderson (2000) who constructed this matrix, also included an effectiveness rating system, where '0' indicates that a legal response does not exist, '1' indicates the legal response exists, but is inadequate, and '2' indicates that the legal response is adequate.

IMPACT	LEGISLATION	AGENCY RESPONSIBLE	PREVENTION RESPONSE	STATUS	REDUCTION RESPONSE	STATUS
Coastal Erosion	CZMA	Coastal Zone Management Unit (CZMU)	Integrated CZM Sea defence structures Beach Nourishment EIA	2221	Integrated CZM Economic instruments	22
	TCPA	Town & Country Planning Office	Building Set Back Land Use Control EIA Selective Relocation	2200		
	Health Services Act	Ministry of Health, Environmental Engineering Division (EED)	Control of Land-Based Sources of Pollution	2	Land based sources of pollution	2
	Trees Preservation Act	Town & Country Planning Office	Protection of Trees	1	Protection of Trees	1
	Cultivation of Trees Act	Ministry of Agriculture	Promotes Tree Cultivation	1	Economic incentives	1
	Land Acquisition Act	Town & country Planning Office	Land Use Acquisition for public use	2		
	Crown Lands Act (Vesting 7 disposal Act)	Town & country Planning Office	land use and tenure control	2		
	Marine Pollution Act	Ministry of Health, EED	Marine Pollution Land-based sources	22	Marine Pollution Land-based sources Economic instruments	222
	Building Code	Town & Country Planning Office; CZMU ?	Design & construction standards	0		
	Environmental Management Act	Ministry of Environment, Energy & Natural Resources (?)	Environmental Planning Standards and Policies EIA	0	Environmental Planning Standards and Policies EIA	0

**Table 1:** Matrix to analyse Legal framework for adaptation to coastal erosion.

IMPACT	LEGISLATION	AGENCY RESPONSIBLE	PREVENTION RESPONSE	STATUS	REDUCTION RESPONSE	STATUS
Flooding	CZMA	Coastal Zone Management Unit (CZMU)	Sea defense structures Integrated Coastal Zone Management (ICZM) EIA	221	ICZM EIA	21
	TCPA	Town & Country Planning Office	Building Set back Land Use Control Building Standards (type, density, setting) EIA Selective Relocation	22200	Land Use Control EIA Selective relocation	200
	Prevention of Floods	Ministry of Public Works & Transport, Drainage Unit	Execution of Flood Works Prohibition on activities in flood areas	22	Execution of flood works Declaration of flood areas	21
	Health Services Act Health Services (Building) regulations, 1969	Ministry of Health	Prevention, treatment and suppression of disease Maintenance of sewerage works	22	Drainage and grading of lands before construction Building standards	21
	Land Acquisition	Town & Country Planning Office	Land Use Control	2		
	Trees Preservation	Town & Country Planning Office	Protection of Trees	1	Protection of Trees	1
	Cultivation of Trees	Ministry of Agriculture	Planting of trees	1	Economic Incentives	1
	Crown Lands (Vesting & disposal)	Town & Country Planning Office	Land Use Control	2		
	Building Code	Town & Country Planning Office (?)	Design Standards	0	Building design administration, monitoring & enforcement	0
	Caribbean Disaster Management Act	Caribbean Disaster Response Agency; ministry	Disaster Preparedness	0	Disaster Mitigation & Management Response & relief	0
	Emergency Powers				State of emergency	

**Table 2 : Matrix to analyse Legal framework for adaptation to flooding.**

IMPACT	LEGISLATION	AGENCY RESPONSIBLE	PREVENTION RESPONSE	STATUS	REDUCTION RESPONSE	STATUS
Salinization	TCPA	Town & Country Planning Office	Land Use Control	2	Building Standards	0
	CZMA	Coastal Zone Management Unit	Standards for Water Quality	2		
	Health Services Act	Ministry of Health, Environmental Engineering Division (EED)	Water quality monitoring Water Quality control	11		
	Barbados Water Authority Act	Barbados Water Authority	Water Quality  Water Production  Water consumption	222	Conservation Measures  Water Saving incentives  Economic instruments, fines  Building requests eg. water tanks	1012
	Underground Water Act	Barbados Water Authority	Management of water resources through licences	1	Monitoring of water resources	2
	Environmental Management Act	Ministry of Environment, Energy & Natural Resources	Environmental Planning  Environmental Standards	0	Environmental Management	0

**Table 3:** Matrix to analyse Legal framework for adaptation to salinization.

### 3.3.1. Adequacy of the Legal Framework with respect to Coastal Erosion.

The legal response to the *prevention* of coastal erosion might be expected to include:-

- standards and guidelines to control pollution;
- land use standards and policies to control development;
- EIA guidelines to evaluate proposed development;
- integrated coastal zone planning to identify sensitive coastal resources and restrict harmful activities, thereby strengthening the resilience of the coastal ecosystem and enhancing their capacity to protect coastal regions;
- provision for the controlled erection of coastal defence structures and coastal engineering works;
- compulsory land acquisition;

whilst the legal response for the *reduction* of the impacts of coastal erosion would include:-

- physical development plans and policies (eg. set back guidelines, selective relocation of critical agencies currently within susceptible areas);
- coastal zone management plans, clearly demarcating coastal zone management areas;
- environmental management plans, which encourage protection and conservation of natural resources.

The existing laws which best address erosion issues are:

- (i) Coastal Zone Management Act (CZMA);
- (ii) Town & Country Planning Act (TCPA) (acting jointly with the Development Order (1972), which prescribes detailed planning standards and development guidelines within the TCPA overarching planning framework);
- (iii) Health Services Act
- (iv) Marine Pollution Act
- (v) Trees Preservation Act
- (vi) Land Acquisition Act
- (vii) Crowns Land Act.

Between them, these legal instruments provide:-

- (i) preparation of the national Physical Development Plan, which ensures the achievement of national settlement objectives, sensitive areas requiring special management such as groundwater protection areas and national parks systems;
- (ii) development standards, densities, building set backs, restricted building and development zones;



- (iii) some element of prevention, control and management of land-based sources of pollution;
- (iv) the ability to compulsorily acquire land to reduce the number of persons at risk to the impacts of erosion and allow for the implementation of appropriate preservation and conservation strategies.

However, with the exception of perhaps the CZMA , none of these laws directly considers the impacts of climate change. As a result the overarching weakness of these laws is a failure to incorporate the precautionary principle and other principles of best practice.

Other gaps and omissions are:-

- lack of EIA guidelines
- lack of provisions that promote the selective relocation of critical services (eg. fire, ambulance, public utilities)
- lack of comprehensive environmental legislation
- lack of comprehensive environmental standards and practices

As aforementioned, the draft Accretion Bill, should it come into force, should go a long way towards addressing erosion issues. In addition, in guiding physical development, the TCPO has long practiced an informal EIA process involving key government agencies, and draft EIA guidelines have been completed.

