Environmental Impact Assessment

PHASE 2 OF THE PALISADOES REHABILITATION AND SHORELINE PROTECTION PROJECT, KINGSTON

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A	AADT	Annual average daily traffic
	ACGIH	American Conference of Industrial Hygienists
	AMC	Antecedent moisture conditions
	amsl	Above mean sea level
B	BA	Basal area
C	C	Celsius
	CBD	Convention on Biological Diversity
	CCCL	Caribbean Cement Company Limited
	CDMP	Caribbean Disaster Mitigation Project
	CN	Curve number
	CO	Carbon Monoxide
	CO2	Carbon Dioxide
D	DAFOR	Dominant, Abundant, Frequent, Occasional, Rare
	dBA	A-weighted sound level (decibel)
	DBH	Diametre at breast height
	DEM	Digital elevation model
	DO	Dissolved oxygen
E	E	East/ Easting
	EIA	Environmental Impact Assessment
	EMP	Environmental Monitoring Programme
	ESRI	Environmental Systems Research Institute
	FHA	Federal Highway Administration
	FOG	Fats Oil and Grease
F	ft	Feet
G	g/l	Grams per litre
	GIS	Geographic information system
	GOJ	Government of Jamaica
	GPS	Global Positioning System
H	HA	Hectares
	hr	Hour
	Hz	Hertz
I	IPCC	Intergovernmental Panel on Climate Change
	IUCN	International Union for Conservation of Nature
J	JAD 2001	Jamaica Grid 2001
	JGQ	Jamaica Gypsum and Quarries Limited
	JNHT	Jamaica National Heritage Trust
K	km	Kilometre
L	LDUC	Land Development and Utilization Commission
	Leq	Time-average sound level
	Lj	jth sound level
M	m	Metre

	m/s	Metres per second
	m3/sec	Cubic metres per second
	mg/l	Milligrams per litre
	mg/m^3	Milligrams per cubic metre
	min	Minute (s)
	mm	Millimetre
	mm/24 hr	Millimetres per 24 hour period
	mS/cm	milli Siemens per cm
	MSDS	Material Safety Data Sheets
N	N	North/ Northing
	NAAQS	National Ambient Air Quality Standards
	NEPA	National Environment and Planning Agency
	NMIA	Norman Manley International Airport
	NO2	Nitrogen Dioxide, Nitrite
	NO3	Nitrate
	NOx	Nitrogen Oxides
	NRCA	Natural Resources Conservation Act
	NSWMA	National Solid Waste Management Authority
	NTU	Nephelometric turbidity units
	NWA	National Works Agency
	NWC	National Water Commission
O	ODPEM	Office of Disaster Preparedness and Emergency Management
	OSHA	Occupational Safety and Health Administration
P	PCQ	Point-Centred Quarter
	PEL	Hearing Conservation and Permissible Exposure Limit
	PIF	Project Information Form
	PM10	Particulate matter smaller than 10 microns in diametre, respirable particulate matter
	PM2.5	Particulate matter smaller than 2.5 microns in diametre, fine particulate matter
	ppm	parts per million
	ppt	parts per thousand
Q	QSP II	Quest suite Professional II
S	s	Second
	SCS	US Soil Conservation Service
	SIA	Social Impact Area
	SO2	Sulfur Dioxide, sulfite
	SO4	Sulfate
	SOx	Sulfur Oxides
	STATIN	Statistical Institute of Jamaica
T	TCP Act	Town and Country Planning Act
	TDS	Total dissolved solids
	TSS	Total Suspended Solids

	TCL	Trinidad Cement Limited
U	USEPA	United States Environmental Protection Agency
W	WHO	World Health Organization
	WRA	Water Resources Authority
Y	yr	Year

EXECUTIVE SUMMARY

INTRODUCTION

Following the passage of hurricane Ivan in 2004 the Palisadoes shoreline was severely damaged, the sand dunes were overtopped and the roadway blocked. The Government of Jamaica in an effort to protect the Palisadoes shoreline from such damage in the future and to rehabilitate the area implemented the "*Palisadoes Shoreline Protection and Rehabilitation Project*" and tasked the National Works Agency (NWA) with the responsibility of designing a method of restoring the stability of the Palisadoes. This project involves the dredging of 99,208 m^3 of sand from an offshore sand reserve (borrow area) and placing this dredged material over the buried revetments along the Caribbean Sea side of the Palisadoes. There is also the need to create areas in the Harbour side of the tombolo to facilitate the planting of mangroves within the Harbour.

CEAC Solutions Limited has been commissioned by the NWA to provide technical assistance to plan, execute and monitor dredging operations for the creation of suitable substrate for re-vegetation of the dunes to be formed; and plan, execute and monitor the creation of suitable areas for the planting of mangroves on the Harbour Side of the Palisadoes. The consultancy is expected to be executed in the phases outlined below:

1. Phase 1 is the preparation of the Bid document; completion of engineering works for preparation of both replanting areas; and preparation of EIA.
2. Phase 2 is the engineering consultancy and assistance during implementation and construction.
3. Phase 3 is post-construction monitoring of the structure and relocated sensitive species.

The approach taken involved: conducting stakeholders meetings; gathering anecdotal information; field investigations; defining the trends in the climate change drivers; wave, hydrodynamic and sediment analysis studies; laboratory testing; construction methodology study and cost estimating. . An *Engineering Design Report* was submitted in February 2014 that detailed the results of this work. Parallel to this, an environmental impact assessment (EIA) was undertaken of the engineering proposal relative to the environmental resources and socio-economic concerns. This report serves to present the findings of the EIA.

COMPREHENSIVE DESCRIPTION OF PROJECT

Planning and Design

Calibrated cross-shore models were used to determine the stability and resistivity of the sand dune during both 50 year and 100 year storm events, both for the post project and climate change scenarios. The design process determined that the proposed sand dunes should have a 1:3 slope on both the seaward and landward sides with a 12 m wide crest at an elevation 6.24 m.

Planning of how the dredging operations may affect navigation and utility interests is currently still being investigated with the Port Authority and utility providers. Feedback is still pending.

Draft Dredge Management Plan (DMP)

The most suitable dredging setup is a trailing suction hopper (TSH) which uses a trailing suction drag head to pump fluidized seabed materials to an on board hopper. Sediments are retained in the hopper while water used to pump the material is allowed to discharge from the vessel at the dredging site.

The TSH will operate in 20 m depth of water and be required to pump 99,208 m^3 of sand with a mean grain size ranging between 0.5 – 0.7 mm. This volume and type of material will be dredged from one of the 2 proposed dredge areas identified in the borrow area and placed onshore in a sediment pond to allow the sand to settle. The contractor will then remove this material from the pond and use it to form the sand dunes over the 2 buried revetments. The material will also be used to construct the sand dune between the high revetment and the NWC WWTP once the NWA has agreed to include this option in the project.

Dredging activities result in a number of impacts on the marine environment including the following:

- Changes to water quality,
- Changes to coastal processes (waves and currents)
- Effects on marine ecology (flora and fauna)
- Mobilisation of sediment and pore water contamination

Material Verification and Constructability

Construction of the sand dunes will involve a dredge pumping sand material to a stockpile area along the buried revetment from the borrow area. Excavators will then place the material over the buried revetment for labourers to shape into the design outlined in the engineering drawings submitted; 99,208 m^3 of material is required for the sand dunes.

The mangrove nourishment phase of this project involves using a backhoe, or similar equipment, to place the sand obtained from the Hope River desilting operation along the harbour side of the Palisadoes. The UWI team requires 5,400 m^3 of this material to plant the 6,000 mangroves stipulated.

Engineering Cost Estimate

Procurement is envisaged in two parts, namely: dredging and placement of sand along the Palisadoes (dune nourishment) and the supply and placement of mangrove nourishment along the Harbour side. The dredging contract is expected to involve a dredging contractor with the requisite skills and equipment, while the mangrove nourishment contractor is expected to engage local sources of material working under a main contractor. The engineers estimate for the project is US$4,223,154.10, made up as follows:

- Dredging and Placement of Sand: US$3,971,220

- Supply and Placement of mangrove nourishment: US$251,934.10

It is expected that in the internal project team meetings that various components of the costs will be discussed and prioritized in order to arrive at an agreed approach in the tender document.

DESCRIPTION OF EXISTING ENVIRONMENT

Physical

Geomorphology

Robinson and Rowe (2005) believe that the Palisadoes was formed by the joining of the Port Royal island and a series of spits extending from the mouth of the Hope River, to the mainland. Dominant waves from the southeast caused currents to bring sediments (sand and gravel) from the Hope River and Cane River westward along these shores. It is suggested that its present form is some 4,000 years old. Rare destructive events were highlighted, including earthquakes in 1962 and 1907, and a hurricane in 1722. The hurricane in 1722 was reported to cause storm surge of 5m in Port Royal, isolated Port Royal as an island and resulted in five channels through the eastern part of the Palisadoes.

Robinson & Rowe (2005) conclude by saying that the future development of the Palisadoes can only speculated. Based on the way in which the Palisadoes, one possible future direction is that the Palisadoes will incorporate the cays now outside the Kingston Harbour.

Geology and Sediments

Hardy and Croucher (1933) describes the substratum of the Palisadoes coastal environment as being comprised of sand with a significant difference between soil composition on the north (coral sand base) and south coast (siliceous sand base). Hendry (1979) determined that the first stage of the bedrock formation is that of infiltrated carbonate mud with the beach rock cement mineralogy being Magnesium calcite with semi-opaque microcrystalline micrite morphology. Coarse sediment size at the base of the foreshore on the south side of the Palisadoes is affected by abrasion, with the fine particles being removed by wave action. However there exists throughout the remainder of the foreshore a wide assortment of sediment sizes with the most common being in the granule size class (Hendry 1979). These features play an important role in determining floral and faunal composition of the Palisadoes area.

Sediment samples in sand donor areas show that there was no detectable presence of Total Petroleum Hydrocarbons (GRO and DRO), cadmium or mercury at any of the sampling stations. The metal concentrations of arsenic varied little among stations however lead concentrations fluctuated between stations.

Water Quality

In 2007, Wilson-Kelly and Kelly looked at the impact of shoreline stabilization works along the Palisadoes. Their study focused on total suspended solids (TSS) and turbidity to assess the water quality with a total of 8 stations. They found that stations closest to the shore (<1m depth) had TSS values of greater than 60mg/l, while stations further away from shore (<10m depth) had values less than 11mg/l. CLE (2010) sampled at similar stations from the shore (<10m depth) and found similar results of TSS, however no samples were collected in <1m depth. The Harbour is generally accepted as being eutrophic with the main sources of pollutants being run-off from the sewage treatment plants and fluvial input (D. F. Webber and Kelly 2003; Bigg and Webber 2003). The sources of pollutants to the Harbour associated with the various industries and communities are located mainly along the northern coastline. This has resulted in varying levels of pollutants across the Harbour (Bigg and Webber 2003; D. F. Webber and Kelly 2003).

Water quality samples taken showed physicochemical parameters such as temperature, salinity, pH, D.O. turbidity and total dissolved solids (TDS), varied slightly across similar stations. Stations on the leeward side of the Palisadoes spit (Harbour side) showed warmer temperatures, lower salinity, pH, TDS and dissolved oxygen levels compared to the windward side of the spit. Total Suspended Solid, oil and grease and phosphate levels were on average higher in the harbour compared to the windward side of the spit.

Oceanographic and Meteorological Data

A bathymetric survey for the project area was developed based on the following surveys:

- CEAC survey conducted along the Caribbean Sea and Harbour side of the Palisadoes, but not including the burrow area
- Cuban survey of the Caribbean Sea side of the Palisadoes conducted in 2008 as a part of their technical report,
- NWA as-built topography carried out after the completion of the revetments along the Palisadoes

Current and wave data was also collected via an Acoustic Doppler Current Profiler (ADCP) and verified using data gathered from two drogue tracking missions. Likewise, water surface elevations were collected during the campaign and it determined a tidal range of 0.43 m. The moored current meter data indicated that the currents moved predominantly in a north-south direction.

A water quality sampling mission was undertaken over 6 stations along the Caribbean Sea side of the project, including a control point in deep water. The water quality parameters measured were TSS, turbidity, pH, salinity and temperature; and all parameters fell within the limits outlined in the 2009 Draft Marine Standards. The water quality readings were also compared to long term water quality data provided by CL Environmental for the 2010 – 2012 period. The TSS, turbidity and salinity parameters were below the long term values while pH and temperature values were greater than the long term values. The TSS typically ranged from 0.5 to 1.5 mg/l.

Sediment grain size collection and analysis confirmed that the sand along the Caribbean Sea side of the Palisadoes ranges between coarse sand and gravel (0.7 – 4.3 mm), the sand was well graded and most samples were positively skewed having more fines in the tail of the distribution.

Samples were also taken from the offshore borrow area and they ranged between fine and coarse sand (0.2 – 0 0.6 mm), the sand samples were mostly poorly sorted. These results were also similar to that obtained by the Cubans for their samples collected from the same borrow area. Two priority areas within the borrow area were identified as providing coarse sand, having a mean grain size between 0.5 – 0.6 mm and a total carbonate composition ranging between 7 – 17%, for use in the sand dune nourishment exercise. This sand is however unsuitable for use in the mangrove nourishment exercise. An alternate source having sand of a suitable nature for mangrove growth was identified for the mangrove replanting areas; this source is in the lower reaches of Hope River where desilting operations are often carried out.

Climate Change, Wave Studies and Storm Surge

A sub-regional climate change study using global and regional scale peer-reviewed information was undertaken by the University of the West Indies Climate Studies Group. The predictions are for global sea levels to rise through to the 21st century at a rate of 3.7 mm/ yr and for annual mean significant wave heights to decrease marginally by 1 – 2%. Additionally, severe storms and hurricanes are predicted to increase in both frequency (5.2%) and magnitude of wave height (4.0%).

Deepwater wave conditions for operational, swell and hurricane waves were derived in order to undertake the near shore wave transformation, sediment transport and structural design studies. These deepwater waves were then used in a special near shore wave transformation model to study pre and post project scenarios with climate change.

The National Oceanic and Atmospheric Administration (NOAA) database of hurricane track data from 1886 to present was utilized in a wave hindcast model to generate historical data on hurricane waves. During the period of data 86 hurricanes passed within 300 km of the project, 6 of which were classified as catastrophic (Category 5). There appears to be a cyclic trend in the number of hurricanes that have passed within 300 km of the project site and that implies that there will be an increase in the number of systems passing the site over the next 40 years, with a general shift in the intensity of the storms from predominantly category 1, 2 and 3 to mostly categories 4 and 5 since the 1940s. South westerly, southern and south easterly waves are the most intense and the 100 year wave height was determined to be 7.6 m. Similarly, the 100 year wave setup inclusive of wave run up was determined to be 1.31 m.

Operational and swell deepwater waves were determined from NOAA long term buoy data to have a wave height of 1.2 m and 2.2 m respectively for the Caribbean Sea side of the project. Nearshore transformations of these waves suggest 0.7 – 1.2 m operational deepwater conditions and 0.8 – 2 m during swell wave conditions. Hurricane conditions result in wave heights of 2 - 3m. The post-construction wave climate (following offshore dredging which will alter the bathymetry) was predicted to have no change in the operational, swell and hurricane wave conditions reaching the shoreline. The two locations to be dredged are approximately 0.6 km and 1.6 km offshore, and they will be dredged to a depth of 1.5m.

Along the harbour side of the project a two-dimensional JONSWAP wind-wave model was used to establish the storm surge over a seven year period (2000 – 2006) for a point just off the harbour. The model determines wave height and period from fetch, storm duration and depth of water in the generating area. The operational and swell deepwater waves have a wave height of 0.2 and 0.6 m respectively. Nearshore transformations of these waves suggest 0.1 – 0.2 m operational deepwater conditions in the pre-project scenario and 0.2 – 0.6 m during swell wave conditions. Hurricane conditions results in wave heights of 1 – 2.5 m. Wave transformation modelling indicates there will be no change in the operational, swell and hurricane wave conditions in the post construction scenarios.

The wave transformation model clearly indicates the vulnerability of the Caribbean Sea side of the project to waves from the south and south west while the Harbour side is vulnerable to waves from the north and North West.

Shoreline Vulnerability

Long term shoreline trends were assessed to identify areas along the Palisadoes that might require stabilization and to also verify wave transformation modelling. Special note was taken of the areas behind the buried revetments. The analysis determined that currently the western section of the Palisadoes (near Gun boat beach) is experiencing erosion while the central and eastern sections (towards Harbour head) are experiencing accretion; as such erosion is occurring along buried revetment 1 whilst along buried revetment 2 accretion is occurring. The shoreline (80%) is accreting at an overall accretion rate of between 0.1 m/year and 0.6m/year, the remaining 20% was observed to be eroding at rates between 0.04 m/year and 0.4 m/year rate.

The alongshore and cross-shore sediment transport modelling determined that the eastern and central sections of the Palisadoes are most vulnerable to erosion due to storm events, this concurs with the long term shoreline data obtained for the same period. It should be noted that the passage of hurricane Ivan in 2004 contributed greatly to the erosion predicted in the alongshore and cross-shore sediment models.

Hydrodynamic Modelling

Currents in the project are driven predominantly by tides with the general movements being from east to west. Current speeds vary from 0.4cm/s to a high of 12cm/s in the near shore areas whereas the offshore areas (in the vicinity of the dredge sites) tend to have a speeds of less than 4cm/s. Sediment dispersion modelling indicate turbidity plumes that can be generated from the operations will be above the NEPA standards. The turbidity plumes are expected to extend up to 2km from the points of operation if precautions are not taken to limit sediments getting to the water column. The offshore plumes are expected to remain offshore and meet the NEPA guidelines for distances further than 1km away from the operations. Similarly the near shore plumes will remain in the near shore and are expected to meet the NEPA guidelines for distances further than 1km away from the operations.

Biological

As part of mitigation, rehabilitation and protection works of the Palisadoes roadway, two main biological/ecological projects have been proposed;

1. Dune nourishment and re-vegetation
2. Island creation and mangrove planting

Sand Dune Nourishment

Coastal dunes are formed at the interface between the sea and land. This is a very dynamic system, ever changing with the natural environment. Vegetation found on these dunes act as anchors, stabilizing the otherwise lose sediment and providing additional habitat, foraging ground and nesting site for sea birds. Sea turtles and crocodiles have been known to utilize areas colonized by runners for nesting. The ecosystem services provided by these dunes includes shoreline protection by reducing wave and wind energy during storm events, benefits which can even be had further inland by reduced wind energy.

Construction of revetments along the sea side of the roadway, was done for a 4km stretch between the Harbour View roundabout and the NMIA roundabout. Dunes of varying lengths (98m to 943m) along three sections of the Palisadoes have been proposed. Two of these dunes, BR1 and BR2, which are located approximately 3.7 and 1.2km to the west of the Harbour view roundabout, consist of an internal low revetment structure covered by sand dune. The third and closest dune to the roundabout (D3) is 100% sand.

It was determined by (Juanes, et al., 2007) that the material for dune nourishment can be sourced approximately 1.5km offshore. This EIA study has determined that there appears to be suitable material of the required quantity in two areas of the (Juanes, et al., 2007) footprint. Additional design considerations/requirements include the ability to withstand the passage of hurricanes and storm surge events

Sand Dune Species

Fifty thousand (50,000) plants will be established in a sand dune nursery at the UWI. Sand dune species will be planted in accordance with their natural profile, dune position and successional capabilities. Species to be planted include beach runners such as, *Ipomea*, *Sesuvium*, *Sporobolus* and shrubs/trees such as *Acacia, Capariss, Coccoloba* and *Thespesia.* Beach runners will be planted at 1 m spacing intervals in rows. Approximately 1,000 plants will be planted on each event, for approximately 50 planting days. The introduction of additional seeds/cuttings (e.g. cacti) of sand dune species in selected areas will be done 6-12 months following pioneer species establishment.

The Borrow Area

The borrow areas were previously identified by Juanes et al. (2007). Ground-truthing each borrow area was carried out by grab samples and roving SCUBA surveys. Both borrow sites corresponded with original survey results with exception of a small patch of seagrass (*Syringodium filiforme*) identified at the western boundary of Borrow Area 1. The seagrass was along the western edge with the bed extending southwest and away from the impact area. The area generally has poor visibility making several attempted surveys impossible. The sand in the borrow areas were coarse grained with some *Halimeda* calcareous algal skeleton interspersed. A sea horse, sea stars and helmet conch were observed in Borrow Area 1.

Coral Reefs

The Palisadoes Coastal ecosystems; mangroves, sand dunes and coral reefs are a delicate system with each ecosystem depending on the other to achieve environmental balance. The area is severely affected by human interference in particular pollution that enters the Kingston Harbour as well as the removal of vegetation for coastal development (widening of the Norman Manley High from two to four lanes).

Reefs act as natural shoreline protection; studies continue to reassess and increase the actual value that's coastal ecosystems. Major ecosystem services include shoreline protection. The reefs surrounding the Palisadoes have played a major role in its protection, formation and maintenance. The global decline in reef health as a result of climate change, major natural and manmade disasters is further magnified by site specific influences. Jamaica suffers greatly form over fishing, poor sewage treatment, unmanaged gullies, polluted rivers and improper coastal development. The reefs associated with the Palisadoes are greatly stressed; the reef community at each study site have low diversity, dominated by macroalgae and has low coral cover. Grazing fish species occurrence is low and *Diadema* are almost absent from most sites. Some disease was seen within the hard coral communities but the occurrence was low. The presence of rubble at each site shows the effect of storm surges on each community (the reefs reduce and dissipate wave energy) which causes the breaking up of sections of the reef. The reduced water quality (increased nutrients) and the lack of grazers (caused by overfishing) allow macroalgae to proliferate, smothering other species and preventing recruitment. The preservation and improvement of these reef communities is essential to any protection and rehabilitation plan.

A previously undescribed reef was found just on the outside of Borrow Area 2. Although located outside of the dredge footprint, this reef now called Dos Tortugas (DT) falls within the area of influence. Careful and well planned mitigation practices are need both for any marine based actives as well as land based actives. Dos Tortugas is the only site in close proximity to the proposed project dredge area. Groyne Field however is closer to the shoreline works and Windward Edge is furthest from all the proposed activities.

Fisheries

As part of an EIA in 2007 by Wilson-Kelly and Kelly, fish surveys were conducted at three (3) locations. Two stations were located near shore and one offshore (~20m depth). Eighteen (18) species of fish were noted in the study with the offshore station being the most species rich; however the numbers reported were the lowest of the three sites (13 fish). The numbers reported at the Palisadoes reef site was the greatest (>100 fish) but consisted mainly of fish less than 5cm in length.

Beach Assessment

Sand dune environments located along the south coast of the Palisadoes, as determined by Thompson (1997) are greatly influenced by the local climatic and soil conditions, particularly in the distribution of coastal plant species. The control site had nine (9) different species of plants in sand dune area. The control area showed a mixture of pioneer (running) species (3) and six (6) different climax species (trees and cacti). *Acacia* was the most dominant tree, appearing in 90% of quadrats and having a maximum height of three (2.8) meters. *Sesuvium* was the most dominant running plant, appearing in all the quadrats in the control site. The mean *Sesuvium* coverage of 36.5% per quadrat was marginally greater in the established sand dune of the control site.

The species diversity for the sand nourishment site was marginally lower, with five (5) species of plants occurring in the sampled areas. However, no trees were found at the impact site. *Sesuvium* showing average coverage of 29.53% per quadrat, colonizing the recovering sand dune area in the majority of the quadrats sampled.

<u>Mangrove Replanting</u>

The harbour side of the Palisadoes roadway has modified extensively over many years; this included the removal of large stands of mangroves. During phase 1 of the roadway construction, several pockets of the remaining mangroves were removed. As part of phase 1mitigation and NEPA requirements, islands and replanting will be undertaken. In the absence of preconstruction surveying data, the mangrove nourishment locations were chosen based on the best information available which included the following:

- Aerial imagery identifying the historic location of mangroves between 1961 and 2004. This information was provided by the National Land Agency (NLA),
- Current survey information along the harbour identifying areas where sand is accreting,
- Alongshore sediment transport modelling from which a determination was made that sand is most likely to accrete along the western and central areas of the harbour.

A total of six (6) planting areas have been identified on the harbour side of the tombolo along the Palisadoes shoreline for mangrove re-planting. The total planting area that will be provided is approximately 6,534 m^2. Four of these areas are located in the western section of the project area (3.7 – 4.1 km from the Harbour View Roundabout), and the other two are located in the central section of the project area (1.8 – 3.2km from the Harbour View Roundabout). These sites coincide well with the areas that had historically supported mangroves before the construction.

Mangrove Island Creation

The creation of mangrove islands involves;

1. Attempts to re-create /re-establish the ecology previously disturbed on mangrove areas by the execution of the Palisadoes Protection and Rehabilitation Project (PPRP).
2. Adhere to the natural zonation observed in a characteristic mangrove forest.
3. Reduce the visual impact of the hard solutions that have been implemented.

4. Improve the vegetative cover of the entrance to Kingston from the Norman Manley International Airport, contributing to the overall aesthetics of the area.

No sensitive ecosystems, plants or animals were found in or near the islands footprint; approximately 6,400 hardened and acclimated 18 - 36 month old mangrove saplings and seedlings grown in the nursery at the UWI Port Royal Marine Laboratory will be planted in the newly created islands “Wild seedlings” will be introduced within the white and black mangrove zone. These seedlings will be introduced randomly in this area 3-6 months following rooted (sapling) introductions. Approximately 4,000 ‘wild’ seedlings will be introduced away from the swash zone

The mangrove species which were removed from the Palisadoes shoreline included all four species found in Jamaica: *Rhizophora mangle* (Red Mangrove), *Conocarpus erectus* (Button Mangrove), *Laguncularia racemosa* (White Mangrove) and *Avicennia germinans* (Black Mangrove).

The impact of the solid waste in the area will be the major deterrent to their survival. A solid waste barrier and regular cleaning regimen will be necessary to maximize plant survival.

A comparison of the mangrove replanting site and the control site showed stark differences. The control site boasted an expected tree density for mangrove trees, with both *Rhizophora* and *Avicennia* occurring at a density of 0.2 plants per m2, along the sampling area. Each quadrat of the total sampled area, showed approximately 2.8 trees. *Rhizophora* trees showed the greatest height, averaging 3.97m.

Human and Social

<u>Demography</u>

The Social Impact Area (SIA) was demarcated as two (2) kilometres from the Palisadoes main road, encompassing the communities of Port Royal and Harbour View. At the time of this study (2014) the population was approximately 15,984 persons and the overall population density was 1,377.7 persons/km^2, this being comparable with the St. Andrew regional density of 1,321.7 persons/km^2. The SIA population generally has less than 10% of persons living in poverty (Harbour View and Port Royal).

<u>Services and Activity</u>

Social, Health and Emergency

Two health centres exist within the SIA; however there are no hospitals within the SIA. One fire station, three police stations and three post office are located within the demarcated SIA. The Norman Manley International Airport (NMIA), situated in the centre of the SIA is the primary airport for business travel to and from Jamaica and for the movement of air cargo. Docks are located at the Jamaica Flour Mills and the Caribbean Cement Company at Rockfort and two marinas, namely Morgan’s Harbour Marina (Port Royal) and the Royal Jamaica Yacht Club (RJYC) are located in the SIA. In addition, the Jamaica Defence Force (JDF) Coast Guard headquarters is situated in Port Royal and the Plumb Point Lighthouse exists at Great Plumb Point.

Transportation

The Norman Manley Highway, commonly known as the Palisadoes road, is a two lane highway that stretches from the roundabout at Harbour View along the Palisadoes towards Port Royal. The Normal Manley Highway is the sole roadway between Port Royal, NMIA and the mainland and is important for persons travelling to and from the airport, commercial transport of freight, passage of residents to and from Port Royal, and those persons travelling for recreational purposes to RJYC, Morgan's Harbour and Port Royal.

Industrial and Economic Activity

The Norman Manley Highway gives visitor's access to Kingston, which accounted for 11.5% of stopover arrivals and 8.2% of total room island wide in 2012. In 2012, Kingston, Port Antonio and the South coast accounted for 12.3% of employment in the accommodation sector. Two fishing beaches exist within the 2 km SIA boundary, namely Port Royal and Seven Miles; the former beach (Port Royal) accounts for 832 fishers and 350 vessels, this being the greatest numbers in the general study area. In addition, the area surrounding Kingston Harbour is a major industrial area; the Jamaica Flour Mills and the Caribbean Cement Company at Rockfort are located within the SIA.

Recreational

Two public bathing beaches exist in the SIA, namely Gunboat and Buccaneer; though not popular attractions today. Major recreational use within the SIA also includes yachting, running, walking, recreational fishing and sightseeing.

Cultural and Archaeological

The Port Royal Heritage Site is situated in the western section of the SIA. Port Royal was founded in the 17th century and was a headquarters for buccaneers and pirates, earning its title of "the richest and wickedest city in the world". Owing to this rich history, there are numerous places of significance located there.

<u>Land/Beach/ Marine Use and Zoning</u>

Existing land use within the SIA is mixed. Buildings and other infrastructure are associated with residential and commercial, industrial facilities, institutional /educational facilities, transportation services and recreational activity. The existing development order for the Kingston area is the Kingston Confirmed Development Order 1966, though it is considered outdated, this is the main piece of legislation used to guide development in the parishes of Kingston and St. Andrew. The proposed project is located within an area zoned as open space. However, the area is protected under various laws and conventions; it is a protected area (the Palisadoes/ Port Royal Protected Area (PPRPA)), a National Heritage Site and a Wetland of International Importance (Ramsar Site).

<u>Perception Survey</u>

A perception survey of residents, individuals and organized groups was undertaken by various means, including key informant consultations; stakeholder meetings/consultations; direct observations; and surveys using questionnaires. The survey instrument was administered to a total of 32 stakeholders along the Palisadoes and in the town of Port Royal during the period April 30 to May 3, 2014. Most persons were not knowledge about the proposed project; however when the project was described, there was generally not much concern. There was a general belief amongst fishers and recreational users that the mangrove islands and sand dunes should be constructed and that they will assist in protecting the roadway.

1.0 INTRODUCTION

1.1 CONTEXT AND RATIONALE

This document presents the findings of the Environmental Impact Assessment (EIA) for the proposed works to be conducted in Phase 2 of the *Palisadoes Rehabilitation and Shoreline Protection Project*. As a requirement of NEPA's "no net loss principle", the replanting of mangroves and revegetation of dunes along the Palisadoes have been identified as necessary components in fulfilling this criteria for this Phase 2 project. Additionally, these activities will improve the aesthetics of the project site, habitats and biodiversity. There is the potential added benefit of improved ecosystem services in the form of shoreline protection. This project is a legal requirement for the completion of the Palisadoes project; it realises the National Works Agency's commitment to the conditions of the permit and licenses issued by NEPA.

The Palisadoes, which borders the Kingston Harbour to its south, is considered an area of national importance owing to the various ecological, economic and social functions that it supports. The main roadway running along the Palisadoes represents the only access point to the town of Port Royal, its historic sites and fishing beaches; Norman Manley International Airport (NMIA), one of the islands international airport; the Caribbean Maritime Institute (CMI); the Royal Jamaica Yacht Club (RJYC); and the Plumb Point Lighthouse. The proposed Project is located within the Palisadoes – Port Royal Protected Area, which is also a Ramsar site and is in proximity to numerous national heritage sites. Further, the Palisadoes is also considered a natural defence from storm waves for the capital city of Kingston.

The shoreline along Palisadoes has experienced the effects of several severe storm events and in particular, the overtopping and blocking of the roadway by sediment. In 2004, following the passage of Hurricane Ivan, 310 m of the shoreline was deemed to be in a critical state. The storm caused total destruction of the sand dunes, inundation and blockage of the roadway with sediment and debris (Plate 1-1, Plate 1-2, Plate 1-3), which led to the complete shutdown of the Norman Manley International Airport (NMIA), and inability of Port Royal residents to drive to the mainland. Ivan also led to the formation of the "Palisadoes New Beach", 50m-wide strips of deposited sand along the Kingston Harbour side of the Palisadoes. Robinson & Khan, 2011 suggest that if Ivan was a more powerful event, it is likely that the sea would have completely overtopped the narrow section of road between Harbour View and the NMIA to form a channel connecting the Caribbean Sea and the harbour; the formation of such a channel was recorded following a hurricane in 1722 (Robinson & Khan, 2011).

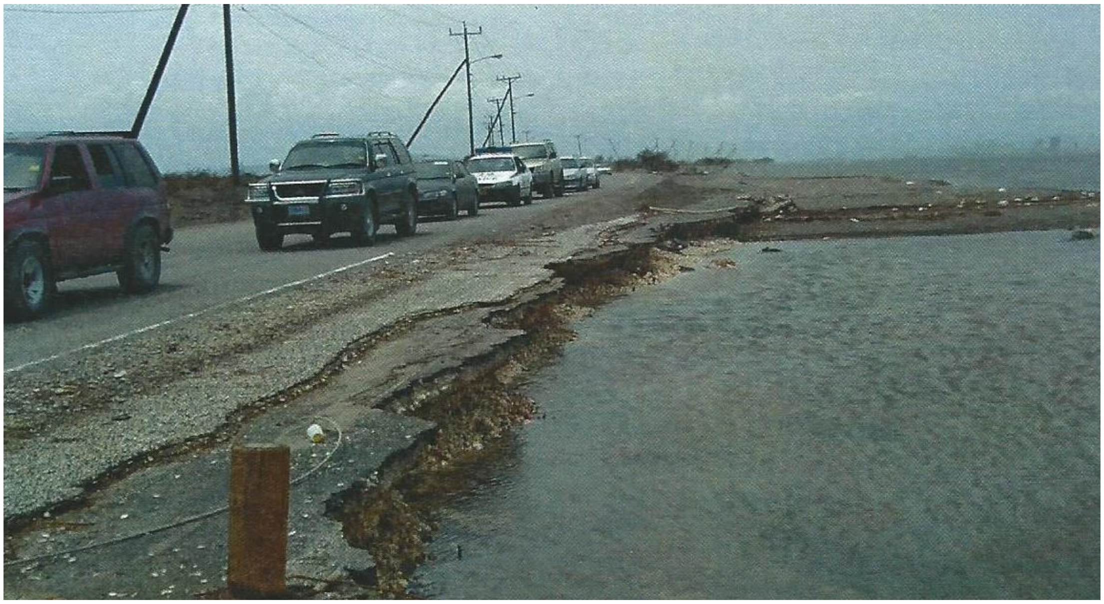
Source: Photo courtesy of J. Tyndale-Biscoe Ltd.in Robinson & Khan, 2011

Plate 1-1 View of eastern Palisadoes taken a few days following the passage of Hurricane Ivan showing overwash sediment fans on Harbour side of Palisadoes and trough behind bar forming the foreshore on the Caribbean Sea side, both of which were absent pre-Ivan

Source: Hurricane Ivan Palisadoes 007 by Brian Pengelley, Jamaican.com [1]

Plate 1-2 View of the Palisadoes showing damage as a result of the passing of Hurricane Ivan in 2004

[1] http://www.jamaicans.com/gallery/ivan/Hurricane_Ivan_Palisadoes_007



(a)

(b)

Source: Robinson & Khan, 2011

Plate 1-3 View of eastern Palisadoes showing erosion on Harbour side of Palisadoes following the passage of Hurricane Ivan (a) and Hurricane Dean (b)

Overwash and deposition of debris was also observed following Hurricane Emily in 2005, temporarily rendering the roadway impassable (Plate 1-4). In 2007, the passage of Hurricane Dean caused approximately 2.65 km of the Palisadoes shoreline to be in a critical state (Plate 1-3, Plate 1-5). Damage to electric poles occurred; whereas such damage did not occur following Hurricane Ivan (Robinson & Khan, 2011). Following a subsequent event in 2007, namely Hurricane Felix, sediment deposition along the Palisadoes was not as severe, perhaps owing to the fact that much of the dune sediment was removed by Dean previously.

Source: Robinson & Khan, 2011

Plate 1-4 View of eastern Palisadoes during Hurricane Emily showing movement of sediment

Source: Robinson & Khan, 2011

Plate 1-5 View of eastern Palisadoes following Hurricane Dean showing sediment moved on to the road in the vicinity of gypsum stockpiles

Owing to the repetitive damage caused by the passage of storm events, the existence, maintenance and improvement of the Palisadoes and its vital roadway has been a national concern for several years. Various structures were built in an aim to curb the destruction caused by storm events. Following Hurricane Emily in 2005, a trial rampart of boulders was constructed at a vulnerable area; however these were destroyed as a result of Hurricane Dean in 200 (Robinson & Khan, 2011). In 1952, after the passage of Hurricane Charley a series of groynes were constructed to stabilize a section of the roadway that had been severely eroded by wave action from the storm. These groynes were however damaged in 2004 from Hurricane Ivan. Forgoing the rehabilitation of the entire roadway has been considered as well, and various alternatives have been suggested. These include the construction of a bridge across the harbour; the creation of channels across the roadway with bridges to connect the segmented parts; and the relocation of the NMIA, Port Royal residents and other infrastructure in place for industrial, institutional and recreational activities existing along the Palisadoes.

1.2 PROJECT BACKGROUND

In 2008, the National Works Agency (NWA) was tasked with the responsibility of designing a method of restoring the stability of the Palisadoes, this project being called the "*Palisadoes Shoreline Protection and Rehabilitation Project*". The NWA, in partnership with the Ministry of Local Government and the Environment, and with the technical input from the Ministry of Science, Technology and Environment of Cuba, prepared a report that proposed methods for the re-stabilization. This involved dredging a burrow area close to the shore of the Caribbean Sea side of the Palisadoes and using this material to form dunes along the shoreline. The funding source for the proposed project however required that a reassessment of the design be done and the original proposal was modified as follows:

- The dune was replaced with rock revetment along the entire shore and elevated road with some 3.7 km of high revetment and 1.3 km of the dune revetments to be buried under the dredged sand.
- Revetments along the Harbour Side of the Palisadoes replaced sand bars and mangrove forests. Mangrove seedlings less than 1m in height were transplanted to alternate sites or housed at the mangrove nursery at the Port Royal Marine Laboratory.

The revetment construction and elevation of the road seen in Plate 1-6 and Plate 1-7 was completed in December 2012. The work carried out necessitated the removal of coastal vegetation from both sides of the Palisadoes and this was a major concern shared by stakeholders and relevant planning authorities. Based on the conditions of the Beach licenses and Environmental Permits issued for the project, the NWA is mandated to replant and restore as much of the native vegetation as possible, in order that there is no net loss of mangroves from the project. This coastal forest rehabilitation forms a part of Phase 2 of the *Palisadoes Rehabilitation and Shoreline Protection Project,* which comprises two main components:

1. Dune nourishment and re-vegetation

2. Island creation and mangrove planting

The re-vegetation of dunes and the establishment of mangrove islands address stakeholder concerns and fulfil the criteria stipulated in the Beach licenses and Environmental Permits issued for the project.

(a)


(b)


Plate 1-6 View of the elevated road and rock revetment along the Kingston Harbour side of the Palisadoes, erected as part of the Palisadoes Shoreline Protection and Rehabilitation Palisadoes project

Plate 1-7 Rock revetment along the Caribbean Sea side of the Palisadoes, erected as part of the Palisadoes Shoreline Protection and Rehabilitation Palisadoes project

1.3 THE PROPONENT

The National Works Agency is the main government organisation directly responsible for Jamaica's main road network and bridges. The transportation network under the purview of the NWA consists of approximately 5,000 km of class A, B and C roads and 736 bridges. The mission of the NWA is to "plan, build and maintain a reliable, safe and efficient main road network and flood control system, which: protect life and property; support the movement of people, goods and services; reduce the cost of transportation; promote economic growth and quality of life; and protect the environment.

2.0 PROJECT BRIEF

2.1 SCOPE OF WORKS

The Phase 2 work for the *Palisadoes Rehabilitation and Shoreline Protection Project* involves the dredging of approximately 99,208 m^3 of sand from the borrow area outlined by Juanes et al. (2007), and placing this dredged material over the low crest revetment along the Caribbean Sea side of the Palisadoes spit complex. There is also the need to create areas in the Harbour side of the tombolo to facilitate the planting of mangroves within the Harbour. Mangrove and coastal vegetation will be provided by the Port Royal Marine Laboratory (PRML) from their existing nurseries and replanted according to the guidelines outlined by the University of the West Indies (UWI, Mona) study.

CEAC Solutions Co. Ltd. has been commissioned by the NWA to provide technical assistance to plan, execute and monitor dredging operations for the creation of suitable substrate for re-vegetation of the dunes to be formed; and plan, execute and monitor the creation of suitable areas for the planting of mangroves on the harbour side of the Palisadoes. The approach taken by CEAC Solutions involved: conducting stakeholders meetings; gathering anecdotal information; field investigations; defining the trends in the climate change drivers; wave, hydrodynamic and sediment analysis studies; laboratory testing; construction methodology study and cost estimating. An *Engineering Design Report* was submitted in February 2014 that detailed the results of this work. Parallel to this, an environmental impact assessment (EIA) was undertaken of the engineering proposal relative to the environmental resources and socio-economic concerns. The Terms of Reference (TORs) for this EIA may be seen in Appendix 1 and this report serves to present the findings of the EIA.

2.2 PROJECT LOCATION

The Palisadoes is situated along the south coast of Jamaica, in its capital city of Kingston. It forms the southernmost extent of the Kingston Harbour, and the Caribbean Sea is located to its south. It is approximately 14 km long and connects the mainland at Harbour View to Port Royal on its western tip. Figure 2-1 depicts the general location of the proposed mangrove planting and sand dune nourishment areas; further location detail is given in section 4.2.1 and 4.2.2.

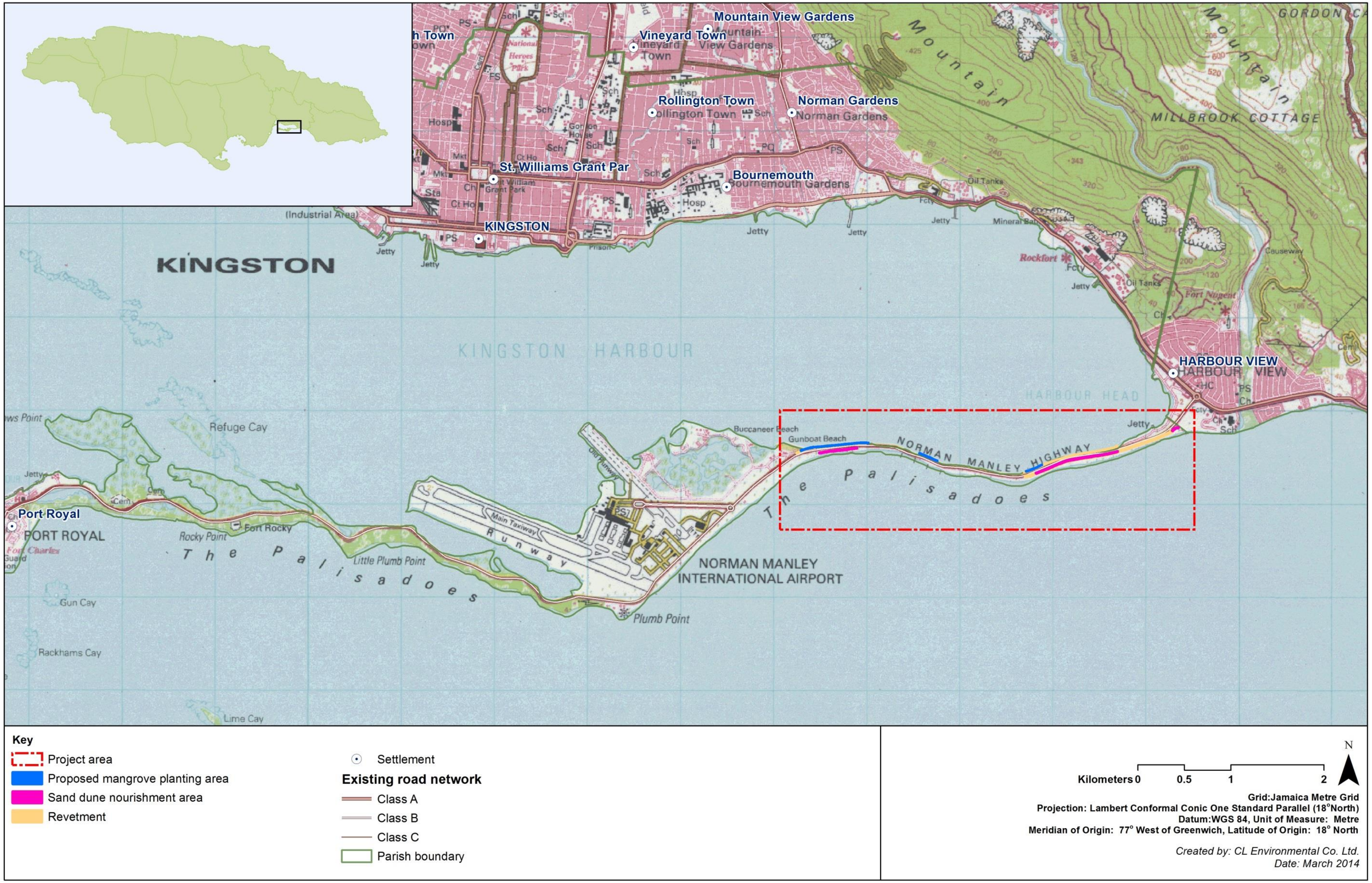


Figure 2-1 Location of proposed mangrove planting and sand dune nourishment areas for Phase 2 of the Palisadoes Rehabilitation and Shoreline Protection Project

2.3 PROJECT PHASING AND SCHEDULE

2.3.1 Project Stages

The Project consists of three phases:

- **Stage 1** - Preparation of the Bid document; completion of engineering works for preparation of both replanting areas; and preparation of EIA.
- **Stage 2** – Project implementation
    - Dune nourishment and re-vegetation
    - Island creation and mangrove planting
- **Stage 3** – Post project monitoring.

Figure 2-2 illustrates the various activities and associated timelines according to each project phase.

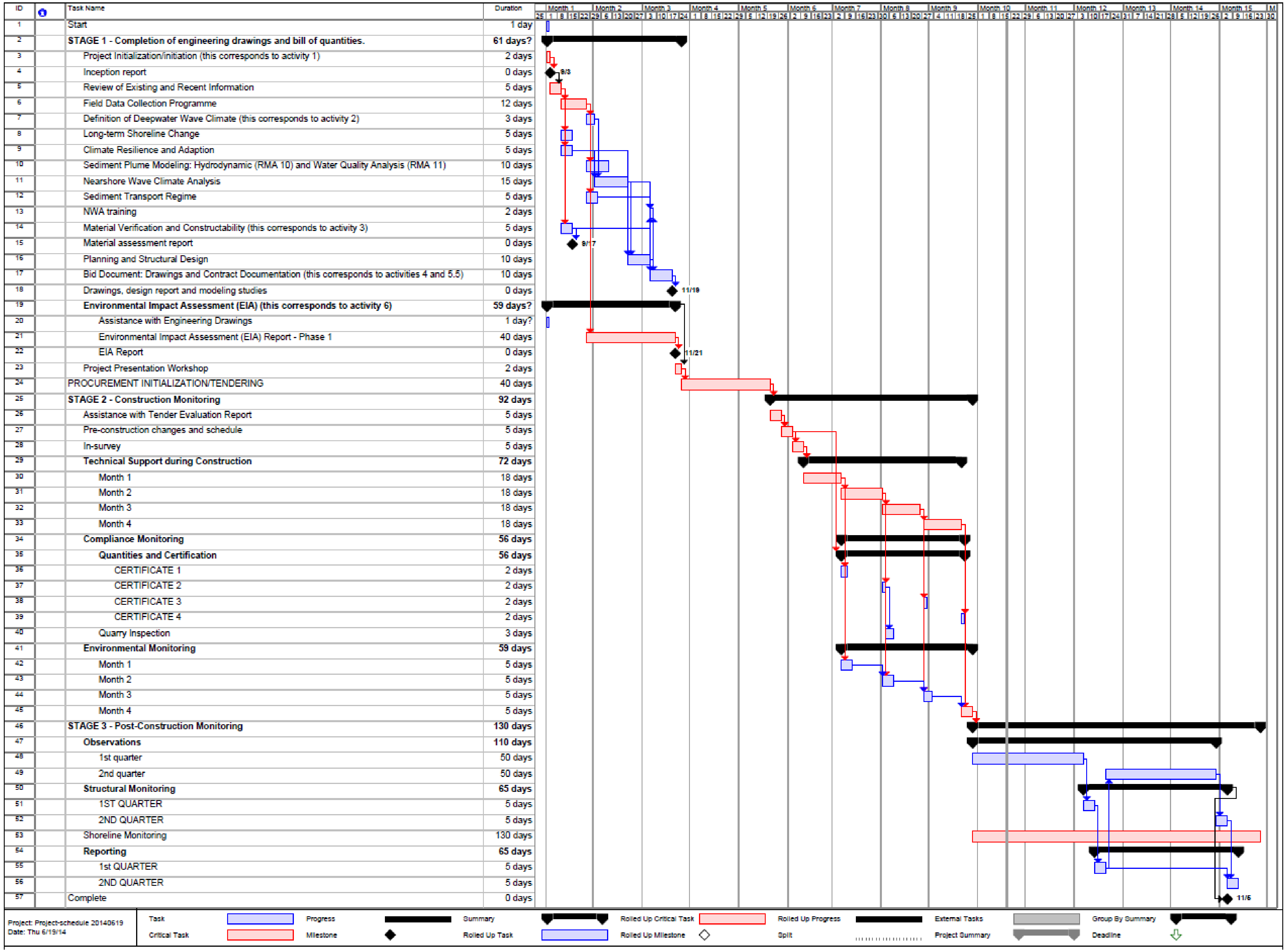


Figure 2-2 Gantt chart showcasing phased activities for proposed project

2.3.2 Procurement and Costing

2.3.2.1 Summary of Costs

Procurement is envisaged in two parts, namely: dredging and placement of sand along the Palisadoes (dune nourishment) and the supply and placement of mangrove nourishment along the harbour side. The dredging contract is expected to involve a dredging contractor with the requisite skills and equipment, while the mangrove nourishment contractor is expected to engage local sources of material working under a main contractor. The engineers estimate for the project is US$4,223,154.10, made up as follows:

- Dredging and Placement of Sand for Dune Nourishment: US$3,971,220
- Supply and Placement of Mangrove Nourishment: US$251,934.10

It is expected that in the internal project team meetings that various components of the costs will be discussed and prioritized in order to arrive at an agreed approach in the tender document.

2.3.2.2 Dredging and Placement of Sand for Dune Nourishment

An international dredging contractor is expected to supply the material needed for the dune nourishment activity; this consists of dredging the designated borrow areas 1 and 2 to achieve the required volume for land reclamation of dunes 1 and 2. This material will be deposited in thin layers over the buried revetments with sufficient intervals between successive increases in the depth of fill to ensure that the underlying soil does not fail. Each layer shall be compacted and maintained at all times with a sufficiently even surface in order to drain away the surface water. Quality control measures include:

- Protection of all vegetation and/ or property within limits of disturbance.
- Periodic inspections and/ or verification by the Engineer during and after the dredging work.
- Testing of the dredged material at regular intervals to determined its uniformity/ conformity with the source samples. Any discrepancies discovered with sediment characterization shall be immediately brought to the attention of the engineer.

2.3.2.3 Supply and Placement of Sand for Mangrove Nourishment

This section of the project is aimed at providing sufficient soft coastal protection for the Palisadoes and to rehabilitate the coastal ecosystem through mangrove re-vegetation. Four (4) mangrove replanting areas along the Kingston Harbour will be formed to create over 6,000 m^2 of replanting area. The filling operation shall be done by mechanical placement in the nourishment areas and shall follow the recommended engineering and EIA guidelines.

Quality control measures include the regular sampling and testing of the fill material to determine its uniformity/ conformity with the source samples.

3.0 POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

3.1 EIA FRAMEWORK

3.1.1 Rationale and Basis

An Environmental Impact Assessment (EIA) is "a structured approach for obtaining and evaluating environmental information prior to its use in decision-making in the development process. This information consists, basically, of predictions of how the environment is expected to change if certain alternative actions are implemented and advice on how best to manage environmental changes if one alternative is selected and implemented" (Bisset, 1996).

The basis and rationale of an EIA has been summarised as follows[2]:

- Beyond preparation of technical reports, EIA is a means to a larger end - the protection and improvement of the environmental quality of life.
- It is a procedure to discover and evaluate the effects of activities on the environment - natural and social. It is not a single specific analytical method or technique, but uses many approaches as appropriate to the problem.
- It is not a science but uses many sciences in an integrated inter-disciplinary manner, evaluating relationships as they occur in the real world.
- It should not be treated as an appendage, or add-on, to a project, but regarded as an integral part of project planning. Its costs should be calculated as a part of adequate planning and not regarded as something extra.
- EIA does not 'make' decisions, but its findings should be considered in policy - and decision-making and should be reflected in final choices. Thus, it should be part of decision-making processes.
- The findings of EIA should focus on the important or critical issues, explaining why they are important and estimating probabilities in language that affords a basis for policy decisions.

3.1.2 National Environment and Planning Agency

The National Environment and Planning Agency (NEPA) is the government executive agency and represent a merger of the Natural Resources Conservation Authority (NRCA), the Town Planning Department (TPD) and the Land Development and Utilization Commission (LDUC). Among the reasons for this merger was the streamlining of the planning application process in Jamaica. The Agency is moving towards one application to NEPA for new developments and new modifications that will review

[2] Wood, C., "Environmental Impact Assessment: A Comparative Review" p. 2. (from Caldwell, 1989, p.9)

and approve environmental aspects as well as planning, building control and zoning considerations. It is this agency that will review the Environmental Impact Assessment.

The National Environment and Planning Agency (NEPA) has been given responsibility for environmental management in Jamaica under the NRCA Act of 1991. Since the promulgation of the Act, the NRCA has been developing local standards. The Act was strengthened by supporting regulations, which became effective in January 1997. The underlying principles, which have been used in the development of the Act, are:

- The Polluter pays Principle
- The Cradle to Grave approach to waste management

3.1.3 Permits and Licenses

The Environmental Permit and License System (P&L) is administered by NEPA through the Applications Section. It was introduced in 1997 to ensure that all developments meet required standards and negative environmental impacts are minimized. Under the NRCA Act of 1991, the NRCA has the authority to issue, suspend and revoke environmental permits and licenses. An applicant for a Permit or License must complete a Permit Application Form (PAF) as well as a Project Information Form (PIF) for submission to the NRCA/NEPA.

3.1.4 EIA Components

3.1.4.1 Process

The EIA Process is described below:

- The NRCA permit procedure is initiated by the submission of the Project Information Form (PIF) to the Authority. The PIF screening form is reviewed to determine whether an EIA is required and to begin determining areas of environmental significance, especially in waste discharge.
- Based on the review of the PIF, the NRCA advises if an EIA would be required for the proposed project and determines the scope of the EIA through proposed Terms of Reference (TORs). The TORs are proposed using NRCA guidelines and are ultimately approved by the NRCA. Appendix 1 gives the approved final TORs for the proposed project.
- The NRCA requires that the EIA include the following:
    - A description of the present environment, i.e. physical, biological and social environment. This includes, for example, consideration of economic situations, cultural heritage and ecological preservation;
    - A description of the significant impacts the environmental professionals expect the development to have on the environment, compared to the environment that would remain if there were no development. This will include indirect and cumulative impacts;

  - An analysis of alternatives that were considered in order to consider means of minimising or eliminating the impacts identified above; and
  - An Environmental Management Plan, which includes a Monitoring & Hazard Management Plan and an Auditing schedule.
- The NRCA guidance on EIAs states that this process “should involve some level of stakeholder consultation in either focus groups or using structured questionnaires.” A draft EIA is submitted to the developer to solicit the proponents’ input into the description of the project (to check for accuracy of statements, and to enter into realistic discussions on the analysis of alternatives, as well as to inform the proponents of any other relevant legislation with which they must comply).
- Eleven copies of the finalised draft are then submitted to NRCA, two to the client, and the consultant keeps one (14 in all are produced). The NRCA distributes these to various other public sector institutions who sit on the Technical Committee (e.g. Water Resources Authority (WRA), Environmental Control Division in the Ministry of Health (ECD), Jamaica National Heritage Trust (JNHT)) for their comments. Typically this depends on the nature of the project.
- As deemed necessary by the NRCA, Public Meetings are then held, following the deposition of the Draft EIA at Parish Libraries (by the NRCA). A verbatim report of the public meetings is required, as well as a summary report of the main stakeholder responses which emerged.
- The comments of the NRCA, the other GOJ interests and the public are compiled and submitted in writing to the consultant not only for finalisation of the report, but for incorporation into the development’s design.
- The NRCA then reviews this report again, and if further clarifications are needed, these are again requested. Once the NRCA is satisfied, the EIA is submitted to the Technical Committee of the NRCA Board for final approval. If the EIA is not approved, the proponents may appeal to the Office of the Prime Minister.

3.1.4.2 Public Participation

There are usually two forms of public involvement in the EIA process. The first is direct involvement of the affected public or community in public consultations during the EIA study. These consultations allow the developer to provide information to the public about the project and to determine what issues the public wishes to see addressed. The extent and results of these consultations are included in the documented EIA report.

The second level of involvement is at the discretion of the NRCA and takes place after the EIA report and addendum, if any, has been prepared and after the applicant has provided the information needed for adequate review by NRCA and the public.

Community interaction and transparency is a critical area of focus for the success of this development and the second level of involvement described above is possible. Please see Appendix 3 for the NRCA reference document entitled “Guidelines for Public Participation” in EIAs.

3.2 NATIONAL LEGISLATION

EIAs are not only recommended in project design, but also required by Jamaican legislation. The following sections include a discussion of relevant national legislation, regulations/standards, policies and other material thought to be relevant to the proposed project. The following main areas are covered:

- *Development Control*: construction (including building codes and site management controls) and subsidiary inputs (quarry material, etc.), public safety and vulnerability to natural disasters
- *Environmental Conservation*: forestry, wildlife and biodiversity, protected areas and species, water resources, heritage and cultural resources.
- *Public Health & Waste Management*: air quality, noise levels, public health, solid waste, storm water, etc.

The roles of agencies with responsibility for implementing legal mechanisms are described where applicable.

3.2.1 Development Control

3.2.1.1 The Town and Country Planning Act (TCP Act) 1957 (Amended 1987)

The Town and Country Planning Act (TCP Act) 1957 (Amended 1987) provides the statutory requirements for the orderly development of land through planning, as well guidelines for the preparation of Development Orders. A Development Order is a legal document which is used to guide development in the area to which it applies and the TCP Act is only applicable in an area where a Development Order exists. It constitutes land use zoning map/s, policy statements and standards relating to land use activities. It is intended to (among other things) secure proper sanitary conditions and conveniences, co-ordinate the delivery of roads and public services, protect and extend amenities and conserve and develop the resources of the area to which it applies. Other stipulations under the TCP Act are made for Advertisement Control Regulations, Petrol Filling Stations and Tree Preservation Orders. Tree Preservation Areas and Conservation Areas (as specified areas the gazetted Development Orders) are two types of protected areas associated this Act.

The TCP Act establishes the Town and Country Planning Authority, which in conjunction with the Local Planning Authorities (Parish Councils), are responsible for land use zoning and planning regulations as described in their local Development Orders. The TCP Act is administered by the National Environment and Planning Agency.

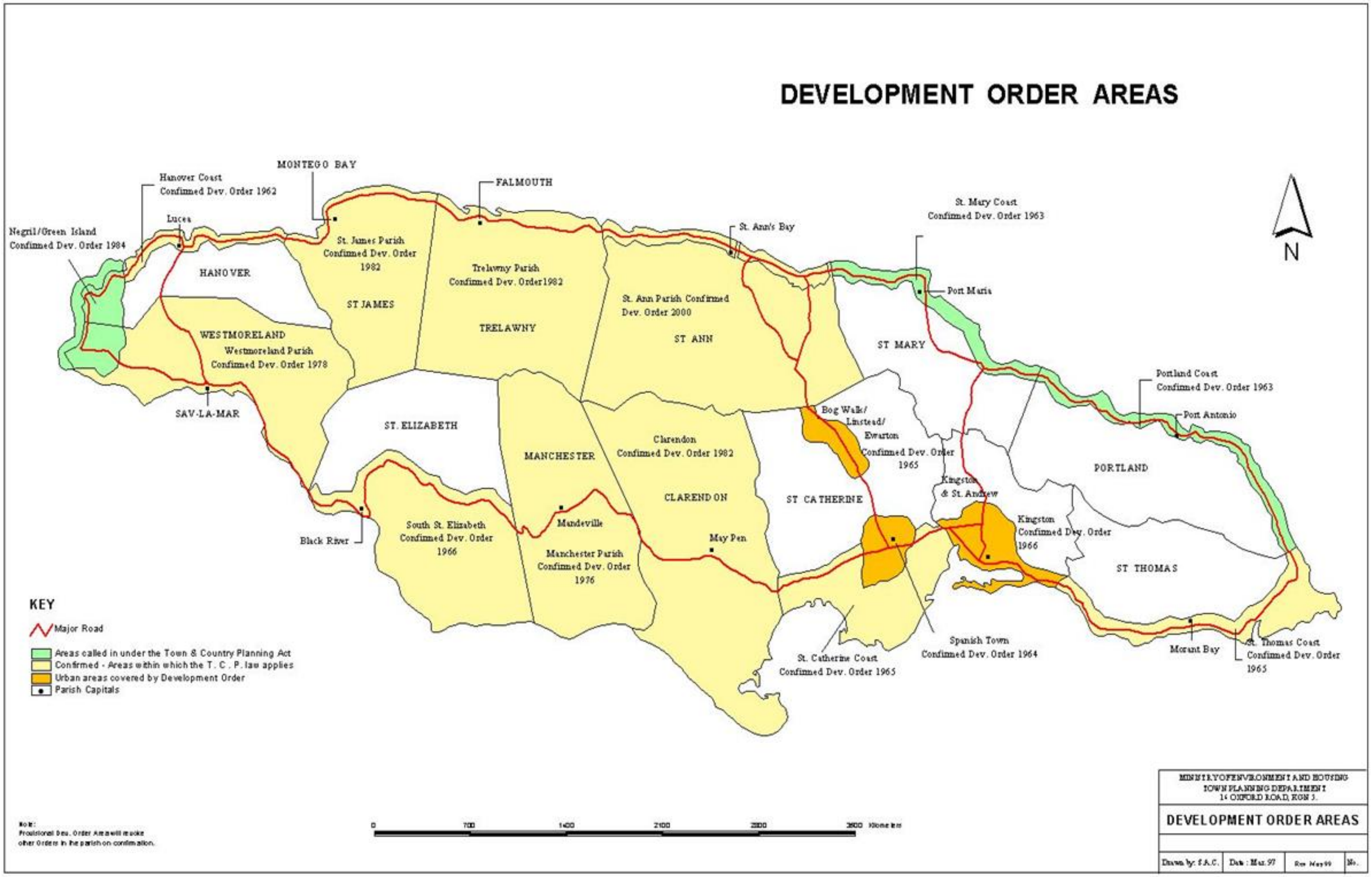
As seen in Figure 3-1, the Development Order relevant to this proposed is the Kingston Confirmed Development Order 1966. Though outdated, this is the main piece of legislation used to guide the development within the parishes of Kingston and St. Andrew. Efforts were made to update this document; in 2010, the Local Area Planning Branch (NEPA) reported that the Draft Kingston and St. Andrew Development Order is intended to bring the entire parishes of Kingston and St. Andrew under Planning Law (The Local Area Planning Branch, NEPA, 2010). In addition, a Draft Kingston and St.

Andrew Sustainable Development Plan (2005) exists (Kingston and St. Andrew Parish Corporation, 2012). The Sustainable Development Plan (SDP) for KSA focuses on planning and the need for innovative and dynamic planning initiatives in order to respond to demands[3]. Strategic goals include:

- Improve living Conditions for KSA residents
- Promote growth and increased productivity of City outputs, broad based employment, investment and trade
- Sustainable manage and conserve natural, cultural and built environment
- Establish a safe city and ensure a significant reduction in crime and violence
- Support stronger, more effective system and local governance

The local planning authority for the development is the Kingston and St. Andrew Parish Corporation (KSAC). Its functions include granting permission to develop land (based on the Development Order and subject to approval by TCPA), maintaining a public register on land development applications, and enforcing planning controls. Continued proactive communication with the Parish Council is recommended in order to keep them informed and in dialogue on the activity in their jurisdiction. This will also be the approach of the environmental consulting team in deliberating environmental aspects of the planning and approval process.

[3] http://www.iuc.edu.jm/imagine/subpage.php?id=context



Source: National Environment and Planning Agency[4]

Figure 3-1 Development Order Areas in Jamaica

[4] http://www.nepa.gov.jm/symposia_03/Laws/Maps/Map_of_Development_Orders.htm

3.2.1.2 Parish Councils Act 1901 (Amended2007)

Under the Parish Council Act each Local Planning Authority (Parish Councils) may revoke or alter regulations concerning the construction and restrictions as to the elevation, size and design of buildings built with the approval of the relevant Minister. It may also make regulations concerning the installation of sewers on premises. As mentioned previously, the Kingston and St. Andrew Parish Corporation (KSAC) is the local planning authority with responsible for development within the study area for the proposed project.

3.2.1.3 The Exclusive Economic Zone Act 1993

The Exclusive Economic Zone Act is designed to protect the living and non-living resources in the Exclusive Economic Zone (EEZ). It speaks to the establishment of the EEZ, a marine zone prescribed by the *United Nations Convention on the Law of the Sea* with its inner limit the boundary line of the seaward limit of the territorial sea (and subject to subsection (3) of the Act) and its outer limit two hundred nautical miles from the baselines from which the breadth of the territorial sea is measured. The Act stipulates conditions for the exploration for and exploitation of living and non-living resources of the zone, in addition to the powers and duties of marine officers.

It should be borne in mind during the construction phases of the project, that under this Act, it is an offence, to exploit living and non-living creatures and conduct research without a licence.

3.2.1.4 The Maritime Areas Act 1996

Under this Act, Jamaica is declared an archipelagic State and defines the internal waters as areas of the sea which are on the landward side of the closing lines within the archipelagic waters. It states that the archipelagic baselines shall consist of straight baselines joining the outermost points of the outermost islands and drying reefs of Jamaica and the breadth of the territorial sea, the contiguous zone and the continental shelf shall be measured from the archipelagic baselines. As an archipelagic State, the sovereignty of Jamaica extends to the waters enclosed by the archipelagic baselines, as well as the air space over the archipelagic waters, their bed and subsoil and the resources, living and non-living, with the boundaries. Stipulations regarding infrastructure within and passage through the archipelagic waters are made as well as limits and jurisdictions regarding the contiguous zone and continental shelf

Offences under this Act must be borne in mind during construction activities. Offenses include the refusal, neglect or failure to comply with directive of Marine Officer or to produce licence to Marine Officer and participation while on the vessel in acts contrary to Jamaica's peace, order or security.

3.2.1.5 The Port Authority Act 1972

Under the Port Authority Act, the Port Authority was established as the primary maritime agency responsible for the regulation and development of Jamaica's port and shipping industry. The Marine Board was further established to make rules for the regulation and control of harbour and ship channels. It allows for the prohibition of the discharge of rubbish, earth, stone, ballast, mud, oil, mixtures with oil or its residues, as well as the removal of stones and gravel from reefs, shoals, or cays. In addition, the construction of structures on or over the water, or dredging activities is regulated under this Act.

3.2.1.6 The Harbours Act 1874

The Harbours Act speaks to the declaration of harbours and appointment of Harbour Masters. Section 7 allows the Marine Board to make rules for the regulations and control of any harbour. Under this section, the *Harbour Rules 1971* were passed and these apply to any boat or vessel using any harbour in the Island, or the channels or approaches to such harbour. Stipulations pertaining to safety and conduct are included.

3.2.1.7 The Shipping Act 1998

The Act speaks to a range of shipping activities, including registration of ships and small vessels, taxation, manning, welfare of seamen, safety, wreck and salvage. The Maritime Authority was established to implement the provisions of the Shipping Act, and amongst its functions are administration of the registration of ships, regulation of shipping safety and inspection of ships for the purposes of maritime safety and prevention of marine pollution.

3.2.1.8 The Beach Control Act 1956 and the Beach Control (Amendment) Act 2004

This Act was passed in 1956 to ensure the proper management of Jamaica's coastal and marine resources by means of a licensing system. This system regulates the use of the foreshore and the floor of the sea. In addition, the Act speaks to other issues including access to the shoreline, rights related to fishing and public recreation and establishment of marine protected areas. Under section 5 of this act, it is an offence to encroach on the foreshore or floor of the sea for a public or commercial purpose without a licence.

The *Beach Control (Licensing) Regulations 1956* require a permit for any works on a beach, coastline or foreshore. Application for this permit must be made to NEPA. The requirements of the permit include a Notice of Application to be posted on the landward and seaward sides of the property and said Notice should be served on adjoining neighbours. Member of the Natural Resources Conservation Authority or any officer authorised by the Authority may conduct investigations to ensure compliance with licence and require information to be furnished.

In addition, the following regulations also fall under the Beach Control Act 1956:

- *The Beach Control (Hotel, Commercial and Public Recreational Beaches) Regulations 1978*
- *The Beach Control (Safety Measures) Regulations 1957*

3.2.1.9 The Jamaica National Heritage Trust Act 1985

The Jamaica National Heritage Trust Act established the Jamaica National Heritage Trust (JNHT) and has been in operation since 1985. The main goal is the preservation and protection of the country's national heritage. The Palisadoes/ Port Royal area was declared a National Heritage Site on July 22, 1999 under the Jamaica National Heritage Trust Act 1985. This area includes part of Harbour Head Pen, the Palisadoes and Port Royal in the parishes of Kingston and St. Andrew, and the adjoining sea and cays.

The Act states the following offences are liable to a fine and/or imprisonment:

- Wilfully defacing, damaging or destroying any national monument or protected national heritage;
- Wilfully defacing, destroying, concealing or removing any mark affixed or connected to a national monument or protected national heritage;
- Altering any national monument or marking without the written permission of the Trust;
- Removing any national monument or protected national heritage to a place outside of Jamaica.

3.2.1.10 The Mining Act 1947 (Amended 1995)

The Mining Act provides the legal framework governing mining and its operations. It also indicates the sanctions or penalties for non-compliance. According to this Act, any person who prospects or mines otherwise than in accordance with the provisions unlawful of the Act shall be guilty of unlawful prospecting or unlawful mining. The Mining Act details provisions regarding prospecting rights and licenses; mining leases and operation; passage ways; and possessions and purchase of materials. *The Mining Regulations 1947* and *the Mining (Safety and Health) Regulations 1977* are the two ancillary regulations associated with this Act. It is administered by the Mines and Geology Division, Ministry of Water, Land, Environment and Climate Change.

3.2.1.11 The Quarries Control Act 1984 and the Quarries Control (Amendment) Act 1994

The Quarries Control Act is administered by the Mines and Geology Division It regulates the extraction of material such as sand, marl, gypsum, and limestone for construction purposes. Quarry zones and licenses, quarry tax, enforcement, safety, Quarry Advisory Committee, fines for illicit quarrying and bonds for restoration are addressed in this act.. A license is required for establishing or operating a quarry, unless the Minister decides to waive this requirement based on the volume of material to be extracted (if the mineral to be extracted is less than 100 cubic metres, a license may not be required).

3.2.2 Environmental Conservation

3.2.2.1 Policy for the National System of Protected Areas 1997

The system of protected areas should be an essential tool for environmental protection, conserving essential resources for sustainable use, helping to expand and diversify economic development, and contributing to public recreation and education. Six types of protected areas are proposed in order to encompass the diverse natural resources and landscape, and are comparable to those of the IUCN (International Union for Conservation of Nature)[5]:

1) National Nature Reserve/Wilderness Area (Equivalent to IUCN Category I)
2) National Park, Marine Park (Equivalent to IUCN Category II).
3) Natural Landmark/National Monument (Equivalent to IUCN Category III)
4) Habitat/Species Management Area (Equivalent to IUCN Category IV)
5) National Protected Landscape, or Seascape (Equivalent to IUCN Category V)
6) Managed Resource Protected Area (Equivalent to IUCN Category VI)

This legislative instrument is a White Paper and essentially proposes a comprehensive protected areas system for Jamaica. However, as seen in Table 3-1, there are a greater number of protected area categories existing at present than being proposed, with varying responsible agencies and legislative tools.

Table 3-1 Existing categories of protected areas in Jamaica (as at 1 January 2012) - protected area system categories

Source: (Protected Areas Committee, 2012)

CATEGORY	RESPONSIBLE AGENCY	LAW
Protected Area	Forestry Department: Water, Land, Environment and Climate Change (MWLECC)	Forest Act, 1996 and Forest Regulations
	NEPA: MWLECC	NRCA Act, 1991
	NEPA: MWLECC	Beach Control Act, 1956
National Park	NEPA: MWLECC	NRCA Act, 1991
Marine Park	NEPA: MWLECC	NRCA Act, 1991
Environmental Protection Area	NEPA: MWLECC	NRCA Act, 1996
Forest Reserve	Forestry Department: MWLECC	Forest Act, 1996 and Forest Regulations
Fish Sanctuary	Fisheries Division: Ministry of Agriculture and Fisheries	Fishing Industry Act, 1976
National Monument	Jamaica National Heritage Trust(JNHT) Ministry of Youth and Culture (MYC)	JNHT Act, 1985
Protected National Heritage	JNHT: MYC	JNHT Act, 1985
Game Sanctuary	NEPA (NRCA): MWLECC	Wild Life Protection Act, 1945
Game Reserve	NEPA (NRCA): MWLECC	Wild Life Protection Act, 1945

Table 3-2 Existing categories of protected areas in Jamaica (as at 1 January 2012) - other designations not considered part of the system

[5] It should be noted that since the publication of the Policy for Jamaica's System of Protected Areas 1997, the IUCN has revised the categories system and guidelines (http://cmsdata.iucn.org/downloads/guidelines_for_applying_protected_area_management_categories.pdf)

Source: (Protected Areas Committee, 2012)

CATEGORY	RESPONSIBLE AGENCY	LAW
Tree Order Preservation	Local Authority (Town and Country Planning Authority): MWLECC and Local Government Department, through Parish Councils	Town and Country Planning Act, 1958
Conservation Area	NEPA (Town and Country Planning Authority, parish councils): MWLECC	Town and Country Planning Act, 1958
Protected Watershed	NEPA (NRCA): MWLECC	Watershed Act, 1963 Protection

Table 3-3 Existing categories of protected areas in Jamaica (as at 1 January 2012) - international designations

Source: (Protected Areas Committee, 2012)

CATEGORY	RESPONSIBLE AGENCY	CONVENTION
Ramsar Site	NEPA (NRCA): MWLECC	Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention)
World Heritage Site (no existing sites, however submissions have been made)	Jamaica National Heritage Trust: MYC	World Heritage Convention

The Natural Resources Conservation Authority (NRCA)/National Environment and Planning Agency (NEPA) is the lead agency with responsibility for the protected area system; however a number of other government , local management entities, non-governmental entities, privet sector and individuals are outlined as important role players as well.

The proposed study falls within an area (Palisadoes/ Port Royal) protected under various legal instruments and agreements:

- Natural Resources Conservation Authority Act (NRCA) (1991) - The Palisadoes/ Port Royal Protected Area (PPRPA) was declared as a protected area on September 18, 1998.
- Jamaica National Heritage Trust Act - Declared a National Heritage Site on July 22, 1999.
- Convention on Wetlands of International Importance (Ramsar) - Designated a Wetland of International Importance (Ramsar Site) in April 2004.

National Environment and Planning Agency (NEPA) is the primary management institution; NRCA, Fisheries Division, JNHT, TPDCo and the University of the West Indies (UWI) also participate in management efforts. [6]

[6] http://campam.gcfi.org/CaribbeanMPA/pdfexport/pdf_generator.php?mpaId=347

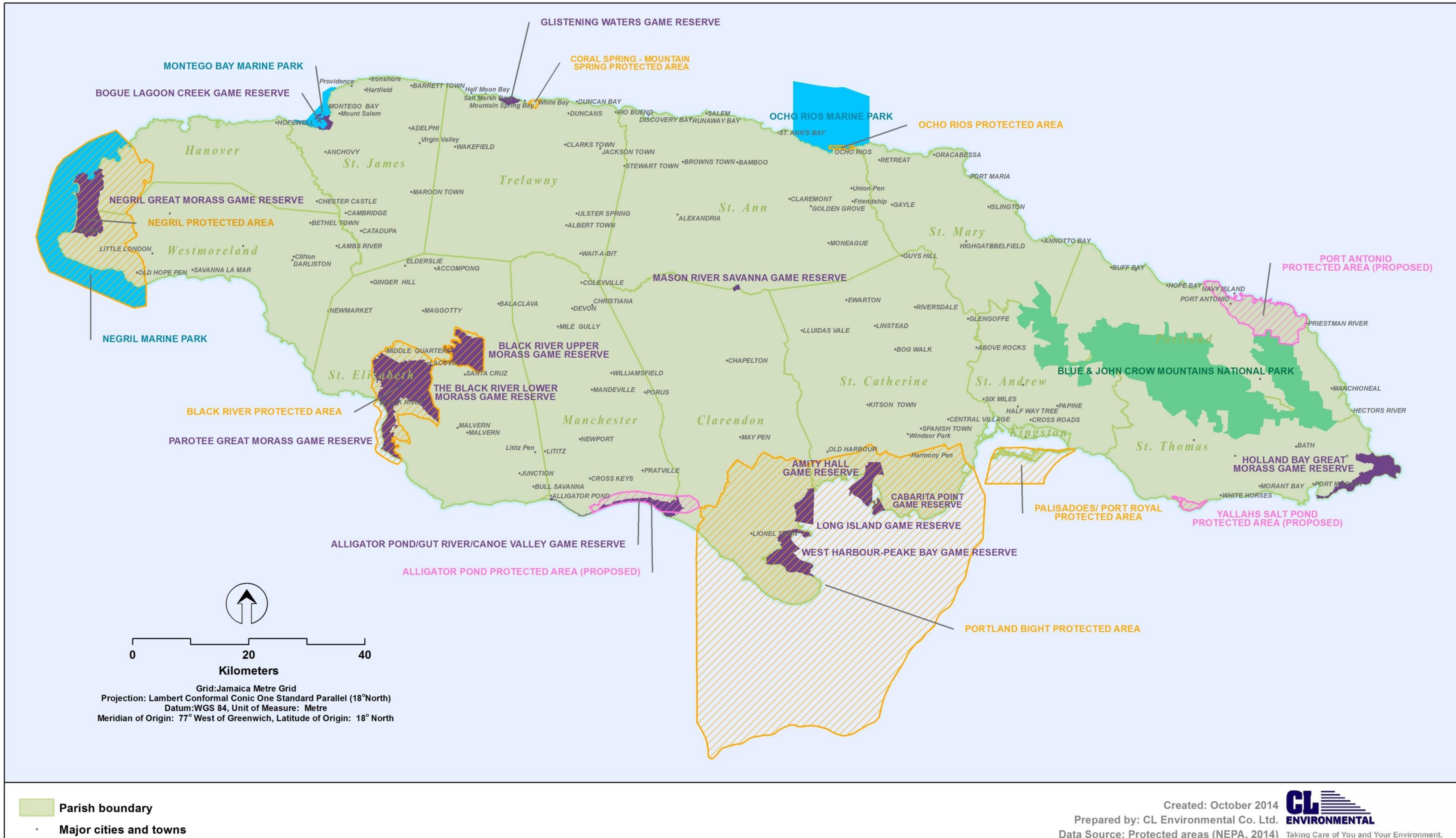


Figure 3-2 Protected areas system in Jamaica

3.2.2.2 Natural Resources Conservation Act 1991

The Natural Resources Conservation Act (NRCA) may be considered Jamaica's umbrella environmental law. The purpose of the Act is to provide for the management, conservation and protection of the natural resources of Jamaica. This Act was passed in the Jamaican Parliament in 1991 and subsequent to this; the Natural Resources Conservation Authority (NRCA) was established. The NRCA Act, under Sections 9 and 10 specifies that an Environmental Impact Assessment (EIA) is required from an applicant for a permit for undertaking any new construction, enterprise or development. It also speaks to the designation of national parks, protected areas etc.

The Act also gave power of enforcement of a number of environmental laws to the NRCA, namely the *Beach Control Act*, *Watershed Act* and the *Wild Life Protection Act*, as well as a number of regulations and orders including

- *The Natural Resources (Permit and Licences) Regulations (1996)*
- *The Natural Resources (Marine Park) Regulations 1992, The Natural Resources (Marine Park) (Amendment) Regulations 2003*
- *The Natural Resources (Prescribed Areas) (Prohibition of Categories of Enterprise, Construction and Development) Order 1996*

As mentioned previously, the proposed study falls within a protected area, the Palisadoes/ Port Royal Protected Area (PPRPA) and is also a designated National Heritage and Ramsar Site. Management and oversight of this protected area is primarily the responsibility of the National Environment and Planning Agency (NEPA), as well as other supporting organizations including Fisheries Division, JNHT, TPDCo and the University of the West Indies (UWI).

3.2.2.3 The Natural Resources (Permit and Licences) Regulations (1996)

A permit and licencing system was established under these regulations in order to control the undertaking of any new construction or development of a prescribed nature in Jamaica and the handling of sewage or trade effluent and poisonous or harmful substances discharged into the environment.

3.2.2.4 The Natural Resources (Prescribed Areas) (Prohibition of Categories of Enterprise, Construction and Development) Order 1996

The Natural Resources (Prescribed Areas) (Prohibition of Categories of Enterprise, Construction and Development) Order (1996) and the Permits & Licensing Regulations was passed as a result of section 9 of the NRCA Act. Section 9 of the NRCA Act declare the entire island and the territorial sea as ‘prescribed area’, in which specified activities require a permit, and for which activities an environmental impact assessment may be required. As discussed previously, an EIA was required for the proposed project and this report fulfils one component of the EIA process.

3.2.2.5 The Fishing Industry Act 1975

The Fishing Industry Act 1975 is the overarching instrument relating to fishing activities within Jamaica. The Act also speaks to registration and licensing, fisheries protection, prohibited activities and the declaration of an area as a fish sanctuary. The following instruments fall under the Fishing Industry Act 1975:

- *The Fishing Industry (Exemption) Order 1976*
- *The Fishing Industry (Declaration of Close Season) (Lobsters) 1987*
- *The Fishing Industry Regulations 1976*
- *The Fishing Industry (Conservation of Conch (Genus Strombus)) Regulations 2000*
- *The Fishing Industry (Special Fishery Conservation Area) Regulations 2012*

Under the most recent Fishing Industry (Special Fishery Conservation Area) Regulations 2012, Special Fishery Conservation Areas (SFCAs), more commonly known as fish sanctuaries, are declared. SFCAs do not exist in proximity to the proposed project area. Further, although fishing is not an activity to be carried out intentionally during the proposed project, it must be kept in mind during construction activities that it is an offence, during closed seasons, to take, disturb or injure fish, as well as to destroy or land berried lobster and spiny lobster smaller than 3 inches (7.5 cm).

3.2.2.6 Wild Life Protection Act 1945

The Wild Life Protection Act of 1945 is mainly concerned with the protection of specified faunal species and is the only statute in Jamaica specifically designated to this. This Act protects several rare and endangered faunal species including six species of sea turtle, one land mammal, one butterfly, three reptiles and a number of game birds. A list of these protected species is provided in this Act under the Second and Third Schedules and is presented in Figure 3-3. The establishment of two types of protected areas, namely Game Sanctuaries and Game Reserves is authorized under this Act.

Offenses cited under this Act and relevant to the marine realm should be borne in mind particularly during construction phases. These include possession of all or part of protected animal or bird; possessing, killing, injuring or taking immature fish; cause or knowingly allowing entry of trade effluent/industrial waste, noxious, polluting substances into any body of water with fish; and taking, possessing or trying to sell turtle eggs, amongst others. Further, it is imperative that all persons are mindful of the endangered species protected under this law and as shown in Figure 3-3. Mention must also be made of the wetland areas designated as Ramsar sites.

Protected Jamaican Animals

Common Names	Scientific Names
Sperm Whale	*Physeter macrocephalus*
Baird's beaked Whale	*Berardius bairdii*
Short-finned pilot Whale	*Globicephala macrorhynchus*
Humpback Whale	*Megaptera novaeangliae*
Common Bottlenose Dolphin	*Tursiops truncatus*
Pantropical spotted Dolphin	*Stenella attenuata*
West Indian Manatee	*Trichechus manatus manatus*
Caribbean Monk Seal (Pedro Seal)	*Monachus tropicalis*
Jamaican Hutia (Coney)	*Geocapromys brownii*
American Crocodile	*Crocodylus acutus*
Jamaican Iguana	*Cyclura collei*
Yellow Snake/Jamaican Boa	*Epicrates subflavus*
Green Turtle	*Chelonia mydas*
Hawksbill Turtle	*Eretmochleys imbricata*
Loggerhead Turtle	*Caretta caretta*
Atlantic Kemps Ridley	*Lepidochelys kempii*
Leatherback turtle	*Dermochelys coriacea*
Reid Seahorse	*Hippocampus reidii*
Jamaican Kite Swallowtail	*Eurytides marcellinus*
Giant Swallowtail Butterfly	*Papilio homerus*
Black Coral	*Antipathes* species
White Coral	Scleractinian or Madreporarian

All birds are protected except the following:

Cattle Egret	*Bubulcus ibis*
Rock Dove (Pigeon)	*Columba livia*
Ringed-turtle Dove (Barble Dove)	*Streptopelia risoria*
European Starling	*Sturnus vulgaris*

nepa National Environment and Planning Agency

Protected Jamaican Animals Cont'd

All birds are protected except the following:

Saffron Finch (Wild Canary)	*Sicalis flaveola*
House Sparrow	*Passer domesticus*
Yellow-crowned Bishop	*Euplectes afer*
Red Bishop	*Euplectes orix*
Nutmeg Mannikin	*Lonchura punctulata*
Chestnut Mannikin	*Lonchura Malacca*
Shiny Cowbird	*Molothrus bonariensis*
Chickens	*Gallus gallus*
Geese	*Anser* spp.
Turkey	*Meleagris gallopavo*
Guinea fowl	*Numida meleargris*
Pea fowl	*Pavo cristatus*
Budgerigars	*Melopsittacus undulates*
Cockatiel	*Nymphicus hollandicus*
Ducks excluding endemic and migratory species	

GAME BIRDS (These are protected outside of the bird shooting season)

Mourning Dove (Long-tailed Pea Dove)	*Zenaida macroura*
White-winged Dove	*Zenaida asiatica*
White-crowned Pigeon (Bald pate)	*Columba leucocephala*
Blue-winged Teal	*Anas discors*
Green-winged Teal	*Anas crecca*

Prepared by the Biodiversity Branch, National Environment and Planning Agency
Updated March, 2005

Source: National Environment and Planning Agency (NEPA) [7]

Figure 3-3 Protected animals in Jamaica

[7] http://www.nepa.gov.jm/publications/brochures/flyers/protected%20Jamaican%20animals.pdf

3.2.2.7 The Endangered Species Act 2000

The Endangered Species (Protection, Conservation and Regulation of Trade) Act was created in 2000 in order to ensure the codification of Jamaica's obligations under the Convention for the International Trade in Endangered Species of Wild Fauna and Flora. This Act governs international and domestic trade in endangered species in and from Jamaica. Under this act, the functions of NEPA include the grant of permits and certificates for the purpose of international trade, the determination of national quotas and the monitoring of the trade in endangered species. Sea turtles, in addition, to yellow snakes and parrots are often traded illegal internationally and are endangered. Offenses cited under this Act, including the trade in any endangered species without a certificate or permit should be borne in mind throughout the project duration.

3.2.2.8 Water Resources Act 1995

The Water Resources Act (1995) was promulgated in the Jamaican Parliament in September 1995 and ratified in April 1996. It ensures the proper administration, development and optimal use of Jamaica's water resources. This Act established the Water Resources Authority (WRA), which is authorized to regulate, allocate, conserve and manage the water resources of the island.

3.2.2.9 Towards an Ocean and Coastal Zone Management Policy in Jamaica 2000

The Council on Ocean and Coastal Zone Management was established in 1998, with responsibility of defining a national policy for Ocean and Coastal Zone Management. The aim of this policy document is to develop a policy that will "enhance the contribution of economic sectors to the integrated management of coastal areas by developing awareness in sector line agencies and resource users." The document recognises the extensive use and resulting degradation of coastal and ocean resources in Jamaica, including coral reefs, mangroves and seagrass beds, as well as non-living resources such as sand.

3.2.2.10 Towards a Beach Policy for Jamaica (A Policy on the Foreshore and the Floor of the Sea) 2000 (DRAFT)

This green paper recognizes the value of beaches in Jamaica and importance of proper management and protection. It was developed in order review and update existing policies, as well as prepare a comprehensive policy that considered new areas of concern at the time, including erosion and pollution. The policy seeks to balance, the different interests of the main users of the beach - the public, the private sector and fishermen.

3.2.2.11 National Policy for the Conservation of Seagrasses 1996 (DRAFT)

This policy is in its drafting stage and was created in recognition of the values that seagrass possess. The issuing of licenses or permits for development activities including dredging and the disposal of dredged material which have the potential to affect seagrass beds are covered by this draft policy. Though a draft policy at present, the value of seagrass ecosystems should be kept in mind and efforts must be made to conserve these habitats as best as possible. For these reasons, marine assessments were included as part of the biological surveys.

3.2.2.12 Coral Reef Protection and Preservation Policy and Regulation 1997 (DRAFT)

This draft policy and regulation document aims to regulate coastal zone development as it relates to coral reef destruction and or degradation. It discusses the functions and uses of coral reefs, as well as the various issues affecting coral reef ecosystems. The aim of the policy is to ensure the conservation of coral reefs in order to sustain their ecological and socio-economic functions. Though in its drafting stage, the value of coral reef ecosystems should be kept in mind and efforts must be made to avoid destruction and degradation of these habitats as best as possible. For these reasons, marine assessments were included as part of the biological surveys.

3.2.2.13 A Policy towards Dolphin Conservation in Jamaica 2003

This document recognises regional and local threats to Bottlenose Dolphins, including habitat degradation, fishery conflicts, pollution and overkilling.

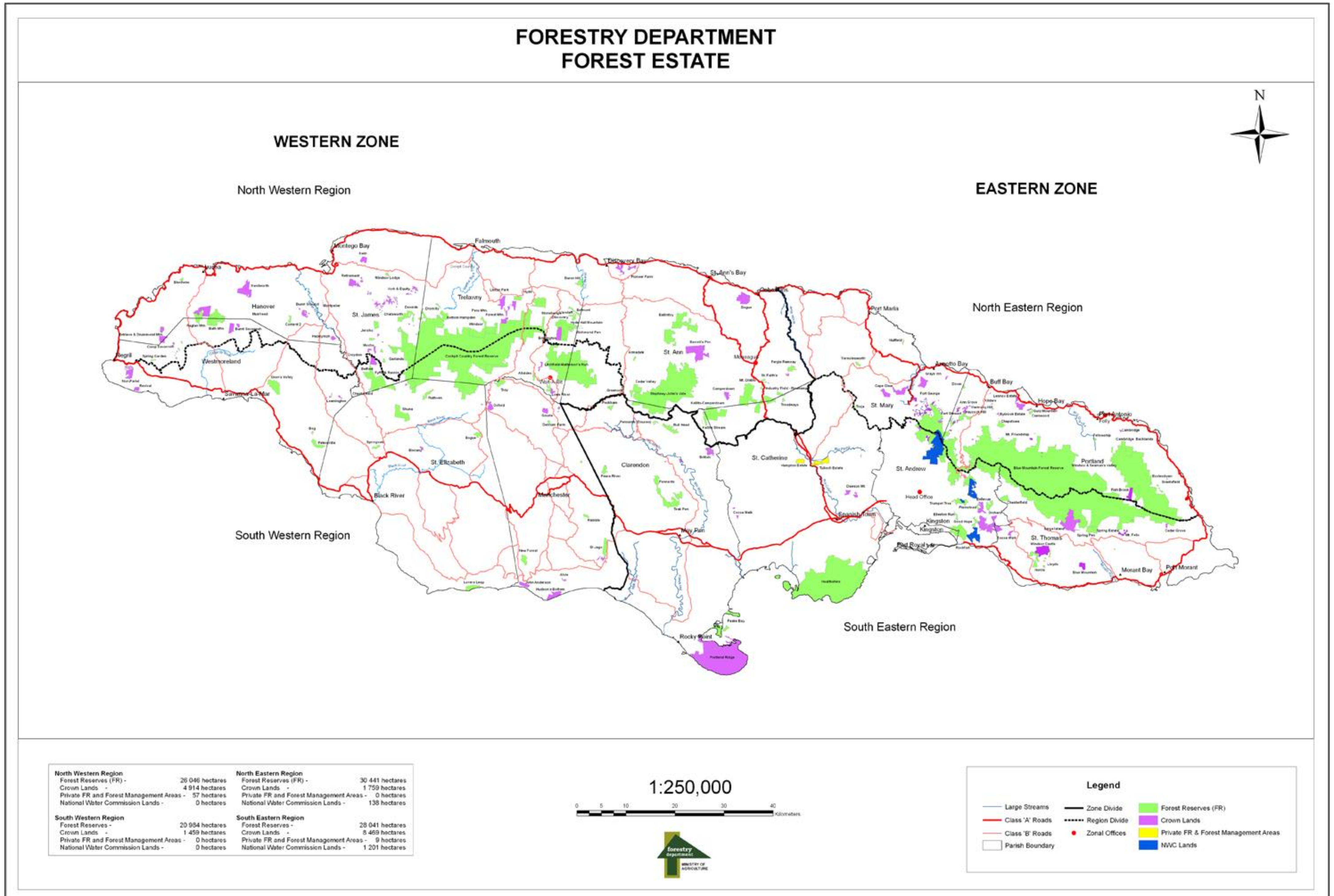
3.2.2.14 DRAFT Policy and Regulation for Mangrove & Coastal Wetlands Protection

As outline in this draft policy, the Government of Jamaica has adopted the policy and regulation in order to promote the management of coastal wetlands. The policy seeks to:

- Provide protection against dredging, filling, and other development;
- Designate wetlands as protected areas;
- Protect wetlands from pollution particularly industrial effluent sewage, and sediment;
- Ensure that all developments planned for wetlands are subject to an Environmental Impact Assessment (EIA);
- Ensure that traditional uses of wetlands are maintained;

3.2.2.15 The Forest Act 1996

The 1996 Forest Act repealed the 1937 legislation and was the legal basis for the organization and functioning of the Forestry Department. The Forestry Department is the lead agency responsible for the management and conservation of the forest resources in Jamaica. The management of forests on a sustainable basis in an aim to maintain and increase the environmental services and economic benefits is the Forestry Department’s main function. A "Forest Reserve" is defined to be any area of land declared by or under this Act to be a forest reserve. In 1938, the Forest Branch gazetted some 78,800 hectares of Crown Lands as forest reserves, this making up more than 75% of the present day forest reserves (Figure 3-4). Though the proposed project is marine-based and does not fall within forest reserve, mention should still be made as it relates to any land-based project operations associated with the project that may be in proximity of any forest estates (see Figure 3-4).



Source: Forestry Department [8]

Figure 3-4 Map showing forest estates across the island, including reserves, crowned lands, private areas and NWC lands

[8] http://www.forestry.gov.jm/images/res250k_bg.jpg

3.2.3 Public Health & Waste Management

3.2.3.1 Water Quality Standards

The NRCA has primary responsibility for control of water pollution in Jamaica. National Standards for industrial and sewage discharge into rivers and streams, in addition to standards for ambient freshwater exist. For drinking water, World Health Organization (WHO) Standards are utilized and these are regulated by the National Water Commission (NWC).

Table 3-4 Draft national ambient marine water quality standards for Jamaica, 2009

Source: National Environment and Planning Agency (NEPA)

Parameter	Measured as	Standard Range	Unit
Phosphate,	P*	0.001-0.003	mg/L
Nitrate,	N**	0.007-0.014	mg/L
BOD_5	O	0.0-1.16	mg/L
pH		8.00-8.40	
Total Coliform		2-256	MPN/100mL
Faecal Coliform		<2-13	MPN/100mL

*Reactive phosphorus as P
**Nitrates as Nitrogen

Water quality is a crucial aspect of the proposed project and efforts must be made to ensure water quality is not adversely affected. Water quality assessment is a main part of the environmental description for the project and various parameters were assessed prior to project implementation for the purposes of this EIA, and are to be monitored throughout breakwater construction and post-construction.

3.2.3.2 The National Solid Waste Management Authority Act 2001

The National Solid Waste Management Authority Act of 2001 is "an act to provide for the regulation and management of solid waste; to establish a body to be called the National Solid Waste Management Authority and for matters connected therewith or incidental thereto". The National Solid Waste Management Authority (NSWMA) was established in April 2002 as a result of this Act to effectively manage and regulate the collection and disposal of solid waste in Jamaica. As such, the NSWMA aims to safeguard public health and the environment by ensuring that domestic waste is collected, sorted, transported, recycled, reused or disposed of in an environmentally sound manner. In addition, public awareness and education is a part of their responsibilities.

3.2.3.3 Public Health Act 1985

The Public Health Act is administered by the Ministry of Health through Local Boards, namely the parish councils. *The Public Health (Nuisance) Regulations 1995* aims to, control reduce or prevent air, soil and water pollution in all forms. KSAC is the local authority responsible for development within the study area. Offences listed above must be adhered to during the project cycle.

3.2.3.4 The Natural Resources (Hazardous Waste) (Control of Transboundary Movement) Regulations 2003

These regulations control transboundary movement and prevent the illegal trafficking of certain hazardous wastes. These regulations seek to implement the *Basel Convention on the Transboundary Movement of Hazardous Waste*. It is an offence to unlawfully dump or otherwise dispose of hazardous waste in area under jurisdiction of Jamaica. “Area under Jamaica’s jurisdiction” includes any land, marine area or air space within which Jamaica exercises administrative or regulatory responsibility; internal waters and the Exclusive Economic Zone; and any ship or aircraft registered in Jamaica. Waste resulting from the proposed project should be properly disposed of, and special attention should be paid to those considered hazardous under these regulations and as listed above.

3.2.3.5 Noise Abatement Act 1997

The Noise Abatement Act of 1997 was created in order to regulate noise caused by amplified sound and other specified equipment. This act has been said to address “some concerns but is too narrow in scope and relies on a subjective criterion” (McTavish). Given this, McTavish conducted a study to recommend wider and more objective criteria in accordance with international trends and standards, but tailored to Jamaica’s conditions and culture. To date, apart from the Noise Abetment Act (1997), Jamaica has no other national legislation for noise.

3.2.4 Additional Guidelines

In addition to the legislative instruments outlined in previous sections, there are a number of guidelines prepared by NEPA that are important to the execution of this project:

- NRCA Guidelines for the Environment Impact Assessment 1998
- NRCA Guidelines for the Deployment of Benthic Structures 1996
- NRCA Guidelines for Development in the Coastal Zone in Jamaica 1998
- NRCA Guidelines for the Planning and Execution of Coastal and Estuarine Dredging Works and Disposal of Dredge Materials
- NRCA Guidelines Pertaining to Marinas and Small Craft Harbours
- NRCA Guidelines for the Planning, Construction and Maintenance of Facilities for Enhancement and Protection of Shorelines
- NRCA Handbook for Development in the Coastal Zone of Jamaica

3.3 REGIONAL AND INTERNATIONAL LEGISLATIVE AND REGULATORY CONSIDERATIONS

3.3.1 Cartagena Convention (Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region), 1983

Adopted in March 1983 in Cartagena, Colombia, the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, more commonly referred to as the Cartagena Convention, is the sole legally binding environmental treaty for the Wider Caribbean. The Convention came into force in October 1996 as a legal instrument for the implementation of the Caribbean Action Plan and represents a commitment by the participating countries to protect, develop and manage their common waters individually and jointly. The Convention is currently supported by three Protocols as follows:

- *The Protocol Concerning Co-operation in Combating Oil Spills in the Wider Caribbean Region* (The Oil Spills Protocol), which was adopted and entered into force at the same time as the Cartagena Convention;
- *The Protocol Concerning Specially Protected Areas and Wildlife in the Wider Caribbean Region* (The SPAW Protocol), which was adopted in two stages, the text in January 1990 and its Annexes in June 1991. The Protocol entered into force in 2000;
- *The Protocol Concerning Pollution from Land-based Sources and Activities in the Wider Caribbean Region* (LBS Protocol), which was adopted in October, 1999.

3.3.2 United Nations Convention on Biological Diversity

Signed by 150 government leaders at the 1992 Rio Earth Summit, the Convention on Biological Diversity (CBD) is committed to promoting sustainable development. The CBD is regarded as a means of translating the principles of Agenda 21 into reality and recognizes that "biological diversity is about more than plants, animals and microorganisms and their ecosystems – it is about people and our need for food security, medicines, fresh air and water, shelter, and a clean and healthy environment in which to live". The CBD may be considered the first global, comprehensive agreement which focuses on all aspects of biodiversity, to include genetic resources, species and ecosystems. Jamaica's Green Paper Number 3/01, 'Towards a National Strategy and Action Plan on Biological Diversity in Jamaica', is evidence of Jamaica's continuing commitment to its obligations as a signatory to the Convention.

3.3.3 Convention on Wetlands of International Importance especially as Waterfowl Habitat, "Ramsar Convention" 1971

The Ramsar Convention is an intergovernmental treaty that focuses on maintaining ecological wetland systems and planning for sustainable use of their resources. It was adopted on 2 February 1971 in Ramsar, Iran. The mission of the Convention was adopted by the Parties in 1999 and revised in 2005 - "the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world". Under Article 2.2 it is stated:

> Wetlands should be selected for the List on account of their international significance in terms of ecology, botany, zoology, limnology or hydrology" and indicates that "in the first instance, wetlands of international importance to waterfowl at any season should be included.

Jamaica became a contracting party on 7 February 1998 and has 4 sites covering a combined total of 37,847 hectares (378.47 km^2).

3.3.4 United Nations Convention on the Law of the Sea (UNCLOS III) 1982

The United Nations Convention on the Law of the Sea (UNCLOS), also referred to as the Law of the Sea Convention and the Law of the Sea treaty, defines the rights and responsibilities of nations in their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources. UNCLOS III supersedes the Convention on the Territorial Sea and the Contiguous Zone (entered into force on 10 September 1964), as well as the Convention on the Continental Shelf (entered into force 10 June 1964), and both agreed upon at the first United Nations Convention on the Law of the Sea (UNCLOS I). Jamaica was the fourth country to ratify the UNCLOS III of 10 December 1982 on 21st March 1983. As of August 2013, 166 countries have joined in the Convention.

3.3.5 Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter

This instrument was adopted at the Inter-Governmental Conference on the Convention on the Dumping of Wastes at Sea, in London, United Kingdom in November 1972 and is commonly known as the London Convention. The London Convention, one of the first international conventions for the protection of the marine environment from human activities, came into force on 30 August 1975. Since 1977, it has been administered by the International Maritime Organization (IMO). The London Convention prohibits the dumping of certain hazardous materials and specifies that a special permit is required prior to dumping of a number of identified materials and a general permit for other wastes or matter. In 1996, Parties adopted a Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972 (known as the London Protocol) which entered into force in 2006. It is expected that this Protocol will eventually replace the 1972 Convention. It stressed a "precautionary approach" and introduces a different approach to regulate the use of the sea as a depository for waste materials.

3.3.6 Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES)

CITES generally seeks to protect endangered plants and animals and owing to the cross boundary nature of animals and plants, this protection requires international cooperation. It aims to ensure that international trade of wild animal and plant species does not threaten the survival of the species in the wild, and it accords varying degrees of protection to over 35,000 species. This convention was drafted in 1963 at a meeting of members of the International Union for Conservation of Nature (IUCN) and finalised in 1973. After being opened for signatures in 1973, CITES entered into force on 1 July 1975.

3.3.7 International Convention on Oil Pollution Preparedness, Response and Co-operation 1990

The International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC Convention) is an international maritime convention that sets measures for the preparation for and response to marine oil pollution incidents. The OPRC Convention was drafted within the framework of the International Maritime Organization (IMO) and entered into force in 1995. Jamaica is one of 107 parties to the convention (as of July 2013).

4.0 COMPREHENSIVE DESCRIPTION OF THE PROPOSED PROJECT

4.1 PROJECT DESIGN OBJECTIVES

4.1.1 Objectives and Design Requirements

Table 4-1 lists the objectives and related design basis for the project. Both project components (dune and mangrove nourishment) were designed to meet the following conditions:

1. 1 in 100 year return period deep water wave conditions;
2. Project life up to 2050 (37 years);
3. Climate change factors for the SRES A1B or A1 scenario up to the design life; and
4. Use of locally available materials and burrow area proposed by the Cuban team.

Table 4-1 Design parameters for the Palisadoes Shoreline Protection and Rehabilitation Project

Objectives	Design Basis	Reasons
Wave protection and Structural Resilience	1 in 100 year return period deep water wave conditions	Equivalent to a remote chance of occurrence on an annual basis with a 31% probability over the life time of 37 years, (CIRIA, 2007)
Climate Resilience	Climate change factors for the SRES A1B or A1 scenario up to the design life	Most adverse set of scenarios and most consistent with current global trends for emissions and observations. (Roeckner, et al., 2011) (Knutson, et al., 2013) (Murakami, 2012)
	Project life up to 2050 (37 years)	Extrapolation beyond 2050 to 2100 will be subject to more uncertainty. As model predictions become increasingly more consistent with predictions (especially with waves) then these can be considered.
Minimize life cycle costs and local economic relevance	Maximize the use of local sand materials	To minimize foreign exchange requirements and maximize local input/economic impact

4.1.2 Design Methodology

The following subsections outline the approach taken by CEAC Solutions.

4.1.2.1 Anecdotal Evidence

Anecdotal information on the major hurricanes and storm events that have affected the Palisadoes was gathered from interviews held with residents and employees in the Harbour View and Port Royal area. The results of these interviews were collated and used to calibrate and verify numerical the models.

4.1.2.2 Wave Study

Deepwater Hurricane Wave Climate

It was necessary to define the deepwater hurricane wave climate in order to define the Palisadoes environ. A thorough statistical analysis of wind-wave hindcasting of hurricane data within the Caribbean was conducted in order to determine the hurricane wind and wave conditions at a deep water location offshore the project area.

Deepwater Operational Wave Climate

The NOAA database provided information used to establish the operational wave climate over an eight (8) year period (2000 – 2006) for a point just off the continental shelf.

Nearshore Operational Wave Climate

The deepwater wave climate obtained from the NOAA database was used to run a Refraction-Diffraction wave model in order to carry the deepwater waves from the continental shelf to the Palisadoes shoreline.

4.1.2.3 Hydrodynamic Modelling

Bathymetric data and data on current speed and direction were collected and used to develop a detailed three-dimensional hydrodynamic model (RMA-10) of the area. Both pre and post-project bathymetric configurations of Palisadoes were considered and the effects on flushing and circulation assessed.

4.1.2.4 Climate Change

A climate change assessment for water level, wave heights and hurricane intensities was conducted with help from the University of the West Indies. This information was used to model the 50 and 100 year return period storm events used in the design.

4.1.2.5 Dune Design and Mangrove Re-planting Areas

Calibrated sediment transport models were used to design the dune cross sections for that will remain in place after the passage of the 50 and 100 year storm event. Similarly, the mangrove areas should have sufficient area to maintain the mangroves after the annual swell event.

4.2 PROJECT DESCRIPTION

As explained previously, Phase 2 of the *Palisadoes Rehabilitation and Shoreline Protection Project* comprises two main components:

1. Dune nourishment and re-vegetation
2. Island creation and mangrove planting

4.2.1 Sand Dune Nourishment

4.2.1.1 Description and Location

The proposed sand dune nourishment is a part of the Phase 2 shoreline rehabilitation works to be undertaken along the Palisadoes. As mentioned previously Phase 1 included the construction of revetments on both sides of the Palisadoes (harbour side and sea side) for a 4km stretch between the Harbour View roundabout and the NMIA roundabout. Phase 2 which is described herein consists of building dunes of varying lengths (98m to 943m) along three sections of the Palisadoes. Two of these dunes, BR1 and BR2, which are located approximately 3.7 and 1.2km to the west of the Harbour view roundabout, consist of an internal low revetment structure covered by sand dune. The third and closest dune to the roundabout (D3) is 100% sand.

It was determined by (Juanes, et al., 2007) that the material for dune nourishment can be sourced approximately 1.5km offshore. This EIA study has determined that there appears to be suitable material of the required quantity in two areas of the (Juanes, et al., 2007) footprint. The drawing shown in Figure 4-1 summarizes the dune locations as well as the proposed source (borrow) areas.

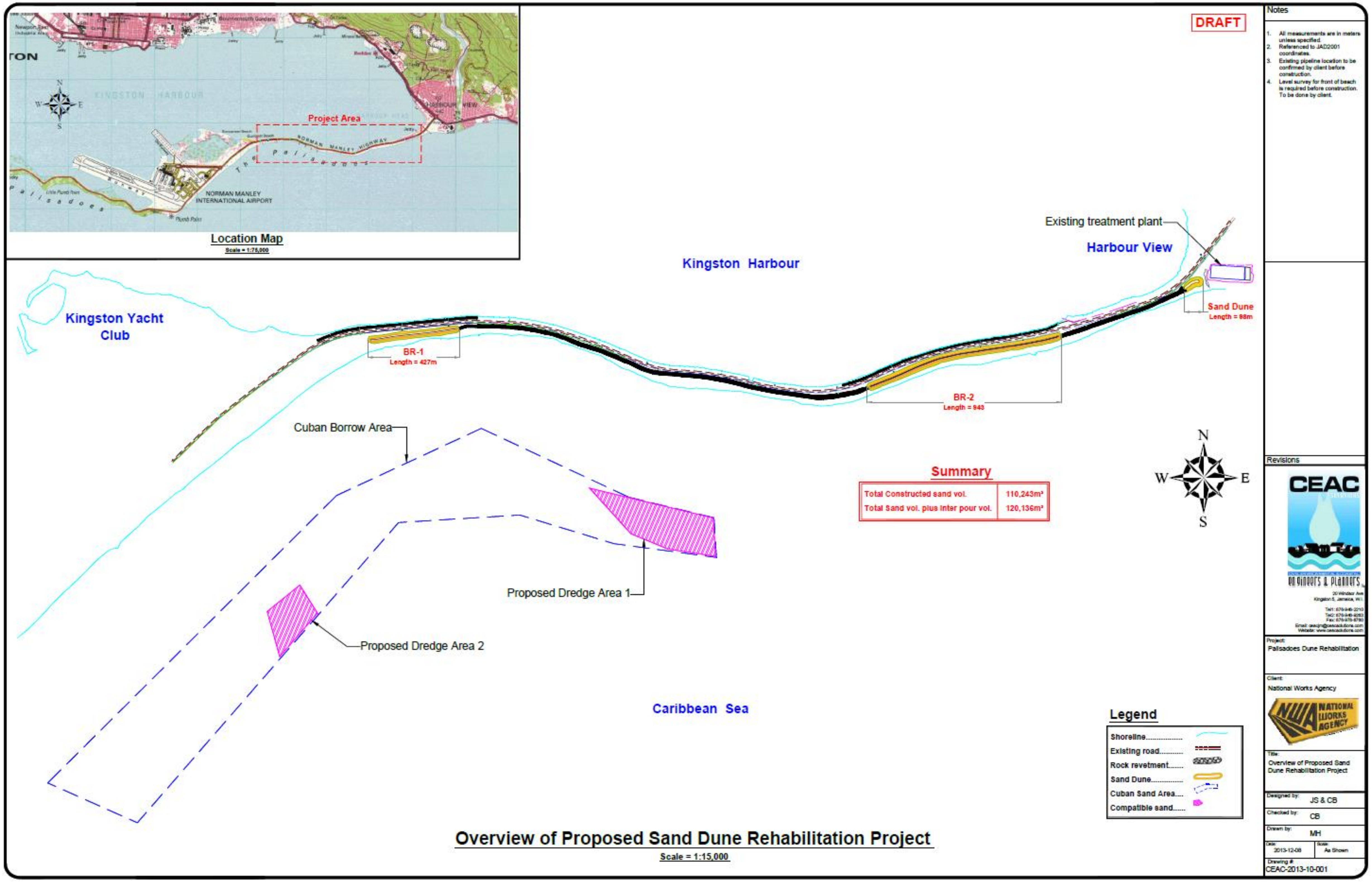


Figure 4-1 Overview of proposed dredging areas for the Palisadoes Shoreline Protection and Rehabilitation Project

4.2.1.2 Proposed Design

Additional Design Considerations

In addition to the project design requirements discussed previously, characteristics of sand dunes that survived the passage of Hurricane Ivan were assessed and included in the design considerations. Hurricane Ivan severely damaged sections of the Palisadoes and attained a category 5 status in 2004. Not all sand dunes along the Palisadoes were damaged, some survived, including those situated in front of the NMIA end of runway and the dunes in the vicinity of Gunboat Beach. Topographic information concerning the shape and size of these dunes was collected from a 2011 topographic survey conducted by NMIA and from a 2013 topographic survey conducted by CEAC technicians. The surveys provided a range of crest elevations and seaward and landward side slopes for sand dunes that had survived this hurricane event. Additional information was also garnered from photographs that were taken (by others) right after the hurricanes. The dune heights ranged from 4.4 – 7.5 m and the side slopes varied between 1: 3 and 1: 30 (Table 4-2). This information was useful for the design exercise as the dunes were in various stages of very slow recovery and so gave a fair idea of the immediate post hurricane condition.

