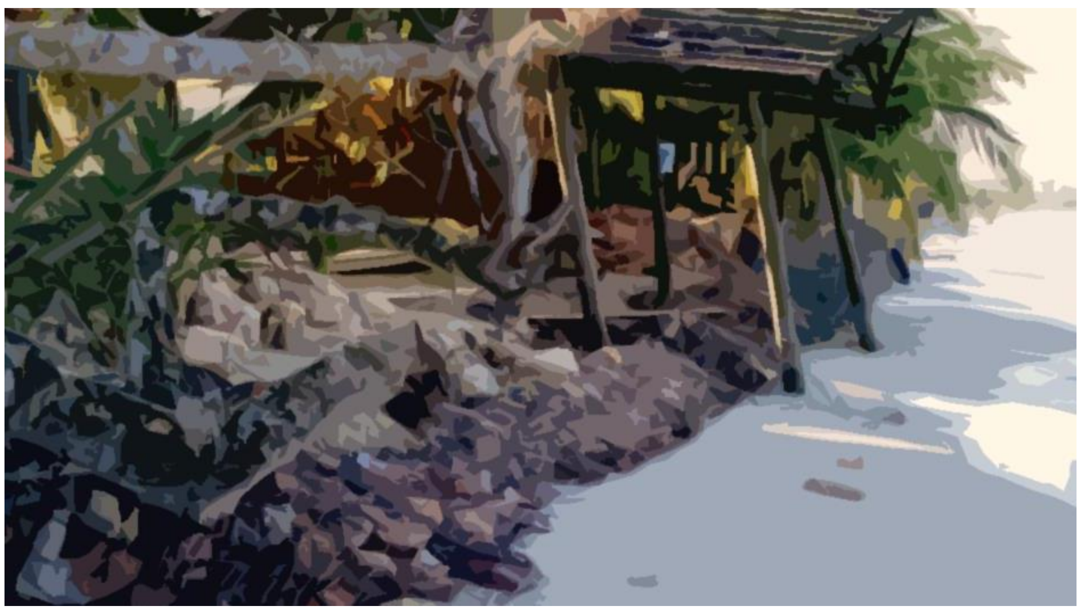

# *Environmental Impact Assessment*

# CONSTRUCTION OF TWO BREAKWATERS AT LONG BAY, NEGRIL, WESTMORELAND

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|---|---|
| *Report Version:* | **FINAL (Amended No. 1)** |
| *Date:* | **November 2014** |
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| *Submitted to:* | **NATIONAL ENVIRONMENT & PLANNING AGENCY** |

# ENVIRONMENTAL IMPACT ASSESSMENT FOR THE CONSTRUCTION OF TWO BREAKWATERS AT LONG BAY, NEGRIL, WESTMORELAND

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*Front Cover Photograph Sources:* Smith Warner International Limited, Marine Geology Unit, UWI Mona

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| | | |
|---|---|---|
| **A** | AADT | Annual average daily traffic |
| | amsl | Above mean sea level |
| **C** | C | Celsius |
| | CBD | Convention on Biological Diversity |
| | CDMP | Caribbean Disaster Mitigation Project |
| **D** | DAFOR | Dominant, Abundant, Frequent, Occasional, Rare |
| | dBA | A-weighted sound level (decibel) |
| | 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 |
| | 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 |
| **N** | N | North/ Northing |

| | | |
|---|---|---|
| | NAAQS | National Ambient Air Quality Standards |
| | NEPA | National Environment and Planning Agency |
| | 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** | PIF | Project Information Form |
| | PM10 | Particulate matter smaller than 10 microns in diameter, respirable particulate matter |
| | PM2.5 | Particulate matter smaller than 2.5 microns in diameter, 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 |
| | STATIN | Statistical Institute of Jamaica |
| **T** | TCP Act | Town and Country Planning Act |
| | TDS | Total dissolved solids |
| | TSS | Total Suspended Solids |
| **U** | USEPA | United States Environmental Protection Agency |
| **W** | WHO | World Health Organization |
| | WRA | Water Resources Authority |
| **Y** | yr | Year |

# 1.0 EXECUTIVE SUMMARY

## INTRODUCTION

The Government of Jamaica has implemented the "*Enhancing the Resilience of the Agriculture Sector and Coastal Areas to Protect Livelihoods and Improve Food Security Project*". Under Component 1 of this project, the "*Construction of Break Water Structures Offshore Negril (Negril Breakwaters)"* sub-project was formulated to rehabilitate and protect the Negril coastal area. CEAC Solutions Limited has been commissioned by the NWA to provide technical assistance to plan, execute and monitor construction operations for the Negril breakwaters.

Negril boasts the longest continuous stretch of white sand beach in Jamaica and it is lined with hotels, bars, villas and restaurants. According to the World Travel & Tourism Council (2012), Negril alone accounts for 20.9% of the stopover arrivals for 2012, making this area the third most visited resort area in the island. Through the tourism industry, Negril provided the second highest number of direct jobs in Jamaica in 2012 (9,365), accounting for 26.6% within the entire island. However, an erosion problem has faced Long Bay beach; in terms of long term trends over the past 40 years, the beach along Long Bay was said to have been dominated with erosion totalling approximately 40m (SWIL, 2007).

## POLICY, LEGAL AND ADMINISTRATIVE FRAMEWORK

### *National Legislation*

<u>Development Control</u>

- The Town and Country Planning Act (TCP Act) 1957 (Amended 1987)
- Parish Councils Act 1901 (Amended2007)
- The Exclusive Economic Zone Act 1993
- The Maritime Areas Act 1996
- The Port Authority Act 1972
- The Harbours Act 1874
- The Shipping Act 1998
- The Beach Control Act 1956 and the Beach Control (Amendment) Act 2004
- The Jamaica National Heritage Trust Act 1985
- The Quarries Control Act 1984 and the Quarries Control (Amendment) Act 1994
- The Mining Act 1947 (Amended 1995)
- The Main Roads Act 1932

<u>Environmental Conservation</u>

- Policy for the National System of Protected Areas 1997

- Natural Resources Conservation Act 1991
- Negril Environmental Protection Plan (EPP) 1997
- The Natural Resources (Permit and Licences) Regulations 1996
- The Natural Resources (Marine Park) Regulations 1992, the Natural Resources (Marine Park) (Amendment) Regulations 2003
- Natural Resources Conservation (Negril Marine Park) (Declaration) Order 1998
- The Natural Resources (Prescribed Areas) (Prohibition of Categories of Enterprise, Construction and Development) Order 1996
- The Fishing Industry Act 1975
- Wild Life Protection Act 1945
- The Endangered Species Act 2000
- Water Resources Act 1995
- Towards an Ocean and Coastal Zone Management Policy in Jamaica 2000
- Towards a Beach Policy for Jamaica (A Policy on the Foreshore and the Floor of the Sea) 2000 (DRAFT)
- National Policy for the Conservation of Seagrasses 1996 (DRAFT)
- Coral Reef Protection and Preservation Policy and Regulation 1997 (DRAFT)
- A policy towards Dolphin Conservation in Jamaica 2003
- DRAFT Policy and Regulation for Mangrove & Coastal Wetlands Protection
- The Forest Act 1996

Public Health & Waste Management

- Water Quality Standards
- Noise Abatement Act 1997
- The National Solid Waste Management Authority Act 2001
- Public Health Act 1985
- The Natural Resources (Hazardous Waste) (Control of Transboundary Movement) Regulations 2003
- Additional Guidelines

### *Regional and International Legislative Considerations*

- Cartagena Convention (Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region), 1983
- United Nations Convention on Biological Diversity
- United Nations Convention on the Law of the Sea (UNCLOS III) 1982
- Convention on Fishing and Conservation of the Living Resources of the High Seas 1958
- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter

- Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES)
- International Convention on Oil Pollution Preparedness, Response and Co-operation 1990

## COMPREHENSIVE DESCRIPTION OF THE PROJECT

### *The Proponent*

The Government of Jamaica has implemented the larger umbrella project "*Enhancing the Resilience of the Agriculture Sector and Coastal Areas to Protect Livelihoods and Improve Food Security*" through the Planning Institute of Jamaica (PIOJ). With specific regard to the *Construction of Break Water Structures Offshore Negril (Negril Breakwaters)" sub*project, execution is being managed by the National Works Agency (NWA).

### *Project Location*

The following two proposed breakwaters are located 1,500 - 1,600 m offshore the Negril coastline in Long Bay:

- *Northern breakwater* - 516 metres long in 3.0 to 4.0 m of water depth (MSL) that is partially emergent and submerged in some sections.
- *Southern breakwater* - 422 metres long in 3.7 to 4.1 m of water depth that is partially emergent.

### *Breakwater Design*

The breakwaters were designed to meet the following conditions:

- Withstand the 1 in 100 year return period deep water wave conditions with minimal damage (Structural damage number of less than 2 to 3).
- Project life up to 2050 (37 years).
- Climate change factors for the IPCC SRES (Intergovernmental Panel on Climate Change Special Report: Emissions Scenarios) A1B or A1 scenario up to the design life.
- Employ the use of locally available materials.

Materials
A range of specific densities and stone sizes are available for the project based upon the quarry surveys. An assumed density of 2.5 with a possible range of 2.411 to 2.574 was used.

Deepwater Wave Climate and Climate Change Factors

Present climate deep-water hurricane wave hindcast analysis was undertaken for a node offshore Negril and summarized in a bi-directional format. The hindcast results were subjected to frequency analysis to define the 5 to 100 year RP.

Pre-testing Structural Analysis

Structural stability analysis indicated that the 100 year design will essentially be statistically stable with breaking wave conditions and transmission of 0.53. The transmission indicates that approximately 28% of the energy will be transmitted over the breakwater and about 72% will be dissipated within the structure and reflected. A 4.2 to 8.8 tonnes stone size was determined to be required with a mean of 6.5 T.

Scale Model Testing

The key objectives of the scale modelling exercise were to determine the viability of the proposed design; optimize the elements of the cross-section and confirm its climate change resilience. Test series 1, 2 and 3 clearly confirmed the very low stability number (< 1) to be expected from the design. The increase in wave height and water levels by climate change (0.2 m) is relatively small in comparison to storm surge (1 to 1.2 m).

Geotechnical Considerations/Settlement

Seafloor photography and investigations revealed a pavement type floor over the entire footprint, with shallow (<0.6 metres) of sand. Settlement by seafloor eroding is expected to be minimal with a geotextile or filter stone provision.

Material Verification and Constructability

The scale model test allowed CEAC to determine the quality requirements of the rocks to be used in this project. All armour stone should meet or exceed the following properties:

- A Specific density of 2.50 for more than 90% of the samples. No sample less than 2.45
- Water Absorption less than 3.0%. If > 3% but less than 4.5%, then LA must be acceptable.
- LA Abrasions less than 35% losses after 500 revolutions.
- $MgSO_4$ soundness of less than 15% losses after 5 cycles.
- Field drop test: less than 10% breakage or cracking (from 3 metres) for 10 samples, on a bed

Quarry surveys were undertaken at several potential quarries in the region to determine suitability for the supply of armour stones. Nationwide Design Co. is reported to have the most suitable rocks for the project.

Stockpile Area Assessment

A shoreline stockpile area will be required for the project in order to facilitate the loading of the barge with stones and this will be located at the South Negril River. Site preparation will involve land filling next to the southern groyne seaward for approximately 47 metres to the tip of the groyne to create an area 30 metres wide.

## *Construction Phases Activities*

Campsite Preparation and River De-silting

- Driving Sheet Pile to Define Area
- Landfilling and Dredging (dredging no longer a part of project scope)

Placement of Boulders

- Removal of Bio-physical Features in Footprint and Relocation
- Placement of Turbidity Barriers
- Placement of Geotextile
- Retrieval of Boulders from Stockpile Area
- Placement of Boulders in Footprint:
- Summary of logistics are as follows:
    - Total weight of stones (T): 45,014
    - Weight on barge per load: 400
    - No. of barge trips: 113
    - Duration (months): 6
    - Truck/ Trailer Trips per day: 24
    - Total no. Truck/ Trailer loads: 2,923

## *Project Activities and Schedule*

The project is phased as follows:

- *Phase 1* – The preparation of the Bid document; completion of engineering design works; and preparation of EIA.
- *Phase 2* – The engineering consultancy and assistance during implementation and construction.
- *Phase 3* – The post-construction monitoring of the structure and relocated sensitive species.

A total duration of 30 months from start is envisaged. Construction activities are expected to take no more than eleven months. This phase will be initiated with the completion of the procurement process. Originally a twelve month monitoring period was envisaged but it is recommended that this be increased to 36 months. During this monitoring exercise structures, water quality and shoreline parameters will be observed.

# DESCRIPTION OF THE EXISTING ENVIRONMENT

## *Physical*

Water Quality

Eighteen (18) stations were sampled within Long Bay and analysed for Biochemical Oxygen Demand (BOD), Fats Oil and Grease (FOG), Total Suspended Solids (TSS), phosphates, nitrates and faecal coliform. Temperature, conductivity, salinity, pH, Dissolved Oxygen (D.O.), turbidity, Total Dissolved Solids (TDS) and light irradiance (Photosynthetically Active Radiation – PAR) were measured *in situ* using a Hach Hydrolab DataSonde-5 multi probe water quality. In many of the physicochemical variables examined, there was little variation seen among the stations with the exception one station (Station 1). The influence of the South Negril River at Station 1 was demonstrated in the lower temperature, salinity, specific conductivity and TDS. Station 1 showed the highest average BOD, phosphate and faecal coliform values that could be attributed to the outflow from the sewage plant or the presence of a fishing village located along the banks of the River.

Heavy Metals in Sediments

Sediment samples were collected at seven (7) stations within the Bay and analyzed for the presence of Arsenic (As), Cadmium (Cd), Lead (Pb), Mercury (Hg) and TPH. The levels of heavy metals at each station were generally none to very low. When compared to the average levels found in Jamaican soils, all values were below reported average.

Bathymetry

The Long Bay shoreline in Negril has a concave shape stretching from Bloody Bay in the north to west end just beyond the south Negril River. The overall length is approximately 7 km with an average beach width average width of approximately 15 m. The shallow coastal shelf has a depth between 4 m and 12 m, and extends up to 2 km offshore whereas the continental shelf is approximately 3km offshore. There is a 500m long patch reef located 1.4 km offshore in front of the central and widest section of beach, and a fringing reef situated 2 – 3km offshore on the outer shelf of the reef.

Currents

Information on currents 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. ADCP measured currents were generally in a north-south direction and the average recorded current speeds were below 0.2m/s. Two- two-day drogue tracking missions were executed during which four (4) surface and four (4) sub-surface drogues were deployed at fifteen (15) offshore locations. Between September 26 and 27 the current speeds varied from between 1.9 cm/s to 15.9 cm/s and 1.7 cm/s to 10.1 cm/s for the surface and sub-surface drogues respectively. Between October 16 and 17 these current speeds varied from between 1.8 cm/s to 17.8 cm/s and 2.6 cm/s to 16.8 cm/s for the surface and sub-surface drogues respectively. The current speeds are generally higher for the falling tides than for the rising tide session.

Wind

The NOAA long term wind wave data model was searched for long term wind data for Negril. Analysis of this data revealed that overall the average wind speed and direction is between 2 to 4m/s from the ENE. Current wind data was collected for the days on which drogue tracking exercise were carried out. The majority of the winds were out of the NE to SE directions with averaged hourly speeds of up to 5m/s. The second period had fewer variations in terms of wind directions and speeds. Wind speeds were mostly between 1 and 3.5m/s whereas the majority of the winds were out of the SSE.

Grain Size Analysis of Shoreline Sediments

Sand samples were collected for analysis from both the beach face and back of the beach at 6 locations along the shoreline. Grain size analysis was done using the Unified Soil Classification System (USCS). All the samples analysed had uniformity coefficient less than 6; this indicates the wave climate arriving at the shoreline is on the aggressive side, causing the particle sizes to be poorly graded. Also, the samples collected were all well sorted as and this is indicative of relatively high wave energy at the shoreline which sorts the particles into their discrete sizes.

Past Erosion Events and Anecdotal Data

Anecdotal data collected indicated hurricanes Gilbert and Ivan and were among the worst storms to have affected the Negril shoreline in recent years. The respondents revealed that employees and residents in the area manually remove or reshape sand accretion and debris after the passing of a storm event thereby minimizing the short term recovery time.

Beach Profile

NEPA provided CEAC with beach profile information collected at the benchmarks located at Sandals, Swept Away and Negril Gardens – a northern, central and southern point along the beach respectively. These profiles show that after the passage of Hurricane Sandy the beach in the vicinity of Sandals eroded by 3 m while at Negril Gardens there was 1 m of accretion following the same event. The profile at Swept Away shows that after the passing of Tropical Storm Nicole in 2010 no erosion took place, the beach was stable.

Geotechnical Description

The substrate was inspected during biophysical assessments to be primarily pavement throughout the footprint of the structures.

Climate Change Considerations

The IPCC projects that because of global warming global sea levels will continue to rise through to the 21$^{st}$ century at a rate of 3.7 mm/year, they also project that the annual mean significant wave heights will decrease marginally by 1 – 2% resulting in a marginal decrease in the operational wave height.

Deep Water Wave Climate

*Hurricane Waves*

Analysis of the National Hurricane Center (NOAA) database of hurricane track data revealed that 128 hurricane systems came within 300 kilometres of the project area, 9 of which were classified as catastrophic (Category 5) and 21 were classified as extreme (Category 4). 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. Hurricane waves originating from the west (W) are the most severe of all the directions investigated, followed closely by the south westerly (SW) winds. The 100-year return period event has a wave height of 6.2 m for western waves.

*Hurricane Storm Surge and Winds*

The maximum storm surge that is estimated for this location for the 100 year event is approximately 1.25m. The Software programme CRESS (Coastal and River Engineering Support System) was utilized to estimate run-up. The estimated wave run-up levels range from 1.18m to 2.51m for the 2 to 100 year hurricanes and were added to the model predicted storm surge results.

*Near Shore Wave Climate Analysis (Hurricane)*

- *Pre-Project Scenario* - Wave plots generated from the model showed that during hurricane conditions, wave heights of up ranging from 1.8 – 3.1m and 1.9 to 3.6m reaches the shoreline from the NNW, NW, W and SW directions for 50 and 100 year return periods respectively.
- *Post-Project* - The implementation of the two breakwaters resulted in a reduction in the magnitude of hurricane waves reaching the shoreline to 1.5 to 2.5m and 1.6 to 2.8m for the 50 and 100 year return period respectively. The smallest wave heights observed reaching the central and northern section of the bay.
- *Future Climate* - Hurricane waves (50 and 100 year return periods) had impacts on the shoreline as wave setup increased from 1.15m and 1.25m to 1.29m and 1.39 m for the 50 and 100 year return period respectively.

Shoreline Vulnerability

An overall level of erosion was observed at a rate between 0.2 m/year and 1.4 m/year. Over the past 45 years, a maximum of 62.6 metres of erosion has occurred on the Negril beach. These results also indicate that the central section of the beach is the most vulnerable to long term as well as short term erosion. The 2050 shoreline was projected and this highlighted the fact that most of the erosion is expected to take place between chainages 2+500 and 4+500. The overall maximum erosion expected to occur could be as much as 43.2m over the next 37 years.

Hydrodynamic and Sediment Dispersion Modelling

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. An overall average decrease of around 22 percent is estimated with the construction of the breakwaters. Flushing times will increase by 13 to 16% (to 3.4 to 4.1 days), and will be well within estimated required time limits (6 to 7 days) to prevent eutrophication. The proposed structures will therefore not have an adverse effect on the flushing time of the bay.

Traffic

The proposed project is anticipated to generate a total of 3,653 truck/trailer trips over a 6 month period to deliver the boulders; this equates to approximately 28 truck trips per day.

Ambient Particulates (PM 2.5 & PM 10)

PM2.5 and PM10 particulate sampling was conducted for 24 hours each, on two separate occasions, using Airmetrics Minivol Tactical Air Samplers. Sampling was conducted at three (3) locations in the vicinity of the staging area. For both the PM 10 and PM 2.5 sampling events all locations had particulate values compliant with the 24-hour US EPA standards.

Noise

*Ambient Noise*

A data logging noise survey exercise was conducted using Quest Technologies SoundPro DL Type 1 hand held sound level meters. All locations had noise levels compliant with the NEPA daytime and night time noise guidelines.

*Noise Prediction*

Noise prediction was done by using SoundPlan 7.3 software with the Federal Highway Administration (FHWA) TNM module. Along the Negril to Sheffield main road, approximately 56% or 9 out of the 16 locations accessed already had noise levels exceeding the NEPA daytime noise standard. Along the Norman Manley Boulevard, approximately 90% or 69 out of the 77 locations accessed already had noise levels exceeding the NEPA daytime noise standard.

## *Biological*

Benthic Community

*Breakwaters, Reef Crest/Forereef and Dive Sites*

Benthic surveys were conducted using 100m long transect line with a 0.7 x 0.7 m photo quadrat (0.5$m^2$ area). Pictures were taken every metre along the line and analysed using CPCE. A total of 3 transect lines in the northern breakwater (150 $m^2$), 2 in the southern (100 $m^2$), 3 in-between (reef crest/forereef) and 1 at each dive site was conducted. The proposed locations of both the northern and southern breakwaters occur in pavement zone areas. The low-relief, high wave action, heavy usage by divers and fishermen along with other natural and anthropogenic stresses have caused this community to be dominated by macroalgae, with low coral species diversity and few other invertebrates. The algal community is composed of fleshy macroalgae and turfs, with little calcareous (Halimeda) or coralline algae present. The CPCE analysis indicates a coral community with a percent cover less than or equal to 1% in both breakwater footprints. The coral community is dominated by small encrusting colonies of *Siderastrea* sp. Both soft corals (various species of seawhips and fans) as well as the sponge community are also located with holdfasts and bases on pavement.

*Groyne Assessment*

The groyne is covered by large numbers of fleshy macoralgae, coralline algae, sponges, hard corals and many other invertebrates (i.e. urchins, bivalves and lobsters). The coral community was composed of several large colonies including *Montastrea annularis, Porites asteroides* and *Diploria sp*. Numerous small colonies of *Siderastrea sp*. were also seen on the groyne as well as dislodged pieces alongside.

*Seagrass and Backreef Communities*

Seagrass beds of varying densities were located within the backreef and consisted mainly of *Thalassia sp*. and *Syringodium sp*. Areas of mixed beds were also observed in close proximity to the reef crest. This area was also covered with algae and had several patch reefs behind the crest.

<u>Phytoplankton and Chlorophyll a</u>

A 5L Niskin bottle was used to collect whole water samples at eighteen (18) stations within Long Bay. The phytoplankton community of Long Bay, Negril is highly diverse and dominated by small diatom species. Seventeen percent (17%) of the species comprising the community are classified as rare with 7% classified as potentially toxic. Phytoplankton abundance and biomass concentrations are both low despite the high number of species and this data combined with the moderately high diversity values suggests that the water quality of the area is presently mesotrophic.

<u>Fish Counts</u>

Fish counts were conducted at each dive transect location using roving fish count methods defined for the Atlantic Gulf Rapid Reef Assessment (AGRRA) protocol. The lowest numbers of fish species (10 species) were observed within the North and South breakwater area. In comparison, the recreational dive sites, Throne Room and Sharkreef, showed the highest species diversity of 23 and 25 respectively. Within the North breakwater area, the dominant fish was the French Gruntfish with the majority within the 11-20cm size class. Barjacks, Parrotfish and Damselfish were also numerous with most being on the smaller size classes. Barjack dominated the area for the South breakwater within the 6-10 cm size class. The richness of each species was generally low at these two sites with the exception of barjacks, which had high numbers at both areas.

### *Human/Social*

The Social Impact Area (SIA) for this study was demarcated as four (4) kilometres from the proposed breakwater footprints. This impact area traverse two parishes, namely Hanover in its northern section and Westmoreland in its southern, and encompasses sections of three communities, namely Orange Bay, Negril and Sheffield. Population data were extracted from the STATIN 2011 and 2001 Population Census database for the SIA by enumeration district.

<u>Demography</u>

At the time of this study (2013), the population was approximately 4,698 persons and is expected to reach 7,840 persons over the next twenty five years if the current population growth rate remains the same. Sex ratio for the SIA was calculated to be 114.5 males per one hundred females. The child dependency ratio for the SIA in 2011 was 377.3 per 1000 persons of labour force age; old age dependency ratio stood at 62.2 per 1000 persons of labour force age; and societal dependency ratio of 439.5 per 1000 persons of labour force. The overall population density was calculated to be 193.6 persons/km$^2$ and the largest concentrations of the SIA population are located south of the SIA in the Negril, Whitehall and Westlands areas in the parish of Westmoreland. The SIA population generally does not have more than 15% of persons living in poverty. There were 1,140 housing units, 1,278 dwellings and 1,352 households within the SIA in 2001. The average number of dwellings in each housing unit was 1.1 and the average household to each dwelling was similarly 1.1. The average household size in the SIA was 2.7 persons/ household.

Infrastructure and Services

The parishes of Westmoreland and Hanover, as well as the study area are served with landlines provided by LIME Jamaica Limited. Wireless communication (cellular) is provided by LIME and Digicel Jamaica Limited. A network to support internet connectivity is also provided by LIME and Flow. Seventy-five percent (75.1%) of the households within the SIA received their domestic water supply from a public source, namely the National Water Commission (NWC) in 2001. The majority of households used water closet disposal methods (60.1 %) and had their garbage collected by public means (National Solid Waste Management Authority) (69.8%).

One health centre exists within the SIA, namely Negril Health Centre towards the southern section of the SIA in the town of Negril. There are currently no public or private hospitals within the SIA. One fire station, Negril Fire Station is located in Red Ground, approximately 3.5 km south of the proposed breakwaters and one police stations (Negril Police Station) is situated about 3 km south of the southern breakwater. The Negril Post Office is the only post office located within the demarcated SIA.

Marine and Beach Use

*Tourism*

Negril has a total of 5,350 rooms, which represents 25.5% of all rooms in the island. In 2012, average room capacity grew by 0.7%, whilst total room nights sold increased by 4.0%. For the Negril area, hotel room occupancy was 61.3% in 2012, which shows an increase of 2.8% from 2011. In 2011, it was estimated that the average number of employees per room in Negril was 1.23. In addition to this direct employment, the tourism industry in Negril also gives rise to a number of indirect and induced jobs; in 2012, it can be estimated that in Negril another 18,730 jobs were indirectly generated or induced.

*Snorkel and Dive Sites*

Of the 48 snorkel and dive sites within the Negril area, five are less than 100 m away from the northern breakwater.

*Fisheries*

A "Fishing Village" is located near the mouth of the South Negril River and in the Negril area, there are currently 349 registered fishers, with 3 persons per vessel (by email correspondence Junior Squire, Fisheries Division/CL Environmental).

*Protected Areas and Zoning*

Of particular interest to this study, are the Negril/ Green Island Development Order, the Negril Environmental Protection Area (EPA) and the Negril Marine Park, as the proposed breakwaters are located within the extents of these boundaries.

*Historical/Cultural Heritage*

There is only one JNHT Heritage Sites in the vicinity of the study area, namely Negril Point Lighthouse which is a national landmark.

Community Consultation and Perception

*Social Survey*

A total of 344 questionnaires were administered in the Negril SIA in order garner feedback from persons whose livelihoods or recreational activity depend on the beach and bay. Key groups considered included persons residing within the SIA communities, fishers, watersports operators, tourists, as well as shops/ stalls and persons providing other services along Long Bay beach.

# IDENTIFICATION OF POTENTIAL IMPACTS

## *Impact matrix for site preparation and construction phases of breakwaters*

| ACTIVITY / POTENTIAL IMPACT | DIRECTION | | DURATION | | LOCATION | | MAGNITUDE | | | EXTENT | | | SIGNIFICANCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Pos** | **Neg** | **Long** | **Short** | **Direct** | **Indirect** | **High** | **Moderate** | **Low** | **National** | **Regional** | **Local** | **Large** | **Medium** | **Small** |
| **1. Site Preparation and Construction** | | | | | | | | | | | | | | | |
| **Biological Impacts:** | | | | | | | | | | | | | | | |
| Impact on coral communities: | | | | | | | | | | | | | | | |
| Direct loss and removal (within breakwater footprint) | | X | X | | X | | | X | | | | X | | X | |
| Indirect (e.g. smothering from sediment, reduced water quality) | | X | | X | | X | | X | | | | X | | X | |
| Indirect impact on seagrass communities (e.g. smothering from sediment, reduced water quality) | | X | | X | | X | | X | | | | X | | X | |
| Fish and invertebrate displacement | | X | | X | X | | | | X | | | X | | | X |
| Loss of natural habitat (pavement zone) | | X | X | | X | | | X | | | | X | | X | |
| Habitat fragmentation (seagrass, coral etc.) | | X | X | | X | | | X | | | X | | | X | |
| **Physical Impacts:** | | | | | | | | | | | | | | | |
| Increased noise pollution | | X | | X | X | | | | X | | | X | | | X |
| Sedimentation of marine environment | | X | | X | X | | | X | | | | X | | X | |
| Increased water pollution (oils, solid waste etc.) | | X | | X | X | | | X | | | X | | | X | |
| Increased accident potential | | X | | X | X | | | X | | | | X | | X | |
| Visual aesthetics | | X | | X | X | | | | X | | | X | | | X |
| **2. Transport** | | | | | | | | | | | | | | | |

| ACTIVITY / POTENTIAL IMPACT | DIRECTION | | DURATION | | LOCATION | | MAGNITUDE | | | EXTENT | | | SIGNIFICANCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pos | Neg | Long | Short | Direct | Indirect | High | Moderate | Low | National | Regional | Local | Large | Medium | Small |
| Potential spillage of material and harmful substances (oils, gasoline etc.) | | X | | X | X | | | | X | | | X | | | X |
| Increased maritime traffic | | X | | X | X | | | X | | | | X | | X | |
| **4. Construction Crew** | | | | | | | | | | | | | | | |
| Solid waste management | | X | | X | X | | | | X | | | X | | | X |
| Workers safety | | X | | X | X | | | | X | | | X | | X | |
| **5. Socioeconomics** | | | | | | | | | | | | | | | |
| Local fishing community | | | | | | | | | | | | | | | |
| Logistic changes (e.g. travel route, times, increased costs) | | X | X | | X | | | X | | | X | | | X | |
| Reduced access to fishing area | | X | | X | X | | | | X | | | X | | | X |
| Impact on watersports operations and other maritime activities | | X | X | | X | | X | | | | | X | | X | |
| Impact on retail and other services along Long Bay | | | | | | | | | | | | | | | |
| Increased number of clients(construction workers) | X | | | X | | X | | | X | | | X | | | X |
| Decrease in tourist clientele | | X | | X | | X | | | X | | | X | | | X |
| Employment | X | | | X | X | | | X | | | | X | | | X |

### *Impact matrix for site preparation and construction phases of staging area*

| ACTIVITY / POTENTIAL IMPACT | DIRECTION | | DURATION | | LOCATION | | MAGNITUDE | | | EXTENT | | | SIGNIFICANCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pos | Neg | Long | Short | Direct | Indirect | High | Moderate | Low | National | Regional | Local | Large | Medium | Small |
| **1. Site Preparation and Construction** | | | | | | | | | | | | | | | |
| **Marine Biological Impacts:** | | | | | | | | | | | | | | | |

| ACTIVITY / POTENTIAL IMPACT | DIRECTION | | DURATION | | LOCATION | | MAGNITUDE | | | EXTENT | | | SIGNIFICANCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pos | Neg | Long | Short | Direct | Indirect | High | Moderate | Low | National | Regional | Local | Large | Medium | Small |
| Impact on coral communities (e.g. smothering from sediment, reduced water quality) | | X | | X | | X | | X | | | | X | | X | |
| Impact on seagrass communities (e.g. smothering from sediment, reduced water quality) | | X | | X | | X | | X | | | | X | | X | |
| Fish and invertebrate displacement | | X | | X | X | | | X | | | | X | | | X |
| **Physical Impacts:** | | | | | | | | | | | | | | | |
| Increased pollutants in the air shed | | X | | X | X | | | X | | | | X | | X | |
| Increased noise pollution | | X | | X | X | | | X | | | | X | | X | |
| Dredging and filling | | X | | X | X | | | X | | | | X | | X | |
| Sedimentation of marine environment | | X | | X | X | | | X | | | | X | | X | |
| Increased water pollution (oils, solid waste etc.) | | X | | X | X | | | X | | | | X | | X | |
| Visual aesthetics | | X | | X | X | | | X | | | | X | | X | |
| **2. Construction Works** | | | | | | | | | | | | | | | |
| Refueling of vehicles and fuel storage | | X | | X | X | | | X | | | | X | | X | |
| Increased accident potential | | X | | X | X | | | X | | | | X | | X | |
| Repair of vehicles and marine vessels | | X | | X | | X | | | X | | | X | | | X |
| **3. Material Storage and Transport** | | | | | | | | | | | | | | | |
| Spillage of boulders and other material | | X | | X | X | | | X | | | X | | | X | |
| Traffic congestion and road wear | | X | | X | X | | | X | | | X | | | X | |
| Suspended solid runoff | | X | | X | | X | | X | | | | X | | X | |
| **4. Construction Crew** | | | | | | | | | | | | | | | |
| Sewage/wastewater generation | | X | | X | X | | | | X | | | X | | | X |
| Solid waste management | | X | | X | X | | | | X | | | X | | | X |
| Workers safety | | X | | X | X | | | | X | | | X | | X | |
| **5. Socioeconomics** | | | | | | | | | | | | | | | |
| Local fishing community | | | | | | | | | | | | | | | |
| Logistic changes | | X | | X | X | | | X | | | | X | | X | |
| Improved river access | X | | X | | X | | | X | | | | X | | X | |
| Impact on retail and other services | | | | | | | | | | | | | | | |

| ACTIVITY / POTENTIAL IMPACT | DIRECTION | | DURATION | | LOCATION | | MAGNITUDE | | | EXTENT | | | SIGNIFICANCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pos | Neg | Long | Short | Direct | Indirect | High | Moderate | Low | National | Regional | Local | Large | Medium | Small |
| Increased number of clients(construction workers) | X | | | X | | X | | | X | | | X | | | X |
| Decrease in tourist clientele | | X | | X | | X | | | X | | | X | | | X |
| Employment | X | | | X | X | | | X | | | | X | | X | |
| Traffic flow and access roads | | X | | X | X | | | X | | | X | | X | | |

## *Impact matrix for operational phase of breakwaters*

| ACTIVITY / POTENTIAL IMPACT | DIRECTION | | DURATION | | LOCATION | | MAGNITUDE | | | EXTENT | | | SIGNIFICANCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pos | Neg | Long | Short | Direct | Indirect | High | Moderate | Low | National | Regional | Local | Large | Medium | Small |
| **1. Biological Impacts** | | | | | | | | | | | | | | | |
| Increase in suitable recruitment substrate for coral communities | X | | X | | X | | | | X | | | X | | X | |
| Indirect impact on seagrass communities (e.g. changes in current regime, reduced water quality) | | X | X | | | X | | X | | | | X | | X | |
| Fish and invertebrate colonization (FAD) | X | | X | | X | | | X | | | | X | | X | |
| Increase ecological volume (new artificial habitat) | X | | X | | X | | | X | | | | X | | X | |
| Habitat fragmentation (seagrass, coral etc.) | | X | X | | X | | | X | | | X | | | X | |
| **2. Physical Impacts** | | | | | | | | | | | | | | | |
| Reduced flushing time (decreased water quality) | | X | X | | X | | | X | | | | X | | X | |
| Reduced wave heights and current speeds (swimmer safety) | X | | X | | X | | | X | | | | X | | X | |
| Reduction in wave energy and beach erosion | X | | X | | X | | | X | | | | X | X | | |
| Visual aesthetics | | X | X | | X | | | | X | | | X | | | X |
| **3. Maritime Activity** | | | | | | | | | | | | | | | |
| Increased accident potential (maritime vessels) | | X | X | | X | | | | X | | | X | | | X |

| ACTIVITY / POTENTIAL IMPACT | DIRECTION | | DURATION | | LOCATION | | MAGNITUDE | | | EXTENT | | | SIGNIFICANCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Pos** | **Neg** | **Long** | **Short** | **Direct** | **Indirect** | **High** | **Moderate** | **Low** | **National** | **Regional** | **Local** | **Large** | **Medium** | **Small** |
| Recreational safety (swimmers, snorkelers, divers etc.) | X | | X | | X | | | | X | | | X | | | X |
| **4. Socioeconomics** | | | | | | | | | | | | | | | |
| Logistic changes to local fishing (e.g. travel route, times, increased costs) | | X | X | | X | | | X | | | X | X | | X | |
| Impact on watersports operations and other maritime activities | | | | | | | | | | | | | | | |
| Changes in logistics | | X | X | | X | | X | | | | | X | | X | |
| Additional dive/snorkel site option | X | | X | | X | | | | X | | | X | | | X |
| Increased number of clients (retail and other services along Long Bay) | X | | X | | | X | | | X | | | X | | X | |

## 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 is 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) Traffic
5) Maritime Operations
6) Solid Waste Generation and Disposal
7) Sewage Generation and Disposal
8) Equipment Maintenance
9) Health and Safety

## PUBLIC PARTICIPATION AND CONSULTATION

To date, public consultation has included a perception survey (community, watersports operators, fishers, tourists and shops/stalls/ mobile), stakeholder meeting and focus group meetings. In addition, one (1) Public Presentation will be scheduled and this will be conducted in the manner as outlined in NEPA's "Guidelines for Conducting Public Presentations". 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 EIS report.

# 2.0 INTRODUCTION

## 2.1 PROJECT BRIEF

The Government of Jamaica through the Planning Institute of Jamaica (PIOJ) has implemented the "*Enhancing the Resilience of the Agriculture Sector and Coastal Areas to Protect Livelihoods and Improve Food Security Project*". This project falls under the Adaptation Fund Programme and is being executed by the National Environment and Planning Agency (NEPA), the National Works Agency (NWA), the Ministry of Agriculture and Fisheries and the Ministry of Tourism. The main components of the project are as follows[1]:

> **Component 1:** Protect Negril's beaches from coastal erosion caused by intense storms and sea-level rise by building breakwater structures
>
> **Component 2:** Enhancing the climate resilience of the agricultural sector by improving water and land management practices through water storage, soil conservation, microdams, small-scale irrigation, and other initiatives
>
> **Component 3:** Improving institutional and local level capacity for coastal and agricultural adaptation and awareness raising for behaviour modification through training, the design of replicable technical standards, and spreading information on effective adaptation measures

Under Component 1 of the larger project, the "*Construction of Break Water Structures Offshore Negril (Negril Breakwaters)*" sub-project was formulated to rehabilitate and protect the Negril coastal area, thereby making the coastline more climate-resilient. CEAC Solutions Limited has been commissioned by the NWA to provide technical assistance to plan, execute and monitor construction operations for the Negril breakwaters. The subproject is conceptualized in three phases, specifically:

- **Phase 1** – The preparation of the Bid document; completion of engineering design works; and preparation of EIA.
- **Phase 2** – The engineering consultancy and assistance during implementation and construction.
- **Phase 3** – The post-construction monitoring of the structure and relocated sensitive species.

As part of Phase 1, an Engineering Design Report covering the engineering design aspects of the project was drafted by CEAC Solutions and submitted to NWA in December 2013. Also as part of

[1] https://www.adaptation-fund.org/project/enhancing-resilience-agricultural-sector-and-coastal-areas-protect-livelihoods-and-improve-f

Phase 1, an Environmental Impact Assessment (EIA) was undertaken, the results of which are presented in this document.

## 2.2 PROJECT RATIONALE

### 2.2.1 Erosion Problem and Previous Studies

PIOJ in recognizing Jamaica's vulnerability to climate change hazards and in particular Negril's vulnerability applied to the Adaption Fund for financing. This detailed proposal sets out the proposal and the engineering considerations. Negril beach has been experiencing a long-term erosion trend that has been properly documented over the past forty years by at least three studies in the last ten (10) years. Previous studies have pointed to the combination of human and natural factors that have resulted in the erosion and degraded state of the coral reef and seagrass beds. No study has definitively partitioned the role of the factors, however, RiVAMP noted that Sea Level Rise cannot explain the observe rates alone. And that increase in regional wave climate intensities and reductions in coastal ecosystems area coverage have diminished both the natural protection and sand production. The increase in storm intensity is also likely to remove seagrass beds, which produces sand. The increased storm intensities are probably the reason why large amounts of seagrass are dumped by waves on the shoreline after storms. This background clearly points to the need to enhance reef and structural intervention to protect seagrass beds that play an important part in protecting and maintaining Negril's beaches.

The erosion trend along the Negril beach, Long Bay, Westmoreland and Hanover is well known and documented (Plate 2-1 through to Plate 2-4). It is stated that erosion rates are between 0.5 metre and 1.0 metre per annum, with sections of the shoreline having lost between 20 and 55 metres of beach in this period, with some sections losing more than 70 metres. This 40-year problem facing Negril has attracted numerous studies focused on studying the causes of the beach erosion and researching various mitigation measures. Studies included those undertaken by the University of the West Indies (UWI) (2002), Smith Warner International Limited (SWIL) (2007) and the United Nations Environment Programme (UNEP) in collaboration with the Planning Institute of Jamaica (PIOJ) (2010). Prior to these, a comprehensive study on Long Bay was undertaken by Hendry (1982).

***Source: Unknown***

*Plate 2-1 Erosion that occurred along Long Bay beach as a result of Hurricane Michelle, November 2001*

*Plate 2-2 Photographic comparison between November 2004 eroded beach (top) and November 2005 recovery period (bottom) at same stretch of beach within central section of Long Bay*

***Source: Marine Geology Unit, UWI Mona***

*Plate 2-3 Erosion along central part of Long Bay as a result of damage from Hurricane Ivan, 10 November, 2004*

***Source: (Smith Warner International Limited 2007)***

*Plate 2-4 Photograph looking north of Foote Prints hotel, Long Bay Negril*

As outlined in SWIL's 2007 report, the erosion problem in Negril has worsened owing to a series of hurricanes and severe swell events, in addition to other factors which some believe include the erection of seawalls and infrastructure along the shoreline. The erosion pattern is not observed to be constant along Long Bay and as reported by the Department of Geography and Geology, UWI, there are four varying erosion behaviours that differentiate the beach into sections as follows:

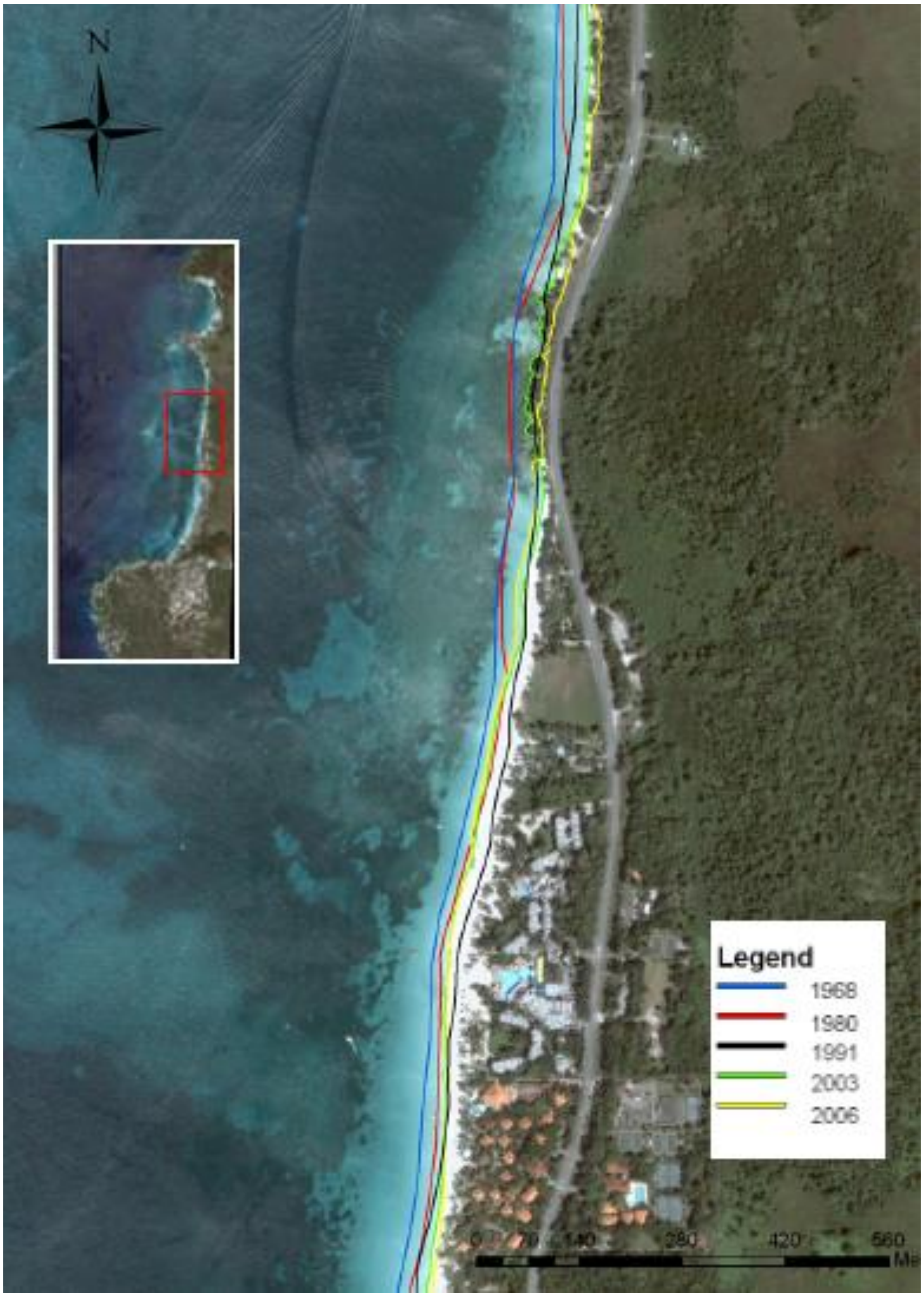
1) Hedonism south to the UDC Beach - constant erosion.
2) North of Cosmos to just south of Swept Away - accretion

3) North of Foote Prints to just south of Crystal Waters - cycles of erosion followed by recovery.
4) Chances to the South Negril River - relatively stable.

SWIL assessed the erosion trends by utilising historical beach profile data, historical aerial photographs and recent satellite imagery. It was found that the beach widths along the entire length of coastline vary by about ±30m annually. In terms of long term trends over the past 40 years, the beach along Long Bay was said to have been dominated with erosion totalling approximately 40m (not occurring at constant rate), with some periods of accretion. Figure 2-1, Figure 2-2 and Figure 2-3 showcase the shoreline trends along Long Bay as depicted by SWIL.


***Source: (Smith Warner International Limited 2007)***

*Figure 2-1 Historical shoreline changes, northern Long Bay*




***Source: (Smith Warner International Limited 2007)***

*Figure 2-2 Historical shoreline changes, central Long Bay*


***Source: (Smith Warner International Limited 2007)***

*Figure 2-3 Historical shoreline changes, southern Long Bay*

In addition to studying the nature of the erosion along Long Bay beach, examining various management measures have also been an important aspect. Management responses suggested by the Department of Geography and Geology study included the protection of the biogenic sediment producers (seagrass meadows), as well as beach nourishment and the management of back beach hydrology as alternatives to the use of breakwaters and groynes. Consideration of ecosystems in the assessment of disasters was also a focus of the Risk and Vulnerability Assessment Methodology Development Project (RiVAMP), carried out by UNEP, with the aim of allowing decisions to be made in line with sustainable development through improved ecosystems management. For the UNEP RiVAMP study, existing information (including historical shorelines between 1968 and 2006 and beach profiles from November 2006) were analysed in addition to newly acquired satellite imagery (January 2008) in order to analysis the beach erosion problem in Negril. A number of useful outputs resulted from this project, including spatial ecosystem data, hydrodynamic models, statistical analyses, storm surge exposure models and community-drawn disaster maps for the study area. Similar to results of past studies, this study also showed that the Negril shorelines have been experiencing severe and irreversible erosion and retreat. Further, estimations based on global sea level rise projections and local storm wave predictions showed that the impact on Negril will be devastation – using the lowest projections of accelerated sea level rise (ASLR) for 2060, an extreme 50-year return storm, it was shown that approximately 50 percent of the beach will lose more than half of its present width. The study emphasised the importance of coastal ecosystems and specifically coral reefs and sea grasses protecting the shoreline. It found that beach areas with coral reefs and thick sea grasses located seaward statistically experienced less erosion in the past.

Following the RiVAMP study, the PIOJ was requested to provide detailed costing and information for the revised proposal to the Adaptation Fund for the "*Enhancing the Resilience of the Agriculture Sector and Coastal Areas to Protect Livelihoods and Improve Food Security*" project. Programme objectives identified under the project include:

- Component 1: Increase climate resilience of the Negril coastline.
    - Installation of breakwater structures and
    - Planting and rehabilitation of seagrass beds.
- Component 3: Improving institutional and local level capacity for sustainable management of natural resources and in disaster risk reduction in the targeted vulnerable areas; and raising awareness for behaviour modification.
    - Communication and awareness
    - Training
    - Development of guidelines
    - Development of adaption plans
    - Documentation of lessons from implementation plan

In 2012, CEAC Solutions Co. undertook a study entitled "*Identification of Soft and Hard Engineering Solutions for Negril, Jamaica*" which explored various solutions for the erosion problem in Negril. In this study, both hard and soft solutions were considered. The hard solutions are detailed in section 10.3 of this report; however in summary, four (4) configurations were presented:

1) 2 breakwaters 400m long approximately 300m from the shoreline, in 3.6m of water.
2) 3 breakwaters 264, 350 and 400m long approximately 240m from the shoreline in 2.9 – 3.8m of water.
3) 4 breakwaters, 3 of them 400m long and the other 500m long, they were 1,500m from the shoreline in 4 – 6m of water.
4) 2 breakwaters 480 and 600m long in 4 – 4.2m of water, approximately 1,500 from the shoreline.

Nearshore solutions were not pursued owing to consultations with hoteliers, PC and water sports stakeholders in February 2012 which indicated that near shore structures were not compatible with Negril's tourism product either in the construction or operational phase. CEAC's analysis determined that the above listed Option 4 provided the most benefits, consistent with the SWIL (2007) recommendations for stabilization before nourishment, for the budget available. SWI Integrated solution #4 was modelled and a comparable CEAC reef extension proposal considered. The modification was based upon a salient formation criterion of (total length of reef to distance from shoreline). The intentions of the modification were as follows:

- Minimize rock volume in deepwater by carefully observing the bathymetry and placing the footprint in shallow waters.
- Maximize shoreline response by closing the gap between the reef and breakwater without encroaching on reefs.
- Protect parts of the northern and central portion of Long Bay and the central part

The SWI solution, components relating to the reef extension, envisaged 4 breakwaters, three of which are 400 metres long and the other 500 metres long approximately 1,500 metres from the shoreline. The breakwaters are deep waters of 4 to 6 metres with a lot of the rock volume being used per metre length. The major concern about this option is the depth of water it is located in. Notwithstanding this a modification was considered to optimize this solution, and it was modelled. It consisted of two breakwaters using less material than the SWI proposed solution. The breakwaters would be 480 and 600 metres in length in water depths of 4.0 to 4.2 metres. The advantages of the proposed modified solution being:

- The reduced rock volume because of the shallower water
- Increased stability of the beach in light of the reduced number of gaps in the breakwater.

The effectiveness of the structures can be summarized by the reduction of the wave heights behind the structures. The possibility of improving the performance dramatically by increasing the crest elevation of the structures from 0.7 metres below MSL to MSL was discussed with stakeholders.

The preferred hard structure solution is the Modification of the integrated solution for reef extension. It fits into a range of solutions and offers cost effective protection with the following advantages:

1) It provides wave protection to the most vulnerable section of Long Bay (central and northern portions of Long Bay)
2) The cost of the proposes solution (USD 4.4 Million) is in line with the budget of the project and appreciable less than the comparable solution (USD 11.3 Million), which exceeds the budget considerably.
3) The length of shoreline stabilized (2,009 metres) is proportional to the cost and effectiveness of the comparable solution (4,472 metres).
4) The integrated solution (which is 1,500 metres offshore) is less visually obstructive in both the construction phase and the operational phase, in comparison to the nearshore solutions which are 280 to 300 metres offshore.

The reasons for this choice are further summarized below.

A public consultation was held in Negril on 28th of February, 2012. The consultation with the stakeholders yielded a clear direction on the preferred focus on central and north Long Bay and limitations on the designs to preserve aesthetics by a strong preference for the offshore solution. In summary:

1) The focus on the central and north area of Long Bay is consistent with the shoreline lost observations and thus the reef extension is preferred
2) The crest elevation for the reef extension can be increased from -0.7 metres to Mean Sea Level thus maximizing the effectiveness of the breakwaters. This is in light of the fact that no light crafts are expected to frequent the offshore reef area (one mile from shore).
3) The soft solutions can be done over time with local ENGO efforts and institutional strengthening.
4) The budget of USD 5.0Million should be focused on the hard solutions.

The preferred option was therefore further evaluated and modified for the final proposed design presented in 2013, as the first of several phases to be carried out. It is acknowledged that further stabilization and beach nourishment would be required after this first phase. The proposed follow-up phases are dependent on availability of funding.

The Genesis model developed by the US Army Corps was used to investigate the long term shoreline change. Two options were investigated to maximize or evenly spread the area of stability and growth along the shoreline, they were:

- Option 1: the southern breakwater being 417m and northern breakwater 517m as per the initial design and,

- Option 2: the southern break water extended to 617m in a southerly direction and the northern breakwater shortened by 200m to 317m (on the northern end).

Option 1 resulted in 109,400 cubic metres of accretion over 80 percent (4.95 km) of the shoreline, with an average shoreline growth of 13.5 metres. Most of the growth occurred at the northern section of Long Bay with a maximum predicted growth of 41.7 metres. Option 2 resulted in the 74,100 cubic metres of accretion over 68 percent (4.23 km) of the shoreline, with an average shoreline growth of 5.5 metres. Although Option 2 resulted in a more evenly distributed growth along the shoreline, Option 1 resulted in more accretion along the shoreline and protection to the central and northern section consistent with erosion. Option 1 was therefore preferred, having more positive impact on the shoreline for the investment contemplated.

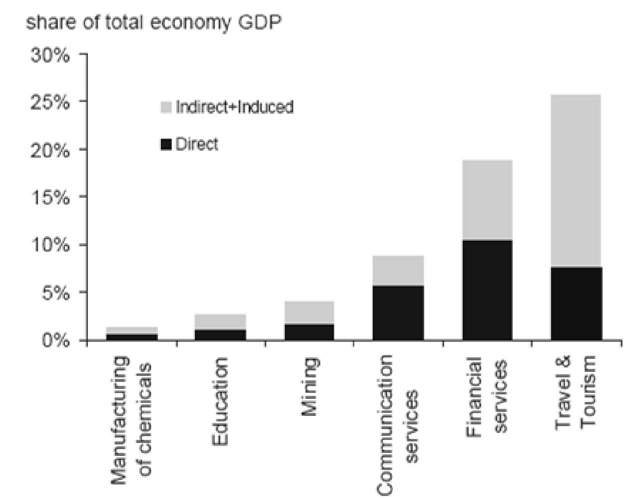
The two breakwaters now proposed are 417 and 517 m long and 1,300 metres offshore in 3 to 4.0 metres of water depth. It should be noted that this solution pertained to the extension of the existing reef structure and did not aim to replace any structure lost from past severe weather. This EIA is based on this 2013 breakwater design.

It should be mentioned that as it relates to soft solutions, seagrass restoration was investigated based on the stated objectives of the initial PIOJ submission/proposal. The assessment of artificial reefs and beach nourishment were considered in the 2012 SWIL study. At the time 30m of beach nourishment in Long Bay and 20m in Bloody Bay were estimated to cost USD 12.5 Million, which is greater than the project budget of USD5.0 Million. In terms of the seagrass replanting option, 100,000 $m^2$ of planting was proposed. At the time this would have cost USD1.0 Million. The focus was also kept on seagrass restoration in the context of both budgetary constraints and the local efforts underway at the time. However this approach was not thought to be prudent based on the meetings held with stakeholders, where they stated that the desired approach was to make seagrass replanting a local institutional capacity activity and to focus resources on protection from extreme waves and the installation of breakwaters.

### 2.2.2 Importance of Long Bay Beach

Situated on the western tip of Jamaica, Negril boasts the longest continuous stretch of white sand beach in Jamaica (approximately 7 km). The shoreline of Long Bay is lined with hotels, bars, villas and restaurants and is a famous holiday spot for tourists and Jamaicans alike. According to the World Travel & Tourism Council (2012), Negril alone accounts for 20.9% of the stopover arrivals for 2012, making this area the third most visited resort area in the island. Further, through the tourism industry, Negril provided the second highest number of direct jobs in Jamaica in 2012 (9,365), accounting for 26.6% within the entire island. Indeed, the "7-Mile Beach", as it is often referred to, is a major attraction for many persons visiting Negril and through this, a number of indirect services that have blossomed along Long Bay as well. These include water sports activities, craft vending, hair braiding and itinerant vending, all of which are income earning activities for the residents in the area.

The beach erosion along Long Bay not only poses a direct threat to the tourist industry in Negril, but nationally as well. On the national scale, Travel & Tourism generated 25.6% of Jamaica's GDP in 2011 based on its direct, indirect and induced GDP impact and was found to be larger than that of the financial services, communication services, and all other sectors in Jamaica. In 2011, Travel & Tourism sustained a total of 0.28 million direct, indirect, and induced jobs in Jamaica (World Travel & Tourism Council 2012) and directly employs more persons than the financial services, education, communication services, and chemicals manufacturing sectors.




***Source: World Travel & Tourism Council, 2012***

*Figure 2-4 Jamaica GDP impact by industry*

Long Bay beach also contributes to the fishing industry. Within the fishing industry, approximately 14.4% of registered vessels[2] and 15% of registered fishers[3] in Jamaica were collectively located in the parishes of Hanover and Westmoreland in 2008 (Ministry of Agriculture and Fisheries).

2 http://www.moa.gov.jm/Fisheries/data/Number%20and%20percentage%20of%20registered%20vessels%20by%20parish%202008.pdf

3 http://www.moa.gov.jm/Fisheries/data/Number%20and%20percentage%20of%20registered%20fishers%20by%20parish%202008.pdf

# 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[4]:

- 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

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

that will review 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.
- An EIA is required for this development. The scope of the EIA through the Terms of Reference (TORs) were approved NEPA (Appendix 1).
- 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 expects the development to have on the environment, compared to the environment that would remain if there were no development. This 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).
- Fourteen copies of the finalised draft are then submitted to NRCA, two to the client, and the consultant keeps one (17 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.

The list of the study team members are found in Appendix 2.

#### *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)*

**Description**

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. The Development Order enables the Local Planning Authority and/or the Town and Country Planning Authority to regulate land developments within the area defined as the Development Order Area. 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.

**Associated Agency**

- Natural Resources Conservation Authority (NRCA)/ National Environment and Planning Agency (NEPA)
- Town and Country Planning Authority (TCPA) - Negril Green Island Area Local Planning Authority (NGIALPA)
- Local Planning Authorities (Parish Councils) - Hanover and Westmoreland Parish Councils

**Relevance to Proposed Project**

As seen in Figure 3-1, the Development Order relevant to this proposed is the Negril and Green Island Area Development Order, which is "called in" by the TCPA. Detailed information regarding the boundary of the area and provisions necessary or expedient for prohibiting or regulating development in the order area is presented in section 6.3.3 (Marine and Beach Use) and illustrated in Figure 6-105.

The Negril Green Island Area Local Planning Authority (NGIALPA) is the local planning authority responsible for the Negril and Green Island Area Development Order area. The main objectives of the NGIALPA are:

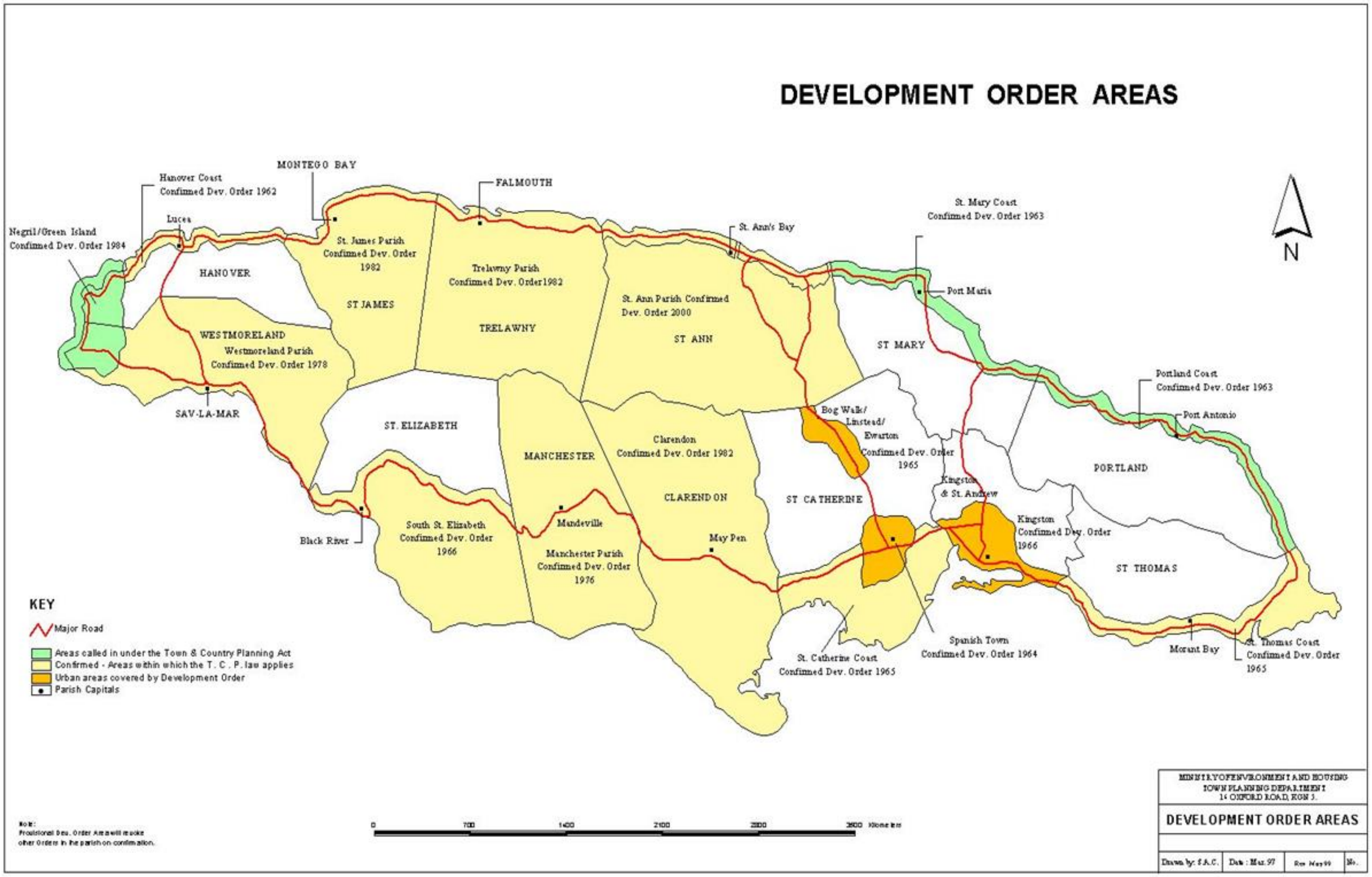
a. The orderly and progressive development of land described in the Development Order. However, the Negril Development Order area is "called in" by the TCPA and therefore the main functions of the NGIALPA are advisory and enforcement of planning control.
b. To administer the proper management of the assets of the NGIALPA.

It should be noted that the NGIALPA is not a Parish Council, however has similar planning functions as other local planning authorities. The NGIALPA falls under the purview of the Minister of Water, Land, Environment and Climate Change. The powers and duties of the NGIALPA are declared to be the powers and duties conferred or imposed on the local planning authority by the Town and Country Planning Act.

The NGIALPA Board consists of representatives from the Hanover and Westmoreland Parish Councils and Negril organisations, including the Negril Area Environmental Protection Trust (NEPT), Negril Chamber of Commerce (NCC), and the Jamaica Hotel and Tourism Association (JHTA).

One of the main functions of interest to the project is the granting or refusal of permission for development, which is undertaken by the local planning authority. A local planning authority receives and considers development applications and having regard to the provisions of the Development Order, and any other material considerations, to which the land which is the subject of the application relates. The local planning authority may grant permission either unconditionally or subject to such conditions as the authority thinks fit or it may refuse permission. However, this function has been "called in" by the Town and Country Planning Authority. Any application for permission to develop land shall be referred to the TCPA instead of being dealt with by the NGIALPA, the local planning authority for the area. The NGIALPA appointees cannot approve these applications, however recommends approval or refusal for applications for planning permission, which are then submitted to the TCPA for approval. Other applications which are not called in are processed and determined by the NGIALPA, for example, residential applications within an approved subdivision scheme.

Of note as well, is the Negril Royal Palm Reserve, which is a specified Tree Preservation Area under this Act, and is mentioned here as it is located in proximity of the proposed breakwaters.




***Source: National Environment and Planning Agency*[5]**

*Figure 3-1 Development Order Areas in Jamaica*

5 http://www.nepa.gov.jm/symposia_03/Laws/Maps/Map_of_Development_Orders.htm

#### *3.2.1.2 Parish Councils Act 1901 (Amended2007)*

**Description**

Under the Parish Council Act each Local Planning Authority 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.

Associated Agency

- Local Planning Authorities (Parish Councils)

**Relevance to Proposed Project**

As mentioned previously, the Negril Green Island Area Local Planning Authority (NGIALPA) is the local planning authority with responsible for development within the study area for the proposed project. Though the NGIALPA is not a Parish Council, it has similar planning functions as other local planning authorities. Detailed information is described in section 3.2.1.1 (The Town and Country Planning Act (TCP Act) 1957 (Amended 1987)).

#### *3.2.1.3 The Exclusive Economic Zone Act 1993*

**Description**

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.

**Associated Agency**

Administered by:

- Ministry of Foreign Affairs and Foreign Trade

As it pertains to designation of Marine Officers:

- Customs and Excise Department
- National Environment and Planning Agency (Game Warden approved under the Wild Life Protection Act 1945)
- Jamaica Constabulary Force

- Jamaica Defence Force
- Fisheries Division (Fishery Inspector under the Fishing Industry Act 1975)

**Relevance to Proposed Project**

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

**Description**

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. 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

**Associated Agency**

Administered by:

- Ministry of Foreign Affairs
- Maritime Authority of Jamaica

As it pertains to designation of Marine Officers:

- Customs and Excise Department
- National Environment and Planning Agency (Game Warden approved under the Wild Life Protection Act 1945)
- Jamaica Constabulary Force
- Jamaica Defence Force
- Fisheries Division (Fishery Inspector under the Fishing Industry Act 1975)

**Relevance to Proposed Project**

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

**Description**

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.

**Associated Agency**

- Port Authority of Jamaica

### *3.2.1.6 The Harbours Act 1874*

**Description**

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.

**Associated Agency**

- Harbour Department, Port Authority of Jamaica (headed by the Harbour Master)

### *3.2.1.7 The Shipping Act 1998*

**Description**

The Act speaks to 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.

**Associated Agency**

Administered by:

- The Maritime Authority of Jamaica

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

**Description**

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. 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

**Associated Agency**

Administered by:

- Natural Resources Conservation Authority/National Environment and Planning Agency

**Relevance to Proposed Project**

The Beach Control Authority (Licensing) Regulations of 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.

#### *3.2.1.9 The Jamaica National Heritage Trust Act 1985*

**Description**

The Jamaica National Heritage Trust Act has been in operation since 1985 with the main goal of preserving and protecting the country's national heritage. 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.

**Associated Agency**

Administered by:

- Jamaica National Heritage Trust (JNHT)

#### *3.2.1.10 The Quarries Control Act 1984 and the Quarries Control (Amendment) Act 1994*

**Description**

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.

**Associated Agency**

Administered by:

– Mines and Geology Division, Ministry of Water, Land, Environment and Climate Change

**Relevance to Proposed Project**

It is an offence to open, establish or operate a quarry to extract quarry material or mineral without a licence.

#### *3.2.1.11 The Mining Act 1947 (Amended 1995)*

**Description**

The Mining Act provides the legal framework governing mining and its operations. According to the Mining 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.

**Associated Agency**

Administered by:

– Mines and Geology Division, Ministry of Water, Land, Environment and Climate Change

#### *3.2.1.12 The Main Roads Act 1932*

**Description**

The Main Roads Act of 1932 details the legal basis pertaining to main roads and specifically look s at management, laying out of roads, taking of lands, encroachments, offences, lights and carriages, power to arrest and other legalities. The Chief Technical Director (with permanent staff), under the directive of the Minister, is responsible for the laying out, making, repairing, widening, altering, deviating, maintaining, superintending and managing main roads, and controlling the expenditure of allotted moneys.

**Associated Agency**

- Ministry of Transport, Works and Housing

## 3.2.2 Environmental Conservation

### *3.2.2.1 Policy for the National System of Protected Areas 1997*

**Description**

According to the NEPA, a protected area is "an area of land or water that is managed for the protection and maintenance of its ecological systems, biodiversity and/or specific natural, cultural or aesthetic resources." As stated in the green paper, 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) [6]:

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. Areas with protection status relevant to this project are listed in section 3.0 of this document.

*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 |

[6] 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)

| CATEGORY | RESPONSIBLE AGENCY | LAW |
|---|---|---|
| **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*

***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 |

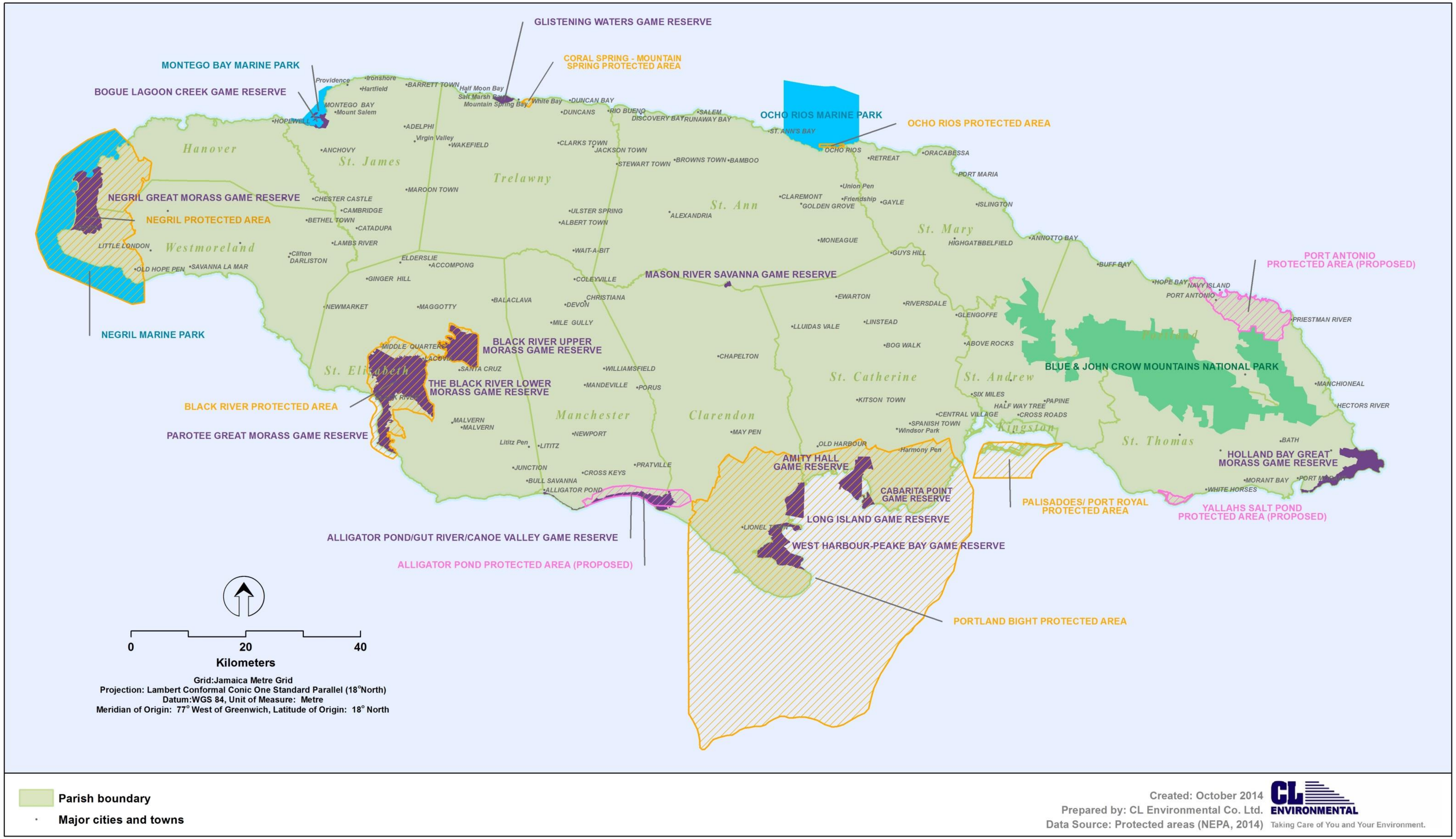



*Figure 3-2 Protected areas system in Jamaica*

**Associated Agency**

It is recognised that the institutional framework requires partnership among various agencies. 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, private sector and individuals are important role players.

Natural Resources Conservation Authority (NRCA)/ National Environment and Planning Agency (NEPA) have responsibility under the Wild Life Protection Act, the Watersheds Protection Act and the Beach Control Act for certain protected areas, including game sanctuaries and game reserves. Management authority for other areas is conferred on the responsible agency by its establishing legislation, such as the Fishing Industry Act (1975), the Forest Act (1937), and the Jamaica National Heritage Trust Act (1985).

In Jamaica, environmental non-government organisations play a key role in the management of protected areas. The Negril Area Environmental Protection Trust (NEPT), an umbrella environmental NGO representing most of the smaller NGOs and CBOs in Negril is responsible for the management of the Negril Environmental Protection Area, whilst the Negril Marine Park management entity is the Negril Coral Reef Preservation Society (NCRPS).

**Relevance to Proposed Project**

The proposed study falls within an Environmental Protection Area (EPA), namely the Negril Environmental Protection Area. Environmental Protection Areas (EPAs) typically are large areas of mixed and complex ownership and use with interlinked ecological systems. To achieve environmental protection, they require coordinated management of the whole area by a variety of means, including use of Prescribed Area regulations. Primary uses and management authority will vary by zones that may be set forth in an environmental policy framework or determined later in a management plan.

EPAs are not exclusive and may contain other types of protected areas such as fish sanctuaries, game or nature reserves. A Marine Park namely the Negril Marine Park is located within the EPA and the breakwaters are located within this park boundary as well (see sections 3.2.2.5 and 3.2.2.6). Further, the Orange Bay Fish Sanctuary (see section 3.2.2.8) and the Great Morass Game Reserve (see section 3.2.2.9) are considered a part of the EPA and are in proximity of the proposed breakwater locations.

Further detail regarding activities within various protected areas within which the proposed study falls is given in section 6.3.3 (Marine and Beach Use).

#### 3.2.2.2 Natural Resources Conservation Act 1991

**Description**

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 with the function of taking necessary steps to ensure the sustainable development of Jamaica through the protection and management of Jamaica's physical environment.

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

**Associated Agency**

Administered by:

- Natural Resources Conservation Authority (NRCA)/National Environment and Planning Agency (NEPA)

Management of areas with protection status under NRCA Act:

- Negril Marine Park - Negril Coral Reef Preservation Society (NCRPS)
- Negril Environmental Protection Area - Negril Area Environmental Protection Trust (NEPT)

Designated personnel include:

- A member of the JCF authorised by the Minister.
- Any person duly authorised by the Minister or the Natural Resources Conservation Authority.

**Relevance to Proposed Project**

Under the Act, the NRCA has a number of powers relevant to the proposed project including the issuing, revocation and suspension of permits to persons responsible for undertaking any construction, enterprise or development of a prescribed category in a prescribed area, including power generation facilities. Further, requesting an Environmental Impact Assessment (EIA) from an applicant for a permit or the person responsible for undertaking any construction, enterprise or development, as was done with this proposed project. Additional details were described previously in section 3.1 (EIA Framework).

As mentioned previously, the proposed study falls within a Marine Park (see sections 3.2.2.5 and 3.2.2.6), as well as an Environmental Protection Area (EPA), namely the Negril Environmental Protection Area. Further detail regarding activities within these two protected areas is given in section 6.3.3 (Marine and Beach Use).

#### *3.2.2.3 Negril Environmental Protection Plan (EPP) 1997*

**Description**

The Negril Environmental Protection Area (EPA) was declared in November 1997 and encompasses the Negril watershed, coastal, and marine areas, as well as the Green Island areas. The aim of this protected area is to promote sustainable development. It is therefore significant that the EPA overlaps with the proposed Development Order area under the Town and Country Planning Act. NEPT worked closely with the two most relevant government agencies – the NRCA and the NGIALPA to develop an EPP to guide environmental activities within the EPA.

Part of EPA management is to coordinate environmental activities between the various groups in the area by sitting on or leading committees. These include the Norman Manley Sea Park Management Committee, Greening Negril Steering Committee, NGIALPA Board, Environmental Legislation Enforcement Committee and the Resort Board. In addition, NEPT reminds other organisations of the role that they should be playing in the management of the EPA.

The EPA includes encompasses the Negril Marine Park.

**Associated Agency**

- Negril Environmental Protection Area - Negril Area Environmental Protection Trust (NEPT)

**Relevance to Proposed Project**

The EPP lists the following as issues that will be relevant in the proposed development:

- Encroachment on verges
- Use of sea for garbage disposal
- Sewage disposal – inadequate facilities for residents and boats

- Inadequate enforcement of environmental laws
- Fisheries depleted
- Inadequate enforcement of litter laws

Detailed information regarding the Negril EPA is presented in section 6.3.3 (Marine and Beach Use).

#### *3.2.2.4 The Natural Resources (Permit and Licences) Regulations 1996*

**Description**

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.

**Associated Agency**

Administered by:

- Natural Resources Conservation Authority (NRCA)/National Environment and Planning Agency (NEPA)

"Authorised person" is any person duly authorised by the Minister or the Authority.

#### *3.2.2.5 The Natural Resources (Marine Park) Regulations 1992, the Natural Resources (Marine Park) (Amendment) Regulations 2003*

**Description**

The Natural Resources (Marine Park) Regulations are designed to achieve and maintain the sustainability of and protect the Marine Parks of Jamaica. It is an offence to use an area in a manner contrary to the zone. Some specific offenses are as follows:

- Extract/mine minerals without written permission
- Destroy, injure, deface, move, dig, harmfully disturb or remove any sand, gravel, minerals, corals, sea fans, shells, shellfish, starfish, marine invertebrates, seaweed, grass, soil, artefact, rock or stone.
- Cut, injure, mutilate, move, displace or break any growth or sea bottom formation.
- Attach any rope, wire or other contrivance to coral or rock.
- Knowingly use, sell, dispose of or remove from the marine park stolen seaweed, coral, gravel, sand, or mineral.
- Dredge, excavate, fill/deposit anything in the sea
- Erect any building/structure or public service facility without permission of Authority

- Discharge or deposit in water any refuse, oily liquids, wastes, acids, chemicals, toxic/polluting substances, which injures plant/animal life.
- Wilfully mark, deface/damage, remove, mooring buoy, park sign /Notice
- Research/collect objects or specimens without a permit

**Associated Agency**

Administered by:

– Natural Resources Conservation Authority (NRCA)/National Environment and Planning Agency (NEPA)

"Authorized Officer" is an officer employed to the Authority, member of the Security Forces, Fishery Inspector under the Fishing Industry Act or public officer designated as an authorized officer by the Authority.

**Relevance to Proposed Project**

The proposed project is located within the Negril Marine Park boundary and further detail is given in the subsequent section (Natural Resources Conservation (Negril Marine Park) (Declaration) Order 1998).

#### *3.2.2.6 Natural Resources Conservation (Negril Marine Park) (Declaration) Order 1998*

**Description**

The Negril Marine Park was legally established under the Natural Resources Conservation (Negril Marine Park) (Declaration) Order in 1998 and was officially designated in March of that year. The park is approximately 160 $km^2$, with its coastal boundary extending from Davis Cove, Hanover in the north to St. John's Point, Westmoreland in the south. The Order describes the area and its boundaries in further detail. It bans dredging, excavating, discharge of pollutants, littering, use of explosives and poisons and fishing within the protected area boundaries except subject to permit, and allows research and collection for educational and research purposes under permit.

**Associated Agency**

Administered by:

– Natural Resources Conservation Authority (NRCA)/National Environment and Planning Agency (NEPA)

Park management:

– Negril Coral Reef Preservation Society (NCRPS)

"Authorized Officer" is an officer employed to the Authority, member of the Security Forces, Fishery Inspector under the Fishing Industry Act or public officer designated as an authorized officer by the Authority.

**Relevance to Proposed Project**

The Natural Resources Conservation (Marine Parks) (Amendment) Regulations, 2003 (discussed previously) provided the basis for the zoning of the Negril Marine Park by the Natural Resources Conservation Authority. Demarcated zones exist within the Park and the permissible and prohibited activities within these zones must be adhered to during construction and monitoring phases. Further detail is given in section 6.3.3 (Marine and Beach Use).

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

**Description**

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. 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.

**Associated Agency**

Administered by:

- Natural Resources Conservation Authority (NRCA)/National Environment and Planning Agency (NEPA)

**Relevance to Proposed Project**

As discussed previously, an EIA was required for the proposed project and this report fulfils one component of the EIA process.

#### *3.2.2.8 The Fishing Industry Act 1975*

**Description**

The Fishing Industry Act 1975 is the overarching instrument relating to fishing activities within Jamaica. The registration and licensing of fishers and fishing boats are covered under this piece of legislation. In addition, the Act also speaks to 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. Within these SFCAs, fishing may be allowed under a set of licensing conditions and directives of the Minister, such as fishing for conservation and management purposes.

**Associated Agency**

Administered by:

– Fisheries Division, Ministry of Agriculture and Fisheries

SFCA management:

– Orange Bay SFCA - Negril Area Environmental Protection Trust (NEPT)

"Fishery Inspector" means any public officer appointed to be a Fishery Inspector under this Act, Game Warden approved under the Wild Life Protection Act, Officer of JCF, JDF.

**Relevance to Proposed Project**

Though the proposed project does not fall within the boundaries of the Orange Bay SFCA (Orange Bay, Hanover), it is located within the Negril Marine Park, north of the proposed breakwater locations.

Though 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).

#### *3.2.2.9 Wild Life Protection Act 1945*

**Description**

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.

**Associated Agency**

Administered by:

- Natural Resources Conservation Authority (NRCA)/National Environment and Planning Agency (NEPA)

Designated personnel include:

- Game Warden / Constable / Fishery Inspector

**Relevance to Proposed Project**

Offenses cited under this Act and relevant to the marine realm should be borne in mind particularly during construction phases. These include:

- Hunting protected animal or bird
- Possession of all or part of protected animal or bird
- Possessing, killing, injuring or taking immature fish
- Using dynamite, poisons or other noxious material to kill or injure fish
- Cause or knowingly allowing entry of trade effluent/industrial waste, noxious, polluting substances into any body of water with fish
- Taking, possessing or trying to sell turtle eggs
- Hunting animal/bird in Exclusive Economic Zone without licence

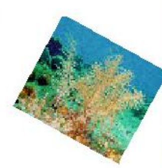
Further, it is imperative that all persons are mindful of the endangered species protected under this law and as shown in Figure 3-3.

Mention must also be made of the Great Morass Game Reserve, located in Negril, Westmoreland/ Hanover.

## 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 reidi* |
| 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* |

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## 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

#### *3.2.2.10 The Endangered Species Act 2000*

**Description**

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.

**Associated Agency**

Administered by:

- Natural Resources Conservation Authority (NRCA)/National Environment and Planning Agency (NEPA)

Designated personnel include person designated by NRCA; Customs Officer; Game Warden; member of JCF or JDF; Fishery Inspector; Marine Officer; Inspector; Forest Officer; National and Marine Park Ranger.

**Relevance to Proposed Project**

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.

#### *3.2.2.11 Water Resources Act 1995*

**Description**

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. Section 25 advises that a proposed user will have to obtain planning permission, if this is a requirement, under the Town and Country Planning Act. In addition, under Section 21 it states that if the water to be used will result in the discharge of effluents, an application for a license to discharge effluents will have to be made to the Natural Resources Conservation Authority or any other relevant body as indicated by the Minister.

**Associated Agency**

Administered by:

- Water Resources Authority

### *3.2.2.12 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.

### *3.2.2.13 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 to 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.

### *3.2.2.14 National Policy for the Conservation of Seagrasses 1996 (DRAFT)*

**Description**

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.

**Relevance to Proposed Project**

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.

### *3.2.2.15 Coral Reef Protection and Preservation Policy and Regulation 1997 (DRAFT)*

**Description**

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. Additionally, five specific goals are listed and these include the reducing of pollutants, reversing the trend in overharvesting reef fish, reducing physical damage to reefs, improving response capability and ensuring that coastal development does not lead to coral reef destruction and/ or degradation.

**Relevance to Proposed Project**

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 and further detail pertaining to existing coral reef communities and possible impacts and mitigation measures may be seen in sections 6.1.16 and 6.3.5.

#### *3.2.2.16 A policy towards Dolphin Conservation in Jamaica 2003*

**Description**

This document recognises regional and local threats to Bottlenose Dolphins, including habitat degradation, fishery conflicts, pollution and overkilling. The following strategic directions and goals are listed:

- Goal 1 Conserve Jamaica's dolphin species and their habitats
- Goal 2 Ensure Sustainable Use of Dolphins
- Goal 3 Promote and Facilitate Research and Training
- Goal 4 Public Education and Awareness
- Goal 5 Facilitate International Trade
- Goal 6 Permit Compliance

#### *3.2.2.17 DRAFT Policy and Regulation for Mangrove & Coastal Wetlands Protection*

As outlined 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;

#### *3.2.2.18 The Forest Act 1996*

**Description**

The 1996 Forest Act repealed the 1937 legislation and was the legal basis for the organization and functioning of the Forestry Department. 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. Following this, these reserve areas were added to by purchase, lease and other arrangements. Please see Figure 3-4 for the location of forest estates across the island.

The following are some offences under this act:

- Cut a tree in forest reserve without valid permit
- Fell, cut, girdle, mark, lop, tap, uproot, burn, damage, debark, strip/remove leaves of a tree
- Kindle, keep, carry lit material
- Clear or break up land
- Establish or carry on forest industry
- Remove soil, gravel or sand
- Unlawfully/illegally affix forest officer mark to any tree/timber
- Alter, deface/obliterate mark placed by forest officer on tree/timber
- Pasture/allow cattle trespass

There are also a set of *Forest Regulations (2001)* which are administered by the Forestry Department as well.

A "Forest Reserve" is defined to be any area of land declared by or under this Act to be a forest reserve.

**Associated Agency**

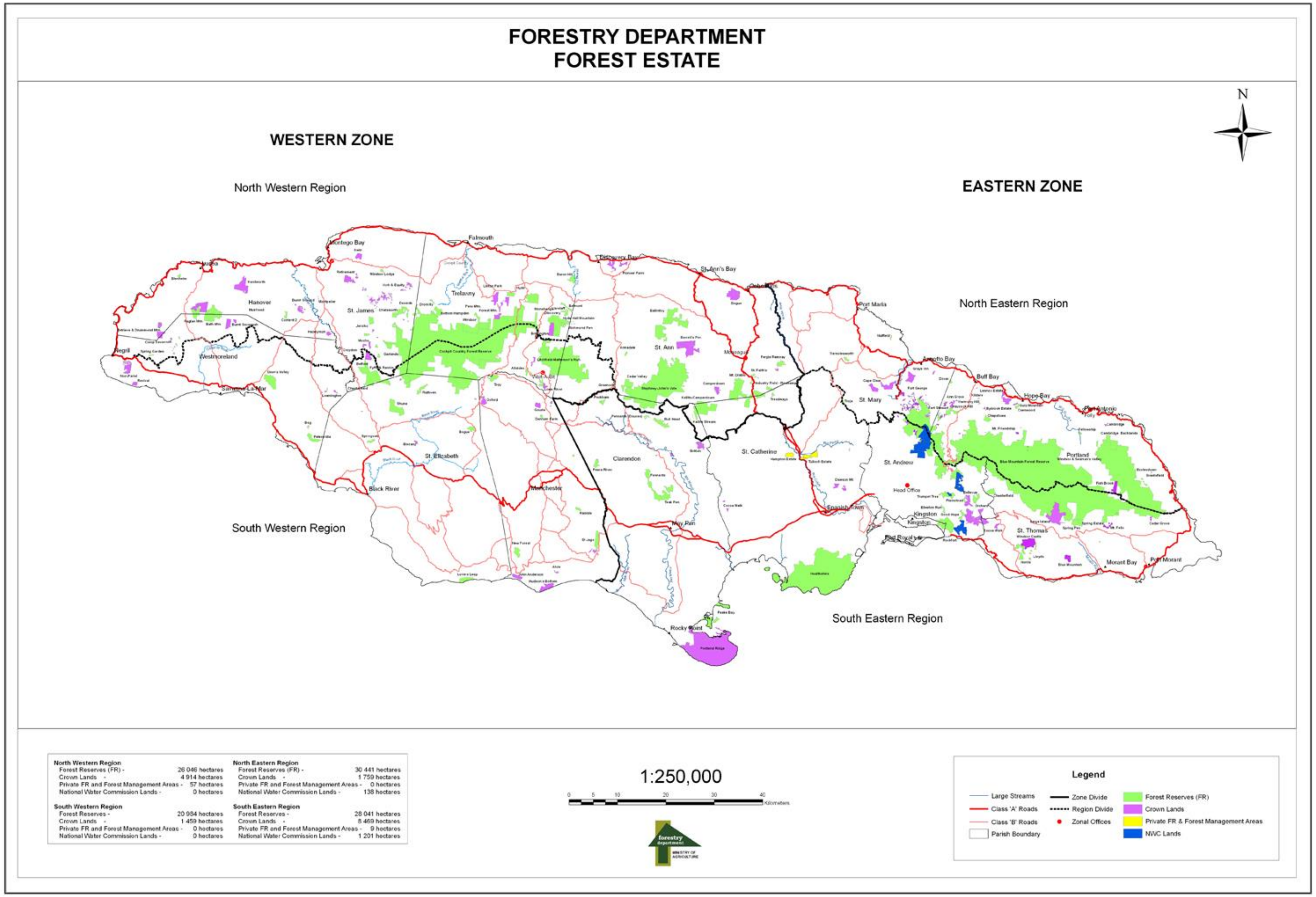
Administered by:

– Forestry Department

Authorized officer" means a forest officer, a member of the Jamaica Constabulary Force or any other person designated as such by the Minister.

**Relevance to Proposed Project**

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 and 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*

**Description**

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

**Associated Agency**

Administered by:

- Natural Resources Conservation Authority (NRCA)/National Environment and Planning Agency (NEPA)

**Relevance to Proposed Project**

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. Please refer to section 6.1.1 for further details.

### *3.2.3.2 Noise Abatement Act 1997*

**Description**

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.

**Associated Agency**

Administered by:

- Natural Resources Conservation Authority (NRCA)/National Environment and Planning Agency (NEPA)

**Relevance to Proposed Project**

Likely sources of noise pollution include tucks transporting material along roadways; offloading of rocks; driving of sheet piles to create the staging area; and the loading of barges.

#### *3.2.3.3 The National Solid Waste Management Authority Act 2001*

**Description**

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.

**Associated Agency**

Administered by:

- National Solid Waste Management Authority (NSWMA)

#### *3.2.3.4 Public Health Act 1985*

**Description**

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. Under the regulations:

- No individual or organization is allowed to emit, deposit, issue or discharge into the environment from any source;

- Whoever is responsible for the accidental presence in the environment of any contaminant must advise the Environmental Control Division of the Ministry of Health and Environmental Control, without delay;
- Any person or organization that conducts activities which release air contaminants such as dust and other particulates is required to institute measures to reduce or eliminate the presence of such contaminants; and
- No industrial waste should be discharged into any water body, which will result in the deterioration of the quality of the water.

**Associated Agency**

Administered by:

- Ministry of Health
- Local Planning Authorities (Parish Councils)

**Relevance to Proposed Project**

The Negril Green Island Area Local Planning Authority (NGIALPA) is the local planning authority with responsible for development within the study area for the proposed project.

Offences listed above must be adhered to during the project cycle.

#### *3.2.3.5 The Natural Resources (Hazardous Waste) (Control of Transboundary Movement) Regulations 2003*

**Description**

These retaliations 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. Further, it is an offence to import, transit through, or export hazardous waste into or from an area under Jamaica's jurisdiction:

a) Without notification to every State involved,
b) Without a permit and the consent of every State involved.
c) With consent obtained from a State concerned through falsification, misrepresentation or fraud.
d) That does not conform to the documents.
e) That results in the unlawful disposal of hazardous wastes in contravention of the Convention, Act, or these Regulations.

"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.

**Associated Agency**

Administered by:

- Natural Resources Conservation Authority (NRCA)/National Environment and Planning Agency (NEPA)

Inspectors include persons duly authorised by the Natural Resources Conservation Authority or public officers so appointed.

**Relevance to Proposed Project**

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.

### 3.2.4 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 was ratified by twenty (20) countries and acts as a framework agreement that sets out the political and legal foundations for actions to be developed. The operational Protocols, which direct these actions, are designed to address special issues and to initiate concrete actions. 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. In order to achieve its main goal of sustainable development, signatories are required to:

- Develop plans for protecting habitat and species.
- Provide funds and technology to help developing countries provide protection.
- Ensure commercial access to biological resources for development.
- Share revenues fairly among source countries and developers.
- Establish safe regulations and liability for risks associated with biotechnology development.

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 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.

The United Nations has no direct operational role in the implementation of the Convention; however organizations such as the International Maritime Organization, the International Whaling Commission, and the International Seabed Authority do play roles in the implementation.

### 3.3.4 Convention on Fishing and Conservation of the Living Resources of the High Seas 1958

This convention considers that the development of modern techniques for the exploitation of the living resources of the sea has increased man's ability to meet the need of the world's expanding population for food and has exposed some of these resources to the danger of being over-exploited. It was done at Geneva on 29 April 1958.

### 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. Article 4 outlines the prohibition of dumping wastes or other matter with the exception of those listed in Annex 1 of the document.

### 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 1 of 107 parties to the convention (as of July 2013).

# 4.0 PUBLIC PARTICIPATION AND CONSULTATION

Community interaction and transparency was considered a critical area of focus for the success of this development. Public consultation has taken the following forms for the purposes of this EIA:

1) A Social Impact Assessment (SIA) carried out as part of the EIA research; and
2) Public meetings held subsequent to the submittal of the draft EIA.