### **3.3.2. Adequacy of the Legal Framework with respect to Flooding.**

The legal response to the prevention of flooding might be expected to include:-

- erection and maintenance of coastal defence works;
- land use standards and policies such as building set back, flood plain mapping, restricted development areas;
- integrated coastal zone planning;
- EIA guidelines to evaluate proposed development;
- compulsory acquisition of land and selective relocation of critical emergency agencies;
- implementation of disaster plans that include the identification of vulnerable areas;
- provisions for the declaration of a state of emergency
- implementation of minimum design and construction standards.

In reducing the effects of SLR induced flooding, however, one must employ a combination of anticipatory management and mitigation strategies such as:-

- implementation of disaster plans including warnings, relief and response;
- monitoring and enforcement of minimum design and construction standards;
- selective relocation of critical emergency agencies;
- public health policies to reduce incidences of vector borne and water borne diseases.

The existing laws which address SLR induced erosion issues also address those of flooding/inundation, with the additional backing of:-

- (i) the Prevention of Floods Act (provides for the execution of works necessary to prevent and control flooding caused by excessive rains and high tides); and the
- (ii) Emergency Powers Act (provides for the declaration of a state of emergency in the event of severe public crisis)

Again, the Prevention of Floods Act does not directly consider the additional implications of sea level rise, which can act to make the assessment of vulnerable areas inaccurate.

The gaps or omissions of existing laws as pertains to their ability to address SLR induced flooding or inundation have been summarised as follows:-

- lack of EIA guidelines;
- lack of provisions which promote selective relocation of emergency services;
- lack of a building code and design, construction standards;
- lack of disaster management legislation;
- weak enforcement procedures and anticipatory planning requirements relating to the management and maintenance of drains, culverts, gullies and other water courses, private wells etc.;
- general failure to incorporate the precautionary principle and other principles of best practice.

Again the informal EIA process currently practiced by the TCPO as well as the draft Accretion Bill may speak to the issue of flooding or inundation. It remains to be seen whether the draft Building Code currently being completed will contain coastal engineering design criteria, which take into account flooding/inundation impacts on structures.

### **3.3.3. Adequacy of the Legal framework with respect to Salinization.**

Salinization can result both from the inland migration of the saline-freshwater interface that generally accompanies sea level rise, as well as the over abstraction of groundwater. Legal responses to the prevention of salinization might include:-

- control of land uses and water use within catchment areas

- water quality monitoring and control
- mandating practices which favour ground water recharge

The response for the *reduction* of salinization:-

- water conservation
- water quality monitoring
- land use control
- provision for the non-traditional supply of water to the public eg. desalinisation

In Barbados currently, legislation which might address salinization issues are;-

- (i) TCPA
- (ii) CZMA
- (iii) Health Services Act
- (iv) Barbados Water Authority Act
- (v) Underground Water Act

The TCPA, CZMA and Health Services Act have been described previously. Under the Barbados Water Authority Act, the Barbados Water Authority (BWA) has sole authority for the supply of potable water to the public. In the face of increasing demand, the BWA has introduced a number of conservation strategies including the provision of water saving devices, application of economic instruments (fines, penalties), prohibition of certain activities in the dry season (watering of lawns; washing of cars), the augmentation of water supply through desalinisation, and the augmentation of groundwater recharge of the aquifer. As aforementioned, the Underground Water Act provides the licencing system for private persons and companies, that allows the BWA to control the rate and amount of draw down on groundwater.

Again, there is limited acknowledgment of the possible added effects of sea level rise and its salinization effects.

A summary of the weaknesses in the legal response to salinization:-

- overlap and duplication of the functions of water quality monitoring and control;
- lack of a comprehensive environmental management act;
- lack of comprehensive environmental standards, guidelines etc.;
- absence of EIA guidelines.

## **4.0 TOWARDS AN ADAPTATION POLICY**

### **4.1 Guiding principles**

Given the discussions in the previous sections of this paper some general guiding principles for the development of adaptation policy might be laid out:-

#### **Coastal infrastructure/Human Settlement**

In light of the potential for SLR induced inundation and erosion at the coast, there is a need for a more comprehensive system for the control of coastal development. This includes not only better assessment of the location of new structures relative to the shore (enforcement of building setback etc.), but also relocation of critical services (such as Fire, Public Utilities like Barbados Light & Power, Government Headquarters etc.) currently located in the vulnerable corridor.

There is also a need for a Building Code which takes into account the coastal engineering specifications which would provide minimum design and construction standards to address not only increased wind resistance of structures, but also adaptation to increases in flooding/inundation.

#### **Beach/Shoreline Stability**

There must be strict regulation of activities which affect shoreline stability such as sand mining, destruction of reefs, uncontrolled construction of groynes, breakwaters, sediment-trapping devices or any structures which might affect accretion/erosion processes, since these can exacerbate the threat of erosion posed by climate change and sea-level rise.

#### **Water Supply**

Given the potential changes in rainfall regime, there is a need to more strictly regulate water use, as well as to introduce mandatory augmentation of water supply for new development which might significantly stress supplies. This is especially crucial in the face of the rapid development of upscale golf course tourism on the island.

### **4.1.1. Tasks, Needs & Requirements for the Development of Effective Policy**

In considering general areas of adaptation policy, however, one can recognise a need for certain areas of research to inform such policy, such that truly comprehensive and effective, regulatory instruments can be developed. Key research to inform such a process might include the following tasks, needs and requirements:-

- A reassessment of Barbados' specific projected rates for sea level rise under

high, medium and low scenarios.

- Quantification of beach/shoreline loss for high, medium and low projected scenarios for 2000, 2005, 2050, 2075, 2100 from a selected base year.
- Development of an integrated climate change adaptation plan which is fully incorporated into the national physical development planning process.
- Quantification of economic losses from shoreline loss due to sea level rise in comparison to the cost of shoreline works and maintenance; along with a general assessment of adaptation costs.
- Training of relevant government officers in remote sensing, climate change modeling and vulnerability assessment.
- A re-assessment of all historic technical data from a sea level rise climate change perspective (to identify previously unrecognized trends etc).
- An assessment of sediment transport pathways, transport rates and production supply rates based on sea level rise scenarios.
- Study of the effects of sea level rise on coastal wells taking into account ground water recharge, seasonal precipitation patterns and abstraction rates based on projected water supply demands.
- An assessment of existing shoreline protection infrastructure with respect to functionality under sea level rise scenarios.
- An assessment of the design and functionality of key fisheries complexes and jetties under sea level rise scenarios.
- An assessment of vulnerability to produce adaptation options for coastal water and sewage mains under sea level rise scenarios.