Table 4-2 Characteristics of sand dunes that survived and were not over topped with the passage of Hurricane Ivan

Dune Height (m)	Representative locations	Dune Height (m)	Side Slope	
			Seward Slope	Landward Slope
Survived with some damage and limited over topping	South of Gunboat beach and east of CMI/RJYC entrance Between plumb point and end or NMIA runway	4.4 to 6.4	1 : 3	1: 9 to 1: 30
Not significantly overtopped or damaged	Entrance to CMI/RJYC and 300 meters east of NMIA runway and opposite meteorological station	7.68 to 9.06		

The cross sections of the sand dunes to be located on the Caribbean Sea side of the Palisadoes will have 12m wide berms and elevations of 6m and 7m for the dunes with and without core revetment structures respectively (Figure 4-2and Figure 4-3). The dunes will have a seaward and landward slope of 1: 3, this will prevent the waves from the 50 and 100 year storm event, with climate change considerations made, from damaging the roadway. The volume of sand needed for construction is placed in Table 4-3.

Table 4-3 Volume of sand required for sand dune construction

Sand Dune	Volume (m^3)
Buried Revetment 1	21,750
Buried Revetment 2	77,565
Sand Dune Option at Harbour Head	10,928
Total	**110,243**

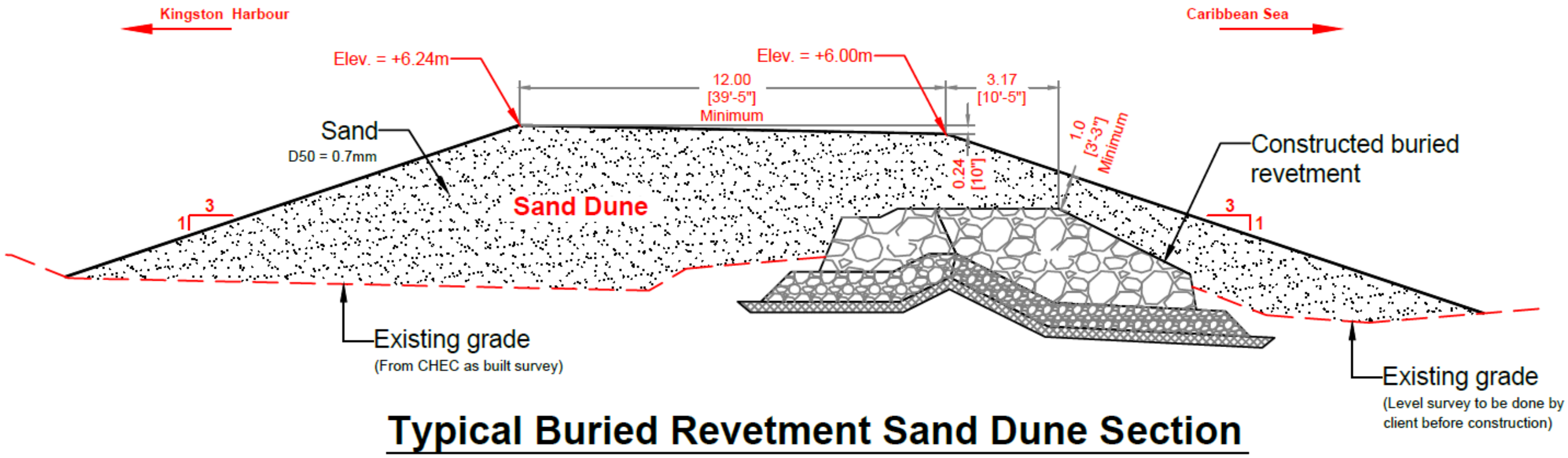


Figure 4-2 Typical section of the sand dune to be placed over the buried revetment along the Caribbean Sea side of the Palisadoes

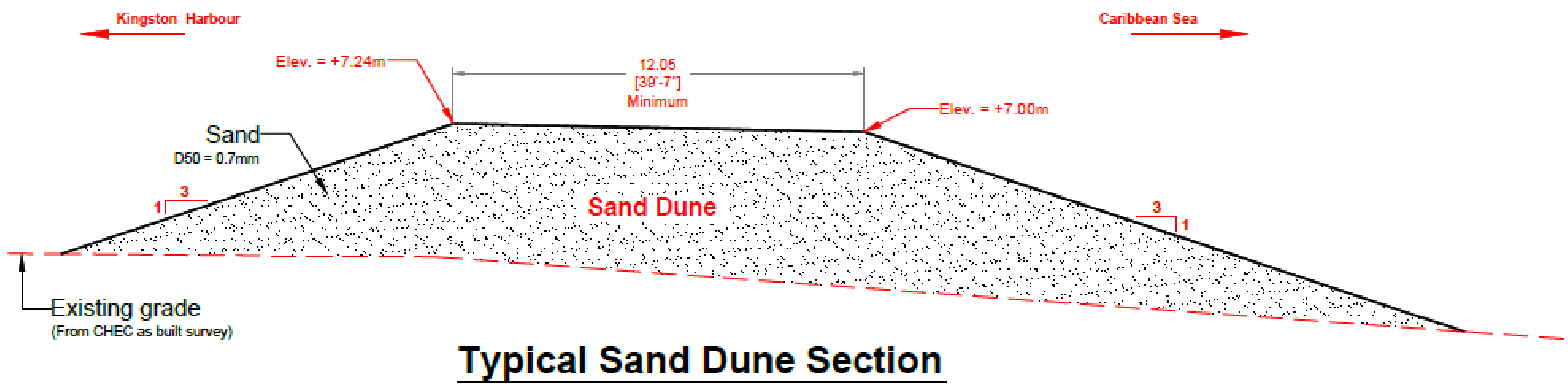


Figure 4-3 Typical section of the sand dune to close the 104 m gap between the high revetment and the NWC WWTP. This is an optional structure to be decided upon by NWA

4.2.1.3 Draft Dredge Management Plan (DMP)

Introduction

The draft Dredge Management Plan (DMP) details the proposed dredging work and the measures recommended in managing its potential environmental impacts. The draft DMP specifically addresses:

- The probable dredging methods (capital and maintenance work)
- The quantity and characteristics of material to be dredged, and the use of this material in forming the sand dunes
- The environmental management framework for the proposed dredging work, comprising the environmental management objectives, performance criteria, mitigation measures and reporting and monitoring requirements.

The purpose of this draft DMP is to provide a general framework for planning and implementation of dredging and soil management activities along the Palisadoes. It is prepared at a high level and refers to broad principles and objectives, nominating potential actions and equipment/ plant for adoption.

Geotechnical Information

Eight (8) core samples were taken from the borrow area to determine the characteristics of the sand in the area and to determine their suitability for use in this project. The analysis determined that silt and medium to coarse sand is present in the area, and that the most suitable sand is in the vicinity of the CS2, CS3, CS7 and CS8 samples.

Dredging Method

Dredging will be undertaken using a Trailing Suction Hopper (TSH). This dredger uses trailing suction drag heads to pump fluidized seabed materials to an on-board hopper. Sediments are retained in the hopper, while water used to pump the material is allowed to discharge from the vessel at the dredging site. Dredged material is transported in the hopper to the placement location, in this case, the project area along the Palisadoes. A schematic of a TSH is shown below in Figure 4-4.

A TSH dredge is best suited to:

- Deep water such as in the area of the borrow area.
- The dredging of loose, unconsolidated materials like sand, and this is present in the borrow area based on the coring results.
- The dredging of large volumes of material located a long distance from the placement site. The borrow area is some 600 m – 1,200 m from the nearest buried revetment.
- Dredging under offshore conditions where the dredge must move off-line to allow for the passage of commercial vessels. Commercial vessels do move in the area of the borrow area and the TSH dredge will be able to respond to these changes while operating.

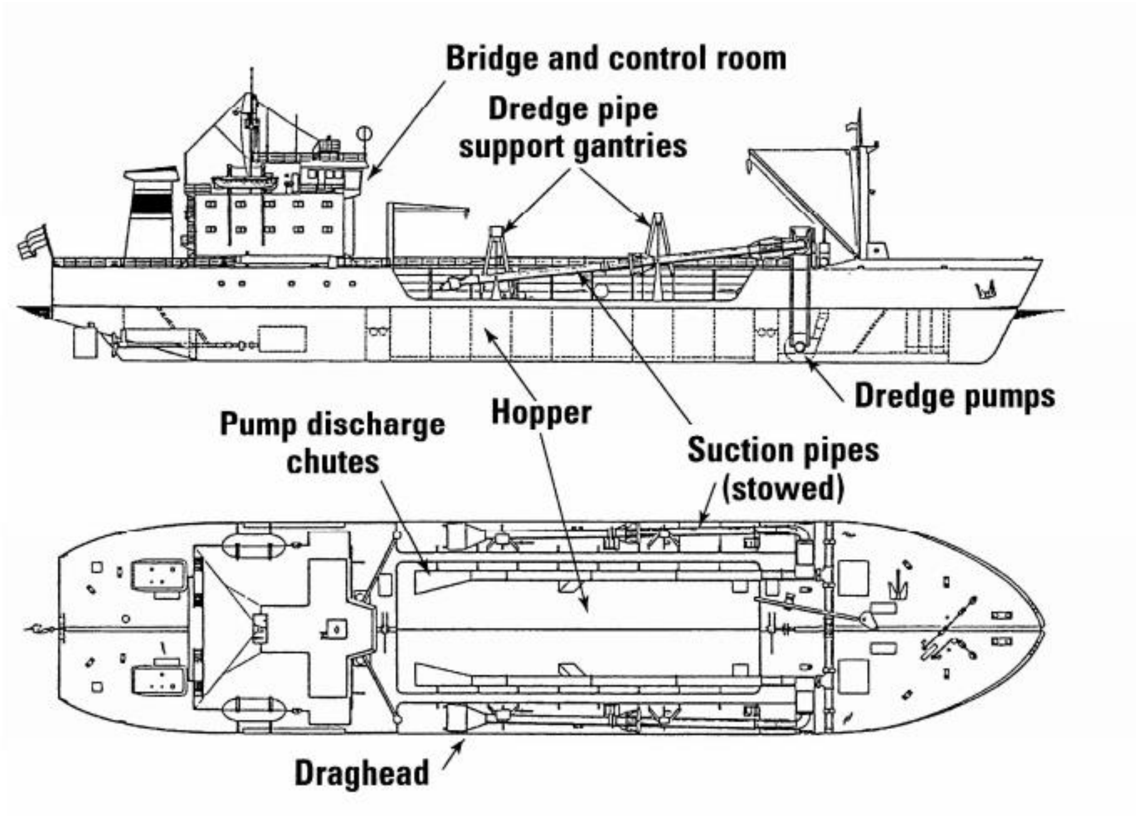


Figure 4-4 Schematic of Trailing Suction Hopper Dredger

The dredging operations likely to be required are summarized in Table 4-3; it should be noted that the optional sand dune adjacent to the NWC WWTP has not been included.

Table 4-4 Summary of dredging operations required for the Palisdaoes Shoreline Protection and Rehabilitation project

Area of Operation	Palisadoes (Caribbean Sea)
Vessel Type	TSH
Dredge elevation	-20 m MSL
Estimated Dredge Volume (m^3)	99,208

Dredge Material Placement

The sand dune design requires approximately 99,208 m^3 of sand with a mean grain size ranging between 0.5 – 0.7 mm. This volume and type of material will be dredged from one of the 2 proposed dredge areas identified in the borrow area and placed onshore in a sediment pond to allow the sand to settle (Figure 4-1). The contractor will then remove this material from the pond and use it to form the sand dunes over the 2 buried revetments. The material will also be used to construct the sand dune between the high revetment and the NWC WWTP once the NWA has agreed to include this option in the project.

Environmental Effects

Dredging activities result in a number of impacts on the marine environment. Environmental issues that are relevant for this project include the following:

- Changes to water quality,
- Changes to coastal processes (waves and currents)
- Effects on marine ecology (flora and fauna)
- Mobilisation of sediment and pore water contamination

4.2.1.4 Material Verification and Construction

The Trailing suction hopper dredger will first dredge the sand from the borrow area into the hopper, travel to the sand discharge pipeline that will extend from the dewatering area, across the shoreline and into suitable depths to accommodate the dredge. The sand will be pumped to dewatering basing from the dredge, and it is from this area that sand dune construction will be initiated. The methodology is depicted in Figure 4-5 and Figure 4-6and described according to the following stages below:

Dewatering Basin Preparation and Dredging

CONSTRUCTION OF THE MATERIAL STORAGE AREA

The storage site will be formed by placing a berm with a 3 m wide crest along the seaward side of the buried revetment so that the sand that is pumped from the dredger can be placed between the buried revetment and the berm. This will be done by the placement contractor using either a bulldozer or excavator using the sand from the beach to form the berm.

PLACEMENT OF TURBIDITY BARRIERS AROUND THE STORAGE AREA

Turbidity barriers/curtains 6' to 8' deep will be placed offshore the dewatering areas and anchored properly. These will move with the work and damaged sections will have to be replaced in order to maintain water quality requirements.

DREDGING AND FILLING THE DEWATERING AREA

The dredger will pump the sand from the borrow area offshore to the storage areas via a flexible hose anchored to the seafloor. This sand will be a part of a slurry mix and so it will be given time to settle in the storage area before the contractor begins to place the sand over the buried revetments. The storage area will also have discharge pipes to remove the water that is a part of the slurry mix.

Sand Dune Construction

The placement contractor will use a bulldozer tractor or excavator to place the sand over the buried revetments so that the crest width is at an elevation of 6.0 m above MSL, and the landward and seaward slopes are 1: 3.

Relocation of Storage Areas

Once the sand dunes have been placed over a buried revetment, the placement contractor will level the berms to the surrounding grade. Another dewatering/storage area shall then be placed along the second buried revetment using sand from that area, and the above steps repeated.

Quality Control Measures

Quality control activities will be required of both the contractor and dredger including sand sampling tests of the dredged material. Environmental specifications will be enforced and will require strict observance of the NWA and NEPA guidelines and conditions.

Equipment Requirements

It is envisaged that the works will be carried out by a team consisting of bulldozers and/ or excavator.

Options for Construction Method

The contractor is at liberty to modify the method and seek approval from the client for variations to the method outline. Another possible method that is to include a central dewatering basin at harbour head/Harbour View Roundabout opposite gypsum quarry pier. This area has the required land space. However, trucks will have to transport the material to the dune construction sites.

Sheet piling temporary basins is another possible option for quickly creating the basin for dewatering. The contractor will have to pull the sheetpiles after each stretched and re drive in the adjacent location.

4.2.1.5 Sand Dune Species

Fifty thousand (50,000) plants will be established in a sand dune nursery at the UWI. Sand dune species will be planted in accordance with their natural profile, dune position and successional capabilities. Species to be planted include beach runners such as, *Ipomea*, *Sesuvium*, *Sporobolus* and shrubs/trees such as *Acacia, Capariss, Coccoloba* and *Thespesia.* Beach runners will be planted at 1 m spacing intervals in rows. Approximately 1,000 plants will be planted on each event, for approximately 50 planting days. The introduction of additional seeds/cuttings (e.g. cacti) of sand dune species in selected areas will be done 6-12 months following pioneer species establishment.

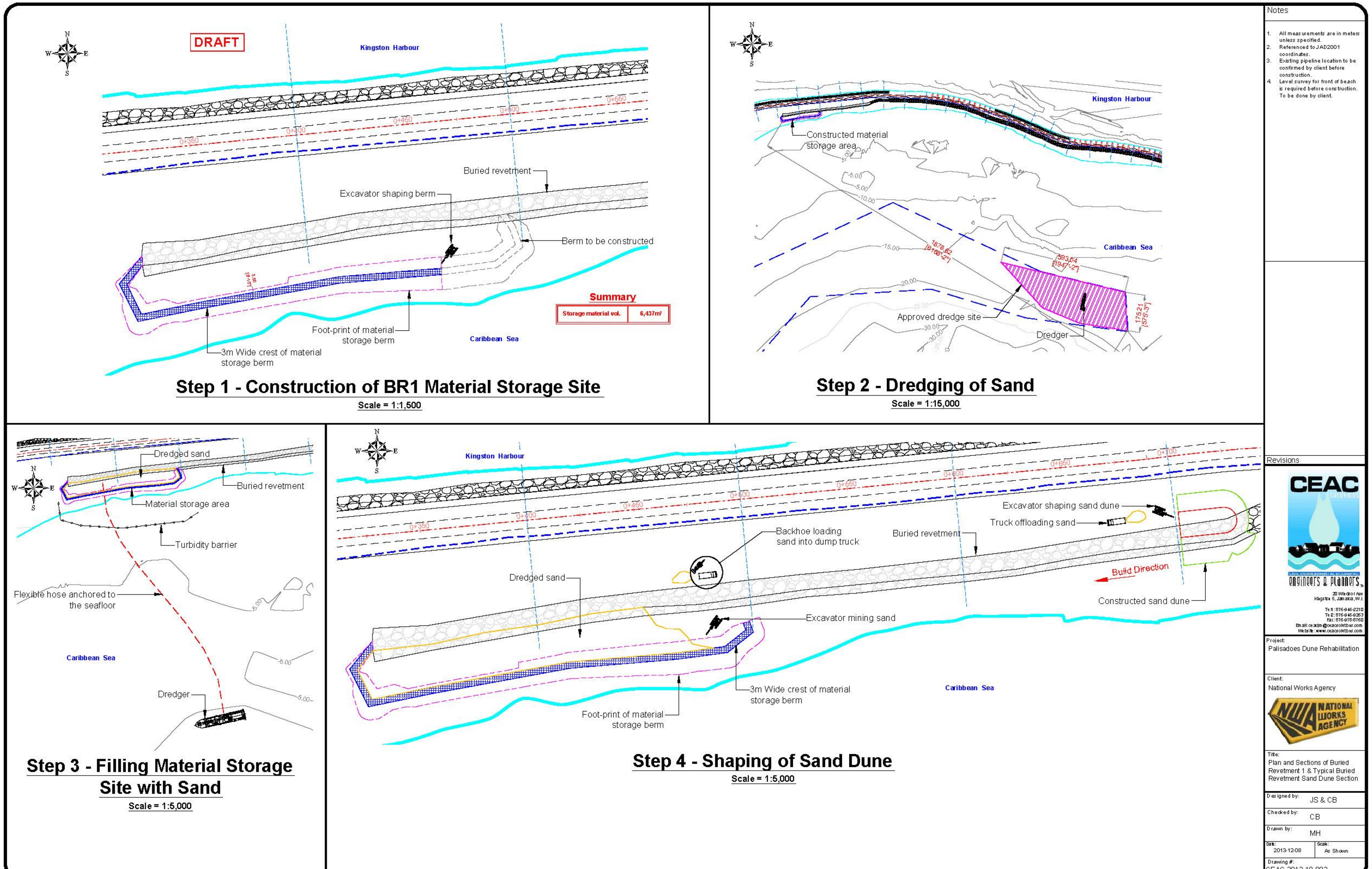


Figure 4-5 Construction methodology for sand dune nourishment, steps 1 to 4

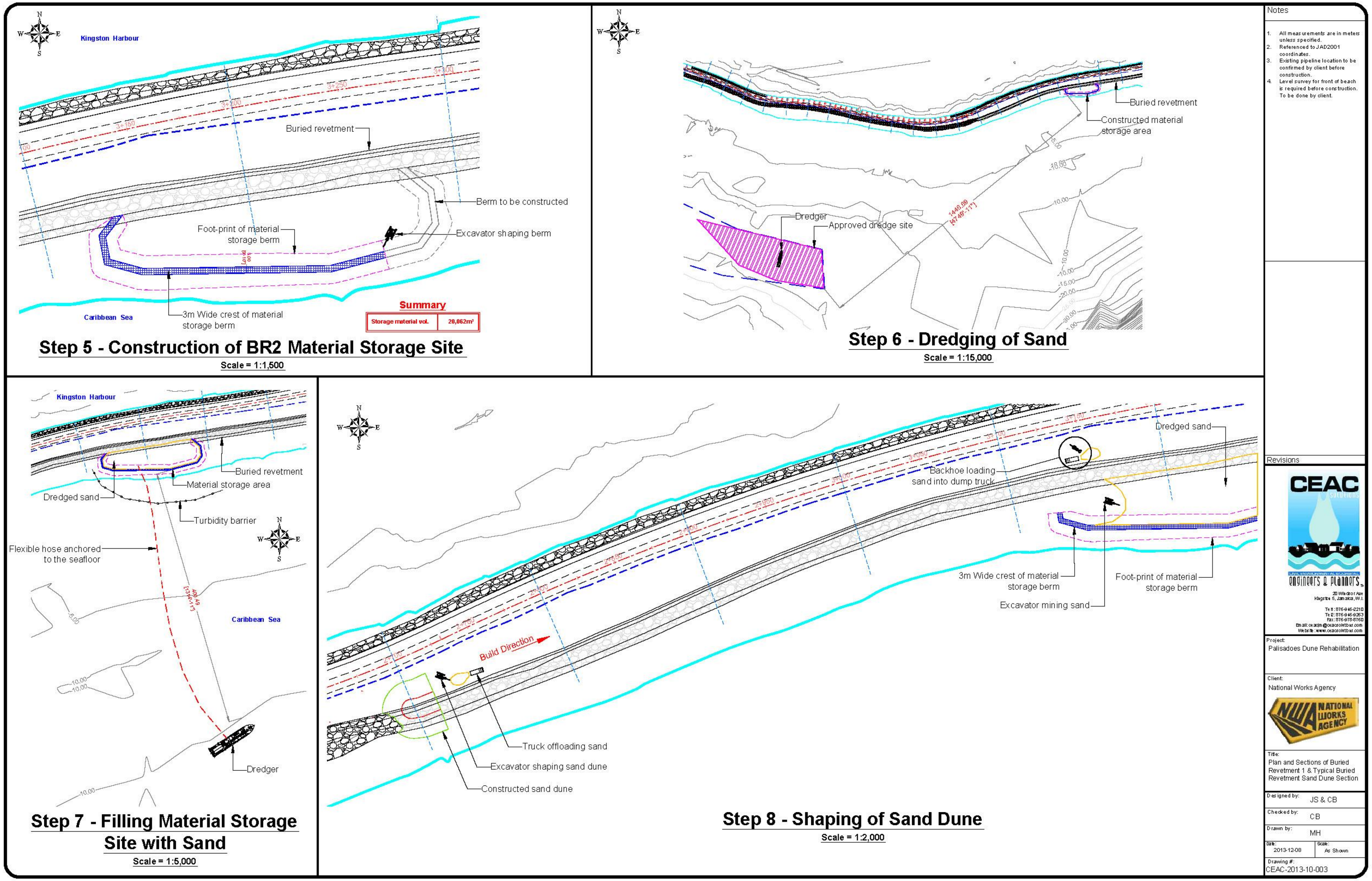


Figure 4-6 Construction methodology for sand dune nourishment, steps 5 to 8

4.2.2 Mangrove Replanting

4.2.2.1 Location

The construction of the revetments required the clearing of the work areas on the harbour side of the Palisadoes. The cleared areas included the intermittent pockets of mangroves that were located on that stretch of shoreline. A part of the permitting/licence requirement from NEPA included replanting the mangroves lost in the post construction stage of the rock revetments.

In the absence of preconstruction surveying data, the mangrove nourishment locations were chosen based on the best information available which included the following:

- Aerial imagery identifying the historic location of mangroves between 1961 and 2004. This information was provided by the National Land Agency (NLA),
- Current survey information along the harbour identifying areas where sand is accreting,
- Alongshore sediment transport modelling from which a determination was made that sand is most likely to accrete along the western and central areas of the harbour.

A total of six (6) planting areas have been identified on the harbour side of the tombolo along the Palisadoes shoreline for mangrove nourishment. The total planting area that will be provided is approximately 6,534 m^2. Four of these areas are located in the western section of the project area (3.7 – 4.1 km from the Harbour View Roundabout), and the other two are located in the central section of the project area (1.8 – 3.2km from the Harbour View Roundabout). These sites coincide well with the areas that had historically supported mangroves before the construction (Figure 4-7).

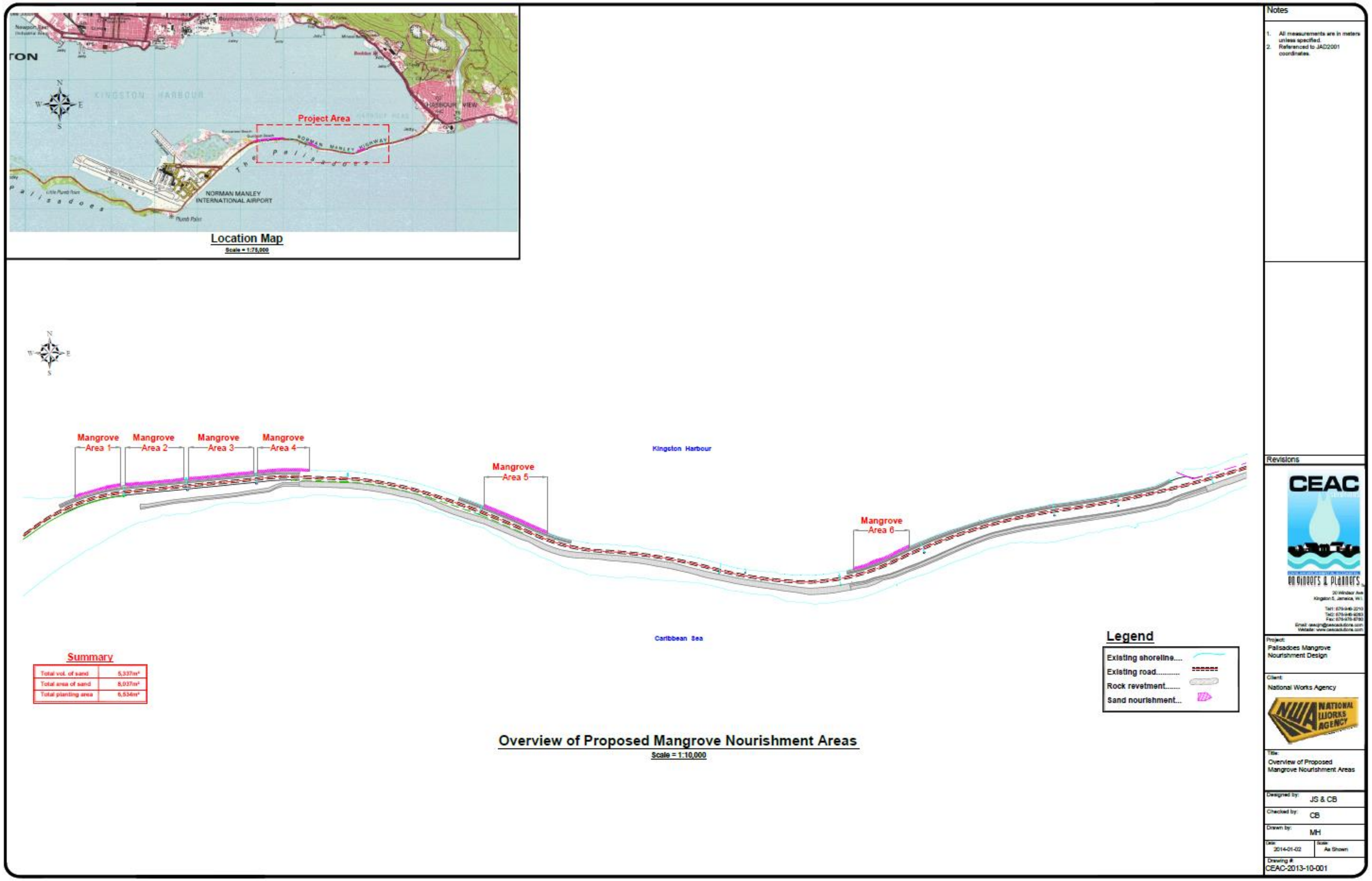


Figure 4-7 Overview of proposed mangrove nourishment areas for the Palisadoes Shoreline Protection and Rehabilitation Project

4.2.2.2 Material Verification

Sand samples were collected for analysis from the mangrove forest adjacent to the project area, and tested to determine the sand requirements for the mangrove nourishment exercise. Quarry surveys were undertaken at 3 sand mining operations in St. Thomas and two desilting operations in Kingston to determine which source would provide a suitable source of sand for use in the mangrove nourishment exercise. The three mining operations were Coast to Coast Quarries Ltd., Norman Murray's Quarry and Ludlow Rennicks. Sand samples were taken from each operation and analysed. The Hope River desilting operation's un-sieved sand proved to be the most suitable sand for the project (CEAC Solutions Co. Ltd., 2013).

4.2.2.3 Proposed Design and Construction

Cross-shore sediment stability analysis/modelling was also carried out to confirm the stable slopes and sediment sizes that are required for the mangrove replanting areas. The results indicated that slopes of 1:7 are stable during operational and swell wave conditions.

Samples were then taken from the three quarries and two de-silting operations in Kingston and St. Thomas, along with the offshore borrow area, to identify a suitable source of sand. The Hope River in Kingston is a suitable of sand and this sand will be manually spread and shaped to achieve the design cross section as outlined in Figure 4-8. Replanting will be done at minimum of 3m from the water lines and 2m from the constructed revetments.

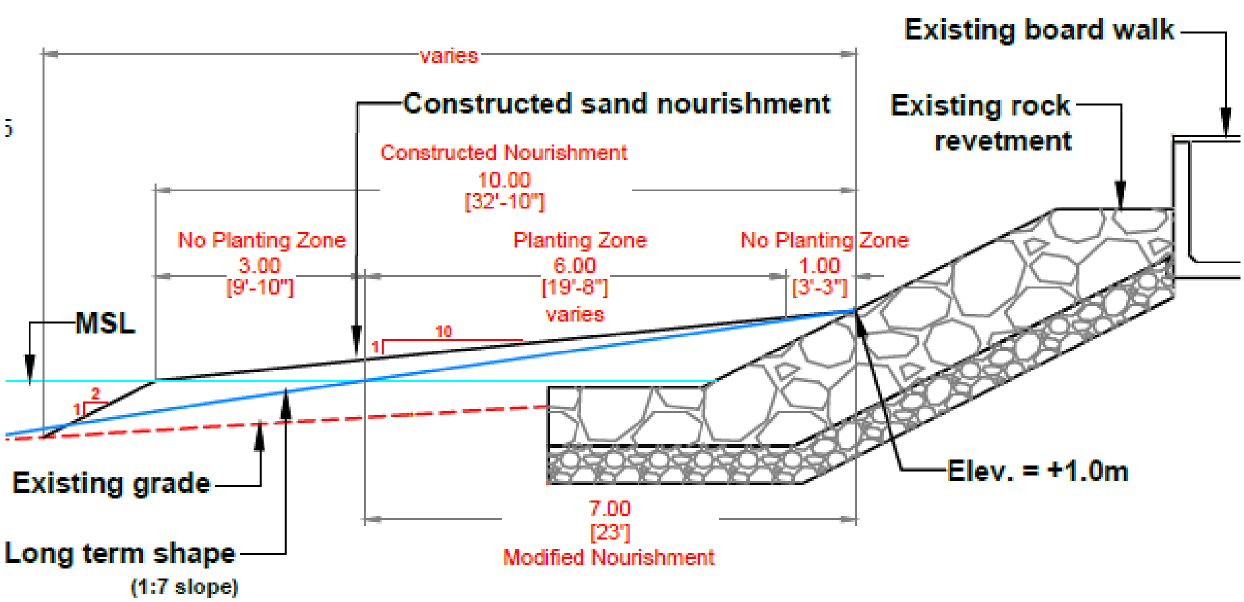


Figure 4-8 Typical cross section for sand nourishment to be placed along the Harbour side of the Palisadoes

Construction Methodology

Sand from the Hope River desilting operation will be placed along the harbour side of the Palisadoes for the mangrove nourishment activity. The following construction stages are depicted in Figure 4-9:

SITE PREPARATION

To protect the boardwalk along the harbour side of the Palisadoes during the sand placement exercise, a 3 x 10 m metal sheet will be installed over the boardwalk before the works begin. Sand will then be trucked from the Hope River desilting operation and placed alongside the protective metal sheeting.

PLACEMENT AND SHAPING OF SAND

A backhoe, or a suitable alternative, with a cleaning bucket, will work from the metal sheeting where it will place the sand over the revetment along the harbour side. Due care will be taken to avoid electrical wires. Construction workers will shape the sand over the revetment so that it has a back of beach elevation of 1.0 m and a seaward slope to MSL of 1: 10.

QUALITY CONTROL MEASURES

Quality control activities will be required of both the contractor and dredger including sand sampling tests of the dredged material. Environmental specifications will be enforced and will require strict observance of the NWA and NEPA guidelines and conditions.

EQUIPMENT REQUIREMENTS

It is envisaged that the works will be carried out by a team consisting of a backhoe and/ or excavator. Once enough sand is placed in a section the metal sheeting and trucked sand is moved to another area along the harbour for sand placement.

4.2.2.4 Mangrove Species

The mangrove species which were removed from the Palisadoes shoreline included all four species found in Jamaica: *Rhizophora mangle* (Red Mangrove), *Conocarpus erectus* (Button Mangrove), *Laguncularia racemosa* (White Mangrove) and Avicennia *germinans* (Black Mangrove).

The species selected for the replanting/rehabilitation exercise should include all four species. Approximately 6,400 hardened and acclimated 18 - 36 month old mangrove saplings and seedlings grown in the nursery at the UWI Port Royal Marine Laboratory will be planted in the newly created islands. Red mangroves will be planted closest to the shoreline (1 m away from MSL). Black and white mangroves will be planted randomly behind Red mangrove zone and saplings will be planted with random 1 m spacing (not in rows). “Wild seedlings” will be introduced within the white and black mangrove zone. These seedlings will be introduced randomly in this area 3-6 months following rooted (sapling) introductions. Approximately 4,000 ‘wild’ seedlings will be introduced away from the swash zone.

The impact of the solid waste in the area will be the major deterrent to their survival. A solid waste barrier and regular cleaning regimen will be necessary to maximize plant survival.

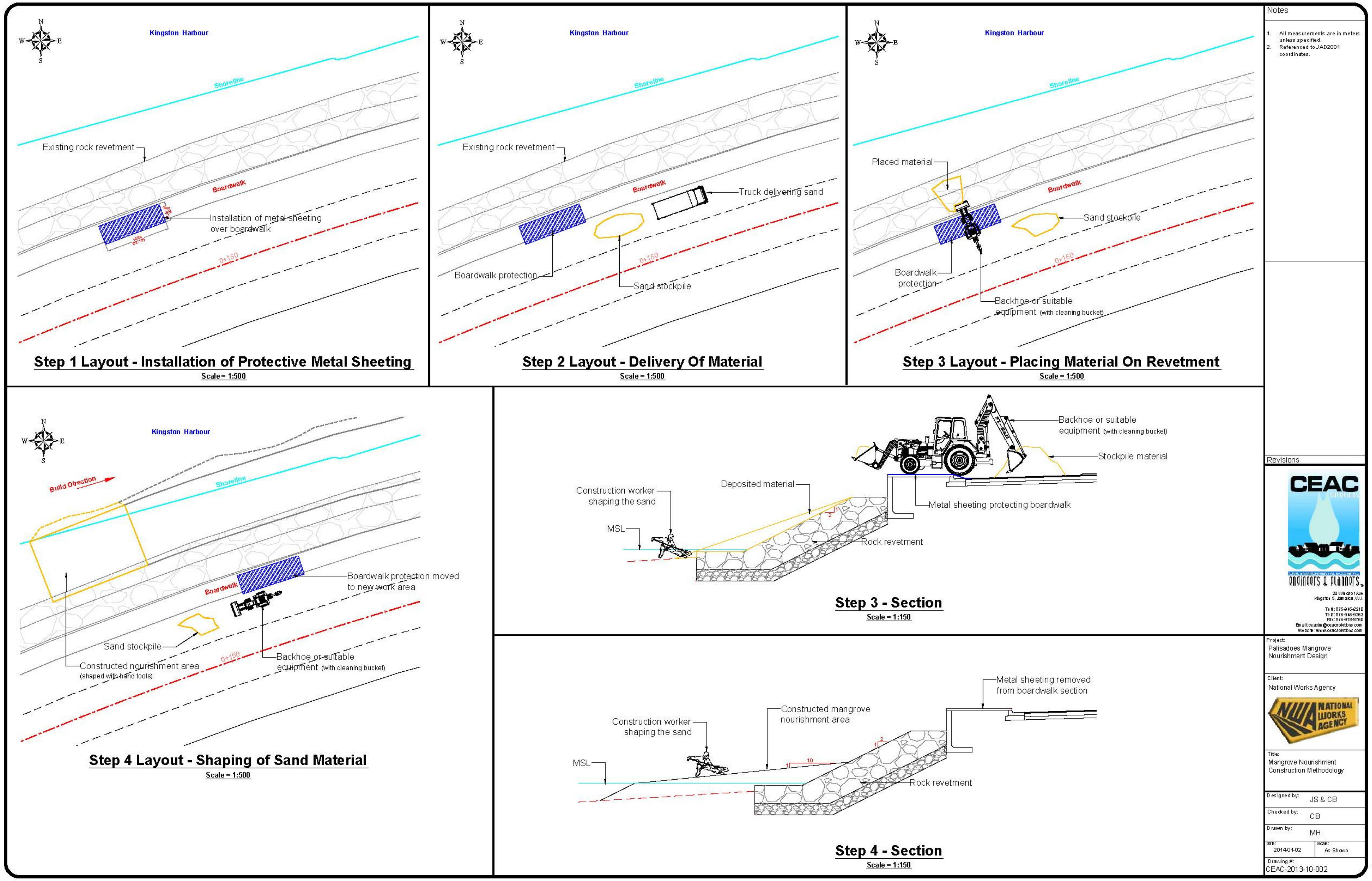


Figure 4-9 Construction methodology for mangrove nourishment

5.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

5.1 OVERVIEW

The coastal environment is a dynamic class of ecosystems located at the interface of the terrestrial and marine ecosystems. This interface creates unique environments influenced by factors from both systems; one major factor is that of the high salinity of the marine environment. Other noteworthy factors include the high temperatures, wind and high substrate mobility (Thompson 1997). The flora and fauna located in this class of environments are specially adapted to establish themselves in these environments. The ecosystems that are classified as coastal environments include coral reefs, beaches, sand dune environs, mangrove forests and seagrass beds. Coastal environments are of great importance as they provide a cornucopia of finite resources that play a crucial role in maintaining environmental balance. For example, mangrove and seagrass beds are ideal nursery habitats for juvenile fish species that will develop into adults and spread into the deeper marine environment. Mangrove forests also perform a protective role along the coast, lessening and even preventing coastal erosion. Coastal environments in today's world are under threat from numerous detrimental factors inclusive of climate change and coastal development among other anthropogenic factors.

The Palisadoes is a 16km complex spit found along the south-eastern section of Jamaica that acts as the southern border of the Kingston Harbour. It is a Ramsar site and a protected area that is characterized by mangrove forests on the northern leeward coast of the area and sand dune vegetation along the windward south (Thompson & Webber 2003). The Port Royal cays are a set of uninhabited islands off the southern coast that are associated with the Palisadoes. Their shallow waters are occupied by reefs and seagrass beds. The land use of the Palisadoes includes residential, industrial, commercial, government operations and statutory undertaking (National Resources Conservation Authority, 1998). Of note are the Port Royal residential community, Royal Jamaica Yacht Club, the Caribbean Maritime Institute and the Norman Manley International Airport. There is a roadway, the Norman Manley Highway, running central along the full length of the Palisadoes connecting Port Royal (most western point) to the Harbour View roundabout (most eastern end) on the mainland. Coastal ecosystems present in the Palisadoes area comprise of beaches, coral reefs, seagrass beds, mangrove forests and sand dune communities. All these ecosystems are influenced greatly by the geology and wind/wave interactions of the area. These environments are home to a multitude of floral and faunal species with some of them being endemic species (see Appendix 4 for the complete list of floral and faunal species).

The southern coast of the Palisadoes is significantly affected by wave energy created by the trade winds as well as wave refraction that occurs due to interaction of these winds with the coastal topography of Jamaica east of the Palisadoes. This creates a perennial east-west longshore drift, carrying sediment seasonally deposited by rivers, mainly the Cane and Hope rives, exiting east of the Palisadoes (Hendry 1979). This sediment, comprised of limestone and volcanic rock from the Blue

Mountains, is deposited on the Palisadoes by this drift current. A diurnal land-sea breeze cycle is also established in the area with a dominant sea breeze being persistent from May-August and being strongest in June. The sea breeze is strongest in the day coming from an east south-easterly direction while land breeze dominates at night from a north-westerly direction only when sea breeze subsides. This cycle plays a crucial role in beach erosion and accretion caused by sea breeze and longshore drift respectively. The level of erosion by sea breeze is dependent on wind strength and the cohesiveness of beach sediment influenced by sea spray. Land breeze plays a role in replenishing sediments lost by erosion; it does this by removing sediment from the backshore and sand dunes unto the foreshore also dependent on wind strength and sediment cohesiveness (Hendry, 1998). These natural processes of erosion and accretion are severely disrupted by hurricanes and earthquakes completely removing sediment from the shore negating years of natural accretion (Hendry 1979).

The planktonic community of Kingston Harbour and the Cays area have been studied by numerous authors (Hopcroft, Lombard, and Roff 1998; Dunbar and Webber 2003; Ranston, Simmonds, and Webber 2003; M. K. Webber et al. 2003; Persad et al. 2003), however the waters outside of these areas have been seldom studied (Moore and Sander 1979). Planktonic abundance and community composition have been used to describe and show zonation of the waters within the Harbour. Three main zones have been established accordingly; one being the upper basin and inner harbour, the second being the outer harbour and Hunts Bay forming the third (Ranston, Simmonds, and Webber 2003).

According to Goodbody (1970), these four regions of the harbour can be described as follows: The upper basin is the easternmost area inside the harbour, with a uniform depth of around 18 m. Around most of the margins of the upper basin the shoreline is steep and there are few shoals. The inner harbour constitutes an area of approximately 30 km^2 and is comprised mainly of a deep basin, which slopes gradually from a depth of about 12 m in the western end and deepens towards the east in the upper basin to a depth of just over 18 m. At the southern end of the inner harbour there is an extensive sand shoal, known as Middle Ground Shoal, and the Port Royal Mangrove Swamp with depths from 0.3–5.5 m. To the north and west of Middle Ground Shoal is a narrow passage, the Ship Channel; with a minimum depth of 12 m. Middle Ground Shoal and the Ship Channel together act as a sill, which separates the deep waters of the inner harbour from those of the outer harbour. The outer harbour is designated as the area south of the Ship Channel and west of Middle Ground Shoal extending to the entrance of the harbour. This area is mainly a deep basin, the bottom topography of which is variable, but mostly lies between 12 m and a maxi- mum depth of about 18 m near the entrance of the harbour. Hunts Bay is located at the north-western end of the harbour and is a shallow, semi- enclosed estuarine arm of the harbour, with an average depth of 2.4 m and an area of approximately 6.5 km^2. Most of its volume was cut off from exchange with the rest of the harbour in 1969 by the construction of a solid-fill causeway with a narrow opening of only 213 m to the harbour proper.

Phytoplankton abundance and biomass throughout the harbour is generally high, indicative of the highly eutrophic state. However, distribution patterns observed in abundance and biomass was used to better define the zones. Hunts Bay has previously been reported as the most eutrophic area of Kingston Harbour with generally the highest abundance and biomass concentrations. Webber et al.

(2003) reported phytoplankton abundance values of 1.38 x 10^8 in Hunts Bay which was similar to those by Ranston et al. (2003) with abundance values of 5.6 x 10^7 - 8.2 x 10^7 cells /L for surface water. The abundance and biomass levels in the upper basin and inner harbour are generally lower when compared to Hunts Bay but were found to be higher than the outer harbour region (Ranston, Simmonds, and Webber 2003; M. K. Webber et al. 2003).

Wet and dry seasons also affect the phytoplankton biomass and abundance levels in the harbour. During the wet season, a temporary vertical stratification of the water column with a less saline surface layer and a more saline deep layer is defined. This is shown by the differences in total phytoplankton biomass and abundance (Ranston, Simmonds, and Webber 2003). Higher values for both parameters were found in surface waters with biomass being the more reliable parameter to show this difference.

5.2 PHYSICAL

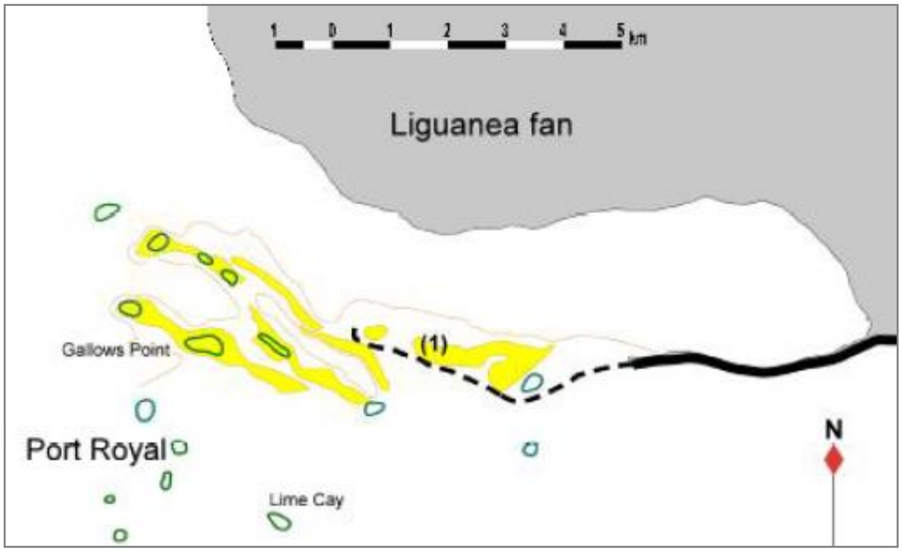
5.2.1 Geomorphology

Many articles have been written about the Palisadoes speculating its formation, existence and future state. In 2005 the Marine Geology Unit (MGU), University of the West Indies (UWI) (Robinson & Rowe, 2005) contributed to this discussion in light of the severe damage caused by the passage of Hurricane Ivan in 2004. The main points of the article are presented herein to provide an understanding of the geomorphological process affecting the Palisadoes.

5.2.1.1 Formation

Robinson and Rowe (2005) believe that the Palisadoes was formed by the joining of the Port Royal island and a series of spits extending from the mouth of the Hope River, to the mainland. Dominant waves from the southeast caused currents to bring sediments (sand and gravel) from the Hope River and Cane River westward along these shores (Figure 5-1). It is suggested that its present form is some 4,000 years old.

It is important to note here that the Palisadoes is often referred to as tombolo, defined as “a spit of sand linking an island to the mainland or to another island, usually forming on the sheltered side of the island” (Keary, 2001 in Robinson & Rowe, 2005). A spit is described to be a long narrow land area, made up of beach sediment carried along a coastline, with one end attached to the coastline and the other protruding into the sea. Given these definitions, Robinson & Rowe (2005) propose that Palisadoes is best referred to as a spit complex, given evidence that it was formed from a number of spits

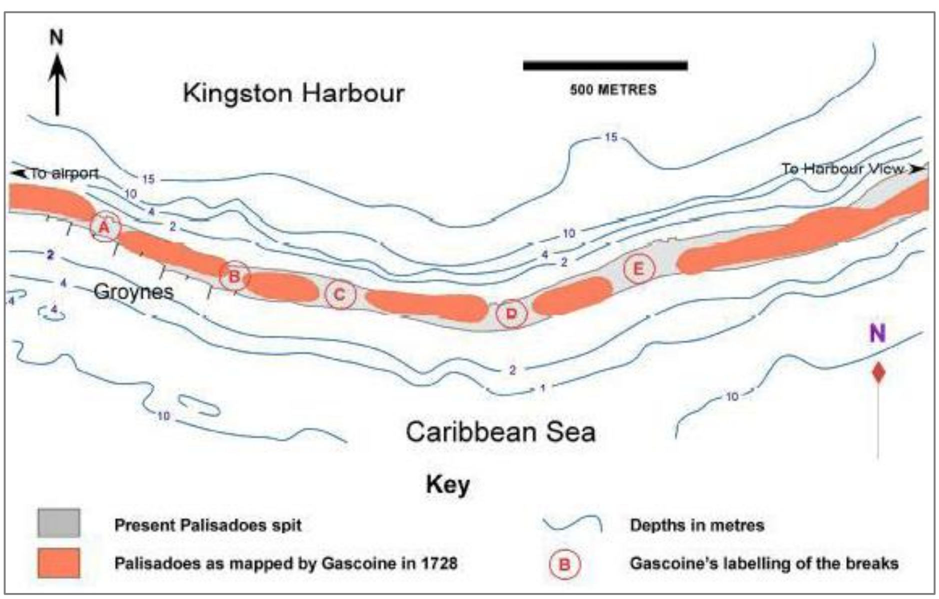


Source: Robinson & Rowe, 2005

Figure 5-1 Representation of the formation of the Palisadoes: extension of spit (black line) over shallows northwest of the present airport; green, cays; yellow, shoals; peach line, extent of shallow water

5.2.1.2 Response to Natural Hazards

Rare destructive events were highlighted, including earthquakes in 1962 and 1907, and a hurricane in 1722. The hurricane in 1722 was reported to cause storm surge of 5m in Port Royal, isolated Port Royal as an island and resulted in five channels through the eastern part of the Palisadoes (Figure 5-2).



Source: Robinson & Rowe, 2005

Figure 5-2 Representation of the Palisadoes showing positions of breaks (A to E) that occurred as a result of Hurricane in 1722.

It is believed that the likelihood of a tsunami occurring in the Caribbean, and more specifically, along the Palisadoes, is small. If such an event were to occur, the storm surge would likely bring water, sand and debris from the Caribbean Sea side across the Palisadoes and into the harbour, similar to that which occurred during Hurricane Ivan. In an extreme case, it is possible for channels to be created along the narrowest part of the Palisadoes (which coincides with the study area for this project). Beach elevation will naturally rise in response to sea level rise (SLR) because the sediments from the rivers are continuously being moved by the sea. However, the roadway and structures along the Palisadoes will not respond in a similar manner as they are permanent man-made structures.

5.2.1.3 Future State

Robinson & Rowe (2005) conclude by saying that the future development of the Palisadoes can only speculated. Based on the way in which the Palisadoes, one possible future direction is that the Palisadoes will incorporate the cays now outside the Kingston Harbour.

5.2.2 Geology and Sediments

5.2.2.1 Coastal Setting

Hardy and Croucher (1933) describes the substratum of the Palisadoes coastal environment as being comprised of sand with a significant difference between soil composition on the north (coral sand base) and south coast (siliceous sand base). Hendry (1979) determined that the first stage of the bedrock formation is that of infiltrated carbonate mud with the beach rock cement mineralogy being Magnesium calcite with semi-opaque microcrystalline micrite morphology. Coarse sediment size at the base of the foreshore on the south side of the Palisadoes is affected by abrasion, with the fine particles being removed by wave action. However there exists throughout the remainder of the foreshore a wide assortment of sediment sizes with the most common being in the granule size class (Hendry 1979). These features play an important role in determining floral and faunal composition of the Palisadoes area.

5.2.2.2 Donor Sediment Analysis

Heavy Metals

Heavy metals affect living organisms and at certain levels can be lethal. Chronic exposure to heavy metals is normally due to food chain transfer and acute poisoning is rare through ingestion. Of importance are the following metals:

- **Arsenic** - Arsenic is a natural component of the earth's crust and is distributed throughout the environment. It is highly toxic in inorganic form and is easily soluble in water. Long-term exposure causes skin poisoning, affects the kidneys and central nervous system. International guidelines for arsenic levels vary by country; the USEPA has a regional screening level for soils under unrestricted use at 0.39mg/kg whereas Japan (JME 2003) has a general soil value at 150mg/kg (Teaf et al. 2010).
- **Cadmium** - Cadmium is hazardous in any form and its lethal dose ranges from 30 to 40 mg. Long-term exposure affects the kidneys, liver and gastrointestinal (GI) tract. Cadmium enters

food chains due to industrial emissions and human intake is mainly associated with vegetable food products, as plants easily adsorb cadmium from soil. Dredged river silt containing cadmium should not be used on farm lands, as sugar beets, potatoes and celeries are known to accumulate cadmium (Speranskaya 2008).

- **Lead** - Lead is highly toxic and easily accumulates in the human body. Lead intake is mainly associated with inhalation or ingestion. Long-term exposure to lead can cause chronic problems such as mental lapses. The USEPA has a recommended level of ≥400mg/Kg of lead in soils that require clean-up.
- **Mercury** - Mercury is classed as a thyol toxin: block HS-groups of proteins, disrupting protein metabolism and enzymatic processes. The lethal dose of contents of the metal range from 150 to 300mgHg, however pure mercury of 0.4mg will give adverse effects (Speranskaya 2008).

The ambient levels of heavy metals in Jamaican soils are shown in Table 5-1.

Table 5-1 Metal concentrations in Jamaican soils

Metal	Avg. Conc. (mg/KG)	Range (mg/Kg)	95^{th} Percentile (mg/KG)
Arsenic	25	1.4-203	<64.9
Cadmium	20	0.2-409	<77.6
Lead	46.5	6-897	<90
Mercury	0.2	0.04-0.83	<0.46

Source: A geochemical atlas of Jamaica, Centre for Nuclear Sciences, UWI, 1995, Canoe Press.

Sampling Method

Five (5) sediment samples were collected for analyses from the two donor sites. Three (3) samples from donor site 1 and Two (2) samples from donor site 2. The samples were stored on ice and analysed at International Analytical Group (IAG). The samples were tested for gasoline range organics (GRO), diesel range organics (DRO), arsenic, cadmium, lead and mercury. The general locations of the samples are shown in Figure 5-3.

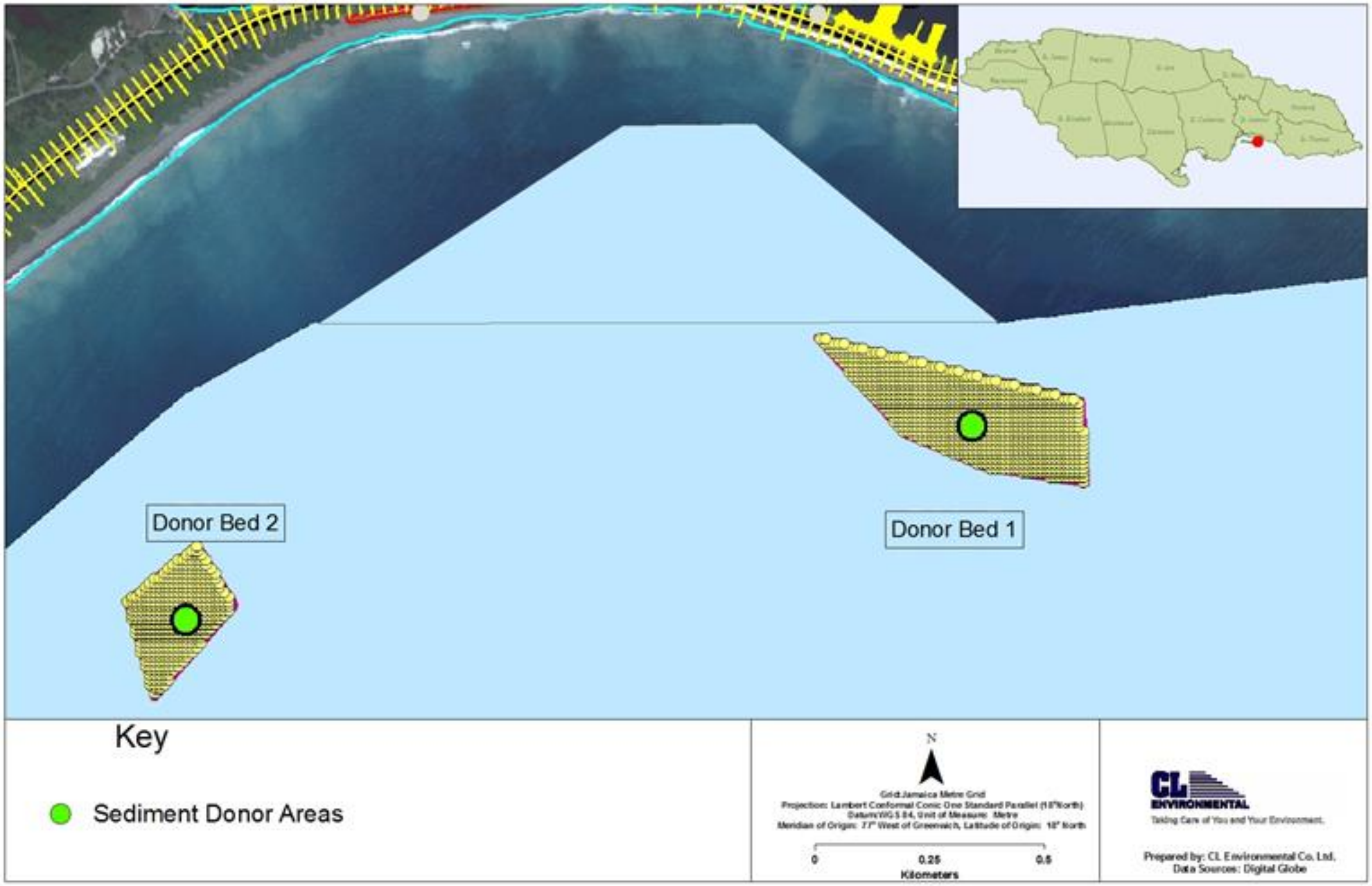


Figure 5-3 Map showing locations of Sediment donor areas where sediment samples were taken

Results

The results obtained for the sediment analysis are shown in Table 5-2. There was no detectable presence of GRO, DRO, cadmium and mercury at all stations. The metal concentrations of arsenic varied little among stations however lead concentrations fluctuated between stations.

Table 5-2 Results of the sediment analyses for the locations sampled.

Station	GRO (mg/Kg)	DRO (mg/Kg)	Arsenic (mg/Kg)	Cadmium (mg/Kg)	Lead (mg/Kg)	Mercury (mg/Kg)
1 (Donor Bed 1)	ND	ND	14	ND	2.0	ND
2 (Donor Bed 1)	ND	ND	12	ND	1.7	ND
3 (Donor Bed 1)	ND	ND	9.1	ND	0.74	ND
4 (Donor Bed 2)	ND	ND	11	ND	5.1	ND
5 (Donor Bed 2)	ND	ND	11	ND	4.4	ND

5.2.3 Water Quality

5.2.3.1 Past Studies

Few studies are present which investigate the water quality of the Sea along the Palisadoes (Wilson-Kelly & Kelly 2007, CLE 2010) with most studies focusing on the Harbour and Cays area (Bigg & Webber 2003; Dunbar & Webber 2003; Ranston, Simmonds, & Webber 2003; D. F. Webber & Kelly 2003; M. K. Webber, Webber, Ranston, Dunbar, & Simmonds 2003).

In 2007, Wilson-Kelly and Kelly looked at the impact of shoreline stabilization works along the Palisadoes. Their study focused on total suspended solids (TSS) and turbidity to assess the water quality with a total of 8 stations. They found that stations closest to the shore (<1m depth) had TSS values of greater than 60mg/l, while stations further away from shore (<10m depth) had values less than 11mg/l. CLE (2010) sampled at similar stations from the shore (<10m depth) and found similar results of TSS, however no samples were collected in <1m depth. Wilson-Kelly and Kelly (2007) used a secchi disc to measure turbidity which gave a similar trend to the TSS values. However, CLE (2010) made measurements using a turbidity meter and found similar readings except at certain stations the subsurface value was higher than surface values. These trends were attributed to the re-suspension of suspended solids through wave action near shore.

Water quality in the Harbour has been studied by numerous authors (D. F. Webber and Kelly 2003; Dunbar and Webber 2003; M. K. Webber et al. 2003; Bigg and Webber 2003; Ranston, Simmonds, and Webber 2003). The Harbour is generally accepted as being eutrophic with the main sources of pollutants being run-off from the sewage treatment plants and fluvial input (D. F. Webber and Kelly 2003; Bigg and Webber 2003). The sources of pollutants to the Harbour associated with the various industries and communities are located mainly along the northern coastline. This has resulted in varying levels of pollutants across the Harbour (Bigg and Webber 2003; D. F. Webber and Kelly 2003).

5.2.3.2 Method

Fifteen (15) stations were sampled throughout the area. Whole water samples were collected at a depth of approximately 0.5 m; this was facilitated with the use of a boat. Samples were collected in pre-sterilized bottles, stored on ice and taken to Caribbean Environmental Testing and Monitoring Services Limited (CETMS Ltd.) for analysis. The samples were analysed for Biochemical Oxygen Demand (BOD), Fats Oil and Grease (FOG), Total Suspended Solids (TSS), phosphates and nitrates. Temperature, conductivity, salinity, pH, Dissolved Oxygen (D.O.), turbidity and total dissolved solids (TDS) were measured *in situ* using a Hach Hydrolab MiniSonde-5 multi probe water quality meter (See Appendix 5 for Calibration Certificate). The locations of the stations are listed in Table 5-3 and shown in Figure 5-4.

Table 5-3 Location of the water quality stations in JAD2001

Station	Northing (m)	Easting (m)
1	643,962.05	779,645.81
2	643,622.11	778,363.90
3	642,991.40	778,433.52
4	643,568.87	776,377.54
5	642,950.44	776,967.31
6	641,862.10	776,659.12
7	642,525.09	775,256.65
8	642,389.76	774,469.93
9	643,720.41	777,892.85
10	643,918.90	777,409.51
11	643,891.12	776,832.60
12	644,017.04	776,054.86
13	644,205.07	775,794.22
14	643,957.98	775,541.16
15	643,888.62	775,256.14

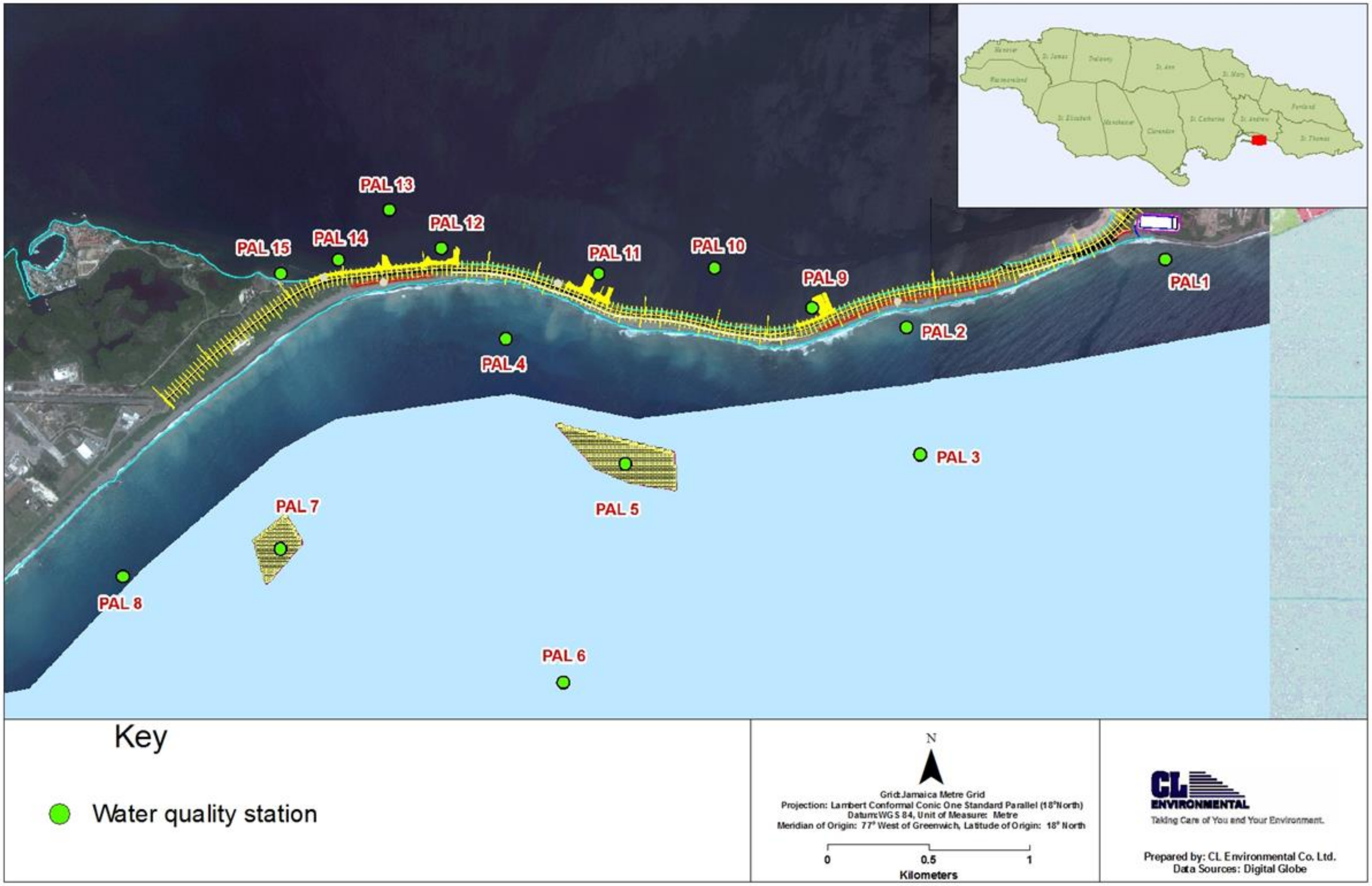


Figure 5-4 Map showing location of water quality stations

5.2.3.3 Results

Table 5-4 Average physical data for all stations

Stn.	Depth (m)	Temp (°C)	Spc (mS/cm)	Sal (ppt)	pH	DO (mg/l)	Turbidity (NTU)	TDS (g/l)
1	0	28.09	53.83	35.65	8.65	7.22	109.67	34.45
	1	28.09	53.84	35.65	8.66	7.10	9.20	34.45
	2	28.07	53.83	35.65	8.67	7.15	0.70	34.45
	3	28.03	53.83	35.65	8.67	6.93	1.37	34.45
	4	28.00	53.75	35.63	8.67	6.84	2.33	34.43
2	0	28.12	53.79	35.62	8.65	7.78	3.13	34.42
	1	28.12	53.79	35.62	8.65	6.87	1.93	34.43
	2	28.11	53.81	35.62	8.65	6.67	3.27	34.44
	3	28.17	53.78	36.11	8.70	6.64	4.00	34.42
3	0	28.16	53.81	35.63	8.65	7.20	0.53	34.42
	1	28.17	53.81	35.64	8.67	6.96	0.47	34.44
	2	28.13	53.82	35.64	8.68	6.87	0.23	34.44
	3	28.13	53.61	35.64	8.68	6.84	0.40	34.44
	4	28.12	53.82	35.65	8.68	6.78	0.47	34.44
	5	28.11	53.82	35.64	8.68	6.82	0.57	34.44
	6	28.10	53.81	35.63	8.68	6.69	0.50	34.43
	7	28.08	53.80	35.63	8.68	6.57	0.57	34.43
	8	28.08	53.73	35.57	8.68	6.43	0.63	34.38
4	0	28.50	53.83	35.64	8.64	7.75	0.07	34.84
	1	28.26	53.81	35.63	8.65	6.84	0.13	34.84
	2	28.23	53.79	35.63	8.66	6.73	1.37	34.82
	3	28.21	53.81	35.63	8.67	6.74	1.17	34.83
	4	28.25	53.79	35.62	8.70	6.68	1.50	35.02
	5	28.25	53.78	35.62	8.70	6.60	1.65	35.02
	6	28.24	53.78	35.63	8.69	6.72	1.90	35.07
	7	28.24	53.74	35.57	8.69	6.58	2.15	35.02
	8	28.13	53.71	35.56	8.60	6.70	3.80	35.56
5	0	28.26	53.78	35.62	8.67	8.73	151.50	34.42
	1	28.23	53.79	35.62	8.68	7.24	0.53	34.42
	2	28.20	53.80	35.63	8.68	7.09	0.43	34.44
	3	28.19	53.80	35.63	8.68	6.98	0.60	34.43
	4	28.18	53.83	35.63	8.69	6.91	0.60	34.43
	5	28.18	53.81	35.63	8.68	6.95	0.67	34.44
	6	28.16	53.81	35.64	8.69	6.89	0.53	34.43
	7	28.14	53.82	35.64	8.69	6.90	0.60	34.45
	8	28.12	53.81	35.98	8.69	6.85	0.57	34.44
	9	28.11	53.81	35.64	8.69	6.84	0.60	34.44
	10	28.11	53.80	35.63	8.69	6.84	0.60	34.43
	15	28.06	53.74	35.58	8.68	6.67	0.63	34.40

Stn.	Depth (m)	Temp (°C)	Spc (mS/cm)	Sal (ppt)	pH	DO (mg/l)	Turbidity (NTU)	TDS (g/l)
	19	28.02	53.68	35.53	8.68	6.68	0.73	34.35
6	0	28.24	53.81	35.64	8.66	8.39	0.77	34.43
	1	28.20	53.83	35.65	8.67	7.39	5.23	34.43
	2	28.16	53.83	35.64	8.67	7.19	0.97	34.44
	3	28.11	53.82	35.64	8.67	7.06	0.73	34.44
	4	28.10	53.82	35.64	8.67	6.96	0.63	34.44
	5	28.09	53.83	35.63	8.67	6.90	0.70	34.44
	6	28.08	53.78	35.60	8.67	6.86	0.67	34.41
	7	28.07	53.72	35.58	8.67	6.83	0.70	34.39
	8	28.07	53.73	35.57	8.67	6.81	0.77	34.38
	9	28.06	53.72	35.58	8.67	6.73	0.70	34.39
	10	28.06	53.71	35.56	8.66	6.67	0.70	34.38
	15	28.07	53.66	35.54	8.68	6.54	0.95	34.35
7	0	28.36	53.81	35.64	8.66	7.43	13.67	34.45
	1	28.27	53.81	35.65	8.66	7.13	2.00	34.46
	2	28.24	53.83	35.66	8.67	7.06	1.17	34.46
	3	28.40	53.82	35.65	8.67	7.05	0.80	34.44
	4	28.21	53.81	35.64	8.66	7.03	0.83	34.44
	5	28.19	53.82	35.64	8.67	6.98	0.93	34.45
	6	28.19	53.82	35.63	8.67	6.96	0.87	34.45
	7	28.18	53.89	35.64	8.67	6.97	0.93	34.43
	8	28.16	53.74	35.60	8.67	6.93	0.83	34.39
	9	28.14	53.71	35.57	8.67	6.96	0.80	34.39
	10	28.13	53.74	35.57	8.67	6.93	0.80	34.39
	15	28.07	53.70	35.56	8.67	6.91	0.97	34.36
	19	28.05	53.69	35.55	8.67	6.82	1.37	34.36
8	0	28.31	53.81	35.63	8.58	7.40	22.13	34.45
	1	28.30	53.82	35.64	8.64	7.03	9.83	34.45
	2	28.20	53.83	35.64	8.65	6.98	0.50	34.44
	3	28.18	53.83	35.65	8.65	7.03	1.03	34.45
	4	28.17	53.82	35.65	8.66	6.98	0.87	34.45
	5	28.17	53.82	35.65	8.66	6.98	0.83	34.45
	6	28.16	53.83	35.65	8.66	6.95	0.73	34.45
	7	28.16	53.83	35.64	8.66	6.96	0.83	34.45
	8	28.14	53.81	35.65	8.66	6.91	1.00	34.45
	9	28.16	53.80	35.64	8.66	6.90	1.40	34.44
9	0	29.05	53.31	35.29	8.54	7.66	4.40	34.12
	1	28.91	53.33	35.29	8.44	7.54	0.50	34.14
	2	28.78	53.33	35.30	8.53	7.34	0.75	34.15
	3	28.69	53.37	35.32	8.52	7.15	0.75	34.16
	4	28.68	53.21	35.22	8.51	6.92	0.65	34.06

Stn.	Depth (m)	Temp (°C)	Spc (mS/cm)	Sal (ppt)	pH	DO (mg/l)	Turbidity (NTU)	TDS (g/l)
	5	28.65	53.51	35.20	8.50	6.82	0.70	34.05
	6	28.60	53.19	35.18	8.50	6.60	0.65	34.05
	7	28.54	53.18	35.18	8.51	6.58	1.10	34.04
	8	28.49	53.20	35.18	8.48	6.06	1.75	34.04
	9	28.47	53.19	35.18	8.44	5.72	2.05	34.04
10	0	29.01	53.25	35.22	8.56	7.22	21.80	34.08
	1	28.98	53.26	35.23	8.55	7.44	0.70	34.09
	2	28.74	53.30	35.23	8.54	7.46	0.75	34.11
	3	28.64	53.32	35.25	8.53	7.30	0.75	34.13
	4	28.62	53.28	35.24	8.53	7.17	0.70	34.11
	5	28.56	53.18	35.17	8.53	6.87	0.70	34.04
	6	28.54	53.17	35.16	8.52	6.73	0.75	34.03
	7	28.52	53.18	35.16	8.51	6.54	0.75	34.03
	8	28.50	53.19	35.17	8.50	6.25	0.75	34.03
	9	28.48	53.18	35.18	8.50	6.13	0.75	34.03
	10	28.46	53.16	35.16	8.50	5.95	0.75	34.03
	16	28.45	53.04	35.03	8.48	5.06	8.70	33.56
11	0	28.93	53.21	35.16	8.53	7.31	0.40	34.05
	1	28.86	53.19	35.18	8.53	7.20	2.75	34.05
	2	28.80	53.15	35.15	8.53	6.98	0.80	34.02
	3	28.75	53.14	35.16	8.53	6.65	0.65	34.02
	4	28.68	53.14	35.12	8.53	6.63	0.65	34.00
	5	28.66	53.14	35.13	8.52	6.52	0.65	34.01
	6	28.60	53.14	35.14	8.39	6.29	0.75	34.02
	7	28.58	53.15	35.13	8.51	6.05	0.70	34.02
	8	28.55	53.15	35.14	8.51	5.97	0.70	34.01
	9	28.47	53.16	35.15	8.50	5.58	0.75	34.02
	10	28.48	53.14	35.15	8.50	5.45	0.85	34.02
	15	28.42	53.15	35.15	8.47	4.49	1.35	34.02
12	0	28.97	53.06	35.07	8.53	7.15	0.95	33.95
	1	28.86	53.06	35.09	8.53	6.95	0.70	33.97
	2	28.79	53.08	35.09	8.52	6.61	0.70	33.97
	3	29.24	53.04	35.07	8.49	6.41	0.75	33.95
	4	28.69	53.00	35.02	8.52	6.50	0.80	33.91
	5	28.65	52.99	35.02	8.51	6.41	0.75	33.92
	6	28.64	52.98	35.03	8.52	6.35	0.80	33.91
	7	28.62	52.97	35.02	8.50	6.20	0.85	33.90
	8	28.59	52.98	35.02	8.50	6.01	0.85	33.91
	9	28.56	52.97	35.02	8.49	5.81	1.05	33.92
	10	28.52	52.98	35.00	8.47	5.73	0.95	33.91
	13	28.31	53.13	35.03	8.36	3.05	2.80	33.92

Stn.	Depth (m)	Temp (°C)	Spc (mS/cm)	Sal (ppt)	pH	DO (mg/l)	Turbidity (NTU)	TDS (g/l)
13	0	28.98	52.95	35.03	8.55	7.29	0.00	33.91
	1	28.94	52.77	34.84	8.56	7.20	0.70	33.77
	2	28.90	52.76	34.87	8.55	7.22	0.75	33.77
	3	28.84	52.78	34.85	8.55	7.40	0.75	33.78
	4	28.77	52.83	34.86	8.55	7.26	0.75	33.83
	5	28.74	52.82	34.92	8.55	7.12	0.75	33.81
	6	28.69	52.81	34.89	8.54	6.87	0.75	33.81
	7	28.64	52.80	34.89	8.53	6.66	0.75	33.79
	8	28.55	52.83	34.89	8.50	6.08	0.70	33.79
	9	28.55	52.80	34.89	8.49	5.87	0.75	33.79
	10	28.53	52.73	34.84	8.49	5.56	0.70	33.74
	15	28.26	52.60	34.65	8.37	2.89	8.10	33.72
14	0	28.81	52.62	34.74	8.51	7.30	0.00	33.67
	1	28.81	52.63	34.77	8.52	6.67	3.30	33.69
	2	28.78	52.62	34.76	8.53	6.49	0.65	33.68
	3	28.76	52.61	34.74	8.52	6.46	0.80	33.67
	4	28.74	52.59	34.75	8.52	6.21	1.15	33.68
15	0	28.89	52.87	34.92	8.61	7.07	1.30	33.83
	1	28.80	52.86	34.93	8.59	6.87	1.80	33.82

Table 5-5 Average biophysical data for all stations

Station	BOD (mg/l)	TSS (mg/l0	Nitrate (mg/l)	Phosphate (mg/l)	FOG (mg/l)
1	5.7	1.0	0.8	0.20	0.35
2	4.3	4.3	0.9	0.70	0.57
3	7.0	0.3	1.3	0.13	0.23
4	5.7	1.7	1.1	0.21	0.23
5	3.0	0.0	1.1	0.77	0.50
6	4.0	1.0	1.5	0.46	0.23
7	2.7	1.7	1.1	0.98	0.35
8	3.0	2.3	1.6	0.20	0.45
9	5.5	2.0	1.3	0.36	1.10
10	2.5	1.5	1.2	0.23	1.22
11	3.0	2.0	0.8	0.69	1.29
12	4.0	2.5	0.9	1.25	1.10
13	3.0	2.5	1.0	0.70	1.60
14	2.5	2.5	0.8	0.20	1.02
15	5.5	2.0	1.2	1.85	1.29

Temperature

Average temperature values varied little across the stations ranging from 28 – 29.4°C (Figure 5-5 and Figure 5-6). When compared with depth, the temperature at each station showed a general decrease. The stations within the Harbour (9-15) appeared to have slightly higher temperature compared to the seaside stations (1-8). The small difference noticed could be due to the time of day sampling, whereby the harbour stations were sampled from midday.

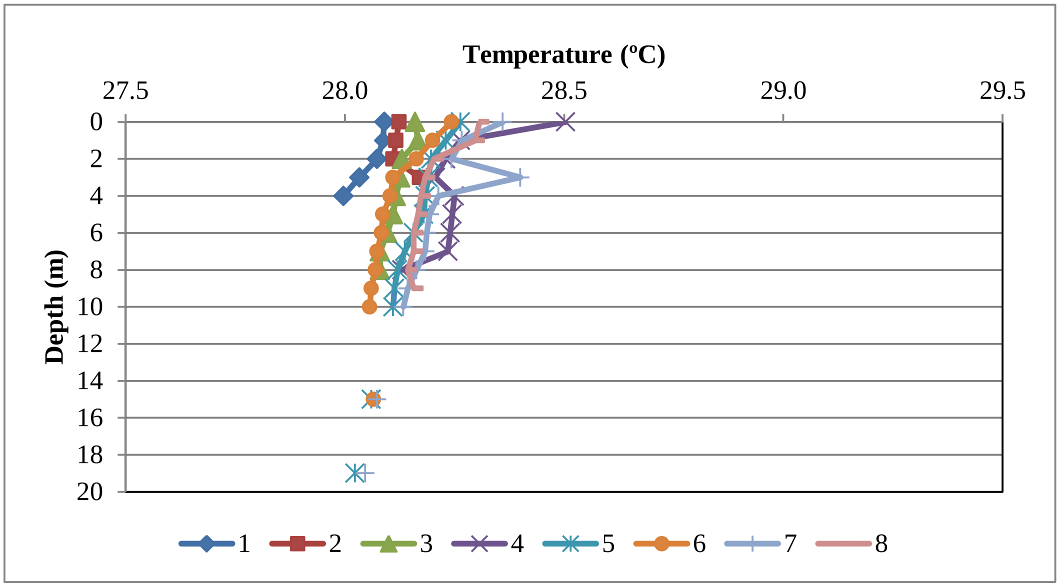


Figure 5-5 Average temperature variation across sampling stations 1-8

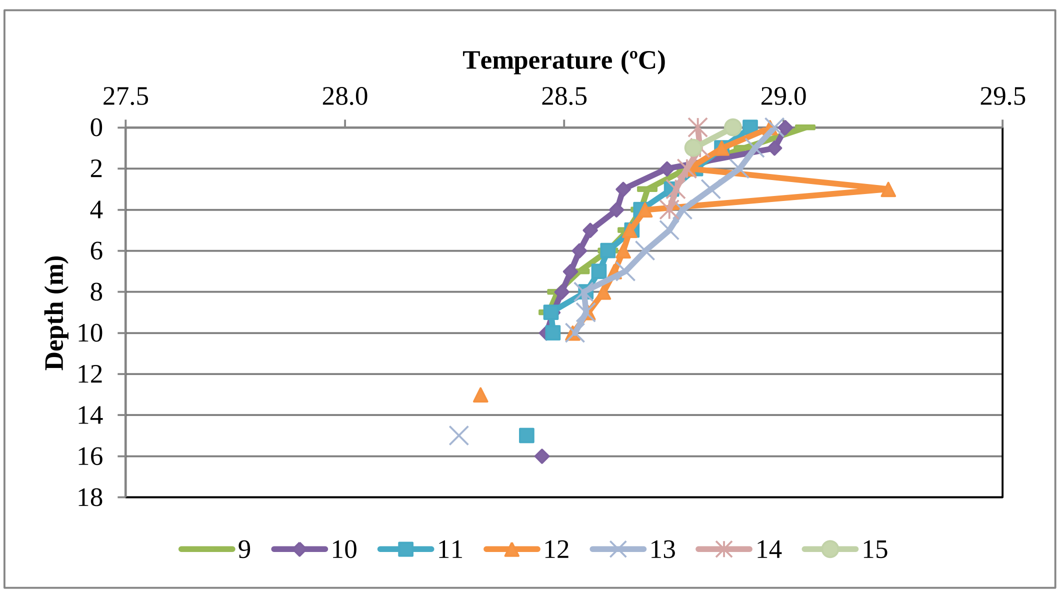


Figure 5-6 Average temperature variation across sampling stations 9-15

Specific Conductivity

Average specific conductivity values varied across the stations ranging from 52.29 – 53.39mS/cm. The lowest conductivity was observed at station 14 and the highest was observed at station 7. The stations within the harbour (9 -15) appeared to have lower conductivity values in comparison to the stations on the outside of the harbour (1-8) (Figure 5-7 and Figure 5-8). When compared with depth, the conductivity values at each station showed a general decrease.

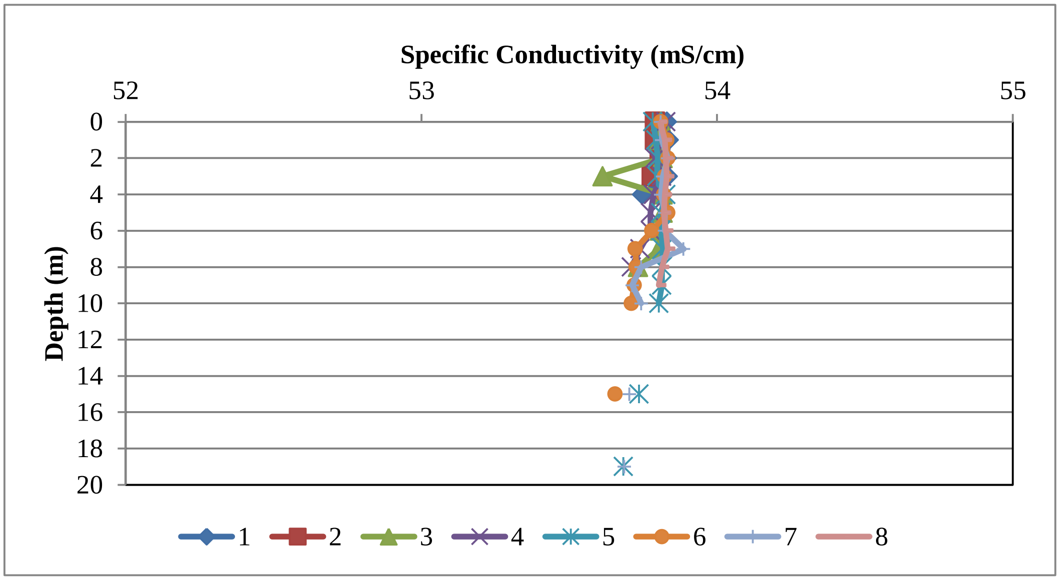


Figure 5-7 Average conductivity variation across sampling stations 1-8

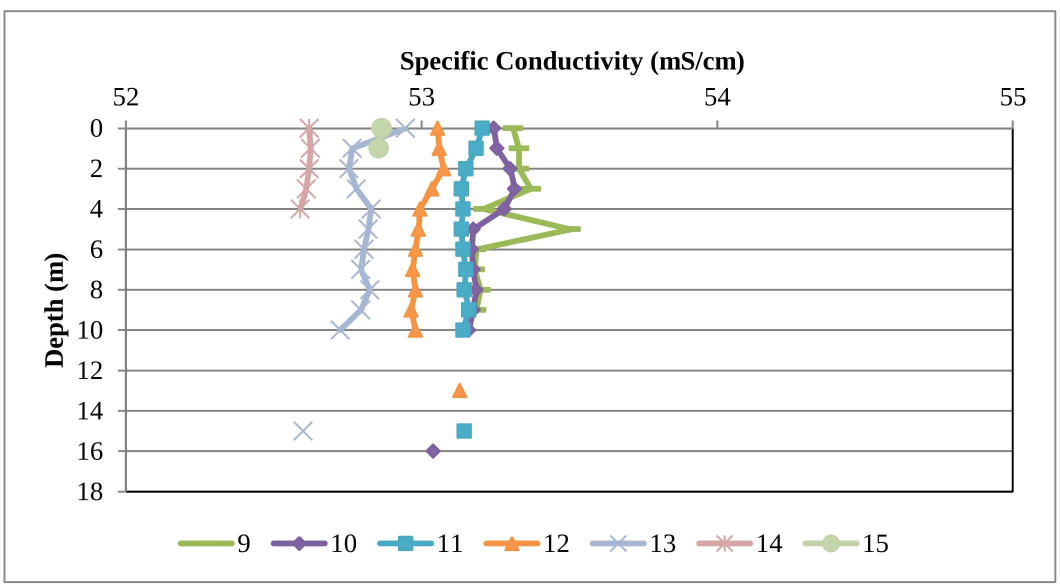


Figure 5-8 Average conductivity variation across sampling stations 9-15

Salinity

Average salinity values varied across the stations ranging from 34.65 – 36.11ppt. The highest value was observed at station 2 and the lowest value was observed at station 13. A trend similar to conductivity was observed between the stations for salinity. The stations inside the Harbour (9-15) showed lower salinity levels compared to the stations on the outside of the Harbour (Figure 5-9 and Figure 5-10). Low salinities have been reported within the Harbour and have been attributed to fluvial input from the numerous gullies and rivers that empty therein (Ranston, Simmonds, and Webber 2003; Bigg and Webber 2003).

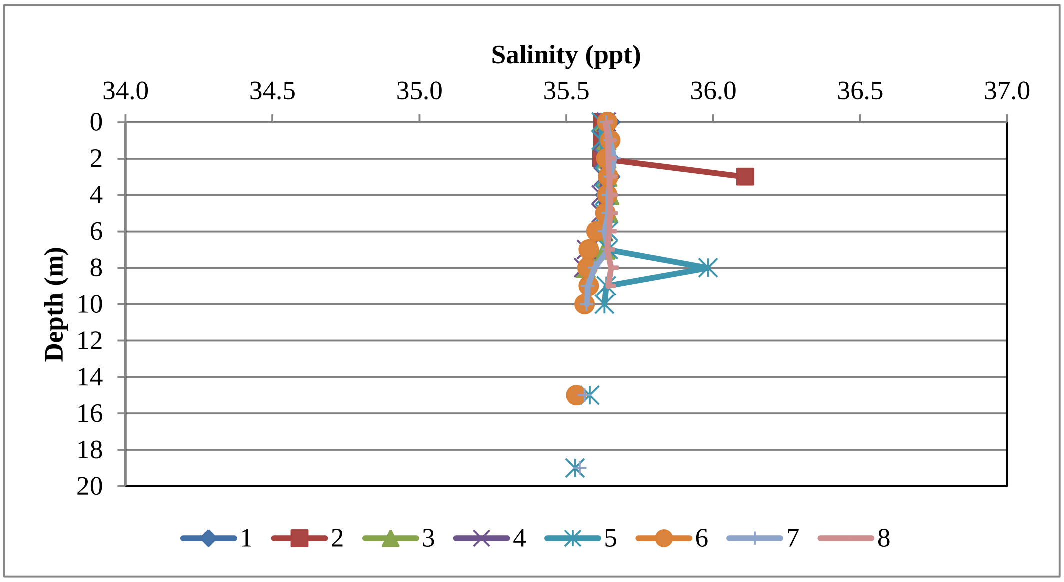


Figure 5-9 Average salinity variation across sampling stations 1-8

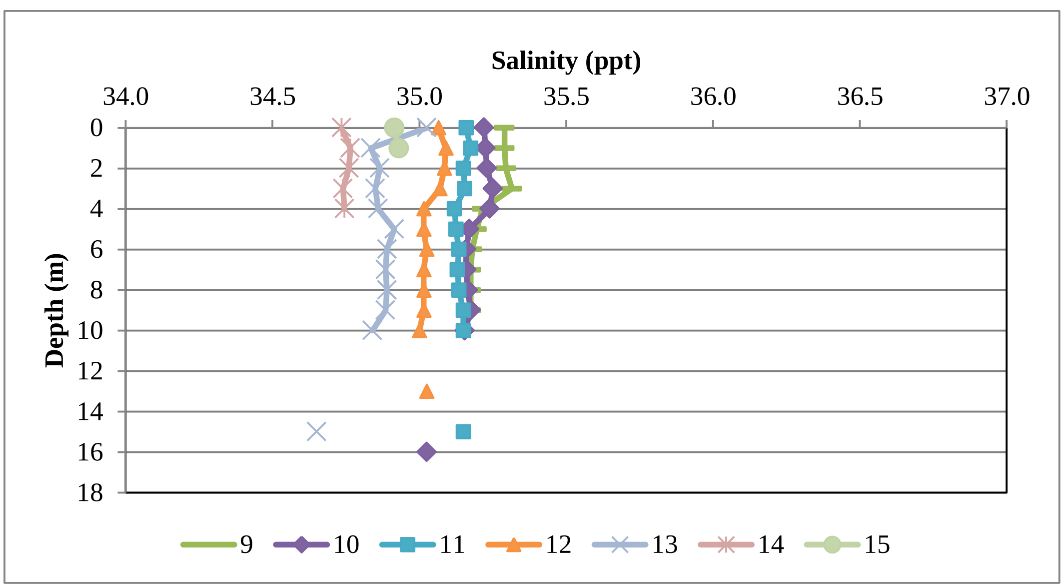


Figure 5-10 Average salinity variation across sampling stations 9-15

pH

Average pH values varied across the stations ranging from 8.36 – 8.70. The highest pH was observed at station 4 and the lowest pH was observed at station 12. When compared with depth there was little variation observed at each station (Figure 5-11 and Figure 5-12). Most stations were above the ambient water quality standard of 8.4 for marine water.

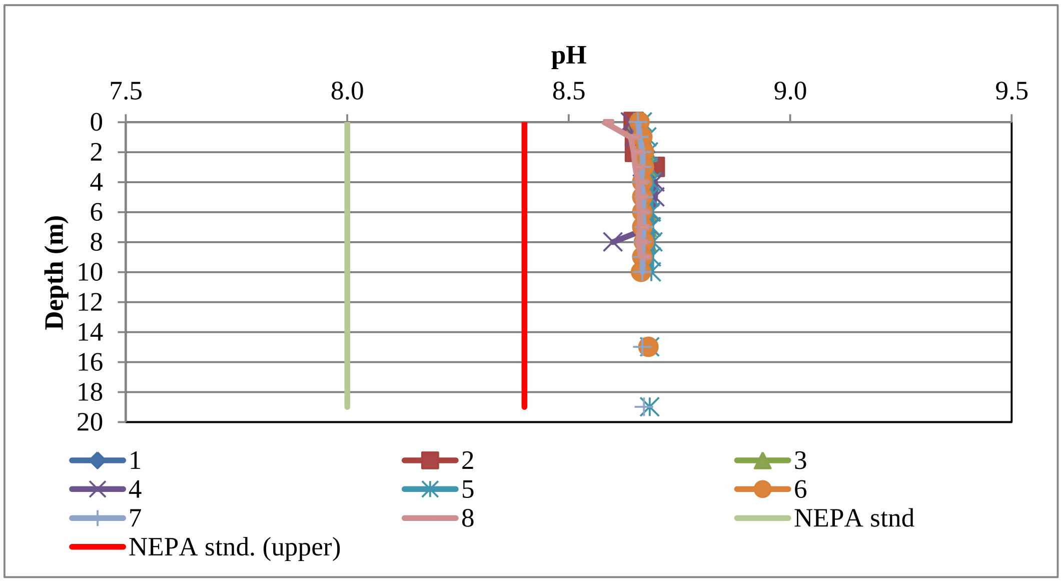


Figure 5-11 Average pH variation across sampling stations 1-8

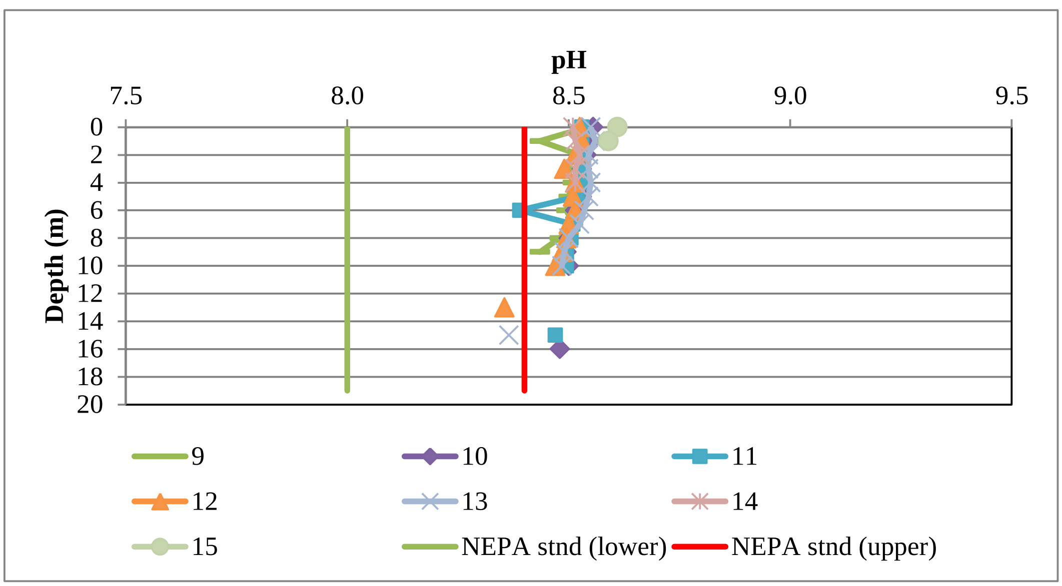


Figure 5-12 Average pH variation across sampling stations 9-15

Dissolved Oxygen (DO)

The average DO values varied greatly across stations ranging from 2.89 – 8.73mg/l. The highest value was observed at station 5 and the lowest value was observed at station 13. Surface levels of dissolved oxygen were high for all stations but there was a general decrease in dissolved oxygen level with stations in the Harbour showing the lowest levels (Figure 5-13). Stations 9-15 are located in the Upper basin region of the Harbour and is the area with the longest residence time and lowest mixing with other water masses in the Harbour (Dunbar and Webber 2003) with anoxic subsurface waters and anoxic sediment pore water (D. F. Webber and Kelly 2003).

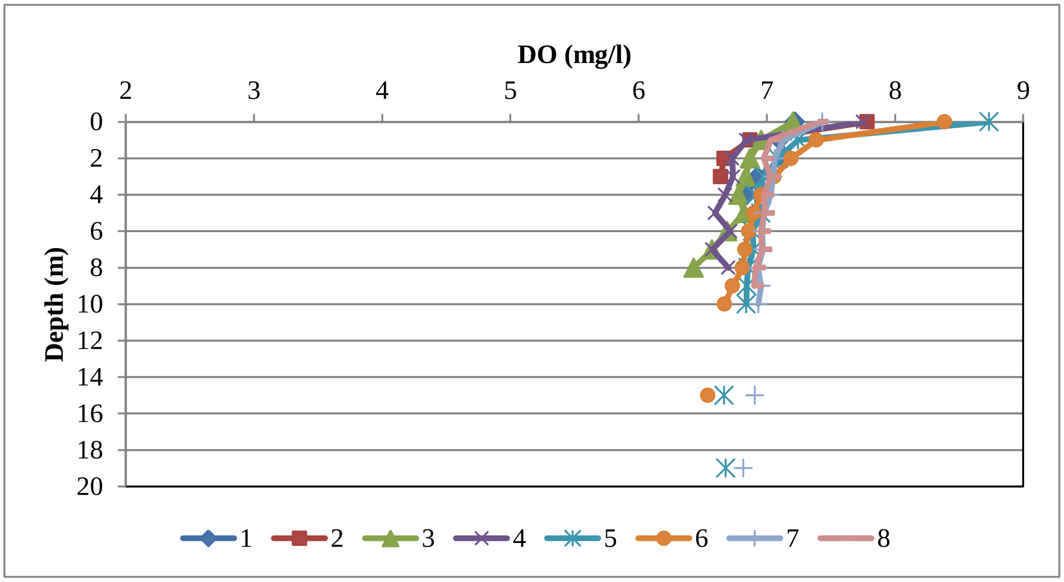


Figure 5-13 Average dissolved oxygen variation across sampling stations 1-8

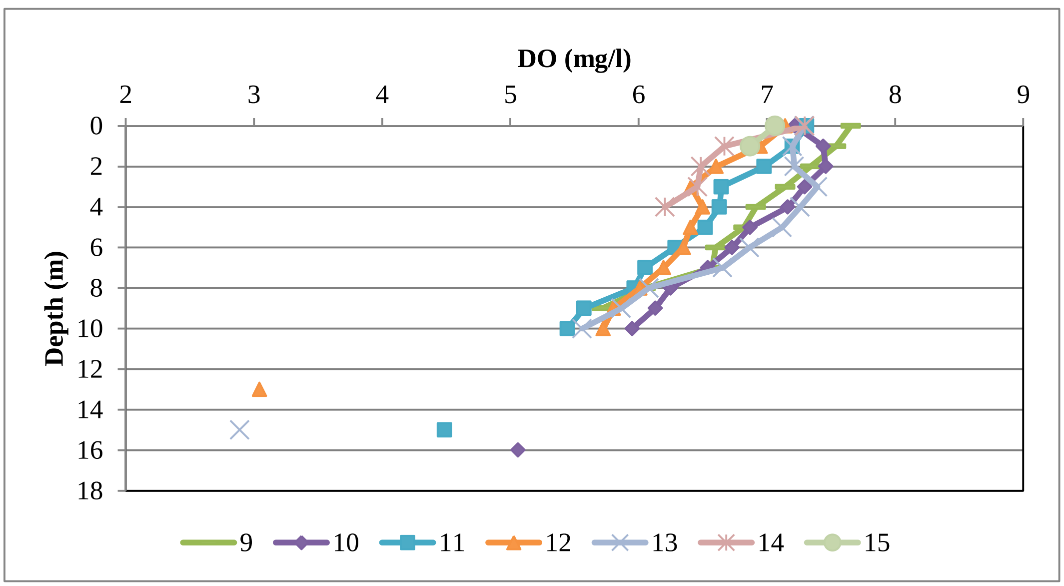


Figure 5-14 Average dissolved oxygen variation across sampling stations 9-15

Turbidity

Average turbidity values varied across stations ranging from 0 – 151.5NTU. The highest value was observed at station 5 and the lowest value was observed at stations 14 and 15 (Figure 5-15 and Figure 5-16). Station 1 and 5 had elevated levels compared to the other stations which could be due to the suspension of particles by wave action (Wilson-kelly and Kelly 2007).

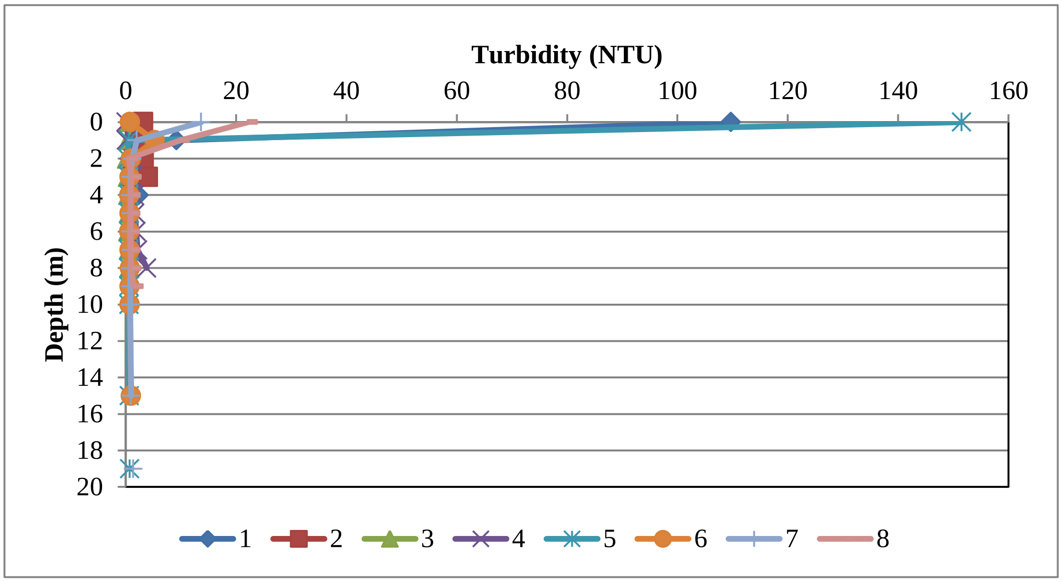


Figure 5-15 Average turbidity variation across sampling stations 1-8

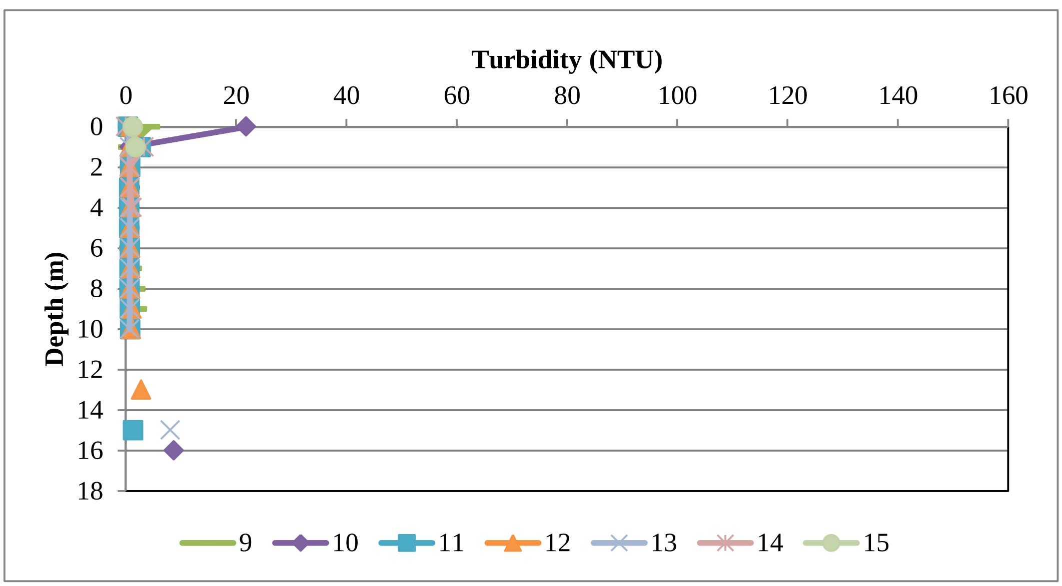


Figure 5-16 Average turbidity variation across sampling stations 9-15

Total Dissolved Solids (TDS)

Average TDS values varied across stations ranging from 33.56 – 35.07g/l. The highest TDS value was observed at station 4 and the lowest value was observed at station 10. Generally, the stations within the Harbour showed lower TDS values when compared to the stations outside of the Harbour (Figure 5-17 and Figure 5-18). This trend was also observed in the conductivity and salinity values. The greater presence of dissolved ions on stations outside of the Harbour is evident in the levels obtained.

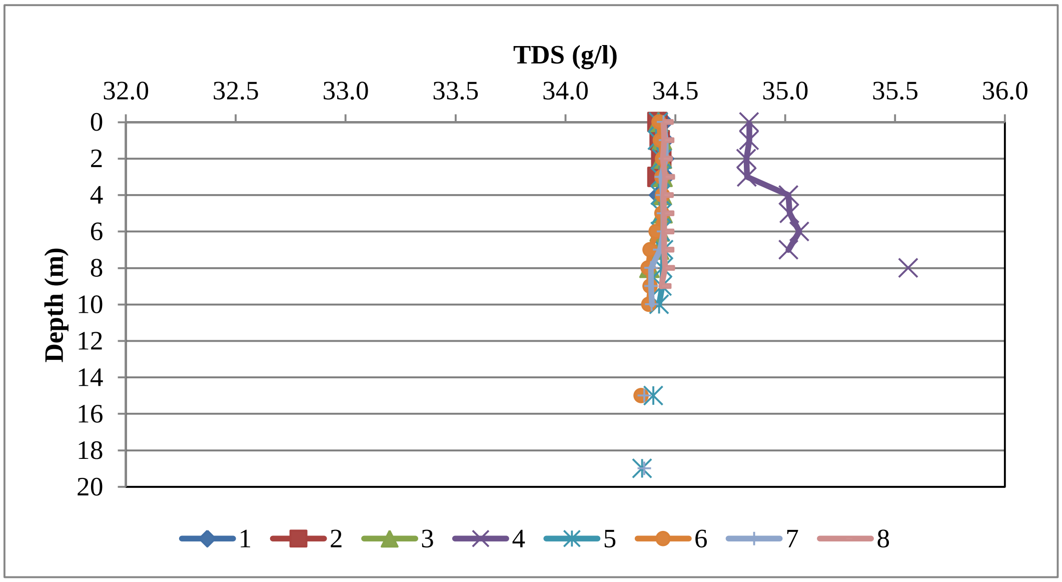


Figure 5-17 Average TDS variation across sampling stations 1-8

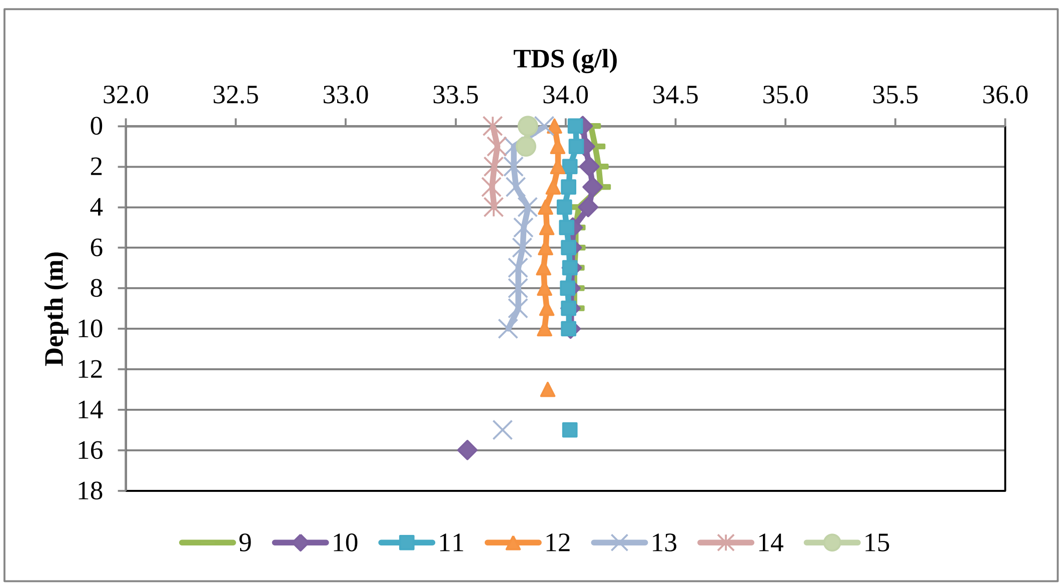
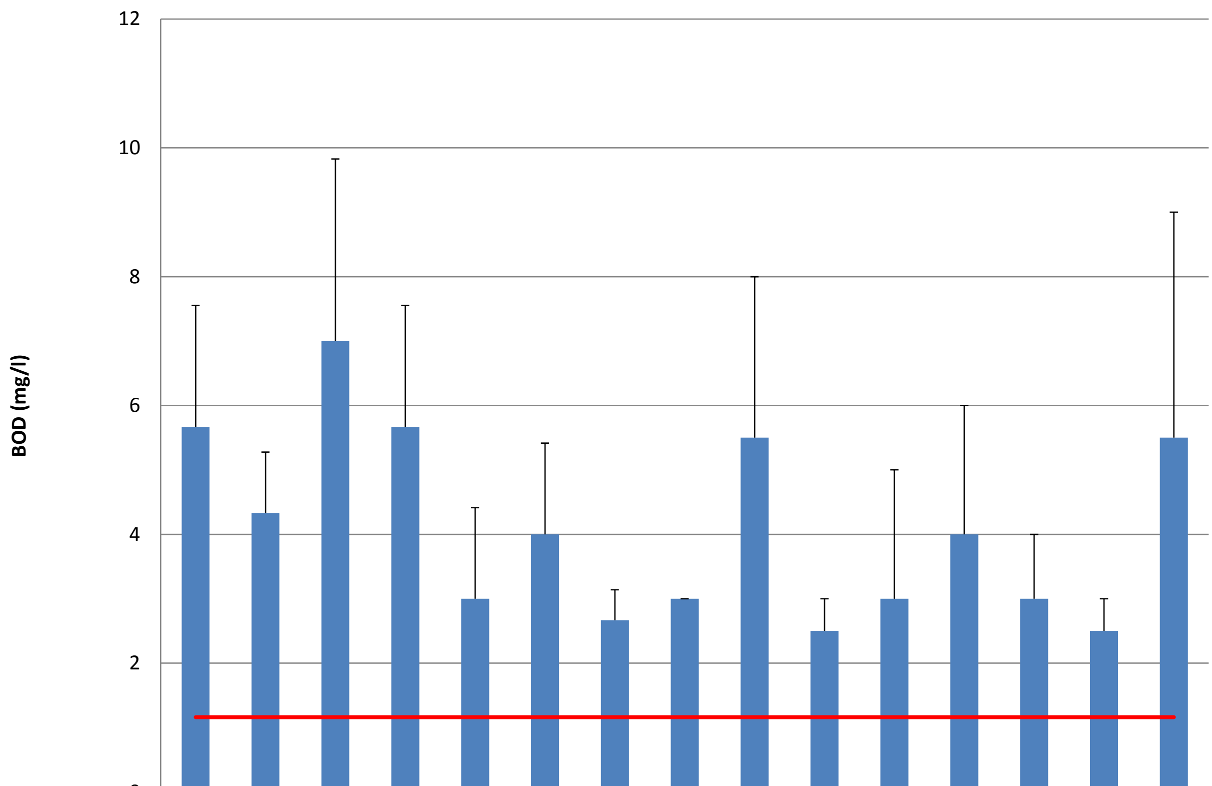


Figure 5-18 Average TDS variation across sampling stations 9-15

Biological Oxygen Demand (BOD)

Average BOD values varied across the stations ranging from 2.5 – 5.7mg/l. The highest value was observed at station 3 and the lowest value was observed at station 10 (Figure 5-19). BOD values within the Harbour have previously been reported as high (>35mg/l) and was attributed to a number of sources; run-off, industrial waste, sewage and domestic waste (D. F. Webber and Kelly 2003). The high BOD values and high standard deviations at the stations likely indicate high organic matter input to these areas. All stations were above the national standard of water quality for marine water of 1.16mg/l.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
BOD	5.7	4.3	7.0	5.7	3.0	4.0	2.7	3.0	5.5	2.5	3.0	4.0	3.0	2.5	5.5
NEPA stnd.	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16	1.16

Figure 5-19 Average BOD variation across sampling stations with standard deviation

Total Suspended Solids (TSS)

Average TSS values varied across stations ranging from 0 – 4.3mg/l. The highest value was observed at station 2 and the lowest value was observed at station 5 (Figure 5-20). The low TSS and relatively low standard deviations at the stations in the upper harbour and outside the harbour indicate low levels of suspended solids input to these areas. These values are low compared to the study by Wilson-Kelly and Kelly (2007) and could be due to the low wind and wave action during sampling. TSS values within the Harbour have been reported at a maximum of 420mg/l, but this was due to the direct input from sewage treatment plants along the northern shoreline (D. F. Webber and Kelly 2003).