The SIA comprised a perception survey involving residents, watersports operators, fishers, tourists and shops/stalls/ mobile operators, as well as stakeholder meeting and focus group meetings. The main goal of the SIA for this project was gleaned from the TORs for the Project which required "*... some level of stakeholder consultation in either focus groups or using structured questionnaires*." The process of engagement with stakeholders along the Long Beach sought to treat with specific issues contained in the project description, such as the erosion in the area, stakeholders' perceptions on the causal factors responsible for the erosion, their views on the proposed breakwaters project and any concerns they may have had about the said project.

A Public Consultation Meeting was held on July 29, 2014 at the Negril Community Centre, and conducted in the manner as outlined in NEPA's "Guidelines for Conducting Public Presentations" (Appendix 3). Please see Appendix 4 for the attendance list and Appendix 5 for the presentation given at this meeting. Verbatim notes may be accessed at http://www.nepa.gov.jm/eias/Westmoreland/Negril/Long_Bay/Negril_breakwater_project_eia_meeting_notes.pdf. Subsequent to this meeting, a second public meeting was held on November 10, 2014 in order to inform stakeholders of two material changes to the project. Specifically, the original proposal included the dredging of the mouth of the river; this however is no longer being considered and instead material will be sourced from licenced quarries for the creation of the stockpile area. Secondly, after the construction of the breakwaters, the stockpile area will now be removed. Please see http://www.nepa.gov.jm/eias/Westmoreland/Negril/Long_Bay/minutes_for_second_eia.pdf for notes of this meeting.

Further, in response to issues raised by stakeholders during the EIA process, a presentation was created in order to address the concerns of the public (see Appendix 6).

# 5.0 COMPREHENSIVE DESCRIPTION OF THE PROPOSED PROJECT

## 5.1 THE PROPONENT

As mentioned previously, the Government of Jamaica has implemented the larger umbrella project "*Enhancing the Resilience of the Agriculture Sector and Coastal Areas to Protect Livelihoods and Improve Food Security*" through the Planning Institute of Jamaica (PIOJ). The agencies include the National Environment and Planning Agency (NEPA), the National Works Agency (NWA), the Ministry of Agriculture and Fisheries and the Ministry of Tourism. With specific regard to the *Construction of Break Water Structures Offshore Negril (Negril Breakwaters)" sub*project, execution is being managed by the National Works Agency (NWA) (the client).

The National Works Agency is the main government organisation directly responsible for Jamaica's main road network, bridges and sea defence systems. 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.

## 5.2 PROJECT LOCATION

The proposed breakwaters are located 1,500 - 1,600 m offshore the Negril coastline in Long Bay. The general project location is situated in two parishes, namely Hanover in its northern section and Westmoreland in its southern (Figure 5-1). Three communities, namely Orange Bay, Negril and Sheffield are within the general area. Dimensions of the breakwaters are as follows:

- **Northern breakwater** - 516 metres long in 3.0 to 4.0 m of water depth (MSL) that is partially emergent and submerged in some sections. The breakwater width is 15m at its narrowest end and 23m at its widest end.
- **Southern breakwater** - 422 metres long in 3.7 to 4.1 m of water depth that is partially emergent. The breakwater width is 20m at its narrowest end and 23m at its widest end.

As seen in Figure 5-2, both Long Bay Beach Park locations as well as Negril Beach Villa are situated opposite the northern breakwater along the shoreline. Hotels in proximity of the southern breakwater include Couples Swept Away, Foote Prints Villas, Seawind Resorts, The Palms, Gardenia Resort and others.

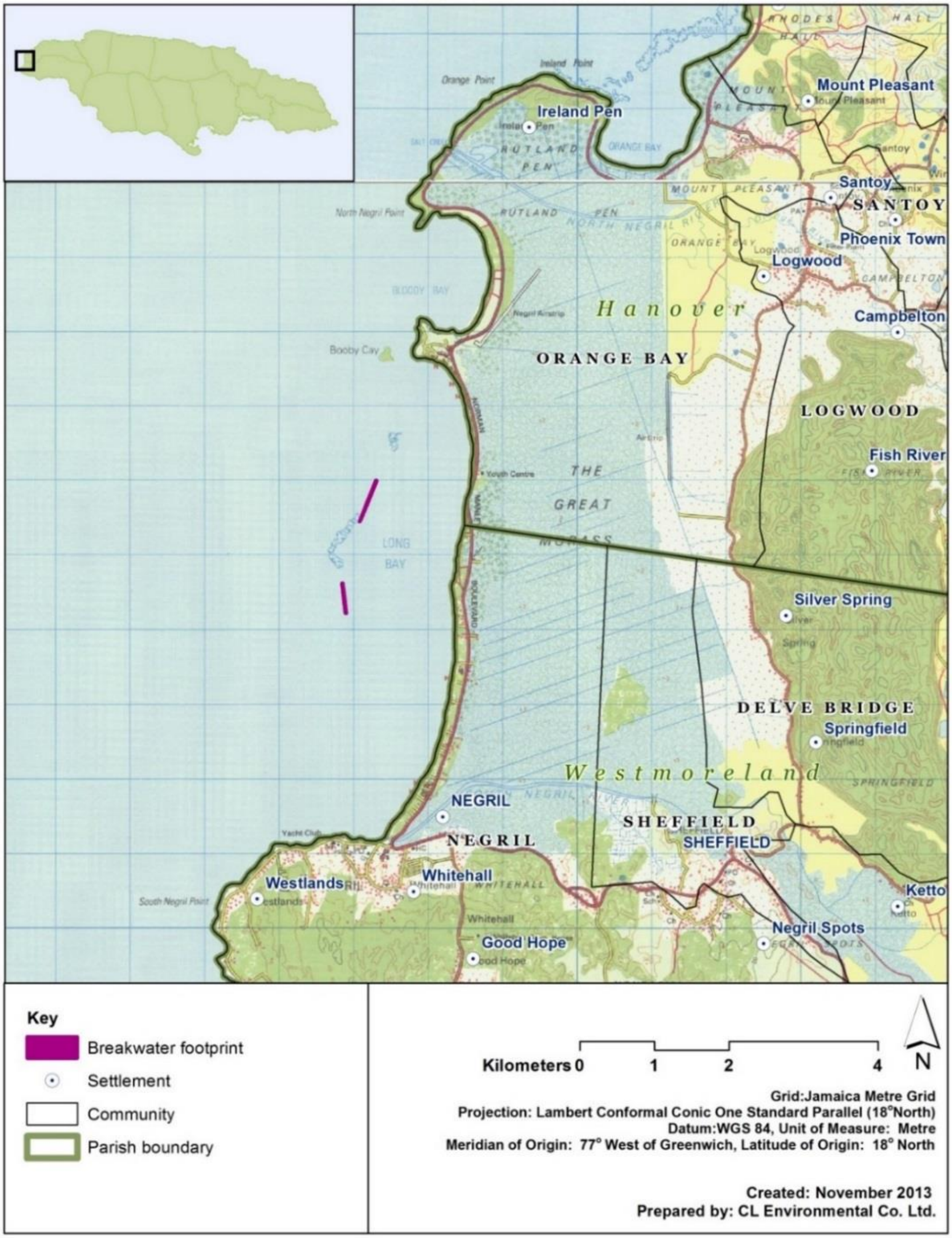



*Figure 5-1 Location of proposed breakwaters, Long Bay, Negril*

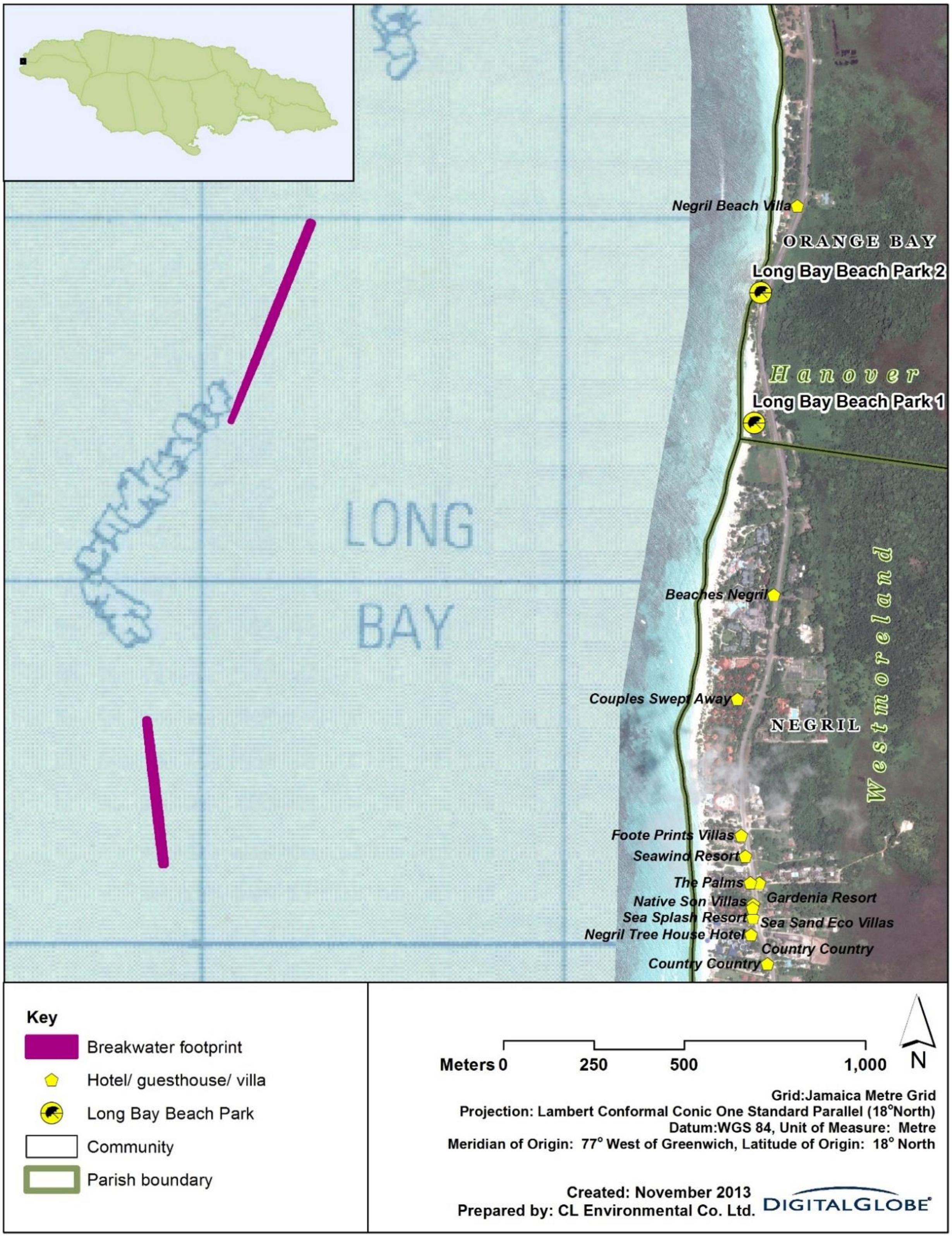



*Figure 5-2 Hotels in vicinity of proposed breakwaters, Long Bay, Negril*

# 5.3 PROJECT CONCEPT & DESCRIPTION

The project is phased as follows:

- **Phase 1** – The preparation of the Bid document; completion of engineering design works; and preparation of EIA.
- **Phase 2** – The engineering consultancy and assistance during implementation and construction.
- **Phase 3** – The post-construction monitoring of the structure and relocated sensitive species.

## 5.3.1 Breakwater Design

### *5.3.1.1 Design Requirements*

The breakwaters were designed to provide effective sheltering of the shoreline and to provoke beach growth as much as possible in order to provide the maximum benefit to all stakeholders. Additionally, they should meet the following conditions in order to remain relevant up to the end of the design period:

1. Withstand the 1 in 100 year return period deep water wave conditions with minimal damage (Structural damage number of less than 2 to 3).
2. Project life up to 2050 (37 years).[9]
3. Climate change factors for the IPCC SRES (Intergovernmental Panel on Climate Change Special Report: Emissions Scenarios) A1B or A1 scenario up to the design life.
4. Employ the use of locally available materials.

The reasons for these design parameters are discussed in Table 5-1.

[9] The design life of a component or product is the period of time during which the item is expected by its designers to work within its specified parameters. The uncertainties associated with climate change makes it unwise to predict too far into the future so the designer suggested that the design parameters be revisited in 2050.

*Table 5-1 Reasons for design parameters*

| Objectives | Design Basis | Reasons |
|---|---|---|
| **Climate Change Mitigation though shoreline growth/accretion** | Wave transmission of 0.4 to 0.55 for swell | Provide effective sheltering to the shoreline of central Long Bay, Negril (see section 5.3.1.2). |
| **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) |
| | Estimate structural damage of 2 to 3 | Relatively stable design with limited damage (<5%) with designation of initial to intermediate after design event. (Meer and W. 1993) |
| **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 armour stone materials | To minimize foreign exchange requirements and maximize local input/economic impact |

#### *5.3.1.2 Methodology*

The following subsections briefly present the design considerations, methods and tests used to inform the final location and design of the proposed breakwaters. Also, a summary of the findings in support of the final design is given. It should be noted that further detail of these methods and findings are presented in sections 6.1 and 7.2.1.

**Anecdotal Evidence**

Anecdotal information on the major hurricanes and storm events that have affected the Negril coastline was gathered from interviews held with residents and employees in the area. The results of these interviews were collated and used to calibrate and verify the models used in the design.

**Wave Study**

*Deepwater Hurricane Wave Climate*

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 a five year period 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 Negril shoreline.

**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 period storm events used in the design.

**Review of Existing Studies**

The preliminary engineering report developed by Smith Warner International Limited (SWIL) in 2007 (Smith Warner International Limited [Swil] 2007), the engineering report developed by CEAC in 2012 for the PIOJ and two (2) articles from Volume 43 of the Caribbean Journal of Earth Science (McKenzie 2012; Robinson et al. 2012) were reviewed and incorporated in the design report as a means of calibrating and verifying the design process. The key points are outlined below:

- Shoreline erosion along the beach was on average 1 m between 1968 and 2006, as determined by SWIL.
- The SWIL report, CEAC preliminary engineering report and the (Robinson et al. 2012) article identified the central and the northern sections of the beach as the most vulnerable to shoreline erosion. The central section being the most critical.
- (Robinson et al. 2012) - Projected possible shoreline changes in the future by using two (2) methods. The first determined that 1.5 to 3 m of erosion would occur by 2015, 5 to 9 m by 2030, 10 to 17 m by 2050, and as much as 25 m for the 'hot spots' (unusually high rates of erosion) using the 2008 shoreline as the base . The second method returned average erosion of 12 to 21 m by 2050 and up to 30 to 55 m for the 'hot spots'.
- (McKenzie 2012) - Determined the level of beach erosion following the passage of five (5) hurricanes (2000 – 2008) on monitored post-storm recovery at Long Bay. The overall data suggested that the beach requires a minimum of 3 – 4 years to recover to its pre-storm position following the near passage of a category 4 storm event.
- SWIL offered four (4) hard solutions to reduce the erosion occurring along the Long Bay beach and the preferred solution was the integrated solution, which combined - reef extension in the vicinity of the offshore reef; nearshore breakwaters in the south portion of Long Bay; and beach nourishment in both Bloody Bay and Long Bay. This option proposed the construction of nine (9) breakwaters varying in length from 350 m to 500 m.

- CEAC modified the SWIL solution so as to minimise rock volume in deepwater and maximize shoreline response by closing the gap between the reef and breakwater without encroaching on the reefs. It consisted of two (2) breakwaters using less material than the SWIL proposed solution. The breakwaters would be 480 and 600 m in length in water depths of 4.0 to 4.2 m.

In addition to the existing studies outlined above, beach profile monitoring along Long Bay beach conducted by NEPA was included in the analysis (see section 6.1.9).

**Summary of Findings**

Several engineering and technical reports were reviewed and used as a means of calibrating and verifying the design process. These included two preliminary engineering reports by Smith Warner International (SWIL) in 2007 and CEAC Solutions Ltd in 2012, and two NEPA studies undertaken in 2012 by Robinson and McKenzie. All reports identified the central and northern sections of the Long Bay Beach as the most vulnerable to shoreline erosion, with the central section being the most critical.

In designing the breakwaters a long term shoreline change analysis was conducted for the 1968 – 2013 period. The shoreline position of the Long Bay Beach was monitored over the period and a general trend of erosion was identified. The overall erosion rate was deduced to be between 0.2 – 1.4 m/yr. The results also indicated that the central section of the beach is most vulnerable to short term and long term erosion.

An alongshore transport modelling exercise was undertaken for three scenarios: without breakwater, with proposed breakwaters and with a modified configuration with a longer southern breaker and shorter northern breakwater. The investigation was conducted to determine the long term shoreline trends due to the operational, swell and hurricane wave climate; and the necessity for providing protective structures (breakwaters). The investigations revealed that the proposed configuration was optimal and produced the greatest area of accretion in comparison to the other options.

The beach is expected to have nominal growth of 84,000 $m^2$, in particular the most vulnerable sections of the beach, the central and northern sections. Approximately 80% of the shoreline will accrete (4.95 km) with an average shoreline growth of 13.5m resulting in approximately 109,400 $m^3$ of sand accreting. Most of the growth will occur at the northern section of Long Bay with a maximum predicted growth of 41.7 m. This growth will be realized after a number of swell events have occurred to mobilize the sand.

#### *5.3.1.3 Design Considerations*

**Materials**

A range of specific densities and stone sizes are available for the project based upon the quarry surveys. An assumed density of 2.5 with a possible range of 2.411 to 2.574 was used. It is expected that stones with this minimum density would also have acceptable water absorption (<3.5%). Boulders up to 13.9 tonnes are available based upon the quarry surveys as well.

**Deepwater Wave Climate and Climate Change Factors**

Present climate deep-water hurricane wave hindcast analysis was undertaken for a node offshore Negril and summarized in a bi-directional format. The hindcast results were subjected to frequency analysis to define the 5 to 100 year return period (RP).

Stationarity in the frequency distribution of waves and water levels and their associated driving processes cannot be assumed in a climate change scenario. As a result climate change will be considered in both the empirical functions and scale model testing through the use of change factors applied to present climate values for water levels and wave heights. It follows a similar concept to (Wigley 2009) and makes allowances for the observations of (Wang 2006; Ruggiero 2010; Emanuel et al. 2008). Summary of the climate change considerations are presented in Table 5-2.

*Table 5-2 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 |
| **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% |

#### *5.3.1.4 Pre-testing Structural Analysis*

The Van der Meer Stability Equation as per the Rock Manual (2006) and Kamphuis (2000) was utilized to size the armour stones. The equation is valid for the estimation of the stability of armour stone for the trunk, head and toe of coastal structures, for both breaking and non-breaking wave conditions. The design procedure for the sizing of the armour stone involved:

1. Estimating the at-toe wave height for the design deepwater wave conditions
2. Estimating the surf-similarity parameter and thereby determine if the waves were breaking or non-breaking
3. Applying the design parameters to yield a recommended armour weight

Crest armour was sized on the basis of low water levels and H2% (two percent highest waves). The method outlined in (van der Meer 1994) was used to determine the stability number that was then used to determine the crest armour. A narrow grading of 1.25 (D85/D15) was applied to the armour stone median sizes.

Structural stability analysis indicated that the 100 year design will essentially be statistically stable with breaking wave conditions and transmission of 0.53. The transmission indicates that approximately 28% of the energy will be transmitted over the breakwater and about 72% will be dissipated within the structure and reflected. A 4.2 to 8.8 tonnes stone size was determined to be required with a mean of 6.5 T. The required armour stone, filter stones and toe stone sizes required are summarized in Table 5-3.

*Table 5-3 Summary of empirical design results for Negril Breakwaters for 100 year Return period*

| | Crest armour | Armour Stones | Filter Stones | Toe Stones |
|---|---|---|---|---|
| **M15 (kg)** | | 4398 | 91 | |
| **M50 (kg)** | 9354 | 6498 | 198 | 546 |
| **M85 (kg)** | | 8590 | 307 | |

### 5.3.1.5 Scale Model Testing

**Objectives**

Stability was the primary criterion with low damage levels for the 100 year return period. Climate resilience to the 2050 period was also considered. However, higher water over the crest of the breakwater also allows for more wave transmission and a more stable structure in wave breaking conditions. The combination of both increased wave height and present day water levels were therefore examined preferentially than the increased water levels.

The key objectives of the scale modelling exercise were to determine the viability of the proposed design; optimize the elements of the cross-section and confirm its climate change resilience. The exercise was carried out at the Ocean Engineering Laboratory at the University of Delaware in Newark Delaware. During the exercise the following key questions were answered:

1. Is the preliminary design viable?
    a. If so, what cost savings and/or construction improvements are possible
    b. Is the toe design viable?
    c. Can one stone size for the primary armour be used
    d. What is the required end detail
2. What are the wave transmission characteristics?
    a. Swell wave climate
    b. Hurricane 100 year wave climate
3. What is the impact of climate change?

a. Combined effects of increase wave height 9.5% per 100 year and wave levels to 2050
b. Combined effects of increase wave height 20% per 100 year and wave levels to 2100

Both swell and hurricane wave transmission were monitored in the scale model and verified with the empirical models of (Tomasicchio & Tundo 2011). The empirical model results were taken as more accurate given the difference in the sea floor slope in the scale model that would vary from location to location along the structure versus the empirical model, where several offshore profiles could be examined. Test series 1, 2 and 3 clearly confirmed the very low stability number (< 1) to be expected from the design. The increase in wave height and water levels by climate change (0.2 m) is relatively small in comparison to storm surge (1 to 1.2 m). Climate change was therefore not modelled any further in the scale model as the order of magnitude of change in the damage was expected to be very small.

**Conclusion and Recommendations**

The following were concluded from the scale model testing:

- Packing and gradation is crucial to the performance of the structure. A three point lateral packing arrangement was used in the scale model, similar to land based construction. Underwater monitoring of the works will be crucial to ensure tight packing.
- Landward armour stones are in general more stable than the seaward stones. The seaward stones have a tendency to be removed from just above the toe region on the downwash. Special gradation sizes should be utilized here, more specifically the largest sizes in the specified range.
- Seaward toe stability is less than the landward toe and the spreading of the toe in this region is best addressed by the use of toe stone/heavier gradation in this region.

The following were recommended:

- A stable design for the cross section can be achieved for the 100 year RP: with and without storm surge or climate change considerations consisting of the following stone sizes:
  - Primary armour 5 to 10 T
  - Filter armour of 0.5 to 1.5 T
- Special gradation of the seaward primary stones to use an 8 to 10 T mix should be employed in the region most susceptible to displacement. Likewise a 1 to 1.5 T mix for the first three stones in the toe will be used.
- Careful daily observations of the packing are required in order to ensure adequate performance of the structure. Given the nature of the marine based construction the packing of the boulders and any repacking is best done before the barge is moved along and re-spudded/positioned. The cleanliness of the stones will also help to reduce the dispersion of milky fines into the water column to allow for better visibility.

#### 5.3.1.6 Final Breakwater Design

The proposed configurations and designs of the breakwater structures are illustrated in Figure 5-3 through to Figure 5-7 and summarised in Table 5-4 below. Additional design information may also be gleaned from the Engineering Design Report prepared by CEAC Solutions.

*Table 5-4 Design parameters for northern and southern breakwaters*

| | Northern breakwater | Southern breakwater |
|---|---|---|
| Length (m) | 517 | 417 |
| Elevation relative to MSL (m) | -0.45 to 0.0 | 0 |
| Footprint (m2) | 10,192 | 9,071 |
| Filter stones (m2) | 8,438 | 7,378 |
| Primary armour (m2) | 14,332 | 14,866 |

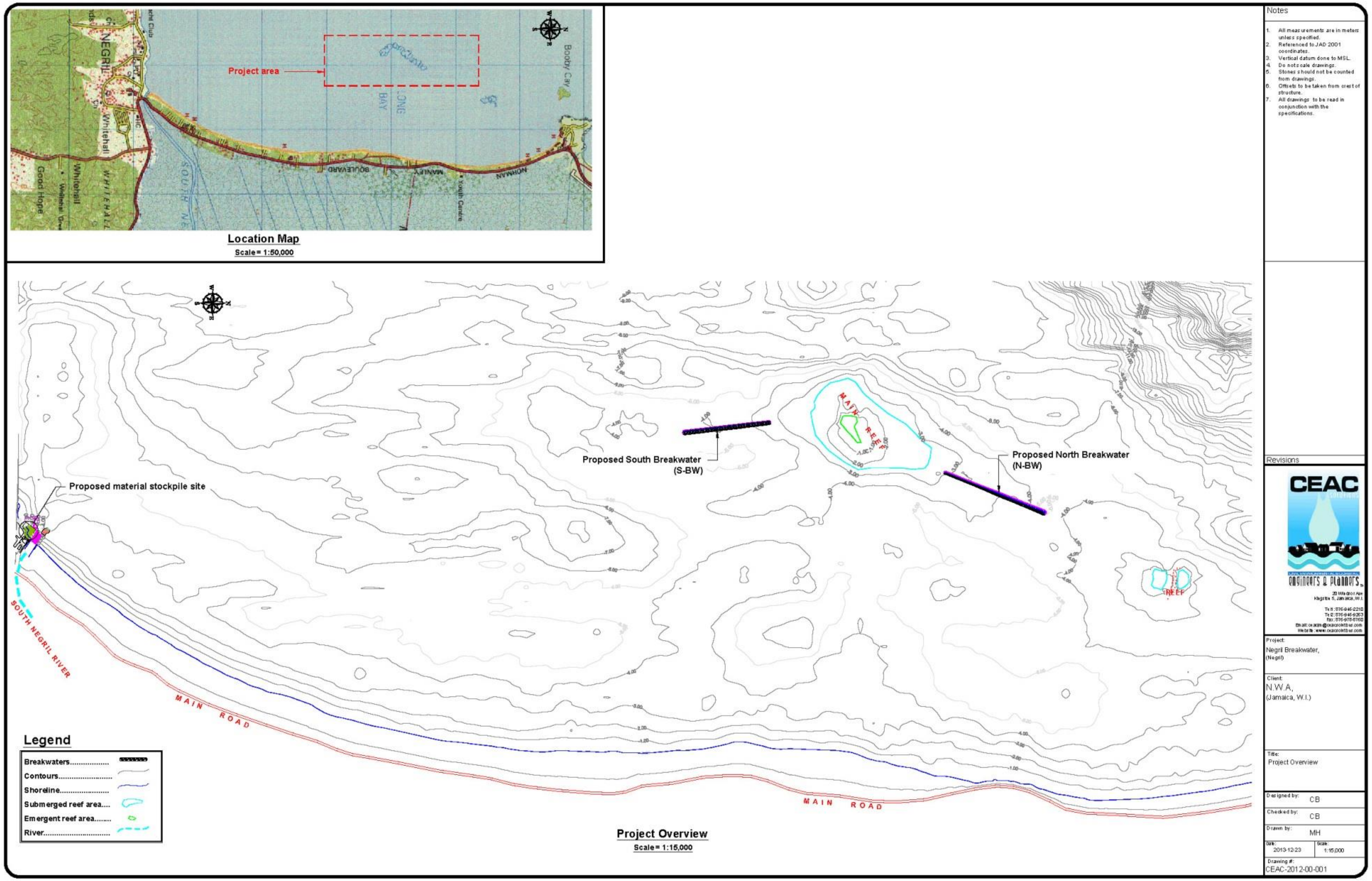



*Figure 5-3 Project overview and location*

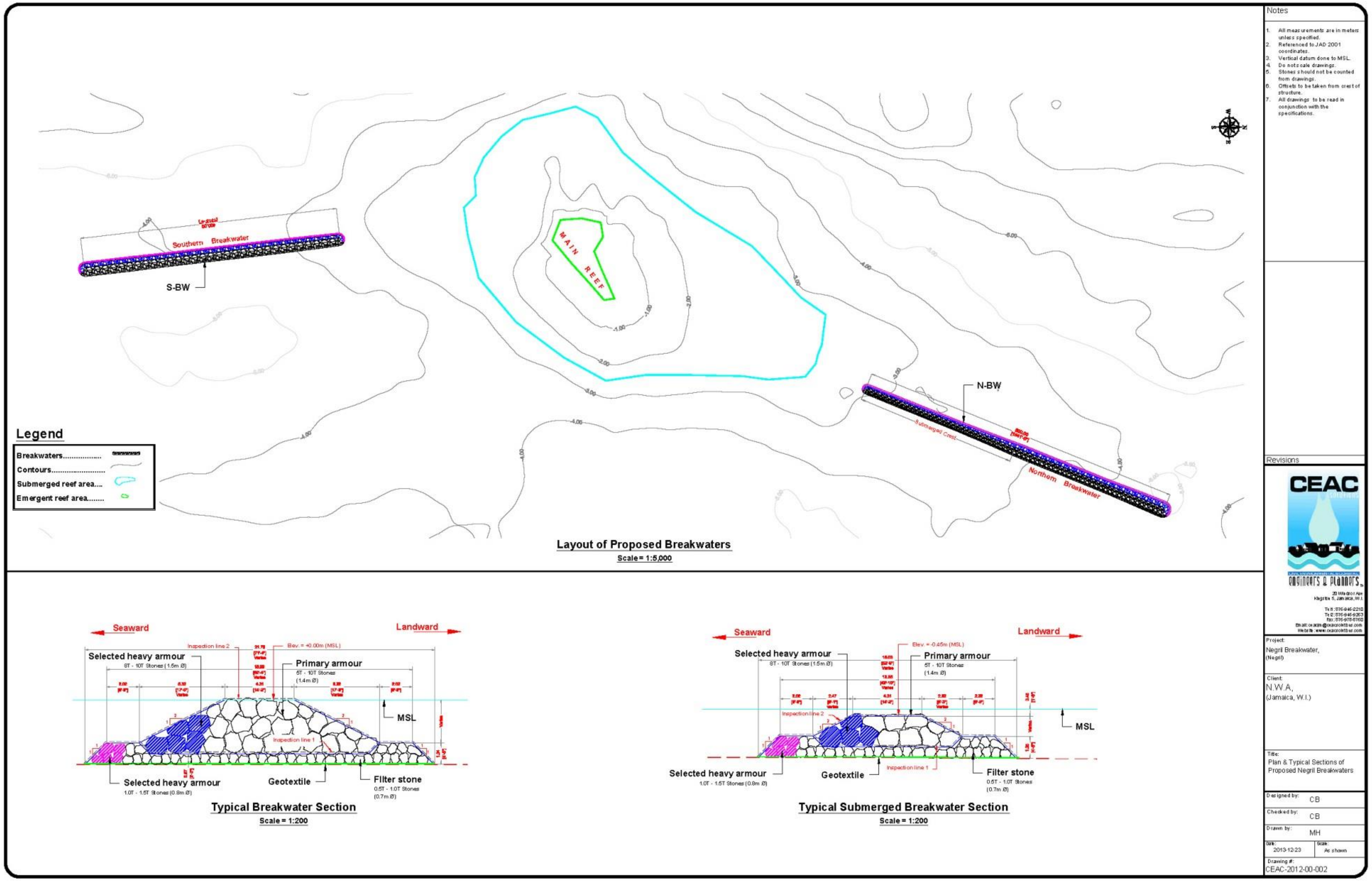



*Figure 5-4 Plan and typical section of proposed breakwaters*

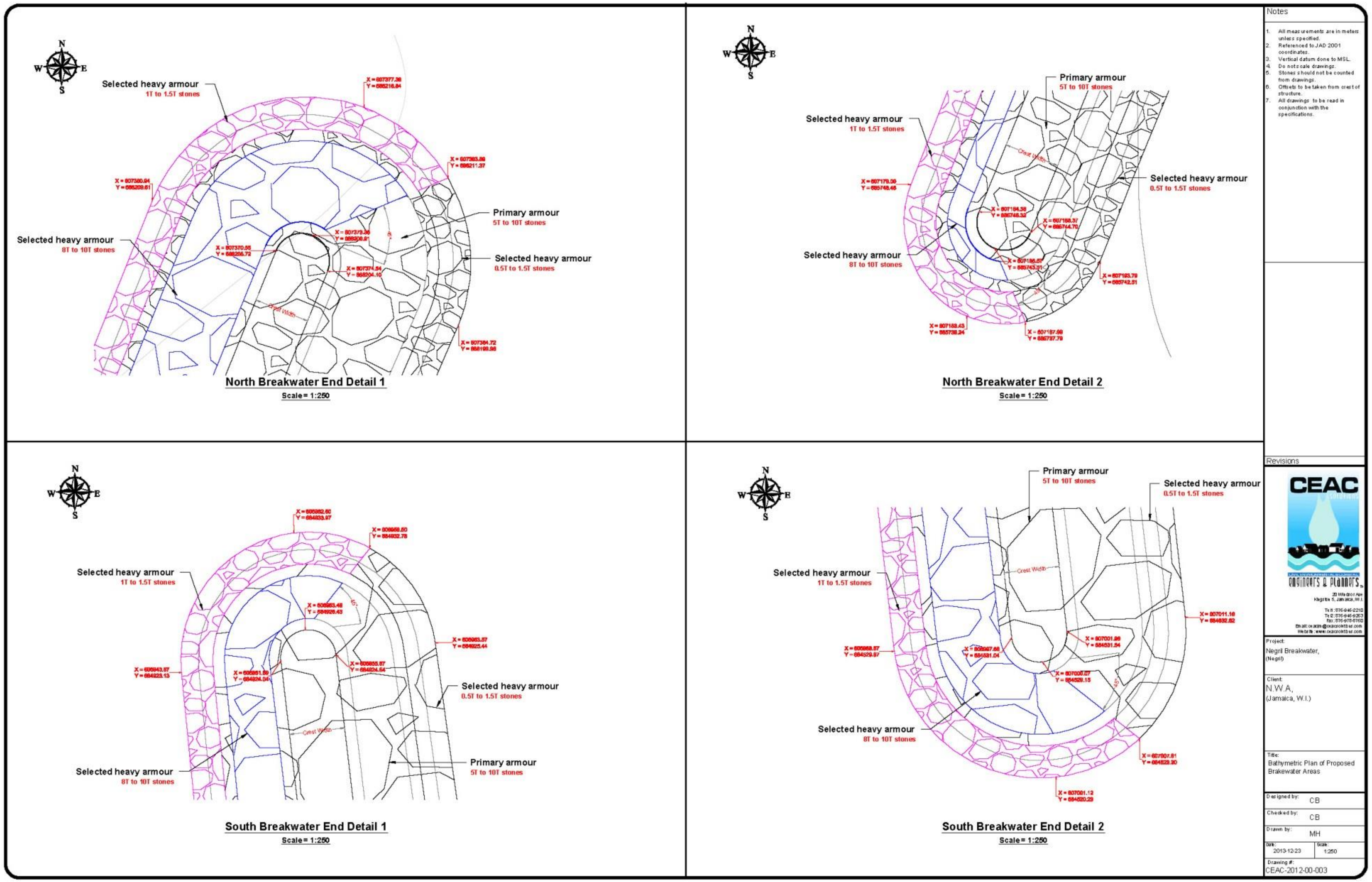



*Figure 5-5 Bathymetric plan of proposed breakwater areas*

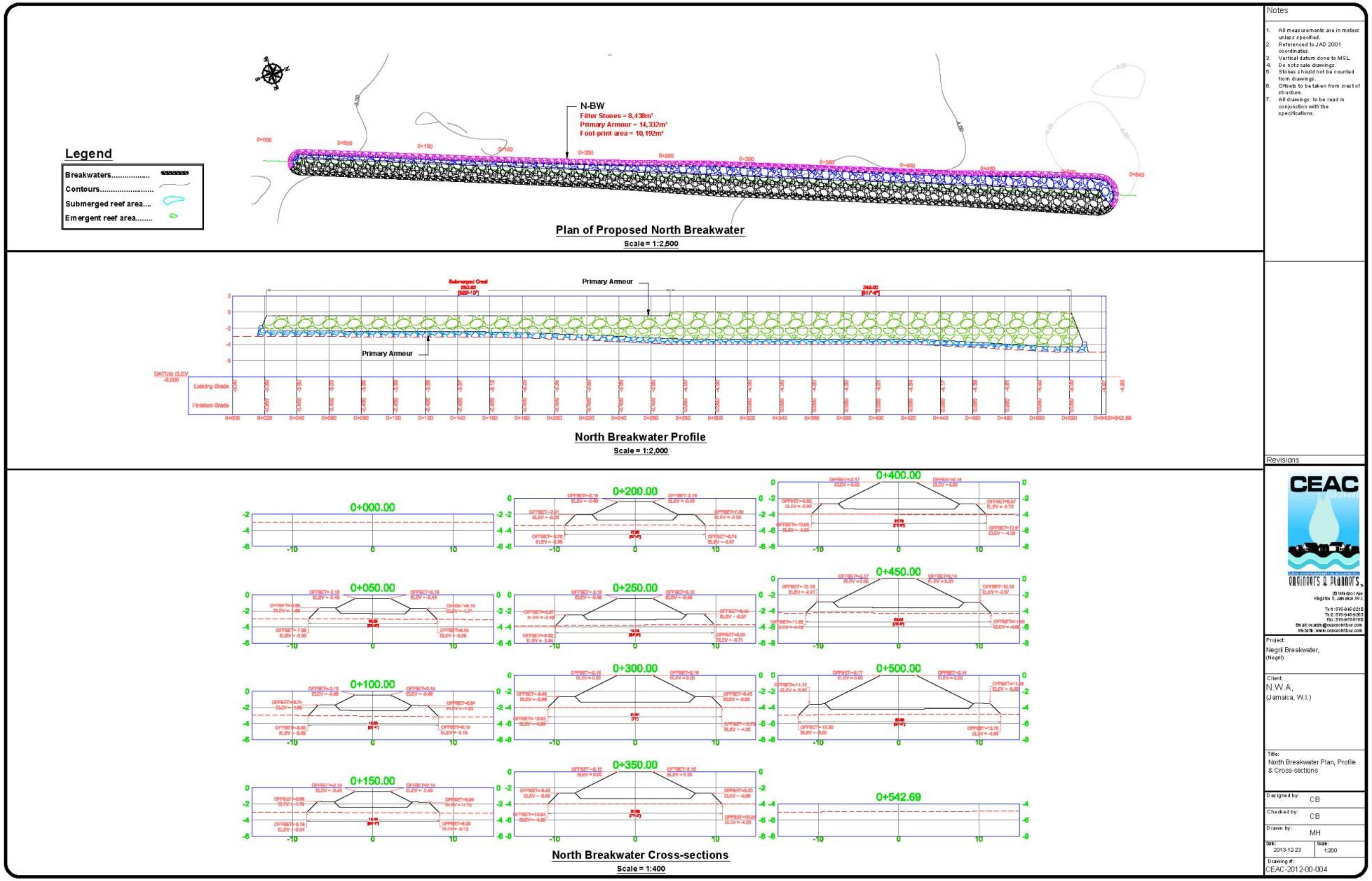



*Figure 5-6 North breakwater plan, profile and cross-sections*

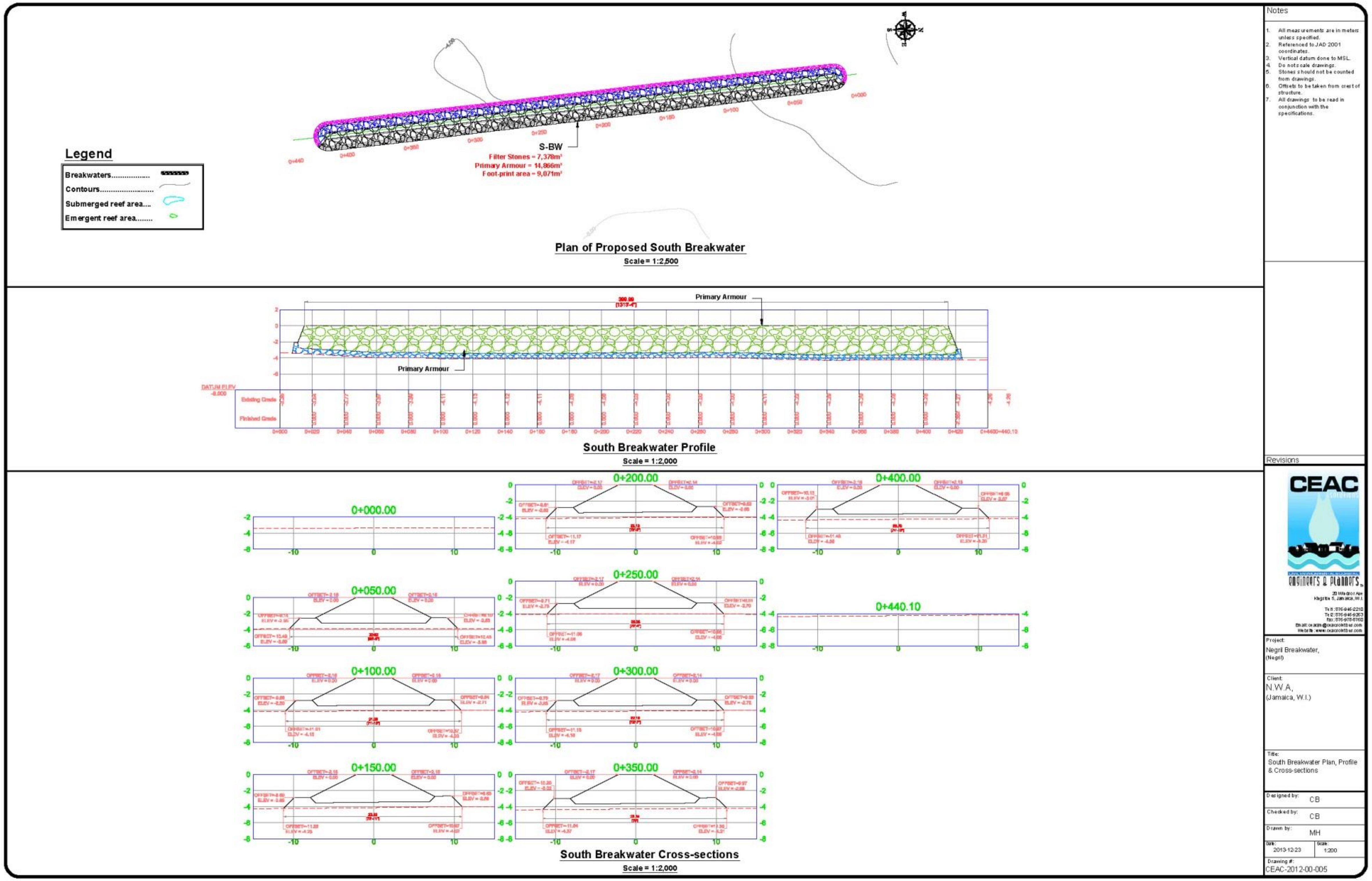



*Figure 5-7 South breakwater plan, profile and cross-sections*

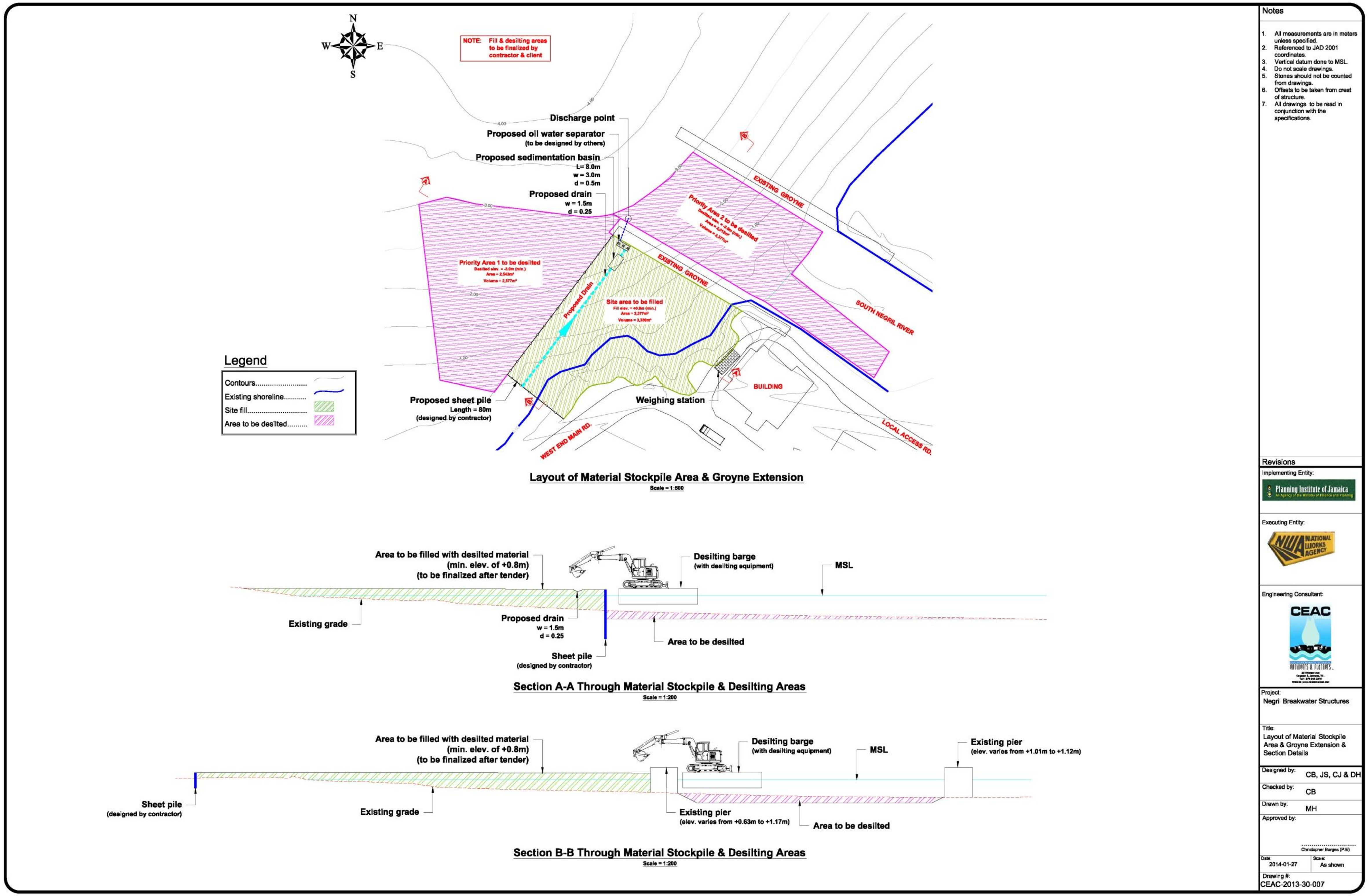



*Figure 5-8 Layout of material stockpile area/ staging area and desilting areas*

#### 5.3.1.7 Planning and Structural Design

**Navigation Impacts Assessment and Recommendations (Port Authority of Jamaica)**

Meetings have been held with the major telecoms providers as well as the Port Authority of Jamaica. The telecoms providers have indicated that they have infrastructure in Negril but this is so far offshore that they will not be impacted by the construction. Similarly, the Port Authority will provide a report indicating any issues they may have with the placement of the structures.

**Geotechnical Considerations/Settlement**

Seafloor strata and the weight of the proposed rock volume were considered in order to minimize the risk of settlement. The use of bare sand and clay sea floors, without adequate filter protection or pore pressure reducing mechanisms can fail and lead to excess settlement, (Browder et al. 1996). Rock is a strong strata and is an asset in coastal shoreline protection works, by reducing settlement risks. Seafloor photography and investigations revealed a pavement type floor over the entire footprint, with shallow (<0.6 metres) of sand. Settlement by seafloor eroding is expected to be minimal with a geotextile or filter stone provision. Settlement on fine sand substrate is expected to be in the range of 3 to 15 cm immediately after construction (Burcharth et al. 2006). However, the project will employ a geotextile and filter stone layer to ensure the settlement is minimal in order that design crest elevation is achieved with minimal material.

#### 5.3.1.8 Material Verification and Constructability

**Quarry Survey**

Quarry surveys were undertaken at several potential quarries in the region to determine suitability for the supply of armour stones. Site visits were made to eleven (11) quarries, 9 in Westmoreland and 2 in Hanover as follows:

- Dump
- Over River
- Jamwest Aggregates Ltd
- Chris Forrester
- Starline Construction and Starline Construction and Realty Ltd
- Nationwide Design Co. Ltd
- DR Foote Construction
- ABR Quarries Ltd
- Great Valley Aggregates
- Delroy Pearce's

A rapid assessment was undertaken for each quarry, the results of which are summarised in Table 5-5. In general the potential quarries are within 50 kilometres of the site and have a history of providing both aggregate and armour stones for similar projects. Mining is done by blasting and with the use of bulldozers. Licensed blasters are used where required.

*Table 5-5 Summary of quarry survey findings*

| Name | Distance from Site (km) | Operations | Comments |
|---|---|---|---|
| **Dump Quarry** | 40 | 40 years of activity | History of producing good quality aggregates for construction |
| **Over River Quarry** | 17 | Abandoned and re-established in 2004 | Outcrops of rock that can be readily mined without blasting. operations are not elaborate by any means and production is relatively low compared to potential |
| **Jamwest Aggregates Ltd** | 20 | Well established and equipped | The only quarry assessed that blasts on a regular basis |
| **Chris Forrester** | 45 | New quarry that hasn't started harvesting stones | Blasting will be used to harvest stones and the quarry is capable of harvesting the required stone sizes |
| **Starline Construction** | 40 | Some experience in clearing and cutting roads in development. Has access to the port | Limestone rock is the dominant stone type at the quarries but it appears to be chalky and fractured. Can produce 12,000 tonnes/ day |
| **Nationwide Design Co** | 45 | Outstanding experience in Montego Bay | Quarry is reported to have the strongest/ hardest and most suitable rocks for the project |
| **DR Foote Construction** | 36 | Material is suspect | Limestone rock is the dominant material but the stones appear to be chalky, fractured, weathered and porous |
| **ABR Quarries Ltd.** | 30 | Issues with MG to be clarified | Smaller sized stones (300 – 600 kg) can be harvested from this quarry |
| **Great Valley Aggregates** | 51 | Inactive for about 3 years but can be put in production in short order | The equipment has not been in use for some time but the heavy duty equipment can be serviced and put back in good working order with some effort |
| **Delroy Pearce Quarry** | 10 | Well established and equipped | All haulage is sub contracted and blasting is done as necessary and such operation is outsourced |

**Quality Requirements**

The scale model test allowed CEAC to determine the quality requirements of the rocks to be used in this project. The rocks should be clean; hard; resistant to weathering and degradation; free from continuous cracks or fractures, others flaws and from soft, weathered or decomposed parts. Unsuitable rocks include, but are not limited to, shale and rocks containing layers of shale, extreme foliation, chert, inclusion of objectionable amounts of dirt, woody debris, sand and clay. Rocks that are laminated, porous or otherwise physically weak will also be rejected

All armour stone should meet or exceed the following properties:

- A Specific density of 2.50 for more than 90% of the samples. No sample less than 2.45

- Water Absorption less than 3.0%. If > 3% but less than 4.5%, then LA must be acceptable.
- LA Abrasions less than 35% losses after 500 revolutions.
- MgSO4 soundness of less than 15% losses after 5 cycles.
- Field drop test: less than 10% breakage or cracking (from 3 metres) for 10 samples, on a bed

Rocks used need to be rough and angular cubicle. Under no circumstances should rounded or very rounded stones be used in the works. River stones can be utilized in the works, subject to meeting the shape, material and other relevant specifications and after the approval of the engineer.

The ratio of the length to thickness of stone measured at right angles should not be greater than 2.5:1 for more than 5.0% of the stones and under no circumstance greater than 3:1. Also, 90% of the stones from the source shall meet or exceed the following additional criteria:

- Blockiness greater than or equal to 50%, and
- Fourier Asperity Roughness or Roundness (Pr) greater than 0.01

It should be noted that in Westmoreland, limestone quarries are interspersed with marl quarries suggesting differing geology within the same region. The possibility of wide variations in the stone sizes and quality as a result of differing geology, blasting patterns and operators makes the quality control of the this aspect particularly important and potentially chaotic. This issue will have to be addressed by a combination of awareness of the requirements and centralizing the quality control aspects. With that being said, a few of the quarries assessed do not have rocks that are suitable for the project, in particular, Starline Construction and DR Foote Construction.  Nationwide Design Co however, is reported to have the most suitable rocks for the project and is known for delivering outstanding work.

**Stockpile Area Assessment**

A shoreline stockpile area will be required for the project in order to facilitate the loading of the barge with stones. Three potential sites were identified:

1. The north river entrance to the sea; and
2. The south river entrance to the sea.
3. Savannah-La-Mar

*North Negril River*

The initially proposed North Negril River stockpile site is on the western side of the highway approximately 1 kilometre north of the RIU Hotel. It has relatively low utility lines, a high density of flora life and significantly large rock outcrops which make it difficult to make ready for construction. The river may need some amount of dredging to accommodate a loaded barge. This site should not be considered a first option at this time.

*Plate 5-1 A section of the North River site showing mangroves and other flora species*

*South Negril River*

The South Negril River stockpile area is favoured because of the reduced environmental impacts to the flora and fauna receptors and tolerable social impacts. Whereas the north Negril river location would encounter reefs and a longer round trip travel distance of 9.3 kilometres, the south Negril River has a clearer path with less obstructions and a round trip distance of 7.6 kilometres. The incremental distance between the two options for 220 estimated trips with boulders is 374 kilometres. Additionally, the site preparation will be cheaper and provide easier access for the trucks. These factors are expected to translate into lower tendered amounts/cost savings.

Site preparation will involve land filling next to the southern groyne seaward for approximately 47 metres to the tip of the groyne to create an area 30 metres wide. Filling can be facilitated by dredging the south Negril River to 2 to 3 metres where it has choked because of both marine and terrestrial sediments and by dredging the Caribbean Sea section in front of the site area. This de-silting will have a positive social impact in facilitating the fishermen's entry to the fishing beach. The estimated volumes of fill requirements and desilting are relatively close and believed to be a viable approach, once socially acceptable. They are as follows:

1. Fill volume of **3,339 m$^3$**
2. De-silting/dredging south Negril river for fill, volume taken from two priority areas:
    a. South Negril River volume of **2,377 m$^3$**
    b. Caribbean Sea volume of **2,377 m$^3$**

*Plate 5-2 Section of the Southern site proposed for boulder stockpiling*


*Plate 5-3 Proposed stockpile area (white shaded area 30x 47) and proposed river area to be desilted (33 x 42 to 3 metres)*

*Savannah La-Mar*

The proposed Savannah-La-Mar stockpile area would be located 40km, one way, by barge, from the project area. This option is considered inferior to the South Negril River option as it will increase the time to complete the project and the cost of the project.

**Summary**

Practicalities and stakeholder's consultation with local and national governance officials dictate that the South Negril stockpile site is the best option at this time. Dredging of the Negril River will be beneficial to the access to the river by fisher folks. Additionally, the stockpile area is proximal to the breakwater site and will minimize travel times and costs. Environmental scoping and assessment will dictate if there are any serious concerns.

Letters sent to land owners who may be potentially affected by the construction stockpile area may be seen in Appendix 7.

## 5.3.2 Construction Phase

### *5.3.2.1 Construction Methodology*

Breakwater construction will be initiated from the shoreline stockpile area where licensed quarried will deliver the required boulders, washed and sorted. The material shall be sorted in the quarries into the respective size classes and washed of any impurities that may have a deleterious effect. The boulders shall be free from dirt, mud, marl or other material that may unnecessarily discolour the marine environment or result in dust nuisance during transportation, storage or otherwise. Washing facilities must not result in any damage, nuisance or deposits in water courses or other surface or groundwater bodies and shall be conducted in a manner that is acceptable to the local environmental regulators. Sources of water for the washing of stones may be the public water system (NWC), wells, ponds or rivers, depending on the location of the quarry.

The construction methodology is depicted in Figure 5-9 and Figure 5-10 and is detailed in subsequent sections.

**Campsite Preparation and River De-silting**

*Driving Sheet Pile to Define Area*

Seventy-five (75) metres of sheet pile will be required along the stockpile area in order to facilitate the barge and creation of the stockpile area. Piling will be done for 1 to 2 weeks. This will be done after some filling has occurred to create a platform for the crane with the pile driver. The stockpile area will be surrounded by turbidity barriers during construction.

*Landfilling and Dredging*

The draft around the groynes of the South Negril River was determined to be 1.0 to 2.5 metres outside and alongside the proposed sheet piles, and 2.0 to 3.0 metres alongside the groyne. These are at the limits of the expected draft of the barge at 2.4 metres fully loaded. The work area will be de-silted by excavators operating primarily from land or from the barge if needs be. The land based approach is preferred and would be required from the supply contractor in order to generate the fill for the stock pile area. A long-reach excavator with shaping bucket will be used for this purpose (Plate 5-4). It must be noted that dredging was included the original proposal; however this has been changed and there will no longer be dredging of any section of the river. Instead, material will be sourced from licenced quarries for the creation of the stockpile area.

The camp site wearing surface will be finished with crushed aggregate or the river fill (if adequate) to ensure a practical driving surface for the trucks with boulders. Site office for the engineer, resident engineer, and supply and placement contractor will be established likewise in container offices. Sewage services will be provided by way of portable toilets and temporary on site disposal methods. The stormwater generated on site will be collected and sent to a sediment basin, followed by an oil water separator before being discharged into the Negril River.


*Plate 5-4 Example of a long-reach excavator with shaping bucket*

**Placement of Boulders**

*Removal of Bio-physical Features in Footprint and Relocation*

The footprint will be clear of all species as per the requirements of the environmental permit and verified by NEPA. Once cleared, the contractor will be given the go ahead to place geotextile and to establish the offshore working platform.

*Placement of Turbidity Barriers*

Curtains 6' to 8' deep will be deployed around the work areas and anchored properly. These will be adjusted daily or as required to move with the work and replace damaged sections in order to maintain water quality requirements.

*Placement of Geotextile*

Geotextile will be placed in the footprint in 10 metre segments. The need for this component is still being assessed given that observations are that the sea floor in the footprint is pavement. The material will be weighted with small boulders placed by divers.

*Retrieval of Boulders from Stockpile Area*

Supply barges will dock alongside the southern groyne of the South Negril River. The three boulder stone classes will be loaded on the barge either by crane on land or by loaders. This will be done by the placement contractor to ensure care in the handling of the supply barges.

*Plate 5-5 Retrieval of boulders using front end loader*

*Placement of Boulders in Footprint*

Placement will be initiated with the filter stones on the seafloor or geotextile. The shapes will be achieved and surveyed by the contractor for accuracy to the designs. This will be undertaken by a grapple with mechanical mechanism versus hydraulic mechanisms to mitigate hydraulic fluid leakage in the marine environment. A spudded barge with a minimum capacity of 600 tonnes will be used for this purpose with a crane with a minimum capacity of 130 tonnes. The actual process envisaged will be:

1) Retrieve boulders from supply barge
2) Place boulders on seafloor
3) Move placement barge with spud traveller or tug if needed
4) Continue placement of filter stones for 30 to 50 metres
5) Survey placement
6) Retrieve primary armour from supply barge, and repeat process 2 to 5 for crest armour as well.

*Plate 5-6 Spudded barge with crane*

*Quality Control Measures*

Quality control activities will be required of the contractor including: hydrographic surveying, under-water photography and weight sensor recording. 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 placement barge with crane and grapple and a crew of one or two boulder barges, plus support vessels, including tugs.

*Logistics Movements*

Stones will be delivered in both open back tipper trucks and flat beds with the boulders secured. An estimated 24 trips per day will be required in order to meet the project schedule. Barge capacities will determine the number of trips but with a nominal capacity of 400 tonnes, then 113 trips will be required or 2 trips per day. Only daytime operations are expected. See Table 5-6 for the logistic calculations for construction.

*Table 5-6 Logistics calculations for construction*

| Stone range | Volume (cm) | Quantity per load | Number of truck/ trailer loads |
|---|---|---|---|
| 400 to 800 Kg | 15,816 | 18 | 879 |
| 5 to 9T | 23,359 | 15 | 1,557 |
| 8 to 13 T | 5,840 | 12 | 487 |

Summary of logistics are as follows:

- Total weight of stones (T): 45,014
- Weight on barge per load: 400
- No. of barge trips: 113
- Duration (months): 6
- Truck/ Trailer Trips per day: 24
- Total no. Truck/ Trailer loads: 2,923

#### *5.3.2.2 Emergency Management Plans*

The construction sites are expected to be affected by natural and manmade disasters (such as storm surges and winds associated with severe storms). The Specifications developed for the project outline the conditions for preparing emergency management plans for natural and manmade disasters. These plans will also cover early warning systems to enhance site preparation and clearance depending on the magnitude of the storm anticipated.

#### *5.3.2.3 Post Construction Purposing*

The stockpile area will be removed upon completion of the breakwater construction project. The contractor is responsible for submitting a closure plan for this at the relevant time.

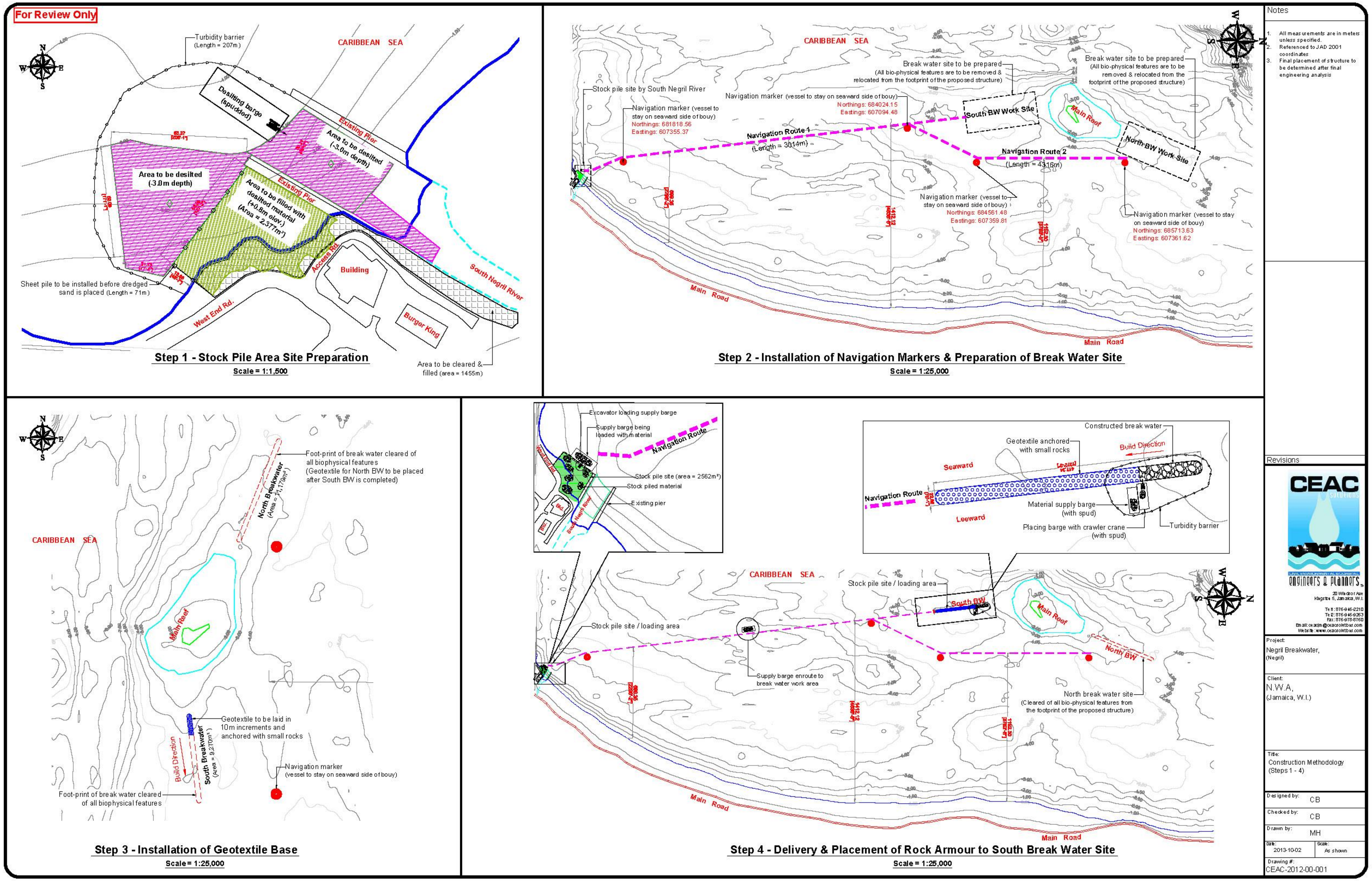



*Figure 5-9 Engineer drawings depicting steps 1 through to 4 of construction methodology*

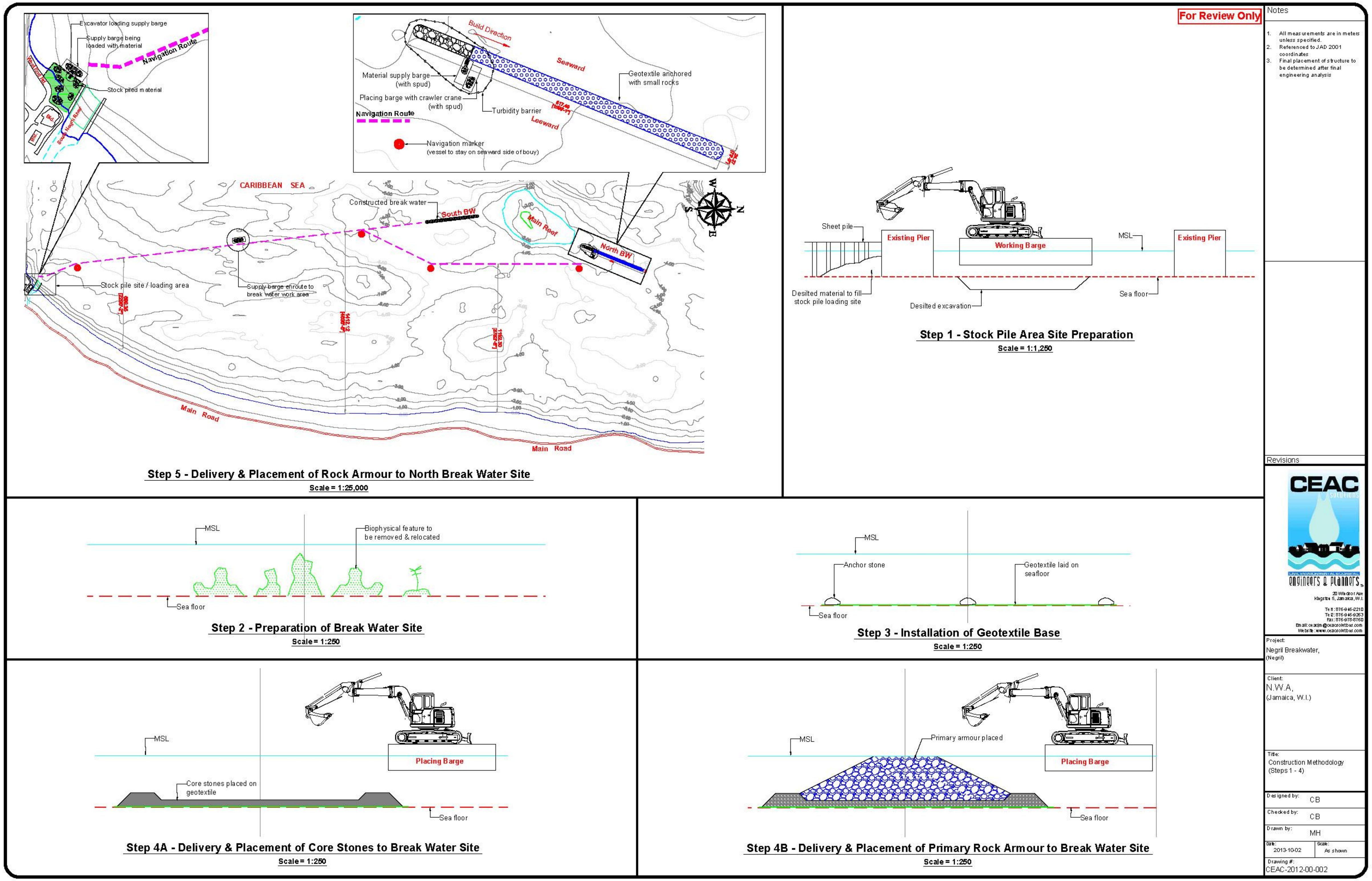



*Figure 5-10 Engineer drawings depicting steps 1 through to 4 of construction methodology in cross-section*

### 5.3.3 Monitoring

The following monitoring recommendations were made by CEAC based on the design analysis conducted to date:

1. **Long Term Post Construction Monitoring**
    a. Currents - Given the breakwaters are expected to reduce the currents in the Bay, long term monitoring is recommended for the currents in the Bay. ADCP should be deployed continuously at least for a year to monitor the currents and waves for comparison to preconstruction conditions. A pre-construction monitoring period of at least a month is recommended, then during construction and then one year post-construction
    b. Shoreline location - shoreline vulnerability analysis has shown climate change is responsible for most of the shoreline erosion (63 to 73 percent) over the past 45 years. It is therefore prudent that the cross-shore profile (from the back of beach to 0.9m depth offshore) be measured at 100 (in areas with most accretion or erosion) to 200 meters (at extremities) intervals along the shoreline for at least 2 years. Measurements should be taken at monthly intervals and just after major swell or hurricane events.
    c. Water Quality - water quality must be measured as well monthly given the reduced currents and flushing time in the bay coupled with the already elevated nutrient levels in the bay.
2. **A Construction and Environmental Monitoring Programme** is recommended for the duration of the construction period. These programmes should consist of:
    - Material and workmanship monitoring to ensure compliance with engineering specifications and drawings.
    - Environmental monitoring of water quality, dust and noise to ensure that reasonable local and relevant international guidelines are being followed and met.

## 5.4 PROJECT ACTIVITIES AND SCHEDULE

As mentioned previously, the project was conceptualized by the NWA in three phases - (1) Design phase; (2) Construction phase and (3) Monitoring phase. A total duration of 30 months from start (originally August, 2013) was envisaged.

Detailed field data collection, engineering design, EIA and procurement were activities planned for the first phase (Design). Construction activities are expected to take no more than eleven months. This phase will be initiated with the completion of the procurement process. Construction activities will be initiated with the preparation of the South Negril River stock pile area and cleaning of the river mouth. This phase can be conceptualized in two discrete set of activities (boulder supply and placement) and are broken down as follows (Table 5-7):

*Table 5-7 Construction phase activities and timelines*

| Months | Camp site and stock pile area preparation | Boulder Supply | Placement of boulders |
|---|---|---|---|
| **1** | • Driving sheet pile to define area<br>• Dredging south Negril river<br>• Landfilling camp site with desilting material<br>*(It must be noted that dredging was included the original proposal; however this has been changed and there will no longer be dredging of any section of the river. Instead, material will be sourced from licenced quarries for the creation of the stockpile area.)* | • Drilling and blasting<br>• Sorting and washing<br>• Stockpiling | • Removal of bio-physical features in footprint<br>• Relocation<br>• Dredging around stockpile area to make allowances for draft and loads |
| **2** | | Delivery to site | • Retrieve boulders from stock pile area<br>• Place boulders in footprint |
| " | | Delivery to site | |
| **11** | Demobilize stock pile area | Delivery to site | |

A thirty six month monitoring period in Phase 3 is envisaged where structures, water quality and shoreline parameters will be observed.

The Project timeline is depicted in Table 5-8.

*Table 5-8 Project timeline*

| N° | Activity | Months | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 |
| 0 | **Commencement** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 1 PHASE 1 – Completion of engineering drawings and bill of quantities | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | 1.1 Project Initialization/initiation (this corresponds to activity 1) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | 1.2 Review of Existing and Recent Information | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | 1.3 Field Data Collection Programme | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | 1.3.1 Moored ADCP Current Survey | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | 1.3.2 Drogue Tracking | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | 1.3.3 Currents verification: ADCP/Drogues | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | 1.3.4 Hydrographic/Bathymetric Surveys (this corresponds to activity 4) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | 1.3.5 Water Quality Survey | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | 1.3.6 Shoreline Survey | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | 1.3.7 Sediments and Depth to Rock | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | 1.3.8 Anecdotal Information on previous storms | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | 1.4 Definition of Deepwater Wave Climate (this corresponds to activity 2) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | 1.4.1 Hurricane Waves | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | 1.4.2 Operational and Swell | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | 1.5 Long-term Shoreline Change | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | 1.5.1 Rate of Change assessment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | 1.5.2 Future Shoreline Projections without Project | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | 1.5.3 Comparison to other beaches across Jamaica | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 1.5.4 Relative Impact of Sea Level Rise (SLR) versus Extreme Events | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | 1.6 Climate Resilience and Adaption | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | 1.7 Hydrodynamic (RMA 10) and Water Quality Analysis (RMA 11) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | 1.7.1 Water Quality Assessment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | 1.7.2 Beach Safety Assessment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | 1.7.3 Flushing Analysis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 26 | 1.8 Nearshore Wave Climate Analysis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | 1.8.1 Pre-Project, Post-Project and Future Climate | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | 1.8.2 Sediment Stability Assessment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | 1.9 Sediment Transport Regime | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | 1.10 Material Verification and Constructability (this corresponds to activity 3) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | 1.10.1 Quarry Survey | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 32 | 1.10.2 Stockpile Area Assessment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 33 | 1.10.3 Construction Methodology Study | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 34 | 1.11 Scale Model Study (Laboratory Flume Study) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 35 | 1.11.1 Design Criteria, Formulation of Information for Laboratory and Model set-up | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 36 | 1.11.2 Design Iterations | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 37 | 1.11.3 NWA Training and Observations | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 38 | 1.11.4 Model Recommendations/Report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 39 | 1.12 Planning and Structural Design | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 40 | 1.12.1 Navigation Impacts Assessment and Recommendations (Port Authority of Jamaica) (this corresponds to activity 6.6) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 41 | 1.12.2 Geotechnical Considerations/Settlement | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 42 | 1.12.3 Performance and Design Criteria | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 43 | Criterion | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 44 | 1.13 Drawings and Contract Documentation (this corresponds to activity 5) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 45 | 1.13.1 Drawing Preparation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 46 | 1.13.2 Bill of Quantities | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 47 | 1.13.3 Specifications | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 48 | 1.13.4 Engineers Estimate | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 49 | 1.13.5 Client Review | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 50 | 1.13.6 Bid Document Preparation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 51 | 1.14 Environmental Impact Assessment (EIA) (this corresponds to activity 6) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 52 | 1.15 Project Presentation Workshop | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | **REGULATORY PROCESSES/APPROVALS AND PROCUREMENT** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 53 | 2 PHASE 2 – Construction Monitoring | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 54 | 2.1 Assistance with Tender Evaluation Report | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 55 | 2.2 Pre-construction changes and schedule | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 56 | 2.2.1 Pre-construction meeting | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 57 | 2.2.2 Revision of Drawings and Specifications | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 58 | 2.2.3 Review Contractor Schedule | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 59 | 2.3 Technical Support during Construction | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 60 | 2.4 Compliance Monitoring | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 61 | 2.4.1 Monthly Reporting | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 62 | 2.5 Quantities and Certification | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 63 | 2.6 Quarry Inspection | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 64 | 2.7 Environmental Monitoring | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 65 | 2.8 Reporting | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 66 | 3 PHASE 3 – Post-Construction Monitoring | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 67 | 3.1 Structural Monitoring | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 68 | 3.2 Shoreline Monitoring | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 69 | 3.3 Water Quality Monitoring | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 70 | 3.4 Biological Adaption and Relocation Monitoring | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 71 | **COMPLETION** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

# 6.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

## 6.1 PHYSICAL

### 6.1.1 Water Quality

#### *6.1.1.1 Methodology*

Eighteen (18) stations were sampled within Long Bay. The locations of the stations are listed in Table 6-1 and shown in Figure 6-1.

Each of the water samples was 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, nitrates and faecal coliform.

Temperature, conductivity, salinity, pH, Dissolved Oxygen (D.O.), turbidity, Total Dissolved Solids (TDS) and light irradiance (Photosynthetically Active Radiation – PAR) were measured *in situ* using a Hach Hydrolab DataSonde-5 multi probe water quality meter (See Appendix 8 for Calibration Certificate).

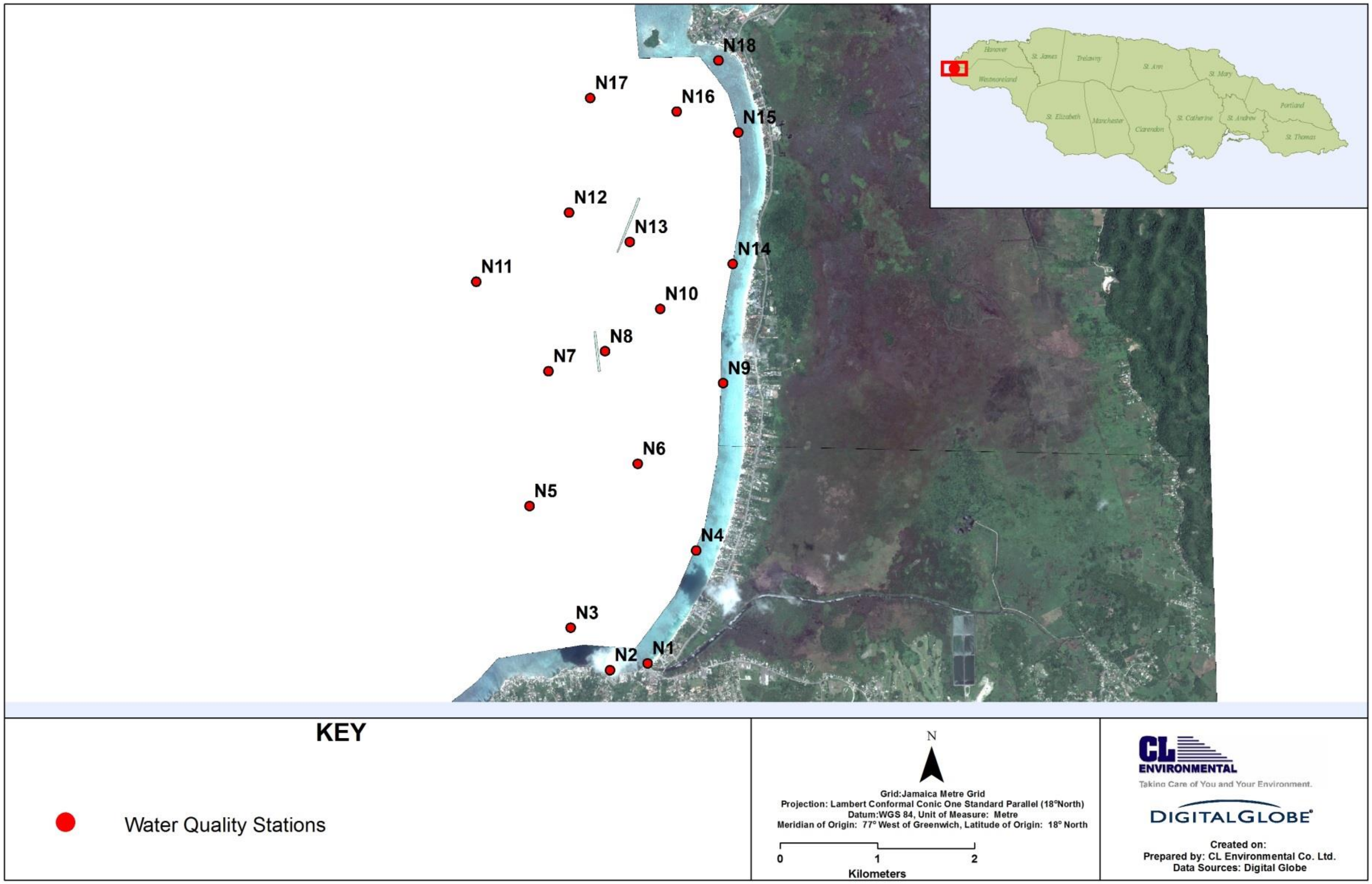



*Figure 6-1 Locations of the water quality stations and phytoplankton samples within Long Bay*

*Table 6-1 Location of water quality stations (JAD 2001), Long Bay*

| Station | Northing (m) | Easting (m) |
|---|---|---|
| N1 | 607,489.12 | 681490.94 |
| N2 | 607,107.70 | 681432.26 |
| N3 | 606,696.94 | 681872.36 |
| N4 | 607,997.68 | 682664.54 |
| N5 | 606,276.40 | 683114.42 |
| N6 | 607,391.32 | 683554.52 |
| N7 | 606,472.00 | 684512.97 |
| N7 | 607,058.80 | 684718.35 |
| N8 | 608,271.52 | 684385.83 |
| N9 | 607,616.26 | 685158.45 |
| N10 | 605,728.71 | 685432.29 |
| N11 | 606,687.16 | 686142.32 |
| N12 | 607,313.08 | 685848.92 |
| N13 | 608,369.32 | 685623.98 |
| N14 | 608,428.004 | 686975.58 |
| N15 | 607,792.30 | 687190.74 |
| N16 | 606,902.32 | 687337.44 |
| N17 | 608,232.40 | 687718.86 |
| N18 | 607,489.12 | 681490.94 |

### 6.1.1.2 Results

In many of the physicochemical variables examined, there was little variation seen among the stations with the exception of Station 1. The low variability in physicochemical parameters has been noted in Bays and Harbours around Jamaica (CL Environmental 2001; M. K. Webber et al. 2003; M. Webber et al. 2005) with changes attributed to run-off and proximity to shore (D. F. Webber and Kelly 2003; M. Webber et al. 2005; D'Croz, Del Rosario, and Gondola 2005).

The influence of the South Negril River at Station 1 was demonstrated in the lower temperature, salinity, specific conductivity and TDS. The South Negril River also receives partially-treated sewage with increased concentrations of N:P (~13) which flows into Long Bay and around Negril's "West End" which results in increased algal biomass (Lapointe et al. 2011). In the present study, Station 1 showed the highest average BOD, phosphate and faecal coliform values that could be attributed to the outflow from the sewage plant or the presence of a fishing village located along the banks of the River.

*Table 6-2 Average physical data for the parameters for all stations*

| Stn. | Depth (m) | Temp. (ºC) | SpC. (mS/cm) | Sal. (ppt) | pH | DO (mg/l) | Tur. (NTU) | TDS (g/l) | PAR (uE/m2/s) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 27.67 | 32.66 | 21.14 | 8.30 | 4.04 | 5.67 | 31.24 | 364.7 |
| 2 | 0 | 29.21 | 52.76 | 34.86 | 8.24 | 5.47 | 3.30 | 33.76 | 367.7 |
| | 1 | 29.21 | 52.76 | 34.87 | 8.24 | 5.22 | 3.57 | 33.78 | 213.0 |
| | 2 | 29.28 | 53.84 | 34.91 | 8.24 | 4.92 | 3.40 | 33.82 | 131.3 |
| | 3 | 29.14 | 52.77 | 34.86 | 8.23 | 5.22 | 4.00 | 33.78 | 176.0 |
| 3 | 0 | 29.23 | 52.85 | 34.92 | 8.24 | 6.06 | 1.53 | 33.83 | 1130.3 |
| | 1 | 29.25 | 52.86 | 34.94 | 8.23 | 6.03 | 1.57 | 33.83 | 605.3 |

| Stn. | Depth (m) | Temp. (ºC) | SpC. (mS/cm) | Sal. (ppt) | pH | DO (mg/l) | Tur. (NTU) | TDS (g/l) | PAR (uE/m2/s) |
|---|---|---|---|---|---|---|---|---|---|
| | 2 | 29.25 | 52.85 | 34.93 | 8.23 | 6.04 | 1.60 | 33.84 | 468.0 |
| | 3 | 29.26 | 52.88 | 34.95 | 8.23 | 6.03 | 1.67 | 33.85 | 399.0 |
| | 4 | 29.25 | 52.87 | 34.94 | 8.23 | 5.99 | 1.90 | 33.85 | 315.7 |
| | 5 | 29.24 | 52.89 | 34.95 | 8.23 | 5.89 | 2.10 | 33.86 | 309.7 |
| | 6 | 29.24 | 52.89 | 34.96 | 8.23 | 5.81 | 2.10 | 33.86 | 249.7 |
| | 7 | 29.25 | 52.89 | 34.95 | 8.23 | 5.79 | 2.23 | 33.85 | 233.7 |
| 4 | 0 | 28.96 | 52.83 | 34.91 | 8.22 | 5.95 | 2.17 | 33.81 | 1429.0 |
| | 1 | 28.98 | 52.83 | 34.93 | 8.22 | 5.94 | 2.13 | 33.82 | 802.0 |
| | 2 | 28.97 | 52.82 | 34.90 | 8.22 | 5.95 | 2.17 | 33.80 | 682.0 |
| | 3 | 28.95 | 52.81 | 34.90 | 8.22 | 5.95 | 2.27 | 33.80 | 486.7 |
| | 4 | 28.92 | 52.82 | 34.90 | 8.22 | 5.94 | 2.57 | 33.80 | 384.7 |
| 5 | 0 | 29.16 | 52.93 | 34.98 | 8.22 | 6.00 | 2.80 | 33.85 | 1095.3 |
| | 1 | 29.17 | 52.91 | 34.97 | 8.22 | 5.98 | 2.67 | 33.86 | 633.7 |
| | 2 | 29.17 | 52.89 | 34.96 | 8.22 | 6.00 | 2.70 | 33.86 | 599.0 |
| | 3 | 29.17 | 52.89 | 34.96 | 8.22 | 5.99 | 2.73 | 33.86 | 481.7 |
| | 4 | 29.18 | 52.90 | 34.96 | 8.21 | 5.99 | 2.77 | 33.84 | 422.0 |
| | 5 | 29.17 | 52.90 | 34.96 | 8.22 | 6.00 | 2.93 | 33.86 | 446.3 |
| | 6 | 29.17 | 52.90 | 34.96 | 8.22 | 6.00 | 3.07 | 33.84 | 339.7 |
| | 7 | 29.17 | 52.90 | 34.95 | 8.22 | 5.99 | 3.03 | 33.86 | 320.0 |
| | 8 | 29.17 | 52.89 | 34.96 | 8.22 | 6.00 | 3.00 | 33.85 | 263.0 |
| | 9 | 29.18 | 52.89 | 34.96 | 8.22 | 6.02 | 3.20 | 33.85 | 260.7 |
| 6 | 0 | 29.12 | 52.90 | 34.96 | 8.21 | 5.93 | 3.40 | 33.85 | 1122.3 |
| | 1 | 29.14 | 52.89 | 34.95 | 8.21 | 5.90 | 3.33 | 33.84 | 910.0 |
| | 2 | 29.14 | 52.88 | 34.95 | 8.21 | 5.90 | 3.13 | 33.85 | 667.7 |
| | 3 | 29.14 | 52.87 | 34.93 | 8.35 | 5.91 | 2.90 | 33.82 | 457.0 |
| | 4 | 29.11 | 52.86 | 34.93 | 8.21 | 6.01 | 2.90 | 33.84 | 478.0 |
| | 5 | 29.14 | 52.89 | 34.94 | 8.21 | 5.95 | 2.87 | 33.85 | 395.3 |
| | 6 | 29.14 | 52.87 | 34.96 | 8.21 | 5.91 | 2.73 | 33.84 | 380.7 |
| | 7 | 29.42 | 52.83 | 34.91 | 8.24 | 5.91 | 3.05 | 33.81 | 346.5 |
| 7 | 0 | 29.00 | 52.88 | 34.94 | 8.39 | 5.95 | 3.13 | 33.84 | 424.7 |
| | 1 | 29.02 | 52.91 | 34.97 | 8.38 | 5.93 | 2.13 | 33.87 | 225.3 |
| | 2 | 29.02 | 52.91 | 34.97 | 8.37 | 5.94 | 1.87 | 33.86 | 173.7 |
| | 3 | 29.02 | 53.93 | 34.98 | 8.37 | 5.95 | 1.40 | 33.88 | 145.0 |
| | 4 | 29.02 | 52.91 | 34.98 | 8.37 | 5.94 | 1.50 | 33.88 | 131.3 |
| | 5 | 29.03 | 52.93 | 34.98 | 8.37 | 5.95 | 1.73 | 33.86 | 116.7 |
| | 6 | 29.02 | 52.93 | 34.98 | 8.37 | 5.93 | 1.83 | 33.87 | 99.0 |
| | 7 | 29.02 | 52.91 | 34.97 | 8.37 | 5.90 | 1.90 | 33.87 | 84.7 |
| 8 | 0 | 29.06 | 52.94 | 34.98 | 8.27 | 5.96 | 6.43 | 33.87 | 875.0 |
| | 1 | 29.07 | 52.92 | 34.98 | 8.24 | 5.78 | 4.13 | 33.87 | 597.3 |
| | 2 | 29.08 | 52.91 | 34.96 | 8.24 | 5.78 | 4.03 | 33.86 | 716.3 |
| | 3 | 29.08 | 52.90 | 34.96 | 8.23 | 5.80 | 3.83 | 33.86 | 408.7 |
| | 4 | 29.09 | 52.91 | 34.96 | 8.21 | 5.82 | 3.57 | 33.86 | 441.0 |
| 9 | 0 | 29.10 | 52.85 | 34.93 | 8.21 | 5.88 | 3.83 | 33.82 | 991.3 |
| | 1 | 29.10 | 52.84 | 34.92 | 8.22 | 5.84 | 3.53 | 33.81 | 1365.0 |
| | 2 | 29.10 | 52.84 | 34.91 | 8.21 | 5.84 | 3.47 | 33.82 | 792.0 |
| | 3 | 29.11 | 52.85 | 34.92 | 8.21 | 5.84 | 3.37 | 33.82 | 665.7 |
| 10 | 0 | 29.06 | 52.91 | 34.95 | 8.22 | 5.95 | 26.20 | 33.85 | 1049.0 |
| | 1 | 29.07 | 52.88 | 34.95 | 8.22 | 5.91 | 30.40 | 33.84 | 1238.7 |
| | 2 | 29.07 | 52.87 | 34.95 | 8.22 | 5.90 | 29.13 | 33.84 | 650.0 |
| | 3 | 29.08 | 52.87 | 34.93 | 8.22 | 5.92 | 20.67 | 33.84 | 538.0 |
| | 4 | 29.10 | 52.88 | 34.94 | 8.22 | 6.00 | 3.25 | 33.83 | 872.5 |

| Stn. | Depth (m) | Temp. (°C) | SpC. (mS/cm) | Sal. (ppt) | pH | DO (mg/l) | Tur. (NTU) | TDS (g/l) | PAR (uE/m2/s) |
|---|---|---|---|---|---|---|---|---|---|
| | 5 | 29.67 | 52.73 | 34.84 | 8.27 | 6.21 | 3 | 33.75 | 860 |
| 11 | 0 | 29.04 | 52.93 | 34.98 | 8.35 | 6.27 | 2.93 | 33.87 | 521.0 |
| | 1 | 29.08 | 52.90 | 34.97 | 8.35 | 6.26 | 2.57 | 33.86 | 402.0 |
| | 2 | 29.07 | 52.90 | 34.96 | 8.34 | 6.26 | 2.40 | 33.86 | 299.0 |
| | 3 | 29.09 | 52.90 | 34.97 | 8.34 | 6.27 | 2.40 | 33.86 | 234.0 |
| | 4 | 29.09 | 52.90 | 34.96 | 8.34 | 6.26 | 2.40 | 33.85 | 208.0 |
| | 5 | 29.10 | 52.89 | 34.96 | 8.34 | 6.26 | 2.40 | 33.85 | 166.3 |
| | 6 | 29.10 | 52.87 | 35.12 | 8.34 | 6.27 | 2.53 | 33.85 | 165.7 |
| | 7 | 29.10 | 52.88 | 34.95 | 8.34 | 6.22 | 2.67 | 33.86 | 162.0 |
| | 8 | 29.09 | 52.89 | 34.96 | 8.34 | 6.27 | 2.77 | 33.85 | 161.0 |
| | 9 | 29.09 | 52.89 | 34.95 | 8.34 | 6.25 | 2.80 | 33.84 | 146.3 |
| | 10 | 29.10 | 52.89 | 34.96 | 8.34 | 6.23 | 3.13 | 33.85 | 126.3 |
| | 15 | 29.11 | 52.90 | 34.98 | 8.34 | 6.25 | 3.00 | 33.86 | 101.7 |
| | 20 | 29.17 | 52.99 | 35.03 | 8.34 | 6.28 | 3.07 | 33.92 | 54.0 |
| 12 | 0 | 29.03 | 52.97 | 35.00 | 8.34 | 6.07 | 1.47 | 33.89 | 867.3 |
| | 1 | 29.03 | 52.94 | 35.00 | 8.34 | 6.05 | 1.40 | 33.88 | 378.0 |
| | 2 | 29.04 | 53.06 | 34.99 | 8.33 | 6.06 | 1.40 | 33.88 | 301.3 |
| | 3 | 29.04 | 52.95 | 35.00 | 8.33 | 6.05 | 1.50 | 33.88 | 300.3 |
| | 4 | 29.04 | 52.93 | 34.98 | 8.33 | 6.04 | 1.60 | 33.88 | 291.0 |
| | 5 | 29.04 | 52.93 | 34.98 | 8.33 | 6.05 | 1.67 | 33.88 | 237.0 |
| | 6 | 29.05 | 52.92 | 34.97 | 8.33 | 6.06 | 1.83 | 33.87 | 201.7 |
| | 7 | 29.05 | 52.94 | 34.99 | 8.33 | 6.05 | 7.67 | 33.87 | 151.0 |
| 13 | 0 | 29.13 | 52.90 | 34.97 | 8.23 | 6.03 | 4.10 | 33.85 | 1583.7 |
| | 1 | 29.14 | 52.89 | 34.95 | 8.22 | 5.98 | 3.97 | 33.85 | 1193.3 |
| | 2 | 29.13 | 52.88 | 34.94 | 8.21 | 6.06 | 3.83 | 33.84 | 804.0 |
| | 3 | 29.15 | 52.88 | 34.94 | 8.21 | 6.03 | 3.60 | 33.83 | 879.3 |
| 14 | 0 | 29.01 | 52.89 | 34.95 | 8.26 | 5.98 | 8.17 | 33.84 | 1723.3 |
| | 1 | 29.01 | 52.87 | 34.95 | 8.26 | 5.89 | 7.70 | 33.84 | 990.3 |
| | 2 | 29.01 | 52.87 | 34.95 | 8.26 | 5.92 | 8.07 | 33.83 | 934.7 |
| 15 | 0 | 28.91 | 52.93 | 34.98 | 8.32 | 5.55 | 19.43 | 33.88 | 798.7 |
| | 1 | 28.91 | 52.94 | 34.99 | 8.32 | 5.64 | 16.73 | 33.87 | 656.7 |
| | 2 | 28.90 | 52.92 | 35.06 | 8.31 | 5.69 | 14.93 | 33.87 | 652.7 |
| | 3 | 28.88 | 52.91 | 34.95 | 8.31 | 5.65 | 10.97 | 33.86 | 409.0 |
| 16 | 0 | 29.00 | 52.93 | 34.99 | 8.33 | 5.85 | 2.80 | 33.86 | 863.7 |
| | 1 | 29.01 | 52.91 | 34.97 | 8.33 | 5.76 | 2.97 | 33.87 | 606.0 |
| | 2 | 29.00 | 52.90 | 34.96 | 8.32 | 5.75 | 3.17 | 33.85 | 447.0 |
| | 3 | 28.99 | 52.91 | 34.96 | 8.32 | 5.72 | 3.27 | 33.86 | 345.3 |
| | 4 | 28.99 | 52.90 | 34.96 | 8.32 | 5.68 | 3.53 | 33.85 | 334.0 |
| 17 | 0 | 29.04 | 52.98 | 35.01 | 8.34 | 6.06 | 49.90 | 33.89 | 901.3 |
| | 1 | 29.07 | 52.94 | 35.00 | 8.33 | 6.03 | 9.37 | 33.89 | 366.7 |
| | 2 | 29.07 | 52.94 | 34.99 | 8.33 | 6.03 | 7.97 | 33.89 | 472.7 |
| | 3 | 29.07 | 52.95 | 35.00 | 8.32 | 6.03 | 7.83 | 33.90 | 375.3 |
| | 4 | 29.08 | 52.95 | 34.99 | 8.32 | 5.99 | 5.37 | 33.88 | 276.3 |
| | 5 | 29.07 | 52.93 | 34.99 | 8.32 | 6.00 | 4.93 | 33.90 | 241.3 |
| | 6 | 29.08 | 52.94 | 34.99 | 8.32 | 6.02 | 4.33 | 33.88 | 188.7 |
| | 7 | 29.07 | 52.95 | 34.99 | 8.32 | 6.02 | 4.03 | 33.88 | 185.0 |
| | 8 | 29.07 | 52.93 | 34.99 | 8.32 | 6.02 | 3.60 | 33.88 | 148.3 |
| | 9 | 29.05 | 52.93 | 34.99 | 8.32 | 6.01 | 3.47 | 33.88 | 142.7 |
| | 10 | 29.07 | 52.94 | 34.98 | 8.32 | 6.03 | 3.37 | 33.88 | 128.3 |
| | 15 | 29.06 | 52.94 | 34.99 | 8.32 | 6.01 | 3.57 | 33.87 | 100.0 |
| 18 | 0 | 28.74 | 52.89 | 34.96 | 8.33 | 5.01 | 10.13 | 33.84 | 1128.0 |

| Stn. | Depth (m) | Temp. (ºC) | SpC. (mS/cm) | Sal. (ppt) | pH | DO (mg/l) | Tur. (NTU) | TDS (g/l) | PAR (uE/m2/s) |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 28.70 | 52.85 | 34.95 | 8.33 | 4.93 | 5.60 | 33.82 | 570.0 |
| | 2 | 28.65 | 52.87 | 34.93 | 8.32 | 4.88 | 6.33 | 33.83 | 412.7 |

*Table 6-3 Average biophysical data for the parameters for all stations*

| Station | BOD (mg/l) | TSS (mg/l) | Nitrate (mg/l) | Phosphate (mg/l) | F. Coli (MPN/100ml) |
|---|---|---|---|---|---|
| 1 | 9.7 | 5.0 | 0.5 | 1.08 | 133.7 |
| 2 | 5.3 | 19.3 | 0.4 | 0.31 | <11 |
| 3 | 6.0 | 2.3 | 1.6 | 0.12 | 120 |
| 4 | 5.7 | 1.7 | 1.0 | 0.66 | <11 |
| 5 | 7.0 | 0.7 | 0.9 | 0.81 | <11 |
| 6 | 5.0 | 1.3 | 0.8 | 0.24 | <11 |
| 7 | 4.7 | 1.0 | 0.6 | 0.32 | <11 |
| 8 | 5.3 | 1.7 | 0.9 | 1.05 | <11 |
| 9 | 7.3 | 1.0 | 1.4 | 0.11 | 32.3 |
| 10 | 6.3 | 1.0 | 0.6 | 0.54 | <11 |
| 11 | 5.0 | 1.3 | 1.7 | 0.20 | 66.3 |
| 12 | 5.0 | 1.7 | 1.4 | 0.25 | <11 |
| 13 | 7.0 | 1.3 | 1.0 | 0.07 | <11 |
| 14 | 6.7 | 1.7 | 0.7 | 0.44 | <11 |
| 15 | 5.3 | 1.7 | 1.9 | 0.74 | <11 |
| 16 | 5.3 | 1.7 | 0.5 | 0.15 | <11 |
| 17 | 5.7 | 1.0 | 1.0 | 0.85 | <11 |
| 18 | 4.0 | 2.3 | 2.6 | 0.14 | 38.3 |

**Temperature**

Average temperature values varied across the stations ranging from 27.67 – 29.67ºC. The highest temperature was reported at station 6 and the lowest temperature was at station 1. Compared with depth, the temperature at each station varied little with most stations showing a decrease with depth (Figure 6-2); however, stations 6 and 12 showed an incremental increase with depth of approximately 0.5ºC. Station 11, the background, shows a well-mixed layer for the first 20m. The low temperature observed at station 1 would be due to the outflow from the South Negril River located at the south end of the Bay.