#### **4.1.1.2. Government/political level in support of policy framework and implementation**

In developing the policy framework, as well as its implementation plan, it is also vital to have consultations and education of several groups. Without such interaction, there is a risk of producing policy that is incomplete in its scope and/or weak in its ability to be enforced. Apart from the Ministry of Environment and the Town Planning Department, the consultative process should include the following:-

- Stakeholder level - dissemination of technical information to professional groups, eg. engineers, architects, planners, developers

- General Public education programme:
- consequences for general population, eg. loss of beaches, property, infrastructure
- loss/damage to property
- National Consultation - public and private sector
  - Ministry of Housing
  - Ministry of Tourism & International Transport
  - Ministry of Industry & International Business
  - Ministry of Finance & Economic Affairs
  - Ministry of Agriculture
  - Ministry of Public Works & Transport
  - Insurance
  - Business/Industry
  - Professional Communities

## **4.2 Specific Options for Adaptation (by Sector)**

### **Tourism and Settlement**

- coastal tourist facilities and properties need to be made more resilient with limited use of the ground floor, the incorporation of stringent coastal engineering into structures (eg. raised floors) and other strengthening.
- stronger hurricane and storm preparedness measures are needed, e.g. shelters to cater to the most vulnerable hotels; ensuring that structures are built to withstand hurricane force winds.
- building codes and set backs for new buildings need to take climate change projections into account.
- protection with breakwaters, other structures, as constructed by or overseen by government, coastal engineers.
- limit surface runoff effects on coastal erosion by minimising paved surface on coastal properties and the like.
- practice integrated coastal zone management.
- limit occupancy of flood plains of small watercourses.
- provide heavy rain and flash flood warnings.

### **Fisheries and Marine Ecosystems**

- reduce other stresses on reef systems and sea grass beds by reducing erosion, pesticides, fertilizers from land.
- protect against mechanical destruction of reefs, mangroves and coastal vegetation (eg. better regulation of mooring of boats, indiscriminate clearing of mangrove and coastal vegetation and structures)

### **Water Resources**

- augment supplies - desalination already planned.
- intensify water conservation efforts including higher tariffs for greater consumption.
- limit salinity to protect health and agricultural soils.

### **Disaster Preparedness**

- adequate storm warning and preparedness systems.
- publicize past events (e.g. Hurricane Janet of 1955) to ensure greater alertness.
- develop a more effective disaster management plan in tourism sector.
- enlist support of insurance industry to provide and publicize lower premiums for less vulnerable buildings.

### **Human Health**

- strengthen public health services and prevention programs for tropical diseases.

### **Utilities/Services**

- where possible, the relocation of critical services from within the coastal inundation zone.

## **4.3 Opportunities and constraints**

As the impacts of sea-level rise have been ranked as the most crucial for Barbados, the assessment for potential opportunities which might arise in the face of climate change has been based on sea-level rise being of greatest affect for the island.

### ***(i) Diversification in the Tourism Product***

A potential opportunity might be inland tourism development, which currently relies almost exclusively on coastal assets. Eco-tourism is already being investigated by the Government of Barbados, as is the development of sports-based tourism, particularly golf course tourism. Such a move reduces dependance on coastal areas and resources, and could act to decrease the number of vulnerable facilities and services at the coast, thereby reducing the potential for economic losses.

The constraint to such development, however, lies mainly in the relatively poor infrastructure inland, eg., roads and signage are in poor condition, and unsuited to heavy traffic. Also, there is a need to assess the viability of ecotourism, and the ability of fragile land-based ecosystems (such as gully systems) to withstand increased exposure to humans. Another problem arising is the fact that golf course tourism is extremely water intensive, and as a result there is an urgent need for water augmentation processes to accompany such development. To date, desalinisation has been investigated, but such processes are limited to the coast, since the sea acts as a source

of saline/brackish water needed. Therefore, extremely costly water saving options, and extra measures in golf course design are likely to be needed, if the island's water supply is not to be critically affected by such development.

## ***(ii)Development of Renewable Energy***

A focus on climate change and the role man plays in the process, has also given impetus to the development of renewable energy. Barbados has already gone a considerable way in such research and development, and a synopsis of executed and planned renewable energy projects is set out below. These projects have been carried solely or in part by: the Centre for Resource Management & Environmental Studies (CERMES) University of the West Indies (Cave Hill Campus); the National Commission on Sustainable Development (NCSD); and/or the Ministry of Environment, Energy & Natural Resources, Barbados.

### ***Projects already executed:***

The CERMES team has executed a number of solar projects in Barbados and the wider Caribbean.

#### **1. Solar Photovoltaic Projects:**

- 17.3 kW installation at Harrison's Cave, Barbados - One of the island's main tourist attractions
- 11 kW installation to power a 1 tonne ice machine at a rural fishing village in Barbados – being set up
- 5 kW system at Government Headquarters in Barbados for exterior lighting and emergency power supply – being set up
- 3 kW system installed at the Combermere School in Barbados to power computers in science laboratories
- 1.1 kW installation at CERMES used for the testing and research of various solar installations including a small ice-making machine and solar air conditioning

#### **2. Solar Drying Projects:**

- 149m<sup>2</sup> dryer at Friendship Plantation in Barbados
- 40m<sup>2</sup> dryer in Antigua
- 30m<sup>2</sup> dryer at the National Flour Mills – Barbados
- 30m<sup>2</sup> drying system at Toco, Trinidad



- 7m<sup>2</sup> dryer in Grenada

### 3. Solar Distillation projects:

- 100m<sup>2</sup> of distillation units operated by Mr. Selwyn Bharath in Diego Martin, Trinidad
- 67m<sup>2</sup> of distillation units on the roof of the Chemistry department at the University of the West Indies, Trinidad
- 20 solar stills produced for government secondary schools in Barbados
- 50 solar stills at schools in Trinidad and Tobago
- 50 solar stills at schools in Jamaica

### ***Planned Projects:***

Future projects planned by the CERMES and NCSD teams include solar projects as well as wind and ocean thermal energy conversion projects.

#### 1. Solar Photovoltaic Projects:

- 500 kW to be installed at Cave Hill Campus of the University of the West Indies
- 200 kW to be added to the installation at Harrison's Cave in Barbados
- 110 kW to be installed on a new Government building
- 90 kW to be added to the installation at Combermere School in Barbados
- 15 kW to be installed at Wildey House in Barbados, the headquarters of the Barbados National Trust.

#### 2. Wind Projects:

- 9.2 MW windfarm at Lambert's in Barbados – Ministry of Environment, Energy and Natural Resources (MEENR)
- 4 MW windfarm also at Lambert's in Barbados - Ministry of Environment, Energy and Natural Resources (MEENR)

#### 3. Ocean Thermal Energy Conversion (OTEC)

- A 10 MW OTEC installation is planned for North Point in St. Lucy, Barbados – Jointly planned with UWI, Mona and the Ministry of Environment, Energy and Natural Resources (MEENR), Barbados.

- 7m<sup>2</sup> dryer in Grenada

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#### 3. Ocean Thermal Energy Conversion (OTEC)

- A 10 MW OTEC installation is planned for North Point in St. Lucy, Barbados – Jointly planned with UWI, Mona and the Ministry of Environment, Energy and Natural Resources (MEENR), Barbados.

#### 4. Other

- The Barbados Light & Power Company is currently working on a 60MW co-generation plant, which is to produce electricity utilising sugar can bagasse during the crop season. There is currently a search on for the alternative fuel to be used during the rest of the year, although it is likely that natural gas will be used.

Much of the difficulty encountered in developing renewables locally has been cost-related. The need for initial capital investment has largely slowed progress in this area, although the recent increase in oil prices, as well as the fact that climate change is slowly being recognised as a very real phenomenon, has spurred government to assist in the advancement of this area.