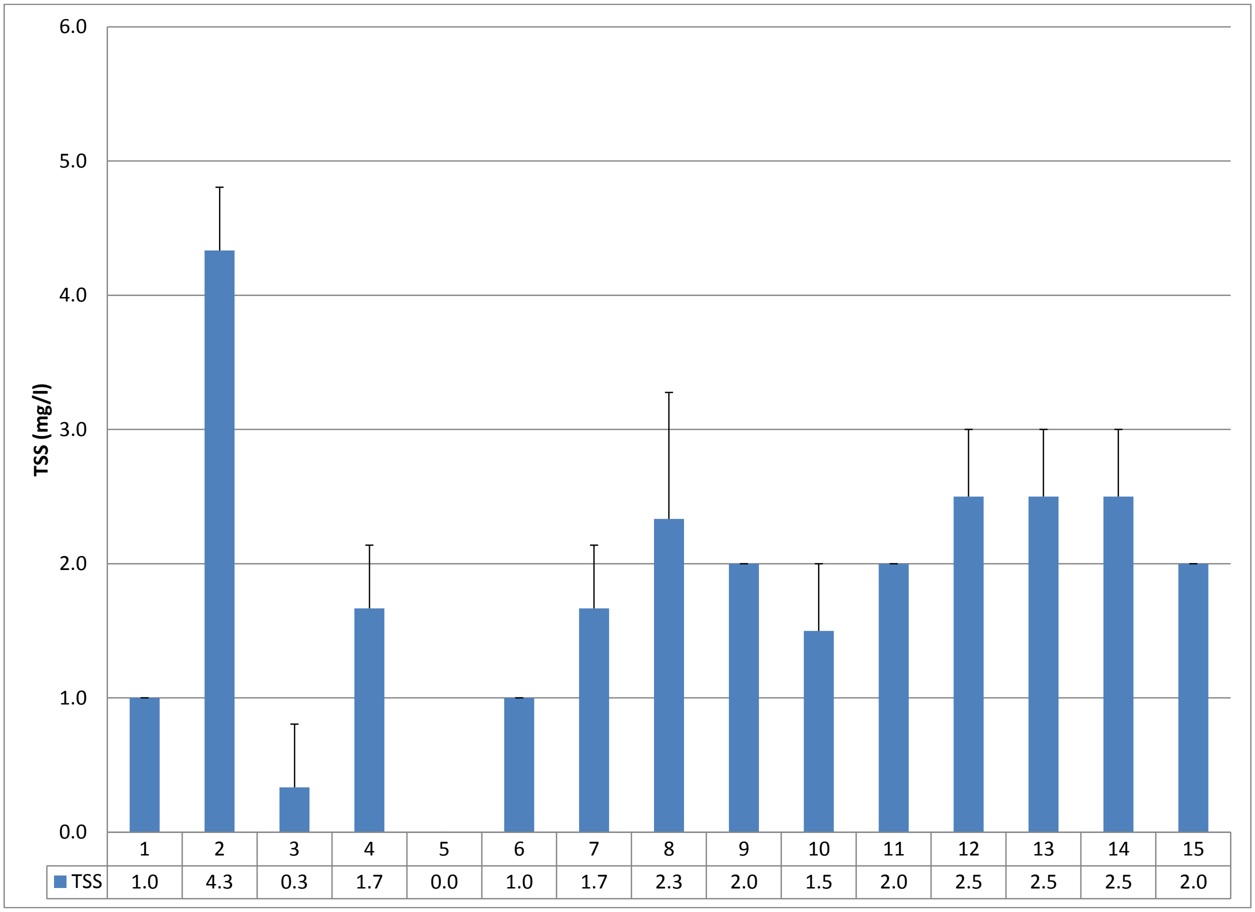
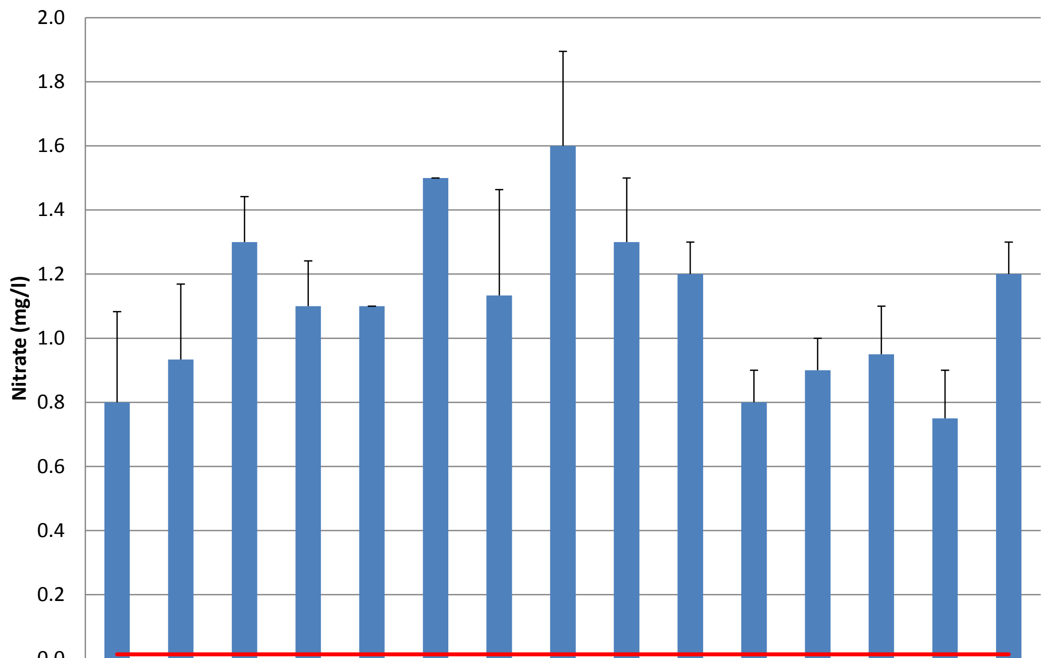


Figure 5-20 Average TSS variation across sampling stations with standard deviation

Nitrates

Average nitrate values varied across stations ranging from 0.8 – 1.6mg/l. The highest was obtained at station 8 and the lowest value was obtained at station 1, 11 and 14 (Figure 5-21). Nitrate levels within the Harbour have increased since the 1970's with a maximum reported level of 45.3μM (M. K. Webber et al. 2003) and were mainly attributed to sewage outfalls and gully run-off. The levels of nitrates observed at the harbour stations (9-15) were lower when compared to Webber at al. (2003) and the relatively low standard deviations likely indicate similar nutrient input to the area. However, the stations outside of the harbour (1-8) had high levels of nutrients and relatively high standard deviations for some stations which likely indicate episodic high input of nutrients to the area. All stations were above the national ambient water quality standard for marine water of 0.014mg/l.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Nitrate	0.8	0.9	1.3	1.1	1.1	1.5	1.1	1.6	1.3	1.2	0.8	0.9	1.0	0.8	1.2
NEPA stnd. (upper)	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014	0.014

Figure 5-21 Average nitrate variation across sampling stations with standard deviation

Phosphates

Average phosphate values varied across stations ranging from 0.1 – 1.8mg/l. The highest value was observed at station 15 and the lowest was observed at station 3 (Figure 5-22). The high phosphate values and relatively high standard deviations at the stations indicate episodic high nutrient input to the area. A source of organic material containing phosphates is located close to station 15 as indicated by the high levels obtained. Sewage outfall has been cited as a major source of phosphate to the Harbour but concentrations are low (≤4.62μM), however the data represented orthophosphates with sewage commonly containing polyphosphates (D. F. Webber and Kelly 2003). All stations were above the ambient water quality standard for phosphates of 0.003mg/l.

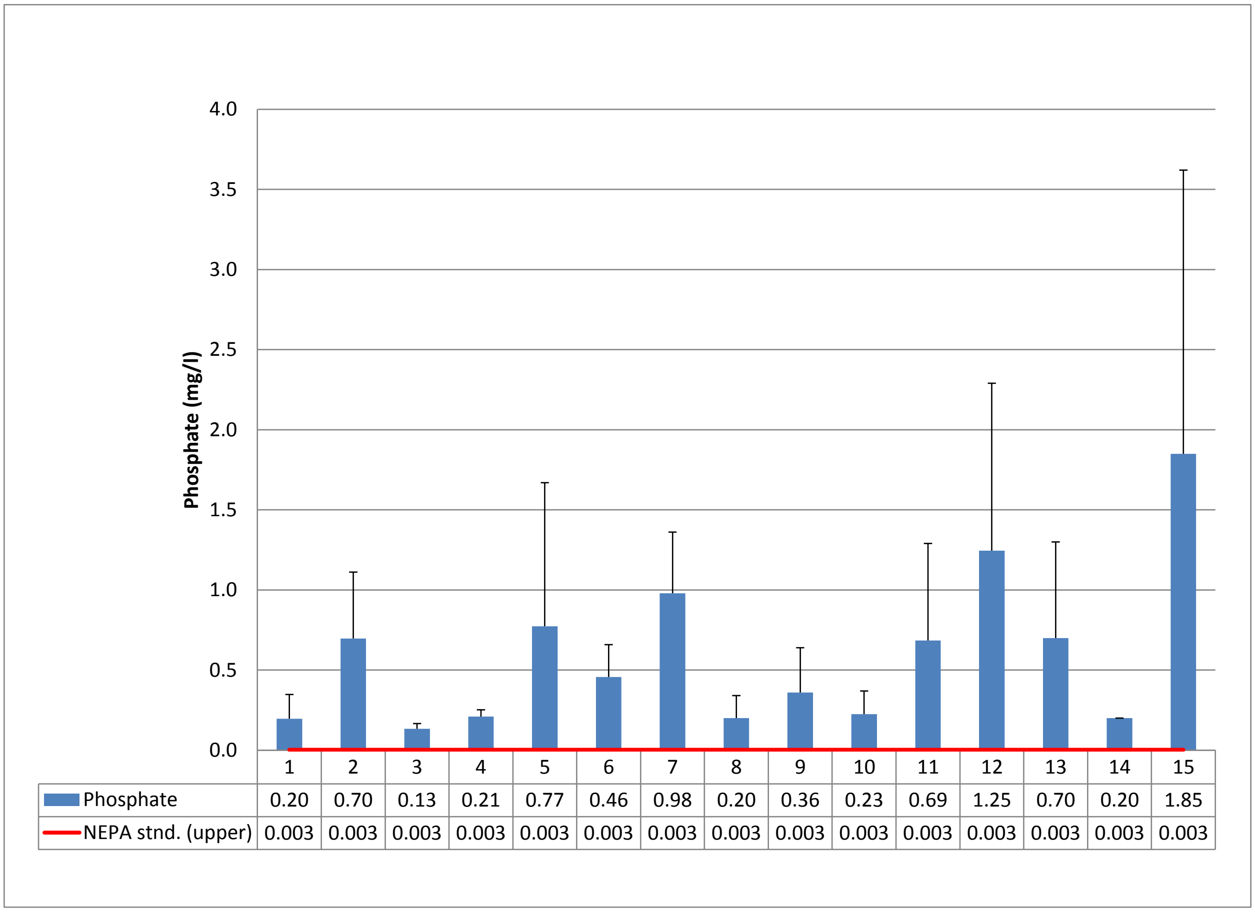
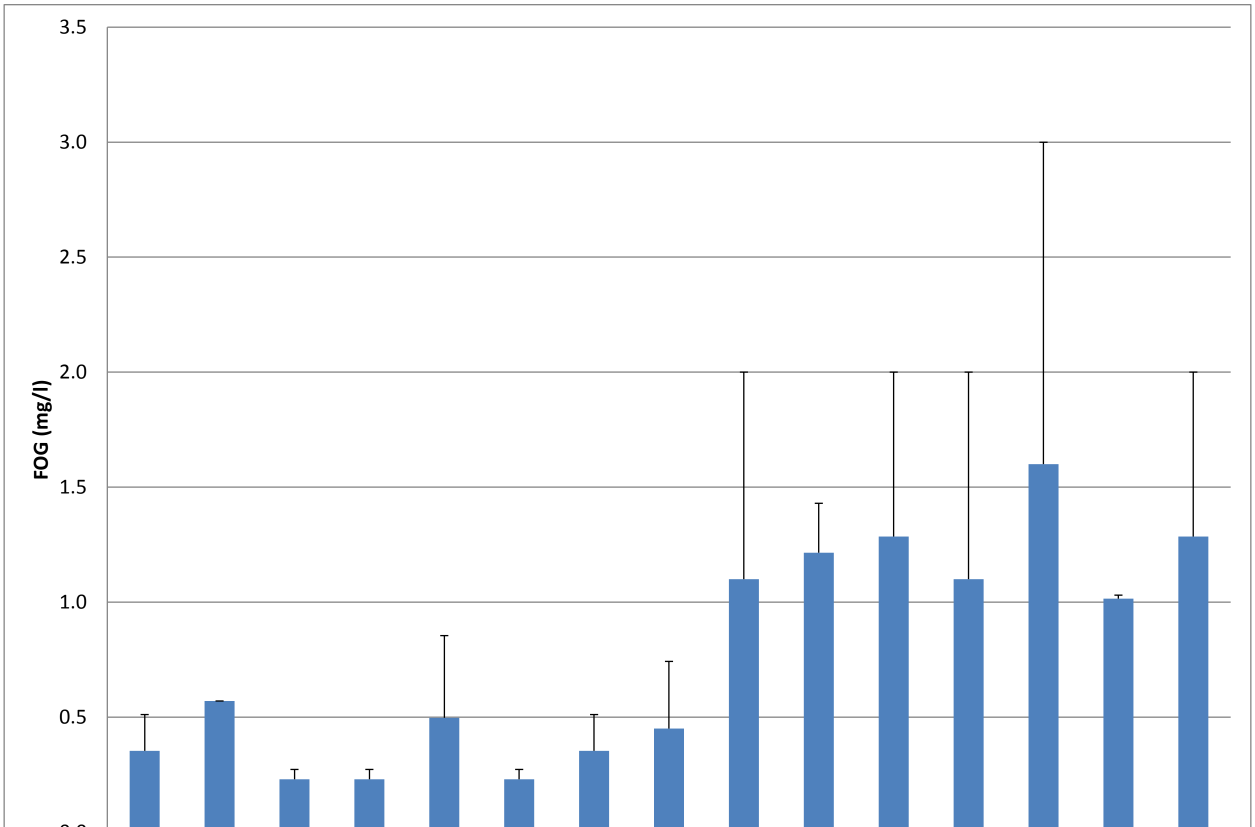


Figure 5-22 Average phosphate variation across sampling stations with standard deviation

Fats, Oils and Grease (FOG)

Average FOG values varied across stations ranging from 0.2 – 1.6mg/l. The highest value was observed at station 13 and the lowest value was observed at station 3, 4 and 6 (Figure 5-23). The stations located inside the Harbour had relatively higher levels of FOG and standard deviations compared and to the seaside stations, which likely indicate higher input of oils to these areas. Run-off from gullies, industrial and domestic waste within the Harbour could account for the levels observed.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
FOG	0.35	0.57	0.23	0.23	0.50	0.23	0.35	0.45	1.10	1.22	1.29	1.10	1.60	1.02	1.29

Figure 5-23 Average FOG variation across sampling stations with standard deviation

5.2.4 Oceanography

In addition to describing the existing oceanographic setting within the project area, it was necessary to collate various oceanographic variables for input to models described in subsequent sections. The following subsections describe the various oceanographic parameters in further detail.

5.2.4.1 Bathymetry

Method

Bathymetric data was required in order to facilitate the estimation of fill volume for dune placement and mangrove nourishment – project components which are directly related to costs. In addition, bathymetric data forms the basis for wave transformation and hydrodynamic modelling which then allows for modelling of the size, shape and location of the required structures.

The Bathymetric survey was developed based on the following three surveys:

- CEAC survey conducted along the Caribbean Sea and harbour side of the Palisadoes on November 15 and 20, 2013, not including the burrow area. The CEAC survey was done to using a Garmin echo sounder along gridlines running parallel and perpendicular to the Caribbean Sea side and harbour side shoreline were followed to collect the bathymetric data. Along the Caribbean Sea side the survey was taken between the NWC treatment plant and the end of the most western low revetment, while the Harbour side survey was taken between Gypsum Quarry and Gun Boat Beach.

- Cuban survey of the Caribbean Sea side of the Palisadoes conducted in 2008 as a part of their technical report. The Cuban survey was carried out using a Biosonics echosounder from Cane River to Little Plumb Point along 37 survey lines perpendicular to the shore between 5 and 30 m deep. The survey was able to identify a sandy basin that would be useful as a borrow area.
- NWA as-built topography carried out after the completion of the revetments along the Palisadoes. The NWA completed the as-built topography survey after the revetments were constructed, and this information defined the shoreline along both sides of the Palisadoes. All three (3) surveys were then used to develop a comprehensive bathymetry for the project area.

Bathymetry Description

The Palisadoes constitutes the extension of land of about 14 km in length, with an East-West projection, that protects Kingston Harbour from the open waters of the Caribbean Sea[9]. The narrow strip of land ends at Port Royal, leaving a deep channel through which even the largest ships can sail. The area lies within 13,000 hectares of cays, reefs and mangroves and is also a National Heritage site. Figure 5-24 depicts the bathymetry of the study area.

[9] Juanes, Perez, Izquierdo, Caballero, Rivero (2007), Palisadoes Protection and Rehabilitation Project,

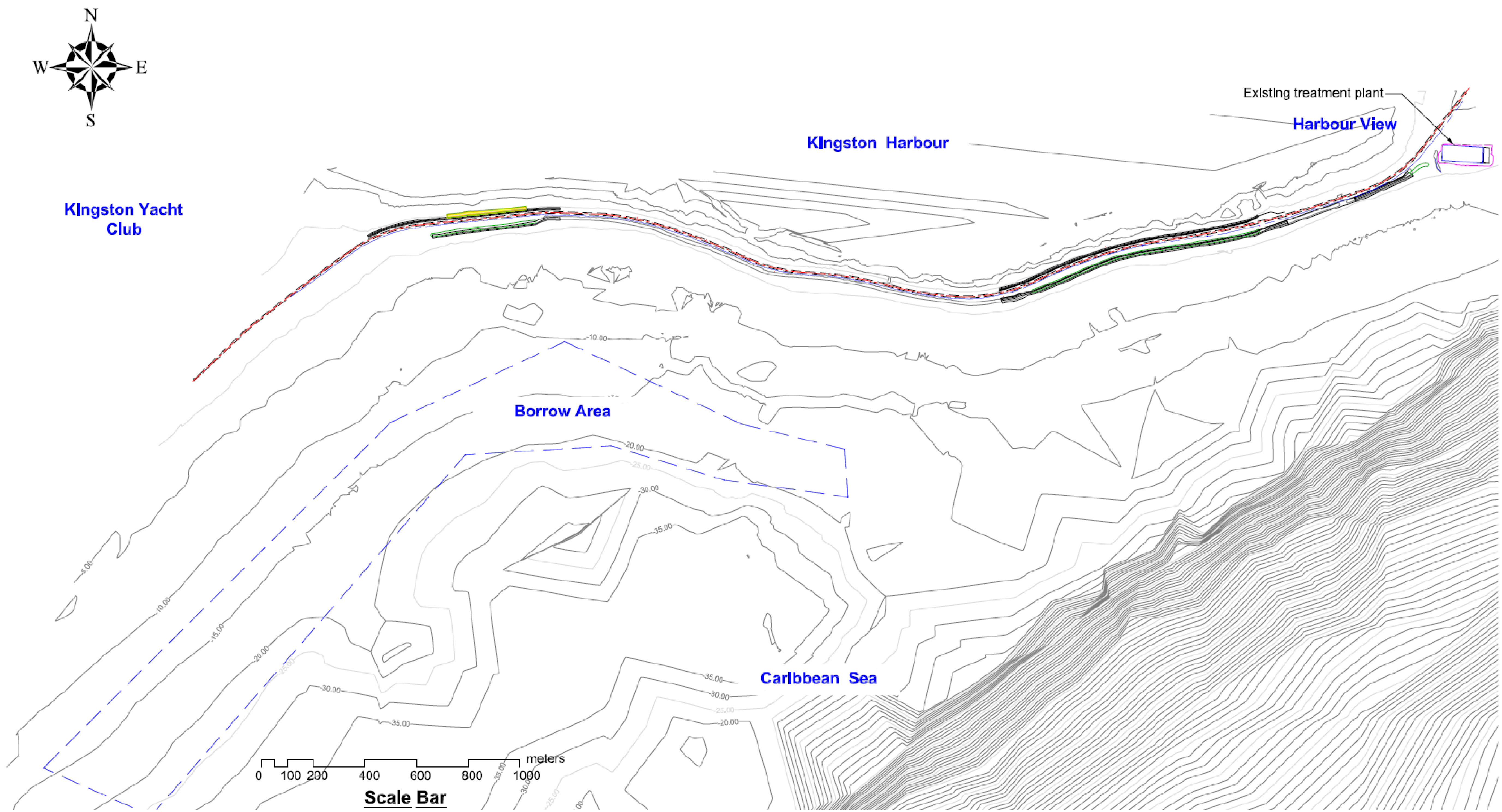


Figure 5-24 Bathymetry for the Palisadoes Shoreline Protection and Rehabilitation Project

5.2.4.2 Currents

In order to facilitate the development of the hydrodynamic model for the area it was necessary to collect information on tides, winds and currents. This information was acquired by carrying out two drogue tracking missions and deploying an Acoustic Doppler Current Profiler (ADCP) on the sea floor for approximately one month.

Moored ADCP

An ADCP was deployed in two locations over a 4 week period, and two drogue tracking missions were carried out in the vicinity of the moored ADCP to verify its measurements/readings. An ADCP operates using acoustic signals, and determines the current speed and direction by detecting the Doppler shift of reflected acoustic signals, which bounce off particles moving with the water. With this method of measurement it is therefore able to measure separate section/bins in the water column.

The ADCP was deployed in 20 meters of water at plumb point in the west and 18m in the central section of the project area within the Caribbean Sea (Figure 5-25). It was set to record averaged current and wave readings at 1 hour intervals.

Figure 5-25 Google imagery showing the two locations where the ADCP was deployed in the Caribbean Sea for the Palisadoes Shoreline Protection and Rehabilitation Project

The time series graphs below (Table 5-7 and Table 5-7) indicate that the current velocities decrease as you move deeper into the water column, that is, the surface currents are faster than the currents at mid depth, and the currents at mid depth are faster than those at the sea floor. This observation is generally the case as surface currents are more likely to be impacted by winds whenever the wind velocities are sufficiently high as well as waves and so they will have larger current velocities.

The scatter plots in Table 5-6 and Table 5-7 indicate the currents were generally moving in a north-south direction in the area where the ADCP was first deployed. During the second deployment however the only trend observed was for the surface currents, they were moving in a general north-south direction. There mid depth and sea floor currents displayed no general trend, the currents were erratic moving in all directions.

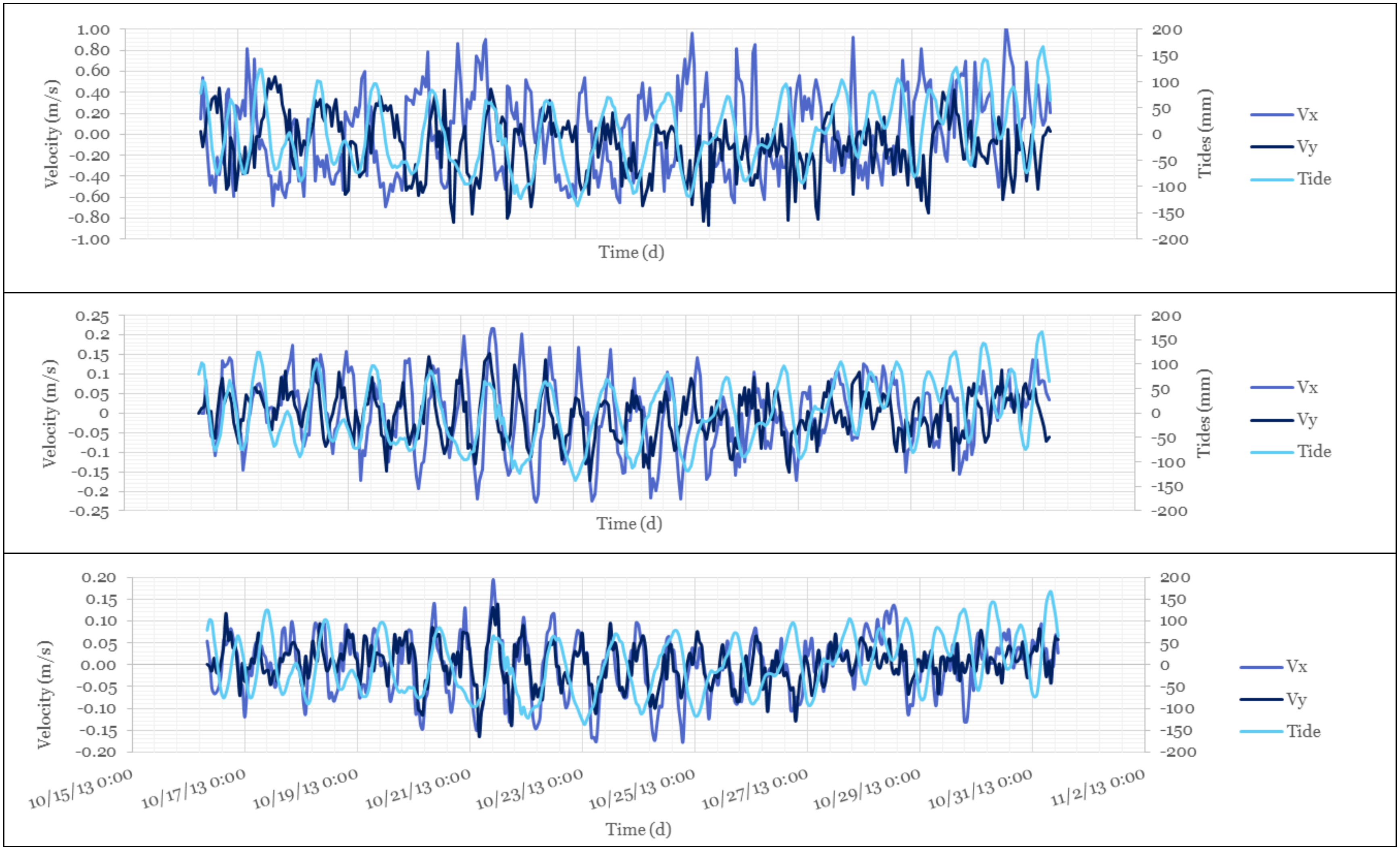


Table 5-6 Current velocities and tide recordings during the first ADCP deployment of the centre of Palisadoes in line with the burrow area for the surface (top panel), mid depth and sea floor (bottom panel) respectively

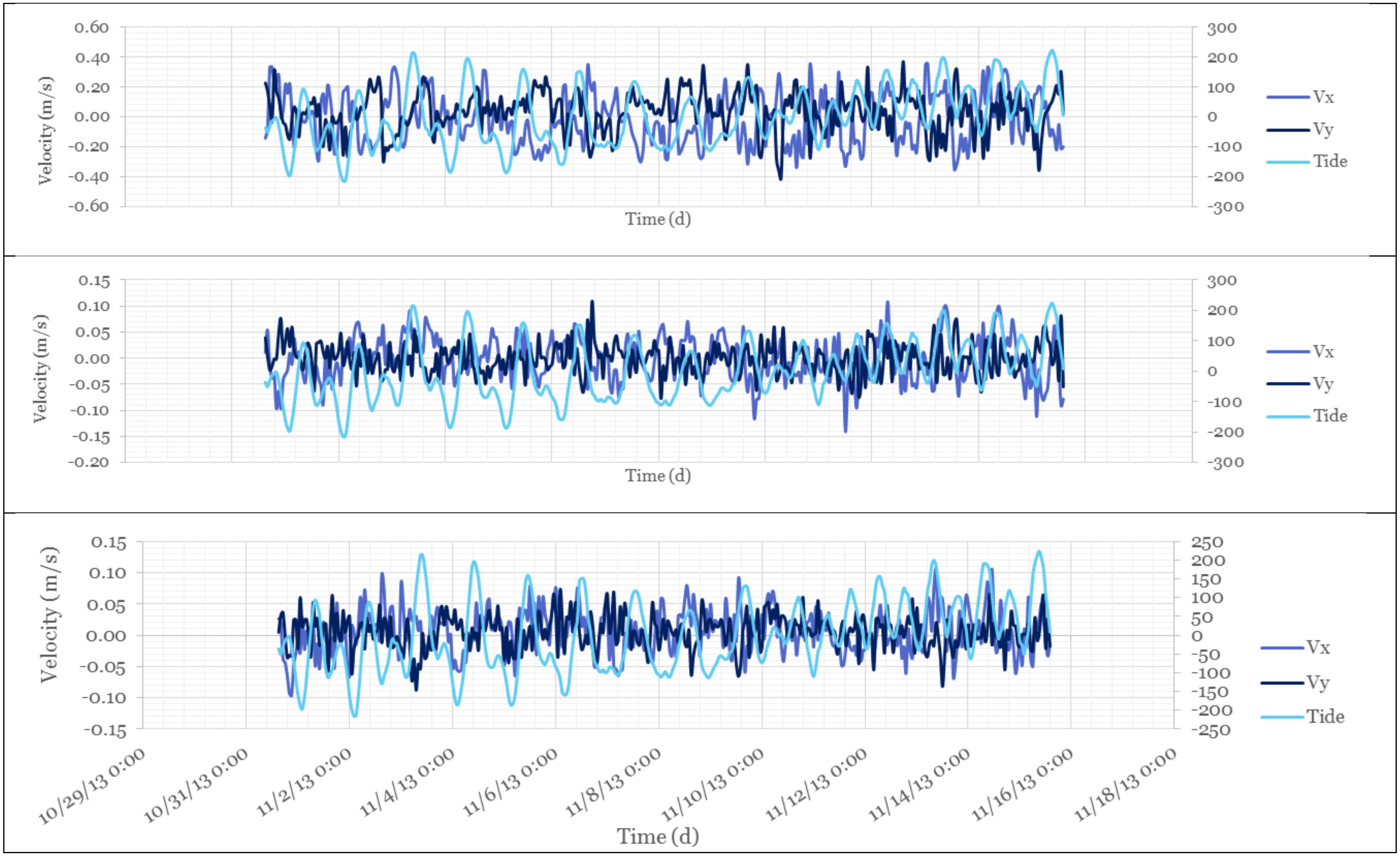
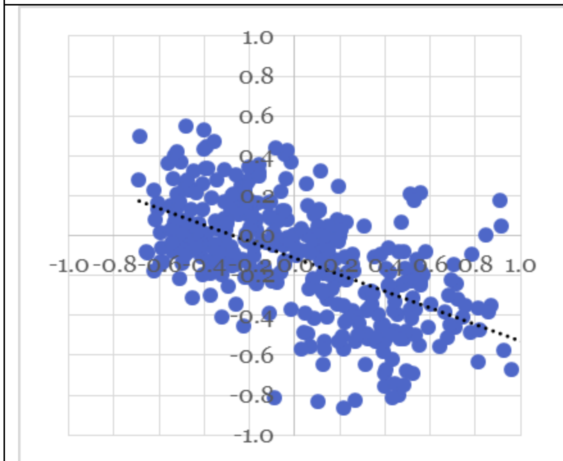
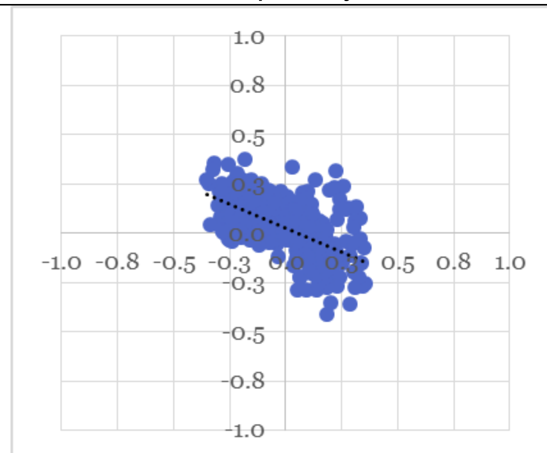
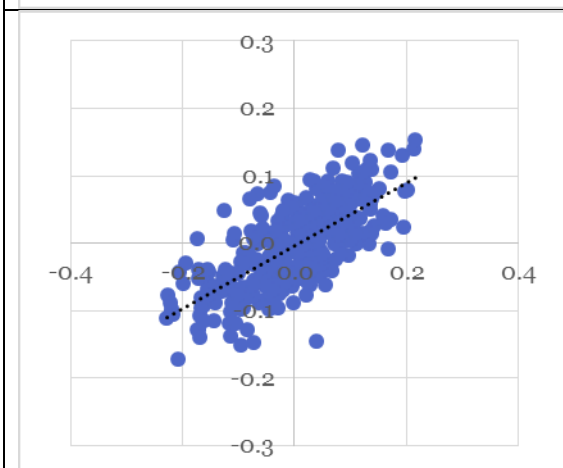
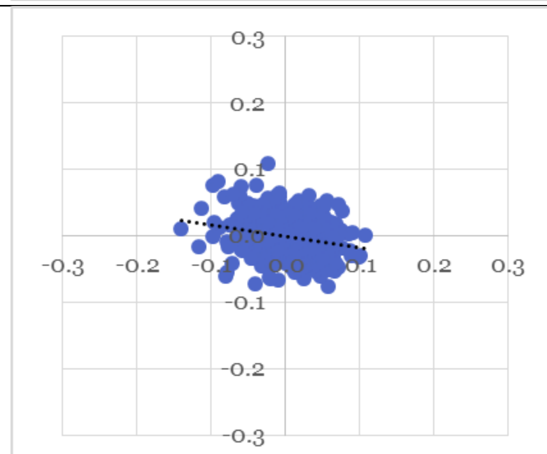
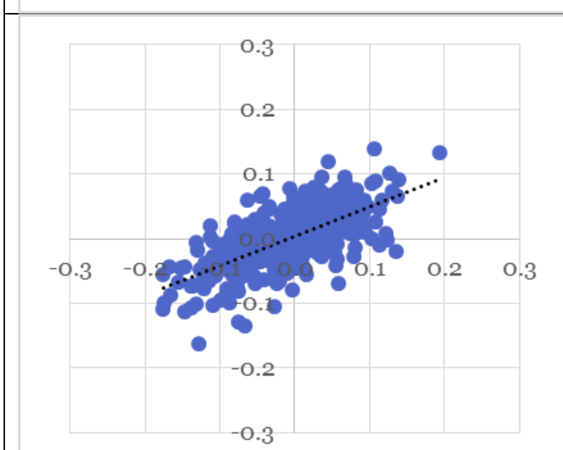
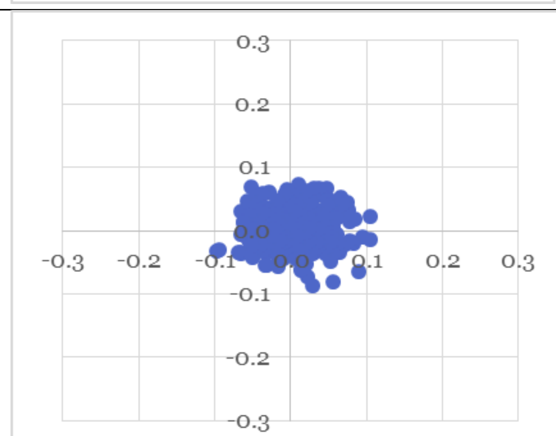


Table 5-7 Current velocities and tide recordings during the second ADCP deployment of Plumb Point for the surface, mid depth and sea floor respectively

Table 5-8 Current velocities recorded along the Palisadoes for the first and second ADCP deployment

First ADCP deployment (south of Plumb Point) at the surface, mid depth and sea floor respectively	Second ADCP deployment (centre of project site) at the surface, mid depth and sea floor respectively
	
	
	

The occurrence of high wind speeds were noted to not correlate with higher surface currents (Figure 5-26). For example during the period 24th to 28th of October when wind speeds were elevated, the mean (24 hour moving average vx and vy remained approximately the same. It is therefore apparent that currents from surface to sub-surface are predominantly tidally driven and influenced by oceanic currents.

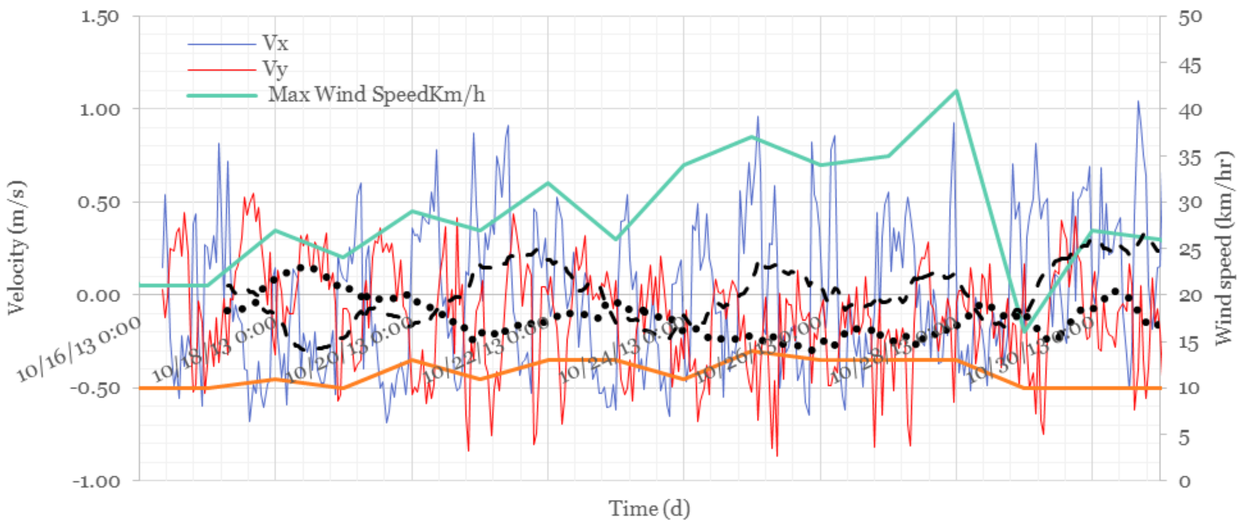


Figure 5-26 ADCP location 1 (central to Palisadoes) and maximum and mean wind speeds for the period October to November, 2013

Waves and Tides

RAW DATA

Tidal information was important in order to drive the Finite Element Hydrodynamic Model (FEM) and to also set up the water level in the wave model. More importantly, it was necessary to determine the tide range in order to determine the minimum crest height for the sand placed over the buried revetments and along the Harbour side of the project so as to minimize overtopping and erosion during swell events. The tide range measured during the deployment period was 0.43 m.

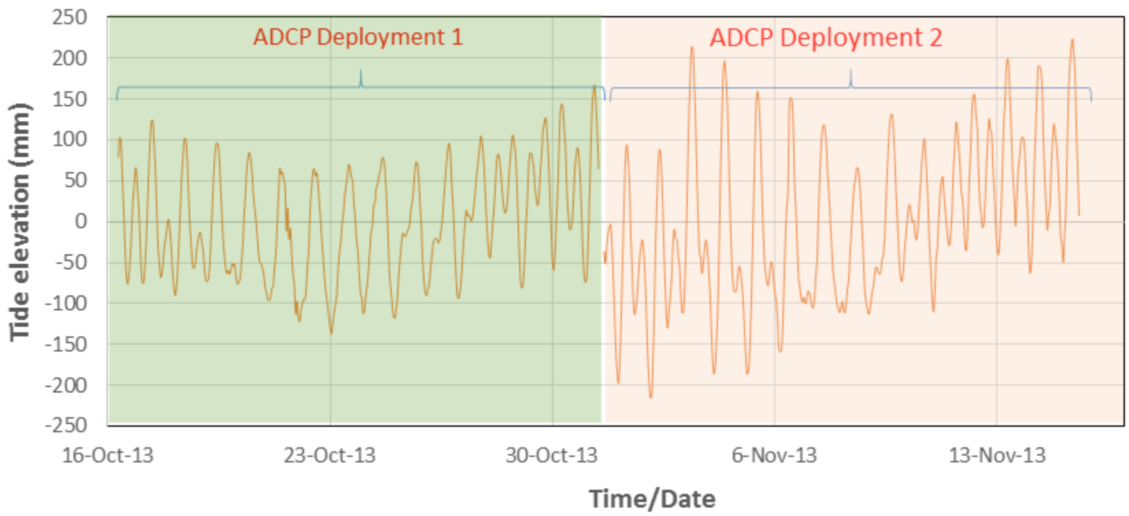


Figure 5-27 Tidal signal recorded during the ADCP deployment for the period 17th of October to 15th of November, 2013 for Palisadoes

TIDAL HARMONICS

Tidal harmonics is essentially the blending of the different sinusoidal curves for each harmonic constituent of the tide until it closely matches that obtained from the recorded tidal signature. This is useful for predicting the tides for future times when there is no data available.

The amplitudes of the seven most significant harmonic constituents were determined from the raw tide data by utilizing the *least squares method*. In this method, a set of cosine terms is used as a model. The blended curve is made to fit the data recorded by the ADCP by choosing the combination of R and N that causes the sum of the squared differences between observed and model-predicted tides is as small as possible. The resulting amplitudes and phase lag are outlined below in Figure 5-28, and it allowed us to make reasonable tide predictions for future times when running FEM and wave models. It is evident that the K1 consistent that is a diurnal tide is dominant. Both semi-diurnal and diurnal tidal constituents were detected.

Table 5-9 Tidal constituents obtained from the harmonic analysis of the raw ADCP data collected along the Palisadoes

Tide constituent	M2	S2	O1	K1	N2	P1	L2
Speed	12.42	12	25.82	23.93	12.66	24.07	12.19
Phase lag	-5.11	0.84	1.97	5.11	0.75	-3.92	-2.63
Amplitude	0.028	0.023	0.050	0.124	0.032	0.067	0.015

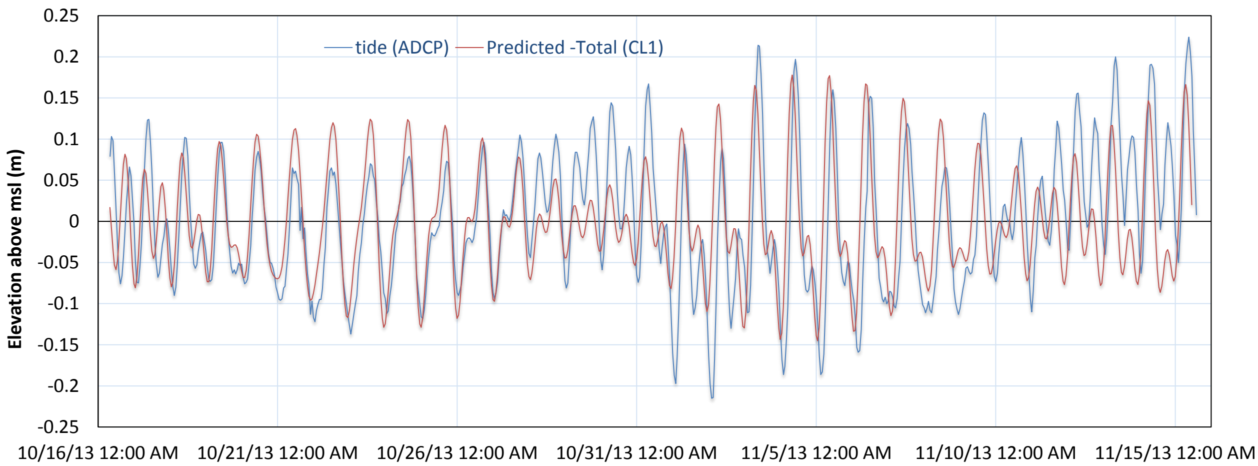


Figure 5-28 Measured and predicted tidal signature for the Palisadoes for the period October 16, 2013 to November 15, 2013

Drogue Tracking

Drogue tracking information was necessary in order to verify the ADCP readings, and to provide information on the water circulation pattern throughout the project area. Drogues provide area wide short duration information, whereas ADCP provide a site specific long duration continuous record.

Two sets of drogue tracking missions were executed on October 31 and November 15, 2013. The missions were done to coincide with the first and second ADCP deployment. Six (6) drogues were deployed; three (3) surface and three (3) sub-surface drogues (with depths ranging from 1 to 10 meters). The drogues were deployed at three (3) offshore locations during each mission, and at each location the drogues were tracked during two separate sessions each day to capture the rising and falling tides. Drogues were also deployed at each ADCP location so as to provide information that could be used to verify the ADCP data. The GPS and drogue log sheet results from the drogue tracking missions were reduced and incorporated into a database. The data was then analyzed in order to determine current speed and directions, and current speed vectors were produced for the rising and falling tides.

TRACKING RESULTS

October 31, 2013 – Rising Tide

During this session the drogues were deployed at three locations – Near shore, Plum Point and offshore over the ADCP. The tide was observed to be moving in a generally south westerly direction similar to the average wind direction, as the near shore drogues were moving south westerly and the plum point drogues were moving westerly. The drogues in the vicinity of the ADCP (deep water) however were moving south easterly. The surface drogues were observed to be moving at an average speed of 7.11 cm/s while the subsurface drogues were slower moving at 6.56 cm/s.

October 31, 2013 –Falling Tide

The drogues were deployed at the same three locations used in the previous session and during this session the tide was observed to be moving in a generally north easterly direction similar to the average wind direction. The near shore drogues were moving northerly and the plum point drogues were moving north easterly, while the deep water drogues were moving southerly. The surface drogues were observed moving at an average speed of 3.32 cm/s while the subsurface drogues were slower at 1.75 cm/s.

November 15, 2013 – Falling Tide

During this session the three sets of drogues were deployed at three locations: Near shore, offshore over the ADCP and further offshore. The ADCP Location was westward of that used in the previous session. During this session the tide was observed to be moving in a generally north westerly direction, similar to the average wind direction. The surface drogues were observed at an average speed of 3.47 cm/s while the subsurface drogues were slower at 2.14 cm/s.

November 15, 2013 – Rising Tide

The drogues were deployed at the same three locations used in the previous session and during this session the tide was observed to be moving in a generally north westerly direction, similar to the average wind direction and similar to the previous session. The surface drogues were observed at an average speed of 8.75 cm/s while the subsurface drogues were slower at 3.83 cm/s.

SUMMARY

The drogue tracking missions comprised of 4 sessions – two falling tide and two rising tide sessions – that covered 6 offshore locations on October 31 and November 15, 2013. The current speeds varied between 2.29 cm/s to 10.25 cm/s and 1.48 cm/s to 10.30 cm/s for the surface and sub-surface drogues respectively.

Knowledge of the prevailing wind conditions allowed for the determination of the effect of wind speed and direction. The current speeds are generally higher for the rising tides than for the falling tide session. It is evident that when the wind speed is slow, the tides dominate the currents; however when the wind speeds increase to above 10 cm/s (2.78m/s) then the effect of the tides is negligible.

Currents Verification (ADCP/Drogues)

The currents recorded by the ADCP were checked against the drogues to confirm that the ADCP was recording the correct currents (speeds and direction). The X and Y components of the currents were compared; for the surface drogues a 76 and 72% correlation was obtained for the X and Y components respectively, while for the sub-surface drogues the correlation was 84 and 88% for the X and Y components respectively. The coefficient of correlation is used as a comparative measure of association of two or more datasets (in this case the X-Y components for the currents). Even though the relationship between the ADCP and drogues were generally good in terms of magnitude, the directions in some cases were slightly different. Similarly the variance can be used to estimate the dispersion about the average measured values. The variances for the surface and subsurface drogues were all below two percent. Overall, it can be concluded that the ADCP was functioning properly.

The graphs in Table 5-10 below highlight the correlation using scatter plots while Table 5-11 below summarizes the correlation in the data.

Table 5-10 Comparison plots for the X and Y components of velocity for the drogues (surface and sub-surface currents) and the ADCP deployed in the Caribbean Sea for the Palisadoes project. The ADCP was deployed twice in the project area.

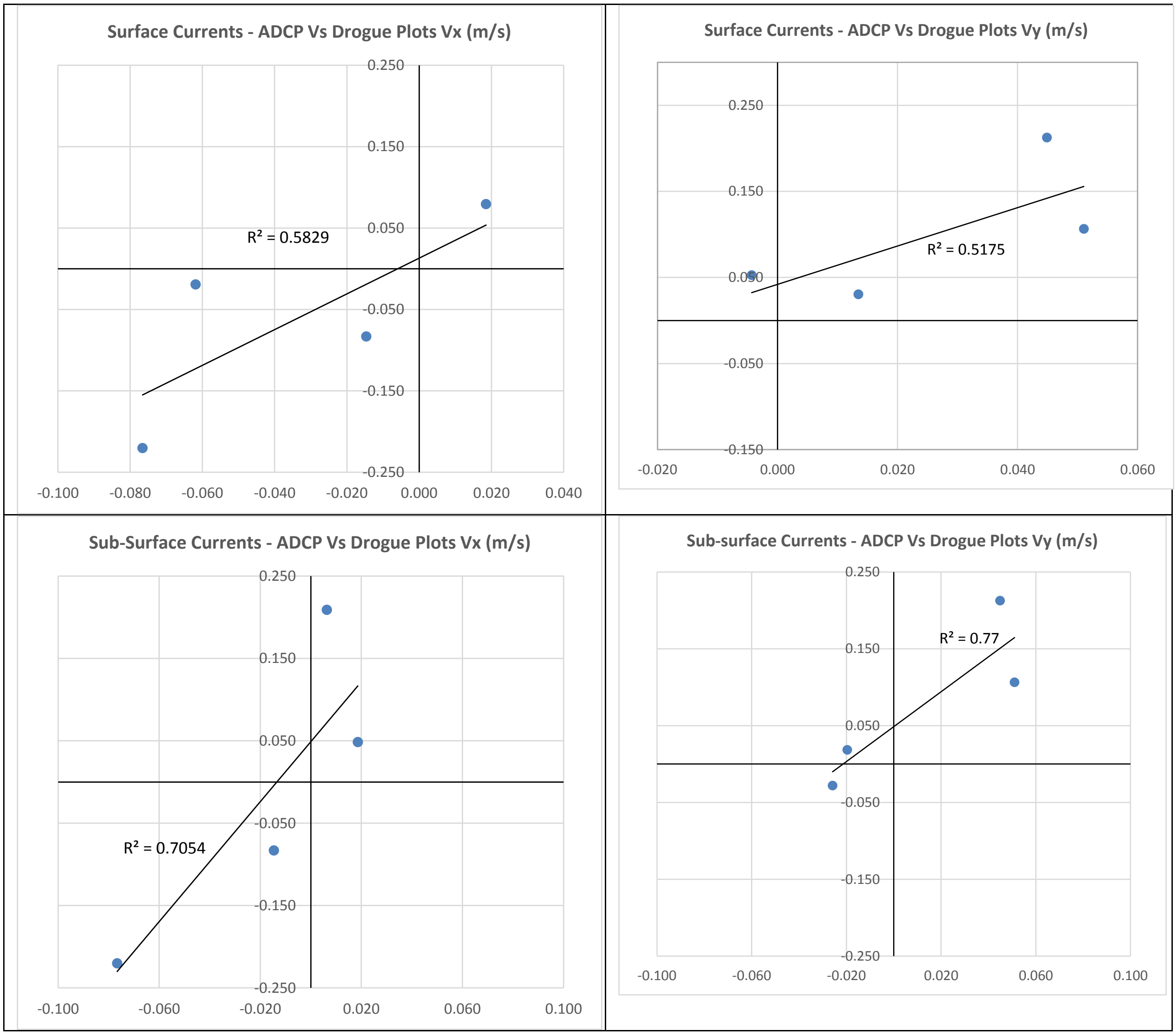


Table 5-11 Statistical comparison of the currents measured by the drogues and DCP deployed in the Caribbean Sea for the Palisadoes project

Correlation			Variance	
Depth	Vx	Vy	Vx	Vy
Surface	0.76	0.72	0.5%	0.2%
Subsurface	0.84	0.88	1.11%	0.20%

5.2.4.3 Water Quality Modelling Parameters

Methodology

Whole water quality samples were collected at different locations. Samples were collected and stored on ice before being taken to the Laboratory for analysis of TSS and turbidity. Temperature, pH and salinity were measured in situ using a Hydrolab MS5 water quality multi-probe. A total of 6 water quality stations were strategically placed across the bay, one of which was a deep water station placed approximately 2.4 km offshore and was designated as the control point (station CC), see Figure 5-29. The control point was an offshore/deep water point that was used to compare the near shore parameters to determine if the bay is polluted, and at stations WQ4, 5 and 6 both deep and surface samples were taken, while only surface samples were collected at the other stations. Water quality data collected between 2010 and 2012 by CL Environmental during the first phase of the *Palisadoes Shoreline Protection and Rehabilitation Project* was also used as a reference (station CL-P1) providing long term measurements for the water quality parameters.

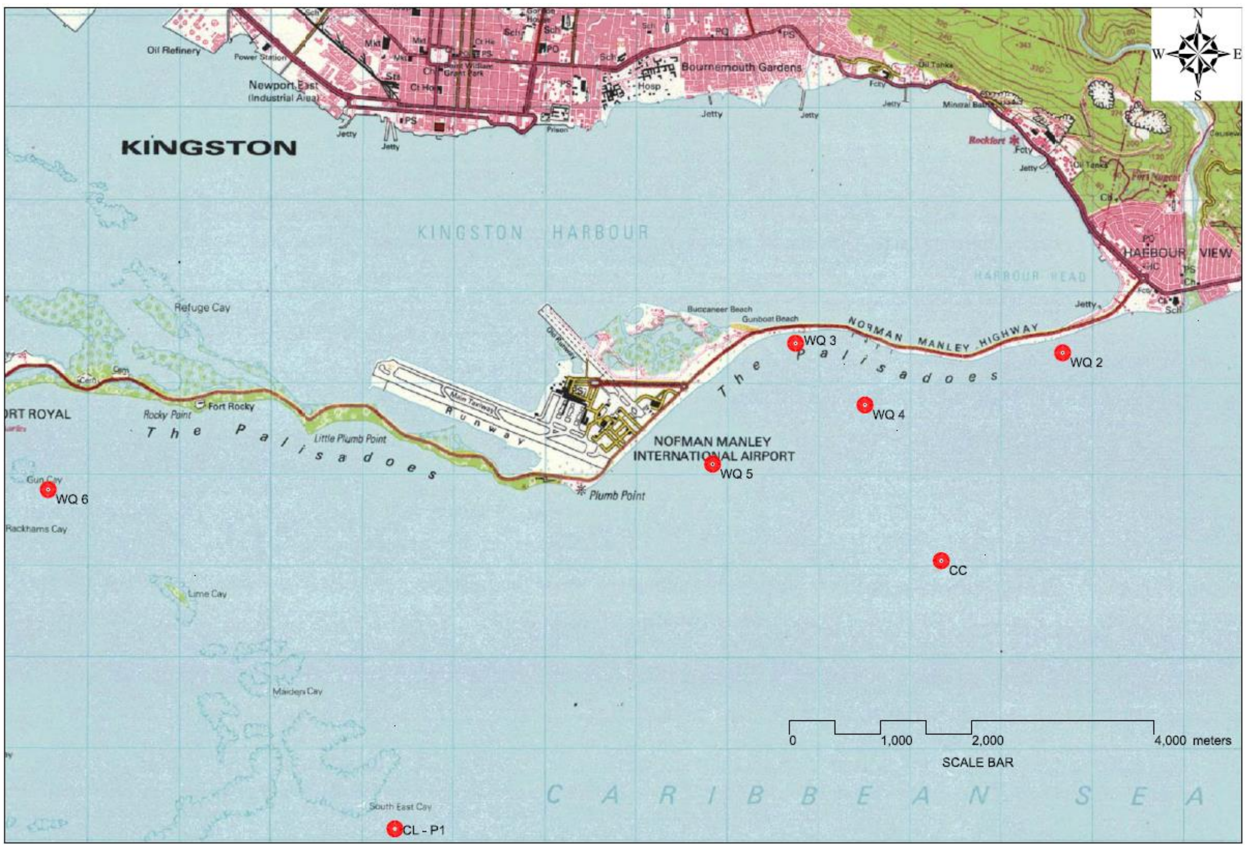


Figure 5-29 Water quality monitoring points in the Caribbean Sea on November 19, 2013

Comparative Assessment to NEPA Guidelines

The results were averaged and compared to the 2009 Draft Jamaica National Ambient Water Quality Standard for Marine Water, as well as long term values measured by CL Environmental between 2010 and 2012. The values are presented in Table 5-12 below, whereas the summary discussions for the individual parameters are found in the subsections below.

Table 5-12 Recorded values for the water quality parameters assessed in the Palisadoes along with the long term values recorded by CL Environmental

ID	TSS	TUR	TEM	PH	SAL
WQ2	1	3.7	29.29	8.33	34.86
WQ4 (S)	1	3.2	29.55	8.33	34.74
WQ4 (D)	0	3.7	29.34	8.32	34.75
WQ3	1	4.8	29.58	8.23	34.76
WQ5 (S)	0	3.5	29.51	8.24	34.74
WQ5 (D)	0	4.6	29.46	8.24	34.76
WQ6 (S)	0	2.9	29.71	8.15	34.76
WQ6 (D)	0	1.7	29.5	8.15	34.76
CC (S)	***0***	***3.3***	***29.31***	***8.26***	***34.71***
CC (D)	***0***	***3.8***	***29.12***	***8.25***	***34.68***
CL - P1	***1.50***	***7.66***	***28.46***	***8.15***	***36.76***

TOTAL SUSPENDED SOLIDS (TSS)

Whilst there are no standards for the TSS levels, in the Caribbean Sea the control point (station CC) gives some indication as to what the ambient levels should be (<1 mg/L). No station had TSS levels greater than 1 mg/L, most were in fact recording TSS levels of 0 mg/L including the control point. The reference data provided by CL Environmental however, determined that the average TSS during the 2010 – 2012 period was 1.5 mg/L, see Figure 5-30.

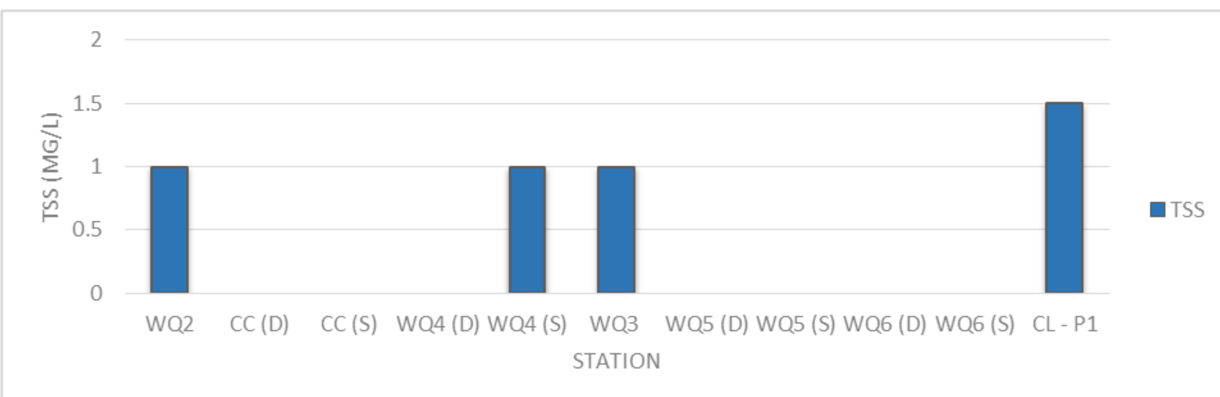


Figure 5-30 Concentration of Total Suspended Solids (TSS) at the selected stations in the Caribbean Sea on November 19, 2013

TURBIDITY

All the water quality samples were below the NEPA standard of 39 (NTU). A comparison plot is shown in Figure 5-31 below.

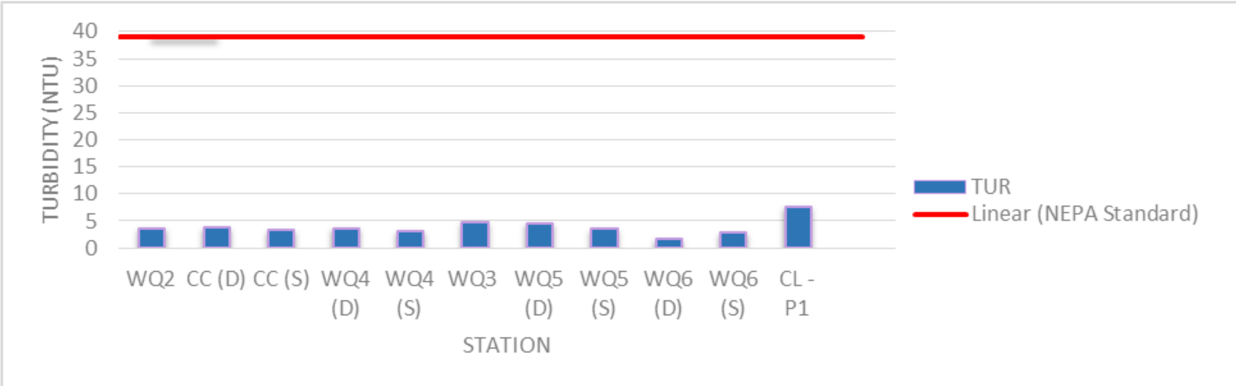


Figure 5-31 Concentration of Turbidity at the selected stations in the Caribbean Sea on November 19, 2013

TEMPERATURE

The water temperatures measured were all higher than the offshore control station. This can be attributed to the fact that the waters near shore are shallower and therefore require less solar radiation to warm. The long term temperature reading provided by CL Environmental is however smaller than the values recorded on November 2013, and this may be because this station is further offshore than the values we recorded, in deeper water. See Figure 5-32.

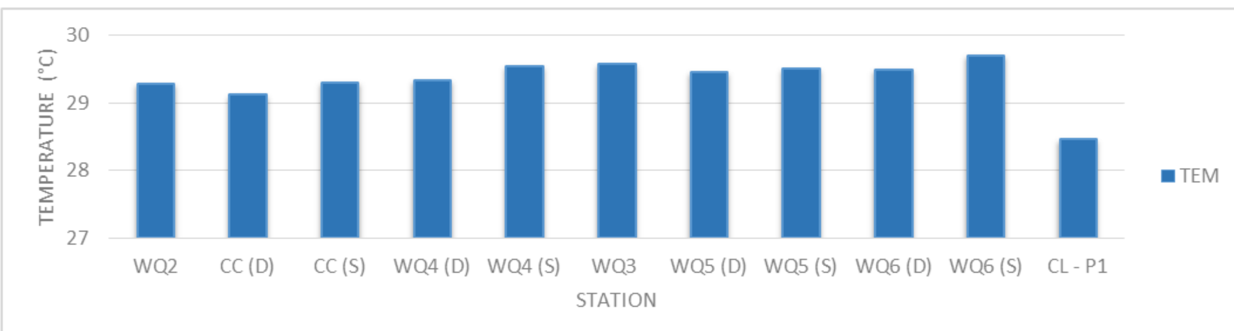


Figure 5-32 Temperature readings at the selected stations in the Caribbean Sea, on November 19, 2013

PH

All the stations met the NEPA standard of 8.0 – 8.4 but only station 6 had values similar to the long term pH value determined by CL Environmental, see Figure 5-33.

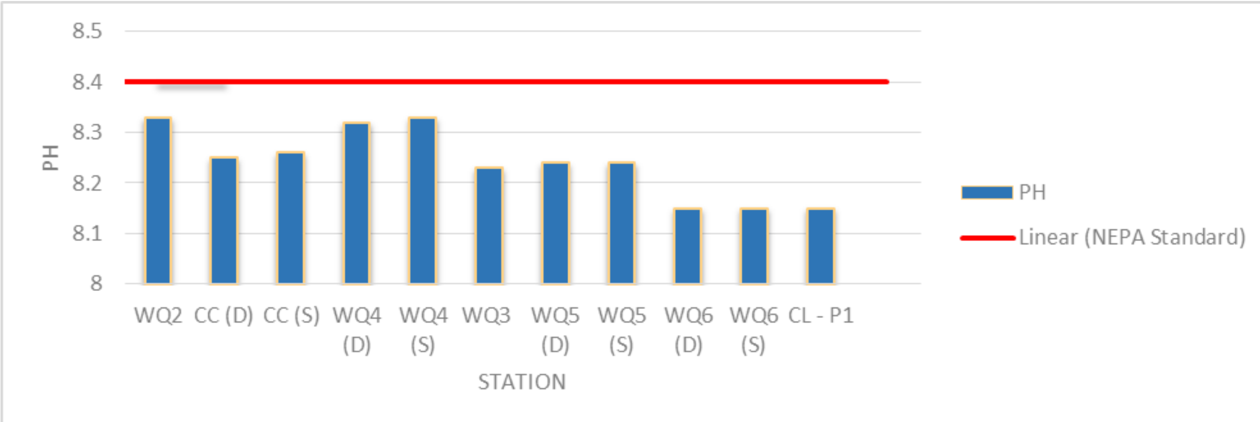


Figure 5-33 pH readings at the selected stations in the Caribbean Sea on November 19, 2013

SALINITY

Salinity is generally used to gauge whether the water sample is saline/marine or non-saline/fresh water. All stations met the normal seawater salinity standard of 35 ppt except the CL Environmental station and this may be because that particular station is further offshore, and in deeper water. See Figure 5-34.

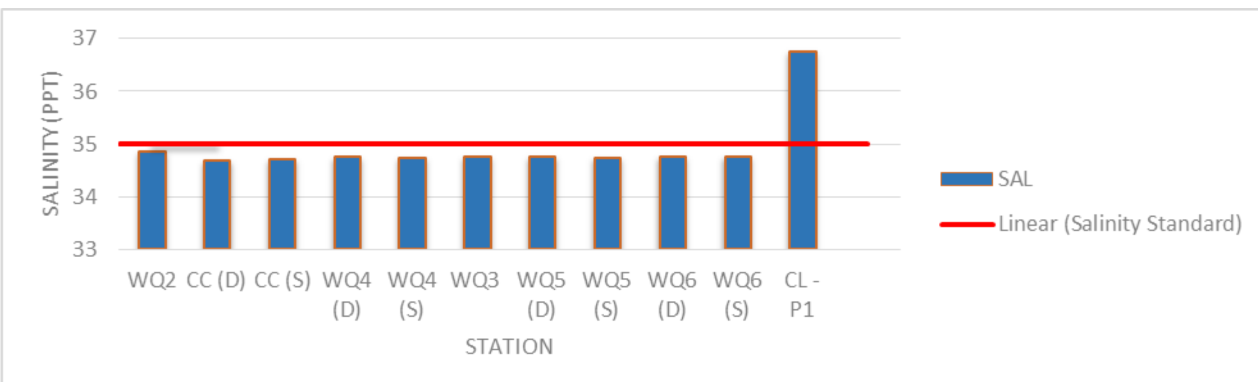


Figure 5-34 Salinity readings at the selected stations in the Caribbean Sea on November 19, 2013

Summary

A water quality testing exercise was conducted on November 19, 2013 at 5 offshore stations in the Caribbean Sea side of the project. The measurements recorded were compared to long term readings obtained by CL Environmental and the limits presented in the 2009 Draft Marine Standards. All parameters fell below the limits outlined but there were differences between the measurements for the control station and the long term values. The TSS, turbidity and Salinity parameters were below the long term values while pH and temperature values obtained were greater than the long term values.

5.2.4.4 Wind

Historical and current wind data for the project area was obtained from three main sources:

- Norman Manley met station,
- NOAA Climate Service and
- Weather Underground's online database.

NMIA (1999 TO 2004)

The NMIA provided wind data for the airport spanning the period 1999 to 2004 and this information is presented in Figure 5-36. The data revealed that most of the winds are from the N to SE direction and moving at speeds ranging from 8 to 20 m/s.

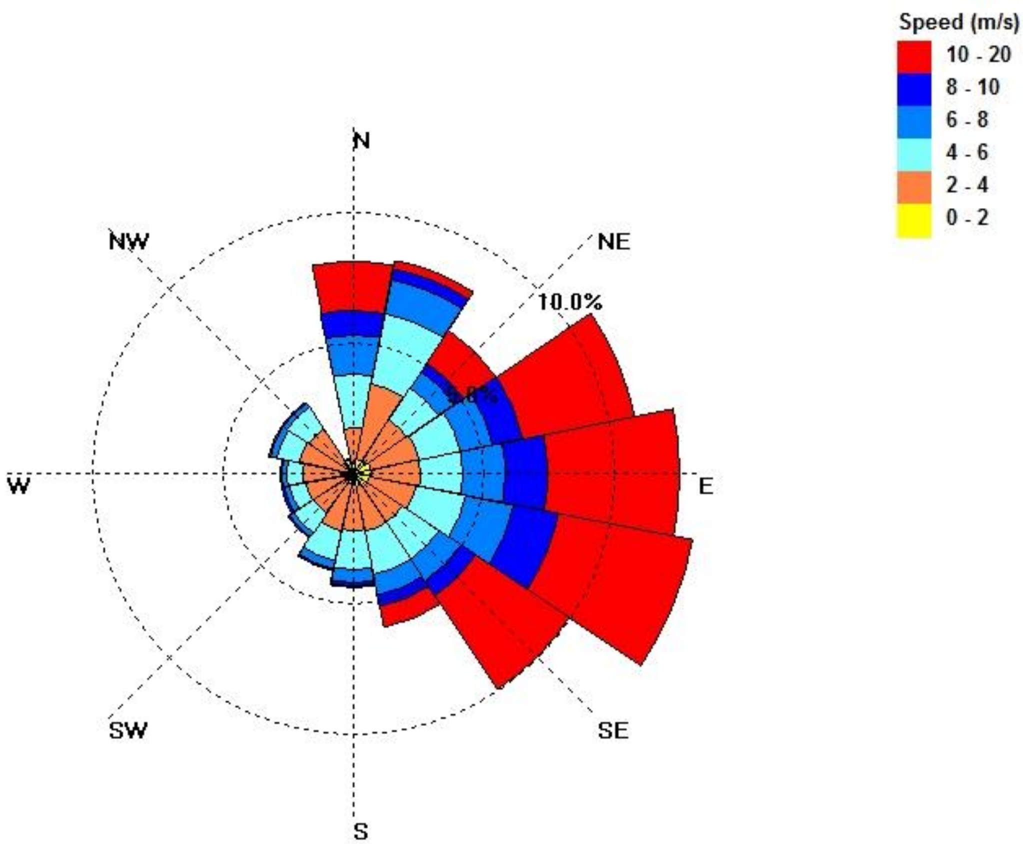


Figure 5-35 Historical wind data for NMIA for data spanning 1999 to 2004

NOAA Climate Service

The NOAA long term wind wave data model was searched for long term wind data for the Palisadoes. A node was chosen along the Caribbean Sea side of the Palisadoes and the wind data corresponding to that node obtained. The node used was:

The data spanned the years 1999 to 2000 and recorded daily values at 3 hour intervals; and it is presented in Figure 5-36. The data was analyzed in terms of the percentage occurrence of various wind speed and direction combinations in order to characterize the wind climate for the site. The analysis revealed that the winds are primarily from the ENE to ESE direction with moving at between 2 – 4 m/s.

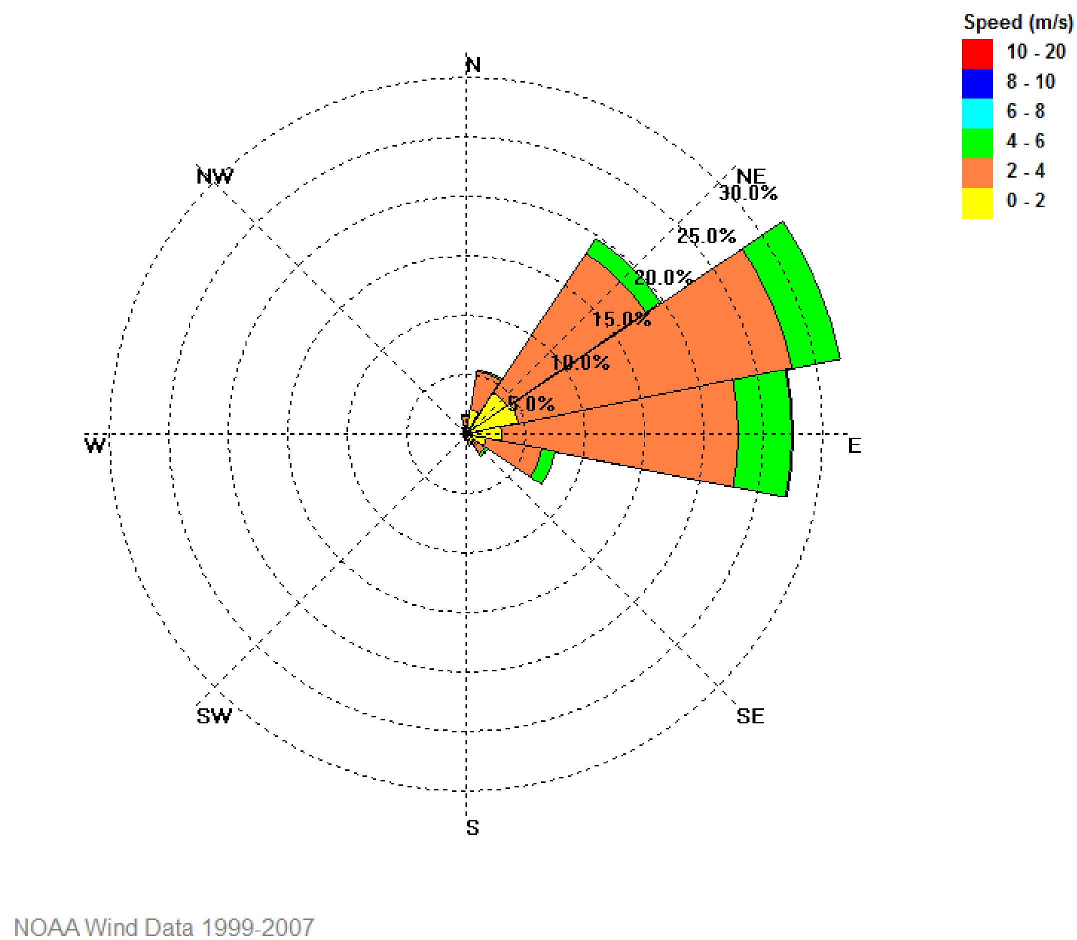


Figure 5-36 NOAA long term wind data for a node offshore the Palisadoes for data spanning 1999 to 2007

Weather Underground

Current wind data was collected for the days on which the drogue tracking missions were carried out from the Weather Underground online database for the Palisadoes area for October 31 and November 15, 2013. Most of the winds on October 31, 2013 were from the SW and SE moving at an approximate speed of 3 to 4 m/s. On November 15, 2013 the winds were again primarily from the SW and SE moving at approximately 5 m/s. See Figure 5-37 and Figure 5-38.

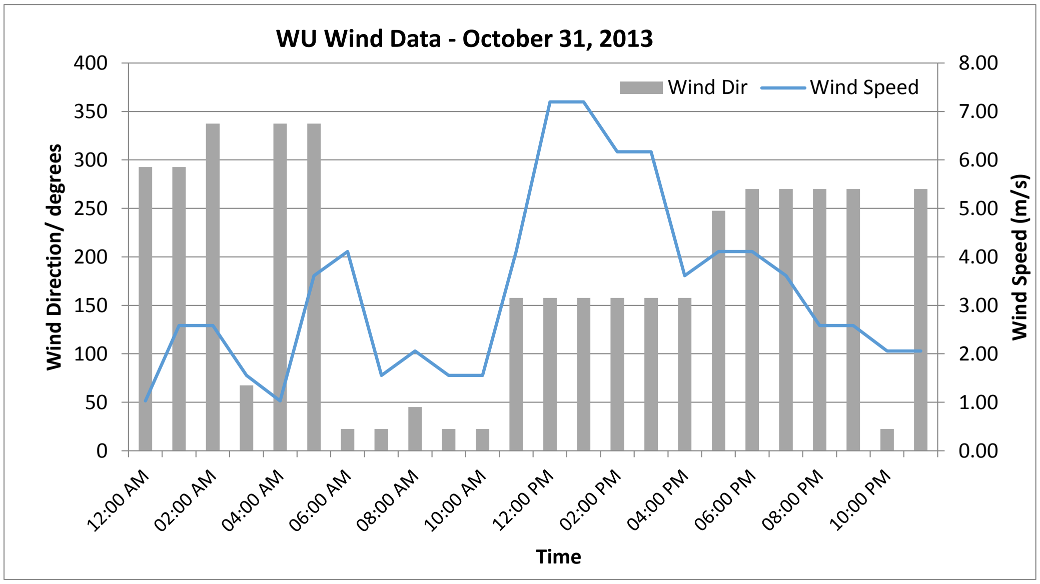


Figure 5-37 Weather Underground wind directions and speeds for the Palisadoes on October 31, 2013

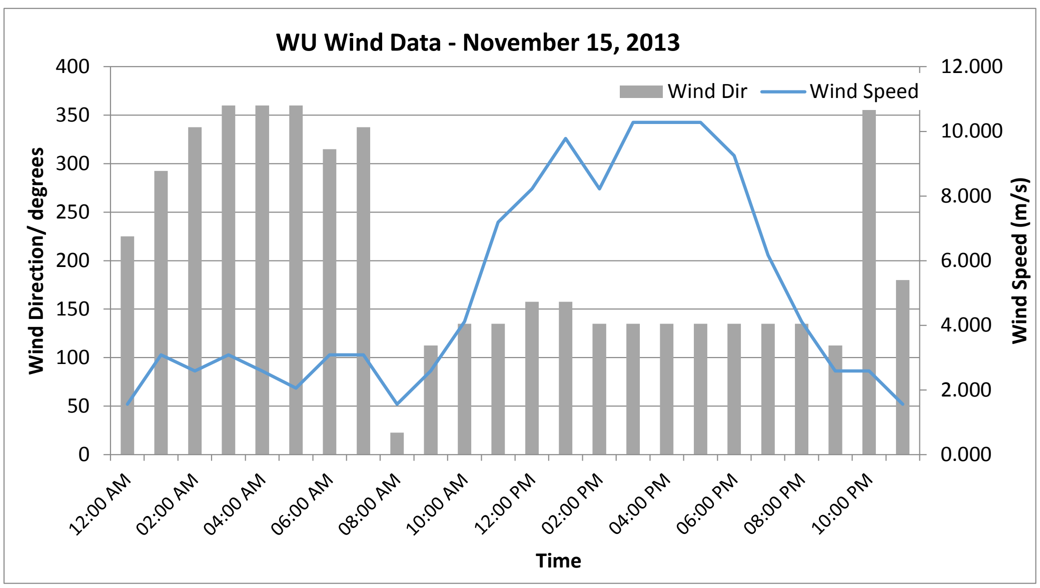


Figure 5-38q Weather Underground wind directions and speeds for the Palisadoes on November 15, 2013

Summary

Wind data for our analysis was obtained from three sources – NMIA, NOAA Climate Service and Weather underground database. NMIA and NOAA provided long term wind data for periods spanning 1999 to 2007, while Weather Underground provided data for the days on which the drogue tracking missions were carried out. Both long term sources indicated that majority of the winds are from the NE to SE, NMIA determined that the average wind speed was between 8 – 20 m/s and NOAA determined the average wind speed to be between 8 – 20 m/s. Current data provided by Weather

Underground indicated that most of the wind came from the SW and SE direction at an average wind speed of 4 – 5 m/s.

5.2.4.5 Sediment Modelling Characteristics

Grain size analysis was done using the Unified Soil Classification System (USCS) which is widely used for the classification of granular material. Sand samples were dried and sieved using ASTM standard sieves and analysed to determine the coefficient of uniformity, standard deviation, skewness and kurtosis. The results are further assessed in the following sections.

Method

Sand samples were collected for analysis along the Palisades shoreline at 8 locations on October 10, 2013, and at each location 3 samples were taken: at the beach face, back of beach and dune. The sampling locations are shown below in Figure 5-39 and the results of this analysis will be incorporated into the dune design outlined in a later section of this report.

Core samples were also taken at 8 points within the offshore sand reserve (burrow area) identified within the Cuban study (Juanes, 2007)on October 16 and 17, 2013 to confirm that this material is indeed suitable for use in the project. NEPA has granted approval for dredging this burrow area for the execution of the dune nourishment section of the project based on the original proposal completed by the NWA and the Cuban Government. See Figure 5-40 for the sample locations.

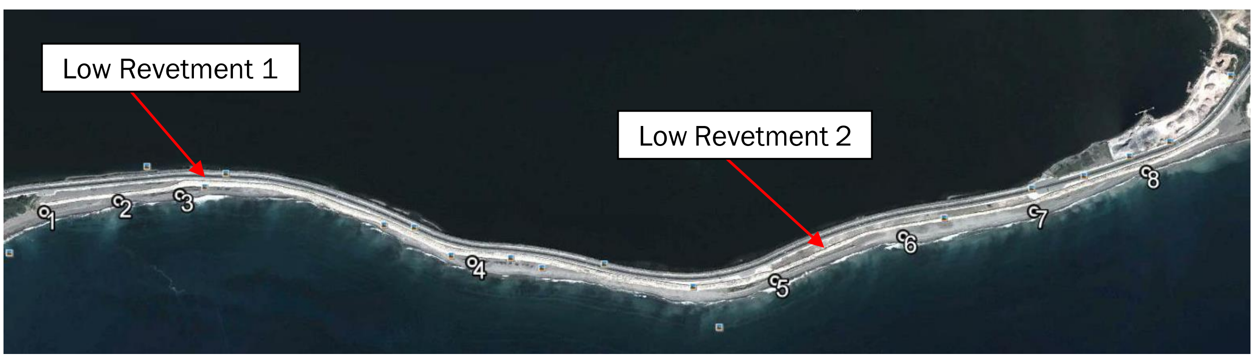


Figure 5-39 Google imagery showing location of sand samples collected along the Palisadoes

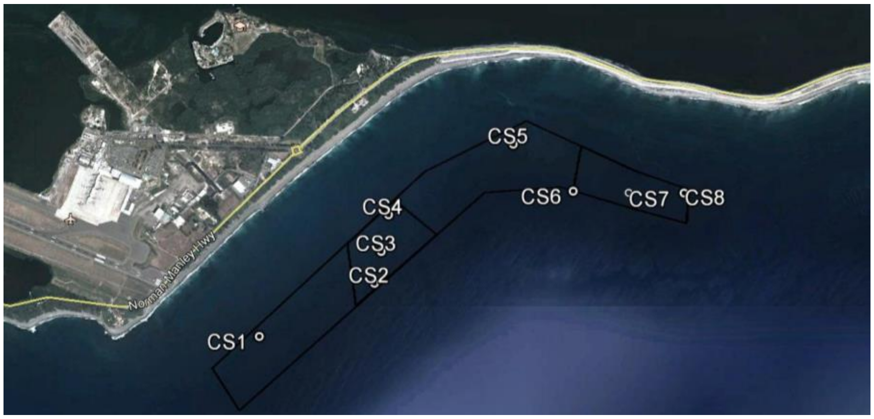


Figure 5-40 Google imagery showing offshore sample locations inside outlined sand reserve

Results

The grain size analysis for the shoreline samples provided the following results (see Table 5-13, Table 5-15 and Table 5-15):

- For low revetment 1 (locations 1 to 3) all the samples were of coarse to very coarse sand with a mean grain size ranging from 0.69 mm to 1.36 mm.
- For low revetment 2 the sand ranged from coarse sand to gravel (locations 5 to 7) having a mean grain size ranging between 0.93 mm to 4.32 mm.
- Along the high revetments (locations 4 and 8) the sand was on average very coarse sand, with the mean grain size ranging between 0.70 mm and 1.94 mm for the beach face, dune and back of beach, except along the beach face (location 8) .

The percentage finer grain plot for the samples is shown in Figure 5-41, Figure 5-42 and Figure 5-43 and they indicate that the sand along the beach face and sand dune is coarser than that at the back of beach.

Table 5-13 Grain size analysis results for sand samples collected along the Palisadoes' beach face at the 8 sample locations

Location	1	2	3	4	5	6	7	8
Mean Grain size (mm)	1.07	0.77	0.80	0.95	1.68	1.15	3.77	1.42
Mean (phi)	-0.097	0.384	0.330	0.074	-0.744	-0.197	-1.913	-0.508
Description	V. coarse sand	coarse sand	coarse sand	coarse sand	V. coarse sand	V. coarse sand	gravel	V. coarse sand
Percentage silt	0.003	0.001	0.000	0.000	0.000	0.001	0.000	0.000
Percentage >0.06mm and <6.0 mm	0.997	0.995	0.803	0.998	0.992	0.960	0.729	0.893
Uniformity Coefficient	3.631	1.600	2.336	1.688	1.772	2.836	1.915	2.076
Standard Deviation	1.213	0.544	1.013	0.642	0.521	1.041	0.588	0.685
	poorly sorted	moderately well sorted	poorly sorted	moderately well sorted	moderately well sorted	poorly sorted	moderately well sorted	moderately well sorted
Skewness	0.376	0.654	0.118	-0.217	-1.523	-0.318	-2.148	-0.576
	strongly positively skewed	strongly positively skewed	positively skewed	negatively skewed	strongly positively skewed	strongly positively skewed	strongly positively skewed	strongly positively skewed
Kurtosis	1.115	1.463	0.294	0.811	1.147	1.017	-0.661	0.723
	leptokurtic	leptokurtic	extremely leptokurtic	platykurtic	leptokurtic	mesokurtic	extremely leptokurtic	platykurtic

Table 5-14 Grain size analysis results for sand samples collected along the Palisadoes' back of beach at the 8 sample locations

Location	1	2	3	4	5	6	7	8
Mean Grain size (mm)	1.16	0.69	1.36	1.94	0.93	2.21	1.89	0.70
Mean (phi)	-0.211	0.525	-0.445	-0.957	0.105	-1.143	-0.919	0.513
Description	very coarse sand	coarse sand	very coarse sand	very coarse sand	coarse sand	gravel	very coarse sand	coarse sand
Percentage silt	0.001	0.000	0.000	0.000	0.001	0.000	0.000	0.000

Location	1	2	3	4	5	6	7	8
Percentage >0.06mm and <6.0 mm	0.999	0.994	0.986	0.857	0.924	0.855	0.873	0.945
Uniformity Coefficient	1.509	1.858	3.098	1.810	1.889	2.148	3.013	1.766
Standard Deviation	0.445	0.807	0.910	1.012	0.869	0.453	0.790	0.955
	well sorted	moderately sorted	moderately sorted	poorly sorted	moderately sorted	well sorted	moderately sorted	moderately sorted
Skewness	-0.614	0.331	-0.293	0.482	-0.195	-0.631	-0.301	0.267
	strongly positively skewed	strongly positively skewed	positively skewed	strongly positively skewed	negatively skewed	positively skewed	strongly positively skewed	positively skewed
Kurtosis	0.820	0.821	1.053	0.276	0.957	0.347	0.445	2.640
	platykurtic	platykurtic	mesokurtic	extremely leptokurtic	mesokurtic	extremely leptokurtic	very platykurtic	very leptokurtic

Table 5-15 Grain size analysis results for sand samples collected along the Palisadoes' dunes at sample locations 1 thru 7

Location	1	2	3	4	5	6	7
Mean Grain size (mm)	0.71	1.03	0.71	1.51	0.86	4.32	1.00
Mean (phi)	0.491	-0.039	0.487	-0.596	0.223	-2.110	0.001
Description	coarse sand	V. coarse sand	coarse sand	V. coarse sand	coarse sand	gravel	coarse sand
Percentage silt	0.001	0.000	0.000	0.001	0.001	0.000	0.002
Percentage >0.06mm and <6.0 mm	0.998	0.999	0.971	0.944	0.979	0.561	0.996
Uniformity Coefficient	2.674	2.103	2.333	2.431	1.887	3.243	1.944
Standard Deviation	0.874	0.681	1.002	0.851	0.713	-0.230	0.670
	moderately sorted	moderately well sorted	poorly sorted	moderately sorted	moderately sorted	well sorted	moderately well sorted
Skewness	0.745	0.009	0.348	-0.720	0.114	8.498	0.009

Location	1	2	3	4	5	6	7
	strongly positively skewed	nearly symmetrical	strongly positively skewed	strongly positively skewed	positively skewed	V. strongly positively skewed	nearly symmetrical
Kurtosis	1.177	0.889	1.317	1.135	1.254	-144.536	0.922
	leptokurtic	platykurtic	leptokurtic	leptokurtic	leptokurtic	extremely leptokurtic	mesokurtic

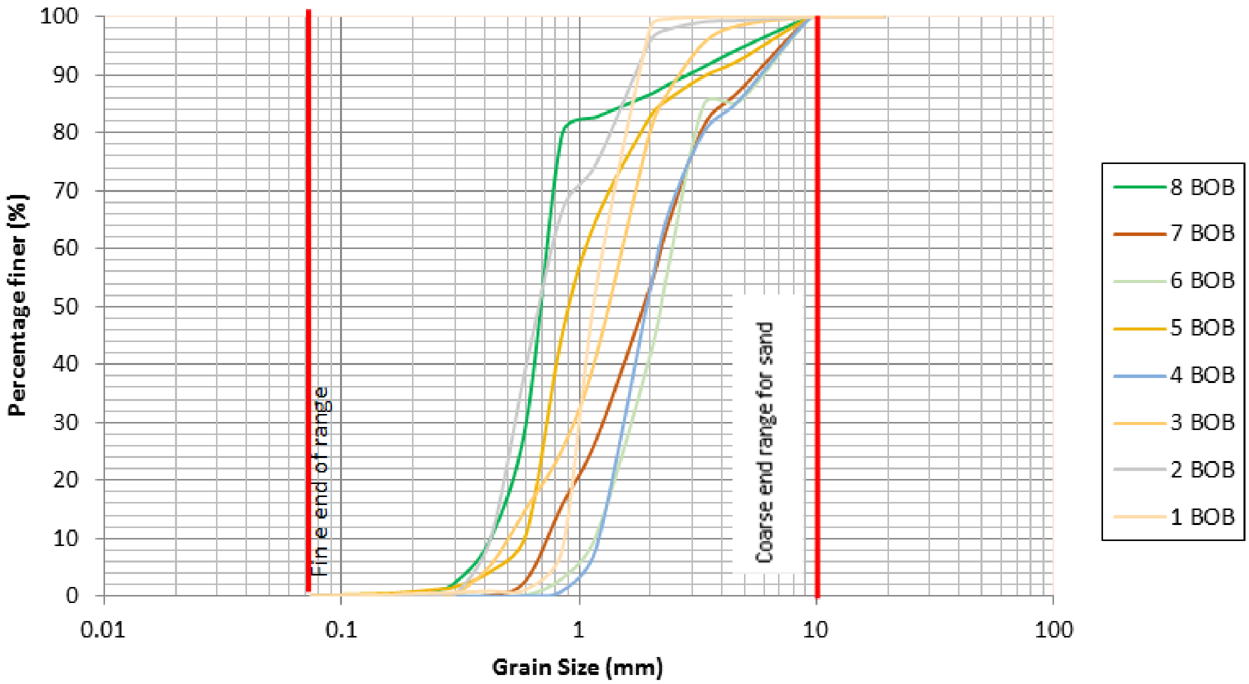


Figure 5-41 Graph showing the grain size results for the sand taken from the Palisadoes along its back of beach (BOB)

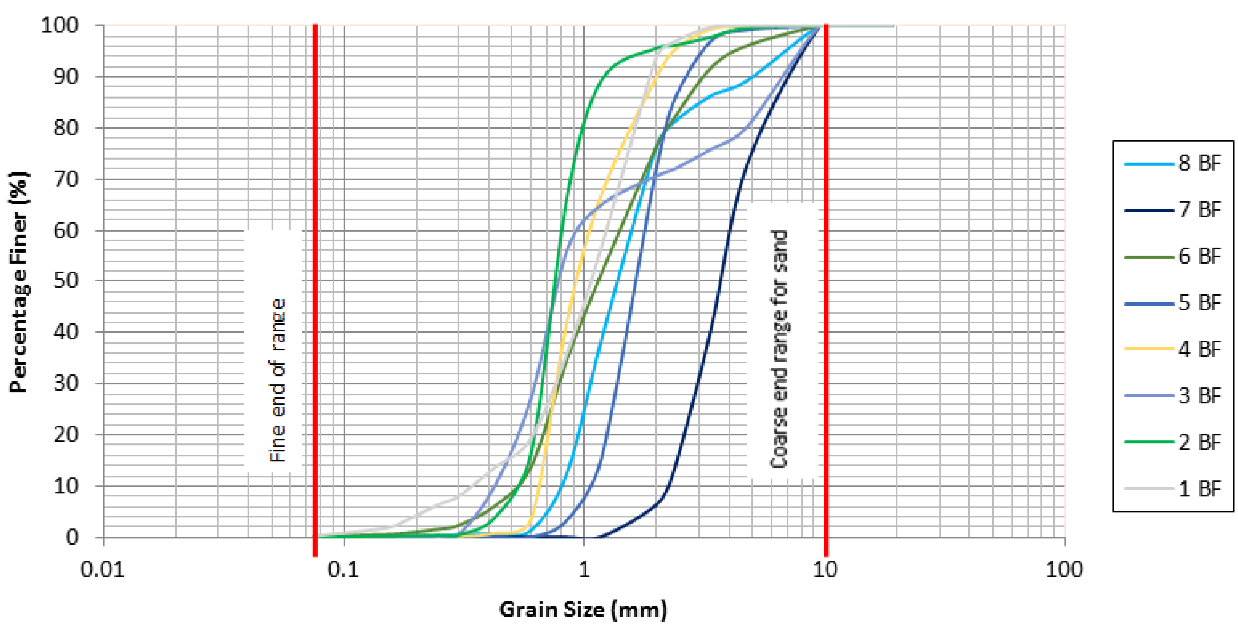


Figure 5-42 Graph showing the grain size plots for the sand taken from the Palisadoes along its beach face (BF)

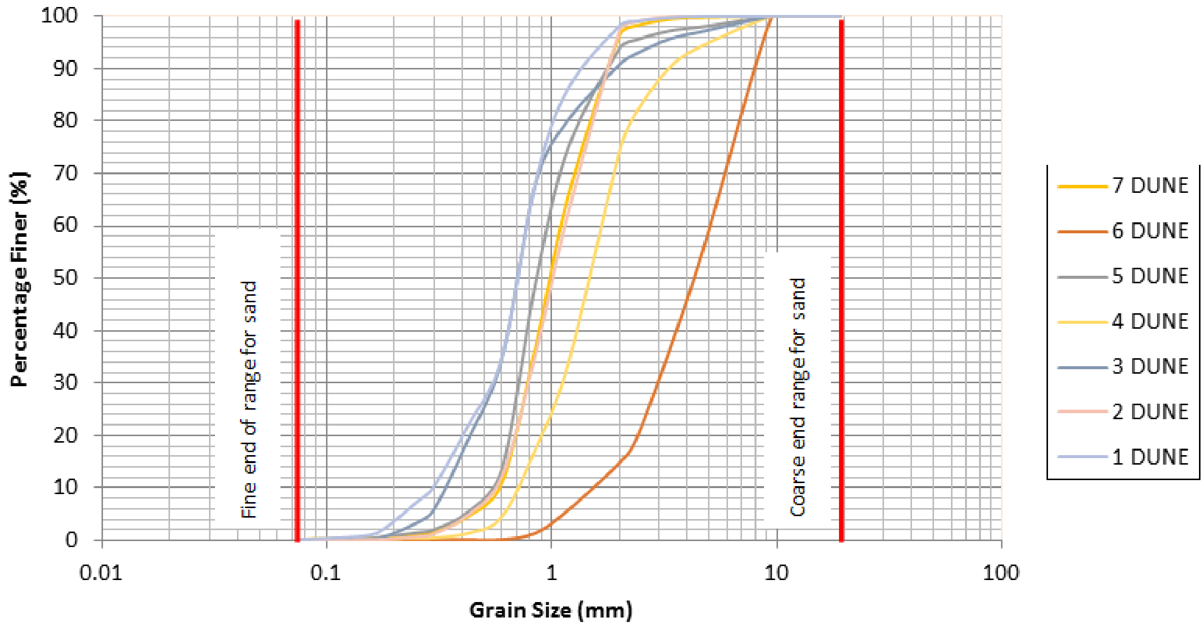


Figure 5-43 Graph showing the grain size results for the sand taken from the burrow area proposed for the Palisadoes sand dune

The grain size analysis for the offshore samples provided the following results:

- The grain size within the area range from fine sand (0.16 mm) to coarse sand (0.60 mm).
- The coarsest sand is found in sample locations CS2, CS3, CS7 and CS8 ($d_{50} \geq 0.50$mm), and this sand is the most suitable for the dune nourishment exercise as outlined in the previously submitted Material Assessment Report (CEAC Solutions Co. Ltd., 2013). The sample results for these 4 locations are highlighted in Table 5-16.

The percentage finer grain plot for the samples is shown in Figure 5-44.

Table 5-16 Grain size analysis for sand samples collected from the sand reserve (borrow area). The most suitable, and coarsest sand is found in the area of CS2, CS3, CS7 and CS8 (highlighted in red).

Sample ID	CS1	CS2	CS3	CS4	CS5	CS6	CS7	CS8
Mean Grain size (mm)	0.164	0.604	0.588	0.306	0.379	0.460	0.515	0.550
Mean (phi)	2.611	0.727	0.766	1.709	1.401	1.121	0.957	0.862
Description	Fine sand	coarse sand	coarse sand	medium sand	medium sand	medium sand	coarse sand	coarse sand
Percentage silt	10.86%	0.23%	1.0%	9.2%	0.7%	2.7%	0.2%	0.3%
Percentage >0.06mm and <6.0 mm	89%	98%	99%	90%	99%	97%	99%	94%
Uniformity Coefficient	0.000	2.232	4.199	4.545	1.707	2.998	1.822	1.923
Standard Deviation	1.060	0.851	1.197	1.453	1.123	1.029	0.848	1.123
	poorly sorted	moderately sorted	poorly sorted	poorly sorted	poorly sorted	poorly sorted	moderately sorted	poorly sorted
Skewness	3.865	0.904	0.912	1.413	1.005	1.269	0.939	0.332
	V. strongly positive skewed	strongly positive skewed	strongly positive skewed	V. strongly positive skewed	V. strongly positive skewed	V. strongly positive skewed	strongly positive skewed	strongly positive skewed
Kurtosis	3.097	1.352	1.405	1.389	1.670	1.365	1.289	1.568
	extremely leptokurtic	leptokurtic	leptokurtic	leptokurtic	very leptokurtic	leptokurtic	leptokurtic	very leptokurtic

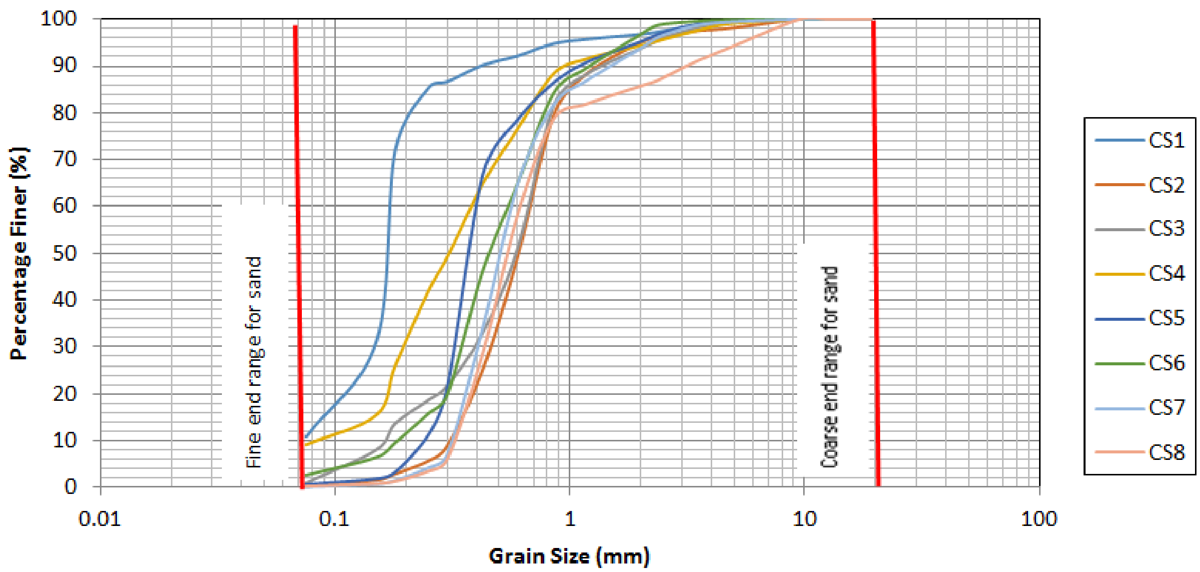


Figure 5-44 Graph showing the grain size plots for the sand samples from the sand reserve (borrow area)

UNIFORMITY COEFFICIENT

The uniformity coefficient is a measure of the variation in particle sizes. It is defined as the ratio of the size of particle that has 60 percent of the material finer than itself, to the size of the particle that has 10 percent finer than itself. The uniformity coefficient is calculated as $U_C = D_{60}/D_{10}$, where:

U_C – Uniformity coefficient
D_{60} – The grain size, in mm, for which 60% by weight of a soil sample is finer
D_{10} – The grain size, in mm, for which 10% by weight of a soil sample is finer

Within the unified classification system, the sand is well graded if U_C is greater than or equal to 6. A plot of the uniformity coefficients are shown in Figure 5-45 and Figure 5-46.

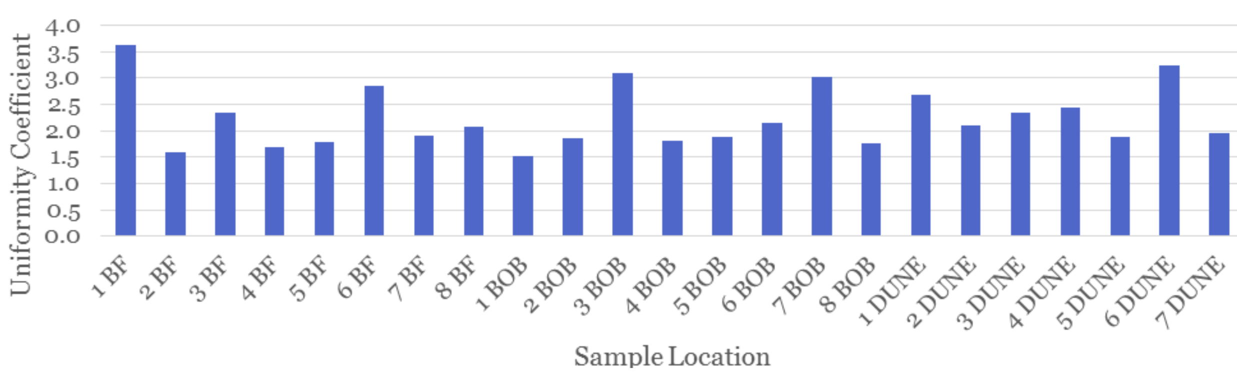


Figure 5-45 Uniformity coefficient for the sand samples taken from the shoreline

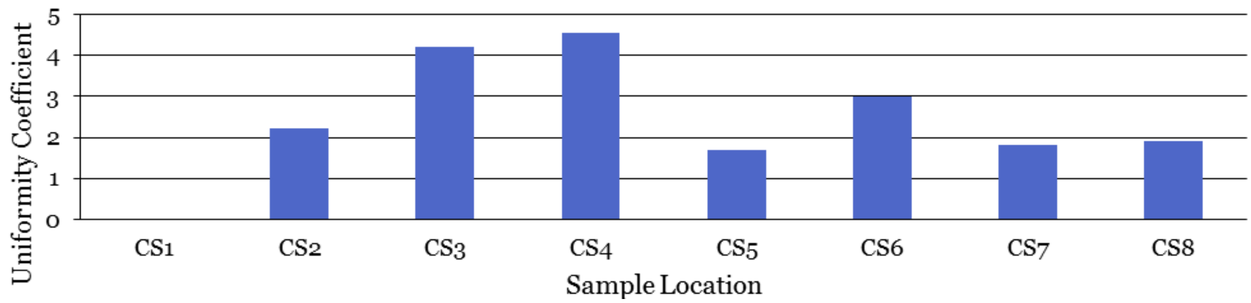


Figure 5-46 Uniformity coefficient for the samples from the sand reserve

The uniformity co-efficient of the shoreline samples ranges from 1.5 to 3.6, indicating that the samples are in the poorly sorted to well sorted range. While the uniformity co-efficient of the offshore reserve samples range from poorly to moderately sorted (0 to 4.5).

STANDARD DEVIATION

The Standard deviation is a measure of the degree of sorting of the particles in the sample. A standard deviation of one or less defines a sample that is well sorted while values above one are poorly sorted. The majority of the shoreline samples were well sorted which is indicative of relatively high wave energy at the shoreline which sorts the particles into their discrete sizes. The sample taken from the dune in location 6 is an exception as it had a negative standard deviation because it comprised of very coarse sand (d_{50} = 4.3 mm). The opposite was true for the sand reserves samples, as majority of the samples had a standard deviation of 1 or greater indicating that they were poorly sorted. The standard deviation plots of the samples are shown in Figure 5-47 and Figure 5-48.

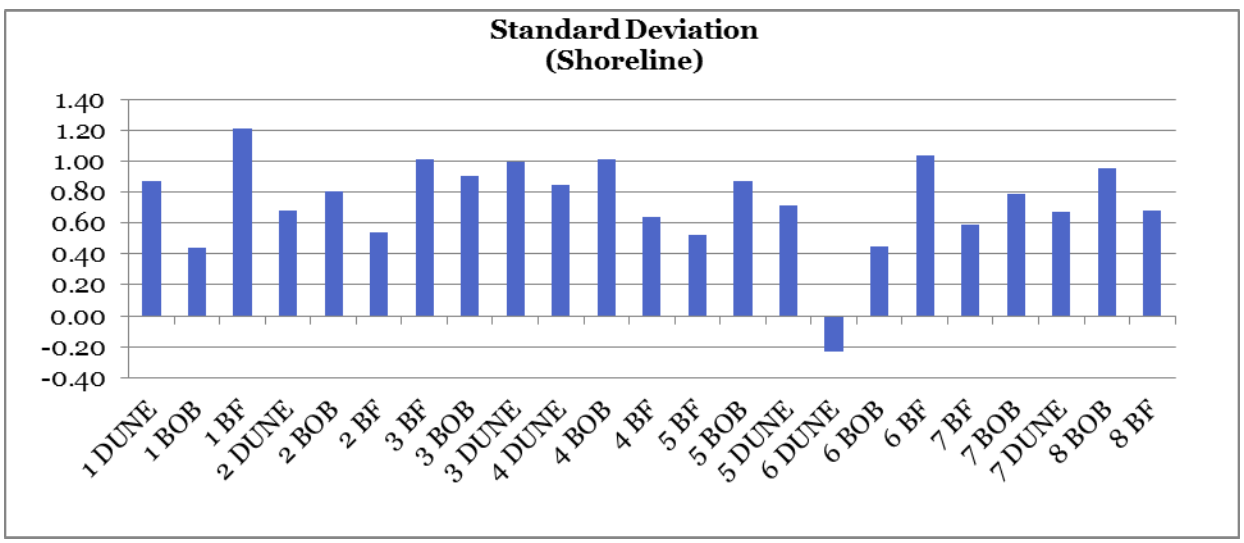


Figure 5-47 Graph showing standard deviation for the shoreline sand samples

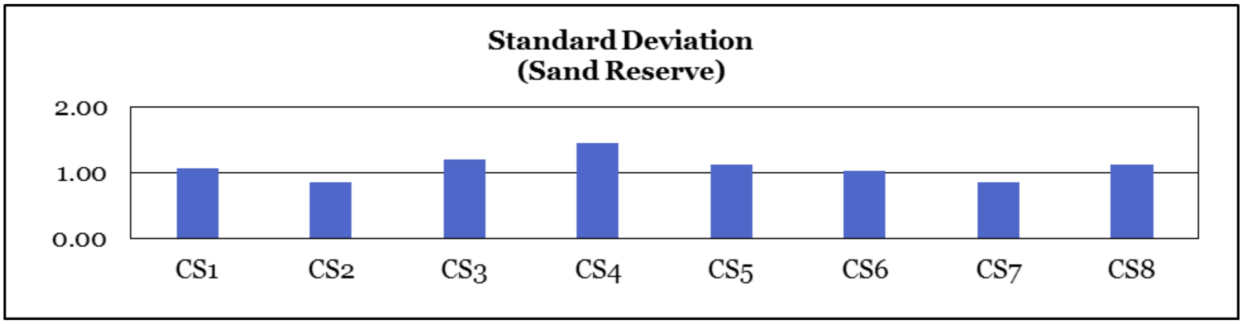


Figure 5-48 Graph showing standard deviation for the sand reserve samples

SKEWNESS

Skewness describes the shift in the distribution about the normal. The skewness is described by the equation:

$$S = \frac{\phi 84 + \phi 16 - 2(\phi 50)}{2(\phi 84 - \phi 16)} + \frac{\phi 95 + \phi 5 - 2(\phi 50)}{2(\phi 95 - \phi 5)}$$

This formula simply averages the skewness obtained using the 16 phi and 84 phi points with the skewness obtained by using the 5 phi and 95 phi points, both determined by exactly the same principle. This is the best skewness measure to use because it determines the skewness of the "tails" of the curve, not just the central portion, and the "tails" are just where the most critical differences between samples lie. Furthermore, it is geometrically independent of the sorting of the sample. Symmetrical curves have skewness=0.00; those with excess fine material (a tail to the right) have positive skewness and those with excess coarse material (a tail to the left) have negative skewness. The more the skewness value departs from 0.00, the greater the degree of asymmetry. The following verbal limits on skewness are suggested for values of skewness:

Table 5-17 Verbal limits for skewness

Values from	To	Mathematically:	Graphically Skewed to the:
+1.00	+0.30	Strongly positive skewed	Very Negative phi values, coarse
+0.30	+0.10	Positive skewed	Negative phi values
+0.10	- 0.10	Near symmetrical	Symmetrical
- 0.10	- 0.30	Negative skewed	Positive phi values
- 0.30	- 1.00	Strongly negative skewed	Very Positive phi values, fine

The shoreline samples ranged from negatively (-2.1) skewed to strong positively skewed (8.5), most were within the positively skewed to strongly positively skewed range indicating the presence of excess fines. While the sand reserve samples ranged from positively (0.3) to strongly positive (3.9) indicating that they have excess fine material, see Figure 5-49 and Figure 5-50.

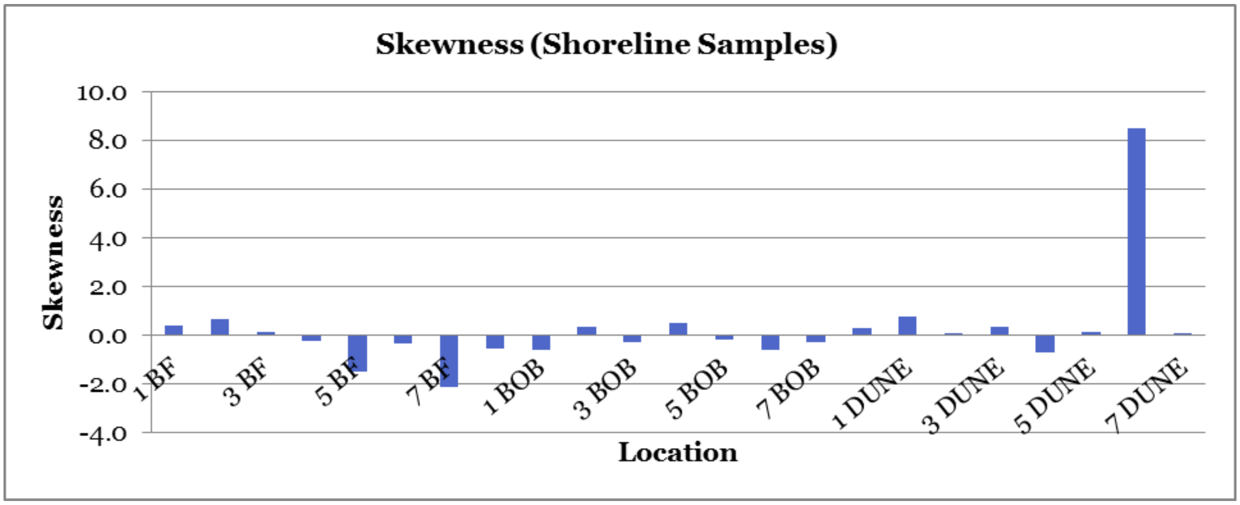


Figure 5-49 Graph showing skewness for the shoreline samples

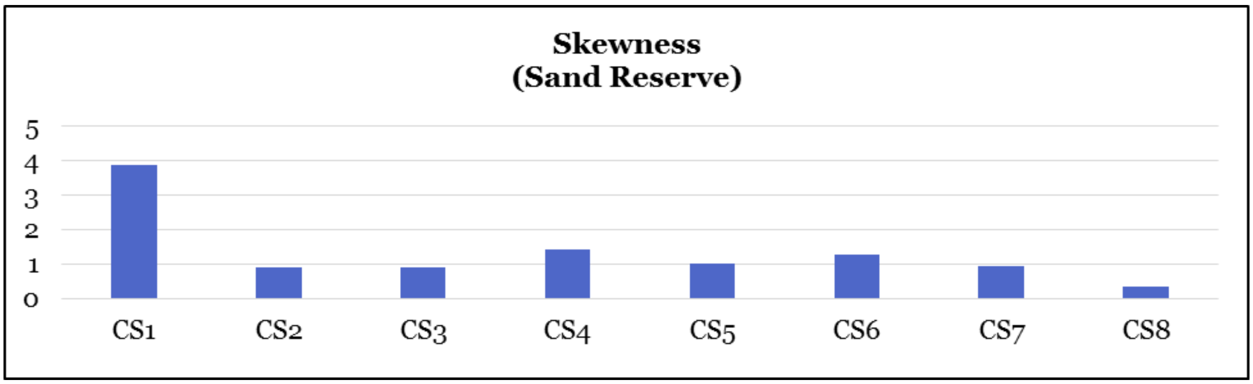


Figure 5-50 Graph showing skewness for the sand reserve samples

KURTOSIS

Kurtosis describes the degree of peakedness or departure from the "normal" frequency or cumulative curve. In the normal probability curve, defined by the gaussian formula; the phi diameter interval between the 5 phi and 95 phi points should be exactly 2.44 times the phi diameter interval between the 25 phi and 75 phi points. Kurtosis is the quantitative measure used to describe this departure from normality. It measures the ratio between the sorting in the "tails" of the curve and the sorting in the central portion. If the central portion is better sorted than the tails, the curve is said to be excessively peaked or leptokurtic; if the tails are better sorted than the central portion, the curve is deficiently or flat-peaked and platykurtic.