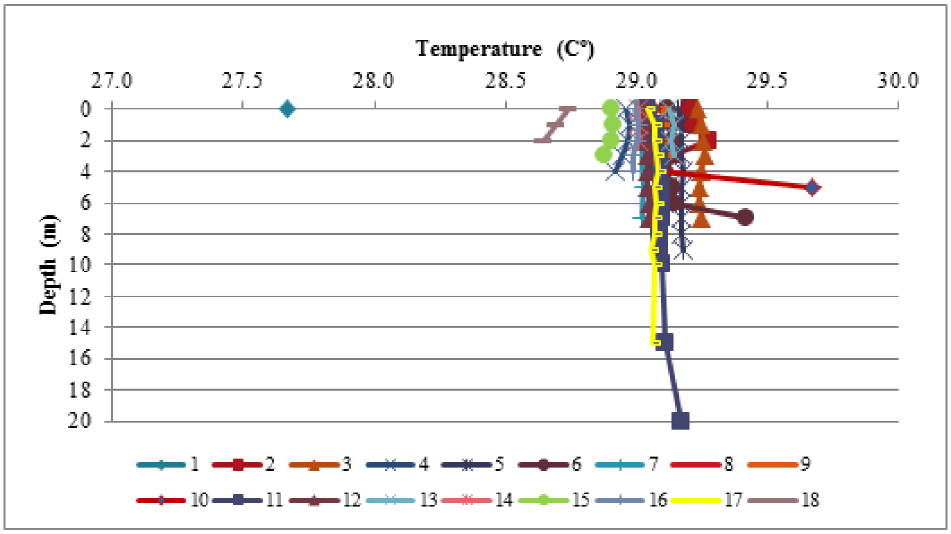



*Figure 6-2 Average Temperature variation across sampling stations*

**Specific Conductivity**

Average specific conductivity values varied little across the stations ranging from 32.66 – 53.93mS/cm. The lowest value was reported at station 1 and the highest value was at station 7 (Figure 6-3). When compared with depth the conductivity varied little with some stations showing a slight increase (<3mS/cm). Station 1 showed the lowest conductivity as freshwater from the river mixes in the area.

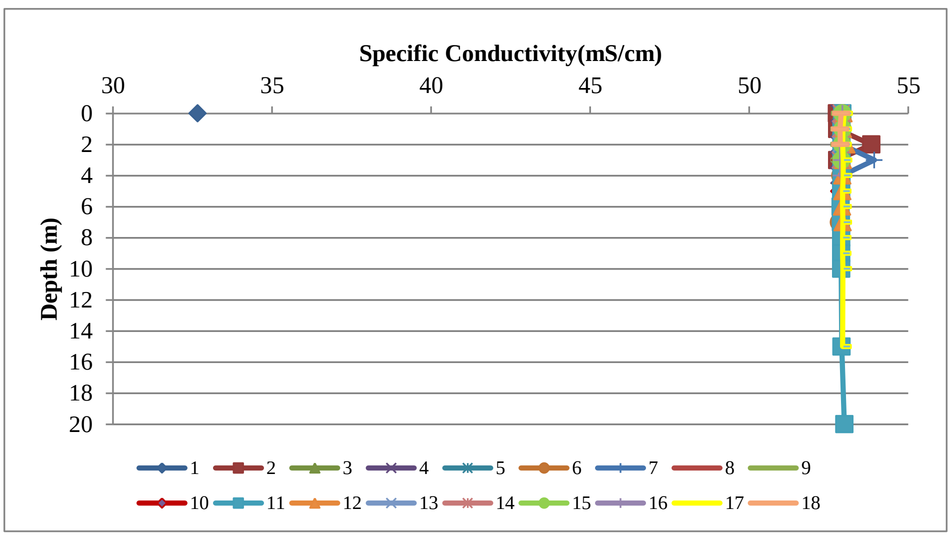



*Figure 6-3 Average Conductivity variation across sampling stations*

## Salinity

Average salinity values varied little across the stations ranging from 21.14 – 35.12ppt. Station 1 reported the lowest value and the highest value was observed at station 11. When compared to depth, the values showed little variation at all stations (Figure 6-4). Station 1 had low salinity, which was expected, due to its location near to the river mouth. This trend was also observed in the temperature and conductivity for station 1.

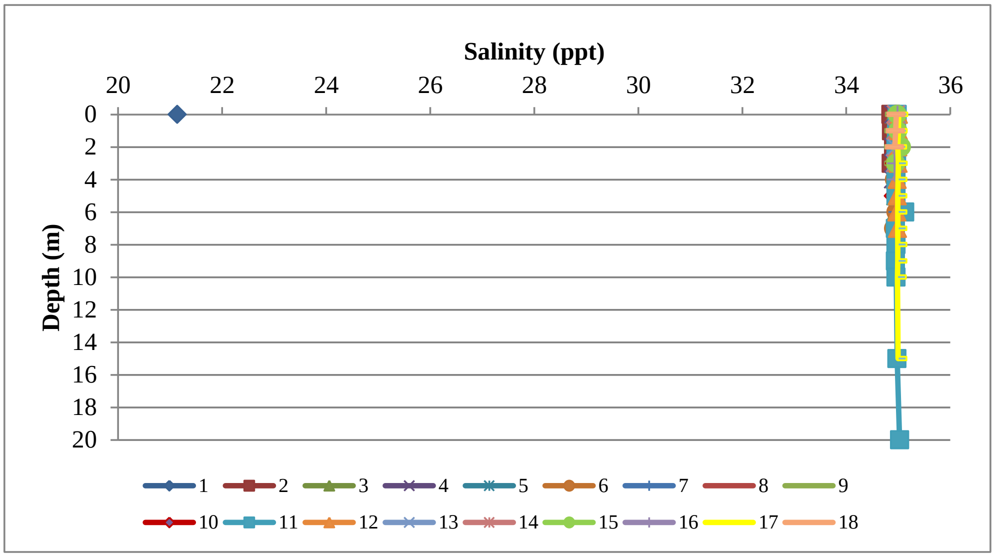



*Figure 6-4 Average Salinity variation across sampling stations*

## pH

Average pH values varied little across stations ranging from 8.21 – 8.39. The lowest pH value was reported at stations 5, 6, 9 and 13 while the highest value was observed at station 7. When compared to depth the pH values at each station showed little variation

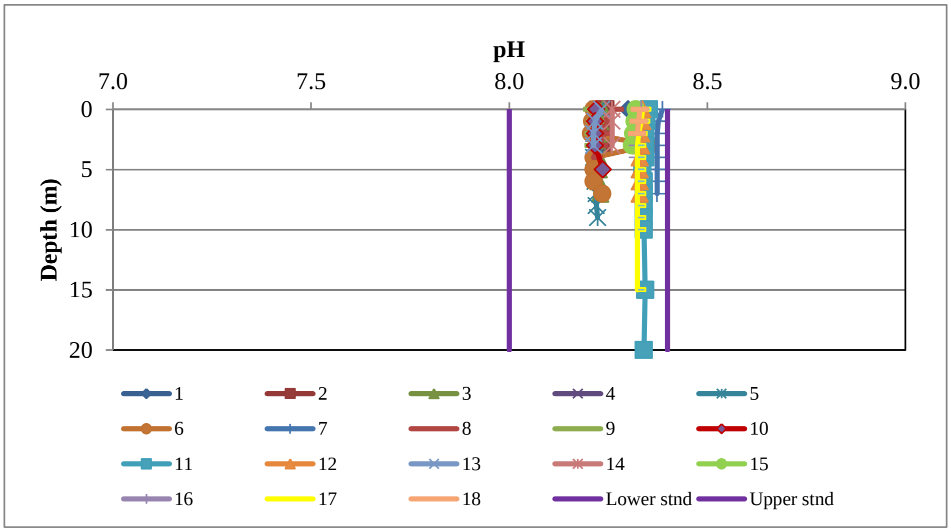



*Figure 6-5 Average pH variation across sampling stations*

**Photosynthetically Active Radiation (PAR)**

Average PAR varied greatly across stations ranging from 54 – 1723.33uE/m²/s. The highest PAR value was observed at station 14, and the lowest value was reported at station 11. When compared to depth, the PAR values showed a general decrease at each station except at station 10 (Figure 6-6). The decrease in PAR is expected, as less light is able to penetrate with increasing depth. Cloud cover, time of day, and the presence of organic and inorganic material also affect the amount of PAR available.

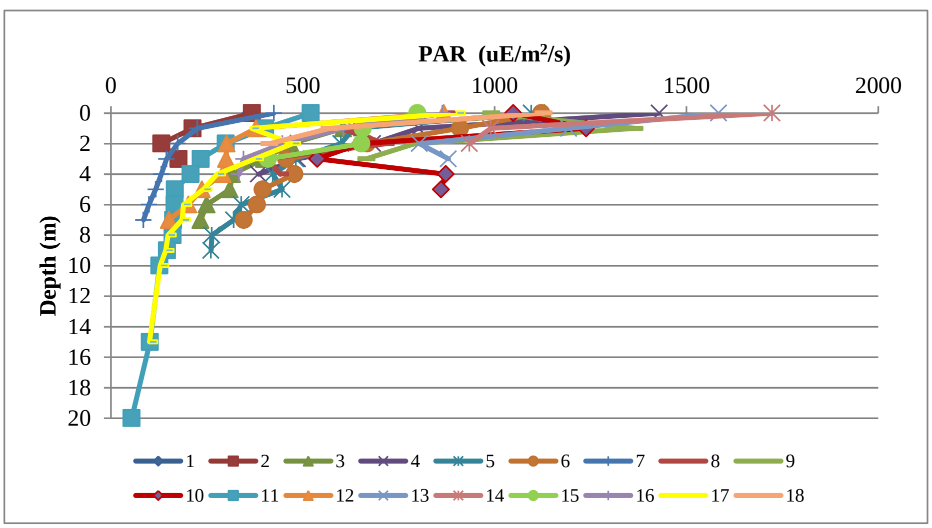



*Figure 6-6 Average PAR variation across sampling stations*

**Light Extinction Coefficient**

Average light extinction coefficient values varied across the stations ranging from 0.05 – 0.47. The lowest coefficient value was obtained at station 9, which indicates the greatest light penetration. The highest EC value was obtained at station 18, located towards the north of the Bay, showed the worst light penetration (Figure 6-7). An extinction value was not calculated for station 1, as it was too shallow.

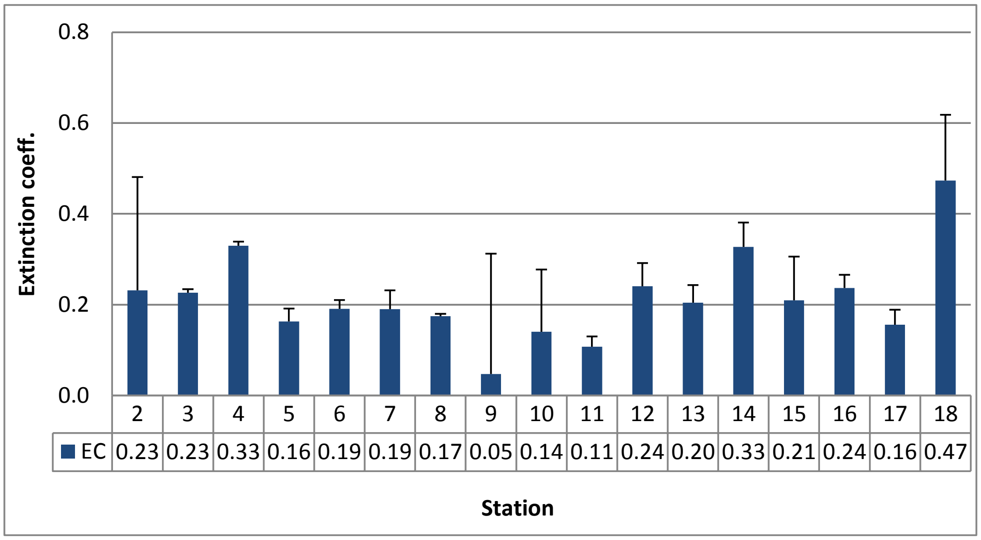



*Figure 6-7 Average light extinction coefficient across sampling stations with standard error*

**Dissolved Oxygen (DO)**

Average dissolved oxygen values varied across the stations ranging from 4.04 – 6.28mg/l. The highest DO values were reported at station 10 and the lowest values were at station 1. When compared to depth, the DO levels varied at each station with station 2 showing the largest change with depth (Figure 6-8). The low DO values at station 1 and 2 could be due to elevated levels of decaying organic matter flowing from the river.

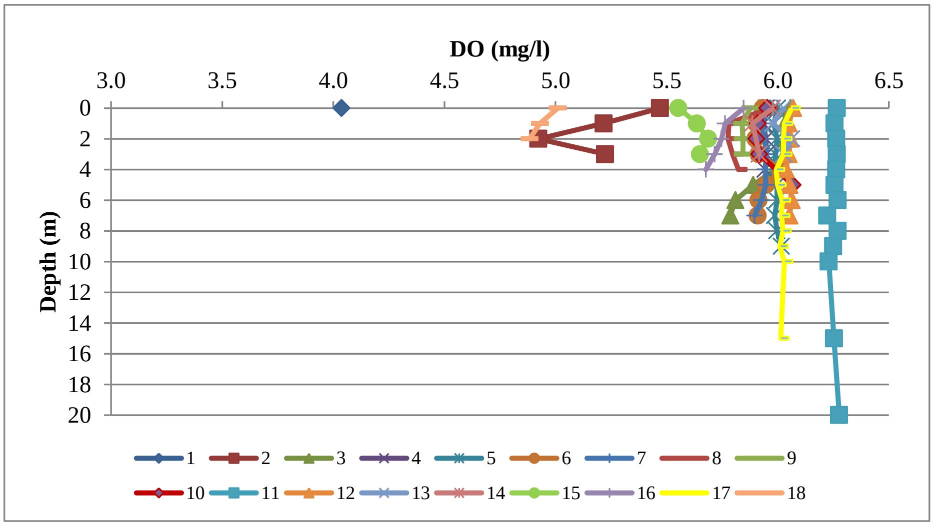



*Figure 6-8 Average D.O. variation across sampling stations*

## Turbidity

Average turbidity values varied across the stations ranging from 1.4 – 49.9NTU. The lowest turbidity value was reported at station 12 and station 17 had the highest value. Turbidity values varied when compared to depth at each station, with most stations showing a slight decrease. Low turbidity values indicate the low presence of suspended particles (Figure 6-9). Stations located near the northern end of the Bay had elevated turbidity values which could be due to the substrate type or currents in the area.

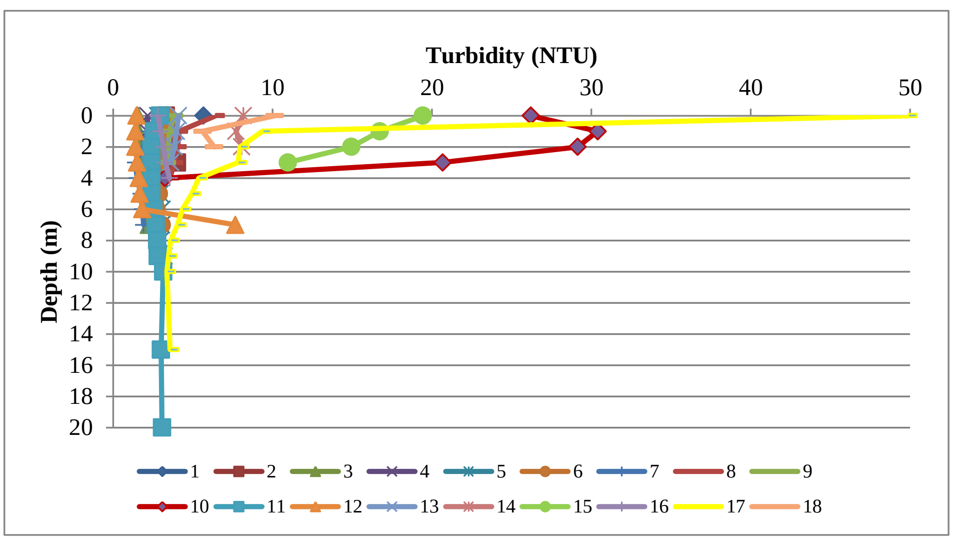



*Figure 6-9 Average Turbidity variation across sampling stations*

## Total Dissolved Solids (TDS)

Average TDS varied little across the stations ranging from 31.24 – 33.92g/l. Lowest TDS value was reported at station 1 and the highest value was observed at station 11. When compared to depth at each station, the values showed little variation (Figure 6-10).

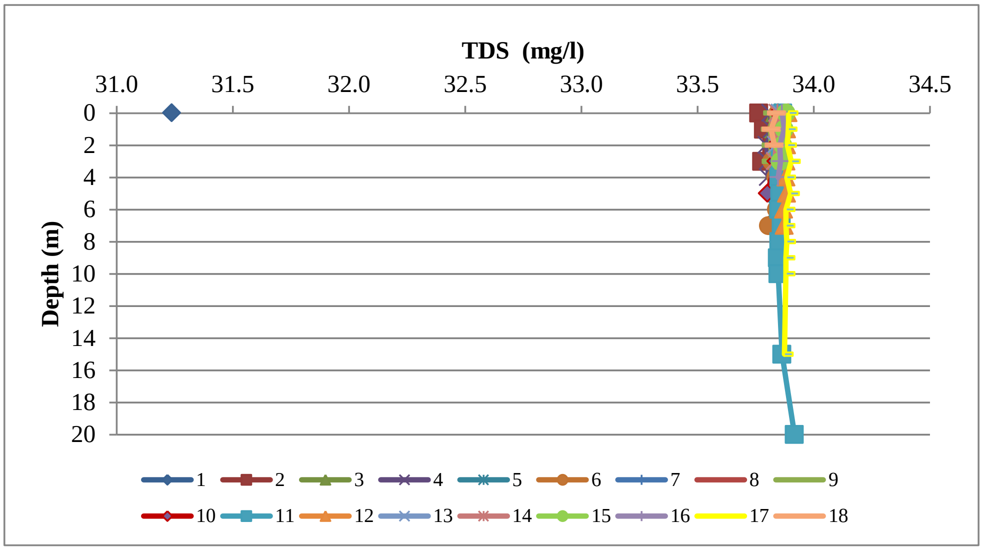



*Figure 6-10 TDS variation across sampling stations*

## Biological Oxygen Demand (BOD)

Average BOD varied across stations ranging from 4.0 – 9.7mg/l (Figure 6-11). The highest average was observed at station 1 and the lowest value was observed at station 18. The elevated BOD value observed at station1 could be due to the influence of the river, which contains organic matter. In comparison, Kingston Harbour a known eutrophic harbour had maximum levels of >35mg/l due to the organic loading from the numerous gullies and rivers that empty into the Harbour (D. F. Webber and Kelly 2003). All stations were above the NEPA standard for seawater of 1.16mg/l.

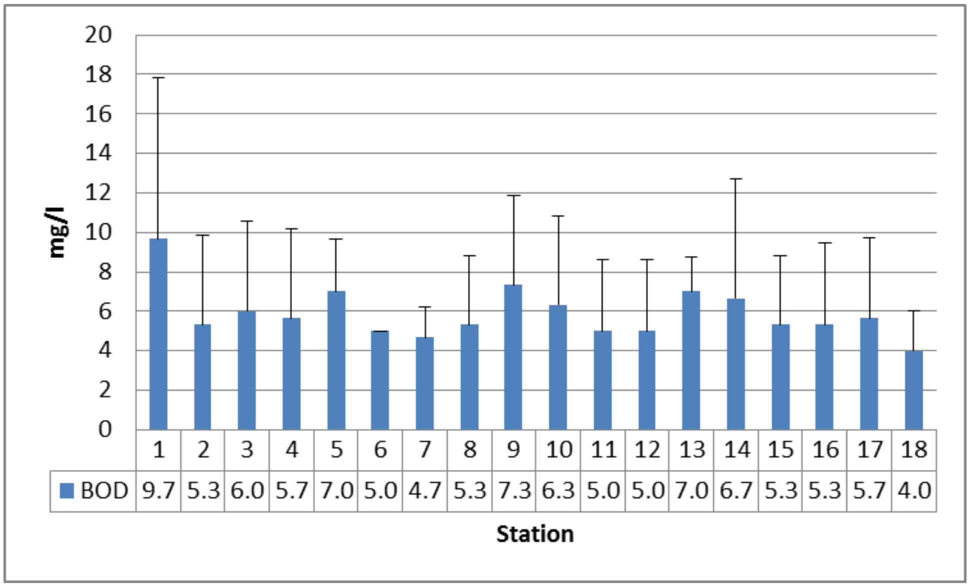



*Figure 6-11 Average BOD variation across sampling stations with standard deviation*

**Total Suspended Solids (TSS)**

Average TSS values varied across the stations ranging from 0.7 – 5mg/l. Station 1 reported the highest value and the lowest value was observed at station 5 (Figure 6-12). These concentrations are considered to indicate clear water as they are below 20mg/l. Station 1, located near the mouth of the river, and was expected to have the highest value due to the presence of debris and sediment flowing outwards. However, it should be of note that this is episodic due to tidal features and periods of heavy rainfall.

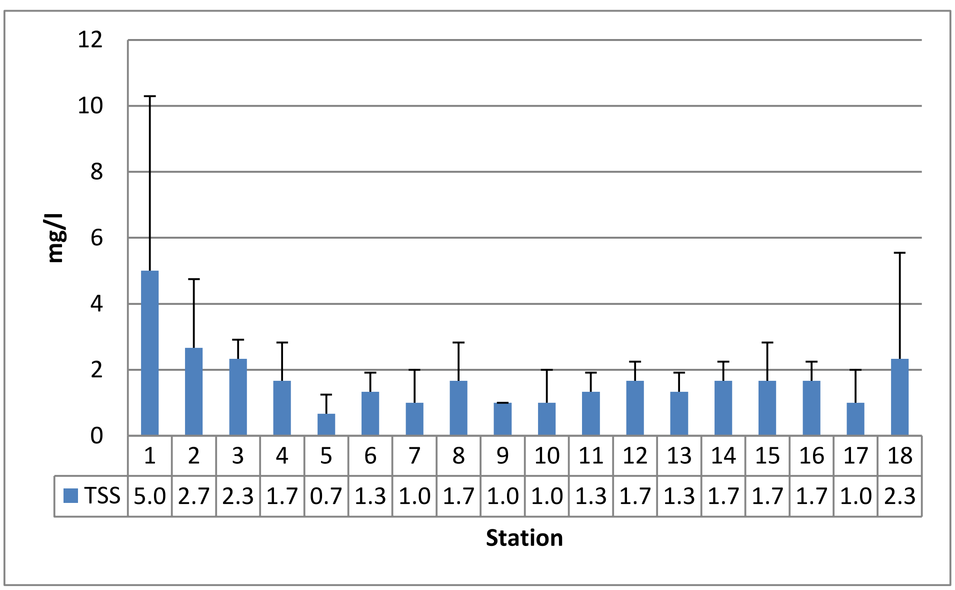
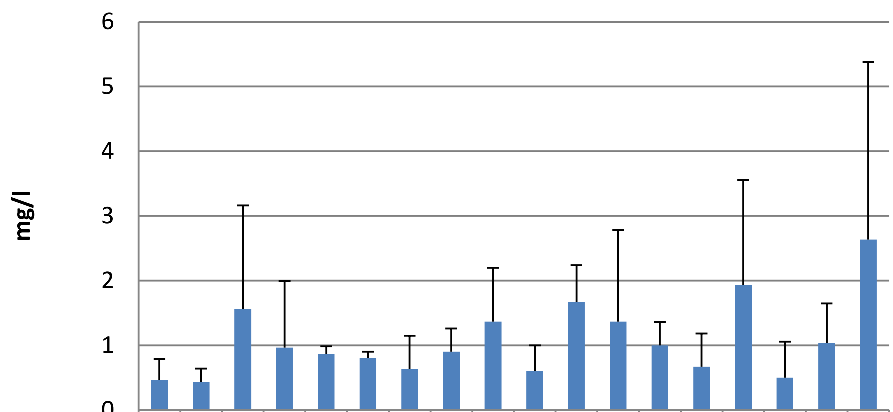



*Figure 6-12 Average TSS variation across sampling stations with standard deviation*

**Nitrates**

Average nitrate values varied across the stations ranging from 0.4 – 2.6mg/l. The lowest nitrate value was reported at station 2 and the highest value was observed at station 18 (Figure 6-13). All stations were above the NEPA standard for Seawater for nitrates of 0.007 – 0.014mg/l.




| Station | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrates | 0.5 | 0.4 | 1.6 | 1.0 | 0.9 | 0.8 | 0.6 | 0.9 | 1.4 | 0.6 | 1.7 | 1.4 | 1.0 | 0.7 | 1.9 | 0.5 | 1.0 | 2.6 |

*Figure 6-13 Average Nitrate variation across sampling stations with standard deviation*

**Phosphates**

Phosphate values varied across the stations ranging from 0.1 – 1.1mg/l. Highest phosphate value was reported at station 1 whereas the lowest value was observed at stations 3, 9 13 and 18 (Figure 6-14). All stations were above the NEPA Standard for Seawater for phosphates of 0.001 – 0.003mg/l. Lapointe et al. (2011) reported elevated levels of soluble reactive phosphorus (SRP) in Negril waters, with higher concentrations towards the "West End". However, in the present study elevated phosphate levels were observed throughout the bay.

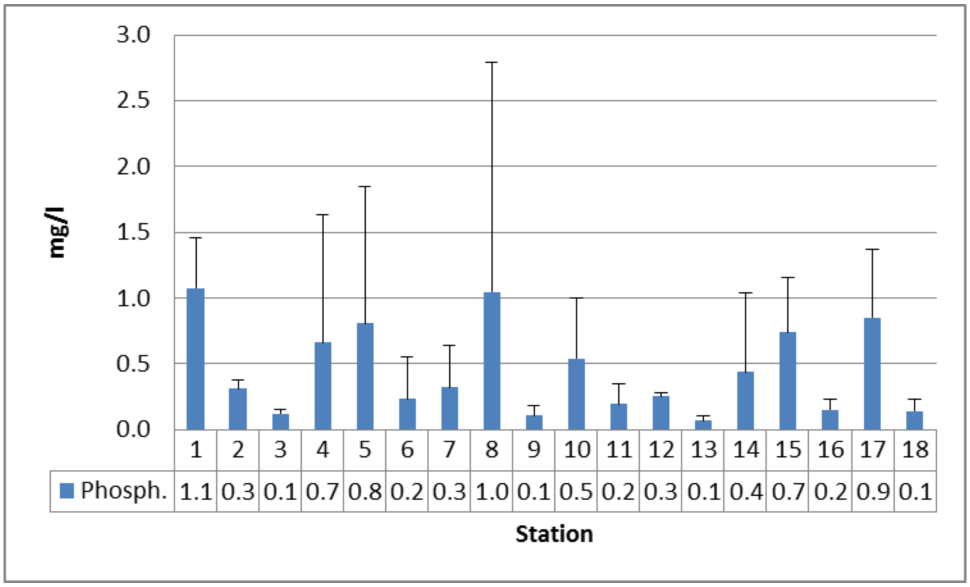



*Figure 6-14 Average Phosphate variation across sampling stations with standard deviation*

**Faecal Coliform**

F. coliform values varied across the stations ranging from <11 - 134MPN/100ml. The presence of faecal coliform can be used as an indicator of sewage contamination. Station 1, the southernmost sample, had the highest value (Figure 6-15). Most stations were below the NEPA standard for seawater of 13MPN/100ml except stations 1, 3, 9, 11 and 18. These stations were located close to shore with the exception of station 9.

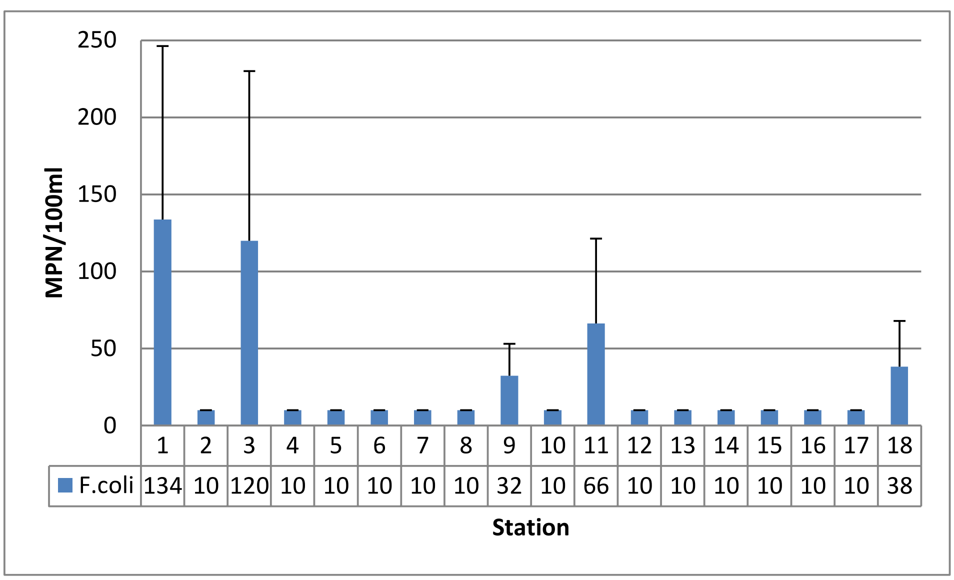



*Figure 6-15 Average Faecal Coliform variation across sampling stations with standard deviation*

The complete results of data for the water quality surveys are found in Appendix 9 and Appendix 10.

### 6.1.2 Heavy Metals in Sediments

**Sampling**

Sediment samples were collected at seven (7) stations within the Bay. The samples were collected using a grab sampler and stored in a 100ml glass bottle. The samples were analyzed for the presence of Arsenic (As), Cadmium (Cd), Lead (Pb), Mercury (Hg) and TPH.

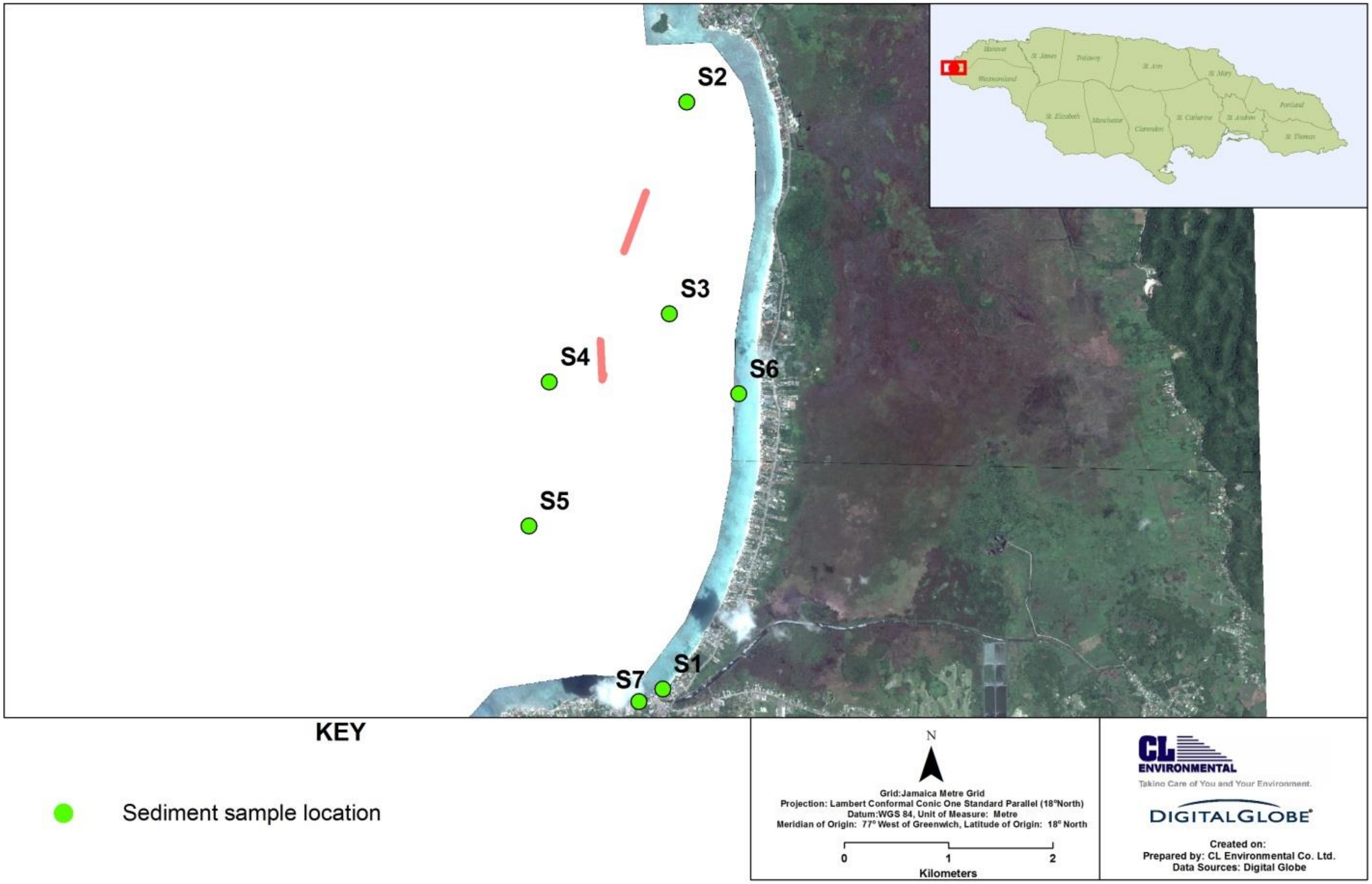



*Figure 6-16 Locations of the sediment samples*

**Results**

The levels of heavy metals at each station were generally none to very low (Table 6-4). When compared to the average levels found in Jamaican soils (Table 6-5) all values were below reported average. TPH values varied across the stations ranging from ND – 1100mg/KG. Station S2 showed the highest levels and could be due to the high number of boats observed within the area.

*Table 6-4 Results of the sediment analysis at the selected stations*

| Station | Arsenic (mg/KG) | Cadmium (mg/KG) | Lead (mg/KG) | Mercury (mg/KG) | TPH (mg/KG) |
|---|---|---|---|---|---|
| S1 | 1.1 | ND | 0.93 | ND | 140 |
| S2 | 4.5 | ND | 1.4 | ND | 1100 |
| S3 | 4.2 | ND | ND | ND | 770 |
| S4 | 3 | ND | 4.4 | ND | 420 |
| S5 | 1.4 | ND | 1.5 | ND | ND |
| S6 | ND | ND | 1.2 | ND | ND |
| S7 | 1.8 | ND | 5 | ND | ND |

*Table 6-5 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.***

**Comparison with other Sites**

The heavy metal concentrations are within the average soil concentrations in Jamaica as listed in the Soil Atlas of Jamaica and had lower concentrations when compared with sediment concentrations at three other marine areas around Jamaica (Table 6-6). Comparison with other international ports and harbours has also shown that the concentrations obtained in Negril were well below those obtained at the other locations (Table 6-7). Total Petroleum Hydrocarbon (TPH) is not considered a heavy metal, however, the concentrations obtained in Negril were in compliance with the NRCA standard of 1000 mg/KG except at one station (S2) which recorded 1,100 mg/KG. This value is perhaps high owing to the use of boast in the area.

*Table 6-6 Heavy metal concentrations at various sites in Jamaica and worldwide*

| METAL | NEGRIL | OLD HARBOUR 360 MW | OLD HARBOUR 190 MW | PALISADOES CARIBBEAN SEA SIDE | GEOCHEMICAL ATLAS OF JAMAICA | COMMERCIAL PORTS SAMOA | FISIHING PORTS SAMOA | EAST LONDON HARBOUR | PORT ELIZABETH HARBOUR |
|---|---|---|---|---|---|---|---|---|---|
| **Arsenic (As) (mg/KG)** | 1.1 – 4.5 | 6.50 – 8.67 | 5.9 – 8.9 | 9.1 - 14 | 25 | | | | |
| **Cadmium (Cd) (mg/KG)** | ND | ND | ND | ND | 20 | | | 0.3 – 0.7 | 0.3 – 1.2 |
| **Lead (Pb) (mg/KG)** | 0.93 – 4.0 | 9.77 – 13.33 | 8.4 - 12 | 0.74 – 5.1 | 46.5 | 1,230 – 2,820 | 790 – 2,030 | 11.3 – 36.8 | 15.4 - 44 |
| **Mercury (Hg) (mg/KG)** | ND | 0.04 – 0.05 | 0.088 – 0.18 | ND | 0.2 | | | | |
| **TPH (mg/KG)** | 140 - 1100 | 11 – 68.67 | ND | ND | | | | | |

*Table 6-7 Heavy metal concentration (mg/g) in the sediment from the different regions of the world*

***Source: Imo T et al. 2014***

| Rivers | Cu | Pb | Reference |
|---|---|---|---|
| This study | 0.97-3.82 | 1.23-2.82 | |
| Cochin estuary, India | 53.15 | 71.28 | Balachandran *et al.* (2005)[16] |
| Jurujuba sound, Brazil | 51.0 | 61.0 | Baptista Neto *et al.* (2000)[17] |
| Tolo harbour, Hong Kong | 84.0 | 144.0 | Owen and Sandhu, (2000)[18] |
| Izmit Bay, Turkey | 67.6 | 102.0 | Pekey (2006)[19] |
| Koahsiung Harbour, Taiwan | 5-946 | 9.5-470 | Chen *et al.* (2004)[20] |
| Eastern Harbour, Egypt | 14.09 | - | Abdallah and Abdallah (2007)[21] |
| River Ganga, India | 0.09 | - | Singh *et al.* (2012)[22] |
| Mudflat of Salinas de San Pedro Lagoon, California, USA | 0.085 - 0.47 | 0.05 - 0.38 | Mohammad H.R *et al.* (2013)[23] |

### 6.1.3 Geomorphology and Physiography

Detailed examination of the historic and physical evidence for beach erosion, and general geomorphological characteristics of Long Bay was undertaken by DOGG (2002). The study confirmed that the beach erosion along the along the Negril is not a uniformly occurring phenomenon along the entire 7 km length of the beach at Long Bay. The study also identified that Long Bay may be divided into four sections:

1. The northern section of the bay (from Hedonism to Cosmos) which was undergoing more severe, long-term erosion,
2. The section between Cosmos and Swept Away which appears to be protected from on-coming waves by a small shallow reef that lies about 1.4 km offshore from Beaches Resort,
3. The stretch of beach immediately south of Swept Away up to Crystal Waters, which appeared to be periodically affected by significant storm related erosion, from which the beach eventually recovers; and
4. The southernmost sections of the beach appear to be generally stable.

DOGG (2002) also identified scouring related to tidal fluctuations appears to also affect the beach. During spring tides, the difference between high and low tide can be as much as 52 cm, resulting in temporary beach scouring during high tides.

The extensive line of shore parallel deep reefs lying between 2.25 – 2.6 km offshore of Long Bay and Bloody Bay forms a distinct physiography feature on the offshore slope, with the reef crest at depths of – 18 m (below sea level). The crests of these reefs is unlikely to feed into the beach system of Long Bay as the reef occur seaward of a major break slope (the drowned cliff line) (DOGG 2002).

The trend of protracted recovery times of beach erosion caused by lower-magnitude storm events and the evidence of longer-term shoreline erosion in the northern section of the beach suggest that the system is indeed in some form of crisis, where the normal parameters are changing. These changing parameters are likely to include:

1. A reduction in the space available for the beach system to adjust itself.
2. An inadequate supply of sediment.
3. An increase in scouring events (brought on by increased levels of storminess as well as higher levels of run-offs from the land).

The composition of the sand grains along Long Bay were investigated in 1980 and 1999 and the results reported in Department of Geography & Geology, UWI (2002). It reported that amorphous and recrystallized grains made up a large percentage of the grains present. The mean value for the 1980 dataset is 34.8% for amorphous grains and 29.3% for recrystallized grains while the corresponding means for the 1999 dataset were, 37.3% and 28.4% respectively. The data suggested that there was a slight increase (2.5%) in the proportion of amorphous grains from 1980 to 1999. The spatial distribution of amorphous and recrystallized grains exhibited some distinct differences which is seen between 1980 and 1999 dataset. There were no direct pattern in the distribution of amorphous grains, the highest percentages were found at sites along the middle portion of Long Bay in the 1999 dataset. Similar peaks were not evident in the 1980 dataset. On the other hand samples from the 1999 dataset consistently had more recrystallized grains than samples from the 1980 dataset.

Amorphous grains are not crystalline and can be formed in various ways. Methods of formation for these grains include micritization of bioclasts (by endolithic fungi, and algae) and faecal pallets. They may also be introduced through seeding (addition of crushed marl) of the beach. Recrystallized grains are produced as lithic fragments (from the boring activities of marine organisms), through neomorphic replacement of grains in diagenesis, and by seeding of the beach. The distinctive increase in recrystallized grains along the mid and southern portions of the beach, is most likely to be explained by the beach seeding.

The variation in the percentage of bioclasts clearly demonstrates that there has been a significant drop in the percentage of foraminifera and bivalves and a corresponding increase in red algae between the 1980 and 1999. The percentage of *Halimeda* remains relative unchanged, and is significantly lower than reported by Hendry (1982). Hendry (1982) undertook whole grain identification using a binocular microscope, where as we used thin sections of grains. The significant shift in bioclasts types with a relative decrease in the proportion of foraminifera and a relative increase in the proportion of red algae between 1980 and 1999, might have been achieved by a decrease in production rate of foraminifera, and increase in the production rate of red algae, or a combination of the two.

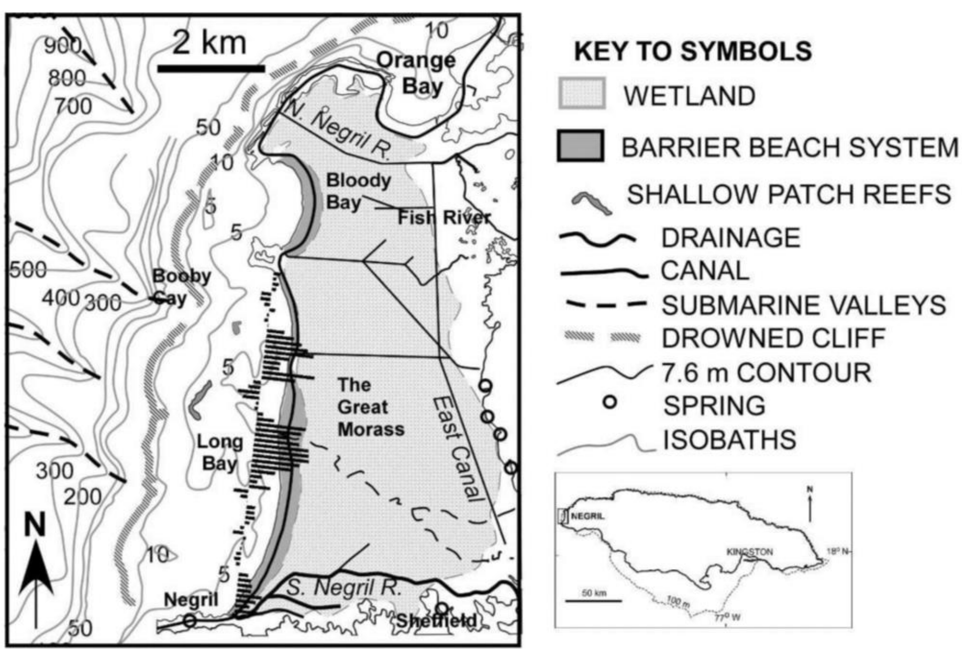
The bioclasts are dominated by foraminifera, bivalves, *Halimeda* and branching red algae, echinoids and corals are minor elements of the beach sand. The foraminifera are dominated by eqifauna taxa, which lives on sea grass, while the bivalves are liable to be infaunal forms such as *Donax* which have been reported to live in sands close to shore (Hendry, 1982) and which are commonly washed up on the beach today (although removed by raking). The green alga *Halimeda* and the branching red algae live in a variety of environment ranging from shallow shelf, bay, reef to fore reef environments. The significant lack of coral in the beach sand indicates that algae are probably not derived from the reef are probably derived from the shallow shelf environments in the inner bay area.

Foraminifera are dominated by epifunal types that live attached to sea grass. The red algae dominated by branching forms. A decrease in the proportion of foraminifera might be caused by the removal of sea grass beds. This has been detected in some of the aerial photographic surveys. Red algae (largely encrusting forms) have been noted as an increased component on the Negril reef. However, the dominance of branching forms in the beach sediment and the lack of coral fragments and paucity of echinoid fragments (which have been recorded to have increased in large numbers on the reef) suggests that sediment is not coming from the reef (DOGG 2002).

The study identified four main causes of beach erosion in Negril; two of these are global phenomena (sea level rise and increasing incidences of high magnitude storms). The other two are closely related and can be effectively mitigated with appropriate management strategies as they stem from human activities in the coastal zone (increasing density of beach front use and declines in sediment supply). In addition to these factors there is likely to be routine scouring (~50 cm vertical down cutting) that is related to spring tides. These are:

1. Sea level rise,
2. Adverse wave climate,
3. Land borne flooding; and
4. Sediment supply.

Robinson, E. et al. (2012) outlined that the resort areas of Long Bay and Bloody Bay are built on a narrow strip of low-lying land (mainly sand) between the sea and the Great Morass, forming a barrier beach system (Figure 6-17). The Negril beaches are divided into the two segments of Long Bay and Bloody Bay by the limestone promontory at Point Village (Figure 6-17). The morass is a low, more or less level wetland, underlain for the most part by peat of varying thickness. The peat exceeds 12 m in some places in the south western part of the wetland. Elevations over most of the morass do not exceed one metre. A survey of the Negril Morass and near-shore region carried out in the 1950s (Town & Country Planning Development Order for Negril, 1959) when corrected indicated that morass elevations nearly everywhere were below one metre above MSL except in the southeast corner.

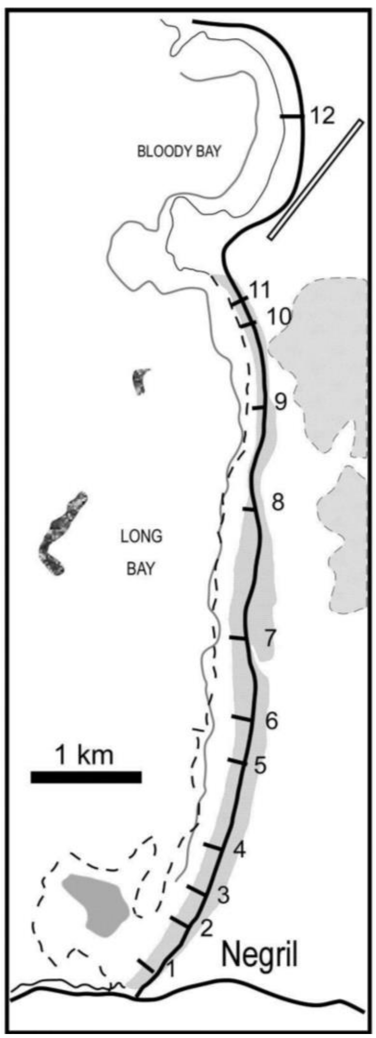



***Source: Robinson, E. et al. (2012)***

*Figure 6-17 Shoreline changes since 1971 along Long Bay (seaward bars indicate erosion, landward bars indicate accretion)*

This relatively narrow barrier beach complex, consists of unconsolidated to poorly consolidated carbonate sand overlying limestone bedrock, clay or peat deposits at depth (Robinson, E. et al. 2012.). The active beach at Long Bay is 6.4 km long, and backed by a strip of sand, forming, in places, low relief beach ridges and originally with extensive forest cover, as evidenced by aerial survey photographs dating from 1940.

There is a notable absence of a storm berm/aeolian dune complex behind the beach along both bays (DOGG, 2002; Mitchell et al. 2002) and the presence of a beach ridge complex suggests that the barrier has been prograding until relatively recent times (Robinson, E. et al. 2012). Geologically, the Long Bay beach is divided into two segments near the centre where limestone bedrock is exposed in the swash zone (just north of transect 8, Figure 6-18).




***Source: Robinson, E. et al. (2012)***

*Figure 6-18 Positions of cross-profiles used to evaluate shoreline changes in Robinson, E. et al. (2012) study*

### 6.1.4 Bathymetry

Bathymetric data was required in order to facilitate the accurate estimation of rock volume required given the existing water depths. In addition, bathymetric data forms the basis for wave transformation and hydrodynamic modelling.

#### *6.1.4.1 Method*

CEAC (in conjunction with Mr. Noel Francis, CLS and category A IHO hydrographic surveyor) conducted a detailed bathymetric survey of the Long Bay Beach between September 23 and October 5, 2013. The survey was done to Jamaica's national grid (JAD 2001 System) using a single beam sonar with real time kinematic (RTK) GPS correction. Gridlines based on the proposed location of the breakwaters were surveyed with the instrument using the Hypack surveying platform for calibration, navigation, data capturing and post-processing. In the area of the breakwaters these gridlines were more densely spaced. See Figure 6-19 below for a section of the bathymetric survey plan. The surveys were referenced to the Survey department's MSL datum through a tide staff specifically setup and referenced to the datum before the hydrographic surveys were conducted.

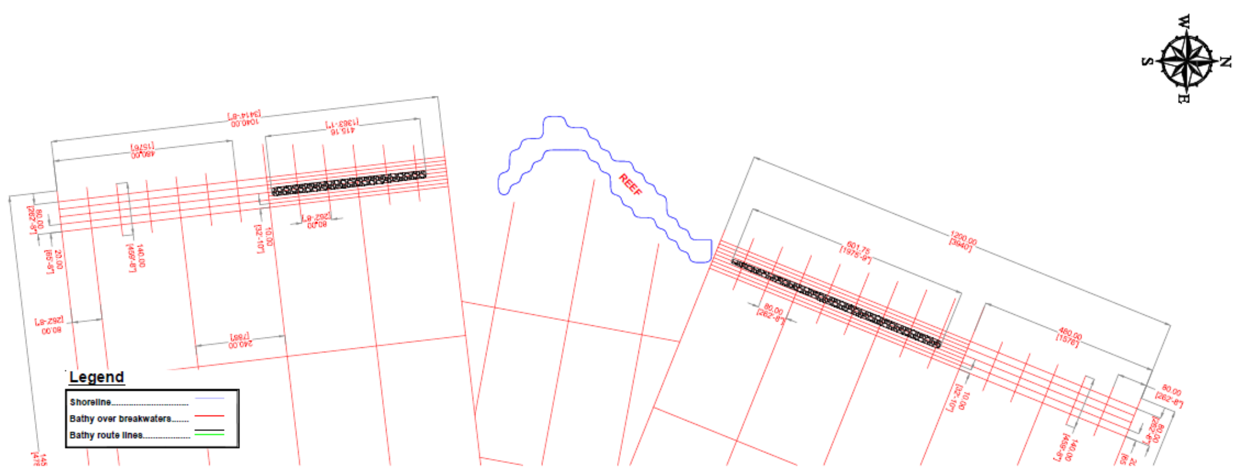



*Figure 6-19 Bathymetric Survey Plan for Negril Breakwaters*

#### *6.1.4.2 Description of Long Bay*

The Long Bay shoreline in Negril has a concave shape stretching from Bloody Bay in the north to west end just beyond the south Negril River. The overall length is approximately 7 km with an average beach width average width of approximately 15 m.

The shallow coastal shelf has a depth between 4 m and 12 m, and extends up to 2 km offshore whereas the continental shelf is approximately 3km offshore. There is a 500m long patch reef located 1.4 km offshore in front of the central and widest section of beach, and a fringing reef situated 2 – 3km offshore on the outer shelf of the reef.

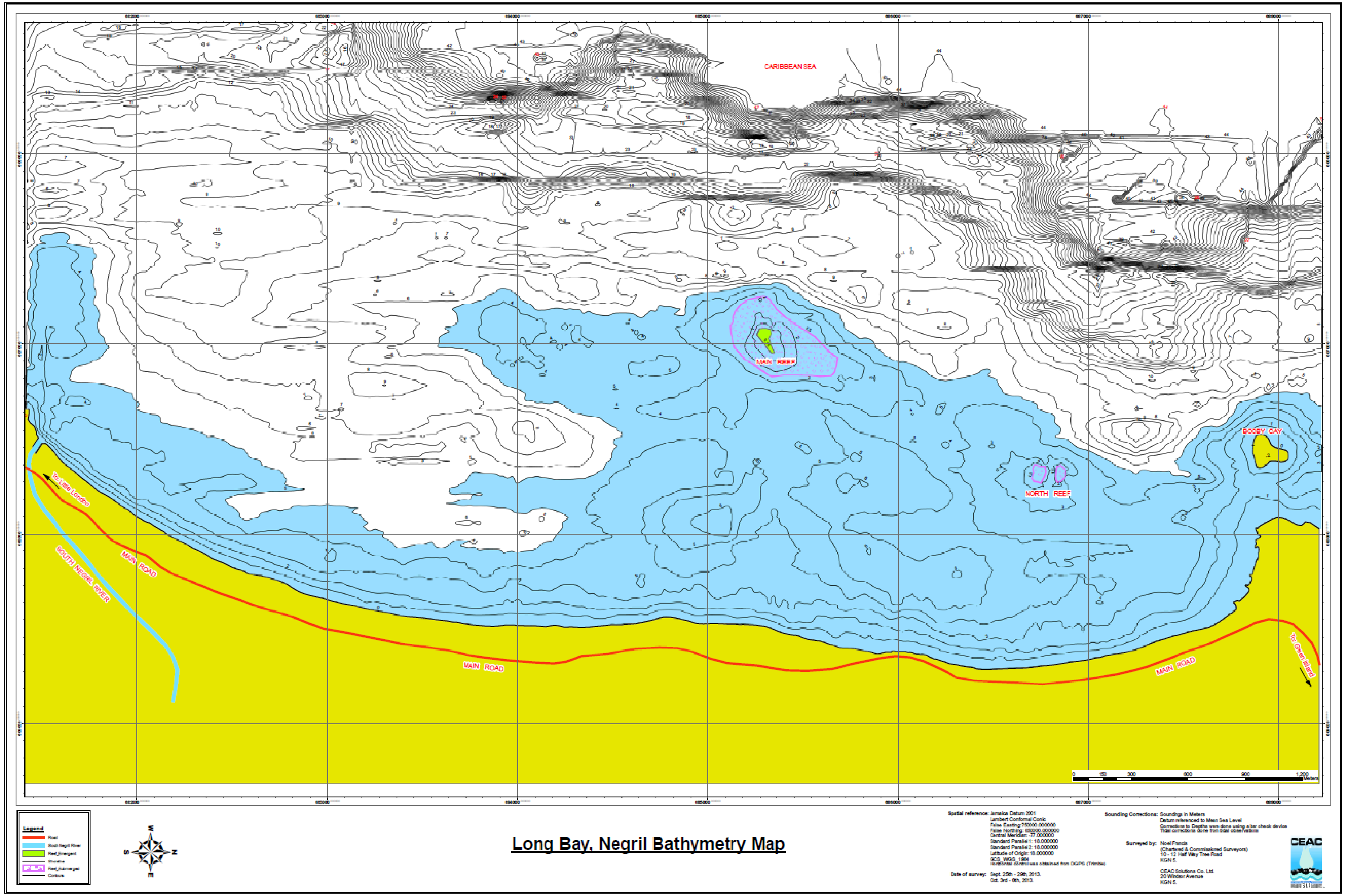



*Figure 6-20 Bathymetric Map for Long Bay, Negril*

### 6.1.5 Currents

In order to facilitate the development of the hydrodynamic model for the area and to fully understand the flushing and circulation patterns, 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.

#### *6.1.5.1 Moored ADCP*

During the drogue tracking missions drogues were deployed over two separate missions 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 depth cells or bins in the water column, each of which is 0.5m in depth. The surface bins tend to be noisy and less reliable than the subsurface ones.

The ADCP was deployed in 3.8 metres of water in the central section of the bay. It was set to record averaged current and wave readings at intervals of 1 hour.

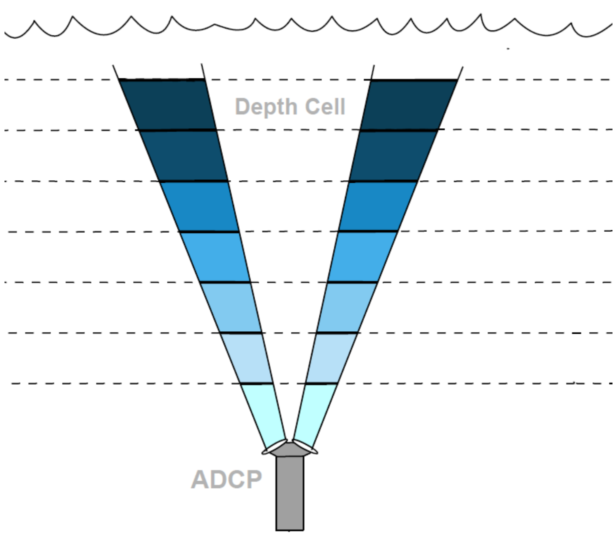


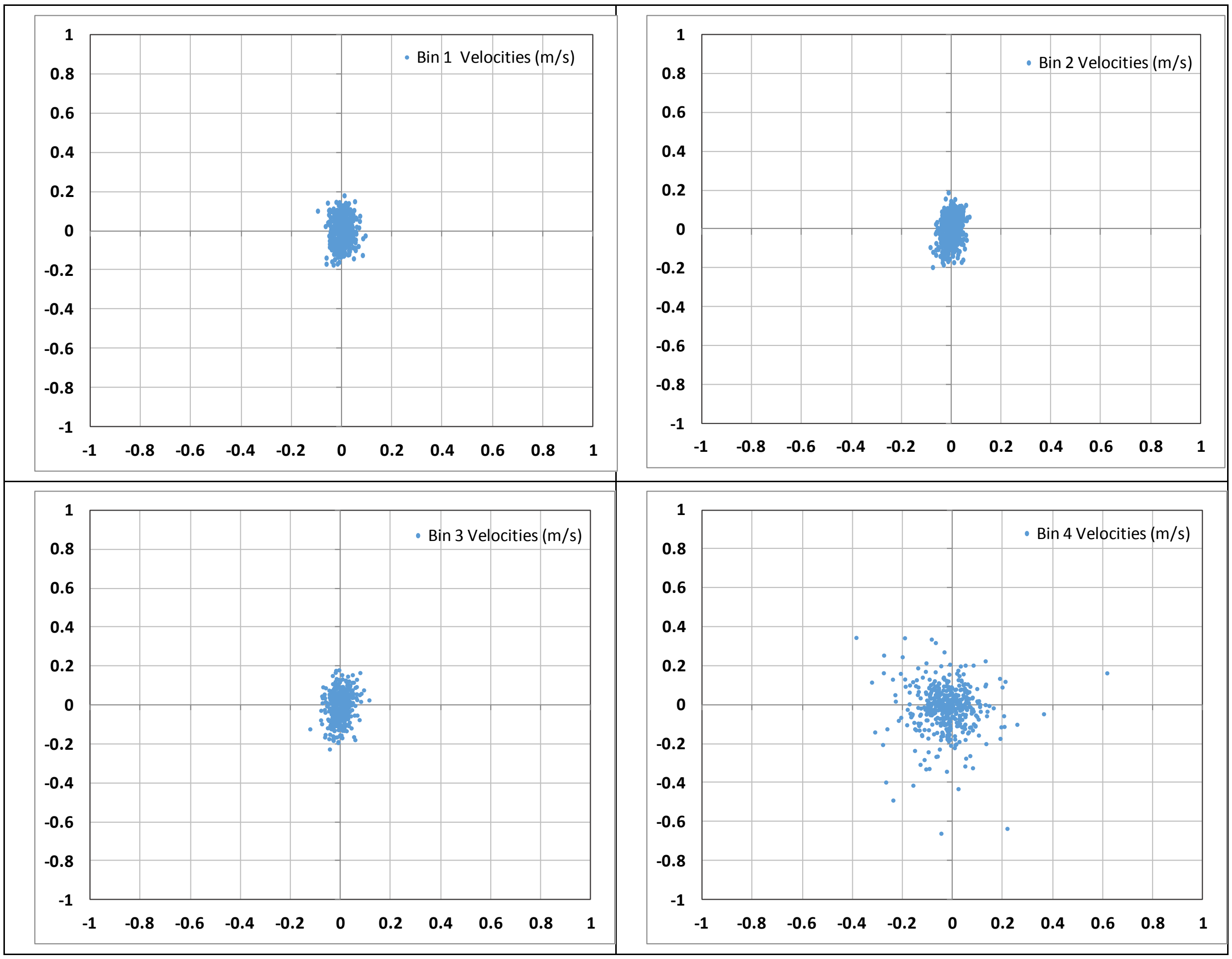

*Figure 6-21 ADCP depth cells/bins measured*


Figure 6-22 Location of Moored ADCP during the period September 23, 2013 to October 16 2013

*Plate 6-1 Moored ADCP*

The graphs and scatter plots (Table 6-8) indicate the currents were generally in a north-south direction with similar velocities in the first three bins/depth cells. The final and fourth bin is the uppermost 0.5m of the water column which has more erratic points which indicate a wider spread of currents speeds over a wider range of directions. This 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. In general the average recorded current speeds were below 0.2m/s.

*Table 6-8 Current velocities recorded in Long Bay using a 600MHz ADCP (m/s)*



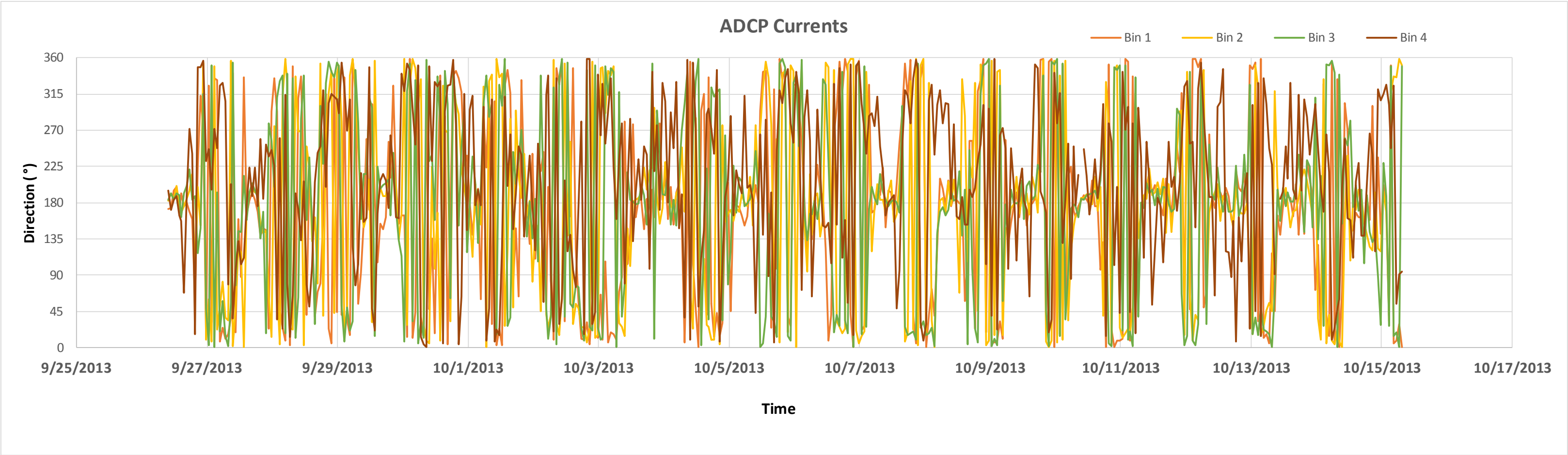



*Figure 6-23 Currents direction measured by the ADCP in the water column during the period September 26 2013 to October 16, 2013*

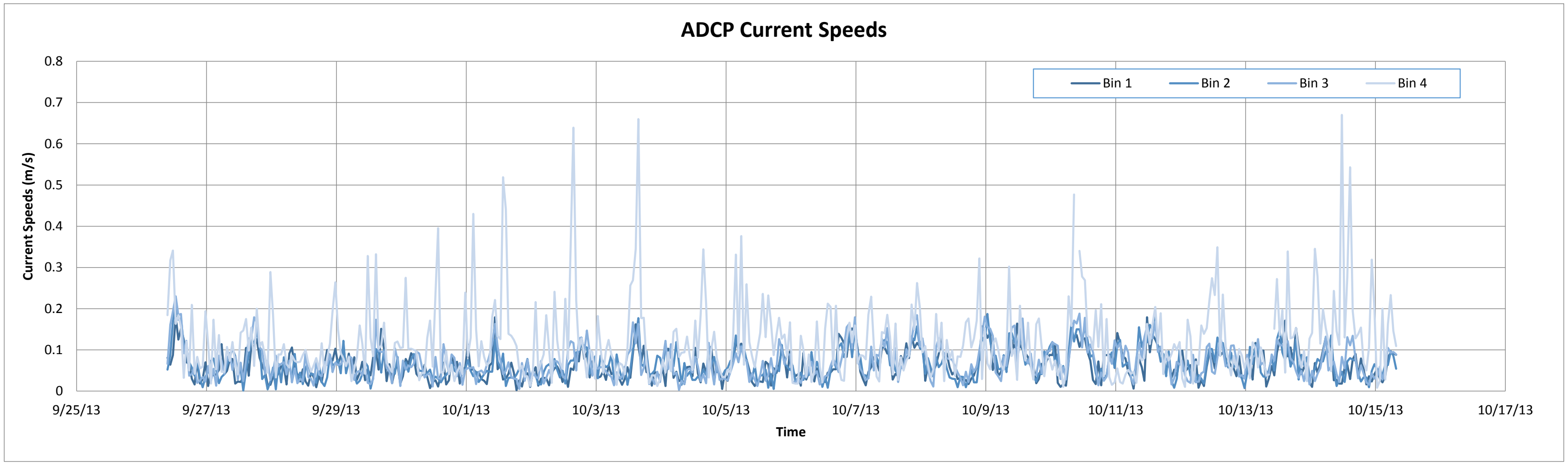



*Figure 6-24 Current Speeds measured by the ADCP in the water column during the period September 26 2013 to October 16, 2013*

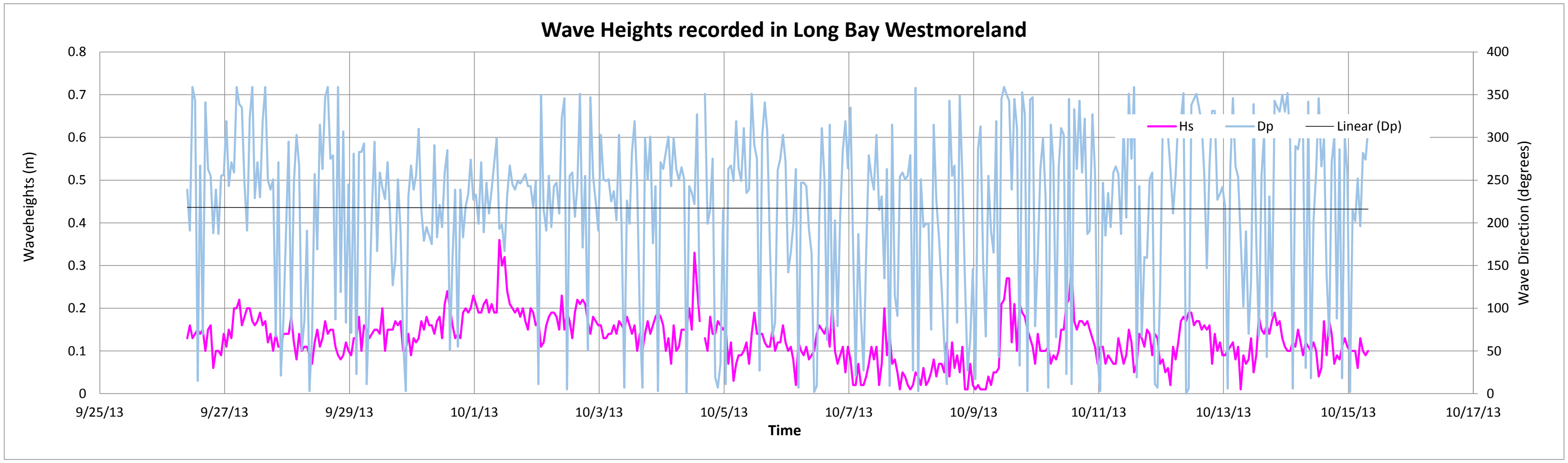



*Figure 6-25 Wave heights and directions measured by the ADCP in the water column during the period September 26 2013 to October 16, 2013*

#### 6.1.5.2 Tides

**Raw Data**

Tidal information was important in order to drive the Finite Element Hydrodynamic Model (FEM) and also to 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 breakwater structures so as to minimize overtopping during swell events.

The tidal range measured during the deployment period was 0.345m during the spring tides. Figure 6-26 shows semidiurnal tides which can be seen more clearly during the neap tides.

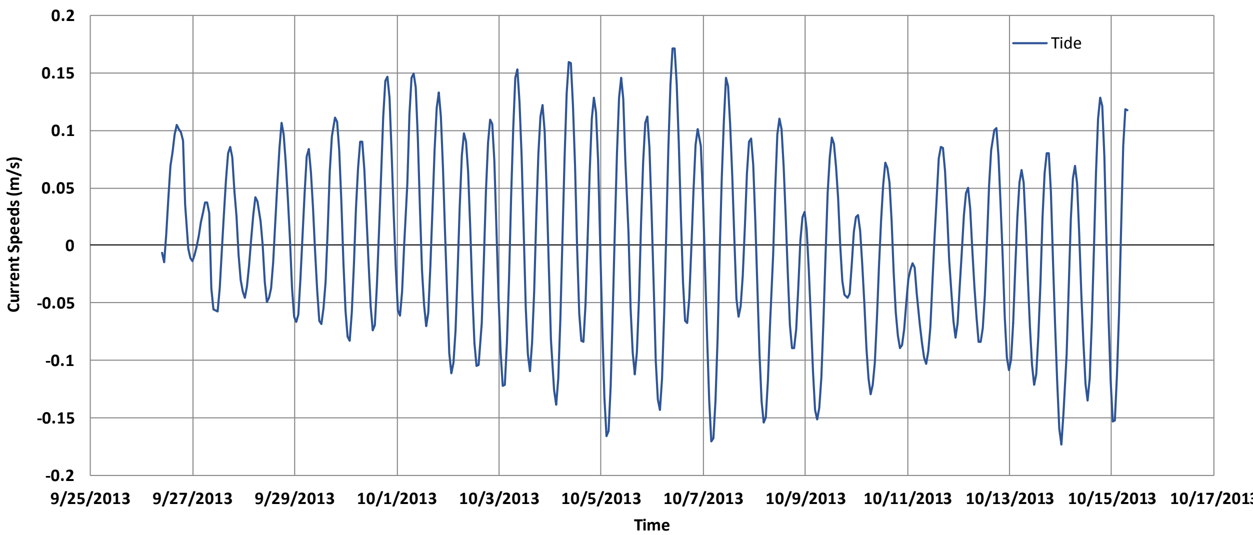



*Figure 6-26 Tide signal recorded during the deployment period September 26 to October 16, 2013*

**Tidal Harmonics**

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

The amplitudes of the seven most significant harmonic constituents were determined from the raw tide data by utilizing the *method of least squares*. In this method, a set of cosine terms is used as a model. The blended curves is made to fit the data according the harmonics model and to the least squares criterion by choosing the combination of R and N that causes the sum of the squared differences between observed and model-predicted tides to be as small as possible. The resulting amplitudes and phase lag are outlined in Table 6-9.

*Table 6-9 Tidal constituents obtained from the harmonic analysis of the Raw ADCP data collected in Long Bay during the period September 26 2013 to October 16th 2013*

| 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 | -0.60 | 1.67 | 0.84 | 2.99 | 2.29 | -3.64 | 0.77 |
| Amplitude | 0.095 | 0.048 | 0.020 | 0.033 | 0.027 | 0.018 | 0.010 |

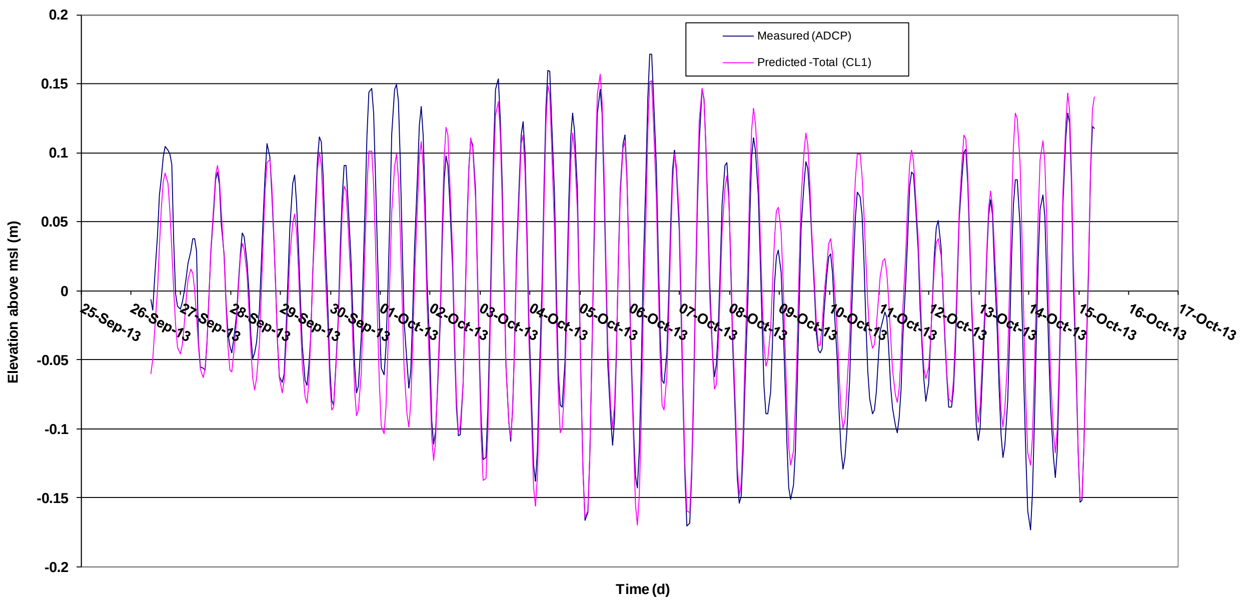



*Figure 6-27 Measured and predicted tidal signatures for Long Bay Negril for the period September 26 2013 to October 16th 2013*

### 6.1.5.3 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- two-day drogue tracking missions were executed on September 26–27 and October 16–17, 2013. Eight (8) drogues were deployed; four (4) surface and four (4) sub-surface drogues (with depths ranging from 1 to 6 metres). The drogues were deployed at fifteen (15) offshore locations and at each location the drogues were tracked during two separate sessions each day. One session was held in the morning and one in the evening, so as 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 analysed in order to determine current speed and directions, and current speed vectors were produced for the rising and falling tides below.

**Wind Data**

Weather underground provided wind data for each drogue tracking session that was used to determine whether the wind or current was predominant in moving the drogues. This information is summarized in Table 6-10.

*Table 6-10 Wind data during the drogue tracking seasons provided by Weather Underground*

| Date (2013) | Session | | Average Wind Speed (km/h) | Average Wind Direction |
|---|---|---|---|---|
| | Tide | Duration | | |
| **September 26** | Rising | 2:49 – 5:13pm | 9.3 | W |
| **September 27** | Falling | 6:21 – 8:21am | 4.1 | W |
| | Rising | 1:37 – 3:36pm | 13.9 | N |
| **October 16** | Falling | 11:12am – 1:50pm | 11.9 | N |
| | Rising | 3:20 – 4:44pm | 7.4 | SSE |
| **October 17** | Falling | 10:53am – 1:10pm | 8.9 | SSW |
| | Rising | 3:33 – 5:37pm | 8.9 | NNE |

**Tracking Results**

*September 26, 2013*

A drogue tracking session was not held in the morning to capture the falling tide. For the rising tide session in the afternoon the drogues were deployed at 8 offshore locations and it was observed that the tide was moving in a south westerly direction. It was also observed that the surface drogues moved faster than the deeper, sub-surface drogues, and that the drogues deployed near shore moved slower than those deployed closer to the reef.

*September 27, 2013*

FALLING TIDE

During this session the drogues were deployed at the same 8 offshore locations used on the previous day. This time the tide moved in a north westerly direction and it was weaker than the tide observed the day before. The surface and deeper, sub-surface drogues, moved at almost the same speed but the drogues deployed near shore still moved slower than those deployed closer to the reef.

RISING TIDE

It was observed that the tide was moving in a southerly direction and that the surface drogues moved faster than the deeper, sub-surface drogues. The faster moving drogues were also deployed closer to the reef.

*October 16, 2013*

FALLING TIDE

During this session the drogues were deployed at 6 different offshore locations, these were south of the 8 locations previously used. Two (2) of these were deployed south of the reef, one (1) west of the reef, one (1) behind the reef and two (2) north of the reef. For those deployed south and west of the reef the tide was observed to be moving in a south easterly direction and for the others the tide moved in a northern direction similar to the wind direction. The surface drogues also moved faster than the deeper, sub-surface drogues.

RISING TIDE

The drogues were deployed at 5 of the 6 locations used earlier in the day and it was observed that the tide was moving in a southern direction similar to the wind direction. The surface and deeper, sub-surface drogues, moved at almost the same speed but the drogues deployed at the southern-most point moved faster than the other drogues.

*October 17, 2013*

FALLING TIDE

During this session the drogues were deployed at 7 offshore locations, 6 of which were used on the previous day. It was noticed that the tide moved all the drogues in a northern direction and that the surface drogues also moved slightly faster than the deeper, sub-surface drogues.

RISING TIDE

The drogues were deployed at the 7 locations used earlier in the day. The drogues deployed in the vicinity of the reef and north of the reef moved in a northern direction similar to the wind direction, while the drogues deployed south of the reef moved primarily in a southern direction.

**Summary**

The two, two- day drogue tracking missions comprised of 7 sessions – three falling tide and four rising tide sessions – that covered 15 offshore locations. Between September 26 and 27 the current speeds varied from between 1.9 cm/s to 15.9 cm/s and 1.7 cm/s to 10.1 cm/s for the surface and sub-surface drogues respectively. Between October 16 and 17 these current speeds varied from between 1.8 cm/s to 17.8 cm/s and 2.6 cm/s to 16.8 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 falling tides than for the rising 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 10km/hr (2.78m/s) then the effect of the tides is negligible especially for surface currents.

### *6.1.5.4 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 and a 97 and 97.3 percent correlation was obtained for the x and y components respectively. This indicates the order of magnitude of the currents were generally very close. Similarly, the data was checked to determine the bias that may exist. It was found that the bias did not vary significantly about zero. Overall, it can be said that the ADCP was functioning correctly. The graphs in Table 6-11 below highlights the correlation using scatter plots while Table 6-12 below summarizes the correlation and bias in the data.

*Table 6-11 Comparison Plots for the X and Y components of velocity for the Drogues and ADCP deployed in Long Bay*

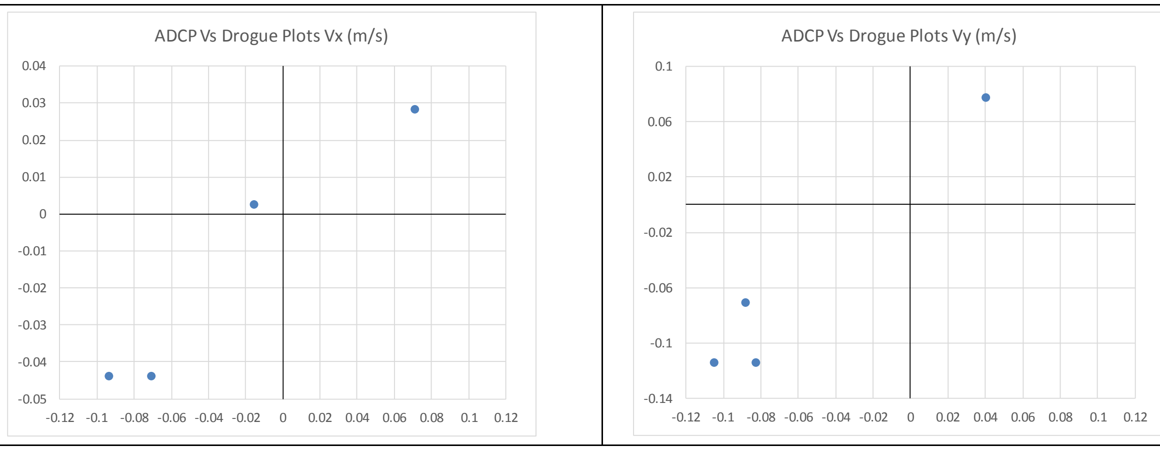



*Table 6-12 Statistical comparison of the currents measured by the drogues and ADCP deployed in Long Bay*

| Direction (component) | Correlation | Bias |
|---|---|---|
| Vx | 97.01% | -67% |
| Vy | 97.34% | 30% |

## 6.1.6 Wind

### 6.1.6.1 NOAA Long Term Data

The NOAA long term wind wave data model was searched for long term wind data for Negril. A node was chosen in front of the bay and the wind data corresponding to that node obtained. The node used was Latitude 18- 18.58N, Longitude 078-27.59W.

The data spanned the years of 1999 to 2007 recorded on a daily basis at three hour intervals. The data is shown in a wind rose in Figure 6-28. The data was analysed in terms of 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 have directions predominantly of NE to E direction with wind speeds of 20 m/s or less approximately. North to North West and southerly wind directions were noted to occur but rarely. Overall the average wind speed and direction is between 2 to 4m/s from the ENE.

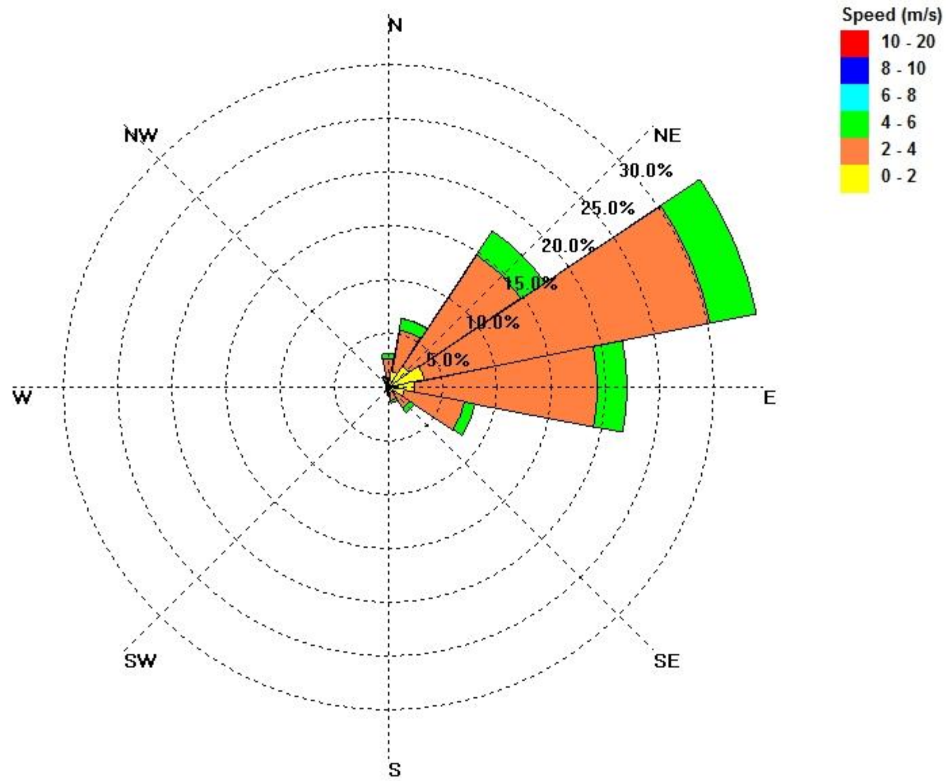



*Figure 6-28 NOAA Long term wind data for Negril offshore node Spanning 1999 to 2007*

### 6.1.6.2 Short Term Wind Data

Current wind data was collected for the days on which drogue tracking exercise were carried out. In total four days of data were collected from the Weather Underground online database for the Negril Point station. The first set of data was collected for September 26 and 27 2013. The majority of the winds were out of the NE to SE directions with averaged hourly speeds of up to 5m/s. The second period had fewer variations in terms of wind directions and speeds. Wind speeds were mostly between 1 and 3.5m/s whereas the majority of the winds were out of the SSE. See Figure 6-29 and Figure 6-30 below.

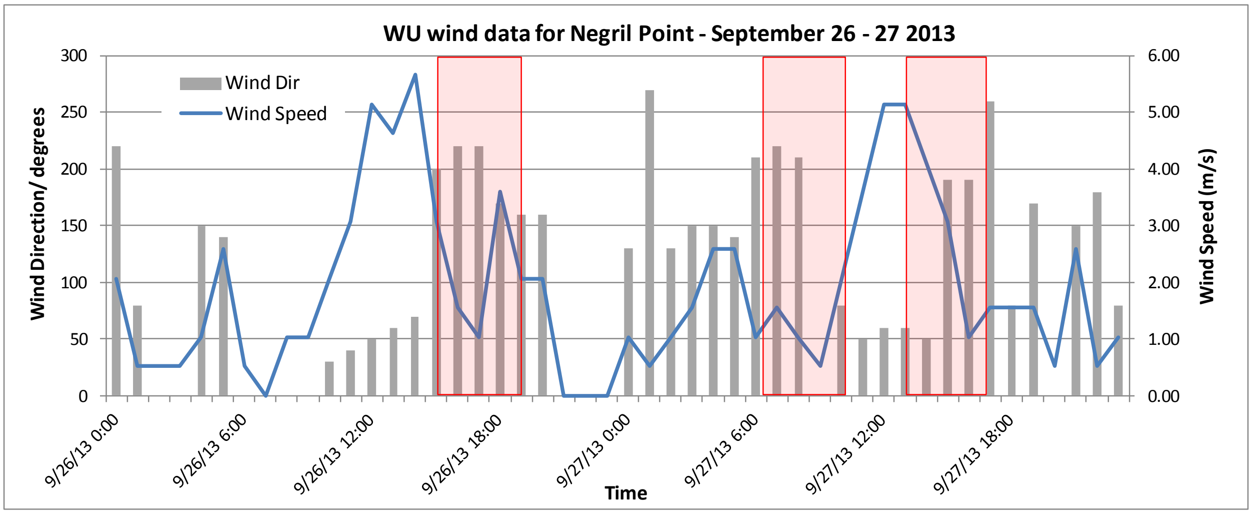



*Figure 6-29 WU wind speeds for Negril Point on September 26 - 27 2013*

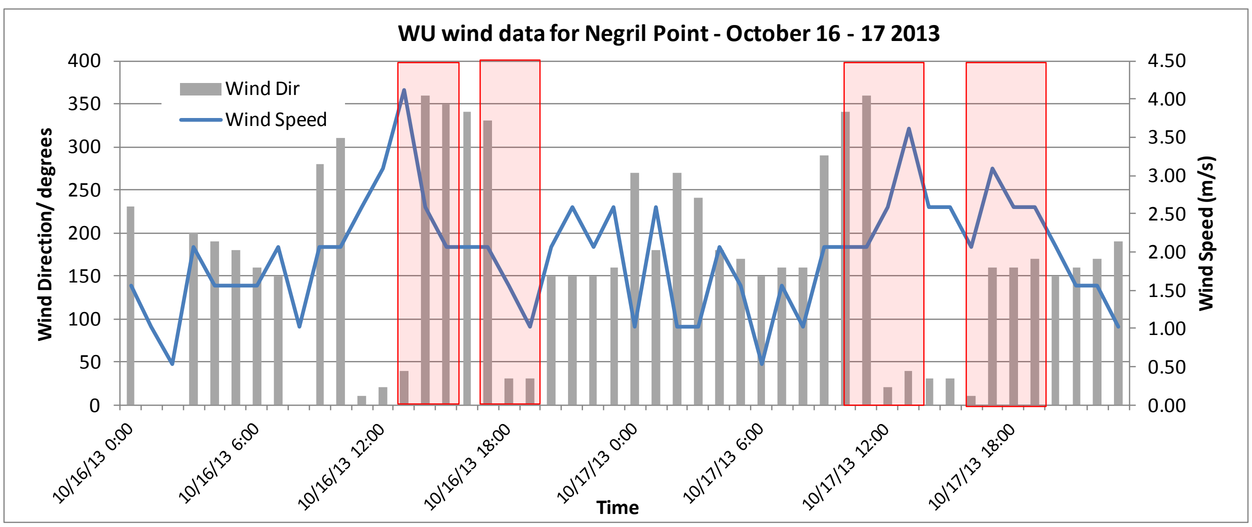



*Figure 6-30 WU wind speeds for Negril Point on October 26 - 27 2013*

## 6.1.7 Shoreline Sediments

Sand samples were collected for analysis from the beach face and back of the beach at 6 locations along the shoreline. The sample locations are shown in Figure 6-31.