### **5.0 SUMMARY AND CONCLUSIONS**

As a small, low-lying island, Barbados faces sea level rise as the biggest impact of climate change. This vulnerability is heightened by the near exclusive location of settlement, critical services and infrastructure, hotels and other businesses and industry within the coastal corridor. In addition, climate change-induced changes in rainfall regime, should they result in reduced rainfall, could affect inland development on the island, which is already characterised as water scarce.

Given these facts, it is clear that adaptation policy should include the following:-

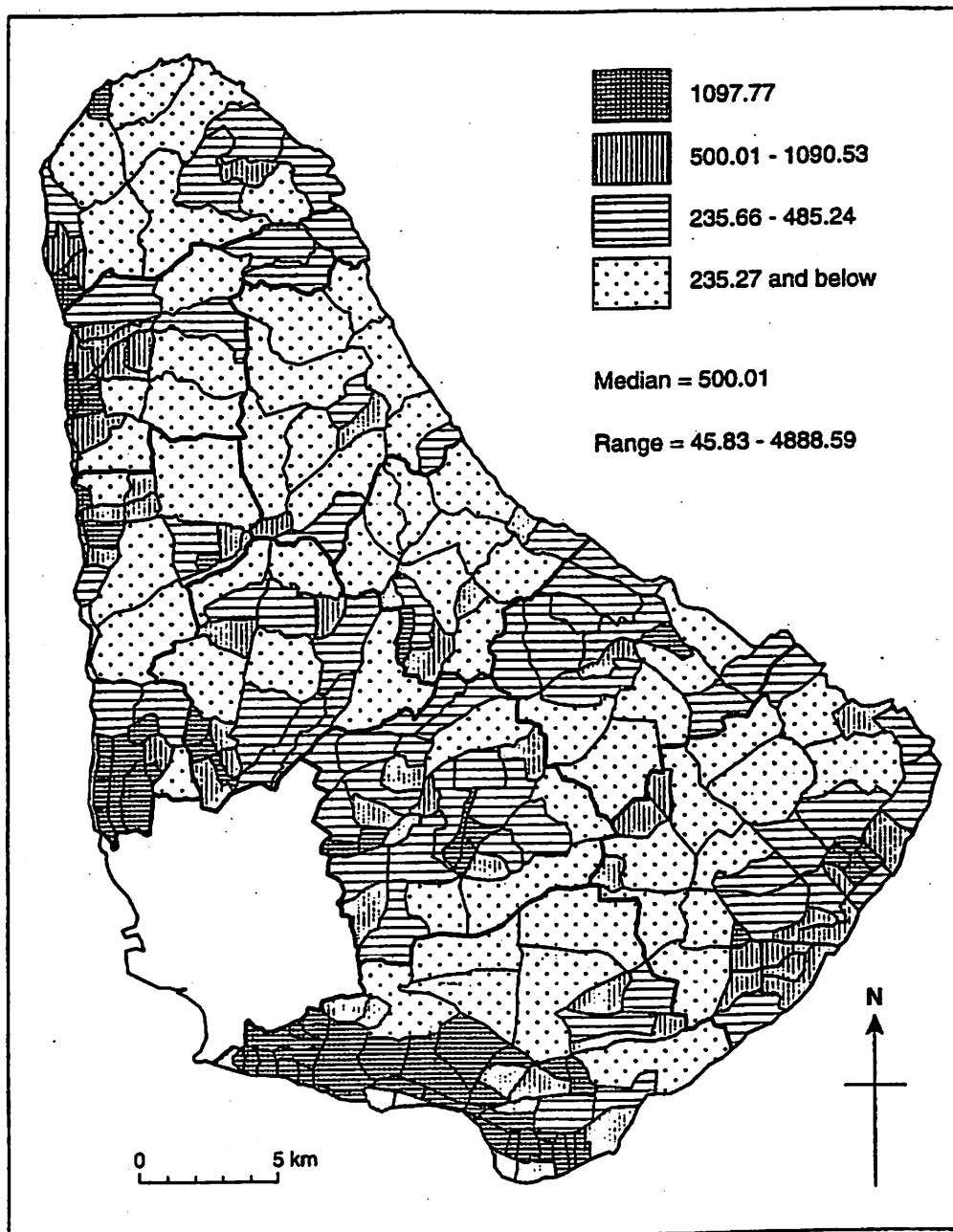
- ▶ provision for the reinforcement of existing coastal structures and infrastructure;
- ▶ where possible, relocation of critical services from within vulnerable coastal areas;
- ▶ for new coastal development, a comprehensive regulatory system, to guide proper location of structures relative to tide marks, as well as to ensure that strict coastal engineering standards are met to enhance structural resistance to extreme inundation and wind events;
- ▶ provision to ensure that government alone constructs, or guides the construction of, coastal protection structures or devices;
- ▶ provision to better prevent any activities which might exacerbate erosion processes;
- ▶ provision to make mandatory water supply augmentation for certain types of development which might pose a particularly dire strain on national water supply;
- ▶ provision making mandatory that a certain percentage of the island's power be derived from renewable energy.

Whilst the incorporation of the aforementioned elements would be advantageous, it must be recognised that there are likely to be several constraints to the development and implementation of policy. As outlined in Section 4.1.1., there are several areas of

technical research which would, if carried out, be of great benefit to informing policy. The capital and expertise to carry out such tasks, however, is lacking locally. The construction of coastal engineering works, as well as other structures, such that they might be resistant to impacts, is likely to be similarly hindered by a lack of technical and financial resources; as may be the actual implementation and enforcement of the adaptation policy.

Despite this, it should be noted that in the face of such scarcity, Barbados has to date managed to do considerable research into coastal vulnerability as well as the pursuit of renewable energy. Government initiative alone has put certain practices such as the informal EIA process into the regular process of project assessment. Thus, a precedent has already been set to make advances in Barbados' programme for the adaptation to Climate Change, even with a paucity of resources. What is now needed, however, are the necessary capital and tools to facilitate wide scale advancement of work, both in the technical and policy aspects, so that Barbados might truly derive the benefits of a comprehensive adaptation system.