Strongly platykurtic curves are often bimodal with subequal amounts of the two modes; these plot out as a two-peaked frequency curve, with the sag in the middle of the two peaks accounting for its platykurtic character. For normal curves, kurtosis equals 1.00. Leptokurtic curves have a kurtosis over 1.00 (for example a curve with kurtosis=2.00 has exactly twice as large a spread in the tails as it should have, hence it is less well sorted in the tails than in the central portion); and platykurtic have kurtosis under 1.00. The following verbal limits are suggested for values of kurtosis:

Table 5-18 Verbal limits for Kurtosis

Values from	To	Equal
0.41	0.67	Very platykurtic
0.67	0.90	Platykurtic
0.90	1.11	Mesokurtic
1.10	1.50	Leptokurtic

Kurtosis was determined to be generally within the range 0.3 to 2.6 for the shoreline samples while the sand reserve samples ranged from 1.3 to 3.0. Plots of the kurtosis values are shown in Figure 5-51 and Figure 5-52.

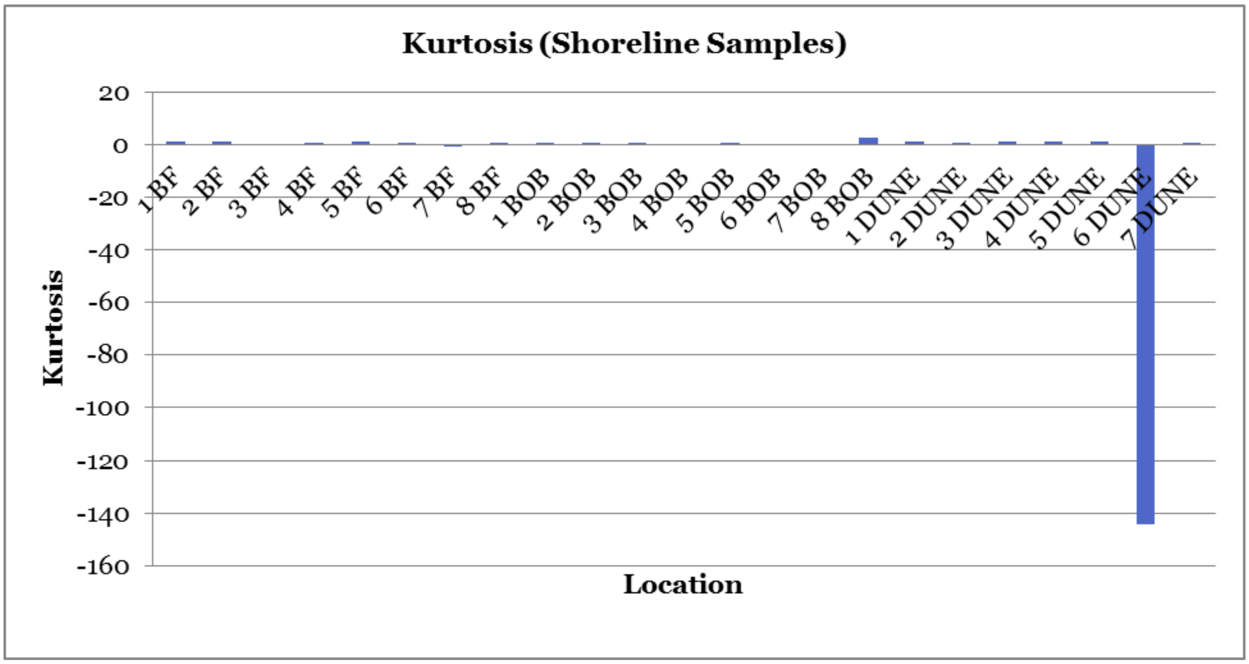


Figure 5-51 Graph showing the kurtosis results for the shoreline sand samples

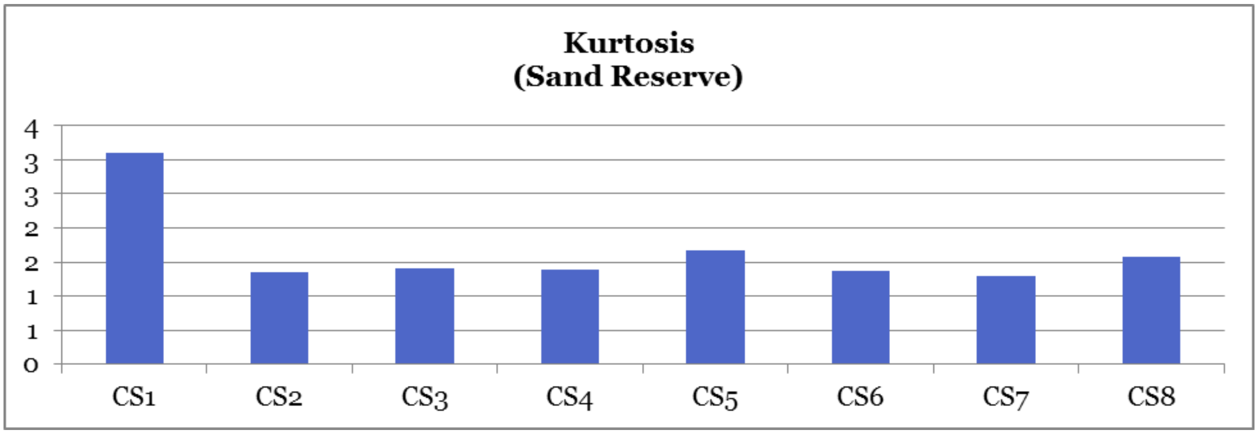


Figure 5-52 Graph showing the kurtosis results for the sand samples from the sand reserve

Suitability Comparison

The shoreline samples and the reserve samples were compared to determine the suitability of the reserve sand for use on the shoreline in creating the dunes. First, a visual inspection was done. Figure 5-53 below shows that there is not much difference in the colour of the samples however the back of beach samples are distinctly coarser than burrow area samples.

Second, the grain size analysis results for the shoreline and sand reserve samples were compared and it revealed that the mean grain sizes of the sand reserve samples are smaller than that of the shoreline samples. This is presented in greater detail in the Material Assessment Report. The percentage finer than grain size were also plotted for both sets of samples. The dunes samples were first plotted and then upper and lower bounds were fitted that would encompass majority of the samples. The same upper and lower bounds were placed on a plot of the sand reserve samples to see how they match up. The results are shown below in Figure 5-54. From the plots we can see that the sand reserve samples in the vicinity of CS2, CS3, CS7 and CS8 fall within the bounds (black lines) set by the shoreline samples and have a mean grain size between 0.5 – 0.7 mm. This mean grain size will be used in the dune design modelling exercise.

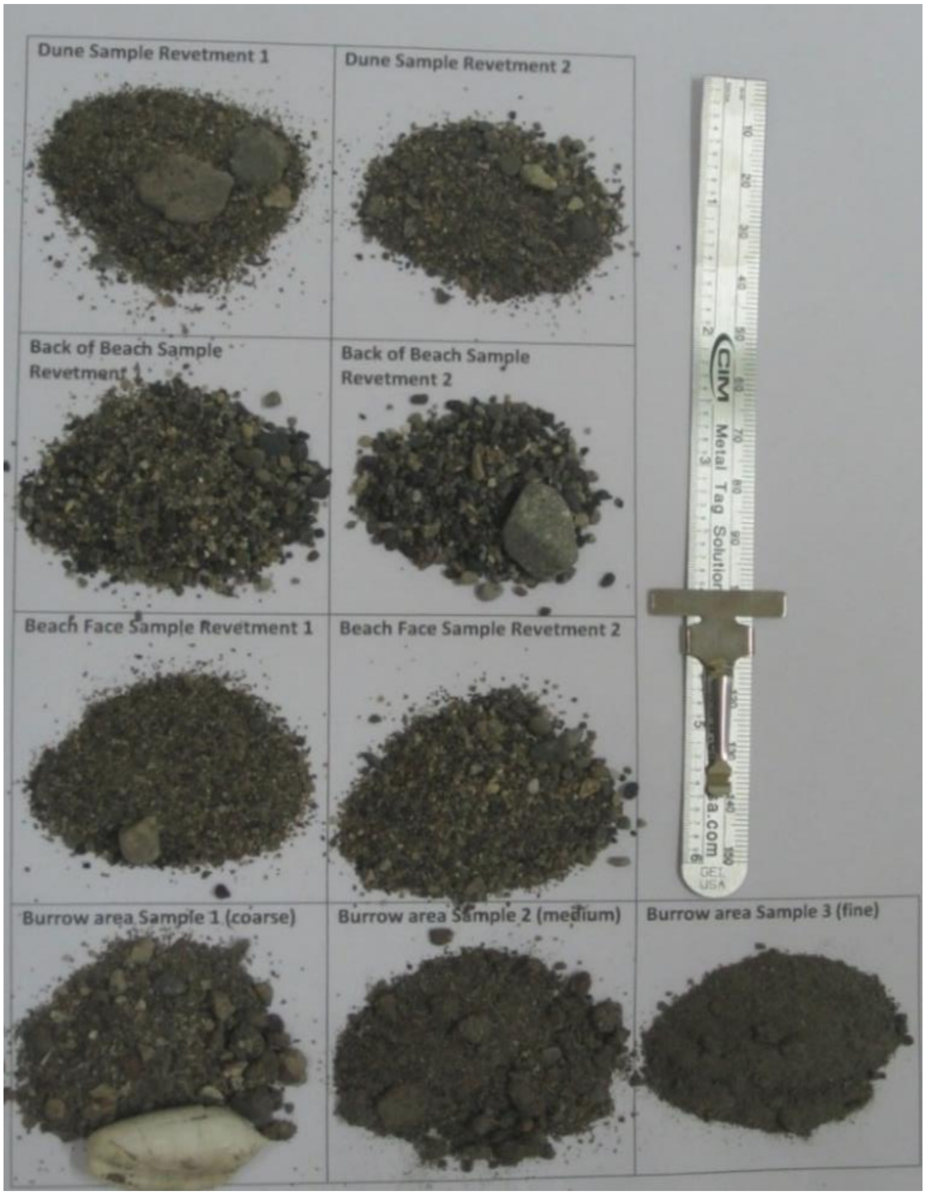


Figure 5-53 Photograph of sand samples collected from the sand reserve (borrow area) and the shoreline

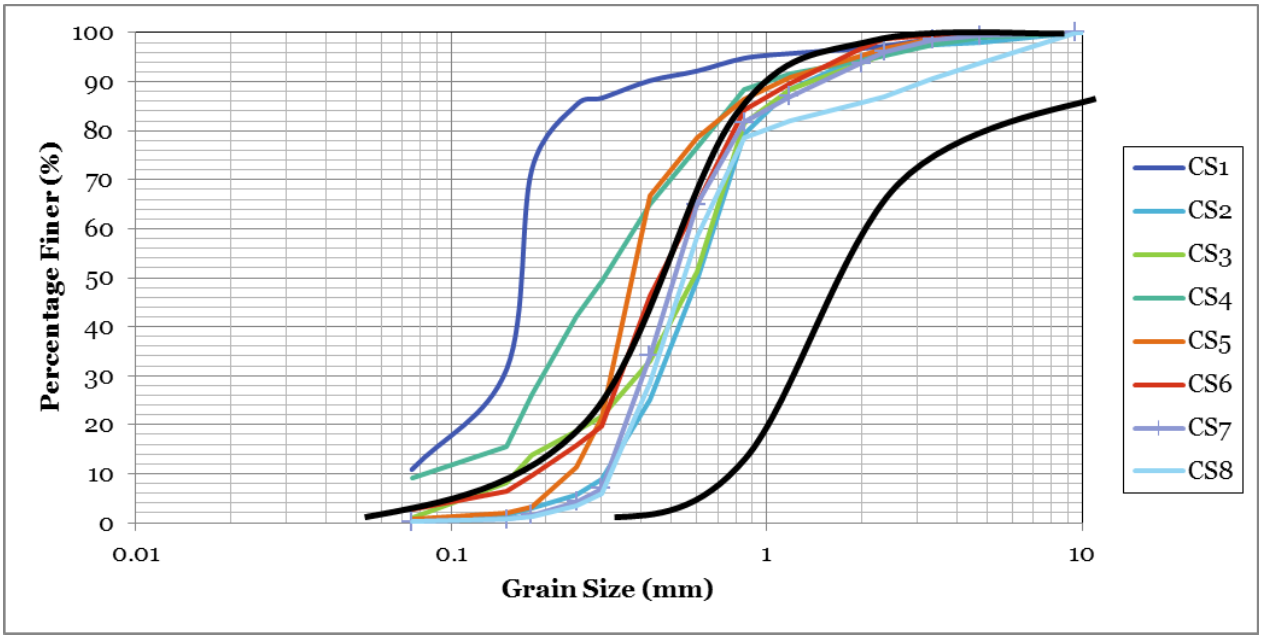


Figure 5-54 Graph showing the grain size for the sand reserve samples with the upper and lower bounds for the shoreline samples (in black) indicating where suitable sand is located

Table 5-19 present the volume of sand suitable for covering the low revetments available within the borrow area and Figure 5-55 shows the location of the suitable sand within the borrow area.

Table 5-19 Estimated fill volume available in the borrow area when dredged to a depth of 1.5 m

Proposed Dredge Area	Area (m^2)	Volume (m^3)
1	87,432	59,132
2	39,421	131,148
Total	**126,853**	**190,280**

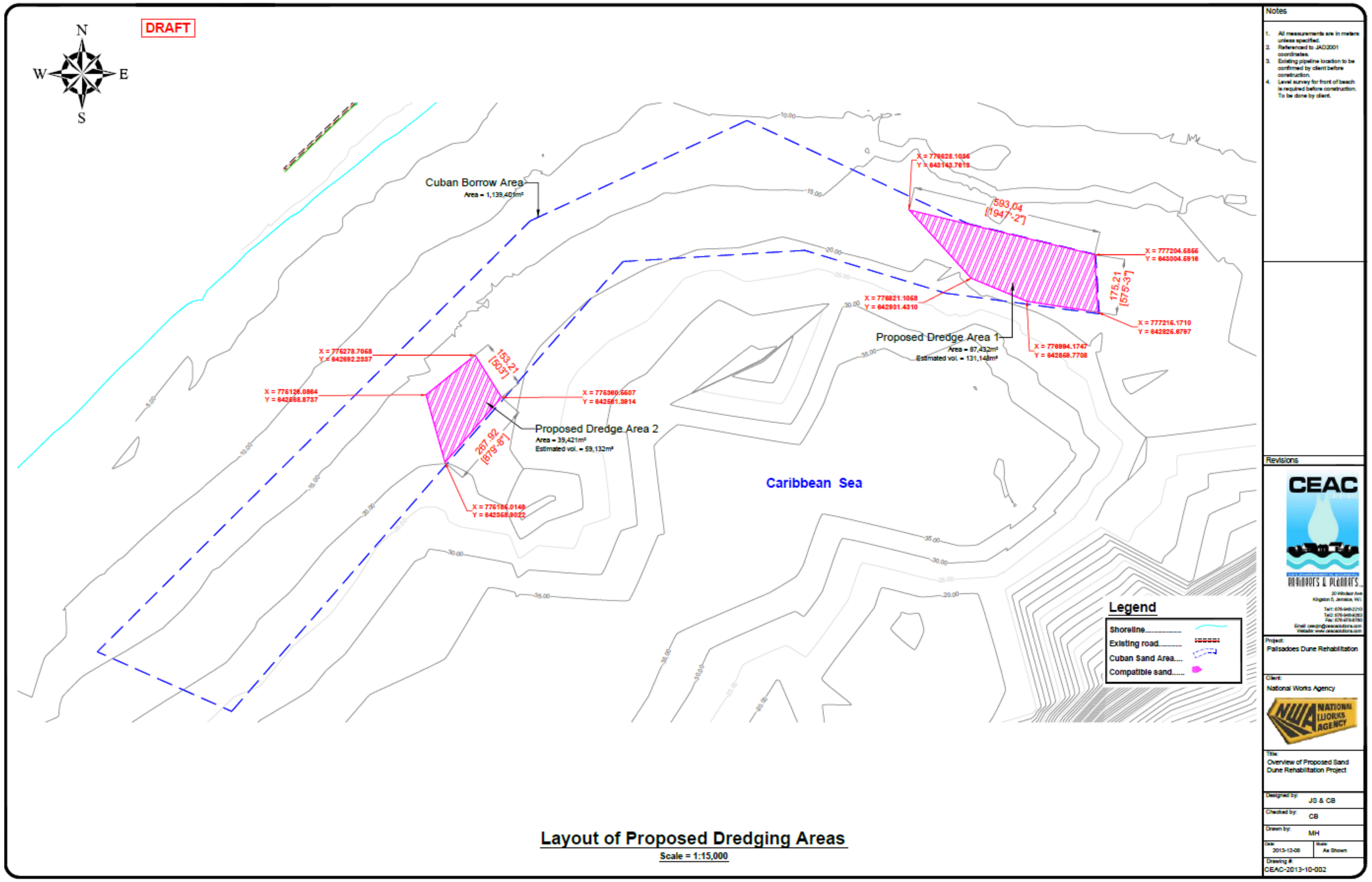


Figure 5-55 Location of sand with a mean grain size of between 0.5 – 0.7 mm within the borrow area. This area should be dredged to a depth of 1.5 m to obtain the required volume

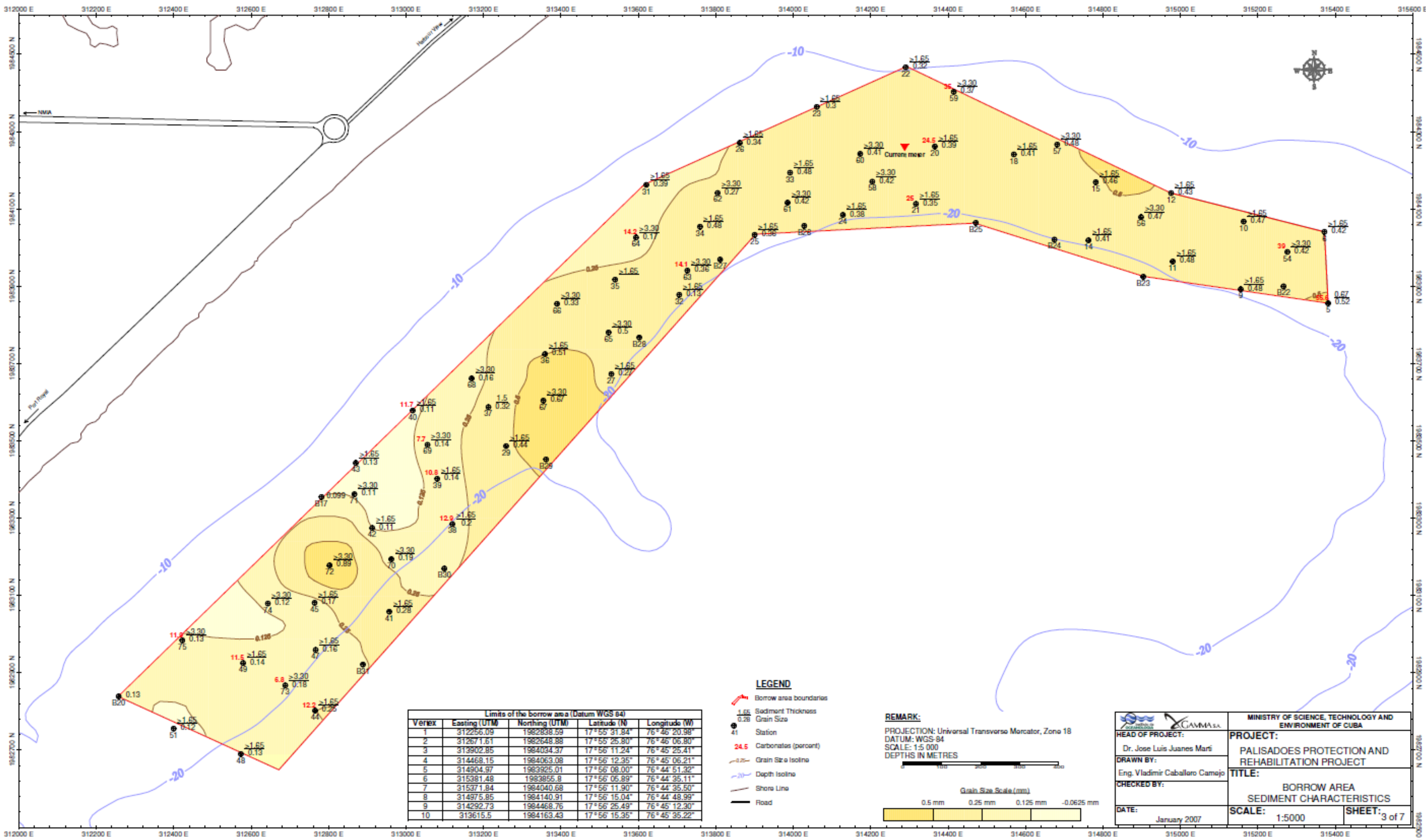


Figure 5-56 Location of sand samples taken from the borrow area by the Cuban technical team

Composition of Sand from the Borrow Area

In the Cuban study 97 sand samples were collected from the borrow area and tested to determine their characteristics and composition. The tests determined that the mean grain size of sand in this area varies between 0.11 – 0.89 mm and the standard deviation varies between 0.5 – 1.0. The tests also determined that the material was predominantly terrigenous, non-carbonated material which compares well with the sediment formations found in the region and presented in other studies. This study also determined that the carbonate composition of sand within the priority borrow areas varies between 7 – 17%, see Table 5-20.

Table 5-21 and Table 5-22 present the test results for the sand samples taken from Proposed Dredge Area 1 and 2 as identified in Figure 5-55 and Figure 5-56. It also presents the maximum, minimum and average values of these results and compares them with the sediment analysis results obtained for the sand samples we took from same.

The analysis indicated that the sand samples from both studies are similar, producing comparable results for the mean grain size, mean phi, kurtosis values and standard deviation. The mean grain size varied between 0.5 and 0.6 mm, and the mean phi varied between 0.9 and 1.1. The kurtosis values for both samples were greater than 1.1, indicating that the samples were excessively peaked, having the sand in the centre of the distribution better sorted than at the ends. The standard deviation for both samples was also moderately to poorly sorted.

Table 5-20 Chemical composition of sand from the proposed dredge areas within the borrow areas determined by the Cuban study

Constituent	Proposed Dredge Area 1 (%)	Proposed Dredge Area 2 (%)
Total Carbonate	17.07	7.01
Crystalline	17.48	0.00
Opaque	0.81	0.00
Rock Fragments	10.57	0.00
Amphibole	0.81	1.40
Feldspar	2.85	4.67
Quartz	50.41	86.92

Table 5-21 Composition of sand in Proposed Dredge Area 1 as determined by both the Cuban and CEAC study

Sample	Depth (m)	D50 (mm)	Bottom Description and laboratory information	Mean (φ)	Std Dev	Skewness	Kurtosis
M5	20.6	0.52	Sandy bottom. Course sand. Beige-white colour. Very low density of benthic organisms (molluscs, Halimeda algae and gorgonians). Spread skeleton remains of calcareous algae and corals were observed in a low density. Sediment thickness: 0.67 m	0.93	0.46	-0.43	6.49

Sample	Depth (m)	D50 (mm)	Bottom Description and laboratory information	Mean (φ)	Std Dev	Skewness	Kurtosis
M6	20.2	0.42	Sandy bottom. Medium sand. Beige-white colour. Very low density of benthic organisms (molluscs, Halimeda algae and gorgonians). Spread skeleton remains of calcareous algae and corals were observed in a low density. Sediment thickness: > 1.5 m	1.26	0.3	-0.81	11.9
M9	19	0.48	Sandy bottom. Medium sand. Beige-white colour. Very low density of benthic organisms (molluscs, Halimeda algae and gorgonians). Spread skeleton remains of calcareous algae and corals were observed in a low density. Sediment thickness: > 1.5 m	1.06	0.72	-1.02	5.35
M10	18	0.47	Sandy bottom. Medium sand. Beige-white colour. Very low density of benthic organisms (molluscs, Halimeda algae and gorgonians). Spread skeleton remains of calcareous algae and corals were observed in a low density. Sediment thickness: > 1.5 m	1.23	0.64	-2.01	8.8
M11	19	0.48	Sandy bottom. Medium sand. Beige-white colour. Very low density of benthic organisms (molluscs, Halimeda algae and gorgonians). Spread skeleton remains of calcareous algae and corals were observed in a very low density. Sediment thickness: > 1.5 m	1.16	1.2	-0.92	3.2
M12	19	0.43	Sandy bottom. Medium sand. Beige-white colour. Very low density of benthic organisms (molluscs, Halimeda algae and gorgonians). Spread skeleton remains of calcareous algae and corals were observed in a low density. Sediment thickness: > 1.5 m	1.28	0.56	-1.7	8.75
M15	18.4	0.46	Sandy bottom. Medium sand. Beige-white colour. Absence of benthic organisms. Spread skeleton remains of calcareous algae were observed in a very low density. Sediment thickness: > 1.5 m	1.48	0.53	-0.62	8.62

Sample	Depth (m)	D50 (mm)	Bottom Description and laboratory information	Mean (φ)	Std Dev	Skewness	Kurtosis
M18	15	0.41	Sandy bottom. Medium sand. Beige-white colour. Absence of benthic organisms. Spread skeleton remains of calcareous algae were observed in a very low density. Sediment thickness: > 1.5 m	1.36	0.51	-1.46	8.49
M54	20	0.42	Sandy bottom. Medium sand. Beige-white colour. Absence of benthic organisms. Spread skeleton remains of calcareous algae were observed in a very low density. Sediment thickness: > 3.3 m	1.25	0.61	-1.62	9.97
M56	19	0.47	Sandy bottom. Medium sand. Beige-white colour. Absence of benthic organisms. Spread skeleton remains of calcareous algae were observed in a very low density. Sediment thickness: > 3.3 m	1.28	0.71	-1.55	8.08
Max	**20.60**	**0.52**		**1.48**	**1.20**	**-0.43**	**11.90**
Min	**15.00**	**0.41**		**0.93**	**0.30**	**-2.01**	**3.20**
Average	**18.82**	**0.46**		**1.23**	**0.62**	**-1.21**	**7.97**
CS7	**17.98**	**0.52**	**Coarse sand, dark grey in colour; shells and corals present in the sample**	**0.96**	**0.85**	**0.94**	**1.29**
CS8	**18.77**	**0.55**		**0.86**	**1.12**	**0.33**	**1.57**

Table 5-22 Composition of sand in Proposed Dredge Area 2 as determined by both the Cuban and CEAC study

Sample	Depth (m)	D50 (mm)	Bottom Description and laboratory information	Mean (φ)	Std Dev	Skewness	Kurtosis
M27	20	0.27	Sandy bottom. Medium sand. Beige-white colour. Very low density of benthic organisms (molluscs, Halimeda algae and gorgonians). Spread skeleton remains of calcareous algae and coral were observed in a very low density. Sediment thickness: > 1.5 m	1.36	0.6	-0.39	7.1
M29	18	0.44	Very low density of benthic organisms (molluscs, Halimeda algae and gorgonians). Spread skeleton remains of calcareous algae and corals were observed in a very low density. Sediment thickness: > 1.5 m	1.06	0.6	-0.34	4.83

Sample	Depth (m)	D50 (mm)	Bottom Description and laboratory information	Mean (φ)	Std Dev	Skewness	Kurtosis
M36	16.3	0.51	Sandy bottom. Course sand. Beige-Black colour. Absence of benthic organisms. Spread skeleton remains of calcareous algae were observed in a very low density. Sediment thickness: > 1.5 m	2.81	0.89	-1.12	3.97
M67	18	0.67	Sandy bottom. Course sand. Beige-white colour. Very low density of benthic organisms (molluscs, Halimeda algae and gorgonians). Spread skeleton remains of calcareous algae were observed in a very low density. Sediment thickness: > 3.3 m	3.23	0.59	-1.64	8.24
Max	**20.00**	**0.67**		**3.23**	**0.89**	**-0.34**	**8.24**
Min	**16.30**	**0.27**		**1.06**	**0.59**	**-1.64**	**3.97**
Average	**18.08**	**0.47**		**2.12**	**0.67**	**-0.87**	**6.04**
CS2	**19.28**	**0.60**	**Coarse sand, dark grey in colour; shells and corals present in the sample**	**0.73**	**0.85**	**0.90**	**1.35**
CS3	**17.83**	**0.58**		**0.77**	**1.20**	**0.91**	**1.41**

Mangrove Nourishment

Sand samples were collected for analysis from the mangrove forest adjacent to the project area (Port Royal) to determine the optimal sand slope and sediment characteristics to be used in the project. UWI team is responsible for replanting the mangroves and they provided three (3) sand samples from an adjacent mangrove forest to be used in our analysis. These samples were compared with samples collected from 3 quarries in St. Thomas, 2 desilting operations in Kingston, and from the 8 points within the sand reserve to determine which source would provide the most suitable sand for mangrove nourishment. A detailed analysis was completed and submitted in the Material Assessment Report previously submitted and it determined that sand with a mean grain size between 1 – 2mm should be used and that un-sieved sand from the Hope River desilting operation would be the most suitable. Table 5-23 and Figure 5-57 provide a summary of the results and indicate that the Hope River will provide on average very coarse sand with a mean grain size of 1.9 mm which falls within the required range.

Table 5-23 Grain size analysis results for the sand samples from the mangrove forest and from the Hope River

Sample ID	Fine	Course	All purpose	Hope River
Mean Grain size (mm)	0.823	4.046	1.755	1.912
Mean (phi)	0.281	-2.016	-0.812	-0.935
Description	coarse sand	gravel	very coarse sand	very coarse sand
Percentage silt	0.14%	0.01%	0.1%	0.2%
Percentage >0.06mm and <6.0 mm	100%	63%	84%	66%

Sample ID	Fine	Course	All purpose	Hope River
Uniformity Coefficient	2.593	2.376	4.937	6.109
Standard Deviation	0.829	-0.221	1.108	0.611
	moderately sorted	well sorted	poorly sorted	moderately well sorted
Skewness	0.378	16.329	0.149	1.242745
	strongly positive skewed	V. strongly positive skewed	positive skewed	V. strongly positive skewed
Kurtosis	1.008	-2.234	0.367	0.194
	mesokurtic	extremely leptokurtic	extremely leptokurtic	extremely leptokurtic

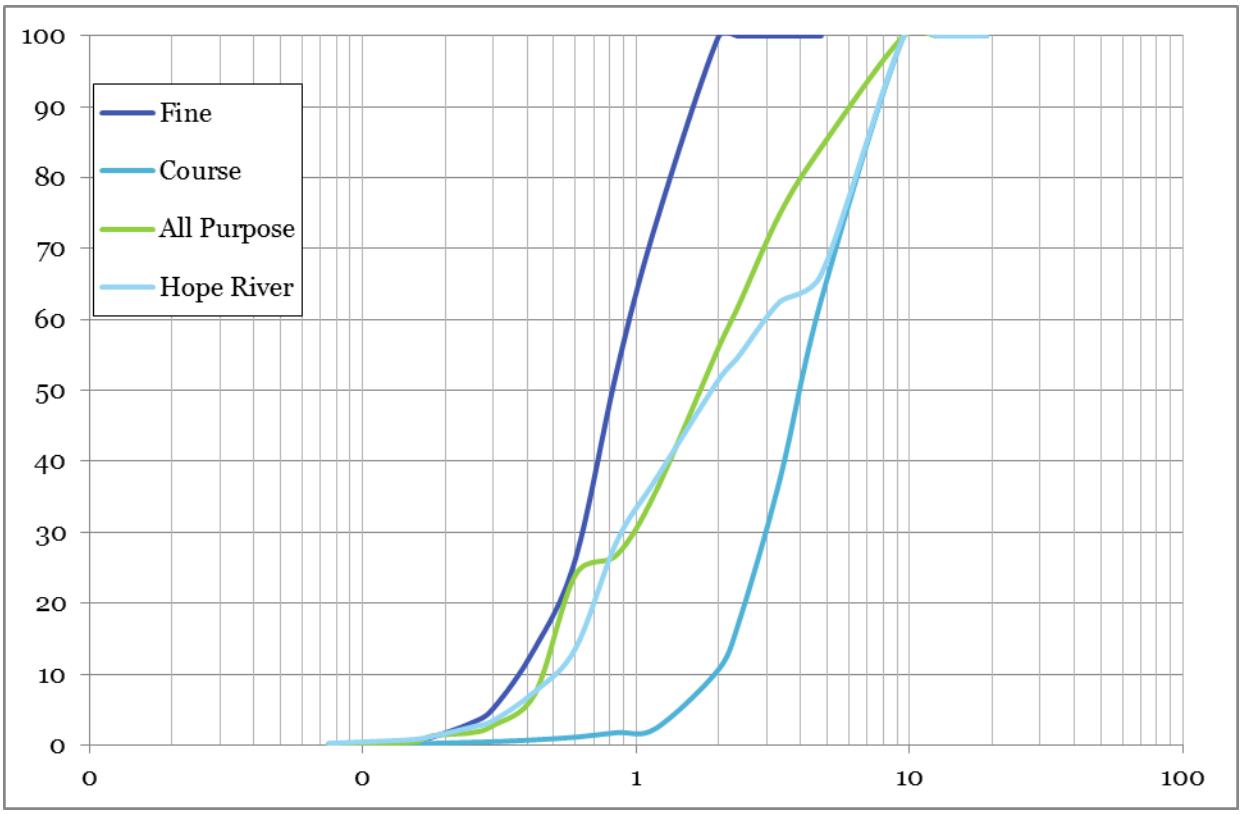


Figure 5-57 Graph showing the grain size for the sand from the mangrove forest and from the Hope River

Summary

Sand samples were collected along the Palisadoes shoreline and from the offshore borrow area identified by the Cuban study. The shoreline samples ranged between coarse sand and gravel (0.7 – 4.3 mm), the sand was well graded, well sorted, and most samples were positively skewed having more fines in the tail of the distribution.

The samples from the borrow area ranged between fines and coarse sand (0.2 – 0 0.6 mm), the sand was well graded, poorly sorted, and positively skewed. These results were also similar to that obtained by the Cubans for their samples collected from the same borrow area. Two priority areas within the borrow area were identified as providing coarse sand to be used for the sand dune nourishment exercise, this sand has a mean grain size ranging between 0.5 – 0.6 mm. This sand is however unsuitable for use in the mangrove nourishment exercise. Mangrove nourishment is best carried out with unsieved sand from the Hope River desilting operation.

5.2.4.6 Anecdotal Data Collection

Anecdotal evidence of past storms was collected to aid in the verification of the CSHORE and SBEACH models defined for the project. Interviews were held with persons currently residing and/ or employed in Harbour View, Port Royal and its environs. They reported that Hurricane Ivan (2004) caused the most damage to the Palisadoes and that by the end of its passing the Palisadoes was completely impassable with sand and stones brought up on the road. On average sand mounds were 4 ft high but in some areas they were as high as 6ft. (Juanes, 2007) also agreed with interviewees and reported that during Ivan 'an intense process of sand migration from Palisadoes external side toward the Kingston Harbour side took place, which had never before been observed since the event in 1722'. The sand dunes along the Palisadoes were totally destroyed, and there was inundation of the road which led to the complete shutdown of the Norman Manley International Airport (NMIA).

Interviewees also reported that since the construction of the revetments along the Palisadoes in 2010 damage to the extent caused by Ivan has not occurred, even with the passing of Hurricane Sandy in 2012 which was a Category 1 hurricane that pummeled the St. Thomas coastline, St. Mary and Portland.

5.2.5 Waves and Storm Surge Modelling

5.2.5.1 Climate Change Considerations

In completing the design, considerations were made for the effect climate change would have on the design life of the dunes and mangrove nourishment areas. A study[10] was conducted by the Climate Studies Group at the University of the West Indies (UWI) Mona and this was used to inform our design approach; it assessed literature on current and projected trends in sea level rise, wave heights and storm intensities with a particular emphasis on future values for the Palisadoes, in Jamaica.

Current and Projected Trends for Mean and Extreme Sea Levels

At Port Royal sea level measurements indicated a 0.9 mm/ yr rising trend between 1955 and 1971. This however is much lower than global and regional trends and these trends are expected to accelerate through to the 21st century and beyond because of global warming, but their magnitude remains uncertain. Two main factors contribute to this increase: thermal expansion of sea water due to ocean warming and water mass input from land ice melt and land water reservoirs.

[10] Climate Studies Group, UWI Mona (2013), Evaluation of trends in sea levels, ocean wave characteristics and tropical storm intensities, *Report prepared for CEAC Solutions Co. Ltd.*

In Jamaica, and the region near it, the sea level rise is approximately the global average[11] of 3.2 mm/yr (± 0.4). Projected increases in global and Caribbean mean sea level by 2100 relative to the 1980-1999 is 0.37m[12] (± 0.5 m relative to global mean) and this is equivalent to 3.7 mm/yr.

Current and Projected Trends in Mean and Significant Wave Heights

In 2000 Wang and Swail detected statistical significant changes in the seasonal extremes of significant wave heights in the North Atlantic only for the winter (January – March) season; these changes were found to be linked with the North Atlantic Oscillation. Specifically, significant increases in significant wave heights in the Northeast North Atlantic matched by significant decreases in the subtropical North Atlantic are found to be associated with an intensified Azores High and a deepened Icelandic low.

The IPCC AR5 projects that the annual mean significant wave heights will decrease by approximately 1 – 2%. This marginal figure was however not included in the design so as to enable the dunes and mangrove nourishment areas to best withstand any possible changes to the climate change projections.

Current and Projected Trends in Storm Intensities

The AR5 notes that evidence suggests a virtually certain increase in the frequency and intensity of the strongest cyclones in the Atlantic since the 1970s. It is further noted that the average lifetime of North Atlantic tropical cyclones show an increasing trend 0f 0.07 day/yr for the same period which is statistically significant[13].

The AR4 concluded that a range of modelling studies project a likely increase in peak wind intensity and near storm precipitation in future tropical cyclones. Simulations consistently find that greenhouse warming causes tropical cyclone intensity to shift towards stronger storms by the end of the 21st century (2 to 11% increase in mean maximum wind globally).

Summary

Based on the assessments and literature reviewed the following climate change factors will be incorporated into the design (Table 5-24), specifically the deep water and near shore wave climate analysis carried out in the following sections, thus ensuring the dunes can adequately withstand the future climate change environment.

Table 5-24 Summary of climate change considerations

	Present Climate		Climate Factor (Cf)	Future Climate	
	50 YR	100 YR		50 YR	100 YR
Water Level	0	0	3.75 mm/yr	0.139	0.139
Operational Wave Height	0.8 (o)	1.6 (s)	1 - 2 % decrease	0.8	1.6

[11] IPCC 2013
[12] IPCC 2007
[13] Climate Studies Group, UWI Mona (2013), Evaluation of trends in sea levels, ocean wave characteristics and tropical storm intensities, *Report prepared for CEAC Solutions Co. Ltd.*

Hurricane Wave Height	5.94	6.23	1.040	6.17	6.48
Wave Frequency (Increase)			2.2 = 100*log(A1B/CTRL)	5.2%	5.2%

5.2.5.2 Deep Water Wave Climate Analysis

Wave information on the site is crucial in order to understand the likely conditions that the shoreline will be subjected to and hence adequately design the sand dunes to provide maximum protection to the shoreline.

Hurricane Waves

METHODOLOGY

The following procedure was carried out:

- A database of hurricanes, dating back to 1886, was searched for storms that passed within a 300 km radius of an offshore node located at Latitude 17.76 degrees North and Longitude 76.67 degrees West.
- Hurricane wave track data in the Caribbean Sea was available which enabled us to carry out a thorough statistical analysis to determine the hurricane wind and wave conditions at a deep-water location offshore the site.

After the database was searched the following procedure was carried out:

1. Extraction of Storms and Storm Parameters from the historical database
2. Application of the JONSWAP Wind-Wave Model - A wave model was used to determine the wave conditions generated at the site due to the rotating hurricane wind field. This is a widely applied model and has been used for numerous engineering problems. The model computes the wave height from a parametric formulation of the hurricane wind field.
3. Application of Extremal Statistics - Here the predicted maximum wave height from each hurricane was arranged in descending order and each assigned an exceedance probability by Weibull's distribution.

All the returned values were then subjected to an Extremal Statistical analysis and assigned exceedance probabilities with a Weibull distribution.

RESULTS

Occurrences and Directions

The results of the search from the database for hurricanes that came within the search radius of the site are shown in the Appendices. Extremal analysis results are summarized in the bi-variant Figure 5-59. The results of the search clearly indicate the sites overall vulnerability to such systems. In summary:

- 86 hurricane systems came within 300 kilometres of the project area
- 6 of which were classified as catastrophic (Category 5)

- 15 were classified as extreme (Category 4)

The bi-variant table analysis indicates that the waves generated offshore the site have approached from all seaward possible. However, the most frequent hurricane waves have been noted to come from a **south-westerly** direction, see Table 5-25. In summary, there are:

- 23 (x6 hours) occurrences from the west
- 61 (x6 hours) occurrences from the east
- 66 (x6 hours) occurrence from the south,
- 66 (x6 hours) occurrence from the south-east
- **68 (x6 hours) occurrence from the south-west**

The southern directions are more prevalent for the node considered because of the seaward projection of the northern part of the island that somewhat buffer the site from remote northern waves. The site however becomes more exposed as soon as the passing hurricane systems are more south and west of the island.

Wind direction- NW

Tp(s)	Wave height(m)										Total
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6											
8											
10											
12											
14											
16											
18											
20											
Total											

Wind direction- N

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6											
8											
10											
12											
14											
16											
18											
20											
Total											

Wind direction- NE

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6											
8											
10											
12											
14											
16											
18											
20											
Total											

Wind direction- W

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6		4									4
8		13	2								15
10			2	1							3
12				1							1
14											
16											
18											
20											
Total		17	4	2							23

All directions

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4		1									1
6		21									21
8		111	42	1							154
10			49	12							61
12				3							3
14											
16											
18											
20											
Total		133	91	16							240

Wind direction- E

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6		2									2
8		17	13								30
10			17	2							19
12											
14											
16											
18											
20											
Total		19	30	2							51

Wind direction- SW

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6		7									7
8		39	7								46
10			3								3
12											
14											
16											
18											
20											
Total		46	10								56

Wind direction- S

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4		1									1
6		5									5
8		26	5								31
10			15	3							18
12											
14											
16											
18											
20											
Total		32	20	3							55

Wind direction- SE

Tp(s)	Wave height(m)										
<value	2	4	6	8	10	12	14	16	18	20	
2											
4											
6		3									3
8		16	15	1							32
10			12	6							18
12				2							2
14											
16											
18											
20											
Total		19	27	9							55

Figure 5-58 Bi-variate table for extremal wave action from hurricanes occurring along the Caribbean Sea side of the Palisadoes

Wave Heights and Directions

The bi-variant table generated indicates that hurricane waves originating from the south east (SE) and south (S) are the most severe of all directions (see Table 5-25). The northern waves are not expected to significantly impact the site due to the angle (orientation) of the shoreline and the shape of the land.

Table 5-25 Summary of wave heights and periods from various directions for different return periods

	Wave height (m)											
	All		SW		W		E		SE		S	
Return Periods	Hs	Tp	Hs	Tp	Hs	Tp	Hs	Tp	Hs	Tp	Hs	Tp
1	2.5	8.0	1.5	6.2	1.5	6.2	1.5	6.2	1.5	6.2	1.5	6.2
2	3.8	9.8	3.4	9.3	3.5	9.4	4.5	10.6	4.4	10.5	3.9	9.9
5	5.1	11.3	3.9	9.9	4.5	10.6	5.5	11.7	5.6	11.7	5.1	11.3
10	6.0	12.2	4.2	10.2	5.1	11.3	6.0	12.2	6.2	12.3	5.8	12.0
20	6.8	13.0	4.4	10.5	5.6	11.8	6.5	12.6	6.7	12.8	6.4	12.5
25	7.1	13.2	4.4	10.5	5.7	11.9	6.6	12.8	6.8	13.0	6.5	12.7
50	7.9	13.9	4.6	10.7	6.2	12.4	6.9	13.1	7.2	13.3	7.0	13.2
75	8.4	14.3	4.7	10.8	6.4	12.6	7.1	13.3	7.5	13.5	7.3	13.4
100	8.7	14.6	4.7	10.9	6.6	12.7	7.3	13.4	7.6	13.7	7.5	13.6
150	9.1	14.9	4.8	10.9	6.8	12.9	7.4	13.5	7.8	13.8	7.7	13.8
200	9.4	15.2	4.8	11.0	7.0	13.1	7.6	13.6	7.9	14.0	7.9	13.9

The extremal analysis results indicate that the 100-year return period event has a wave height of 7.6 m for south eastern waves. Overall, these are relatively large waves with potential for causing severe damage along the shoreline. They are however deepwater waves that will be impacted by the bathymetry as they approach the shoreline. Their potential for resulting near shore climates were investigated using a wave refraction and diffraction model as outlined in the following section.

Storm Surge and Winds

The maximum storm surge that is estimated for this location for the 100 year event is approximately 1.31 m (Table 5-26). This is essential information when it pertains to construction within the project area in regards to the placement of the sand dunes.

One factor that was unaccounted for in the model prediction, however, is the effect of wave run-up which will inevitably increase the water levels. This parameter would not have been easily differentiable to the observers and would have thus been a part of what was observed. It is against this background that wave run-up was determined and added to the storm surge elevations.

Table 5-26 Extremal storm surge (metres) predictions for the Palisadoes along the profile from shoreline to deepwater for all directional waves possible for the project area

Return Period	Total setup (m)

	All	SW	W	NW	N	NE	E	SE	S
1	NaN	0.05	NaN	0.00	0.00	0.00	NaN	0.05	0.05
2	0.42	0.40	0.22	0.00	0.00	0.00	0.27	0.57	0.54
5	0.63	0.57	0.35	0.00	0.00	0.00	0.48	0.82	0.78
10	0.76	0.67	0.44	0.00	0.00	0.00	0.61	0.96	0.92
20	0.86	0.75	0.51	0.00	0.00	0.00	0.74	1.08	1.03
25	0.89	0.77	0.53	0.00	0.00	0.00	0.78	1.12	1.07
50	0.98	0.84	0.60	0.00	0.00	0.00	0.89	1.22	1.17
75	1.03	0.88	0.64	0.00	0.00	0.00	0.96	1.28	1.22
100	1.07	0.91	0.66	0.00	0.00	0.00	1.00	1.31	1.25
150	1.11	0.94	0.70	0.00	0.00	0.00	1.06	1.37	1.30
200	1.14	0.97	0.72	0.00	0.00	0.00	1.11	1.40	1.34

The Software programme CRESS (Coastal and River Engineering Support System) was utilized to estimate the run-up. This software uses the model for wave run-up on smooth and rock slopes of coastal structures according to (Meer & W., 1993)The estimated wave run-up levels range from 1.27m to 2.57m for the 2 to 100 year hurricanes and were added to the model predicted storm surge results (see Table 5-27).

Table 5-27 Summary of CEAC model predicted storm surge with and without wave run-up for different return periods

Return Period	Predicted storm surge from model without run-up (m)	Predicted storm surge from model with run-up (m)
2	0.57	1.27
5	0.82	1.69
10	0.96	1.94
25	1.12	2.22
50	1.22	2.41
100	1.31	2.57

The CEAC model predictions with run-up are more intense than the reported trends within the immediate area. The CEAC model with run-up was therefore chosen as the benchmark model for use in determining the 10, 25, 50 and 100yr return period storm surge levels for the Palisadoes.

Operational and Swells

Historical wave climate data was obtained from the NOAA weather service database for the period 1999 to 2007 at 3 hour intervals for an offshore node (Easting: 760900.04, Northing: 632921.46). This data was used to generate bi-variant tables for the mean wave heights versus periods as well as the wave height versus direction. The operational wave was then determined as the 50 percent wave occurring at the site whereas the swell waves were estimated by taking the highest 5 percent waves from the bi-variant table.

The analysis determined that operational waves have heights of up to 1.2 m, and periods of 6.5s and direction of 112.5° . The swell waves had a wave height of 2.2 m, a wave period f 8 s and a direction of 202.5°. Please see Figure 5-59 and Figure 5-60 which shows the bi-variant tables generated from the historical data and Table 5-28 and Table 5-29 which shows the incident operational and swell wave data deduced and used in the wave model.

Row Labels	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3	3.2	3.4	3.6	3.8	4	4.2	4.4	4.6	4.8	5.2	5.4	5.8	6	6.2	6.4	6.6	6.8	7		Grand Total
2.5		4	4	1																															9
3	2	28	50	16	5																														101
3.5		1	39	57	9																														106
4	6	30	28	41	57	6	2																												170
4.5	92	122	79	17	47	45	14	3																											419
5	21	219	120	77	35	59	25	8	1																										565
5.5	11	230	527	298	166	81	56	25	4																										1398
6	6	126	562	907	606	277	83	46	15	3			1																						2632
6.5	6	53	278	1020	1516	1129	477	167	48	14	10	3	4																						4725
7	12	29	79	321	919	1629	1167	876	309	96	24	10	6	1	1																				5479
7.5	29	32	23	77	181	527	830	988	722	432	208	42	13	5		1		1	1																4112
8	38	33	10	23	21	81	166	376	434	418	274	95	25	5	3	2					1														2005
8.5	25	24	1	5	3	6	13	58	124	198	249	148	67	33	12	1	2			1				1											971
9	20	8	10	1		2	3	13	20	26	43	17	17	27	11	9	2	2	1	1		1					1								235
9.5	6			1				1	2	2	2	22	16	10	12	3	1				1	1										1			81
10	6	11			1		1	2	6	4	1	1	2	1	1						1				1						1			8	48
10.5	5	7					2					1	1													1									17
11	2																												1						3
11.5																																	1		1
12																														1					1
12.5									1		1			1				1					1					1			2				8
13								1										1		1															3
14						1	1																												2
15			1	1																															2
	5	2	4																																11
Grand Total	**292**	**959**	**1815**	**2863**	**3566**	**3843**	**2840**	**2564**	**1686**	**1193**	**812**	**339**	**152**	**83**	**40**	**16**	**5**	**5**	**2**	**3**	**3**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**3**	**1**	**1**	**8**	**23104**

Figure 5-59 Bi-variant table generated from historical data provided by NOAA for an offshore node. The table presents the wave heights and the corresponding wave periods, and allowed us to deduce the characteristics for the operational and swell occurring at the Palisadoes.

Table 5-28 The wave heights and periods for the operational and swell waves determined from the bivariant table presented in Figure 3-3

	Operational	Swell
Wave Height (m)	1.2	2.2
Wave Period (seconds)	6.5	8

Count of Wave hieght Round	Column Labels																													
Row Labels	**0.2**	**0.4**	**0.6**	**0.8**	**1**	**1.2**	**1.4**	**1.6**	**1.8**	**2**	**2.2**	**2.4**	**2.6**	**2.8**	**3**	**3.2**	**3.4**	**3.6**	**3.8**	**4**	**4.2**	**4.4**	**4.8**	**5.2**	**5.4**	**5.8**	**6.2**	**6.6**	**6.8**	**7**	**Grand Total**
101.25	18	45	117	213	266	356	321	313	252	211	128	52	20	6	8	2				2	1	2								1	2334
112.5	18	55	99	125	155	171	153	142	87	90	73	19	8	1	2	4					1						1				1204
123.75	6	30	61	85	73	77	41	50	33	22	32	14	11	2	1		1	2						1							542
135	8	25	36	48	38	50	32	20	15	9	14	12	6	1		1	1								1						317
146.25	6	16	16	33	30	32	22	13	15	8	6	2	3		1			1										1	1		206
157.5	7	22	23	10	22	27	18	8	4		3	3		2		1			1				1			1					153
168.75	3	13	14	10	5	13	11	2	3	2	1	4	2	2																	85
180	6	10	7	9	4	7	1	2	2			1	1								1										51
191.25	5	9	13	10	5	8	1	3	1				1																		56
202.5	1	12	11	10	4	2	3	2	1			1																			47
213.75	1	11	6	7	3	4	1																								33
225	3	7	7	9	3	4	1				1																				35
236.25	7	12	6	1	1	5		1			1																				34
247.5	2	10	6	5	1	1	1																								26
258.75	2	12	8	6	2	1		2																							33
	8	6	18	15	13	10	3		2	3																					78
Grand Total	**101**	**295**	**448**	**596**	**625**	**768**	**609**	**558**	**415**	**345**	**259**	**108**	**52**	**14**	**12**	**8**	**2**	**3**	**1**	**2**	**3**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**5234**

Figure 5-60 Bi-variant table generated from historical data provided by NOAA for an offshore node. The table presents the wave heights and the corresponding wave directions, and allowed us to deduce the characteristics for the operational and swell occurring at the Palisadoes.

Table 5-29 The wave height and corresponding wave direction for the operational and swell waves determined from the bivariant table presented in Figure 3-4

	Operational	Swell
Wave Height (m)	1.2	2.2
Direction (degrees)	112.5	202.5

Storm Surge

Static storm surge was investigated in the analysis for all major components of storm surge. The phenomena considered were:

- Wave breaking and shoaling
- Wind set-up
- Refraction
- Tides
- Global Sea Level Rise (over a 37 year project life - 2050)
- Inverse Barometric Pressure Rise

For the Caribbean Sea side of the Palisadoes the south-eastern and western profiles were focused on in this analysis as they were the most extreme. The results indicate that the expected 100 Year storm surge is 1.31 meters, see Table 5-30.

Table 5-30 Extremal storm surge predictions for the wave height an wave period along the profile

Return Periods	Wave height (m)								
	All	SW	W	NW	N	NE	E	SE	S
1	2.5	1.5	1.5	0.0	0.0	0.0	1.5	1.5	1.5
2	3.8	3.4	3.5	0.0	0.0	0.0	4.5	4.4	3.9
5	5.1	3.9	4.5	0.0	0.0	0.0	5.5	5.6	5.1
10	6.0	4.2	5.1	0.0	0.0	0.0	6.0	6.2	5.8
20	6.8	4.4	5.6	0.0	0.0	0.0	6.5	6.7	6.4
25	7.1	4.4	5.7	0.0	0.0	0.0	6.6	6.8	6.5
50	7.9	4.6	6.2	0.0	0.0	0.0	6.9	**7.2**	7.0
75	8.4	4.7	6.4	0.0	0.0	0.0	7.1	7.5	7.3
100	8.7	4.7	6.6	0.0	0.0	0.0	7.3	**7.6**	7.5
150	9.1	4.8	6.8	0.0	0.0	0.0	7.4	7.8	7.7
200	9.4	4.8	7.0	0.0	0.0	0.0	7.6	7.9	7.9
Return Periods	**Wave Period (s)**								
	All	SW	W	NW	N	NE	E	SE	S
1	8.0	6.2	6.2	0.0	0.0	0.0	6.2	6.2	6.2
2	9.8	9.3	9.4	0.0	0.0	0.0	10.6	10.5	9.9
5	11.3	9.9	10.6	0.0	0.0	0.0	11.7	11.7	11.3
10	12.2	10.2	11.3	0.0	0.0	0.0	12.2	12.3	12.0
20	13.0	10.5	11.8	0.0	0.0	0.0	12.6	12.8	12.5
25	13.2	10.5	11.9	0.0	0.0	0.0	12.8	13.0	12.7
50	13.9	10.7	12.4	0.0	0.0	0.0	13.1	**13.3**	13.2
75	14.3	10.8	12.6	0.0	0.0	0.0	13.3	13.5	13.4
100	14.6	10.9	12.7	0.0	0.0	0.0	13.4	**13.7**	13.6
150	14.9	10.9	12.9	0.0	0.0	0.0	13.5	13.8	13.8
200	15.2	11.0	13.1	0.0	0.0	0.0	13.6	14.0	13.9

Table 5-31 Extremal storm surge predictions for the wind speed and total setup along the profile

Return Period	Wind speeds (m/s)								
	All	SW	W	NW	N	NE	E	SE	S
1	15.0	NaN	NaN	0.0	0.0	0.0	NaN	NaN	NaN
2	34.5	NaN	NaN	0.0	0.0	0.0	20.1	19.6	17.3
5	46.5	18.6	24.5	0.0	0.0	0.0	24.8	25.4	23.3
10	53.7	21.4	32.5	0.0	0.0	0.0	27.4	29.2	27.4
20	59.9	24.1	40.4	0.0	0.0	0.0	29.6	32.7	31.3
25	61.7	25.0	42.9	0.0	0.0	0.0	30.3	33.7	32.5
50	67.2	27.8	50.7	0.0	0.0	0.0	32.2	37.0	36.2
75	70.2	29.4	55.2	0.0	0.0	0.0	33.3	38.8	38.4
100	72.3	30.6	58.3	0.0	0.0	0.0	34.0	40.0	39.9
150	75.1	32.2	62.8	0.0	0.0	0.0	35.0	41.8	41.9
200	77.0	33.4	66.0	0.0	0.0	0.0	35.7	43.0	43.4
Return Period	Total setup (m)								
	All	SW	W	NW	N	NE	E	SE	S
1	NaN	0.05	NaN	0.00	0.00	0.00	NaN	0.05	0.05
2	0.42	0.40	0.22	0.00	0.00	0.00	0.27	0.57	0.54
5	0.63	0.57	0.35	0.00	0.00	0.00	0.48	0.82	0.78
10	0.76	0.67	0.44	0.00	0.00	0.00	0.61	0.96	0.92
20	0.86	0.75	0.51	0.00	0.00	0.00	0.74	1.08	1.03
25	0.89	0.77	0.53	0.00	0.00	0.00	0.78	1.12	1.07
50	0.98	0.84	0.60	0.00	0.00	0.00	0.89	1.22	1.17
75	1.03	0.88	0.64	0.00	0.00	0.00	0.96	1.28	1.22
100	1.07	0.91	0.66	0.00	0.00	0.00	1.00	1.31	1.25
150	1.11	0.94	0.70	0.00	0.00	0.00	1.06	1.37	1.30
200	1.14	0.97	0.72	0.00	0.00	0.00	1.11	1.40	1.34

Along the harbour side of the project a two-dimensional JONSWAP wind-wave model was used to establish the storm surge over a seven year period (2000 – 2006) for a point just off the Harbour. The model determines wave height and period from fetch, storm duration and depth of water in the generating area; where fetch is the distance into the wind direction from a point of interest to the nearest shoreline[14]. The points chosen in this model provided the greatest fetch for each wind direction (Table 5-32). For this project the waves generated in deep water are fetch limited where:

- $H_{mo} = 0.0016 (F^*)^{1/2}$
- $T^*_p = 0.286 (F^*)^{1/3}$
- And H_{mo} = wave height
- T^*_p = wave period
- F^* = fetch

[14] Kamphuis, J (2002), Introduction to Coastal Engineering and Management, *Advanced Series on Ocean Engineering – Volume 16*

The largest fetch corresponds to a wind angle of 270° and the wave height and period calculations were determined based on this value and presented in Table 5-33.

Table 5-32 Fetch corresponding to wind angle for the Harbour

Angle	Fetch (m)
0	2600
30	2700
60	3500
90	3800
120	3100
150	2300
180	200
210	900
240	1400
260	5600
270	14800
280	14500
300	5000
330	3000

Table 5-33 Results from the JONSWAP method of determining wave height and period based on fetch limited conditions

Wind direction (Degrees)	Wind Speed (m/s)	Fetch (km)	Duration (hr)	Depth (m)	F*	t*	Feff*	Hmo*	Tp*	Hmo (m)	Tp (s)	Setup (m)	RP/yr
270	50.7	14.80	1	10	57	697	32	0.01	0.91	2.38	4.70	0.79	**50**
270	58.3	14.80	1	10	43	606	26	0.01	0.85	2.83	5.04	1.04	**100**

5.2.5.3 Nearshore Wave Climate Analysis (Hurricane, Operational and Swells)

Objectives and Approach

Deepwater water wave data by itself offers limited information on how waves reach the shoreline. It was therefore necessary to determine the nearshore bathymetry and wave climate in order to identify areas of the study area that might be vulnerable to shoreline erosion or direct wave attack and to estimate the impact on the proposed structures.

The approach adopted in order to achieve these objectives was as follows:

- Use the deepwater wave data as input for the analysis.
- Determine the operational, swell and hurricane environments along the Harbour side and Caribbean Sea Side shoreline for pre and post project.
- Determine the impact of climate change along the Harbour side and Caribbean Sea Side Shoreline during operational, swell and hurricane event.
- Prepare a bathymetric database of the project domain for extremal analysis.
- Conduct spatial wave transformation analysis within the study area.

Wave Climate Model: STWAVES

The model considers time-independent advection, refraction shoaling, and wave growth as a function of winds. It is a half-plane model in the sense that it only includes spectral energy directed into the computational grid at the seaward boundary. This version does not include diffraction due to surface-piercing structures or islands. Computationally, the model uses a thin-film approach for land and very shallow regions and solves the model equations at all grid points within the domain. As input, the model requires some basic configuration data, a uniform rectilinear grid, and directional spectra given at the seaward boundary. Due to the nature of the integral solutions for some of the terms, this version of the model requires square (dx = dy) grid spacing. STWAVE is a solution of the steady-state spectral balance equation for wave transformation, and it was written by Dr. Donald T. Resio. It is a finite difference model which considers the propagation, growth and dissipation of spectral energy on a 2-dimensional uniform rectilinear grid.

Modelling Approach and Summary Incident Wave Conditions

The output from the storm surge model used for hurricane impact analysis provided us with the incident wave height and period as well as the water setup for the deepwater extremal analysis. These incident wave heights and periods were then used in the STWAVES model to generate the nearshore wave climate. The spatial patterns of wave breaking and shoaling were noted in relation to the proposed site. Should intense wave focusing be noted, then it would probably be advisable that this be considered in the design of adequate structural engineering provisions. See Table 5-34 and Table 5-35 for a summary of the incident wave conditions used for the analysis. Based on deepwater wave climate and storm surge analysis along with the shape of the shoreline and geographical location of the study area.

Table 5-34 Summary of operational and swell wave heights and periods used to model STWAVES

HARBOUR SIDE				CARIBBEAN SEA SIDE			
OPERATIONAL		SWELL		OPERATIONAL		SWELL	
Hs (m)	Ts (s)	Hs (m)	Ts (s)	Hs (m)	Ts (s)	Hs (m)	Ts (s)
0.2	1.5	0.6	2.5	1.2	6.5	2.2	8

Table 5-35 Summary of hurricane wave heights and periods used to model STWAVES

HARBOUR SIDE				CARIBBEAN SEA SIDE			
50 YEAR		100 YEAR		50 YEAR		100 YEAR	
Hs (m)	Ts (s)	Hs (m)	Ts (s)	Hs (m)	Ts (s)	Hs (m)	Ts (s)
2.38	4.70	2.83	5.04	7.2	13.3	7.6	13.7

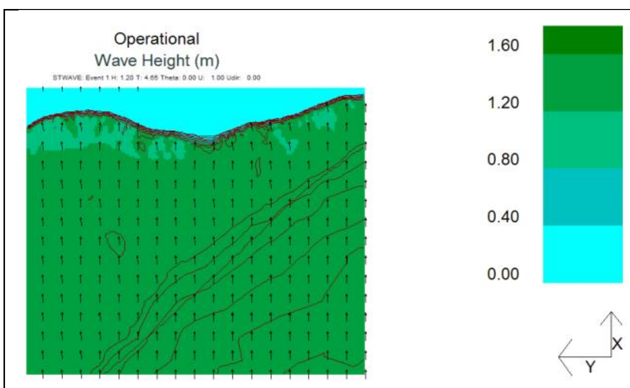
Caribbean Sea Side

The model was calibrated to run operational, swell and hurricane waves for the E, SE, S, SW and W directions. The existing shoreline was modelled first to better understand the areas which are most vulnerable as well as to estimate the magnitude of wave heights reaching the shoreline based on the wave predictions. The model showed that the S and SE directions had the greatest impact on the shoreline during operational, swell and hurricane conditions.

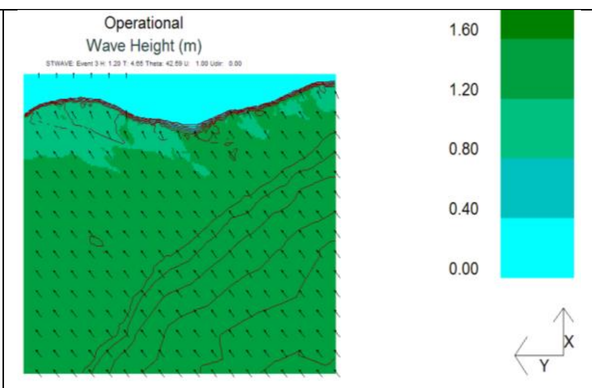
Operational Waves – Caribbean Sea Side

The model showed that the shoreline under operational conditions may experience wave heights ranging from 0.7 to 1.2 m from the S and SE directions. Table 5-36 which shows the waves generated during operational conditions.

Table 5-36 STWAVES Caribbean Sea side resultant plots of operational waves for the S and SE directions



South (S)

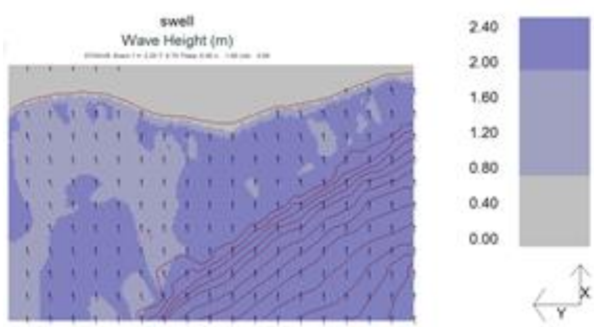
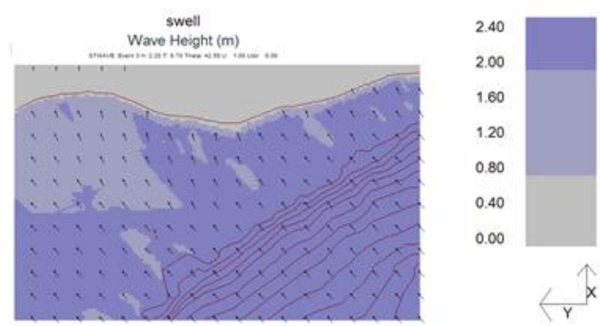


South East (SE)

Swell Waves – Caribbean Sea Side

It was also important to look at the swell wave climate to understand the impact on the existing shoreline and to design shoreline protective structures which can withstand these scenarios. The model showed that the shoreline under swell wave conditions may experience wave heights ranging from 0.8 to 2.0 m from the south and southeast direction. Table 5-37 shows the waves generated due to swells. It is evident that the eastern and central portions of Palisadoes experience more significant wave heights (0.8 to 1.6 meters) than the western sections (0.4 and 0.8 meters). This speaks to the increased vulnerability of the dune at Harbour View side versus NMIA end.

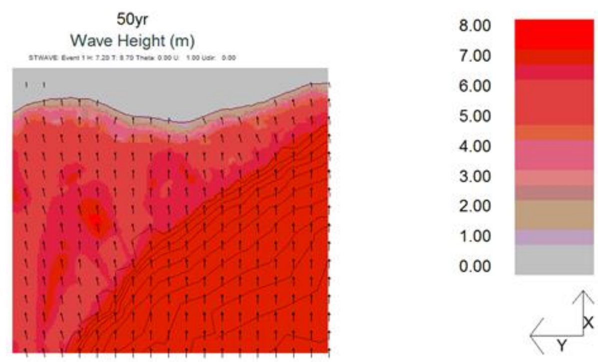
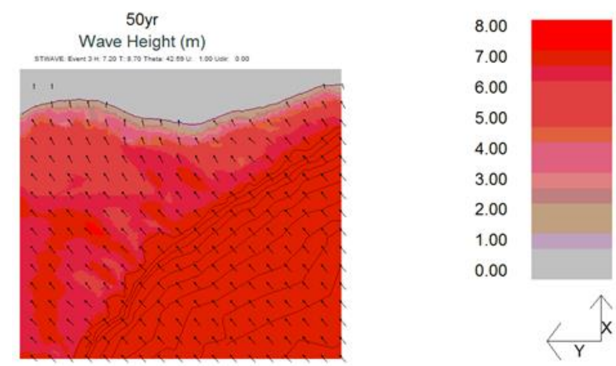
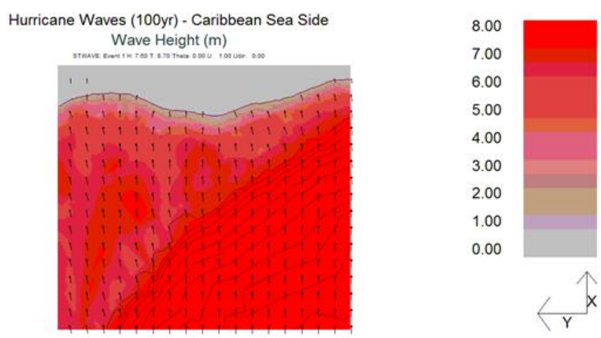
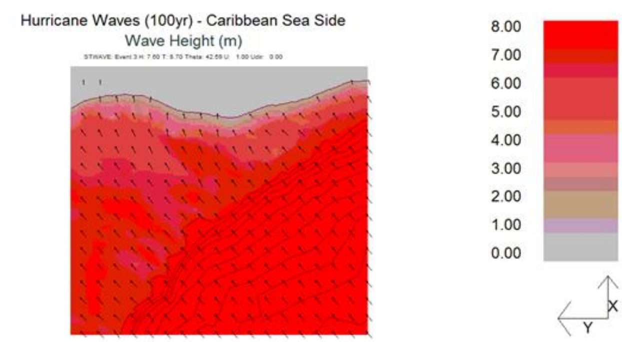
Table 5-37 STWAVES Caribbean Sea side resultant plots of swell waves for the S and SE directions

 South (S)	 South East (SE)

Hurricane Waves – Caribbean Sea Side

It is also important that hurricane winds generated waves are modelled and investigated. During a storm event there will be wave setup, and so a water set up elevation of 1.22 and 1.31 m were added to the simulation for the 50 and 100 year return period respectively. These elevations were obtained from the storm surge model discussed in an earlier section of the report. The wave plots generated from the model showed that during hurricane conditions wave heights of 2.0m and 3.0 m reach the shoreline for the 50 and 100 year return period respectively. Table 5-38 shows the waves generated due to hurricane waves.

Table 5-38 STWAVES Caribbean Sea side resultant plots for hurricane waves from the S and SE direction

 50 year- South (S)	 50 year - South East (SE)
 100 year- South (S)	 100 year - South East (SE)

DISCUSSION

The wave refraction analysis clearly indicates the vulnerability of the shoreline from waves approaching from the south and south east directions, particularly along the eastern section of the Palisadoes. In all scenarios, 7 to 8 m waves are expected some 2.5 km offshore and 2 to 4 m waves are expected at the shoreline during storm events..

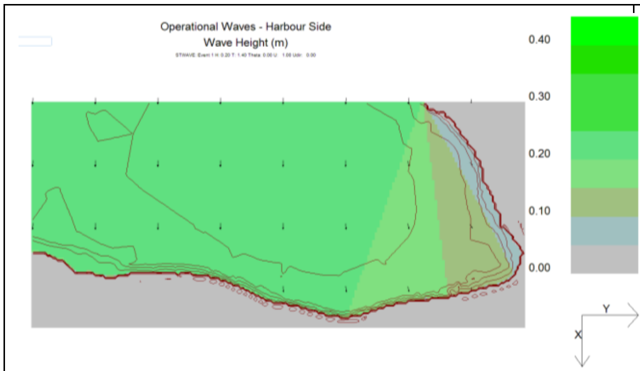
Harbour Side

The model was calibrated to run operational, swell and hurricane waves from W, NW, N, NE and E directions. The existing shoreline was modelled first to better understand the areas which are most vulnerable as well as to estimate the magnitude of wave heights reaching the shoreline based on the wave predictions. The model showed that the N and NW directions had the greatest impact on the shoreline during operational, Swell and hurricane conditions. See Table 5-39.

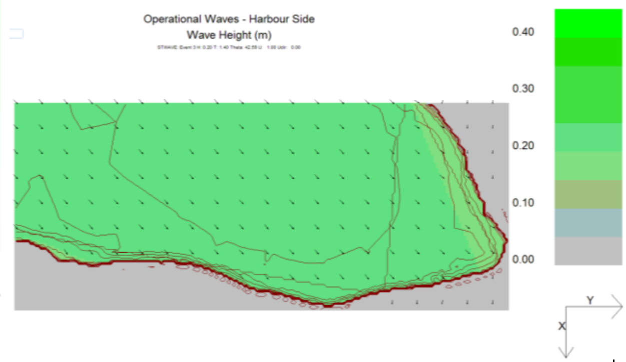
Operational Waves – Harbour Side

The model showed that the shoreline under operational conditions may experience wave heights ranging from 0.1 to 0.2 m from the N and NW directions. The model predicts the largest waves (0.2m) to impact the shoreline occurring from the NW direction. Table 5-39 which shows the waves generated during operational conditions.

Table 5-39 **STWAVES Harbour side resultant plots of operational waves for various directions**



N

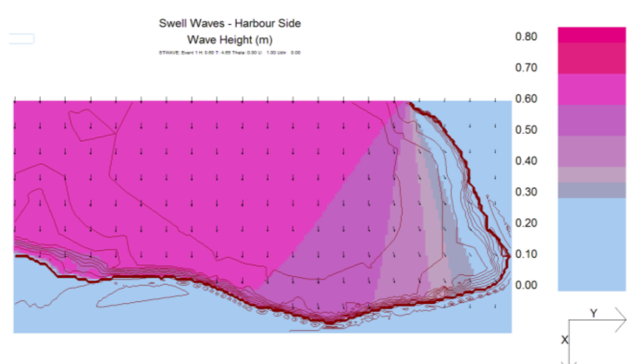


NW

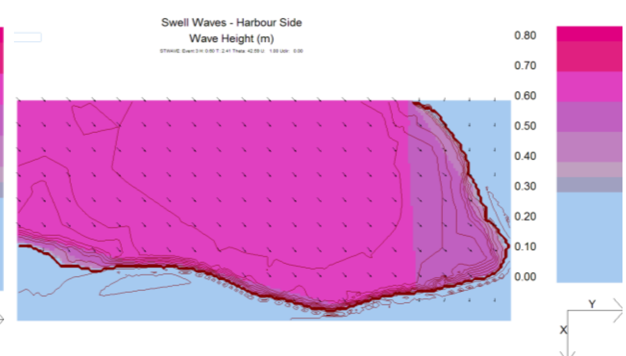
Swell Waves – Harbour Side

It was also important to look at the swell wave climate so as to understand the impact on the existing shoreline and to design shoreline protective structures which can withstand these scenarios. The model showed that the shoreline under operational conditions may experience wave heights ranging from 0.2 to 0.6 m from the N and NW directions. The model predicts the largest waves (0.6m) to impact the shoreline occurring from the NW direction. Table 5-40 which shows the waves generated during operational conditions.

Table 5-40 **STWAVES Harbour side resultant plots of swell waves for various directions**



N

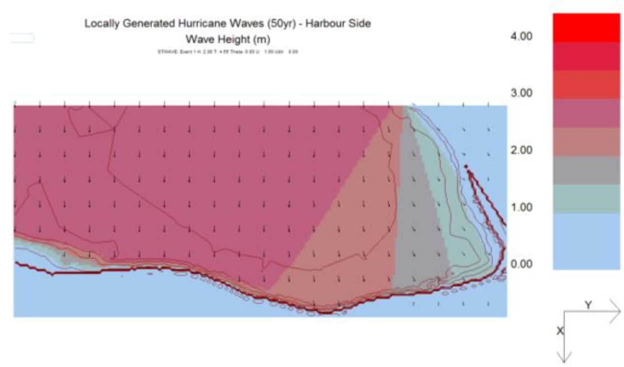
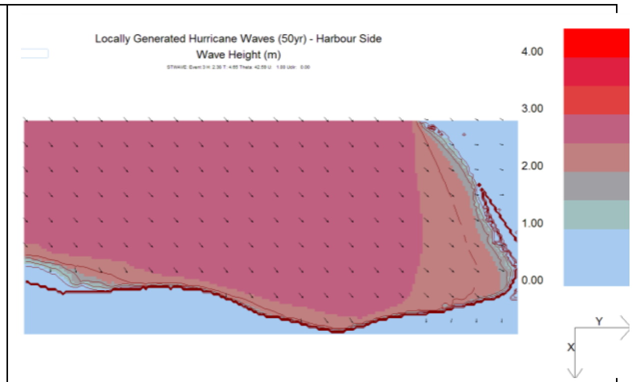
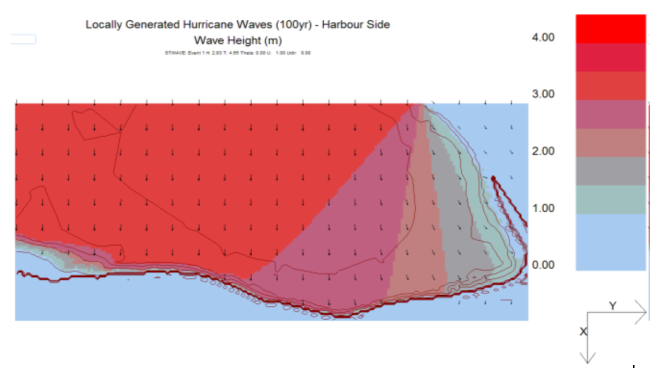
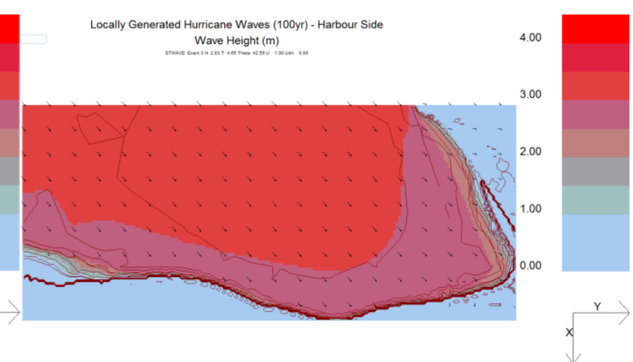


NW

Hurricane Waves – Harbour Side

It is also important that hurricane winds generated waves are modelled as well, these can cause the most damage to the beach. During a storm event there will be wave setup, hence a water set up elevation of 0.74 and 0.98 m were added to the simulation for the 50 and 100 year return period respectively based on the storm surge model results. The model showed that the shoreline under hurricane conditions may experience wave heights ranging from 1 to 2 m from the N and NW directions for the 1 in 50 year event. The 1 in 100 year event showed wave heights ranging from 2 to 2.5 meters reaching the shoreline from the N and NW directions. The model predicts the largest waves impacting the shoreline occurring from the NW direction for both return periods. See Table 5-41 which shows the waves generated during operational conditions.

Table 5-41 STWAVES Harbour side resultant plots of hurricane waves for various directions

 N-50 yr.	 NW – 50 yr.
 N - 100 yr.	 NW – 100 yr.

DISCUSSION

The wave refraction analysis clearly indicates the vulnerability of the shoreline from waves approaching from the N and NW directions. Under existing conditions 2.5 m waves are expected approximately 1 km offshore and under storm conditions 1.5 to 3 m waves are expected at the shoreline. The central to Western end of the shoreline is more vulnerable to wave attacks as the model predicts larger wave heights reaching these sections of the shoreline from the directions modelled.

5.2.6 Shoreline Vulnerability Modelling

5.2.6.1 Long-term Shoreline Change

The shoreline positions along the Palisadoes shore were plotted from 1977 to 2012 and compared in order to determine the long-term spatial and temporal erosion trends across the shore. This was important in order to identify the actual erosion hotspots that might require stabilization and in order to verify wave transformation modelling.

Methodology

The overall long-term erosion trend was estimated by observing:

1. Actual long-term shoreline positions from dated aerial photography and Google Earth imagery – Historical Shoreline Analysis;
2. The global sea level rise component to determine the erosion that was due to chronic global trends versus event based erosion events (i.e. hurricanes and swell events) – Bruun Model.

Rate of Change Assessment

HISTORICAL SHORELINE ANALYSIS

Figure 5-64 shows the available satellite imagery (December 2012) over which the observed shorelines from Google Earth and aerial imagery for the years 1977,1991,2002, 2006, 2009 and 2012.The rates of accretion and or erosion between the time intervals and the overall time interval were determined using the following relationship:

$E_y^1 = \frac{D}{N}$, where

E = the rate of erosion or accretion between two successive intervals (metres per year)
D = the displacement between two intervals (metres)
N = the number of years between two successive intervals (years)

And

$E_y^0 = \frac{D_T}{N_T}$, where

E_y^0 = the rate of erosion or accretion from the datum year to the final interval
D_T = the displacement from the datum to the final interval
N_T = the number of years from datum year to final interval

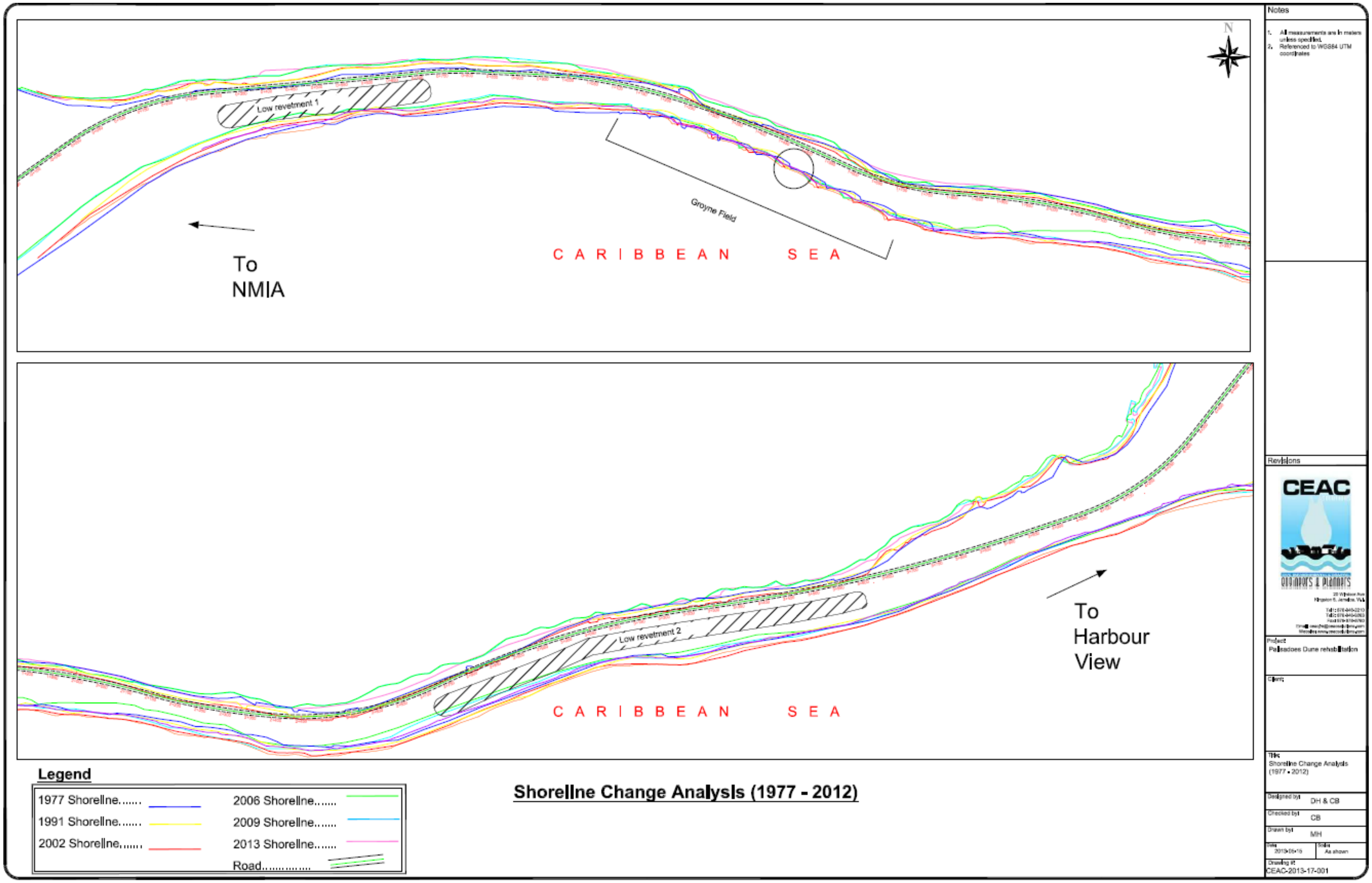


Figure 5-61 Shoreline plots between 1977 and 2013 about the 1968 section for the western section of the Palisadoes closest to the NMIA roundabout (top) and eastern section of the Palisadoes closest to the Harbour View roundabout (bottom)

RESULTS

The shoreline analysis was done for the 5km coastline taking note of certain areas of interested namely behind the buried revetments and in the groyne field. A summary of the analysis data is shown in Table 5-42. Figure 5-64 shows a plot of the shoreline movement over the period, it indicates that there has been a general trend of accretion along the Palisadoes shoreline.

The trends observed for the locations of interest are as follows:

Low revetment 1 (0 +200 to 0+600)

- The shoreline show trends of both erosion and accretion between the years 1977 and 2012.
- The highest rate of erosion of 3.9m/year was observed between 2002 and 2006, and this is expected because hurricane Ivan occurred in 2004 and caused severe damage to the shoreline.
- The highest accretion rate of 10.7 m/year was observed between 2009 and 2012.

Low revetment 2 (2 +600 to 3+400)

- The shoreline shows trends of accretion between the years 1977 and 2012 except for between 2002 and 2006 where erosion was observed following the passage of hurricane Ivan.
- The highest rate of erosion of 8.1 m/year was observed between 2002 and 2006, while the highest accretion rate of 10.1 m/year was observed between 2009 and 2012.

Groyne Field (1 +200 to 1+600)

- The shoreline show trends of both erosion and accretion between the years 1977 and 2012.
- The highest rate of erosion of 2.1m/year was observed between 2002 and 2006, while the highest accretion rate of 4.1 m/year was observed between 2009 and 2012.

Hurricane Trends (2002 to 2006)

- Hurricane Ivan was the most significant event in the over thirty years of shoreline observations. Whilst the overall trend was an accreting trend the mode during this period was obviously erosion.
- During the period 2002 to 2006 the entire shoreline eroded by an annual rate of -3.7 to -4.3 meters per annum.
- The estimated impact of the hurricane on the shoreline was a 16 meters erosion of the shoreline with a range of 4 to 26 meters.

General Trends

- The shoreline shows general trends of accretion occurring between 1991 and 2002. The rate of accretion varied between 0.3 m/year and 1.8 m/year.
- High levels of erosion were observed ranging from 1.5 m/year and 8.1 m/year and occurring between 2002 and 2006 following the passage of hurricane Ivan in 2004.
- The shoreline shows trends of accretion between 2009 and 2012 at rates between 0.8 m/year and 10.7 m/year.
- An overall trend of accretion was observed for 80% of the shoreline at rates between 0.1 m/year and 0.6m/year. The remaining 20% was observed to be eroding at rates between 0.04 m/year and 0.4 m/year

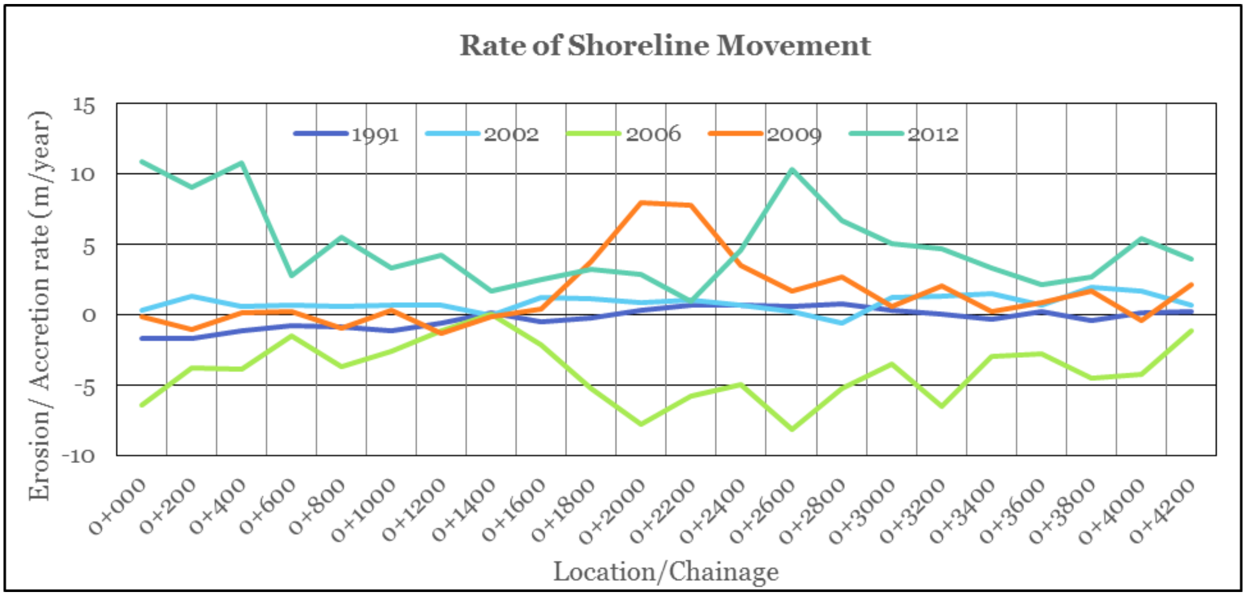


Figure 5-62 Graph showing the rates of erosion/ accretion for the shoreline about the 1968 shoreline for different time intervals between 1991 and 2013. Erosion occurred between 2002 and 2006 because of the passage of hurricane Ivan.

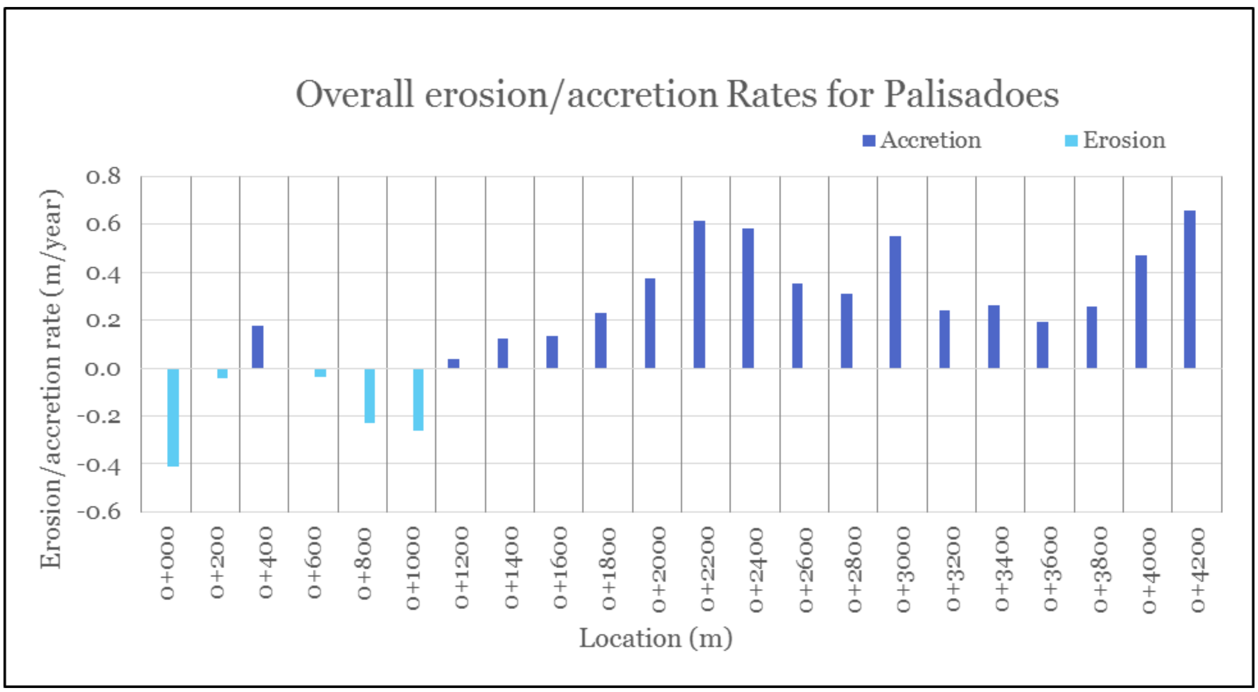


Figure 5-63 Graph showing the overall displacements of the shoreline about the 1968 shoreline for Palisadoes between 1991 and 2013. This graph indicates that the Palisadoes is in accretion mode

Table 5-42 Summary of the displacements of the shoreline for 1991, 2002, 2006, 2009 and 2012 about the 1977 shoreline at 200m intervals

		1991		2002		2006		2009		2012		Overall	
Location		*Process*	*Accretion/ Erosion Rate (m/year)*	*Process*	*Accretion/ Erosion Rate (m/year)*	*Process*	*Accretion/ Erosion Rate (m/year)*	*Process*	*Accretion/ Erosion Rate (m/year)*	*Process*	*Accretion/ Erosion Rate (m/year)*	*Process*	*Rate (m/year)*
	0+000	erosion	-1.689	accretion	0.278	erosion	-6.488	erosion	-0.153	accretion	10.870	erosion	-0.411
Buried Revetme	0+200	erosion	-1.746	accretion	1.320	erosion	-3.848	erosion	-1.113	accretion	9.037	erosion	-0.044
	0+400	erosion	-1.169	accretion	0.535	erosion	-3.940	accretion	0.097	accretion	10.730	erosion	-0.196
	0+600	erosion	-0.795	accretion	0.664	erosion	-1.523	accretion	0.177	accretion	2.690	erosion	-0.251
High Revetment 1	0+800	erosion	-0.918	accretion	0.586	erosion	-3.762	erosion	-0.983	accretion	5.430	erosion	-0.384
	1+000	erosion	-1.170	accretion	0.651	erosion	-2.650	accretion	0.297	accretion	3.257	erosion	-0.497
	1+200	erosion	-0.665	accretion	0.613	erosion	-1.150	erosion	-1.367	accretion	4.180	erosion	-0.018
	1+400	accretion	0.069	erosion	-0.095	erosion	-0.038	erosion	-0.140	accretion	1.630	erosion	-0.063
	1+600	erosion	-0.558	accretion	1.155	erosion	-2.190	accretion	0.380	accretion	2.473	accretion	0.020
	1+800	erosion	-0.281	accretion	1.106	erosion	-5.285	accretion	3.753	accretion	3.213	accretion	0.000
	2+000	accretion	0.246	accretion	0.813	erosion	-7.852	accretion	7.903	accretion	2.810	accretion	0.088
	2+200	accretion	0.604	accretion	0.965	erosion	-5.838	accretion	7.700	accretion	0.883	accretion	0.233
	2+400	accretion	0.648	accretion	0.653	erosion	-4.993	accretion	3.480	accretion	4.553	accretion	0.168
Buried Revetment 2	2+600	accretion	0.511	accretion	0.206	erosion	-8.183	accretion	1.657	accretion	10.240	erosion	-0.195
	2+800	accretion	0.764	erosion	-0.630	erosion	-5.253	accretion	2.687	accretion	6.660	erosion	-0.136
	3+000	accretion	0.284	accretion	1.153	erosion	-3.518	accretion	0.580	accretion	4.990	accretion	0.083
	3+200	accretion	0.041	accretion	1.291	erosion	-6.580	accretion	2.010	accretion	4.613	erosion	-0.041
	3+400	erosion	-0.352	accretion	1.428	erosion	-3.015	accretion	0.207	accretion	3.297	erosion	-0.036
High Revetment 2	3+600	accretion	0.176	accretion	0.599	erosion	-2.798	accretion	0.823	accretion	2.133	erosion	-0.066
	3+800	erosion	-0.444	accretion	1.875	erosion	-4.575	accretion	1.660	accretion	2.653	erosion	-0.131
	4+000	accretion	0.074	accretion	1.597	erosion	-4.245	erosion	-0.487	accretion	5.413	erosion	-0.915
	4+200	accretion	0.188	accretion	0.665	erosion	-1.208	accretion	2.070	accretion	3.907	accretion	0.001

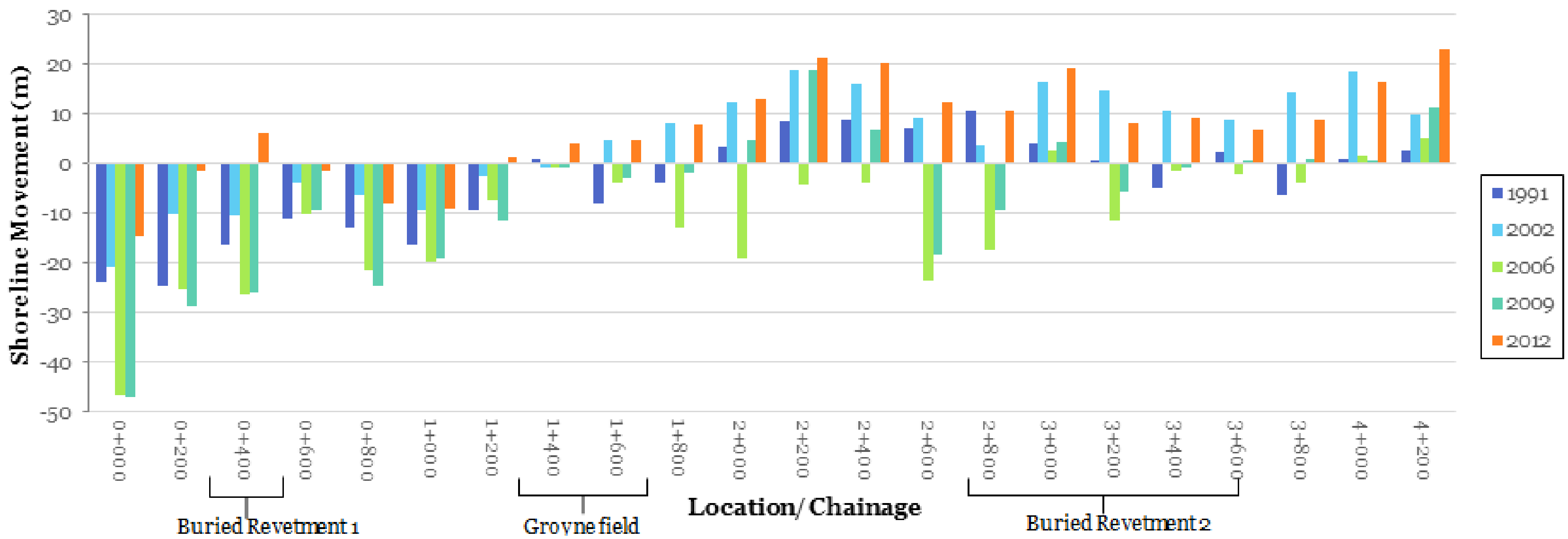


Figure 5-64 Graph showing the displacements of the shoreline for different years about the 1977 shoreline for Palisadoes (1991 to 2012)

Future Shoreline Projections without Project

RELATIVE IMPACT OF SEA LEVEL RISE (SLR) VERSUS EXTREME EVENTS

The Bruun model is perhaps the best-known and most commonly used of the models that relate shoreline retreat to sea level rise. This two-dimensional model assumes an equilibrium profile. Thus, it inherently assumes that the volume of sediment deposited is equal to that eroded from the dunes and that the rise in the nearshore bottom as a result of the deposited sediment is equal to the rise in sea level.

The original Bruun model is expressed below and this mathematical relationship was the basis for estimating shoreline retreat within the study area.

$$\Delta y = \frac{\Delta s \cdot l*}{h*}$$

Where:

Δ y – Dune line erosion (meters/ year)

Δ s – Rate of sea level rise (meters/ year)

$l*$ – Length of the offshore profile out to a supposed depth, $h*$, of the limit of material exchange from the beach and the offshore (meters)

$h*$ – Depth at offshore limit, $l*$, to which near shore sediments exist (as opposed to finer- grained continental shelf sediments) (metres)

Rate of SLR, Δ s

Inspection of research in this area revealed that global sea level has risen as a result of greenhouse gas-induced global warming. Indeed, there will be regional variation in the sea level rise signal, and for this reason regions may undertake sea-level rise scenario modelling, which takes into account various factors such as land movement and region-specific oceanographic data.

For the purposes of this project, a simple scenario, based on one estimate of sea level rise will be utilized (not taking into account any vertical tectonic movements of the shoreline or any discernible change in the ocean geodynamic surface). Typically, a mid-range or upper estimate is chosen for such types of scenarios (A1B scenario from IPCC). The Intergovernmental Panel on Climate Change's (IPCC) Special Report on Emissions Scenarios (SRES) project global and Caribbean mean sea level to rise by on average 0.37 m by 2100 relative to 1980 – 1999 and so it was considered for the calculations, and specially the upper limit of this range.

Sea-level rise was projected to the year 2099, as the project life was chosen to be 2050 years. Using the upper limit value of 6 cm by 2050 allowed this analysis to test whether the Palisadoes is vulnerable to a plausible upper limit of climate change and simultaneous storm-induced short-term erosion for the 100-year return period.

Length of Offshore Profile, $l*$

The calculated critical depth (or $h*$) was used to estimate the length of the offshore profile. This was done by inspecting bathymetric data for both the Caribbean sea and harbour side of the Palisadoes and obtaining profile lengths for the corresponding critical depth. These profile lengths obtained were incorporated into the Bruun Model.

Depth to which Nearshore Sediments exist, $h*$

A beach profile has a practical seaward limiting depth, where the wave conditions can no longer change the profile. Sand may move back and forth along this equilibrium profile, but there is no perceptible change in depth. This seaward limiting depth is equivalent to the depth at which nearshore sediments exist ($h*$). Hallermeier (Hallermeier, 1981 in Kamphuis, 2000) refers to this depth as the critical or closure depth (d_c), and approximates it using the equation below:

$$d_c = 1.6H_{s,12}$$

Where:

$H_{s,12}$ – Significant wave height which occurs 12 hrs/yr on average

It was therefore necessary to determine the operational wave climate within the study area. Long term wave data available for the Palisadoes was analysed to determine the 12 hour wave ($H_{s,12}$) and it was determined that $H_{s,12}$ is a 2.2 m swell wave for the Caribbean sea side.

Calculation and Results

Table 5-43 shows the calculation of the long term trends expected in 25 and 50 years along the coast. As seen in this table, the following input values were incorporated into the Bruun Model to arrive at an estimate for the long-term erosion trend at each of the 3 profile shoreline positions:

- Rate of sea-level rise = 0.0037 m/yr (IPCC 2007)
- Depth to which nearshore sediment exists ($h*$, d_c) = 3.5 m
- The offshore profile lengths were found to be approximately 200m

It should be emphasized here that the results of these calculations are an estimate of the projected shoreline retreat using a simplistic approach with an upper limit of global sea level rise. Indeed, the changes in beach profile over the years may have been impacted by the annual sea level rise as well as operational and storm-induced erosion estimated. This estimation of the sea level rise will assist in the determination of the true impacts that are due to operational a storm induces erosion.

The shoreline along the study area was estimated to retreat at a rate of 0.21 metres per year as a result of global sea level rise.

Table 5-43 Estimation of long-term erosion trends for Palisadoes using Bruun Model

Parameter	Profile		
	Low Revetment 1	Groyne field	Low Revetment 2
Chainage	0+500	1+400	3+000
Rate of sea level rise, Δs (m/yr)	0.0037	0.0037	0.0037
Offshore profile, l* (m)	200	200	200
Depth of offshore limit, h* (m)	3.52	3.52	3.52
Dune line Erosion, Δy (m)	0.21	0.21	0.21
Projected change/erosion in 25 years (m)	5.26	5.26	5.26
Projected change/erosion in 50 years (m)	10.51	10.51	10.51

DISCUSSION AND COMPARISON OF RESULTS

The historical model shows a general trend of accretion of about 0.35 meters per year, for the period between 1991 and 2013, except for between 2002 and 2006.The significant erosion observed can be attributed to the passage of Hurricane Charley (August 2004) and Hurricane Ivan (September 2004). Both hurricanes passed to the south of the island with Charley being a category 1 and Ivan category 4 at the time of passing.

The Bruun model, even though it deals specifically with erosion due to sea level rise, can still be applied to our case of general accretion. This means that even though the coastline is accreting, the rate at which it is growing is reduced by the effect of sea level rise. According to the Bruun model the rate of shoreline change for the Palisadoes is 0.21 m/year while the historical analysis determined an overall accretion rate of between 0.1 m/year and 0.6m/year for 80% of the shoreline, and the remaining 20% was observed to be eroding at rates between 0.04 m/year and 0.4 m/year rate.

LIMITATIONS

Both methods of estimating long term erosion trends have their own imitations. For the Brunn method, estimating long-term erosion trends as result of global sea level rise was not the main focus of this section. Given the anecdotal information in the area, it was important to know how the area is affected by long term and short term weather/climate events.

While for the historical model, the maps obtained were only snapshots at a moment in time that cannot be manipulated to show years or times of interest (such as immediately before and after the hurricanes). Therefore some of the maps may be displaying short term shoreline configurations while others long term. The accuracy of the rates is therefore subjected to the use of more Arial photos at strategic times which cannot be sourced.

COMPARISON TO OTHER BEACHES ACROSS JAMAICA

It was possible to compare the observations for Palisadoes to that of nine other beaches across Jamaica. A report provided by CEAC Solutions[15] determined if there was an underlying erosion pattern across Jamaica and estimated the risk associated. Specifically, nine beaches were analysed to

[15] C. Burgess, C. Johnson, Shoreline Change in Jamaica: Observations for the period 1968 to 2010 and Risks for up to 2060

determine their historical erosion rate and the influence of sea level rise versus storm induced erosion: Plumb Point, Long Bay (Portland), San San, Fort Clarence, Old Harbour Bay, Little Ochi, Priory, Annotto Bay and Long Bay Beach (Negril).

Short-term analysis revealed that eight of the nine beaches experienced short-term erosion varying between 0.1 to 0.52 metres per year. Only Little Ochi beach in St. Elizabeth exhibited accretion of the shoreline, see Table 4-4. The average short-term erosion rate observed was 0.26 metres per annum. Long-term shoreline retreat rates were observed to vary between 0.17 to 0.76 metres per annum, with an average of 0.26 metres per annum. The fastest eroding beaches were observed to be the Long Bay Beach (Negril) at 0.76 metres per annum followed by the Old Harbour Bay (St. Catherine) at 0.74 metres per annum. While the slowest eroding beaches were Annotto Bay (St. Mary) at 0.08 m/ yr, and Priory (St. Ann) at 0.10 m/yr followed by Plumb Point (Kingston) at 0.19 m/yr. Plumb Point is 2 km from the Palisadoes project and the erosion rate determined in this study (0.19 m/yr) compares favourably with the erosion rate determined by the Bruun Method (0.21 m/yr), the historical shoreline analysis however, determine a general accretion trend for 80% of the shoreline between 0.04 – 0.4 m/yr.

It is evident that the Palisadoes shoreline is accreting whilst just downstream at Plumb Point there is underlining erosion. Likewise, what is happening at Palisadoes is relatively unique (but similar to Little Ochi/Alligator Pond) where accretion is underway. It is therefore likely that localized processes with spatial variations of accretion and erosion are underway for the project, against a backdrop of island wide erosion. In light of these uncertainties it is recommended that monitoring be emphasized.

Table 5-44 Summary of analysis for the 9 beaches selected for the period 1968 to 2010

Beaches	Short-term rate of shoreline loss (m/ yr)	Long-term rate of shoreline loss (m/ yr)	Length of beach	Interval between profile (m)	No. of profiles used	Location/ Parish
Long Bay	-0.52	-0.36	1400	200	8	Portland
Priory	-0.10	-0.08	1000	200	11	St Ann
Fort Clarence	-0.48	-0.42	1250	250	4	St Catherine
Old Harbour Bay Fishing Beach	-0.59	-0.74	1000	200	6	St Catherine
Little Ochi	0.57	0.61	3000	500	4	St Elizabeth
Negril	-0.56	-0.76	5000	500	6	Westmoreland
Annotto Bay	-0.08	-0.25	3633	200	7	St Mary
San San	-0.38	-0.17	1600	500	8	Portland
Plumb Point, Palisadoes	-0.19	-0.21	1200	200	8	Kingston
Overall average	**-0.26**	**-0.26**				

5.2.6.2 Alongshore Sediment Transport Regime

Sediments in the near shore are susceptible to movements in the direction of the shoreline or alongshore due to waves arriving at the shoreline at an angle less than ninety degrees. It was therefore necessary to investigate the long-term shoreline trends due to the operational, swell and hurricane wave climate in the near shore to determine the ideal areas placing the sand dunes and for replanting the mangroves.

Model Description and Development

The tool used for investigating the long term shoreline change was the Genesis model developed by the US army Corps. This Generalized Model for Simulating Shoreline Change simulates the long-term platform evolution of the beach in response to imposed wave conditions, coastal structures, and other engineering activity (e.g., beach nourishment). The region modelled was the Harbour Side and Caribbean Sea side Shoreline along the Palisadoes see Figure 5-65.

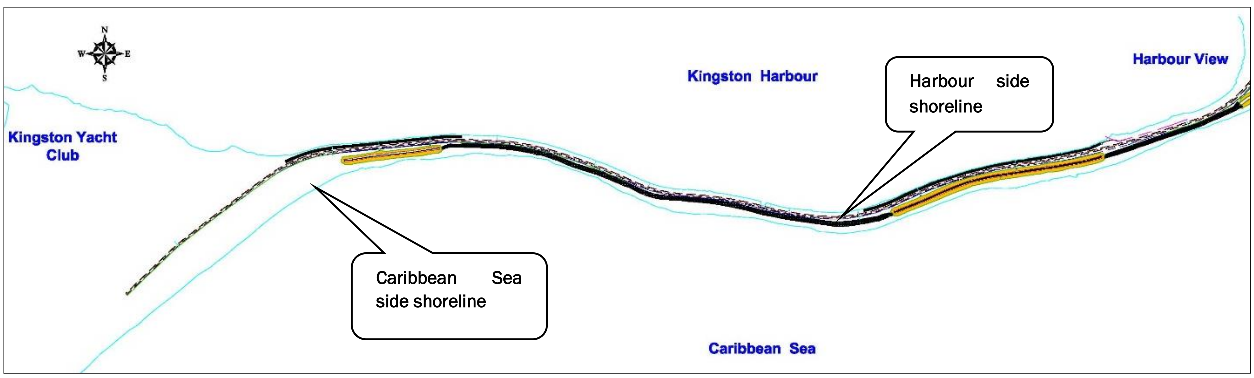


Figure 5-65 Shoreline locations used in the Genesis model

Wave Climate Input, Calibration and Verification

WAVE DATA

The most recent and complete annual wave data available for the Caribbean Sea and the Harbour side was for 2006. Wave data documented at three hour intervals were used to run the model, for the period 2000 through 2006 see Figure 5-66 and Figure 5-67.