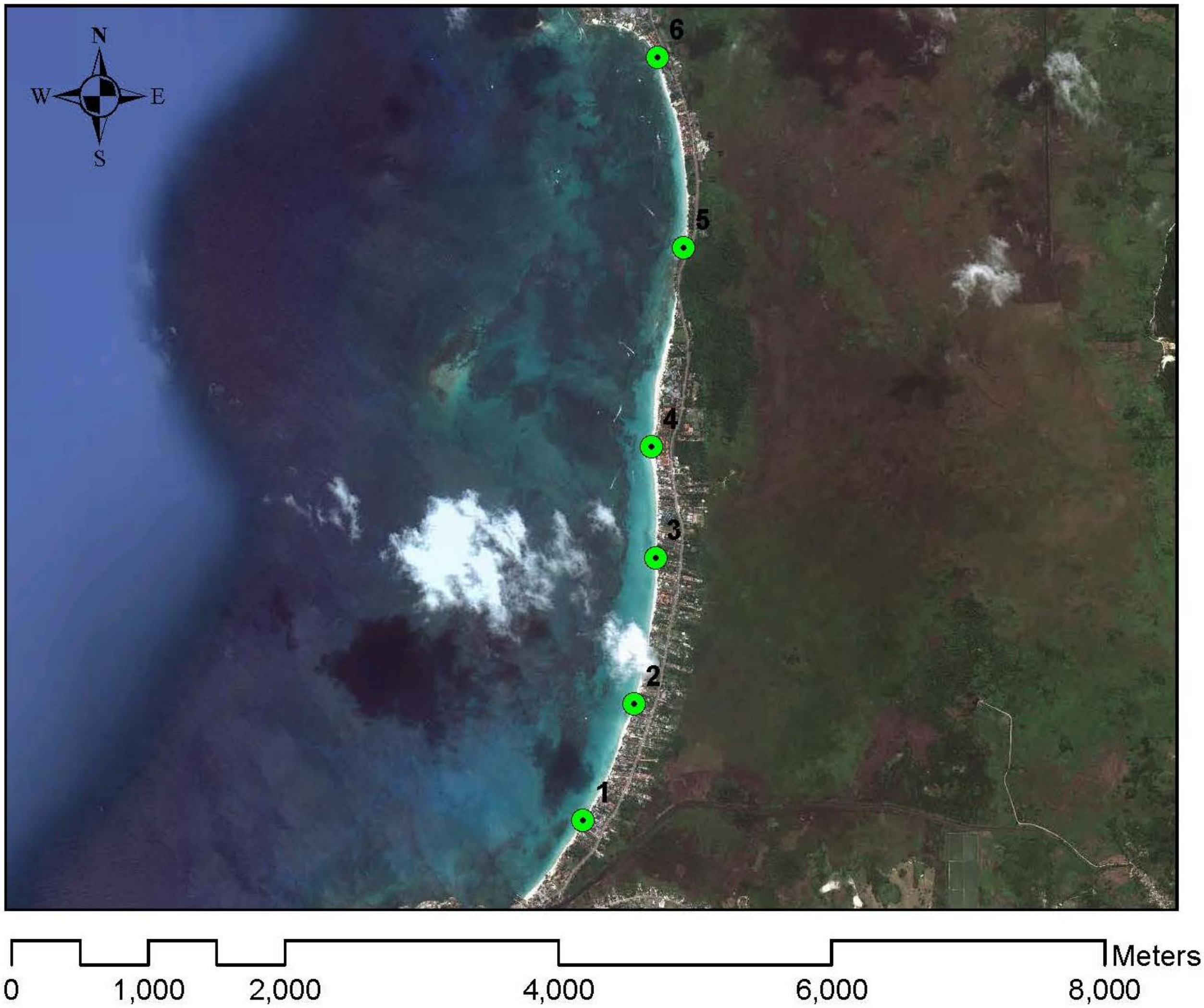



*Figure 6-31 Sand sample locations along the Long Bay Beach, Negril*

The grain size analysis was done using the Unified Soil Classification System (USCS) which is widely used for the classification of granular material for engineering and geological applications. The UCSC classification systems utilizes plasticity however this was not considered as the samples are all sand the plasticity index characteristics are irrelevant and thus both grain size and sorting used to define the samples. ASTM standard sieves consisting of 16 sieves were used (3/4, 1/2, 3/8, 4, 6, 8, 10, 16, 20, 30, 40, 50, 60, 80, 100, 200 and Pan) but not the typical 8 ASTM "stack" used in most laboratories. The reason for this is because of the relative close grading of the particles of beach sand and the need to have more information on grain size typical of beach sand for analytical purposes. Method of moments were used to determine mean, skewness, kurtosis.

The samples were dried and sieved using ASTM standard sieves and analysed to determine the coefficient of uniformity, standard deviation, skewness and kurtosis. A summary of the results are shown in Table 6-13 as well as Figure 6-32.

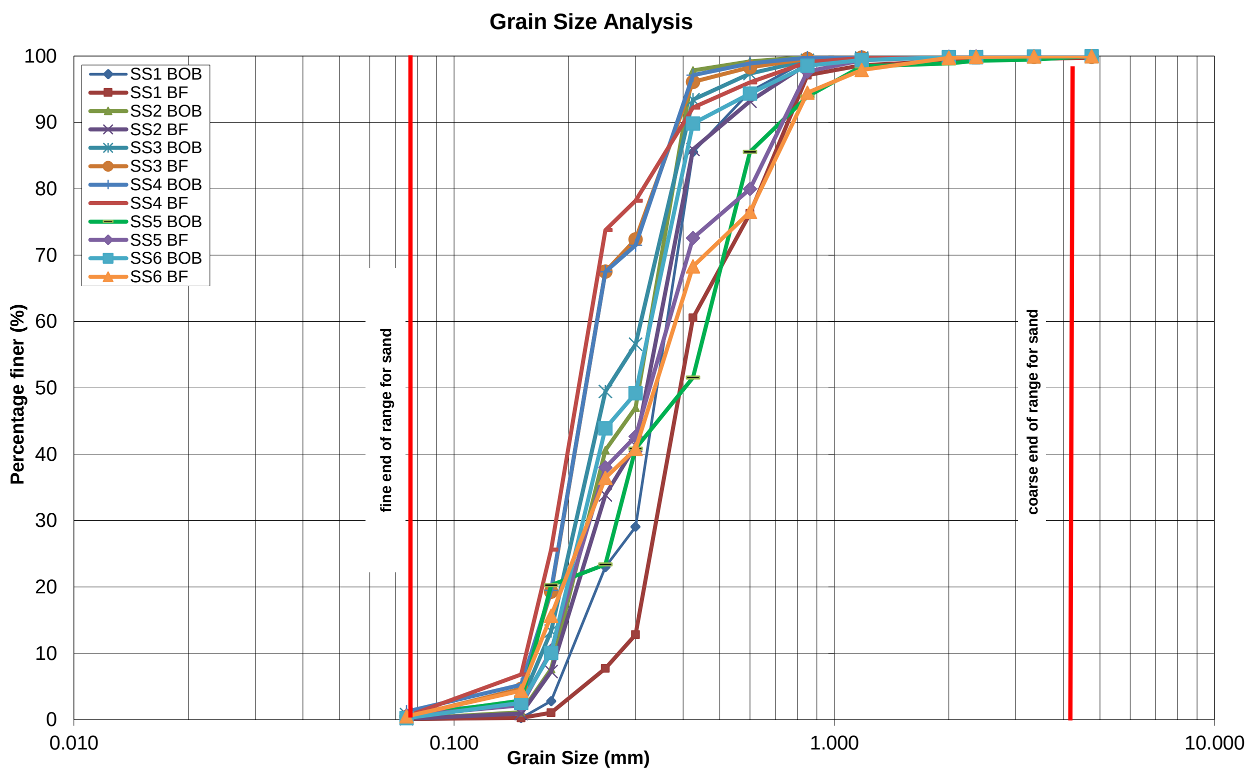



*Figure 6-32 Plot of the grain size distribution for samples along Long Bay beach in Negril October 2013*

*Table 6-13 Grain Size Analysis results*

| GRAIN SIZE ANALYSIS RESULTS | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample Location** | **1.0** | | **2.0** | | **3.0** | | **4.0** | | **5.0** | | **6.0** | |
| **Sample ID** | **SS1 BOB** | **SS1 BF** | **SS2 BOB** | **SS2 BF** | **SS3 BOB** | **SS3 BF** | **SS4 BOB** | **SS4 BF** | **SS5 BOB** | **SS5 BF** | **SS6 BOB** | **SS6 BF** |
| **Location on beach cross section** | **Back of beach** | **Beach front** | **Back of beach** | **Beach front** | **Back of beach** | **Beach front** | **Back of beach** | **Beach front** | **Back of beach** | **Beach front** | **Back of beach** | **Beach front** |
| **Mean Grainsize (mm)** | 0.346 | 0.397 | 0.307 | 0.324 | 0.254 | 0.225 | 0.224 | 0.215 | 0.407 | 0.331 | 0.302 | 0.342 |
| **Mean (phi)** | 1.530 | 1.332 | 1.702 | 1.624 | 1.978 | 2.155 | 2.155 | 2.215 | 1.298 | 1.597 | 1.725 | 1.549 |
| **Description** | medium sand | medium sand | medium sand | medium sand | medium sand | fine sand | fine sand | fine sand | medium sand | medium sand | medium sand | medium sand |
| **Percentage silt** | 0.00% | 0.12% | 0.2% | 0.1% | 0.8% | 0.4% | 1.2% | 0.5% | 0.5% | 0.6% | 0.3% | 0.5% |
| **Percentage >0.06mm and <6.0 mm** | 100% | 100% | 100% | 100% | 99% | 99% | 99% | 99% | 100% | 99% | 100% | 99% |
| **Uniformity Coefficient** | 1.798 | 1.555 | 1.794 | 1.882 | 1.827 | 1.485 | 1.494 | 1.483 | 2.887 | 2.086 | 1.854 | 2.348 |
| **Standard Deviation** | 0.486 | 0.579 | 0.445 | 0.566 | 0.523 | 0.489 | 0.495 | 0.593 | 0.838 | 0.794 | 0.574 | 0.879 |
| | well sorted | moderately well sorted | well sorted | moderately well sorted | moderately well sorted | well sorted | well sorted | moderately well sorted | moderately sorted | moderately sorted | moderately well sorted | moderately sorted |
| **Skewness** | 3.593 | 2.040 | 3.772 | 3.215 | 3.482 | 3.807 | 3.822 | 3.756 | 1.696 | 1.699 | 3.253 | 1.505 |
| | V. strongly positive skewed | V. strongly positive skewed | V. strongly positive skewed | V. strongly positive skewed | V. strongly positive skewed | V. strongly positive skewed | V. strongly positive skewed | V. strongly positive skewed | V. strongly positive skewed | V. strongly positive skewed | V. strongly positive skewed | V. strongly positive skewed |
| **Kurtosis** | 1.191 | 0.949 | 0.704 | 1.030 | 0.811 | 0.820 | 0.822 | 1.542 | 0.968 | 0.833 | 0.968 | 0.739 |
| | leptokurtic | mesokurtic | platykurtic | mesokurtic | platykurtic | platykurtic | platykurtic | very leptokurtic | mesokurtic | platykurtic | mesokurtic | platykurtic |

### 6.1.7.1 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. All the samples analysed had uniformity coefficient less than 6 as shown in Figure 6-33. This indicates the wave climate arriving at the shoreline is on the aggressive side, causing the particle sizes to be poorly graded.

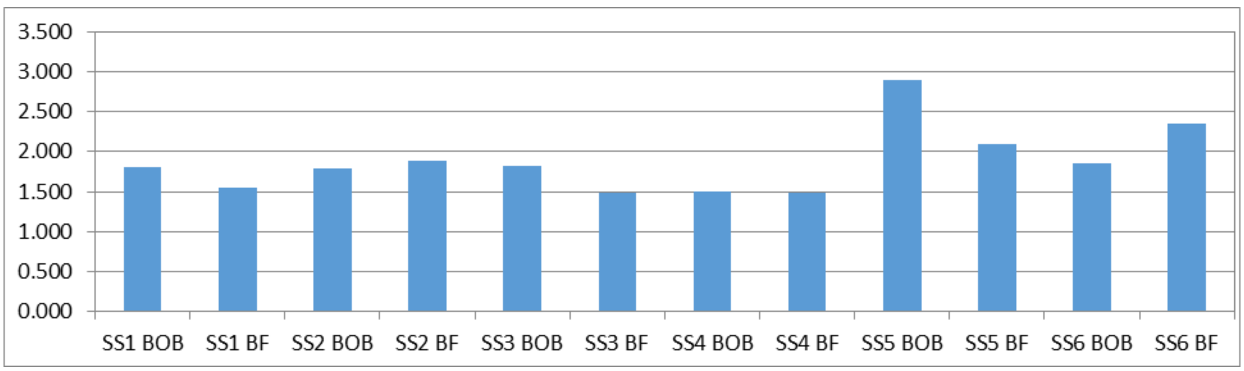



*Figure 6-33 Uniformity coefficient for each sample*

### 6.1.7.2 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 samples collected were all well sorted as indicated in Figure 6-34. This is indicative of relatively high wave energy at the shoreline which sorts the particles into their discrete sizes.

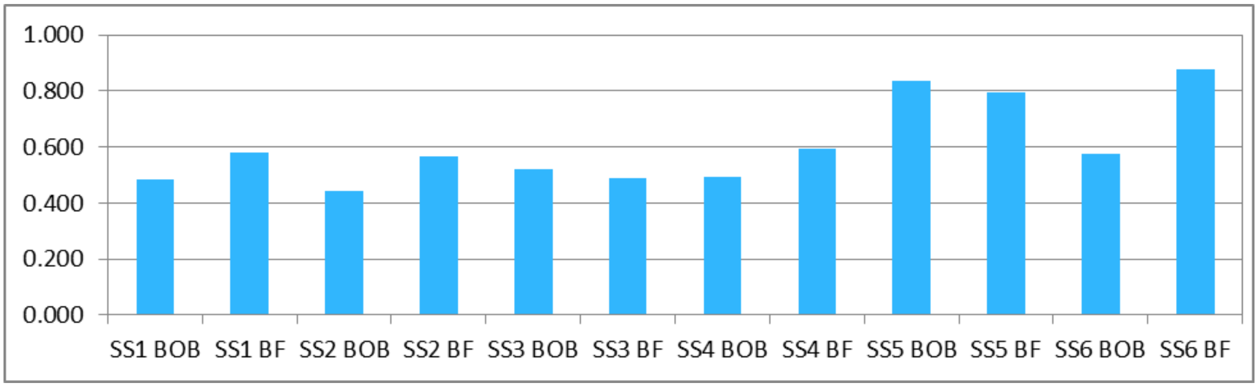



*Figure 6-34 Standard Deviation for each sample*

### *6.1.7.3 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 are 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.

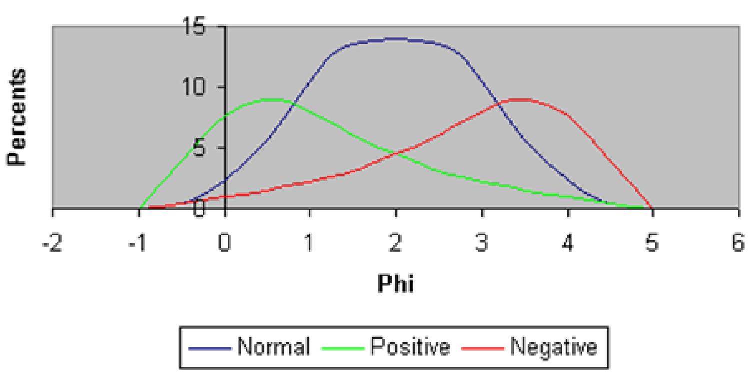



*Figure 6-35 Typical skewness curves*

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 6-14 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 results for skewness for the stretch of shoreline showed high positive skewness ranging from 1.5 to 11.25. A plot of the skewness results are shown in Figure 6-36**.**

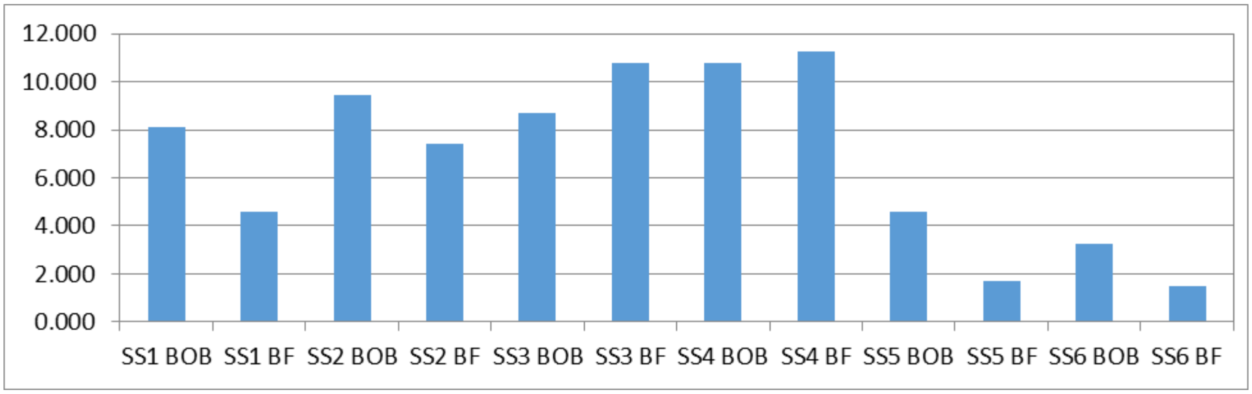



*Figure 6-36 Skewness for each sample*

### *6.1.7.4 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. If the sample curve plots as a straight line on probability paper (i.e., if it follows the normal curve), this ratio will be obeyed and we say it has normal kurtosis (1.00). Departure from a straight line will alter this ratio, and 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.

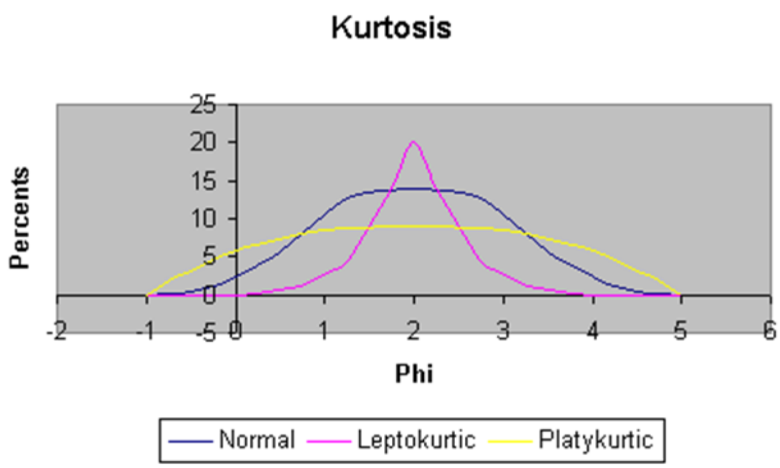



*Figure 6-37 Typical kurtosis curves*

Strongly platykurtic curves are often bimodal with sub equal 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. Kurtosis involves a ratio of spreads; hence it is a pure number and should not be written with a phi attached. The following verbal limits are suggested for values of kurtosis:

*Table 6-15 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 |
| **1.50** | **3.00** | very leptokurtic |
| **3.00** | **∞** | extremely leptokurtic |

### 6.1.7.5 Comparison to Preliminary Engineering Report and Summary

The results of the sediment analysis were compared to the results of the preliminary design report completed by Smith Warner International Limited (2007). For both studies two sand samples were collected at each location and a sieve analysis conducted on each sample. Both analyses concluded that the sand was poorly graded but there were discrepancies in the grain size results. Table 6-16 summarises these results and indicates that on average, the back of beach sand grain size results from Smith Warner were twice the size of that obtained from CEAC. However the table also shows that the companies have similar values for the grain size for the beach face sand. The difference in grain sizes could be attributed to the fact that Smith Warner's analysis was conducted in 2007 during a period when there was increased swell waves entering the bay while CEAC's was conducted in 2013 during a quiet period.

*Table 6-16 Comparison of CEAC Solutions and Smith Warner's d50 results from grain size analysis of sand samples from the Long Bay Beach*

| Sampling Location (with reference to CEAC Locations) | | CEAC Solutions Co. Ltd (Oct 2013) | Smith Warner International (2007) |
|---|---|---|---|
| **1** | **Back of beach** | 0.01 | 0.73 |
| | **Beach face** | 0.397 | 0.81 |
| **2** | **Back of beach** | 0.307 | 0.29 |
| | **Beach face** | 0.324 | 0.27 |
| **3** | **Back of beach** | 0.254 | 0.57 |
| | **Beach face** | 0.225 | 0.26 |
| **4** | **Back of beach** | 0.224 | 0.50 |
| | **Beach face** | 0.215 | 0.25 |
| **5** | **Back of beach** | 0.407 | 1.06 |
| | **Beach face** | 0.331 | 0.25 |
| **6** | **Back of beach** | 0.302 | 0.26 |
| | **Beach face** | 0.342 | 0.24 |

### 6.1.8 Past Erosion Events and Anecdotal Data

#### *6.1.8.1 Vox-Pop Surveys October 2013*

Information regarding historical hurricane and rainfall events was obtained by conducting interviews with persons living and or working in the Negril area. This information was useful in calibrating and verifying the accuracy of shoreline erosion models presented herein. A total of 18 persons were interviewed along the Long Bay shoreline. Most of the respondents indicated that Hurricanes Gilbert (1988) and Ivan (2004) caused the most damage to the area.

#### *6.1.8.2 Previous Reports*

Information on shoreline movements obtained from the (McKenzie 2012) study undertaken in 2012 as well as the Preliminary engineering report prepared by Smith Warner International (SWIL); to supplement the anecdotal data. McKenzie (2012) evaluated beach profile data collected over a nine year period (2000-2008) to determine the effects of 5 hurricanes on the level of beach erosion along the Long Bay beach, whereas the SWIL report measured and recorded erosion along the Long Bay Beach after a major swell event.

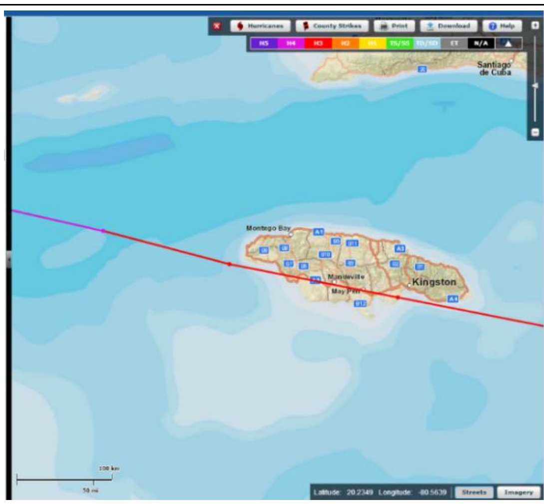
#### *6.1.8.3 Hurricane Gilbert (1988)*

Hurricane Gilbert, a Category 3 hurricane, at the time, passed within 50 km south of Negril and within 8 hours had travelled over 100km to the west of Negril. Respondents indicated Gilbert was one of the most destructive hurricanes to have affected the area in recent times. It caused the erosion of the beach in the south central and northern sections (See Table 6-17).

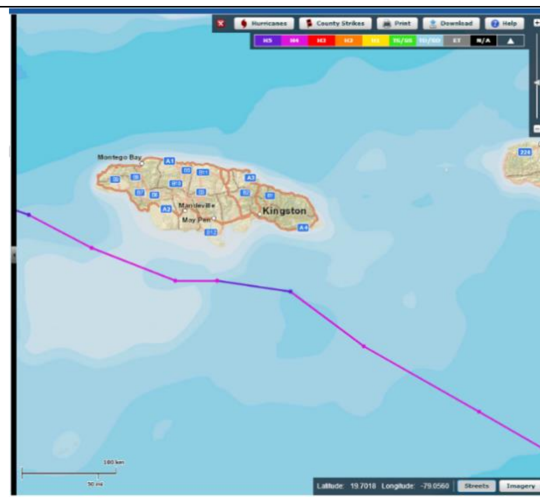
#### *6.1.8.4 Hurricane Ivan (2004)*

Hurricane Ivan was a Category 4 with wind speeds of 222 to 240 kph. Most residents and employees reported that Ivan produced the most widespread damage - it caused damage to both the beach and structures. At Rondel Village the beach bar had to be relocated further inland after the wave runup travelled some 45m from the shoreline. At Negril Treehouse further north of Rondel Village, the wave runup travelled 50m inland and into the hotel's lobby, Table 6-17.

*Table 6-17 Comparison of NOAA best track estimated projection for Hurricane Gilbert (1988) and Hurricane Ivan (2004)*




***Hurricane Gilbert (1988)***




***Hurricane Ivan (2004)***

McKenzie (2012) also indicated that Ivan caused some of the greatest damage to the shoreline and had determined that the average erosion along the beach was 16m, and in some areas it was as much as 23m inland. Table 6-18 below highlights the effect of Ivan on the beach; information regarding the length of water was obtained from the interviewees whereas the erosion rates were provided by the McKenzie (2012) report.

*Table 6-18 Effects of Hurricane Ivan along the Long Bay Beach in 2004*

| **Location** | **Length of Water (m)** | **Erosion (m)** |
|---|---|---|
| Craft Village | 45 | 10 |
| Rondel Village | 38 | 13 |
| Negril Tree House | 35 | 15 |

#### *6.1.8.5 Storm Swell (November 21 – 24, 2006)*

In November 2006 Smith Warner International (SWIL) measured the erosion that took place before and after a swell event at the Long Bay Beach. The observation noted that in the northern section of the beach, approximately 1 m erosion occurred; in the central section of the beach the shoreline remained unchanged, while in the southern section between 1 to 1.5 m of erosion took place.

#### *6.1.8.6 Summary*

Anecdotal data collected, indicated hurricanes Gilbert and Ivan were among the worst storms to have affected the Negril shoreline in recent years. Even though hotels and other businesses are typically back to normal within three to ten weeks of the passage of these storm events, the McKenzie study concluded that it takes a minimum of 3 – 4 years for the beach to 'to recover to its pre-storm position following the near passage of a category 4 storm event'.

The respondents revealed that employees and residents in the area manually removed or reshaped sand and debris after the passing of a storm event thereby minimizing the recovery time of the beach

### 6.1.9 Beach Profile

NEPA has been using bench marks established in 2000 to record shoreline changes along the Long Bay Beach. The agency collects this data a minimum of 3 times per year and provided CEAC with the information collected at the benchmarks located at Sandals, Swept Away and Negril Gardens – a northern, central and southern point along the beach respectively. This information supplemented the anecdotal data used to calibrate and verify the cross shore sediment transport model (SBEACH). The beach profile is measured and referenced to a bench mark at each location, facilitating the assessment of the beach profile changes in responses to storm or swell events.

The following figures illustrate the beach profile at Sandals, Swept Away and Negril Gardens between 2008 and 2013. These profiles showed that after the passage of Hurricane Sandy the beach in the vicinity of Sandals eroded by 3 m, while at Negril Gardens there was 1 m of accretion. The profile at Swept Away showed that after the passing of Tropical Storm Nicole in 2010 no erosion took place, the beach was stable.

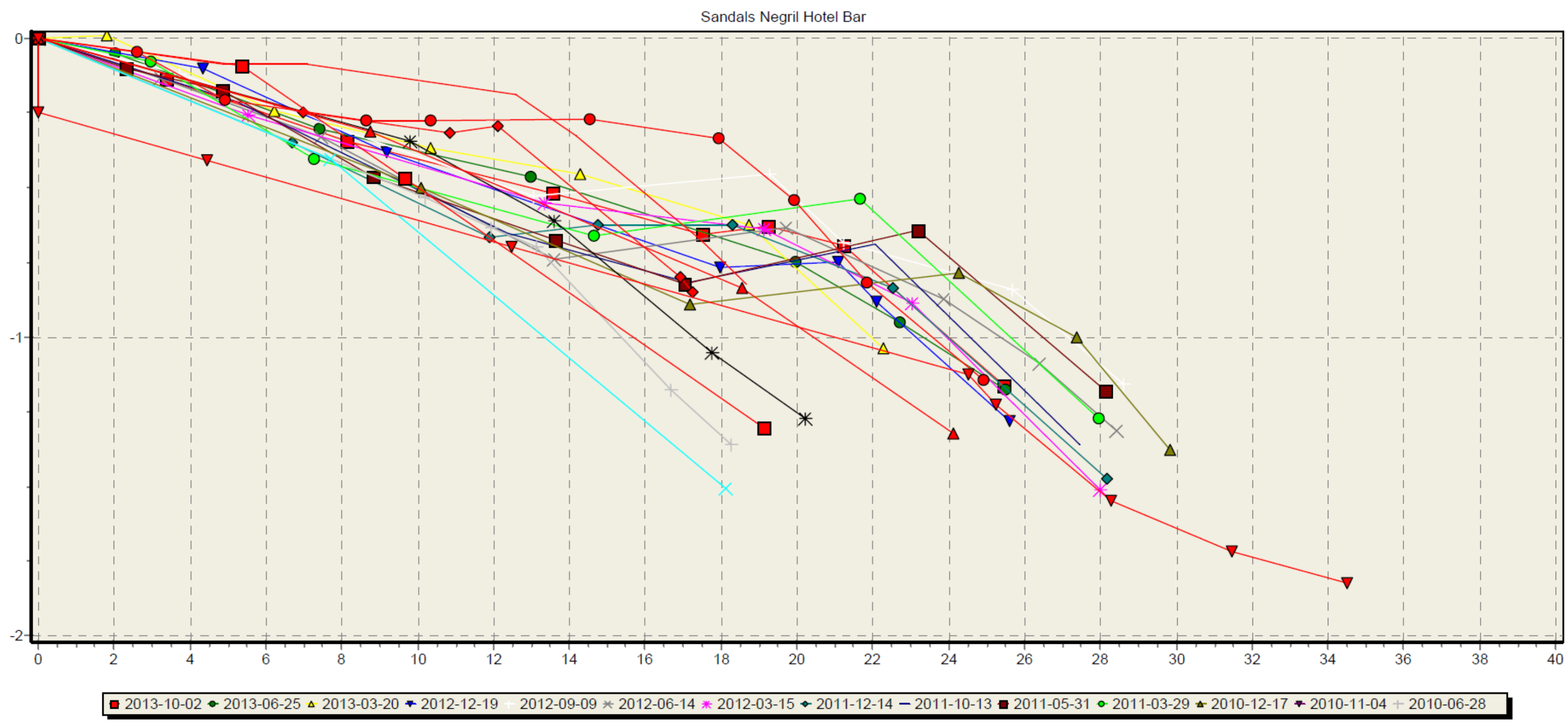



*Figure 6-38 Profile data in the vicinity of Sandals Negril Hotel and Bar collected by NEPA between 2010 and 2013 showing that the shoreline eroded by 3m following the passage of Hurricane Sandy in 2012*

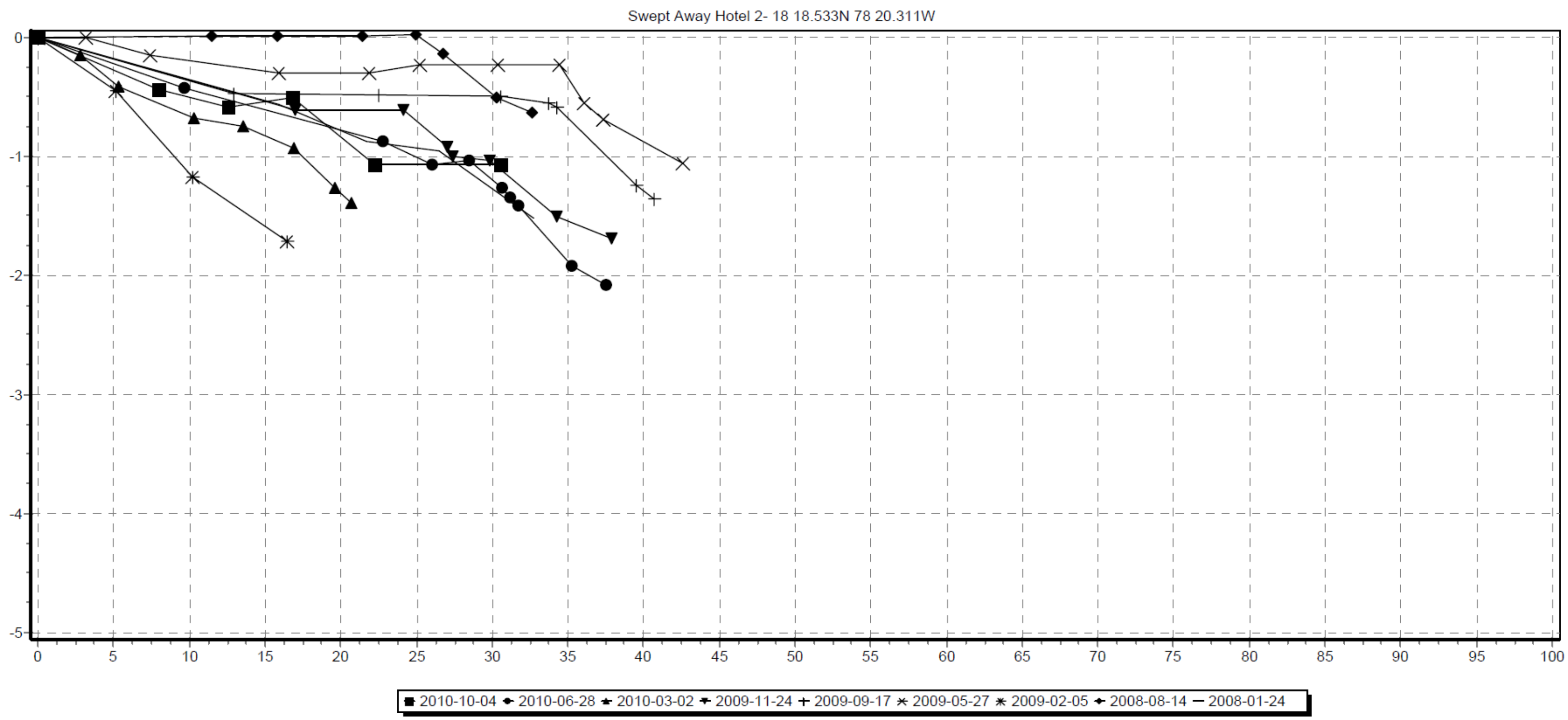



*Figure 6-39 Profile data in the vicinity of Swept Away Hotel collected by NEPA between 2008 and 2010 showing that there was no erosion following the passage of Tropical Storm Nicole in 2010*

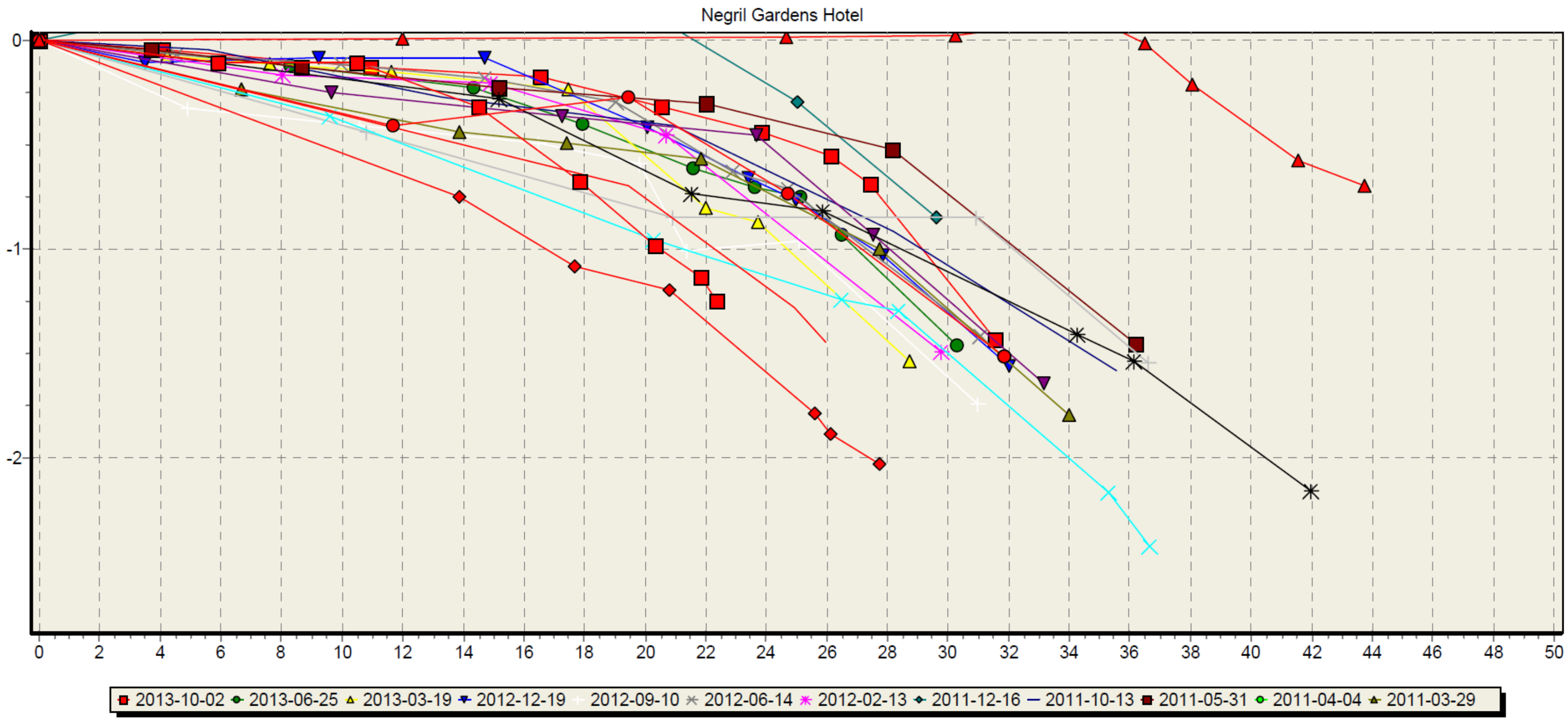



*Figure 6-40 Profile data in the vicinity of Negril Gardens Hotel collected by NEPA between 2011 and 2013 showing that the shoreline experienced accretion by 1m following the passage of Hurricane Sandy in 2012*

## 6.1.10 Geotechnical Description

It is important to determine the geological environment in which the proposed breakwaters will exist. The substrate on which the breakwaters will be installed can determine whether the structure will settle. If the substrate is sand, the structure will settle thereby increasing the material volumes and construction costs. However if it is on pavement/solid surface, then the structure will not settle.

The substrate was assessed during biophysical surveys to be primarily pavement throughout the footprint of the structures (Plate 6-2). Wherever sands were observed, the layers were generally less than 0.6 metres thick.

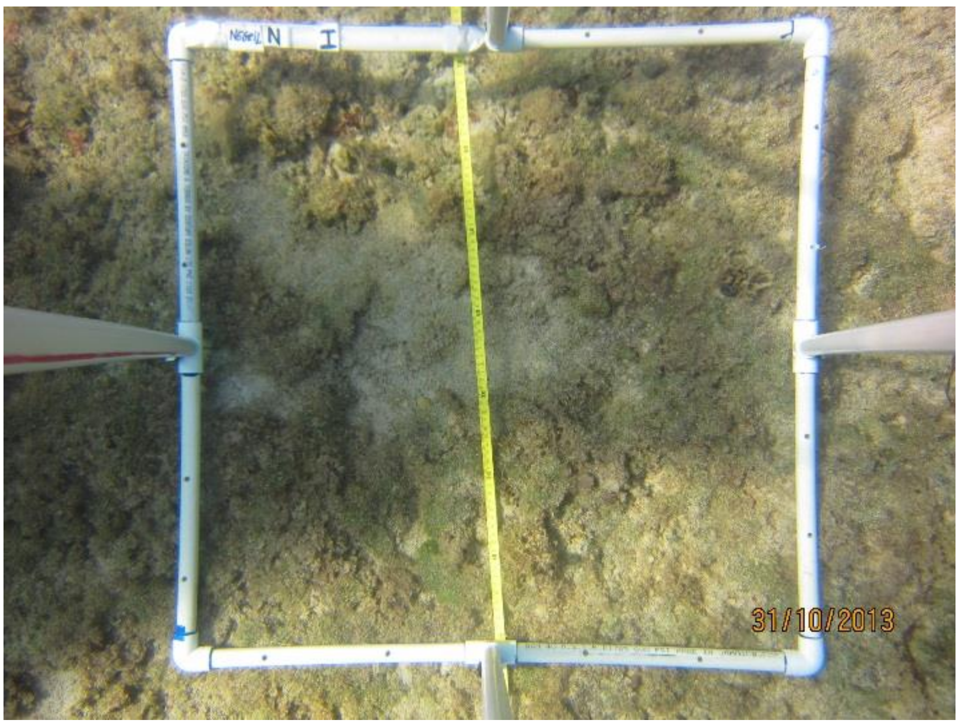



*Plate 6-2 Hard bottom in footprint of breakwater*

## 6.1.11 Climate Change, Wave Studies and Storm Surge

### *6.1.11.1 Climate Change Considerations*

The design life of the project is 37 years, and incorporates climate change considerations in the design. A study by Stephnson (2013) of the Climate Studies Group at the University of the West Indies (UWI) Mona which was used to inform the 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 Negril Westmoreland, in Jamaica.

**Current and Projected Trends for Mean and Extreme Sea Levels**

Global sea levels have risen through the 20th century and it is 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.

In Jamaica, and the surrounding region, the sea level rise is approximately the global average (IPCC 2013) 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 (IPCC 2007) (± 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**

Wang (2006) observed 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.

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 breakwaters to best withstand any possible changes to the climate change projections.

**Current and Projected Trends in Storm Intensities and Frequencies**

The AR5 notes that evidence suggests a certain increase in the frequency and intensity of the strongest cyclones in the Atlantic since the 1970s. Further (Emanuel et al. 2008) found that the increase in storm frequency for the Caribbean region can be determined based on the following relationship:

$$2.2 = 100 * \log(\frac{A1B}{CTRL})$$

It is further noted that the average lifetime of North Atlantic tropical cyclones show an increasing trend of 0.07 day/yr for the same period which is statistically significant (Stephnson 2013). 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 found 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**

The IPCC projects that due to global warming, global sea levels will continue to rise through to the 21st century at a rate of 3.7 mm/year. They also projected that the annual mean significant wave heights will decrease marginally by 1 – 2% resulting in a marginal decrease in the operational wave height. Furthermore, a study by Emanuel et al. (2008) determined that storm events will occur more frequently in the future. These results are summarized in Table 5-2 and this information is particularly critical when conducting the deep water and near shore wave climate analysis carried out in the following sections, to ensure that the breakwaters can adequately withstand and perform as required in the future climate change environment.

#### *6.1.11.2 Deep Water Wave Climate*

**Introduction**

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 breakwaters to provide maximum protection to the shoreline. The operational and swell waves typically determine the layout and crest elevations of the structure, whereas the hurricane waves will define the permeability and armour sizes and configurations.

**Hurricane Waves**

*Methodology*

It was necessary to define the deepwater hurricane wave climate at a point offshore Long Bay. The point chosen was 4.5km offshore. The point was located at the following coordinates: Latitude: 18.31 degrees North and Longitude: 78.38 degrees West.

The National Hurricane Center (NOAA) database of hurricane track data in the Caribbean Sea was utilized to carry out a hindcast, wave breaking (along two tracks) followed by a statistical analysis to determine the hurricane waves, wind and set-up conditions. The database of hurricanes, dating back to 1886, was searched for storms that passed within a 300km radius from an offshore point approximately 4.5km west of the Long Bay shoreline. The following procedure was carried out:

1. Extraction of Storms and Storm Parameters from the historical database. A historical database of storms was searched for all storms passing within a search radius of 300km radius of the site.
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 exceedence probability by Weibull's distribution.
4. A bathymetric profile from deepwater to the site was then defined and each hurricane wave transformed along the profile. The wave height at the nearshore end of the profile was then extracted from the model and stored in a database. All the returned nearshore values were then subjected to an Extremal Statistical analysis and assigned exceedance probabilities with a Weibull distribution.


*Figure 6-41 Offshore point used for storm surge analysis*

*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 Table 6-19. Extremal analysis results are summarized in the bi-variant Figure 6-42. The results of the search clearly indicate the sites overall vulnerability to such systems. In summary:

- 128 hurricane systems came within 300 kilometres of the project area
- 9 of which were classified as catastrophic (Category 5)
- 21 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. In summary, there are:
- 46 (x6 hours) occurrence from the south,
- 57 (x6 hours) occurrence from the north,
- 86 (x6 hours) occurrences from the north-west,
- 100 (x6 hours) occurrences from the west and
- **104 (x6 hours) occurrence from the south-west.**

The western, north-western and south-western 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 when the passing hurricane systems are more south and west of the island.

There appears to be a cyclic trend in the number of hurricanes that have passed within 300 km of the project site. Since 1852, there have been two troughs and one peak in the 1900 – 1920 intervals. The last trough was between 1980 and 2000. This trend therefore implies that there will be an increase in the number of systems passing the site over the next 40 years. Table 6-19 and Figure 6-42 show 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. In the last decade, 3 category 5 hurricanes have pasted the site, in comparison to 1 for each of the two decades before. It can be concluded that the project site is becoming more vulnerable to hurricanes due to the increasing numbers and frequency of more intense hurricanes occurring, and which have tracked within 300km of site over the past 70 years.

*Table 6-19 Classification of storms that passed within 300 km of Negril since 1886*

| | Storm No. | Name | Date | Max. SS Category |
|---|---|---|---|---|
| 1 | 3 | NOTNAMED | 1851 | 3- EXTENSIVE |
| 2 | 10 | NOTNAMED | 1852 | 2- MODERATE |
| 3 | 38 | NOTNAMED | 1857 | 2- MODERATE |
| 4 | 83 | NOTNAMED | 1864 | 1- WEAK |
| 5 | 89 | NOTNAMED | 1865 | 3- EXTENSIVE |
| 6 | 94 | NOTNAMED | 1866 | 3- EXTENSIVE |
| 7 | 110 | NOTNAMED | 1868 | 2- MODERATE |
| 8 | 127 | NOTNAMED | 1870 | 2- MODERATE |
| 9 | 150 | NOTNAMED | 1873 | 3- EXTENSIVE |
| 10 | 157 | NOTNAMED | 1874 | 2- MODERATE |
| 11 | 160 | NOTNAMED | 1875 | 3- EXTENSIVE |
| 12 | 165 | NOTNAMED | 1876 | 1- WEAK |
| 13 | 168 | NOTNAMED | 1876 | 2- MODERATE |
| 14 | 178 | NOTNAMED | 1878 | 1- WEAK |
| 15 | 187 | NOTNAMED | 1878 | 2- MODERATE |
| 16 | 193 | NOTNAMED | 1879 | 1- WEAK |
| 17 | 194 | NOTNAMED | 1879 | 1- WEAK |
| 18 | 198 | NOTNAMED | 1880 | 4- EXTREME |
| 19 | 235 | NOTNAMED | 1885 | 1- WEAK |
| 20 | 241 | NOTNAMED | 1886 | 2- MODERATE |
| 21 | 242 | NOTNAMED | 1886 | 3- EXTENSIVE |
| 22 | 246 | NOTNAMED | 1887 | 1- WEAK |
| 23 | 248 | NOTNAMED | 1887 | 1- WEAK |
| 24 | 252 | NOTNAMED | 1887 | 2- MODERATE |
| 25 | 256 | NOTNAMED | 1887 | 2- MODERATE |
| 26 | 277 | NOTNAMED | 1889 | 2- MODERATE |
| 27 | 288 | NOTNAMED | 1891 | 1- WEAK |
| 28 | 312 | NOTNAMED | 1893 | 1- WEAK |
| 29 | 313 | NOTNAMED | 1893 | 1- WEAK |
| 30 | 321 | NOTNAMED | 1895 | 2- MODERATE |

| | Storm No. | Name | Date | Max. SS Category |
|---|---|---|---|---|
| 31 | 324 | NOTNAMED | 1895 | 3- EXTENSIVE |
| 32 | 329 | NOTNAMED | 1896 | 3- EXTENSIVE |
| 33 | 344 | NOTNAMED | 1898 | 1- WEAK |
| 34 | 345 | NOTNAMED | 1898 | 1- WEAK |
| 35 | 352 | NOTNAMED | 1900 | 4- EXTREME |
| 36 | 360 | NOTNAMED | 1901 | 1- WEAK |
| 37 | 364 | NOTNAMED | 1901 | 1- WEAK |
| 38 | 375 | NOTNAMED | 1903 | 3- EXTENSIVE |
| 39 | 383 | NOTNAMED | 1904 | 1- WEAK |
| 40 | 385 | NOTNAMED | 1904 | 1- WEAK |
| 41 | 400 | NOTNAMED | 1906 | 4- EXTREME |
| 42 | 403 | NOTNAMED | 1906 | 1- WEAK |
| 43 | 418 | NOTNAMED | 1909 | 4- EXTREME |
| 44 | 419 | NOTNAMED | 1909 | 1- WEAK |
| 45 | 420 | NOTNAMED | 1909 | 3- EXTENSIVE |
| 46 | 422 | NOTNAMED | 1909 | 4- EXTREME |
| 47 | 424 | NOTNAMED | 1909 | 3- EXTENSIVE |
| 48 | 426 | NOTNAMED | 1910 | 1- WEAK |
| 49 | 427 | NOTNAMED | 1910 | 3- EXTENSIVE |
| 50 | 433 | NOTNAMED | 1911 | 1- WEAK |
| 51 | 439 | NOTNAMED | 1912 | 4- EXTREME |
| 52 | 446 | NOTNAMED | 1915 | 4- EXTREME |
| 53 | 448 | NOTNAMED | 1915 | 2- MODERATE |
| 54 | 449 | NOTNAMED | 1915 | 4- EXTREME |
| 55 | 453 | NOTNAMED | 1916 | 3- EXTENSIVE |
| 56 | 455 | NOTNAMED | 1916 | 3- EXTENSIVE |
| 57 | 462 | NOTNAMED | 1916 | 3- EXTENSIVE |
| 58 | 466 | NOTNAMED | 1917 | 3- EXTENSIVE |
| 59 | 467 | NOTNAMED | 1918 | 2- MODERATE |
| 60 | 492 | NOTNAMED | 1923 | 1- WEAK |

| | Storm No. | Name | Date | Max. SS Category |
|---|---|---|---|---|
| 61 | 522 | NOTNAMED | 1927 | 1- WEAK |
| 62 | 526 | NOTNAMED | 1928 | 1- WEAK |
| 63 | 539 | NOTNAMED | 1931 | 3- EXTENSIVE |
| 64 | 540 | NOTNAMED | 1931 | 2- MODERATE |
| 65 | 550 | NOTNAMED | 1932 | 3- EXTENSIVE |
| 66 | 553 | NOTNAMED | 1932 | 4- EXTREME |
| 67 | 556 | NOTNAMED | 1933 | 2- MODERATE |
| 68 | 557 | NOTNAMED | 1933 | 1- WEAK |
| 69 | 560 | NOTNAMED | 1933 | 1- WEAK |
| 70 | 569 | NOTNAMED | 1933 | 2- MODERATE |
| 71 | 572 | NOTNAMED | 1933 | 4- EXTREME |
| 72 | 585 | NOTNAMED | 1934 | 1- WEAK |
| 73 | 590 | NOTNAMED | 1935 | 3- EXTENSIVE |
| 74 | 591 | NOTNAMED | 1935 | 1- WEAK |
| 75 | 619 | NOTNAMED | 1938 | 2- MODERATE |
| 76 | 620 | NOTNAMED | 1938 | 2- MODERATE |
| 77 | 630 | NOTNAMED | 1939 | 2- MODERATE |
| 78 | 646 | NOTNAMED | 1942 | 3- EXTENSIVE |
| 79 | 648 | NOTNAMED | 1942 | 1- WEAK |
| 80 | 666 | NOTNAMED | 1944 | 1- WEAK |
| 81 | 668 | NOTNAMED | 1944 | 3- EXTENSIVE |
| 82 | 675 | NOTNAMED | 1944 | 3- EXTENSIVE |
| 83 | 686 | NOTNAMED | 1945 | 2- MODERATE |
| 84 | 698 | NOTNAMED | 1947 | 1- WEAK |
| 85 | 708 | NOTNAMED | 1948 | 3- EXTENSIVE |
| 86 | 734 | KING | 1950 | 3- EXTENSIVE |
| 87 | 739 | CHARLIE | 1951 | 4- EXTREME |
| 88 | 761 | FLORENCE | 1953 | 3- EXTENSIVE |
| 89 | 763 | NOTNAMED | 1953 | 1- WEAK |
| 90 | 786 | HILDA | 1955 | 3- EXTENSIVE |

| | Storm No. | Name | Date | Max. SS Category |
|---|---|---|---|---|
| 91 | 788 | JANET | 1955 | 5- CATASTROPHIC |
| 92 | 842 | GERDA | 1961 | 1- WEAK |
| 93 | 857 | FLORA | 1963 | 4- EXTREME |
| 94 | 864 | CLEO | 1964 | 4- EXTREME |
| 95 | 886 | INEZ | 1966 | 4- EXTREME |
| 96 | 890 | BEULAH | 1967 | 5- CATASTROPHIC |
| 97 | 910 | FRANCELIA | 1969 | 3- EXTENSIVE |
| 98 | 923 | ALMA | 1970 | 1- WEAK |
| 99 | 960 | GILDA | 1973 | 2- MODERATE |
| 100 | 966 | CARMEN | 1974 | 4- EXTREME |
| 101 | 969 | FIFI | 1974 | 2- MODERATE |
| 102 | 974 | CAROLINE | 1975 | 3- EXTENSIVE |
| 103 | 976 | ELOISE | 1975 | 3- EXTENSIVE |
| 104 | 1011 | CLAUDETTE | 1979 | 1- WEAK |
| 105 | 1018 | ALLEN | 1980 | 5- CATASTROPHIC |
| 106 | 1029 | ARLENE | 1981 | 1- WEAK |
| 107 | 1039 | KATRINA | 1981 | 1- WEAK |
| 108 | 1067 | DANNY | 1985 | 1- WEAK |
| 109 | 1095 | GILBERT | 1988 | 5- CATASTROPHIC |
| 110 | 1154 | GORDON | 1994 | 1- WEAK |
| 111 | 1186 | MARCO | 1996 | 1- WEAK |
| 112 | 1207 | MITCH | 1998 | 5- CATASTROPHIC |
| 113 | 1220 | LENNY | 1999 | 4- EXTREME |
| 114 | 1228 | HELENE | 2000 | 1- WEAK |
| 115 | 1244 | IRIS | 2001 | 4- EXTREME |
| 116 | 1259 | ISIDORE | 2002 | 3- EXTENSIVE |
| 117 | 1262 | LILI | 2002 | 4- EXTREME |
| 118 | 1326 | IVAN | 2004 | 5- CATASTROPHIC |
| 119 | 1336 | DENNIS | 2005 | 4- EXTREME |
| 120 | 1337 | EMILY | 2005 | 5- CATASTROPHIC |

| | Storm No. | Name | Date | Max. SS Category |
|---|---|---|---|---|
| 121 | 1354 | WILMA | 2005 | 5- CATASTROPHIC |
| 122 | 1374 | DEAN | 2007 | 5- CATASTROPHIC |
| 123 | 1385 | OLGA | 2007 | 1- WEAK |
| 124 | 1391 | FAY | 2008 | 1- WEAK |
| 125 | 1392 | GUSTAV | 2008 | 4- EXTREME |
| 126 | 1401 | PALOMA | 2008 | 4- EXTREME |
| 127 | 1427 | KARL | 2010 | 3- EXTENSIVE |
| 128 | 1433 | RICHARD | 2010 | 2- MODERATE |

**Wind direction- NW**

| Tp(s) | Wave height(m) | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <value | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | |
| 2 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 6 | | 16 | | | | | | | | | 16 |
| 8 | | 35 | 16 | | | | | | | | 51 |
| 10 | | | 17 | 2 | | | | | | | 19 |
| 12 | | | | | | | | | | | |
| 14 | | | | | | | | | | | |
| 16 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| Total | | 51 | 33 | 2 | | | | | | | 86 |

**Wind direction- N**

| Tp(s) | Wave height(m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <value | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | |
| 2 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 6 | | 9 | 1 | | | | | | | | 10 |
| 8 | | 27 | 8 | | | | | | | | 35 |
| 10 | | | 11 | 1 | | | | | | | 12 |
| 12 | | | | | | | | | | | |
| 14 | | | | | | | | | | | |
| 16 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| Total | | 36 | 20 | 1 | | | | | | | 57 |

**Wind direction- NE**

| Tp(s) | Wave height(m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <value | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | |
| 2 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 6 | | 1 | | | | | | | | | 1 |
| 8 | | 2 | | 1 | | | | | | | 3 |
| 10 | | | | | | | | | | | |
| 12 | | | | | | | | | | | |
| 14 | | | | | | | | | | | |
| 16 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| Total | | 3 | | 1 | | | | | | | 4 |

**Wind direction- W**

| Tp(s) | Wave height(m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <value | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | |
| 2 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 6 | | 16 | 1 | | | | | | | | 17 |
| 8 | | 48 | 8 | | | | | | | | 56 |
| 10 | | 1 | 26 | | | | | | | | 27 |
| 12 | | | | | | | | | | | |
| 14 | | | | | | | | | | | |
| 16 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| Total | | 65 | 35 | | | | | | | | 100 |

**All directions**

| Tp(s) | Wave height(m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <value | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | |
| 2 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 6 | | 70 | 4 | | | | | | | | 74 |
| 8 | | 189 | 45 | 2 | | | | | | | 236 |
| 10 | | 1 | 78 | 8 | | | | | | | 87 |
| 12 | | | | | | | | | | | |
| 14 | | | | | | | | | | | |
| 16 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| Total | | 260 | 127 | 10 | | | | | | | 397 |

**Wind direction- E**

| 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- SW**

| Tp(s) | Wave height(m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <value | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | |
| 2 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 6 | | 18 | 2 | | | | | | | | 20 |
| 8 | | 55 | 6 | 1 | | | | | | | 62 |
| 10 | | | 18 | 4 | | | | | | | 22 |
| 12 | | | | | | | | | | | |
| 14 | | | | | | | | | | | |
| 16 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| Total | | 73 | 26 | 5 | | | | | | | 104 |

**Wind direction- S**

| Tp(s) | Wave height(m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <value | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | |
| 2 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 6 | | 10 | | | | | | | | | 10 |
| 8 | | 22 | 7 | | | | | | | | 29 |
| 10 | | | 6 | 1 | | | | | | | 7 |
| 12 | | | | | | | | | | | |
| 14 | | | | | | | | | | | |
| 16 | | | | | | | | | | | |
| 18 | | | | | | | | | | | |
| 20 | | | | | | | | | | | |
| Total | | 32 | 13 | 1 | | | | | | | 46 |

**Wind direction- SE**

| 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 | | | | | | | | | | | |

*Figure 6-42 Bivariate table of extremal wave climate*

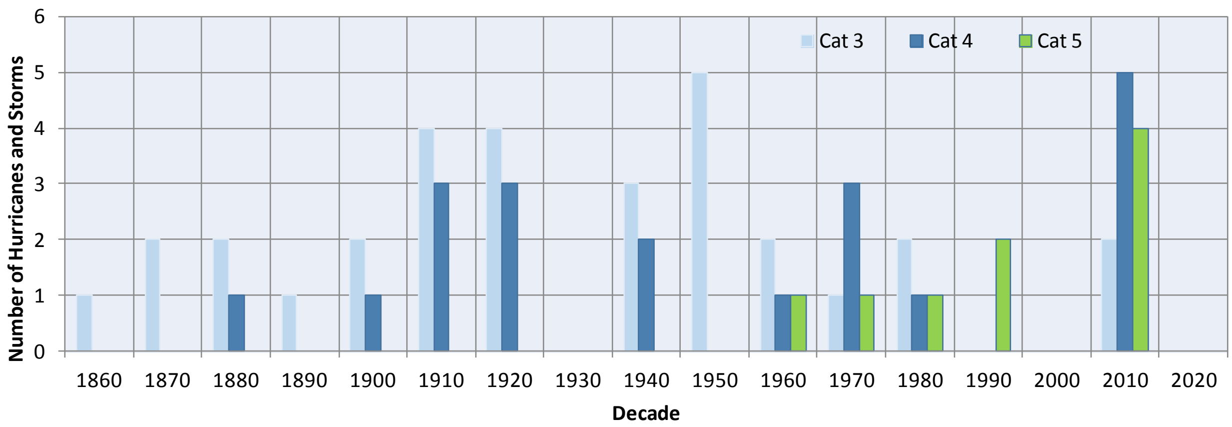



*Figure 6-43 Trend in the number and intensity of the category 3 to 5 storms that have passed within 300 km of the project site between 1852 and 2013*

WAVES HEIGHTS AND DIRECTIONS

A bivariate table was generated to display the waves versus directions for each return period, (see Table 6-20). The bivariate table generated indicates that hurricane waves originating from the west (W) are the most severe of all the directions investigated, followed closely by the south westerly (SW) winds (see Table 6-20). The southern and northern waves generated off the south and north coast respectively, are not expected to significantly impact the site due to the angle (orientation) of the shoreline and the shape of the land.

*Table 6-20 Summary of wave heights and periods from various directions for different return periods*

| Return Periods | Wave height (m) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | All | | SW | | W | | E | | SE | | S | |
| | Hs | Tp | Hs | Tp | Hs | Tp | Hs | Tp | Hs | Tp | Hs | Tp |
| 1 | 2.0 | 7.2 | 1.0 | 5.1 | 1.0 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 5.1 |
| 2 | 3.5 | 9.4 | 3.5 | 9.4 | 3.6 | 9.5 | 0.0 | 0.0 | 0.0 | 0.0 | 3.4 | 9.3 |
| 5 | 4.6 | 10.7 | 4.5 | 10.6 | 4.5 | 10.6 | 0.0 | 0.0 | 0.0 | 0.0 | 4.4 | 10.5 |
| 10 | 5.3 | 11.4 | 5.0 | 11.1 | 5.0 | 11.2 | 0.0 | 0.0 | 0.0 | 0.0 | 4.9 | 11.0 |
| 20 | 5.8 | 12.0 | 5.4 | 11.6 | 5.4 | 11.6 | 0.0 | 0.0 | 0.0 | 0.0 | 5.3 | 11.5 |
| 25 | 6.0 | 12.2 | 5.5 | 11.7 | 5.6 | 11.7 | 0.0 | 0.0 | 0.0 | 0.0 | 5.4 | 11.6 |
| 50 | 6.6 | 12.7 | 5.9 | 12.1 | 5.9 | 12.1 | 0.0 | 0.0 | 0.0 | 0.0 | 5.8 | 11.9 |
| 75 | 6.8 | 13.0 | 6.1 | 12.3 | 6.1 | 12.3 | 0.0 | 0.0 | 0.0 | 0.0 | 5.9 | 12.1 |
| 100 | 7.0 | 13.2 | 6.2 | 12.4 | 6.2 | 12.4 | 0.0 | 0.0 | 0.0 | 0.0 | 6.1 | 12.3 |
| 150 | 7.3 | 13.4 | 6.4 | 12.5 | 6.4 | 12.5 | 0.0 | 0.0 | 0.0 | 0.0 | 6.2 | 12.4 |
| 200 | 7.5 | 13.6 | 6.5 | 12.7 | 6.5 | 12.6 | 0.0 | 0.0 | 0.0 | 0.0 | 6.3 | 12.5 |

The extremal analysis results indicated that the 100-year return period event had a wave height of 6.2 m for western waves. Overall, these are relatively large waves with potential for causing severe damage along the shoreline. The potential resulting near shore climates were investigated using a wave refraction and diffraction model as outlined in the following section.

## Hurricane Storm Surge and Winds

*Introduction*

Hurricane storm surge is an increase in the water levels during the passage of a hurricane. The increases are due to several factors, the major ones include:

1) Inverse barometric pressure
2) Tides
3) Waves
4) Wind
5) Bathymetry

Increases in water levels will cause further flooding of the near shore area as well as it will cause more destructive waves to reach further inland. It is crucial to determine the setups that will be generated at the project site in order set the design parameters for the break water as well as to calibrate wave and sediment transport models. Typical design return periods for coastal defence structures are 50 to 100 year events.

*Methodology and Results*

The methodology adopted was as follows:

1. Wind and waves generation (same as items 1-4 from hurricane waves methodology)
2. Calculation of setup from hurricane and wave parameters, including also sea levels rise for duration of project life. The parameters considered were:
    a. Wave breaking and shoaling
    b. Wind set-up
    c. Refraction
    d. Tides
    e. Global Sea Level Rise (over a 37 year project life)
    f. Inverse Barometric Pressure Rise

The predicted wind speeds that can affect the area are expected to be most intense from the north (34.7 - 50yr and 38.4 - 100yr). However this direction will have a lower impact on the overall storm surge levels than for those from the west. The maximum storm surge that is estimated for this location for the 100 year event is approximately 1.25m. This is essential information when it pertains to construction within the project area in regards to the setting of the breakwaters for the site.

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 6-21 Hurricane wind speed predictions for the site direction of possible surge impact*

| Return Period | Wind speeds (m/s) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **All** | **SW** | **W** | **NW** | **N** | **NE** | **E** | **SE** | **S** |
| **1** | 10.0 | NaN | NaN | NaN | NaN | 0.0 | 0.0 | 0.0 | NaN |
| **2** | 32.3 | 14.9 | 14.3 | 16.5 | 15.4 | 0.0 | 0.0 | 0.0 | 14.7 |
| **5** | 46.8 | 20.2 | 18.6 | 21.9 | 21.6 | 0.0 | 0.0 | 0.0 | 19.4 |
| **10** | 55.5 | 23.7 | 21.4 | 25.3 | 25.8 | 0.0 | 0.0 | 0.0 | 22.5 |
| **20** | 63.2 | 27.1 | 23.9 | 28.5 | 29.7 | 0.0 | 0.0 | 0.0 | 25.3 |
| **25** | 65.5 | 28.1 | 24.7 | 29.4 | 31.0 | 0.0 | 0.0 | 0.0 | 26.1 |
| **50** | 72.3 | 31.3 | 27.0 | 32.3 | 34.7 | 0.0 | 0.0 | 0.0 | 28.7 |
| **75** | 76.1 | 33.1 | 28.3 | 33.9 | 36.9 | 0.0 | 0.0 | 0.0 | 30.2 |
| **100** | 78.7 | 34.4 | 29.2 | 35.0 | 38.4 | 0.0 | 0.0 | 0.0 | 31.2 |
| **150** | 82.2 | 36.2 | 30.4 | 36.5 | 40.5 | 0.0 | 0.0 | 0.0 | 32.6 |
| **200** | 84.6 | 37.4 | 31.3 | 37.6 | 41.9 | 0.0 | 0.0 | 0.0 | 33.6 |

*Table 6-22 Extreme Storm surge (metres) predictions for the site along the profile from shoreline to deep-water for all directional waves possible for project area*

| Return Period | Total setup (m) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **All** | **SW** | **W** | **NW** | **N** | **NE** | **E** | **SE** | **S** |
| **1** | NaN | 0.10 | 0.10 | 0.10 | NaN | 0.00 | 0.00 | 0.00 | NaN |
| **2** | 0.35 | 0.41 | 0.48 | 0.43 | 0.12 | 0.00 | 0.00 | 0.00 | 0.19 |
| **5** | 0.60 | 0.60 | 0.72 | 0.64 | 0.21 | 0.00 | 0.00 | 0.00 | 0.34 |
| **10** | 0.76 | 0.72 | 0.87 | 0.77 | 0.28 | 0.00 | 0.00 | 0.00 | 0.45 |
| **20** | 0.92 | 0.83 | 1.00 | 0.88 | 0.34 | 0.00 | 0.00 | 0.00 | 0.56 |
| **25** | 0.96 | 0.86 | 1.04 | 0.91 | 0.36 | 0.00 | 0.00 | 0.00 | 0.59 |
| **50** | 1.11 | 0.95 | **1.15** | 1.01 | 0.43 | 0.00 | 0.00 | 0.00 | 0.70 |
| **75** | 1.19 | 1.00 | 1.21 | 1.06 | 0.47 | 0.00 | 0.00 | 0.00 | 0.77 |
| **100** | 1.24 | 1.03 | **1.25** | 1.10 | 0.49 | 0.00 | 0.00 | 0.00 | 0.81 |
| **150** | 1.32 | 1.08 | 1.31 | 1.15 | 0.53 | 0.00 | 0.00 | 0.00 | 0.88 |
| **200** | 1.37 | 1.11 | 1.35 | 1.18 | 0.56 | 0.00 | 0.00 | 0.00 | 0.92 |

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 Mir & W (1993). The estimated wave run-up levels range from 1.18m to 2.51m for the 2 to 100 year hurricanes and were added to the model predicted storm surge results (see Table 6-23).

*Table 6-23 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** | 0.48 | 1.18 |
| **5** | 0.72 | 1.59 |
| **10** | 0.87 | 1.85 |
| **25** | 1.04 | 2.14 |
| **50** | 1.15 | 2.34 |
| **100** | 1.25 | 2.51 |

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 Long Bay, Negril.

**Operational and Swell Waves**

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: 776997.83, Northing: 2026481.15). This data was subjected to statistical analysis to determine the mean wave heights, 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 swells were waves estimated by taking the highest 5 percent waves from the bi-variant table. See Table 6-24.

*Table 6-24 Wave heights and periods used in the wave model for study area*

| DIRECTION | OPERATIONAL CONDITIONS | | SWELL CONDITIONS | |
|---|---|---|---|---|
| | Ts (s) | Hs (m) | Ts (s) | Hs (m) |
| NNW | 5 | 0.3 | 7.5 | 1.6 |
| NW | 5 | 0.3 | 7.5 | 1.6 |
| WNW | 5 | 0.3 | 7.5 | 1.6 |
| W | 5 | 0.3 | 7.5 | 1.6 |
| WSW | 5 | 0.3 | 7.5 | 1.6 |
| SW | 5 | 0.3 | 7.5 | 1.6 |
| SSW | 5 | 0.3 | 7.5 | 1.6 |

### 6.1.11.3 Near Shore Wave Climate Analysis (Hurricane, Operational and Swells)

**Objectives and Approach**

Deepwater wave climate offers limited information on how waves reach the shoreline as waves travelling from deepwater to the shoreline are subjected to conditions that can either cause energy loss or gain. Waves are generally affected by bathymetry (including reefs, headlands, cays, etc.), wind and fetch.

It was therefore necessary to conduct wave transformation modelling to simulate the movement of the waves from deep water. This is in order to determine the operational swells and operational wave climates near shore and to identify areas of the study area that might be vulnerable to shoreline erosion or direct wave attack.

The overall objective of this exercise was to derive a near shore wave climate in order to estimate the impact of the proposed structures. The approach adopted in order to achieve these objectives was as follows:

- Determine the operational, swell and hurricane environments along the beach and the break waters for pre and post project.

- Determine the impact of climate change along the beach and at the breakwater during operational, swell and hurricane event.
- Prepare a bathymetric database of the project domain for extremal analysis.
- Conduct spatial wave transformation analysis around the reefs and proposed breakwater in the model.

**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 ($d_x=d_y$) grid spacing. STWAVE is a solution of the steady-state spectral balance equation for wave transformation. The model 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 of Incident Wave Conditions Modelled**

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. A summary of the incident wave conditions used for the analysis is seen in Table 6-25 and Table 6-26. Based on the deepwater wave climate and storm surge analysis along with the shape of the shoreline and geographical location of the study area; it was noted that only the westerly and south-westerly directions directly impacted the study area. The northerly directions were also investigated for comparative purposes.

*Table 6-25 Summary of operational and swell wave heights and periods used to model STWAVES*

| DIRECTION | OPERATIONAL | | SWELL | |
|---|---|---|---|---|
| | Ts (s) | Hs (m) | Ts (s) | Hs (m) |
| W | 5 | 0.3 | 7.5 | 1.6 |
| SW | 5 | 0.3 | 7.5 | 1.6 |
| NW | 5 | 0.3 | 7.5 | 1.6 |

*Table 6-26 Summary of hurricane wave heights and periods used to model STWAVES*

| DIRECTION | RETURN PERIOD (50 YR) | | RETURN PERIOD (100 YR) | |
|---|---|---|---|---|
| | Ts (s) | Hs(m) | Ts(s) | Hs(m) |
| W | 5.9 | 12.1 | 6.2 | 12.4 |
| SW | 5.9 | 12.1 | 6.2 | 12.4 |
| NW | 5.9 | 12.1 | 6.2 | 12.4 |

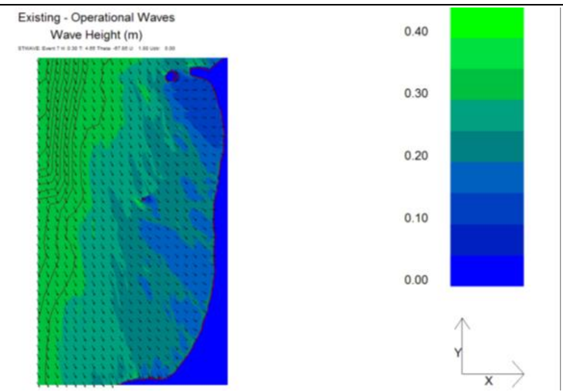
**Pre-Project Scenario**

The model was calibrated to run operational, swell and hurricane waves for the North-North West (NNW), North West (NW), West (W) and South West (SW) directions. The existing shoreline was modelled to better understand the areas that were most vulnerable as well as to estimate the magnitude of wave heights reaching the shoreline, based on the deep water wave predictions.

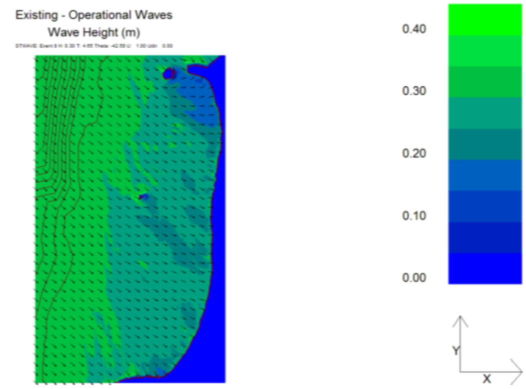
*Operational Waves*

The model showed that the shoreline, under operational conditions, may experience wave heights of up to 0.3 metres, reaching up to the shoreline from the NNW, NW, W and SW directions. The model indicated the shoreline was most vulnerable to waves from the west whereas NNW and the SW are the least vulnerable directions (Table 6-27).

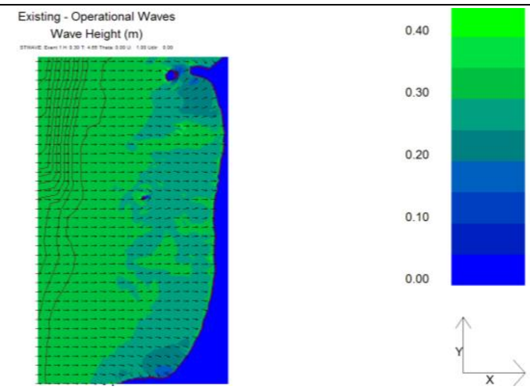
*Table 6-27 STWAVES resultant plots of operational waves for various directions*



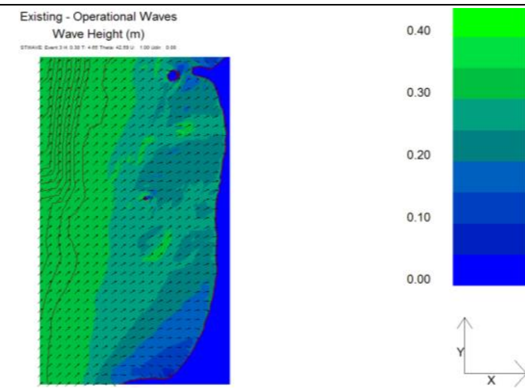

NNW




NW




W



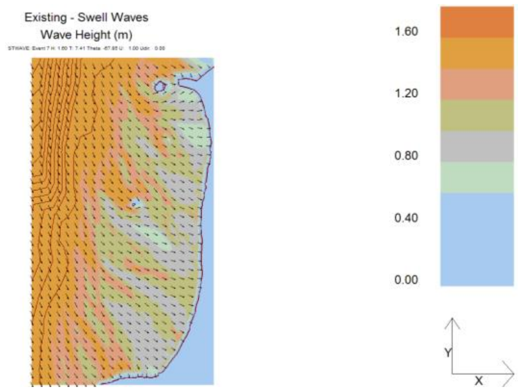
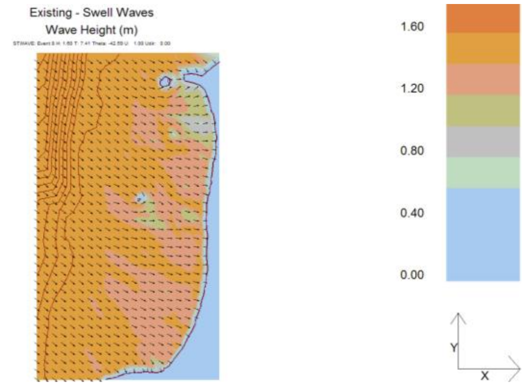
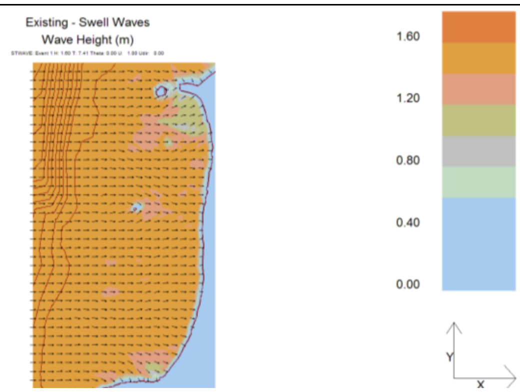
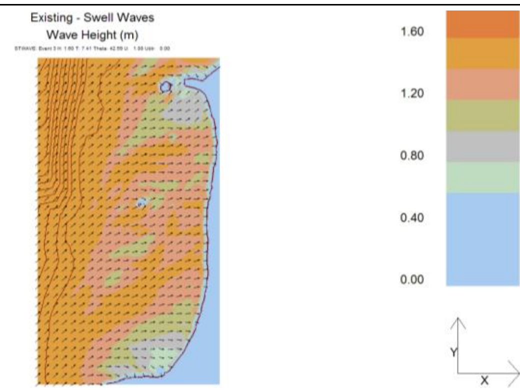

SW

*Swell Waves*

It was also important examine 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 was configured to run swell waves from NNW, NW, W and SW directions.

The model showed that the shoreline, under swell wave conditions, may experience wave heights ranging from 0.6 to 1.6 metres reaching the shoreline from the directions modelled (Table 6-28).

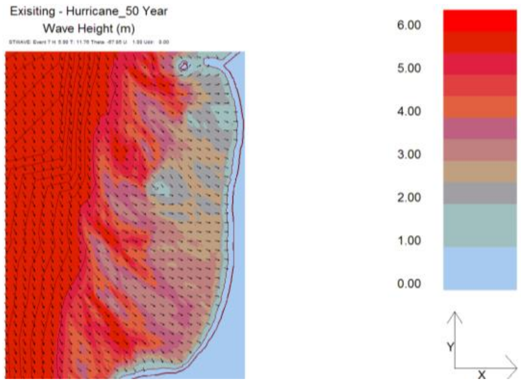
*Table 6-28 STWAVES resultant plots of Swell waves entering Long Bay Negril for various directions*

| | |
|---|---|
|   NNW |   NW |
|   W |   SW |

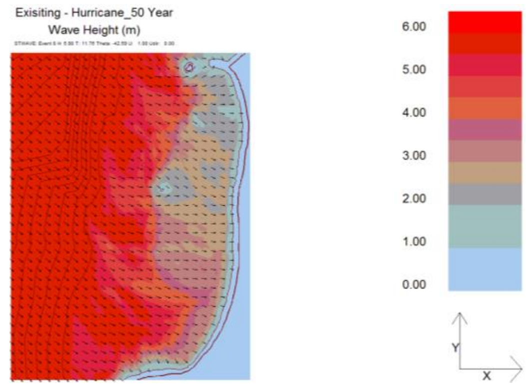
*Hurricane Waves*

It is also important that hurricane winds generated waves are modelled as well, these can cause the most damage to the beach. The modelled directions were NNW, NW, W and SW for the 50 and 100 year return period. During a storm event there will be wave setup, hence a water setup elevation of 1.15 and 1.25 metres were added to the simulation for the 50 and 100 year return period respectively. The wave plots generated from the model showed that during hurricane conditions, wave heights ranging from 1.8 – 3.1m and 1.9 to 3.6m reaches the shoreline from the NNW, NW, W and SW directions for 50 and 100 year return periods respectively.

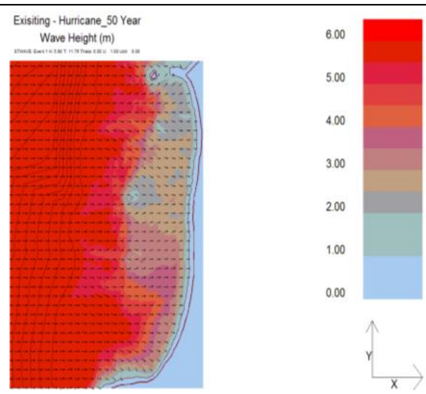
*Table 6-29 STWAVES resultant plots of Hurricane waves (50 year) for various directions (Pre-Project)*



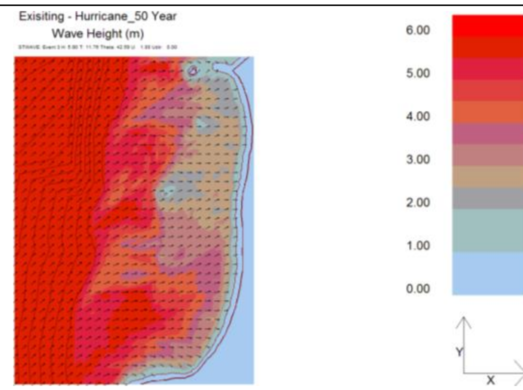

NNW




NW

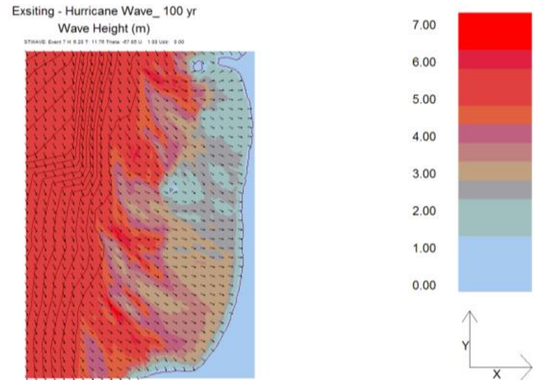



W

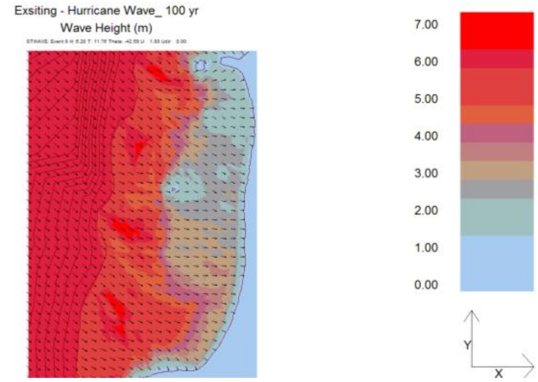



SW

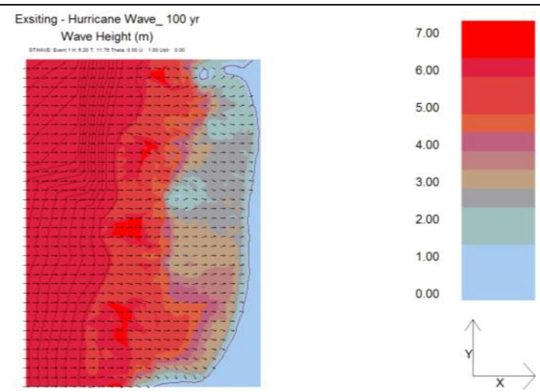
*Table 6-30 STWAVES resultant plots of Hurricane waves (100 Year) for various directions (Pre-Project)*



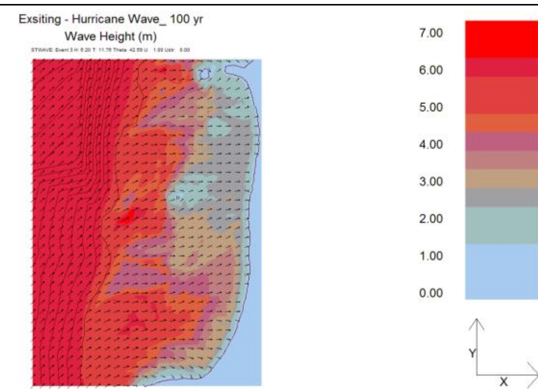

NNW




NW




W




SW

**Future Climate (Pre-Project)**

It was important to consider the effect of climate change inclusive of global sea level rise on the study area and the design life of the breakwaters. Based on a study done by the Climate Studies Group, UWI Mona (2013) as outlined within the previous section of this report, stated that sea level rise would result in a water level rising to 0.14m by the year 2050.

Considering future climate change, no changes were observed with the magnitude of waves reaching the shoreline for the pre and post project scenarios for operation and swell wave's condition. However Hurricane waves (50 and 100 year return periods) had impacts on the shoreline as wave setup increased from 1.15m and 1.25m to 1.29m and 1.39 m for the 50 and 100 year return period respectively.

*Table 6-31 Summary of hurricane wave heights and periods used to model STWAVES with the consideration of future climate change*

| DIRECTION | RETURN PERIOD (50 YR) | | RETURN PERIOD (100 YR) | |
|---|---|---|---|---|
| | Ts (s) | Hs(m) | Ts(s) | Hs(m) |
| NNW | 6.2 | 12.6 | 6.5 | 12.9 |
| NW | 6.2 | 12.6 | 6.5 | 12.9 |
| W | 6.2 | 12.6 | 6.5 | 12.9 |
| SW | 6.2 | 12.6 | 6.5 | 12.9 |

When considering the pre project scenario for the NNW, NW, W, and SW directions under future climate change conditions, the model showed that the shoreline under hurricane event may experience wave heights ranging from 2 to 3.4 metres and 2.3 to 3.8 metres, reaching up to the shoreline for the 50 and 100 year event respectively.

*Table 6-32 STWAVES resultant plots for future climate Hurricane waves (50 year) for various directions (Pre Project)*

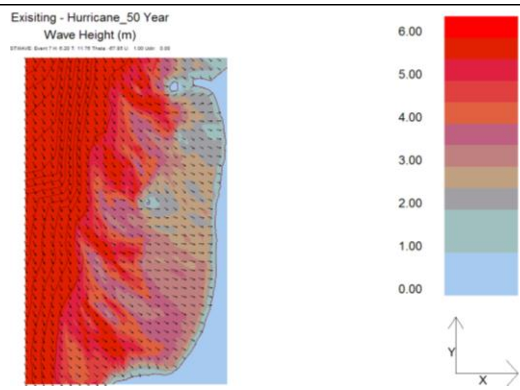
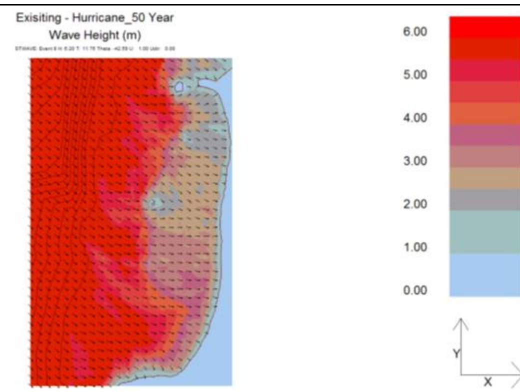
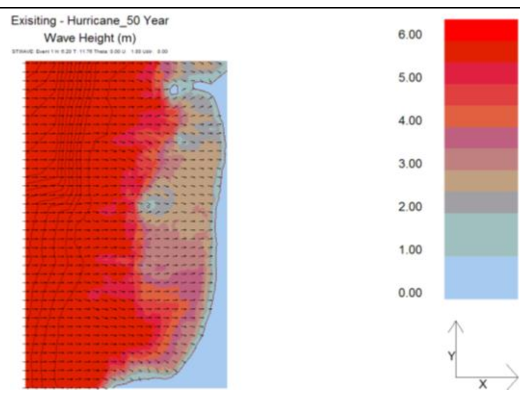
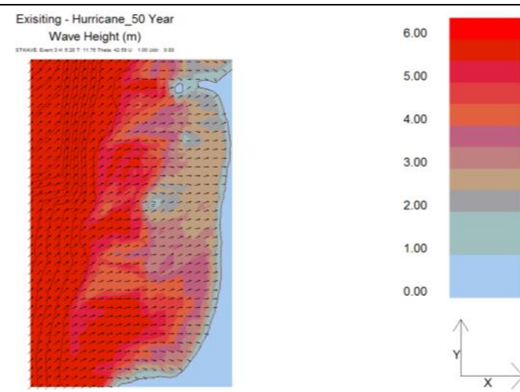
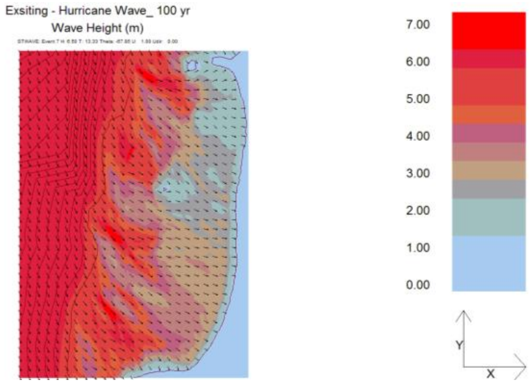
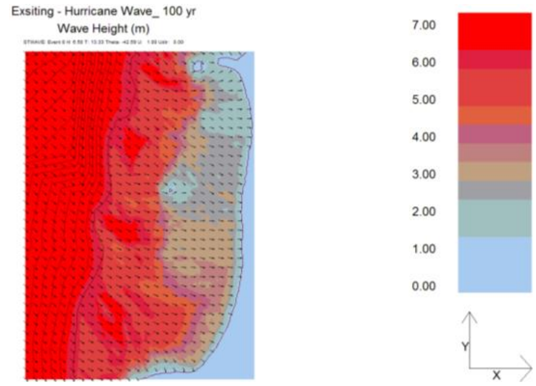
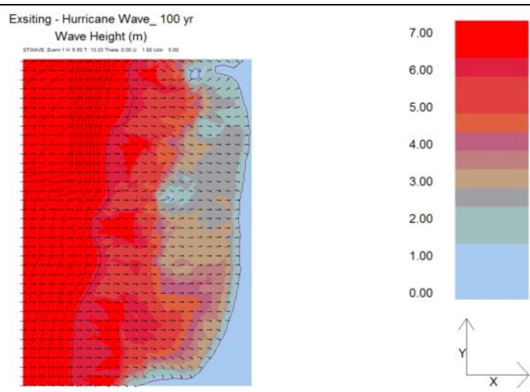
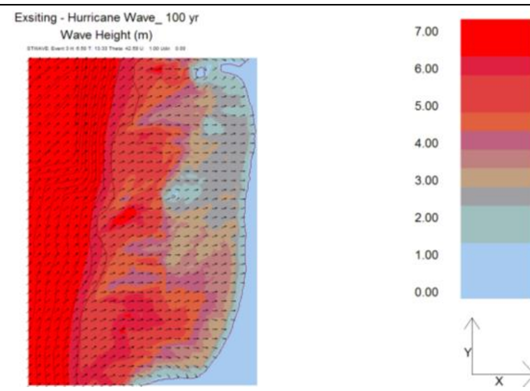
| | |
|---|---|
|   NNW |   NW |
|   W |   SW |

*Table 6-33 STWAVES resultant plots for future climate Hurricane waves (100 year) for various directions (Pre-Project)*

| | |
|---|---|
| <br>NNW | <br>NW |
| <br>W | <br>SW |

## 6.1.12 Shoreline Vulnerability

### *6.1.12.1 Long-term Shoreline Change*

The shoreline positions along the Long Bay Beach were plotted over a number of years and compared in order to determine the long-term spatial and temporal erosion trends across the shore. This was in order to identify the actual erosion hotspots that might require stabilization and to verify the wave transformation modelling. The overall long-term erosion trend was estimated by observing:

1) Actual long-term shoreline positions from dated 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*

The observed shorelines from satellite and aerial imagery for the years 1968, 1991, 1999 and 2005 are shown in Figure 6-44. The most recent (September 2013) shoreline position was marked manually by walking the beach and taking GPS points. The shoreline movement was analysed by measuring and noting the displacements of the shoreline at intervals of 500m along the shoreline. The rates of accretion and/or erosion between the time intervals and the overall time interval were determined using:

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

E – Rate of erosion or accretion between two successive intervals (metres per year)
D – Displacement between two intervals (metre s)
N – Number of years between two successive intervals (years)

And

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

$E_y^0$ – Rate of erosion or accretion from the datum year to the final interval
$D_T$ – Displacement from the datum to the final interval
$N_T$ – Number of years from datum year to final interval

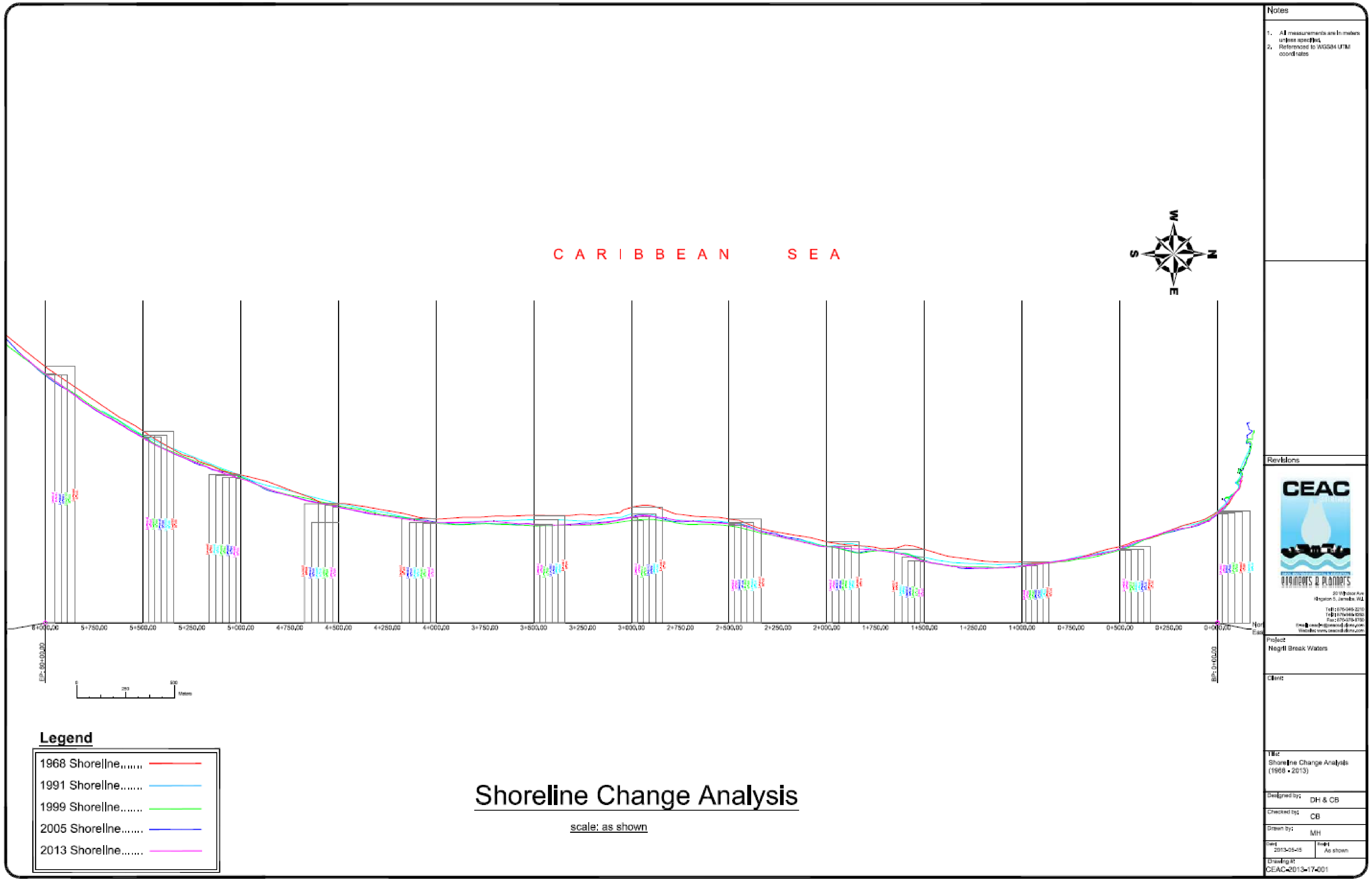



*Figure 6-44 Shoreline plots between 1991 and 2013 about the 1968 shoreline for chainages 1 to 6000 on ground*

*Results*

A summary of the analysis data is shown below in Table 6-34. The analysis shows a general trend of erosion occurring from 1968 to 2013. Some accretion was observed between 1999 and 2005 as well as between 2005 and 2013. An overall level of erosion was observed at a rate between 0.2 m/year and 1.4 m/year (Table 6-34). Plots of the shoreline movement can be seen in Figure 6-45 below. Over the past 45 years, a maximum of 62.6 metres of erosion has occurred on the Negril beach based on the observation of historical aerial and satellite images of the area.