# **APPENDIX A**



**POPULATION DENSITY PER SQUARE KILOMETRE**




# MAP 2

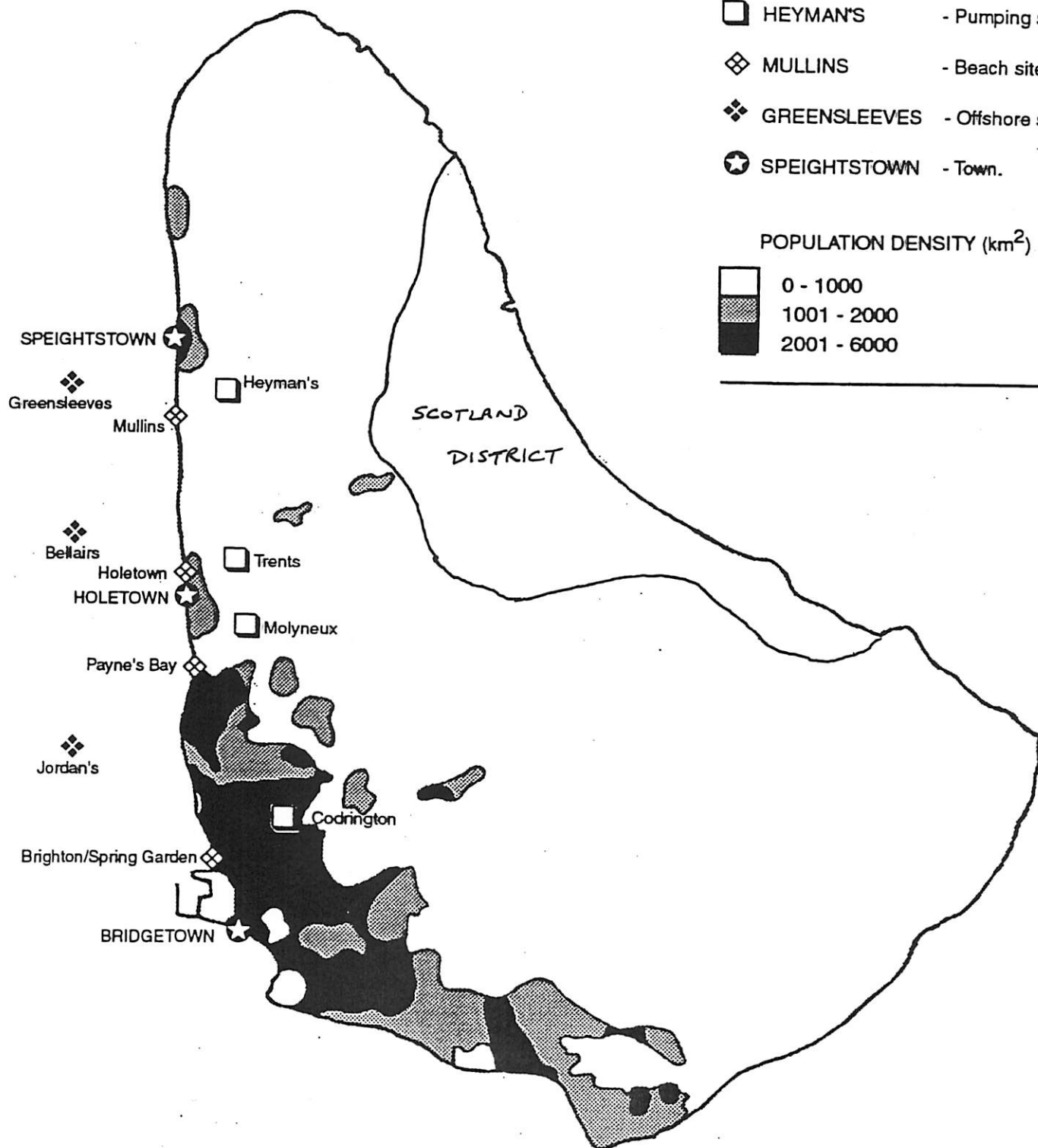
: BARBADOS - Public water supply wells, nearshore and offshore study sites and population density highlighted ( adapted from Harries, 1997).

## KEY

-  HEYMAN'S - Pumping station.
-  MULLINS - Beach site.
-  GREENSLEEVES - Offshore site.
-  SPEIGHTSTOWN - Town.

## POPULATION DENSITY (km<sup>2</sup>)

-  0 - 1000
-  1001 - 2000
-  2001 - 6000



0 5 km  
SCALE

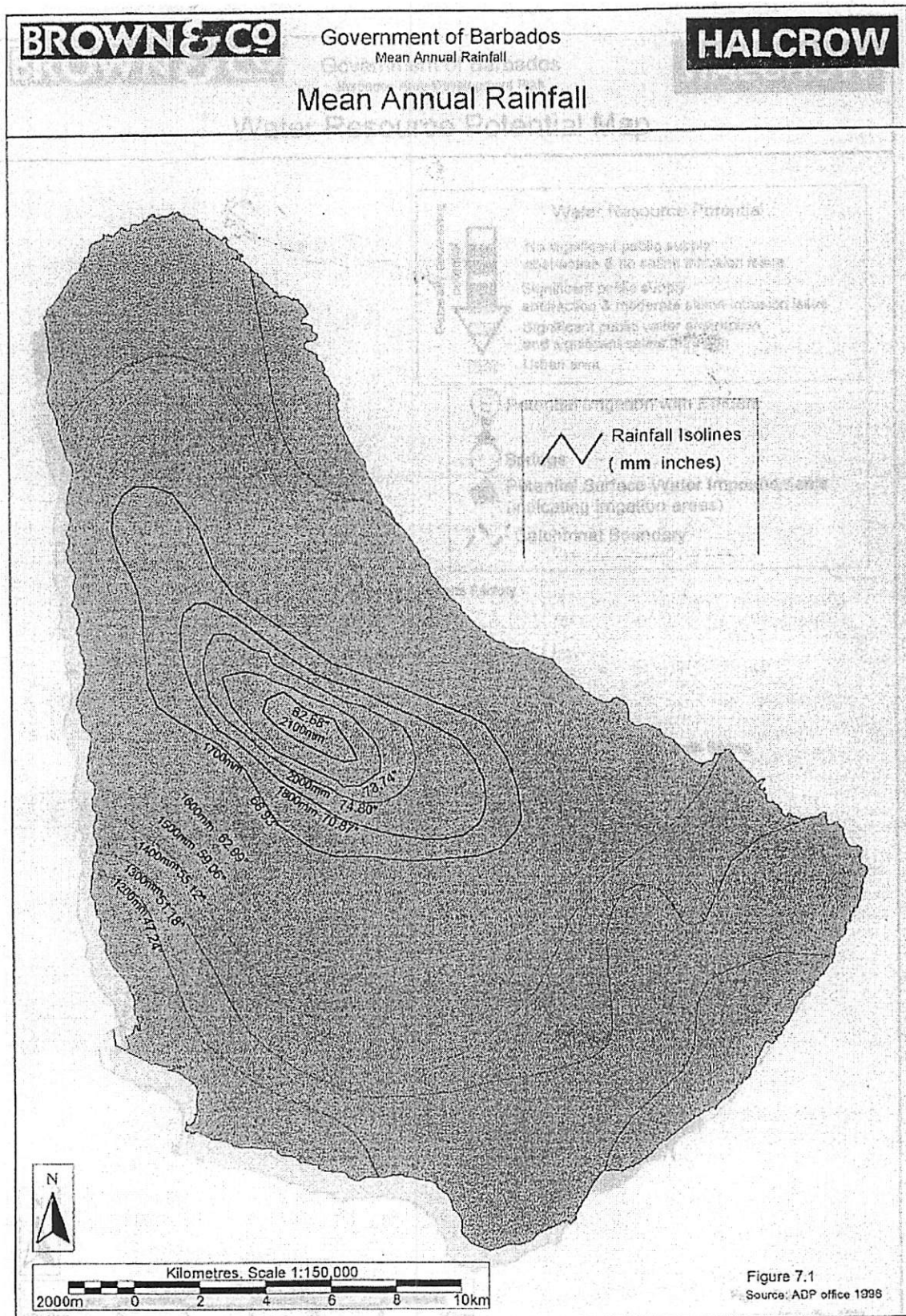




TABLE 1

INDEX - LIST OF RAINFALL AND WIND EVENTS (1990 - 2000)