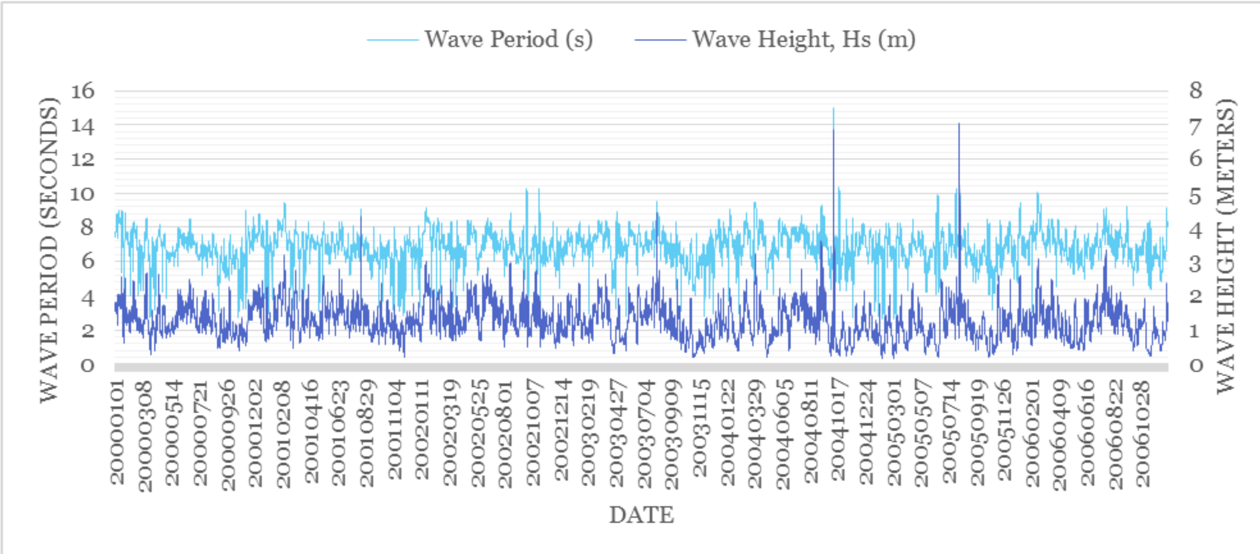


Figure 5-66 NOAA grib wave data for 2000 - 2006 that was used in sediment transport modelling for the Caribbean Sea side

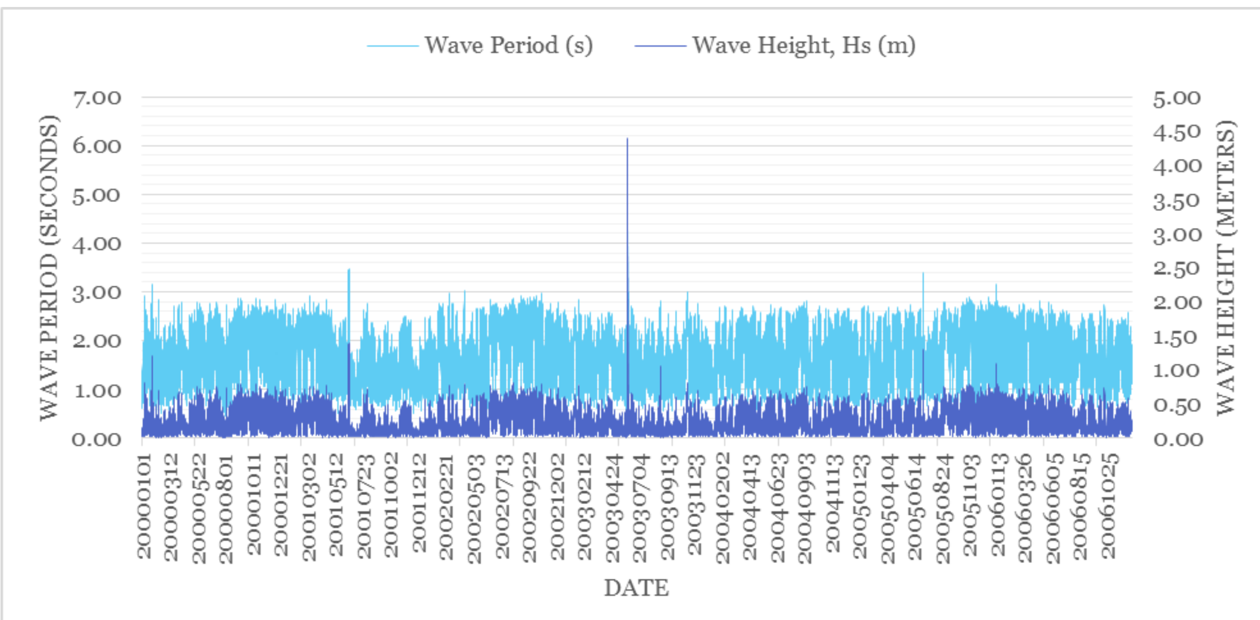


Figure 5-67 NOAA grib wave data for 2000 - 2006 that was used in sediment transport modelling for the Harbour Side

INITIAL SETUP

The shoreline and bathymetry were defined as XYZ points and imported to setup the files required to run GENESIS. The operational, swell and hurricane wave data for a point offshore the Caribbean Sea Side and Harbour side Shoreline of the Palisadoes was obtained from the NOAA grib database for

2000 to 2006 (see Figure 5-66 and Figure 5-67 above) and implemented within the model to simulate the beach platform. An effective grain size of 0.3 and 1.1 mm determined from the sand sieving exercise conducted and used in the model for the Caribbean Sea Side and Harbour side respectively.

CALIBRATION

Caribbean Sea Side

The model was calibrated based on movement of the Caribbean Sea side's shoreline observed from Google Earth and aerial imagery for the years 2000 and 2006 as outlined in previous sections of this report, and during this period there was a major storm event (hurricane Ivan, 2004). The calibration run (with long shore sand transport calibration coefficients parameters K1 = 0.15 and K2 = 0.075) was able to predict similar shoreline movement along the Caribbean Sea side Shoreline. The model's prediction is in line with observations even though the model, albeit slightly more conservative, and it was decided that this was sufficient to give accurate pre dictions. See Figure 5-68 below.

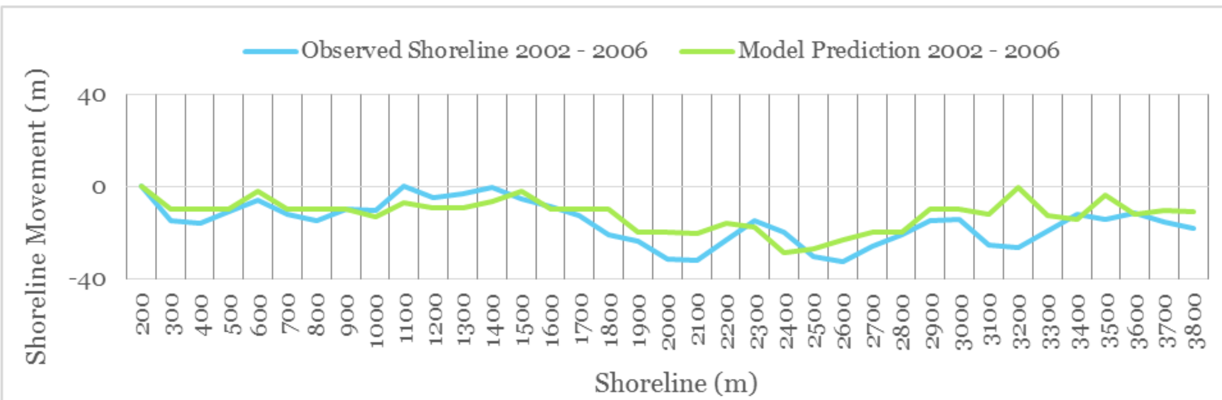


Figure 5-68 Calibration plots for the observed accretion patterns along the Harbour Side Shoreline in comparison to the models (Genesis) predication.

Harbour Side

The model was calibrated based on current accretion pattern along the Harbour side shoreline as observed and measured by CEAC Solutions. The calibration run (with long shore sand transport calibration coefficients parameters K1 = 0.75 and K2 = 0.375) was able to predict similar accretion patters along the Harbour side shoreline. The model's predation is in line with observations of accretion (post the shoreline project in 2012) and historical where mangrove grew in significant patches. It was decided that this was sufficient to give accurate predictions. See Figure 5-69 below.

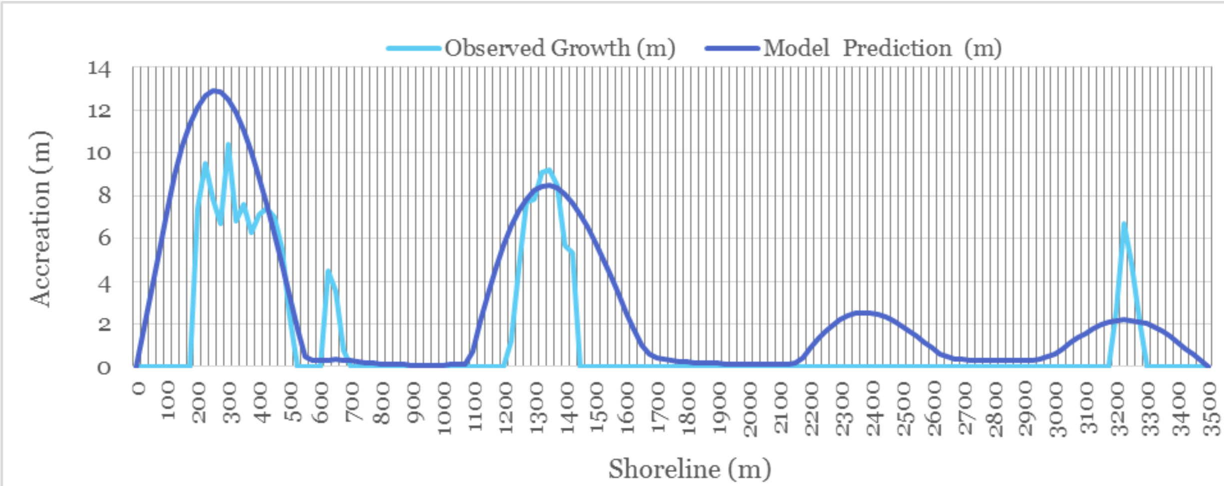


Figure 5-69 Calibration plots for the observed accretion patterns along the Harbour Side Shoreline in comparison to the models (Genesis) predication.

Results

CARIBBEAN SIDE

The pre- project/existing Caribbean Sea side scenario revealed that the shoreline modelled is in erosion mode, resulting in a total volumetric loss of 647,000 m^3 in numerical simulations for the period 2000 to 2006. The model predicts that the central and eastern section of the Caribbean Sea side is more vulnerable to erosion with erosion widths of 20 to 30 m respectively. The average erosion along the shoreline is predicted to be 12 m in width. This correlates with the observations of 3.7 to 4.3 meters per annum over the four year period of 2002 to 2006. The total average erosion was 16 meters that is slightly larger than the model predictions for the same period with the intense hurricane Ivan.

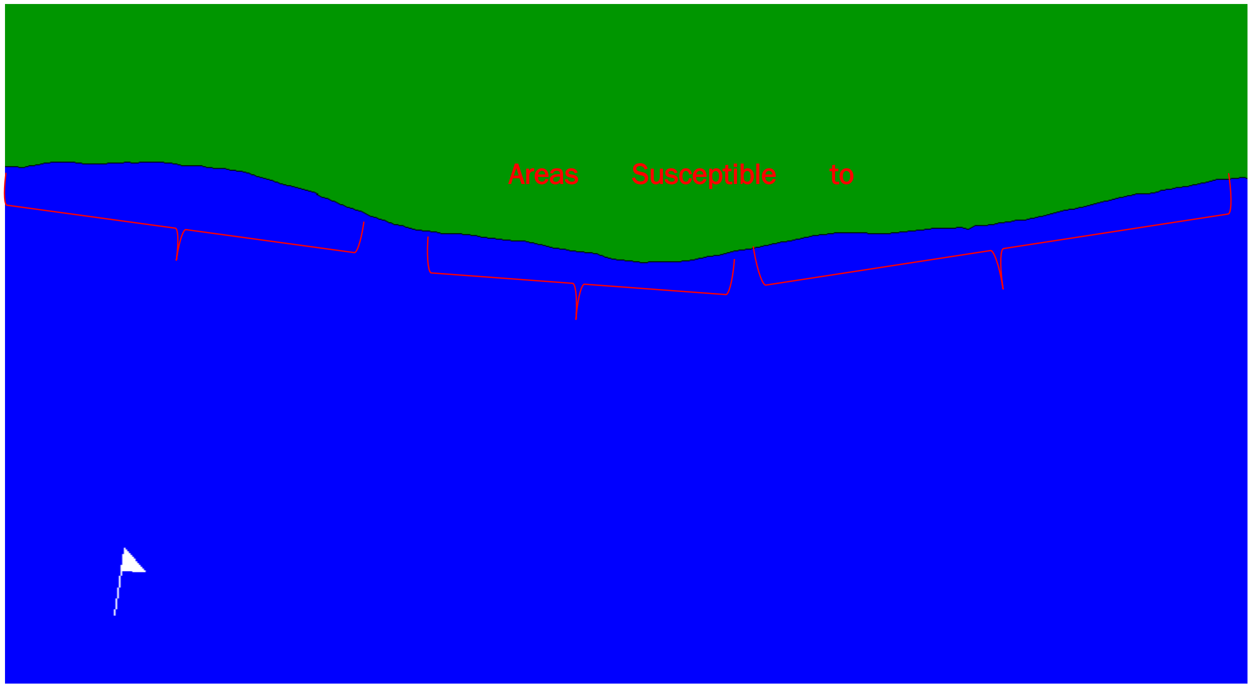


Figure 5-70- Beach planform after 6 years of simulation for the pre-project Palisadoes Caribbean Sea side shoreline

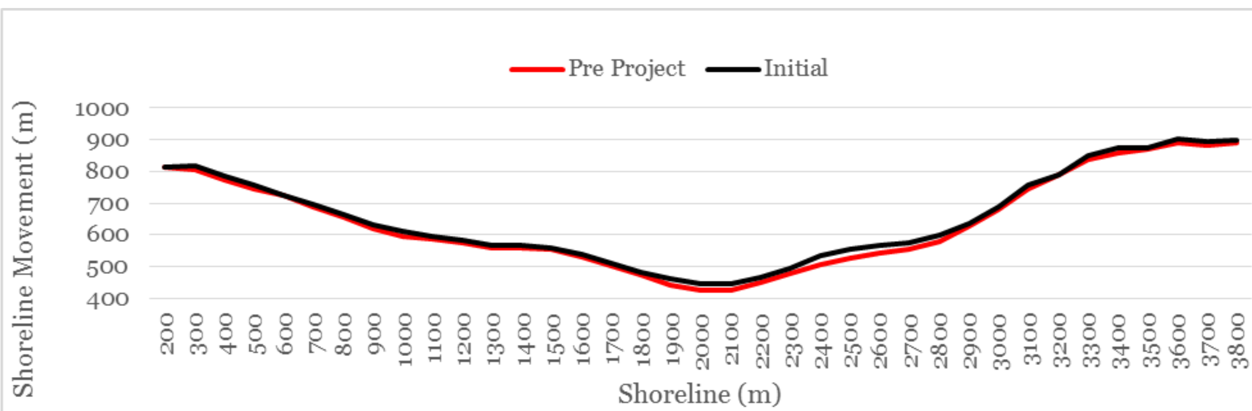


Figure 5-71 Comparative analysis of initial and pre-project shorelines for the Caribbean Sea side of the Palisadoes project

HARBOUR SIDE

The model predicts that the Western Section of the Harbour side shoreline is most stable and consistent with growth. Additionally a small area along the central and eastern section of the shoreline shows growth and stability, indicating that the shoreline model is in an accretion mode resulting in a total volumetric growth of 6,000 m³, see Figure 5-72 and Figure 5-73.

Figure 5-72 Beach planform after 6 years of simulation for the existing bathymetry and conditions showing pre-project (north arrow shown) along the Palisadoes Harbour Side shoreline

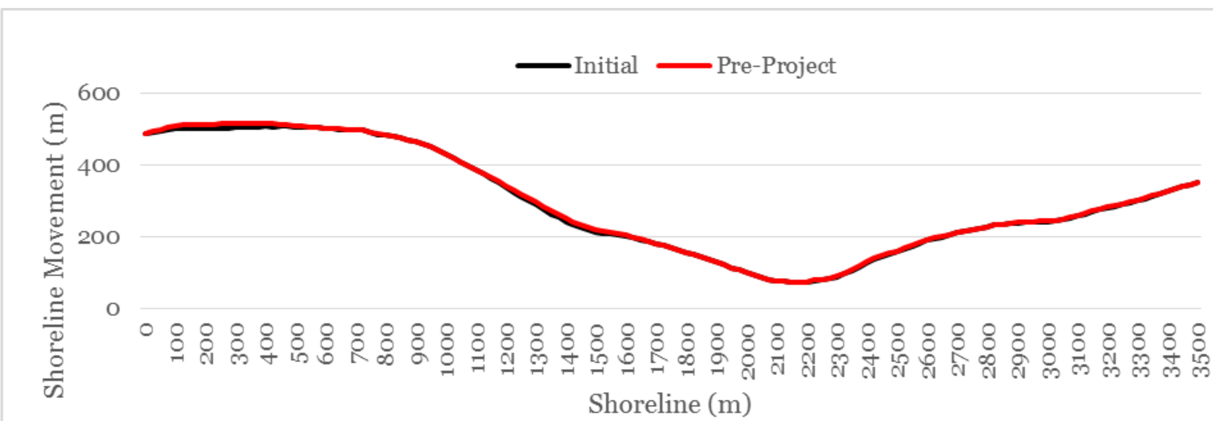


Figure 5-73 Comparative analysis of initial and pre-project shorelines for the Palisadoes Harbour Side shoreline

5.2.7 Hydrodynamic Modelling and Sediment Dispersion Modelling

5.2.7.1 Introduction

The current regime (i.e. patterns and speeds) in the coastal setting determines the ability of an area to flush and maintain sufficiently good water quality. Currents are generated mostly by winds, tides and waves. For tides and winds the simplified mechanisms are as follows:

- **Tides** - Rising tides will cause water to enter the bay and a portion will leave on falling tide that follows. This will result in some exchange of water between the outside and inside of the project area. This result is dependent on the ratio of the water entering to the water leaving; this ratio is dependent on the tide range, hydraulic efficiency of the entrance, and the water internal depths.
- **Wind** - Wind action over the water surface will generate a surface current that will essentially be in the direction of the wind. The wind generated current will be a few degrees to the right of the wind, (in the northern hemisphere), owing to the Coriolis effect (Bowden, 1983)[16]. If the fetch and duration are sufficient, the surface current speeds may approach 2-3% of the wind speeds.

Circulation patterns can be predicted by numerical, physical models or by field studies. Numerical models are most often used as they simply require collection of field data to calibrate and verify the model for use in a predictive mode. The models are also robust enough to include prediction of sediments and nutrients dispersion in the project area.

5.2.7.2 Description of Models

Investigation of currents was undertaken using RMA10. It utilizes bathymetric information on the project area and driving forces from tides and winds to solve the 3-dimensional flow equations. This model is calibrated on the observations of currents through the project area from drogues and the moored ADCP. The sediment plume models were generated using RMA11. RMA11 is a finite element water quality model for simulation of three-dimensional estuaries, bays, lakes and rivers. It is also capable of simulating one and two dimensional approximations to systems either separately or in combined form. It is designed to accept input of velocities and depths, either from an ASCII data file or from binary results files produced by the two-dimensional hydrodynamic model, RMA2, or the three-dimensional stratified flow model, RMA10. Results in the form of velocities and depth from the hydrodynamic models are used in the solution of the advection diffusion constituent transport equations.

RMA 10

RMA-10 is a three-dimensional finite element model for stratified flow by King (1993). The primary features of RMA-10 are:

[16] Bowden, KF . 1983. *Physical Oceanography of Coastal Waters*, John Wiley, NY

- The solution of the Navier-Stokes equations in three-dimensions;
- The use of the shallow-water and hydrostatic assumptions;
- Coupling of advection and diffusion of temperature, salinity and sediment to the hydrodynamics;
- The inclusion of turbulence in Reynolds stress form;
- Horizontal components of the non-linear terms are included;
- A capacity to include one-dimensional, depth-averaged, laterally-averaged and three-dimensional elements within a single mesh as appropriate;
- No-, partial- and full-slip conditions can be applied at both lateral boundaries;
- Partial or no-slip conditions can be applied at the bed;
- Depth-averaged elements can be made wet and dry during a simulation; and
- Vertical turbulence quantities are estimated by either a quadratic parameterization of turbulent exchange or a Mellor-Yamada Level 2 turbulence sub-model.

RMA 11

The RMA 11 sediment transport model by (King & Rachiele, 1989) (King & DeGeorge, 1995) is a three dimensional finite element model that can also function as a two dimensional depth averaged model. The primary features of RMA11 are as follows.

- RMA11 shares many of the same capabilities of the RMA2/RMA10 hydrodynamics models including irregular boundary configurations, variable element size, one-dimensional elements, and the wetting and drying of shallow portions of the modelled region.
- RMA11 may be executed in steady-state or dynamic mode. The velocities supplied may be constant or interpolated from an input file (This may be RMA2 or RMA10 output).
- Source pollutants loads may be input to the system either at discrete points, over elements, or as fixed boundary values.
- In formulating the element equations, the element coordinate system is realigned with the local flow direction. This permits the longitudinal and transverse diffusion terms to be separated, with the net effect being to limit excessive constituent dispersion in the direction transverse to flow.
- For increased computational efficiency, up to fifteen constituents may be modelled at one time, each with separately defined loading, decay and initial conditions.
- The model may be used to simulate temperature with a full heat exchange with the atmosphere, nitrogen and phosphorous nutrient cycles, BOD-DO, algae, cohesive or non-cohesive suspended sediments and other non-conservative constituents.

A multi-layer bed model for the cohesive sediment transport constituent keeps track of thickness and consolidation of each layer.

The process of mesh developments entails the following steps:

- Input of bathymetric data for the wider area and in detail for the project area
- Specifying of nodes in the mesh
- Element construction in the mesh
- Interpolation for depth at nodes
- Specifying of open boundaries

The mesh constructed for the calibration and existing configuration extended some 7.7 kilometer s in a westerly direction. The outer deep water areas were gridded with large mesh which gradually decreases on approach to the project area. See Figure 5-74 below. The eastern and western boundaries were used as the open boundaries on which tides were applied.

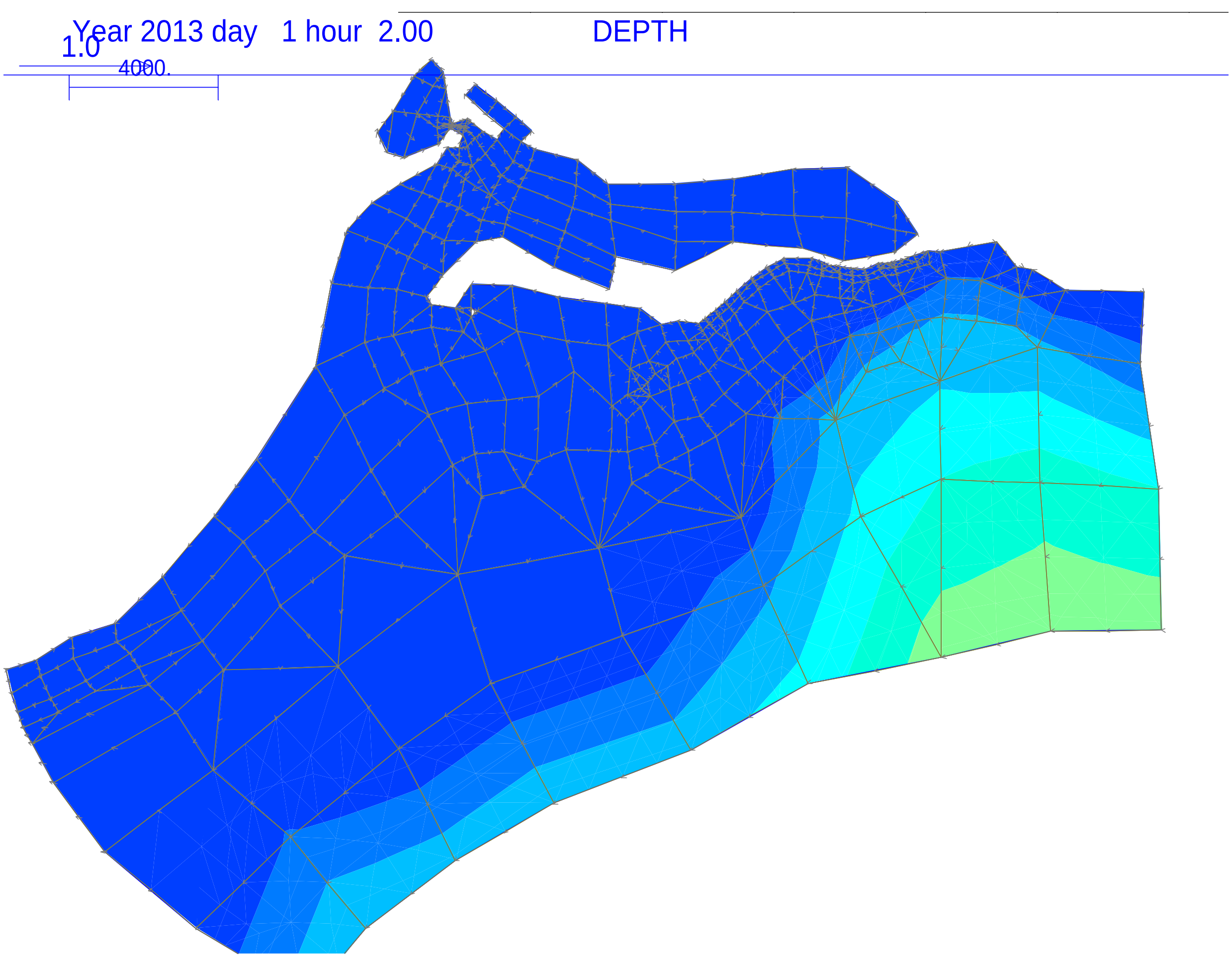


Figure 5-74 Overview of entire Finite Element Mesh used for this project showing depth in meters

5.2.7.3 Calibration

The model was calibrated by adjusting the tide elevation signal on the model boundaries, turbulence and viscosity parameters, until there was reasonable agreement between the observed currents and model predictions.

Correlations were 0.7 and 0.8 for the Vx and Vy components respectively, when obvious outliers were not considered. The predicted current speeds and directions, versus the data from the drogue tracking sessions are summarized in Table 5-45 for the correlation coefficient and variance between the predicted and observed currents. The model predictions agreed with the observations in most instances and indicate that the model can be used with confidence.

Table 5-45 Correlation coefficient and bias between the observed (ADCP for October 15 2013 and November 15 2013) and predicted (hydrodynamic model) currents.

Direction (vector)	Vx (m/s)	Vy (m/s)
Correlation (model predictions VS ADCP readings)	0.7	0.8
Variance	1.0%	0.3%
Std. Deviation	0.10	0.06

5.2.7.4 Current Predictions

Approach

The current speeds were investigated for different wind speeds and directions given their impacts on currents in the bay. The wind directions and speeds investigated were the Easterly direction as the occurrences were predominantly from the ENE to ESE directions. See Table 5-46 below for the wind speeds and directions used. The results are summarized in the sections below as well as in Table 5-41.

Table 5-46 Wind Speeds and Directions investigated in the Hydrodynamic model

Wind Speed (M/S)	Wind Direction
	ENE
Slow	1.5
Average	5.5
Fast	15.5

Slow Wind Speed Days

During rising tides, the currents were predominantly east to west in the vicinity of the offshore dredge sites. The western dredge site also had currents moving to the southwest to align with the coast. The currents are generally between 6 and 12cm/s western limits of the project both for offshore and near shore currents. The eastern section of the site however has currents of up to 12cm near shore whereas offshore currents are in the order of 4-6cm/s.

During the falling tides, the currents are generally faster in the near shore and tend to move to west along the shoreline. The speeds are predicted be as high as 0.6 to 0.9cm/s. the offshore currents are however less defined in terms of a direction. Most if the currents appeared to be moving offshore to the south at speeds of less than 3cm/s.

The winds speeds were general slow during both sessions and did not appear to have any noticeable impact on the currents.

Average Wind Speed Days

During rising tides, the currents were predominantly east to west in the vicinity of the offshore dredge sites. The western dredge site also had currents moving to the southwest to align with the coast. The currents are generally between 6 and 12cm/s western limits of the project both for offshore and near shore currents. The eastern section of the site however has currents of up to 12cm/s near shore whereas offshore currents are in the order of 4 - 6 cm/s.

During the falling tides, the currents are generally faster in the near shore and tend to move to west along the shoreline. The speeds are predicted be as high as 0.6 to 0.9cm/s. the offshore currents are however less defined in terms of a direction. Most if the currents appeared to be moving offshore to the south at speeds of less than 3cm/s.

The average wind speeds used during both rising and falling tides. The winds did not appear to have any more impact on the currents than the slow winds.

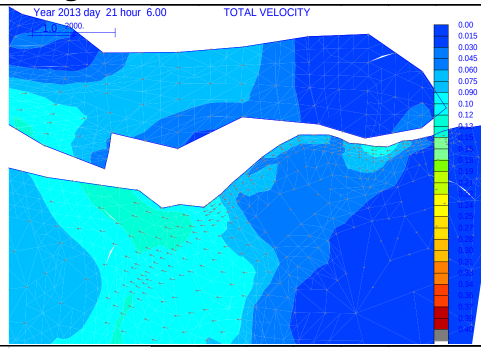
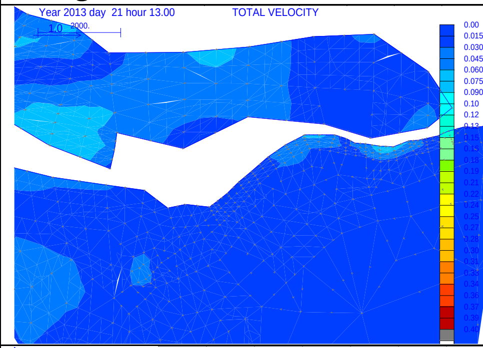
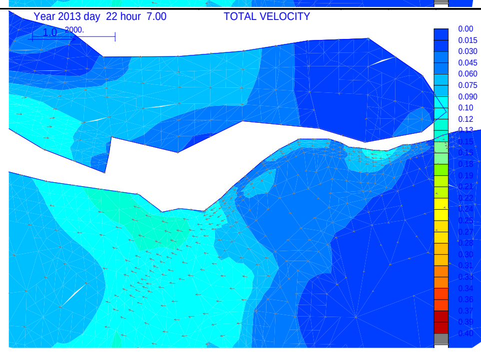
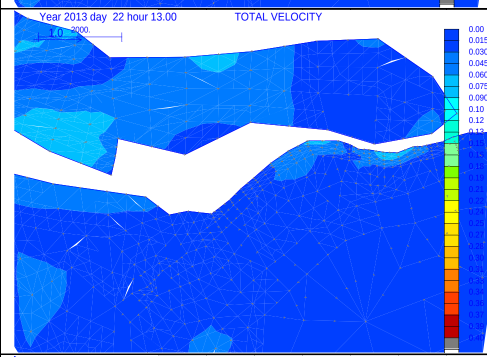
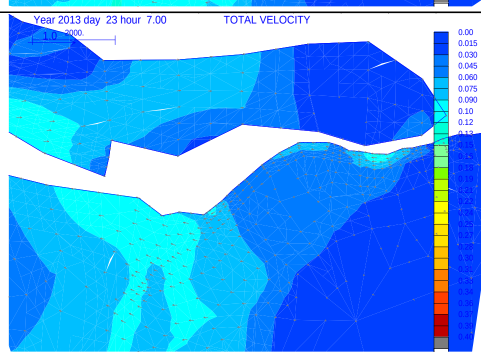
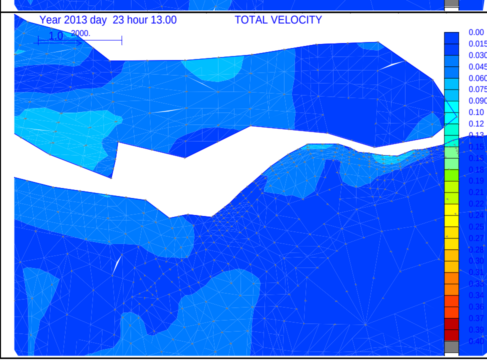
Fast Day

During rising tides, the currents were predominantly east to west in the vicinity of the offshore dredge sites. The western dredge site also had currents moving to the southwest to align with the coast. The currents are generally between 6 and 12cm/s western limits of the project both for offshore and near shore currents. The eastern section of the site however has currents of up to 12cm/s near shore whereas offshore currents are in the order of 4-6cm/s.

During the falling tides, the currents are generally faster in the near shore and tend to move to west along the shoreline. The speeds are predicted be as high as 0.6 to 0.9cm/s. The near shore fast current speeds had a wider offshore spread than the slow and average wind days. The offshore currents are less defined in terms of a direction. Most if the currents appeared to be moving offshore to the south at speeds of less than 3cm/s.

The fast wind speeds used during both rising and falling tides. The winds did not appear to have any more impact on the currents than the slow winds.

Table 5-47 Current speed predictions for the preconstruction and post-construction scenarios at Long Bay Negril for predominantly ENE winds

Wind speed	Rising	Falling
Slow (1.5 m/s)		
Average (5.5 m/s		
Fast (15.5 m/s)		

5.2.7.5 Summary

The currents in the bay move predominantly in a westerly and south westerly direction during the rising and falling tides. The currents are generally similar for all three scenarios (slow average and fast wind days. On slow wind days (1.0m/s) the current speeds are generally below 6cm/s. On average and fast days the current speeds will go up to as much as 9 and 12 cm/s respectively in the bay. The greatest speeds are generally in the central and northern section of Long Bay.

During rising tides, the currents are generally between 4 and 12cm/s to the western limits of the project site for offshore and near shore currents. During the falling tides, the currents are generally faster in the near shore than the offshore and tend to move westerly along the shoreline. The speeds are predicted be as high as 6 to 9cm/s near shore whereas the offshore currents are less than 3cm/s. The wind speeds do not appear to have any significant impact on the currents at the project site.

Sediment dispersion modelling underlines the importance utilizing turbidity barriers at the dredge site as well as the locations onshore where the sedimentation basins will overflow into the sea. The turbidity plumes are expected to extend up to 2km from the points of interest if precautions are not taken to limit sediments getting to the water column. The offshore plumes are expected to remain offshore and meet the NEPA guidelines for distances further than 1km away from the operations. Similarly the near shore plumes will remain in the near shore and are expected to meet the NEPA guidelines for distances further than 1km away from the operations.

5.2.8 Air Quality (PM 10)

Coarse particles (PM10) are airborne pollutants that fall between 2.5 and 10 micrometers in diameter. Sources of coarse particles include crushing or grinding operations and dust stirred up by vehicles traveling on roads.

5.2.8.1 Method

PM10 particulate sampling was conducted for 24 hours, using Airmetrics Minivol Tactical Air Samplers (Plate 5-1). Sampling was conducted at one (1) location within the project environs. This was located at the start of the revetment closest to Gun Boat Beach. Sampling was conducted for 24 hours from 3:00pm June 17th, 2014 to 3:00pm June 18th, 2014.

Plate 5-1 Particulate Sampler attached to light post at start of revetment

5.2.8.2 Results

The sampling location had a value of 106.94 μg/m^3 which was compliant with the US EPA standard of150 μg/m^3.

5.3 BIOLOGICAL

5.3.1 Mangrove Replanting

The main objectives of the mangrove island creation are to:

1. Attempts to re-create /re-establish the ecology previously disturbed on mangrove areas by the execution of the Palisadoes Protection and Rehabilitation Project (PPRP).
2. Adhere to the natural zonation observed in a characteristic mangrove forest.
3. Reduce the visual impact of the hard solutions that have been implemented.
4. Improve the vegetative cover of the entrance to Kingston from the Norman Manley International Airport, contributing to the overall aesthetics of the area.

Approximately 6,400 hardened and acclimated 18 - 36 month old mangrove saplings and seedlings grown in the nursery at the UWI Port Royal Marine Laboratory will be planted in the newly created islands. Red mangroves will be planted closest to the shoreline (1 m away from MSL). Black and white mangroves will be planted randomly behind Red mangrove zone and saplings will be planted with random 1 m spacing (not in rows). "Wild seedlings" will be introduced within the white and black mangrove zone. These seedlings will be introduced randomly in this area 3-6 months following rooted (sapling) introductions. Approximately 4,000 'wild' seedlings will be introduced away from the swash zone.

5.3.1.1 Marine Assessment

Method

The footprints of the proposed mangrove islands were assessed on April 3rd, 2014 using a combination of snorkelling and sediment grab samples. Snorkelling was conducted for shallower areas closer to shore, while grab samples were taken for those areas deeper and further away from shore.

Results

There was no mangrove, seagrass or coral observed within the proposed mangrove island footprints. The sediment on the seafloor within the footprint ranged from being muddy, fine and silty to coarse and sandy. Table 5-48 shows the type of sediment observed at each of the mangrove island footprints.

Table 5-48 Sediment Type within each Mangrove Island

Grab Sample Point near Water Quality Station	Sediment Type
Pal 9 (away from shore)	Muddy
Pal 9 (nearshore)	Coarse and sandy
Pal 11 (away from shore)	Coarse and pebbly
Pal 11 (nearshore)	Pebbly with small stones
Pal 12 (away from shore)	Coarse and sandy
Pal 12 (nearshore)	Coarse and sandy

Grab Sample Point near Water Quality Station	Sediment Type
Pal 14 (nearshore)	Coarse and sandy with pebbles and small stones

The photos below show the sediments observed within the mangrove island footprints. Station Pal 9 had very muddy sediment away from shore (Plate 5-2) while sediments closer to shore were coarse and sandy (Plate 5-3). Station Pal 11 had coarse, pebbly sediment away from shore (Plate 5-4) and pebbly sediment with small stones closer to shore (Plate 5-5). Deposited sand and debris above the water surface was observed at this location (Plate 5-6). Station Pal 12 also had coarse, sandy sediment away from shore (Plate 5-7) as well as closer to shore. Deposited sand and debris above the water surface was also observed at this location (Plate 5-8). Station Pal 14 closest to Gun Boat Beach had coarse sandy sediment with pebbles and small stones interspersed (Plate 5-9). *Thalassia testudinum* seagrass was observed outside of the proposed mangrove island footprint at this location (Plate 5-10).

Plate 5-2 Muddy sediment away from shore at Station Pal 9

Plate 5-3 Coarse and sandy sediment nearshore at Station Pal 9

Plate 5-4 Coarse and pebbly sediment away from shore at Station Pal 11

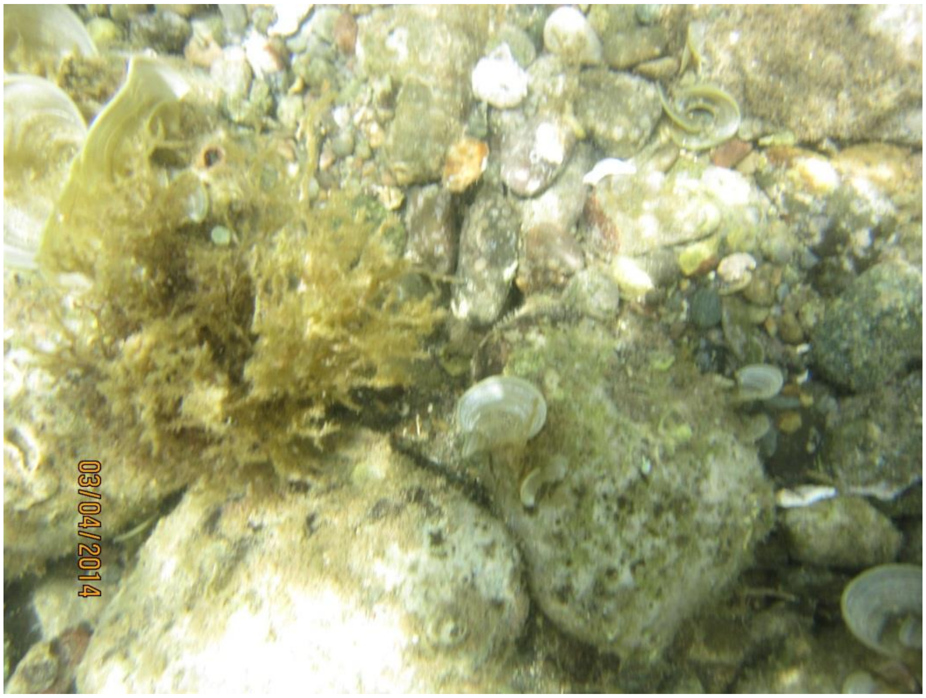


Plate 5-5 Pebbly sediment with small stones nearshore at Station Pal 11

Plate 5-6 Deposited sand and debris above water surface at Station Pal 11

Plate 5-7 Coarse and sandy sediment away from shore at Station Pal 12

Plate 5-8 Deposited sand and debris above water surface at Station Pal 12

Plate 5-9 Coarse and sandy sediment with pebbles and small stones nearshore at Station Pal 14

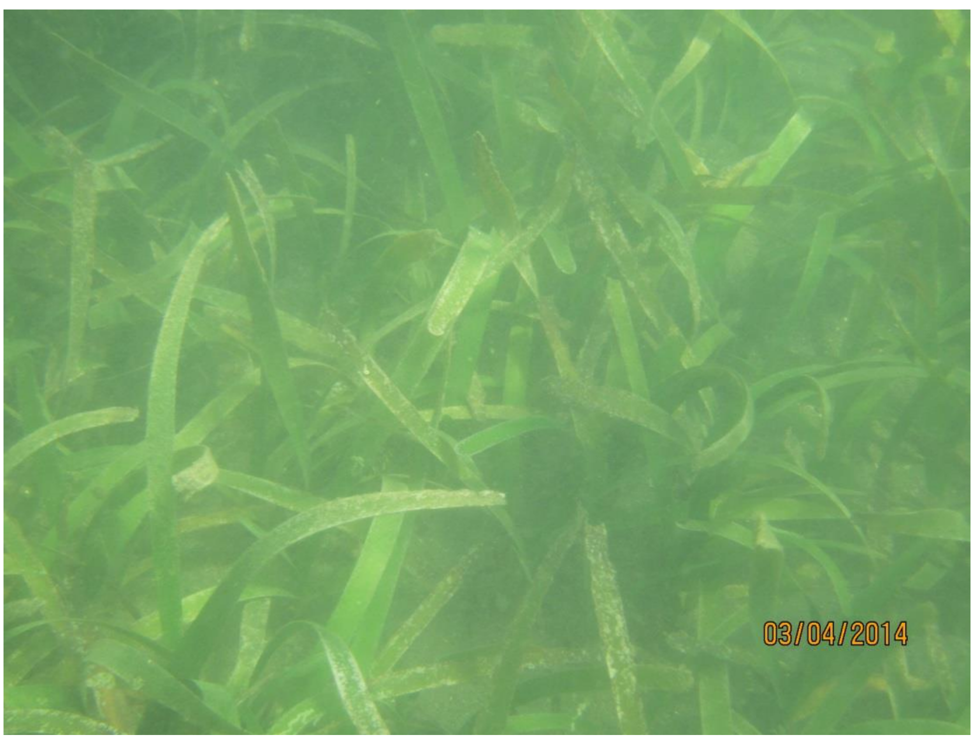


Plate 5-10 *Thalassia testudinum* seagrass observed outside of mangrove island footprint at Station Pal 14

5.3.1.2 Coastal Vegetation Assessment

Introduction

The Mangrove forests of the Palisadoes as noted before are found primarily along the north coast with the majority of relatively undisturbed forests being located to the western section of the tombolo, the Port Royal Mangroves. Mangroves that were once present along the eastern section of the Palisadoes were removed for commercial and industrial purposes. The Port Royal mangroves consist of a number of lagoons connected by channels. These lagoons are the Port Royal Lagoon, Cemetery Lagoon, Fort Rocky Lagoon, Ecteinascidia Lagoon, Fort Rupert Lagoon and the Hurricane Refuge Lagoon. The area also boasts three mangrove cays which are Refuge cay, Little Refuge cay and Gallow's point (Goodbody, 2003). The Red Mangrove, *Rhizophora mangle*, line the rim of these lagoons with their prop roots acting as habitats for hundreds of species, absorbing nutrients from the polluted harbour water as well as improving water quality (Webber & Goodbody, 1997). Webber and Goodbody (1997) have described the distribution of the mangrove forest species as not having any distinct zonation but instead have a seaside border of *Rhizophora* and a landward border of *Conocarpus* (Button mangrove) which separates the mangrove forest from the sand dune ecosystem. In between these borders is a mixed assortment of mangrove species which make up the majority of the forest cover. They also noted that this mixed region of the forest compose of undisturbed mature forest and those that have been subject to stress either natural or man-made. The main mangrove species present in this mixed area are *Rhizophora* (Red mangrove), *Avicennia* (Black mangrove) and *Languncularia* (White mangrove). These forests sustain significant damage caused by hurricanes; uprooting trees, breaking branches and tree defoliation with vegetation facing the harbour receiving the most damage (Webber & Goodbody, 1997).

The Port Royal Mangrove ecosystem inclusive of the mangrove forest and lagoons with seagrass beds are home to a plethora of faunal species. Refuge cay serves as a nesting site for the birds in the area namely the Brown Pelican, Magnificent Frigate, herons and egrets (Webber & Goodbody, 1997). See Appendix 4 for a list of the faunal species found there.

Method

A survey of the existing mangrove forests was conducted at the impact site and a comparative control site along the Port Royal area. The control site was surveyed by sampling a 5m wide belt transect in a north to south direction (Harbour-side shoreline towards roadway). The impact sites (sand bars along Palisadoes mangroves area) could not be surveyed in the comparative north to south direction due to the narrow nature of the exposed sand bars. These areas were sampled parallel to the Palisadoes roadway (West to East direction). Data collected within the belt transect included: Plant species, heights, percentage canopy and root cover, number of seedlings and faunal presence.

Results

A comparison of the mangrove replanting site and the control site showed stark differences (Table 5-49). The control site boasted an expected tree density for mangrove trees, with both *Rhizophora* and *Avicennia* occurring at a density of 0.2 plants per m2, along the sampling area. Each quadrat of the total sampled area, showed approximately 2.8 trees. *Rhizophora* trees showed the greatest height, averaging 3.97m.

The Palisadoes' remaining sand bars boasted only 1 adult tree. This tree was regarded as an adult as it was found to be flowering, despite its 1m height. This resulted in a very low overall tree density of 0.14 trees per quadrat. The area also boasted salt marsh/sand dune plants e.g *Sesuvium sp*. occupying the ground. A comparison of the propagule density showed the mature control forest boasting 24.83 seedlings per quadrat, representing approximately 1 propogule each m^2. The seedling density of the impact site is currently 1 .23 seedlings per $25m^2$(per quadrat).

It is important to mention the large volume of solid waste observed at the impact site. This refuse was dominated by plastic bottles and other naturally buoyant objects.

Table 5-49 Comparison of mangrove trees and seedling at each site

	Control site	Mangrove replanting site
Adult *Rhizophora* (Red) per m^2	0.20	0
Avg. Height (m)	3.97	
Adult *Avicennia* (Black) per m^2	0.20	0.10
Avg. Height (m)	3.77	1
Adult *Laguncularia*(White) per m^2	0.04	0
Avg. Height (m)	3.75	
Adult *Conocarpus* (Button)per m^2	0.1	0
Avg. Tree Height (m)	2	1
Average Trees per quadrat	2.8	0.14
Total propagules(seedlings)	745	16
Average seedlings per quadrat	24.83	1.23
Seedling density	0.99	0.05

Plate 5-11 Mangrove impact site showing narrow sand bars

Plate 5-12 Survey line for mangrove impact site

Plate 5-13 Solid waste along impact site

Plate 5-14 Black mangrove sapling and salt marsh plant surrounded by garbage

5.3.2 Dune Nourishment

5.3.2.1 Introduction

Coastal dunes are formed at the interface between the sea and land. This is a very dynamic system, ever changing with the natural environment. Vegetation found on these dunes act as anchors, stabilizing the otherwise lose sediment and providing additional habitat, foraging ground and nesting site for sea birds. Sea turtles and crocodiles have been known to utilize areas colonized by runners for nesting. The ecosystem services provided by these dunes includes shoreline protection by reducing wave and wind energy during storm events, benefits which can even be had further inland by reduced wind energy.

Fifty thousand (50,000) plants will be established in a sand dune nursery at the UWI. Sand dune species will be planted in accordance with their natural profile, dune position and successional capabilities. Species to be planted include beach runners such as, *Ipomea*, *Sesuvium*, *Sporobolus* and shrubs/trees such as *Acacia, Capariss, Coccoloba* and *Thespesia.* Beach runners will be planted at 1 m spacing intervals in rows. Approximately 1,000 plants will be planted on each event, for approximately 50 planting days. The introduction of additional seeds/cuttings (e.g. cacti) of sand dune species in selected areas will be done 6-12 months following pioneer species establishment.

5.3.2.2 Marine Benthos

Borrow Areas

The borrow areas were previously identified by Juanes et al. (2007). Ground-truthing each borrow area was carried out by grab samples and roving SCUBA surveys.

METHOD

Grab samples were taken within each of the borrow areas. A total of five (5) grab samples were collected; three (3) in Borrow Area 1 and two (2) in Borrow Area 2. Roving SCUBA surveys were conducted in variations sections in and around the proposed dredge footprint.

RESULTS

Both borrow sites corresponded with original survey results with exception of a small patch of seagrass (*Syringodium filiforme*) identified at the western boundary of Borrow Area 1. The seagrass was along the western edge with the bed extending southwest and away from the impact area. The area generally has poor visibility making several attempted surveys impossible.

The sand in the borrow areas were coarse grained with some *Halimeda* calcareous algal skeleton interspersed. A sea horse, sea stars and helmet conch were observed in Borrow Area 1.

Seagrass

Seagrass (*Syringodium filiforme*) is sparse in the borrow area with the density increasing slightly in a south westerly direction from the western edge of Borrow Area 1.

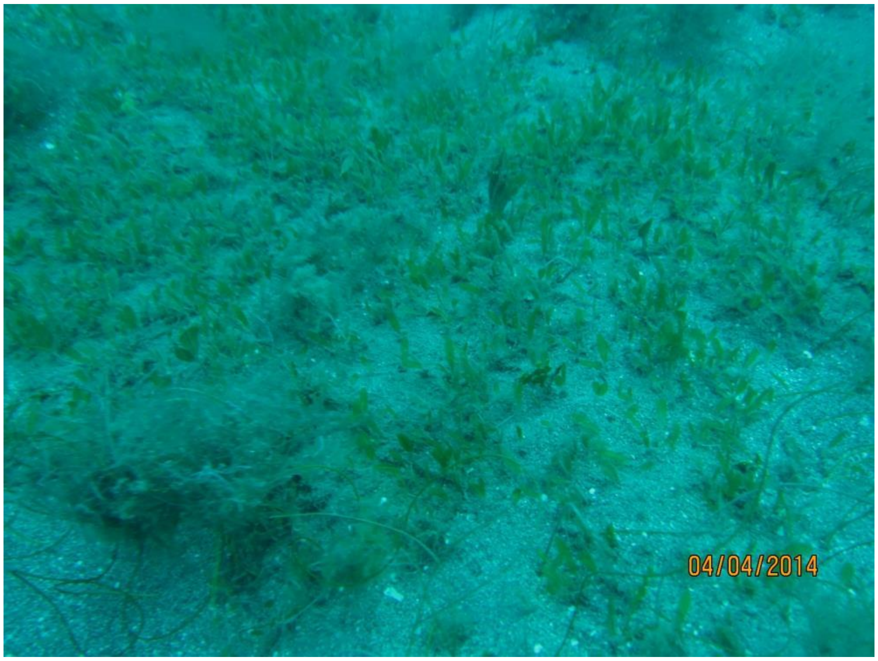


Plate 5-15 Syringodium filiforme at west of borrow area 1

Plate 5-16 Syringodium filiforme at west of borrow area 1

Plate 5-17 Coarse grain sand in Borrow Area

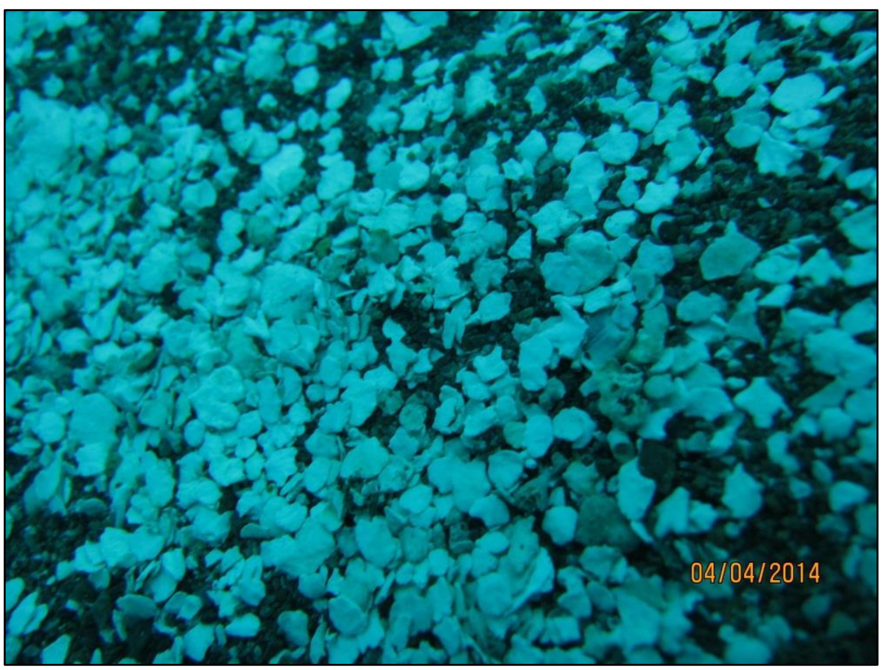


Plate 5-18 Coarse grain sand mixed with *Halimeda* calcareous algae skeleton in Borrow Area

Plate 5-19 Sea horse observed in Borrow Area

Plate 5-20 Sea Star observed in Borrow Area

Plate 5-21 Helmet Conch observed in Borrow Area

Coral Reef

A previously undescribed reef was found just on the outside of Borrow Area 2 (Figure 5-75). Although located outside of the dredge footprint, this reef now called Dos Tortugas (DT) falls within the area of influence. The reef was named based on the presence of a pair of hawksbill turtles seen in the area at the time of the survey. This site was then chosen to be surveyed in detail along with other reef communities outlined in the Reef Community section of this document. Plate 5-22 shows the Dos Tortugas reef.

Plate 5-22 A section of the Dos Tortugas reef near Borrow Area 2

Reef Community

The major reef systems present in the area are those associated with the Port Royal Cays. In a report done by the Centre for Marine Sciences, UWI (2009) the reefs of the cays are algal dominated with hard coral cover being significantly low. This shift from a coral dominated community to a macroalgae dominated community is most likely the result of several factors including multiple hurricanes that have decimated the fragile system. Natural disasters are not the only cause for the poor state of the Port Royal reefs. Climate change, pollution and overfishing are other significant factors (National Environment and Planning Agency 2010).

The Palisadoes Coastal ecosystems; mangroves, sand dunes and coral reefs are a delicate system with each ecosystem depending on the other to achieve environmental balance. The area is severely affected by human interference in particular pollution that enters the Kingston Harbour as well as the removal of vegetation for coastal development (widening of the Norman Manley High from two to four lanes).

Reefs act as natural shoreline protection; studies continue to reassess and increase the actual value that's coastal ecosystems. Major ecosystem services include shoreline protection. The reefs surrounding the Palisadoes have played a major role in its protection, formation and maintenance. The global decline in reef health as a result of climate change, major natural and manmade disasters is further magnified by site specific influences. Jamaica suffers greatly form over fishing, poor sewage treatment, unmanaged gullies, polluted rivers and improper coastal development. The reefs associated with the Palisadoes are greatly stressed; the reef community at each study site have low diversity, dominated by macroalgae and has low coral cover. Grazing fish species occurrence is low and *Diadema* are almost absent from most sites. Some disease was seen within the hard coral communities but the occurrence was low. The presence of rubble at each site shows the effect of storm surges on each community (the reefs reduce and dissipate wave energy) which causes the breaking up of sections of the reef. The reduced water quality (increased nutrients) and the lack of grazers (caused by overfishing) allow macroalgae to proliferate, smothering other species and preventing recruitment. The preservation and improvement of these reef communities is essential to any protection and rehabilitation plan.

Careful and well planned mitigation practices are need both for any marine based actives as well as land based actives. Dos Tortugas is the only site in close proximity to the proposed project dredge area (FIG). Groyne Field however is closer to the shoreline works and Windward Edge is furthest from all the proposed activities.

METHOD

Survey points were identified based on: Initial surveys conducted by Juanes et al. (2007); Monitoring sites used during the first phase of the Palisadoes Rehabilitation work; Ground truthing during grab sampling and; SCUBA diving roving surveys as part of this study. Photo transects survey were conducted at three chosen sites; Groynefield, Windward Edge and a previously un-surveyed site now called 'Dos Tortugas' as two turtles were seen in the area (Figure 5-75).

Each transect line was run parallel to the shoreline for 60m, a 0.5m photo-framer (Plate 5-23) was used to take a picture every meter, each picture was then analysed in CPCe random dot analysis. CPCe was also the method used during the monitoring works (however the previous surveys were over 30m transect line and not all were run parallel to the shoreline). The results from the CPCe analyses were then compared to randomly chosen surveys in 2011, 2012 and 2013 and the relevant data extracted.

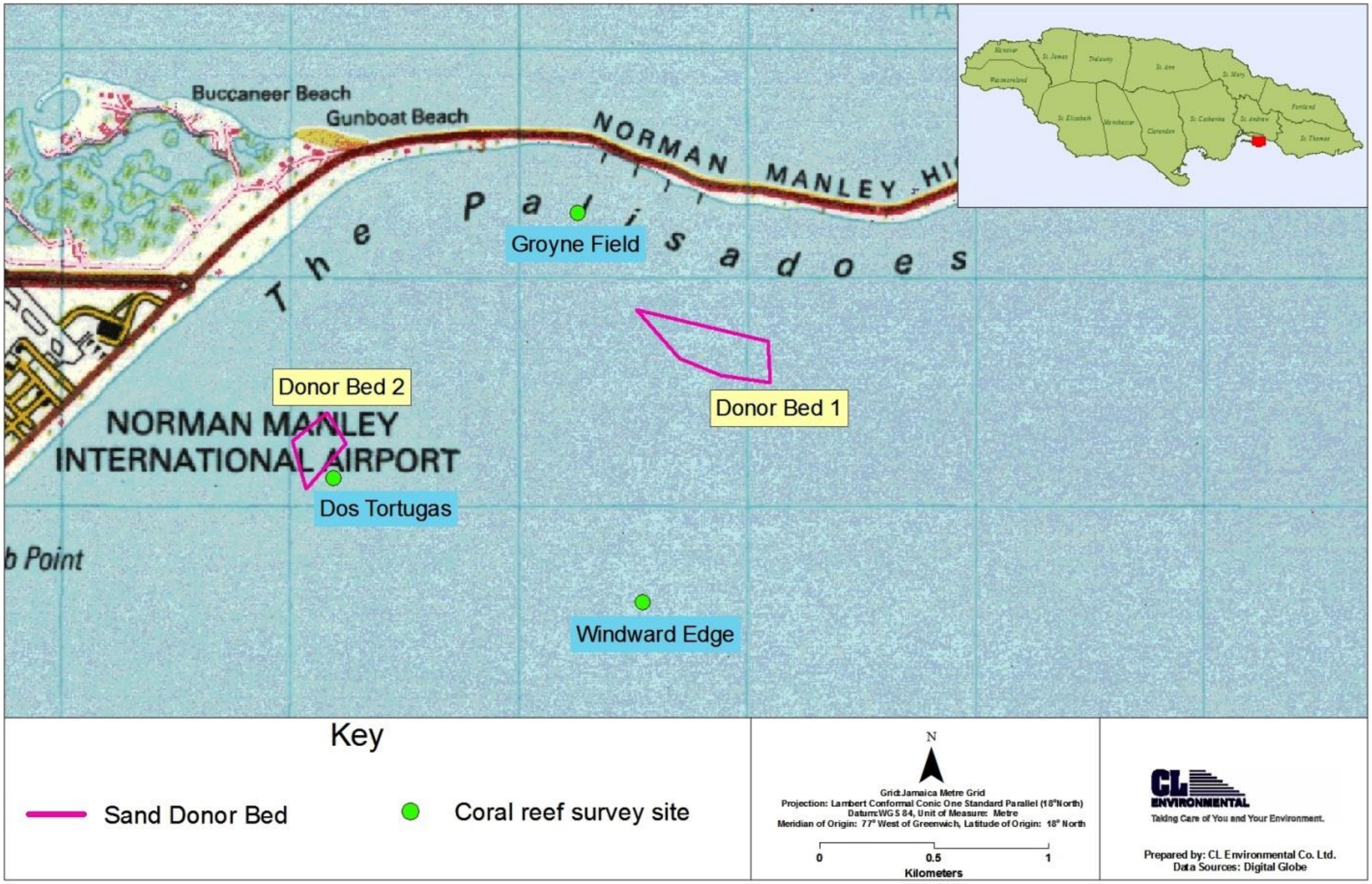


Figure 5-75 Map showing the locations of the coral reef survey sites

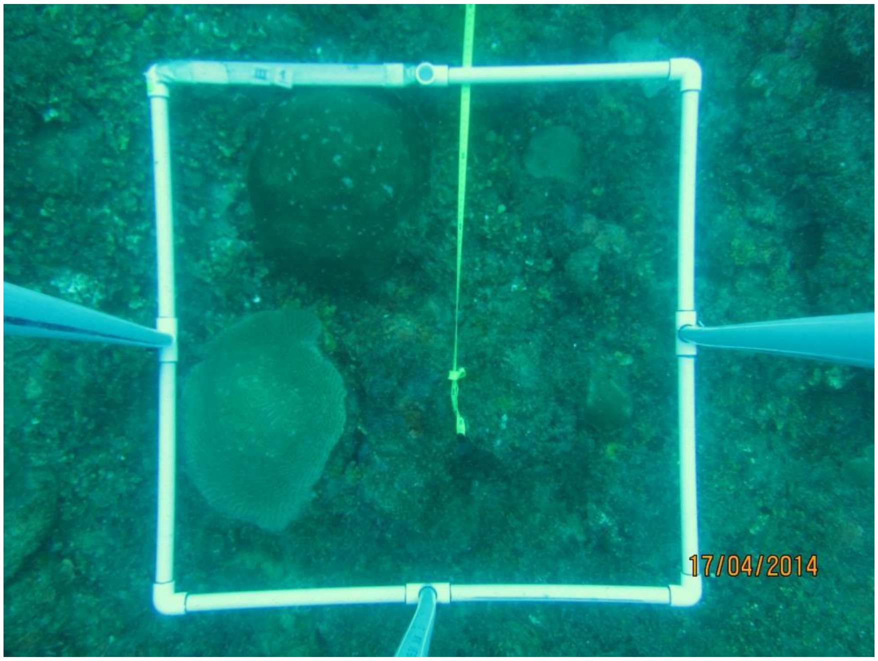


Plate 5-23 Quadrat, photo-framer and transect line used in the survey

RESULTS -MONITORING SURVEYS

Table 5-50 shows the general composition of each site over a three year monitoring period. Hard coral cover was highest at Groyne Field while Windward Edge had the highest sponge percentage cover. Windward edge also had a lower percentage cover of macroalgae.

Table 5-50 Average percent composition of the historical data

Category	Groyne Field (GF) (%)	Windward Edge (WE) (%)
Coral	10.92	9.03
Gorgonians	0.33	3.86
Sponges	0	0.38
Zoanthids	0	0
Macroalgae	64.75	56.56
Other Live	0.67	0.31
Dead Coral	55.50	49.79
Coralline Algae	0	0
Diseased Coral	1.17	0
Sand, Pavement, Rubble	22.08	29.63

RESULTS - CURRENT STUDY

Groyne Field

Groyne field has a typical spur and groove formation (Plate 5-24 Plate 5-25) with moderately sized spurs and sand channels of varying sizes. The current benthic community composition of Groyne Field (Figure 5-76) is similar to previous studies, the community is dominated by macroalgae with occurrences of key species; hard corals, soft corals and sponges. Diversity indices indicate a community of low diversity and moderate evenness; Shannon-Weaver Index- 1.15 is low while evenness is moderate Simpson Index of Diversity - 0.57. This is expected in a community that has experienced prolonged and most likely on-going stresses. Hard coral diseases were seen both in the current and previous studies but the occurrence continues to be low. No bleaching was seen at the time of the survey. This was the only site where *Diadema* were recorded in the transect area at the time of the study. Lionfish were seen in the area.

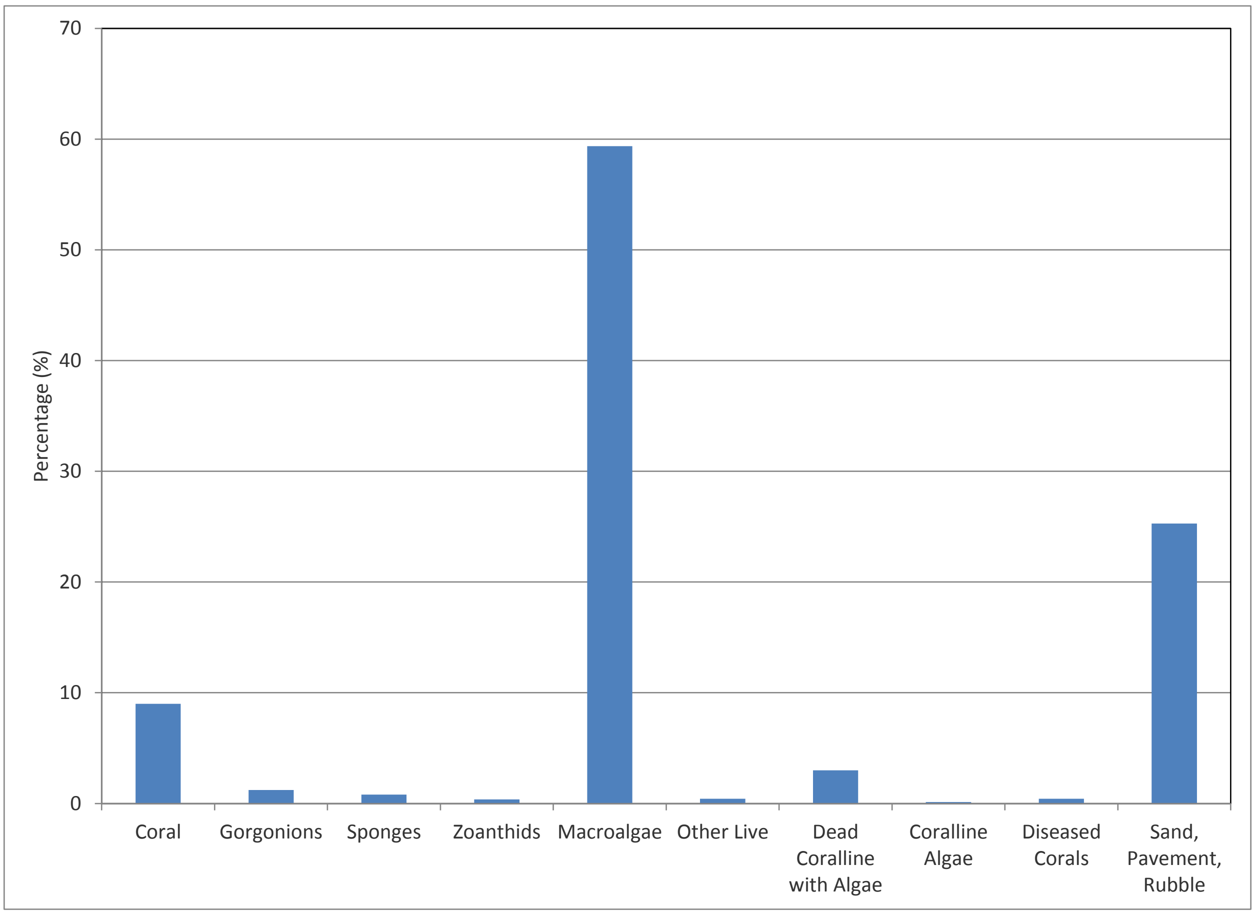


Figure 5-76 Groyne Field substrate percentage coverage

Plate 5-24 Spur and groove formation at Groyne Field

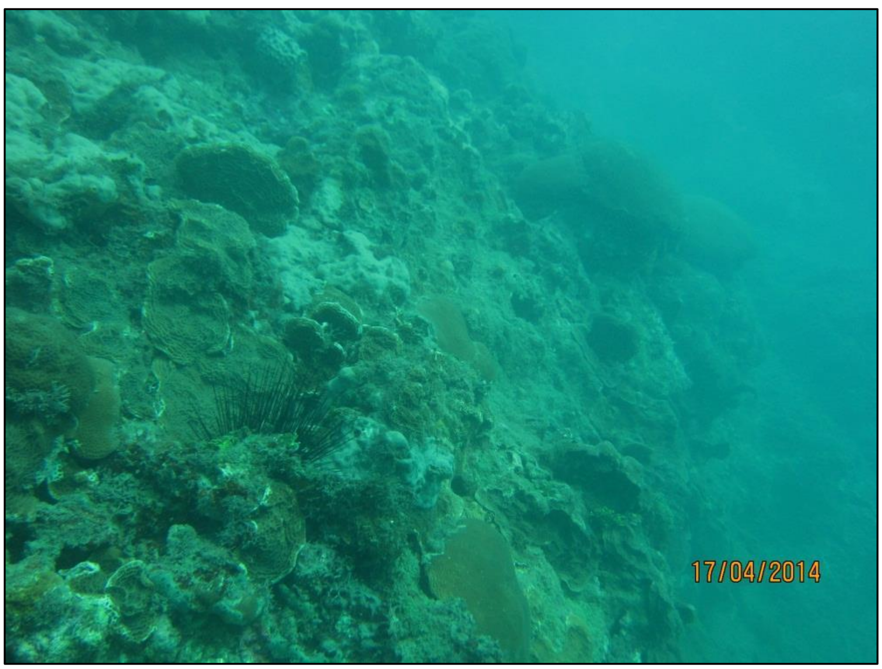


Plate 5-25 A section of a typical spur

Plate 5-26 Small lionfish

Current hard coral coverage decreased from 10.92% to 9% while macroalgae percentage decreased from 64.75% to 59.36% (Figure 5-77).

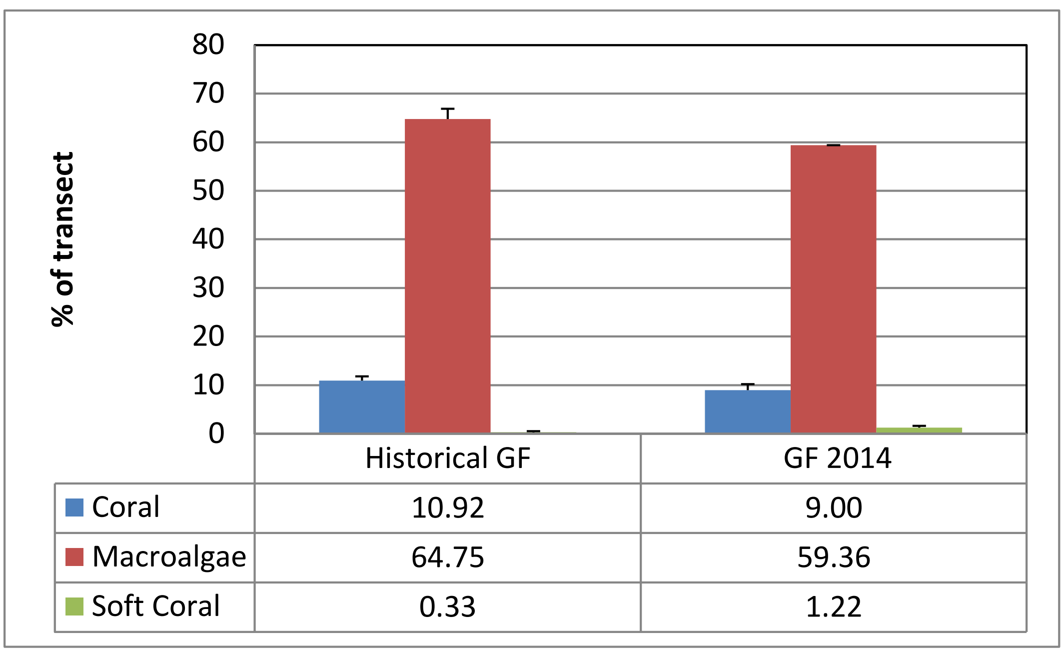


Figure 5-77 Groynefield historical and current hard coral, macroalgae and soft coral coverage

Windward Edge

Windward Edge has a typical spur and groove formation (Plate 5-27 and Plate 5-28), with small buttresses or spurs divided by sand channels. The current benthic community composition of Windward Edge (Figure 5-78) is similar to previous studies of the area; the community is dominated by macroalgae with low occurrences of key species as with GF. Diversity indices indicate a community of low diversity and moderate evenness; Shannon-Weaver Index- 1.15 is low while evenness is moderate Simpson Index of Diversity - 0.57, similar to GF; low and typical of a stressed community. No hard coral diseases or bleaching were observed in the transect area at the time of the survey. Endangered *Acropora palmata* colonies were observed (Plate 5-29) in the area but none were seen in the transect area. Lionfish were seen in the area (Plate 5-30).

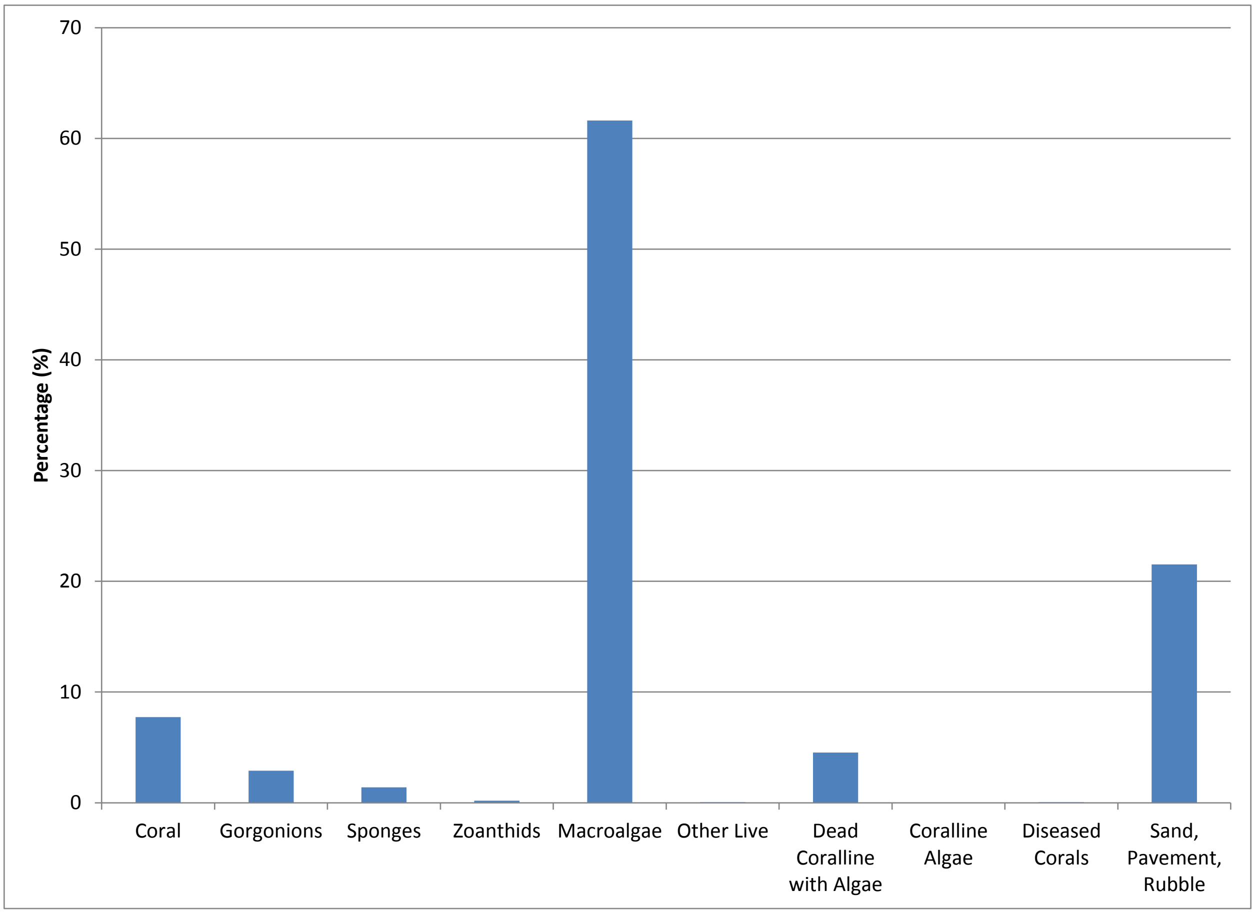


Figure 5-78 Windward Edge substrate percentage coverage

Plate 5-27 Spur and groove formation at Windward Edge

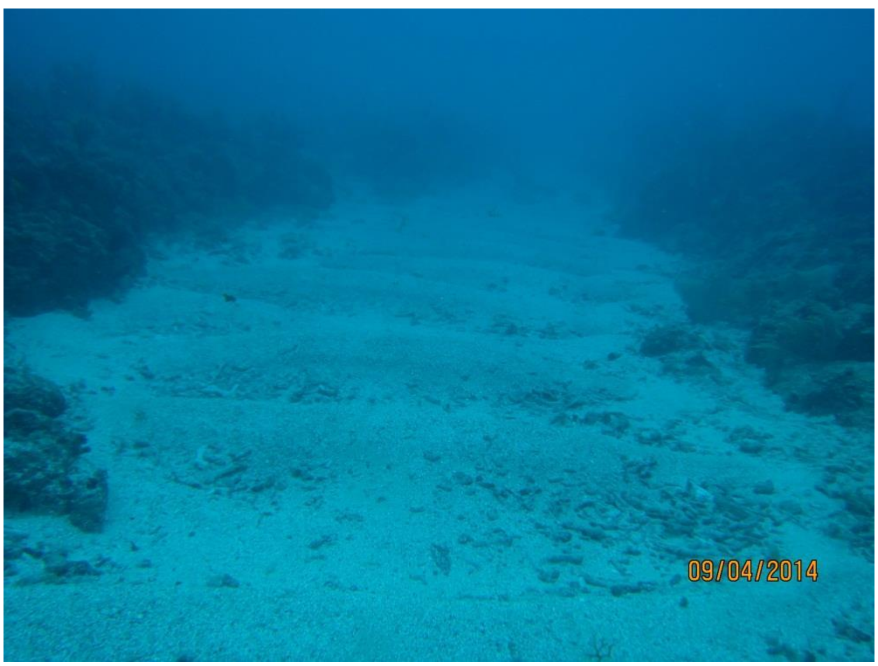
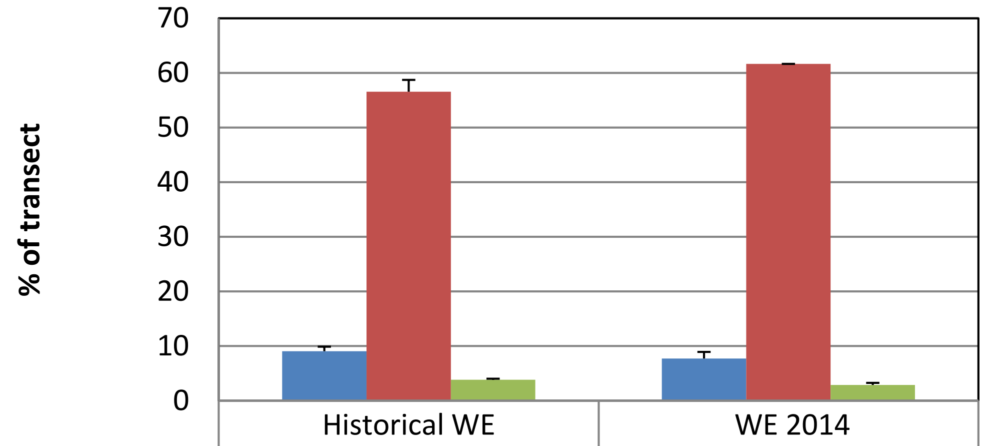


Plate 5-28 Groove at Windward Edge

Plate 5-29 *Acropora palmata* coral

Plate 5-30 Lionfish killed during survey

Current hard coral coverage decreased from 9.03% to 7.74% while macroalgae percentage increased from 56.56% to 61.61% (Figure 5-79).



	Historical WE	WE 2014
Coral	9.03	7.74
Macroalgae	56.56	61.61
Soft Coral	3.86	2.90

Figure 5-79 Windward Edge historical and current hard coral, macroalgae and soft coral coverage

Dos Tortugas

The benthic community composition of Dos Tortugas (DT) (Figure 5-80) was not described in previous studies however the site is located in a nearby area and under similar conditions to other survey sites (GF and WE). DT has a spur and groove formation and similarly is dominated by macroalgae with low occurrences of key species as with GF and WE (Plate 5-31). Diversity indices for DT also indicate a community of low diversity and moderate evenness; Shannon-Weaver Index- 1.01 (low) and Simpson Index of Diversity - 0.48 (moderate evenness). Although both diversity indices indicate a community of low diversity and moderate evenness, it is slightly improved when compared to both GF and WE. No hard coral diseases or bleaching were observed in the transect area at the time of the survey. A diseased coral was observed outside of the transect area however (Plate 5-32).

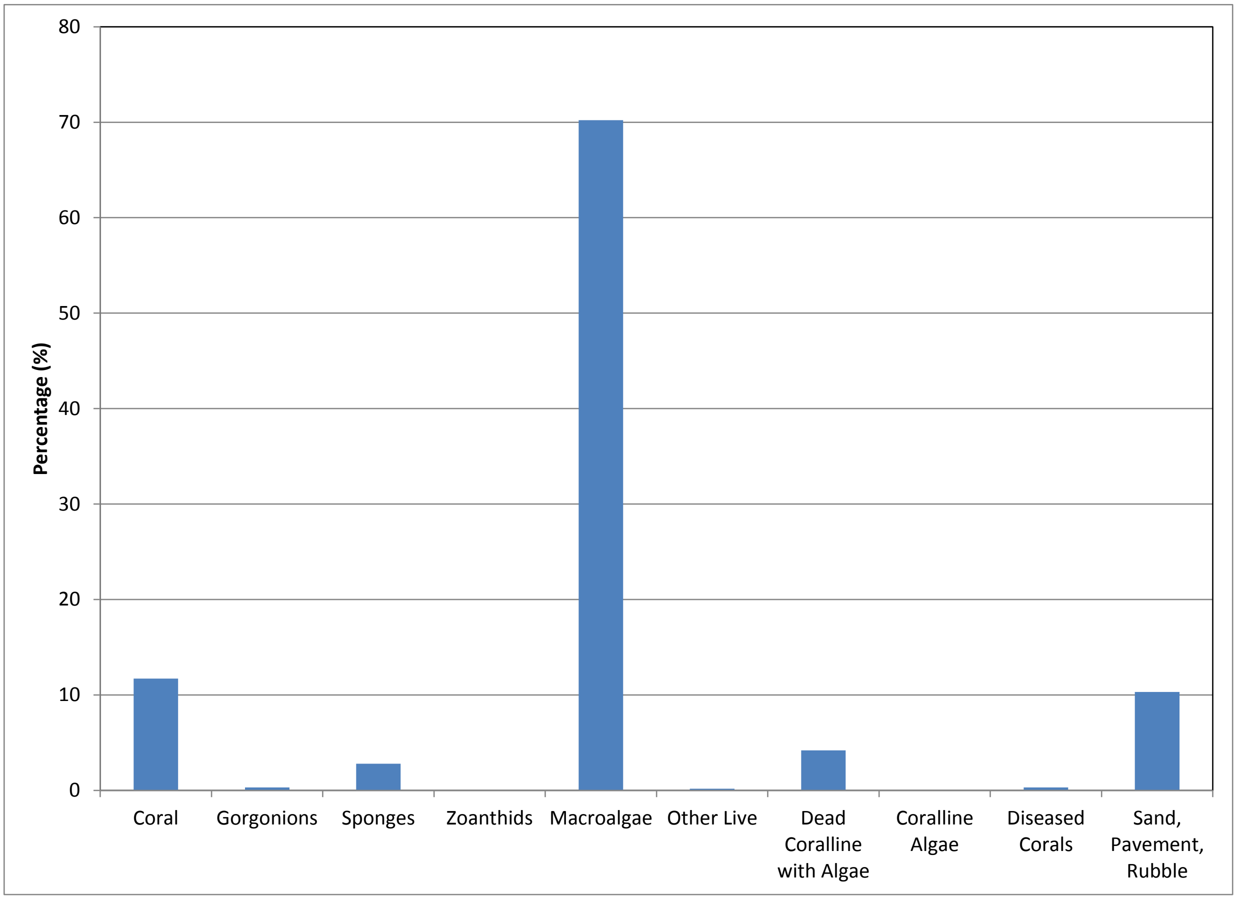


Figure 5-80 Dos Tortugas substrate percentage coverage

Plate 5-31 Spur and groove at Dos Tortugas

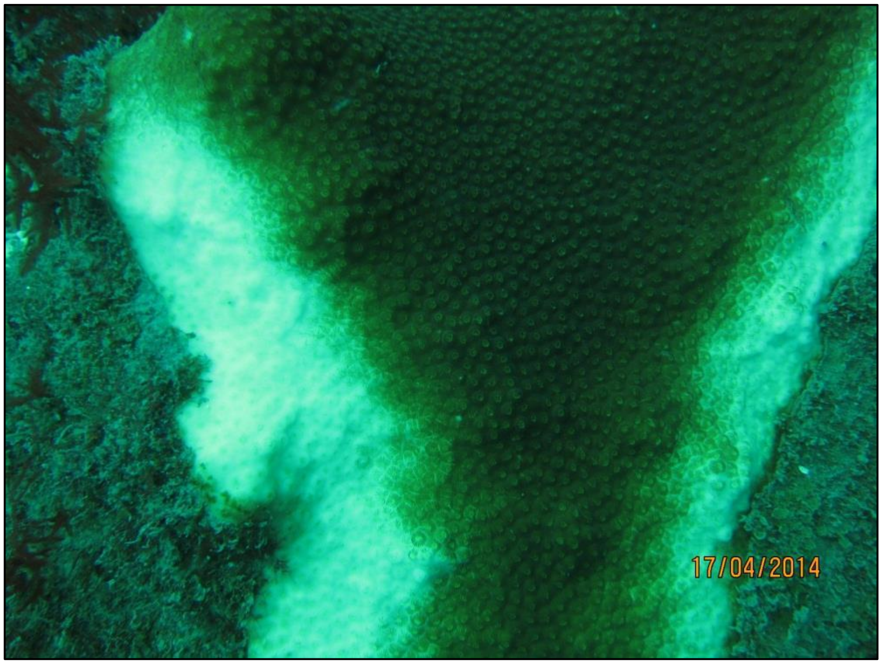


Plate 5-32 Diseased coral outside of transect area

Comparison between Sites

Dos Tortugas (DT) had the highest hard coral over, the lowest soft coral cover and the highest percentage cover of macroalage (Table 5-51). Windward Edge (WE) had the lowest percentage hard coral cover and the highest percentage of soft coral while Groyne Field (GF) had the lowest macroalgal cover and the highest occurrence of diseased hard corals

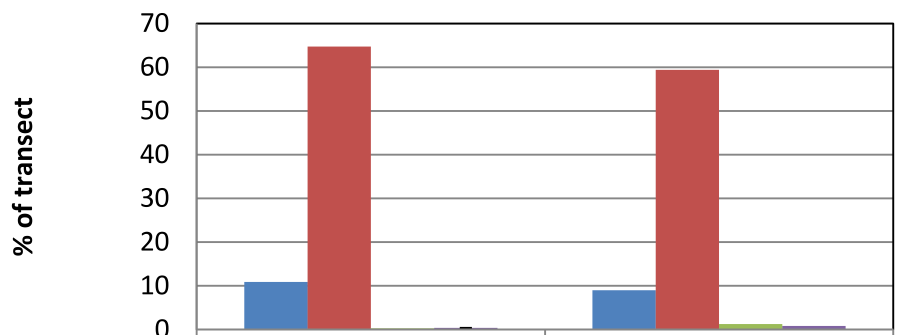
Groyne Field was the only site *Diadema* were observed in the transect area as well as having more coralline algae present.

Table 5-51 Percent composition at each site

MAJOR CATEGORY (% of transect)	Windward Edge (WE)	Groyne Field (GF)	Dos Tortugas (DT)
Coral	7.74	9.00	11.70
Gorgonions	2.90	1.22	0.30
Sponges	1.39	0.80	2.79
Zoanthids	0.18	0.37	0.00
Macroalgae	61.61	59.36	70.22
Other Live	0.06	0.43	0.18
Dead Coralline with Algae	4.53	3.00	4.18
Coralline Algae	0.00	0.12	0.00
Diseased Corals	0.06	0.43	0.30
Sand, Pavement, Rubble	21.52	25.28	10.31

Windward Edge continues to have a lower hard coral cover (7.74%) than Groyne Field (9.00%) this was similar to previous studies (9.03% and 10.92% respectively). Both sites appear to have decreased in hard coral cover. Macroalgal cover was similar 61.61% WE and 59.36%GF and highest at DT (70.22%). GF and WE showed increases in macroalgal cover; GF showed a small decrease of 64.75% to 59.36% (Figure 5-81), while WE had a much larger increase of 56.56%-61.61% (Figure 5-82).

GF showed an increases in Soft Coral percent cover (0.33%-1.22%) while WE showed a decrease (3.86% -2.90) while sponge percent cover increased at both sites (0.38%-0.80% GF and 0-1.39% WE). No Zoanthids or coralline algae were recorded during the monitoring periods.



	Historical GF	GF 2014
Coral	10.92	9.00
Macroalgae	64.75	59.36
Soft Coral	0.33	1.22
Sponge	0.38	0.80

Figure 5-81 Comparison of historical and present data (2014) for Groyne Field

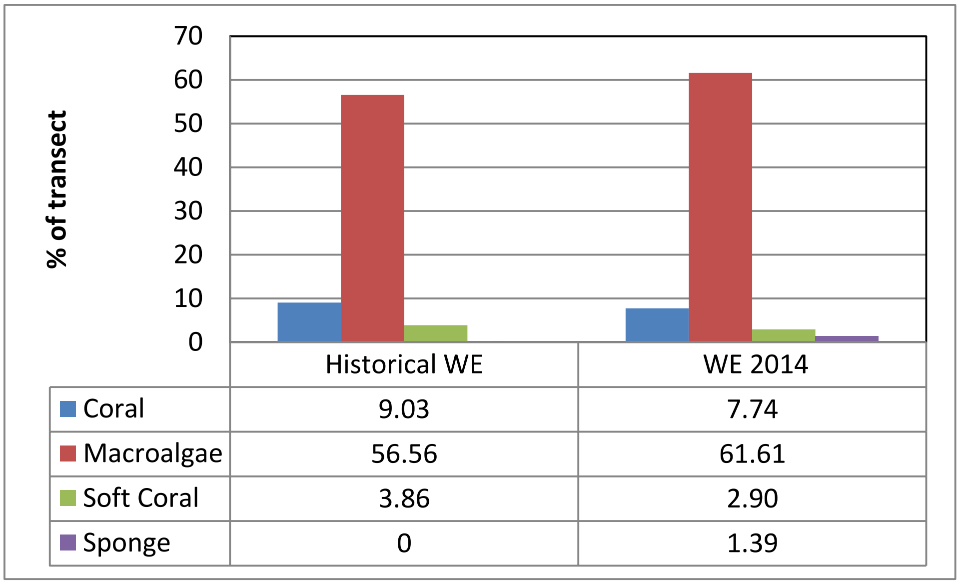


Figure 5-82 Comparison of historical and present data (2014) for Windward Edge

Hard coral community composition was similar; Dos Tortugas is dominated by *Agaricia sp.*, *Montastrea flaveolata, Porites asteroides and Montastrea cavernosa*; Groyne Field is dominated by *Siderastrea siderea, Agaricia sp.*, and *Montastrea annularis*; Windward Edge was also dominated by *Siderastrea sidera* and *Agaricia* sp. (Table 5-52).

Table 5-52 Coral species composition at each site

Coral Species (% of transect)	Windward Edge (WE)	Groyne Field (GF)	Dos Tortugas (DT)
Agaricia sp.	1.93	2.26	4.00
Colpophyllia natans	0.00	0.24	0.12
Diploria strigosa	0.12	0.00	0.73
Madracis decactis	0.06	0.00	0.12
Meandrina meandrites	0.06	0.00	0.30
Millipora sp	0.06	0.06	0.00
Montastraea annularis	0.79	1.04	0.18
Montastraea cavernosa	0.18	0.67	1.27
Montastrea faveolata	0.00	0.31	2.18
Mycetophyllia ferox	0.00	0.00	0.12
Porites astreoides	1.93	0.55	1.52
Siderastrea radians	0.12	0.06	0.06
Siderastrea siderea	2.48	3.73	0.97
Solenastrea bournoni	0.00	0.06	0.12

All three study sites are dominated by macroalgae with low coral cover. The number of grazing fish species seen at each site was also very low. GF had the lowest macroalgal cover and was also the site with the most grazers recorded. WE had less grazing fish than DT but had lower macroalgal cover, WE was the only site were *Diadema sp*. were recorded. The *Diadema* at Windward Edge although in low numbers help to reduce the macroalgal cover. Hard coral cover is highest at DT. All three sites are similar small differences in benthic composition are more than likely due to chance. The community dynamics, stresses and influences appear to be similar between sites. It is possible that DT is a less utilized by fishermen, previously unstudied and unnamed by fishermen we asked while in the area.

Conclusion

This shift from a coral dominated community to one dominated by macroalgae is typical of reefs studied along Jamaica's south coast. Macroalgae out-competes existing corals and sponges and other benthic slower growing organisms for space within the reef community. Macroalgae also prevents the recruitment and settlement of species, in particular corals. The lack of major grazing species, *Diadema* and fish indicates that these communities have little chance of recovery.

Natural disasters such as hurricanes and storm surge events have also more than likely impacted these communities over time. The area is utilized by local fishermen for line fishing and trawling; spearfishing; netting and fishpots, however evidence of anchor damage was low. Some debris was seen in and around each study area but in moderate amounts.

Reduced water quality (increased nutrients- Nitrates and Phosphates) has also contributed to the proliferation and dominance of macroalgae. This is as a result of land based activities such as poor sewage treatment and influences from polluted rivers such as Yallahs River and gullies. The area general experiences low visibility or high turbidity conditions as a result of wave action, current flow and patterns, it is unlikely that the rehabilitation works have greatly impacted these communities.

Unless the proliferation of macroalgae can be reduced, the reef communities in this area will continue to suffer and deteriorate. The importance of reefs as shoreline protection has been well documented, a value continuously revised and increased as we learn more about the actual protection provided by coastal systems. Reefs form a natural barrier between storm surge events and the coastline, the protection of these systems is essential part of any attempts at shoreline rehabilitation and protection. This will have the added benefit of improving other surrounding reef communities and thus preserving and perhaps enhancing the existing natural protection both of the Palisadoes but also the cays and other areas of influence along the south coast.

5.3.2.3 Fisheries

As part of an EIA in 2007 by Wilson-Kelly and Kelly, fish surveys were conducted at three (3) locations. Two stations were located near shore and one offshore (~20m depth). Eighteen (18) species of fish were noted in the study with the offshore station being the most species rich; however the numbers reported were the lowest of the three sites (13 fish). The numbers reported at the Palisadoes reef site was the greatest (>100 fish) but consisted mainly of fish less than 5cm in length.

Method

Fish counts were conducted at three (3) locations. The types of fish observed and estimates of their numbers were obtained using roving fish count methods defined for the Atlantic Gulf Rapid Reef Assessment (AGRRA) protocol.

A 60 m long and 2m x 2m transect (cube) was used at each site. The belt transect included the overlying water column. The numbers and species of fish observed along the transect was recorded and divided into size classes with the aid of a graduated T-bar. General site observations such as; the presence of fish pots, nets, spearfishers, invasive and rare species were also recorded. The locations of the fish survey are shown in Table 5-53 and Figure 5-83.

Table 5-53 Location of the fish survey stations in JAD2001

Station	Northing (m)	Easting (m)
Windward Edge	641862.10	776659.12
Dos Tortugas	642403.67	775308.15
Groyne Field	643568.87	776377.54

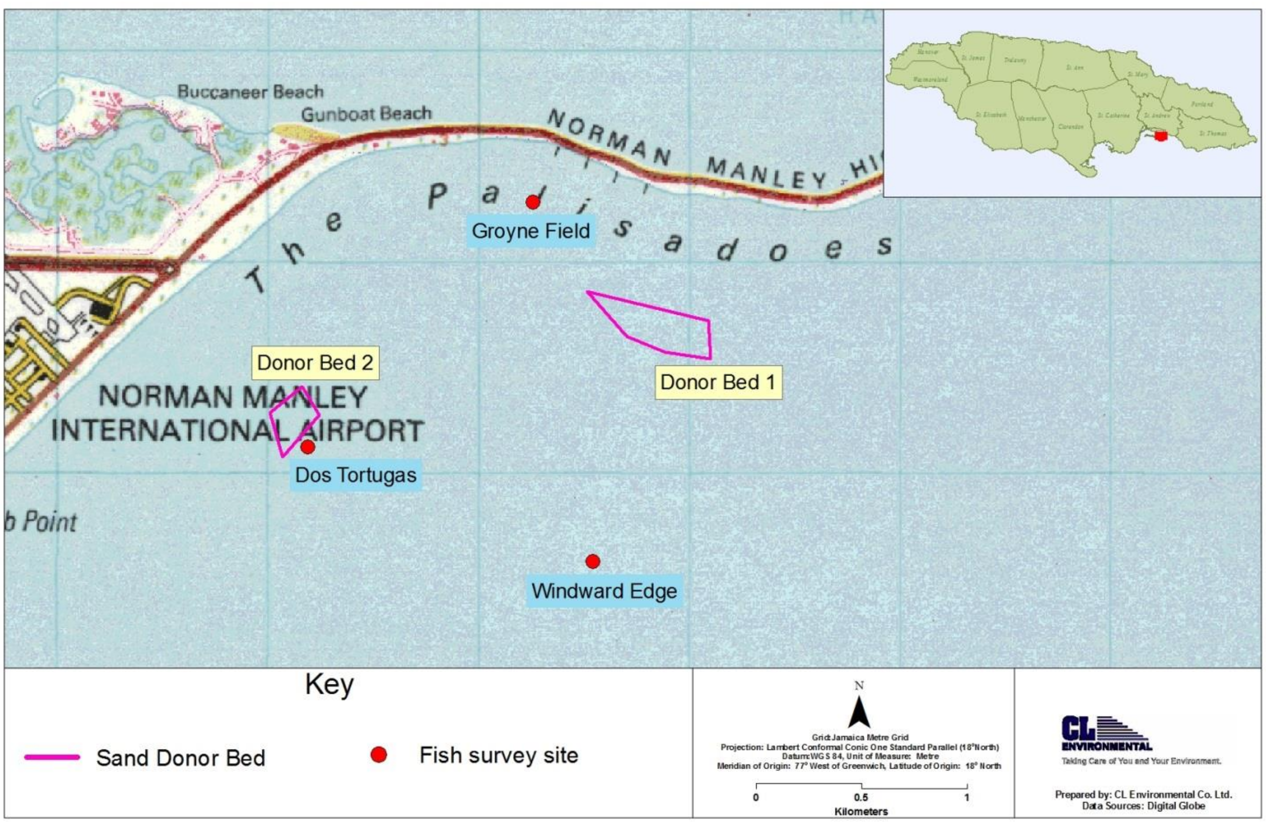


Figure 5-83 Map showing the locations of the fish survey sites

Results

Table 5-54 lists the fish species observed and further details is given in subsections to follow.

Table 5-54 List of fish species observed

Generic name	Taxon or Scientific name	Feeding habit
Spanish Hogfish	*Bodianus rufus*	Invertivore
Yellowhead Wrasse	*Halichoeres garnoti*	Invertivore
Bluehead Wrasse	*Thalassoma bifasciatum*	Invertivore
Harlequin Bass	*Serranus tigrinus*	Invertivore
Yellowtail Damselfish	*Microspathodon chrysurus*	Herbivore
Dusky Damselfish	*Stegastes fuscus*	Herbivore
Bicolour Damselfish	*Stegastes partitus*	Herbivore
French Grunt	*Haemulon flavolineatum*	Invertivore
French Angelfish	*Pomacanthus paru*	Omnivore
Parrotfish	Scaridae	Herbivore
Ocean Surgeonfish	*Acanthurus bahianus*	Herbivore
Squirrelfish	Holocentridae	Carnivore
Goatfish	Mullidae	Carnivore

GROYNE FIELD

This site was located nearshore and visibility was limited to approximately 5 metres. The dominant fish observed at the site was damsel fish with 31 individuals along the transect in the size class 0 -5 cm. Only one species of fish, French grunt, was observed in the 11 – 20cm size class (Figure 5-84). Lion fish were also observed at this site but were not found along the transect line.

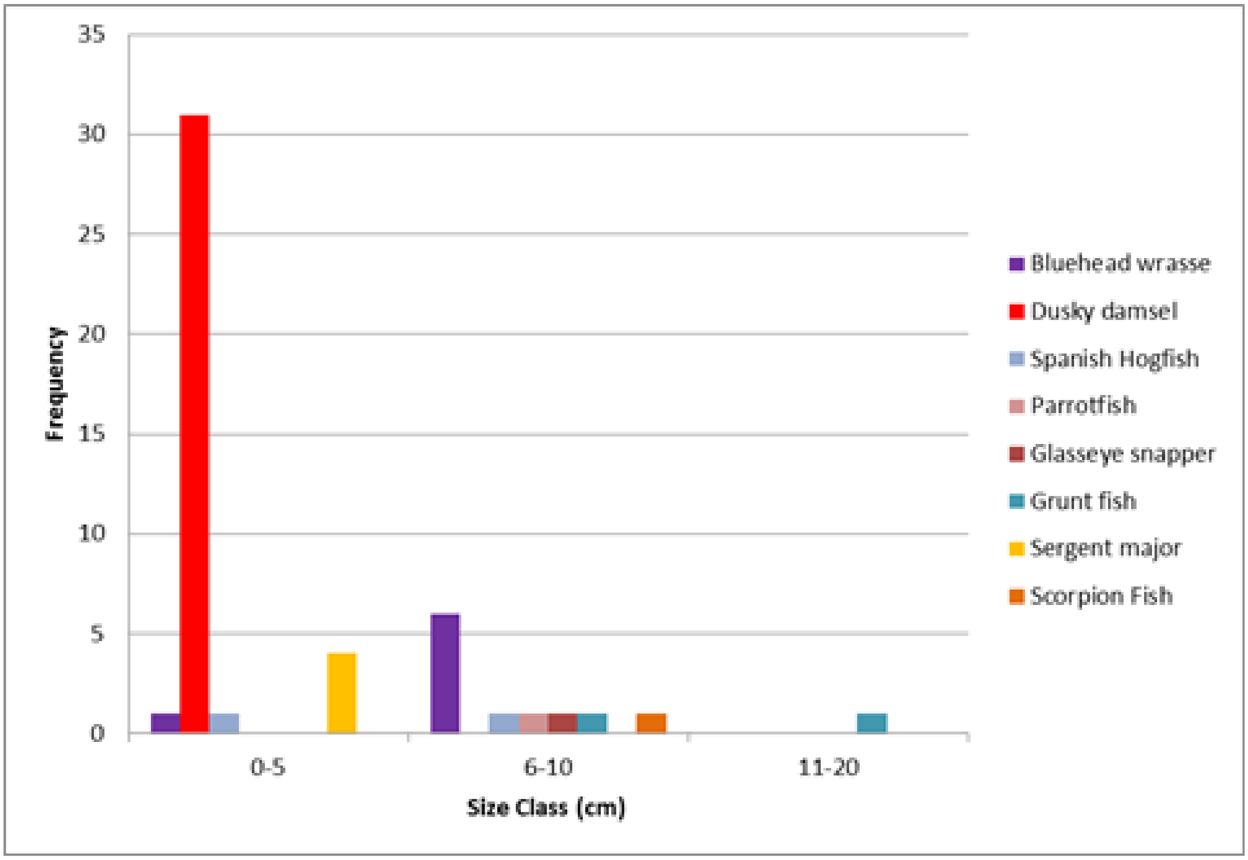


Figure 5-84 Abundance and size of fish species observed at the Groyne Field site

DOS TORTUGAS

This site was located offshore in approximately 15 metres depth of water. The largest size class of fish observed was 11 – 20cm, which was dominated by parrot fish. The most abundant fish observed on the transect was damsel fish in the 0 – 5cm size class (Figure 5-85).

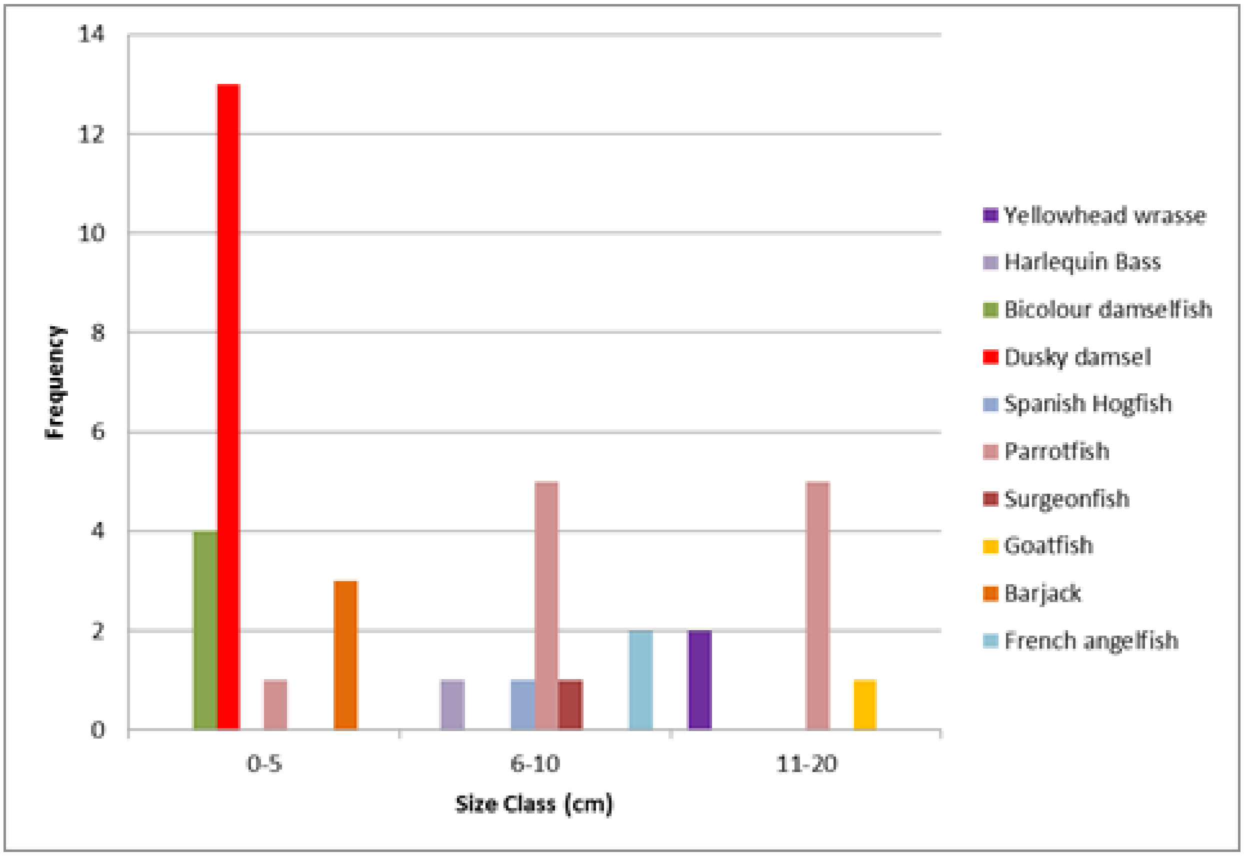


Figure 5-85 Abundance and size of fish species observed at the Dos Tortugas site

WINDWARD EDGE

This site is located the furthest from shore, approximately 2km with a general reef formation of grooves and spurs. The most abundant fish observed at this site was the bluehead wrasse in the 6 – 10cm size class. Parrotfish were observed in all three size classes but were noted in low numbers (Figure 5-87).

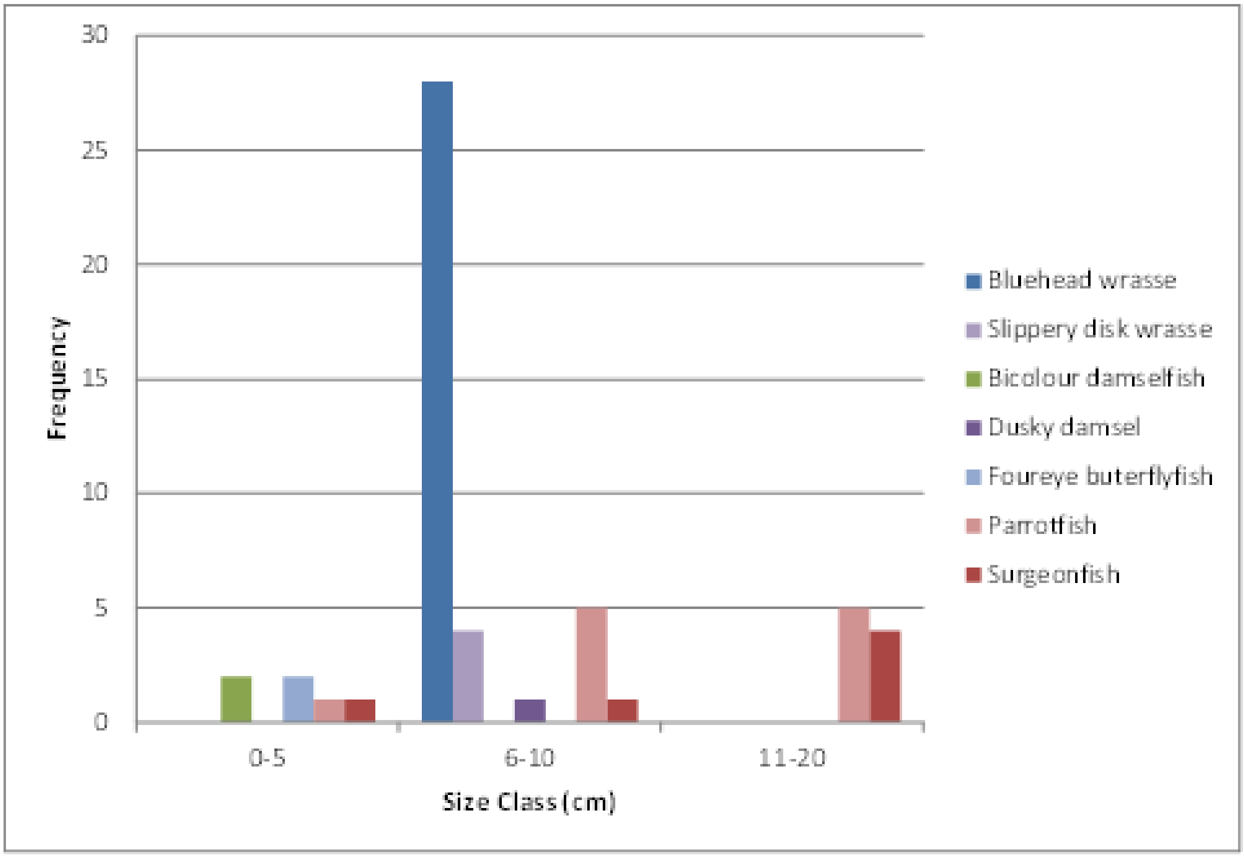


Figure 5-86 Abundance and size of fish species observed at the Windward Edge site

5.3.2.4 Sea Turtles

Sea turtles are classified as a globally endangered species and receive special consideration and protection under such international laws as CITES (Convention on International Trade in Endangered Species of Wild Flora and Fauna) and local laws such as the Wild Life Protection act. Jamaica has five recognised species; The most common and well known, is the Hawksbill turtle (*Erethmochelys imbricata*), followed by the Green turtle (*Chelonia mydas*), Leatherback turtle (*Dermochelys coriacea*) Loggerhead turtle (*Caretta caretta*), and Kemps Ridley (*Lepidochelys kempii*)]. The Hawksbill is the most common nesting turtle on the island while other species are known to utilize local waters for travelling and food.

NEPA has implemented several island wide surveys for turtle nesting and hatchling activity, utilizing various methods, in particular the annual surveying on known nesting beaches. This includes the proposed project area. The Palisadoes roadway has been known as a hotspot for turtle activity, however the most active area have been reported as extending from the light house towards Port Royal. A 2009 NEPA survey showed some turtle activity within the project area but no confirmed nests of hatchlings. Current surveys focus on areas between the light house and Port Royal and not the project area.

According to the Agency, turtles in the area are threatened by:

(i) Fishermen- poach nests, nesting turtles and turtles foraging in the area

(ii) Predation by dogs, rats, mongoose and other invasive species

(iii) Debris and garbage; preventing nesting and or beach access as well as causing strangulation, starvation and other hazardous conditions for turtles and hatchlings.

(iv) Beach usage such as deep tyre tracks in nesting areas; these hinder access as well as prevent hatchlings from successfully reaching the ocean

The Agency along with other global authorities can provide guidelines and recommendations to not only monitor for turtle activity but also to improve conditions for turtles in the area. Improved conditions may include;

- Beach profile monitoring of turtle nesting beaches to determine rate of accretion/erosion.
- Monitoring sand and/or nest temperatures using data loggers and record nest success
- Monitor use of each area of beach by nesting females.
- Replant native coastal vegetation
- Identify and protect cooler beaches

Information about sea turtle activity in the project area was taken from 2008-2012 NEPA turtle survey information.