These results also indicate that the central section of the beach is the most vulnerable to long term as well as short term erosion. The least vulnerable section is the northern beach which is less exposed to the more frequent northern passing systems and operational waves. These results are supported by the studies done by SWIL in 2007 as well as the 2010 RIVAMP study published by PIOJ.

*Table 6-34 Summary of shoreline change between 1968 and 2013 for Long Bay, Negril*

| | 1968 | 1991 | | 1999 | | 2005 | | 2013 | | Overall | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Location | Datum | 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 | 569.01 | accretion | 0.165 | erosion | -1.340 | erosion | -1.088 | accretion | 0.503 | erosion | -0.210 |
| 0+500 | 391.21 | erosion | -0.744 | erosion | -0.223 | accretion | 0.793 | accretion | 0.413 | erosion | -0.241 |
| 1+000 | 312.25 | erosion | -0.395 | erosion | -1.531 | accretion | 0.308 | erosion | -0.337 | erosion | -0.493 |
| 1+500 | 376.54 | erosion | -1.809 | erosion | -2.151 | accretion | 0.327 | erosion | -0.711 | erosion | -1.390 |
| 2+000 | 415.01 | erosion | -0.966 | erosion | -0.083 | erosion | -0.253 | erosion | -0.069 | erosion | -0.554 |
| 2+500 | 531.96 | erosion | -0.803 | erosion | -2.088 | accretion | 2.413 | erosion | -0.618 | erosion | -0.570 |
| 3+000 | 591.21 | erosion | -1.480 | erosion | -4.149 | accretion | 3.008 | erosion | -0.421 | erosion | -1.168 |
| 3+500 | 550.44 | erosion | -0.934 | erosion | -4.024 | accretion | 1.058 | accretion | 0.261 | erosion | -1.005 |
| 4+000 | 531.3 | erosion | -0.811 | erosion | -0.291 | accretion | 0.838 | erosion | -0.329 | erosion | -0.413 |
| 4+500 | 609.93 | accretion | 0.009 | erosion | -1.323 | erosion | -14.035 | accretion | 9.599 | erosion | -0.395 |
| 5+000 | 756.78 | erosion | -0.128 | erosion | -1.003 | erosion | -0.005 | erosion | -1.029 | erosion | -0.427 |
| 5+500 | 981.8 | erosion | -0.896 | erosion | -0.375 | erosion | -1.313 | erosion | -0.585 | erosion | -0.804 |
| 6+000 | 1311.13 | | | | | erosion | -0.598 | accretion | 1.051 | erosion | -0.800 |

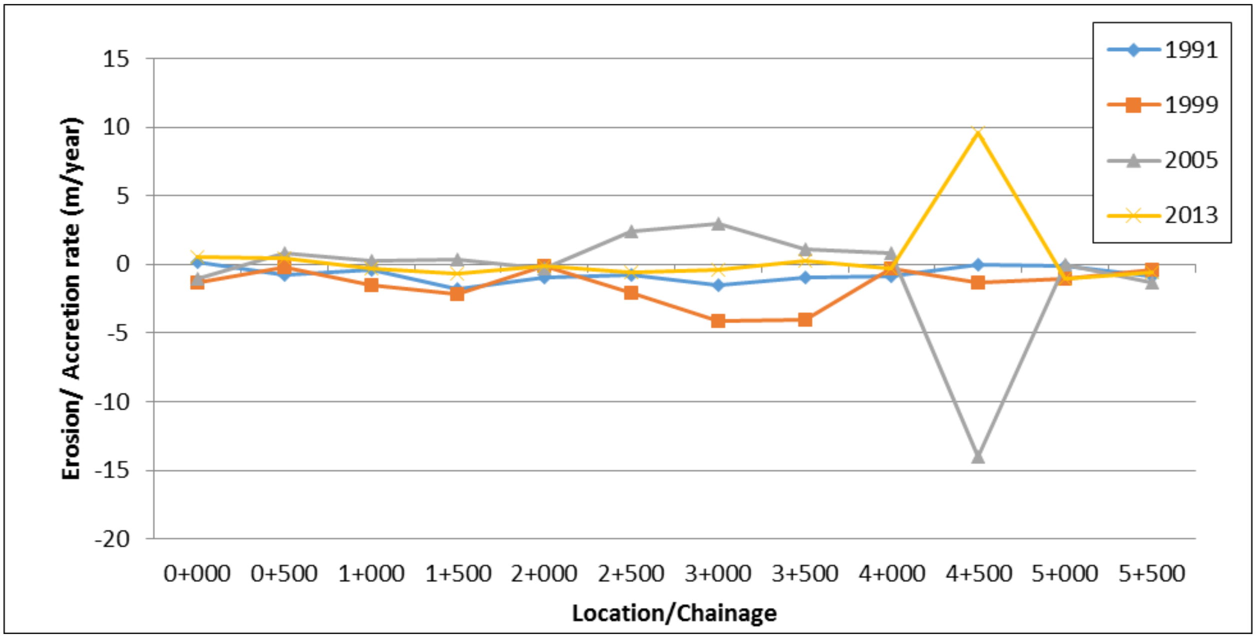



*Figure 6-45 Rates of erosion/ accretion for the shoreline about the 1968 shoreline for different time intervals for Negril Shoreline (1991 to 2013)*

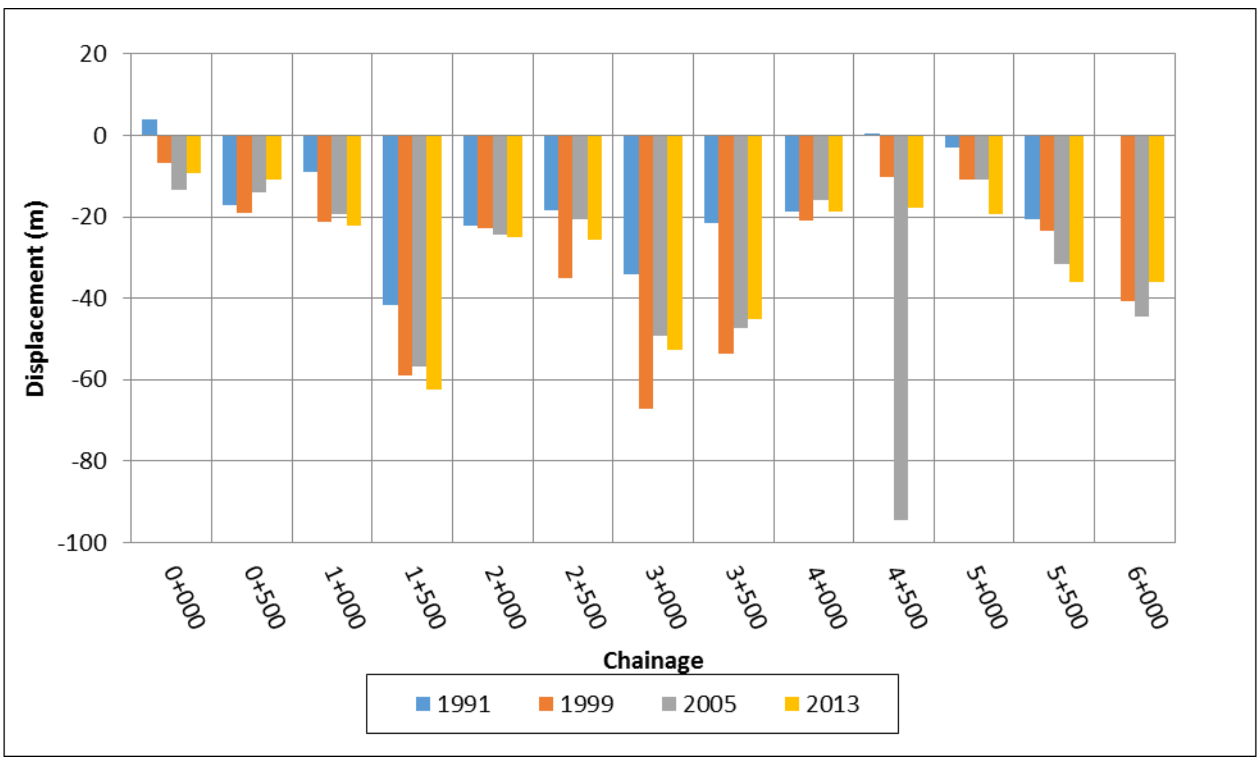



*Figure 6-46 Displacement of the shoreline for different years about the 1968 shoreline for Negril (1991 to 2013)*

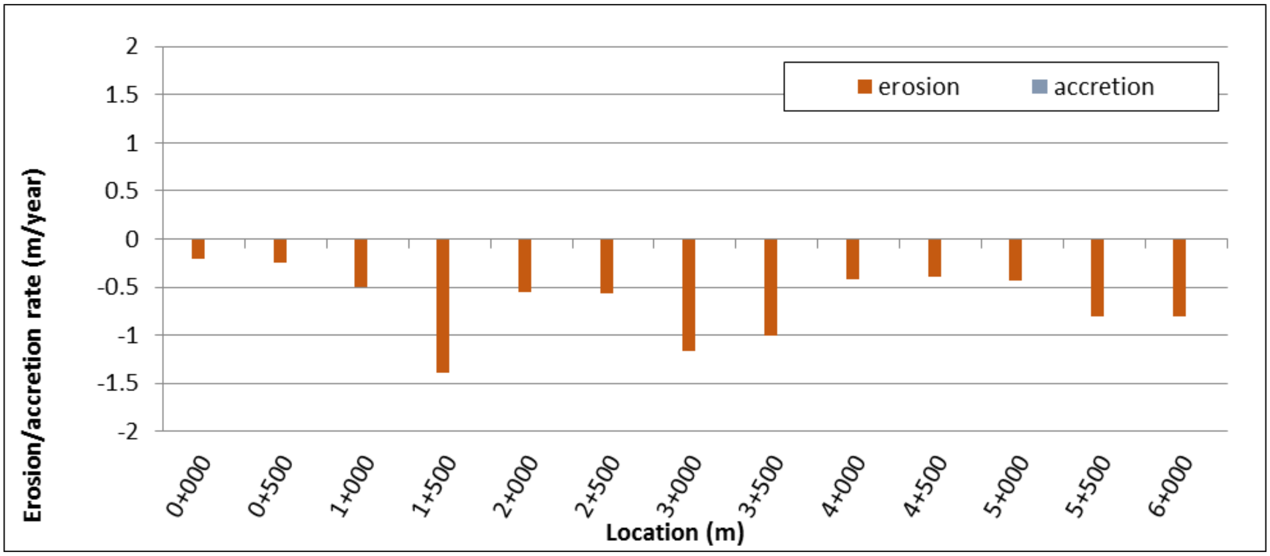



*Figure 6-47 Overall erosion/ accretion rates for Negril (1991 to 2013)*

*Future Shoreline Projections without Project*

The 2050 shoreline was projected relative to the datum by applying the overall rate of erosion determined from the historical shoreline analysis (Table 6-35 and Figure 6-48). This projection highlights the fact that most of the erosion is expected to take place between chainages 2+500 and 4+500. The overall maximum erosion expected to occur could be as much as 43.2m over the next 37 years.

*Table 6-35 Future shoreline projection based on the 1968 shoreline*

| | 2013 | 2050 Projection | | |
|---|---|---|---|---|
| **Location** | **Datum** | **Process** | **Overall Rate of erosion (m/year)** | **Distance from 2013 datum (m)** |
| 0+000 | 0 | erosion | -0.210 | -7.76 |
| 0+500 | 0 | erosion | -0.241 | -8.90 |
| 1+000 | 0 | erosion | -0.493 | -18.24 |
| 1+500 | 0 | erosion | -1.390 | -51.42 |
| 2+000 | 0 | erosion | -0.554 | -20.51 |
| 2+500 | 0 | erosion | -0.570 | -21.07 |
| 3+000 | 0 | erosion | -1.168 | -43.20 |
| 3+500 | 0 | erosion | -1.005 | -37.19 |
| 4+000 | 0 | erosion | -0.413 | -15.28 |
| 4+500 | 0 | erosion | -0.395 | -14.63 |
| 5+000 | 0 | erosion | -0.427 | -15.81 |
| 5+500 | 0 | erosion | -0.804 | -29.73 |
| 6+000 | 0 | erosion | -0.800 | -29.59 |

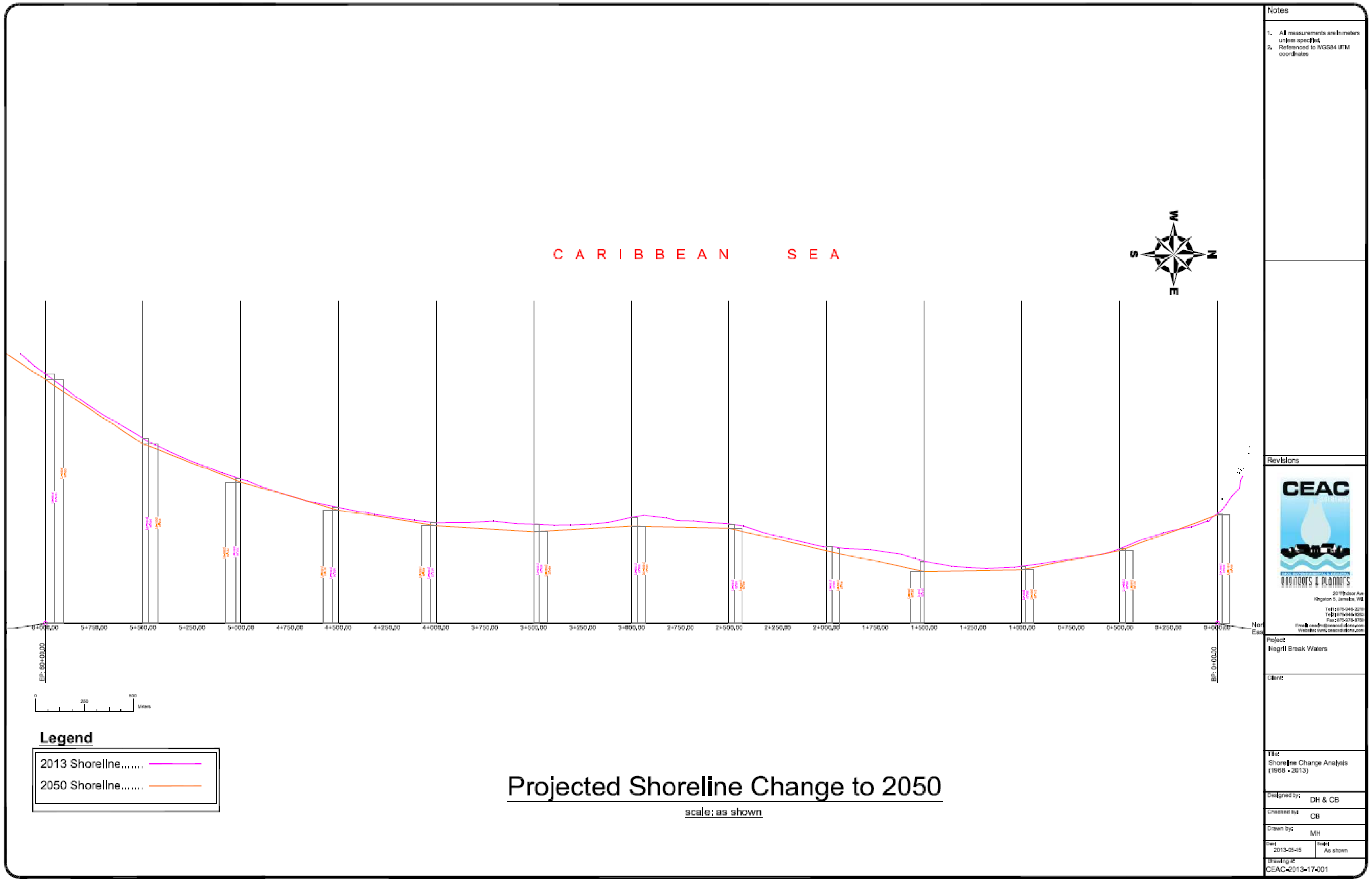



*Figure 6-48 Projected 2050 shoreline compared to the 2013 shoreline using the overall rate of erosion calculated*

*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:

$\Delta$ y – Dune line erosion (metre s/ year)
$\Delta$ s – Rate of sea level rise (metre s/ 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 (metres)
$h*$ – Depth at offshore limit, $l*$, to which near shore sediments exist (as opposed to finer- grained continental shelf sediments) (metres)

*Rate of Sea Level Rise, $\Delta$ 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. This average was considered for the calculations, and the upper limit of this range.

Using the upper limit value of 6 cm by 2050 allowed this analysis to test whether the coastal region of Negril 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 ($l*$). This was done by inspecting bathymetric data for Long Bay and obtaining profile lengths for the corresponding critical depth. These profile lengths obtained were incorporated into the equation above (Table 6-36).

*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 between the shoreline and the reefs in order to estimate the critical depth. Long term wave data available for the Long Bay area was analysed to determine the 12 hour wave ($H_{s,12}$). The $H_{s,12}$ was determined to be a 1.6 m swell wave.

*Calculation and Results*

The calculation of the long term trends expected in 25 years along the Long Bay beach is shown in Table 6-36. The Bruun Model was used to arrive at an estimate for long term erosion trends at four (4) shoreline positions along the beach (the beach was not treated as a single isotropic unit). 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 four (4) profile shoreline positions:

- Rate of sea-level rise = 3.7 mm/yr (IPCC 2007)
- Depth to which near shore sediment exists ($h^*$, $d_c$) = 2.56 m

It should be emphasized 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 estimates. This estimation of the sea level rise will assist in the determination of the true impacts that are due to operational and storm induced erosion.

The shoreline along the study area was estimated to retreat at varying rates between 0.3 and 1.17 metres per year as a result of global sea level rise. Profile 1 has the largest erosion rate of 1.17 m/year, while the remaining profiles have erosion rates between 0.30m/year to 0.43 m/year (Table 6-36).

*Table 6-36 Bruun Model projected erosion over the next 25 and 50 years*

| Parameter | Profile | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| | 0+ 500 | 2+000 | 3+500 | 5+500 |
| Rate of sea level rise, Δs (m/yr) | 0.0037 | 0.0037 | 0.0037 | 0.0037 |
| Offshore profile, l* (m) | 782 | 200 | 287 | 261 |
| depth of offshore limit, h* (m) | 2.56 | 2.56 | 2.56 | 2.56 |
| Dune line Erosion, Δy (m) | 1.13 | 0.29 | 0.41 | 0.38 |
| Projected change in 25 years (m) | 28.26 | 7.23 | 10.37 | 18.86 |
| Projected change in 50 years (m) | 56.51 | 14.45 | 20.74 | 18.86 |

### *Discussion and Prediction Comparison*

#### MCKENZIE STUDY VS HISTORICAL SHORELINE ANALYSIS

The McKenzie study confirmed that the 2004 to 2007 period has been one of the most active hurricane periods for Jamaica, and particularly for the Long Bay Beach as 5 hurricanes came within 250 miles of Jamaica. The study concluded that this particular beach requires a minimum of 3-4 years to recover to its pre-storm position following the near passage of a category 4 storm event. Our Historical Shoreline Analysis supports this conclusion as after the passage of three category 4 and 5 hurricane events (Hurricane Mitch in 1998, Hurricane George in 1998 and Hurricane Lenny in 1999), accretion was observed where there was once erosion about 6 – 7 years after the storm events. However the analysis shows that even now, 5 years after the passage of Hurricane Gustav in 2008 (category 4), the beach has not yet recovered to its pre-storm position.

This may give an indication as to how long the beach will take to respond to the breakwaters once installed. The response of the beach is typically dependent on a number of factors which includes the availability of sand to nourish the shoreline naturally. Given the operational waves are predominantly from the north-westerly directions, the northern and central sections of the beaches will recover much more slowly than the southern sections due to the alongshore movements of the sands.

#### HISTORICAL SHORELINE ANALYSIS VS BRUUN MODEL

The Bruun model determines the rate of shoreline change due to sea level rise while the historical shoreline analysis determines this rate based on observed changes in the shoreline. According to the Bruun model, the rate of shoreline change for the Long Bay Beach ranges between 0.3 m/year to 1.17 m/year while the historical analysis determined a rate between 0.2 m/year and 1.4 m/year. It can thus be concluded that between 63- 73 percent of the erosion rate experienced in the Long Bay Beach is due to sea level rise (Table 6-37).

*Table 6-37 Comparison of erosion rates determined by the historical shoreline analysis and the Bruun model*

| Location | Historical Shoreline Analysis Erosion (m/yr) | Bruun Model Erosion (m/yr) | Erosion due to Rising Sea Level (%) |
|---|---|---|---|
| 0+500 | 0.241 | 1.17 | 485% |
| 2+000 | 0.554 | 0.30 | 54 |
| 3+500 | 1.005 | 0.43 | 43 |
| 5+500 | 0.427 | 0.39 | 91 |

LIMITATIONS

Both methods of estimating long term erosion trends have their own limitations. For the Bruun method, estimating long-term erosion trends as a 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 aerial photos at strategic times which cannot be sourced.

**Comparison to other Beaches across Jamaica**

A report provided by CEAC Solutions (Burgess & Johnson 2013) examined if there was an underlying erosion pattern across Jamaica and estimated the risk associated. Specifically, nine beaches were analysed to 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 (Table 6-38). 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.

*Table 6-38 Summary of analysis for the nine 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) | Number 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 |

| Beaches | Short-term rate of shoreline loss (m/ yr)) | Long-term rate of shoreline loss (m/ yr) | Length of beach | Interval between profile (m) | Number of profiles used | Location/ Parish |
|---|---|---|---|---|---|---|
| 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** | | | | |

### *6.1.12.2 Alongshore Sediment Transport Regime (GENESIS)*

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 necessity of providing protective structures.

**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 Long Bay area from the groyne at the southern end to Sandals at the northern end, 6.2 km in length.

**Wave Climate Input, Calibration and Verification**

The most recent and complete annual wave data available for this location was for 2006. Wave data documented at three hour intervals were used to run the model, for the period 2000 through 2006 (Figure 6-49).

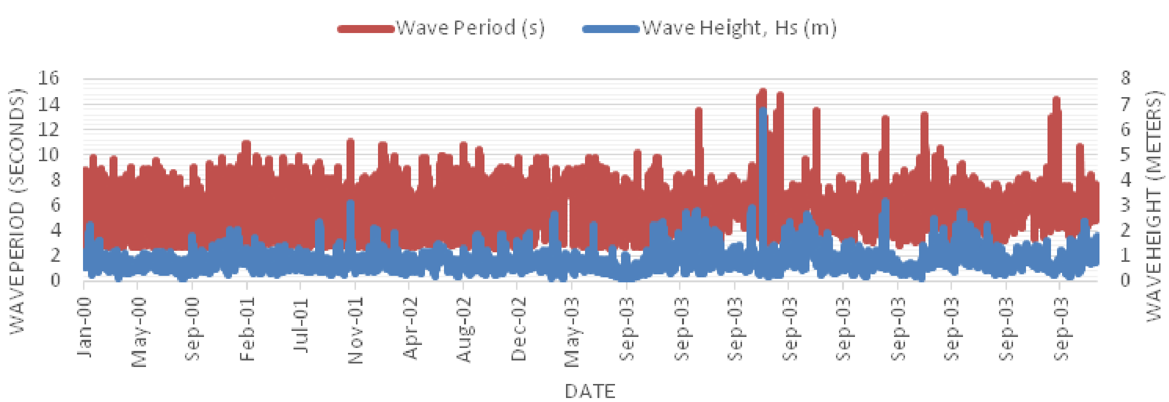



*Figure 6-49 NOAA Grib wave data (2000 to 2006) used in sediment transport modelling for Negril for a point offshore Long Bay*

### Initial Setup

The shoreline, bathymetric and reefs were defined as XYZ points and imported to setup the files required to run GENESIS. The operational and swell wave data for a point offshore Long Bay was obtained from the NOAA database for 2000 to 2006 and implemented within the model to simulate the beach platform. An effective grain size ($D_{10}$) of 0.34 millimetres determined from the sand sieving exercise conducted and used in the model.

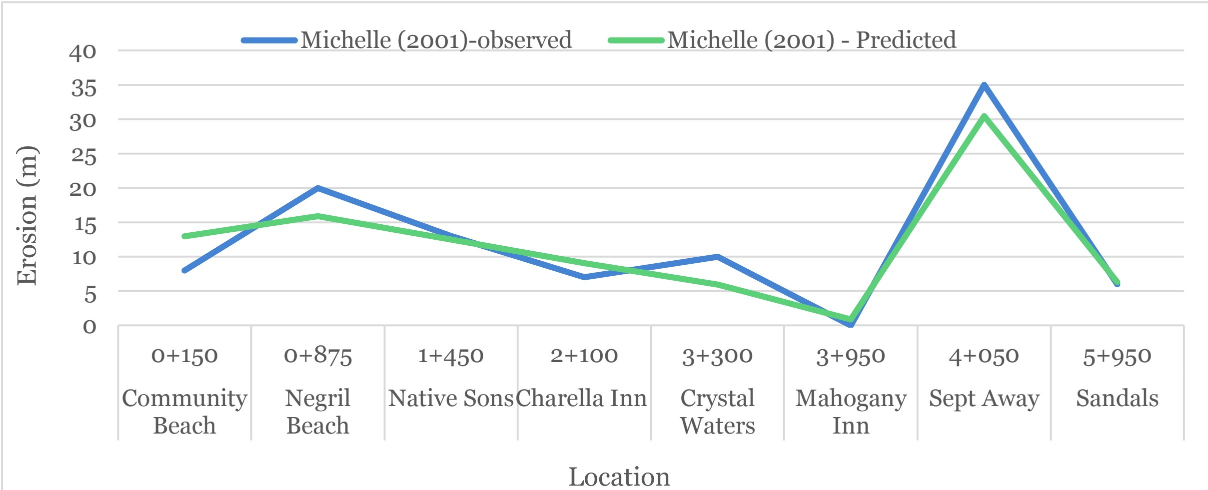
### Calibration

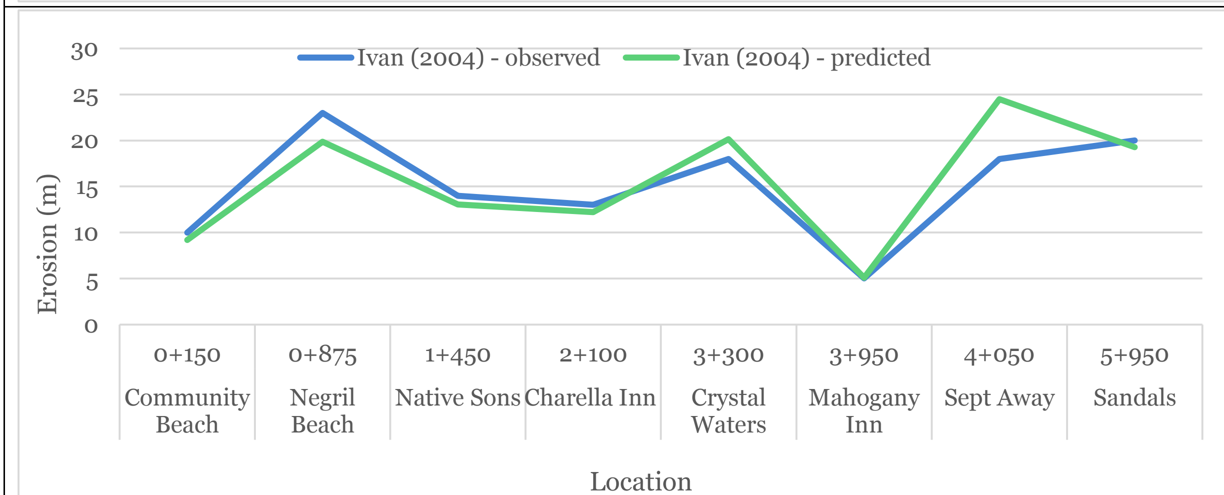
The model was calibrated based on erosion levels observed at specific locations along the Long Bay shoreline for 3 known hurricane events; Michelle (2000), Ivan (2004) and Wilma (2006). The level of erosion was recorded and document by McKenzie (2012). The calibration run (with long shore sand transport calibration coefficients parameters K1 = 0.35 and K2 = 0.25) was able to predict similar erosion levels as recorded by McKenzie (2012). The correlation between the observed and model shoreline positions were in the order of 81 to 96 percent. This is a reasonable calibration for using the model in the prediction mode.

*Table 6-39 Observed/measured erosion levels compared to the models predictions*

| Location | Chainage (m) | Observed Erosion (m) based on McKenzie, A. 2012 Beach Responses to Hurricane Impacts: A case Study of Long Bay Beach, Negril, Jamaica | | | Model Prediction - Erosion (m) | | |
|---|---|---|---|---|---|---|---|
| | | Michelle (2001)-observed | Ivan (2004) - observed | Wilma (2006)-observed | Michelle (2001) - Predicted | Ivan (2004) - predicted | Wilma (2006) - predicted |
| Community Beach | 0+150 | 8 | 10 | 22 | 13.0 | 9.2 | 28.6 |
| Negril Beach | 0+875 | 20 | 23 | 17 | 15.9 | 19.9 | 14.4 |
| Native Sons | 1+450 | 13 | 14 | 17 | 12.5 | 13.1 | 21.7 |
| Charella Inn | 2+100 | 7 | 13 | 22 | 9.1 | 12.2 | 22.5 |
| Crystal Waters | 3+300 | 10 | 18 | 10 | 6.0 | 20.1 | 7.3 |
| Mahogany Inn | 3+950 | 0 | 5 | 20 | 0.9 | 5.1 | 21.7 |
| Swept Away | 4+050 | 35 | 18 | 24 | 30.5 | 24.5 | 19.8 |
| Sandals | 5+950 | 6 | 20 | 20 | 6.3 | 19.3 | 23.0 |
| **Correlation** | | | | | 96% | 90% | 81% |

*Table 6-40 Calibration plots for the observed storm events, Michelle 2001, Ivan, 2004 and Wilma 2006 in comparison to the models (Genesis) prediction for the Long Bay Beach, Negril*




**Results (Existing Scenario)**

The pre-project/existing Long Bay beach scenario showed that 95% (5.9km) of the 6.2km shoreline modelled is in an erosion mode. This resulted in a total volumetric loss of approximately 114,000 cubic metres in the numerical simulations. The model predicts that the central and northern section of the shoreline is most vulnerable to erosion with erosion widths of 30 and 90 metres respectively. The average erosion along the shoreline is predicted to be 27 metres in width.


*Figure 6-50 Model prediction of the Long Bay Beach shoreline after 6 years of simulation for the pre-project scenario*

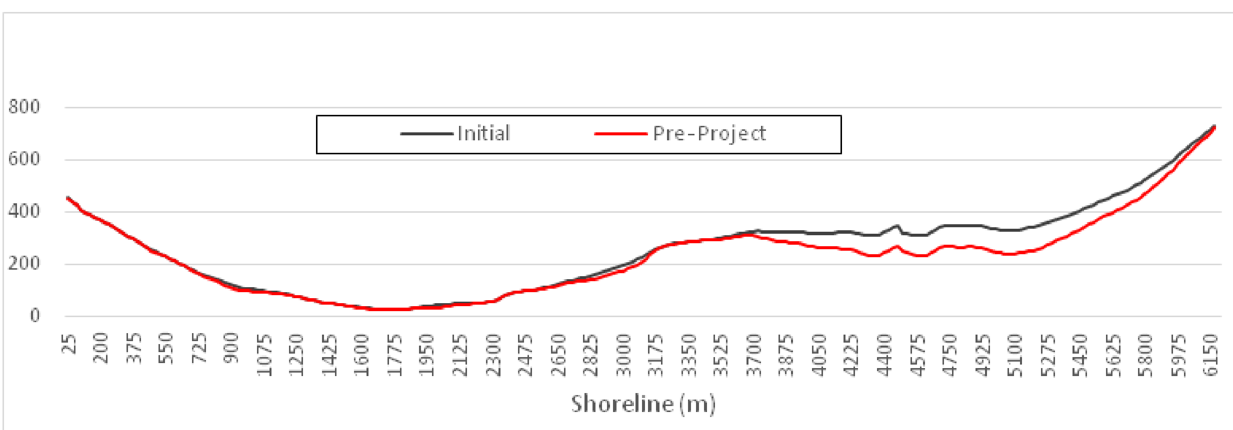



*Figure 6-51 Comparative analysis of initial and predicted pre-project shorelines for Long Bay*

### 6.1.13 Climate and Meteorology

#### *6.1.13.1 Methodology*

Temperature, relative humidity, wind speed and direction, rainfall and barometric pressure were recorded at one location along West End Road (across from the proposed staging area) where noise and particulate monitoring was conducted over the forty eight (48) hours (Monday March 3rd to Wednesday March 5th, 2014) by using a Davis Instruments wireless Vantage Pro2 weather system with a data logger and a complete system shelter erected on a tripod (Plate 6-3). Data were collected every fifteen minutes and stored on the data logger. This information was downloaded using the WeatherLink 5.9.2 software.

*Plate 6-3 Weather station deployed on roof of commercial area building along West End Road*

#### *6.1.13.2 Results*

Average temperature over the noise and dust assessment was 24 °C and ranged from a low of 19.9 °C to a high of 31.3 °C. Average relative humidity was 79.6% and ranged from a low of 49% to a high of 94%. Average wind speed was 0.4 m/s and ranged from a low of 0 m/s to a high of 6.7 m/s. Dominant wind direction was from the southeast.Measurable precipitation during the noise assessment was 0.5 mm. Barometric pressure ranged from a low of 1012 millibar to 1015.4 millibar over the noise assessment.

### 6.1.14 Ambient Particulates (PM 2.5 & PM 10)

Coarse particles are airborne pollutants that fall between 2.5 and 10 micrometers in diameter. Fine particle are airborne pollutants that fall below 2.5 micrometres in diameter.

Sources of coarse particles include crushing or grinding operations, and dust stirred up by vehicles traveling on roads. Sources of fine particles include all types of combustion, including motor vehicles, power plants, residential wood burning, forest fires, agricultural burning, and some industrial processes.

#### 6.1.14.1 Methodology

PM2.5 and PM10 particulate sampling was conducted for 24 hours each, on two separate occasions, using Airmetrics Minivol Tactical Air Samplers (Plate 6-4). Sampling was conducted at three (3) locations in the vicinity of the staging area. Noise readings were conducted at the same locations as the particulates. Coordinates are listed in Table 6-41. Particulate sampling was conducted from 12:00 am Monday March 3rd to 12:00 am Tuesday March 4th, 2014 on the first occasion, and from 12:00 am Tuesday March 4th to 12:00 am Wednesday March 5th, 2014 on the second occasion. PM10 and PM2.5 sampling was conducted concurrently.

*Table 6-41 Particulate and Noise sampling locations in JAD 2001*

| STATION | LOCATION | JAD 2001 | |
|---|---|---|---|
| | | Northing (m) | Easting (m) |
| 1 | Behind Burger King | 681463.66 | 607517.60 |
| 2 | Commercial Area along West End Road (across from pier) | 681439.04 | 607451.12 |
| 3 | Craft Market/Fish Market | 681476.92 | 607613.75 |

*Plate 6-4 Photo showing particulate samplers behind Burger King Complex*

#### 6.1.14.2 Results

For the PM 10 sampling event all locations had particulate values compliant with the 24-hour US EPA standard of 150µg/m³. Average values ranged from 38.54 µg/m³ at Station 3 to 39.72 µg/m³ at Station 2. The results of the PM10 sampling runs are shown in Table 6-42 below. Only one PM10 sampling run for Station 1 was conducted.

*Table 6-42 PM 10 Results*

| Station | Mean Result (µg/m³) | Range (µg/m³) | US EPA Std. (µg/m³) |
|---|---|---|---|
| 1 | 39.03 | 39.03 | **150** |
| 2 | 39.72 | 34.72 – 44.72 | **150** |
| 3 | 38.54 | 38.33 – 38.75 | **150** |

For the PM 2.5 sampling event all locations had particulate values compliant with the 24-hour US EPA standard of 35 µg/m³. Values ranged from 13.82 µg/m³ at Station 2 to 15.28 µg/m³ at Station 3. The results of the PM2.5 sampling runs are shown in Table 6-43 below. Only one PM2.5 sampling run for Station 1 was conducted.

*Table 6-43 PM 2.5 Results*

| Sfttion | Average Result (µg/m³) | Range (µg/m³) | US EPA 24-hr Std. (µg/m³) |
|---|---|---|---|
| 1 | 14.17 | 14.17 | **35** |
| 2 | 13.82 | 12.22 – 15.42 | **35** |
| 3 | 15.28 | 13.75 – 16.81 | **35** |

### 6.1.15 Noise

#### 6.1.15.1 Ambient Noise Methodology

A data logging noise survey exercise was conducted to establish baseline conditions within the environs of the staging area location. The noise data logging exercise was conducted for forty eight (48) hours between 7:00 hrs Monday March 3rd to 7:00 hrs Wednesday March 5th, 2014. The readings were taken at three (3) locations within the project area listed in Table 6-41.

Noise level readings were taken by using Quest Technologies SoundPro DL Type 1 hand held sound level meters with real time frequency analyser setup in outdoor monitoring kits. The octave band analysis was conducted concurrently with the noise level measurements. Measurements were taken in the third octave which provided thirty three (33) octave bands from 12.5 Hz to 20 kHz (low, medium and high frequency bands).

The noise meters were calibrated pre and post noise assessment by using a Quest QC - 10 sound calibrator (Appendix 11). The meters were programmed using the Quest suite Professional II (QSP II) software to collect third octave, average sound level (Leq) over the period, Lmin (The lowest level measured during the assessment) and Lmax (The highest level measured during the assessment) every ten (10) seconds.

Average noise levels over the period were calculated within the QSP II software using the formula:

$$\textbf{Average dBA} = 20 \log 1/N \sum_{j=1}^{N} 10^{(Lj/20)}$$

where $N$ = number of measurements
$L_j$ = the $j$th sound level
$j$ = 1, 2, 3 .... $N$

A windscreen (sponge) was placed over the microphone to prevent measurement errors due to noise caused by wind blowing across the microphone. Plate 6-5 shows one of the noise monitoring outdoor kits.

*Plate 6-5 - Photo showing noise meter behind Burger King*

#### 6.1.15.2 Results

This section outlines the results of the forty eight (48) hour noise monitoring exercise at the three (3) monitoring stations. The noise monitoring at Station 1 had to be stopped after 12 hours 4 minutes due to vandalism of the noise monitoring equipment.

**Station 1**

During the period, noise levels at this station ranged from a low (Lmin) of 14.3 dBA to a high (Lmax) of 93.9 dBA. Average noise level for this period was 60 $L_{Aeq}$. The fluctuation in noise levels over the period is depicted in Figure 6-52.

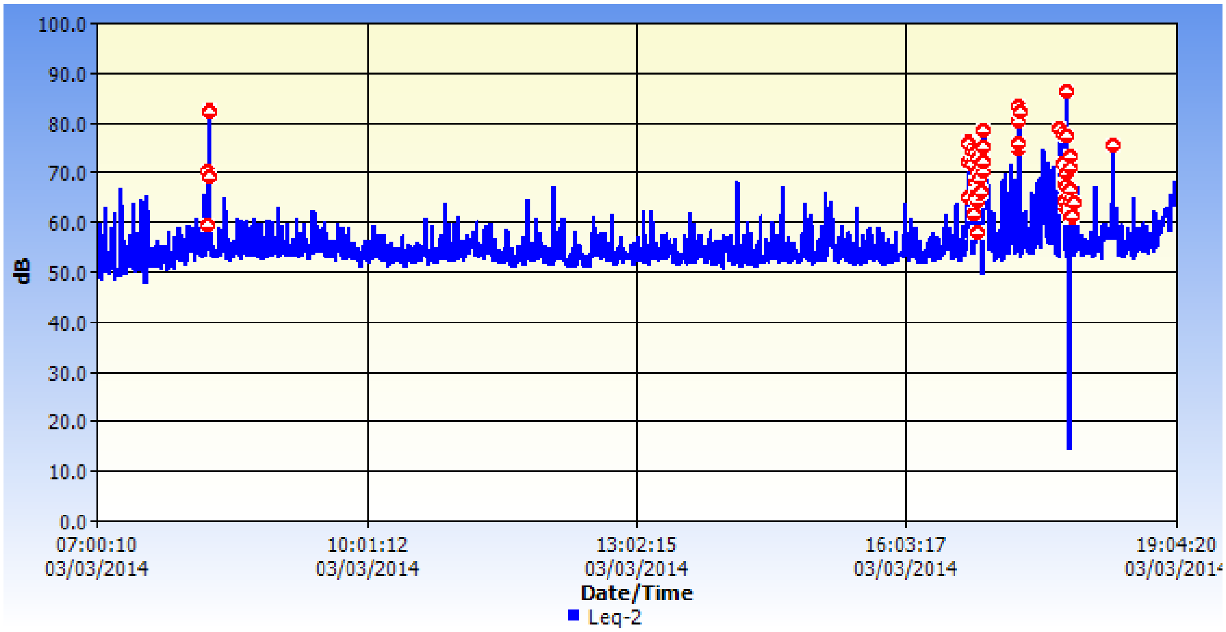



*Figure 6-52 Noise fluctuation (Leq) at Station 1*

*Octave Band Analysis at Station 1*

The noise at this station during the period was in the low frequency band centred around the geometric mean frequency of 16 Hz (octave frequency range is 11 - 14 Hz) and 40 Hz (octave frequency range is 36 - 45 Hz) (Figure 6-53).

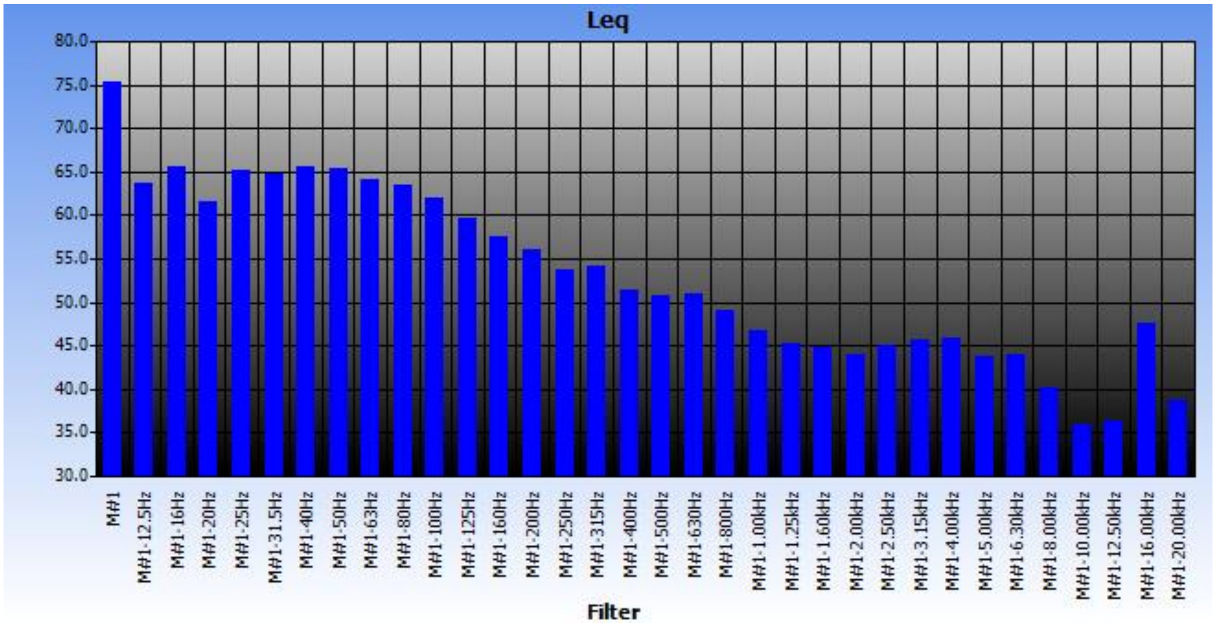



*Figure 6-53 Octave band spectrum of noise at Station 1*

*L10 and L90 – Station 1*

The two most common **$L_n$** values used are **$L_{10}$** and **$L_{90}$** and these are sometimes called the 'annoyance level' and 'background level' respectively. **$L_{10}$** is almost the only statistical value used for the descriptor of the higher levels, but **$L_{90}$**, is widely used to describe the ambient or background level. L10-L90 is often used to give a quantitative measure as to the spread or "how choppy" the sound was.

L10 is the noise level exceeded for 10% of the time of the measurement duration. This is often used to give an indication of the upper limit of fluctuating noise, such as that from road traffic. L90 is the noise level exceeded for 90% of the time of the measurement duration.

The difference between L10 and L90 gives an indication of the noise climate. When the difference is < 5 dBA then it is considered that there are no significant fluctuations in the noise climate, moderate fluctuations 5-15 dBA and large fluctuations >15 dBA.

Figure 6-54 depicts the hourly L10 and L 90 statistics for this station over the noise assessment period. The data shows moderate fluctuations (L10 – L90) ≈46% and no significant fluctuations (L10 – L90) ≈54% of the time in the noise climate at this station.

The overall L10 and L 90 at this station for the time assessed were 59.2 dBA and 51.8 dBA respectively.

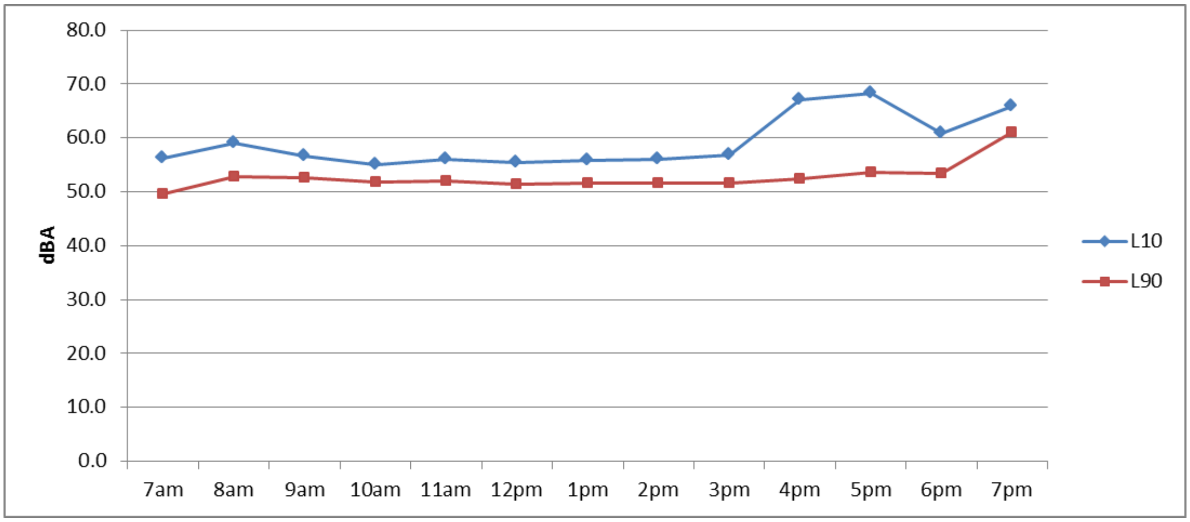



*Figure 6-54 L10 and L90 for Station 1*

**Station 2**

During the 48-hour period, noise levels at this station ranged from a low (Lmin) of 38.6 dBA to a high (Lmax) of 86.9 dBA. Average noise level for this period was 61.1 $L_{Aeq}$ (48h). The fluctuation in noise levels over the 48 hour period is depicted in Figure 6-55.

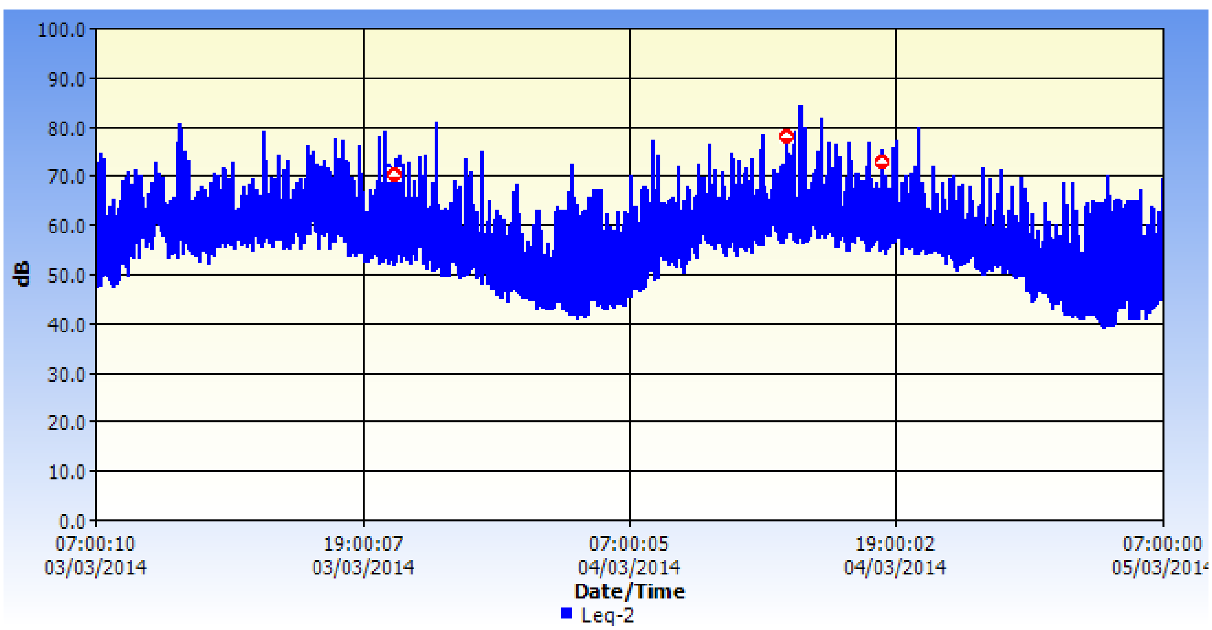



*Figure 6-55 Noise fluctuation (Leq) over 48 hours at Station 2*

*Octave Band Analysis at Station 2*

The noise at this station during the 48 hour period was in the low frequency band centred around the geometric mean frequency of 50 Hz. (octave frequency range is 45 - 56Hz) (Figure 6-56).

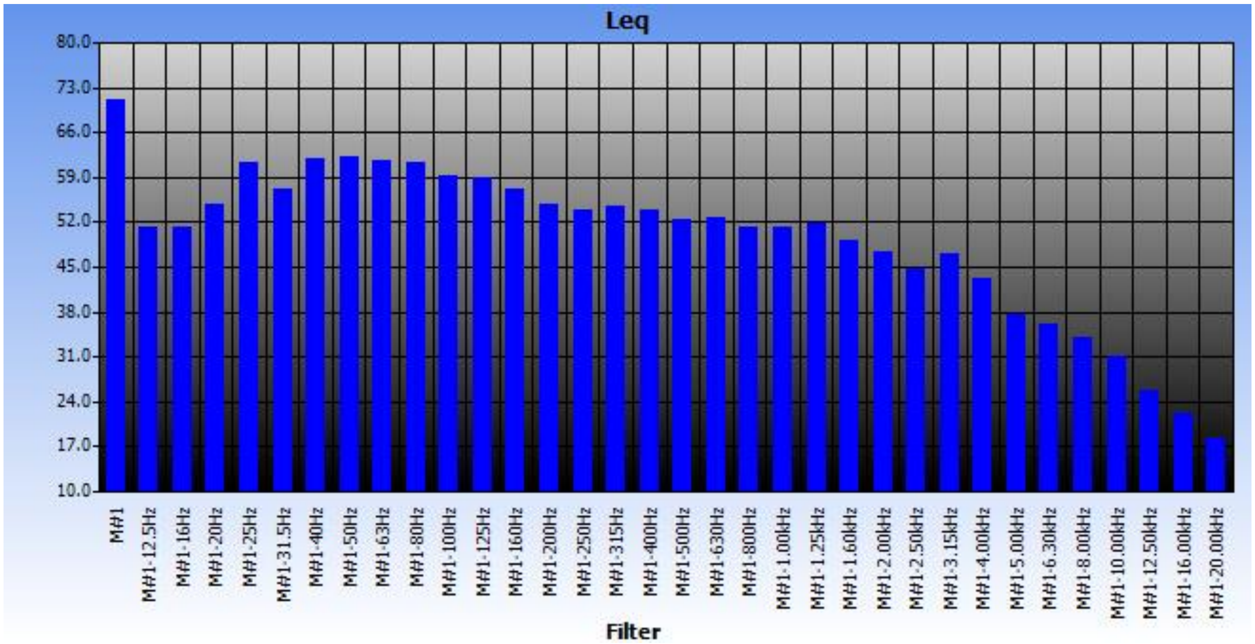



*Figure 6-56 -Octave band spectrum of noise at Station 2*

*L10 and L90 – Station 2*

Figure 6-57 depicts the hourly L10 and L 90 statistics for this station over the noise assessment period. The data shows moderate fluctuations in the noise climate (L10 – L90) ≈89.6% of the time, no significant fluctuations any of the time and large fluctuations (L10 – L90) ≈10.4% of the time in the noise climate at this station.

The overall L10 and L 90 at this station for the time assessed were 63.2 dBA and 46.3 dBA respectively.

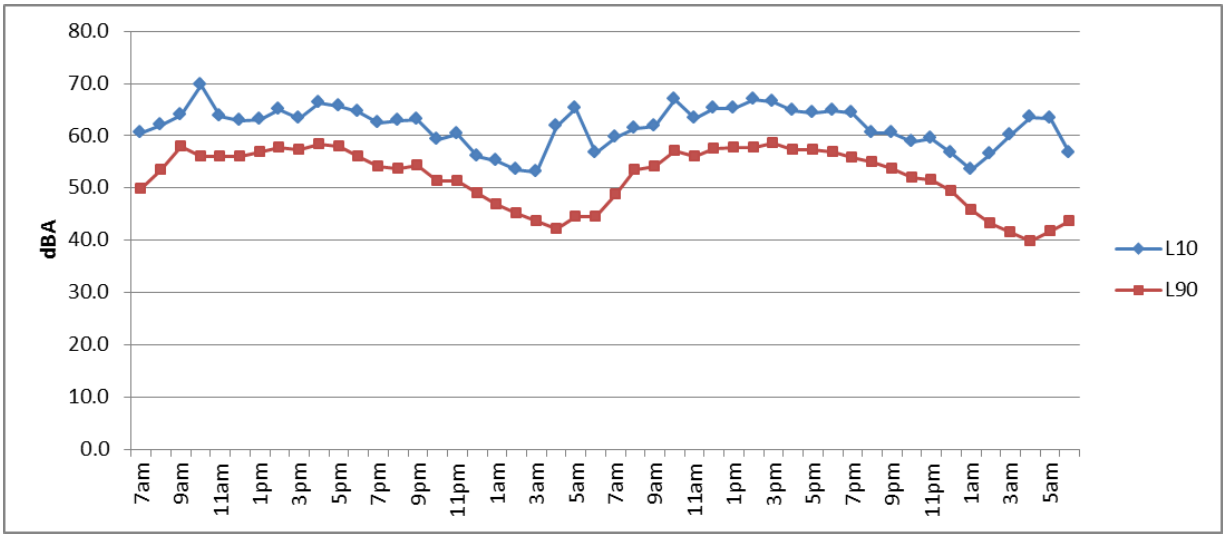



*Figure 6-57 L10 and L90 for Station 2*

**Station 3**

During the 48-hour period, noise levels at this station ranged from a low (Lmin) of 36.7 dBA to a high (Lmax) of 81.9 dBA. Average noise level for this period was 57.6 $L_{Aeq}$ (48h). The fluctuation in noise levels over the 48 hour period is depicted in Figure 6-58.

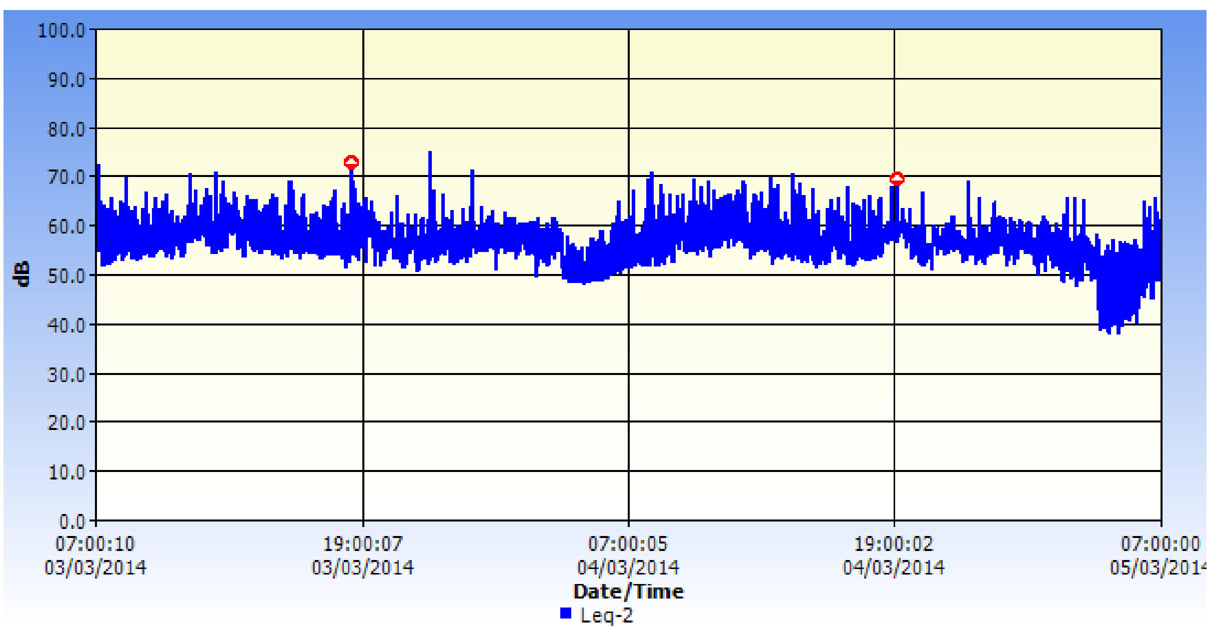



*Figure 6-58 - Noise fluctuation (Leq) over 48 hours at Station 3*

*Octave Band Analysis at Station 3*

The noise at this station during the 48 hour period was in the low frequency band centred around the geometric mean frequency of 40 Hz. (octave frequency range is 36 - 45 Hz) (Figure 6-59).

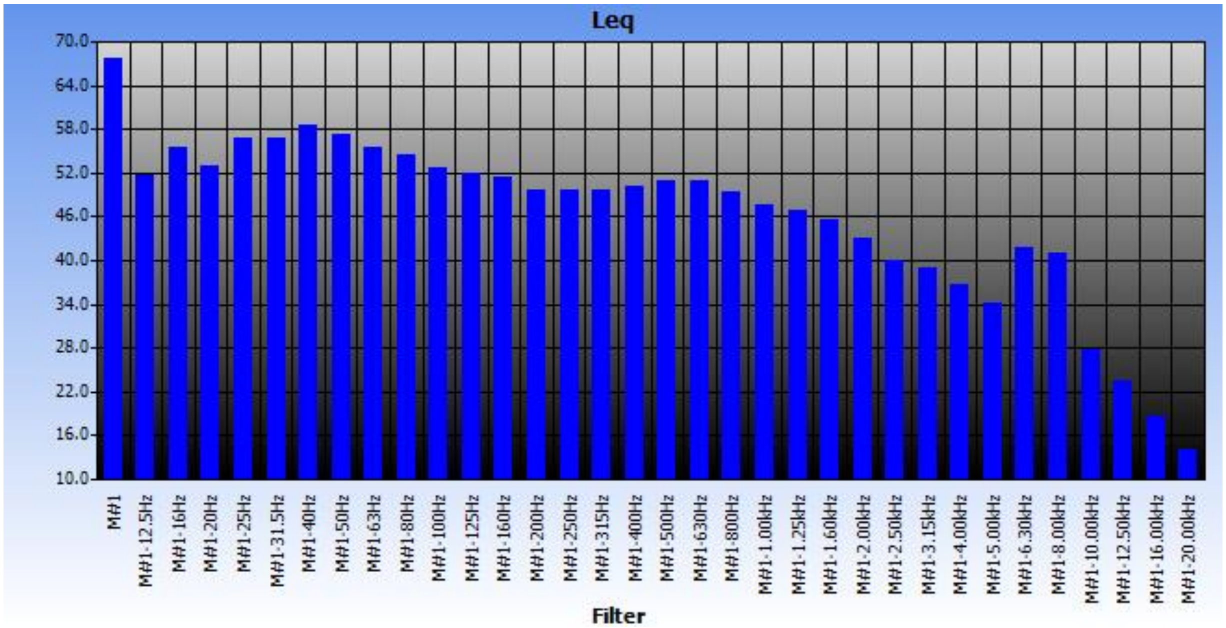



*Figure 6-59 - Octave band spectrum of noise at Station 3*

*L10 and L90 – Station 3*

Figure 6-60 depicts the hourly L10 and L 90 statistics for this station over the noise assessment period. The data shows moderate fluctuations in the noise climate (L10 – L90) ≈70.8% of the time and no significant fluctuations (L10 – L90) ≈29.2% of the time in the noise climate at this station.

The overall L10 and L 90 at this station for the time assessed were 60.2 dBA and 51.9 dBA respectively.

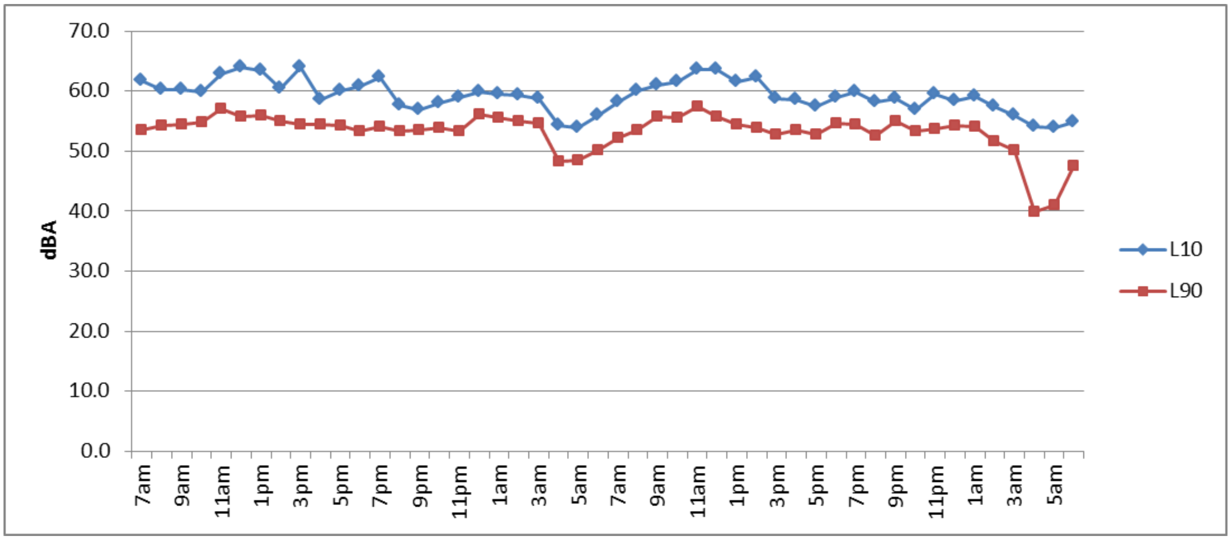



*Figure 6-60 - L10 and L90 for Station 3*

### 6.1.15.3 Comparisons of Ambient Noise Levels with NEPA Guidelines

**NEPA Guidelines**

Comparison of the ambient noise levels in the study area with the National Environmental and Planning Agency (NEPA) guidelines are shown in Table 6-44. All locations had noise levels compliant with the NEPA daytime and night time noise guidelines.

*Table 6-44 Comparison of noise levels at the stations with the NEPA guidelines*

| Stn.# | ZONE | 7 am. - 10 pm (dBA) | NEPA Guideline (dBA) | 10 pm. - 7 am (dBA) | NEPA Guideline (dBA) |
|---|---|---|---|---|---|
| 1 | Commercial | 60 | 65 | N/A | 60 |
| 2 | Commercial | 62.7 | 65 | 55.9 | 60 |
| 3 | Commercial | 58.4 | 65 | 55.7 | 60 |

*NB. Numbers in red are non-compliant with the standard/guideline*

### 6.1.15.4 Noise Prediction

**Methodology**

Noise prediction was done by using SoundPlan 7.3 software with the Federal Highway Administration (FHWA) TNM module. Data from the traffic counts conducted by NWA were inputted into the model to determine the existing noise levels being generated, the project traffic for predicting the noise from traffic generated from the moving of the boulders and cumulative (existing plus project traffic).

The results were compared with NEPA daytime standards as the transportation of boulders will occur during the daytime.

## Existing Traffic

*Negril Round – A - Bout*

The predicted noise levels generated along a section of this thoroughfare from the existing traffic was predicted and detailed in Table 6-45. As seen in Table 6-45, approximately 56% or 9 out of the 16 locations accessed already had noise levels exceeding the NEPA daytime noise standard. The noise emissions are illustrated in Figure 6-61.

*Table 6-45 Predicted noise emissions 24 hours and daytime levels from existing traffic along the Negril to Sheffield main road*

| LOCATIONS | EXISTING Leq $_{(24h)}$ (dBA) | EXISTING 7 a.m. – 10 p.m. (dBA) | NEPA DAY TIME STD. (7 a.m. – 10 p.m.) (dBA) |
|---|---|---|---|
| Burger King | 58.3 | 60.3 | 65 |
| Caribbean Sunset Resort | 42.1 | 44.1 | 55 |
| House 1 | 60.7 | **62.7** | 55 |
| House 2 | 58.0 | **60.0** | 55 |
| House 3 | 57.4 | **59.5** | 55 |
| House 4 | 61.4 | **63.4** | 55 |
| House 5 | 59.9 | **61.9** | 55 |
| House 6 | 59.4 | **61.4** | 55 |
| House 7 | 56.3 | **58.4** | 55 |
| House 8 | 54.3 | **56.4** | 55 |
| Negril Health Centre | 51.4 | **53.4** | 45 |
| Negril Hills Golf Club | 45.7 | 47.8 | 65 |
| Playfield | 44.5 | 46.6 | 65 |
| Plaza 1 | 57.4 | 59.4 | 65 |
| Plaza 2 | 57.7 | 59.8 | 65 |
| Sweet Spice | 58.5 | 60.5 | 65 |

***NB: Values in red are non-compliant with NEPA daytime standard***

*Moon Rise Resort*

The expected noise levels generated along a section of this thoroughfare from the existing traffic along was predicted and detailed in Table 6-46. As seen in Table 6-46, approximately 90% or 69 out of the 77 locations accessed already had noise levels exceeding the NEPA daytime noise standard. The noise emissions from existing traffic along the Norman Manley Boulevard are represented in Figure 6-62.

*Table 6-46 Predicted noise emissions 24 hours and daytime levels from existing traffic along the Norman Manley Boulevard*

| LOCATIONS | EXISTING Leq $_{(24h)}$ (dBA) | EXISTING 7 a.m. – 10 p.m. (dBA) | NEPA DAY TIME STD. (7 a.m. – 10 p.m.) (dBA) |
|---|---|---|---|
| Alfred's Ocean Palace | 63.7 | **65.7** | 55 |
| Ansell's Thatch Walk Cottages | 61.9 | **63.9** | 55 |
| Aqua Negril Resort | 61.5 | **63.5** | 55 |

| LOCATIONS | EXISTING $Leq_{(24h)}$ (dBA) | EXISTING 7 a.m. – 10 p.m. (dBA) | NEPA DAY TIME STD. (7 a.m. – 10 p.m.) (dBA) |
|---|---|---|---|
| Bar B Barn Hotel and Restaurant | 59.0 | **61.0** | 55 |
| Beachcomber Club Hotel and Spa | 62.0 | **64.1** | 55 |
| Beaches | 62.5 | **64.6** | 55 |
| Bungalo Hotel | 60.9 | **63.0** | 55 |
| Caribbean Sunset Resort | 46.5 | 48.6 | 55 |
| Chances | 60.3 | **62.3** | 55 |
| Charela Inn | 61.5 | **63.5** | 55 |
| Charela Inn | 46.6 | 48.7 | 55 |
| Chippewa Village Cafe Bar Lodging | 71.7 | **73.8** | 55 |
| Chuckles | 44.0 | 46.0 | 55 |
| Coco La Palm | 61.2 | **63.2** | 55 |
| Coral Seas Garden Hotel | 62.3 | **64.4** | 55 |
| Cotton Tree Place Hotel | 40 | 42.1 | 55 |
| Country Country | 62.0 | **64.0** | 55 |
| Couples | 59.8 | **61.9** | 55 |
| Couples Swept Away | 49.3 | 51.4 | 55 |
| Crystal Waters Villas | 61.1 | **63.1** | 55 |
| Errol's Sunset Cafe and Guest House | 62.0 | **64.0** | 55 |
| Firefly Cottages & Apartments | 61.1 | **63.2** | 55 |
| Foote Prints Villas | 60.7 | **62.8** | 55 |
| For Real Beach Resort | 60.7 | **62.8** | 55 |
| Fun Holiday Beach Resort | 61.1 | **63.1** | 55 |
| Gardenia Resort | 59.5 | **61.5** | 55 |
| Golden Villas & Rooms | 70.1 | **72.2** | 55 |
| Grand Lido Negril Resort & Spa | 42.8 | 44.8 | 55 |
| Grand Pineapple Beach Resort | 59.1 | **61.2** | 55 |
| Green Leaf Cabins | 71.6 | **73.7** | 55 |
| Hidden Paradise Garden Resort | 71.4 | **73.5** | 55 |
| Idle Awhile | 62.9 | **64.9** | 55 |
| Jamaican Tamboo | 62.2 | **64.2** | 55 |
| Kuyaba | 60.5 | **62.5** | 55 |
| Lazy Dayz | 61.9 | **64.0** | 55 |
| Legends Hotel | 63.3 | **65.4** | 55 |
| Mariner's Negril Beach Club | 61.5 | **63.6** | 55 |
| Mariposa | 59.5 | **61.5** | 55 |
| Merrils 1 Resort | 61.2 | **63.2** | 55 |
| Merrils 2 Resort | 60.3 | **62.4** | 55 |
| Merrils 3 Resort | 61.3 | **63.4** | 55 |

| LOCATIONS | EXISTING Leq (24h) (dBA) | EXISTING 7 a.m. – 10 p.m. (dBA) | NEPA DAY TIME STD. (7 a.m. – 10 p.m.) (dBA) |
|---|---|---|---|
| Moon Dance Villas | 62.7 | **64.8** | 55 |
| Moonrise Villas | 63.7 | **65.7** | 55 |
| Native Son Villas | 65.1 | **67.2** | 55 |
| Negril Beach Villa | 62.0 | **64.1** | 55 |
| Negril Gardens Beach Resort | 63.9 | **66.0** | 55 |
| Negril Tree House Hotel | 55.1 | 57.1 | 55 |
| Nirvana | 63.2 | **65.3** | 55 |
| Palm Grove Manor Apartment and Rooms | 61.1 | **63.1** | 55 |
| Point Village | 37.1 | 39.1 | 55 |
| Rayon Hotel | 67.2 | **69.3** | 55 |
| Riu Hotel & Resorts Negril Club | 60.5 | **62.5** | 55 |
| Riu Hotel & Resorts Tropical Bay | 62.1 | **64.1** | 55 |
| Rondel Village | 63.0 | **65.1** | 55 |
| Rooms | 61.4 | **63.5** | 55 |
| Roots Bamboo Beach Resort | 62.2 | **64.2** | 55 |
| Sandals Negril Beach Resort & Spa | 59.5 | **61.6** | 55 |
| Sea Sand Eco Villas | 62.3 | **64.4** | 55 |
| Sea Scape Hotel | 61.8 | **63.8** | 55 |
| Sea Splash Resort | 61.5 | **63.6** | 55 |
| Seabreeze Apartments | 64.2 | **66.3** | 55 |
| Seascape Hotel | 69.5 | **71.5** | 55 |
| Seawind Resort | 61.4 | **63.4** | 55 |
| Shield's Negril Villas | 60.1 | **62.1** | 55 |
| Sunquest Cottages | 61.8 | **63.8** | 55 |
| Sunrise Club Hotel | 67.5 | **69.5** | 55 |
| Sunset at the Palms Resort and Spa | 67.2 | **69.2** | 55 |
| Sunset on the Beach Resort (Coral Seas B | 66.9 | **69.0** | 55 |
| Sunset Palm Resort | 66.3 | **68.3** | 55 |
| Superclubs Hedonism II | 44.6 | 46.7 | 55 |
| The Palms | 62.5 | **64.5** | 55 |
| Travellers Beach Resort | 61.1 | **63.2** | 55 |
| Villa Mora Rooms & Cottages | 69.8 | **71.8** | 55 |
| Wavz | 62.4 | **64.4** | 55 |
| Whistling Bird | 61.4 | **63.5** | 55 |
| White Sands | 60.8 | **62.8** | 55 |
| Yellow Bird Rooms & Cottages | 59.0 | **61.0** | 55 |

***NB: Values in red are non-compliant with NEPA daytime standard***

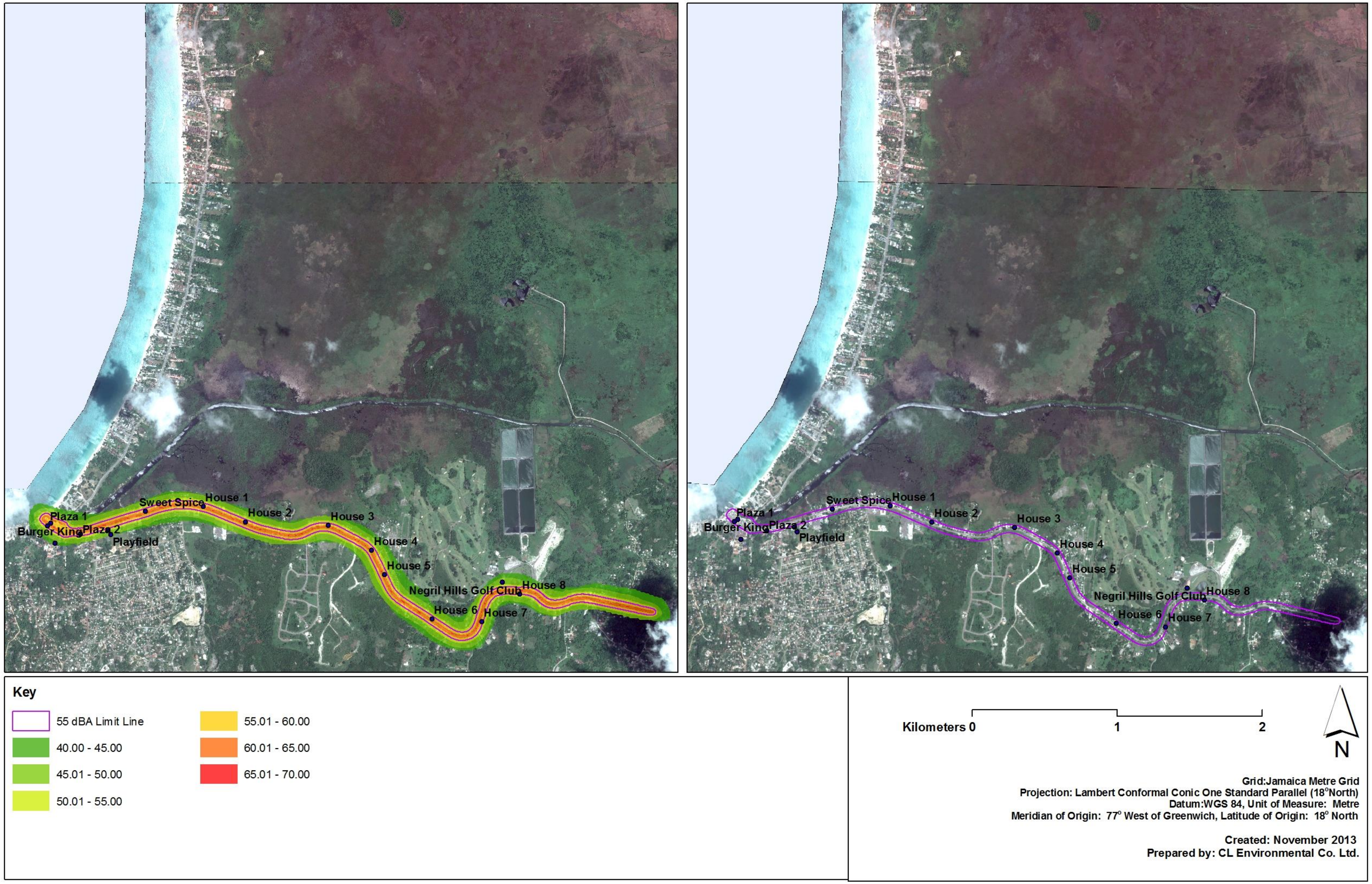



*Figure 6-61 Noise contours from existing traffic along the Negril round-a-bout to Sheffield main road*

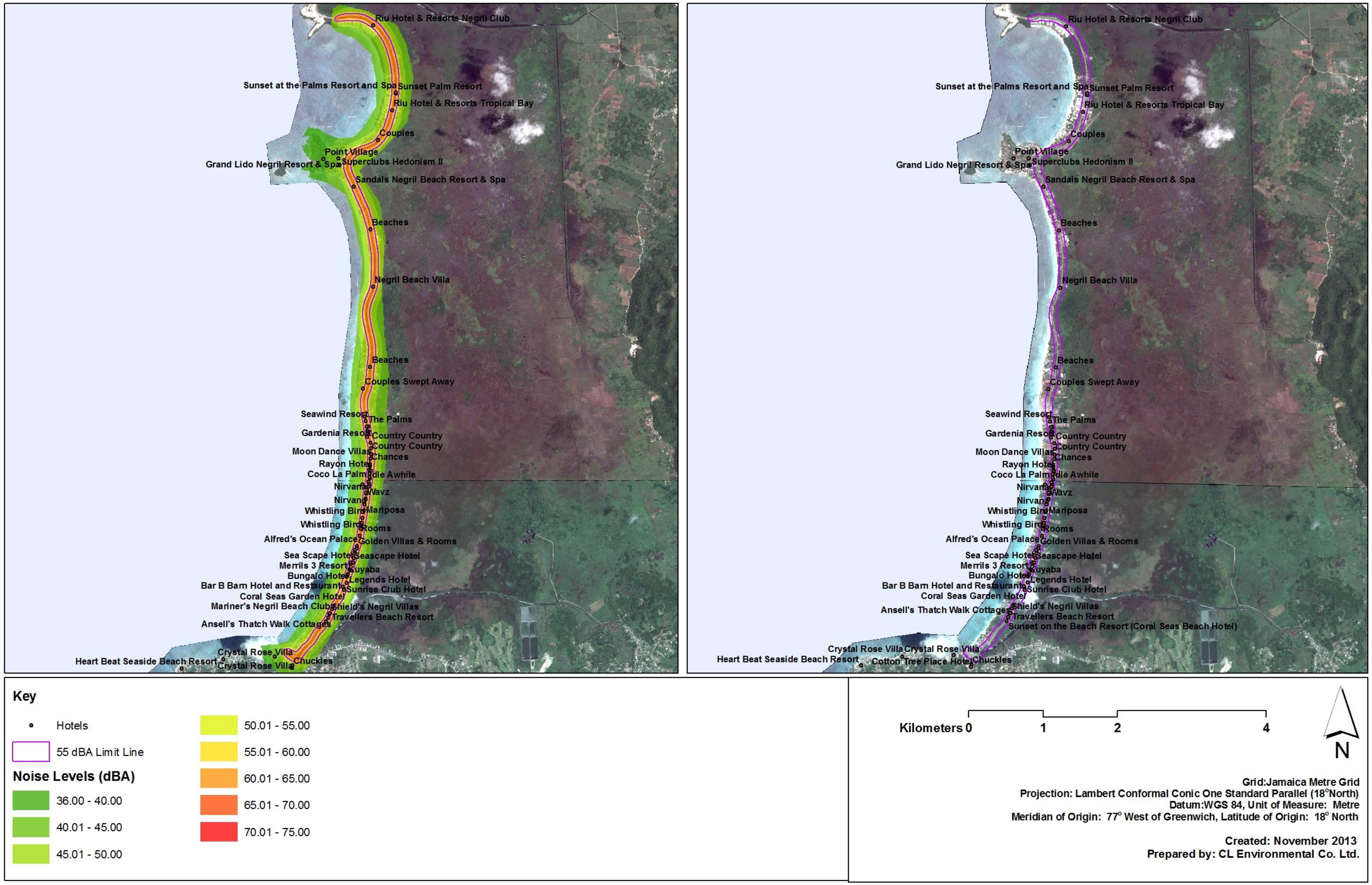



*Figure 6-62 Noise contours from existing traffic along the Norman Manley Boulevard*

## 6.1.16 Traffic

### *6.1.16.1 Existing*

Traffic count data supplied by the National Works Agency (NWA) have indicated that the highest traffic flow during weekdays along both the Negril round a bout and Sheffield main road (east and west bound) and Norman Manley Boulevard (north and south bound) occurred between 6a.m. – 10 p.m. The traffic between 6 a.m. and 10 p.m. accounts for approximately 85% and 92% respectively of the daily traffic (Table 6-47).

*Table 6-47 Average daily traffic per classification*

| LOCATIONS | DATE | AUTOMOBILES | MEDIUM TRUCKS | HEAVY TRUCKS |
|---|---|---|---|---|
| Negril round a bout and Sheffield (Eastbound) | 17 -20.3. 09 | 7,191 | 370 | 10 |
| Negril round a bout and Sheffield (Westbound) | | 7,551 | 385 | 16 |
| Moon Rise Resort (Northbound) | 12-16.11.12 | 2,480 | 169 | 3 |
| Moon Rise Resort (Southbound) | | 3,751 | 306 | 4 |

### *6.1.16.2 Project Related*

The proposed project is anticipated to generate a total of 2,923 truck/trailer trips over a 6 month period to deliver the boulders that are necessary to build the breakwaters to the staging area. This equates to approximately 24 truck trips per day or approximately 3 truck trips per hour. The resultant changes in the traffic mix are depicted in (Table 6-48).

*Table 6-48 Change in the heavy truck traffic as a percentage of total vehicular traffic*

| LOCATIONS | DATE | PERCENTAGE OF TOTAL VEHICULAR TRAFFIC | |
|---|---|---|---|
| | | HEAVY TRUCKS - EXISTING | HEAVY TRUCKS – WITH PROJECT |
| Negril round a bout and Sheffield (Eastbound) | 17 -20.3. 09 | 0.1 | 0.45 |
| Negril round a bout and Sheffield (Westbound) | | 0.2 | 0.50 |
| Moon Rise Resort (Northbound) | 12-16.11.12 | 0.1 | 1.02 |
| Moon Rise Resort (Southbound) | | 0.09 | 0.69 |

# 6.2 BIOLOGICAL

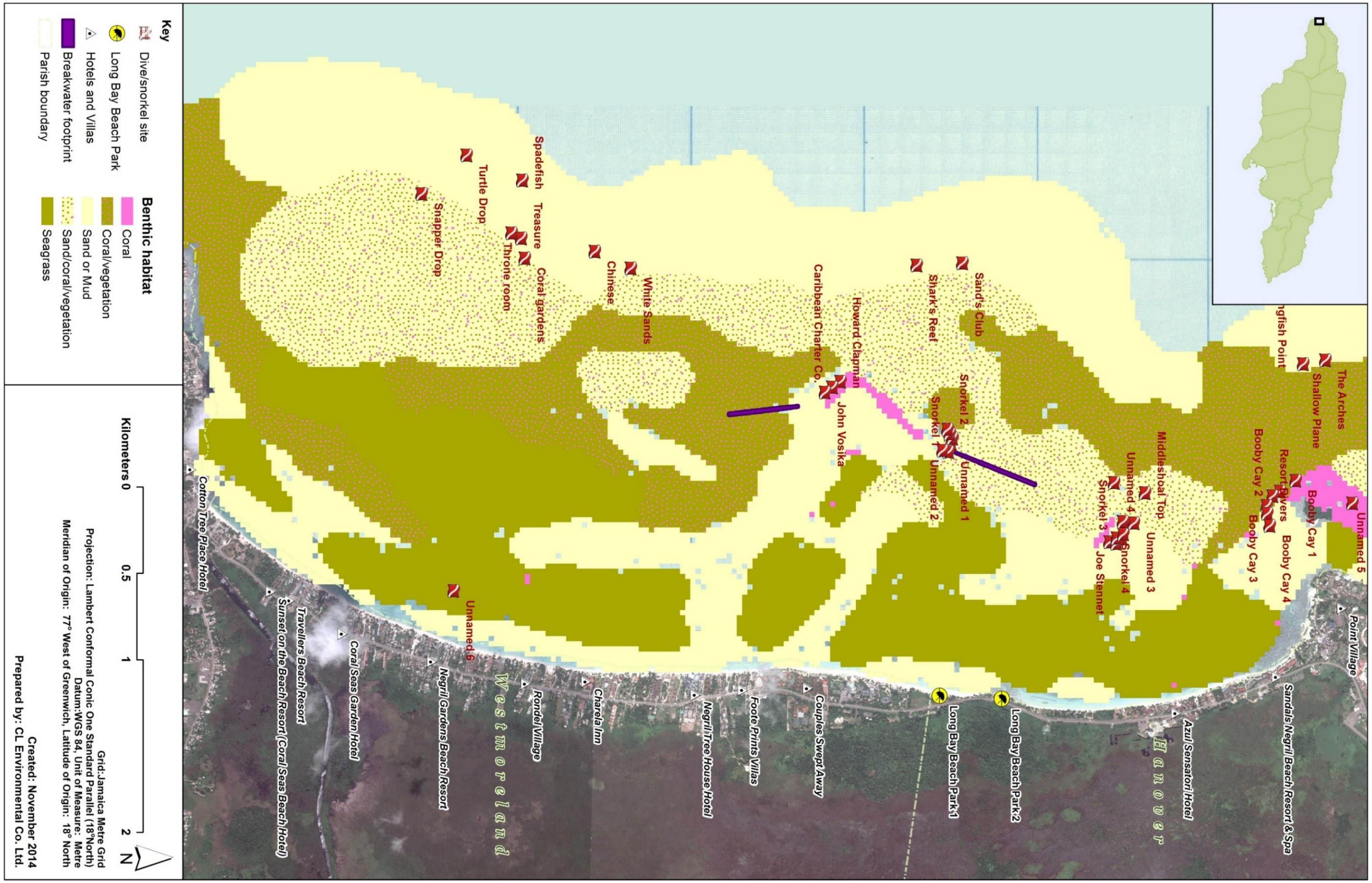
## 6.2.1 Overview of Existing Information

The proposed project falls within the boundaries of the Negril Marine Park. The marine park consists of a variety of interconnected coastal ecosystems. The natural resources found within the park include coral reefs, sea grass beds, mangrove communities and commercially important fisheries. Also of importance within the park are the long expanses of sandy beaches found at Long Bay (7 km) and Bloody Bay (2 km). These beaches are protected by a narrow and shallow coastal shelf consisting of shallow coral reef and sea grass beds and are also nesting areas for sea turtles. The narrow island shelf includes benthic communities and habitats primarily of unconsolidated material (sand, silt and mud), sand channels and sand bottom areas. These areas are important to the connectivity and species dispersal between coral reefs, seagrass beds and terrestrial wetland habitats (NEPA 2012).

Seagrass beds are found just off shore the beaches and are sometimes interspersed with coral reef patches in the near shore areas. These beds play an important role in the mitigation of beach erosion (RiVamp 2010). Two to three kilometres offshore a shallow fringing coral reef system is found with a depth range of 20-50 m. Traveling north or south of Long Bay and Bloody Bay, the fringing reef systems get closer to shore and the long expanse of beaches gives way to limestone cliffs with much smaller pockets of beaches (NEPA 2012). Negril has been experiencing a long-term erosion trend on its shoreline. Previous studies point to a combination of human and natural factors that have resulted in the erosion and degraded state of the coral reef and seagrass beds (CEAC 2012).

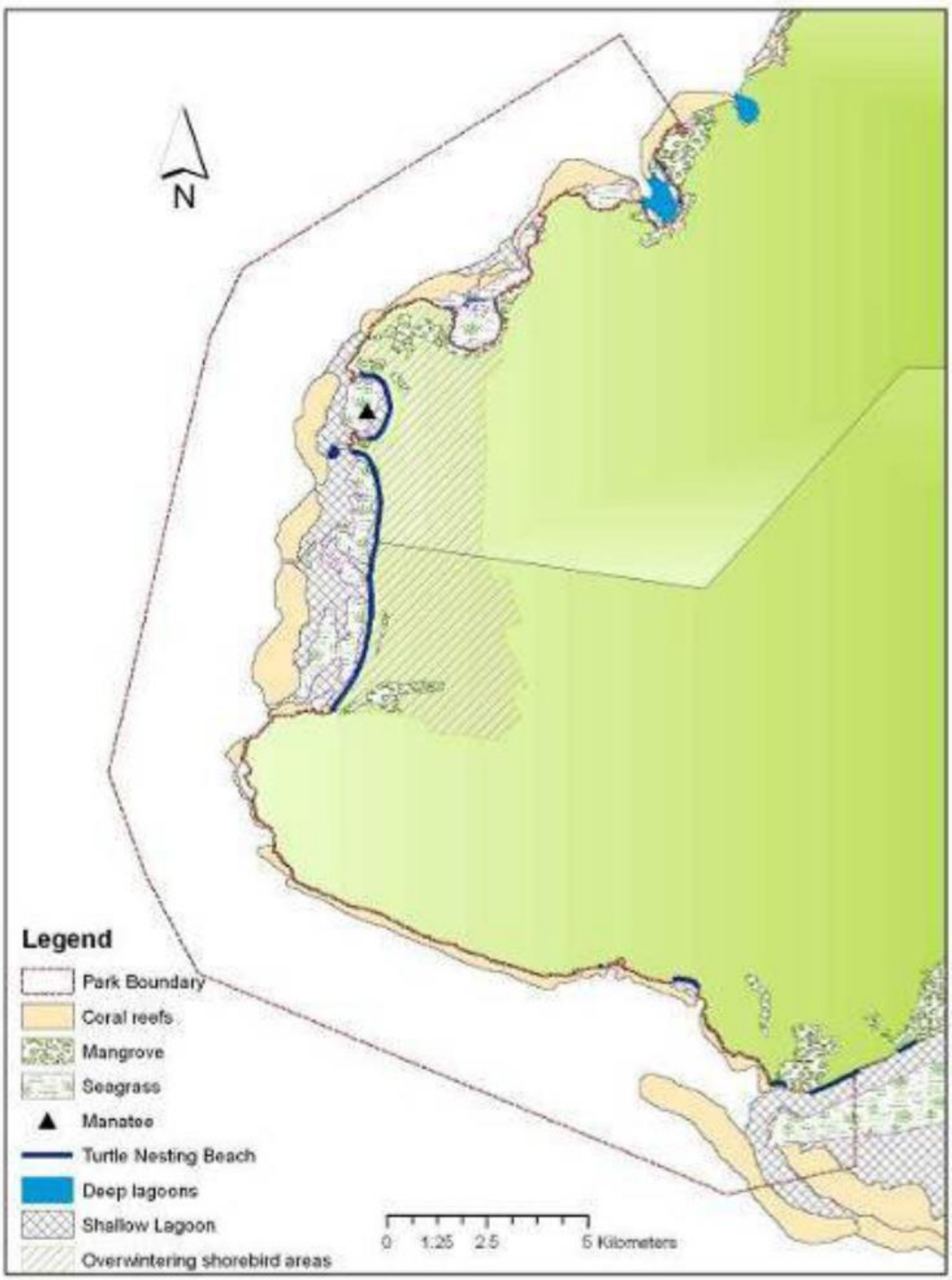
***Source: Dive/snorkel sites (NEPA), benthic habitats (Coastal Atlas, 1997)***

Figure 6-63 shows the benthic habitats mapped in the 1990s as part of the Coastal Atlas project. Figure 6-64 was taken from The Interim Negril Marine Park Zoning Plan 2013-2018 and similarly illustrates the main habitats found within the boundaries of the park. Benthic habitat distribution mapped as part of the RiVAMP project is shown in Figure 6-65. It should be noted that the spatial distribution of the habitats shown in these maps were only used as guidelines and ground truthing exercises were conducted as part of this EIA (see section 6.2.2, Benthic Community).



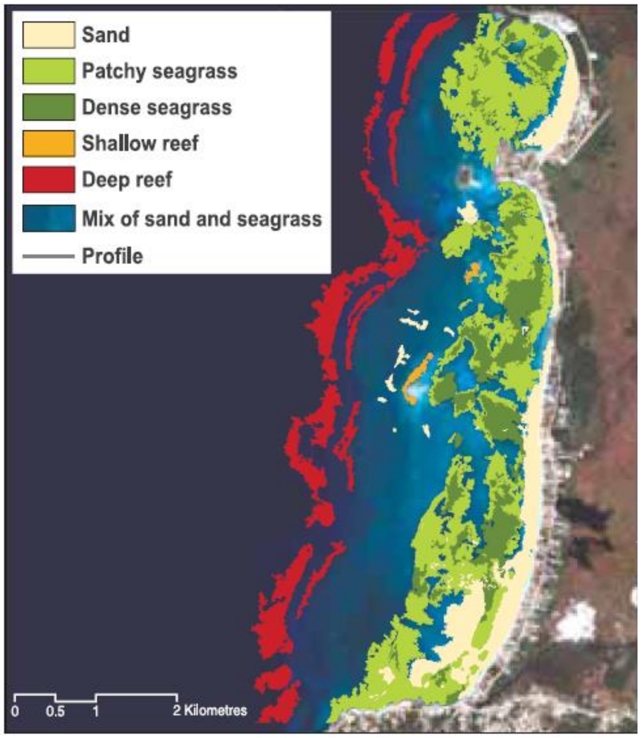

***Source: Dive/snorkel sites (NEPA), benthic habitats (Coastal Atlas, 1997)***

*Figure 6-63 Dive/ snorkel sites and benthic habitats in Long Bay, Negril*




***Source: Ecosystems Management Branch, NEPA 2011***

*Figure 6-64 Map showing the key habitats in the Negril Marine Park*




***Source: (United Nations Environment Programme 2010)***

*Figure 6-65 Distribution of coastal ecosystems based on 2008 satellite imagery as part of RiVAMP study*

A comprehensive risk and vulnerability study (RiVamp) was conducted on Negril in 2010. The link between ecosystems and shoreline protection from sea level rise and storm surge was analysed and seagrass beds and nearshore coral reefs were found to play a critical role in stabilization of the shoreline. The study showed that the absence of reefs in some areas caused 83 % of the shoreline erosion in some areas. The study also proved that the absence of seagrass explained 41 % of the shoreline erosion in a particular area. The width of both the reef and the seagrass bed were found to be significant parameters (RiVamp 2010).