<u>NO.</u>	<u>YEAR</u>	<u>MONTH</u>	<u>DATE</u>	<u>EVENT</u>	<u>NO.</u>	<u>YEAR</u>	<u>MONTH</u>	<u>DATE</u>	<u>EVENT</u>
<u>38.</u>	<u>1990</u>	<u>May</u>	<u>1</u>	<u>Flooding</u>	50.	1998	August	23	Tropical Wave
<u>39.</u>		<u>October</u>	<u>3-4</u>	<u>Flooding</u>	51.		September	1-2	Tropical Wave
<u>40.</u>	<u>1991</u>	<u>November</u>	<u>22</u>	<u>Flooding</u>	52.			8	Tropical Wave
<u>41.</u>	<u>1992</u>	<u>November</u>	<u>20-21</u>	<u>Flooding</u>	53.	1998	October	20	Flooding
<u>42.</u>	<u>1994</u>	<u>September</u>	<u>9</u>	<u>Tropical Storm Debbie</u>	54.		December	27	Flooding
<u>43.</u>	<u>1995</u>	<u>August</u>	<u>3</u>	<u>Tropical Wave</u>	55.	1999	August	26	Micro Burst
<u>44.</u>			<u>25</u>	<u>Tropical Storm Iris</u>	56.		November	1	Flooding
<u>45.</u>		<u>September</u>	<u>13-14</u>	<u>Hurricane Marilyn</u>	57.			17-20	High Sea Swells
<u>46.</u>	<u>1996</u>	<u>October</u>	<u>12</u>	<u>Flooding</u>	58.		December	8	Flooding
<u>47.</u>	<u>1997</u>	<u>August</u>	<u>4</u>	<u>Tropical Wave</u>					
<u>48.</u>			<u>25</u>	<u>Flooding</u>					
<u>49.</u>		<u>September</u>	<u>4</u>	<u>Tropical Storm Erika</u>					

The following summary outlines fifty-seven (57) Rainfall and Wind Events which occurred between 1955-2000. The breakdown is as follows:

<b>Flood Events</b>	<b>30</b>
<b>Severe Weather Reports</b>	<b>12</b>
<b>Tropical Waves</b>	<b>5</b>
<b>Hurricanes</b>	<b>3</b>
<b>Tropical Storms</b>	<b>5</b>
<b>High Wind Events</b>	<b>1</b>
<b>High Sea Swells</b>	<b>1</b>
<b>Micro Burst</b>	<b>1</b>

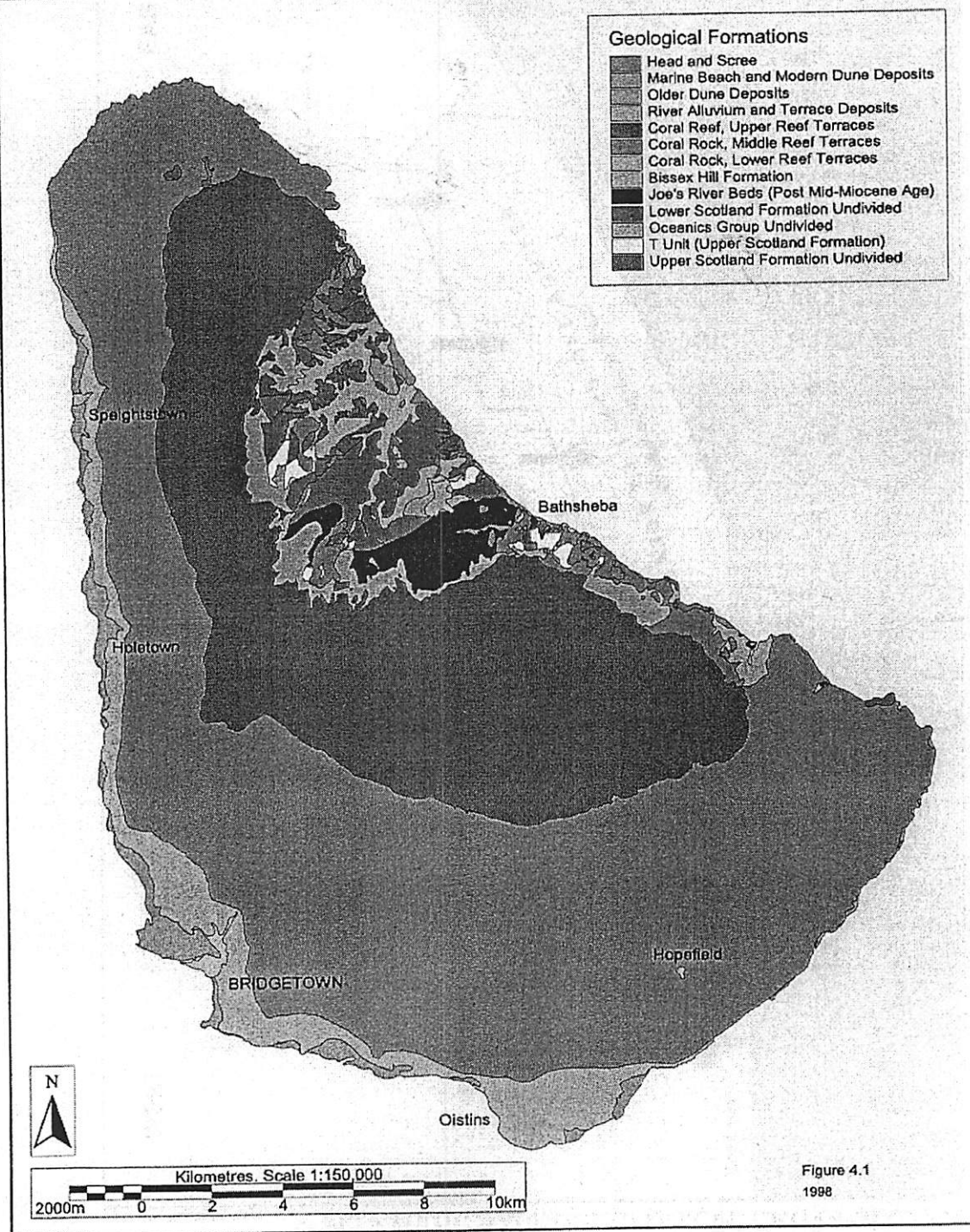
Though most of the major events were documented, many of the summaries related to events which occurred between 1955-1970, lacked the detail present in the more current reports.