5.3.2.5 Beach Assessment

Introduction

Sand dune environments located along the south coast of the Palisadoes, as determined by Thompson (1997) are greatly influenced by the local climatic and soil conditions, particularly in the distribution of coastal plant species. These areas are characteristic of high temperatures, high porosity of the soil and salt loaded winds (Thompson & Webber, 1997). Sand dunes present are low at the eastern end of the area but increase in height as you move westward. The terrestrial vegetation present plays an important role in dune formation and stability. Thompson and Webber (1997) have determined a gradient for environmental and edaphic factors; soil temperature, soil moisture, wind speed and soil salinity decrease as you move from sea to land while percentage vegetation cover, percentage organic matter, leaf litter and relative humidity increase along the same gradient. This gradient allows for the establishment of zones specified by variations in percentage cover, height and species composition. These zones moving from the sea landwards are strand beach, strand dune and strand thorn-scrub (Thompson H. P., 1997). Endemic species that are found in this environment are *Callindra pilosa* and *Opunitia jamaicensis*.

The strand beach zone, the closest zone to the sea is characteristic of receiving the greatest exposure to wind and salt spray created by crashing waves with the porous substrate and being exposed to direct sunlight creating an arid and saline environment. Vegetation present in this area must be adapted to the windy saline hot environ therefore xerophytic plants are dominant. However, due to the high mobility of the substrate created by the intense wind action, distribution of these plants is sparse. The adaptations that xerophytic plants possess to survive in this ecosystem include thick succulent leathery leaves with a thick waxy cuticle layer, reduced or even absence of leaves with grow being horizontal along the substrate (Thompson & Webber, 1997). These adaptations allow the plants to retain water and reduce evapotranspiration as well as to avoid the full force of the wind and mobile sand. Plants which characterize this area are *Sporobolus* sp, *Gomphrena* sp and *Sesuvium* sp. These plants are termed pioneer species because of their ability to colonize on a bare beach and lay the foundation for the establishment of others.

The strand dune zone is home to plants that are both herbaceous and woody with the heights of plants ranging from 0.5 m-3 m. The accumulation of soil in this area allows for the establishment of these vertical growers with the roots of these plants holding the soil together. The plants here grow in a distinct littoral hedge that clusters and runs parallel to the shoreline with these hedges consisting of one or multiple species. Organic matter content is relatively high here due to the increase in vegetation that shed their leaves at times when conditions deviate from their optimal range. This increases the nutrient content of the soil allowing for the establishment of other species (Thompson 1997). According to Thompson and Webber (1997) the dominant plants present in this zone are *Capparis* sp and *Callindra* sp.

The strand thorn-scrub zone differs from previous zones by the relative scarcity of herbaceous plants. The deep root systems of the *Acacia* sp and *Callindra* sp that occupy this zone hinder the growth and long-term establishment of non-ephemeral shallow-rooted shrubs. Other plant species found here are *Capparis* sp and cacti species. This harsh environment created by high soil salinity, temperatures and low soil moisture creates the largest zone of the sand dunes. However, land development such as road construction repeatedly threatens the thickness, density and plant composition.

Method

The vegetation, composition and biological characteristics of the potential sand nourishment site (sand deposition area for dredge spoil) was compared to a pristine sand dune (control) site along the Palisadoes/Port Royal roadway. The sand nourishment site was recently disturbed with the laying a rock revetment. The locations of the sample sites are shown in Figure 5-87 and Table 5-55.

The low revetment (buried) area was surveyed by using two(2) 100m belt transects , parallel to the two (2) buried revetment edges, in a West to East direction.

A survey was performed on a reference site along the Port Royal road. The survey was conducted by sampling a 5m wide belt in a North to South direction (seaward to roadway) which was perpendicular to the shoreline, approximately 50m in length.

Table 5-55 Location of vegetation surveys

Site	Northing (m)	Easting (m)
Mangrove Control Site	643179.80	769806.70
Sand dune Control Site	643179.07	769996.52
Mangrove Site 1	643800.09	776780.45
Sand Dune Site 1	643824.38	775534.25
Sand Dune Site 2	643751.84	778319.15

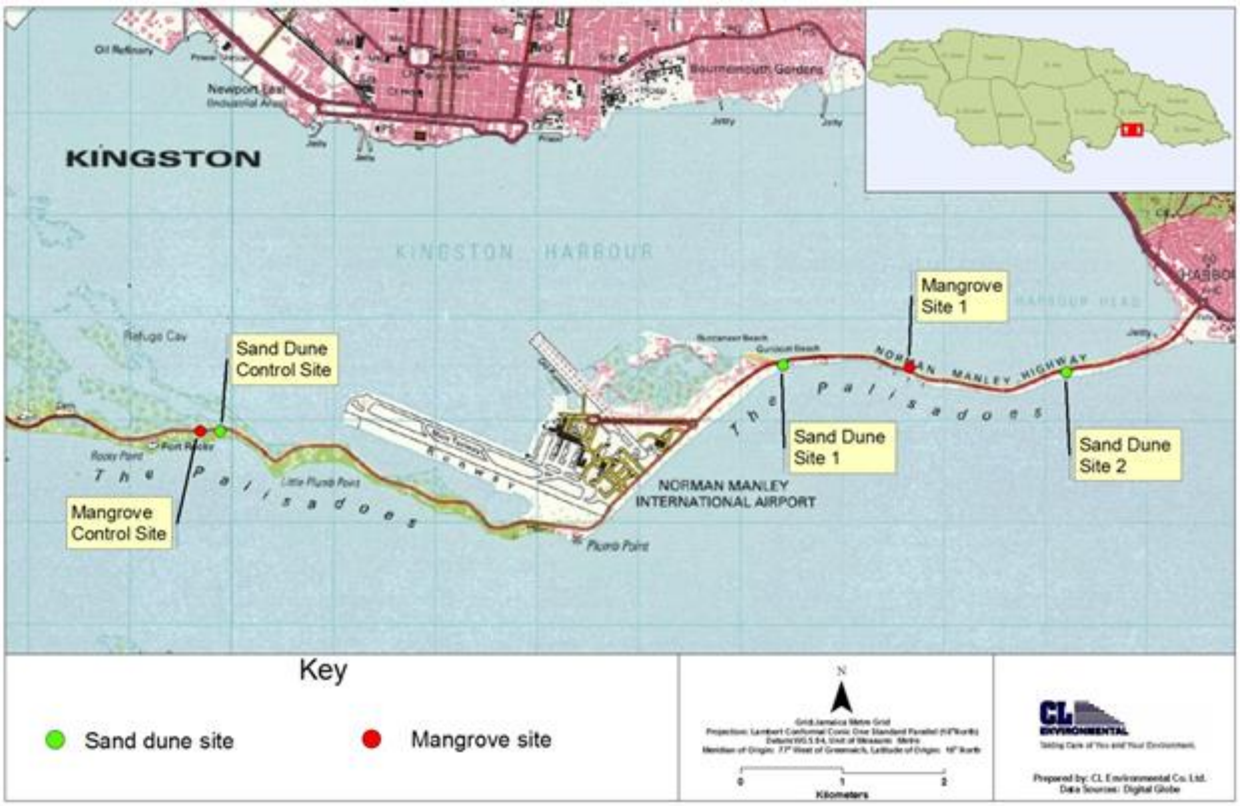


Figure 5-87 Map showing the location of the vegetation surveys

Results

Despite the differences in sampled transect directions for the sand dune, certain observations were made. The control site had nine (9) different species of plants in sand dune area. The control area showed a mixture of pioneer (running) species (3) and six (6) different climax species (trees and cacti). *Acacia* was the most dominant tree, appearing in 90% of quadrats and having a maximum height of three (2.8) meters. *Sesuvium* was the most dominant running plant, appearing in all the quadrats in the control site. The mean *Sesuvium* coverage of 36.5% per quadrat was marginally greater in the established sand dune of the control site.

The species diversity for the sand nourishment site was marginally lower, with five (5) species of plants occurring in the sampled areas. However, no trees were found at the impact site. *Sesuvium* showing average coverage of 29.53% per quadrat, colonizing the recovering sand dune area in the majority of the quadrats sampled. Plate 5-33 and Plate 5-34 show the areas sampled within the nourishment zone. The established trees in the control site also showed ample seeds and flowering trees for further expansion of the forest. The forest floor beneath the trees also had noticeable high levels of leaf litter and organic matter, which was absent in the sand nourishment site (Plate 5-35 to Plate 5-37).

Plate 5-33 Sand dune sampled parallel to the Western buried revetment

Plate 5-34 Transect line along foot of buried revetment

Plate 5-35 Transect line for control site

Plate 5-36 Acacia sp dominated sand dune area, showing seeds and leaf litter

Plate 5-37 Mixed climax vegetation near the sand dune control site

5.4 HUMAN/SOCIAL

5.4.1 Demographic Analysis

5.4.1.1 Social Impact Area

A Social Impact Area (SIA), that is, the estimated spatial extent of the proposed project's effect on the surrounding communities, was demarcated as two (2) kilometres from the Palisadoes main road. As seen in Figure 5-88, this impact area traverses two parishes, namely Kingston along the Palisadoes strip, and St. Andrew at its eastern tip. The communities of Port Royal and Harbour View are situated within the demarcated SIA. It should be noted that there are also several communities adjoining Harbour View, such as Bayshore Park, Harbour Heights, Melbrook Heights, St Benedict's Heights and Crushers.

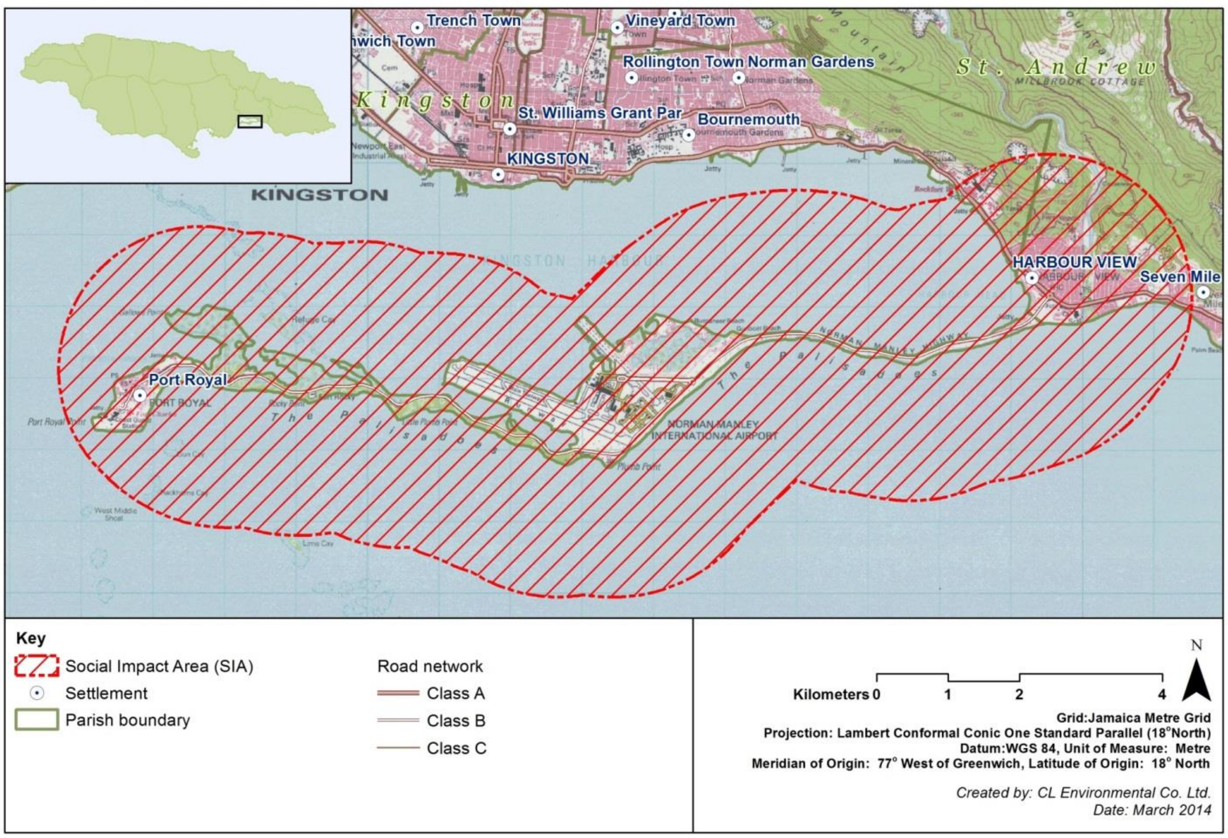


Figure 5-88 Map showing the Social Impact Area (SIA) Population Growth Rate

5.4.1.2 Methodology

Population data were extracted from the STATIN 2011 and 2001 Population Census database for the SIA by enumeration district. This was undertaken using Geographic Information Systems (GIS) methodologies, which were also used to derive visual representations of the data. In order to derive information from the census data the following computations were made:

- ***Population growth*** - was calculated using the formula [$i_2 = i_1 (1 + p)^x$]; where i_1 = initial population, i_2 = final population, p = actual growth rate and x = number of years.
- ***Population density*** – was derived by dividing the population by the land area. This is useful for determining the locations of greater concentrations of population.
- ***Dependency ratio*** – was calculated using the formula [child population + aged population /working population X 100], where the child population is between ages 0-14, the aged population is 65 & over and the working population is between ages 15-64 years. This ratio is useful for understanding the economic burden being borne by the working population.
- ***Male sex ratio*** – was calculated by using the formula [male population / female population X 100]. This in effect denotes the amount of males there are to every 100 females and is useful for determining the predominant gender in a particular area.
- ***Domestic water consumption*** - was calculated based on the assumption that water usage is 227.12 litres/capita/day and sewage generation at 80% of water consumption. Water consumption for workers in Jamaica is calculated at 19 litres/capita/day and sewage generation at 100% water consumption.
- ***Domestic garbage generation*** - was calculated at 4.11 kg/household/day (National Solid Waste Management Authority).

It is important to note that the 2011 Census data forms the basis of the demographic information presented in subsequent sections; however 2011 data for education, employment, housing, land tenure and infrastructure was not available and as such 2001 Census data was utilised for these sections.

The total population within the SIA in 2011 was approximately 16,200 persons (STATIN 2011 Population Census). Examination of the 2001 population data showed that there were approximately 16,942 persons within the 2 km radius of the Palisadoes road in 2001. From this population, and that calculated for the year 2011 (16,200 persons), it was estimated that the actual growth within the SIA between 2001 and 2011 was approximately -0.45% per annum. Based on this decline, at the time of this study (2014), the population was approximately 15,984 persons and is expected to reach 14,291 persons over the next twenty five years if the current population growth rate remains the same.

The annual SIA growth rate of -0.45% is not comparable with the regional rate of 0.33% for St. Andrew (2001-2011)[17], and is slightly less than the negative growth rate for the parish of Kingston (-0.80%). Applying a growth rate similar to the Kingston regional value to the SIA (-0.80%), it is estimated that at the time of the study, the population was 15,814 persons, and in the next twenty five years it will be approximately 12,937 persons. On the other hand, using the regional growth rate of 0.33% similar to

[17] http://statinja.gov.jm/Census/Census2011/Census%202011%20data%20from%20website.pdf

that of the parish of St. Andrew, it is estimated that at the time of the study, the population was 16,361 persons, and in the next twenty five years it will be approximately 17,766 persons.

5.4.1.3 Age & Sex Ratio

The segment of a population that is considered more vulnerable are the young (children less than five years old) and the elderly (65 years and over). In the SIA population, approximately 6.0% comprised the young category and 7.8%, the 65 years and older category.

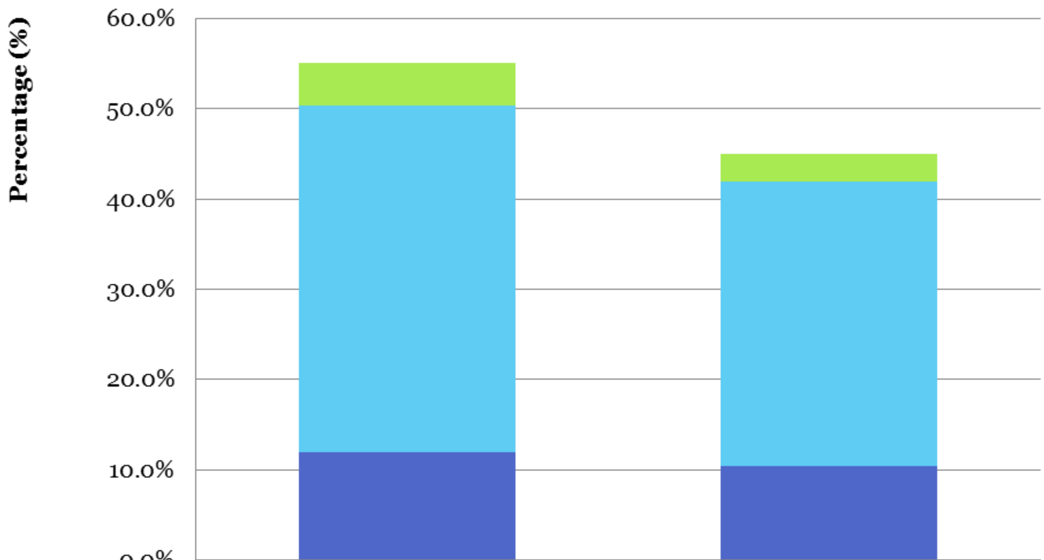
Table 5-56 shows the percentage composition of each age category of the population. This is compared on a national, regional and local (SIA) level. Percentage age distribution is comparable between the SIA and the regional figure for St. Andrew for the 0-14 years age cohort (22.5% and 22.6% respectively); however a greater percentage of children were reported for the parish of Kingston (27.9%) and Jamaica (26.1%). Elderly persons aged 65 years and greater make up 7.8% of the SIA population; this is comparable to the St. Andrew figure of 7.5%, as well as the national figure (8.1%).

Table 5-56 Age categories as percentage of the population for the year 2011

Age Categories	Jamaica	Kingston	St. Andrew	SIA
0-14	26.1%	27.9%	22.6%	22.5%
15 - 64	65.9%	66.0%	69.9%	69.8%
65 & Over	8.1%	6.1%	7.5%	7.8%

Source: STATIN Population Census 2011

Within the SIA, the 15-64 years age category accounted for 69.8% and can therefore be considered a working age population. This SIA percentage was similar to that for St. Andrew (69.9%) and greater than the Kingston and Jamaica percentages for this 15-64 years cohort (Table 5-56). As seen in Figure 5-89, Census 2011 data indicated that there were noticeably more males within the 15-64 years age cohort when compared to females. Sex ratio for the SIA was calculated to be 122.4 males per one hundred females.



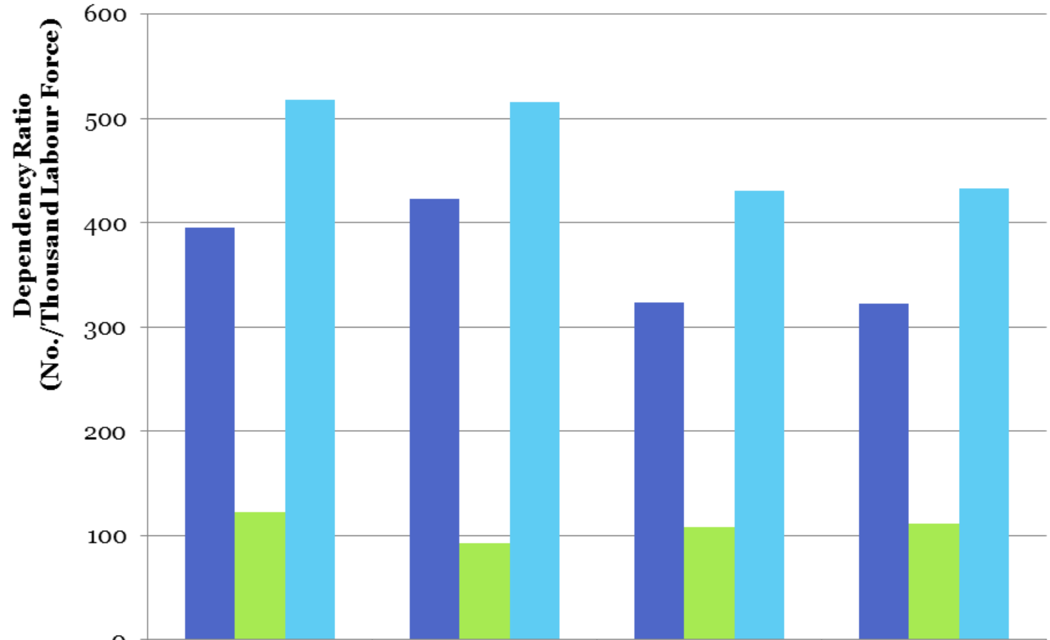
	Male	Female
65 & Over	4.7%	3.0%
15 - 64	38.3%	31.5%
0-14	12.0%	10.5%

Source data: STATIN Population Census 2011

Figure 5-89 Male and female percentage population by age category for the SIA in 2011

5.4.1.4 Dependency Ratios

The child dependency ratio for the SIA in 2011 was 322.0 per 1000 persons of labour force age; old age dependency ratio stood at 111.2 per 1000 persons of labour force age; and societal dependency ratio of 433.2 per 1000 persons of labour force. This indicates that the youth (child dependency) is more dependent on the labour force for support when compared with the elderly. Comparisons of the child dependency ratios at varying extents indicate that the child dependency ratio for the study area (SIA) were lower than the national and regional figures (Figure 5-90).



	Jamaica	Kingston	St. Andrew	SIA
Child Dependency	395.4	423.0	323.0	322.0
Old Age Dependency	122.4	92.2	108.0	111.2
Societal Dependency	517.8	515.2	431.0	433.2

Source: STATIN Population Census 2011

Figure 5-90 Comparison of dependency ratios for the year 2011

5.4.1.5 Population Density

The land area within the SIA was calculated to be approximately 11.76 km². With a population of 16,200 persons, the overall population density was calculated to be 1,377.7 persons/km². This population density is considerably higher than the national level (245.5 persons/km²), however comparable with the St. Andrew regional density of 1,321.7 persons/km² (Table 5-57). Figure 5-91 demonstrates that the largest concentrations of the SIA population are located east of the SIA in Harbour View (according to 2011 Census data).

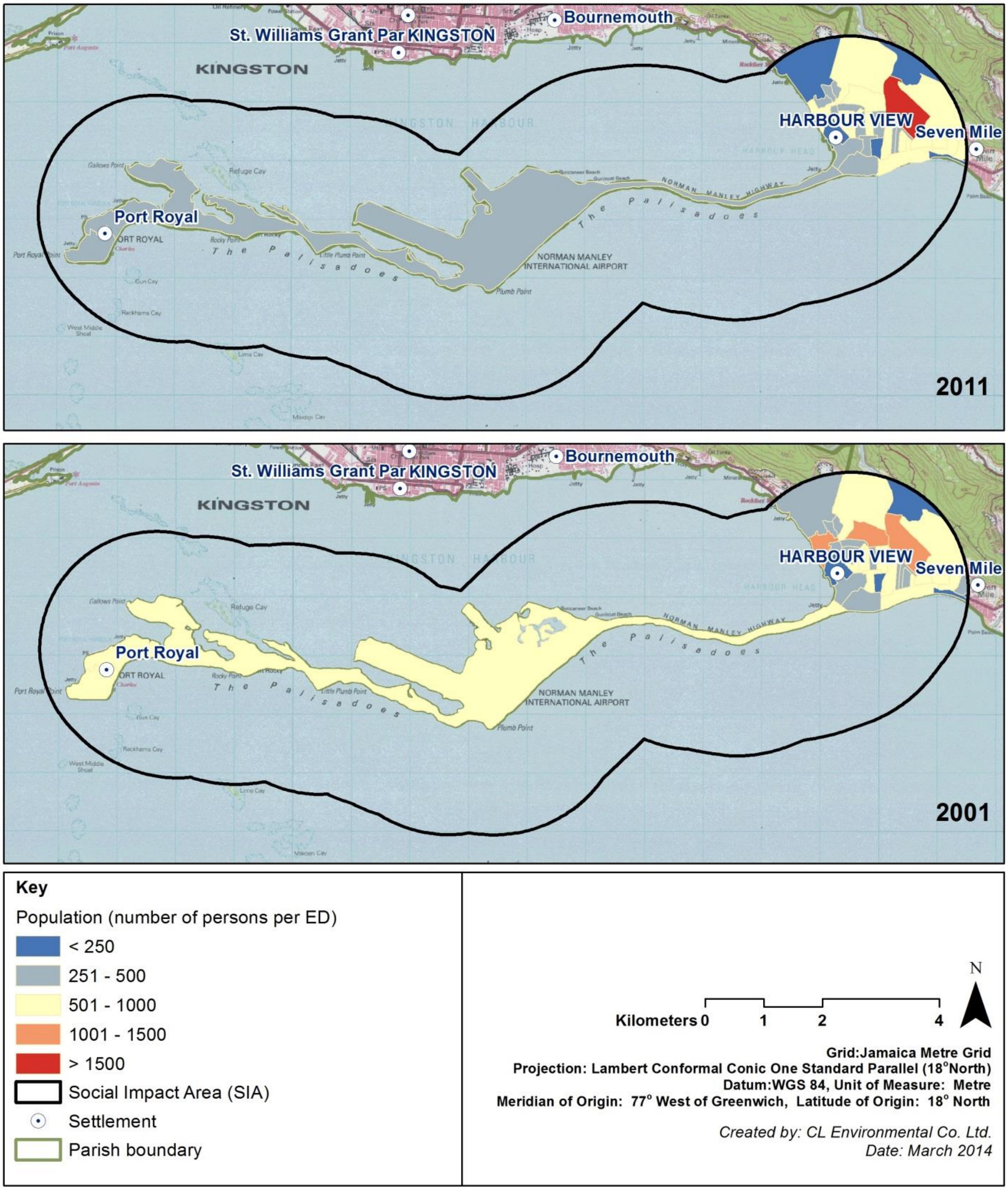
Table 5-57 Comparison of population densities for the year 2011

Category	Jamaica	Kingston	St. Andrew	SIA
Land Area (km²)	10,991.0	22.7	433.8	11.8
Population	2,697,983	89,057	573,369	16,200
Population Density	245.5	3921.5	1321.7	1377.7

Source: STATIN Population Census 2011

5.4.1.6 Population Growth Areas

Figure 5-91 depicts the population within each enumeration district (ED) for the years 2001 and 2011. Total SIA population decreased from 16,942 persons to 16,200 persons within this ten year timeframe. The ED stretching from Port Royal across the Palisadoes saw a decrease in population (from 949 to 495 persons) between 2001 and 2011 and a similar decrease was observed in Port Royal as well (from 703 in 2001 to 389 persons in 2011). Both decreases and increases are seen amongst the EDs located within the Harbour View area; however an overall increase in population from 15,290 to 15,335 persons is observed between 2001 and 2011 for that portion of Harbour View located within the SIA.



Source: STATIN Population Census 2011 and 2001

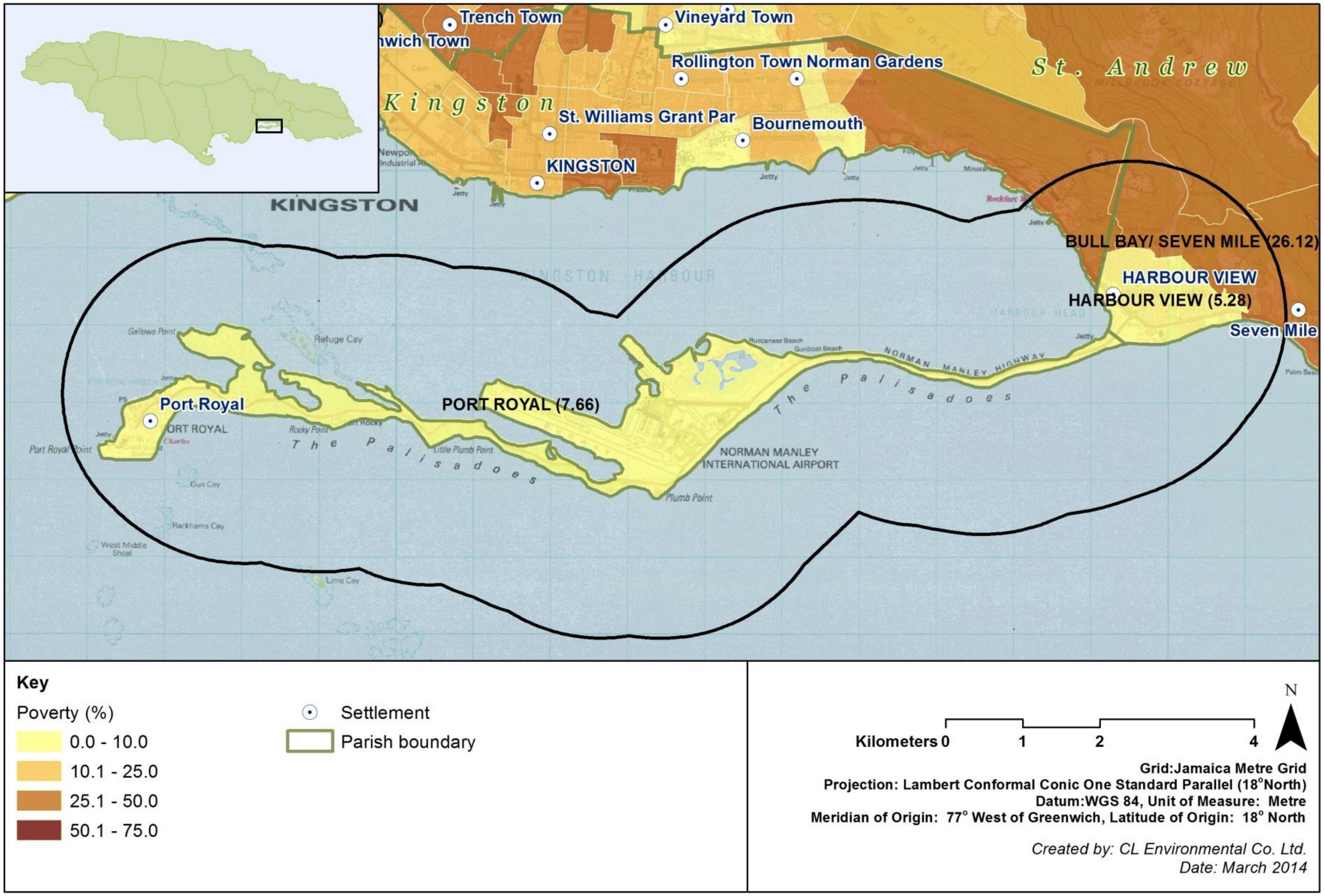
Figure 5-91 SIA 2001 and 2011 population data represented in enumeration districts

5.4.1.7 Poverty

A poverty GIS dataset was developed by the Planning Institute of Jamaica (PIOJ) (with contributions from STATIN, Social Development Commission (SDC) and the University of Technology), primarily to identify areas of poverty by community. As described by PIOJ, for the 2002 poverty map:

> The indicators utilized were those that best predicted per capita consumption levels in households based on data from the Jamaica Survey of Living Conditions (JSLC) 2002. Relevant variables that were common to this survey and the Population Census 2001 were selected and tested for similarity. The satisfactory variables were then applied to the census data to obtain estimates of the consumption levels of the households that had consumption levels islandwide. Members of households that had consumption levels below the poverty line for the region in which their household was located were deemed to be in poverty. The proportion of persons in poverty in each community was used to rank the 829 communities.

As seen in Figure 5-92, the SIA population generally has less than 10% of persons living in poverty (Harbour View and Port Royal), with the exception of the easternmost tip within the Bull Bay/ Seven Mile community, which has poverty levels of 26% .



Source: PIOJ (with contributions from STATIN, Social Development Commission (SDC) and the University of Technology

Figure 5-92 Proportion of persons in poverty in each community

5.4.2 Social, Health and Emergency Services

5.4.2.1 Health Centres

Two Southeast Regional Health Authority health centres exist within the SIA (Figure 5-93), and specifically in the communities of Harbour View and Port Royal. That centre located in Port Royal is an open Type I facility, at which the population served is not more than 4,000. Basic maternal and child health; health education, family planning, immunization and nutrition services are offered. The Harbour View health centre however is a Type III facility, where the population served is about 20,000 people and services include family health (including antenatal, postnatal, child health, nutrition, family planning & immunization); curative, dental, environmental health, Sexually Transmitted Infections (STIs) treatment, counselling & contact investigation; child guidance, mental health and pharmacy.[18]

5.4.2.2 Hospitals

There are currently no public or private hospitals within the SIA. Hospitals closest to the site are situated in Kingston and belong to the Southeast Regional Health Authority[19]:

- Bellevue Hospital (Specialist, public) – Has the legal responsibility to accept all persons needing psychiatric care and provides medical, nursing and rehabilitative services. It has a bed capacity 800, staff complement of 721 and annual patient load of 854.
- Victoria Jubilee Hospital (VJH) (Specialist, public) - Provides services to the maternal community, training and research for doctors, nurses, midwives and other health care personnel. VJH sees more than 70,000 women and approximately 9,000 babies are delivered each year. The institution has a bed capacity of 304 (211 adults and 93 babies) with a staff complement is 171. The VJH was incorporated into the Kingston Public Hospital.
- Kingston Public Hospital (Type A, public) - This is a multi-disciplinary institution which provides both secondary and tertiary care and is a final referral point for such services. The following services are provided by the hospital: Diagnostic Imaging, Diagnostic Laboratory, Pharmacy, Medical & Surgery, Physiotherapy, Dietary, Radiotherapy, General & Emergency Surgery, Neurosurgery, Ear, Nose, Throat Surgery (ENT), and Urological Surgery amongst others. It has a bed capacity of 505, staff complement of 1,100 and annual patient load of 160,000.

5.4.2.3 Ambulance Services

Ambulance services operating within the parishes of Kingston and St. Andrew include:

- Ambucare - Network of life sustaining units on call 24 hours a day. Services include radio dispatched vehicles, pre-hospital medical response, air ambulance link (overseas) and standby for events and functions.
- Deluxe - Service team consists of specially trained emergency drivers and EMTs. Services include emergency and non-emergency transfers, hospitals and nursing homes, individual

[18] http://www.srha.gov.jm/Facilities/HealthCentreClassification.aspx
[19] http://www.serha.gov.jm/Default.aspx

companies, stand-by at public events, ground transportation for air ambulance link-up, pre-arranged transport to & from clinics, treatment facilities and laboratories.

- St. Johns - Home nursing and first aid training to individuals and organisations as well as providing health services at sporting events, parties, corporate events and other events.

5.4.2.4 Fire Stations

One fire station in the town of Port Royal is located within the SIA (Figure 5-93). This station falls under Area I.

5.4.2.5 Police Stations

Three police stations are situated within the SIA, namely Port Royal, Norman Manley International Airport and Harbour View police stations.

5.4.2.6 Post Offices

Post offices are found at three locations within the demarcated SIA: Harbour View Shopping Centre, Norman Manley International Airport and Port Royal.

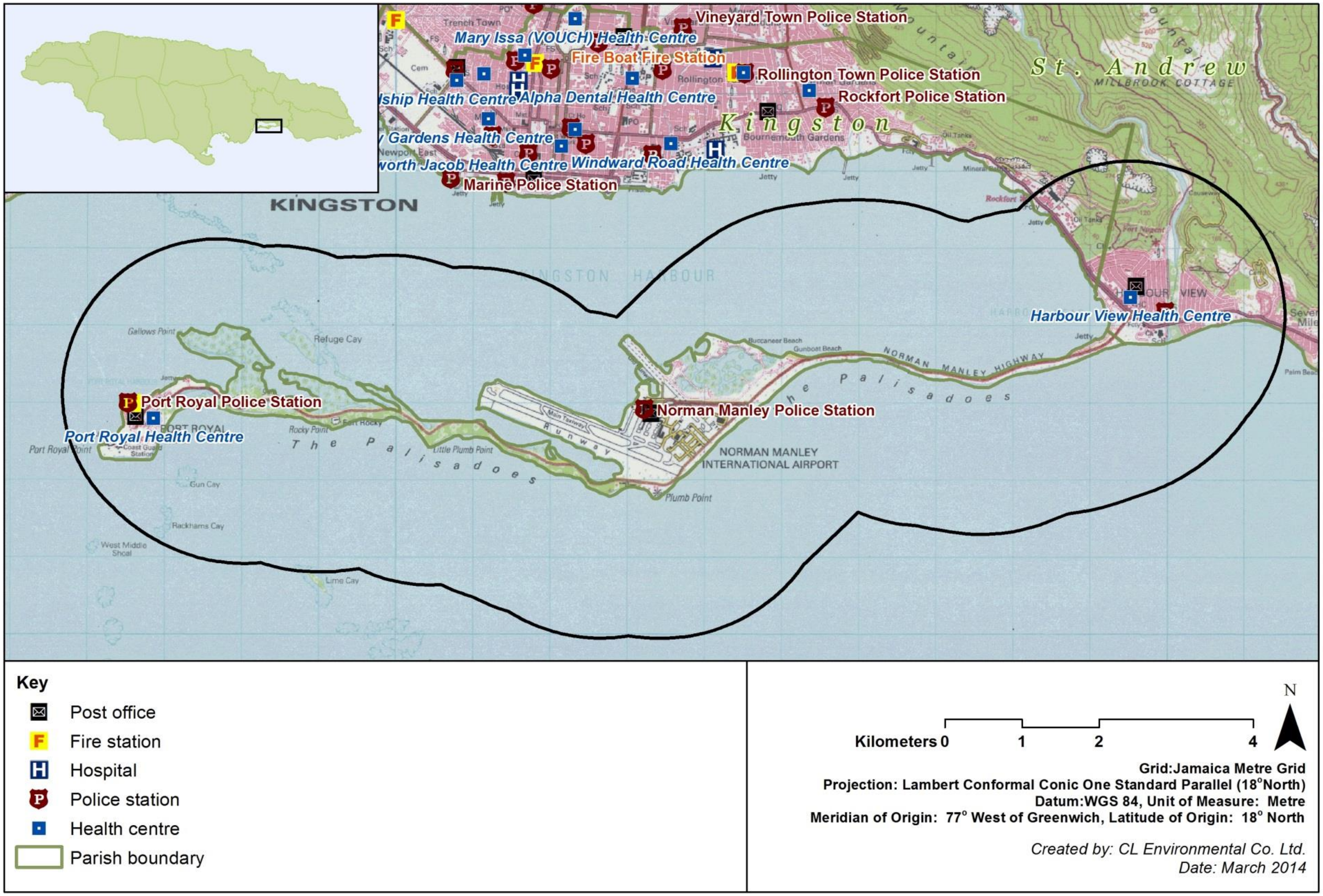


Figure 5-93 Social health and emergency services located in the SIA

5.4.3 Transportation

5.4.3.1 Airfields, Aerodromes and Airports

The Norman Manley International Airport (NMIA) is situated in the centre of the SIA. NMIA Airports Limited is a wholly owned subsidiary of Airports Authority of Jamaica (AAJ) which was incorporated in 2003. The Airport is operated under a 30-year Concession Agreement with AAJ. The NMIA is the primary airport for business travel to and from Jamaica and for the movement of air cargo. There are 13 scheduled airlines serving many international destinations and average daily aircraft movement is 67. In 2013, total passenger movements were approximately 1.37M and freight (cargo/mail) was 11,503 metric tonnes.

The NMIA generates over 13,000 direct and indirect jobs. Located airside, are 13 aircraft gates and 2 remote stands and 9 passenger loading bridges (PLB). The runway is 12/30, with a length of 2,716m (8,910 ft.) and elevation of 3 m (10 ft.). One parallel taxiway with four linked taxiways, including one high-speed exit exists.

5.4.3.2 Ports, Docks and Marinas

Docks located at the Jamaica Flour Mills and the Caribbean Cement Company at Rockfort are located within the SIA. Although not located with the SIA, the Kingston Container Terminal (KCT) situated on the northern edge of the Kingston Harbour is of notable mention. The KCT is operated by Kingston Container Terminal Services Ltd., a subsidiary of the PAJ. It is the largest port in the island and one of the region's leading container transhipment ports. It consists of three terminals—the North, South and West Terminals with a rated capacity of 2.8 Million TEUs. The berth face, channel and turning basin have been dredged to a depth of 13 metres.

Two marinas exist within the SIA, namely Morgan's Harbour Marina (Port Royal) and the Royal Jamaica Yacht Club (RJYC). The RJYC docks about 120 boats in the marina, about two-thirds powered, the remainder being sail of varying sizes. The marina slips can accommodate vessels up to 50 feet in length. In addition, the Jamaica Defence Force (JDF) Coast Guard headquarters is situated in Port Royal.

5.4.3.3 Lighthouse

A lighthouse is defined as a structure erected to carry lights for warning or guidance of ships or aircraft[20]. Lighthouses are operated in conjunction with other navigational aids for example light buoys and beacons. As seen in Figure 5-94, one lighthouse, namely the Plumb Point Lighthouse exists within the SIA at Great Plumb Point along the Palisadoes (WGS 1984 coordinates: 17° 56' N, 76° 47'30"). It was built in 1853 and stands at 70 feet. The light of the Tower is visible as far as twenty-five (25) miles.

5.4.3.4 Road Network

[20] http://www.jnht.com/lighthouses.php

The Norman Manley Highway, commonly known as the Palisadoes road, is a two lane highway that stretches from the roundabout at Harbour View along the Palisadoes towards Port Royal. In 2010, the Government of Jamaica widened and raised the road level from 0.5 - 1 m to 3 – 4 m in response to damage caused repeatedly from hurricanes and storms. In addition, rock revetment has been placed along the entire shore and elevated road, with some 3.7 km of high revetment (1.3 km of the dune revetments to be buried under the dredged sand). The Normal Manley Highway is the sole roadway between Port Royal, NMIA and the mainland. This connection is important for persons travelling to and from the airport, commercial transport of freight, passage of residents to and from Port Royal, and those persons travelling for recreational purposes to RJYC, Morgan's Harbour and Port Royal. Persons also utilise the shoulder of the highway for jogging, walking, leisurely sightseeing and fishing.

In addition to the Norman Manley Highway, a main road exits the roundabout at the NMIA and serves as the entrance to the airport. Roadways branching from the Norman Manley Highway exist in proximity to Gunboat beach and in Port Royal as well.

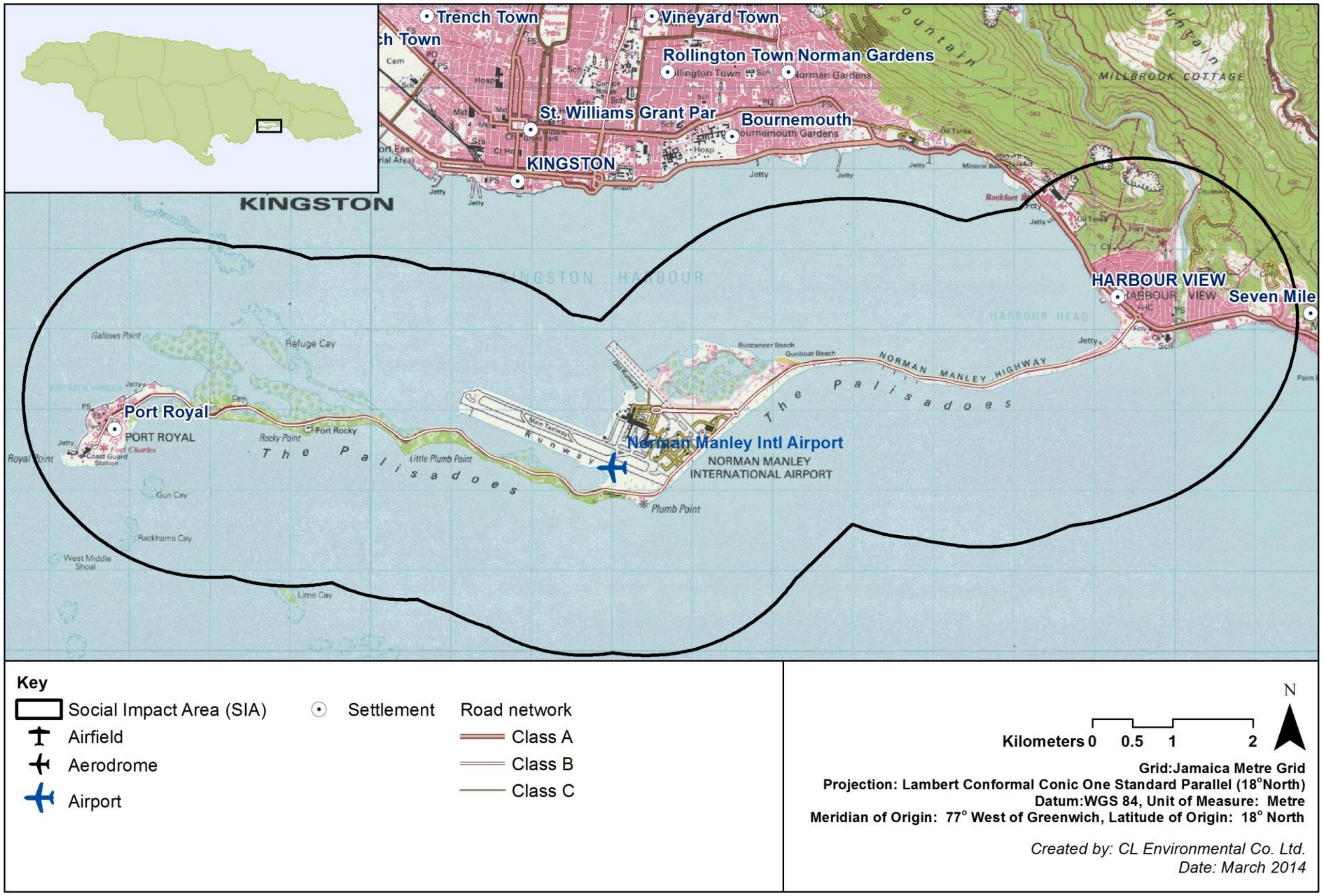
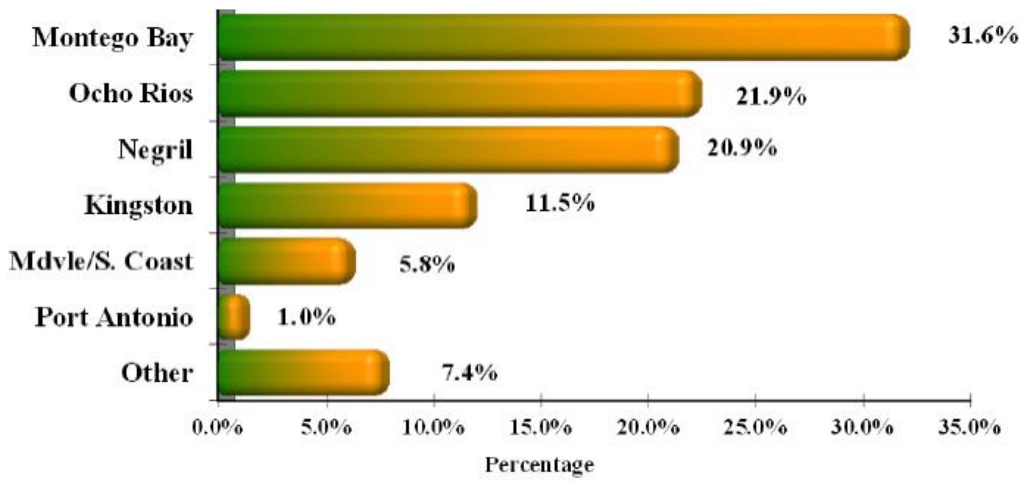


Figure 5-94 Transportation network and infrastructure located in the SIA

5.4.4 Industrial and Economic Activity

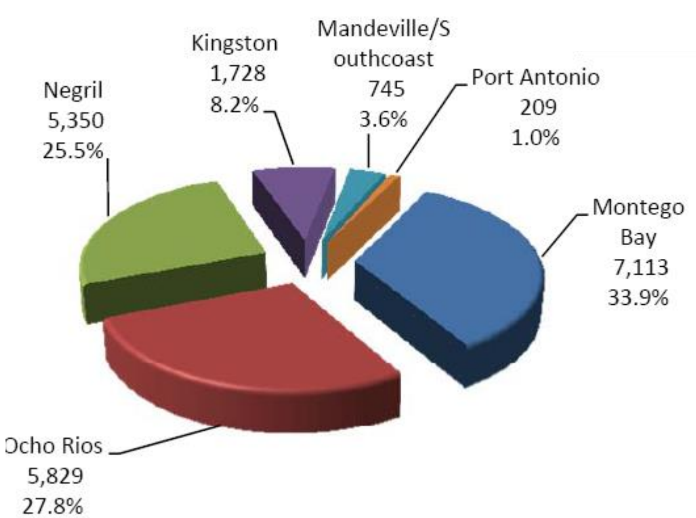
5.4.4.1 Tourism

The Norman Manley Highway along the Palisadoes is the primary road connection between NMIA and the mainland. This link gives visitor's access to Kingston, which accounted for 11.5% of stopover arrivals and 8.2% of total room islandwide in 2012 (Figure 5-95, Figure 5-96). Port Antonio and destinations along the south coast contribute to the national tourism sector as well and NMIA may be the port of arrival for many visitors travelling to these destinations.



Source: Jamaica Tourist Board

Figure 5-95 Stopover arrivals by intended resort areas of stay, 2012



Source: Jamaica Tourist Board

Figure 5-96 Hotel rooms by resort regions, 2012

In 2012, Kingston, Port Antonio and the South coast accounted for 12.3% of employment in the accommodation sector. In addition to direct employment with the tourism industry, there are also a number of indirect (also called inter-industry linkages such as car manufacturing, publishing, furnishing services etc.) and induced jobs (impacts of incomes earned directly and indirectly as they are spent in the local economy, such as wholesalers, food and beverage suppliers, computers etc.). For every $1 million in Travel & Tourism spending, 99 jobs are supported - 30 direct, 50 indirect, and 19 induced (World Travel & Tourism Council 2012). The World Travel & Tourism Council states that for every direct job in the tourism sector, an additional two jobs are created either indirectly or on an induced basis.

5.4.4.2 Fisheries

Fishing is an important economic activity in Kingston; approximately 20.5% of registered vessels[21] and 21% of registered fishers[22] in Jamaica were collectively located in the parishes of Kingston and St. Andrew in 2008 (Ministry of Agriculture and Fisheries). A number of fish landing sites exist in proximity to the proposed works and these are listed in Table 5-58; however only two fishing beaches exist within the 2 km SIA boundary, namely Port Royal and Seven Miles (Figure 5-97). The former beach (Port Royal) accounts for 832 fishers and 350 vessels, this being the greatest numbers in the general study area. Target species at localities in the study area include coral reef finfish, lobster and deep slope/ offshore pelagics.

Table 5-58 Landing sites in proximity to the proposed project works, and associated number of fishers, vessels and target species

Source: Fisheries Division (email correspondence in May 2014)

LANDING SITE	NO OF FISHERS	NO OF VESSEL	SPECIES TARGET
BB – Bull Bay	146	38	Coral reef finfish, lobster
EM - Bull Bay (Eleven Miles)	2		Coral reef finfish, lobster
HH – Harbour Head	148	60	Coral reef finfish, lobster
NM - Bull Bay (Nine Miles)	21		Coral reef finfish, lobster
PR – Port Royal	832	350	Coral reef finfish, lobster, deep slope/ offshore pelagics
Rockfort	73		Coral reef finfish, lobster
RT – Rae Town	463	190	Coral reef finfish, lobster, coastal pelagics
SM - Bull Bay (Seven Miles)	42	11	Coral reef finfish, lobster

5.4.4.3 Manufacturing

The area surrounding Kingston Harbour is a major industrial area. The Jamaica Flour Mills and the Caribbean Cement Company at Rockfort are located within the SIA.

21 http://www.moa.gov.jm/Fisheries/data/Number%20and%20percentage%20of%20registered%20vessels%20by%20parish%202008.pdf

22 http://www.moa.gov.jm/Fisheries/data/Number%20and%20percentage%20of%20registered%20fishers%20by%20parish%202008.pdf

Caribbean Cement Company Limited (CCCL), a member of the Trinidad Cement Limited (TCL) Group, has been producing a consistently high quality of Portland cement for approximately 60 years. One of CCCL's subsidiary companies, namely Jamaica Gypsum and Quarries Limited (JGQ), supplies the Company with the gypsum used in the manufacture of its cement. The Company exports its surplus gypsum to countries such as Colombia, Venezuela, Trinidad and Barbados, whilst a smaller amount is used locally by CCCL in the final stage of cement processing. CCCL is a major contributor to the Jamaican economy and employs over 300 persons. Over 90% of structures present in Jamaica today were built using Carib Cement, as it is commonly known. In 2009, the plant produced 742,208 tonnes of clinker and 736,560 tonnes of cement. The current clinker manufacturing capacity is 1.3 million tonnes and cement manufacturing capacity is 2 million tonnes per annum.

The Jamaica Flour Mills supplies the Jamaican market with a variety of flours and flour-based products for bakeries, homes and restaurants. Cake mixes and breakfast cereals are also produced for the local and export markets.

5.4.5 Recreational

Traditionally, beach use is a recreational experience for many Jamaicans and visitors alike. Two public bathing beaches exist in the SIA, namely Gunboat (55B) and Buccaneer (56B) (Figure 5-94, Figure 5-97). These beaches were popular until the 1980s at which point in time the quality of bathing waters decreased as a result of the pollution in the Kingston Harbour. Major recreational use within the SIA also includes yachting, with facilities at the Royal Jamaica Yacht Club and Morgan's Harbour marinas (Figure 5-94). The Palisadoes strip is also popular for running, walking, recreational fishing and sightseeing.

Owing to degraded water quality of Kingston Harbour, recreation on the harbour side of the Palisadoes is greatly reduced. Prior to the excessive water pollution, water skiing, swimming and cross-the harbour races were popular activities in Kingston Harbour.

5.4.6 Cultural and Archaeological

The town of Port Royal, situated in the western section of the SIA, was founded in the 17th century by the first British settlers who came to Jamaica. It was a headquarters for buccaneers and pirates and become an important economic centre, earning its title of "the richest and wickedest city in the world". Unfortunately it was destroyed by an earthquake in June 1962 and 40 percent of the population died as a consequence of the earthquake. The town was rebuilt following the earthquake, but in 1703 a fire destroyed the town and successive hurricanes throughout the 1700s did not allow Port Royal to regain its former glory. Owing to this rich history, there are numerous places of significance located there, including St. Peter's Church, the Giddy House and the Historic Naval Dockyard and Hospital (Plate 5-38). Forts include Fort Carlisle, Fort Morgan, Fort Rocky, Fort Rupert and Fort Walker. Underwater archaeology is also of significance; underwater explorations and excavations have been conducted in the Sunken City, that portion of Port Royal that sank as a result of the 1962 earthquake.

Source: Jamaica National Heritage Trust Act [23]

Plate 5-38 View of St. Peter's Church and the Historic Naval Hospital, Port Royal

In addition to the Port Royal Heritage Site and associated individual features of significance described previously, Harbour View is the site of Fort Nugent, which was first built by the Spanish slave agent, James Castillo, to guard his home against attack. Rockfort is another area of cultural /archaeological significance located within proximity of the proposed project. Rockfort was once called Harbour Head and was fortified as protection against the possibility of a French invasion in 1694 and properly protected in the 1700s as a result of the vulnerability of the eastern end of city following the 1692 earthquake. Also located at Rockfort, is the Rockfort Spa, which is believed to have appeared miraculously following the 1907 earthquake. The water is very radioactive and is piped from a cold spring in the surrounding hills. The spa has several bathhouses, supplied with warm water, and a large swimming pool. It is believed to have healing properties.

Plate 5-39 View of Rockfort, Kingston

In summary, the following heritage sites fall within or in proximity to the SIA:

- Fort Nugent (Harbour View)
- Fort Charles (Port Royal)
- Port Royal Forts

[23] http://www.jnht.com/site_port_royal.php

- Port Royal
- Rockfort
- Rockfort Spa
- Admiralty Houses (part of the Old Naval Dockyard, Port Royal)
- Port Royal Terrestrial Archaeology
- Port Royal Underwater Archaeology

5.4.7 Land/Beach/ Marine Use and Zoning

5.4.7.1 Beach Classification and Use

In line with the Beach Control Act, the following classification system for beaches has been proposed[24]:

A. Recreational Beaches
   a. Hotel beaches
   b. Commercial beaches
   c. Parish beaches
B. Industrial beaches
C. Fishing beaches

As mentioned previously, two fishing beaches exist within the SIA - Port Royal and Seven Miles and two public bathing beaches exist, namely Gunboat (55B) and Buccaneer (56B) (Figure 5-97).

(a) 

(b) 

Source: National Environment and Planning Agency[25]

Figure 5-97 Fishing (a) and public bathing (b) beaches located across Jamaica

5.4.7.2 Protected Areas and Sites

The Palisadoes/ Port Royal Protected Area (PPRPA) was declared as a protected area on September 18, 1998 and is one of nine (9) protected areas declared under the Natural Resources Conservation Authority Act (NRCA) (1991). On July 22, 1999, the areas was declared a National Heritage Site under

[24] http://www.nepa.gov.jm/policies/beach/Chap5.htm
[25] http://www.nepa.gov.jm/policies/beach/gifs/Map3%20Fishing%20Beach.JPG

the Jamaica National Heritage Trust Act and following this in April 2004, designated a Wetland of International Importance (Ramsar Site) under the Convention on Wetlands of International Importance (Ramsar).

Palisadoes/ Port Royal Protected Area (PPRPA)

The extent of the PPRPA may be seen in Figure 5-98. The area is approximately 13,000 ha (130 km^2) in size and comprises the tombolo (Palisadoes), offshore cays, reefs and mangroves. The area was given protected status owing to historic and archaeological sites of educational and cultural significance; spiritual values; natural resources as a basis for the livelihood for residents and other communities; unique ecosystem (sand/ dune, coral reef, lagoon, seagrass beds); nesting sites for sea turtles, birds and fish; offers protection and a shelter for small vessels/ boats during storms and hurricanes; and acts as major gateway i.e. by sea (sea ports) and air (airports).

Five zones are distinguished:

1. Palisadoes Entrance - Entrance development multiple-use zone, mangrove restoration zone, public recreation zone, closed or no-entry zone, Palisadoes shoreline trail.
2. Airport and Adjacent Developments - Plumb point lighthouse recreation zone, airport mangrove restoration zone/nature reserve, seagrass restoration zone, airport fish sanctuary/nursery, Palisadoes shoreline trail.
3. Mangroves, Dune & Thorn-Cactus Bush - Port Royal Mangroves Fish & Bird Sanctuary, Dune, Cactus and Thorn Forest controlled access zone, Fort Rupert Lagoons recreational development zone, Palisadoes Shoreline Trail
4. Port Royal Town
5. Southern Lagoon, Cays and Reefs

Palisadoes-Port Royal Ramsar Site

The Palisadoes-Port Royal Ramsar Site includes the following cays; Lime Cay (the largest and most popular recreational cay), Gun, South, South East, Rackham's, Drunkenman's, and Maiden Cays. Important species found within this Ramsar site include the American Crocodile (*Crocodylus acutus*), the Reid Seahorse (*Hippocampus reidi*), the Hawksbill turtle (*Eretmochelys imbricata*), the Brown Pelican (*Pelecanus occidentalis*), the West Indian Manatee (*Trichechus manatus manatus*), the Bottlenose Dolphin (*Tursiops truncatus*), the Red Mangrove (*Rhizophora mangle*), the Black Mangrove (*Avicennia germinans*) and the White Mangrove (*Laguncularia racemosa*). The area also has a rich history and is also an important fishing ground. [26]

Port Royal National Heritage Site

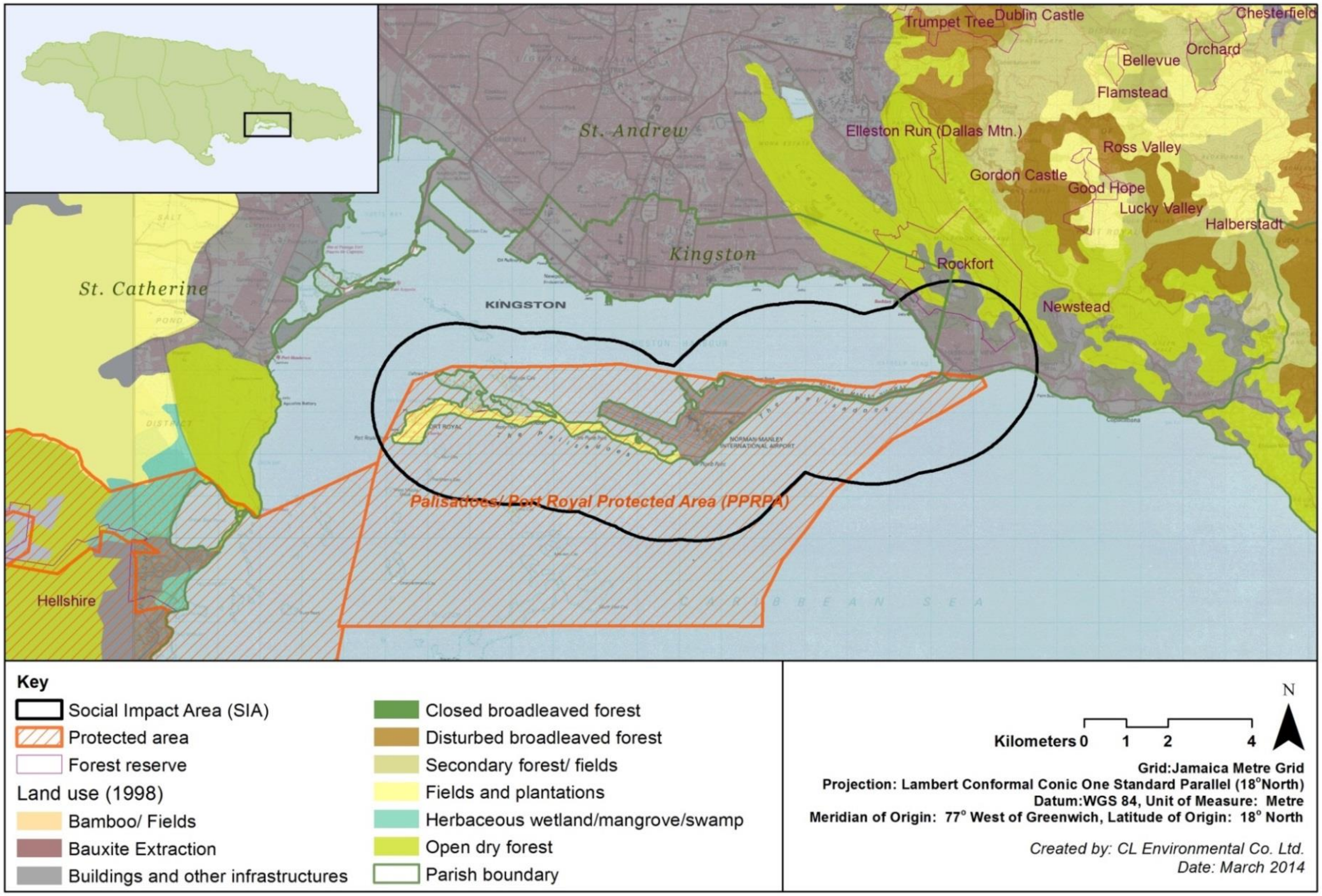
The heritage site encompasses the land and structures as part of Harbour Head Pen, the Palisadoes and Port Royal, and the adjoining sea and cays. As discussed previously, Port Royal was founded in the 17th century by the first British settlers who came to Jamaica. Its rich history brought rise to the

[26] http://www.nepa.gov.jm/poster-competition/protected-areas/Protected%20Areas%20Information%20Sheet_final.pdf

acclaimed title of "the richest and wickedest city in the world" and owing to this history, there are numerous heritage sites located there. These include St. Peter's Church; the Giddy House; the Historic Naval Dockyard and Hospital (Plate 5-38); forts include Fort Carlisle, Fort Morgan, Fort Rocky, Fort Rupert and Fort Walker; and underwater archaeology sites in the "Sunken City".

5.4.7.3 Development Order

The existing development order for the Kingston area is the Kingston Confirmed Development Order 1966. As mentioned previously, though it is considered outdated, this is the main piece of legislation used to guide development in the parishes of Kingston and St. Andrew. As seen in Figure 5-99, the proposed project is located within an area zoned as open space.



Source: Land use and forest reserves (Forestry Department, 1998)

Figure 5-98 Land use and protected areas within and surrounding the SIA

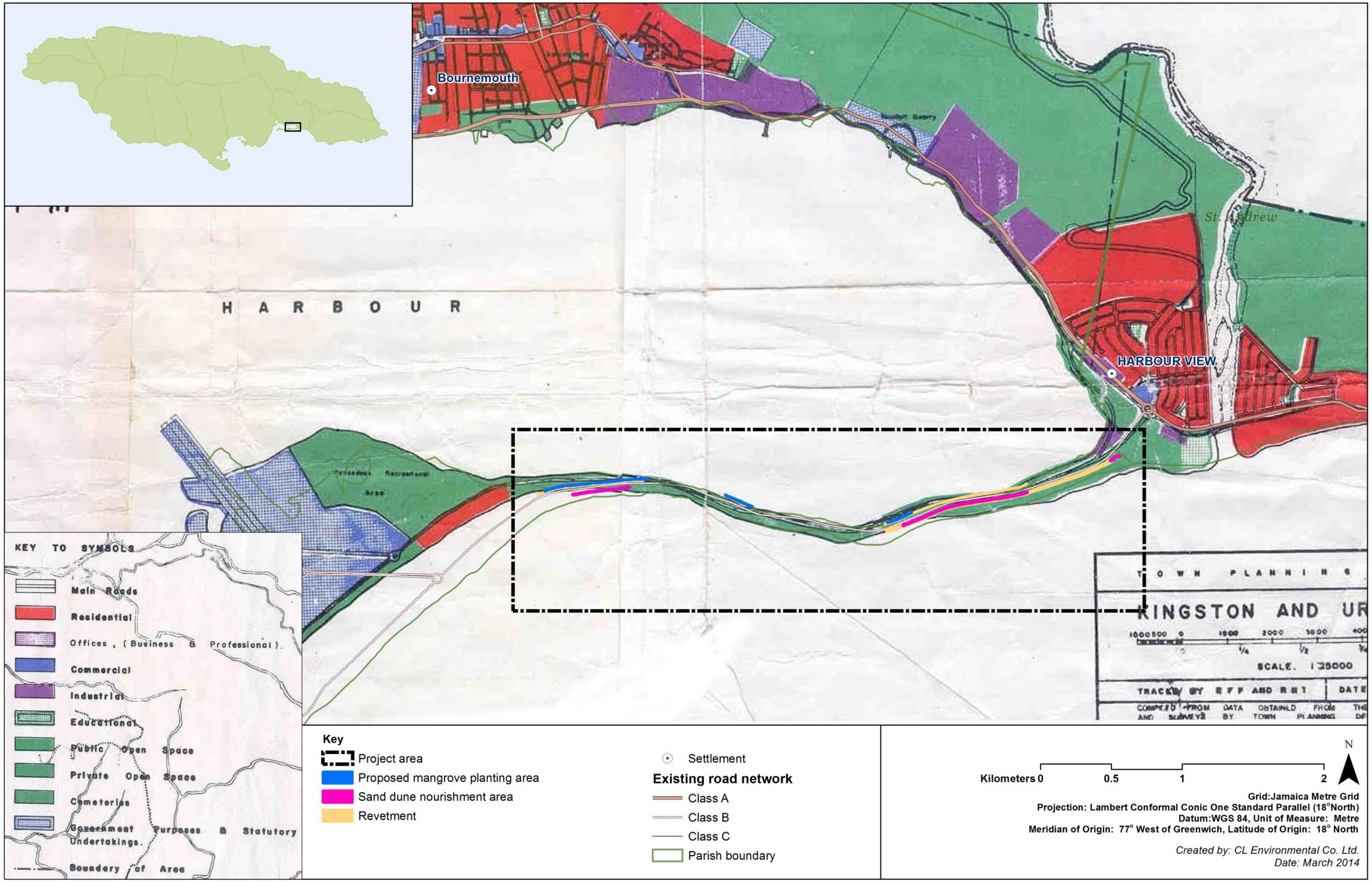


Figure 5-99 Kingston Confirmed Development Order 1966

5.4.7.4 Land Cover/ Use Summary

Historical

The exact origin of the Palisadoes is unknown; however historical records show that Port Royal was once an isolated island and it is possible that Port Royal and other cays were connected to the mainland by a series of spits in order to form what is now known as the Palisadoes (Robinson & Rowe, 2005). Important historical milestones that have influenced the land use along the Palisadoes and within the SIA include:

- 1600s - Port Royal was founded by the first British settlers who came to Jamaica. Rockfort was fortified as protection against the possibility of a French invasion in 1694 and properly protected in the 1700s.
- 1800s - The Jamaica Yacht Club was formed in 1884 by a group of enthusiastic sailors and in November 1889, the Club was granted a Royal Charter by Queen Victoria.[27]
- 1939 – 1945 (World War II) - much of naturally occurring mangrove and marsh vegetation cleared owing to the construction of a Fleet Air Army Station (Environmental Management Consultants (Caribbean) Ltd., 2007).
- 1948 - The Palisadoes Airport (now Norman Manley International) and the Montego Bay Airport was established.
- 1959 - Gunboat beach was developed as a public bathing beach and patrons enjoyed the facilities up until the mid-1980s, at which time recreational activity such as swimming, picnicking and water skiing declined owing to the pollution within the Kingston Harbour (Environmental Management Consultants (Caribbean) Ltd., 2007).
- 1959-1960 - Housing development of 1,865 houses was established by the West Indies Home Contractors, named Harbour View.

Existing

As showcased in previous sections, existing land use within the SIA is mixed. Buildings and other infrastructure (Figure 5-98) are associated with:

- Residential and commercial areas in the communities of Harbour View and Port Royal;
- Industrial facilities such as the Jamaica Flour Mills and the Caribbean Cement Company at Rockfort;
- Institutional /educational facilities at the Caribbean Maritime Institute (CMI) and the University of West Indies Marine Laboratory (Port Royal);
- Transportation services along the Norman Manley Highway and at the Norman Manley International Airport (NMIA);
- Recreational activity at facilities in Harbour View and Port Royal, as well as the Royal Jamaica Yacht Club (RJYC) and the public bathing beaches (Gunboat and Buccaneer). Even though polluted waters and degraded facilities are known to exist at the public bathing beaches, it is

[27] http://rjyconline.com/about.php

still reported more than 200 persons utilise Gunboat beach on public holidays (Environmental Management Consultants (Caribbean) Ltd., 2007). However, Environmental Management Consultants (Caribbean) Ltd. (2007) reported that only approximately ten (10) persons were seen swimming at Gunboat beach on Sunday, December 3, 2006 between 1.00 pm and 2.00 pm; and

- The Quarantine Complex of the Ministry of Agriculture at Plumb Point.

The Palisadoes and Port Royal mangroves are an important ecological feature occurring along the land/water interface and the general area is of environmental and cultural significance as suggested by the declared protected status.

5.4.1 Perception Survey

5.4.1.1 Introduction and Overview

A Social Impact Assessment (SIA) is used to analyse, monitor and manage the social consequences of development" (Vanclay, 2003a) and may be considered a component of an EIA. The specific objective of the SIA for this project was gleaned from the TORs for the project, which required that a perception survey of residents, individuals and organized groups be acquired. This was undertaken by various means, including key informant consultations; stakeholder meetings/consultations; direct observations; and surveys using questionnaires. The process of engagement with stakeholders along the Palisadoes sought to understand any issues, concerns or views about the proposed project. The survey instrument was administered to a total of 32 stakeholders along the Palisadoes and in the town of Port Royal during the period April 30 to May 3, 2014. The specific stakeholders targeted were: members of the community (residents), fisher folk and recreational users. Figure 5-100 shows the distribution of the survey among the various stakeholders.

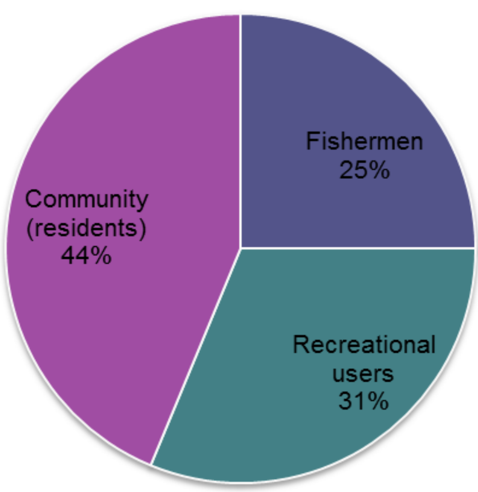


Figure 5-100 Distribution of the survey among various stakeholders

The detailed results of the survey are provided in subsequent subsections; however some of the salient findings are as follows:

1. As illustrated in Figure 5-101 below, there was a higher level of awareness of mangrove islands than sand dunes. Most persons did not have knowledge about the proposed project; however when the project was described, there was generally not much concern. Members of the community surveyed also indicated they had noticed environmental changes to the Palisadoes beach, including erosion.

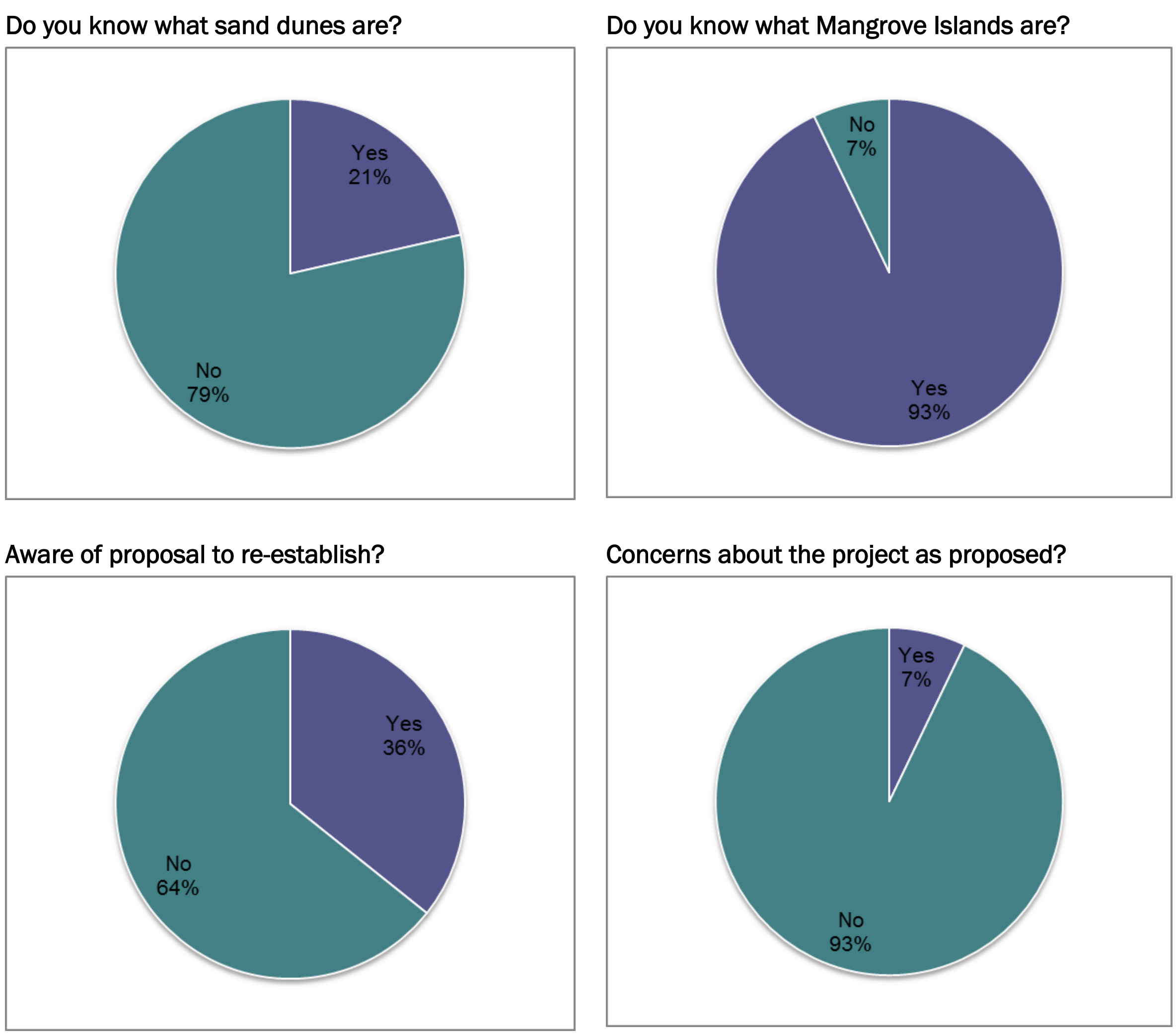
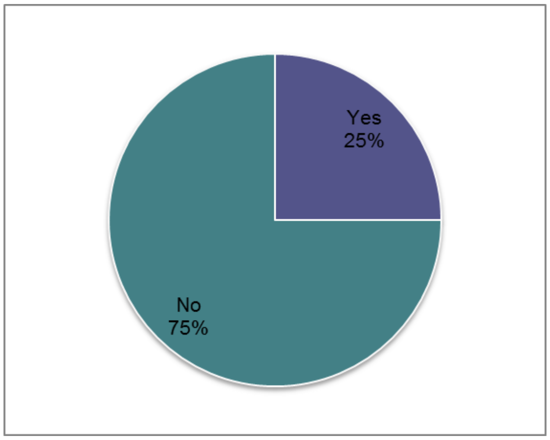


Figure 5-101 Charts showing responses from the community (general population) in Port Royal

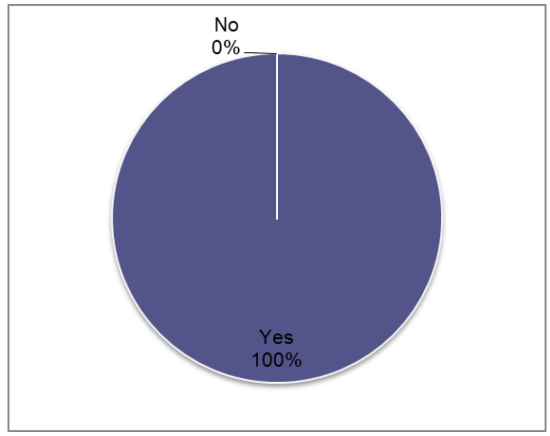
2. Regarding awareness of the proposed project, a similar result was seen when the fishermen were surveyed - those surveyed seemed unaware of the proposal to build mangroves and sand dunes (Figure 5-102).

3. There was a general belief amongst fishers and recreational users that the mangrove islands and sand dunes should be constructed and that they will assist in protecting the roadway (Figure 5-102 and Figure 5-103).

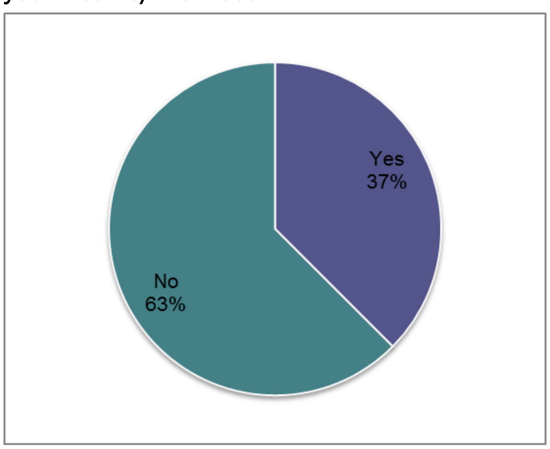
Aware of proposal to create mangrove islands and sand dune?



Should they be constructed?



Do you believe construction activities will impact on your income/livelihood?



Do you think will assist in protecting the roadway?

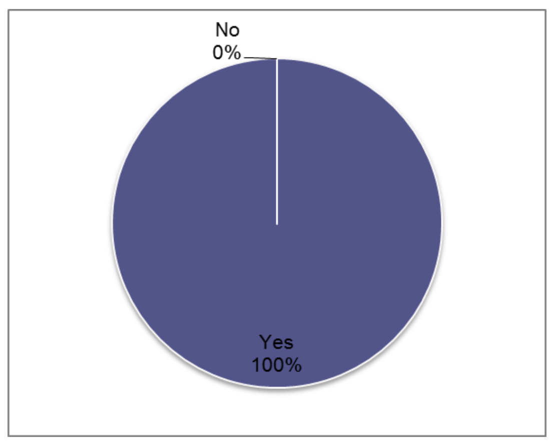
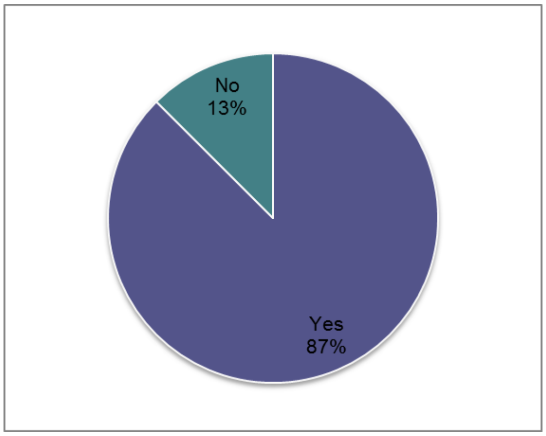
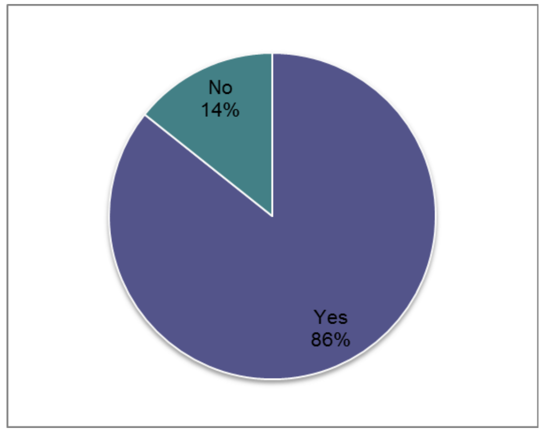


Figure 5-102 Charts showing responses from the fisher folk

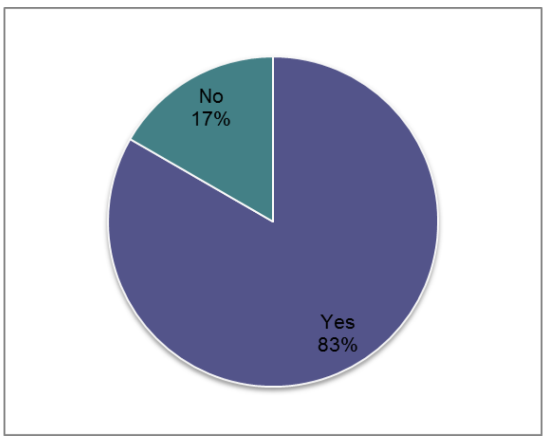
Do you think the mangrove islands should be created?



Do you think the sand dunes should be created?



Do you think the mangrove islands created will assist in protecting the roadway and natural environ?



Do you think the sand dunes created will assist in protecting the roadway and natural environ?

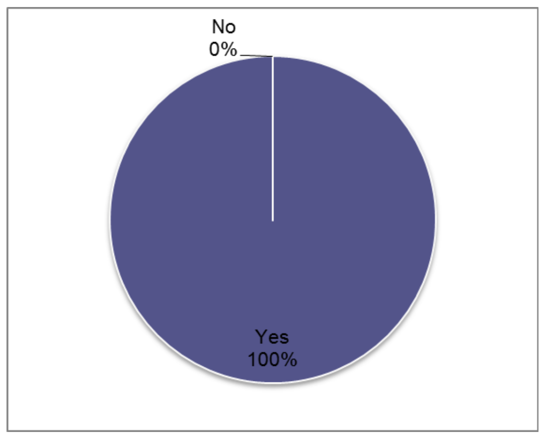


Figure 5-103 Charts showing responses from the recreational users

5.4.1.2 Methodology

A total of 32 questionnaires were administered in the town of Port Royal on April 30 and May 3, 2014 in order to garner feedback from persons whose livelihoods or recreational activity depend on the Palisadoes. Key groups considered included persons residing within the community of Port Royal, as well as fishers and recreational users along the Palisadoes and in the town of Port Royal. A total of 14 community, 10 recreational users and 8 fishermen questionnaires were administered. Questionnaires were developed specific to each grouping; and these are attached as Appendix 6..

5.4.1.3 Results

Response rates were generally high for most questions; however some questions received very low response rates. It must be stressed that all percentages given throughout this section are typically based on the number of interviewees that gave a response to that respective question, and not the total number of questionnaires administered per group, unless otherwise stated. If the number of responses for a particular question is significantly low, this is stated as well.

Community

Of the resident population interviewed, 71.4% were males and 28.6% females. The largest age cohort was less than 25 years (35.7%), followed by the remaining age cohorts (26-40 years, 41-60 years and greater than 60 years) having equal numbers of representatives (21.4%). The majority of the community population interviewed have been living in Port Royal for more than 20 years (64.3%), and 35.7% between 11 and 20 years.

Approximately 57.1% of persons stated that they had not noticed any environmental changes within the community, the remaining 42.9% who did notice changes, stated beach erosion along the seaside of the Harbour and pollution. The majority of persons were not aware of the plans to re-establish sand dunes and mangrove islands along the Palisadoes (64.3%) and 35.7% were aware of this project. The majority did not have any concerns regarding the project (92.9%), whilst one person (7.1%) had concerns, however did not specifically state any. About 66.7% of respondents believed that the project would affect their lives, whilst 33.3% believed it would not. All those that believed it would affect their lives, believed it would be a positive effect, and mentioned roadway protection and fish nurseries as likely effects. In fact, all residents interviewed (100%) believed that shore protection strategies along the Palisadoes by means of the proposed project are needed.

When asked about the construction possibly causing negative impact on businesses, all residents (100%) believed that there would be no affect. As it relates to thoughts on the construction activity being good, the majority (70.0%) answered positively and believed it would be good, whilst 30.0% did not believe it would be. Seventy percent expressed that the construction activity will not affect their income earning capacity, whilst 30.0% stated that it would; those that responded positively stated possible employment opportunities as a likely effect.

The majority of respondents (87.5%) answered "yes" when asked if they thought that the construction of sand dunes and mangrove islands will alleviate some of the problems, and 12.5% stated "no". When asked if they can think of any other measures that could be taken, only 5 persons responded (35.7% of total survey group) and the majority answered positively (80.0%) and gave the following alternative means: cleaning the gutters, raising the road, constructing breakwaters and widening road.

Fishers

Four fishers (50.0%) were between 41 and 60 years, three (37.5%) between 26 and 40 years and one (12.5%) over 60 years of age. All except one fisher interviewed were male. Seventy five percent have been fishing in the Palisadoes area for over 20 years, 12.5% between 11 and 20 years and another 12.5% between 1 and 10 years. Seventy five percent of the fishers utilise both the Harbour and Caribbean Sea sides of the Palisadoes road, whilst 25% do not.

When questioned about environmental problems within the community, 62.5% stated that there are problems, such as sewage, improper garbage disposal along beach and mangroves, squatting and destruction of fishing grounds by ships; the remaining 37.5% did not respond positively. Changes in the environment in the past 10 years and causes for these included mangrove removal resulting from population increase and increases in sewage pollution relating to the NWC.

All fishers who responded to the respective questions depend on the environment as a source of income and for subsistence. With regards to subsistence, 75.0% reported that less than 25% of their total activities are for subsistence, and 25.0% reporting greater than 75%. Responses to the total weekly income varied from less than $1,000 JMD to greater than $10,000 JMD and most fishers stated that income generated was highly variable each week. All fishers except one (87.5%) interviewed stated that locals are their main customers, whilst 37.5% (3 fishers) included restaurants as customers, 25.0% (2 fishers) mentioned vendors and one fisher (12.5%) stated that his fishing activities were recreational.

Half (50.0%) of those who answered the question regarding engagement in practices with positive effects on the environment responded positively, whilst the remaining 50.0% stated that they were not engaged in such practices. Practices believed to have positive effects included the killing of lionfish, removal of garbage, landscaping and neighbourhood watch. Conversely, all fishers who responded stated that they were not involved in practises that affected the environment negatively. With regards to the challenges faced that prevent persons from engaging in positive environmental practices, fishers expressed that lack of technical assistance and cost were major challenges. The fishers' community believe that the following practices would be applicable in preserving the environment as well as sustaining it for the future: removal of garbage; cleaning of the mangrove areas; and reduction of sewage/ use as grey water or irrigation perhaps. Only three fishers responded to the question pertaining to willingness to pay for services such as the provision of information on and technical assistance with ways to improving quality of yield and positive environmental effects; all were willing to pay.

Specifically regarding the creation of mangrove islands and sand dunes, 75.0% of fishermen interviewed were not aware of the project; whilst 25.0% were. All interviewed believed that the mangrove islands and sand dunes should be constructed. Seven fishers (87.5%) did not believe that the mangroves and sand dunes would affect their daily activities and one (12.5%) believed that they would, for example the construction would increase fish populations. Fishers were also asked if they believe construction activities will impact on their income/livelihood, to which 62.5% responded negatively and 37.5% negatively. All fishers (100.0%) believed that the mangroves and sand dunes would assist in protecting the roadway. When asked if they think any other means can be used to protect the bay, 33.3% stated "no", whilst 66.7% said yes, and gave the following possible means: raising the road level and constructing walls in front of the boulders for better aesthetics (this question only had a 37.5% response rate).

Recreational Users

Recreational users approached for interview were mixed in age, with 40.0% between 26 and 40 years, 30.0% greater than 60 years, 20.0% between 41 and 60 years of age and 10.0% younger than 25 years. There were 30.0% males and 70.0% females. Those interviewed primarily utilised the Palisadoes for jogging, walking, running, cycling and scenery, at least once per week, with three persons (30.0%) using the area on a daily basis. Respondents did not perceive that the activities they partake in impact the environment negatively. For 100.0% of recreational users who responded, environmental quality plays an important role in choosing an area (60.0% response rate). With regards to the environmental quality of the Harbour side of the Palisadoes, 50.0% rated it as “poor”, 30.0% as “good” and 20.0% as “fair”. On the Caribbean Sea side, environmental quality was perceived to be fair, satisfactory and good by equal numbers of respondents (33.3% each).

When asked if they share the view that the proposed project should include the environment, all respondents gave positive answers. When asked if they were aware of environmental problems along the Palisadoes, 90.0% stated “yes”, whilst 10.0% stated “no”. Problems described include garbage in the harbour, removal of vegetation, cement dust, odour from the sewage plant and lack of natural barriers.

Specific to the mangrove creation, 87.5% believed that the mangroves should be constructed, whilst 12.5% did not. Similarly, 85.7% believed that the sand dunes should be constructed, whilst 14.3% did not. When asked if they thought constructing the mangroves and sand dunes would assist in protecting the roadway and natural environment, the majority responded positively (83.3% and 100.0% respectively for mangroves and sand dunes).

6.0 IDENTIFICATION AND ASSESSMENT OF POTENTIAL DIRECT AND INDIRECT IMPACTS AND RECOMMENDED MITIGATION

Impact matrices for the site preparation/construction and operational phases were created utilising the following criteria[28]:

- **Direction of Impact**- This describes the nature of the potential impact; positive, negative or no impact of a particular activity on a receptor.
- **Magnitude of Impact:** This is defined by the severity of each potential impact and indicates whether the impact is irreversible or, reversible and estimated potential rate of recovery. The magnitude of an impact cannot be considered high if a major adverse impact can be mitigated.
- **Extent of Impact:** The spatial extent or the zone of influence of the impact should always be determined. An impact can be site-specific or limited to the project area; a locally occurring impact within the locality of the proposed project; a regional impact that may extend beyond the local area and a national impact affecting resources on a national scale and sometimes trans-boundary impacts, which might be international.
- **Duration of Impact:** Environmental impacts have a temporal dimension and needs to be considered in an EIA. Impacts arising at different phases of the project cycle may need to be considered.
- **Significance of the Impact:** This refers to the value or amount of the impact. Once an impact has been predicted, its significance must be evaluated using an appropriate choice of criteria. The most important forms of criterion are:
    - Specific legal requirements e.g. national laws, standards, international agreements and conventions, relevant policies etc.
    - Public views and complaints
    - Threat to sensitive ecosystems and resources e.g. can lead to extinction of species and depletion of resources, which can result, into conflicts.
    - Geographical extent of the impact e.g. has trans- boundary implications.
    - Cost of mitigation
    - Duration (time period over which they will occur)
    - Likelihood or probability of occurrence (very likely, unlikely, etc.)
    - Reversibility of impact (natural recovery or aided by human intervention)
    - Number (and characteristics) of people likely to be affected and their locations
    - Cumulative impacts e.g. adding more impacts to existing ones.

[28] Taken from - Ogola, P. F. A. 2007. Environmental Impact Assessment General Procedures, presented at Short Course II on Surface Exploration for Geothermal Resources, organized by UNU-GTP and KenGen, at Lake Naivasha, Kenya, 2-17 November, 2007

- Uncertainty in prediction due to lack of accurate data or complex systems. Precautionary principle is advocated in this scenario.

Table 6-1 Impact assessment criteria for potential environmental impacts

SCORE	0	1	2	3
CRITERIA	Negligible	Minor	Moderate	Significant
DURATION	None	Physical impacts lasting less than a few months before recovery occurs. Impact does not persist after the activity ends.	Physical impacts lasting from a few months to two years before signs of recovery. It is not inter-generational.	Physical impact is persistent after 2 years. Impacts on a biological population over a number of recruitment cycles or generations of the population.
MAGNITUDE	No measurable change in availability of resources or function of systems. No measurable effect on people.	Changes in form and/or ecosystem function and/or a resource. The system maintains the ability to support ecosystem/ resource functions with only minor changes in community value and no overall loss/gain. Only a small fraction of the local community is affected.	Changes in form and/or ecosystem function and/or a resource. The system's ability to support ecosystem/ resource functions and economic benefit is affected but not lost. Only a moderate fraction of the local community is affected.	Changes in form and/or ecosystem function and/or a resource. The system's ability to support ecosystem/resourc e functions and economic benefit is highly affected. A large fraction of the local community is affected.
EXTENT	None	Isolated effects within activity site.	Localized area close to borders or offsite dispersion pathways.	Widespread: offsite regional effects

6.1 DUNE REHABILITATION

Table 6-2 Impact matrix for site preparation and construction phases of Dune rehabilitation

	RECEPTOR	ACTIVITY	IMPACT	DIRECT/INDIRECT		DIRECTION			DURATION	MAGNITUDE	EXTENT	SIGNIFICANCE SCORE
				DIRECT	INDIRECT	POS	NONE	NEG				
Site Preparation and Construction Phases – Dune Rehabilitation												
Biological Impacts	Meiofauna	Dredging	Species loss , displacement and loss of habitat	X				X	2	2	1	-1.67
		Nourishment	Species loss and displacement	X				X	1	1	1	-1
	Dune Invertebrates	Dredging	Species loss , displacement and loss of habitat	X				X	2	2	1	-1.67
		Dredging-sedimentation	Smothering, species displacement affecting local food chains		X			X	2	2	2	-2
		Nourishment	Species loss , displacement and loss of habitat	X				X	1	1	1	-1
	Filter feeders (Meiofauna and zooplankton)	Dredging-sedimentation	Clogging of gill filaments and feeding apparatus		X			X	1	2	2	-1.67
		Nourishment	Species loss and displacement		X			X	1	1	2	-1.33
	Fish	Dredging	Species loss , displacement and loss of habitat Opportunities for feeding on re-suspended fauna in sediments	X				X	1	1	1	-1
		Dredging-sedimentation	Clogging of gills		X			X	2	2	2	-2
	Marine invertebrates	Dredging	Species loss, habitat destruction	X				X	2	2	2	-2
	Reptiles (Marine Turtles, Crocodiles)	Dredging	displacement, loss of habitat and disruption of nesting	X				X	1	1	1	-1
		Nourishment	Displacement, loss of habitat and disruption of nesting	X				X	2	2	1	-1.67
	Avifauna	Dredging	Displacement	X				X	1	1	1	-1
		Nourishment	Displacement	X				X	1	1	1	-1
	Reefs	Dredging-Sedimentation	Smothering of sessile organisms (corals, sponges, etc.)		X			X	2	2	2	-2
		Mechanical abrasions (anchor damage, spuds, etc.)	Habitat and species loss	X				X	2	2	2	-2
	Vegetation – Beach Runners	Covering of plants, destruction by heavy machinery	Species loss, temporary loss in vegetation cover, accelerated wind erosion	x				x	1	3	1	-1.67
		Covering of plants, destruction by heavy machinery	Wind erosion	X				X	1	3	1	-1.67

	RECEPTOR	ACTIVITY	IMPACT	DIRECT/INDIRECT		DIRECTION			DURATION	MAGNITUDE	EXTENT	SIGNIFICANCE SCORE
				DIRECT	INDIRECT	POS	NONE	NEG				
	Seagrass	Dredging-Sedimentation	Smothering beds and epiphytes. Reduced light penetration. Habitat and species loss.		X			X	1	1	2	-1.33
		Damage (anchor damage, spuds, etc.)	Habitat and species loss	X				X	2	2	1	-1.67
	Beach	Dredging and Nourishment- transport of material	Sand compaction- species displacement and habitat loss.	X				X	2	1	1	-1
		Settlement Ponds	Sand compaction- species displacement and habitat loss.	X				X	2	2	2	-2
	Water Column	Settlement Ponds	Increased TSS and Turbidity from dredge slurry in ponds- which affects gills filaments, filter feeders and Plankton	X				X	1	1	1	-1
Physical Impacts	Nearshore Wave Environment	Dredging	No changes in Bathymetry that will impact waves	X			X		0	0	0	0
	Sediment Transport Regime	Dredging and Nourishment	No changes anticipated	X			X		0	0	0	0
	Currents	Dredging	No changes to current regime	X			X		0	0	0	0
	Beach Profile	Nourishment	Increased sand material along the beach	X				X	1	1	1	-1
	Water Column	Dredging	Increased Suspended solids (Sediment plume to extend up to 2km away.)	X				X	2	1	2	-1.67
			Increased turbidity and reduced PAR (Sediment plume to extend up to 2km away.)	X				X	2	1	2	-1.67
			Increased BOD/Reduced DO (Sediment plume to extend up to 2km away.)		X			X	2	1	2	-1.67
			Suspension of heavy metals	X				X	2	2	2	-2
			Increased water pollution (oils, solid waste etc.)	X				X	2	2	2	-2
			Increased noise pollution – displace sensitive fauna	X				X	1	2	2	-1.67
			Increased TSS and Turbidity	x				x	1	1	1	-1
		Nourishment	Increased turbidity and reduced PAR		X			X	2	1	2	-1.67
			Increased Suspended solids		X			X	2	1	2	-1.67
	Airshed	Settlement Pond -Storage and dewatering of dredged material- Dredging and Nourishment	Reduced Air quality	X				X	2	1	1	-1.33

	RECEPTOR	ACTIVITY	IMPACT	DIRECT/INDIRECT		DIRECTION			DURATION	MAGNITUDE	EXTENT	SIGNIFICANCE SCORE
				DIRECT	INDIRECT	POS	NONE	NEG				
	Dunes	Settlement Pond -Storage and dewatering of dredged material- Dredging and Nourishment	Quality control of dredge material to be used for nourishment.	X		X			2	1	1	1.33
Transport	Maritime operations	Dredging	Increased maritime accident potential	X				X	1	1	1	-1
			Disrupts marine traffic flow in the area.	X				X	1	1	1	-1
	Air shed	Dredging	Reduced air quality-CO_2, NO_x and SO_2	X				X	1	1	2	-1.33
		Nourishment	Reduced air quality- particulates, CO_2, NO_x and SO_2	X				X	2	1	2	-1.67
	Noise Climate	Dredging	Increased noise pollution	X				X	1	1	1	-1
		Nourishment	Increased noise pollution	X				X	1	1	1	-1
Construction Crew	Existing natural and social environment	Dredging	Increased solid waste generation	X				X	1	1	1	-1
			Increased wastewater generation	X				X	1	1	1	-1
			Increased accidental potential	X				X	1	1	1	-1
			Increased water usage	X				X	1	1	1	-1
		Nourishment	Increased solid waste generation	X				X	1	1	1	-1
			Increased wastewater generation	X				X	1	1	1	-1
			Increased accidental potential	X				X	1	1	1	-1
			Increased water usage	X				X	1	1	1	-1
			Increased solid waste generation	X				X	1	1	1	-1
Aesthetics	Observers	Dredging	Increased turbidity and TSS	X				X	2	1	2	-1.67
			Ocean view obstructed by construction equipment and activities	X				X	1	1	1	-1
		Nourishment	Increased turbidity and TSS	X				X	2	1	1	-1.33
			Ocean and beach view obstructed by construction equipment and activities	X				X	1	1	1	-1
Social	Local fishing community	Dredging	Temporary loss of fishing grounds	X				X	1	1	1	-1
			Loss of access to fishing grounds	X				X	1	1	1	-1
			Reduced catch	X				X	1	1	1	-1
			Increased maritime travel time and cost	X				X	1	1	1	-1
			Increased maritime accident potential	X				X	1	1	1	-1
			Damage to fishing equipment	X				X	1	1	1	-1
			Increased conflict potential	X				X	1	1	1	-1
	Recreational Users	Dredging	Increased maritime traffic	X				X	1	1	1	-1
			Displacement of users	X				X	1	1	1	-1
		Nourishment	Decreased air quality	X				X	1	1	2	-1.33
			Decreased water quality	X				X	2	1	1	-1.33

	RECEPTOR	ACTIVITY	IMPACT	DIRECT/INDIRECT		DIRECTION			DURATION	MAGNITUDE	EXTENT	SIGNIFICANCE SCORE
				DIRECT	INDIRECT	POS	NONE	NEG				
			Displacement of users	X				X	1	1	1	-1
	Labour Force/Local Economy	Dredging	Increased employment	X		X			1	1	2	1.33
			Increased Commercial Activity		X	X			1	1	2	1.33
		Nourishment	Increased employment	X		X			1	1	2	1.33
			Increased Commercial Activity		X	X			1	1	2	1.33
	Roadway	Dredging	Traffic Congestion and Reduced Access (NMIA, Coast Guard, Port Royal, CMI, RJYC, etc.)		X			X	1	1	1	-1
		Nourishment	Traffic Congestion and Reduced Access (NMIA, Coast Guard, Port Royal, CMI, RJYC)	X				X	1	1	1	-1
												-1.19

Table 6-3 Impact matrix for operational phase of Dune Rehabilitation

	RECEPTOR	ACTIVITY	IMPACT	DIRECT/INDIRECT		DIRECTION			DURATION	MAGNITUDE	EXTENT	SIGNIFICANCE SCORE
				DIRECT	INDIRECT	POS	NONE	NEG				
Operational Phase – Dune Rehabilitation												
	Meiofauna	Re-vegetated Sand Dune	Increased habitat diversity/usage/suitability. Re-colonization of the borrow area	X		X			3	3	1	2.33
	Invertebrates	Re-vegetated Sand Dune	Increased habitat diversity/usage/suitability. Re-colonization of the borrow area	X		X			3	3	1	2.33
	Filter feeders (Meiofauna and zooplankton)	Re-vegetated Sand Dune	Improved water quality- less run off from stabilized dune sediment		X	X			3	1	2	2
	Fish	Re-vegetated Sand Dune	Improved water quality- less run off from stabilized dune sediment		X	X			3	1	2	2
	Reptiles (Marine Turtles, Crocodiles)	Re-vegetated Sand Dune	Increased habitat diversity/usage/suitability Increased biodiversity and ecosystem diversity(food for birds etc)	X		X			3	2	1	2
	Avifauna	Re-vegetated Sand Dune	Increased habitat diversity/usage/suitability	X		X			3	2	1	2
	Reefs	Re-vegetated Sand Dune	Improved water quality; decreased turbidity/TSS		X	X			3	1	2	2

	RECEPTOR	ACTIVITY	IMPACT	DIRECT/INDIRECT		DIRECTION			DURATION	MAGNITUDE	EXTENT	SIGNIFICANCE SCORE
				DIRECT	INDIRECT	POS	NONE	NEG				
	Vegetation - (Sand dune runners and coastal saplings)	Rehabilitation using pioneers species	Return of ecological functions	X		x			3	3	1	2.67
			Reduction in erosion- wind and wave action	X		X			3	3	1	2.67
			Increased habitat diversity, biodiversity	X		X			3	3	1	2.67
	Seagrass	Re-vegetated Sand Dune	Improved water quality; decreased turbidity/TSS		X	X			3	1	2	2
	Beach	Re-vegetated Sand Dune	Increased stability	X		X			3	2	1	2
Physical Impacts:												
	Nearshore Wave Environment	Re-vegetated Sand Dune	N/A	-	-		X		0	0	0	0
	Sediment Transport Regime	Re-vegetated Sand Dune	N/A	-	-		X		0	0	0	0
	Sediment Plume Modelling	Re-vegetated Sand Dune	N/A	-	-		X		0	0	0	0
	Currents	Re-vegetated Sand Dune	N/A	-	-		X		0	0	0	0
	Beach Profile	Re-vegetated Sand Dune	Increased shoreline protection	X		X			3	3	2	2.67
	Water Column	Re-vegetated Sand Dune	Ambient water quality; decreased turbidity/TSS		X	X			3	1	2	2
Transport	Maritime operations	Re-vegetated Sand Dune	N/A	-	-		X		0	0	0	0
	Airshed	Re-vegetated Sand Dune	Improved air quality-CO_2, NO_x and SO_2 reduced	X		X			3	1	1	1.67
Aesthetics	Observers	Re-vegetated Sand Dune	Improved viewshed	X		X			3	1	1	1.67
Social	Local fishing community	Re-vegetated Sand Dune	N/A	-	-		X		0	0	0	0
	Recreational Users	Re-vegetated Sand Dune	Improved viewshed	X		X			3	1	1	1.67
	Local economy	Re-vegetated Sand Dune	Increased employment	X		X			2	1	1	1.33
	Roadway	Re-vegetated Sand Dune	Shoreline protection	X		X			3	3	2	2.67
			Preserving access to local and regionally important historical/ cultural sites, NMIA Airport, recreational and educational facilities.		X	X			3	3	3	3
	NMIA	Re-vegetated Sand Dune	Shoreline protection road protection	X		X			3	2	2	2.33
Protected area	Ramsar site	Re-vegetated Sand Dune	Establishment and vegetating sand dunes	X		X			3	3	2	2.67
												2.2

6.1.1 Site Preparation and Construction

6.1.1.1 Biological

Invertebrates and Meiofauna

IMPACT

Meiofauna includes; worms, bivalves, crabs, lobsters, sea stars, sea cucumbers and conch, living in or on the sand and may be affected by construction activities.

Dredging

Dredging may result in the loss and/or displacement of these species as well as habitat loss. Filter feeding in meiofauna, invertebrates and zooplankton may be affected due to the clogging of gill filaments and other feeding apparatus as a result of excess sediments in the water column.

Nourishment

Dune Invertebrates and terrestrial meiofauna may be temporarily or permanently displaced, smothered or lost as a result of dune nourishment.

Marine meiofauna and invertebrates' maybe affected during dune nourishment by the resultant runoff/sedimentation which may occur.

RECOMMENDED MITIGATION

Recommended Mitigation 1B – Sediment Barriers and Silt Screens
Dredging

Sediment barriers/silt screens are recommended to be used around all dredging activities. These should be placed so as to reduce/contain the resultant sediment plume during the dredge activities. Dredging activities should only continue when these barriers are fully operational, that is; placed correctly; calm to moderate sea conditions; without damage. These barriers are particularly important when operations occur near or may influence sensitive ecosystems and species such as coral reefs and seagrass beds and or filter feeding organisms and fish. Care should be taken to dredge only in approved dredge areas.

Silt screen can help to reduce the sediment plume area and as such reduce the impact of dredge activities on the natural environment.

Nourishment

Silt screens should be used to reduce or contain any runoff/sedimentation from nourishment activities to the surrounding marine environment. Berms, trenches and barriers should be used to reduce runoff/sedimentation to the marine environment.

Recommended Mitigation 2B – Retention Ponds

Retention ponds should be put in place to reduce the amount of water in the dredge spoil thereby reducing run off from the dredge material. Dredge rates should also allow for adequate retention in these retention ponds.

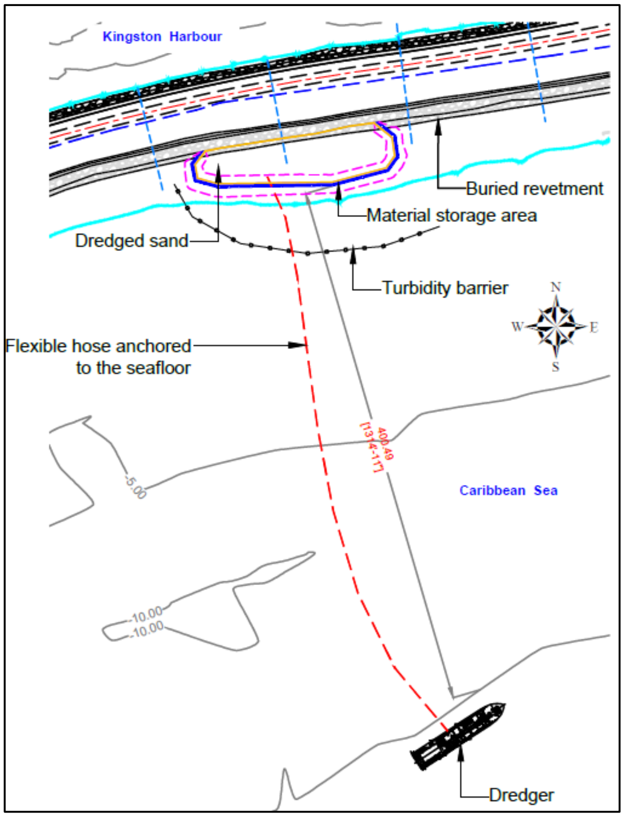


Figure 6-1 Silt Screen positioning

Dredging operations should be continually monitored to ensure equipment and machinery are in good repair and regularly serviced to prevent oil leaks during regular operations.

Fish

IMPACT

Dredging

Dredging activities may result in the temporary or permanent loss and/or displacement of any fish and or fish habitat. The excess sedimentation as a result of the dredge plume may also cause clogging of fish gills and may result in their death.

The re-suspension or displacement of meiofauna and other invertebrates may create a temporary additional food source for some fish species.

Nourishment

Runoff and or siltation as a result of nourishment activities may result in reduced water quality resulting in the temporary displacement of some fish species in the impact area. The excess sedimentation can also result in the clogging of fish gills.

RECOMMENDED MITIGATION

See Silt screens and retention ponds ***Recommended Mitigation 1B and 2B.***

Reptiles- Sea Turtles and Crocodiles and Mammals- Dolphins

IMPACT

Dredging

Dredging activities may result in the temporary displacement of any reptiles and mammals that utilize the dredge area. Displacement may occur as a result of; silt screens and other barriers being utilized, this may prevent/limit access to various habitats and pathways (fragmentation); Noise generated by the activities; avoidance as a result of the dredge plume. This may affect nesting and feeding activities in the area.

The dredging activities will result in increased maritime activities this may increase the interactions between these animals and humans, vessels and machinery. This may increase the risk of accident potential.

Nourishment

Dune nourishment may disrupt nesting activities for turtles and crocodiles and temporarily displace these animals. The compaction of sand as a result of heavy equipment and machinery used in nourishment activities may reduce the suitability of the beach as a nesting site. Any nest on the beach maybe destroyed by nourishment activities.

Recommended Mitigation 3B – Sensitisation and Education of Construction Crew

Sensitisation and education of all construction personnel about all marine fauna (reptiles and mammals) and birds must be undertaken prior to any major works. This should include, but not limited to; proper procedures in the event of an accident/entanglement/interaction; protocol if a nest is discovered. The use of a spotter may also be necessary in-order to prevent incidents.

Where possible, all work activities should be conducted outside of crocodile and turtle nesting seasons in particular the nourishment phase of the proposed project.

RECOMMENDED MITIGATION

Silt screens and retention ponds; see ***Recommended Mitigation 1B and 2B.***

Avifauna

IMPACT

Dredging

Dredge activities may result in the displacement of sea birds as a result of; loss or displacement in their food supply (foraging grounds); avoidance/displacement as a result of noise, general construction activities and increased human presence.

Nourishment

Dune nourishment may disrupt nesting activities and temporarily displace any birds which use the dunes for feeding or roosting. Compaction of the sand as well as the loss or displacement of meiofauna, zooplankton and fish may also affect the foraging/feeding patterns of sea birds that utilize the area.

RECOMMENDED MITIGATION

Sediment barriers/silt screens and retention ponds are recommended; *see* ***Recommended Mitigation 1B and 2B***

Education and Sensitization; see ***Recommended Mitigation 3B***

Reefs

IMPACT

Dredging

Nearby and surrounding reef systems may be exposed to high levels of sediment as a result of the dredge activities. The sedimentation of these sensitive ecosystems may result in the smothering of sessile organisms, in particular coral colonies and sponges. Other sessile and filter feeding species living in or on these reef systems may also be affected by dredge activities.

There is a potential for mechanical abrasions (loss and damage) from the dredge activities, including; anchor damage, spud damage or other accidents. This may result in habitat loss, fragmentation and even death of sensitive species such as corals.

Nourishment

Run-off and excess sedimentation may impact nearby reef systems, similar to the sedimentation resulting from dredge activities discussed above.