To effectively manage reef resources, information on benthic communities (mainly growth and recruitment) and herbivore densities are required. Healthy reefs must have coral recruits because their presence is a function of the resilience of the coral population and its ability to repopulate a reef. *Diadema* sp. and herbivorous fish densities and their impact on the benthic community also influence reef health (NEPA 2013). Overfishing on the reefs has contributed to a decline in the herbivorous, algal-grazing fish, resulting in reefs that are dominated by algae. Jamaica's reefs have become dominated by algae highly dependent on *Diadema antillarum* to keep algal levels down (NEPA 2011).

Reef Check data is collected annually by the National Environment and Planning Agency (NEPA) from long-term monitoring sites. This is done using a combination of Reef Check and photographic surveys to assess the substrate. The Reef Check methodology produces data in the field via a point intercept method which assesses every 0.5m and provides mean percentage cover for the categories assessed along four discrete 20m transects. The photographic surveys were conducted on five 20m transects at 0.5m intervals with the camera placed at a fixed distance of 0.5 m above the substrate. The images are analysed using *Coral Point Count with Excel extensions* (CPCe). Data generated using this protocol is also represented as percentage cover for substrate categories per site. An assessment of coral recruits was conducted along the same 20m transects laid for the substrate surveys (NEPA 2013).

Table 6-49 shows data recorded at sites within the Negril Marine Park in 2012. The percentage of new recruits per 100m² was very low (average 1.58 %/m²). An average of 24.38 % hard coral was recorded in 2012 (Negril 2013). This is an increase from an average of 16.64 % which was recorded in 2010 (Negril 2011).

*Table 6-49 Biological data recorded at sites within the Negril Marine Park in 2012*

| Site | Hard Coral (%) | Macro-algae (%/100m²) | Bare Substrate (%/100m²) | Recruits (%/100m²) | Diadema (#/m²) | Herbivorous Fish (#/100m²) |
|---|---|---|---|---|---|---|
| Bloody Bay | 25.6 | 36.9 | 29.4 | 0.0 | 96.8 | 119 |
| El Punto Negrilo | 28.8 | 11.9 | 41.3 | 2.5 | 108.3 | 148 |
| Ireland Pen | 15.6 | 35.6 | 45.6 | 3.0 | 21.8 | 162 |
| Little Bay | 27.5 | 16.9 | 25.6 | 0.8 | 0.3 | 144 |
| Average | 24.38 | 25.33 | 35.48 | 1.58 | 56.8 | 143.25 |

Fish communities in the Negril Marine Park were also assessed by NEPA in 2012, as part of their 2012 Status Report (NEPA 2013). This was done using the Roving Diver Technique, in which data were collected for approximately 2 hours along a 200 m line. Fish density and biomass were also assessed using 20m x 5m belts. Twenty-four sites across the island were assessed. Negril was among the top three sites with the highest species richness. Surgeonfish, parrotfish, grunts, snappers and groupers represented the commercially important species found on the Negril reefs, with an overall average fish density of 30.7. The most abundant was the parrotfish (avg. density = 24.4), followed by the ocean surgeonfish (density = avg. 9.5). The snapper and grouper were found in fairly low densities (NEPA 2013).

## 6.2.2 Benthic Community

### *6.2.2.1 Methodology*

Benthic surveys were conducted using 100m long transect line with a 0.7 x 0.7 m photo quadrat (0.5m² area). The lines were placed parallel to the shoreline in a general north-south direction. Pictures were taken every metre along the line and analysed using CPCE.

In order to achieve a minimum sample area of 1% for each breakwater footprint, the total impact area was calculated for each (11,179 $m^2$ in the Northern and 9,270 $m^2$ in the southern). A species area curve (Appendix 12) was then calculated to ensure the CPCE analysis was representative for both the northern and southern. Additional surveys were conducted between the breakwaters (backreef) and in two popular dive sites (Shark reef and Throne room) outside the project footprint (Figure 6-66). A total of 3 transect lines in the northern breakwater (150 $m^2$), 2 in the southern (100 $m^2$), 3 in-between (reef crest/forereef) and 1 at each dive site was conducted.

Manual counts of each photo were also done for both the north and south breakwater. It was observed that majority of the coral community within each breakwater footprints, is composed of small encrusting coral colonies. These colonies are not likely to show up in a typical reef analysis, such as the CPCE analysis. However, as with other pavement zone areas, these types and sizes of corals are common in this area and as such needed to be analysed separately.

General surveys of the backreef seagrass areas were conducted using a glass bottom boat and roving snorkel surveys in order to ground-truth the beds previously mapped (Smith Warner International Limited 2007).

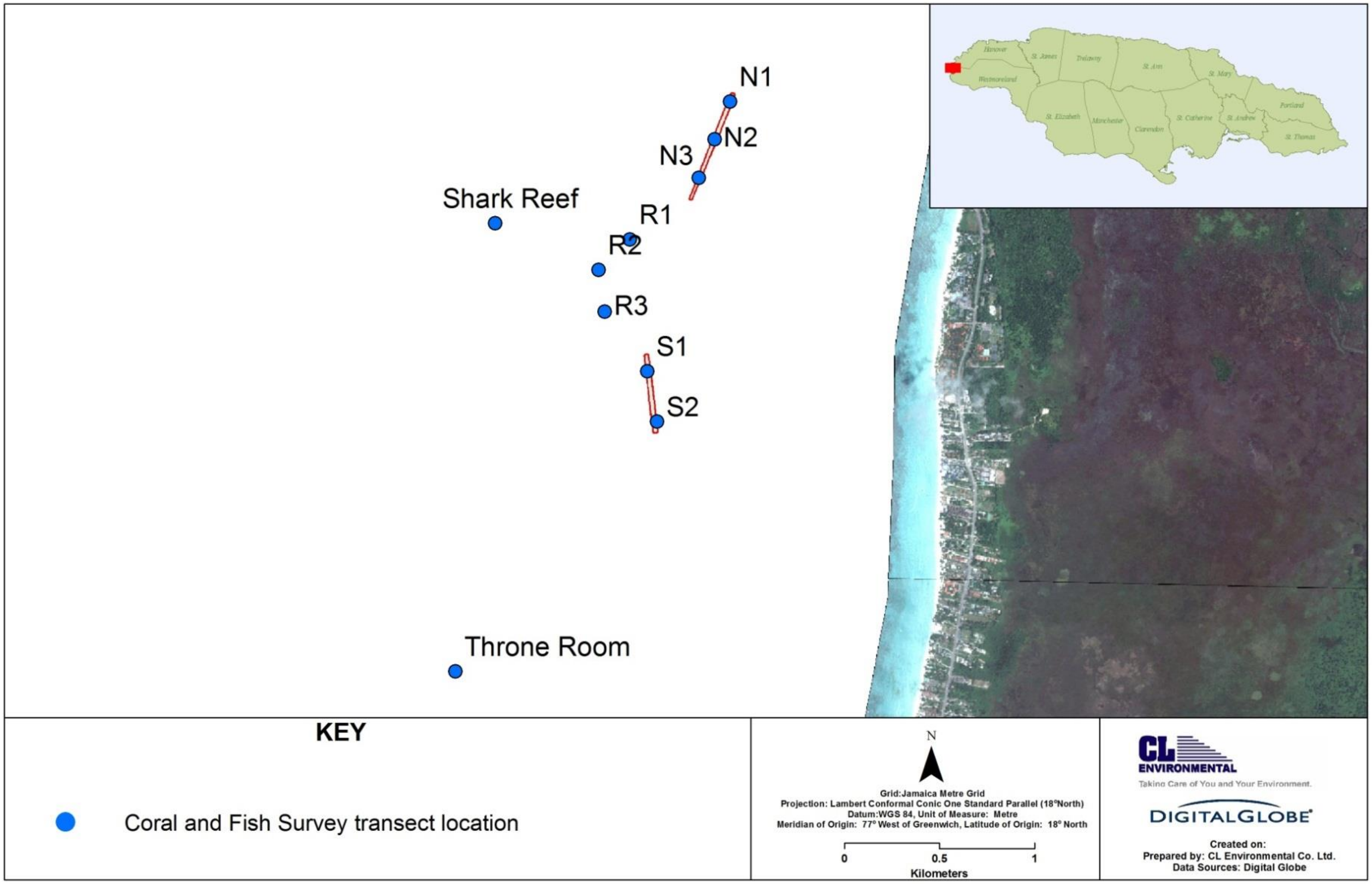



*Figure 6-66 Location of benthic transect lines*

#### *6.2.2.2 Results*

The proposed locations of both the northern and southern breakwaters occur in pavement zone areas. A pavement community is flat, with low-relief, solid carbonate rock with little or no fine-scale rugosity. It is covered with algae, hard coral, gorgonians or other sessile organisms that are dense enough to partially obscure the underly-ing surface in some areas while less colonized sections are covered by a thin sand veneer.

The low-relief, high wave action, heavy usage by divers and fishermen along with other natural and anthropogenic stresses have caused this community to be dominated by macroalgae, with low coral species diversity and few other invertebrates. The algal community is composed of fleshy macroalgae and turfs, with little calcareous (*Halimeda*) or coralline algae present. The coral community is dominated by small encrusting colonies of *Siderastrea* sp. Both soft corals (various species of seawhips and fans) as well as the sponge community are also located with holdfasts and bases on pavement.

The CPCE analysis indicates a coral community with a percent cover less than or equal to 1% in both breakwater footprints. The algal community is composed of fleshy macroalgae and turfs, with little calcareous (*Halimeda*) or coralline algae present. Manual counts of the hard coral community showed that *Favia* and *Siderastrea* sp. accounted for majority of the hard coral community. Both soft corals (various species of seawhips and fans) as well as the sponge community are also located with holdfasts and bases on pavement.

The backreef also has low relief and is dominated by macroalgae. Shark reef and Throne Room, both have more structure and coral diversity but are also dominated by macroalgae. Both dive sites are also deeper than the breakwater and backreef areas.

**Northern Breakwater**

The northern breakwater (Figure 6-67) is dominated by macroalgae 51.9% with a substrate composed of mainly pavement. Hard coral cover is very low 1.0% while soft coral cover is also low but greater than hard coral cover (3.63%). The sponge community accounts for 0.85% and 0.2% were "other-live" organisms identified in the area. No coral disease or bleaching was seen in the transect area and the occurrence appeared to be low in general observations.

The community dynamics expected in a stressed pavement reef area are shown in Figure 6-67. Hard coral cover is low, macroalgae is high. The macroalgal community is dominated by fleshy macroalgae and some turf algae with little or no calcareous or coralline algae seen.

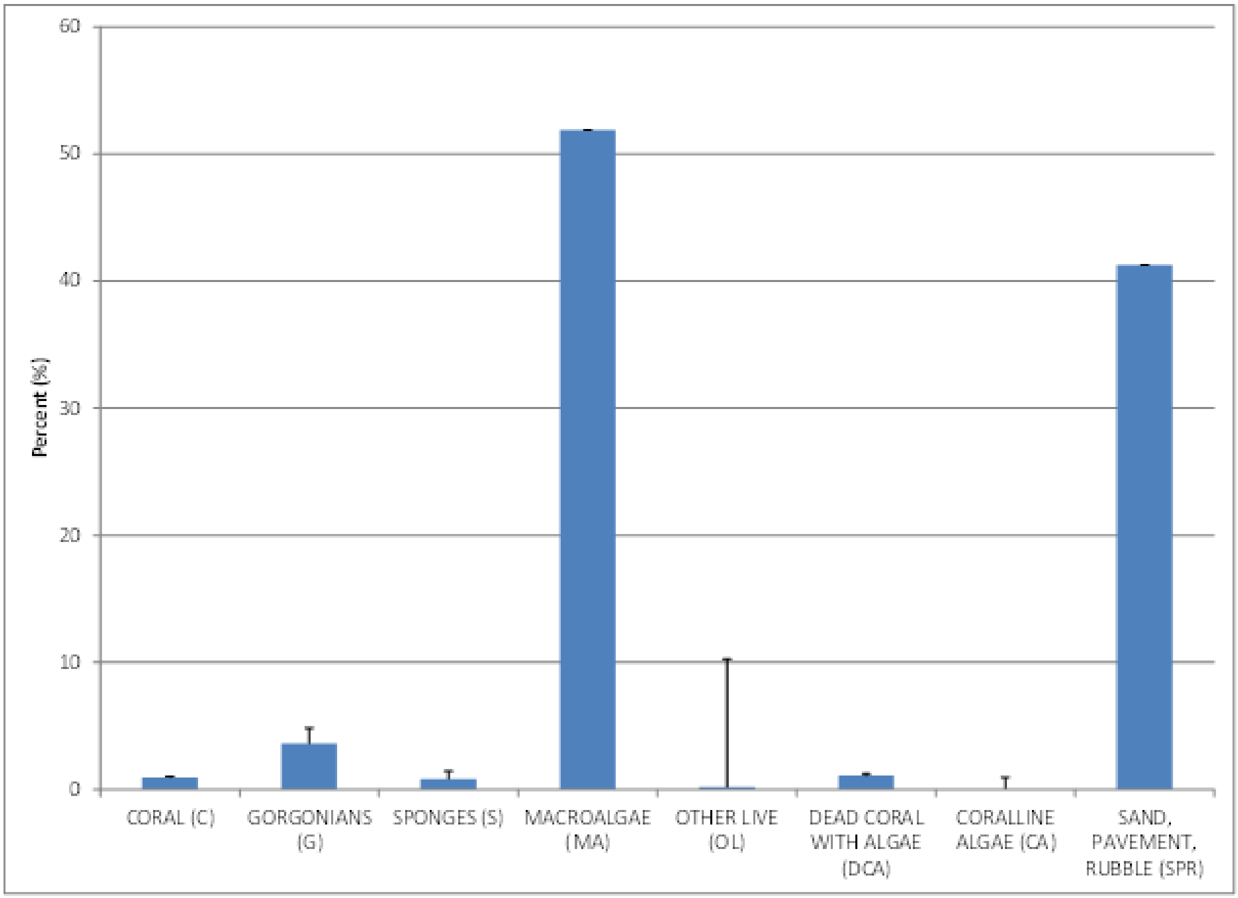



*Figure 6-67 Substrate composition in the Northern Breakwater with standard deviation*

The northern breakwater is dominated by *Siderastrea siderea* followed by *Millepora* and *Mycetopyllia* (Figure 6-68). There is a significant difference between the percent cover of *Siderastrea* when compared to all other species, suggesting low diversity in the community.

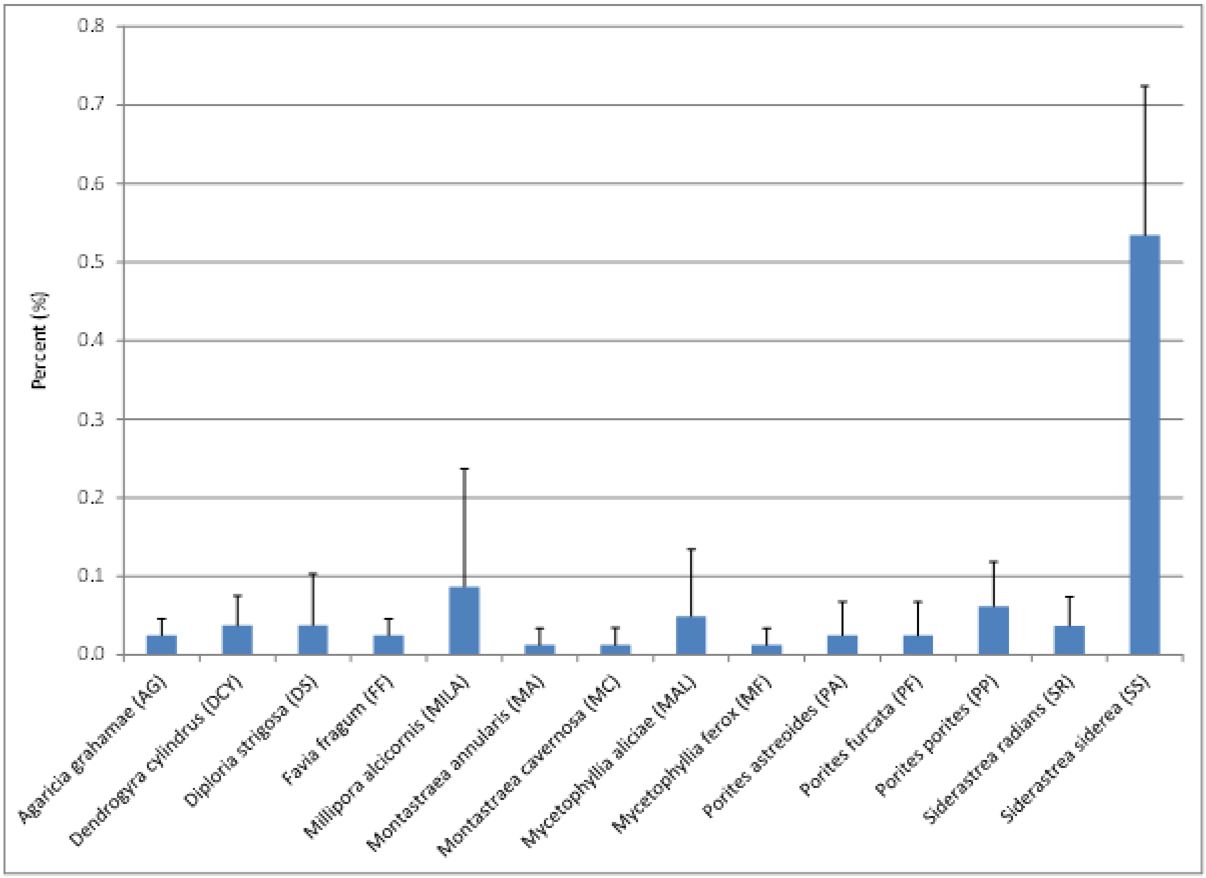



*Figure 6-68 Hard coral species occurrence in the Northern Breakwater with standard deviation*

The overall hard coral species diversity is low, while the eveness appears to be moderate (Table 6-50). The community is dominated by a single species (*Siderastrea siderea*) and the occurrence of that species is consistent throughout the transect areas.

*Table 6-50 Diversity Indices:- Shannon-Weaver and Simpson Diversity in the Northern Breakwater*

| | | | |
|---|---|---|---|
| **Shannon-Weaver Index** | **1.06** | **0.77** | **0.93** |
| **Simpson Index of Diversity (1-D)** | **0.58** | **0.43** | **0.56** |

The typical sections of pavement zone area in the Northern breakwater are shown in Plate 6-6 to Plate 6-8. Plate 6-6 shows some small structures and some soft corals present in the footprint. Plate 6-7 shows a similar area but with almost no structure, while Plate 6-8 shows a typical transect photo of a pavement area covered with macroalgae and thin layer of sand.


*Plate 6-6 Pavement zone in Northern Breakwater*

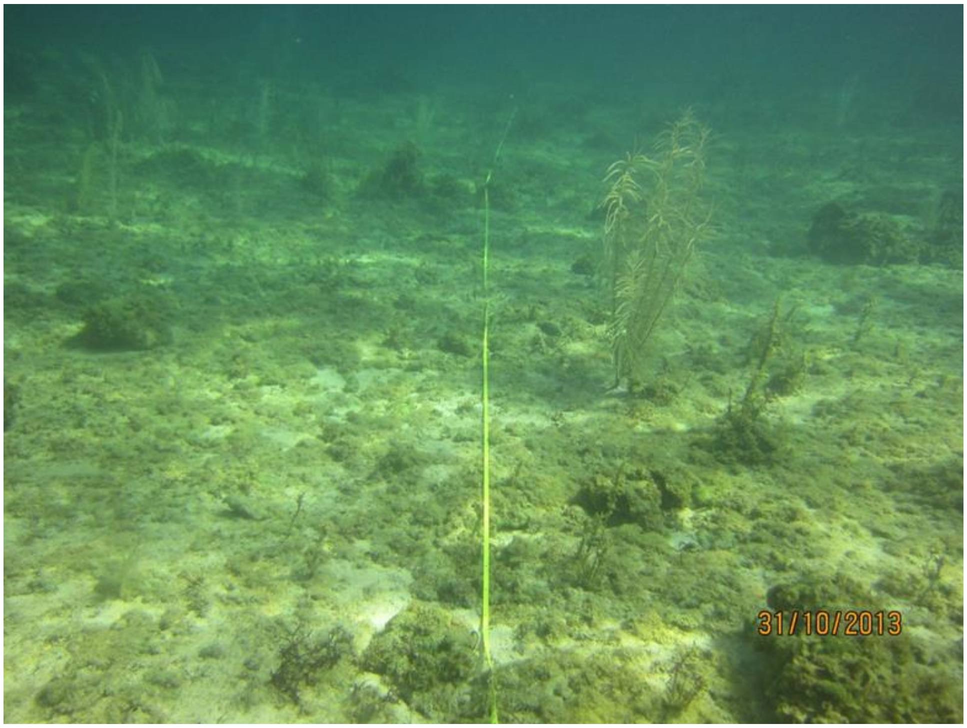



*Plate 6-7 Pavement zone in Northern Breakwater*

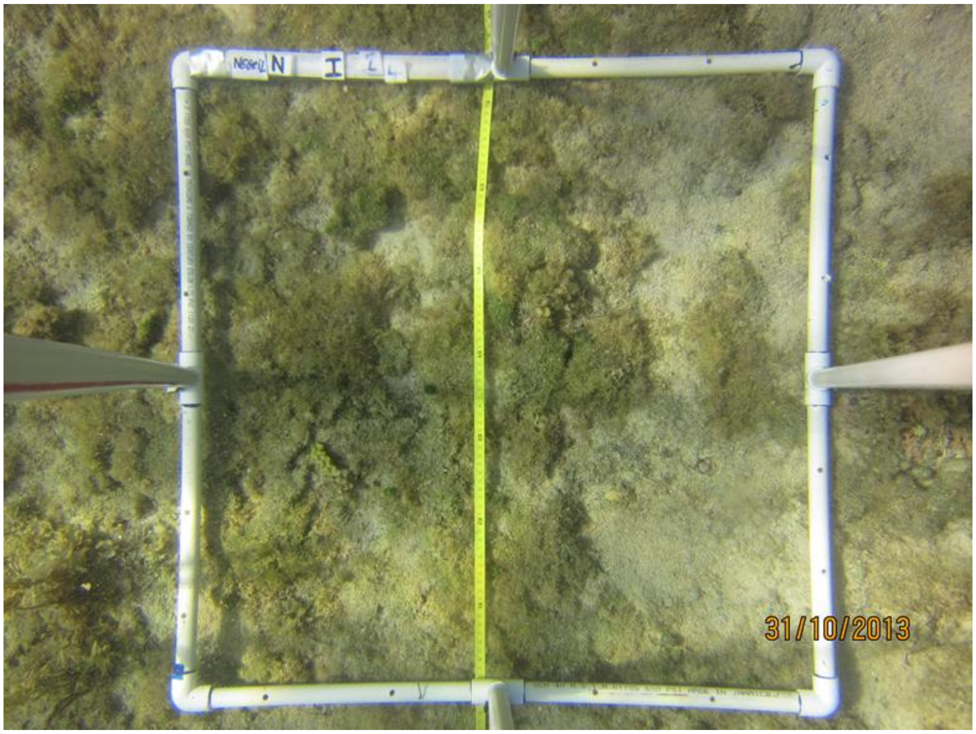



*Plate 6-8 Typical transect photograph showing pavement covered with macroalgae and a thin sand veneer*

**Southern Breakwater**

The southern breakwater (Figure 6-69) is dominated by macroalgae 71.1% with a substrate composed of mainly pavement. Hard coral cover is very low 0.5% while soft coral cover is also low but greater than hard coral cover (3.63%). The sponge community accounts for 1.9% and 0.7% were "other live" organisms identified in the area. No coral disease or bleaching was seen in the transect area and the occurrence appeared to be low in general observations, similar to the Northern breakwater.

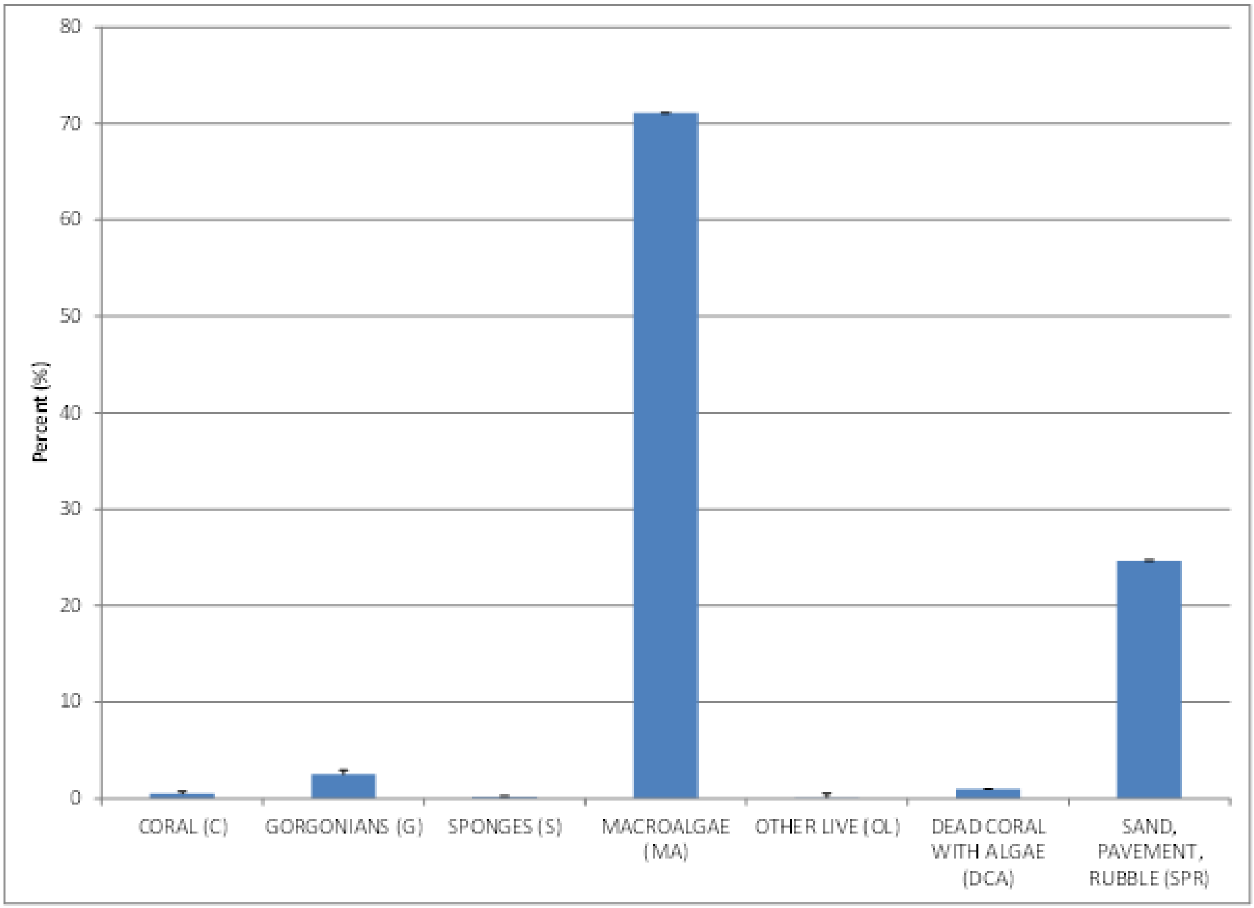



*Figure 6-69 Substrate composition in the Southern Breakwater with standard deviation*

The hard coral community distribution is similar to the northern breakwater (Figure 6-70). The community has low diversity and richness (Table 6-51) and is dominated by a single species, *Siderastrea siderea*.

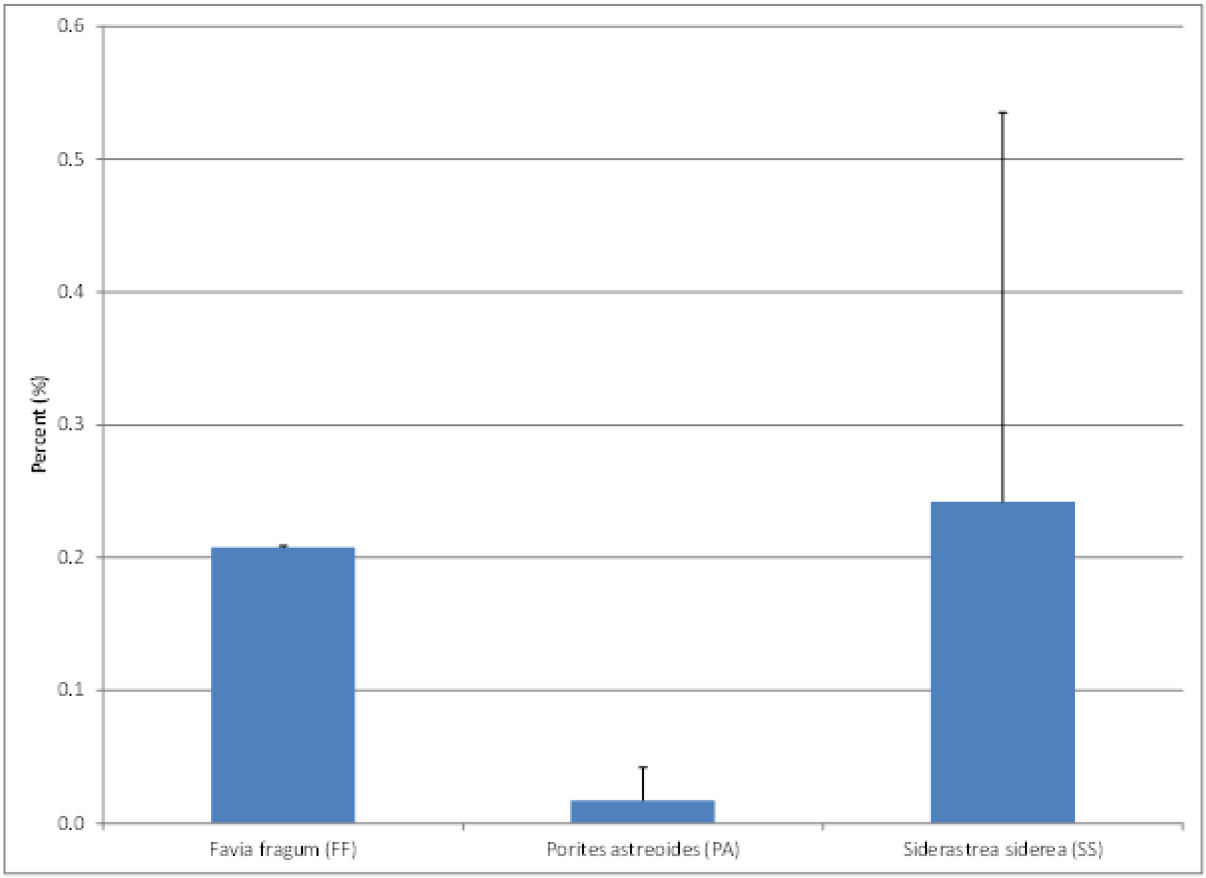



*Figure 6-70 Hard coral species occurrence in the Southern Breakwater with standard deviation*

Similar to the Northern breakwater, coral community diversity is low while the eveness or distribution of each species appears to be patchier than in the Northern.

*Table 6-51 Diversity Indices:- Shannon-Weaver and Simpson Diversity in the Southern Breakwater*

| | | |
|---|---|---|
| **Shannon-Weaver Index** | **0.77** | **0.76** |
| **Simpson Index of Diversity (1-D)** | **0.44** | **0.43** |

Plate 6-9 and Plate 6-10 are examples of sections within the Southern Breakwater. Plate 6-9 shows some structure with a large *Siderastrea* colony, sponges, *Diadema* and other colonising species. Plate 6-10 shows a typical section of pavement with macroalgae and thin layer of sand.

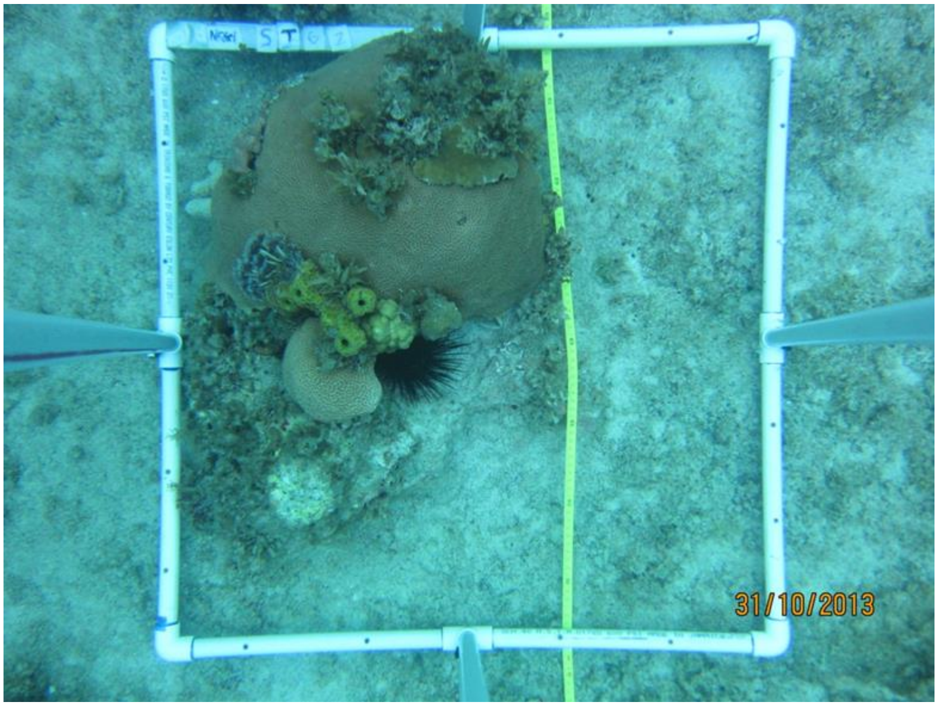



*Plate 6-9 Photo transect with a small patch reef with a large Siderastrea colony*

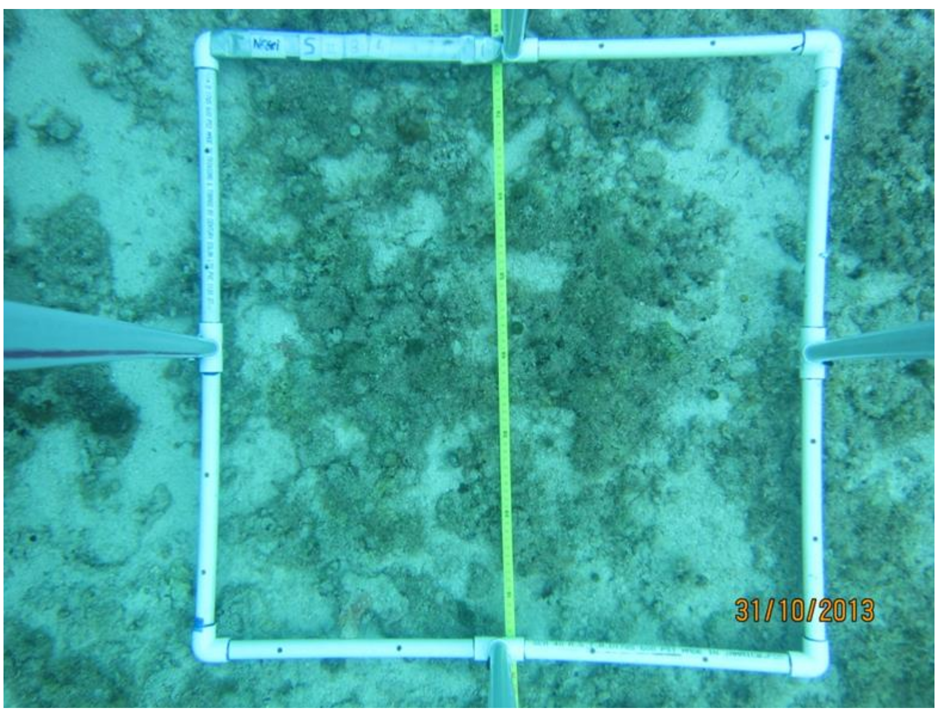



*Plate 6-10 Pavement covered with macroalgae and a thin layer of sand*

**Reef Crest/Forereef**

The forereef (Figure 6-71) is dominated by macroalgae 33.54% with a substrate composed of mainly pavement (50.89%). Hard coral cover is low 1.6% while soft coral cover is also low but greater than hard coral cover (2.33%). The sponge community accounts for 0.71% and 0.27% were other live organisms identified in the area. No coral disease or bleaching was seen in the transect area and the occurrence appeared to be low in general observations. These results have similarities to both the breakwater communities, with slight increases in hard coral cover and deceases in macroalgae. This area has more structure and complexity, unlike the uniform flat pavement in the breakwater footprint.

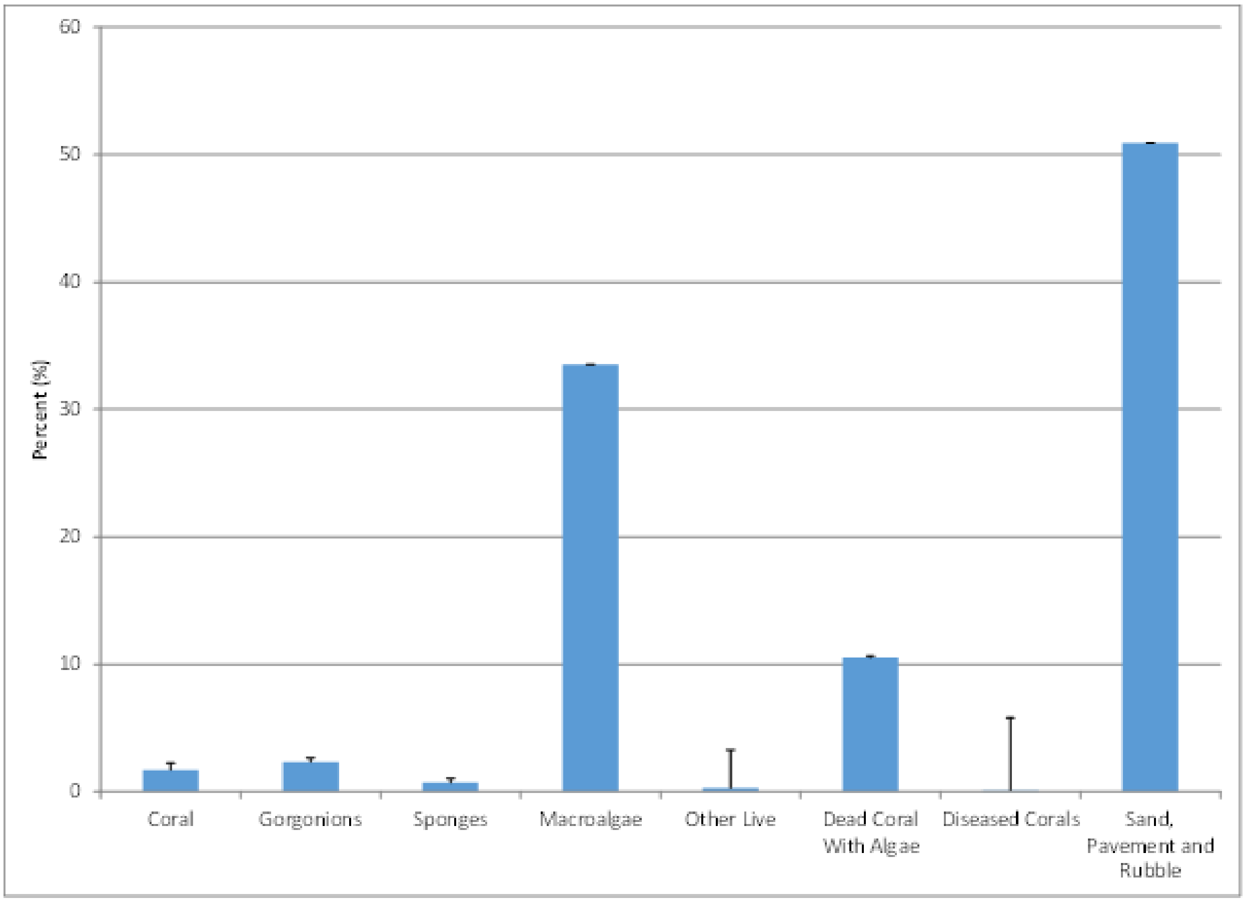



*Figure 6-71 Substrate composition of the Forereef/Reef crest with standard deviation*

The hard coral species community appears to be dominated by *Siderastrea*, however there appears to be a more even diversity (Table 6-52).

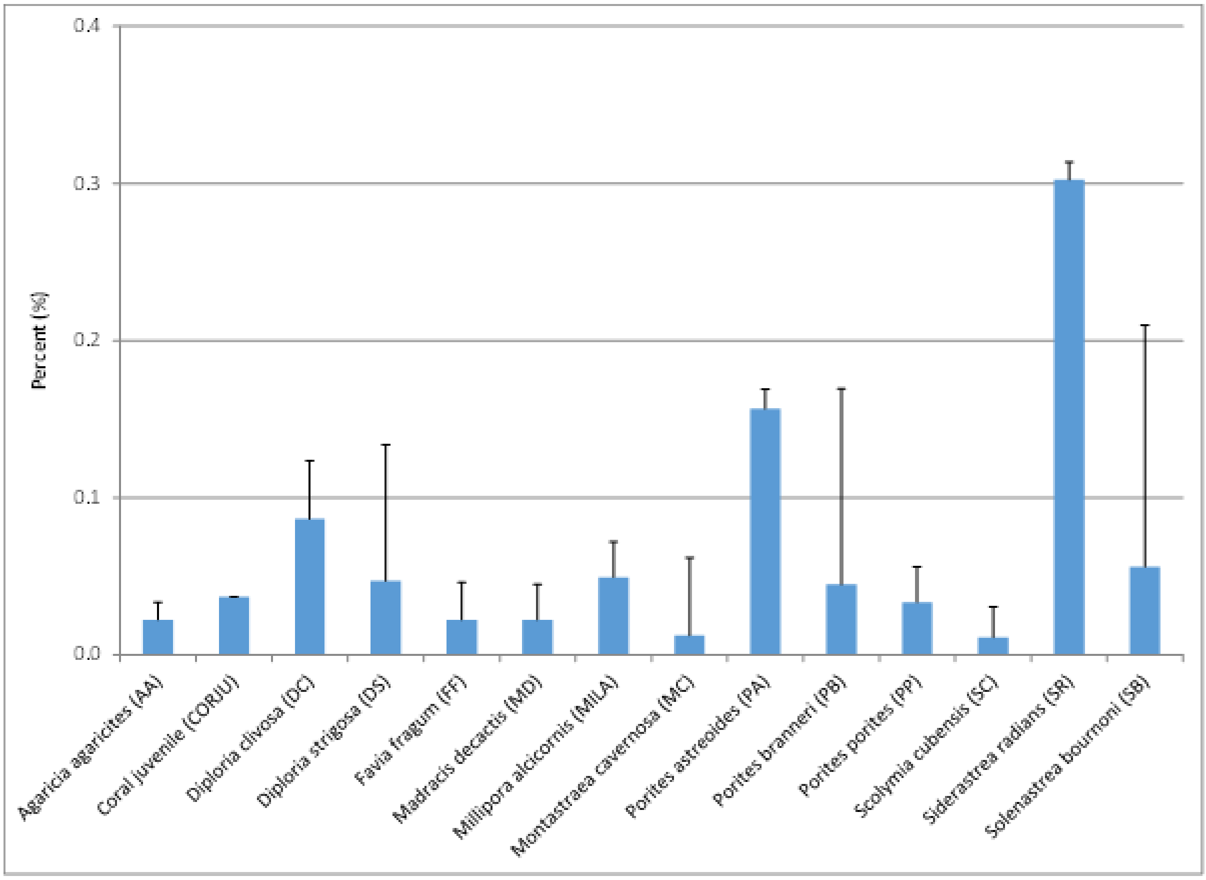



*Figure 6-72 Hard coral species occurrence in the Forereef/Reefcrest with standard deviation*

The coral community of the Forereef is more diverse and evenly distributed than the breakwater areas. The increased reef structure increases ecological volume and surface area of the community, which has resulted in a slightly more diverse community.

*Table 6-52 Diversity Indices:- Shannon-Weaver and Simpson Diversity for the Forereef/Reefcrest*

| | | | |
|---|---|---|---|
| **Shannon-Weaver Index** | **1.12** | **0.79** | **1.35** |
| **Simpson Index of Diversity (1-D)** | **0.61** | **0.47** | **0.69** |

Plate 6-11 is an example of low relief dominated by macroalgae and a moderately sized *Siderastrea* (the most dominant coral), unlike Plate 6-12 which shows the typical pavement with no structure (similar to the pavement zone in both the Northern and Southern breakwaters). Plate 6-13 shows a change in substrate; this area is shallow and near the reef crest and as such is composed of mainly reef rock and rubble.

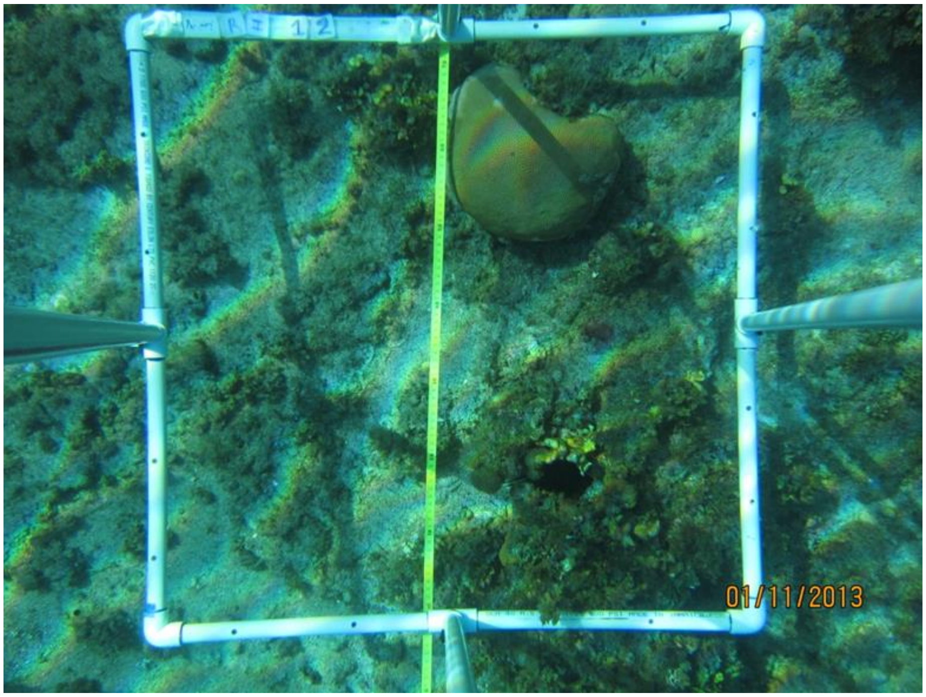



*Plate 6-11 Typical section between the breakwaters with low relief*

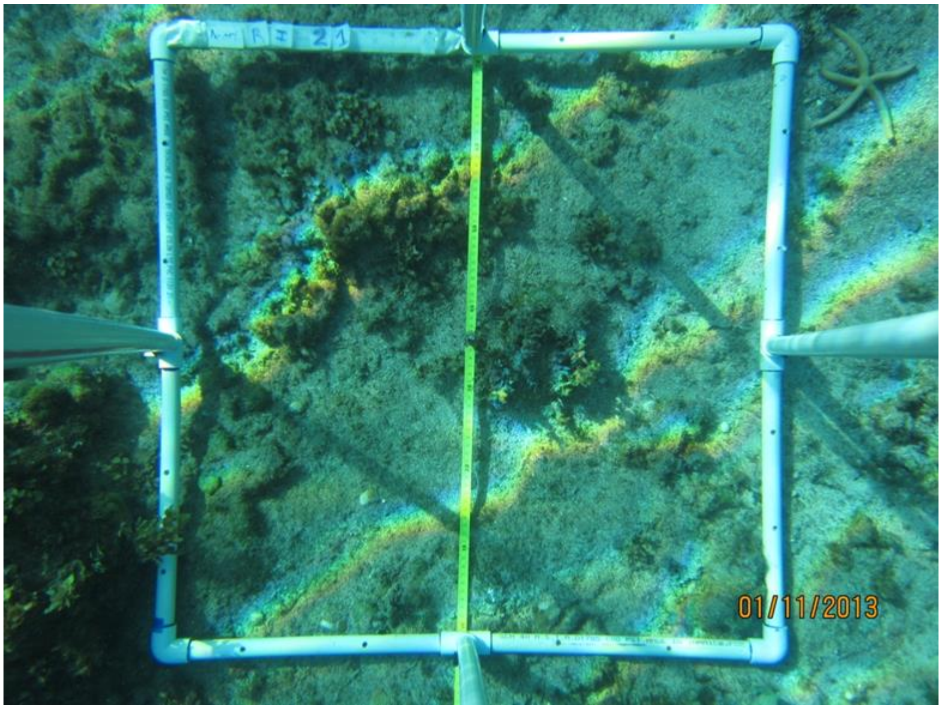



*Plate 6-12 Transect photograph pavement and very small structures*

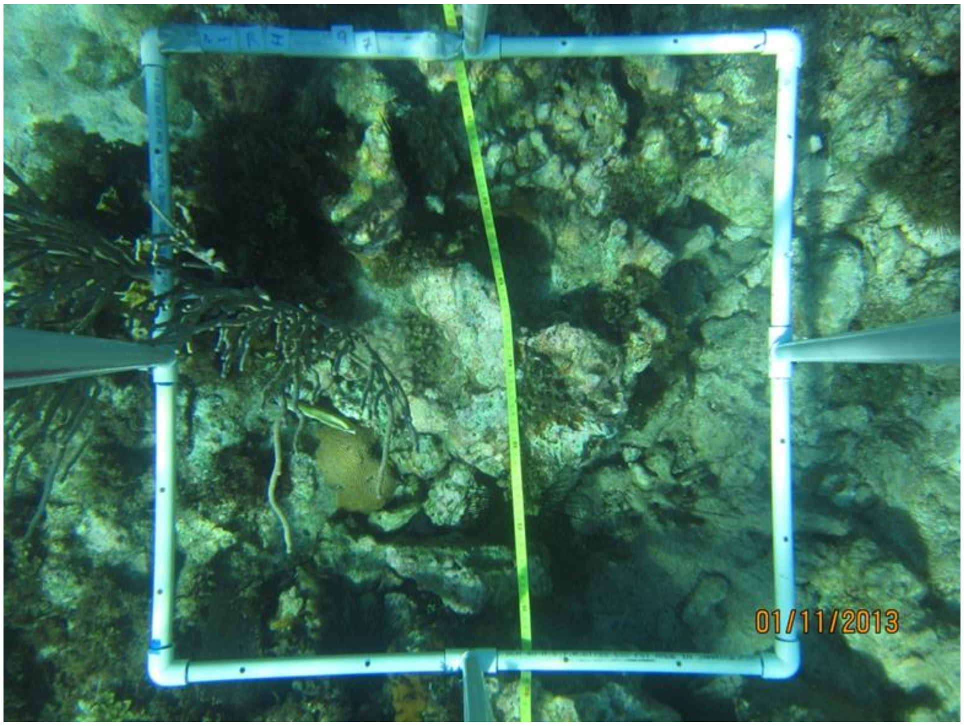



*Plate 6-13 Rubble and reef rock substrate in shallow sections near the crest of the reef*

**Manual Count**

*Hard Coral Community*

The manual count of hard coral species in each breakwater footprint yielded slightly different results from the CPCE analysis. The manual count allowed for determination of species, size class distribution and growth form of all hard corals in the transect line. Additional detail of size class distribution and growth form was also obtained for soft corals and sponges.

In the Northern breakwater, 86.8% of all corals are encrusting (Table 6-53) 96.8% of all corals less than 5cm are encrusting, 66.7% for all corals between 5 and 10 cm are encrusting while only 4.6% of all corals larger than 10cm are encrusting. In the Southern breakwater, 96.8% of the hard coral community is encrusting of that, 100% of all corals less than 5 cm are encrusting, 58.3% between 5 and 10cm and 22.2% of all corals 10cm and larger.

*Table 6-53 Total encrusting and size class distribution for hard corals in Northern and Southern Breakwaters*

| SIZE CLASS (cm) | NORTH BW | SOUTH BW |
|---|---|---|
| <5 | 96.80% | 100% |
| >5<10 | 66.70% | 58.30% |
| >10 | 4.60% | 22.20% |
| Total Encrusting | 86.80% | 96.80% |

The hard coral community is dominated by small encrusting colonies. The most dominate species is *Favia fragum* followed by *Siderastrea* sp. and *Porites* sp. Although these corals are small, they should not be considered recruits or juveniles as many can stay this size for their entire life. Their morphology and size is based on their environment, not age or ability to reproduce.

An estimated 152,880 (Table 6-54) hard corals are located in the north Breakwater footprint. Of these 86.8% are encrusting on pavement while in the Southern Breakwater 9,592 hard corals, 96.8% are encrusting (Table 6-55).

*Table 6-54 Total Hard Corals Found in each Breakwater footprint*

| SIZE CLASS (cm) | NORTH BW | SOUTH BW |
|---|---|---|
| <5 | 123120 | 60648 |
| >5<10 | 19440 | 2016 |
| >10 | 10320 | 1512 |

Due to small size of these corals, CPCE was not sufficient in describing this part of the coral community but was sufficient in giving a general substrate composition.

*Soft Coral and Sponge Community*

A total of 210 soft corals were estimated to occur in the Northern breakwater footprint while 57 were seen in the Southern breakwater (Table 6-55).

*Table 6-55 Soft Coral Summary Table*

| **Gorgonian** | **North Breakwater** | | **South Breakwater** | |
|---|---|---|---|---|
| **SeaWhip** | **Encrusting** | **Other** | **Encrusting** | **Other** |
| Large | 19 | 0 | 0 | 0 |
| Medium | 43 | 1 | 13 | |
| Small | 36 | 4 | 25 | 1 |
| **Total** | **98** | **5** | **38** | **1** |
| **SeaFan** | | | | |
| Large | 5 | 1 | | 0 |
| Medium | 18 | 10 | 2 | 0 |
| Small | 48 | 25 | 15 | 1 |
| **Total** | **71** | **36** | **17** | **1** |
| **TOTAL** | **169** | **41** | **55** | **2** |
| **All Soft Corals** | **210** | | **57** | |

A total of 80.5% of all Gorgonians were encrusting on pavement in the Northern breakwater while 96.5% were in the Southern breakwater (Table 6-56). The Northern breakwater had a few large whips and fans while the south had none.

*Table 6-56 Percentage Summary of Soft Coral*

| **Gorgonian** | **North Breakwater** | | **South Breakwater** | |
|---|---|---|---|---|
| **SeaWhip** | **Encrusting** | **Other** | **Encrusting** | **Other** |
| Large | 9.0% | | | |
| Medium | 20.5% | | 22.8% | |
| Small | 17.1% | 1.9% | 43.9% | 1.8% |
| **Total%** | **46.7%** | **1.9%** | **66.7%** | **1.8%** |
| **SeaFan** | | | | |
| Large | 2.4% | 0.5% | | |
| Medium | 8.6% | 4.8% | 3.5% | |
| Small | 22.9% | 11.9% | 26.3% | 1.8% |
| **Total%** | **33.8%** | **17.1%** | **29.8%** | **1.8%** |
| **TOTAL%** | **80.5%** | **19.1%** | **96.5%** | **3.5%** |

*Sponge Community*

The Northern breakwater has an estimated 12,240 encrusting sponges and 6,540 other sponges (Table 6-57) an estimated total of 18,780 sponges. The southern breakwater has an estimated 504 encrusting sponges and 2,520 other sponges, a total of 3,024 sponges. Most of the sponge community in the Northern breakwater was composed of small encrusting sponges while in the south, the sponge community appears to be dominated by small rope, tube and barrel sponges. The Northern breakwater had a much larger sponge community but was composed mainly of encrusting growth forms, including nuisance species such as *Cliona sp.* and *Chondrilla sp.* The Southern Breakwater appeared to lack large sponges and has less encrusting growth forms.

*Table 6-57 Total Number of sponges found in each Breakwater*

| **Size Class** | **NORTH BW Growth Form** | | **SOUTH BW Growth Form** | |
|---|---|---|---|---|
| | *Encrusting* | *Other (rope, tube, colonial, barrel)* | *Encrusting* | *Other (rope, tube, colonial, barrel)* |
| SMALL | 8160 | 5040 | 336 | 2352 |
| MEDIUM | 3840 | 960 | 168 | 168 |
| LARGE | 240 | 240 | 0 | 0 |

**Dive Sites**

Shark Reef and Throne Room are of a similar depth and reef topography and both located in the Long Bay area. Both sites were unlike the breakwater and forereef, in terms of general environmental parameters; depth and structure. However similarly, both reefs are dominated by macroalgae, 42.66% (Figure 6-73). Hard coral cover is higher than in the other study areas (8.51%) while soft coral cover is also low (2.27%). The sponge community accounts for 2.27% and 0.65% were other live organisms identified in the area. No coral disease or bleaching was seen in the transect area and the occurrence appeared to be low in general observations, similar to other study areas. These results are unlike those obtained in the shallow study areas and project footprint.

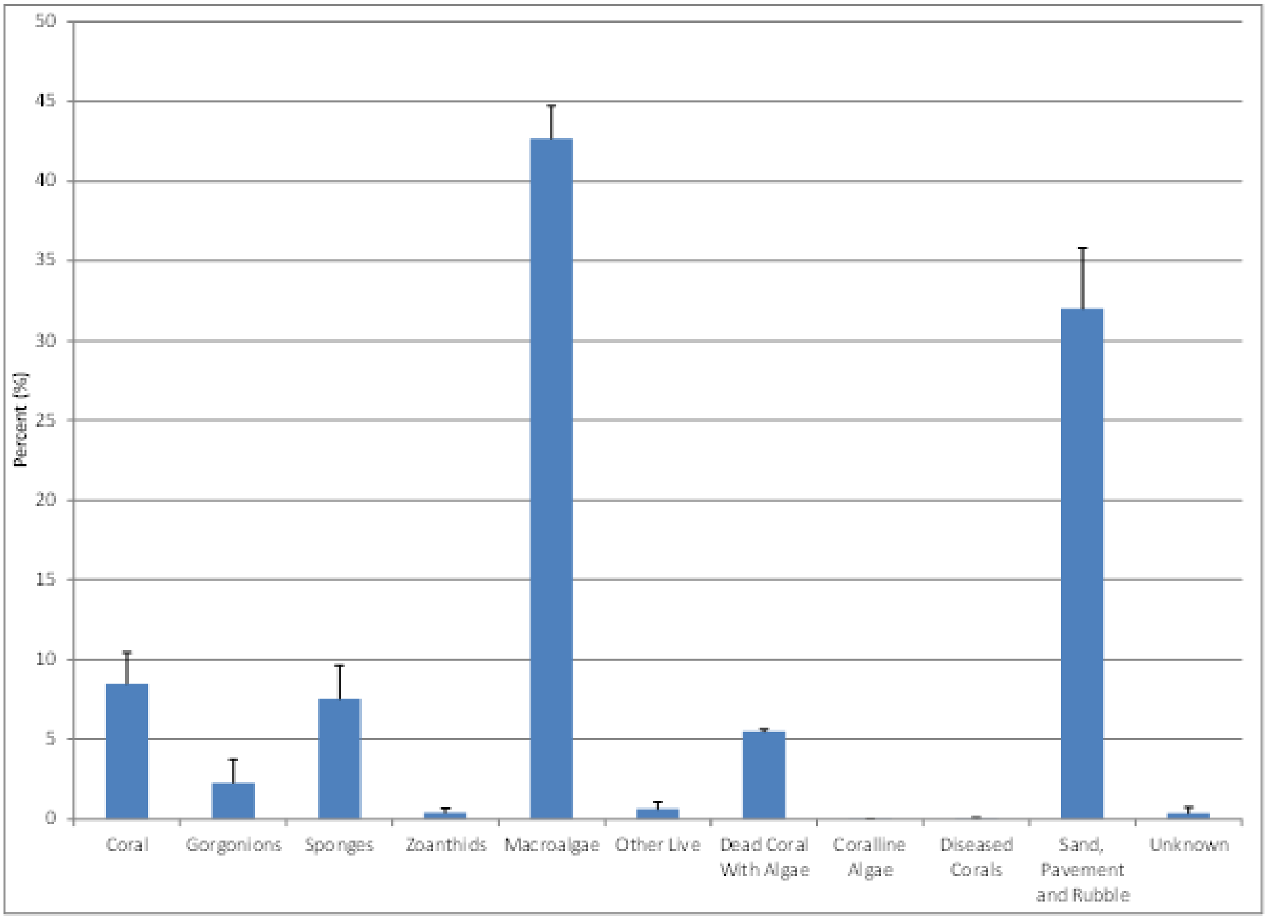



*Figure 6-73 Substrate composition of both dive sites; Sharks Reef and Throne Room with standard deviation*

The hard coral species community appears to be more diverse than previous study and project sites; however both communities contain *Siderastrea siderea* (2.96%) as the most common species, which was significantly more common than all other species. This was closely followed by *Agaricia agaricites* (1.30%) as shown in Figure 6-74.

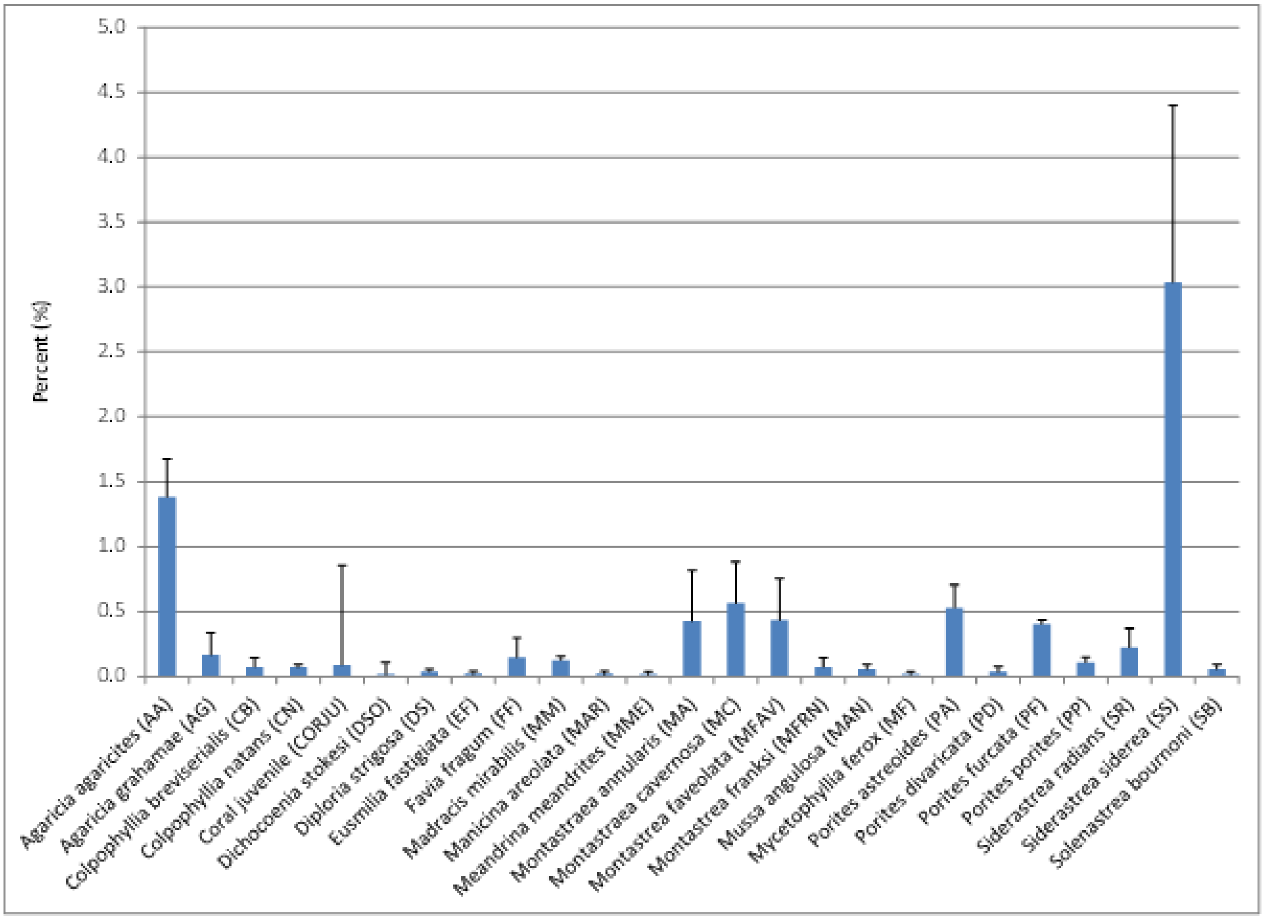



*Figure 6-74 Hard coral species occurrence at Shark Reef and Throne Room with standard deviation*

Hard coral diversity is higher than in other survey areas and there appears to be a slightly more even distribution of hard coral species across the sites (Table 6-58).

*Table 6-58 Diversity Indices:- Shannon-Weaver and Simpson Diversity Sharks Reef and Throne Room*

| | | |
|---|---|---|
| Shannon-Weaver Index | 1.32 | 1.56 |
| Simpson Index of Diversity (1-D) | 0.66 | 0.73 |

Both dive sites, Shark Reef and Throne Room, were similar in depth and structure. Both had several patch reefs with some coral disease, some nuisance invertebrates and lionfish. The coral and sponge community is more diverse than any of the other study sites shown in Plate 6-14 - Plate 6-18.

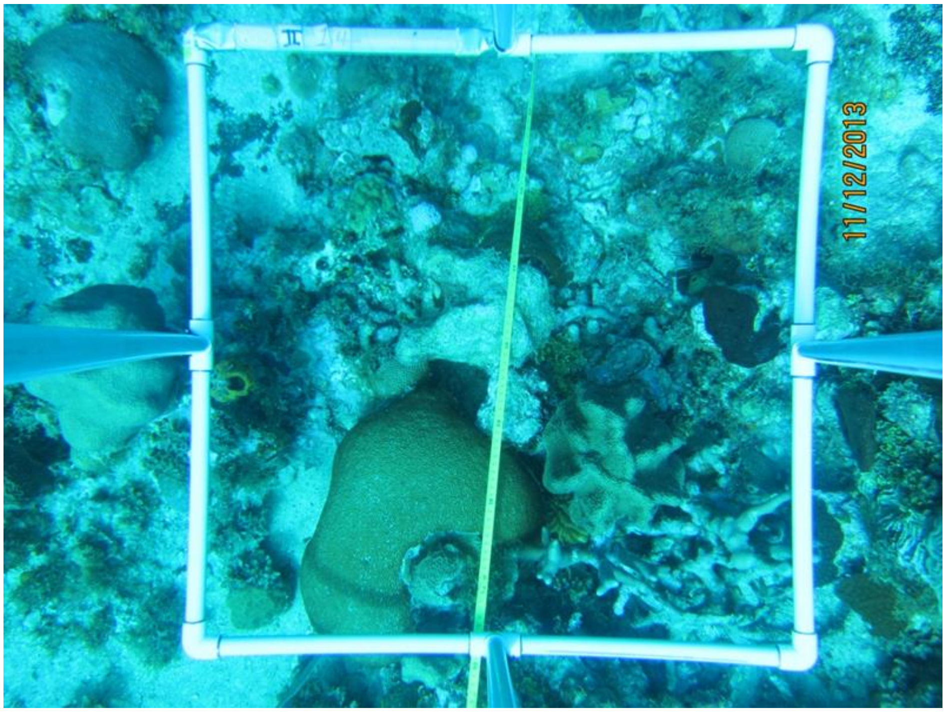



*Plate 6-14 Typical patch reef in transect area*


*Plate 6-15 Patch reef colonised by 5 Lionfish*

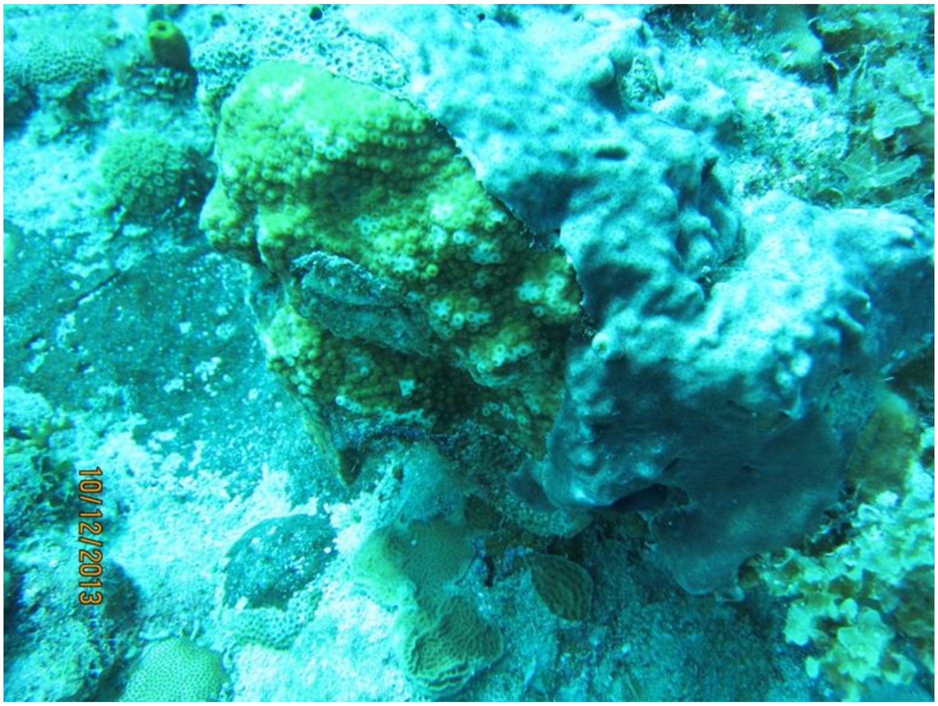



*Plate 6-16 An example of an ascidian (nuisance invertebrate) overgrowing a Montastrea colony*

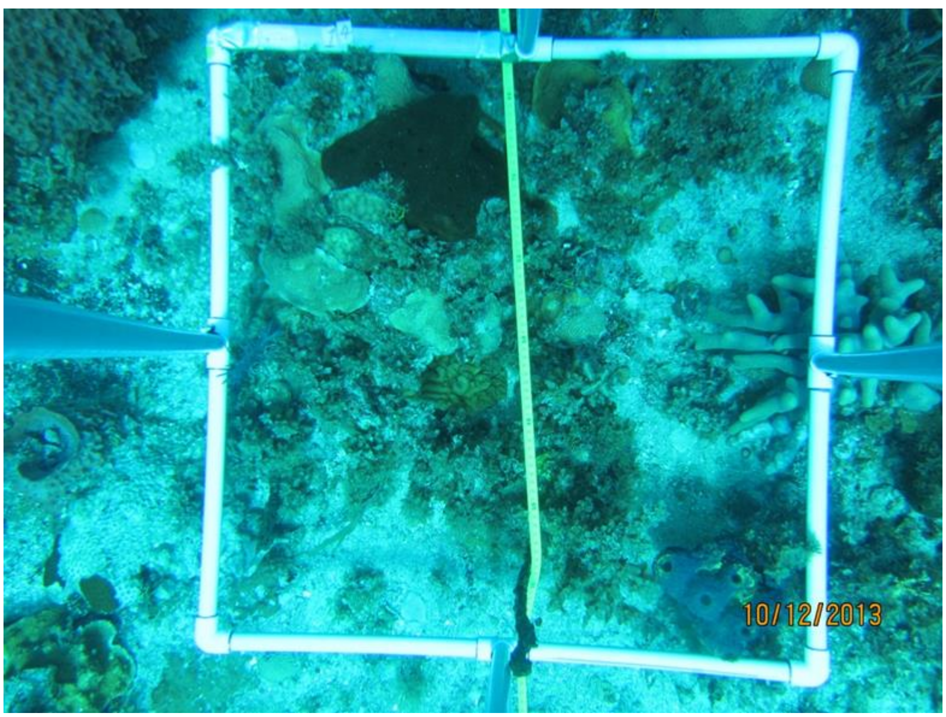



*Plate 6-17 Patch relief with a diverse coral community*


*Plate 6-18 Typical patch reef with several moderately sized structures*

**General Comparisons**

General community dynamics; Hard Coral, Macroalgae and Soft Coral percentage composition are similar across all sites (Figure 6-75). Each site surveyed in this study is dominated by macroalgae with very low hard coral cover and low soft coral cover.

The Southern breakwater had significantly higher macroalgal cover than all other sites while the Forereef had the least. Hard coral cover was significantly higher in the dive site areas than all other survey areas (which were not significantly different from each other). Soft coral cover was similar between all stations.

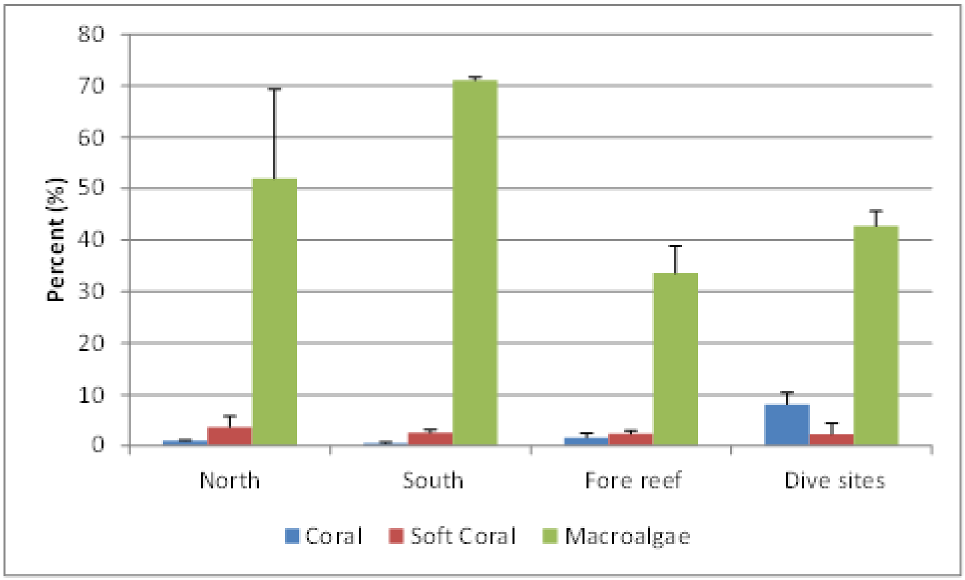



*Figure 6-75 General Community Dynamics; Hard Coral, Macroalgae and Soft Coral across all study sites with standard deviation*

**Groyne Assessment**

A roving survey of the northern groyne was conducted. The groyne community is composed of large amounts of macroalagae (turfs and fleshy), coralline algae, sponges, hard corals, invertebrates (i.e. urchins, bivalves and lobsters) and relatively large schools of fish, including numerous lionfish. The coral community was composed of several large colonies including *Montastrea annularis, Porites asteroides* and *Diploria sp.* Numerous small colonies of *Siderastrea sp.* were also seen on the groyne as well as dislodged pieces alongside. Plates 4-23 – 4-26 show various coral species observed in and around the eastern groyne.

The Groyne is used by a diverse fish community dominated by large schools of Goat fish and juvenile Mahogany Snapper (Plate 6-23), as well as several juvenile and young adult lionfish (Plate 6-24). Other fish species observed associated with the groyne were Yellow Tail Snappers, Sergeant Majors, Parrot fish and Surgeon fish. These fish were observed within cracks and crevices within the groyne, which had several holes and loose blocks.

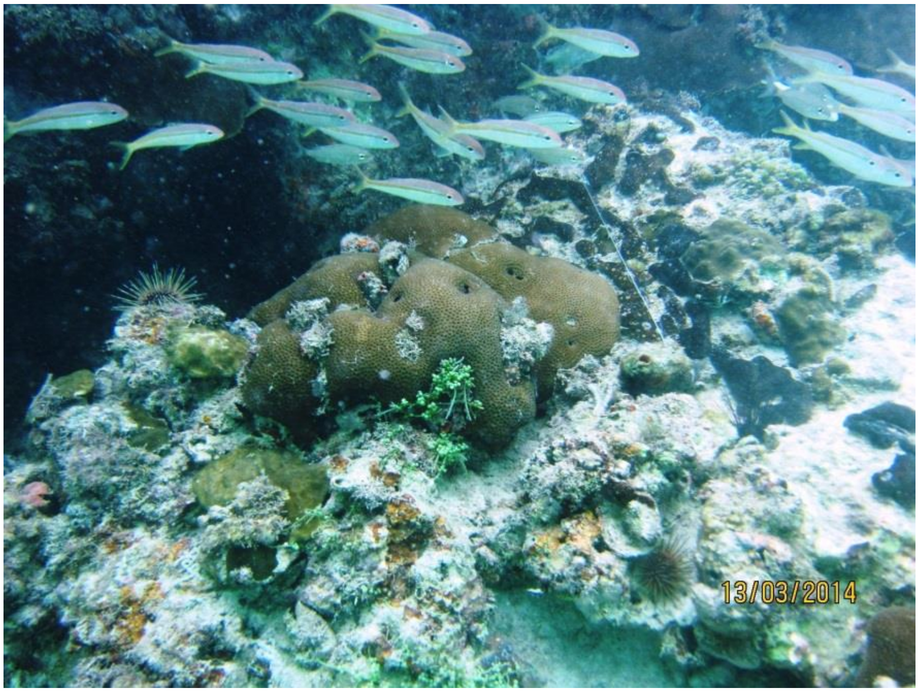



*Plate 6-19 Photo showing Siderastrea colony along groyne*


*Plate 6-20 Photo showing Montastrea colony growing on groyne*


*Plate 6-21 Photo showing Diploria, sponges and ascidians growing on groyne*


*Plate 6-22 Photo showing numerous colonies of Siderastrea sp.*


*Plate 6-23Photo showing large school of fish with consisted mainly of Goat fish and Mahogany Snapper*

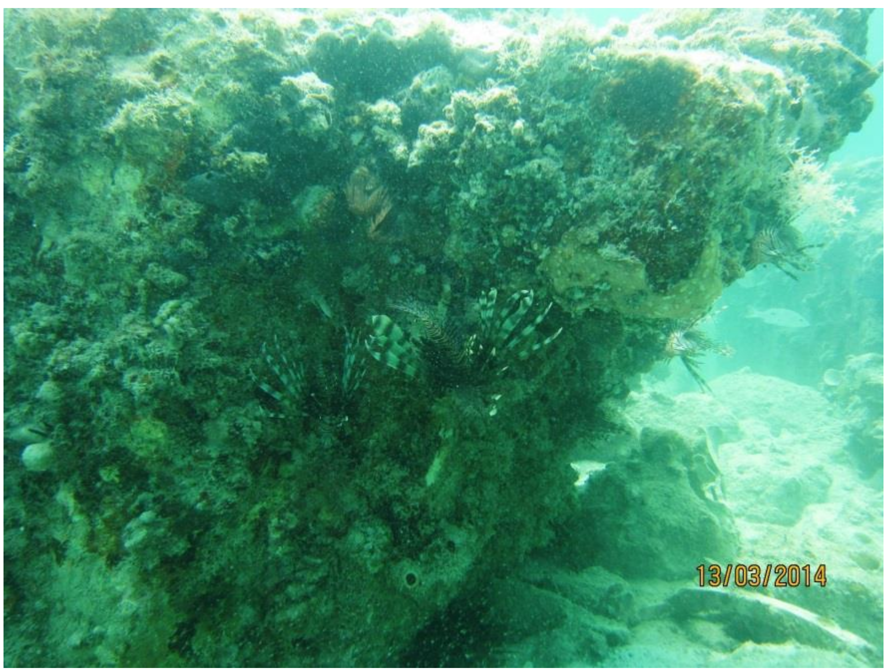



*Plate 6-24 Photo showing numerous lion fish found along the groyne*

## Seagrass and Backreef Communities

*Seagrass Communities*

From the SWIL (2006) study in Long Bay, the extent of the Seagrass bed was determined using satellite imagery and ground truthing exercises. The extents of the beds are shown in Figure 6-76. The report identified *Thalassia* sp. as the dominant type interspersed with *Syringodium* sp. and large sand patches present in some areas.

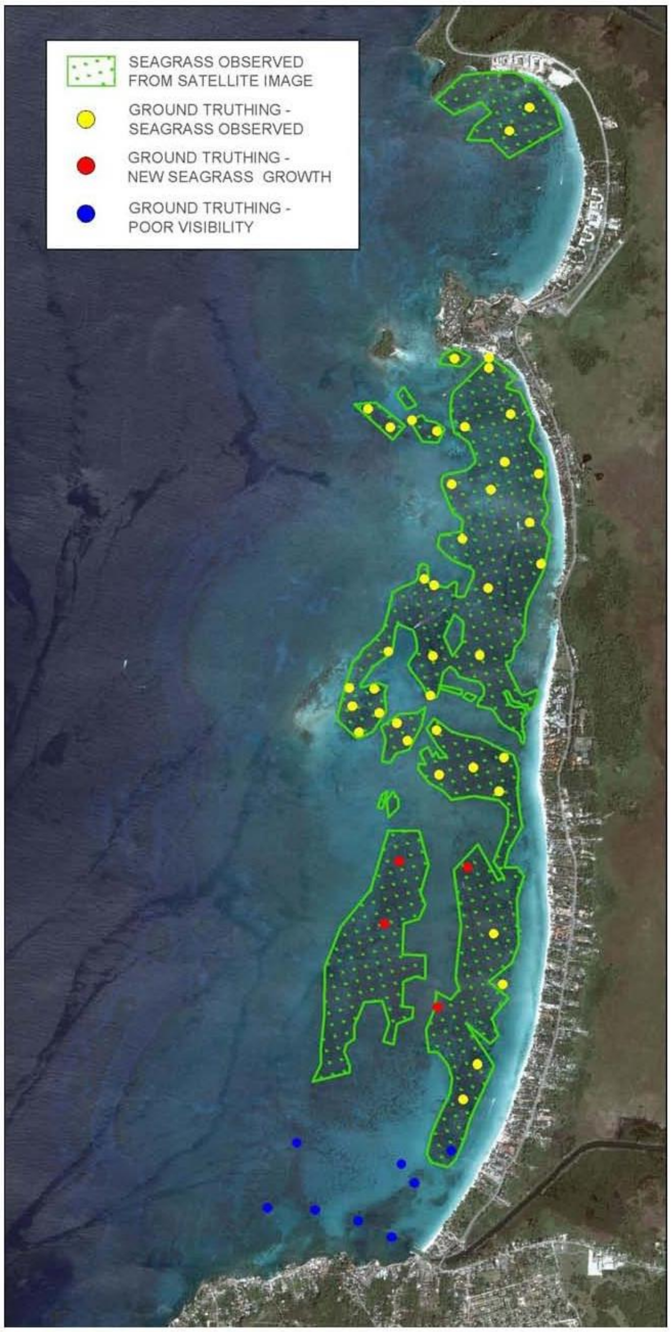



*Figure 6-76 Seagrass beds within Long Bay (taken from Erosion Negril Beach, 2006)*

In the present study the majority of the Seagrass beds were located within the backreef and consisted mainly of *Thalassia sp.* and *Syringodium sp.* (Plate 6-25 and Plate 6-26). The density of these beds varied throughout the bay. Areas of mixed beds were also observed in close proximity to the reef crest (Plate 6-27). This area was also covered with algae (Plate 6-28) and had several patch reefs behind the crest. Typical seagrass fauna were also observed; including *Lytechinus*, *Tripnuestes*, heart urchins and sea cucumbers. *Mancenia areolata* and *Porites divaricata* were also seen within the bed.


*Plate 6-25 Syringodium bed in the backreef*


*Plate 6-26 Thalassia within the backreef*

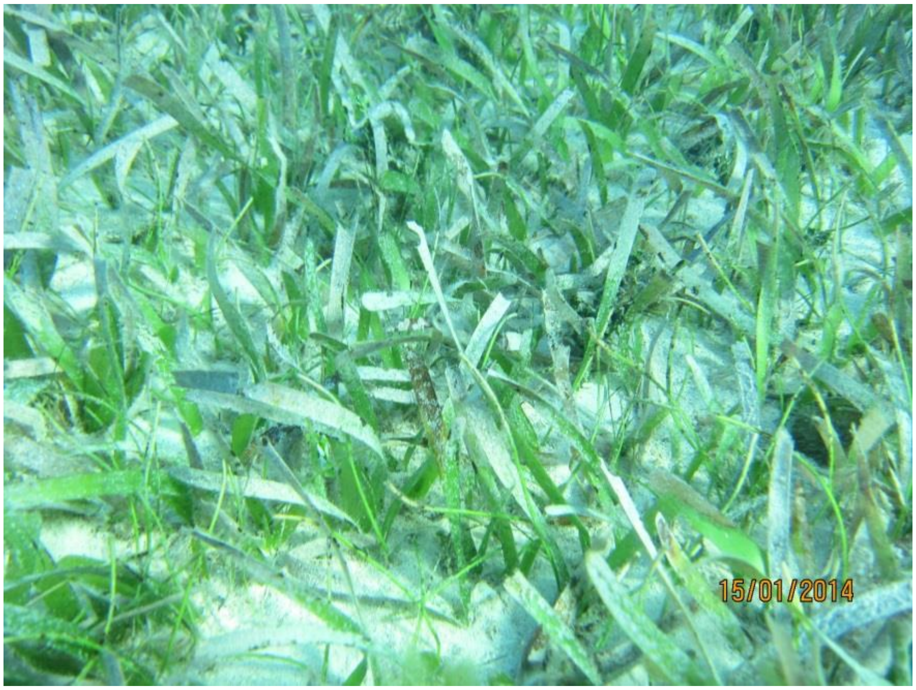



*Plate 6-27 Mixed bed of Thalassia and Syringodium*


*Plate 6-28 Thalassia near to the reef crest area*

*Plate 6-29 Fleshy macroalgae in the seagrass bed*

Numerous sand patches were observed within the Seagrass bed with large tracts showing blowouts or erosion at the seaward facing side (Plate 6-30). These blowouts could be due to high wave energy experienced at these exposed locations, while smaller blowouts can be caused by boat/anchor damage. Very little seagrass was observed within the breakwater footprint areas with the substrate being mainly pavement with some rubble (Plate 6-31).


*Plate 6-30 Seagrass bed showing erosion edge*

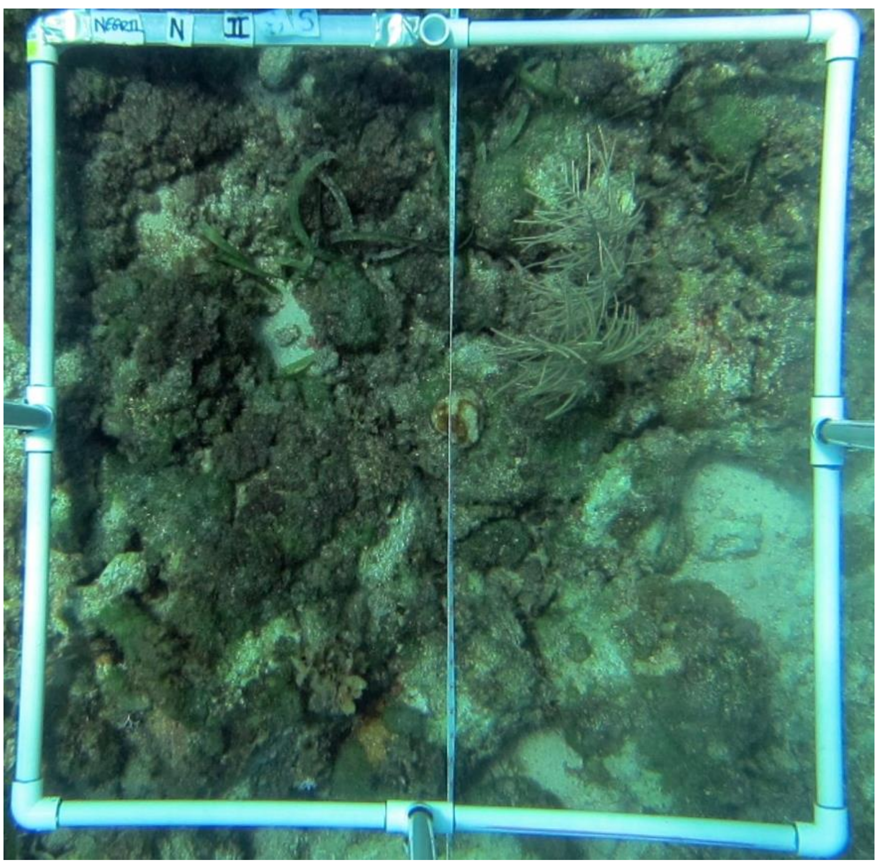


*Plate 6-31 Sparse seagrass within the footprint area growing on a rocky substrate*

*Backreef*

*Acoropora palmata* colonies were seen in the shallow along the length of the reef crest nearest the Northern Breakwater (Plate 6-32). Several patch reefs are located in the backreef area; in particular the areas nearest the reef crest. Hard and soft corals, fish and invertebrates were also observed throughout the area (Plate 6-33). Several sections were similar to the areas seen in the breakwater footprint (Plate 6-34).


*Plate 6-32 Large A. palmata colony*


*Plate 6-33 Shallow reef crest with seagrass, sea fans, Millipora and large amounts of macroalgae*


*Plate 6-34 Small patch reef and pavement area, similar to that seen in the Breakwater footprints*

### 6.2.3 Phytoplankton and Chlorophyll *a*

#### *6.2.3.1 Methodology*

A 5L Niskin bottle was used to collect whole water samples at discrete depths through the water column. Eighteen (18) stations were sampled within Long Bay. Samples for the chlorophyll *a* analysis were collected in 1L plastic bottles and stored in the dark. Phytoplankton samples were collected in 250ml plastics bottles containing 3ml Lugol's preserved and stored in the dark for analysis at a later date. Sample dates were: November 14, 2013; November 27 and 28, 2013 and December 10 and 11, 2013.

For phytoplankton counts, each whole water sample was gently homogenized by inversion, to randomly distribute the phytoplankton cells. In cases where sampling stations had multiple samples collected from various depths, these samples were combined to form integrated whole water samples which were then homogenized. Based on the visible density of the phytoplankton cells, 10 – 100 ml aliquots of each homogenized sample were used to fill settling chambers. The chambers were left to stand overnight to allow settling of the phytoplankton before examination using a Leitz Labovert (model no. 020-435.025) inverted microscope.

The counting technique used, varied according to the density of the settled phytoplankton cells in each sample. Dense concentrations of phytoplankton in settled samples were counted using thirty random fields of view of the base of the settling chamber. The phytoplankton in these thirty fields were identified and enumerated using a X32 objective lens, then the entire base of the chamber was examined using the same lens, to record any phytoplankton species that were not observed during the initial enumeration process. Sparse concentrations of phytoplankton in settled samples were counted by identifying and enumerating phytoplankton species throughout the entire base of the settling chamber using the X32 objective lens.

The concentration of each species was determined by calculating the number of cells per litre in each sample and the species diversity index of the phytoplankton community recorded during each sample run was calculated using the Shannon-Weaver (1949) formula:

$$H = -\Sigma pi(\ln pi)$$

Where pi = Ni/N represents the proportion of species in the community
Ni = number of individuals of a species i
N = total number of individuals

For Chlorophyll *a* analysis, four litres (4L) of seawater was filtered using a stacked column filter. Three different sizes of filters were utilized; 20µm, 2.7µm and 0.7µm. The pigments were extracted from the concentrated algal sample in an aqueous sample of acetone (6ml). The chlorophyll *a* concentration was determined using a spectrophotometer and measuring the absorbance of the extract at a specific wavelength. The resulting absorbance measurements are then applied to a standard equation shown below.

Chlorophyll *a* concentration $mg\ chlorophyll\ a\ m^{-3} = R^*(v/V)$

Where R is the Fluorometer reading
v is the volume of acetone used for extraction in ml
V –is the volume of water sample filtered in litres

### 6.2.3.2 Results

**Phytoplankton Composition**

The phytoplankton community was comprised of 192 species (Appendix 13) represented by seven divisions namely: Bacillariophyta (diatoms - 48 genera, 120 species), Dinophyta (dinoflagellates - 18 genera, 45 species), Cyanophyta (blue-green algae - 13 genera, 18 species), Chlorophyta (green algae - 5 genera, 6 species) Euglenophyta (euglenoids – 1 genus, 2 species) and Chrysophyta (golden algae – 1 genera, 1 species). Based on percentage composition, the diatoms formed the dominant group, comprising 63% of the total species composition. The *Navicula* and *Nitzschia* genera, were the most diverse and common genera of both the diatom group and community as a whole, with *Nitschia* sp. F dominating based on percentage frequency of occurrence and abundance. The diatoms were followed by the dinoflagellates (23%), blue-green algae (9%), green algae (3%), euglenoids (1%) and golden algae (1%) in percentage composition. It should be noted that the species composition of the phytoplankton at some stations, particularly station 1 at the mouth of the South River showed changes from diatom to blue-green algal dominance for sample run 2 conducted on November 27 & 28, 2013. This change in group dominance indicates an increase in both freshwater and nutrient flow to the site as blue-green algae especially species of *Oscillatoria* and *Anabaena* which were both identified, are bio-indicator species of fresh to low brackish water and moderate to high levels of nutrients, likely from organic pollution (Onyema, 2013). Examination of salinity values for sample run 2, station 1 confirmed the suggested increase in freshwater flow to station 1, with a significant decrease in the salinity.

According to Kilham and Kilham (1980) diatoms tend to dominate algal communities in nutrient rich environments such as coastal upwelling systems for example. Diatoms are classified as r-selected species which have high maximum growth rates, usually requiring high concentrations of nutrients to sustain those rates. The diatom dominated community of Long Bay, Negril thus suggests that the area is nutrient rich as a whole or more likely impacted by sporadic inputs of high nutrients from nearby freshwater percolations or inflows. This is evidenced by the change in dominance to blue-green species at station 1, with a decrease in salinity during sample run 2, as well as the presence of a significantly high total phytoplankton abundance (22,600 cells/L) at the shoreline station 15, sample run 1 conducted November 14, 2013 compared to other stations.

Twenty-seven (14 %) of the 192 species comprising the community were classified as rare (Table 6-59), having a total frequency of occurrence of < 10% throughout the samples and generally low total abundance values ranging from 10 – 700 cells/L, and one species having an abundance of 2,840 cells/L but occurring only at one station. These species are important because they contribute to the control of the levels of species diversity of the area. Any changes in the surrounding environmental conditions due to siltation, nutrient loading, and toxic chemicals for example, can result in the loss of rare species as well as abundant species leading to a decrease in the diversity of the area. This can then negatively impact the organisms of higher trophic levels that are dependent on the phytoplankton for survival through their role as the organisms forming the basis of the marine food web.