**BROWN & CO**

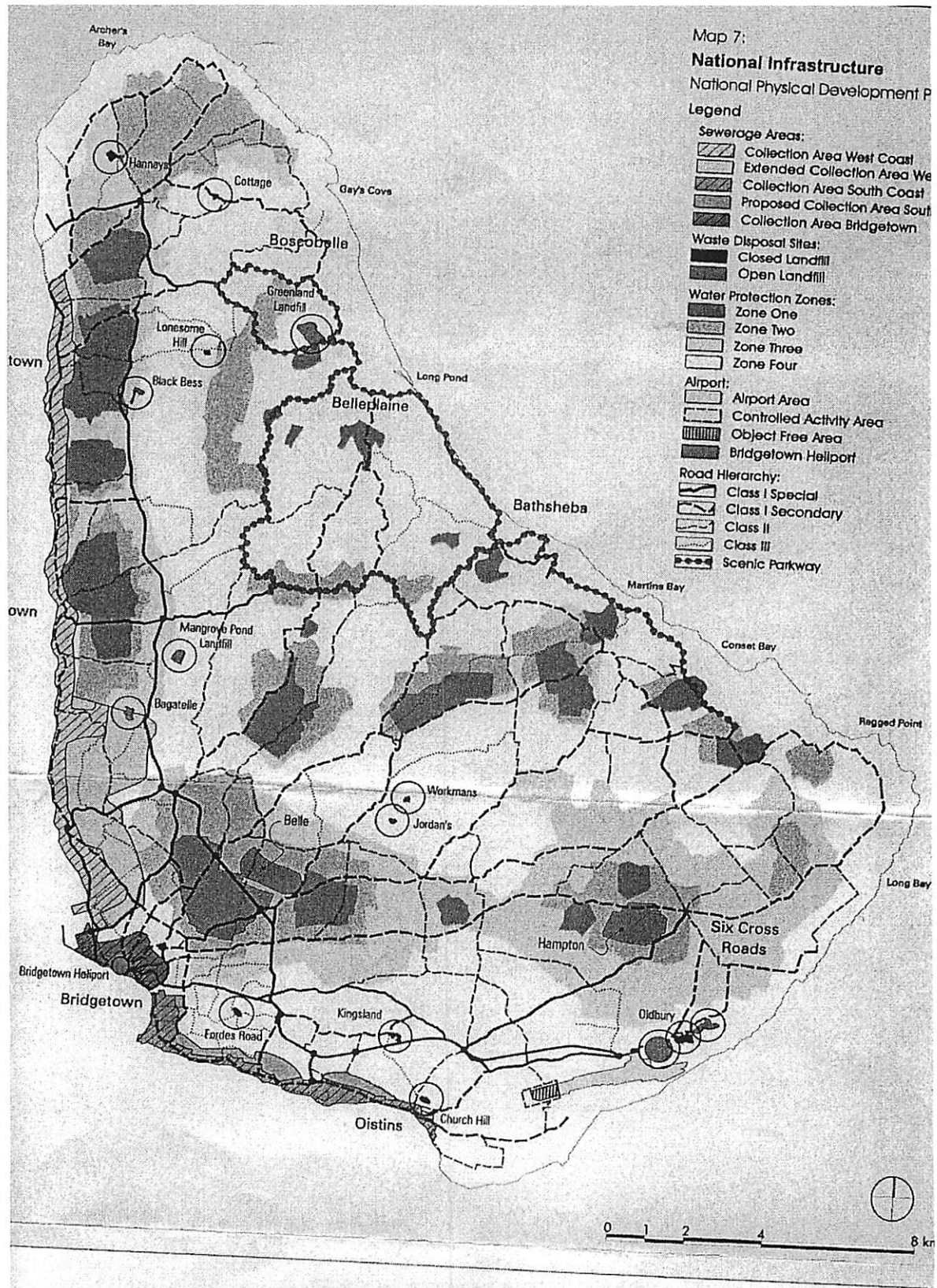
Government of Barbados  
Barbados Area Development Plan

**HALCROW**

# Geological Map of Barbados



# MAP 5





# GENERALIZED NATURAL HERITAGE (1997)

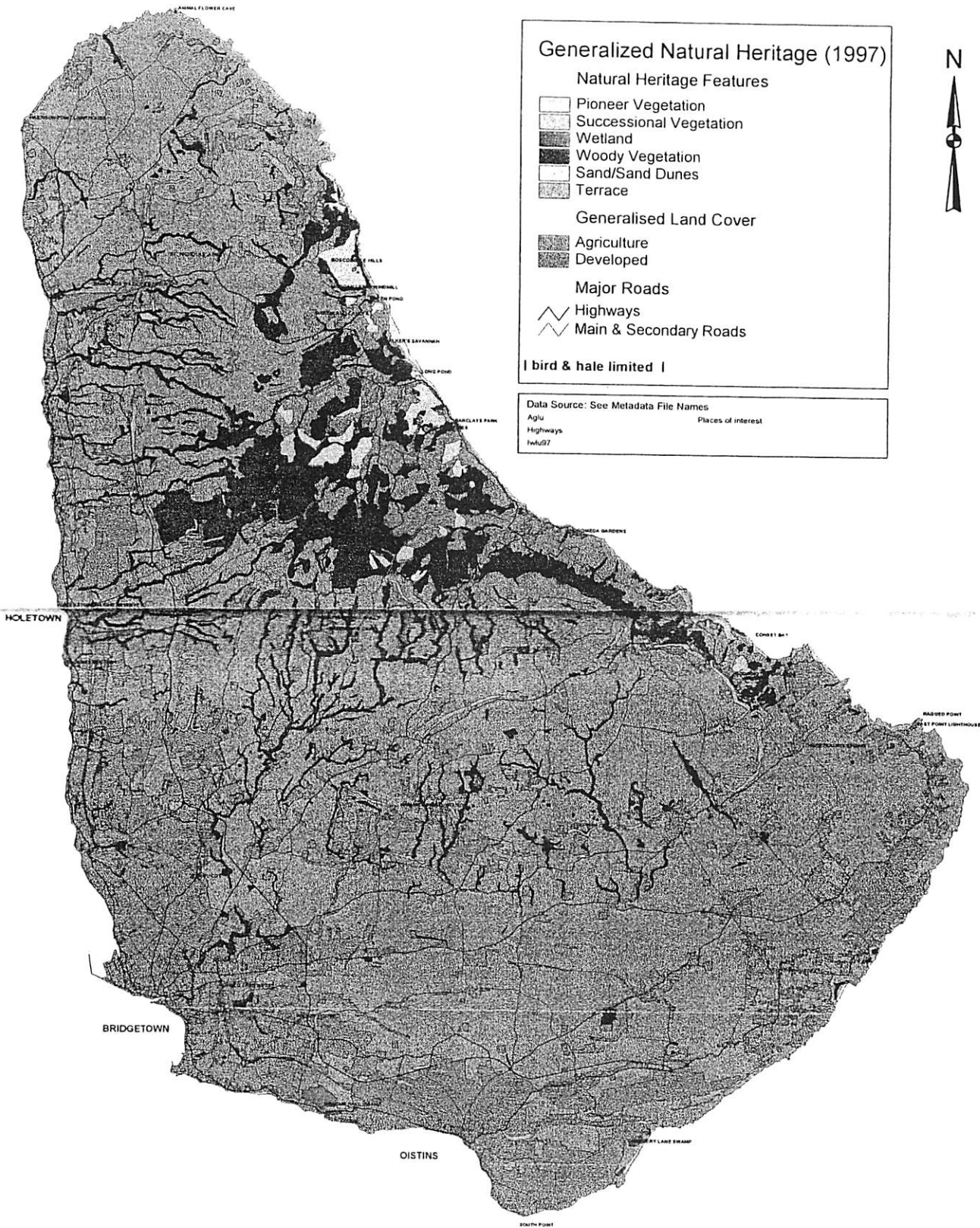


FIGURE 12

ENVIRONMENTAL MANAGEMENT  
AND LAND USE PLANNING FOR  
SUSTAINABLE DEVELOPMENT

**Table 2. Non-indigenous terrestrial vertebrate fauna present and breeding in Barbados. Presence due to expanded geographic range (ER) or deliberate introduction (I). Species present due to expanded range may have had non-deliberate human assistance. Status is a qualitative category only, based on ease with which species can be observed. (pers. comm. Horrocks, 1998). (Compiled from Censky 1988; Feilden 1990; Marsh 1981; Watson 1993, 1996).**