Sediment barriers/silt and retention ponds are recommended *See* ***Recommended Mitigation 1B and 2B***

Further to ***Recommended Mitigation 1B***, special care should be taken in the placement of these screens around these systems. In particular Dos Tortugas is in very close proximity to the borrow area and as a result all placement, operations and maintenance should be done with the extreme caution and care.

RECOMMENDED MITIGATION

Recommended Mitigation 4B – Dredge Management

The dredging contractor will be responsible for ensuring that only the approved areas identified for dredging are dredged thus minimising the possible damage to any nearby reefs. A draft Dredge Management Plan was also presented in the 'Comprehensive Description of the Proposed Project'.

Seagrass

IMPACT

Dredging

Sedimentation from dredging activities may result in the smothering of seagrass blades and the epiphytes which live on these blades resulting in habitat and species loss. Light penetration may also be reduced by the dredging activities. The reduced water quality may result in reduced photosynthesis of the seagrass beds. Other sessile and filter feeding species living in or on these beds may also be affected by dredge activities.

There is a potential for mechanical abrasions (loss and damage) from the dredge activities, including; anchor damage, spud damage or other accidents. This may result in habitat loss, fragmentation and even death of sensitive species.

Nourishment

Run-off and excess sedimentation may impact nearby seagrass beds, similar to the sedimentation resulting from dredge activities discussed above.

RECOMMENDED MITIGATION

Sediment barriers/silt screens are recommended *See* ***Recommended Mitigation 1B***

Further to ***Recommended Mitigation 1B***, special care should be taken in the placement of these screens around these systems, in particular where seagrass beds occur near to borrow areas. Small sections of seagrass were found within the borrow footprint. These areas should be excluded from all dredge activities.

Dredge Contractor and Dredge Management Plan see ***Recommended Mitigation 4B.***

Vegetation (Beach Runners)

IMPACT

Dredging

No expected impact.

Nourishment

Existing vegetation such as *Sesuvium*, *Acacia* and cacti have the potential to be covered and smothered by sand during dune nourishment, as well as by heavy machinery. There will be loss of species and habitats and temporary loss in vegetation cover. As a result, there will be accelerated wind erosion of the sand dunes.

RECOMMENDED MITIGATION

Recommended Mitigation 5B – Nursery for existing vegetation

Existing vegetation (beach runners in particular) in the nourishment area footprint should be transplanted to a nursery before nourishment activities commence. These can then be re-planted on the dune after nourishment activities are completed.

Beach

IMPACT

Dredging

No expected impact.

Nourishment

Dune nourishment activities have the potential to cause sand compaction and resulting species displacement and habitat loss.

RECOMMENDED MITIGATION

Recommended Mitigation 6B – Limited area for vehicular use on beach

All heavy equipment, vehicles and machinery should limit the area they utilize on the beach. That is, stay within defined tracks and turning points where possible. There should be little to no storage, maintenance or other unnecessary activities along the beach and dune areas.

6.1.1.2 Physical

Nearshore Wave Environment

The Areas to be dredged are located in deep waters. The volumes to be removed are not significant enough to cause any change in bathymetry that will impact the waves. Generally the waves will be impacted if the depth of water is in the order of 1.3 to 2 times the wave height. In this case the depths of the dredge are is in the order of 30 metres whereas the largest hurricane waves will be in the order of six or seven metres. No change to the nearshore wave climate is anticipated that will be either directly or indirectly as a result of this project.

Alongshore Sediment Transport Regime

No change to the near alongshore sediment transport regime is anticipated that will be either directly or indirectly as a result of this project.

Currents

No change to the currents regime is anticipated that will be either directly or indirectly as a result of this project. The Areas to be dredged are located in deep waters. The volumes to be removed are not significant enough to cause any change in the current patterns in the area.

Water Quality

IMPACT

Dredging

Dredging activities may result in deterioration of the water quality of the immediate area as well as the modelled plume distance of 2km away. Dredging may result in the increase of suspended solids, turbidity, BOD and the reduction in light penetration and dissolved oxygen in the water column. Suspension of heavy metals from the substrate is also possible and leakages and spillages of oil and solid waste from the marine vessels associated with dredging.

Dredging activities may result in noise pollution resulting in the temporary displace some sensitive marine fauna and sea birds.

Nourishment

Dune nourishment activities may also result in increased turbidity, suspended solids and reduced light penetration in the water column.

RECOMMENDED MITIGATION

Recommended Mitigation 1P – Sediment Barriers and Silt Screens

Dredging: Sediment barriers/silt screens are recommended to be used around all dredging activities. These should be placed so as to reduce/contain the resultant sediment plume during the dredge activities. Dredging activities should only continue when these barriers are fully operational, that is; placed correctly; calm to moderate sea conditions; without damage. These barriers are particularly important when operations occur near or may influence sensitive ecosystems and species such as coral reefs and seagrass beds and or filter feeding organisms and fish. Care should be taken to dredge only in approved dredge areas. The silt screens should encircle the areas and be deep enough to contain the plumes so that plumes will not travel in the direction of the prevailing currents (Figure 6-2).

Silt screen can help to reduce the sediment plume area and as such reduce the impact of dredge activities on the natural environment.

Nourishment: Silt screens should be used to reduce or contain any runoff/sedimentation from nourishment activities to the surrounding marine environment. Berms, trenches and barriers should be used to reduce runoff/sedimentation to the marine environment.

Recommended Mitigation 2P – Retention Ponds

Retention ponds should be put in place to reduce the amount of water in the dredge spoil thereby reducing run off from the dredge material. Dredge rates should also allow for adequate retention in these retention ponds.

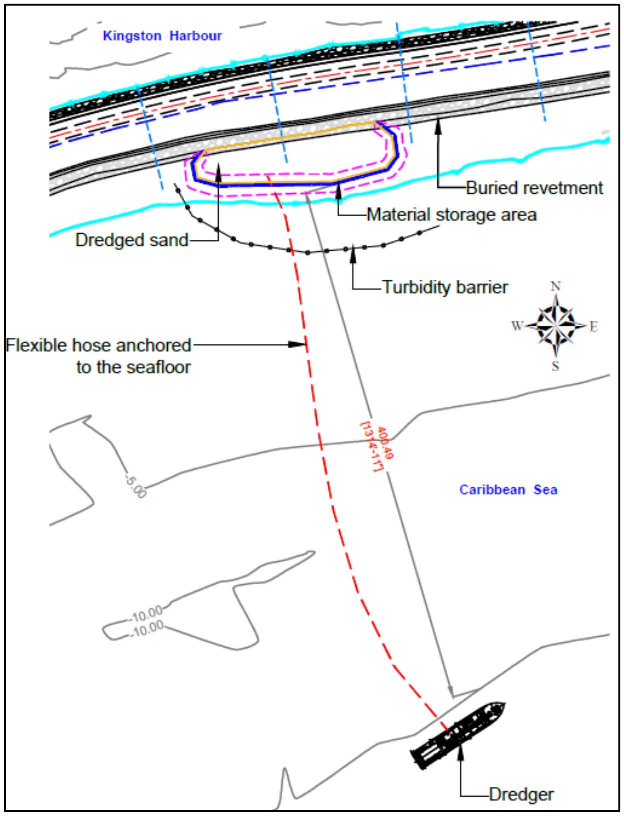


Figure 6-2 Silt Screen positioning

Dredging operations should be continually monitored to ensure equipment and machinery are in good repair and regularly serviced to prevent oil leaks during regular operations.

Recommended Mitigation 3P – Dredge Management

The dredging contractor will be responsible for ensuring that only the approved areas identified for dredging are dredged thus minimising the possible damage to any nearby reefs. A draft Dredge Management Plan was also presented in the 'Comprehensive Description of the Proposed Project'.

Sediment Plume Modelling

During construction, the immediate areas around the dredge site as well as the settling ponds will be susceptible to poor water quality in the form of sediment plumes.

ACCEPTABLE LIMITS OF SUSPENDED SOLIDS

It was important to establish the acceptable sediment plume concentration for use in this study. The National Environment and Planning Agency (NEPA) have guidelines on this matter and recommend a maximum of 10 mg/l (Natural Resources Conservation Authority, 1997). This is in comparison to an existing background level ranging from 3 to 5 mg/l. Observations of requirements and other international guidelines suggest a higher range may be suitable for marine vegetation and corals. For example (Dennison, et al., 1993) and (Gallegos & Kenworthy, 1996) suggest a value of 15 mg/l for both tropical and freshwater lake settings, and (Devlin & Schaffelke, 2009) suggested levels of up to 23 mg/l on the Great Barrier Reef after flood events. Whilst a guideline of 10 mg/l exists locally, the results of the analysis will be interpreted in the context of the range of international guidelines as well of up to 15 mg/l.

SOURCE OF SEDIMENTS

Samples of the sediments (that will be dredged) were observed to have less than 1 percent silt. An attempt was made to rationalize the likely silt load at the dredge sites as well as at the shoreline where the settling ponds will overflow back into the sea. It was estimated that the sediment loading at will be 9.5 and 1.9 grams per litre at the dredge sites and at the shoreline respectively. This rate was applied uniformly over the 24 hours of each day to account for the possibility of the contractors working during the nights.

RESULTS

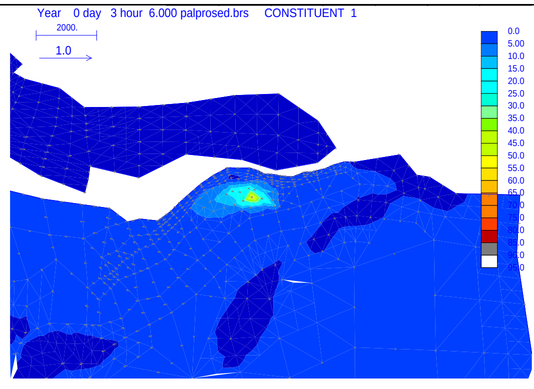
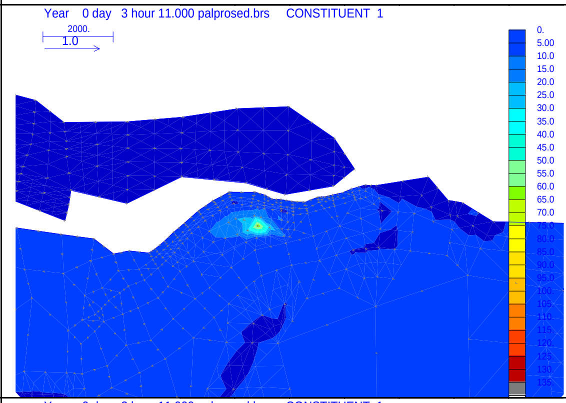
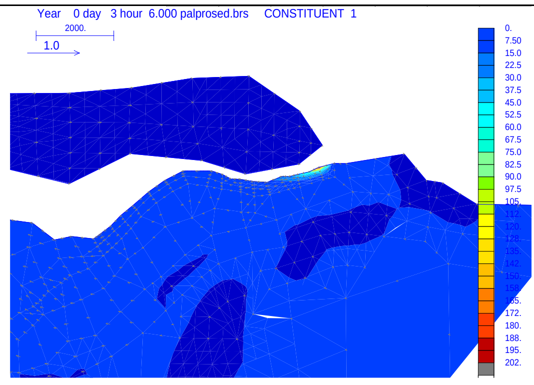
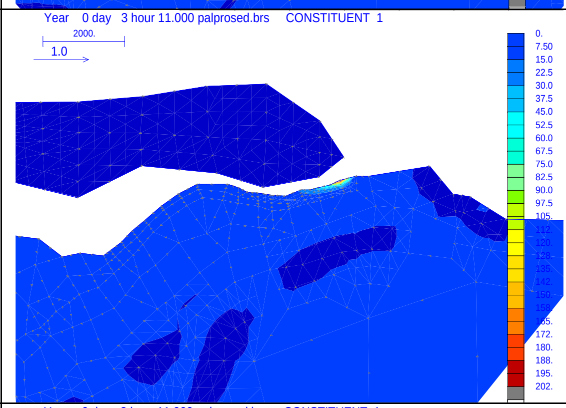
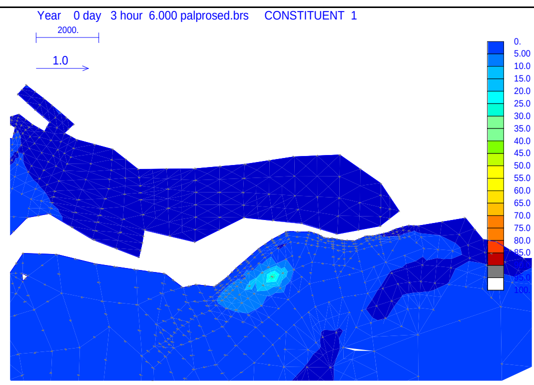
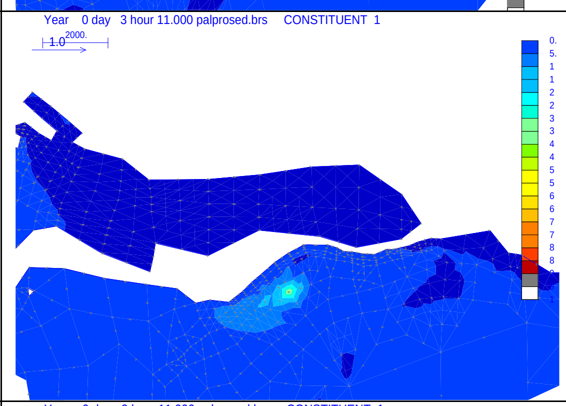
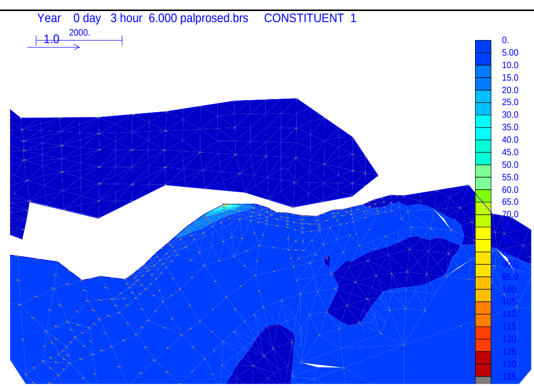
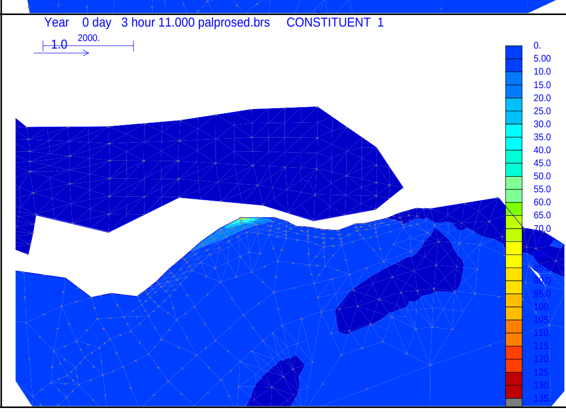
Plume modelling suggests that the extent of the offshore plumes is in general larger than those in the near shore. In all cases the plumes travel to the west up to distances of 2km from the discharge points. In all cases the concentrations were below 20mg/L after 1.5km. This is in comparison to the background concentrations of less than 10mg/L.

Turbidity barriers should be installed around the works especially on the western side where the currents are most likely to travel. The bio-physical features on this side are therefore vulnerable to the associated risks of turbidity in the water column. There is also an increased risk of the plume contacting the shoreline along plumb point shoreline if the turbidity is not adequately controlled.

SUMMARY

Sediment plumes will be generated next to the shoreline where the settling ponds will be created for the dredged material. Similarly, plumes can be generated at the offshore burrow sites. Several scenarios were modelled to determine how the plumes will travel/disperse with distance from the site of impact. In all modelled scenarios the plumes travel to the west up to distances of 2km from the discharge points. In all cases the concentrations were below 20mg/L after 1.5km. This is in comparison to the background concentrations of less than 10mg/L. TSS concentrations exceeding 20mg/L can be harmful to the aquatic flora and fauna in the affected area.

Table 6-4 Sediment plume modeling results (mg/l of TSS) for rising and falling tides

Wind Speed	Rising tide	Falling tide
East offshore		
East Nearshore		
West offshore		
West Nearshore		

Oil Leaks

IMPACT

The potential exists for oil leaks to occur on the beach next to the shoreline where heavy duty front end loaders are operating. The oil leaks from these types of equipment are most often due to ruptured hydraulic hoses. It is therefore anticipated that any spill occurring on the shoreline will be in reasonably small quantities (less than 10 gallons) that can be easily removed for treatment.

All refuelling facilities within the site should be situated on impermeable surfaces served by an oil trap, run-off collection system.

RECOMMENDED MITIGATION

Recommended Mitigation 4P – Equipment to be in good repair

All equipment being deployed to the site should be in good repair and regularly serviced to prevent oil leaks during regular operations. Should an accidental spill occur on the site, the sand or material on which the spill occurred should be removed from the site to an approved location for processing.

Maritime Operations

IMPACT

Dredging

The presence of marine vessels associated with dredging activities has the potential to cause accidents with other marine vessels in the area.

RECOMMENDED MITIGATION

Recommended Mitigation 5P – Safety Plan

A safety plan should be developed in conjunction with the National Works Agency and Port Authority of Jamaica. The use of marker buoys demarcating an exclusion zone should be used to keep out other marine traffic from the work area during construction. Ample notice must be placed in public media concerning the conducting of dredging and dune nourishment activities.

Air Shed

IMPACT

Dredging activities may result in reduced air quality in the form of increased carbon dioxide, NO_x and SO_2 emissions from marine vessels. Nourishment activities will result in same, and include an increase in particulates.

RECOMMENDED MITIGATION

Recommended Mitigation 6P – Dust Control

The surrounding roadway should be dampened every 4-6 hours or within reason to prevent a dust nuisance and on hotter days, this frequency should be increased. Equipment should be covered when not in use and construction materials wetted to prevent a dust nuisance. Where unavoidable, construction workers working in dusty areas should be provided and fitted with N95 respirators.

Noise Pollution

IMPACT

Noise associated with dredging and nourishment activities may also have negative impacts.

RECOMMENDED MITIGATION

Recommended Mitigation 7P – Noise Control

Heavy equipment and machinery used for dredging and nourishment should have low noise emission ratings and mufflers installed. Where unavoidable, construction workers working in noisy surroundings should be provided and fitted with hearing protection.

Construction Crew - Increased Solid Waste/Wastewater Generation

IMPACT

It is anticipated that the increased human and vehicular traffic in the area will generate rubbish and debris along the shoreline. The increases in solid wastes are often attributed to discarded food containers, tools, construction materials and stationary. The presence of construction crews will also result in increased wastewater production.

RECOMMENDED MITIGATION

Recommended Mitigation 8P – Waste Management

Garbage skips and bins should be strategically placed along the work area and on marine vessels associated with the project. The skips and bins should be adequately designed and covered to prevent access by vermin and minimise odours and emptied regularly to prevent overfilling. Disposal of the contents of the skips and bins should be done at an approved disposal site (Riverton Landfill). All personnel working on the site must undergo orientation which will introduce them to the need to keep the area clean.

Portable sanitary conveniences must be provided during construction for the workers for control of sewage waste. A ratio of approximately 25 workers per chemical toilet should be used.

6.1.1.3 Human/Social

Employment

IMPACT

Dune Nourishment activities will provide employment for approximately 20 persons both directly and indirectly during the construction phase, this will include local truckers, heavy equipment operators and labourers. It is anticipated the labourers will be from sourced from nearby communities to include Port Royal, West Kingston, and Harbour View areas. Truckers are normally chosen from a wider geographical area. There is however the potential for decreased commercial activity due to road congestion, yet also increased commercial activity from construction workers willing to purchase lunch and refreshments throughout the work day.

RECOMMENDED MITIGATION

There is no mitigation for this impact.

Fishing Community

IMPACT

Dredging

There is the potential for temporary loss of fishing grounds and reduced fish catch during dredging activities as a result of the excess sedimentation and activities within the area. The temporary loss of fishing grounds in particular may lead to increased conflict amongst fishers. Fishing gear such as surface/subsurface fish pots and nets deployed may get damaged during dredging activities.

If the area is cordoned off, this will result in increased travel time and therefore costs for fishers which use that area.

Nourishment

There is no expected impact.

RECOMMENDED MITIGATION

Recommended Mitigation 1S – Safety Plan

Dredging: A safety plan should be developed in conjunction with the National Works Agency and Port Authority of Jamaica. The use of marker buoys demarcating an exclusion zone should be used to keep out other marine traffic from the work area during construction. Ample notice must be placed in public media concerning the conducting of dredging and dune nourishment activities so that fishers with fishing gear deployed in the work area can remove them before dredging operations start.

Recreational Users

IMPACT

Dredging

Recreational fishers in the dredge area will be temporarily displaced and the accident potential from increased maritime traffic will also be greater.

RECOMMENDED MITIGATION

*See **Recommended Mitigation 1S.***

IMPACT

Nourishment

Dune nourishment will also result in temporary displacement of users of the beach who may jog/run/walk/fish there. Water quality for recreational swimmers may also be reduced and increased particulates during nourishment may affect the air quality.

RECOMMENDED MITIGATION

Recommended Mitigation 2S – Sediment Barriers and Silt Screens

Silt screens should be used to reduce or contain any runoff/sedimentation from nourishment activities to the surrounding marine environment. Berms, trenches and barriers should be used to reduce runoff/sedimentation to the marine environment.

Recommended Mitigation 3S – Dust Control

The surrounding roadway should be dampened every 4-6 hours or within reason to prevent a dust nuisance and on hotter days, this frequency should be increased. Equipment should be covered when not in use and construction materials wetted to prevent a dust nuisance.

Roadway

IMPACT

Dune nourishment activities may result in increased traffic congestion and potential accidents along the roadway thus delaying commuters travelling to the Norman Manley International Airport and other commercial areas.

RECOMMENDED MITIGATION

Recommended Mitigation 4S – Traffic Management

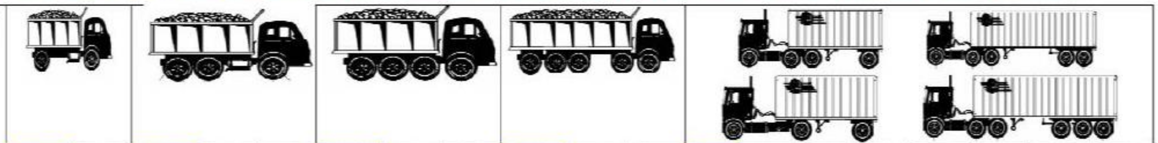
Safety of motorists and other road users is of great concern and the following steps should be taken to mitigate or reduce accidents along Palisadoes roadway:

- Appropriate traffic warning signs informing road users of the construction taking place ahead and instructing users to reduce their speed. These should be placed along the main road for the duration of the construction period.
- Flagmen should be utilized to minimize the likelihood of accidents when heavy units are entering the roadway.

The weight of the heavy vehicles traversing the roads to access and leave the site would be a contributor to the deterioration of the roads, especially during the operational phase. It is therefore recommended that a scale be placed onsite to ensure the trucks transporting material for the project are within the appropriate weight limits as prescribed by the NWA. The NWA has a standard for loads per axel that all trucks exert on roads (Figure 6-3) It is further recommended that a maintenance plan be put in place to address the issue of road degradation over the construction period.

It is recommended that as a part of the engineering contract, the Contractor submit a detailed road traffic management and safety plan prior to construction.

SPECIAL PERMIT REQUIREMENTS vehicles exceeding Permit Column data can be issued ith a Special Permit once the vehicle does not exceed the relevant column etc



Maximum Allowable	Permit	MAX Limit	Permit	MAX Limit	MAX Limit	Permit	MAX Limit	MAX Limit	Permit	MAX Limit	MAX Limit	Permit	MAX Limit	MAX Limit	MAX Limit	MAX Limit	MAX Limit	MAX Limit	MAX Limit
Overall Height (m)	3.6	4.15	3.6	4.15	4.15	3.6	4.15	4.15	3.6	4.15	4.15	3.6	4.15	4.15	4.15	4.15	4.15	4.15	4.15
Gross Weight (tons)	12.2	15	12.2	20	25	12.2	30	35	12.2	30	35	12.2	25	30	35	40	45	50	55
Length (m)	9.14	12.8	9.14	12.8	12.8	9.14	12.8	12.8	9.14	12.8	12.8	12.8	17.3	17.3	17.3	17.3	17.3	17.3	17.3
Width (m)	2.44	2.70	2.44	2.70	2.70	2.44	2.75	2.75	2.44	2.75	2.75	2.44	2.75	2.75	2.75	2.75	2.75	2.75	2.75
No. of Axles	2	2	3	3	3	4	4	4	5	5	5	3	3	4	4	5	5	6	6
No. of Tires	6	6	8	8	10	12	12	14	16	16	12	10	10	12	14	16	18	20	22

Please note that

1. Maximum allowable dual tire axle load is **10 tonnes** except super singles/ flotation
2. Maximum allowable single tire axle load is **5 tonnes** except super singles/ flotation
3. maximum allowances **must not exceed manufacturer ratings**, specifications for **vehicles and tires** etc
4. Special permits are required for tucks that exceed one or more of the following criteria:

   a. ***Overall Length of 9.14m (rigid) or 12.8 m (articulated/trailer)***
   b. ***Overall width of 2.44 m,***
   c. ***Gross weight of 12,273 kg,***
   d. ***overhang of 50% of wheelbase,***
   e. ***height of 3.6 m from ground***

Figure 6-3 National Works Agency of Jamaica weight limit requirements for heavy vehicles

Aesthetics

IMPACT

Decreased water quality in the form of elevated turbidity and TSS concentrations may be aesthetically unappealing for observers. The beach and ocean view may also be obstructed due to heavy construction equipment.

RECOMMENDED MITIGATION

See Recommended Mitigation 2S.

6.1.2 Operation

6.1.2.1 Biological

IMPACT

There is a potential for both the improvement and maintenance of ecosystem function and coastal zone dynamics (dune, beach, seagrass beds and reef interactions). Ecosystem functions and coastal zone dynamics provide natural shoreline protection and as a result will enhance the anticipated outcome of the project.

This is a positive impact, therefore no mitigation is required.

Dune Invertebrates and Meiofauna

IMPACT

The re-vegetated sand dune will serve to increase habitat and species diversity for invertebrates over time. Succession and colonization of the sand and dune vegetation should occur over time. The vegetation may also serve as a food source.

This is a positive impact, therefore no mitigation is required.

Marine Fauna (Fish, Mammals, Meiofauna, Filter feeders and Zooplankton)

IMPACT

A more stabilized shoreline should result in reduced run-off, improving the surrounding water quality. Fish, meiofauna, filter feeder and zooplankton communities will benefit from improved water quality and ecosystem function.

This is a positive impact, therefore no mitigation is required.

Reptiles (Marine Turtles and Crocodiles)

IMPACT

The expected improvements in shoreline stability and coastal dynamics will increase habitat suitability over time, for these protected species. This area is also an existing nesting and basking site.

This is a positive impact, therefore no mitigation is required.

Avifauna

IMPACT

The expected improvements in shoreline stability and coastal dynamics will increase habitat suitability over time, for foraging, nesting and roosting of local and migrant species.

This is a positive impact, therefore no mitigation is required.

Reef and Seagrass Communities

IMPACT

Reef and Seagrass communities , corals and other sessile organisms which live on the reef (sponges, gorgonians, tube worms, fan worms) will benefit from improved water quality as there will be less run-off from land (decreased turbidity and TSS) due to stabilized dune sediments.

This is a positive impact on the reef and seagrass community, therefore no mitigation is required.

Vegetation

IMPACT

Pioneer beach runner species such as *Ipoemea*, *Sesuvium*, *Sporobolus* and coastal sapling such as *Acacia, Capariss, Coccoloba* and *Thespesia* and some cacti present along the dune will increase habitat diversity and restore the full ecological function of the sand dune. Erosion of the sand dune from wind and waves will also be reduced due to the vegetation cover on the dune.

The irrigation of sand used in dune nourishment is necessary to remove excess salinity and to assists in settling the sand between boulders, cobble and/or revetments. Irrigation is highly recommended on the basis that the sand used to nourish these areas will be dredged from the marine burrow locations. Sand preparation prior to planting vegetation should include: irrigation, raking, removal of unwanted debris and the introduction of desired organic material (compost and treated animal manure). An irrigation schedule should be created to assist in the establishment of sand dune plants.

Beach

IMPACT

The re-establishment of the sand dunes will aid in protecting and stabilizing the shoreline and revetment and in turn, the roadway. The Palisadoes shoreline has experienced several severe storm events that have overtopped and blocked the roadway. The sand dunes to be constructed are designed to provide the roadway with effective protection for up to a 100 year return period storm event.

This is a positive impact on the beach and shoreline, therefore no mitigation is required.

6.1.2.2 Physical

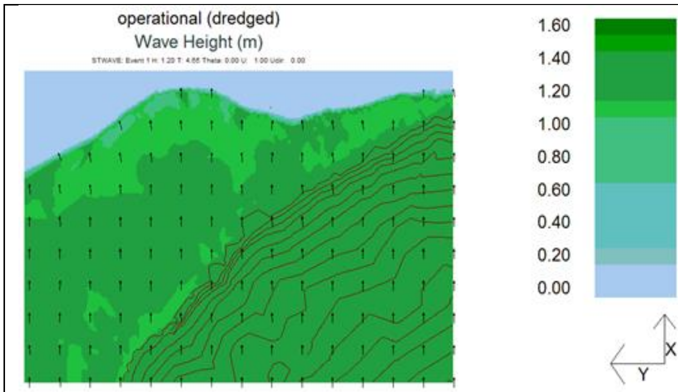
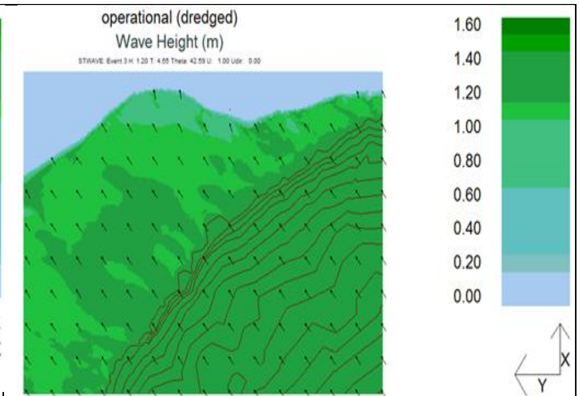
Nearshore Wave Environment

Implementation of the project involves offshore dredging which will alter the bathymetry. The two locations to be dredged are approximately 0.6 km and 1.6 km offshore, and they will be dredged to a depth of 1.5m.

OPERATIONAL WAVES – CARIBBEAN SEA SIDE

Although the dredging exercise altered the bathymetry it did not affect the magnitude of waves reaching the shoreline under operational conditions. Wave heights of 0.7 to 1.2m were observed to reach the shoreline from the S and SE directions. See Table 6-9. These are similar to the wave heights in the pre-project scenario and consistent with the physical understanding of wave breaking and refraction where the refraction coefficient for the small change in the sea floor from 15 meters to 16.5 meters is 0.95 that is relatively small or equivalent to no change, (refraction coefficient = $\sqrt{(16.5/15)}$ = 0.95 ~ 1). The burrow areas are in 12 to 18 meters of wave.

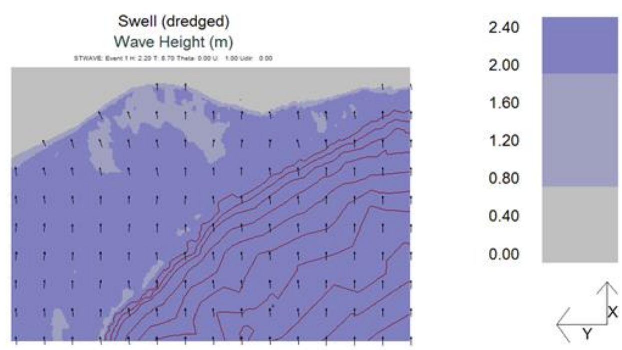
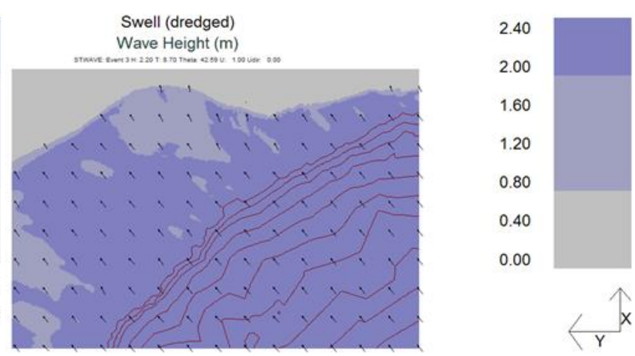
Table 6-5 STWAVES resultant plots of operational waves for various directions (post project)

 South (S)	 South East (SE)

SWELL WAVES – CARIBBEAN SEA SIDE

The pre-project scenario had wave heights of 0.8m to 2.0m reaching the shoreline from the south and south easterly direction during the swell event. The post project scenario saw no change in the resulting wave heights reaching the shoreline.

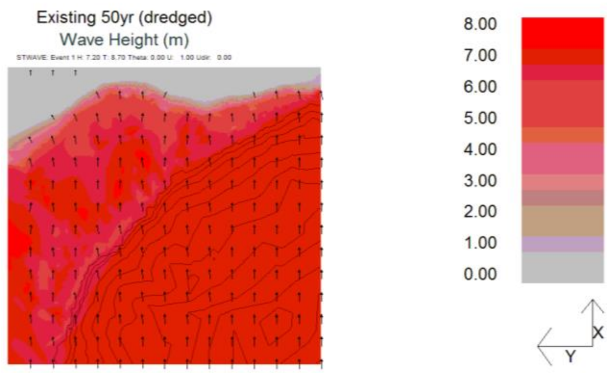
Table 6-6 STWAVES Caribbean Sea side resultant plots of swell waves for the S and SE directions (post project)

 South (S)	 South East (SE)

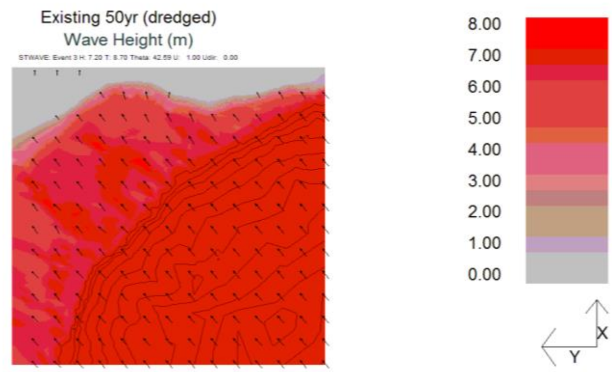
HURRICANE WAVES – CARIBBEAN SEA SIDE

There was also no noticeable change in the wave heights reaching the shoreline under hurricane conditions. The SE and S directions had wave heights of 2 m and 3m for the 50 and 100 year return periods respectively.

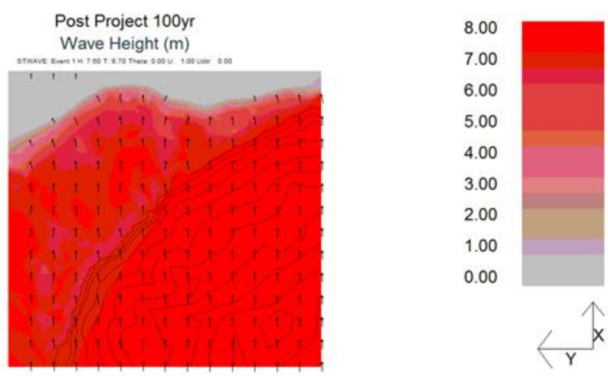
Table 6-7 STWAVES Caribbean Sea Side resultant plots of hurricane waves for various directions (post project)



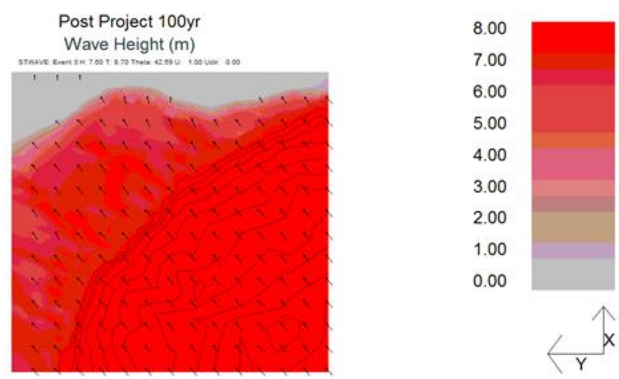
50 year- South (S)



50 year - South East (SE)



100 year- South (S)



100 year - South East (SE)

DISCUSSION

The model predicts that the post project scenario of the burrow area is not expected to have an impact on the waves reaching the shoreline both with and without the climate change considerations made

Alongshore Sediment Transport Regime

The post project scenario for the Caribbean Sea side involves a change in bathymetry due to dredging of the barrow areas to a depth of 1.5 meters below its original depth as outlined in previous sections of this report. However this process did not affect the sediment transport along the shoreline when compared to the pre project scenario, see Figure 6-4.

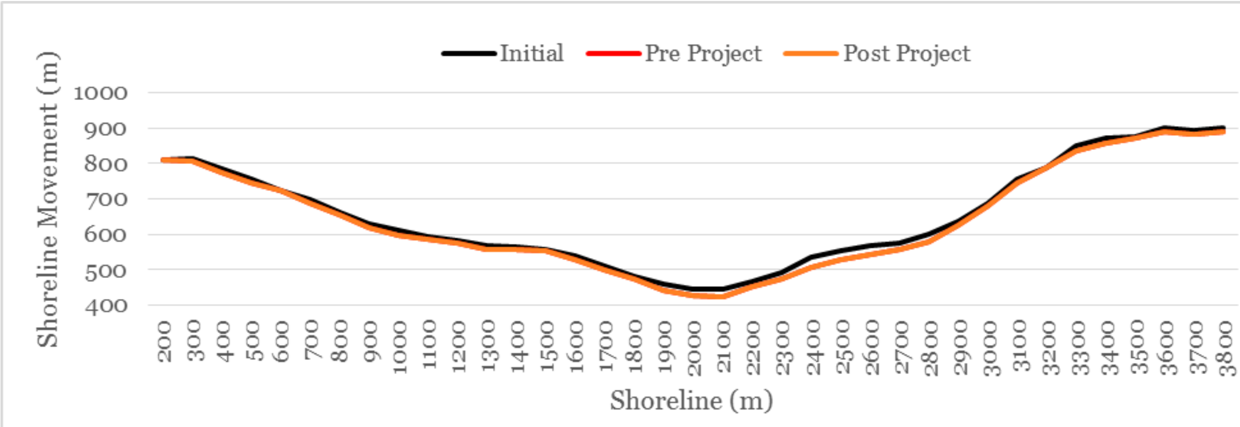


Figure 6-4 Comparative analysis of initial and post-project shoreline for the Caribbean Sea side of the Palisadoes project

Currents

IMPACT

No change to the currents regime is anticipated that will be either directly or indirectly as a result of this project.

Sediment Plume

IMPACT

No plumes are anticipated during operation that can be attributed either directly or indirectly to this project.

Improved Shoreline Stability and Predicted Changes in Beach Profile

The CSHORE modelling exercise was carried out to confirm the proposed dune cross section design and response to the 100 year return period storm event. Oceanographic data utilised are described further in section 4.1.

CROSS-SHORE (CSHORE) DESCRIPTION

Cross-SHORE (CSHORE) is a one-dimensional time-averaged nearshore profile model for predictions of wave height, water level, wave-induced steady currents, and profile evolution. The CSHORE model was originally developed by the University of Delaware to predict nearshore hydrodynamics and beach profile evolution for cases with upper beach profiles. The CSHORE model is a transect model that permits the specification of the actual beach profiles and sediment characteristics, thereby avoiding the ambiguity associated with the application of parametric models. CSHORE assumes alongshore uniformity but computes the wave and current fields simultaneously. The combined wave and current model operates under the assumption of longshore uniformity and includes the effects of a wave roller and quadratic bottom shear stress. Computation times including nearshore morphology are typically

10^{-5} of the modelled time duration. Some of the features within CSHORE include, but are not limited to:

- Longshore Uniform Formulation;
- Steady Formulation;
- Shallow Water Hydrodynamics;
- Probabilistic Representation of Sediment Transport;
- Entrainment driven by Energy Dissipation;
- Includes Wave and Current Transport; and
- Bed load and Suspended load.

INPUTS, CALIBRATION AND VERIFICATION

Wave Characteristics Input

The wave data corresponding to Hurricane Ivan and anecdotal information collected from residents and employees in the area was used to calibrate and verify the model results, while the wave data corresponding to the 50 and 100 year storm events was used to model the existing and climate change scenarios. See Table 6-8 for the input parameters for the calibration and modelling exercise.

Table 6-8 CSHORE input parameters for calibration and modelling for the Caribbean Sea side of the Palisadoes

Storm	H_s (m)	T_p (s)
IVAN	7.6	12.3
50 YR	5.9	12.1
100 YR	6.2	12.4

Calibration

Based on anecdotal information collected, it was determined that the calibration process could be undertaken and verified using this data for hurricane Ivan (2004). It was observed that approximately 1.2m of sand was transported and deposited on the main road, which became the benchmark for calibration. However, the challenge of obtaining shoreline topographic data before the hurricane event proved futile. Hence, the data was obtained from a survey conducted by Cuban team. Although this survey served as the most representative shoreline available, it still did not accurately represent the shoreline at the time of hurricane Ivan. Profiles from varying directions were cut from deep water to land, with a maximum depth below mean seal level (MSL) of 391 m, along the Caribbean Seas side in the vicinity of Plumb Point (near the airport) for the purpose of calibration.

Due to the challenge of obtaining a 2004 shoreline survey, another location near Plumb Point was used for fine tuning the existing calibration. A current eastern dune was observed to not have been affected by the passage of hurricane Ivan and this scenario was duplicated within the calibration. A profile from the western direction was cut and used for the second calibration process. The eastern dune was surveyed to have a crest elevation of 7.4 m and slopes of 1:7. The dimensions were input into the model, where parameters were modified to reflect the resistivity of the dune towards hurricane

Ivan. During the modelling exercise, however, profiles were cut at western and eastern directions along the low revetment (Caribbean Sea side).

Verification

The first calibration method involved simulating the hurricane event Ivan depositing 1.2m of sand on the Palisadoes road in the vicinity of Plumb Point and it illustrated erosion of the seaward dune face of approximately 12 m inland and a reduction in crest height by 0.4m. Aside from these noticeable changes, the main feature used within the calibration was the deposition of sand on the roadway. The anecdotal data collected from both employees and residents within the surrounding areas recalled a height of 1.2 m of sand deposited on the roadway after the passage of Ivan. The model was calibrated to a tolerance of no more than 10%. This resulted in a model predicted accretion of approximately 1.3 m (8.3%) on the roadway.

See Table 6-9 below for the average height of sand deposited on the roadway following the passage of Hurricane Ivan based on anecdotal data in comparison to model predictions obtained after the calibration exercise. The table shows that the model compares favourably with the anecdotal information gathered from residents. This calibration method was also used in the SBEACH modelling exercise.

Table 6-9 Average height of sand on the Palisadoes roadway (Plumb Point) following the passage of Hurricane Ivan

Location	Observed (m)	Model (m)
Plumb Point (roadway)	1.2	1.3

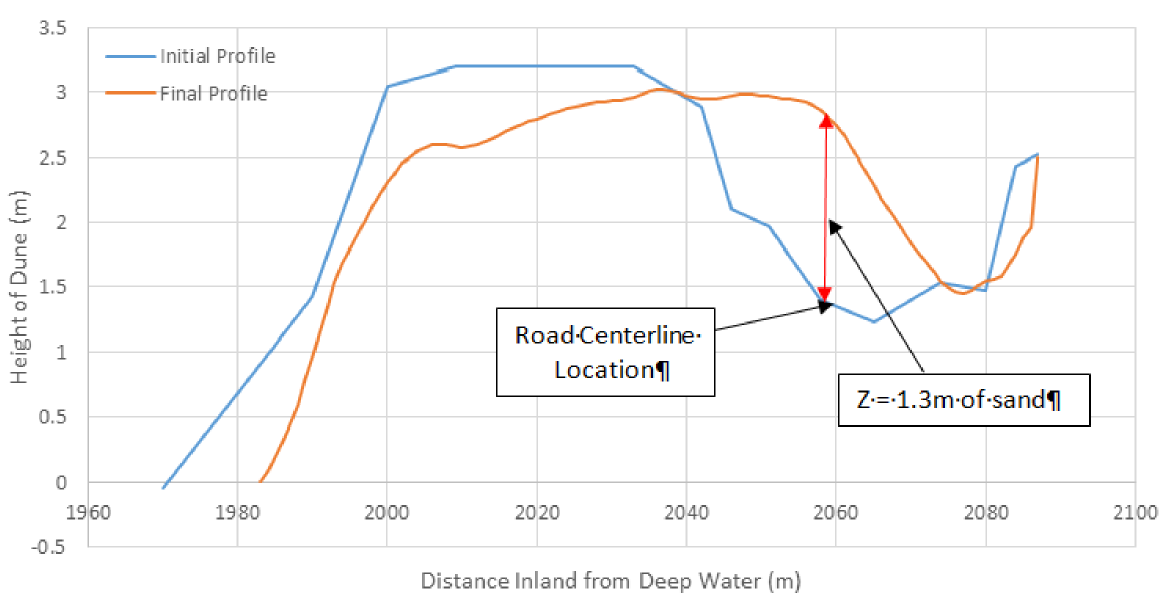


Figure 6-5 Calibration results comparing observed sand deposition versus model predictions

The second calibration method involved simulating the same hurricane event traversing an eastern dune along the shoreline in the vicinity of Plumb Point and it was used to further fine tune the first calibration method. As observed, following the passage of the hurricane, the dune did not sustain any physical changes which were simulated as best as possible within the model. This calibration run illustrated no erosion of the seaward dune face nor a reduction in crest height. Table 6-10 below compares the observed dune height versus that predicted by the model post hurricane Ivan. The table shows that the model compares favourably with the anecdotal information gathered from residents.

Table 6-10 Average height of eastern sand dune along the Palisadoes shoreline

Location	Observed (m)	Model (m)
Plum Point (Eastern Dune)	7.4	7.4

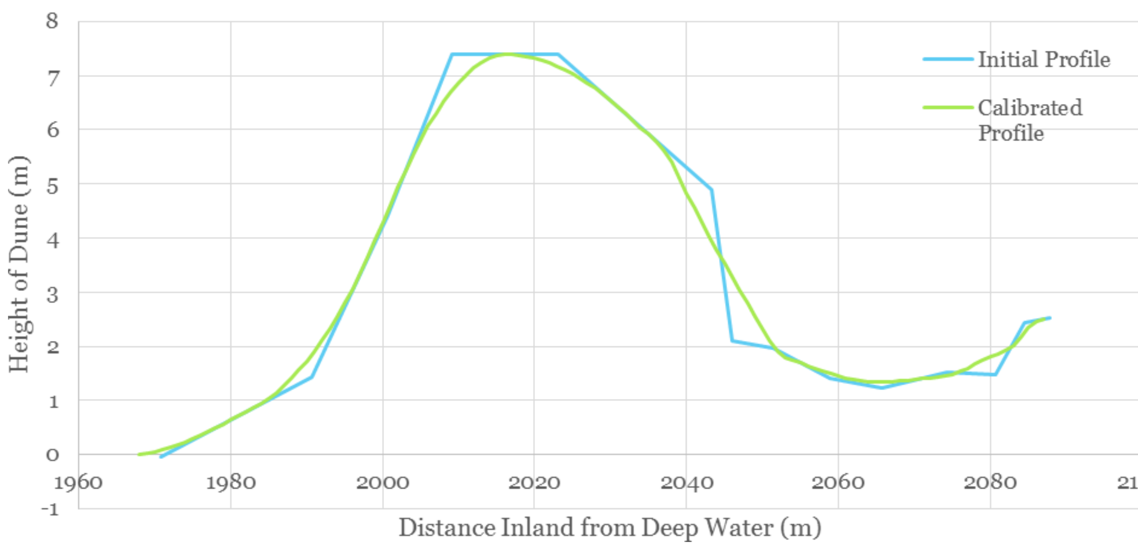


Figure 6-6 Calibration results comparing observed sand dune movement versus model predictions

POST-PROJECT SCENARIO WITH THE CLIMATE CHANGE WAVE CLIMATE – CARIBBEAN SEA

Eastern Direction

The model was run for the post project and climate change scenario so as to determine the stability and resistivity sand dune during both 50 year and 100 year rainfall events. The design process determined that the proposed sand dunes should have a 1:3 slope on both the seaward and landward sides with a 12 m wide crest of an elevation 6.24 m.

The erosion vulnerability of the shoreline along the eastern profile was modelled and plotted for both 50 year and 100 year scenarios. The results revealed that the possibility of erosion of the seaward dune face exists for a distance of up to 2 m inland for the 50yr storm. Sand is also predicted to be deposited on the landward side of the dune 75 m from mean sea level (MSL). Essentially, the height of the dune will be reduced by 2.1% to a height of 6.11 m for this particular storm event. Figure 6-7and

Figure 6-8 below illustrate the possible erosion of the proposed sand dune graphically. It can be determined that smaller return periods will subsequently produce less erosion.

In regards to the 100 year storm event, the results revealed that the possibility of erosion and accretion of the seaward dune face up to a distance of 10m and 15m inland respectively. Sand is also predicted to be deposited on the landward side of the dune 77 m from mean sea level (MSL). Essentially, the height of the dune will be reduced by 7.2% down to a height of 5.82 m for this particular storm event.

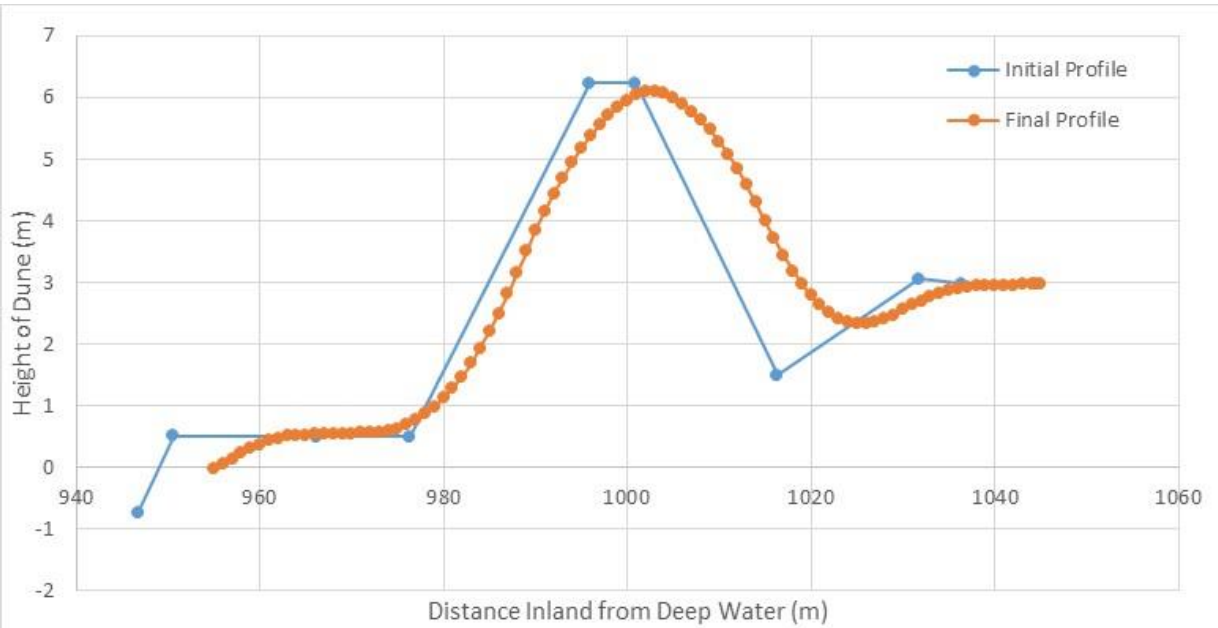


Figure 6-7 Simulation results comparing pre and post sand dune erosion predictions during 50 year event

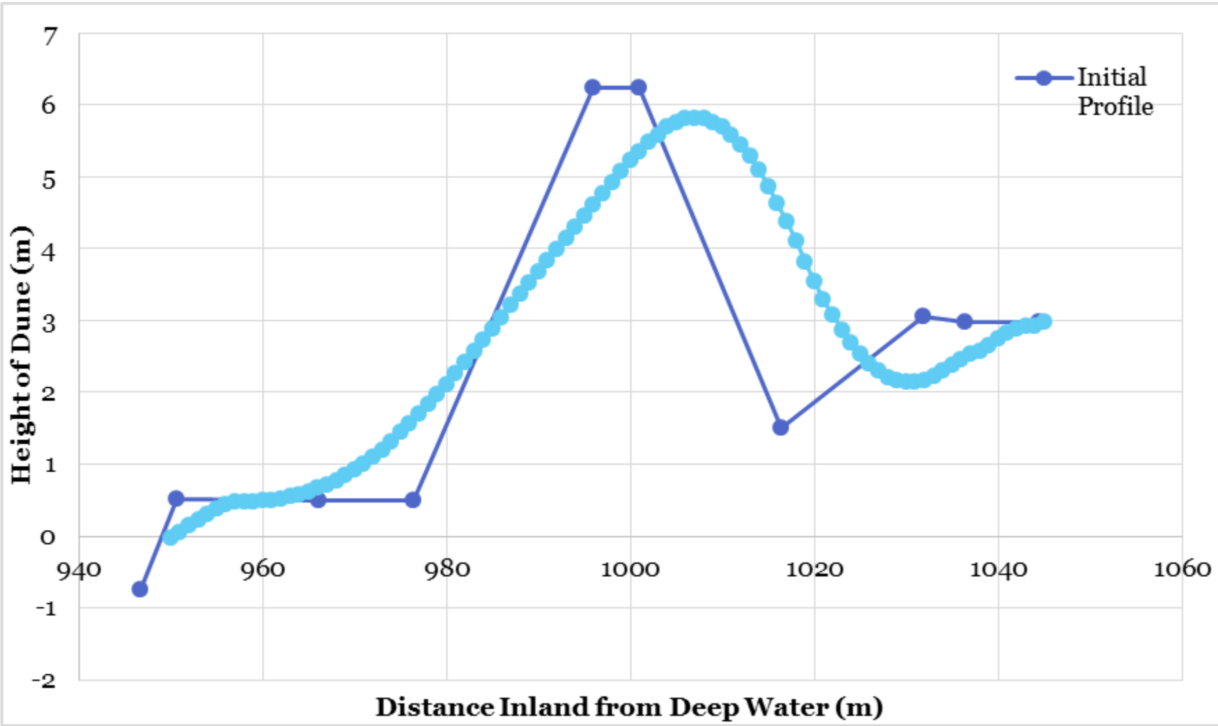


Figure 6-8 Simulation results comparing pre and post sand dune erosion predictions during 100 year event

Western Direction

The model was run for the post project and climate change scenario so as to determine the stability and resistivity of the sand dune during both 50 year and 100 year rainfall events. The design process determined that the proposed sand dunes should have a 1: 3 slope on both the seaward and landward sides with a 12 m wide crest of an elevation 6.24 m.

The erosion vulnerability of the shoreline along the eastern profile was modelled and plotted for both 50 year and 100 year scenarios. The results revealed that the possibility of erosion of the seaward dune face exist up to a distance of 0.5m inland for the 50yr storm. Essentially, the height of the dune will be reduced by 0.81% to a height of 6.19 m for this particular storm event. Figure 6-9 and Figure 6-10 below illustrates the possible erosion of the proposed sand dune graphically. It can be determined that smaller return periods will subsequently produce less erosion.

In regards to the 100 year storm event, the results revealed that the possibility of erosion up to a distance of 0.5m inland. Sand is also predicted to be deposited on the landward side of the dune a height of 0.25m above existing ground. Essentially, the height of the dune will be reduced by 3.3% down to a height of 6.04 m for this particular storm event.

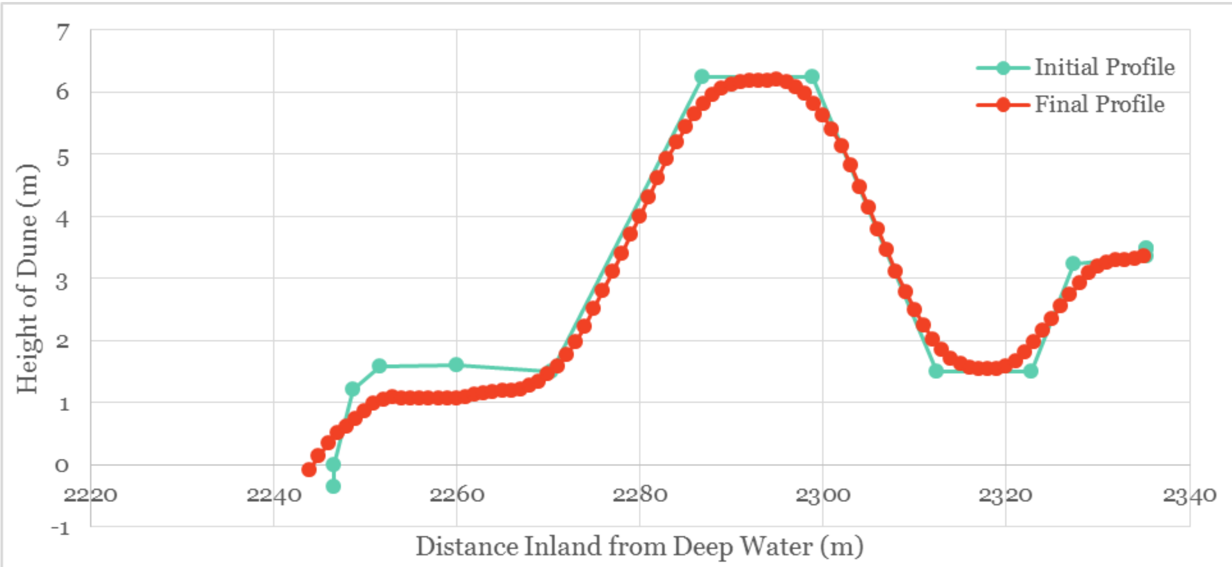


Figure 6-9 Simulation results comparing pre and post sand dune erosion predictions during 50 year event

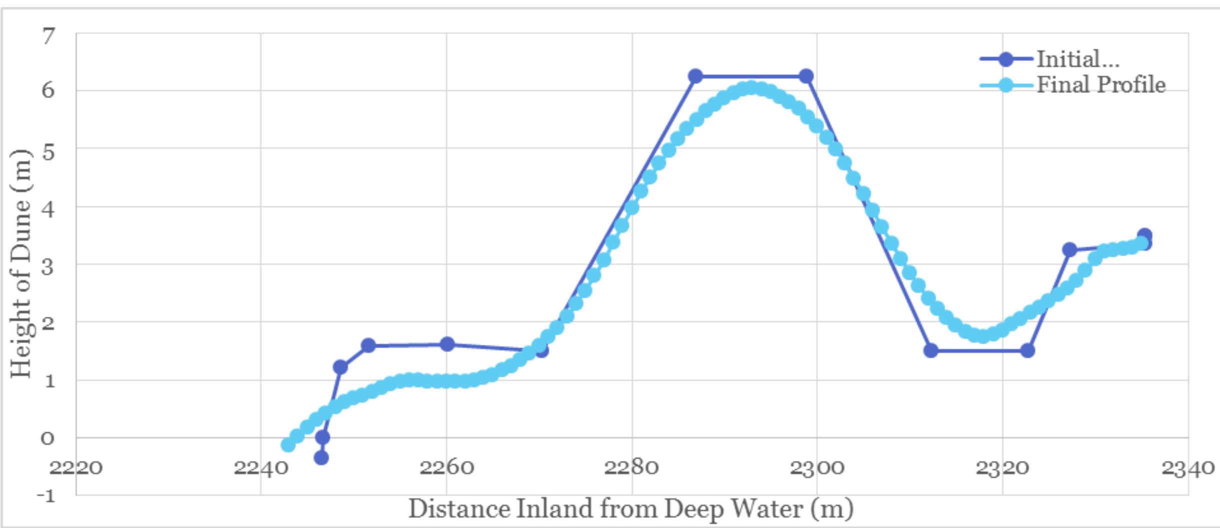


Figure 6-10 Simulation results comparing pre and post sand dune erosion predictions during 100 year event

Discussion

The Cross-SHORE (CSHORE) numerical model used to simulate cross-shore sediment transport allowed for an accurate calibration in conjunction with observations at two (2) different locations. The initial calibration involved anecdotal data obtained from workers and resident in proximity to the Palisadoes roadway after the passage of hurricane Ivan in 2004. This process yielded a percent error of 8.3% which falls below a tolerance of 10%, deeming this calibration run acceptable. In addition, further calibration runs were executed within the model involving a pre and post survey conducted near Plumb Point along the Palisadoes roadway during Ivan.

Based on the simulated model runs, it can be established that the seaward face of the proposed sand dunes are more vulnerable to erosion than the landward side. This was determined for both east and west directions during the 50 year and 100 year rainfall events. More specifically, the waves originating from the eastern direction proved to be more destructive as the model predicted. The eastern profile simulated within the model displayed greater erosion and accretion than that of the western profile. As a result the dunes will need to be inspected and restored as required after construction.

The design recommends western and eastern sand dunes with a 12 m long crest at an elevation of 6.24 m and a seaward and landward slope of 1:3, this will prevent the waves from the 50 and 100 year storm event, with climate change considerations made, from damaging the roadway. Figure 4-2 and Figure 4-3 in Section 3 of this report present the design cross sections for the sand dunes to be placed over the buried revetments. The volume of sand needed for construction is placed in Table 6-11.

Table 6-11 Volume of sand required for sand dune construction

Sand Dune	Volume (m^3)
Buried Revetment 1	21,750
Buried Revetment 2	77,565
Sand Dune Option at Harbour Head	10,928
Total	**110,243**

Water Quality

IMPACT

The re-establishment of the sand dunes will result in improved ambient water quality as there will be reduced run-off from land (decreased turbidity and TSS) due to stabilized dune sediments.

Transport

IMPACT

The revegetated sand dune is not expected to have any impact on maritime operations.

Airshed

IMPACT

The re-establishment of the sand dunes will result in improved ambient air quality; reduced CO_2, NO_x and SO_2.

6.1.2.3 Social

Local fishing community

IMPACT

The revegetated sand dune is not expected to have any impact on fishing community.

Aesthetics

IMPACT

The re-establishment of the sand dunes and vegetation will improve the aesthetics of the area.

Roadway

IMPACT

The re-establishment of the sand dunes will aid in stabilizing the shoreline and revetment and in turn the roadway. The existence of this roadway will preserve access to cultural/heritage sites such as Port Royal as well as locally important establishments such as the Norman Manley International Airport and Jamaica Defence Force Coastguard base. There also exists maritime facilities such as the Royal Jamaica Yacht Club and educational facilities such as the Caribbean Maritime Institute.

6.2 MANGROVE REPLANTING

Table 6-12 Impact matrix for site preparation and construction phases for Mangrove Islands

	Receptor	Activity	Impact	Direct/Indirect		DIRECTION		DURATION	MAGNITUDE	EXTENT	Significance Score
				Direct	Indirect	Pos	Neg				
Site Preparation and Construction Phases – Mangrove Islands											
Biological Impacts:											
	Meiofauna	Reclamation and Planting	Species loss , displacement and loss of habitat	X			X	1	2	1	-1.3
	Invertebrates	Reclamation and Planting	Species loss , displacement and loss of habitat	X			X	1	2	1	-1.3
	Filter feeders (Meiofauna and zooplankton)	Reclamation and Planting	Species loss , displacement and loss of habitat	X			X	1	2	1	-1.3
	Fish	Reclamation and Planting	Displacement and loss of habitat	X			X	1	2	1	-1.3
	Reptiles (Crocodiles)	Reclamation and Planting	Displacement, loss of habitat and disruption of nesting	X			X	1	1	1	-1
	Avifauna	Reclamation and Planting	Loss of feeding grounds	X			X	1	1	1	-1
	Cnidarians and Poriferans	Reclamation and Planting	Species loss	X			X	1	1	1	-1
	Vegetation – Mangrove Saplings	Reclamation and site preparation stage	Tidal conditions restored Species loss	X		X	X	2 2	2 2	2 2	-2
		Replanting stage	Introduction of mangrove saplings and seedlings	X		X		3	3	3	3
	Seagrass	Reclamation (Sedimentation)	Smothering beds and epiphytes. Reduced light penetration. Habitat and species loss.	X			X	1	1	2	-1.3
	Intertidal Zone	Reclamation and Planting	Species displacement and habitat loss.	X			X	3	3	1	-2.33
Physical Impacts:											
	Nearshore Wave Environment	Reclamation and Planting	N/A	-	-				0	0	
	Sediment Transport Regime	Reclamation and Planting	N/A	-	-				0	0	
	Currents	Reclamation and Planting	N/A	-	-	-	-	0	0	0	

	Receptor	Activity	Impact	Direct/Indirect		DIRECTION		DURATION	MAGNITUDE	EXTENT	Significance Score
				Direct	Indirect	Pos	Neg				
	Water Column	Reclamation and Planting	Increased suspended solids (minimal sediment plume. Suspended solids will settle quickly)	X			X	1	1	1	-1
			Increased turbidity and reduced PAR (minimal sediment plume)	X			X	1	1	1	-1
			Increased BOD/Reduced DO (minimal sediment plume)		X		X	1	1	1	-1
			Increased water pollution (oils, solid waste etc.)	X			X	1	1	1	-1
			Increased noise pollution – displace sensitive fauna	X			X	1	1	1	-1
Transport	Maritime operations	Reclamation and Planting	Increased maritime accident potential	X			X	1	1	1	-1
	Airshed	Reclamation and Planting	Reduced air quality-CO_2, NO_x and SO_2	X			X	1	1	2	-1.3
			Increased noise pollution	X			X	1	1	1	-1
Construction Crew	Existing natural and social environment	Reclamation and Planting	Increased solid waste generation	X			X	1	1	1	-1
			Increased wastewater generation	X			X	1	1	1	-1
			Increased accidental potential	X			X	1	1	1	-1
			Increased water usage	X			X	1	1	1	-1
Aesthetics	Observers	Reclamation and Planting	Increased turbidity and TSS	X			X	1	1	1	-1
Social	Local fishing community	Reclamation and Planting	Temporary loss of fishing grounds	X			X	1	1	1	-1
			Reduced fish catch	X			X	1	1	1	-1
			Increased maritime accident potential	X			X	1	1	1	-1
			Increased conflict potential	X			X	1	1	1	-1
	Recreational Users	Reclamation and Planting	Increased maritime traffic	X			X	1	1	1	-1
			Displacement of users	X			X	1	1	1	-1
			Decreased air quality	X			X	1	1	2	-1.3
			Decreased water quality	X			X	1	1	1	-1
	Labour Force/Local Economy	Reclamation and Planting	Increased employment	X		X		1	1	2	-1.3
			Increased commercial activity	X		X		1	1	2	-1.3

	Receptor	Activity	Impact	Direct/Indirect		DIRECTION		DURATION	MAGNITUDE	EXTENT	Significance Score
				Direct	Indirect	Pos	Neg				
	Roadway	Reclamation and Planting	Traffic congestion, reduced access (NMIA, Coast Guard, Port Royal, CMI, RJYC, etc.) and increased potential for accidents	X			X	1	1	1	-1
											-1.06

Table 6-13 Impact matrix for operational phase of Mangrove Island

	Receptor	Activity	Impact	Direct/Indirect		DIRECTION		DURATION	MAGNITUDE	Extent	Significance Score
				Direct	Indirect	Pos	Neg				
Biological Impacts:											
	Meiofauna	Mangrove Islands	Increased habitat diversity/usage/suitability.	X		X		3	3	1	2.3
	Invertebrates	Mangrove Islands	Increased habitat diversity/usage/suitability.	X		X		3	3	1	2.3
	Filter feeders (Meiofauna and zooplankton)	Mangrove Islands	Improved water quality-diversity/usage/suitability.	X		X		3	3	1	2.3
	Fish	Mangrove Islands	Increased habitat diversity/usage/suitability	X		X		3	3	1	2.3
	Mussels and Bivalves	Mangrove Islands	Increased habitat	X		X		3	3	1	2.3
	Reptiles (Crocodiles)	Mangrove Islands	Increased habitat diversity/usage/suitability	X		X		3	2	1	2
			Solid waste screens (impedes croc movements-sunbathing)	X			X	2	1	2	1.67
	Avifauna	Mangrove Islands	Increased habitat diversity/usage/suitability	X		X		3	3	1	2.3
	Cnidarians and Poriferans	Mangrove Islands	Improved water quality; decreased turbidity/TSS	X		X		3	3	1	2.3
	Mangrove trees	Mangrove islands	Increased mangrove plant coverage	X		X		3	3	1	2.3
			Island stablility and erosion reduction	X		X		3	3	1	2.3
	Seagrass	Mangrove Islands	Improved water quality; decreased turbidity/TSS	X		X		3	3	1	2.3

	Receptor	Activity	Impact	Direct/Indirect		DIRECTION		DURATION	MAGNITUDE	Extent	Significance Score
				Direct	Indirect	Pos	Neg				
	Intertidal Zone	Mangrove Islands	Increased stability	X		X		3	3	1	2.3
			Increased shoreline protection					3	3	1	2.3
	Kingston Harbour	Mangrove Islands	Increased ecosystem function and improved water quality	X		X		3	3	1	2.3
Physical Impacts:											
	Nearshore Wave Environment	Mangrove Islands	N/A	-	-	-	-	0	0	0	0
	Sediment Transport Regime	Mangrove Islands	N/A	-	-	-	-	0	0	0	0
	Currents	Mangrove Islands	N/A	-	-	-	-	0	0	0	0
	Sediment Plume Modelling	Mangrove Islands	N/A	-	-	-	-	0	0	0	0
	Beach Profile	Mangrove Islands	Shoreline stability and shoreline growth	X		X		3	2	1	2
	Water Column	Mangrove Islands	ambient water quality; decreased turbidity/tss	X		X		3	2	2	2.3
			Decrease in nutrient concentration	X		X		3	2	2	2.3
Transport	Maritime operations	Mangrove Islands	N/A	-	-	-	-	0	0	0	0
	Airshed	Mangrove Islands	Improved air quality-CO_2, NO_x and SO_2 reduced	X		X		3	1	1	1.67
Aesthetics	Observers	Mangrove Islands	Improved viewshed	X		X		3	1	1	1.67
Social	Local fishing community	Mangrove Islands	Increased habitat functionality and species diversity.	X		X		3	2	2	2.3
		Mangrove Islands	Increased fish catch	X		X		3	2	2	2.3
		Mangrove Islands	Increased oyster/mussels harvesting	X		X		3	2	2	2.3
	Recreational Users	Mangrove Islands	Improved viewshed	X		X		3	1	1	1.67
	Local economy	Mangrove Islands	Employment	X		X		3	2	1	2
	Roadway	Mangrove Islands	Shoreline protection and stability	X		X		3	3	2	2.67
	NMIA	Mangrove Islands	Shoreline protection and stability	X		X		3	2	2	2.3
Protected area	Ramsar site	Mangrove Islands	Shoreline protection and stability	X		X		3	2	2	2.3
											2.19

6.2.1 Site Preparation and Construction

6.2.1.1 Biological

Invertebrates and Meiofauna

IMPACT

Meiofauna includes; worms, bivalves, crabs, lobsters, sea stars, sea cucumbers and conch, living in or on the sand and may be affected by construction activities. The land reclamation may result in the loss and/or displacement of these species as well as habitat loss. Filter feeding in meiofauna, invertebrates and zooplankton may be affected due to the clogging of gill filaments and other feeding apparatus as a result of excess sediments in the water column.

RECOMMENDED MITIGATION

Recommended Mitigation 1B- Relocation of Sensitive Species

Where possible all sensitive species (macro-invertebrates-sea cucumbers, urchins and conch) should be relocated just before any reclamation works in the area.

Recommended Mitigation 2B- Silt screens and Sediment barriers

Sediment barriers/silt screens are recommended to be used around all reclamation activities. These should be placed so as to reduce/contain the resultant sediment plume during the construction activities. Construction activities should only continue when these barriers are fully operational, that is; placed correctly; calm to moderate sea conditions; without damage. These barriers are particularly important when operations occur near or may influence sensitive ecosystems and species such as seagrass beds and mangrove prop roots and or filter feeding organisms and fish. Care should be taken to stay within the designated footprint area.

Silt screen can help to reduce the sediment plume area and as such reduce the impact of construction activities on the natural environment.

Recommended Mitigation 3B- Work in Reclamation Footprint

Care should be taken to keep all works and activities within the designated reclamation and construction areas so as to reduced/limit the overall impact area.

Fish

IMPACT

Reclamation activities may result in the temporary or permanent loss and/or displacement of any fish and or fish habitat. The excess sedimentation as a result of reclamation processes may also cause clogging of fish gills and may result in their death. Runoff and or siltation as a result of these activities may result in reduced water quality resulting in the temporary displacement of some fish species in the impact area.

The re-suspension or displacement of meiofauna and other invertebrates may create a temporary additional food source for some fish species.

RECOMMENDED MITIGATION
Recommended Mitigation 2B- Silt screens and Sediment barriers

Avifauna and Reptiles (Crocodiles)

IMPACT
Reclamation activities may result in the loss and/or displacement of any fish and reptiles in the area as well as habitat loss. Reclamation may also disrupt nesting activities for turtles and crocodiles and temporarily displace any birds which use the proposed mangrove island areas.

RECOMMENDED MITIGATION
Recommended Mitigation 4B- Sensitization and Education of Construction Crew.

Sensitisation and education of all construction personnel about marine animals and reptiles including, proper procedures in the event of an accident/interaction is essential to the protection of these animals. A use of a spotter may also be necessary in order to avoid incidents with marine life but also other users in the area.

Construction activities should be conducted outside of crocodile and turtle nesting seasons when possible.

Cnidarians and Poriferans

IMPACT
Reclamation activities may cause habitat loss and or displacement of sessile organisms within the footprint of each island. These activities may also result in excess sedimentation and runoff into the marine environment; this may result in the smothering and clogging of feeding and or gill apparatus.

RECOMMENDED MITIGATION
Recommended Mitigation 1B- Relocation of Sensitive Species
Recommended Mitigation 2B- Silt screens and Sediment barriers
Recommended Mitigation 3B- Reclamation Footprint

Vegetation-Mangrove saplings

IMPACT
Existing red and black mangrove saplings as well as coastal runners (*Sesuvium*) present on the narrow sand bars adjacent to the revetment, will be smothered and lost during reclamation of the area to create the mangrove islands.

RECOMMENDED MITIGATION

Recommended Mitigation 5B- Replanting Existing Vegetation

Existing vegetation (mangroves saplings) in the mangrove island footprint should be transplanted to a nursery before reclamation activities commence. These can then be re-planted on the island after reclamation activities are completed.

Seagrass

IMPACT

Sedimentation from reclamation activities may result in the smothering of seagrass blades (outside of the footprint area) and the epiphytes which live on these blades resulting in habitat and species loss. Light penetration will be reduced and therefore the ability for seagrasses to photosynthesize will also be reduced.

RECOMMENDED MITIGATION

Recommended Mitigation 1B- Relocation of Sensitive Species
Recommended Mitigation 2B- Silt screens and Sediment barriers
Recommended Mitigation 3B- Reclamation Footprint

Intertidal Zone

IMPACT

Species found along the intertidal zone maybe lost, smothered and or displaced as a result of reclamation activities.

RECOMMENDED MITIGATION

Recommended Mitigation 2B- Silt screens and Sediment barriers
Recommended Mitigation 3B- Reclamation Footprint

6.2.1.2 Physical

Nearshore Wave Environment

IMPACT

No change to the near shore wave climate is anticipated that will be either directly or indirectly as a result of this project.

Alongshore Sediment Transport Regime

IMPACT

No change to the near alongshore sediment transport regime is anticipated that will be either directly or indirectly as a result of this project. The shoreline is in fact dynamic and moves with the seasons, growth is predicted for some section while other will not. None of these predicted changes were noted to be as a result of this project.

Currents

IMPACT

No change to the currents regime is anticipated that will be either directly or indirectly as a result of this project.

Water Quality and Sediment Plume

IMPACT

Reclamation activities may result in deterioration of the water quality of the immediate area as well as the modelled plume of small distance. There is a small possibility that plumes could be generated from the placement of the fill material. It is anticipated that any plume generated would not move offshore as the area is shallow and the currents are generally slow moving. Any suspended sediment generated will settle out quickly. The percentages of silt in the samples from the donor site are generally in the same order of magnitude as those found in the existing mangrove site.

Reclamation will result in the increase of suspended solids, turbidity, BOD and the reduction in light penetration and dissolved oxygen in the water column. Leakages and spillages of oil and solid waste from equipment is also a possibility.

Recommended Mitigation 1P

Sediment barriers/silt screens are recommended for the locations that are expected to be reclaimed. The silt screens should encircle the areas and be deep enough to contain the plumes so that plumes will not travel in the direction of the prevailing currents.

Air Shed

IMPACT

Reclamation activities may result in reduced air quality in the form of increased particulates, carbon dioxide, NO_x and SO_2 emissions from construction equipment. Noise associated with reclamation activities may also have negative impact.

Recommended Mitigation 2P – Dust Control

The surrounding roadway should be dampened every 4-6 hours or within reason to prevent a dust nuisance and on hotter days, this frequency should be increased. Equipment should be covered when not in use and construction materials wetted to prevent a dust nuisance. Where unavoidable, construction workers working in dusty areas should be provided and fitted with N95 respirators.

Transport - Maritime Operations

IMPACT

The presence of marine vessels associated with reclamation activities (deployment of turbidity barriers etc) has the potential to cause accidents with other marine vessels in the area.

Recommended Mitigation 3P – Safety Plan: markers buoys and exclusion zones

A safety plan should be developed in conjunction with the National Works Agency and Port Authority of Jamaica. The use of marker buoys demarcating an exclusion zone should be used to keep out other marine traffic from the work area during construction. Ample notice must be placed in public media concerning the conducting of reclamation activities.

Noise Pollution

IMPACT

Noise associated with reclamation activities may have negative impact on workers.

Recommended Mitigation 4P – Hearing Protection

Where unavoidable, construction workers working in noisy surroundings should be provided and fitted with hearing protection.

Construction Crew - Increased Solid Waste/Wastewater Generation

IMPACT

It is anticipated that the increased human and vehicular traffic in the area will generate garbage and debris along the shoreline. The increases in solid wastes are often attributed to discarded food containers, tools, construction materials and stationary. The presence of construction crews will also result in increased wastewater production.

Recommended Mitigation 5P – Waste Management

Garbage skips and bins should be strategically placed along the work area and on marine vessels associated with the project. The skips and bins should be adequately designed and covered to prevent access by vermin and minimise odours and emptied regularly to prevent overfilling. Disposal of the contents of the skips and bins should be done at an approved disposal site (Riverton Landfill). All personnel working on the site must undergo orientation which will introduce them to the need to keep the area clean.

Portable sanitary conveniences must be provided during construction for the workers for control of sewage waste. A ratio of approximately 25 workers per chemical toilet should be used.

6.2.1.3 Social

Fishing Community

IMPACT

There is the potential for temporary loss of fishing grounds and reduced fish catch during reclamation activities as a result of the activities within the area. The temporary loss of fishing grounds in particular may lead to increased conflict amongst fishers.

Recommended Mitigation 1S

The use of marker buoys demarcating an exclusion zone should be used to keep out other marine traffic from the work area during construction. Ample notice must be placed in public media concerning the conducting of reclamation activities so that fishers with fishing gear deployed in the work area can remove them before work starts.

Recreational Users

IMPACT

Recreational fishers who fish near the proposed mangrove island area will be temporarily displaced. Water quality for recreational swimmers may also be reduced and emissions from equipment may affect the air quality. Persons who swim at Gun Boat beach in particular may be affected from sediment plumes from the proposed mangrove island nearest that area.

Recommended Mitigation 2S – Sediment Barriers and Silt Screens

Sediment barriers/silt screens are recommended for the locations that are expected to be reclaimed. The silt screens should encircle the areas and be deep enough to contain the plumes so that plumes will not travel in the direction of the prevailing currents.

Recommended Mitigation 3S – Dust Control

The surrounding roadway should be dampened every 4-6 hours or within reason to prevent a dust nuisance and on hotter days, this frequency should be increased. Equipment should be covered when not in use and construction materials wetted to prevent a dust nuisance.

Labour Force/Employment

IMPACT

The mangrove island creation will provide employment both directly and indirectly during the construction phase. This will include local truckers, heavy equipment operators and labourers. It is anticipated the labourers will be from sourced from nearby communities. There is however the potential for decreased commercial activity due to road congestion, yet also increased commercial activity from construction workers willing to purchase lunch and refreshments throughout the work day.

Recommended Mitigation 4S – Traffic Management

Appropriate traffic warning signs informing road users of the construction taking place ahead and instructing users to reduce their speed should be placed along the main road for the duration of the construction period. Flagmen should be utilized to minimize the likelihood of accidents when heavy units are entering the roadway.

Roadway

IMPACT

Reclamation activities may result in increased traffic congestion and potential accidents along the roadway thus delaying commuters travelling to the Norman Manley International Airport and other commercial areas.

See Recommended Mitigation 4S.

Aesthetics

IMPACT

Decreased water quality in the form of elevated turbidity and TSS concentrations may be aesthetically unappealing for observers.

See Recommended Mitigation 2S.

6.2.2 Operation

6.2.2.1 Biological

The mangrove islands should increase habitat diversity and suitability and for various species over time and thus increase species diversity. The mangrove islands should create and sustain a variety of niche habitats. These associated niches may range from prop roots, newly made substrate to tree branches and such species diversity may range from crabs and to the brown pelican and other seabirds

Habitat diversity is anticipated to be most significant with the red mangrove prop roots and the associated colonization by bivalves, barnacles, ascidians, sponges and crustaceans. The prop roots themselves act as a food source and nursery for fishes which live in the water around the prop roots. These prop roots area expected to greatly enhance ecosystem function and services.

Once functional, these mangrove islands should improve the surrounding water quality; less run-off from land (decreased turbidity and TSS); decreases in nutrient concentration as a result of nutrient absorption by the mangroves themselves.

This is a positive impact, therefore no mitigation is required.

Fauna; Meiofauna, Invertebrates and Filter Feeders (Meiofauna and Zooplankton)

IMPACT

Meiofauna, Invertebrates and Filter Feeders should benefit from increased habitat suitability, diversity, food availability and improved water quality. This should result in overall improvements in ecosystem services and function.

This is a positive impact, therefore no mitigation is required.

Fish

IMPACT

The mangrove islands and associated prop roots should increase the available nursery area, foraging ground and general habitat and food source availability for several fish species. This can result in improved fish stocks, providing the fishery is properly managed.

This is a positive impact, therefore no mitigation is required.

Reptiles (Crocodiles)

IMPACT

Crocodiles can now utilize these islands as basking areas, feeding and foraging grounds and nursery areas. Both the area and this species are protected and as such increase protection and awareness of the Palisadoes, Port Royal Protected Area and Ramsar site.

This is a positive impact, therefore no mitigation is required.

Avifauna

IMPACT

Avifauna, including the brown pelican and migratory species should be able to utilize these islands as roosting, nesting, feeding and foraging grounds.

This is a positive impact, therefore no mitigation is required.

Cnidarians, Poriferans and Seagrasses

IMPACT

These sensitive species should benefit from improved water quality anticipated with the functioning of these mangrove islands.

This is a positive impact, therefore no mitigation is required.

Mangrove Trees

IMPACT

Replanted and newly transplanted trees and saplings should flourish along and within these islands.

This is a positive impact, therefore no mitigation is required.

Mangrove Trees and Flora

IMPACT

The establishment of red, black and white mangroves on the newly created mangrove islands will serve to increase vegetation coverage and habitat diversity. The mangroves will also aid in stabilizing the newly created islands and protecting the shoreline and revetment and in turn, the roadway.

Epiphytes may colonize mangrove branches and trunks, these may in turn become habitats for other smaller fauna such as small birds and insects and as such increase habitat suitability, diversity and overall ecosystem services and functions.

This is a positive impact, therefore no mitigation is required.

Intertidal Zone

IMPACT

Intertidal species associated with the revetment will per permanently displaced in areas where the new islands have been created. The remaining intertidal species along the surrounding revetment areas should benefits from improved water quality and enhanced ecosystem function of the new islands

This is a positive impact, therefore no mitigation is required.

6.2.2.2 Physical

Nearshore Wave Environment

IMPACT

The post project phase along the Harbour Side will see the establishment of mangrove nourishment sites. There should not be any changes in the bathymetry of the Harbour and as such, no changes to the nearshore wave climate presented in the 'Description of the Existing Environment' section of the EIA.

Alongshore Sediment Transport Regime

IMPACT

No change to the near alongshore sediment transport regime is anticipated that will be either directly or indirectly as a result of this project.

Currents

IMPACT

No change to the currents regime is anticipated that will be either directly or indirectly as a result of this project.

Sediment Plume

IMPACT

No plumes are anticipated during operation that can be attributed either directly or indirectly to this project.

Stable Beach Profile

IMPACT

The sections of the shoreline that can support the growth of the mangroves will become more stable when the mangroves become mature. It is possible that they will encourage the growth of the shoreline over time.

BEACH PLANFORM MODELING FOR THE POST-PROJECT SCENARIO WITH THE CLIMATE CHANGE WAVE CLIMATE

A cross-shore sediment transport model (SBEACH) was calibrated and used to examine the post project and climate change scenario to designs in order to determine the stable sand slope for sand placement and mangrove nourishment. This was an iterative design process that incorporated feedback from the UWI team responsible for planting the mangroves. An effective mean grain sand size of 1 mm was used, based on the average mean grain size for the 3 sand samples taken from the mangrove adjacent to the project area.

The design process determined that the sand should have a back of beach elevation of 1.0 m, a seaward slope of 1: 10 to MSL, and a 1: 2 slope from MSL to the existing grade to provide the 6,000 m^2 of sand required to re-plant the mangroves that were previously lost during hurricane Ivan storm event. The sand in the western section of the harbour, when subjected to wave action of the annual swell, will move to a more stable slope of 1: 7. While for the sand placed in the central section of the harbour the 1: 10 slope is stable and will not move when subjected to the annual swell event. No sand should be placed in the eastern section of the harbour (between road chainage 3+000 and 4+200 m from the NMIA round-a-bout) as the slope of the sea floor is so steep that any sand placed there will be eroded when subjected to the annual swell event. Figure 6-11, Figure 6-12 and Figure 6-13 show the model results following the annual storm event at the western, central and eastern section of the harbour.

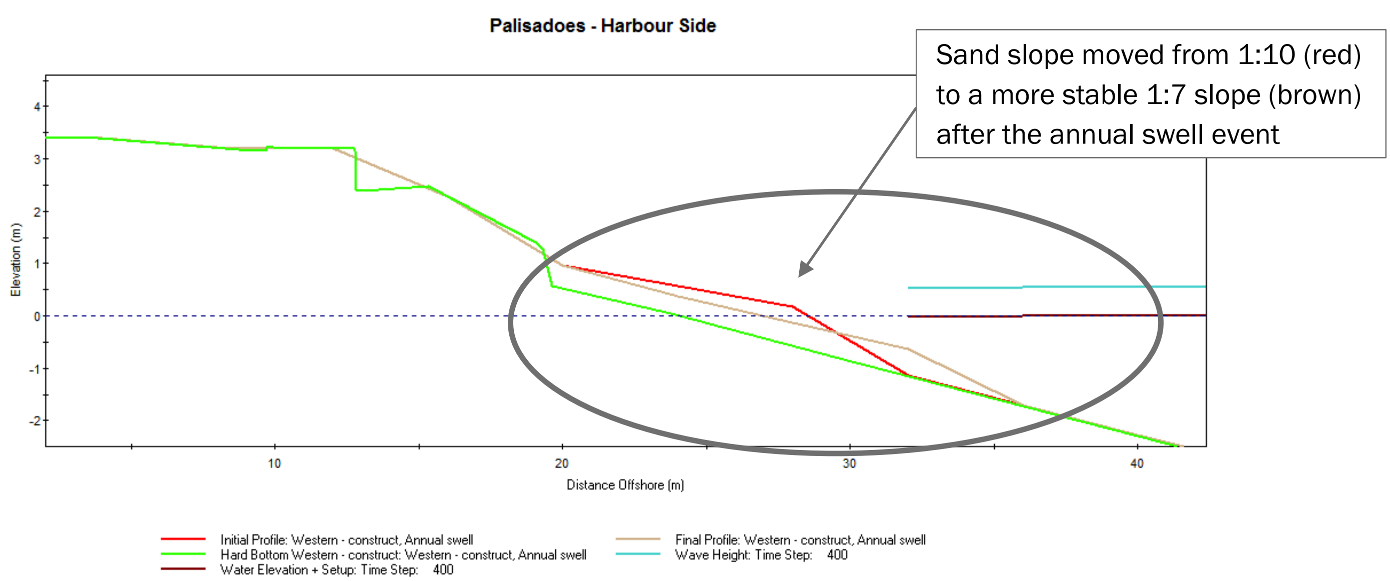


Figure 6-11 Model results showing the sand placement for mangrove nourishment at the western section of the harbour. The sand is placed at a 1: 10 slope and moves to a 1:7 slope after the annual swell event. The 1: 7 slope is the stable slope for sand in this area.

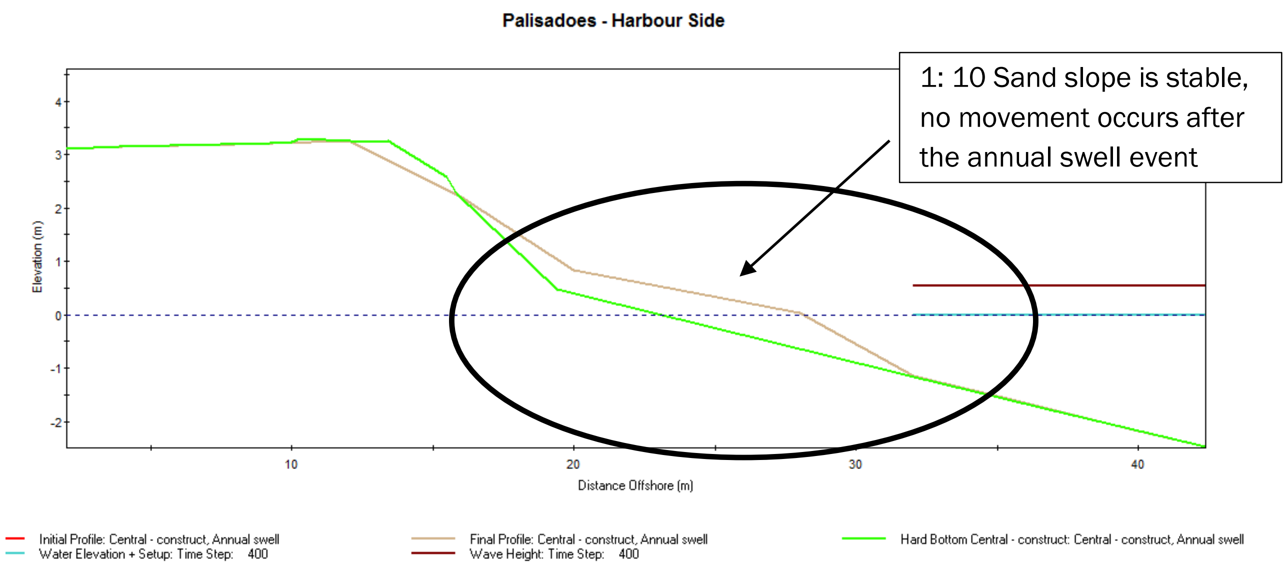


Figure 6-12 Model results showing the sand placement for mangrove nourishment at the central section of the harbour. The sand is placed at a 1: 10 slope and it doesn't move after the annual swell event, the 1:10 slope is stable

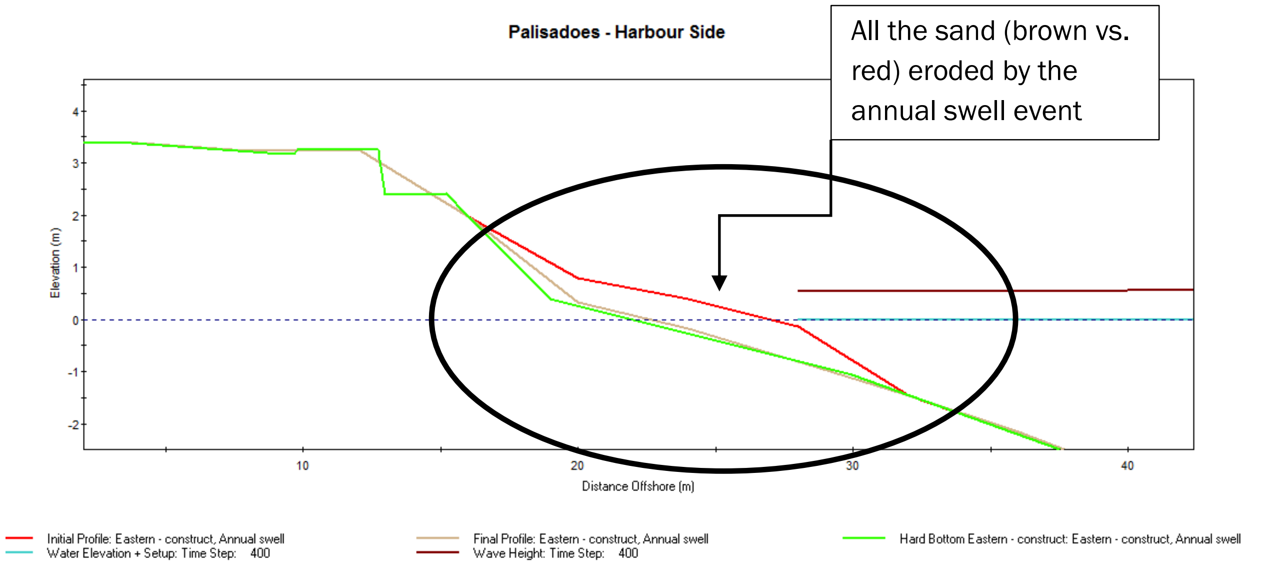


Figure 6-13 SBEACH results showing the sand placement for mangrove nourishment at the eastern section of the harbour.

The sand is placed at a 1: 10 slope and it is almost completely eroded after the passing of the annual swell event.

SUMMARY

The SBEACH model was used to design a stable cross section for sand to be placed for mangrove nourishment. This sand must withstand the annual swell event. The final sand placement design will have a back of beach elevation of 1.0 m and have a seaward slope of 1: 10 to MSL, and a 1: 2 slope from MSL to the existing grade, see Figure 6-14. Reshaping is expected after the initial placement and due consideration should be given to monitoring the slopes before the vegetation is full established.

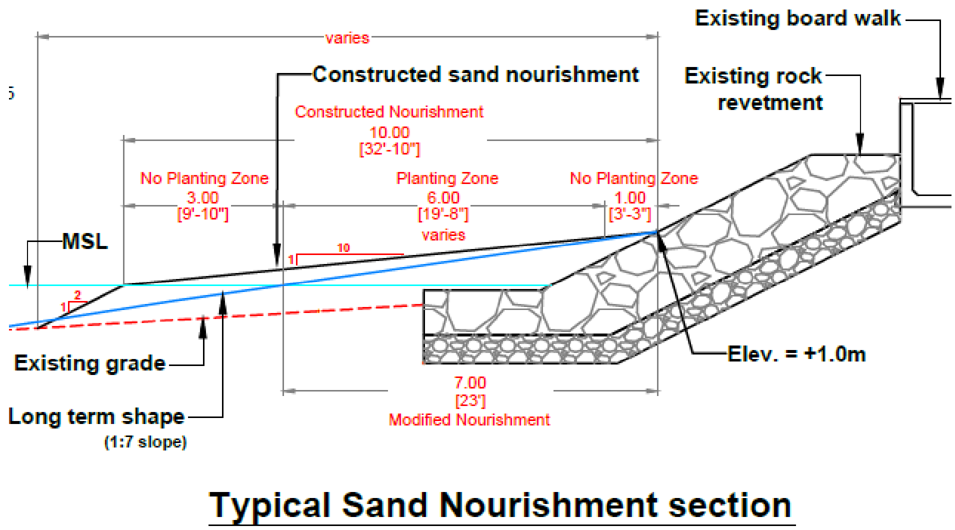


Figure 6-14 Typical cross section for sand nourishment to be placed along the harbour side of the Palisadoes

Water Quality

IMPACT

The mangrove islands should result in improved ambient water quality as there will be less run-off from land (decreased turbidity and TSS), as well as a decrease in nutrient concentration as a result of nutrient absorption by the mangroves.

This is a positive impact, therefore no mitigation is required.

6.2.2.3 Social

Fishers

IMPACT

The mangrove islands, associated prop roots and habitats should act as nursery areas for fish and provide suitable habitat for commercially important species such as oysters and mussels. If managed correctly, this can result in an improved fishery and associated fish stocks.

This is a positive impact, therefore no mitigation is required.

Aesthetics

IMPACT

The establishment of the mangrove islands can potentially improve the aesthetics of the area.

This is a positive impact, therefore no mitigation is required.

Roadway

IMPACT

The establishment of the mangrove islands and the associated ecosystem services and functions, should aid in protecting and stabilizing the shoreline and in turn, the roadway.

This is a positive impact, therefore no mitigation is required.

7.0 CUMULATIVE ENVIRONMENTAL IMPACTS

7.1 OVERALL PROJECT

There are some impacts that will be shared by the works along both sides of the Palisadoes shoreline, and these are presented herein. Special consideration is needed as the project takes place within a Ramsar site and is part of Palisadoes Port Royal Protected Area.

The Palisadoes-Port Royal Protected Area (P-PRPA) is approximately 7,523 hectares (75.23 km^2) and encompasses both terrestrial and marine areas. The area was declared a protected area under the Natural Resources Conservation Authority (NRCA) Act on 18 September 1998. However, prior to this, the Port Royal Protected Area was declared on 8 May 1967 under the Beach Control Act (BCA). The area was also designated as Jamaica's second Wetland of International Importance (Ramsar Site) under the Convention on Wetlands of International Importance especially as a Waterfowl Habitat on 22 April 2005. The protected area also encompasses the Port Royal and the Palisades which is one of five heritage districts in the island, designated by the Jamaica National Heritage Trust (JNHT)1. The zoning plan has undergone a series of consultations and targeted activities with both governmental and non-governmental entities as well as individual members of the user community. This plan is intended to be a five year (2014-2019) framework which seeks to realize the objectives of ensuring the protection of key habitats/sites, whilst promoting the wise and sustainable use of the natural and heritage resources and compliance with applicable laws and regulations within the P-PRPA. The Plan was compiled by staff of the Protected Areas Branch with input from the Ecosystems Management Branch, the Local Area Planning Branch and the Map Registry and Data Management Unit of the National Environment and Planning Agency (NEPA).

Jamaica has three designated Ramsar sites. These are the Black River Lower Morass, the Palisadoes-Port Royal (April 22, 2005) and Portland Bight Wetlands and Cays. The main areas are the Port Royal Mangroves, the Port Royal Cays and the sand dunes of the Port Royal Tombolo. The area has several animal and plant species that have been deemed of enormous importance. Present in this area are the American crocodile, the West Indian manatee and the bottlenose dolphin. Fishing is one of the most significant commercial activities in this area. The Norman Manley International Airport, one of the country's two major gateways, is also located here.

Table 7-1 shows the Cumulative Impacts summary table.

Table 7-1 Cumulative Impacts Summary Table

	Past and Present (Baseline/ Existing Condition)	Future without Project	Future with Project
Palisadoes Port Royal Protected Area, Ramsar			
Leeward Coastline of Palisadoes Roadway	The harbour side of the road way was once lined with mangroves which formed part of a relativley healthy system. Coastal modification, industrial actvities and other ungoing anthropogenic stress continue to shape the ecology of the harbour. The rehabiliation works removed what was left of attempted mangrove replanting along the roadway while potentially impacted seagrasses were relocated. The existing mangroves and seagrass beds are currently stressed by activities and influences in the area. These ecosystems are also affected by hurricanes and other natural disasters. They provide valuable shoreline protection, land accretion and improved coastal dynamics	Without phase two of the rehabilitation project, the roadway will only be protected by the exisiting revetment. The area would have suffered a netloss in habitat and species diversity. This would conflict with the NEPA no net loss principle.	Additional project impacts may include increases in turbidity and noise and temporary habitat displacement during construction. There is a small risk of marine reptiles being struck or being entangled by construction vessels or entrainment. The overall and long term benefits of the project include an improved coastal ecosytem, accretion of land, enhancing shoreline protection and potential improvement in nearshore habitats. The improved ecosystem function should enhance services provided by each of these systems, which includes shoreline protection.
Near Shore Communities			
Local Community (Fishing, recreational, labout force/ employment)	Extreme storm events, including hurricanes, have had negative effects on the local economy and those who use the Palisadoes.	Without this proposed phase of the rehabilitation project there will be minimal impact on those who use the harbour for fishing, recreational and employment purposes.	During construction, in the short term, additional project impacts would primarily involve increased noise, turbidity and traffic congestion. This may temporarily displace those who fish near the proposed mangrove areas; those who swim at Gun Boat beach; and those who use the roadway to access their homes and places of employment.

	Past and Present (Baseline/ Existing Condition)	Future without Project	Future with Project
Threatened and Endangered Species: Crocodiles	Crocodiles, both historically and currently, bask along this area and may use nearshore habitats (seagrass beds and mangroves). Past and current threats to crocodile populations include; coastal modification, harmful fishing practices (netting, vessel strikes, fishing gear entanglement, and ingestion of discarded anthropogenic marine debris), hunting and poaching of nests.	Crocodile basking will continue. They may also use the surrounding mangroves as a nursery and/or for shelter and foraging. Project-specific impacts will be avoided, but ongoing threats include habitat loss and poaching.	In addition to ongoing threats, the project will result in loss of a small area potentially used by crocodiles. They may also be displaced/disturbed by increased noise and activity during construction. Animals are also at risk of being struck by a construction vessel or entrangled in construction equipment. Due to the small spatial extent and short duration of project impacts, no significant negative cumulative impacts are expected. Long term postive cumulative impacts may include the increased suitability of this area for foraging, basking and potential nursery functions. There may also be an increased awareness, sensitivity and manangemnt of the area.
Sea Birds	Sea birds in the area include both local and migratory species. They utilize the exisiting coastline and mangrove areas for nesting, foraging and roosting. They have experienced habitat loss and modification with coastal constriction and habitat destruction over time. Birds may be temporarily displaced due to noise and construction activities.	Without the proposed project, seabird populations and dynamics will remain the same. There can be an expected decline in populations without proper management of the area, preventing habitat loss and protecting food supply.	In addition to the ongoing natural and anthropogenic impacts in the exisiting bird habitats, they may be temporarily disrupted during the construction activities. No negative long term cumulative impacts are expected. With the newly created islands and re-planted mangroves, there will be a positive impact on sea bird populations. The mangroves should provide additional and improved habitat for both resident and migratory bird species. An improved coastal system should also result in improved feeding grounds. Increased awareness and protection of the area will also benefit bird populations.

	Past and Present (Baseline/ Existing Condition)	Future without Project	Future with Project
Hard and Sandy bottom Community	These communities have historically been subjected to the dynamics of the nearshore environment including sand movement, scouring, and alternating burial/exposure.	Nearshore areas will continue to be subject to the natural dynamics of the nearshore environment including sand movement, scouring, and alternating burial/exposure. In the absence of the project, coastal ecosystem dynamics and functions will be reduced and this may impact the stability and function of the associated nearshore communities.	The project is expected to improve form and function of the coastline, dune and beach area resulting in the associated improvements in coastal dynamics and functions. The nearshore communities should see the benefits of improved coastal dynamics. There should also be improved water quality in the area, with less runoff and sedimentation.
Fish and Invertebrate Community	There is an invertebrate and fish community associated with the mangroves, seagrass beds and nearshore habitats. Invertebrates include meiofuana and epifauna species represented primarily by annelid worms, gastropods, bivalves, crustaceans and echinoderms. Mangroves are home to a variety of marine, terrestrial and intertial invertebrates, fish and birds. Seagrass beds work along with these mangroves and nearshore environments as nurseries and foraging habitats. Typical shallow water and bottom feeding fish species as well as commercial fish utilize these areas. Coastal modification and roadway expansion over several years has removed the mangroves along the project area.	Project-specific impacts will be avoided; nearshore and interdial communities will develop overtime; however the continued pollution and excessive collection of marine debris all along the shoreline may impair and/or restrict proper habitat development and function.	In addition to ongoing processes affecting this area, there will be localized effects along the shoreline. Effects are not likely to be significant, therefore no significant cumulative impacts are expected. The associated invertebrate community will experience some temporary habitat loss and some loss of species, also not anticipated to be significant. The overall effect of the project on these communities is expected to be positive, with improved water quality, ecosystem function and increased habitat diversity. These areas may also benefit from additional sensitivity and protection.

	Past and Present (Baseline/ Existing Condition)	Future without Project	Future with Project
Seagrass beds	There is a diverse community associated with seagrass beds. Seagrass was relocated during phase 1 of the project, and are outside the proposed footprint of the mangrove islands. Seagrass beds work in conjunction with the associated mangroves and nearshore habitats as a nursery and foraging ground. Seagrassses located in the harbour are heavily affected by polluted waters, excessive marine debris, coastal modification and harmful fishing practices.	Project-specific impacts will be avoided, seagrass beds near the associated project areas will be avoided and speical care taken to ensure a minimal impact. These beds would continue to be affected by some natural coastal dynamics and greatly affected by human impacts. In the absence of the project, there should be no major changes in these beds and the associated faunal communities. Without the project, the health and stability of these systems is at risk and may continue to deteriorate.	In addition to ongoing processes affecting seagrass, there may be indirect localized effects from construction activities. Effects are not likely to be significant as fish, reptiles and invertebrates can move out of the area. No significant cumulative impacts are expected. The overall effect of the project on these communities is expected to be positive, with improved water quality and ecosystem function. These areas may also benefit from additional sensitivity and protection.
Coral	There are no known reef communities in or around the project area or area of influence. No hard or soft corals were observed in the proposed project area. No hard corals were seen in the seagrass bed or other potentially suitable habitat.	No hard or soft corals	No hard or soft corals
Water Quality	Water quality in the harbour is not uniform but can be generally described as eutrophic. The harbour is greatly influenced by runoff from gullies and roadways; untreated/poorly treated sewage; industrial waste and activities; and extensive shoreline modification including the removal of mangroves and other sensitive ecosystems.	Water quality may remain the same but will more than likely continue to deteriorate under the current conditions.	With the successful establishment of the mangrove islands and their associated flora and fauna, water quality immediately surrounding these islands should improve.

	Past and Present (Baseline/ Existing Condition)	Future without Project	Future with Project
Windward Coastline of Palisadoes Roadway	The dunes and beach along this section of the roadway are constanly exposed to storm surge, high winds and shelter the exisiting roadway and harbour from various natural disasters. Coastal modification was first undertaken with groynes built in 1951 following the passage of Hurricane Charlie. The area experiences beach and dune erosion and is still an active nesting site for hawksbill turtles. Current modification includes the re-creation of dunes with boulders.	Without phase two of the rehabilitation project, the roadway will only be protected by the exisiting revetment. The area would have suffered a netloss in habitat and species diversity as well as beach erosion. Climate change predictions for the future also indicate that more intense storm events will continue and the associated beach erosion will continue. This would conflict with the NEPA no net loss principle.	Additional project impacts may include increases in turbidity and noise and temporary habitat displacement during construction. There is a small risk of marine mammals being struck or becoming entangled by construction vessels or entrainment. The overall and long term benefits of the project include; an increase in shoreline protection and reduction in infrastructure damage experienced along the shoreline following the passage of an extreme storm event. There will also be an improvement in the coastal ecosytem and potential improvements in nearshore habitats. The improved ecosystems will improve and increase the ecosystems services which includes shoreline protection.
Beach area			

	Past and Present (Baseline/ Existing Condition)	Future without Project	Future with Project
Threatened and Endangered Species: Sea Turtles	Hawksbill turtles both historically and currently nest along this beach area. Other turtle species were once thought to also utilize this area, including, Leatherbacks, Olive Ridlley and Green sea turtles. Juvenile turtles may use nearshore and off shore hardbottom and seagrass beds areas for feeding (macroalgae), resting, and shelter from predators. Past and current threats to sea turtle populations include artificial lighting, beach modification, harmful fishing practises (netting, vessel strikes, fishing gear entanglement, ingestion of discarded anthropogenic marine debris) and poaching of nests.	Sea turtle nesting and use of nearshore and surrounding off-shore habitats will continue. Project-specific impacts will be avoided, but ongoing threats include; habitat loss due to erosion of the beach, which may result in loss of nesting habitat and possible impacts on nearshore habitats.	In addition to ongoing threats, the project will result in loss of a small defined area potentially used by turtles present in the area. They may also be displaced/disturbed by increased noise and turbidity during construction. Animals are also at risk of being struck by a construction vessel or entrangled in dredge/construction equipment. Due to the small spatial extent and short duration of project impacts, no significant negative cumulative impacts are expected. Long term positive cumulative impacts may include the increased suitability of this beach for nesting as a result of the revegetaion, dune and beach stabilization. The nearshore foraging grounds should, by extension, also be improved. There may also be an increased awareness, sensitivity and management of the area.

	Past and Present (Baseline/ Existing Condition)	Future without Project	Future with Project
Sea Birds	Sea birds in the area include both local and migratory species. They utilize the exisiting dune and beach areas for nesting, foraging and roosting. They have experienced habitat loss and modification with coastal constriction and beach erosion over time. Birds may be temporarily displaced due to noise and construction activities.	Without the proposed project, seabird populations and dynamics will remain the same. There can be an expected decline in populations without proper management of the area, preventing habitat loss and protecting food supply.	In addition to the ongoing natural and anthropogenic impacts in the exisiting bird habitats, they may be temporarily disrupted during the construction activities. No negative long term cumulative impacts are expected. With the re-vegetated dunes and improved coastal systems, there will be a positive impact on sea bird populations. The dunes should provide additional and improved habitat for both resident and migratory bird species. An improved coastal system should also result in improved marine feeding grounds. Increased awareness and protection of the area will also benefit bird populations.
Near Shore Communities			
Local Fishing Community	Extreme storm events, including hurricanes, have had negative effects on the local economy and those who use the Palisadoes.	Without this proposed phase of the rehabilitation project, there will be minimal impact on those who use the area for fishing.	During construction there is the potential for loss of fishing grounds and reduced fish catch during sand dune construction, along with a possible increase in turbidity. There should, however, be no siginificant cumulative effect on the fishing activity once the construction is completed.
Hard and Sandy bottom Community	These communities have historically been subjected to the dynamics of the nearshore environment including sand movement, scouring, and alternating burial/exposure.	Nearshore areas will continue to be subject to the natural dynamics of the nearshore environment including sand movement, scouring, and alternating burial/exposure. In the absence of the project, coastal ecosystem dynamics and functions will be reduced and this may impact the stability and function of the associated nearshore communities.	The project is expected to improve form and function of the coastline, dune and beach area resulting in the associated improvements in coastal dynmaics and functions. The nearshore communities should see the benefits of improved coastal dynamics. There should also be improved water quality in the area, with the anticipated less runoff and sedimentation.

	Past and Present (Baseline/ Existing Condition)	Future without Project	Future with Project
Fish and Invertebrate Community	There is an invertebrate and fish community associated with nearshore habitats; Invertebrates include meiofuana and epifauna species represented primarily by annelid worms, gastropods, bivalves, crustaceans, and echinoderms. Typical shallow water and bottom feeding fish species as well as commercial fish utilize this area.	Project-specific impacts will be avoided, but nearshore communities would continue to be affected by natural dynamics. In the absence of the project, there may be further affected by runoff and sedimenation associated with the existing coastline; which may result in impacts to nearshore including reduced habitat suitability for invertebrates and bottom feeding fish and as result an overall impact to the associated food web and feeding dynamics.	In addition to ongoing processes affecting nearshore fish and invertebrate communities, there will be localized effects of dredge and fill activities along the beach and in the nearshore areas that may persist for a time after the project. Effects are not likely to be significant because resident fish are wide-foraging or migratory and spend only a portion of their life cycle at the borrow area and beach fill site. No significant cumulative impacts are expected. The associated invertebrate community will experience some temporary habitat loss and some loss of species, also not anticipated to be significant. The overall effect of the project on these communities is expected to be positive, with improved water quality and ecosystem function.. These areas may also benefit from additional sensitivity and protection.
Seagrass beds	There is a diverse community associated with seagrass beds. These are both directly and indirectly affected by coastal dynamics as well as project activities.	Project-specific impacts will be avoided. Seagrass beds in or near the associated borrow/project areas will be avoided and special care taken to ensure minimal impact. These beds would continue to be affected by natural sand movement and coastal dynamics as well as human impacts with the existing fishery. In the absence of the project, there should be no major changes in these beds and the associated faunal communities. Without the project, coastal dynamics may deteriorate and indirectly affect these beds.	In addition to ongoing processes affecting seagrass, there will be localized effects of dredge and nourishment activities that may persist for a time after the project. Effects are not likely to be significant as fish, mammals, reptiles and invertebrates can move out of the area. No significant cumulative impacts are expected. The overall effect of the project on these communities is expected to be positive, with improved water quality and ecosystem function. These areas may also benefit from additional sensitivity and protection.