*Table 6-59 Rare phytoplankton species within the phytoplankton community*

| Species | Total Abundance (cells/L) | % Frequency |
|---|---|---|
| **Bacillariophyta (diatoms)** | | |
| *Amphidinium carteri* | 10 | 6 |
| *Amphiprora* sp. B | 60 | 6 |
| *Attheya* sp. | 10 | 6 |
| *Chaetoceros peruvianus* | 10 | 6 |
| *Chaetoceros* sp. F | 10 | 6 |
| *Chaetoceros* sp. G | 10 | 6 |
| *Gomphonema* sp. | 80 | 6 |
| *Navicula cuspidata* | 180 | 6 |
| *Navicula* sp. I | 45 | 6 |
| *Nitzschia acuminata* | 10 | 6 |
| *Nitzschia* sp. I | 90 | 6 |
| *Nitzschia* sp. J | 45 | 6 |
| *Plagiotropis lepidoptera* | 20 | 6 |

| Species | Total Abundance (cells/L) | % Frequency |
|---|---|---|
| *Pseudoeunotia doliolus* | 10 | 6 |
| **Dinophyta (dinoflagellates)** | | |
| *Ceratium trichoceros* | 10 | 6 |
| *Ceratocorys horrida* | 10 | 6 |
| *Coolia areolata* | 10 | 6 |
| *Coolia monotis* | 20 | 6 |
| *Gonyaulax* sp. B | 20 | 6 |
| *Oxytoxum gigas* | 10 | 6 |
| *Prorocentrum lima* | 2,840 | 6 |
| *Pyrodinium bahamense* var *bahamense* | 30 | 6 |
| **Cyanophyta (blue-green algae)** | | 6 |
| *Anabaena confervoides* | 700 | 6 |
| *Fisherella* sp. | 55 | 6 |
| *Merismopedia* sp. | 10 | 6 |
| *Oscillatoria* sp. C | 10 | 6 |
| *Pleurocapsa minor* | 40 | 6 |

**Species Diversity**

A diversity index is a mathematical measure of species diversity in a community. Species diversity relates to the number of the different species and the number of individuals of each species within any one community. Diversity indices can be used to define the water quality of an area. A high value suggests a rich diversity and therefore healthier, more stable ecosystem with less pollution, whereas a low value suggests a poor diversity and thus a less healthy or stressed, highly disturbed ecosystem with more pollution (Wilhm, 1975). Environmental change is less likely to be damaging to the ecosystem with a higher diversity, as a whole.

According to Shekhar et al. 2008 the Shannon-Weaver diversity index proposed that a diversity index greater than 4 (> 4) indicates clean water; between 3 and 4 is mildly polluted water; between 2 and 3 is moderately polluted water and less than 2 (< 2) is heavily polluted water. The indices computed in the present analysis showed that phytoplankton species diversity was fairly high with an average value of 3.76 indicating mildly polluted water and a relatively healthy, fairly stable system (Appendix 14).

**Phytoplankton Abundance**

The total phytoplankton abundance values for each station sampled during run 1 (November 14, 2013) were generally low with values ranging between 6.2 x $10^2$ to 4.16 x $10^3$ cells/L, with the exception of station 15 with a much higher abundance value of 2.26 x $10^4$ cells/L. This high value could be attributed to localised nutrient enrichment in the vicinity of station 15, possibly from nearby freshwater percolations from waste pipes or a small gully for example. This is supported by the observation that this station was located fairly close to the shoreline and the nitrate concentration recorded was high (3.8 mg/L ) in comparison to values for most of the other stations.

Total phytoplankton abundance values for each station sampled during run 2 (November 27 & 28, 2013) showed an increase over values recorded for run 1, with abundance ranging from 1.33 x $10^3$ to 3.24 x $10^5$ cells/L. This could be due to an increase in nutrient input to the area with increased rainfall or freshwater input as evidenced by the significant decrease in salinity at station 1, from 34.89 for run 1 to 2.8 ppt for run 2, accompanied by an increase in phosphate values from 0.64 to 1.28 mg/L respectively. Abundance values for stations 1, 16 and 18 were significantly higher than those of the other stations. These stations were located fairly close to the shoreline and possibly impacted by localised nutrient enrichment in the vicinity of these stations.

Total phytoplankton abundance values for each station sampled during run 3 (December 10 & 11, 2013) showed an obvious decrease compared to values recorded for run 2, with abundance ranging from 5.7 x $10^2$ to 5.7 x $10^3$ cells/L. This could be due to a decrease in nutrient input to the area with decreased rainfall or freshwater input as evidenced by the increase in salinity at station 1, from 2.8 ppt for run 2 to 25.73 ppt for run 3.

Overall the average total phytoplankton abundance values for each station ranged between 1.5 x $10^3$ to 1.5 x $10^5$ cells/L (Appendix 13). These values are considered to be relatively low when compared with average annual values for eutrophic waters of Kingston Harbour, Jamaica, for example, ranging from 4.9 x $10^5$ to 1.1 x $10^7$ cells/L (Ranston *et al.*, 2003). Variations in the abundance values appear to be controlled partially by changes in the nutrient concentration of the water column associated with changes in the freshwater input to the area.

**Phytoplankton Size Class**

The phytoplankton community was dominated by the smaller size classes of plankton (Appendix 13). This trend was also shown in the data on size fractionated phytoplankton biomass or chlorophyll *a* concentrations for each size fraction of phytoplankton. It is generally accepted that, the larger phytoplankton species are associated with nutrient rich water, whereas smaller species are dominant in less nutrient rich to oligotrophic water (Konstantinos *et al.*, 2002; Bec *et al.*, 2005), as small cells can use nutrients more efficiently than larger ones under nutrient limited conditions. The dominance by the smaller phytoplankton cells thus suggests generally low nutrient water throughout the Long Bay area of Negril. This is further supported by the total chlorophyll *a* concentrations recorded for the area, which were all much less than 2 mg/L. According to Thompson and Ho (1981), chlorophyll *a* concentrations not exceeding 2 mg/L indicate unpolluted waters. This result is different from that of a determination of mildly polluted water throughout the Negril site based on the data on community diversity and composition. One however must keep in mind that this analysis is based on data from water samples from only three sampling occasions and all the data presented needs to be considered in the overall determination of the present water quality status.

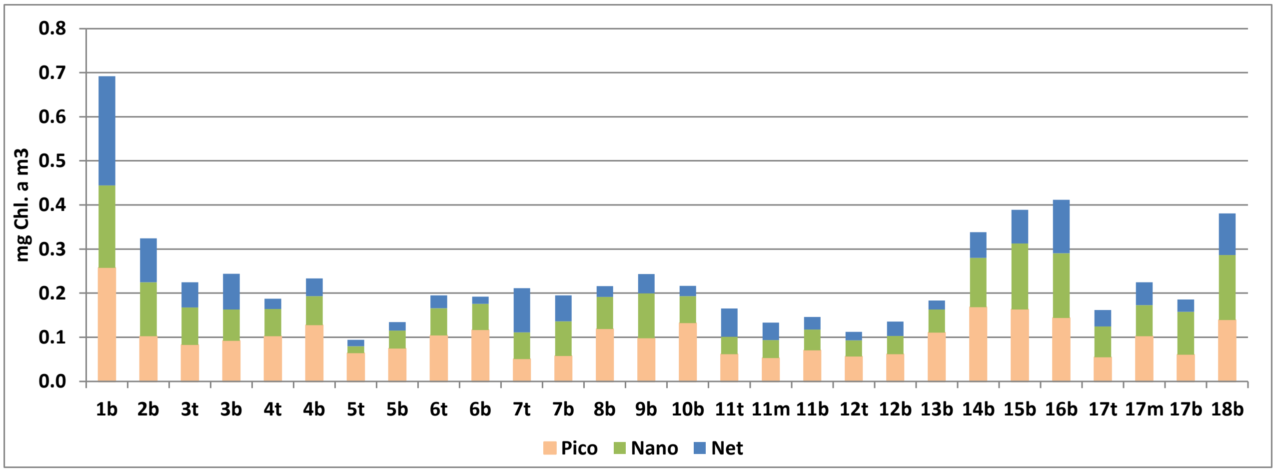



*Figure 6-77 Phytoplankton biomass as chlorophyll a values across stations for different size fractions*

**Economically Important Phytoplankton Species**

Twenty-three (12%) of the 192 species comprising the community were classified as potentially toxic phytoplankton species (Table 6-60), known to have the potential to produce toxins that can lead to human poisonings (Tindall et al., 1984; Juranovic and Park, 1991; Kao, 1993; Steidinger, 1993; Anderson, 1996; Zingone and Enevoldsen, 2000; Anderson et al., 2001; Hallegraeff, 2004; Moestrup, 2004; Lansberg et al., 2006; Ranston, 2008). These toxins can accumulate in food chains, resulting in mortalities of numerous animals including marine fish, mammals and invertebrates, as well as terrestrial animals such as seabirds, which eat contaminated marine organisms that have fed directly on or eaten organisms that have fed on toxic phytoplankton cells (Anderson and White, 1992; Baden and Trainer, 1993; Turner and Tester, 1997; Granéli and Turner, 2006). The toxins are not always harmful to the animals that accumulate them, and can also make their way through the food chain to humans. This is especially seen through the human consumption of fish and shellfish, causing a number of acute and chronic syndromes which may be fatal (Anderson, 1996; Anderson et al., 2001; Hallegraeff, 2004).

The concentration values of the potentially toxic species identified are presently low and within acceptable concentration limits however, it is possible for disturbance of an area to lead to changes in physico-chemical parameters such as increased nutrient loading, which can result in the concentration values of these species exceeding acceptable limits and even forming blooms (Anderson, 1989; Hallegraeff, 2004). These blooms could lead to severe economic losses to fisheries and tourism operations in the Negril area and have major environmental and human health impacts. The abundance of the potentially toxic species should therefore be carefully monitored during and after construction of the breakwaters and any measures that can be put in place to reduce changes in physico-chemical parameters during construction, such as the use of sediment screens should be deployed.

*Table 6-60 Rare phytoplankton species within the phytoplankton community of Long Bay, Negril*

| SPECIES | Total Abundance (cells/L) |
|---|---|
| **Bacillariophyta (diatoms)** | |
| *Pseudonitzschia sp. A* | 95 |
| **Dinophyta (dinoflagellates)** | |
| *Alexandrium* sp. | 1,270 |
| *Coolia areolata* | 10 |
| *Coolia monotis* | 20 |
| *Dinophysis acuminata* | 90 |
| *Dinophysis* cf. *rotundata* | 47 |
| *Gambierdiscus* sp. | 20 |
| *Karenia cf. breviceps* | 43 |
| *Ostreopsis ovata* | 50 |
| *Prorocentrum belizeanum* | 20 |
| *Prorocentrum emarginatum* | 55 |
| *Prorocentrum lima* | 2,840 |
| *Prorocentrum rhathymum* | 3,440 |
| *Pyrodinium bahamense* var *bahamense* | 30 |
| **Cyanophyta (blue-green algae)** | |
| *Anabaena confervoides* | 700 |
| *Anabaenopsis circularis* | 2280 |
| *Merismopedia* sp. | 10 |
| *Oscillatoria limosa* | 3,627 |
| *Oscillatoria* sp. A | 3,623 |
| *Oscillatoria* sp. B | 82 |
| *Oscillatoria* sp. C | 10 |
| *Phormidium favosum* | 1,137 |

**Summary**

The phytoplankton community of Long Bay, Negril is highly diverse and dominated by small diatom species. 14% of the species comprising the community are classified as rare and 12% classified as potentially toxic. Phytoplankton abundance and biomass concentrations are both low despite the high number of species and this data combined with the moderately high diversity values suggests that the water quality of the area is presently mesotrophic. It should be noted that a longer study of the area over a period of at least a year is required to definitively confirm the water quality status, which appears to be controlled by sporadic inputs of high nutrients from nearby freshwater percolations or inflows.

## 6.2.4 Fish Counts

### *6.2.4.1 Methods*

Fish counts were conducted at each transect location. 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 100 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 were recorded and separated into size classes with the aid of a graduated T-bar. General site observations including; the presence of fish pots, nets, spearfishers, invasive and rare species were also recorded. Fish counts were conducted on October 31st, November 1st, 27th, 28th and December 11th 2013. The locations of the fish survey are shown in Figure 6-78.

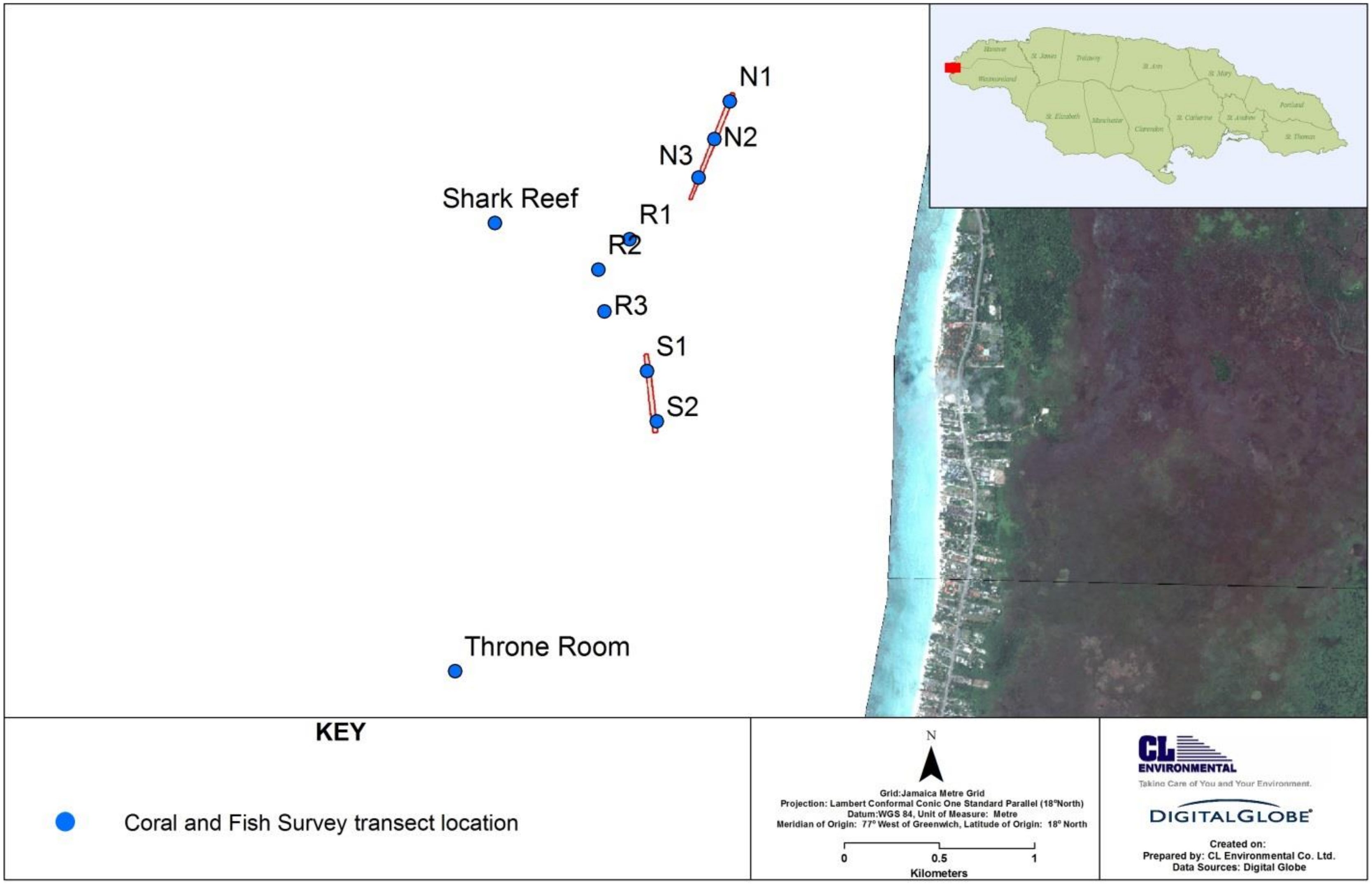



*Figure 6-78 Locations of the fish and coral surveys*

### *6.2.4.2 Results*

The lowest numbers of fish species (10 species) were observed within the North and South breakwater area (Figure 6-79 & Figure 6-80). In comparison, the recreational dive sites, Throne Room and Shark Reef, showed the highest species diversity of 23 and 25 resp. (Figure 6-82 and Figure 6-83). The area between the breakwaters showed moderate species diversity with 17 species observed (Figure 6-81).

Within the North breakwater area, the dominant fish was the French Gruntfish with the majority within the 11-20cm size class. Barjacks, Parrotfish and Damselfish were also numerous and fell within a smaller size class (0-6 cm and 6-10cm). Barjacks dominated the area in the South breakwater within the 6-10 cm size class. The density of each species was generally low at these two sites with the exception of Barjacks, which had high numbers at both areas.

Parrotfish dominated the forereef area with the majority in the 0-5 cm size class (Figure 6-81). Species richness within the forereef was also higher than the breakwater areas. Lionfish were observed in this area, but in low numbers and belonging to a smaller size class 6-10 cm.

The recreational dive sites, Throne Room and Shark Reef, showed higher density and were dominated by Parrotfish, Damselfish and *Chromis spp*. However, the majority of fish were found within the smaller size classes with very few being larger than 11-20 cm (Figure 6-82 and Figure 6-83 respectively).

The differences noted in richness and diversity between the areas sampled could be attributed to the types of habitats present. Within the breakwater areas, the substrate observed was mostly pavement with very few reef structures present (less ecological volume and less live coral). In contrast the recreational dive sites had numerous reef structures providing greater habitat diversity for the fish.

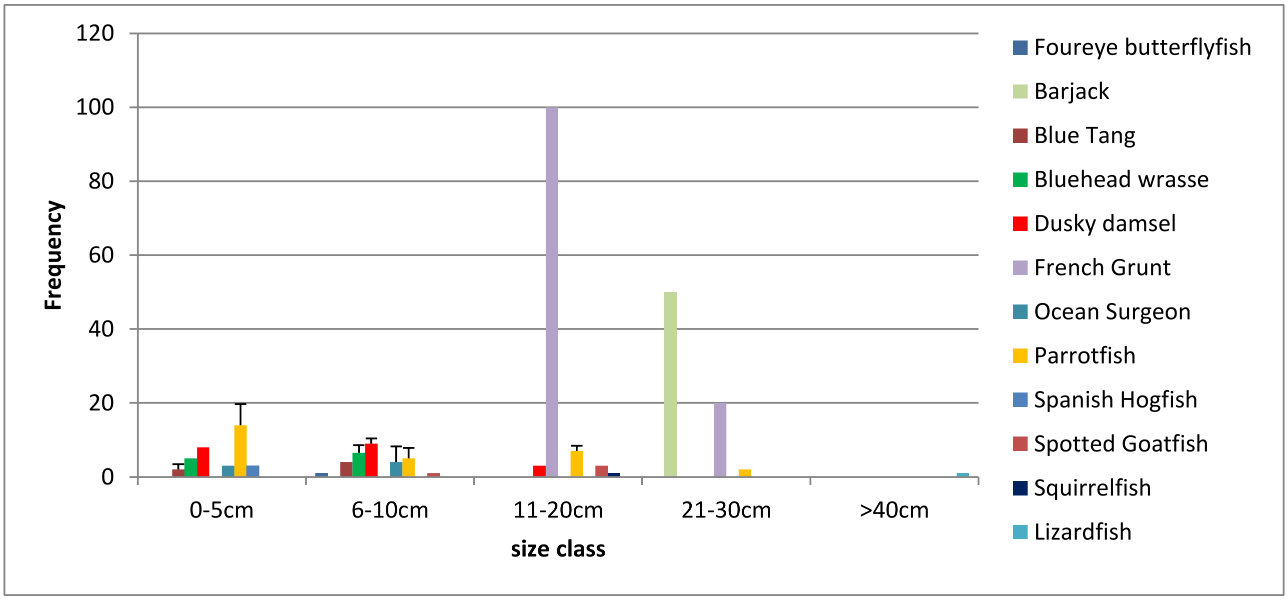



*Figure 6-79 Average number of fish observed in the North breakwater location with standard deviation*

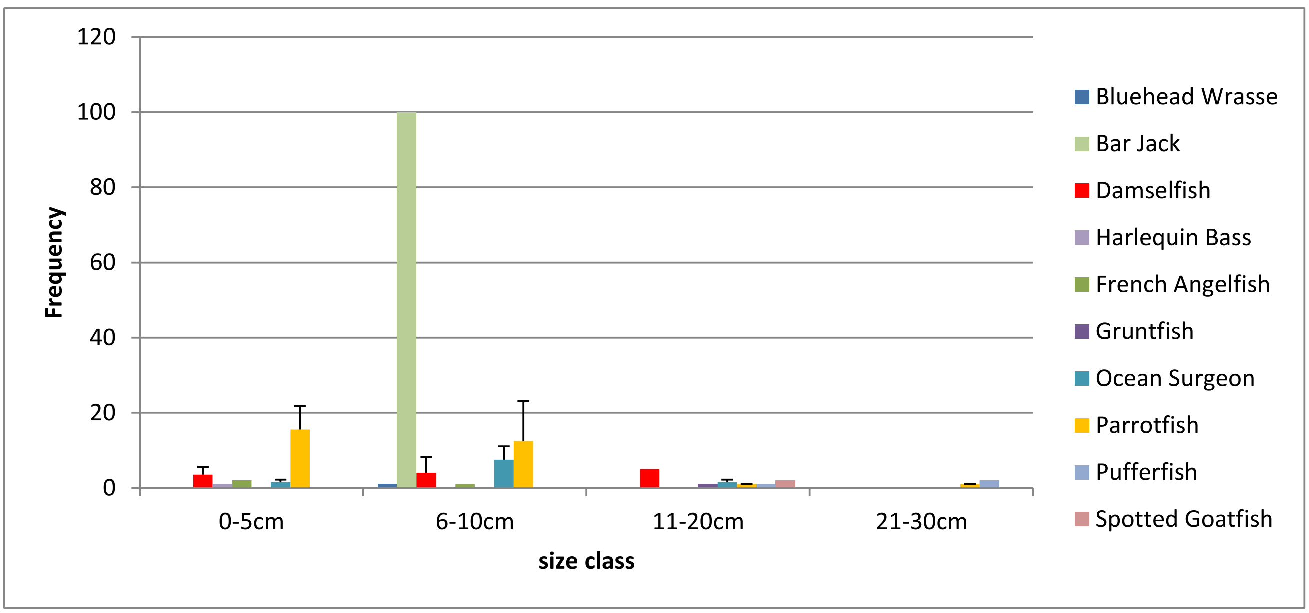



*Figure 6-80 Average number of fish observed in the South breakwater location with standard deviation*

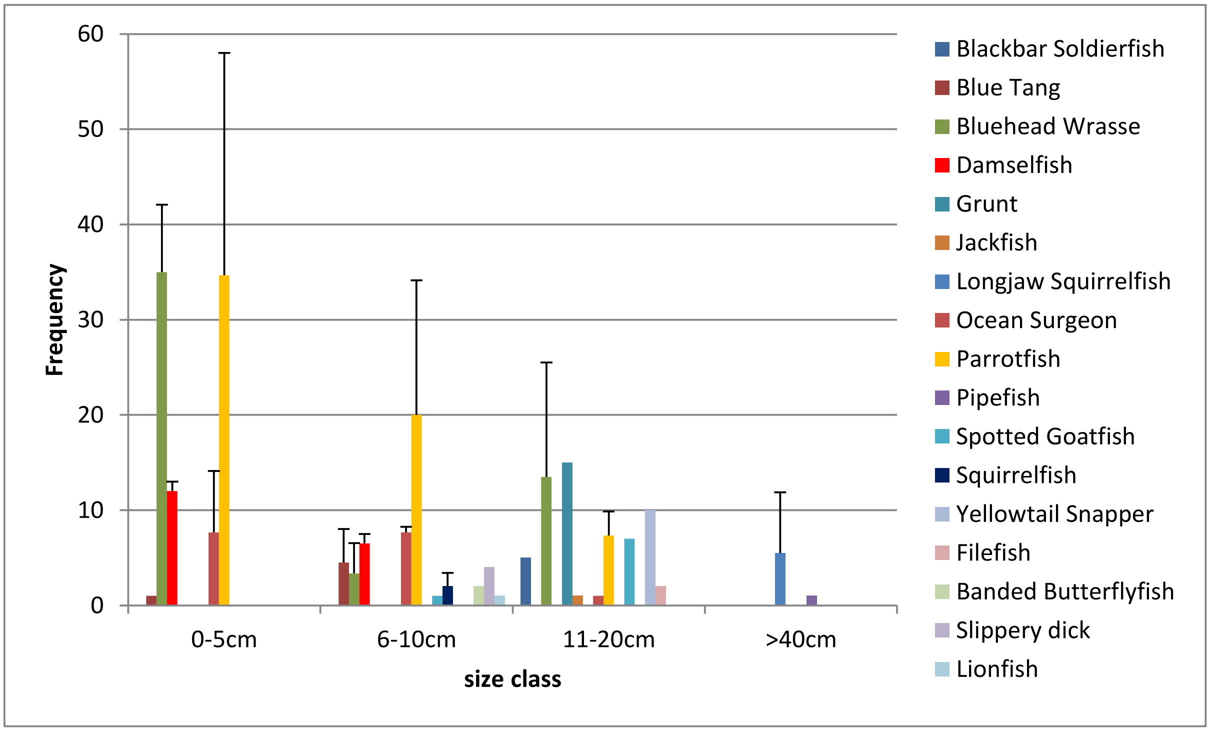



*Figure 6-81 Average number of fish observed along the reef crest with standard deviation*

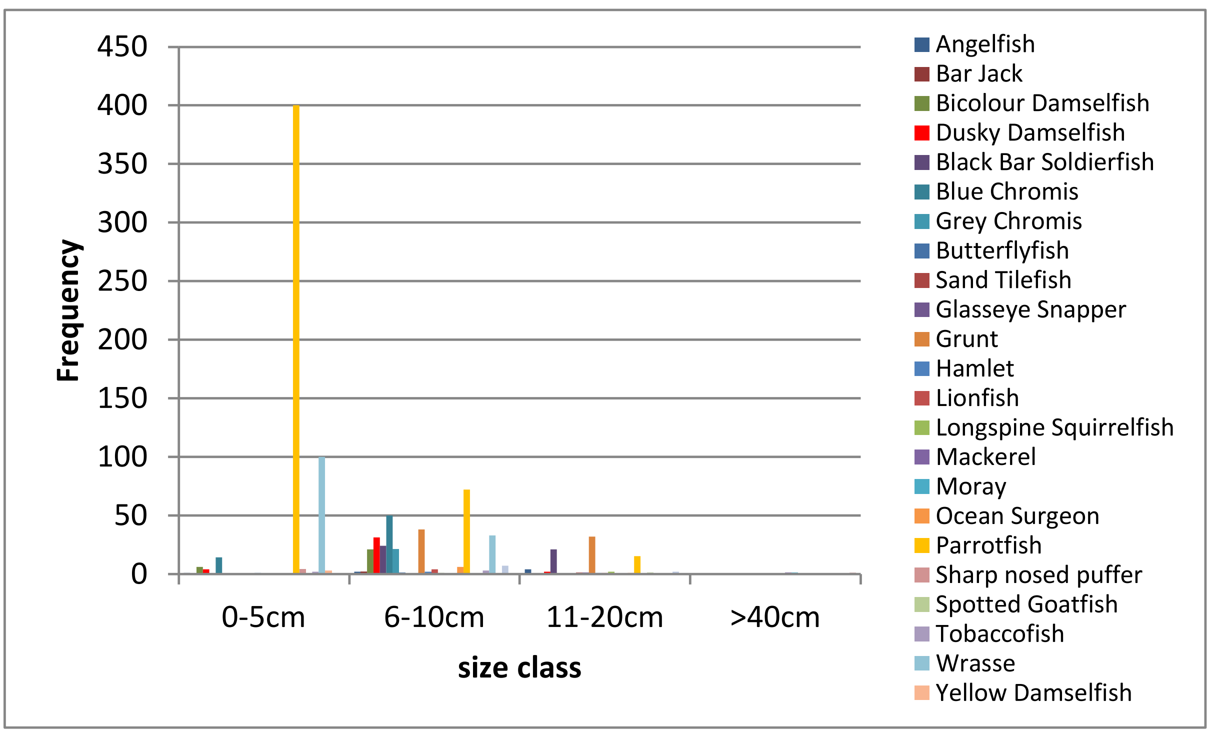



*Figure 6-82 Number of fish observed at Throne Room site*

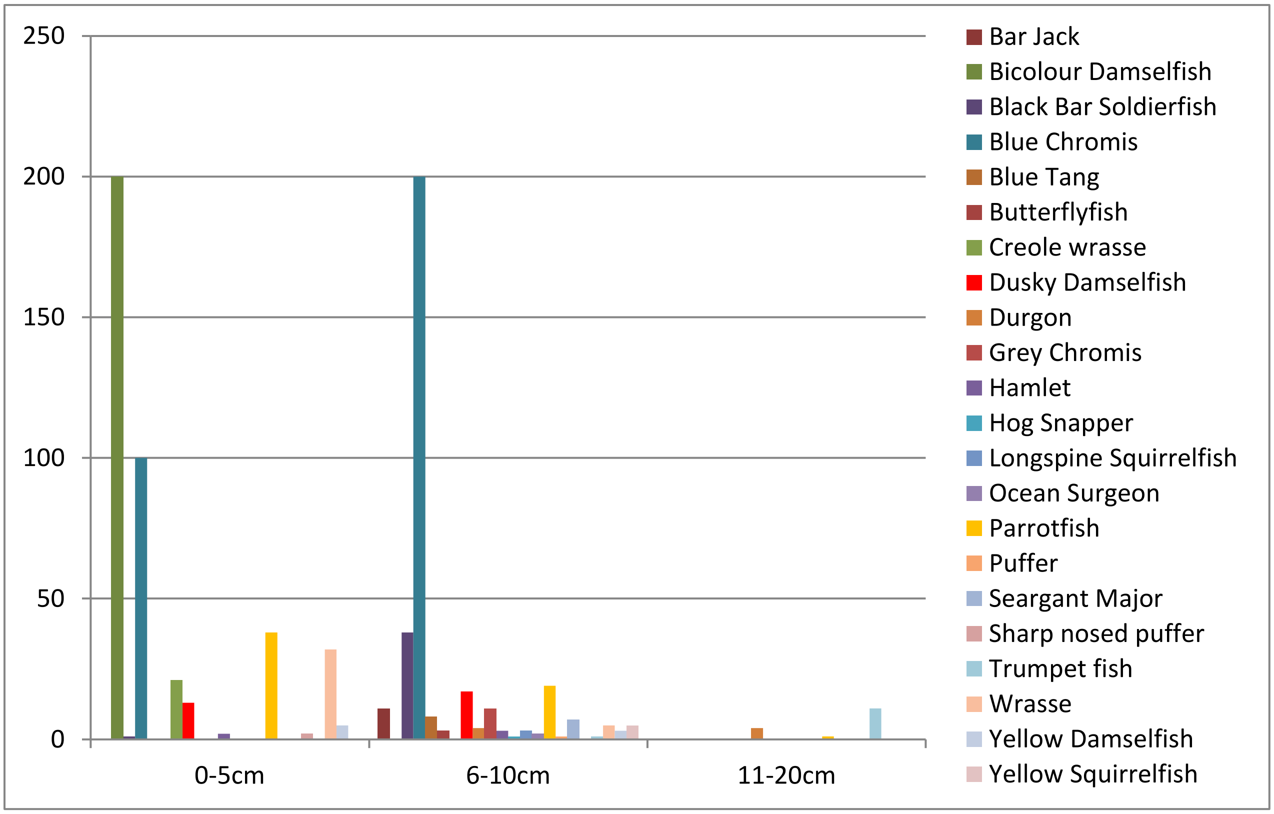



*Figure 6-83 Number of fish observed at Shark Reef site*

*Table 6-61 List of fish species observed during the survey*

| Generic name | Taxon or Scientific name | Feeding habit |
|---|---|---|
| Bar Jack | *Carangoides ruber* | Piscivore/ Invertivore |
| Chromis | *Pomacentridae spp* | Omnivore |
| French Angelfish | *Pomacanthus paru* | Invertivores/Herbivores |
| Slippery Dick | *Halichoeres bivittatus* | Invertivore |
| Bluehead Wrasse | *Thalassoma bifasciatum* | Invertivore |
| Creole Wrasse | *Clepticus parrae* | Invertivore |
| Puddingwife | *Halichoeres. radiates* | Invertivore |
| Harlequin Bass | *Serranus tigrinus* | Invertivore |
| Hamlet | *Hypoplectrus sp* | Piscivore/ Invertivore |
| Tobacco Fish | *Serranus tabacarius* | Carnivore |
| Yellowtail Damselfish | *Microspathodon chrysurus* | Herbivore |
| Dusky Damselfish | *Stegastes fuscus* | Herbivore |
| Bicolour Damselfish | *Stegastes partitus* | Herbivore/ Invertivore |
| Pipefish | *Syngnathidae* | Carnivore |
| Bandtail Pufferfish | *Sphoeroides spengler* | Invertivore |
| French Grunt | *Haemulon flavolineatum* | Invertivore |
| Durgon | *Melichthys* | Omnivore |
| Parrotfish | Scaridae | Herbivore |
| Sergeant Major | Abudefduf saxatilis | Piscivore/ Invertivore |
| Blue Tang | *Acanthurus coeruleus* | Herbivore |

| Generic name | Taxon or Scientific name | Feeding habit |
|---|---|---|
| Lizardfish | Synodontidae | Carnivore |
| Ocean Surgeonfish | *Acanthurus bahianus* | Herbivore |
| Squirrelfish | Holocentridae | Carnivore |
| Black Bar Soldierfish | Myripristis jacobus | Planktivore |
| Trumpet fish | *Aulostomus maculatus* | Herbivore |
| Sand Tilefish | *Malacanthus plumieri* | Carnivore |
| Foureye butterflyfish | *Chaetodon capistratus* | Herbivore |
| Goatfish | Mullidae | Carnivore |
| Spanish Hogfish | *Bodianus rufus* | Invertivore |
| Yellowtail Snapper | *Ocyurus chrysurus* | Piscivores/Invertivore |
| Mackerel | *Scomber spp* | Piscivores/Invertivore |
| Lionfish | *Pterios spp* | Piscivore/Invertivore |

# 6.3 HUMAN/SOCIAL

## 6.3.1 Demographic Analysis

### 6.3.1.1 Social Impact Area

The Social Impact Area (SIA) for this study was demarcated as four (4) kilometres from the proposed breakwater footprints. As seen in Figure 6-84, this impact area traverse two parishes, namely Hanover in its northern section and Westmoreland in its southern, and encompasses sections of three communities, namely Orange Bay, Negril and Sheffield. Though the general area is stereotypically referred to as Negril, distinct settlements including Whitehall and Westland (colloquially known as “West End”) are located in the south of the SIA.

### 6.3.1.2 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.

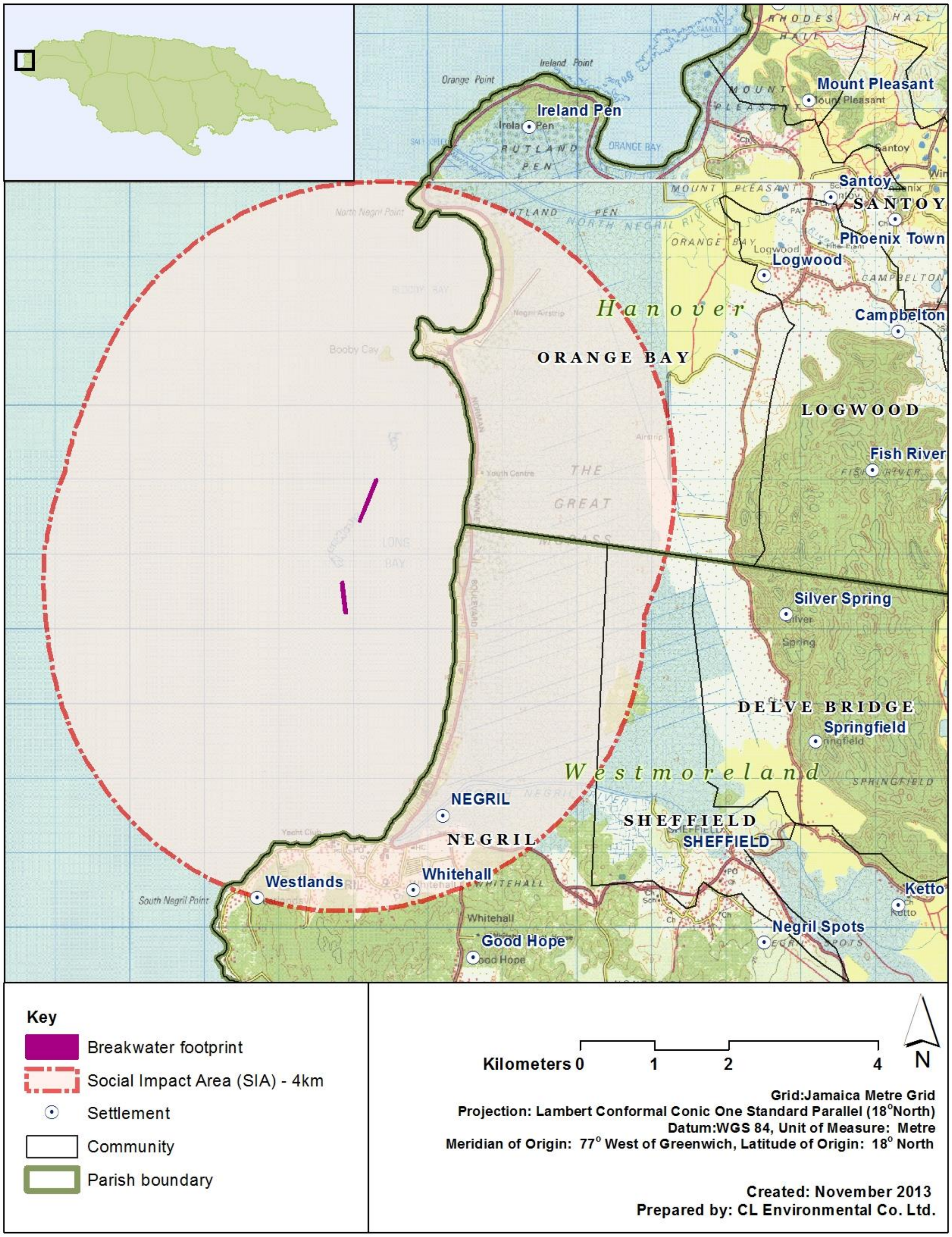



*Figure 6-84 Map showing the Social Impact Area (SIA)*

#### 6.3.1.3 Population Growth Rate

The total population within the SIA in 2011 was approximately 4,509 persons (STATIN 2011 Population Census). Examination of the 2001 population data showed that there were approximately 3,674 persons within the 4 km radius of the proposed breakwater locations in 2001. From this population, and that calculated for the year 2011 (4,509 persons), it was estimated that the actual growth within the SIA between 2001 and 2011 was approximately 2.07% per annum. Based on this increase, at the time of this study (2013), the population was approximately 4,698 persons and is expected to reach 7,840 persons over the next twenty five years if the current population growth rate remains the same.

This annual growth rate for the SIA of 2.07% is greater than the regional rates of 0.38% for both Hanover and Westmoreland (2001-2011)[10]. Applying a growth rate similar to regional values to the SIA (0.38%), it is estimated that at the time of the study, the population was 4,620 persons, and in the next twenty five years it will be approximately 7,710 persons.

#### 6.3.1.4 Age & Sex Ratio

Table 6-62 shows the percentage composition of each age category to the population. This is compared on a national, regional and local (SIA) level.

*Table 6-62 Age categories as percentage of the population for the year 2011*

| Age Categories | Jamaica | Hanover | Westmoreland | SIA |
|---|---|---|---|---|
| 0-14 | 26.1% | 28.4% | 28.7% | 26.2% |
| 15 - 64 | 65.9% | 64.2% | 62.8% | 69.5% |
| 65 & Over | 8.1% | 7.3% | 8.6% | 4.3% |

***Source: STATIN Population Census 2011***

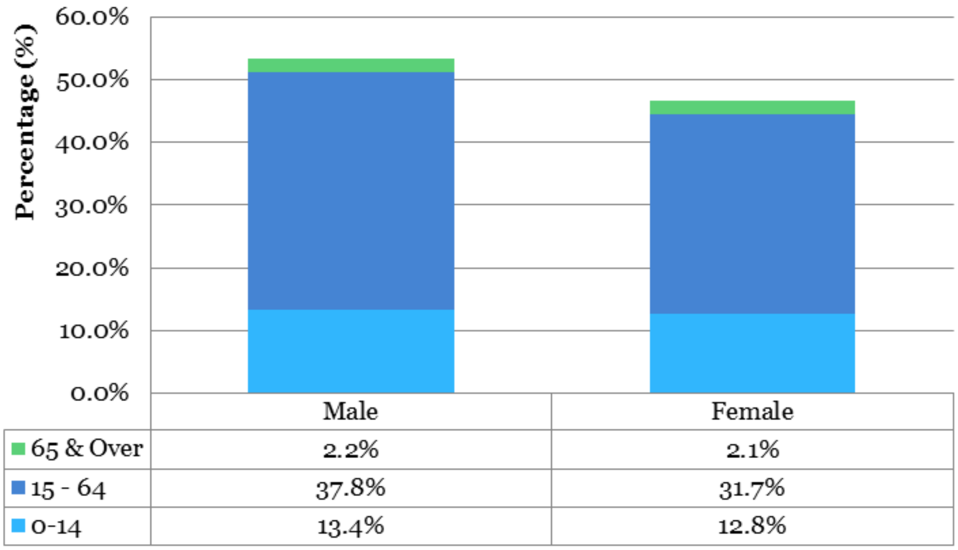
Percentage age distribution is comparable between the SIA and national figures for the 0-14 years age cohort (26.2% and 26.1% respectively); however a greater percentage of children were reported for the parishes of Hanover (28.4%) and Westmoreland (28.7%). Elderly persons of 65+ years are typically less than 10% for all extents; however the SIA has the least percentage of 4.3%, compared to Westmoreland with the highest percentage of 8.6%.

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 9.1% were in the young category and 4.3% within the 65 years and older category.

Within the SIA, the 15-64 years age category accounted for 69.5% and can therefore be considered a working age population. This SIA percentage was the highest percentage within this 15-64 years cohort; national and regional figures were slightly less as shown in Table 6-62. As seen in Figure 6-85, Census 2011 data indicated that there were noticeably more males within the 15-64 years

[10] http://statinja.gov.jm/Census/Census2011/Census%202011%20data%20from%20website.pdf

age cohort when compared to females. Sex ratio for the SIA was calculated to be 114.5 males per one hundred females.



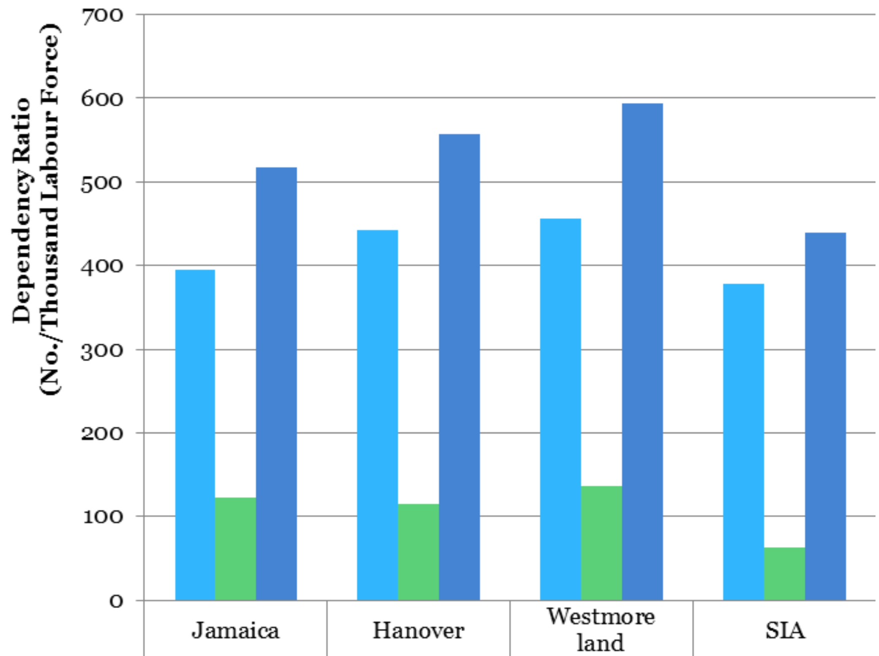

***Source data: STATIN Population Census 2011***

*Figure 6-85 Male and female percentage population by age category for the SIA in 2009*

### 6.3.1.5 Dependency Ratios

The child dependency ratio for the SIA in 2011 was 377.3 per 1000 persons of labour force age; old age dependency ratio stood at 62.2 per 1000 persons of labour force age; and societal dependency ratio of 439.5 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 dependency ratios at varying extents indicate all dependency ratios for the study area (SIA) were lower than the national and regional figures (Figure 6-86).




| | Jamaica | Hanover | Westmore land | SIA |
|---|---|---|---|---|
| Child Dependency | 395.4 | 442.4 | 456.9 | 377.3 |
| Old Age Dependency | 122.4 | 114.1 | 136.4 | 62.2 |
| Societal Dependency | 517.8 | 556.5 | 593.3 | 439.5 |

***Source: STATIN Population Census 2011***

*Figure 6-86 Comparison of dependency ratios for the year 2011*

### 6.3.1.6 Population Density

The land area within the SIA was calculated to be approximately 23.3 km². With a population of 4,509 persons, the overall population density was calculated to be 193.6 persons/km². This population density is considerably lower than the national level (245.5 persons/km²) and higher than both parish densities (Table 6-63).

*Table 6-63 Comparison of population densities for the year 2011*

| Category | Jamaica | Hanover | Westmoreland | SIA |
|---|---|---|---|---|
| Land Area (km²) | 10,991 | 450.8 | 785.2 | 23.3 |
| Population | 2,697,983 | 69,533 | 144,103 | 4,509 |
| Population Density | 245.5 | 154.2 | 183.5 | 193.6 |

***Source: STATIN Population Census 2011***

For the year 2011, Figure 6-87 demonstrates that the largest concentrations of the SIA population are located south of the SIA in the Negril, Whitehall and Westlands areas in the parish of Westmoreland. Less than 250 persons reside within the SIA area in the parish of Hanover (according to 2011 Census data).

#### *6.3.1.7 Population Growth Areas*

Figure 6-87 depicts the population within each enumeration district (ED) for the years 2001 and 2011. Total SIA population increased from 3,674 persons to 4,509 persons within this ten year timeframe. It should be noted that ED boundaries within the SIA between Westlands and Whitehall changed. For example, two Whitehall EDs demarcated for the 2001 census were spilt into a total of seven EDs for the 2011 census, resulting in fewer persons within each of these EDs in 2011; however total population for this area in fact saw an increase from 1,553 to 2,163 persons. EDs west of Whitehall are observed to have seen population increases between these years as well. On the other hand, population in the Hanover ED did not see an increase in population, however a slight decrease from 111 to 94 persons.


***Source: STATIN Population Census 2011 and 2001***

*Figure 6-87 SIA 2001 and 2011 population data represented in enumeration districts*

### 6.3.1.8 Education

The educational attainment of persons in 2001 for the national, regional and SIA extents are represented in Table 6-64. When educational attainment within the SIA is calculated as a percentage, it becomes evident that there is a propensity towards the attainment of a primary and secondary school education. Approximately half the SIA population attained a secondary school education (50.3%) followed by 31.8% attaining a primary education. Secondary educational attainment is comparable to the Jamaica and Hanover figures (49.7% and 49.0% respectively), however lower than that for the parish of Westmoreland (55.3%).

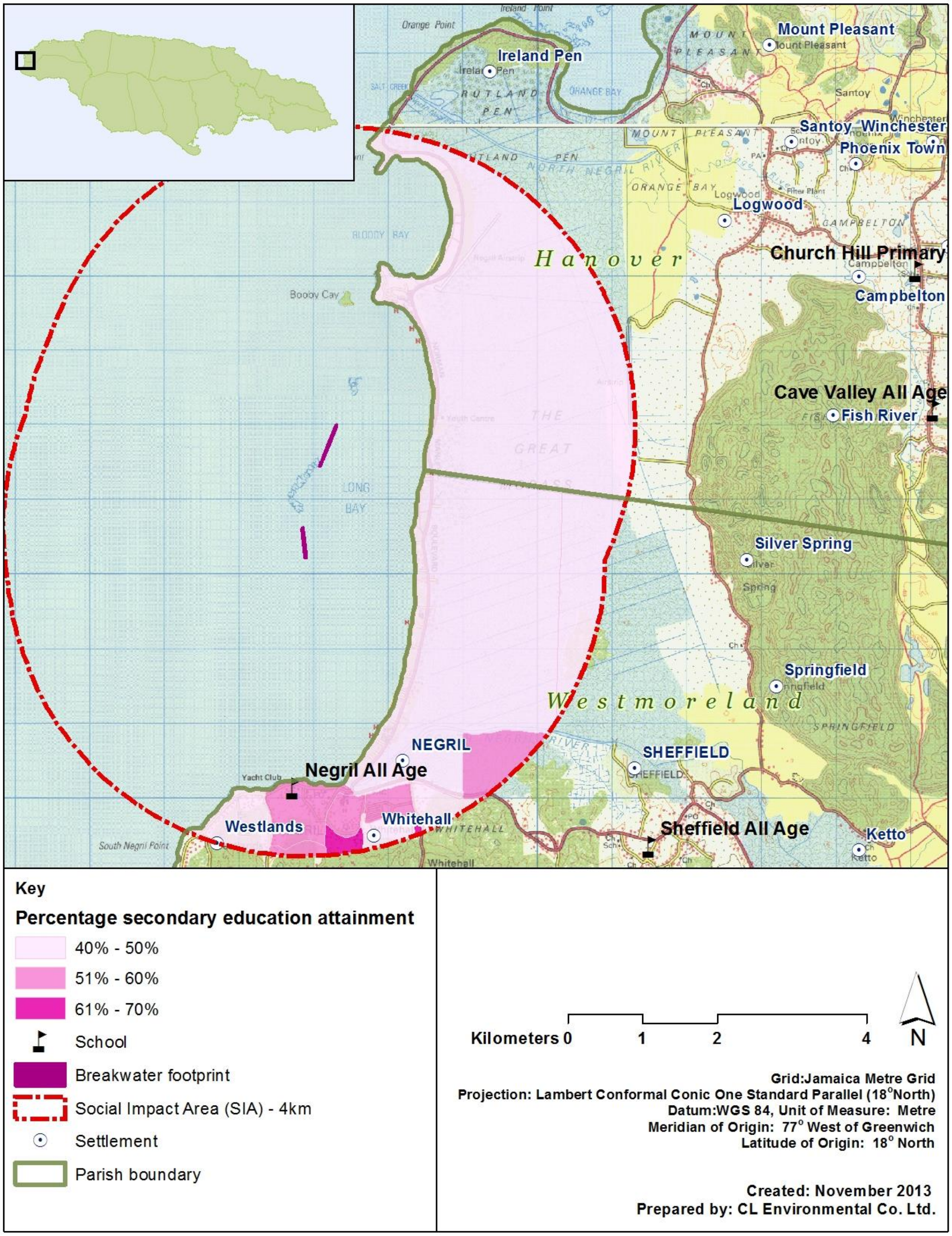
There is a noticeably higher percentage of those attaining a university or other tertiary level in the SIA (10.5%) when compared to the regional and national combined totals of 4.8% for Hanover, 4.1% for Westmoreland and 10.5% for Jamaica. Statistics for pre-primary and no education are similar amongst all extents examined.

*Table 6-64 Educational attainment as a percentage for the year 2001*

| Category | Jamaica | Hanover | Westmoreland | SIA |
|---|---|---|---|---|
| None | 0.9% | 0.9% | 1.1% | 0.5% |
| Pre-Primary | 4.7% | 4.6% | 4.8% | 4.2% |
| Primary | 31.2% | 36.4% | 31.5% | 31.8% |
| Secondary | 49.7% | 49.0% | 55.3% | 50.3% |
| University | 3.1% | 1.2% | 0.9% | 2.9% |
| Other Tertiary | 5.9% | 3.6% | 3.2% | 7.6% |
| Other | 2.8% | 2.9% | 2.1% | 1.5% |
| Not Stated | 1.8% | 1.4% | 1.0% | 1.2% |

***Source: STATIN Population Census 2001***

The relatively high proportion of the population in proximity to the project location attaining a secondary education, as well as tertiary education suggests that the labour pool is relatively educated, and as such, there should be no problem in obtaining non-technical workers from the community. This is shown in Figure 6-88 which also depicts the location of schools in proximity to the proposed location. One school, namely Negril All Age, is found within the 4 km buffer SIA, with another situated about 2 km outside the SIA boundary east of Whitehall (Sheffield All Age).




***Source: STATIN Population Census 2001***

*Figure 6-88 Percentage population attaining a secondary education*

### *6.3.1.9 Housing*

**Housing Ratios and Household Size**

For the purposes of this study the definition of housing unit, dwelling and household are those used in the population census conducted by the Statistical Institute of Jamaica (STATIN). The definition states that:

- A **housing unit** is a building or buildings used for living purposes at the time of the census.
- A **dwelling** is any building or separate and independent part of a building in which a person or group of persons lived at the time of the census". The essential features of a dwelling unit are both "separateness and independence". Occupiers of a dwelling unit must have free access to the street by their own separate and independent entrance(s) without having to pass through the living quarters of another household. Private dwellings are those in which private households reside. Examples are single houses, flats, apartments and part of commercial buildings and boarding houses catering for less than six boarders.

There were 1,140 housing units, 1,278 dwellings and 1,352 households within the SIA in 2001. The average number of dwellings in each housing unit was 1.1 and the average household to each dwelling was similarly 1.1. The average household size in the SIA was 2.7 persons/ household (Table 6-65). Comparisons of the SIA with national and regional ratios indicate that they were generally similar except for the lower SIA average household size.

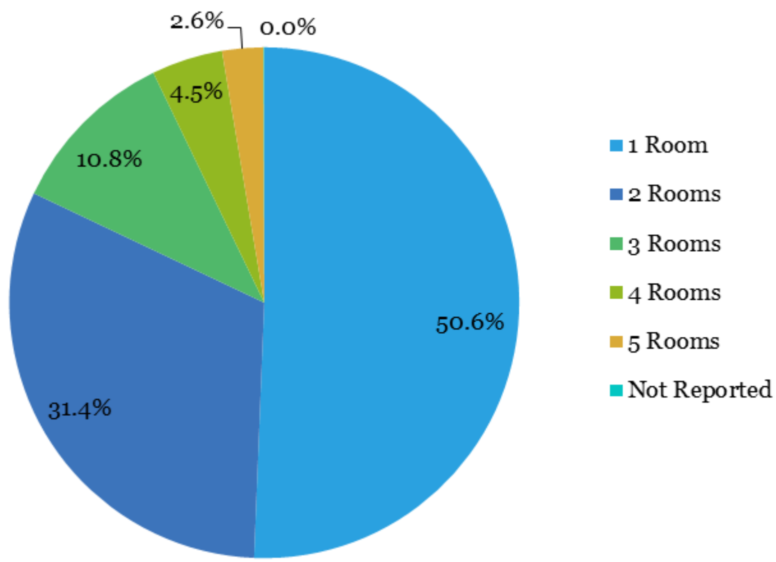
*Table 6-65 Comparison of national, regional and SIA housing ratios for 2001*

| | Jamaica | Hanover | Westmoreland | SIA |
|---|---|---|---|---|
| Dwelling/Housing Unit | 1.2 | 1.1 | 1.0 | 1.1 |
| Households/Dwelling | 1.0 | 1.0 | 1.0 | 1.1 |
| Average Household Size | 3.5 | 3.3 | 3.3 | 2.7 |

***Source: STATIN Population Census 2001***

Approximately 94.0% of the housing units in the SIA were of the separate detached type, 4.9% were attached, 0.6% were part of a commercial building and 0.4% did not state.

More than three quarters (82.0%) of the households in the SIA in 2001 used 1-2 rooms for sleeping (Figure 6-89). Approximately 10.8% of the households occupied three rooms, 4.5% used four rooms, 2.6% used five rooms and 0.04% did not report the number of rooms used for sleeping. About half of the households (50.6%) used one room for sleeping.

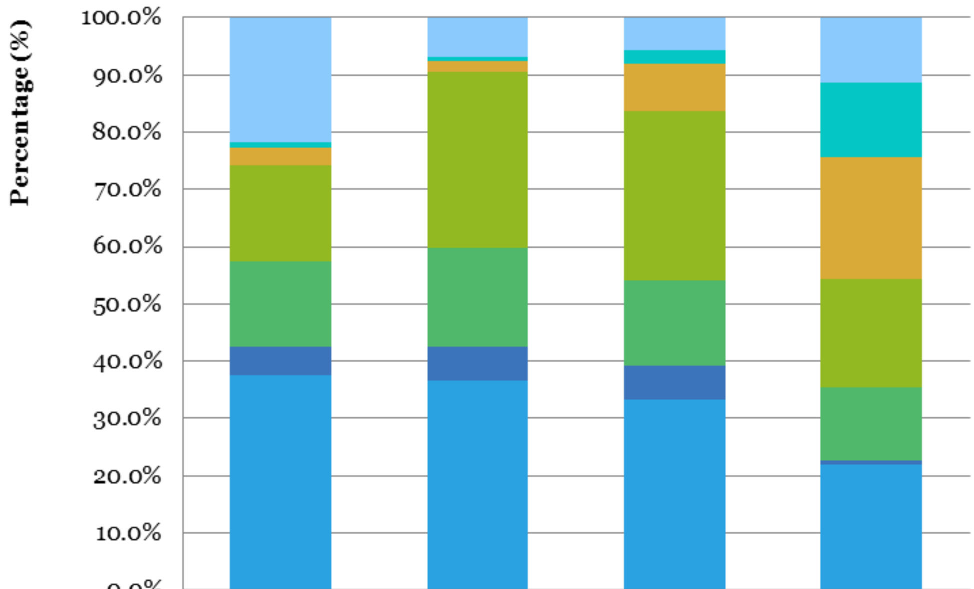



***Source: STATIN Population Census 2001***

*Figure 6-89 Rooms used for sleeping in the SIA as percentage of population*

**Land Tenure**

In 2001, 22.0% of the households in the SIA owned the land on which they lived. Approximately 0.8% leased the land on which they were, 12.7% rented, 18.8% lived rent free, 21.5% "squatted" and 13.0% had other arrangements (Figure 6-90). Compared to higher percentages of no reports for the national (21.9%), the SIA had a lower percentage (11.3%) of persons not reporting the type of ownership arrangements they had. The considerably higher percentage of households in the SIA squatting indicates that there greater number of households in the SIA compared to the national and regional setting with temporary living arrangements.

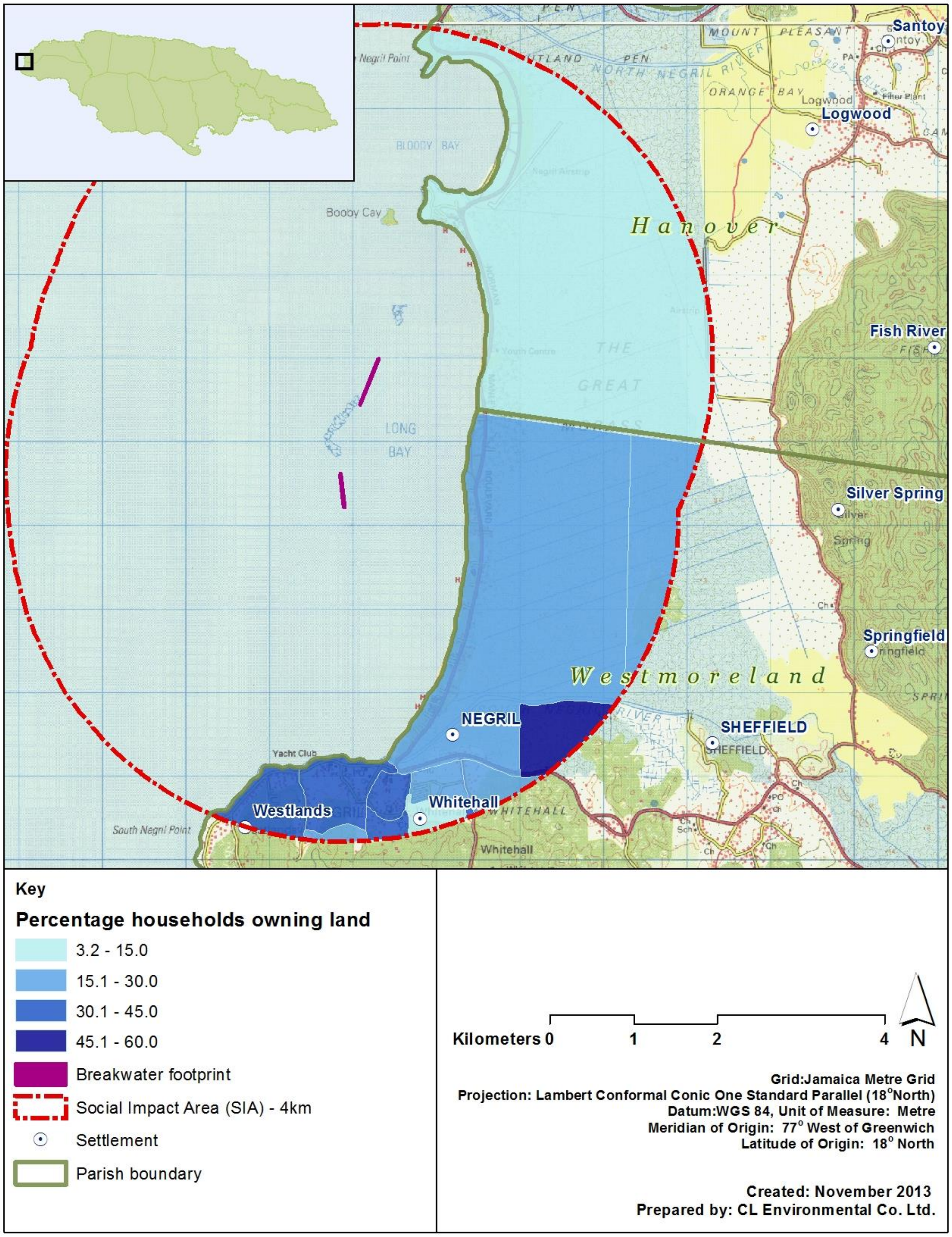



| | All Jamaica | Hanover | Westmoreland | SIA |
|---|---|---|---|---|
| Not Reported | 21.9% | 6.8% | 5.8% | 11.3% |
| Other | 0.9% | 0.8% | 2.4% | 13.0% |
| Squatted | 2.9% | 1.9% | 8.1% | 21.5% |
| Rent free | 17.0% | 30.7% | 29.6% | 18.8% |
| Rented | 14.8% | 17.3% | 14.9% | 12.7% |
| Leased | 5.0% | 6.1% | 5.9% | 0.8% |
| Owned | 37.5% | 36.5% | 33.3% | 22.0% |

***Source: STATIN Population Census 2001***

*Figure 6-90 Percentage household tenure nationally, parish and SIA in 2001*

As shown in Figure 6-91, areas towards the southeast of the SIA are recorded to have the highest percentages of land ownership (> 45%), and lowest percentages to the north of the SIA Hanover (< 15%).




***Source: STATIN Population Census 2001***

*Figure 6-91 Percent land ownership within the SIA for the year 2001*

#### *6.3.1.10 Infrastructure*

**Lighting**

The percentage of households using kerosene as their main means of lighting in the SIA (9.8%) was comparable to the Jamaican level (10.6%); however when compared with the regional context for both parishes (16.1% and 15.5%), the SIA had a lower percentage. Data for all extents (SIA, parish and national) were generally similar for electricity usage. Of note, is the much higher percentage of "other" lighting means in the SIA (3.0%) when compared with the remainder of extents.

Table 6-66 details the percentage of households using a particular category of lighting and Figure 6-92 depicts the percentage households in the SIA using electricity.

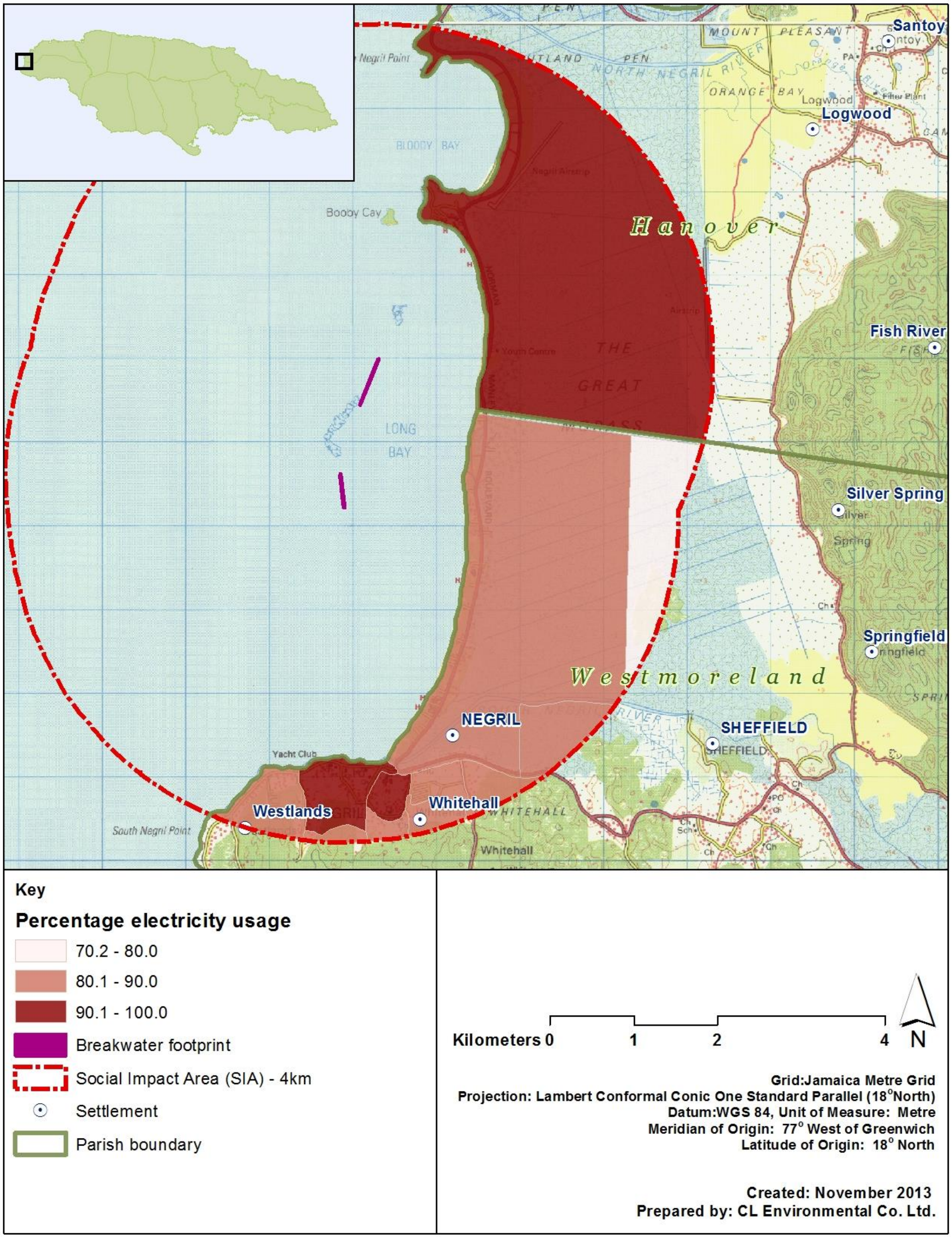
*Table 6-66 Percentage households by source of lighting*

| Category | Jamaica | Hanover | Westmoreland | SIA |
|---|---|---|---|---|
| Electricity | 87.0% | 81.4% | 82.3% | 86.0% |
| Kerosene | 10.6% | 16.1% | 15.5% | 9.8% |
| Other | 0.4% | 0.5% | 0.6% | 3.0% |
| Not reported | 2.0% | 2.0% | 1.5% | 1.2% |

***Source: STATIN Population Census 2001***

**Telephone/Telecommunications**

The parishes of Westmoreland and Hanover, as well as the study area are served with landlines provided by LIME Jamaica Limited. Wireless communication (cellular) is provided by LIME and Digicel Jamaica Limited. A network to support internet connectivity is also provided by LIME and Flow.




***Source: STATIN Population Census 2001***

*Figure 6-92 Percentage dwelling with electricity within the SIA for the year 2011*

**Domestic Water Supply**

Seventy-five percent (75.1%) of the households within the SIA received their domestic water supply from a public source, namely the National Water Commission (NWC) in 2001 (Table 6-67). This public agency is responsible for providing Jamaica's domestic water supply.

*Table 6-67 Percentage of households by water supply for the year 2001*

| | Category | Jamaica | Hanover | Westmoreland | SIA |
|---|---|---|---|---|---|
| Public Source | Piped in Dwelling | 43.8% | 27.1% | 23.6% | 53.1% |
| | Piped in Yard | 16.3% | 15.7% | 20.8% | 19.9% |
| | Stand Pipe | 10.5% | 21.7% | 16.7% | 1.7% |
| | Catchment | 1.9% | 1.7% | 2.1% | 0.4% |
| Private Source | Into Dwelling | 6.3% | 5.3% | 6.8% | 6.2% |
| | Catchment | 9.9% | 14.6% | 18.1% | 2.9% |
| | Spring/ River | 4.6% | 5.6% | 3.2% | 0.2% |
| | Other | 4.5% | 6.0% | 7.0% | 14.1% |
| | Not Reported | 2.2% | 2.5% | 1.6% | 1.4% |

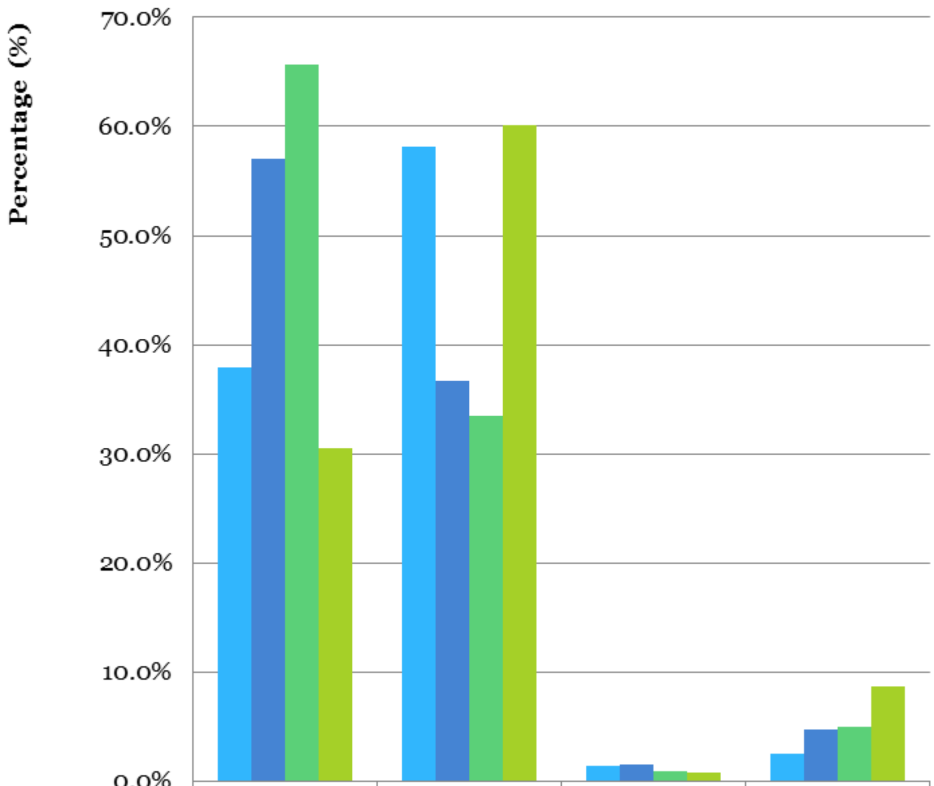
***Source: STATIN Population Census 2001***

Water demand for the SIA in 2013 is estimated to be 1,067,009.8 litres/day (~281,874.2 gals/day) and is expected to increase to 1,780,620.8 litres/day (~470,390.3 gals/day) over the next twenty five years based on population growth rates calculated previously.

**Wastewater Generation and Disposal**

It is estimated that approximately 174,609.9 litres/day (~46,127.1 gals/day) of wastewater is generated within the study area (for 2013) and is expected to decrease to 121,554.6 litres/day (~32,111.3 gals/day) over the next twenty five years based on calculated growth rates.

Within the SIA, a lower percentage of households used pit latrines (30.5%) when compared to the national and parish data (Figure 6-93). Percentage of households with water closet disposal methods was comparable between the SIA and national level (60.1 and 58.2% respectively), however higher than the parish levels.




| | Pit Latrine | Water Closet | Not Reported | No Facility |
|---|---|---|---|---|
| Jamaica | 37.9% | 58.2% | 1.4% | 2.5% |
| Hanover | 57.1% | 36.7% | 1.5% | 4.8% |
| Westmoreland | 65.7% | 33.5% | 0.9% | 5.0% |
| SIA | 30.5% | 60.1% | 0.8% | 8.6% |

***Source: STATIN Population Census 2001***

*Figure 6-93 Sewage disposal methods as a percentage of the households for 2001*

## Solid Waste Generation and Disposal

It is estimated that households in the study area generated approximately 5,556.7 kg (~5.6 tonnes) of solid waste in 2001. Based on the population growth, it has been estimated that at the time of this study (2013), approximately 7,105.5 kg (~7.1 tonnes) of solid waste was being generated and it is expected that within the next twenty five years, if the annual population growth rate remains the same (2.07%), the amount will be 11,859.0 kg (~11.9 tonnes).

The 2001 census data indicated that 69.8% of the households in the SIA had their garbage collected by public means, compared to dramatically lower percentages at the parish and national levels. It also showed that burning was the second most preferred method of disposal in the SIA (17.9%) and this was much lower than the national and regional figures (Table 6-68, Figure 6-94).

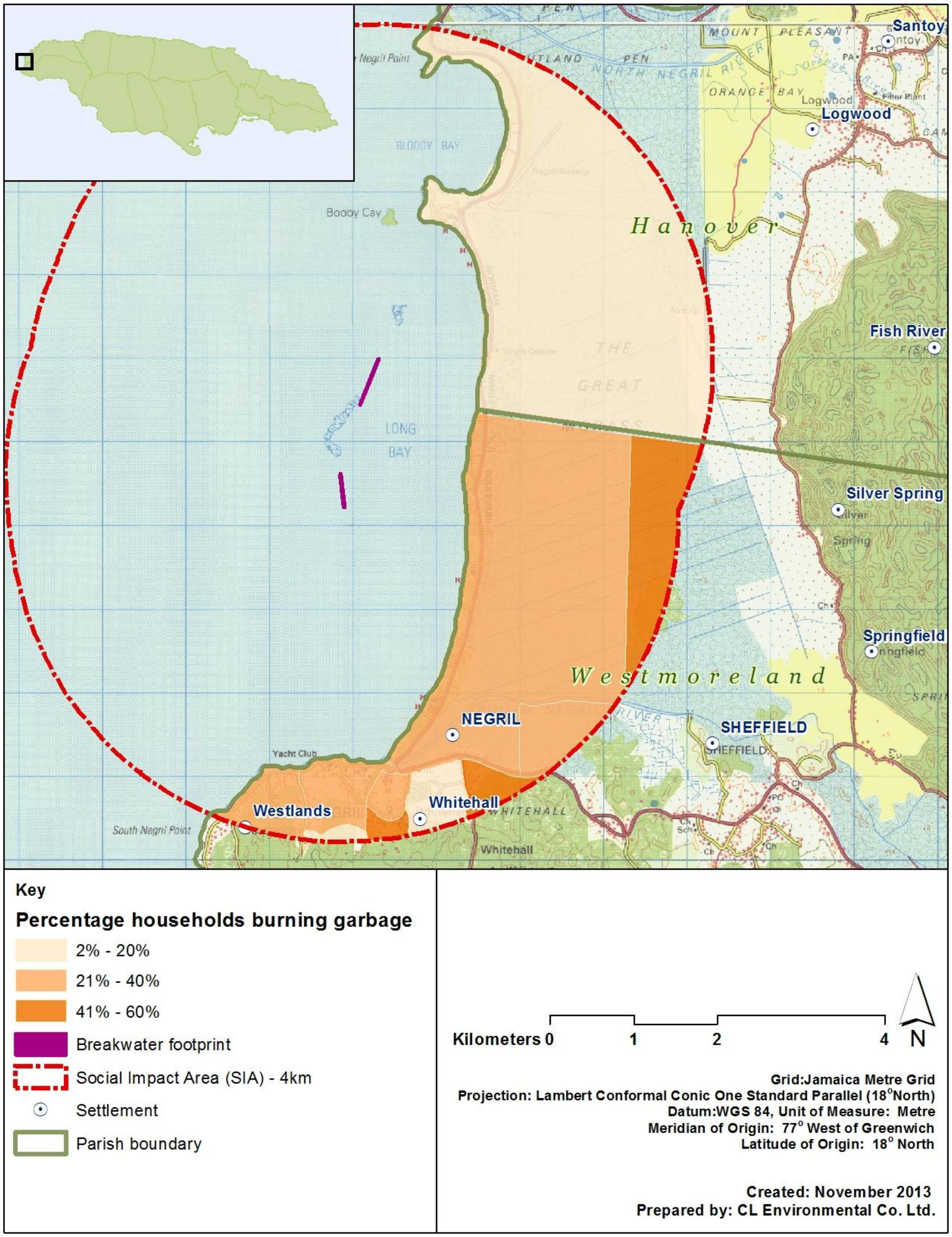
*Table 6-68 Percentage households by method of garbage disposal*

| Disposal Method | Jamaica | Hanover | Westmoreland | SIA |
|---|---|---|---|---|
| Public Collection | 47.7% | 17.9% | 22.2% | 69.8% |
| Private Collection | 0.5% | 0.7% | 0.7% | 7.8% |
| Burn | 43.0% | 65.1% | 68.1% | 17.9% |
| Bury | 1.2% | 2.3% | 1.5% | 1.4% |
| Dump | 6.0% | 12.4% | 6.3% | 1.8% |
| Other Method | 0.3% | 0.3% | 0.3% | 0.0% |
| Not reported | 1.3% | 1.2% | 0.8% | 1.3% |

***Source: STATIN Population Census 2001***

The National Solid Waste Management Authority is responsible for domestic solid waste collection within the SIA. Presently, collection is done once per week for residential areas and is provided free (partial covered by property taxes) for households. Solid waste collection for commercial and industrial facilities is done by arrangements by these entities with private contractors. In a Jamaica Gleaner article dated 21 September 2013, it was stated that the authority was not on target in all zones for garbage collection in Westmoreland. As indicated by the Senior Public-Cleansing Health Inspector Julian Robinson, two trucks have been out of service and trucks from Hanover and St James have been used to assist the garbage-collection efforts.[11]

[11] http://jamaica-gleaner.mobi/gleaner/20130921/western/western4.php




***Source: STATIN Population Census 2001***

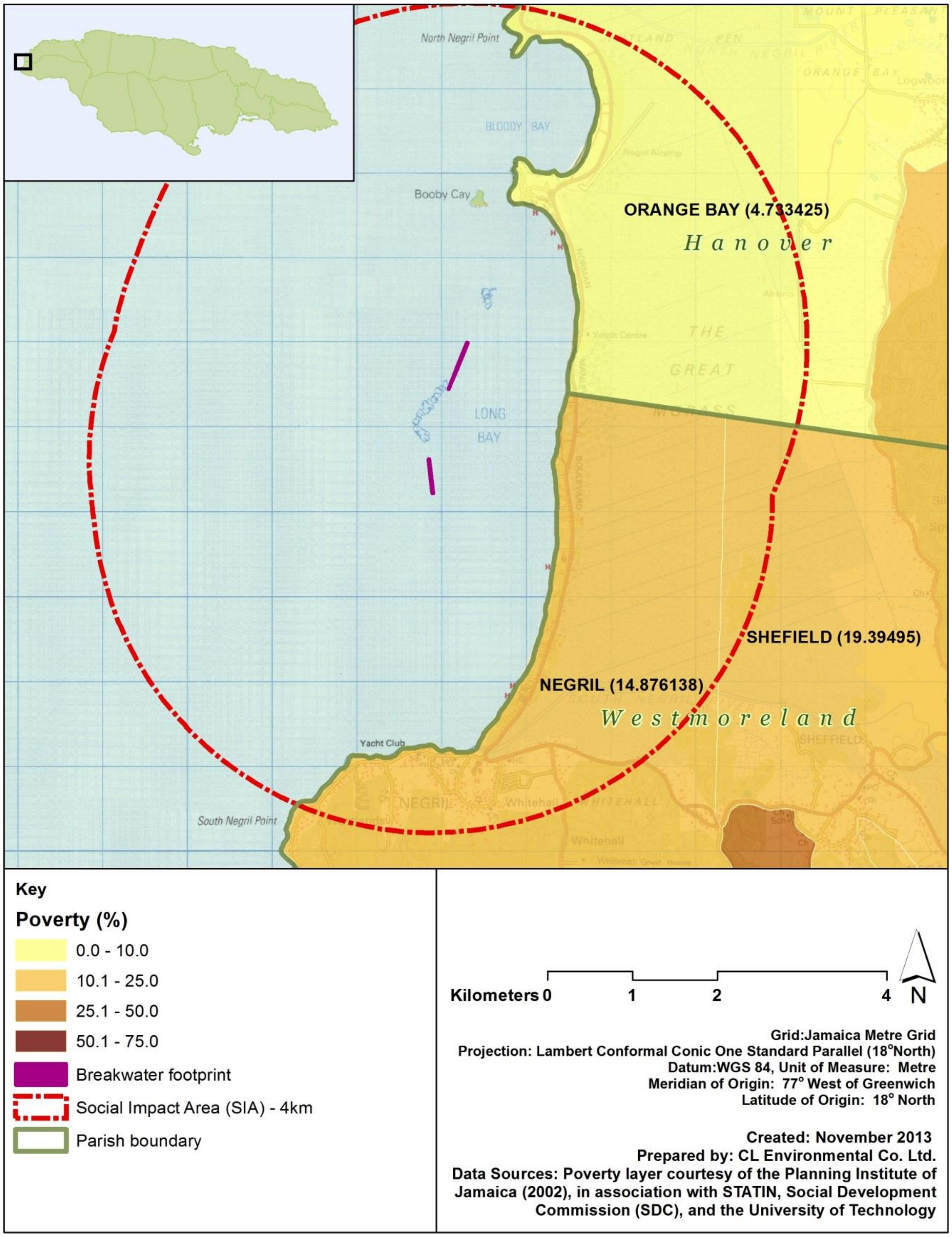
*Figure 6-94 Percentage households in the SIA burning garbage for the year 2001*

#### *6.3.1.11 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 6-95, the SIA population generally does not have more than 15% of persons living in poverty.




***Source: PIOJ (with contributions from STATIN, Social Development Commission (SDC) and the University of Technology***

*Figure 6-95 Proportion of persons in poverty in each community*

## 6.3.2 Services

### *6.3.2.1 Health*

One health centre exists within the SIA (Figure 6-96), namely Negril Health Centre towards the southern section of the SIA in the town of Negril. This centre 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.[12] This centre serves residents in Negril as well as surrounding communities such as Orange Hill, Red Ground, Little London and Savanna-la-Mar. The Negril Health Centre was recently outfitted with two new, furnished examination rooms. This effort was funded by the Sandals Foundation, through its partnership with the Ministry of Health and was undertaken in order to address the need for additional space. [13]

In addition to the public Negril Health Centre, private health clinics and practices exist within the SIA, including a private health centre located along the Norman Manley Boulevard and Omega Medical Services in the town of Negril.

There are currently no public or private hospitals within the SIA. Public hospitals closest to the site are both situated in the western health region are as follows:

- Noel Holmes Hospital, Lucea, Hanover (Type C Hospital, public) - basic district hospital interfacing with the Primary Health Care system at parish level. Inpatient and outpatient services are provided in general medicine, surgery, child and maternity care. Basic X-ray and Laboratory services are usually available to serve hospital patients as well as those from Primary Health Care and the local private sector. Many of these hospitals also provide the services of a specialist surgeon to ensure the availability of emergency surgical services.
- Savanna-la-Mar Public General Hospital, Savanna-la-Mar, Westmoreland (Type B) - provide inpatient and outpatient services in at least the five basic specialties – general surgery, general medicine, obstetrics and gynaecology, paediatrics and anaesthetics. X-ray and Laboratory services are usually available to serve hospital patients as well as those from Primary Health Care and the local private sector.

Noel Holmes Hospital is located about 24 km northeast from the proposed breakwater positions, whilst Savanna-la-Mar Public General Hospital is approximately 25 km southeast. In July 2013, The National Health Fund (NHF) approved $35.5 million for the refurbishing of the Noel Holmes Hospital and this will include, amongst other things, the repair of the infrastructure, addition of

[12] http://www.srha.gov.jm/Facilities/HealthCentreClassification.aspx
[13] http://www.jamaicaobserver.com/westernnews/Negril-Health-Centre-gets-new-examination-rooms_14497441

12 beds in Observation and an additional six cots for the paediatric area as well as re-equipping of the department. [14]

The Negril International Hospital (NIH) is planning to construct a state of the art private hospital in Negril that will aim to excel in emergency, clinical, and surgical services. The proposed facility will feature over 100 acres (0.4 $km^2$) of clinical space with an emergency room, numerous operating rooms, a cardiology lab, and a radiology department. It is expected that the hospital will feature 100 beds for in-patient care. As mentioned previously, private hospitals do not exist in Negril capable of serving residents and the many tourists that travel there annually; the goal of the NIH is to address this need. [15]

#### *6.3.2.2 Fire Stations*

One fire station, Negril Fire Station is located in Red Ground, approximately 3.5 km south of the proposed breakwaters (Figure 6-96). This station falls under Area IV. The Jamaica Fire Brigade Emergency Medical Service (EMS) began in Negril in 1996. Technicians are trained to retrieve, care for and deliver victims to an appropriate medical facility.

#### *6.3.2.3 Police Stations*

The Negril Police Station is situated about 3 km south of the southern breakwater. This is the only police station located within the SIA.

#### *6.3.2.4 Post Offices*

The Negril Post Office is the only post office located within the demarcated SIA.

[14] http://www.jamaicaobserver.com/news/NHF-approves--35-5m-for-Noel-Holmes-Hospital-refurbishing
[15] http://www.negrilinternationalwellnessfoundation.org/2010/11/16/negril-international-hospital-nih-launch/

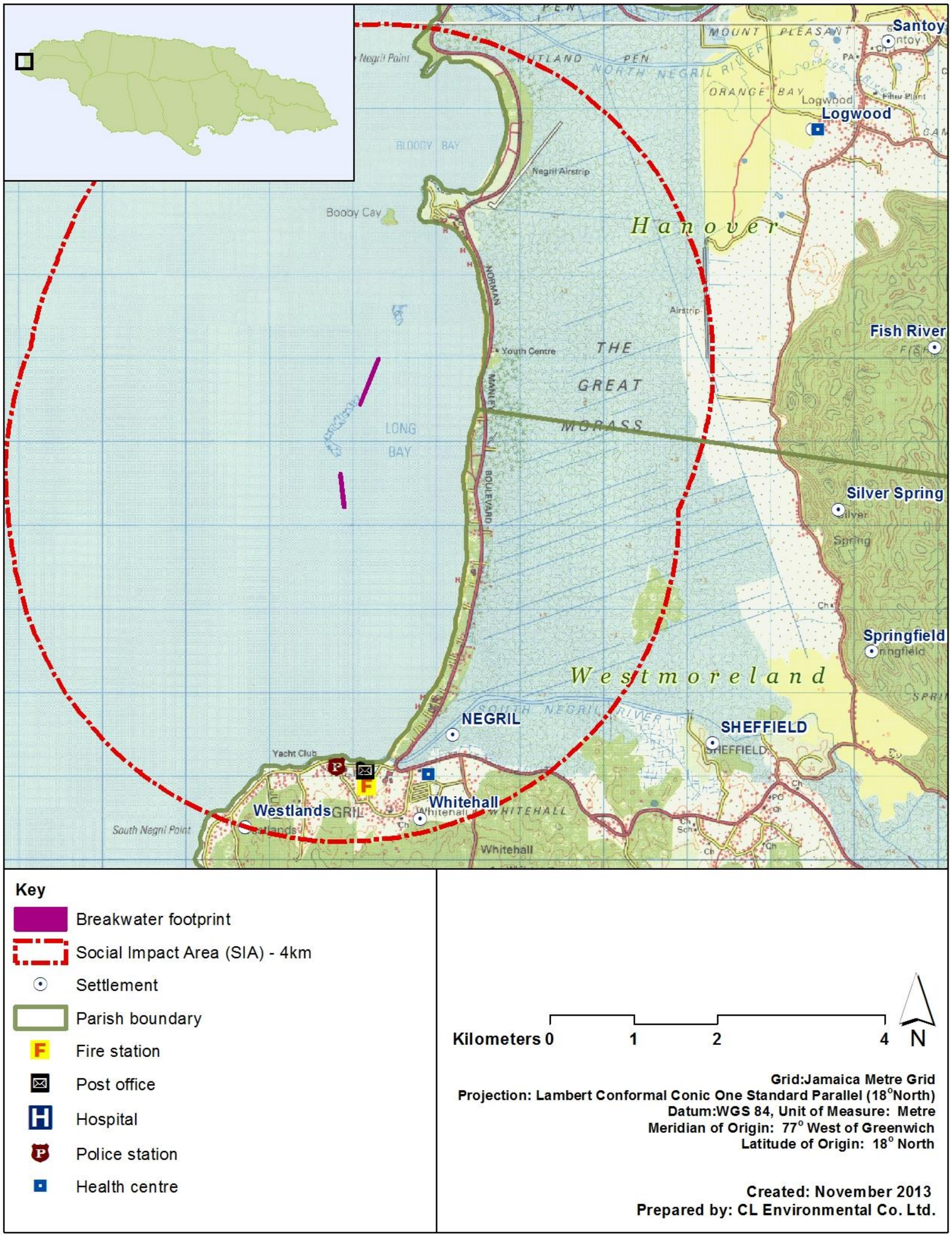



*Figure 6-96 Services located in vicinity of SIA*

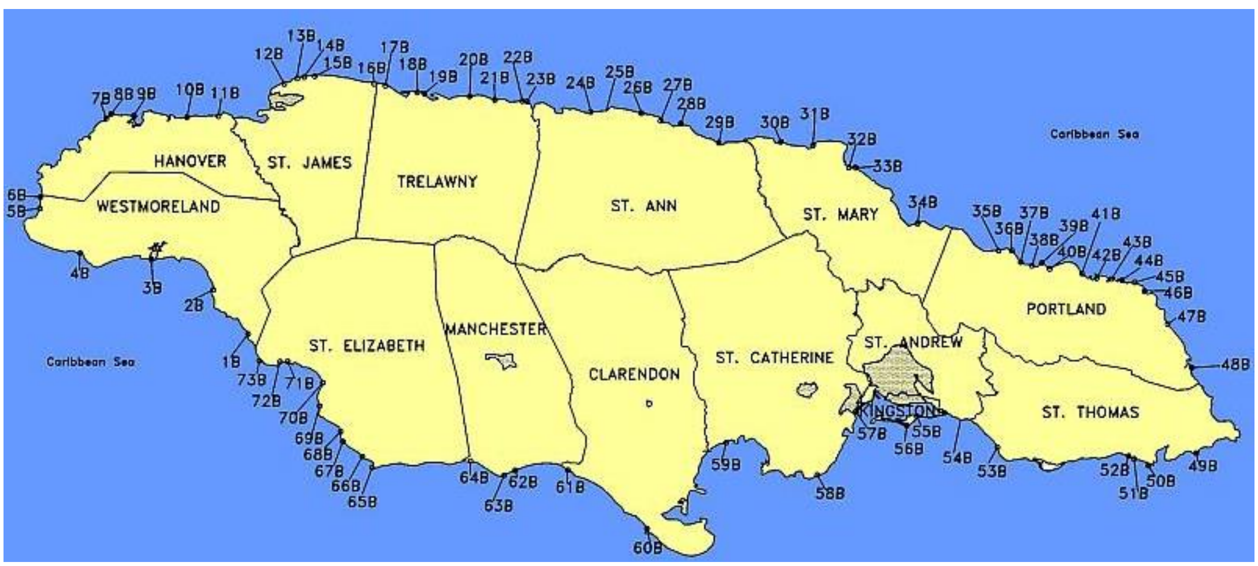
## 6.3.3 Marine and Beach Use

### *6.3.3.1 Beach Classification*

In line with the Beach Control Act, the following classification system for beaches has been proposed[16]:

A. Recreational Beaches
    i. Hotel beaches
    ii. Commercial beaches
    iii. Parish beaches
B. Industrial beaches
C. Fishing beaches

As mentioned previously, a fishing beach is situated within the study area. In addition to this beach type, recreational beaches are also found within the study area. Traditionally, beach use is a recreational experience for many Jamaicans and visitors alike. With the existing tourism industry and infrastructure existing along the Long Bay beach in Negril, a number of hotel beaches exist. Areas along the strip demarcated for public recreational use are depicted in Figure 6-97 and include the Long Bay Beach. In 1997, the UDC established Long Bay Beach 1 (4.16 hectare or 0.0416 km$^2$) and in 2001, Long Bay Beach 2 was developed to complement the existing beach park (2.07 hectares or 0.0207 km$^2$).