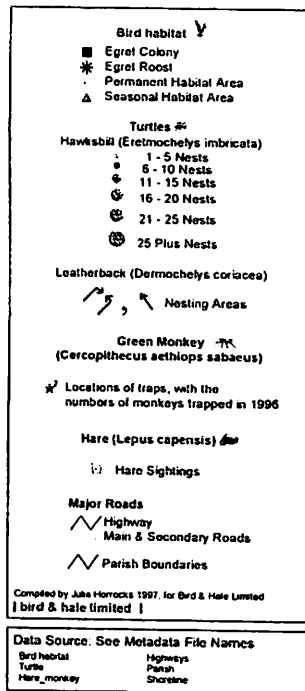
Common name	Scientific name	Status	Places seen	Arrival date if known
Cattle egret RE	<i>Bubulcus ibis</i>	Very common	Four breeding colonies; all over	1957
Ramier RE/I?	<i>Columba squamosa</i>	Very common	All over	
Violet-eared dove RE	<i>Zenaida auriculata</i>	Uncommon	Grassland, scrub in St. Philip, Ch. Ch	
Glossy cowbird RE	<i>Molothrus bonariensis</i>	Common	All over	1923
Cayenne nighthawk RE	<i>Caprimulgus cayennensis</i>	Rare	Eastern parishes	
Yellow-crowned night heron RE	<i>Nyctanassa violacea</i>	Uncommon	Graeme Hall swamp	
Snowy egret RE	<i>Egretta thula</i>	Uncommon	Graeme Hall swamp	
Little egret RE		Uncommon	Graeme Hall swamp	
Orange-winged parrot I	<i>Amazona amazonica</i>	Few, but readily seen	Bridgetown	
Blue-headed parrot I	<i>Pionus menstruus</i>	Few, but readily seen	Bridgetown	
Yellow-shouldered parrot I	<i>Amazona barbardensis</i>	Few, but readily seen	Bridgetown	
Indian ring-necked parakeet I	<i>Psittacula krameri</i>	Few, but readily seen	Bridgetown	
Budgerigar I	<i>Melopsittacus undulatus</i>	Rare	Bridgetown, St. James, St. George	
Caribbean parakeet I	<i>Aratinga pertinax</i>	Uncommon	Bridgetown	
Quaker parakeet I	<i>Myiopsitta monachus</i>	Uncommon	Bridgetown	
Guinea bird I	<i>Numida meleagris</i>	Rare	Feral birds in countryside	
Mallard I	<i>Anas platyrhynchos</i>	Uncommon	Ponds in countryside	
Land turtle I	<i>Geochelone carbonaria</i>	Rare	Central parishes; mostly escaped pets.	Post-European
House gecko RE	<i>Hemidactylus mabouia</i>	Very common	All over; in houses	
Whistling frog RE	<i>Eleutherodactylus johnstonei</i>	Very common	All over	1870s
Cane toad I	<i>Bufo marinus</i>	Very common	Countryside	1830s
Mongoose I	<i>Herpestes javanicus</i>	Common	All over	1870s
Green monkey I	<i>Cercopithecus aethiops sabaeus</i>	Common	All over	Mid 1800s
European hare I	<i>Lepus capensis</i>	Uncommon	Central parishes	1840s
Raccoon I	<i>Procyon glomeralleni</i>	Probably extinct since 1960s		
House mouse RE	<i>Mus musculus</i>	Very common	Houses; all over	
Norway rat RE	<i>Rattus norvegicus</i>	Very common	All over	
Black rat RE	<i>Rattus rattus</i>	Very common	All over	

Table 3. Terrestrial vertebrate fauna either no longer present or no longer breeding in Barbados for which there is pre-historical or historical evidence of former breeding in Barbados (E = endemic), together with notes on their current status (compiled from Ray 1964; Watson 1993, 1996).

Common name	Scientific name	Current status
Broad-winged hawk	<i>Buteo platypterus</i>	Visitor; some indication of attempted nesting in Chaiky Mount area
Trembler	<i>Cinclocerthia rufi cauda</i>	Locally extinct
White-breasted thrasher	<i>Ramphocinclus brachyurus</i>	Locally extinct
Lesser Antillean flycatcher or yellow-bellied elaenia	<i>Myiarchus oberi</i> or <i>Elaenia flavogaster</i>	Locally extinct
Black swift or Lesser Antillean swift	<i>Cypseloides niger</i> or <i>Chaetura martinica</i>	Locally extinct
Blue-winged teal	<i>Anas discors</i>	Visitor
Green-winged teal	<i>Anas crecca</i>	Visitor
Ruddy duck or masked duck	<i>Oxyura jamaicensis</i> or <i>O. dominica</i>	Masked duck rare; breeding observed in countryside ponds
Frigate bird	<i>Fregata magnificens</i>	Visitor
Laughing gull	<i>Larus atricilla</i>	Visitor, breeding suspected
Red-billed tropic bird	<i>Phaethon aethereus</i>	Visitor
Tropical mockingbird	<i>Mimus gilvus</i>	Locally extinct
Black-bellied whistling duck	<i>Dendrocygna arborea</i>	Visitor
Fulvous tree duck	<i>Dendrocygna bicolor</i>	Visitor
Red-footed booby	<i>Sula sula</i>	Visitor
Brown booby	<i>Sula leucogaster</i>	Visitor
Pelican	<i>Pelicanus occidentalis</i>	Visitor
Grey gaulding	<i>Ardea herodias</i>	Visitor
Purple gallinule	<i>Porphyryla martinica</i>	Visitor
Caribbean coot	<i>Fulica caribea</i>	Visitor; breeding suspected
Sora rail	<i>Porzana carolina</i>	Locally extinct
Pied-billed grebe	<i>Podilymbus podiceps</i>	Rare, breeding suspected
Bobwhite quail	<i>Colinus virginianus</i>	Recently reintroduced
Barn owl	<i>Tyto alba</i>	Locally extinct
Rice rat E	<i>Oryzomys</i> sp.	Extinct
Giant tortoise E	<i>Geochelone</i> sp.	Extinct
Iguana	<i>Iguana iguana</i>	Locally extinct; reintroduction suspected

# WILDLIFE I

(Birds, Turtles, Monkeys, Hares)



## ENVIRONMENTAL MANAGEMENT AND LAND USE PLANNING FOR SUSTAINABLE DEVELOPMENT

 — urban corridor