	Past and Present (Baseline/ Existing Condition)	Future without Project	Future with Project
Reef Area	The associated reef communities in the area are diverse, with a variety of form, function and commuinty structure and dynamic. This community is both directly and indirectly affected by coastal dynamics as well as project activities.	Project-specific impacts will be avoided. Reef areas near the associated borrow/project areas will be avoided and special care taken to ensure a minimal impact. These communities would continue to be affected by natural sand movement and coastal dynamics as well as human impacts with the existing fishery. In the absence of the project, there should be no major changes directly related to coastal stability. These areas are at greater risk from climate change and anthropogenic influences. Without the project, coastal dynamics may deteriorate and indirectly affect reef areas.	In addition to ongoing processes affecting reef communities, there will be localized effects of dredge and nourishment activities. Effects are not likely to be significant as mobile fauna can move out of the area. No significant cumulative impacts are expected. The overall effect of the project on these communities is expected to be positive, with improved water quality and ecosystem function. These areas may also benefit from additional sensitivity and protection.
Marine Mammals	Marine mammals include dolphins and other small cetaceans. Past and current threats to marine mammal populations include vessel strikes, fishing (ghost fishing) entanglement, ingestion of marine debris, pollution and underwater noise. Fishermen have been known to hunt dolphins which destroy fishpots in the area.	Marine mammals will continue to occur in the area. Project-specific impacts will be avoided, but ongoing threats to marine mammal populations will continue.	Additional project impacts may include increases in turbidity and noise and temporary habitat displacement during construction. There is a small risk of marine mammals being struck or being entangled by construction vessels or entrainment. The improved coastal ecosystem and beach stability should improve nearshore environments and enhance the assocociated foraging areas.

	Past and Present (Baseline/ Existing Condition)	Future without Project	Future with Project
Borrow Area	There is an invertebrate and fish community associated with borrow areas. Invertebrates include meiofuana and epifauna species represented primarily by annelid worms, gastropods, bivalves, crustaceans and echinoderms. Typical shallow water and bottom feeding fish species as well as commercial fish utilize this area.	Project-specific impacts will be avoided, but borrow areas would continue to be affected by natural sand movement and coastal dynamics. In the absence of the project, there will be no major changes in sand borrow areas and associated faunal communities.	In addition to ongoing processes affecting borrow areas, there will be localized effects of dredge and nourishment activities that may persist for a time after the project. Effects are not likely to be significant because resident fish are wide-foraging or migratory. No significant cumulative impacts are expected. The associated invertebrate community will experience some temporary habitat loss and some loss of species, also not anticipated to be significant. The overall effect of the project on these communities is expected to be positive, with improved water quality and ecosystem function. These areas may also benefit from additional sensitivity and protection.
Water Quality	Water quality in the borrow and nearshore areas can be described as mesotrophic with a tendency to being slightly eutrophic. These areas have anthropogenic influences ranging from runoff from rivers, gullies and roadways to untreated/poorly treated sewage and coastal modifications and natural occurrences such as hurricanes and storm surge.	Project specific impacts will be avoided. Water quality may remain the same but will more than likely continue to deteriorate under the current conditions.	With the project and anticipated improved dynamics between coastal ecosystems (dune, seagrass and reef) there may be improvement in the water quality of the associated water column.

8.0 IDENTIFICATION AND ANALYSIS OF ALTERNATIVES

The following project alternatives have been identified and are discussed in further detail below:

- Alternative 1 - The "No-Action" Alternative
- Alternative 2 - The Project as Proposed
- Alternative 3 – Dune Nourishment Material
- Alternative 4 – Mangrove Island Material

8.1 ALTERNATIVE 1 - THE "NO ACTION" ALTERNATIVE

The original design of the shoreline protection included the dunes and a low revetment at the "less vulnerable" sections of the Palisadoes roadway. This was a cost saving strategy to utilize the dunes in the design instead of the more expensive option of only boulders along the entire area. The dunes would move or deform during a storm thus exposing the underlying rock revetment in extreme circumstances. Not building the revetment would expose the low revetment immediately and expose the roadway to storm surge and high energy waves.

If there is to be no nourishment of the revetments and no mangrove island creation, the shoreline and revetment will continue to be exposed to storm surge and remain aesthetically unappealing.

8.2 ALTERNATIVE 2 – THE PROJECT AS PROPOSED

Dune nourishment and mangrove island creation will aid in protecting and stabilizing the shoreline and revetment and in turn, the roadway. The Palisadoes shoreline has experienced several severe storm events that have overtopped and blocked the roadway. The sand dunes to be constructed are designed to provide the roadway with effective protection for up to a 100 year return period storm event. In addition, the Project will aid in improving the ambient water quality, increase habitat diversity for flora and fauna and improve the overall aesthetics of the Palisadoes roadway. Replanted mangroves and associated prop roots will act as a nursery area for fish and other invertebrates, thus eventually increasing the fish stock in the area. Employment opportunities during the construction phase will also arise.

On the other hand, the following potential negative impacts are anticipated (during the construction period) with the Project as proposed:

- Temporary deterioration of ambient water quality.
- Increased accident potential for maritime, vehicular and pedestrian traffic.
- Increased potential for solid waste generation (both terrestrial and marine).

- Smothering of existing dune vegetation and mangroves during nourishment and reclamation activities respectively.
- Habitat alteration/loss of various fauna and disruption of nesting sites for reptiles.
- Sedimentation and damage of nearby reefs and seagrass beds from dredging activities.

8.3 ALTERNATIVE 3 - DUNE NOURISHMENT MATERIAL

The Port Authority of Jamaica intends to dredge the Kingston Harbour to accommodate larger vessels. A recent EIA study done for the proposed dredging indicated that the estimated total volume to be dredged is 15.7 million cubic metres. The proposed dune nourishment activities requires less than one percent (1%) of this volume. If sufficient material having similar characteristics to the existing dune material can be found, then using this material for dune nourishment should be considered a viable alternative.

Similarly, Petrojam also performs maintenance dredging in the harbour to accommodate fuel tankers/ships and the dredge spoil is typically dumped offshore. If sufficient material having similar characteristics to the existing dune material can be found, then using this material for dune nourishment should be considered a viable alternative.

8.4 ALTERNATIVE 4 – MANGROVE ISLAND MATERIAL

Potential mangrove island reclamation material was collected from three (3) quarries, two (2) de-silting operations and eight (8) locations within an offshore sand deposit. They were each analysed to determine their suitability for mangrove island creation. The only suitable material was that from the nearby de-silting operation along the Hope River. Other alternatives for reclamation material, if considered, would be more costly.

Similarly the maintenance dredge spoil may be sufficient if it has similar characteristics and found to be suitable for the creation of these mangrove islands. This too should be considered a viable alternative.

8.5 THE PREFERRED ALTERNATIVE

The preferred alternative is Alternative 2 – The Project as Proposed.

9.0 ENVIRONMENTAL MANAGEMENT AND MONITORING

An Environmental Management System (EMS) is an important tool which can be used to assist operations managers in meeting current and future environmental requirements and challenges. It can be used to measure a company's operations against environmental performance indicators, thereby helping the company to reach its environmental targets. A good management system will integrate environmental management into a company's daily operations, long-term planning and other quality assurance systems.

It is therefore recommended that several parameters be monitored before during and after the project implementation to record any negative construction impacts and to propose corrective or mitigation measures. The suggested parameters include but not limited to the following:

1) Water Quality to include but not be limited to:
    a. pH
    b. electrical conductivity
    c. turbidity
    d. BOD
    e. Total Suspended solids (TSS)
    f. Grease and Oils
    g. Faecal Coliform
    h. Nitrates and Phosphates
2) Air quality
3) Coral and Fisheries
4) Mangroves
5) Dune Vegetation
6) Traffic
7) Maritime Operations
8) Solid Waste Generation and Disposal
9) Sewage Generation and Disposal
10) Equipment Maintenance
11) Health and Safety

9.1 PHASED RECOMMENDATIONS

9.1.1 Site Preparation Phase

- Daily inspections to ensure that site preparation activities are not being conducted outside of regular working hours (e.g. 7 am – 7 pm).
  The project engineer / site supervisor should monitor the work hours. NEPA should conduct spot checks to ensure that the hours are being followed.
- Daily monitoring to ensure that the activity is not creating a dust nuisance. The project engineer / construction site supervisor should monitor the site preparation. NEPA should conduct spot checks to ensure that this stipulation is followed.
- Background readings should be taken of all water quality parameters prior to site preparation. Readings should be conducted weekly.
- Undertake daily inspections of trucks carrying solid waste generated from site preparation activities to ensure that they are not over laden as this will damage the public thoroughfare and onsite lead to soil compaction.
  Person(s) appointed by NWA may perform this exercise.
- Daily monitoring of vehicle refuelling and repair should be undertaken to ensure that these exercises are carried out on hardstands. This is to reduce the potential of soil contamination from spills. Spot checks should be conducted by NEPA.
  Person(s) appointed by NWA may perform this exercise.
- Traffic should be monitored during preconstruction.
- Undertake daily inspections to ensure that workers are wearing adequate personal protective equipment (PPE), such as hard hats, hard boots, air protection, safety glasses, reflective vests and fall protection is necessary. Ensure that safety signage is in place.
- Health, safety and emergency response plans should prepared prior to site preparation an d construction phases.

9.1.2 Construction Phase

- Undertake weekly water quality monitoring or a frequency agreed to with NEPA to ensure that the construction works **(dredging and nourishment)** are not negatively impacting on water quality.
  Any organization with the capability to conduct monitoring of the listed parameters should be used to perform this exercise. It is recommended that a report should be given to NEPA at the end of each monitoring exercise.
- The Dredge Management Plan stipulated in the specifications must be adhered to by the contractor and monitored by representatives of the NWA.
- Daily inspections to ensure that construction activities are not being conducted outside of regular working hours (e.g. 7 am – 7 pm).
  The project engineer / site supervisor should monitor the construction work hours. NEPA should conduct spot checks to ensure that the hours are being followed.

- Daily monitoring to ensure that fugitive dust from nourishment activities, access roads and raw materials are not being entrained in the wind and creating a dust nuisance. Frequent wetting should be conducted.

  The project engineer / site supervisor should monitor the construction work hours. NEPA should conduct spot checks to ensure that this stipulation is being followed. In addition, any Citizens Association within the area can be used to provide additional surveillance.
- Conduct daily inspections to ensure that flagmen where necessary are in place and that adequate signs are posted along the roadways where heavy equipment interact with existing roads. This is to ensure that traffic have adequate warnings and direction.
- Undertake daily assessment of the quantity of solid waste generated and keep records of its ultimate disposal. Additionally, solid waste generation and disposal of the campsite should also be monitored.
- Weekly assessment to determine that there are adequate numbers of portable toilets and that they are in proper working order. This will ensure that sewage disposal will be adequately treated.
- Daily monitoring of vehicle refuelling and repair should be undertaken to ensure that these exercises are carried out on hardstands. This is to reduce the potential of soil/sand contamination from spills. Spot checks should be conducted by NEPA.
- Traffic and maritime operations should be monitored to ensure approved management plans at critical areas are being followed. NEPA and NWA and other relevant authorities should perform spot checks to ensure compliance. Monitoring should be conducted daily to ensure major disruption is avoided. Reports should be made to NWA on a fortnightly basis.
- Undertake daily inspections to ensure that workers are wearing adequate personal protective equipment (PPE), such as hard hats, hard boots, air protection, safety glasses, reflective vests and fall protection is necessary. Ensure that safety signage is in place.
- Health, safety and emergency response plans should prepared prior to site preparation and construction phases.
- Where possible, construction crews should be sourced from within the study area. This will ensure that the local community will benefit from the investment.
- Coral colonies at the three monitoring sites in this EIA should be monitored monthly or at a frequency agreed to with NEPA. This will include:

  1) Photo Inventory and Roving Surveys:

  Corals of particular interest (endangered species, diseased or bleached colonies for example) and representative corals from each site should be tagged and a new photo inventory established for additional long term monitoring.

  2) Fish Surveys:

  The fish component of the AGRRA survey should be conducted.

  3) General Parameters:

Physicochemical water quality parameters, including but not limited to Temperature, pH, Light Irradiance, Salinity and Turbidity should be obtained both within each site using a Hydrolab DS-5 water quality multiprobe.

4) To monitor the potential sediment impact from construction (dredging and nourishment) activities on the marine environment, one sediment trap should be deployed at each of the coral assessment sites. The settlers should be retrieved on a monthly basis, its contents analysed and redeployed to determine the rate of sedimentation ($mg/cm^2/day$) and dispersal patterns over the area.

9.1.3 Operational Phase

- Water quality monitoring should be done at least monthly after construction. If three to six results demonstrate that the site or parts of the site have stabilised, the sampling frequency and sampling locations may be reviewed and reduced or discontinued as per and approved monitoring plan.
- Replanted mangrove monitoring to be conducted for five years, along with associated solid waste screen monitoring.
- Replanted dune vegetation monitoring to be conducted for five years.

9.2 REPORTING REQUIREMENTS

9.2.1 Water Quality

A report shall be prepared by the Contracted party. It shall include the following data:

i. Dates, times and places of test.
ii. Weather condition.
iii. A defined map of each location with distance clearly outlined in metric.
iv. Test Method used.
v. Parameters measured
vi. Results
vii. Conclusions

The report will be submitted to the Client or his designate within two weeks of the monitoring being completed.

The Client shall distribute the report within four (4) weeks of testing being completed to NEPA.

In the event that the water quality does not meet the required criteria, investigations shall be carried out and corrective actions were necessary taken and a re-test shall be scheduled at the earliest possible time and a new report submitted.

If three (3) to six (6) results demonstrate that the site or parts of the site have stabilised, the sampling frequency and sampling locations may be reviewed and reduced or discontinued as per approved monitoring plan.

Reports will be maintained on file for a minimum of three years.

9.2.2 Coral and Fish

A report shall be prepared by the Contracted party. It shall include the following data:

1) Percentage Coral Cover
   a. Live coral
   b. Recently killed coral
   c. Dead coral
   d. Diseased or bleached coral
2) Percentage Algae Cover
   Where possible Algae will be identified and categorised (fleshy, calcareous and cyanobacteria.
3) General Substrate Composition
   The substrate type will also be identified (sand, pavement rock etc.)
4) *Diadema sp.* Counts
5) Fish counts, species and size classes
6) Presence of fish nets, pots, spearfishers, invasive and rare species.
7) Other Data

Any rare, endangered, commercially important (lobster and conch) and invasive organisms observed will also be noted and photographed, as well as the presence/absence of seagrasses. Any obvious sedimentation, anchor damage, marine debris and other direct impacts will also be recorded.

The report will be submitted to the Client or his designate within two weeks of the monitoring being completed.

The Client shall distribute the report within four (4) weeks of testing being completed to NEPA.

Reports will be maintained on file for a minimum of three years.

9.2.3 Replanted Mangroves

A report shall be prepared by a Contracted party (UWI). It shall include the following data:

1) General plant conditions, vertical growth, areal coverage, number of shoots per planting unit/mangrove sapling.
2) Adverse impacts on saplings from wind, wave action, debris flow.
3) Survival Rate of saplings.
4) Water Quality – temperature, salinity, dissolved oxygen, pH, nitrate and phosphate.

5) Productivity via leaf litter traps (after attaining height of 1.5m)
6) Photo inventory of prop roots.
7) Solid waste screen monitoring.

A total of 13 mangrove monitoring events and subsequent reports to NEPA will be conducted and submitted. The report will be submitted to NEPA, the Client or his designate within two weeks of the monitoring being completed.

Reports will be maintained on file for a minimum of three years.

9.2.4 Replanted Dune Vegetation

A report shall be prepared by a Contracted party (UWI). It shall include the following data:

1) Plant species at specific sections of transects.
2) Shoot extension of plant, # of nodes, % cover of runners.
3) Tree height, # of nodes, diameter at breast height (if attained during the 5 year monitoring period).
4) Natural recruitment of any unplanted species.
5) Observations and recording of any fauna present.

A total of 13 dune vegetation monitoring events and subsequent reports to NEPA will be conducted and submitted. The report will be submitted to NEPA, the Client or his designate within two weeks of the monitoring being completed.

Reports will be maintained on file for a minimum of three years.

10.0 PUBLIC PARTICIPATION AND CONSULTATION

Community interaction and transparency was considered a critical area of focus for the success of this development. Public consultation in the form of A Social Impact Assessment (SIA) carried out as part of this EIA.

The SIA comprised a perception survey involving residents, members of the community (residents), fisher folk and recreational users. The main goal of the SIA for this project was gleaned from the TORs for the Project which required "... *some level of stakeholder consultation*". This was achieved using structured questionnaires. The process of engagement with stakeholders sought to treat with specific issues contained in the project description, such as the erosion in the area, stakeholders' perceptions, their views on the proposed Palisadoes Rehabilitation and Shoreline Protection project, their awareness of sand dunes and mangroves and any concerns they may have had about the said project.

One (1) Public Presentation maybe scheduled and this will be conducted in the manner as outlined in NEPA's "Guidelines for Conducting Public Presentations" (Appendix 3). This meeting will be held after the submission of the Draft EIA Report to NEPA. The Public has thirty (30) days to provide comments on the report, after the Public Consultation Meeting. All findings form the meeting will be presented in the Final EIA report.

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12.0 GLOSSARY OF TECHNICAL TERMS

A

ABRASION
The mechanical wearing away by rock material transported by wind or water.

ACCRETION
May be either natural or artificial. Natural accretion is the buildup of land, solely by the action of the forces of nature, on a beach by deposition of water – or airborne material. Artificial accretion is a similar buildup of land by reason of an act of man, such as the accretion formed by a GROYNE or BREAKWATER, or beach fill deposited by mechanical means.

ADVECTION
Changes in a sea water property (salinity, temperature, oxygen content, etc.) that takes place in the presence of currents. Also, changes in atmospheric properties in the earth's atmosphere.

ALLUVIAL DEPOSIT
Detrital material which is transported by a river and deposited – usually temporarily – at points along the flood plain of a river. Commonly composed of sands and gravels.

ALONGSHORE
Parallel to and near the shoreline; LONGSHORE.

AMPLITUDE, WAVE
(1) The magnitude of the displacement of a wave from a mean value. An ocean wave has an amplitude equal to the vertical distance from still-water level to wave crest. For a sinusoidal wave, the amplitude is one-half the wave height. (2) The semi range of a constituent tide.

ARMOR UNIT or STONE
A relatively large quarrystone or concrete shape that is selected to fit specified geometric characteristics and density. It is usually of nearly uniform size and usually large enough to require individual placement. In normal cases it is used as primary wave protection and is placed in thicknesses of at least two units.

B

BACK REEF
Back reefs are shallow water areas that extend from shore to the reef crest, the highest part of the reef that separates the back reef from the fore reef.

BANK

(1) The rising ground bordering a lake, river, or sea; or of a river or channel, for which it is designated as right or left as the observer is facing downstream. (2) An elevation of the sea floor or large area, located on a continental (or island) shelf and over which the depth is relatively shallow but sufficient for safe surface navigation (e.g., Georges Bank); a group of shoals. (3) In its secondary sense, used only with a qualifying word such as “sandbank,” “gravelbank,” or “spoil bank,” a shallow area consisting of shifting forms of silt, sand, mud, and gravel.

BARRIER REEF
A coral REEF parallel to and separated from the coast by a lagoon that is too deep for coral growth. Generally, barrier reefs follow the coasts for long distances and are cut through at irregular intervals by channels or passes. Example: Great Barrier Reef, Queensland, Australia.

BASIN
A depressed area with no surface outlet, such as a lake basin or an enclosed sea.

BATHYMETRY
The measurement of water depths in oceans, seas, and lakes; also information derived from such measurements.

BAY
A recess in the shore or an inlet of a sea between two capes or headlands, not as large as a gulf but larger than a cove. See also BIGHT, EMBAYMENT.

BEACH
The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach--unless otherwise specified--is the mean low water line. A beach includes foreshore and backshore.

BEACH ACCRETION
See ACCRETION.

BEACH EROSION
The carrying away of beach materials by wave action, tidal currents, littoral currents, or wind.

BEACH FACE
The section of the beach normally exposed to the action of the wave uprush. The FORESHORE of a BEACH. (Not synonymous with SHOREFACE)

BEACH FILL
Material placed on a beach to re-nourish eroding shores, usually pumped by dredge but sometimes delivered by trucks

BEACH NOURISHMENT
See BEACH FILL.

BEACH PROFILE
A cross-section taken perpendicular to a given beach contour; the profile may include the face of a dune or sea wall; extend over the backshore, across the foreshore, and seaward underwater into the NEARSHORE zone.

BEACH WIDTH
The horizontal dimension of the beach measured normal to the shoreline and landward of the higher-high tide line (on oceanic coasts) or from the still water level (on lake coasts)

BED
The bottom of a watercourse, or any body of water.

BENCH MARK, TIDAL
A bench mark whose elevation has been determined with respect to MEAN SEA LEVEL at a nearby tide GAUGE; the tidal bench mark is used as reference for that tide gauge.

BENCH MARK
A permanently fixed point of known elevation. A primary bench mark is one close to a tide station to which the tide staff and tidal datum originally are referenced.

BENEFICIAL USE OF DREDGED MATERIAL
Placement or use of dredged material for some productive purpose. Examples: BEACH FILL or NEARSHORE BERM construction.

BENEFITS
The asset value of a scheme, usually measured in terms of the cost of damages avoided by the scheme, or the valuation of perceived amenity or environmental improvements

BENTHIC
Pertaining to the sub-aquatic bottom.

BIGHT
A bend in a coastline forming an open BAY. A BAY formed by such a bend.

BIOLOGICAL OXYGEN DEMAND (BOD)
The amount of oxygen taken up by aerobic microbes that decompose organic matter in a unit volume of water over a given time. It is used as a measure of the degree of organic pollution of water. The more organic matter the water contains, the more oxygen is used by microorganisms.

BLOWOUT (seagrass)
Blowouts are grass-free depressions within seagrass beds, caused by man-made activities (e.g. vessel groundings, propeller and anchor damage) or natural processes (e.g. erosion, seagrass dynamics and bioturbation).

BOTTOM (nature of)
The composition or character of the bed of an ocean or other body of water (e.g., clay, coral, gravel, mud, ooze, pebbles, rock, shell, shingle, hard, or soft).

BOULDER
A rounded rock more than 256 mm (10 inch) in diameter; larger than a cobblestone. See SOIL CLASSIFICATION.

BREAKING
Reduction in wave energy and height in the surf zone due to limited water depth

BREAKWATER
A man-made structure protecting a shore area, harbor, anchorage, or basin from waves. A harbor work.

BUOY
A float; especially a floating object moored to the bottom, to mark a channel, anchor, shoal rock, etc. Some common types include: a nun or nutbuoy is conical in shape; a can buoy is squat and cylindrical above water and conical below water; a spar buoy is a vertical, slender spar anchored at one end; a bell buoy, bearing a bell, runs mechanically or by the action of waves, usually marks shoals or rocks; a whistling buoy, similarly operated, marks shoals or channel entrances; a dan buoy carries a pole with a flag or light on it.

C

CALCAREOUS
Containing calcium carbonate ($CaCO_3$), chiefly as the minerals calcite and aragonite. When applied to rock, it implies that as much as 50 percent of the rock is carbonate (e.g., calcareous sand).

CHANNEL
(1) A natural or artificial waterway of perceptible extent which either periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. (2) The part of a body of water deep enough to be used for navigation through an area otherwise too shallow for navigation. (3) A large strait, as the English Channel. (4) The deepest part of a stream, bay, or strait through which the main volume or current of water flows.

CHART DATUM
The plane or level to which soundings (or elevations) or tide heights are referenced (usually LOW WATER DATUM). The surface is called a tidal datum when referred to a certain phase of tide. To provide a safety factor for navigation, some level lower than MEAN SEA LEVEL is generally selected for hydrographic charts, such as MEAN LOW WATER or MEAN LOWER LOW WATER. See DATUM PLANE.

CHLOROPHYLL A

A type of chlorophyll that is most common and predominant in all oxygen-evolving photosynthetic organisms such as higher plants, red and green algae. It is best at absorbing wavelength in the 400-450 nm and 650-700 nm of the electromagnetic spectrum.

CHOPPY SEA
Short, rough waves tumbling with a short and quick motion. Short-crested waves that may spring up quickly in a moderate breeze, and break easily at the crest.

CLAY
A fine grained, plastic, sediment with a typical grain size less than 0.004 mm. Possesses electromagnetic properties which bind the grains together to give a bulk strength or cohesion. See SOIL CLASSIFICATION.

CLIFF
A high, steep face of rock; a precipice.

CLIMATE
The characteristic weather of a region, particularly regarding temperature and precipitation, averaged over some significant internal of time (years).

CLOSING LINE
The line dividing inland waters and the territorial sea at the mouth of a river, bay, or harbor.

CLOSURE DEPTH
The water depth beyond which repetitive profile or topographic surveys (collected over several years) do not detect vertical sea bed changes, generally considered the seaward limit of littoral transport. The depth can be determined from repeated cross-shore profile surveys or estimated using formulas based on wave statistics. Note that this does not imply the lack of sediment motion beyond this depth.

COAST
(1) A strip of land of indefinite width (may be several kilometers) that extends from the SHORELINE inland to the first major change in terrain features. (2) The part of a country regarded as near the coast.

COASTAL AREA
The land and sea area bordering the SHORELINE.

COASTAL DEFENSE
General term used to encompass both coast protection against erosion and sea defense against flooding.

COASTAL ZONE
The coastal zone may be simply defined as that transitional area between the land and sea. The coastal zone includes beaches and wetlands. Jamaica's coastal zone has important infrastructure including our ports, airports, oil refinery, road and electricity networks, and many towns and cities. It also includes important tourism related infrastructure (hotels and attractions). Coastal wetlands are valuable habitats for fish and other marine life. Coastal zones provide a buffer from flooding due to storm surges due to hurricanes.[29]

COASTAL ZONE MANAGEMENT
The integrated and general development of the coastal zone. Coastal Zone Management is not restricted to coastal defense works, but includes also a development in economical, ecological and social terms. Coastline Management is a part of Coastal Zone Management.

COASTLINE
(1) Technically, the line that forms the boundary between the coast and the shore. (2) Commonly, the line that forms the boundary between the land and the water, esp. the water of a sea or ocean. The SHORELINE.

COHESIVE SEDIMENT
Sediment containing significant proportion of clays, the electromagnetic properties of which cause the sediment to bind together.

CONSOLIDATION
The gradual, slow compression of a cohesive soil due to weight acting on it, which occurs as water is driven out of the voids in the soil. Consolidation only occurs in clays or other soils of low permeability.

CONTINENTAL SHELF
(1) The zone bordering a continent extending from the line of permanent immersion to the depth, usually about 100 m to 200 m, where there is a marked or rather steep descent toward the great depths of the ocean. (2) The area under active littoral processes during the HOLOCENE period. (3) The region of the oceanic bottom that extends outward from the shoreline with an average slope of less than 1:100, to a line where the gradient begins to exceed 1:40 (the CONTINENTAL SLOPE).

CONTOUR
A line on a map or chart representing points of equal elevation with relation to a DATUM. It is called an ISOBATH when connecting points of equal depth below a datum. Also called DEPTH CONTOUR.

CORAL
Corals are marine invertebrates in class Anthozoa of phylum Cnidaria typically living in compact colonies of many identical individual "polyps". The group includes the important reef builders that inhabit tropical oceans and secrete calcium carbonate to form a hard skeleton.

CORAL REEF

[29] http://myspot.mona.uwi.edu/physics/sites/default/files/physics/uploads/02_CCAndCoastal%20Zones2.pdf

A coral-algal mound or ridge of in-place coral colonies and skeletal fragments, carbonate sand, and organically-secreted calcium carbonate. A coral reef is built up around a wave-resistant framework, usually of older coral colonies.

CORIOLIS EFFECT
Force due to the Earth's rotation, capable of generating currents. It causes moving bodies to be deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. The "force" is proportional to the speed and latitude of the moving object. It is zero at the equator and maximum at the poles.

CPCe (Coral Point Count with Excel extensions)
A visual basic software program for the determination of coral and substrate coverage using random point counts.

CREST
Highest point on a beach face, BREAKWATER.

CROSS-SHORE
Perpendicular to the SHORELINE

CURRENT
(1) The flowing of water, or other liquid or gas. (2) That portion of a stream of water which is moving with a velocity much greater than the average or in which the progress of the water is principally concentrated. (3) Ocean currents can be classified in a number of different ways. Some important types include the following: (1) Periodic - due to the effect of the tides; such Currents may be rotating rather than having a simple back and forth motion. The currents accompanying tides are known as tidal currents; (2)Temporary - due to seasonal winds; (3) Permanent or ocean - constitute a part of the general ocean circulation. The term DRIFT CURRENT is often applied to a slow broad movement of the oceanic water; (4) Nearshore - caused principally by waves breaking along a shore.

CYCLONE
A system of winds that rotates about a center of low atmospheric pressure. Rotation is clockwise in the Southern Hemisphere and anti-clockwise in the Northern Hemisphere. In the Indian Ocean, the term refers to the powerful storms called HURRICANES in the Atlantic.

D

DATUM
Any permanent line, plane or surface used as a reference datum to which elevations are referred.

DATUM, CHART
See CHART DATUM.

DECIBELS (dB)
Is a dimensionless unit used to report sound pressure level (SPL or Lp). Decibels are used to represent the wide pressure range a human ear can detect. It is a logarithmic scale is used to report sound pressures.

DEEP WATER
Water so deep that surface waves are little affected by the ocean bottom. Generally, water deeper than one-half the surface wavelength is considered deep water. Compare SHALLOW WATER.

DEEP WATER WAVES
A wave in water the depth of which is greater than one-half the WAVE LENGTH

DEGRADATION
The geologic process by means of which various parts of the surface of the earth are worn away and their general level lowered, by the action of wind and water.

DELTA
(1) An ALLUVIAL DEPOSIT, usually triangular or semi-circular, at the mouth of a river or stream. The delta is normally built up only where there is no tidal or current action capable of removing the sediment at the same rate as it is deposited, and hence the delta builds forward from the coastline. (2) A TIDAL DELTA is a similar deposit at the mouth of a tidal INLET, the result of TIDAL CURRENTS that flow in and out of the inlet.

DENSITY
Mass (in kg) per unit of volume of a substance; kg/m3. For pure water, the density is 1000 kg/m3, for seawater the density is usually more. Density increases with increasing salinity, and decreases with increasing temperature. More information can be found in "properties of seawater". For stone and sand, usually a density of 2600 kg/m3 is assumed. Concrete is less dense, in the order of 2400 kg/m3. Some types of basalt may reach 2800 kg/m3. For sand, including the voids, one may use 1600 kg/m3, while mud often has a density of 1100 - 1200 kg/m3.

DEPENDENCY RATIOS
It is the portion of a population which is composed of dependents (people who are too young or too old to work). The dependency ratio is equal to the number of individuals aged below 15 or above 64 divided by the number of individuals aged 15 to 64, expressed as a percentage.

DEPRESSION
A general term signifying any depressed or lower area in the ocean floor.

DEPTH
The vertical distance from a specified datum to the sea floor.

DESIGN STORM
A hypothetical extreme storm whose waves coastal protection structures will often be designed to withstand. The severity of the storm (i.e. return period) is chosen in view of the acceptable level of risk of damage or failure. A DESIGN STORM consists of a DESIGN WAVE condition, a design water level and a duration.

DESIGN WAVE
In the design of HARBORS, harbor works, etc., the type or types of waves selected as having the characteristics against which protection is desired.

DESIGN WAVE CONDITION
Usually an extreme wave condition with a specified return period used in the design of coastal works.

DIFFRACTION (of water waves)
The phenomenon by which energy is transmitted laterally along a wave crest. When a part of a train of waves is interrupted by a barrier, such as a BREAKWATER, the effect of diffraction is manifested by propagation of waves into the sheltered region within the barrier's geometric shadow.

DISCHARGE
The volume of water per unit of time flowing along a pipe or channel.

DISPERSION
Pattern of geographic distribution of individuals within a species. (2) Distortion of the shape of a seismic wave train or ocean wave train because of variations of velocity with frequency.

DIURNAL
Having a period or cycle of approximately one TIDAL DAY

DREDGING
The practice of excavating or displacing the bottom or shoreline of a water body. Dredging can be accomplished with mechanical or hydraulic machines. Most is done to maintain channel depths or berths for navigational purposes; other dredging is for shellfish harvesting, for cleanup of polluted sediments, and for placement of sand on beaches.

DUNES
(1) Ridges or mounds of loose, wind-blown material, usually sand. (2) Bed forms smaller than bars but larger than ripples that are out of phase with any water-surface gravity waves associated with them.

DURATION
In wave forecasting, the length of time the wind blows in nearly the same direction over the FETCH (generating area).

DURATION, MINIMUM
The time necessary for steady-state wave conditions to develop for a given wind velocity over a given fetch length.

E

ECHO SOUNDER
An electronic instrument used to determine the depth of water by measuring the time interval between the emission of a sonic or ultrasonic signal and the return of its echo from the bottom.

ECOSYSTEM
The living organisms and the nonliving environment interacting in a given area, encompassing the relationships between biological, geochemical, and geophysical systems.

ELEVATION
The vertical distance from mean sea level or other established datum plane to a point on the earth's surface; height above sea level. Although sea floor elevation below msl should be marked as a negative value, many charts show positive numerals for water depth.

EL NIÑO
Warm equatorial water which flows southward along the coast of Peru and Ecuador during February and March of certain years. It is caused by poleward motions of air and unusual water temperature patterns in the Pacific Ocean, which cause coastal downwelling, leading to the reversal in the normal north-flowing cold coastal currents. During many El Niño years, storms, rainfall, and other meteorological phenomena in the Western Hemisphere are measurably different than during non-El Niño years.

EMBANKMENT
Fill material, usually earth or rock, placed with sloping sides and with a length greater than its height. Usually an embankment is wider than a dike.

EMBAYMENT
An indentation in the shore forming an open bay.

ENTRANCE
The avenue of access or opening to a navigable channel or inlet.

EROSION
The wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation.

ESTUARY
(1) The part of a river that is affected by tides. (2) The region near a river mouth in which the fresh water of the river mixes with the salt water of the sea and which received both fluvial and littoral sediment influx.

F

FAECAL COLIFORM
A group of bacteria normally present in large numbers in the intestinal tracts of humans and other warm-blooded animals. Frequently used as an indicator of sewage pollution.

FAUNA
The entire group of animals found in an area.

FETCH
The area in which SEAS are generated by a wind having a fairly constant direction and speed. Sometimes used synonymously with FETCH LENGTH.

FETCH LENGTH
The horizontal distance (in the direction of the wind) over which a wind generates seas or creates a WIND SETUP.

FETCH-LIMITED
Situation in which wave energy (or wave height) is limited by the size of the wave generation area (fetch).

FILTER
Intermediate layer, preventing fine materials of an underlayer from being washed through the voids of an upper layer.

FLOOD
(1) Period when tide level is rising; often taken to mean the flood current which occurs during this period (2) A flow beyond the carrying capacity of a channel.

FLORA
The entire group of plants found in an area.

FLUVIAL
Of or pertaining to rivers; produced by the action of a river or stream (e.g.,fluvial sediment).

FLUSHING TIME
The time required to replace all the water in an ESTUARY, HARBOR, etc., by action of current and tide.

FOCUS GROUP
It is an organised discussion with a selected group of individuals to gain information about their views and experiences of a topic. The main purpose of focus group research is to draw upon respondents' attitudes, feelings, beliefs, experiences and reactions in a way in which would not be feasible using other methods, for example observation, one-to-one interviewing, or questionnaire surveys.

FORESHORE

The part of the shore, lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low-water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall. See BEACH FACE.

FORE REEF
The fore-reef is found on the oceanic side of the reef crest. It slopes downwards, sometimes to great depths. This is where coral diversity of highest.

FREEBOARD
At a given time, the vertical distance between the water level and the top of the structure. On a ship, the distance from the waterline to main deck or gunwale.

FRINGING REEF
A coral REEF attached directly to an insular or continental shore. There may be a shallow channel or lagoon between the reef and the adjacent mainland.

G

GAUGE (GAGE)
Instrument for measuring the water level relative to a datum or for measuring other parameters

GEOGRAPHICAL INFORMATION SYSTEM (GIS)
Database of information which is geographically referenced, usually with an associated visualization system.

GEOMORPHOLOGY
(1) That branch of physical geography which deals with the form of the Earth, the general configuration of its surface, the distribution of the land, water, etc. (2) The investigation of the history of geologic changes through the interpretation of topographic forms.

GEOTEXTILE
A synthetic fabric which may be woven or non-woven used as a filter.

GDP
Gross domestic product is the market value of all officially recognized final goods and services produced within a country in a given period of time (normally a year).

GLOBAL POSITIONING SYSTEM (GPS)
A navigational and positioning system developed by the U.S. Department of Defense, by which the location of a position on or above the Earth can be determined by a special receiver at that point interpreting signals received simultaneously from several of a constellation of special satellites.

GRADIENT
(1) A measure of slope (soil- or water-surface) in meters of rise or fall per meter of horizontal distance. (2) More general, a change of a value per unit of distance, e.g. the gradient in longshore transport causes erosion or accretion. (3) With reference to winds or currents, the rate of increase or decrease in speed, usually in the vertical; or the curve that represents this rate.

GRADING
Distribution, with regard to size or weight, of individual stones within a bulk volume; heavy, light and fine grading are distinguished.

GRANULAR FILTER
Band of granular material which is incorporated in an embankment, dam, dike, or bottom protection and is graded so as to allow seepage to flow across or down the filter zone without causing the migration of the material adjacent to the filter.

GRAVEL
Unconsolidated natural accumulation of rounded rock fragments coarser than sand but finer than pebbles (2-4 mm diameter).

GROYNE
Narrow, roughly shore-normal structure built to reduce longshore currents, and/or to trap and retain littoral material. Most groins are of timber or rock and extend from a SEAWALL, or the backshore, well onto the foreshore and rarely even further offshore. See T-GROIN, PERMEABLE GROIN, IMPERMEABLE GROIN.

H

HACH HYDROLAB DATASONDE-5
A tethered device used to measure various water quality parameters.

HARBOUR
Any protected water area affording a place of safety for vessels. See also PORT. A harbor may be natural or man-made.

HERTZ (Hz)
The time that it takes for a vibrating particle to complete one vibration is known as the time period. The number of vibrations (pressure variations) per second is called the frequency of the sound, and is measured in Hertz (Hz). The frequency of a sound produces its distinctive tone. Thus, the rumble of distant thunder has a low frequency, while a whistle has a high frequency.

HIGH TIDE, HIGH WATER (HW)
The maximum elevation reached by each rising tide. See TIDE.

HIGH WATER (HW)
Maximum height reached by a rising tide. The height may be solely due to the periodic tidal forces or it may have superimposed upon it the effects of prevailing meteorological conditions. Nontechnically, also called the HIGH TIDE.

HIGH WATER LINE
In strictness, the intersection of the plane of mean high water with the shore. The shoreline delineated on the nautical charts of the National Ocean Service is an approximation of the high water line. For specific occurrences, the highest elevation on the shore reached during a storm or rising tide, including meteorological effects.

HIGH WATER MARK
A reference mark on a structure or natural object, indicating the maximum stage of tide or flood.

HINDCASTING
In wave prediction, the retrospective forecasting of waves using measured wind information.

HISTORIC EVENT ANALYSIS
Extreme analysis based on hindcasting typically ten events over a period of 100 years.

HOPPER DREDGE
Self-propelled floating plant which is capable of dredging material, storing it onboard, and transporting and placing the material at a specified disposal site. Often used to dredge inlets and then deposit the material along the open coast or offshore.

HURRICANE
An intense tropical cyclone in which winds tend to spiral inward toward a core of low pressure, with maximum surface wind velocities that equal or exceed 33.5 m/sec (75 mph or 65 knots) for several minutes or longer at some points. TROPICAL STORM is the term applied if maximum winds are less than 33.5 m/sec but greater than a whole gale (63 mph or 55 knots). Term is used in the Atlantic, Gulf of Mexico, and eastern Pacific.

HURRICANE PATH or TRACK
Line of movement (propagation) of the eye through an area.

HYDROGRAPHY
(1) The description and study of seas, lakes, rivers and other waters. (2) The science of locating aids and dangers to navigation. (3) The description of physical properties of the waters of a region.

I

IMPERMEABLE GROIN
A GROIN constructed such that sand cannot pass through the structure (but sand may still move over or around it).

INCIDENT WAVE
Wave moving landward.

INLET
(1) A short, narrow waterway connecting a bay, lagoon, or similar body of water with a large parent body of water.

(2) An arm of the sea (or other body of water) that is long compared to its width and may extend a considerable distance inland.

IRREGULAR WAVES
Waves with random wave periods (and in practice, also heights), which are typical for natural wind-induced waves.

J

JONSWAP SPECTRUM
Wave spectrum typical of growing deep water waves developed from field experiments and measurements of waves and wave spectra in the Joint North Sea Wave Project.

K

KINEMATIC VISCOSITY
The dynamic viscosity divided by the fluid density.

KNOT
The unit of speed used in navigation equal to 1 nautical mile (6,076.115 ft or 1,852 m) per hour.

L

LANDMARK
A conspicuous object, natural or artificial, located near or on land, which aids in fixing the position of an observer.

LEE
(1) Shelter, or the part or side sheltered or turned away from the wind or waves. (2) (Chiefly nautical) The quarter or region toward which the wind blows.

LEEWARD
The direction toward which the wind is blowing; the direction toward which waves are traveling.

LENGTH OF WAVE

The horizontal distance between similar points on two successive waves measured perpendicularly to the crest.

LITTORAL
Of or pertaining to a shore, especially of the sea. Often used as a general term for the coastal zone influenced by wave action, or, more specifically, the shore zone between the high and low water marks.

LITTORAL DRIFT, LITTORAL TRANSPORT
The movement of beach material in the littoral zone by waves and currents. Includes movement parallel (long shore drift) and sometimes also perpendicular (cross-shore transport) to the shore

LOAD
The quantity of sediment transported by a current. It includes the suspended load of small particles and the BED LOAD of large particles that move along the bottom.

LONGSHORE
Parallel to and near the shoreline; ALONGSHORE.

LOW TIDE (LOW WATER, LW)
The minimum elevation reached by each falling tide. See TIDE.

LOW WATER (LW)
The minimum height reached by each falling tide. Nontechnically, also called LOW TIDE.

LOW WATER LINE
The line where the established LOW WATER DATUM intersects the shore. The plane of reference that constitutes the LOW WATER DATUM differs in different regions.

LUGOL'S PRESERVE
A solution of elemental iodine and potassium iodide in water.

LUNAR DAY
The time of rotation of the Earth with respect to the moon, or the interval between two successive upper transits of the moon over the meridian of a place. The mean lunar day is approximately 24.84 solar hours in length, or 1.035 times as great as the mean solar day. Also called TIDAL DAY.

LUNAR TIDE
The portion of the tide that can be attributed directly to attraction to the moon

M

MANGROVE

A tree or shrub which grows in tidal, chiefly tropical, coastal swamps, having numerous tangled roots that grow above ground and form dense thickets.

MARKER, REFERENCE
A mark of permanent character close to a survey station, to which it is related by an accurately measured distance and azimuth (or bearing).

MARKER, SURVEY
An object placed at the site of a station to identify the surveyed location of that station.

MEAN DEPTH
The average DEPTH of the water area between the still water level and the SHOREFACE profile from the waterline to any chosen distance seaward.

MEAN HIGH WATER (MHW)
The average height of the high waters over a 19-year period. For shorter periods of observations, corrections are applied to eliminate known variations and reduce the results to the equivalent of a mean 19-year value. All high water heights are included in the average where the type of tide is either semidiurnal or mixed. Only the higher high water heights are included in the average where the type of tide is diurnal. So determined, mean high water in the latter case is the same as mean higher high water.

MEAN SEA LEVEL
The average height of the surface of the sea for all stages of the tide over a 19-year period, usually determined from hourly height readings. Not necessarily equal to MEAN TIDE LEVEL. It is also the average water level that would exist in the absence of tides.

MEAN TIDE LEVEL
A plane midway between MEAN HIGH WATER and MEAN LOW WATER. Not necessarily equal to MEAN SEA LEVEL.

MEAN WAVE HEIGHT
The mean of all individual waves in an observation interval of approximately half an hour. In case of a Rayleigh-distribution 63% of the significant wave height.

MEDIAN DIAMETER
The diameter which marks the division of a given sand sample into two equal parts by weight, one part containing all grains larger than that diameter and the other part containing all grains smaller.

MESOTROPHIC
A body of water having a moderate amount of dissolved nutrients.

MINIMUM DURATION
See DURATION, MINIMUM.

MINIMUM FETCH
The least distance in which steady-state wave conditions will develop for a wind of given speed blowing a given duration of time.

MORPHOLOGY
River/estuary/lake/seabed form and its change with time.

MOUTH
Entrance to an inland water body (e.g., river).

MUD
A fluid-to-plastic mixture of finely divided particles of solid material and water.

N

NEAP TIDE
Tide of decreased range occurring semimonthly as the result of the moon being in quadrature. The NEAP RANGE of the tide is the average semidiurnal range occurring at the time of neap tides and is most conveniently computed from the harmonic constants. The NEAP RANGE is typically 10 to 30 percent smaller than the mean range where the type of tide is either semidiurnal or mixed and is of no practical significance where the type of tide is DIURNAL. The average height of the high waters of the neap tide is called NEAP HIGH WATER or HIGH WATER NEAPS (MHWN), and the average height of the corresponding LOW WATER is called NEAP LOW WATER or LOW WATER NEAPS (MLWN).

NEARSHORE
(1) In beach terminology an indefinite zone extending seaward from the SHORELINE well beyond the BREAKER ZONE. (2) The zone which extends from the swash zone to the position marking the start of the offshore zone, typically at water depths of the order of 20 m.

NISKIN
Device used to collect water samples at discrete depths in the water column.

NOISE
Noise is unwanted sound without agreeable musical quality. It is unwanted /undesired sound or sound in the wrong place at the wrong time. It is considered a pollutant and can be measured.

NOURISHMENT
The process of replenishing a beach. It may occur naturally by longshore transport, or be brought about artificially by the deposition of dredged materials or of materials trucked in from upland sites.

NUMERICAL MODELING
Refers to analysis of coastal processes using computational models.

O

OCEANOGRAPHY
The study of the sea, embracing and indicating all knowledge pertaining to the sea's physical boundaries, the chemistry and physics of seawater, marine biology, and marine geology.

OFFSHORE
(1) In beach terminology, the comparatively flat zone of variable width, extending from the SHOREFACE to the edge of the CONTINENTAL SHELF. It is continually submerged. (2) The direction seaward from the shore. (3) The zone beyond the nearshore zone where sediment motion induced by waves alone effectively ceases and where the influence of the sea bed on wave action is small in comparison with the effect of wind. (4) The breaker zone directly seaward of the low tide line.

OFFSHORE BREAKWATER
A BREAKWATER built towards the seaward limit of the littoral zone, parallel (or nearly parallel) to the shore.

OFFSHORE CURRENT
(1) Any current in the offshore zone. (2) Any current flowing away from shore.

ONSHORE
A direction landward from the sea.

OSCILLATION
(1) A periodic motion backward and forward. (2) Vibration or variance above and below a mean value.

OUTCROP
A surface exposure of bare rock, not covered by soil or vegetation.

OUTFALL
A structure extending into a body of water for the purpose of discharging sewage, storm runoff, or cooling water.

OVERTOPPING
Passing of water over the top of a structure as a result of wave runup or surge action.

OVERWASH
(1) The part of the UPRUSH that runs over the crest of a BERM or structure and does not flow directly back to the ocean or lake. (2) The effect of waves overtopping a COASTAL DEFENSE, often carrying sediment landwards which is then lost to the beach system.

P

PARTICLE VELOCITY

The velocity induced by wave motion with which a specific water particle moves within a wave.

PAVEMENT
Flat, low-relief or sloping solid carbonate rock with little or no fine-scale rugosity that is covered with algae, hard coral, gorgonians, zooanthids or other sessile vertebrates that are dense enough to partially obscure the underly-ing surface. On less colonized Pavement features, rock may be covered by a thin sand veneer.

PEAK PERIOD
The wave period determined by the inverse of the frequency at which the wave energy spectrum reaches its maximum.

PERCOLATION
The process by which water flows through the interstices of a sediment. Specifically, in wave phenomena, the process by which wave action forces water through the interstices of the bottom sediment and which tends to reduce wave heights.

PERMEABLE GROYNE
A GROYNE with openings or voids large enough to permit passage of appreciable quantities of LITTORAL DRIFT through the structure.

PHASE
In surface wave motion, a point in the period to which the wave motion has advanced with respect to a given initial reference point.

PHOTO-QUADRAT
Rigid PVC frame used to isolate a standard unit of area at a constant height for photo documentation.

PHOTOSYNTHETICALLY ACTIVE RADIATION (PAR)
The amount of light available for photosynthesis, which is light in the 400 to 700 nanometer wavelength range.

PHYTOPLANKTON
Microscopic plant-like organisms that inhabit oceans and bodies of freshwater requiring sunlight in order to live and grow.

PIER
A structure, usually of open construction, extending out into the water from the shore, to serve as a landing place, recreational facility, etc., rather than to afford coastal protection or affect the movement of water. In the Great Lakes, a term sometimes improperly applied to jetties.

PLANFORM
The outline or shape of a body of water as determined by the still-water line.

PM 10

These are airborne particles that fall between 2.5 and 10 micrometers in diameter. They are considered coarse particles which are generated from sources such as crushing or grinding operations, and dust stirred up by vehicles traveling on roads.

PM 2.5
These are airborne particles that have diameters below 2.5 micrometres. Sources of these fine particles include all types of combustion, including motor vehicles, power plants, residential wood burning, forest fires, agricultural burning, and some industrial processes.

POORLY-SORTED (POORLY-GRADED)
Said of a clastic sediment or rock that consists of particles of many sizes mixed together in an unsystematic manner so that no one size class predominates.

POPULATION DENSITY
The number of persons per square kilometre or acre of land area.

PORE PRESSURE
The interstitial pressure of water within a mass of soil or rock.

POROSITY
Percentage of the total volume of a soil sample not occupied by solid particles but by air and water, $\eta = V_v/V_T \times 100$

PROBABILITY
The chance that a prescribed event will occur, represented by a number (p) in the range 0 - 1. It can be estimated empirically from the relative frequency (i.e. the number of times the particular event occurs, divided by the total count of all events in the class considered).

PROPAGATION OF WAVES
The transmission of waves through water.

PROPAGULE
A vegetative structure that can become detached from a plant and give rise to a new plant, e.g. a bud, sucker, or spore.

Q

QUARRY RUN
Waste of generally small material, in a quarry, left after selection of larger grading.

QUARRYSTONE
Any stone processed from a quarry.

R

RADAR
An instrument for determining the distance and direction to an object by measuring the time needed for radio signals to travel from the instrument to the object and back, and by measuring the angle through which the instrument’s antenna has traveled.

REEF
An offshore consolidated rock hazard to navigation, with a least depth of about 20 meters (10 fathoms) or less. Often refers to coral FRINGING REEFS in tropical waters

REEF, BARRIER
See BARRIER REEF.

REEF BREAKWATER
Rubble mound of single-sized stones with a crest at or below sea level which is allowed to be (re)shaped by the waves.

REEF CREST
The reef crest is found between the back reef and the fore-reef, and ths is the area of the reef with the highest wave action.

REFRACTION (of water waves)
(1) The process by which the direction of a wave moving in shallow water at an angle to the contours is changed: the part of the wave advancing in shallower water moves more slowly than that part still advancing in deeper water, causing the wave crest to bend toward alignment with the underwater contours. (2) The bending of wave crests by currents.

REGULAR WAVES
Waves with a single height, period, and direction.

RETURN PERIOD
Average period of time between occurrences of a given event.

REVETMENT
(1) A facing of stone, concrete, etc., to protect an EMBANKMENT, or shore structure, against erosion by wave action or currents. (2) A retaining wall. (3) Facing of stone, concrete, etc., built to protect an EMBANKMENT or shore structure against erosion by waves of currents.

RIP CURRENT
A strong surface current flowing seaward from the shore. It usually appears as a visible band of agitated water and is the return movement of water piled up on the shore by incoming waves and wind.

With the seaward movement concentrated in a limited band its velocity is somewhat accentuated. A rip consists of three parts: the FEEDER CURRENTS flowing parallel to the shore inside the breakers; the NECK, where the feeder currents converge and flow through the breakers in a narrow band or "rip"; and the HEAD OF RIP, where the current widens and slackens outside the breaker line. A rip current is often miscalled a rip tide. Also called RIP SURF.

RIP SURF
See RIP CURRENT.

RIP TIDE
Incorrect term for RIP CURRENT.

RISK ANALYSIS
Assessment of the total risk due to all possible environmental inputs and all possible mechanisms.

ROCK WEATHERING
Physical and mineralogical decay processes in rock brought about by exposure to climatic conditions either at the present time or in the geological past.

ROCK
(1) An aggregate of one or more minerals; or a body of undifferentiated mineral matter (e.g., obsidian). The three classes of rocks are: (a) Igneous – crystalline rocks formed from molten material. Examples are granite and basalt. (b) Sedimentary – resulting from the consolidation of loose sediment that has accumulated in layers. Examples are sandstone, shale and limestone. (c) Metamorphic – formed from preexisting rock as a result of burial, heat, and pressure. (2) A rocky mass lying at or near the surface of the water or along a jagged coastline, especially where dangerous to shipping.

RUNUP, RUNDOWN
The upper and lower levels reached by a wave on a beach or coastal structure, relative to still-water level.

S

SALIENT
A bulge in the coastline projecting towards an offshore island or breakwater, but not connected to it as in the case of a TOMBOLO. Developed by WAVE REFRACTION and diffraction and long shore drift.

SALINITY
Number of grams of salt per thousand grams of sea water, usually expressed in parts per thousand (symbol: ‰).

SAND

Sediment particles, often largely composed of quartz, with a diameter of between 0.062 mm and 2 mm, generally classified as fine, medium, coarse or very coarse. Beach sand may sometimes be composed of organic sediments such as calcareous reef debris or shell fragments.

SEA
(1) A large body of salt water, second in rank to an ocean, more or less landlocked and generally part of, or connected with, an ocean or a larger sea. Examples: Mediterranean Sea; South China Sea. (2) Waves caused by wind at the place and time of observation. (3) State of the ocean or lake surface, in regard to waves.

SEA GRASS
Members of marine seed plants that grow chiefly on sand or sand-mud bottom. They are most abundant in water less than 9 m deep. The common types are: Turtle grass (Thallasia), Manatee grass (Syringodium) and Eel grass (Zostera).

SEA LEVEL
See MEAN SEA LEVEL.

SEA LEVEL RISE
The long-term trend in MEAN SEA LEVEL.

SEDIMENT
(1) Loose, fragments of rocks, minerals or organic material which are transported from their source for varying distances and deposited by air, wind, ice and water. Other sediments are precipitated from the overlying water or form chemically, in place. Sediment includes all the unconsolidated materials on the sea floor. (2) The fine grained material deposited by water or wind.

SEMIDIURNAL
Having a period or cycle of approximately one-half of a tidal day (12.4 hours). The predominating type of tide throughout the world is semidiurnal, with two high waters and two low waters each tidal day. The tidal current is said to be semidiurnal when there are two flood and two ebb periods each day.

SETBACK
A required open space, specified in shoreline master programs, measured horizontally upland from an perpendicular to the ordinary high water mark.

SETUP, WAVE
Super elevation of the water surface over normal surge elevation due to onshore mass transport of the water by wave action alone.

SETUP, WIND
See WIND SETUP.

SHALLOW WATER

(1) Commonly, water of such a depth that surface waves are noticeably affected by bottom topography. It is customary to consider water of depths less than one-half the surface wavelength as shallow water. See TRANSITIONAL ZONE and DEEP WATER. (2) More strictly, in hydrodynamics with regard to progressive gravity waves, water in which the depth is less than 1/25 the wavelength.

SHOALING
Decrease in water depth. The transformation of wave profile as they propagate inshore.

SHORE
The narrow strip of land in immediate contact with the sea, including the zone between high and low water lines. A shore of unconsolidated material is usually called a BEACH. Also used in a general sense to mean the coastal area (e.g., to live at the shore). Also sometimes known as the LITTORAL.

SHOREFACE
The narrow zone seaward from the low tide SHORELINE, covered by water, over which the beach sands and gravels actively oscillate with changing wave conditions.

SHORELINE
The intersection of a specified plane of water with the shore or beach (e.g., the high water shoreline would be the intersection of the plane of mean high water with the shore or beach). The line delineating the shoreline on National Ocean Service nautical charts and surveys approximates the mean high water line (United States).

SIGNIFICANT WAVE
A statistical term relating to the one-third highest waves of a given wave group and defined by the average of their heights and periods. The composition of the higher waves depends upon the extent to which the lower waves are considered. Experience indicates that a careful observer who attempts to establish the character of the higher waves will record values which approximately fit the definition of the significant wave.

SIGNIFICANT WAVE HEIGHT
The average height of the one-third highest waves of a given wave group. Note that the composition of the highest waves depends upon the extent to which the lower waves are considered. In wave record analysis, the average height of the highest one-third of a selected number of waves, this number being determined by dividing the time of record by the significant period.

SIGNIFICANT WAVE PERIOD
An arbitrary period generally taken as the period of the one-third highest waves within a given group. Note that the composition of the highest waves depends upon the extent to which the lower waves are considered. In wave record analysis, this is determined as the average period of the most frequently recurring of the larger well-defined waves in the record under study.

SILT

Sediment particles with a grain size between 0.004 mm and 0.062 mm, i.e. coarser than clay particles but finer than sand. See SOIL CLASSIFICATION.

SINUSOIDAL WAVE
An oscillatory wave having the form of a sinusoid.

SLOPE
The degree of inclination to the horizontal. Usually expressed as a ratio, such as 1:25, indicating one unit rise in 25 units of horizontal distance; or in a decimal fraction (0.04). Also called GRADIENT.

SLUMP
In mass wasting, movement along a curved surface in which the upper part moves vertically downward while the lower part moves outward.

SOCIAL IMPACT AREA (SIA)
Estimated spatial extent of the proposed project's effect on surrounding communities, demarcated as a buffer of specified distance, e.g. 2 km from the proposed project.

SOIL
A layer of weathered, unconsolidated material on top of bed rock; in geologic usage, usually defined as containing organic matter and being capable of supporting plant growth.

SOIL CLASSIFICATION (size)
An arbitrary division of a continuous scale of grain sizes such that each scale unit or grade may serve as a convenient class interval for conducting the analysis or for expressing the results of an analysis. There are many classifications used.

SORTING
Process of selection and separation of sediment grains according to their grain size (or grain shape or specific gravity).

SOUND
(1) (noun) a relatively long arm of the sea or ocean forming a channel between an island and a mainland or connecting two larger bodies, as a sea and the ocean, or two parts of the same body; usually wider and more extensive than a STRAIT (e.g., Long Island Sound). (2) (verb) To measure the depth of the water.

SOUNDING
A measured depth of water. On hydrographic CHARTS the soundings are adjusted to a specific plane of reference (SOUNDING DATUM).

SOUNDING DATUM
The plane to which soundings are referred. See also CHART DATUM.

SPECIFIC GRAVITY
The ratio of the weight of unit volume of any material to the weight of unit volume of water at 4 deg C, $Gs = \gamma s/\gamma w$. Typical values of Gs for soil solids are 2.65 to 2.72.

SPL (Sound Pressure Level)
A ratio of one sound pressure to a reference pressure.

SPL = 20 log (L/Lr) dB   where Lr is the reference pressure

SPIT

See TOMBOLO.

SPRING TIDE
A tide that occurs at or near the time of new or full moon (SYZYGY) and which rises highest and falls lowest from the mean sea level.

STILL-WATER LEVEL (SWL)
The surface of the water if all wave and wind action were to cease. In deep water this level approximates the midpoint of the wave height. In shallow water it is nearer to the trough than the crest. Also called the UNDISTURBED WATER LEVEL.

STOCKPILE
Sand piled on a beach foreshore to nourish down drift beaches by natural littoral currents or forces. See FEEDER BEACH.

STONE
Quarried or artificially-broken rock for use in construction, either as aggregate or cut into shaped blocks as dimension stone.

STORM SURGE
A rise above normal water level on the open coast due to the action of wind stress on the water surface. Storm surge resulting from a hurricane also includes that rise in level due to atmospheric pressure reduction as well as that due to wind stress.

STRAIT
A relatively narrow waterway between two larger bodies of water (e.g.,Strait of Gibraltar). See also SOUND.

SURGE

(1) The name applied to wave motion with a period intermediate between that of the ordinary wind wave and that of the tide, say from ½ to 60 min. It is low height, usually less than 0.9 m (3 ft). (2) In fluid flow, long interval variations in velocity and pressure, not necessarily periodic, perhaps even transient in nature. (3) see STORM SURGE.

SURVEY, CONTROL
A survey that provides coordinates (horizontal or vertical) of points to which supplementary surveys are adjusted.

SURVEY, HYDROGRAPHIC
A survey that has as its principal purpose the determination of geometric and dynamic characteristics of bodies of water.

SURVEY, TOPOGRAPHIC
A survey which has, for its major purpose, the determination of the configuration (relief) of the surface of the land and the location of natural and artificial objects thereon.

SUSPENDED LOAD
(1) The material moving in suspension in a fluid, kept up by the upward components of the turbulent currents or by colloidal suspension. (2) The material collected in or computed from samples collected with a SUSPENDED LOAD SAMPLER. Where it is necessary to distinguish between the two meanings given above, the first one may be called the "true

SUSPENDED LOAD SAMPLER
A sampler which attempts to secure a sample of the water with its sediment load without separating the sediment from the water.

SWELL
Wind-generated waves that have traveled out of their generating area. Swell characteristically exhibits a more regular and longer period and has flatter crests than waves within their fetch (SEAS).

T

TIDAL PERIOD
The interval of time between two consecutive, like phases of the TIDE.

TIDAL RANGE
The difference in height between consecutive high and low (or HIGHER HIGH and LOWER LOW) waters.

TIDE

The periodic rising and falling of the water that results from gravitational attraction of the Moon and Sun and other astronomical bodies acting upon the rotating Earth. Although the accompanying horizontal movement of the water resulting from the same cause is also sometimes called the tide, it is preferable to designate the latter as TIDAL CURRENT, reserving the name TIDE for the vertical movement.

TIDES, RIP
See RIP.

TOE
Lowest part of sea- and portside BREAKWATER slope, generally forming the transition to the seabed.

TOMBOLO
A bar or spit that connects an island to the mainland or to another island. Also applied to sand accumulation between land and a DETACHED BREAKWATER.

TOPOGRAPHIC MAP
A map on which elevations are shown by means of contour lines.

TOPOGRAPHY
The configuration of a surface, including its relief and the positions of its streams, roads, building, etc.

TOTAL DISSOLVED SOLIDS (TDS)
Compounds in the water that cannot be removed by a traditional filter and are made up of salts or compounds which dissociate in water to form ions.

TOTAL PETROLEUM HYDROCARBON (TPH)
A mixture of chemicals made mainly from hydrogen and carbon.

TOTAL SUSPENDED SOLIDS (TSS)
Solid materials, including organic and inorganic, that are suspended in the water.

TROPICAL CYCLONE
See HURRICANE

TROPICAL STORM
A tropical cyclone with maximum winds less than 34 m/sec (75 mile per hour). Compare with HURRICANE (winds greater than 34 m/sec).

TROUGH
A long and broad submarine DEPRESSION with gently sloping sides.

TROUGH OF WAVE

The lowest part of a waveform between successive crests. Also, that part of a wave below still-water level.

TSUNAMI
A long-period water wave caused by an underwater disturbance such as a volcanic eruption or earthquake. Also SEISMIC SEA WAVE. Commonly miscalled "tidal wave."

TURBIDITY
(1) A condition of a liquid due to fine visible material in suspension, which may not be of sufficient size to be seen as individual particles by the naked eye but which prevents the passage of light through the liquid. (2) A measure of fine suspended matter in liquids.

TURBULENT FLOW
Any flow which is not LAMINAR, i.e., the stream lines of the fluid, instead of remaining parallel, become confused and intermingled.

U

UPLAND
Dry land area above and landward of the ORDINARY HIGH WATER MARK (OHWM). Often used as a general term to mean high land far from the COAST and in the interior of the country.

UPLIFT
The upward water pressure on the base of a structure or pavement.

UPSTREAM
Along coasts with obliquely approaching waves there is a longshore (wave-driven) current. For this current one can define an upstream and a DOWNSTREAM direction. For example, on a beach with an orientation west-east with the sea to the north, the waves come from NW. Then the current flows from West to East. Here, upstream is West of the observer, and East is DOWNSTREAM of the observer.

V

VISCOSITY (or internal friction)

That molecular property of a fluid that enables it to support tangential stresses for a finite time and thus to resist deformation. Resistance to flow.

W

WASH LOAD
Part of the suspended load with particle sizes smaller than found in the bed; it is in near-permanent suspension and transported without deposition; the amount of wash load transported through a reach does not depend on the transport capacity of the flow; the load is expressed in mass or volume per unit of time.

WATER DEPTH
Distance between the seabed and the still water level.

WATER LEVEL
Elevation of still water level relative to some datum.

WATERLINE
A juncture of land and sea. This line migrates, changing with the tide or other fluctuation in the water level. Where waves are present on the beach, this line is also known as the limit of backrush (approximately, the intersection of the land with the still-water level.)

WAVE
A ridge, deformation, or undulation of the surface of a liquid.

WAVE CELERITY
The speed of wave propagation.

WAVE CLIMATE
The seasonal and annual distribution of wave height, period and direction.

WAVE DIRECTION
The direction from which a wave approaches.

WAVE DIRECTIONAL SPECTRUM
Distribution of wave energy as a function of wave frequency and direction.

WAVE FORECASTING
The theoretical determination of future wave characteristics, usually from observed or predicted meteorological phenomena.

WAVE FREQUENCY
The inverse of wave period.

WAVE FREQUENCY SPECTRUM
Distribution of wave energy as a function of frequency.

WAVE HEIGHT
The vertical distance between a crest and the preceding trough. See also SIGNIFICANT WAVE HEIGHT.

WAVE PERIOD
The time for a wave crest to traverse a distance equal to one wavelength. The time for two successive wave crests to pass a fixed point. See also SIGNIFICANT WAVE PERIOD.

WAVE PROPAGATION
The transmission of waves through water.

WAVE SPECTRUM
In ocean wave studies, a graph, table, or mathematical equation showing the distribution of wave energy as a function of wave frequency. The spectrum may be based on observations or theoretical considerations. Several forms of graphical display are widely used.

WAVE TRANSFORMATION
Change in wave energy due to the action of physical processes.

WAVELENGTH
The horizontal distance between similar points on two successive waves measured perpendicular to the crest.

WEIBULL DISTRIBUTION
A model probability distribution, commonly used in wave analysis.

WETLANDS
Lands whose saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities that live in the soil and on its surface (e.g. Mangrove forests).

WELL-SORTED
Clastic sediment or rock that consists of particles all having approximately the same size. Example: sand dunes.

WIND SETUP
On reservoirs and smaller bodies of water (1) the vertical rise in the still-water level on the leeward side of a body of water caused by wind stresses on the surface of the water; (2) the difference in still-

water levels on the windward and the leeward sides of a body of water caused by wind stresses on the surface of the water. STORM SURGE (usually reserved for use on the ocean and large bodies of water).

13.0 APPENDICES

Appendix 1 – Terms of Reference

1

DRAFT TERMS OF REFERENCE FOR ENVIRONMENTAL IMPACT ASSESSMENT FOR SHORELINE PROTECTION WORKS AT PALISADOES, KINGSTON BY THE NATIONAL WORKS AGENCY

The Environmental Impact Assessment (EIA) should include but not be limited to the following:

1) Introduction
2) Project Brief
3) Description of the proposed project in detail
4) Complete description of the existing site proposed for development
5) Policies, Legislation and Regulations relevant to the project
6) Identification and assessment of the potential direct, indirect, cumulative, positive and negative environmental impacts
7) Identification of proposed mitigation measures
8) Presentation of a draft Environmental Monitoring Plan
9) Assessment of public perception of the proposed development
10) Identification of alternatives to the project or aspects of the project that could be considered at that site or at any other location
11) Conclusions
12) List of References
13) Glossary of Technical Terms
14) Appendices (should include reference documents, maps, photographs, data tables, the composition, name and qualification of team that undertook the assessment, notes of public consultation sessions, sample of instruments used in community surveys, etc.)

INTRODUCTION
The Introduction should give a background, explain the need for and the context of the project.

PROJECT BRIEF
Gives a summary of the project activities, including site location maps and project timelines.

PROJECT DESCRIPTION
This section should provide:

I. Detailed description of the project objectives and phases (where applicable), including all applicable timelines for the various aspects of the project (from pre to post development).
II. Site maps illustrating areas to be impacted and areas to be preserved in their existing state.
III. A comprehensive description of all aspects of the project noting areas for modification (dredging, reclamation, temporary storage and material disposal) supported by the use

of maps, diagrams and other visual aids where appropriate. This description should detail all activities and features which will introduce risks or generate an impact (positive or negative) on the environment including but not limited to seagrass and/or coral relocation and sediment transport patterns.

IV. Detailed description of the method for the stabilization of the reclamation area and temporary storage of material.

V. Details of the quantity of material required to be dredged to provide the required amount of material for the reclamation works and the fate of the dredged spoils (if applicable).

VI. Details of the methods and equipment to be employed to undertake each aspect of the project including dredging, transportation of dredged material, disposal of spoils (if applicable), storage of material and secondary activities such as refueling of vessels. Proposed location(s) for equipment storage and establishment of a site office.

VII. Details of mitigation measures to be employed and equipment to be used to mitigate the impacts of the project and details for the maintenance and monitoring of these measures/equipment.

VIII. Details of any required decommissioning of the works and/or facilities.

DESCRIPTION OF THE ENVIRONMENT

PHYSICAL ENVIRONMENT

This section should provide a complete description of the study area including geographical boundaries and methodologies used for the collection of baseline data. The description should include the following aspects of the environment:

WATER QUALITY

I. Baseline water quality should include study areas and associated environs and control sites. These should be accurately mapped and a spatial comparison of the data should be done in order to determine any possible source(s) of pollutants (by using GIS).

II. *In situ* water quality should include but not limited to the following parameters;

   i. Temperature, Conductivity, Salinity, Dissolved Oxygen, pH, Turbidity, Total Dissolved Solids (TDS) and Photosynthetically Active Radiation (PAR)

III. Whole water samples should include but not limited to the following

   i. Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended Solids, Nitrates, Phosphates and Faecal Coliform

IV. Results from the water quality sampling should be compared to local and international water quality standards.

V. Historical data should be used for comparisons where possible.

HYDRODYNAMICS

I. Existing and proposed final bathymetry and/or elevation profiles of the site including areas to be dredged, reclaimed or used as temporary storage.

II. Baseline sediment transport and circulation patterns.

III. Marine benthic sediments samples should be collected from within dune donor bed areas. Analysis should include but not limited to the following heavy metals;

   i. Pb - lead, As - Arsenic, Cd - Cadmium, Hg-Mercury and Total Petroleum Hydrocarbons.

BIOLOGICAL ENVIRONMENT

MANGROVE REPLANTING

Marine Assessment

I. Benthic surveys should be conducted in potential impacted seafloor areas and the associated marine flora and fauna recorded.

II. Ecosystems and habitats identified within the impact areas should be described and mapped. This should include but not limited to the seagrass beds, corals and other ecologically important habitats and or species.

III. The presence of any species considered rare, threatened, endangered, endemic, protected, invasive and economically important will be identified.

IV. Habitat loss and or fragmentation should be identified and described.

V. Any crocodile or turtle nest observed in or around the project area should be recorded and mapped.

VI. A comprehensive literature review should include but not limited to the following;

   i. Potential nesting sites and times of turtles and crocodiles

   ii. Habitat usage of migratory species.

VII. Identification of impact areas and suggested mitigation.

Coastal Vegetation Assessment

Coastal vegetation surveys should be conducted in order to describe the plant community present within the project/impact areas. This should include but not limited to the following;

i. A species list with special emphasis on those plants of environmental, economic and national importance. Endemic and endangered species to be included in species list.

ii. Density, description and classification of the existing community.

iii. Identification of impact areas and suggested mitigation.

DUNE NOURISHMENT

Marine Benthos and Fisheries

Benthic surveys should be conducted at a control site and a representative area of potentially impacted seafloor. The assessment should include but not limited to;

i. Description of the habitat/ecosystem identified.

ii. Photographic inventory of species present.

iii. Counts of fish, *Diadema antillarium* and commercially important macroinvertebrates where possible.
iv. Identification of possible habitat loss and or fragmentation.
v. Identification of potential impacts and suggested mitigation.

Beach Assessment
An assessment of the recipient beach area should be conducted. This should include but not limited to the following:

I. A photograph inventory of any existing flora and fauna
II. Identification of species considered rare, threatened, endangered, endemic, protected, invasive and economically important.
III. Habitat loss and or fragmentation should be identified and described.
IV. Any crocodile, turtle nest or shorebird nest observed in or around the project area should be recorded and mapped.
V. A comprehensive literature review should include but not limited to the following;
    i. Potential nesting sites and times of turtles and crocodiles
VI. Identification of impact areas and suggested mitigation.

SOCIO-ECONOMIC ENVIRONMENT
Cultural and archaeological assessment conducted in collaboration with the Jamaica National Heritage Trust.

Assessment of the present and proposed uses at the site including any land acquisition needs and impacts on current users (fishermen, etc.) of the area during and post development.

A perception survey (of residents, individuals and organized groups) should be acquired by the following;

I. Key informant interviews/consultations, group interviews/consultations,
II. Stakeholders meetings/consultations,
III. Direct observations, foot transects
IV. Examination of satellite imagery and aerial photographs
V. Surveys using questionnaires.

The visual impact (aesthetics) of the development should be assessed.

POLICY, LEGISLATION & REGULATORY CONSIDERATION
This section should provide details of the pertinent regulations, policies and standards governing environmental quality, safety and health, cultural significant finds, protection of endangered species and land use control. The examination of the legislation should include at a minimum the Natural Resources Conservation Authority Act, Beach Control Act, Jamaica National Heritage Trust Act, Wild Life Protection Act, Town and Country Planning Act and the Fishing Industry Act and appropriate international conventions/protocols/treaties, where applicable.

IDENTIFICATION AND ASSESSMENT/ANALYSIS OF POTENTIAL IMPACTS

This section should detail all significant potential environmental, health and safety impacts that may arise as a result of the development. The determination of significance of the identified impacts should be based on the classification of all the identified impacts/risks using appropriate criterion such as severity, duration, reversibility, etc. These should include but not be limited to:

I. Loss of biodiversity at all proposed impacted sites
II. Loss of ecosystem functions as a result of habitat loss and fragmentation
III. Pollution and disturbance of the marine environment as a result of incidents with equipment or vessels, etc.; increased turbidity; and contamination of disposal, reclamation and storage sites
IV. Results of hydrodynamic modelling showing any changes in the sediment transport and wave patterns, coastline dynamics (including erosion and accretion processes) under normal and extreme climatic conditions (hurricane and storm surge)
V. Loss of natural and archaeologically significant features
VI. Socio-economic and cultural impacts including impacts on existing activities at the site and the surrounding areas
VII. Cumulative impacts of the proposed works

MITIGATION

This section should provide practical solutions for avoiding, reducing and compensating (eg. restoration or rehabilitation) for any identified impacts, including the proposed timeline for the implementation of these mitigation measures. Full details of the methods proposed to be employed in the implementation of these measures should be provided, including details on the materials and location. Where appropriate, maps and diagrams should be used to illustrate areas where mitigation measures are proposed to be implemented.

ENVIRONMENTAL MONITORING

The Environmental Monitoring Plan should detail:

I. The locations selected for monitoring
II. The parameters which will be monitored for each activity or implemented mitigation measure
III. The proposed methodology to be employed for the monitoring of the various parameters
IV. The frequency of the monitoring
V. The proposed format that the monitoring reports should take
VI. The frequency of the submission of the monitoring reports
VII. The responsible parties for the monitoring
VIII. Details for special monitoring of sea turtles, birds and crocodiles during and after the proposed works

Public Participation/Consultation

A public presentation of the EIA findings will be required to discuss, inform and solicit the comments of the public on the proposed development. This public presentation should be:

I. Conducted at an appropriate location agreed to by the National Environment and Planning Agency (NEPA)
II. Held in accordance with the NEPA's Guidelines for Conducting Public Presentations which are available on the Agency's website (http://www.nepa.gov.jm/ecentre/guidelines.asp)

Identification of Alternatives

This section should examine and detail alternatives to the project or aspects of the project including the no-action alternative. This examination should incorporate previous uses within and the history of the overall area in which the development is proposed.

All findings must be presented in the EIA report and must reflect the headings in the body of the TOR, as well as references. Ten hard copies and an electronic copy of the report should be submitted. The EIA should include an appendix with items such as; maps, site plans, the study team, photographs, and other relevant information.

Appendix 2 – Study Team

- CL Environmental Co. Ltd.:
  - Carlton Campbell, M. Phil., CIEC (Socio-economics)
  - Matthew Lee, M.Sc. (Water Quality, Marine Survey)
  - Kristoffer Lue, M.Phil. (Water Quality, Marine Survey)
  - Rachel D'Silva, B.Sc. (Water Quality, Marine Survey)
  - Karen McIntyre, B.Sc. (Socioeconomics and GIS)
  - Tamia Harker, M.Phil. (Legislation)
  - Glen Patrick (Field Technician – Air Quality)
  - Errol Harrison (Field Technician – Air Quality)
- CEAC Solutions Ltd.
  - Christopher Burgess M.Sc. Eng., PE (Hydrodynamics Modelling,, Waves and Storm Surge Modelling)
  - Carlnenus Johnson, B.Sc Eng. (Hydrodynamics Modelling,, Waves and Storm Surge Modelling)
  - Jessica Stewart, B Sc, Eng (Oceanography, Shoreline Vulnerability)
  - Kristifer Freeman, B Sc, Eng. (Oceanography, Shoreline Vulnerability)
  - Marc Henry (Drafting and Design)

Appendix 3 – NEPA Guidelines for Public Participation

NATIONAL ENVIRONMENT AND PLANNING AGENCY

NATURAL RESOURCES CONSERVATION AUTHORITY

GUIDELINES FOR CONDUCTING PUBLIC PRESENTATIONS

2007-10-25

SECTION 1: GENERAL GUIDELINES

1.1 Introduction

There are usually two forms of public involvement in the Environmental Impact Assessment (EIA) process. The first is direct involvement of the affected public or community in public consultations during the EIA study. These consultations allow the developer to provide information to the public about the project and to determine what issues the public wishes to see addressed. The extent and results of these consultations are included in the documented EIA report.

The second level of involvement takes place after the EIA report and addendum, if any, have been prepared after the applicant has provided the information needed for adequate review by NEPA and the public.

Public involvement in the review process is in keeping with Principle 7 of the United Nations Environment Programme (UNEP) decision published as Goals and Principles of Environmental Impact Assessment [Decision 14/25 of the Governing Council of UNEP, of 17, June, 1987]

1.2 Purpose

These guidelines are prepared for the use of the developer/project proponent; the consultants involve in conducting the EIA study and prepared the EIA report and the public.

SECTION 2: SPECIFIC GUIDELINES FOR PUBLIC PRESENTATIONS

2.1 **Requirements**

Arrangements for the public presentation must be made in consultation with NEPA in respect of date, time, venue, chairperson and participants.

A permanent record of the meeting is required hence, the project proponent/consultant will submit to NEPA a copy of the verbatim report of the public presentation within seven (7) days of the date of the meeting.

2.2 Public Notification

The public must be notified at least three weeks before the date of the public presentation. The developer/consultants must seek to ensure that in addition to specific invitation letters, at least three (3) notices are placed in the most widely circulated newspapers advertising the event. The notice shall also be forwarded to NEPA for posting on the website. To ensure that the notice is distributed as widely as possible, other methods of notification such as community notice board, flyers, town criers etc. shall be utilized as appropriate. In addition, specific notice to relevant local NGOs and community groups should be made by the developer/consultants.

The notice should indicate that:-

- the EIA has been submitted to NEPA;
- the purpose of the meeting;
- how to access the EIA report for review
- the date, time and venue of the public presentation.

The public presentation should be conducted no less than 3 weeks after the EIA has been made available to the public and no less than 3 weeks after the first notice announcing public presentation has been published by the applicant.

(A typical notice is in Appendix 1).

2. 3 Responsibility of Developer/Consultant Team

The developer/consultant is responsible for distribution of copies of the EIA Report to make them available to the public at least three weeks before the public presentation.

Copies should be placed in the Local Parish Library and the Parish Council Office as well as at the nearest NEPA Regional Office and other community locations as agreed upon.

A summary of the project components and the findings of the EIA in non-technical language should also be prepared for distribution at the public presentation.

2.4 Conduct of the Meeting

With respect to the conduct of the meeting, the chairperson should be independently selected so as to ensure his/her neutrality. NEPA should be consulted regarding the selection of a chairperson. The role and responsibilities of the chairperson are outlined ***Appendix 3***.

The technical presentation by the project proponent/consultant should be simple, concise and comprehensive. The main findings of the EIA including adverse and beneficial impacts identified and analyzed should be presented.

Mitigation measures and costs associated with these measures should be presented. The presentation should inform the public on how they will get access to monitoring results during the construction and operational phases of the project, bearing in mind that the public and non-governmental groups are expected to be involved in post-approval monitoring. Graphic and pictorial documentation should support the technical presentation.

Presenters are advised to keep the technical presentation simple and within a time limit of 20-30 minutes depending on the complexity of the project and to allow a minimum of 30 minutes for questions.

The project proponent/consultant will submit to NEPA a copy of the verbatim report of the public presentation within seven (7) days of the date of the meeting.

Please note that the public will be given a period of thirty (30) days after the Public Presentation to send in written comments to NEPA.

(A typical agenda for a meeting is given in Appendix 2)

APPENDIX 1

NOTIFICATION OF PUBLIC MEETING

THERE WILL BE A PUBLIC PRESENTATION ON THE ENVIRONMENT IMPACT ASSESSMENT REPORT

OF:

VENUE:

DATE:

TIME:

THE PUBLIC IS INVITED TO PARTICIPATE IN THE PRESENTATION BY WAY OF ASKING QUESTIONS RELATING TO THE PROPOSED PROJECT.

A COPY OF THE ENVIRONMENTAL IMPACT ASSESSMENT REPORT MAY BE CONSULTED AT THE
____________________ PARISH LIBRARY
____________________ PARISH COUNCIL OFFICE
____
For further information contact:

APPENDIX 2

AGENDA

1. WELCOME AND INTRODUCTION

2. PRESENTATION OF EIA FINDINGS AND MEASURES TO MINIMIZE IMPACTS

3. QUESTION AND ANSWER SESSION

4. CLOSING REMARKS

APPENDIX 3

ROLE AND RESPONSIBLITIES OF THE CHAIRPERSON

The chairperson has the main role of guiding the conduct of the meeting and seeing to it that the concerns of the public are adequately aired and addressed by the proponent/ consultants.

The responsibilities of the chairperson include explaining the NEPA approval process, that is, the steps involved and the role of the NEPA at these public presentations. In other words, the chairperson should explain the context within which the meeting is taking place.

The chairperson should ensure that adequate time is allowed for questions and answers, and must understand clearly and communicate the purpose of the meeting to the audience. The chairperson is responsible for introducing the presenters.

The chairperson should contribute to but not monopolize the meeting.

Appendix 4 – Species List, Palisadoes

9

5. APPENDIX

Table 1. Flora of the Port Royal / Palisadoes System.

A. ANGIOSPERMAE (Flowering plants)

Hydrocharitaceae

Thalassia testudinum

Gramineae

Chloris sp.

Dactyloctenium aegyptium

Sporobolus virginicus

Anthephora hermaphrodita

Paspalum fimbriatum

P. distichum

Polygonaceae

Coccoloba uvifera — Sea Grape

Bataceae

Batis maritima

Amaranthaceae

Philoxerus vermicularis

Alternanthera ficoidea

Nyctaginaceae

Commicarpus scandens — Easy-to-break

Aizoaceae

Sesuvium portulacastrum

Cactaceae

Opuntia tuna — Tuna

O. spinosissima — Prickly Pear Tree

Hylocereus triangularis	God Okra
Melocactus communis	Turk's Head
Stenocereus hystrix	Dildo Pear
Capparaceae	
Capparis ferruginea	Mustard Shrub
Mimosaceae	
Acacia sp.	
Prosopis juliflora	Cashaw
Papilionaceae	
Tephrosia cinerea	
Canavalia maritima	Seaside Bean
Zygophyllaceae	
Guaiacum officinale	Lignum Vitae
Tribulus cistoides	Turkey Blossom
Euphorbiaceae	
Jatropha gossypifolia	Belly-ache Bush
Euphorbia blodgetti	
E. mesembrianthemifolia	
Malvaceae	
Hibiscus tiliaceus	Seaside Mahoe
Thespesia populnea	Blue mahoe
Rhizophoraceae	
Rhizophora mangle	Red mangrove
Combretaceae	
Laguncularia racemosa	White Mangrove
Conocarpus erectus	Button Mangrove

Asclepiadaceae

Calotropis procera Dumb Cotton

Convolvulaceae

Ipomoea pes-carpae

Boraginaceae

Heliotropium curassavicum

Avicenniaceae

Avicennia germinans Black Mangrove

Compositae

Emilia sonchifolia

Table 2. Fauna of the Port Royal / Pallsadoes System.

Faunal list for the Port Royal mangal

Key to Mangal Sub-habitats.

T. Trees (including roosting, nesting and flying overhead).

R. Rhizophores.

S. Benthic substratum under open water.

W. Water bodies and channels.

M. Mud below the mangroves.

* Commercially important species.

Phylum: Cnidaria

Class: Hydrozoa

Obelia sp.	R.
Aurelia aurita	W.
Class: Scyphozoa	
Dactylometra sp.	W.
Cassiopea xamachana	S.
Class: Anthozoa	
Aiptasia tagetes	R.
Actinostella flosculifera	R.
Calliactis tricolor	S.
Diadumene leucolena	R.
Diadumene sp.	R.
Bartholomea annulata	R.
Bunodeopsis antilliensis	R.

Phylum: Annelida

Class: Polychaeta

Branchiomma conspera	R.
Pseudobranchia emersonia	R.
Sabella melanostigma	R.
Sabellastarte magnifica	R.
Typosyllis corallicola	R.
Polydora ancistrata	R.

Phylum: Arthropoda

Sub-phylum: Crustacea

Class: Copepoda

Acartia tonsa	W.
Paracalanus sp.	W.

Class: Cirripedia

Balanus eburneus	R.
B. amphitrite amphitrite	R.
B. reticulatus	R.
B. improvisus "assimilis"	R.
B. trigonus	R.
Chthamalus poteus	R.

Class: Malacostraca

Mysidium columbiae	W.
Penaeus brasiliensis	S.
P. duorarum	S.

* *P. notialis*	S.
Sicyonia laevigata	S.
Trachypenaeus constrictus	S.
* *Panulirus argus*	S.
Alphaeus sp.	S.
Callinectes danae	S.
C. exasperatus	S.
C. ornatus	S.
* *C. sapidus*	S.
Pachygrapsus gracilis	S.
Goniopsis cruentata	M.
Sesarma ricordi	M.
S. curacaoense	M.
Aratus pisonii	T.R.M.
Uca rapax	M.
U. thayeri	M.
* *Ucides cordatus*	M.
Panopeus herbstii	S.
Eurytium limosum	S.
Lupella forceps	S.

Phylum: Mollusca

Class: Gastropoda

Family: Littorinidae

Littorina angulifera	T.R.

Family: Strombidae

Strombus pugilis	S.
Family: Muricidae	
Murex pomum	S.
Family: Melongeniidae	
* *Melongena melongena*	S.
Family: Ellobiidae	
Melampus coffeus	M.R.
Class: Bivalvia	
Family: Mytilidae	
Brachidontes citrinus	R.S.
Family: Isognomonidae	
* *Isognomum alatus*	R.S.
Family: Pinnidae	
Atrina seminuda	S.
A. serrata	S.
Family: Plicatulidae	
Plicatula gibbosa	S.
Ostrea frons	R.
* *Crassostrea rhizophorae*	R.
Family: Lucinidae	
Phacoides pectinatus	S.
Family: Veneridae	
Pitar albida	S.
Class: Scaphopoda	
Family: Dentaliidae	
Dentalium antillarum	S.

D. didymun	S.

Phylum: Bryozoa

Family: Vesiculariidae

Zoobotryon verticillatum	R.

Family: Bugulidae

Bugula neritina	R.

Phylum Echinodermata

Class: Asteroidea

Luidia clathrata	S.
L. alternata	S.
Echinaster echinophorus	S.
Oreaster reticulatus	S.

Class: Ophiuroidea

Ophiothrix angulata	S.R.

Class: Echinoidea

Lytechinus variegatus	S.
Tripneustes esculentus	S.
Echinometra viridis	S.

Class: Holothuroidea

Stichopus badionotus	S.

Phylum: Chordata

Sub-phylum: Tunicata

Ascidia nigra	R.
A. interrupta	R.
Ecteinascidia turbinata	R.
Perophora bermudensis	R.
Clavelina oblonga	R.
Rhodosoma turcicum	R.
Herdmania momus	R.
Microcosmus exasperatus	R.
Diplosoma listerianum	R.
Symplegma viride	R.
Polyclinum constellatum	R.
Botrylloides nigrum	R.
Eudistoma olivaceum	R.
Styela partita	R.

Sub-phylum: Vertebrata

Class: Pisces

Chondrichthyes

Family: Dasyatididae

Urolophus jamaicensis	W.
Aetobatis narinari	W.

Osteiichthyes

Family: Elopidae

Megalops atlanticus	W.

Family: Clupeidae

Harengula humeralis	W.
H. pensacolae	W.
H. jaguana	W.
Opisthonema oglinum	W.
Family: Chaetodontidae	
Chaetodon capistratus	W.
Family: Poeciliidae	
Gambusia oligosticta	W.
Gambusia sp.	W.
Family: Engraulidae	
Anchoa filifera	W.
A. hepsetus	W.
A. parva	W.
A. lyolepis	W.
Family: Atherinidae	
Atherinomorus stipes	W.
Family: Monacanthidae	
Stephanolepis setifer	W.
Myroplius punctatus	W.
Family: Belonidae	
Strongylura marina	W.
S. notata	W.
Family: Holocentridae	
Holocentrus ascensionis	W.
Family: Syngnathidae	
Hippocampus reidi	W.

Syngnathus rousseau	W.
Family: Centropomidae	
Centropomus undecimalis	W.
Family: Serranidae	
Serranus flauviventris	W.
S. tabacarius	W.
Family: Grammistidae	
Rypticus saponaceus	W.
Family: Carangidae	
Chloroscombrus chrysurus	W.
Caranx latus	W.
Oligoplites saurus	W.
Family: Scombridae	
Scomberomorus cavalla	W.
Family: Lutjanidae	
Lutjanus analis	W.
L. griseus	W.
L. synagris	W.
L. jocu	W.
L. apodus	W.
Ocyurus chysurus	W.
Family: Haemulidae	
Haemulon bonariense	W.
H. plumieri	W.
H. parrai	W.
Family: Gerridae	

Diapterus rhombeus	W.
Eucinostomus argenteus	W.
Gerres cinereus	W.
Family: Mugilidae	
Mugil curema	W.
Family: Sparidae	
Archosargus rhomboidalis	W.
Family: Sciaenidae	
Odontoscion dentex	W.
Stellifer colonensis	W.
Family: Scaridae	
Sparisoma aurofrenatum	W.
Scarus croicensis	W.
Family: Gobiidae	
Bathygobius soporator	W.
Lophogobius cyprinoides	W.
Family: Blennidae	
Paraclinus fasciatus	W.
Dinematichthys cayorum	W.
Family: Sphyraenidae	
Sphyraena barracuda	W.
Family: Acanthuridae	
Acanthurus chirurgus	W.
Family: Tetraodontidae	
Sphaeroides testudineus	W.
S. nephelus	W.

S. eulepidotus	W.
Family: Diodontidae	
Chilomycterus antennatus	W.
Family: Soleidae	
Trinectes inscriptus	W.
Family: Bothidae	
Bothus lunatus	W.
Class: Aves	
Family: Pelecanidae	
Pelecanus occidentalis	T.
Family: Ardeidae	
Egretta alba	T.
E. thula	T.
Dichromanassa rufescens	T.
Bubulcus ibis	T.
Ixobrychus exilis	T.
Nyctanassa violacea	T.
Nycticorax nycticorax	T.
Ardea herodias	T.
Florida caerulea	T.
Butorides virescens	T.
Hydranassa tricolor	T.
Family: Fregatidae	
Fregata magnificens	T.
Family: Threskiornithidae	

Plegadis falcinellus	T.
Eudocimus albus	T.
Family: Cathartidae	
Cathartes aura	T.
Family: Pandionidae	
Pandion haliaetus	T.
Family: Rallidae	
Rallus longirostris	T.
Family: Charadiidae	
Arenaria interpres	T.
Squatarola squatarola	T.
Family: Recurvirostridae	
Himantopus himantopus	T.
Family: Scolopacidae	
Tringa flavipes	T.
Tringa melanoleuca	T.
Catoptrophorus semipalmatus	T.
Crocethia alba	T.
Family: Laridae	
Sterna dougalli	T.
S. hirundo	T.
S. albifrons	T.
S. maximus	T.
Larus atricilla	T.
Family: Columbidae	
Zenaida asiatica	T.

Family: Parulidae

Mniotilta varia	T.
Dendroica petechia	T.
Seiurus noveboracensis	T.

Family: Alcedinidae

Ceryle alcyon	T.

Family: Trochilidae

Anthracothorax mango	T.

Family: Mimidae

Mimus gundlachii	T.
Mimus gilvus	T.

Class: Mammalia

Family: Viverridae

Rattus sp. probably norvegicus	T.

Family: Delphinoidae

Tursiops truncatus	W.

Family: Muridae

Herpestes auropunctatus	T.

Appendix 5 - Hydrolab Calibration Certificate

HACH®

Hydromet

Certificate of Instrument Performance

Agency Name: **CL Environmental**

Certification for Job# **3073519**

Part/Model Number: MiniSonde5	Serial Number: **49186**

RECEIVED CONDITION: *(One must be checked)*	X Within Tolerance Within Tolerance but Limited *(*see service report)* Out of Tolerance *(*see service report)*
RETURNED CONDITION: *(One must be checked)*	X Within Tolerance Within Tolerance but Limited *(*see service report)*

Test Equipment Used, (ID#): ASTM – N.I.S.T traceable glass thermometer (Thermo-Fisher Scientific, Serial ***1781)*** and a Cole-Parmer "*PolyStat*" Constant Temperature Circulator

Environmental Conditions:

Actual Temperature	Instrument Reading	Error
10 °C	10.02°C	.02°C
20 °C	20.00°C	.00°C
30 °C	29.95°C	.05°C

Hach Company does hereby certify that the above listed equipment meets or exceeds all Manufacturers' Service Specifications (unless limited conditions apply). Test equipment used for performance verification are calibrated using standards traceable to the National Institute of Standards and Technology (NIST). Where such standards do not exist, the basis for calibration is documented. The proper operation of the above instrument was established at the time of certificate issuance. To insure continued performance, user must adhere to all requirements listed in the instrument manual.

Certified by: [signature] Title: Instrument Service Technician

Certification Date: 08/12/2013 08/12/2013

5600 Lindbergh Drive • Loveland, CO 80538
(800) 227-4224 / FAX (970) 461-3924

Part # 19773-01
Rev. 2

Appendix 6 – Survey Questionnaires

COMMUNITY Time Start: ____________ Time Finish: ____________

Questionnaire ID: ____________ Name of Interviewer: ____________________________________

Date: ____________________ Location: ____

Hello, my name is ……………… I am part of an environmental team from CL Environmental conducting a perception survey of the proposed Palisadoes rehabilitation project. It is proposed that the rehabilitation Project consists of two phases. Phase 1 is the creation of 8 mangrove islands along the harbour side of the Palisadoes main road. Phase 2 will consist of the re-creation and re-vegetation of sand dunes along the seaward side of the Palisadoes main road.

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Do you have any questions? Yes / No

Further, throughout our discussion, please feel free to ask me any questions you may have.

May we proceed with our survey? Yes / No

COHORT DESCRIPTION

1. (i) Male (ii) Female
2. Age group ☐ <25 ☐ 26-40 ☐ 41-60 ☐ >60 years
3. Are you the head of your household (i) yes (ii) no
4. Including yourself, how many people live in your household? ____ (i) # of adults ____ (ii) # of children under 18 yrs ____
5. How long have you lived in your community?
   ☐ <1 year ☐ 1 – 10 years ☐ 11 – 20 years ☐ > 20 years

HOUSING, HEALTH AND SOCIAL SERVICES

6. Do you ___________ the house you live in?
   (i) Own (ii) Lease (iii) Rent (iv) Government Own (v) Squat (vi) Family own (vii) Other, specify____________
7. Do you ________ the land on which your house is located? (i) Own (ii) Lease (iii) Squat on (iv) Family Owned (v) Government Owned (vi) Other, specify ______________
8. What type of construction material is your residence made from?
   a. **Walls:** (i) Concrete and blocks (ii) Wood/Board (iii) Zinc (iv) Other specify________
   b. **Roof:** (i) Metal sheeting (zinc) (ii) Concrete (iii) Wood (iv) Other specify________

1

9. How many of the following rooms does your residence have? (i) Bedrooms _______ (ii) Bathrooms ________

10. What type of toilet facility do you have?
(i) Water Closet (ii) Pit Latrine (iii) None (iv) Other, specify ____________

11. What does your household use for lighting?
(i) Electricity (ii) Kerosene oil (iii) Gas (iv) Other, specify ___________

12. What type of fuel does the household use most for cooking?
(i) Gas (ii) Electricity (iii) Wood (iv)Coal (v)Other, specify _____________

13. What is the main source of domestic water supply for the household?
(i) Public piped water into dwelling (ii) Private Tank (iii) Community Tank (iv) Government Water Trucks (free) (v)Public Standpipe (vi). Private Water Trucks (paid) (vii) Spring or River (viii) Other, specify________

14. Do you have any problems with domestic/household water supply (i) yes (ii) no

    a. If yes what is the problem? (i) no water at all (ii) no pipes run to the area (iii) irregular water supply (iv) low water pressure

    b. If yes how do you cope with the problem (i) collect rain water (ii) buy water (iii) collect water from a spring/river (iv) water truck supplies water (v) community standpipe (vi) other _______________________

    c. How do you store water (i) drums (ii) underground tank (iii) aboveground tank (iv) other ________________

15. Do you have access to a residential telephone? (i) yes (ii) no
a. If no do you have a mobile/cell phone? (i) yes (ii) no
b. If no do you know of anyone having a residential telephone nearby? (i) yes (ii) no

16. What is the main method of garbage disposal for your household?
(i) Public Garbage Truck (ii) Private Collection (iii) Burn (iv) Other specify ________

    a. If public garbage truck, how often do trucks pick up garbage? (i) once per week (ii) twice per week (iii) every 2 weeks (iv) 1 time per month (v) Other, specify __________________

17. In the event of illness, where do you obtain health care? (i). Public Clinic (ii) Public Hospital (iii) Private Doctor (iv) Private Hospital

18. Do you suffer from any of the following conditions? (i). Asthma (ii). Sinusitis (iii) coughing (iv) congestion/bronchial problems (v) chest pains (vi) bouts of diarrhoea

19. Where do you usually shop (food, clothing etc.)? (i) Supermarket (ii) Market (iii) Supermarket & market (iv) Community Shop (v) Wholesale Shop

20. Are there any recreational centres/spaces in your community? (i). Yes (ii) No
(i) Is yes please give name and type _______________________________

21. What does the average person do for fun within the community? (i) Street dance/parties (ii) Youth Clubs (iii) Sports Clubs/bars (iv) Service clubs/Charity for e.g. Lions Club (v) Church groups/activities (vi) Other, specify________________

SPECIFIC ISSUES THE PROJECT

22. Since living in this community have you noticed any environmental changes
 Yes No
If yes, specify
___

23. Do you know what sand dunes are?
 Yes No **(if no provide a brief non-technical explanation)**

24. Do you know what mangrove islands are?
 Yes No ***(if no provide a** **brief non-technical** **explanation)***

25. Are you aware of the proposal to re-establish sand dunes on the sea side and mangrove islands on the harbor side?
 Yes No ***(if no provide a** **brief non-technical** **summary)***

26. Do you have any concerns about the project as proposed? (i) yes; (ii) no
a. If yes what are they?
___
___

27. Do you think this project will affect your life in (i) positively or (ii) negatively? (i) yes; (ii) no
a. If positive how so?
___
b. If negative how so?
___

28. Do you think that the shoreline protection and rehabilitation are necessary?
 Yes No

29. Do you think that the project may cause any negative impact on business in the area?
 Yes No

30. Do you believe that project activity will be good for the area ?
 Yes No
If yes, please specify ___

31. Do you believe that project activity will affect your income earning capacity?
 Yes No
If yes, please specify ___

32. What do you think are some of the environmental problems occurring along Palisadoes Roadway are?
___
___

33. Do you think that the re-creation and re-vegetation will alleviate some of the problems occurring along the road way?
☐ Yes ☐ No

34. Can you think of any other measures that could be taken to alleviate these problems?
☐ Yes ☐ No
If yes, please specify ____________________

35. How often do you use the roadway?
☐ Dailey ☐ Weekly
☐ Monthly ☐ Specify____________________

EMPLOYMENT & INCOME

36. Including yourself how many people in your household are employed?
____

37. What is the main employment status of household head? (If the interviewee is not the head of the household). (i) employed (ii) unemployed (iii) retired

38. If employed what does the head of household do? ____________________
(i) Casual labour (ii) semi-skilled (iii) skilled (iv) artisan (v) professional

***** Use Table to answer questions below***

1. Below $1,000	5. $4,000-$4,999
2. $1,000-$1,999	6. $5,000-$9,999
3. $2,000-$2,999	7. $10,000 and over
4. $3,000-$3,999	

39. What is the average weekly income of the household head? ____________________

40. What is your average weekly income? ____________________

41. What is the average weekly income of the household? (All sources) ____________________

42. Do you depend on the proposed location for business? (i) yes (ii) no
If yes what do you depend on it for?
____

EDUCATION

43. What is the highest level of education completed? (Which was the last school you attended)
☐ None ☐ Primary ☐ Secondary ☐ Tertiary ☐ Technical Vocational (e.g. HEART)

44. Is there anyone in your household attending school at this time? (i) yes (ii) no
a. If yes how many persons? ____________________
b. What is/are the names of the school(s) ____________________

ANY OTHER COMMENTS

____

____

____

THANK YOU FOR YOUR TIME TODAY. I APPRECIATE YOUR PARTICIPATION IN THIS SURVEY.

FISHERMEN Time Start: ____________ Time Finish: ____________

Questionnaire ID: ____________ Name of Interviewer: ____________________________________

Date: ______________________ Location: ____

Hello, my name is ……………… I am part of an environmental team from CL Environmental conducting a perception survey of the proposed Palisadoes rehabilitation project. It is proposed that the rehabilitation Project consists of two phases. Phase 1 is the creation of 8 mangrove islands along the harbour side of the Palisadoes main road. Phase 2 will consist of the re-creation and re-vegetation of sand dunes along the seaward side of the Palisadoes main road.

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Do you have any questions? Yes / No

Further, throughout our discussion, please feel free to ask me any questions you may have.

May we proceed with our survey? Yes / No

OBJECTIVES:

- ***To determine the extent of environmental dependence by fishermen for livelihoods as well as subsistence;***
- ***To determine the extent of fishermen's contribution to environmental preservation or degradation.***

1. Age: ☐ <25 ☐ 26-40 ☐ 41-60 ☐ >60
2. Gender: ☐ Male ☐ Female
3. How long have you been fishing? ____________________________
4. How long have you been fishing in the Palisadoes area?

   ☐ <1 year ☐ 1 – 10 years ☐ 11 – 20 years ☐ > 20 years

5. Do you use both sides along both sides of the Palisadoes road? ☐ Yes ☐ No
6. If yes explain

   Harbour side

   ____

____

Sea side

____

____

7. What are your main fishing methods?

a)
b)
c)

8. What are your main catch?

a)	b)
c)	d)
e)	f)

SECTION I: Perception of Environmental Quality

9. Are you aware of any environmental problems within your community? ☐ Yes ☐ No

If yes, please state:

•
•
•
•
•

10. What changes (either positive or negative) have occurred in the past 10 years that you have noticed in the environment? *E.g. loss of habitat*

•
•
•
•

11. What do you think have caused these changes? *E.g. increase in population, development or pollution*

•
•
•
•

SECTION II: Dependence on the Environment

12. Do you rely on the environment as a source of income? ☐ Yes ☐ No

2

13. Who are your main customers for your output? (Select where necessary)
    - ☐ Locals
    - ☐ Tourists
    - ☐ Hotels
    - ☐ Hostels
    - ☐ Restaurants
    - ☐ Apartments
    - ☐ Other: ___________________________

14. Would you be willing to state your weekly income (JMD)? ☐ Yes ☐ No
    - _____ Less than $1,000
    - _____ $1,000-$1,999
    - _____ $2,000-$2,999
    - _____ $3,000-$3,999
    - _____ $4,000-$4,999
    - _____ $5,000-$9,999
    - _____ $10,000 and over

15. Do you rely on the environment for subsistence? ☐ Yes ☐ No

16. What % of your total activities is for subsistence?
    a. >75%
    b. 51% - 75%
    c. 25% - 50%
    d. < 25%

SECTION III: Impact on the Environment

17. Are you aware of any activities or practices which impact on the environment positively or negatively?
    ☐ Yes ☐ No
    If yes please specify: ____

18. Are you engaged in any practices that that you think positively affect the environment? *E.g. lionfish, garbage, etc.* ☐ Yes ☐ No
    If yes please specify: ____

19. Are you engaged in any practices that you think negatively affects the environment? *E.g. small net size, dynamite, littering, etc.* ☐ Yes ☐ No
    If yes please specify: ____

20. What challenges do you face which prevent you from engaging in positive environmental practices?
    a. Cost
    b. Lack of information on positive practices
    c. Lack of technical assistance by the Government or external body
    d. Other, please state ___________________________

21. What practice(s) do you think will be applicable in preserving the environment as well as sustaining it for the future?

•
•
•
•
•

22. Suppose that an environmental agency was provide the following:
    - Information on ways to maintaining/improving quality of yield and positive environmental effects

- Technical assistance to maintaining/improving quality of yield and positive environmental effects;

  Would you be willing to pay for these services? ☐ Yes ☐ No

23. If yes, would you be willing to pay for the full cost of these services? ☐ Yes ☐ No

SECTION IV: Creation of mangrove islands and sand dunes along the Palisadoes roadway

24. Are you aware of the proposal to create 8 mangrove islands along the harbour side and the re-creation and re-vegetation of sand dunes along the seaward side of the Palisadoes main road?
    ☐ Yes ☐ No

25. Should the Project be done? ☐ Yes ☐ No

26. Do you think either phase of the Project will affect your daily activities? ☐ Yes ☐ No
If Yes, how: ____
____
____
____

27. Do you believe activities will impact on your income/livelihood? ☐ Yes ☐ No
If Yes, how: ____
____
____
____

28. Do you think recreation of these natural features will assist in protection of the road way? ☐ Yes ☐ No

29. Instead of the proposed Project, do you think any other means can be used to protect the road way?

    ☐ Yes ☐ No

If Yes, please specify:
____
____
____
____

BACKGROUND

30. Highest level of education:

    ☐ Primary ☐ Secondary ☐ Tertiary ☐ Technical Vocational

31. Do you own your own home? ☐ Yes ☐ No
32. Do you rent? ☐ Yes ☐ No
33. Do you own any land? ☐ Yes ☐ No
34. What is your average total household income per week (JMD)?

_____ Less than $2,000 _____ $2,000-$2,999

_____ $3,000-$3,999
_____ $4,000-$4,999
_____ $5,000-$9,999
_____ $10,000 and over

ANY OTHER COMMENTS

____
____
____

THANK YOU FOR YOUR TIME TODAY. I APPRECIATE YOUR PARTICIPATION IN THIS SURVEY.

RECREATIONAL USERS Time Start: ____________ Time Finish: ____________

Questionnaire ID: ____________ Name of Interviewer: ________________________________

Date: ____________________ Location: ____

Hello, my name is ……………… I am part of an environmental team from CL Environmental conducting a perception survey of the proposed Palisadoes rehabilitation project. It is proposed that the rehabilitation Project consists of two phases. Phase 1 is the creation of 8 mangrove islands along the harbour side of the Palisadoes main road. Phase 2 will consist of the re-creation and re-vegetation of sand dunes along the seaward side of the Palisadoes main road.

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Do you have any questions? Yes / No

Further, throughout our discussion, please feel free to ask me any questions you may have.

May we proceed with our survey? Yes / No

OBJECTIVES:

- ***To determine the extent of environmental dependence by users for recreation;***

1. Age: ☐ <25 ☐ 26-40 ☐ 41-60 ☐ >60
2. Gender: ☐ Male ☐ Female
3. Occupation: ________________________________

SECTION I: Main Use of Palisadoes Roadway

4. What is your main use of the roadway?

☐ Run/Jog/Walk ☐ Skating
☐ Cycling ☐ Scenery
☐ Fishing ☐ Relaxation
☐ Other, please state ______________

5. Have often do you use the roadway?

Number of time per week_______________

6. Which other corporate areas do you use for similar recreational purposes?

•
•
•
•
•

7. Please check any other activity that you have or would like to participate in along the roadway.
   ____ Run/Jog/Walk ____ Boating
   ____ Cycling ____ Visiting cultural sites
   ____ Fishing ____ Other, please state______________

8. Do you perceive the activities you are taking part in will impact on the environment negatively?
   ☐ Yes ☐ No

9. Does environmental quality play an important role in choosing this area?
   ☐ Yes ☐ No

10. How will you rate the environmental quality of this area?
   Harbour Side
   a. Poor b. Fair c. Satisfactory d. Good e. Excellent

   Sea Side
   b. Poor b. Fair c. Satisfactory d. Good e. Excellent

SECTION II: Perception of Project

11. How do you view the Palisadoes Shoreline Protection Project?
   a. Long term b. Short term c. Both

12. Do you share the view that the project should include the environment?
   ☐ Yes ☐ No

13. Are you aware of any environmental problems within this area? ☐ Yes ☐ No
If yes, please state:

•
•
•
•
•

14. Based on your experiences along the roadway rate your level of agreement using a scale of 1 to 5 where 1 = Strongly disagree, 3 = Neutral and 5 = Strongly agree. *(Circle one number for each statement)*

I have observed activities along the roadway that:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Minimize negative impacts on the environment	1	2	3	4	5
Minimize negative impacts on the local people	1	2	3	4	5
Increase the awareness of natural and heritage systems	1	2	3	4	5
Contribute to the protection and management of legally protected areas	1	2	3	4	5
Direct economic and other benefits to the local people	1	2	3	4	5
Promote participation and empowerment of local people	1	2	3	4	5

SECTION III: Attitudes towards Environmental Conservation and Ecotourism

15. Visitors place different values on the environment and specifically ecotourism. Please rate your level of agreement using a scale of 1 to 5 where 1 = Strongly disagree, 3 = Neutral and 5 = Strongly agree. *(Circle one number for each statement)*

Statements:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I am concerned about environmental issues	1	2	3	4	5
I think it is rational that restrictions be placed on natural resources e.g. capacity of tourism sites to ensure sustainability and a lesser impact on the environment	1	2	3	4	5
I abide to the restrictions placed on natural resources for its conservation even if it not pleasing to me e.g. no littering	1	2	3	4	5
I will support interventions aimed at improving environmental management within this area	1	2	3	4	5

16. Do you know what Sand dunes are? ☐ Yes ☐ No

17. Do you know what Mangrove Islands are? ☐ Yes ☐ No

18. There is a proposal to Re-create of 8 Mangrove Islands on the harbour side of the roadway. Do you think they should be created? ☐ Yes ☐ No
19. There is a proposal to Re-create and re-vegetate the Sand Dunes on the Sea side of the. Do you think they should be created? ☐ Yes ☐ No
20. Do you think the re-creation of the 8 mangrove Islands will assist in protecting the roadway and the natural environment? ☐ Yes ☐ No
21. Do you think the re-creation and re-vegetation will assist in protecting the roadway and the natural environment? ☐ Yes ☐ No
22. Instead of the proposed project, do you think any other means can be used to protect the roadway? ☐ Yes ☐ No

If yes, please specify:

____
____
____
____
____

BACKGROUND

23. Do you own your own home? ☐ Yes ☐ No

24. Do you rent? ☐ Yes ☐ No

25. Do you own any land? ☐ Yes ☐ No

26. What is your average total household income per month (USD)?

_____ Less than $1,000
_____ $1,000-$1,999
_____ $2000-$2,999
_____ $3000-$3,999
_____ $4000-$4,999
_____ $5,000 and over

ANY OTHER COMMENTS

____
____
____

THANK YOU FOR YOUR TIME TODAY. I APPRECIATE YOUR PARTICIPATION IN THIS SURVEY.