***Source: National Environment and Planning Agency***[17]

*Figure 6-97 Public bathing beaches in Jamaica*

[16] http://www.nepa.gov.jm/policies/beach/Chap5.htm
[17] http://www.nepa.gov.jm/policies/beach/gifs/Map3%20Fishing%20Beach.JPG

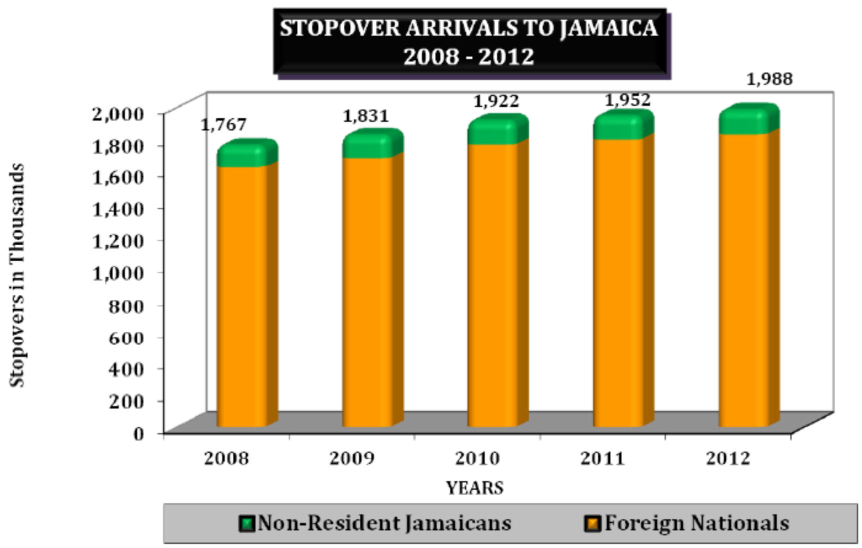

*Plate 6-35 Long Bay Beach Park 1*

*Plate 6-36 Long Bay Beach Park 2*

#### 6.3.3.2 Tourism

The World Travel & Tourism Council concluded that in 2011, travel and tourism produced a total of $4 billion of Jamaica's GDP from a combined impact of direct, indirect and induced benefits (World Travel & Tourism Council 2012). Gross visitor expenditure in 2012 was estimated at approximately US$2.070 billion, an increase of 3.0% against the estimated US$2.008 billion earned in 2011 (Jamaica Tourist Board n.d.). In 2012, almost 25 million tourist arrivals were recorded for the Caribbean region and this was a 5.4% increase from the previous year (Jamaica Tourist Board n.d.). The Jamaica Tourist Board (JTB) concluded that the region had recovered from losses experienced during the 2008/2009 global economic depression and stated that the rate of growth observed in the Caribbean region surpassed the remainder of countries worldwide (3.8% growth in 2012).

Within the region, Jamaica was the third most visited island, whereas Dominican Republic and Cuba were the top two visited. With regards to stopovers in Jamaica, the annual total number of stopover arrivals increased by 1.8% between 2011 and 2012 (Figure 6-98). Of mention, is the fact that for the first time in recorded history, the month of September recorded a growth of 6.2% from the same period in 2011. In comparison to the 2009 depression, tourist arrivals to Jamaica in 2012 were higher with rates of 14.3%, 8.2%, 8.6% and 10.3%, for each respective quarter in the year. Jamaica thereby has sustained its tourism product through the wide range of hotels, attractions and activities offered across the island.

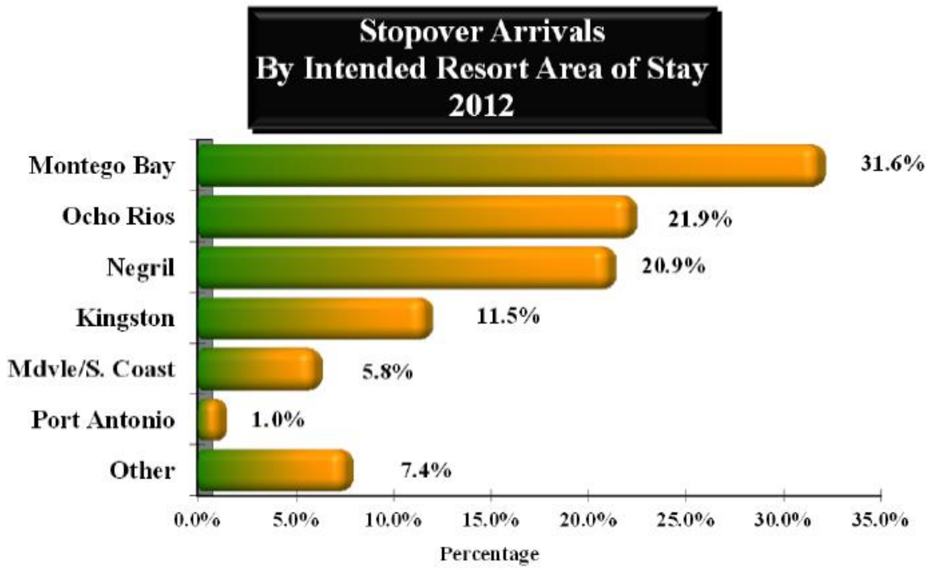



***Source: Jamaica Tourist Board***

*Figure 6-98 Stopover arrivals to Jamaica 2008-2012*

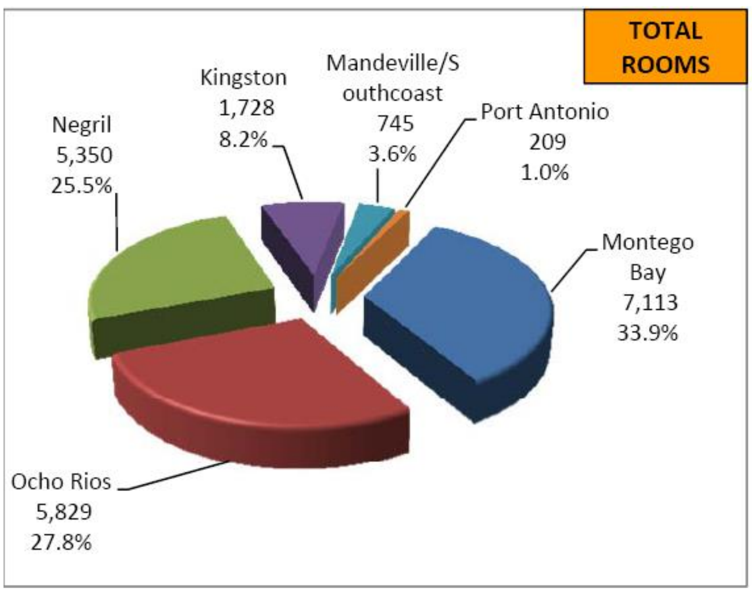
The average intended length of stay for foreign nationals was 8.8 nights in 2012 and this is slightly lower than the 2011 record of 8.9 nights. Visitors in hotels tended to stay for shorter periods on average (6.8 nights) when compared with non-hotel accommodation (14.1 nights). Approximately 79.2% of the total 2012 visitors to Jamaica travelled to the island for leisure, recreation and holiday, 9.3% were visiting relatives or friends, 5.1% were on business, and the remaining 6.4% were travelling for 'other' purposes.

As seen in Figure 6-99, Negril accounts for 20.9% of the stopover arrivals for 2012, making this area the third most visited resort area in the island. In addition, Negril has a total of 5,350 rooms, which represents 25.5% of all rooms (Figure 6-100). The accommodation locations, including hotels, villas and guesthouse in the SIA are depicted in Figure 6-102.




***Source: Jamaica Tourist Board***

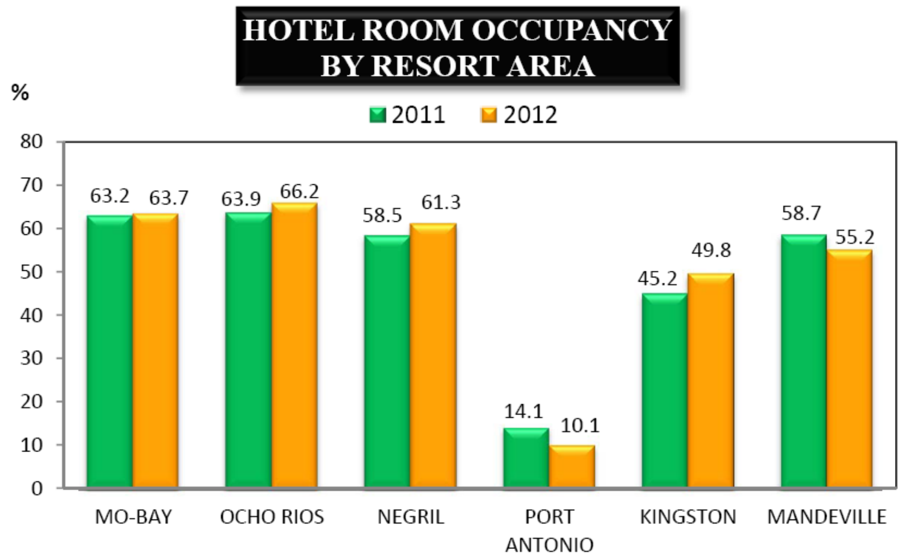
*Figure 6-99 Stopover arrivals by intended resort areas of stay, 2012*




***Source: Jamaica Tourist Board***

*Figure 6-100 Hotel rooms by resort regions, 2012*

In 2012, average room capacity grew by 0.7%, whilst total room nights sold increased by 4.0%. As seen in Figure 6-101, annual hotel room occupancy rates for 2011 and 2012 varied depending on locality. For the Negril area, hotel room occupancy was 61.3% in 2012, which shows an increase of 2.8% from 2011.




***Source: Jamaica Tourist Board***

*Figure 6-101 Hotel room occupancy (percentage) by resort area for 2011 and 2012*

There was an overall increase in the tourist accommodation units in Negril between 2008 and 2012, with fluctuations between the years depending on the number of rooms and type of accommodation (Table 6-69). On the other hand, total number of rooms decreased between 2008 and 2012 by 218 rooms.

*Table 6-69 Tourist accommodations in Negril by category and area, 2008-2012*

***Source: Jamaica Tourist Board***

| | Units | | | | | Rooms | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **2008** | **2009** | **2010** | **2011** | **2012** | **2008** | **2009** | **2010** | **2011** | **2012** |
| **≤ 50 rooms** | 35 | 35 | 36 | 38 | 38 | 965 | 984 | 1,011 | 1,064 | 1,033 |
| **51-100** | 11 | 11 | 10 | 12 | 12 | 752 | 739 | 680 | 815 | 811 |
| **101-200** | 1 | 1 | 1 | 1 | 1 | 130 | 130 | 130 | 130 | 130 |
| **> 200 rooms** | 10 | 10 | 9 | 9 | 9 | 3,706 | 3,706 | 3,376 | 3,376 | 3,376 |
| **Hotels** | 57 | 57 | 56 | 60 | 60 | 5,553 | 5,559 | 5,197 | 5,385 | 5,350 |
| **Guest Houses** | 97 | 101 | 94 | 91 | 91 | 865 | 897 | 833 | 766 | 766 |
| **Resort Villas** | 259 | 261 | 275 | 294 | 296 | 747 | 767 | 821 | 838 | 833 |
| **Apartments** | 36 | 36 | 34 | 34 | 34 | 37 | 37 | 35 | 35 | 35 |
| **Total** | **449** | **455** | **459** | **479** | **481** | **7,202** | **7,260** | **6,886** | **7,024** | **6,984** |

In 2011, it was estimated that the average number of employees per room in Negril was 1.23. In 2012, Montego Bay, Ocho Rios and Negril collectively accounted for 30,874 persons or 87.7% of the total number of persons employed directly in the accommodation subsector. Montego Bay with 12,203 direct jobs represented the highest number of those employed (34.7%), Negril with 9,365 direct jobs, accounted for 26.6%, and Ocho Rios with 9,306, was responsible for 26.4%. Kingston, Port Antonio and the South coast accounted for the remaining 12.3% of employment in the accommodation sector.

Indeed, Negril provided the second highest number of direct jobs in 2012; however in addition to this direct employment, the tourism industry in Negril also gives rise to 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. Given this and the number of jobs reported by the JTB in 2012 for the Negril area (9,365), it can be estimated that in Negril another 18,730 jobs were indirectly generated or induced in 2012.

Recent developments in the tourism sector in the Negril area include Azul Sensatori Negril (formerly Beaches Sandy Bay) and Grand Lido planned expansions, both hotels located towards the northern end of Long Bay (Figure 6-102).

#### *6.3.3.3 Snorkel and Dive Sites*

Of the 48 snorkel and dive sites within the Negril area, five are less than 100 m away from the northern breakwater (Figure 6-102, Table 6-70)

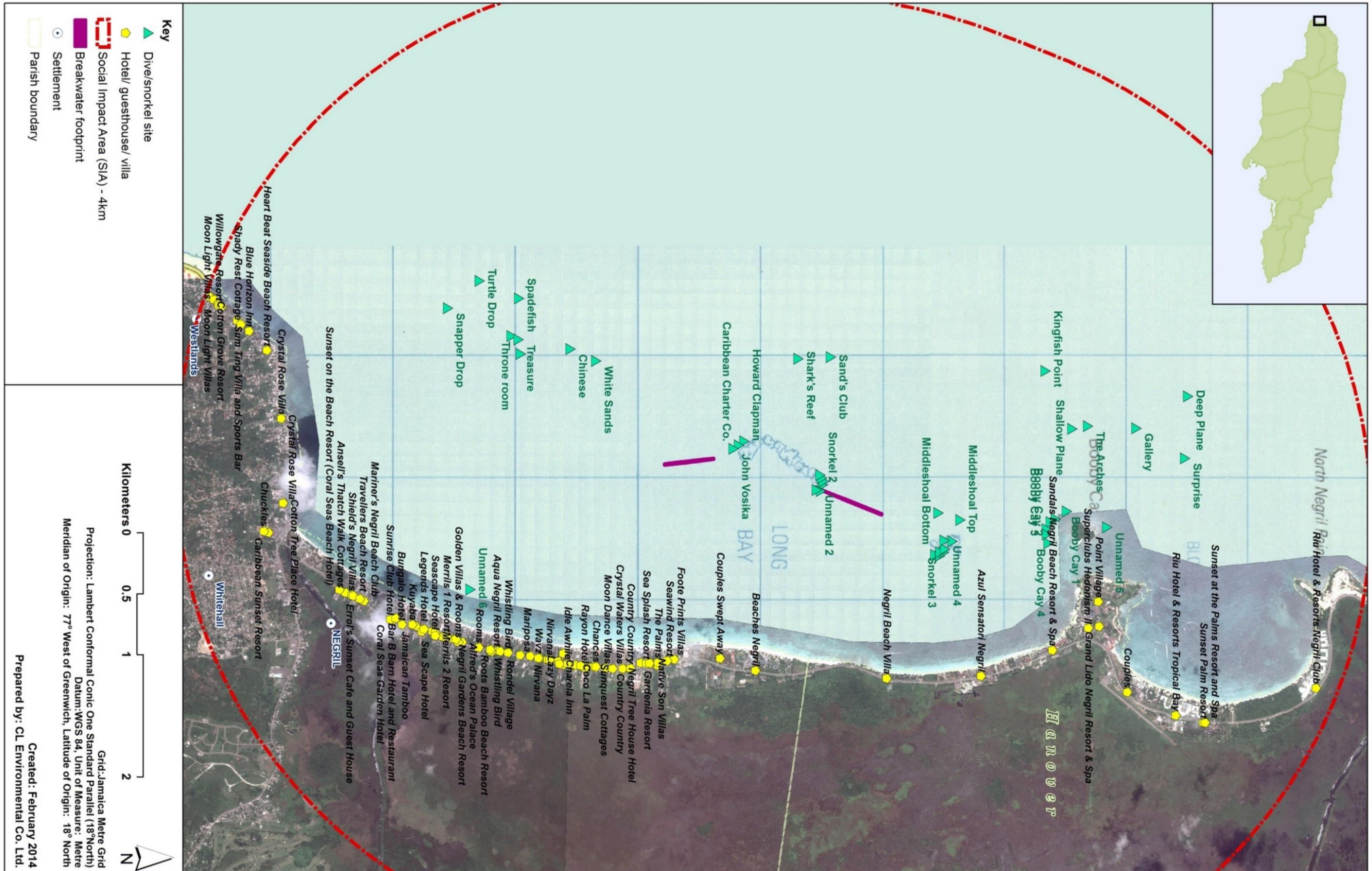



*Figure 6-102 Dive sites and hotels, guesthouses and villas located in vicinity of SIA*

*Table 6-70 Distance between proposed breakwaters and nearest dive/ snorkel sites*

| Dive/ snorkel site | WGS 1984 | | JAD2001 | | Nearest breakwater | Distance to nearest breakwater (m) | Bearing to nearest breakwater (degrees) |
|---|---|---|---|---|---|---|---|
| | Lat | Long | X | Y | | | |
| **Aqua Moon** | 18.318867 | -78.351100 | 607199.083448 | 685802.460728 | Northern | 30.9 | -20.8 |
| **Bailey-Bok** | 18.327583 | -78.345683 | 607416.306885 | 686302.252585 | Northern | 577.8 | -125.3 |
| **Booby Cay 1** | 18.336950 | -78.349200 | 607405.780200 | 686305.865027 | Northern | 1507.8 | -89.2 |
| **Booby Cay 2** | 18.335750 | -78.348350 | 607406.232337 | 686305.857964 | Northern | 1375.9 | -92.8 |
| **Booby Cay 3** | 18.335450 | -78.347817 | 607406.232337 | 686305.857964 | Northern | 1346.3 | -95.3 |
| **Booby Cay 4** | 18.335617 | -78.346717 | 607408.357611 | 686305.585348 | Northern | 1379.2 | -100.0 |
| **Caribbean Charter Co.** | 18.312650 | -78.354133 | 606948.144422 | 684928.279893 | Southern | 224.7 | -62.5 |
| **Chinese** | 18.300150 | -78.361483 | 606989.661439 | 684515.110111 | Southern | 1206.1 | 39.4 |
| **Coral gardens** | 18.296483 | -78.361083 | 606992.043815 | 684512.889533 | Southern | 1472.6 | 52.6 |
| **Deep Plane** | 18.345850 | -78.358183 | 607401.704901 | 686305.041434 | Northern | 2677.9 | -69.0 |
| **Gallery** | 18.342050 | -78.355683 | 607402.725523 | 686305.402108 | Northern | 2191.8 | -71.4 |
| **Howard Clapman** | 18.313067 | -78.354450 | 606947.971288 | 684928.187351 | Southern | 281.3 | -61.0 |
| **Joe Stennet** | 18.327233 | -78.345767 | 607416.984923 | 686301.746377 | Northern | 541.2 | -126.7 |
| **John Vosika** | 18.312267 | -78.353850 | 606948.144422 | 684928.279893 | Southern | 173.4 | -64.7 |
| **Kingfish Point** | 18.335300 | -78.360067 | 607398.347517 | 686302.913557 | Northern | 1771.3 | -49.0 |
| **Margaret Grosh** | 18.336133 | -78.348600 | 607406.043616 | 686305.864378 | Northern | 1417.4 | -91.7 |
| **Middleshoal Bottom** | 18.327450 | -78.349017 | 607405.780200 | 686305.865027 | Northern | 456.1 | -88.9 |
| **Middleshoal Top** | 18.329067 | -78.348467 | 607406.232337 | 686305.857964 | Northern | 636.5 | -94.6 |
| **Peace and Love** | 18.327867 | -78.345950 | 607416.014084 | 686302.445602 | Northern | 588.9 | -121.3 |
| **Pickled Parrot 1** | 18.266033 | -78.368033 | 606994.874919 | 684511.438616 | Southern | 4826.2 | 69.9 |
| **Pickled Parrot 2** | 18.266350 | -78.367833 | 606994.874919 | 684511.438616 | Southern | 4786.1 | 70.0 |
| **Pickled Parrot 3** | 18.266567 | -78.367467 | 606994.874919 | 684511.438616 | Southern | 4750.6 | 70.4 |
| **Randy Kay** | 18.318950 | -78.351383 | 607198.438841 | 685800.767969 | Northern | 62.2 | -20.8 |

| Dive/ snorkel site | WGS 1984 | | JAD2001 | | Nearest breakwater | Distance to nearest breakwater (m) | Bearing to nearest breakwater (degrees) |
|---|---|---|---|---|---|---|---|
| | Lat | Long | X | Y | | | |
| **Resort Divers** | 18.335483 | -78.347383 | 607406.415604 | 686305.840290 | Northern | 1354.7 | -97.2 |
| **Rick's Cafe 1** | 18.253417 | -78.364217 | 606996.440852 | 684511.013300 | Southern | 6065.2 | 78.0 |
| **Rick's Cafe 2** | 18.253533 | -78.363833 | 606996.440852 | 684511.013300 | Southern | 6044.5 | 78.3 |
| **Rick's Cafe 3** | 18.253967 | -78.364050 | 606996.440852 | 684511.013300 | Southern | 6002.0 | 78.0 |
| **Sand's Club** | 18.319417 | -78.361000 | 607178.670070 | 685747.961073 | Northern | 1063.0 | -7.2 |
| **Shallow Plane** | 18.337300 | -78.355600 | 607401.557060 | 686304.984720 | Northern | 1699.5 | -66.0 |
| **Shark's Reef** | 18.317017 | -78.360867 | 607178.698840 | 685746.337996 | Northern | 1050.5 | 7.1 |
| **Snapper Drop** | 18.291067 | -78.364583 | 606992.043815 | 684512.889533 | Southern | 2175.1 | 54.3 |
| **Snorkel 1** | 18.318817 | -78.351633 | 607190.389572 | 685779.545877 | Northern | 81.8 | -20.6 |
| **Snorkel 2** | 18.318700 | -78.351867 | 607183.127655 | 685760.294809 | Northern | 100.5 | -20.6 |
| **Snorkel 3** | 18.327617 | -78.345967 | 607416.178866 | 686302.343049 | Northern | 564.3 | -122.6 |
| **Snorkel 4** | 18.327950 | -78.346200 | 607415.193592 | 686302.920125 | Northern | 583.8 | -118.7 |
| **Spadefish** | 18.296333 | -78.365367 | 606989.661439 | 684515.110111 | Southern | 1793.0 | 41.4 |
| **Surprise** | 18.345667 | -78.353383 | 607404.318516 | 686305.750590 | Northern | 2517.0 | -79.6 |
| **The Arches** | 18.338467 | -78.355817 | 607401.557060 | 686304.984720 | Northern | 1826.8 | -67.0 |
| **Throne room** | 18.295783 | -78.362467 | 606991.054783 | 684513.657744 | Southern | 1624.0 | 50.1 |
| **Treasure** | 18.296300 | -78.362183 | 606991.054783 | 684513.657744 | Southern | 1560.9 | 49.6 |
| **Turtle Drop** | 18.293400 | -78.366717 | 606990.911500 | 684513.791943 | Southern | 2120.8 | 45.3 |
| **Unnamed 1** | 18.318750 | -78.350633 | 607219.118331 | 685800.320535 | Northern | 0.4 | 157.5 |
| **Unnamed 2** | 18.318450 | -78.350717 | 607205.781387 | 685768.995807 | Northern | 5.0 | 157.1 |
| **Unnamed 3** | 18.328500 | -78.346817 | 607410.036839 | 686305.059918 | Northern | 612.5 | -111.1 |
| **Unnamed 4** | 18.327933 | -78.346883 | 607414.235825 | 686303.367668 | Northern | 551.5 | -112.3 |
| **Unnamed 5** | 18.339933 | -78.347983 | 607406.232337 | 686305.857964 | Northern | 1840.2 | -93.4 |
| **Unnamed 6** | 18.292883 | -78.342817 | 607009.545140 | 684513.235886 | Southern | 1879.9 | 122.7 |
| **White Sands** | 18.302050 | -78.360583 | 606989.422550 | 684515.421438 | Southern | 1003.4 | 33.6 |

### *6.3.3.4 Fisheries*

Prior to Negril becoming one of Jamaica's top tourist destinations, it was known to be a small fishing village; however once the tourism industry began to expand along the Long Bay beach, many fishers were displaced (Otuokon 2001). Today, three fishing beaches exist within the general study area and are located in Long Bay, Bloody Bay and Orange Bay (Figure 6-103). The fishing beach in Long Bay is situated towards the southernmost limit of the bay, adjacent to the mouth of South Negril River and is the base for most fishers in Negril. A "Fishing Village" is located near the mouth of the South Negril River (Plate 6-37).

Approximately 14.4% of registered vessels[18] and 15% of registered fishers[19] in Jamaica were collectively located in the parishes of Hanover and Westmoreland in 2008 (Ministry of Agriculture and Fisheries). Specifically in the Negril area, there are currently 349 registered fishers, with 3 persons per vessel (by email correspondence Junior Squire, Fisheries Division/CL Environmental). The main fishing methods are by traps and lines.


***Source: National Environment and Planning Agency***[20]

*Figure 6-103 Fishing beaches in Jamaica*

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18 http://www.moa.gov.jm/Fisheries/data/Number%20and%20percentage%20of%20registered%20vessels%20by%20parish%202008.pdf

19 http://www.moa.gov.jm/Fisheries/data/Number%20and%20percentage%20of%20registered%20fishers%20by%20parish%202008.pdf

20 http://www.nepa.gov.jm/policies/beach/gifs/Map3%20Fishing%20Beach.JPG

*Plate 6-37 View of fishing village, Long Bay*

### *6.3.3.5 Protected Areas and Zoning*

An overview of all protected areas in proximity of the study area may be seen in Figure 6-104. Of particular interest to this study, are the Negril/ Green Island Development Order, the Negril Environmental Protection Area (EPA) and the Negril Marine Park, as the proposed breakwaters are located within the extents of these boundaries.

**Negril/ Green Island Development Order 1991**

Figure 6-105 displays the zooming for the Negril/ Green Island Development Order 1991. The proposed breakwaters are situated within the Development Order boundary, in a conservation area, as denoted by the "C". As stipulated in the Order, conservation or wise use should be practised everywhere and areas of particular concern are outlined as follows:

a) National Park
b) Tree Preservation
c) Wild Life Protection
d) Special Conservation Areas
    i. Sea
    ii. Beaches
    iii. Wetland
    iv. Upland
e) Special Conservation Problems
    i. Sand Dunes System
    ii. Swamp Forest
    iii. Booby Cay
    iv. Overfishing

As it relates to the sea as a conservation area, the order describes the coastal marine resources in Negril and the dynamic ecological balance that exists within and amongst the fringing coral reef with associated flora and fauna, extensive beds of turtle grass, manatee grass and algae and the sandy bottom.

**Negril Environmental Protection Area**

The extent of the Negril Environmental Protection Area (EPA) may be seen in Figure 6-106. As seen in this figure, the proposed breakwaters fall within this boundary. The Environmental Protection Plan (section 3.2.2.3) establishes the goals of the Negril EPA and guides environmental planning and decision making within the area. Twelve selected areas are outlined, including Long Bay beach.

**Negril Marine Park**

The Negril Marine Park covers a total area of approximately 160 $km^2$ and extends from the Davis Cove River, Hanover to St. John's Point in Westmoreland. The proposed project site falls within the Negril Marine Park and Figure 6-107 shows the following main zones within the area:

i. swimming
ii. non-motorized
iii. motorized
iv. replenishment
v. diving
vi. multiple use

The proposed breakwaters fall within the diving zone.

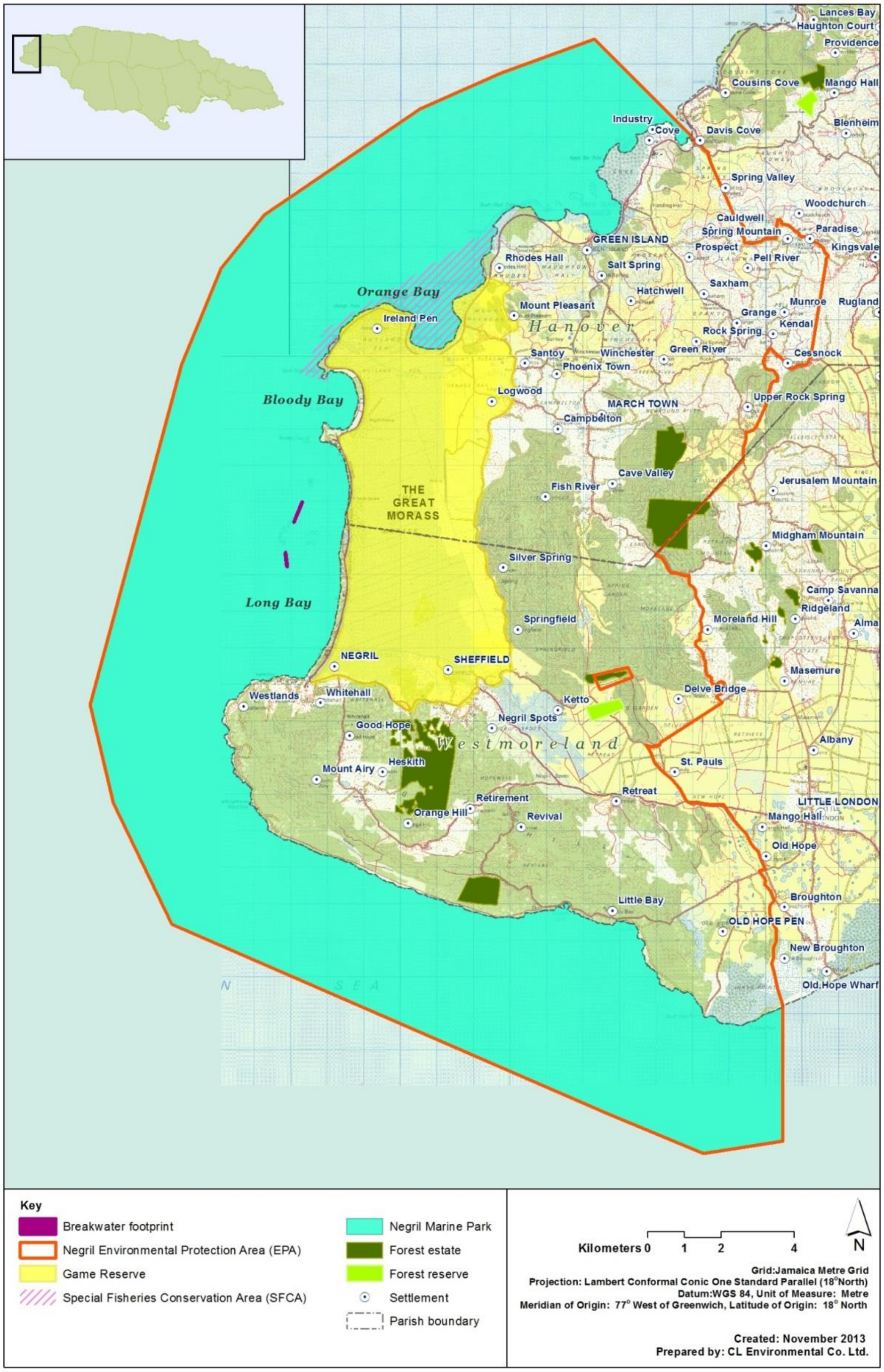



*Figure 6-104 Areas with protection status in proximity of the study area*

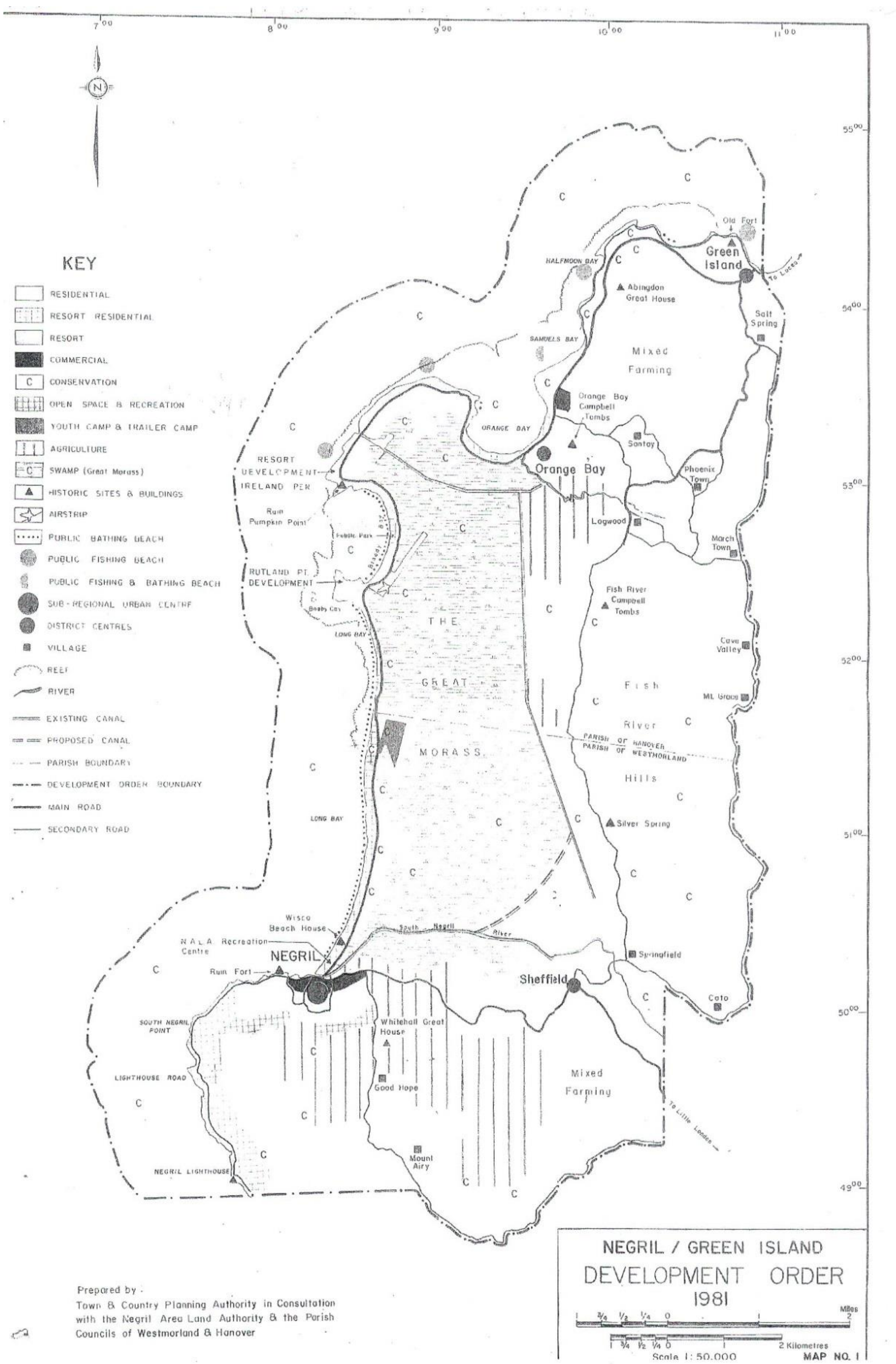



*Figure 6-105 Negril/ Green Island Development Order 1991 Map*


***Source: (Otuokon 2001)*** [21]

*Figure 6-106 Map showing the Negril Environmental Protection Area*

[21] http://www.canari.org/otuokon.pdf


Source: Protected Areas Branch, NEPA 2012

***Source: Interim Negril Marine Park Zoning Plan, NEPA/IPED/PAB 2012***

*Figure 6-107 Map showing the zones of the Negril Marine Park (2013-2018)*

## 6.3.4 Historical/Cultural Heritage

There is only one JNHT Heritage Sites in the vicinity of the study area, namely Negril Point Lighthouse which is a national landmark. It is situated at South Negril Point. The French firm Barber and Bernard built it in 1894. The tower is made of concrete and is approximately 20 metres (66 feet) above ground level and the light is elevated approximately 30 metres (100 feet) above sea level. This light flashes every two seconds and can be seen for up to approximately 16 kilometres (10 miles) away.

## 6.3.5 Social Impact Assessment

### *6.3.5.1 Introduction and Overview*

The Social Impact Assessment (SIA) is used to analyse, monitor and manage the social consequences of development" (Vanclay, 2003a, 6). To some extent, SIA is a component of EIA, especially when "the environment" is understood broadly. SIA is more than a technique or step, and is often times seen as a component of EIA (Vanclay, 2002a).

The specific objective of the SIA for this project was gleaned from the TORs for the Project which required "*… some level of stakeholder consultation in either focus groups or using structured questionnaires*." The process of engagement with stakeholders along the Long Beach sought to treat with specific issues contained in the project description, such as the erosion in the area, stakeholders' perceptions on the causal factors responsible for the erosion, their views on the proposed breakwaters project and any concerns they may have had about the said project.

To conduct the SIA two techniques were employed[22]:

- A survey instrument was administered to 355 stakeholders during the period January 30 to February 1, 2014. The specific stakeholders targeted were: members of the community, fisherfolk, water sports operators, tourists and shop/stall owners. Figure 6-108 shows the distribution of the survey among the various stakeholders.
- Focus Group sessions were conducted among four (4) groups of stakeholders during the period March 12 and 13, 2014.

[22] To reduce the likelihood of biasness careful attention was paid to ensure there was no overlap among those persons who participated in both the survey and the focus group sessions.

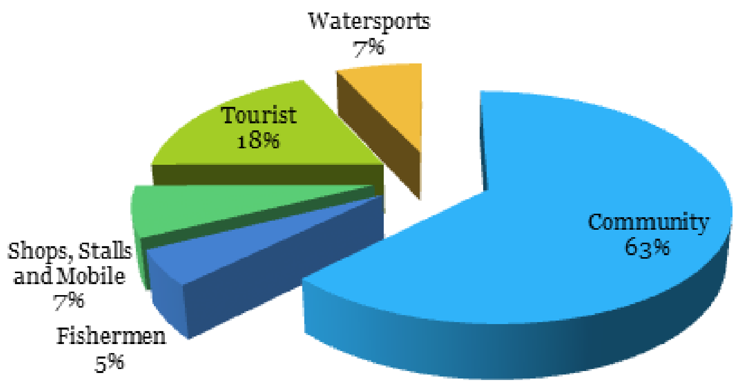



*Figure 6-108 Distribution of the survey among various stakeholders*

Due to the importance of the hotel sector in Negril, it was decided to use the focus group technique to engage this stakeholder group. With using the focus group technique there was no need to engage individual hoteliers by using questionnaires. A point of note is that persons who were interviewed by using the questionnaire technique were not included in the focus groups as this would result in cross counting and errors in the analysis.

The detailed results of the survey and focus group sessions are provided in subsequent subsections; however some of the salient findings are as follows:

1. There appears to be a significant level of awareness among the community surveyed of the erosion that affects Long Beach. However, and as noted in Figure 6-109 below, notwithstanding a high level of awareness of the erosion problem, when surveyed few residents seemed to be aware of the proposal to construct breakwaters to alleviate the erosion problem. Members of the community surveyed also indicated they had noticed environmental changes to the beach, including erosion.

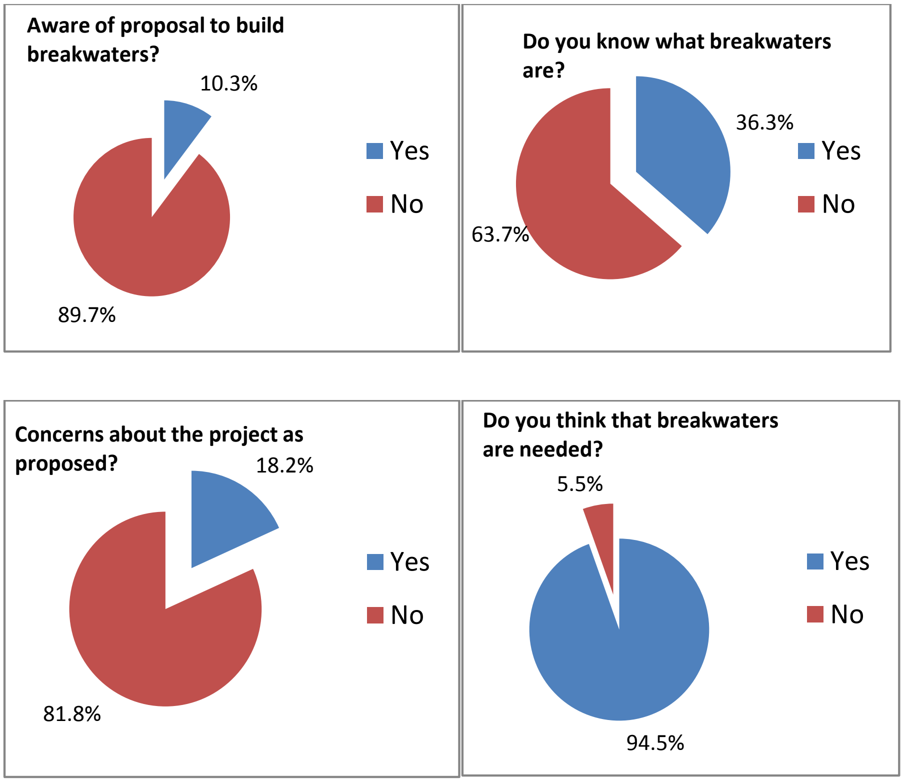



*Figure 6-109 Charts showing responses from the community (general population) in Negril*

2. Regarding awareness of the proposed project a similar result was seen when the fishermen and water sports operators were surveyed - both groups of stakeholders surveyed seemed unaware of the proposal to build the breakwaters (though to a lesser extent than when the community was surveyed).
3. When the fisher folk and water sports operators were given an explanation of how the breakwater is meant to help with the erosion, both sets of stakeholders generally agreed (i) that the breakwaters were needed (ii) that the breakwaters could alleviate the erosion problem at the Bay and (iii) that construction of the breakwater might affect their livelihoods.

Figure 6-110 and Figure 6-111 show the responses from the fisher folk and watersports operators respectively.

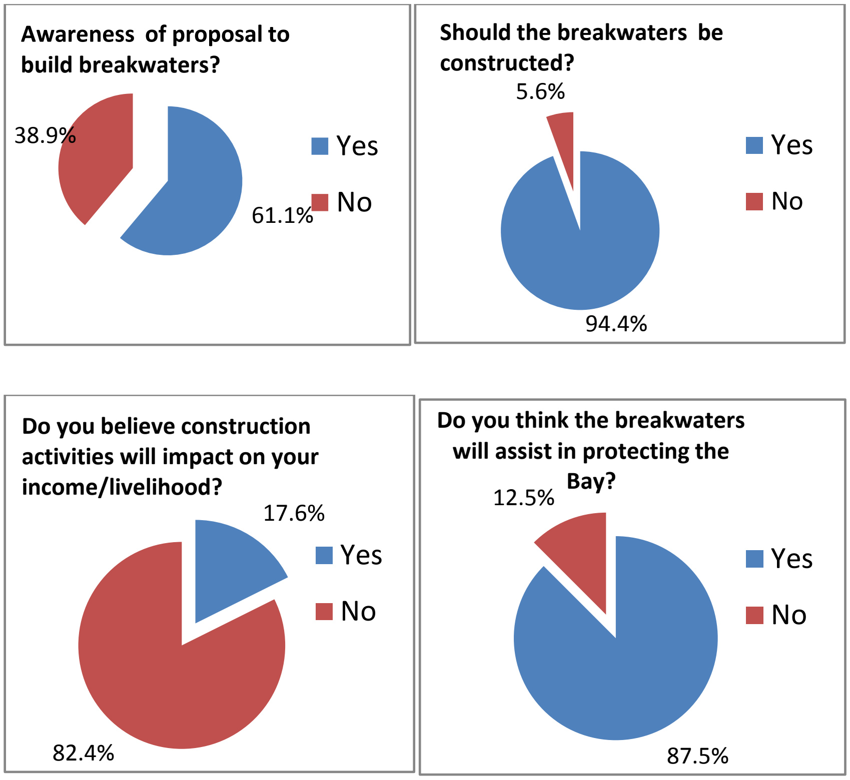



*Figure 6-110 Charts showing responses from the Fisher folk*

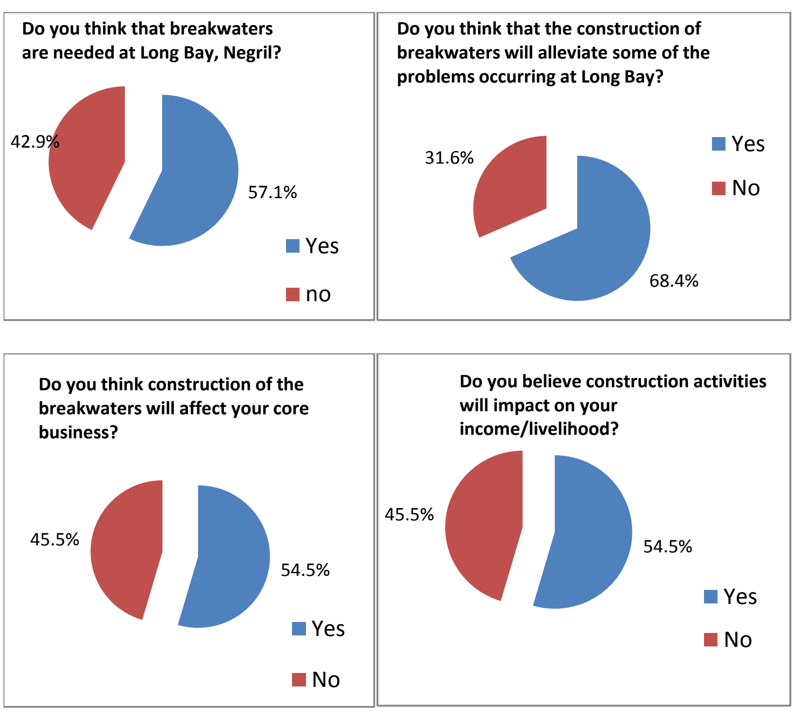



*Figure 6-111 Charts showing responses from the water sports operators*

4. Almost half of the tourists surveyed indicated they were aware of environmental problems along the Long Beach (Figure 6-112). Specifically they identified beach erosion and deterioration of the reef as the main environmental concerns. Tourists also expressed the view that construction of the breakwaters could alleviate the erosion problem.

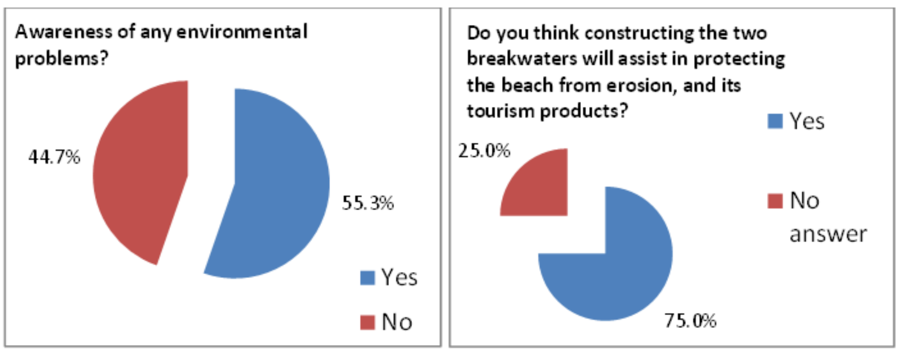



*Figure 6-112 Charts showing responses from the tourists*

### *6.3.5.2 Social Survey*

**Methodology**

A total of 355 questionnaires were administered in the Negril SIA on January 30, January 31 and February 1, 2014 in order garner feedback from persons whose livelihoods or recreational activity depend on the beach and bay. Key groups considered included persons residing within the SIA communities, fishers, watersports operators, tourists, as well as shops/ stalls and persons providing other services along Long Bay beach (Table 6-71). Questionnaires were developed specific to each grouping; and these are attached as Appendix 16. The number of questionnaires to be administered for each group of stakeholders was either based on the total population of the stakeholder group or based on the number of respondents available at the time the survey was being administered.

At the time of the survey data were available for some groups of stakeholders viz, fishers, tourists and the community. As reported earlier, the total SIA population in 2011 was 4,509 persons, and using a statistical margin of error of based of 5% an attempt was made to interview approximately 225 persons residing the Negril area. The distribution of these 225 persons was based on EDs as seen in Figure 6-113. Communities visited included Negril, Sheffield, Whitehall and Westlands and the total number of questionnaires administered was 224. The tourist population was based on the total number of rooms in 2012 (6,984 as in Table 6-69), with two persons per room at 90% occupancy; this resulted in an estimated 12,571 tourists within the Negril area. One percent of this tourist population was estimated at 126 persons for the survey population. Based on estimates from Fisheries, there are currently 349 registered fishers within the Negril area. A 5% survey target was established for this grouping, equating to a total of 17 intended for interview.

Owing to the social climate in Negril, it was decided that ad hoc, in the field decisions for watersports operators and retail/ other services along the beach would be taken since all persons are perhaps not registered or licensed. Shops or stalls permanently erected on the beach were visited and persons selling items on foot, or providing services such as massage and hair braiding were approached for interview as well.

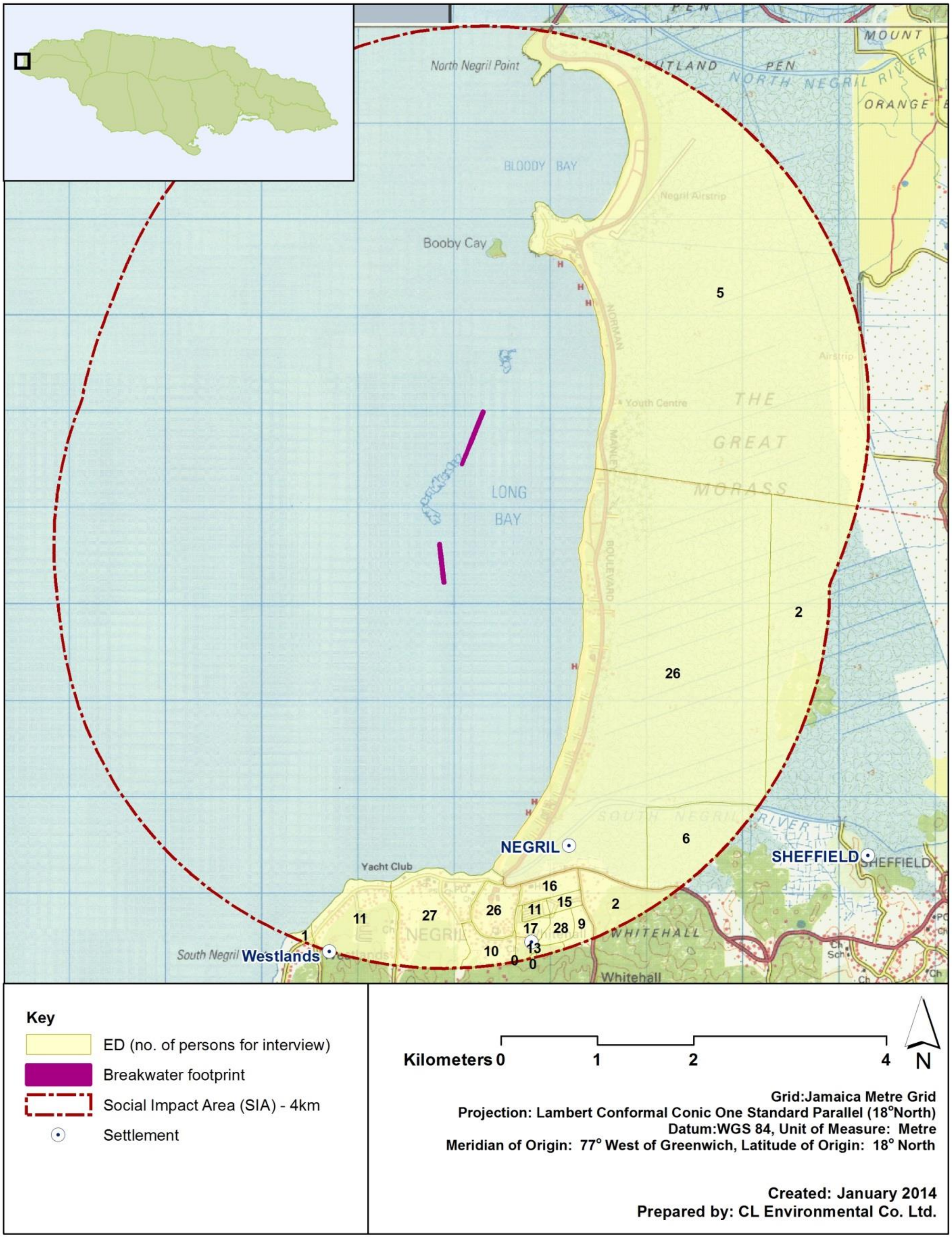



*Figure 6-113 Total number of persons per ED to be included in questionnaire target group*

**Results**

The target community population numbers were achieved and 224 community questionnaires were administered. Response rates for fishers was generally high (72 – 100%), with a total of 18 fishermen being interviewed, again fulfilling the target number of interviewees. A total of 65 tourists were interviewed and this was less than intended; however in the field it was found that tourists were unwilling to participate in the survey. Though some questions received response rates of 98.5% (64 individuals), other questions only received responses from 41.5% of the tourist group (27 individuals). A total of 26 persons were interviewed utilising this retail/ services questionnaire and the lowest response rate was 46%. However, perhaps owing to the watersports accident a week prior to the questionnaire survey[23], watersports operators were not willing to speak and only 22 watersports operators were interviewed with a response rate to one question being as low as 32%.

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, then this is stated as well.

*Table 6-71 Types of questionnaires, numbers administered and response rates*

| Questionnaire grouping | Group population | Intended survey population | No. questionnaires administered | Response rate |
|---|---|---|---|---|
| Community | 4,509 | 225 | 224 | 13 – 99% |
| Watersports operators | *Ad hoc* | | 22 | 32 – 100% |
| Fishers | 349 | 18 | 18 | 72 – 100% |
| Tourists | 12,571 | 126 | 65 | 42 – 99 % |
| Retail and other services | *Ad hoc* | | 26 | 46 – 100% |

*Community*

Of the resident population interviewed, 51.4% were males and 48.6% females. The largest age cohort was 41-60 years (38.3%), followed by 26-40 years (34.2%), less than 25 years (16.2%) and lastly greater than 60 years (11.3%). The majority of the community population interviewed have been living in the Negril area for more than 11 years (74.8%), and 21.2% between 1 and 10 years and 4.1% less than a year.

Approximately 66.2% of persons stated that they had not noticed any environmental changes within the community, the remaining 33.8% who did notice changes, stated the following: both cooler and hotter temperatures; more rainfall as well as drought; more as well as less flooding; less burning; beach erosion; cutting of trees; mosquito infestation; polluted river from sewage and subsequent destruction of reef; urbanization; littering; and fungus infestation. Specific to Long

[23] http://jamaica-gleaner.com/latest/article.php?id=50785

Bay, some of the problems stated to affect Long Bay include odour problems; garbage problems on roads, in river and on beach; destruction of marine life; removal of mangroves; bad road conditions; blockage of river with sand; seaweed on beach; burning of garbage in sink holes; problems with sewage system; building of hotels on beachfront; beach erosion and flooding.

The majority of persons were not aware of the plans to construct a breakwater (89.7%) and only 10.3% were aware of this project. The majority also did not have any concerns regarding the project (81.8%), whilst 18.2% had numerous concerns regarding: recreational activity of children at breakwater site; effect on business and possible work opportunities; effect on fishing activities and possible harm to fish populations and reefs; effects on appearance of beach during construction; effects on tax; duration of construction phase and maintenance programme during operation; safety and; effect on tourism, beach use and boat traffic. In addition to these concerns, a number of persons stated that they don't believe the breakwaters would work and that the project is a waste of time and money.

Only 28.5% of respondents believed that the project would affect their lives, whilst 71.5% believed it would not. All those that believed it would affect their lives, believed it would be a positive effect, and mentioned the following: more customers and possible work opportunities leading to greater income, beach accretion, improved beach aesthetics and increased appreciation for the sustainable use of environment. In fact, 94.5% of residents interviewed believed that the breakwaters are needed in Long Bay, and only 5.5% believed that they were not.

When asked about the construction possibly causing negative impact on businesses, the majority (82.7%) believed that there would be no affect, whilst 17.3% believed there would be an effect. As it relates to thoughts on the construction activity being good, the majority (96.7%) answered positively and believed it would be good owing to alleviation of the beach erosion problem, possible job opportunities and general environmental improvement of the Negril area; whilst 3.3% did not believe it would be good. Seventy two percent expressed that the construction activity will not affect their income earning capacity, whilst 28.0% stated that it would. Those that responded positively to this question, predominately gave positive reasons, such as increased income owing to more customers and possible job opportunities.

The majority of respondents (91.7%) answered "yes" when asked if they thought that the construction of breakwaters will alleviate some of the problems, and 8.3% stated "no". However when asked if they can think of any other measures that could be taken, the majority answered negatively (84.5%), whilst 15.5% of respondents gave the following alternative means: use of gabion baskets, sand bags, bricks, stones, old vehicles and iron packed on the beach and lining the coast; planting more coconut trees to prevent erosion; dredging the river and fixing gullies and drains; allowing nature to takes it course; cleaning the beach and roads, placing more garbage disposal facilities on the road and sensitizing persons about recycling; fixing the main roads; designing breakwaters in a wavy or circular fashion as opposed to straight; developing reefs as natural barrier; and avoiding the removal of sand when removing seaweed from the beach.

*Watersports Operators*

The watersports group was comprised of males younger than 60 years, with 44.4% aged 26-40 years, 40.0% 41-60 years and 16.0% less than 25years[24]. The average length of time that watersports operators have been involved in the business in Negril was calculated to be 14 years, with one individual working as long as 30 years and a few working for 2 or less years.

The services offered by the operators included:

- Jet ski
- Glass bottom
- Snorkelling
- Parasailing
- Sailing
- Tours
- Cruises
- Island picnic
- Scuba diving

Ratio of average percent tourists vs. local customers is 5:1 (82% tourists versus 18% locals). Equal percentage locals and tourists (50% vs. 50%) were only reported by two interviewees. With regards to the question if customers have to be in the water at any time, of those who responded, 52.2% responded positively, whilst 47.8% responded negatively. These customers are carried 1-3 kilometres out from the shore, at snorkel sites, dive sites or visiting Booby Cay.

The majority of watersports operators depend on the environment (95.8%), whilst one operator reported that he (4.2%) does not. Approximately 70% of respondents indicated that they have noticed changes in the water or environment, whilst 30% did not. Changes and likely causes of changes that were suggested included river pollution into the sea as a result of sewage; beach erosion and changing shoreline owing to removal of trees, hotel development, wave action, dying and damaged coral owing to pollution; reduced fish and turtle populations and proliferation of lionfish owing to pollution and natural causes respectively; littering and sewage from humans; and blockage of the river due to sand build up. Responses given for the most significant change varied; however of the 12 responses received, beach erosion was stated the most frequently (6 responses). When asked if there was a particular time of day or season when these changes are most evident, 55.6% stated “no”, and the remaining 44.4% gave the following times during which the changes are more evident: summer, rainy season, January and February, September to November, winter and all year.

With regards to effect on business, 55.6% stated that the observed changes had effects on their business, whilst 44.4% stated that they did not have any effect. Explanations provided included

[24] It should be noted that all percentages given throughout this section are based on the number of respondents for each question.

a reduction in customer number and loss of interest from tourists since there was dead reef and less fish and turtles (therefore not much to see on glass bottom, snorkel and dive expeditions). When asked if any of their customers indicated that they noticed similar changes, 59.1% responded positively and 40.9% negatively. A similar 54.5% of customer were said to complain about these changes, whilst 45.5% did not complain. Fortunately, only two watersports operators (9.5%) stated that customers have experienced illness owing to the changes, and 90.5% stated that no customers had become ill. The majority of respondents stated that they had not lost customers as a result of the changes observed (68.2%), whilst 31.8% had lost customers. The majority of watersports respondents (81.0%) expressed that greater than 75% of their total income is derived from the environment, 14.3% stated 51-75% and 4.8%, less than 25%.

When asked if they were aware of any activities or practices which impact on the environment positively or negatively, the responses were more or less equal amongst the group with 47.8% answering "yes" and 52.2% answering "no". Specific to positive practices, 66.7% of watersports operators believed that their practices impact the environment positively, whilst 33.3% did not. Those that responded positively gave the following examples of positive practices: cleaning up garbage from beach and water, planting trees/ grass, educating costumers and not littering. In terms of negative practices, 90.0% of respondents stated that their practices did not affect the environment negatively, whilst 10.0% (two persons) stated "yes" and expressed their thoughts with regards to the use of gasoline and general watersports activities.

Regarding challenges faced which prevent watersports operators from engaging in positive environmental practices, answers provided included cost, lack of information, lack of technical assistance, too little time, lack of know-how and not viewing it as important. Approximately 66.7% of respondents were willing to pay for information services or technical assistance with ways to have positive environmental services, whilst 33.3% were not willing.

Twelve watersports operators (57.1%) believed that the breakwaters are needed in Long Bay, and the remaining 42.9% did not believe they were necessary. Fifty five percent of respondents thought that the construction of the two breakwaters would affect their core business, whilst 45.5% of respondents did not think it would have any effect. In answer to the question "do you believe construction activities will impact on your income/livelihood?" similar response were received, with 54.4% positive responses and 45.5% negative responses. Some of the environmental problems occurring at Long Bay suggested by watersports operators included river pollution, reef and shoreline erosion, garbage collection and lack of respect. The majority of respondents (68.4%) believed that the breakwaters would alleviate some of the problems in the bay, whilst 31.6% did not. When asked about other means that can be used to protect the bay, 52.6% said that they did not know of any, however 47.4% said that they were aware of some, and mentioned the movement of hotels landward, fixing the sewage problem, cleaning up the communities, implementing mooring restrictions, building an artificial reef or leaving it to natural mechanisms.

*Fishers*

Seven fishers (38.9%) were between 41 and 60 years, six (33.3%) between 26 and 40 years, 4 (22.2%) were younger than 25 years and one (5.6%) over 60 years of age. Fifty six percent have been fishing in the Negril area for less than 10 years, 16.7% between 11 and 20 years and 27.8% over 20 years.

When questioned about environmental problems within the community, 88.2% stated that there are problems, such as sewage problems, river pollution and the block of the river by sand; the remaining 11.8% were not aware of any problems. Changes in the environment in the past 10 years and causes for these included river pollution resulting from sewage discharged from the treatment plant, blocking of river channel owing to build up of sand, beach erosion, unhealthy appearance of reef and the reduction in fish numbers potentially caused from pollution and eggs not being laid by adults. Responses for top three (3) environmental problems facing their community included:

- River and sea pollution
- Dying fish population
- Solid waste pollution (at public beach)
- Blockage of river
- Foul odour
- Dying birds resulting from eating contaminated fish
- Skin problems

All fishers depend on the environment as a source of income and for subsistence, with 88.9% reporting that greater than 51% of their total income was derived from the environment, and the remaining 11.1% reporting less than 50% of total income. Similarly, with regards to subsistence, 83.3% reported that greater than 51% of their total activities are for subsistence, and 16.7% reporting less than 50%. Total weekly income was generally above $3,000 JMD, with 30.8% reporting incomes of $10,000 and over, another 30.8% earning $5,000-$9,999, 15.4% earning $4,000-$4,999, another 15.4% earning $3,000-$3,999 and 7.7% earning between $2,000 and $2,999. All fishers interviewed stated that locals are their main customers, whilst 16.7% (3 fishers) included tourists as customers, and one fisher (5.6%) stated that his output was purchased by hotels as well.

The majority (88.2%) of those who answered the question regarding engagement in practices with positive effects on the environment responded positively, whilst 11.8% stated that they were not engaged in such practices. Practices believed to have positive effects included using nets within the legal limit, killing lionfish, removing bottles from the sea, disposing of garbage properly, cleaning the beachfront and fish feeding. Conversely, only 22.2% of fishers who responded stated that they were involved in practises that affected the environment negatively (burning garbage and smoking) and 77.8% stated that they were not. With regards to the challenges faced that prevent persons from engaging in positive environmental practices, fishers expressed that lack of technical assistance, lack of information and cost were major challenges, and one fisher stated another reason, specifically busy work schedule (too little time).

The fishers' community believe that the following practices would be applicable in preserving the environment as well as sustaining it for the future:

- Fix existing sewage treatment plant or erect a new facility
- Use less chemicals
- Avoid littering and keep the area clean
- Avoid catching small fish, dynamiting and overfishing
- Create fish farms
- Enforce conservation and fisheries laws
- Dredge the river
- Fix the breakwater offshore the Issa property
- Create an artificial reef

As many as 76.5% of fishermen (13) stated that they were willing 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. The remaining four fishers (23.5%) were not willing to pay for such services.

Specifically regarding the breakwater construction, 61.1% of fishermen interviewed were aware of the project; however 38.9% were not. All interviewed but one fisherman believed that the breakwaters should be constructed. Ten fishers (55.6%) did not believe that the breakwaters would affect their daily activities and eight (44.4%) believed that they would, for example the construction would kill or cause fish to migrate, and block passage and access to the beach. Fishers were also asked if they believe construction activities will impact on their income/livelihood, to which 82.4% responded positively and 17.6% negatively. However, 87.5% believed that the breakwaters would assist in protecting the bay from beach erosion, whilst only 12.5% believed that they would not. When asked if they think any other means can be used to protect the bay, 66.7% stated "no", whilst 33.3% said yes, and gave the following possible means: fixing the sewage problem, building separation from the river, fixing breakwater offshore the Issa property and creating an artificial reef.

*Tourist*

Tourists approached for interview were predominantly between 41 and 60 years of age (54.7%), followed by persons older than 60 years (23.4%), then the 26-40 years age cohort (15.6%) and lastly younger than 25 years (6.3%). There were 49.2% males and 50.8% females. The majority of those interviewed were on vacation (73.8%), whilst 9.2% were visiting for business purposes, 7.7% to visit family and/or friends and other reasons (9.2%) included Jazz festival, charity work and temporality residing for winter season. Approximately eighty percent had visited Long Bay, Negril previously and on average 12 times previously, whilst 20.6% were visiting for the first time.

Activities that tourists have participated in or intend to participate in during their visit to Long Bay, along with percentage responses are as follows:

- Sun bathing 60.0%
- Restaurants 53.8%
- Jogging/ walking 50.8%
- Swimming 46.2%
- Glass bottom boat tours 38.5%
- Nightlife 35.4%
- Water sports 29.2%
- Snorkelling/ Diving 29.2%
- Massage 27.7%
- Visiting Booby Cay 16.9%
- Cruises 13.8%
- Other (e.g. Frisbee, charity) 12.3%
- Horseback riding 9.2%
- Fishing 6.2%
- Volleyball 6.2%
- Wedding 6.2%

About 22.2% of those who responded perceive that activities impact the environment negatively, whilst 77.8% do not. For 89.3% of tourists, environmental quality plays an important role in choosing tourism destination, whilst for 10.7% it does not. With regards to the environmental quality of Long Bay beach, 54.7% rated it as "good", 28.3% as "excellent", 11.3% as "satisfactory", 3.8% as "fair" and 1.9% as "poor".

When asked if they share the view that development of the tourism sector should include environment, all respondents gave positive answers. When asked if they were aware of environmental problems in Long Bay, 55.3% stated "yes", whilst 44.7% stated "no". Problems described include beach erosion, garbage pollution on beach and in the water, noise nuisance from jet skis, visually unpleasant beach vegetation, presence of oil in water and reef deterioration. Of those that stated environmental problems, 86.7% had visited Long Bay previously whilst 13.3% had not.

When asked to rate their level of agreement with statements based on observed activities along Long Bay beach, the following average responses were calculated[25]:

- Minimize negative impacts on the environment 2
- Minimize negative impacts on the local people 3
- Increase the awareness of natural and heritage systems 3

[25] Scale of 1 to 5 where 1 = Strongly disagree, 3 = Neutral and 5 = Strongly agree.

- Contribute to protection of legally protected areas 3
- Direct economic and other benefits to the local people 3
- Promote participation and empowerment of local people 3

A similarly set of rated statements were also put forward regarding visitors placement of values on the environment and specifically ecotourism, and the following average responses were received:

- Concerned about environmental issues 4
- Rational that restrictions be placed on natural resources 4
- Abide to restrictions placed on natural resources 4
- Support interventions for environmental management 4

Specific to the breakwater project, 73.8% believed that the breakwaters should be constructed, whilst 26.2% did not. When asked if they thought constructing the two breakwaters would assist in protecting the beach from erosion and its tourism products, the majority responded positively (75.0%) and the remainder negatively (25.0%). Only 23.8% of those interviewed thought that other means could protect the bay and suggested sustainable beach use, healthy mangroves, less hotels, more breakwaters, encouragement of natural reefs, recycling, vegetate beach and dredging and beach replenishment; 76.2% did not state any other means.

The majority of tourists interviewed were not aware of the Long Bay beach park user fee (94.9%) and one individual commented that persons should not have to pay. When asked if they would be willing to pay any additional amount if it is to be used for conservation efforts however, 55.6% said that they would be willing, whilst 44.4% would not be willing.

*Retail and Other Services*

Those involved in retail and other services along Long Bay beach and who were included in the social survey sold art and craft (e.g. wood carvings, basket weaving and jewellery), souvenirs, CDs, clothes, bags, cigarettes, food items (fruit, snacks seafood) as well as food and bar services. The questionnaire respondents varied in age, with about half the group (46.2%) being between 26 and 40 years, another 46.2% 41-60 years of age, and 7.6% less than 25 years or greater than 60 years. Based on responses, the average length of time operating along the beach was calculated to be 12 years, with one person working for longer than 30 years along the beach. Services typically open between 8 and 9 a.m. and close between 5 and 6 p.m. The number of customers served per day was predominately less than 25 (92.3%), with 3.8% serving between 26 and 50 customers and another 3.8% serving between 51 and 75 persons. Average percentage of local customers was estimated at 22%, with a much higher average tourist clientele of 79; in fact, a number of respondents reported that all their customers were tourists.

The majority of respondents reported that they depended on the environment for their business (84.0%), whilst 16.0% do not. A good environment typically attracts tourists and other beach users; some harvest thatch from the mountain side, shells and coral for jewellery or catch fish for sale; and trees provide shelter, though when it rains sales decrease and additionally there are effects on beach quality. Percentage of total income reported to be derived from the environment varied: 52.6% stated greater than 75%, 5.3% for the 51-75% grouping, 15.8% for 25-50% and 26.3% less than 25%.

When asked if they have noticed any changes in the water or the environment, 70.8% responded positively, whilst 29.2% responded negatively. Some of the changes observed include diminished beach width and beach erosion, dying coral reefs, less fish, hotter climate, seasonal water levels, hotels too close to water, rougher waters, higher tides, garbage, loss of trees and crabs on the street. The most significant of these were stated to be beach erosion, hotel development on the beach and smaller fish populations. Possible reasons given for beach erosion include natural causes and the development of hotels. Responses regarding if changes observed have affected business in any way were split more or less evenly, with 53.3% stating “yes” and the other 46.7% stating “no”. The majority of respondents (61.1%) stated that their customers indicated that they have noticed similar changes, whilst 38.9% stated that their customers did not make any such indication. Fifty six percent of respondents said that their customers have complained about the changes, whilst the other 44% did not. One customer as reported to have caught an infection as a result of environmental changes. Only 31.6% of retail persons stated that they have lost customers as a result of the changes, and the majority (68.4%) have not. Times at which the changes were most evident were stated to be during the winter months and during strong weather events.

When interviewees were asked if they were aware of any activities or practices which impacted on the environment positively or negatively, 54.5% responded negatively and 45.5% positively. When specifically asked about positive practices, 68.8% did not engage any and the 31.3% who stated “yes” described cleaning up of garbage from the beach. On the other end, with regard to negative practices, the majority stated that they did not think that any of their practices impacted the environment negatively, and one person (5.9%) stated that the breakage of bottles may lead to possible injury and thereby a negative effect.

Predominant reasons stated as challenges faced which prevented respondents from engaging in positive environmental practices included lack of information, lack of technical assistance and lack of know how. Fifty eight percent of respondents stated that they would be willing to pay if an environmental agency were providing information/technical assistance on ways to improve your environmental practices; 41.7% were not willing to pay.

The majority of respondents (86.4%) believed that the breakwaters are needed in Long Bay, whilst 13.6% did not believe they were needed. Respondents also believed that the construction would not cause their business to have to relocate (85.0%), whilst 15.0% believed that they may have to relocate. About 70% believed that the breakwater construction would not affect their core business and 30% believed it would since tourists may not want to visit the area during construction. When asked if they believed construction activities would impact their income/

livelihood, 50% responded negatively and 50% positively. The reasons provided differed: a few persons believed that the construction will lead to purchase of more goods by workers, whilst another expressed that fewer tourists would mean less income. Some of the problems stated to affect Long Bay include erosion, river pollution, littering, lack of security and law enforcement, odour near Cosmos, and hustlers needed a designated area. Eighty four percent of retail persons interviewed believed that the breakwaters would alleviate some of the problems, however 16% did not. The majority believed that the breakwater was sufficient to alleviate the erosion problem and could not think of any other means (55.6%); however the other 44.4% believed that removal of hotels from the beach, erection of fence lines and proper security, building of barges, desisting from mining and heavy building or allowing nature to take its course are plausible alternative solutions.

#### *6.3.5.3 Focus Group Discussions*

**Methodology**

As noted earlier in the introduction to the SIA, focus group sessions were conducted with four groups of stakeholders during the period March 12 and 13, 2014. A total of fifty-two (52) persons participated in the focus group discussions. The stakeholders represented among the focus groups were (i) Environmental groups (NEPT, NEPA), one hotelier and one representative from the Negril craft-market (ii) fisher folk and water sport operators (iii) planning and law enforcement agencies in Negril such as the police, fire services and health department and (iv) hoteliers who operate in the Negril Area.

In addition to the above an initial meeting was held with the Negril Resort Board on in order to inform Board Members of the proposed project and elicit comments and feedback.

Surveying methods are well established in the literature to allow feedback from respondents to specific sets of questions. In addition to traditional surveys the literature suggests that using focus groups is one of the best tools in qualitative research to allow participants to focus on a particular issue and to engage in discussions that yield various opinions on a particular subject. There is a useful cross fertilisation of ideas that emerge from the discussion as participants can elaborate on opinions generated during the focus group sessions.

Powell et al define a focus group as, "*a group of individuals selected and assembled by researchers to discuss and comment on, from personal experience, the topic that is the subject of the research* (1996: 499)". Gibbs (1997) noted that there are many definitions of focus groups and various authors have identified the contribution that focus groups make to social research. Gibbs has cited the works of (Kitzinger 1994) who characterised focus groups as organised discussion, (Powell et al 1996), who highlighted the strengths of focus groups as a collective activity and(Kitzinger 1995) who focused on the level of interaction that comes from focus group discussions.

While focus groups are a form of group interviewing it is important to distinguish between the two. Group interviewing involves interviewing a number of people at the same time, the emphasis being on questions and responses between the researcher and participants. Focus groups however rely on interaction within the group based on topics that are supplied by the researcher. (Morgan 1997: 12)

**Results from the Focus Group Discussions**

A detailed summary of the focus group discussions as well as attendance lists are provided at Appendix 17; however the salient issues that emerged from the discussions can be categorised as technical, logistical and socio-economic. The specific sets of issues raised under each of the three categories were as follows:

*Technical Issues*

a) Inadequacy of the monitoring period identified - participants were of the view that the monitoring period suggested in the EIA was insufficient.
b) Appropriateness of the location and the design of the breakwater - participants were of the view that the technical specifications of the breakwater should be reviewed.
c) Disagreement with the major points of erosion identified in the proposed project.
d) The counter effects of dredging the river (no longer included in project scope)
e) Effect of the structure on the natural flow of the ocean and sea life

*Logistics Issues*

f) The day to day operational issues at the stockpiling area – there was concern about the ability of the trucks to manoeuvre within the designated stockpile area.
g) The suggestion emerged that there should be indicators on or near the breakwaters to alert boaters of the physical structure.
h) The appropriateness of the season for the project in Negril – construction of the breakwaters could indirectly interrupt the tourist season.
i) Emergency procedures in case of accident (particularly fire)
j) Justification for the route chosen for transport of material and the choice of location for stockpiling area

*Socio-Economic Issues*

k) Air and noise pollution during construction (Mitigation strategies)
l) Traffic congestion in the stock pile area
m) Safety concerns – particularly as trucks transport boulders in the Negril area.
n) Impact of breakwater on livelihoods (snorkelling, diving, fishing, watersports)
o) Aesthetics of breakwater both during construction (boulders transportation) and post construction (visual impact of boulders)

**Conclusion**

This section provides summary conclusions on the SIA gleaned from both the survey and the focus group discussions. The main issues and concerns distilled are as follows:

1. Greater effort needs to be made by the relevant authorities to sensitize the public in Negril about the project. Several stakeholders, both those surveyed and those who participated in the focus group sessions, indicated they were unaware, prior to the survey or the focus group meetings, of the proposed plans to build the breakwaters.
2. There is a high level of awareness of the erosion problem facing the area. This awareness was evident among all stakeholders, tourists, members of the community, hoteliers, fisher folk, water sport operators etc. However there is divergence of opinion, expressed repeatedly during the focus group sessions, about the areas identified in the project proposal as having the greatest amounts of erosion.
3. As a corollary to point two (2) above there is a general opinion, garnered from the survey results and the focus group discussions, that the project is likely to yield benefits in terms of mitigating the erosion problem. However this consensus is somewhat diminished based on the questions raised regarding the design of the breakwaters and related technical issues such as the proposed location of the breakwaters.
4. There are concerns which emerged repeatedly about the impact the project could have on the livelihoods of persons who depend on the bay for income generating activities. There was some difference of opinion between fisher folk surveyed and those who participated in the focus group sessions on the extent to which their livelihoods might be negatively affected by the construction of the breakwater. Only a small number of those surveyed (less than 20%) felt that their income/livelihood could be negatively affected by the construction of the breakwater. By contrast those fisher folk who participated in the focus group sessions highlighted the problems that dredging of the river for the project might have on their livelihoods (dredging was included the original proposal; however this has been changed and there will no longer be dredging of any section of the river). One reason for the difference of opinion could be the information provided to the focus groups on the project design. All the water sports operators were of the view that the project could negatively impact their income generating activities.
5. The logistics pertaining to the trucks in the stockpiling area and the issues of traffic congestion need to be addressed especially in light of the fact that the project is due to commence during a period in which there are many activities taking place in Negril.
6. Greater law enforcement is needed as it relates to monitoring setback distances on the beach.

# 7.0 IDENTIFICATION AND ASSESSMENT OF POTENTIAL DIRECT AND INDIRECT IMPACTS

Impact matrices for the site preparation/construction and operational phases were created utilising the following criteria[26]:

- **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.
    - Uncertainty in prediction due to lack of accurate data or complex systems. Precautionary principle is advocated in this scenario.

[26] 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

The impacts outlined in the EIA were determined based on:

- Years of experienced by various consultants working in their fields,
- Documented impacts from similar projects,
- Data collected,
- Analysis of processes in the proposed project,
- Information generated from models,
- Concerns raised from stakeholders in the social surveys and focus group meetings and
- Discussions among the EIA Study team.

*Table 7-1 Impact matrix for site preparation and construction phases of breakwaters*

| ACTIVITY / POTENTIAL IMPACT | DIRECTION | | DURATION | | LOCATION | | MAGNITUDE | | | EXTENT | | | SIGNIFICANCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pos | Neg | Long | Short | Direct | Indirect | High | Moderate | Low | National | Regional | Local | Large | Medium | Small |
| **1. Site Preparation and Construction** | | | | | | | | | | | | | | | |
| **Biological Impacts:** | | | | | | | | | | | | | | | |
| Impact on coral communities: | | | | | | | | | | | | | | | |
| Direct loss and removal (within breakwater footprint) | | X | X | | X | | | X | | | | X | | X | |
| Indirect (e.g. smothering from sediment, reduced water quality) | | X | | X | | X | | X | | | | X | | X | |
| Indirect impact on seagrass communities (e.g. smothering from sediment, reduced water quality) | | X | | X | | X | | X | | | | X | | X | |
| Fish and invertebrate displacement | | X | | X | X | | | | X | | | X | | | X |
| Loss of natural habitat (pavement zone) | | X | X | | X | | | X | | | | X | | X | |
| Habitat fragmentation (seagrass, coral etc.) | | X | X | | X | | | X | | | X | | | X | |
| **Physical Impacts:** | | | | | | | | | | | | | | | |
| Increased noise pollution | | X | | X | X | | | | X | | | X | | | X |
| Sedimentation of marine environment | | X | | X | X | | | X | | | | X | | X | |
| Increased water pollution (oils, solid waste etc.) | | X | | X | X | | | X | | | X | | | X | |
| Increased accident potential | | X | | X | X | | | X | | | | X | | X | |
| Visual aesthetics | | X | | X | X | | | | X | | | X | | | X |
| **2. Transport** | | | | | | | | | | | | | | | |
| Potential spillage of material and harmful substances (oils, gasoline etc.) | | X | | X | X | | | | X | | | X | | | X |
| Increased maritime traffic | | X | | X | X | | | X | | | | X | | X | |
| **4. Construction Crew** | | | | | | | | | | | | | | | |
| Solid waste management | | X | | X | X | | | | X | | | X | | | X |
| Workers safety | | X | | X | X | | | | X | | | X | | X | |
| **5. Socioeconomics** | | | | | | | | | | | | | | | |
| Local fishing community | | | | | | | | | | | | | | | |
| Logistic changes (e.g. travel route, times, increased costs) | | X | X | | X | | | X | | | X | | | X | |
| Reduced access to fishing area | | X | | X | X | | | | X | | | X | | | X |
| Impact on watersports operations and other maritime activities | | X | X | | X | | X | | | | | X | | X | |
| Impact on retail and other services along Long Bay | | | | | | | | | | | | | | | |
| Increased number of clients(construction workers) | X | | | X | | X | | | X | | | X | | | X |
| Decrease in tourist clientele | | X | | X | | X | | | X | | | X | | | X |
| Employment | X | | | X | X | | | X | | | | X | | | X |

*Table 7-2 Impact matrix for site preparation and construction phases of staging area*

| ACTIVITY / POTENTIAL IMPACT | DIRECTION | | DURATION | | LOCATION | | MAGNITUDE | | | EXTENT | | | SIGNIFICANCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pos | Neg | Long | Short | Direct | Indirect | High | Moderate | Low | National | Regional | Local | Large | Medium | Small |
| **1. Site Preparation and Construction** | | | | | | | | | | | | | | | |
| **Marine Biological Impacts:** | | | | | | | | | | | | | | | |
| Impact on coral communities (e.g. smothering from sediment, reduced water quality) | | X | | X | | X | | X | | | | X | | X | |
| Impact on seagrass communities (e.g. smothering from sediment, reduced water quality) | | X | | X | | X | | X | | | | X | | X | |
| Fish and invertebrate displacement | | X | | X | X | | | X | | | | X | | | X |
| **Physical Impacts:** | | | | | | | | | | | | | | | |
| Increased pollutants in the air shed | | X | | X | X | | | X | | | | X | | X | |
| Increased noise pollution | | X | | X | X | | | X | | | | X | | X | |
| Dredging and filling | | X | | X | X | | | X | | | | X | | X | |
| Sedimentation of marine environment | | X | | X | X | | | X | | | | X | | X | |
| Increased water pollution (oils, solid waste etc.) | | X | | X | X | | | X | | | | X | | X | |
| Visual aesthetics | | X | | X | X | | | X | | | | X | | X | |
| **2. Construction Works** | | | | | | | | | | | | | | | |
| Refueling of vehicles and fuel storage | | X | | X | X | | | X | | | | X | | X | |
| Increased accident potential | | X | | X | X | | | X | | | | X | | X | |
| Repair of vehicles and marine vessels | | X | | X | | X | | | X | | | X | | | X |
| **3. Material Storage and Transport** | | | | | | | | | | | | | | | |
| Spillage of boulders and other material | | X | | X | X | | | X | | | X | | | X | |
| Traffic congestion and road wear | | X | | X | X | | | X | | | X | | | X | |
| Suspended solid runoff | | X | | X | | X | | X | | | | X | | X | |
| **4. Construction Crew** | | | | | | | | | | | | | | | |
| Sewage/wastewater generation | | X | | X | X | | | | X | | | X | | | X |
| Solid waste management | | X | | X | X | | | | X | | | X | | | X |
| Workers safety | | X | | X | X | | | | X | | | X | | X | |
| **5. Socioeconomics** | | | | | | | | | | | | | | | |
| Local fishing community | | | | | | | | | | | | | | | |
| Logistic changes | | X | | X | X | | | X | | | | X | | X | |
| Improved river access | X | | X | | X | | | X | | | | X | | X | |
| Impact on retail and other services | | | | | | | | | | | | | | | |
| Increased number of clients(construction workers) | X | | | X | | X | | | X | | | X | | | X |
| Decrease in tourist clientele | | X | | X | | X | | | X | | | X | | | X |
| Employment | X | | | X | X | | | X | | | | X | | X | |
| Traffic flow and access roads | | X | | X | X | | | X | | | X | | X | | |

*Table 7-3 Impact matrix for operational phase of breakwaters*

| ACTIVITY / POTENTIAL IMPACT | DIRECTION | | DURATION | | LOCATION | | MAGNITUDE | | | EXTENT | | | SIGNIFICANCE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pos | Neg | Long | Short | Direct | Indirect | High | Moderate | Low | National | Regional | Local | Large | Medium | Small |
| **1. Biological Impacts** | | | | | | | | | | | | | | | |
| Increase in suitable recruitment substrate for coral communities | X | | X | | X | | | | X | | | X | | X | |
| Indirect impact on seagrass communities (e.g. changes in current regime, reduced water quality) | | X | X | | | X | | X | | | | X | | X | |
| Fish and invertebrate colonization (FAD) | X | | X | | X | | | X | | | | X | | X | |
| Increase ecological volume (new artificial habitat) | X | | X | | X | | | X | | | | X | | X | |
| Habitat fragmentation (seagrass, coral etc.) | | X | X | | X | | | X | | | X | | | X | |
| **2. Physical Impacts** | | | | | | | | | | | | | | | |
| Reduced flushing time (decreased water quality) | | X | X | | X | | | X | | | | X | | X | |
| Reduced wave heights and current speeds (swimmer safety) | X | | X | | X | | | X | | | | X | | X | |
| Reduction in wave energy and beach erosion | X | | X | | X | | | X | | | | X | X | | |
| Visual aesthetics | | X | X | | X | | | | X | | | X | | | X |
| **3. Maritime Activity** | | | | | | | | | | | | | | | |
| Increased accident potential (maritime vessels) | | X | X | | X | | | | X | | | X | | | X |
| Recreational safety (swimmers, snorkelers, divers etc.) | X | | X | | X | | | | X | | | X | | | X |
| **4. Socioeconomics** | | | | | | | | | | | | | | | |
| Logistic changes to local fishing (e.g. travel route, times, increased costs) | | X | X | | X | | | X | | | X | X | | X | |
| Impact on watersports operations and other maritime activities | | | | | | | | | | | | | | | |
| Changes in logistics | | X | X | | X | | X | | | | | X | | X | |
| Additional dive/snorkel site option | X | | X | | X | | | | X | | | X | | | X |
| Increased number of clients (retail and other services along Long Bay) | X | | X | | | X | | | X | | | X | | X | |

# 7.1 CONSTRUCTION

## 7.1.1 Physical

### *7.1.1.1 Rock Blasting at Quarries*

The main concern with the blasting operations is that there is a potential for:

- Fragments of rocks to be propelled into the air explosions on site. These rocks have the potential to create hazards if they are propelled into nearby residences resulting in harm or death.
- Fumes (toxic and non-toxic) to be released into the atmosphere as a result of using explosives for blasting. Residences may be affected by dust and fumes within 100 m.
- Deposited dust to affect local residents as cars, homes or any surface may have visible deposition.
- Vibrations caused by blasting to affect structures within close proximity to the blasting location.

### *7.1.1.2 Air Quality*

The only potential direct impact from the proposed project as it relates to air quality is dust emissions. Construction has the potential to have a two-folded direct negative impact on air quality. The first impact is air pollution generated from the construction equipment and transportation. The second is from fugitive dust from the proposed construction and staging area and the raw materials stored. Dust pollution may also pose a problem when the South Negril River is being desilted, the stockpile area is being landfilled and when the contractors' office, mess hall and equipment yard are being constructed.

There exist numerous sources of dust nuisances within quarries which can affect nearby residences which include but are not limited to:

- Wind blowing across site;
- The grubbing (stripping) of topsoil;
- The excavation of boulders;
- The transport of quarried material – fine materials deposited along public roads during transit.

Fugitive dust has the potential to affect the health of construction workers, locals, visitors and tourists and the vegetation in proximity to the staging area.

#### *7.1.1.3 Noise Pollution and Vibration Nuisance*

There is a potential for noise from the preparation and construction of the staging area (pile driving of sheet piles, filling, etc.) to cause a noise nuisance especially to the operators and patrons (locals, visitors and tourists) of businesses in close proximity to the proposed site. Construction activities necessitate the use of heavy equipment, including bulldozers, cranes, frontend loaders, excavators, and trucks etc. This equipment possesses the potential to have a direct negative impact on the noise climate.

The delivery of boulders and the loading of boulders on the barge at the staging area have the potential to be a noise nuisance. Noise will be generated from the offloading (trucks) and loading (front end loader to barge) processes. This too will potentially affect the operators and patrons (locals, visitors and tourists) of businesses in close proximity to the proposed staging area.

Mining industries are associated with various noise generating activities, some of which are daily:

- Removal of topsoil and overburden ;
- Excavation with machinery;
- Drilling and blasting of rock;
- Crushing and screening of aggregates;
- The transport of quarried material.

More importantly, blasting can contribute to vibrations, audible noise, flyrock and dust. These vibrations can also be transmitted through the ground and pressure waves through the air which has the potential for buildings and/ or individuals experiencing vibrations accompanied by audible noise.

There is also the potential for a vibration nuisance at buildings and to persons in proximity to the staging area during construction, delivery of boulders and the loading of the barges.

**Predicted Noise Emissions from Project Traffic Only**

*Negril Round –A –Bout to Sheffield Main Road*

Examining the noise emitted from the trucks/trailers alone that would be delivering the boulders to the staging area along the Negril to Sheffield main road has shown that the levels would exceed the NEPA day time standard at four or 25% of the locations assessed (see Table 7-4). Although the NEPA standard will be exceeded it should be noted that the noise levels as a result of the operation of the trucks/trailers alone are lower (3 – 5.5 dBA) than the noise levels during existing traffic. At that level the noise reduction would be noticeable.

*Table 7-4 Predicted noise emissions 24 hours and daytime levels from trucks/trailers delivering boulders travelling along the Negril to Sheffield main road*

| LOCATIONS | PROJECT Leq (24h) (dBA) | PROJECT 7 a.m. – 10 p.m. (dBA) | NEPA DAY TIME STD. (7 a.m. – 10 p.m.) (dBA) | DIFFERENCE IN NOISE LEVELS FROM EXISTING (7 a.m. – 10 p.m.) (dBA) |
|---|---|---|---|---|
| Burger King | 53.0 | 55.0 | 65 | -5.3 |
| Caribbean Sunset Resort | 39.5 | 41.5 | 55 | -2.6 |
| House 1 | 55.4 | **57.5** | 55 | -5.2 |
| House 2 | 52.6 | 54.6 | 55 | -5.4 |
| House 3 | 52.0 | 54.0 | 55 | -5.5 |
| House 4 | 56.1 | **58.1** | 55 | -5.3 |
| House 5 | 54.7 | **56.7** | 55 | -5.2 |
| House 6 | 54.1 | **56.1** | 55 | -5.3 |
| House 7 | 50.9 | 52.9 | 55 | -5.5 |
| House 8 | 49.3 | 51.3 | 55 | -5.1 |
| Negril Health Centre | 46.7 | 48.8 | 45 | -4.6 |
| Negril Hills Golf Club | 42.3 | 44.4 | 65 | -3.4 |
| Playfield | 41.5 | 43.6 | 65 | -3.0 |
| Plaza 1 | 52.0 | 54.1 | 65 | -5.3 |
| Plaza 2 | 52.5 | 54.5 | 65 | -5.3 |
| Sweet Spice | 53.1 | 55.1 | 65 | -5.4 |

*Norman Manley Boulevard*

The trucks/trailers operating alone would result in a 6.3 to 11 dBA reduction in noise levels when compared to the noise emissions from the existing traffic. Although there would be a reduction, there are 34 or 44% of the locations assessed would experience noise in excess of the NEPA day time standard (Table 7-5).

*Table 7-5 Predicted noise emissions 24 hours and daytime levels from trucks/trailers delivering boulders travelling along the Norman Manley Boulevard*

| LOCATIONS | PROJECT Leq (24h) (dBA) | PROJECT 7 a.m. – 10 p.m. (dBA) | NEPA DAY TIME STD. (7 a.m. – 10 p.m.) (dBA) | DIFFERENCE IN NOISE LEVELS FROM EXISTING (7 a.m. – 10 p.m.) (dBA) |
|---|---|---|---|---|
| Alfred's Ocean Palace | 54.6 | **56.6** | 55 | -9.1 |
| Ansell's Thatch Walk Cottages | 53.1 | **55.1** | 55 | -8.8 |
| Aqua Negril Resort | 52.8 | 54.8 | 55 | -8.7 |
| Bar B Barn Hotel and Restaurant | 50.8 | 52.9 | 55 | -8.1 |
| Beachcomber Club Hotel and Spa | 53.2 | **55.2** | 55 | -8.9 |
| Beaches | 53.7 | **55.7** | 55 | -8.9 |
| Bungalo Hotel | 52.1 | 54.1 | 55 | -8.9 |
| Caribbean Sunset Resort | 39.3 | 41.3 | 55 | -7.3 |
| Chances | 51.8 | 53.8 | 55 | -8.5 |
| Charela Inn | 52.8 | 54.8 | 55 | -8.7 |

| LOCATIONS | PROJECT Leq (24h) (dBA) | PROJECT 7 a.m. – 10 p.m. (dBA) | NEPA DAY TIME STD. (7 a.m. – 10 p.m.) (dBA) | DIFFERENCE IN NOISE LEVELS FROM EXISTING (7 a.m. – 10 p.m.) (dBA) |
|---|---|---|---|---|
| Charela Inn | 40.0 | 42.1 | 55 | -6.6 |
| Chippewa Village Cafe Bar Lodging | 60.8 | **62.8** | 55 | -11 |
| Chuckles | 36.1 | 38.2 | 55 | -7.8 |
| Coco La Palm | 52.5 | 54.6 | 55 | -8.6 |
| Coral Seas Garden Hotel | 53.2 | **55.3** | 55 | -9.1 |
| Cotton Tree Place Hotel | 31.8 | 33.8 | 55 | -8.3 |
| Country Country | 53.2 | **55.2** | 55 | -8.8 |
| Couples | 51.5 | 53.5 | 55 | -8.4 |
| Couples Swept Away | 43.1 | 45.1 | 55 | -6.3 |
| Crystal Waters Villas | 52.5 | 54.5 | 55 | -8.6 |
| Errol's Sunset Cafe and Guest House | 53.2 | **55.2** | 55 | -8.8 |
| Firefly Cottages & Apartments | 52.5 | 54.5 | 55 | -8.7 |
| Foote Prints Villas | 52.1 | 54.2 | 55 | -8.6 |
| For Real Beach Resort | 52.1 | 54.2 | 55 | -8.6 |
| Fun Holiday Beach Resort | 52.5 | 54.5 | 55 | -8.6 |
| Gardenia Resort | 51 | 53.1 | 55 | -8.4 |
| Golden Villas & Rooms | 59.5 | **61.6** | 55 | -10.6 |
| Grand Lido Negril Resort & Spa | 35.8 | 37.8 | 55 | -7.0 |
| Grand Pineapple Beach Resort | 50.9 | 53.0 | 55 | -8.2 |
| Green Leaf Cabins | 60.8 | **62.9** | 55 | -10.8 |
| Hidden Paradise Garden Resort | 60.7 | **62.7** | 55 | -10.8 |
| Idle Awhile | 54.0 | **56.0** | 55 | -8.9 |
| Jamaican Tamboo | 53.3 | **55.4** | 55 | -8.8 |
| Kuyaba | 51.9 | 54.0 | 55 | -8.5 |
| Lazy Dayz | 53.1 | **55.1** | 55 | -8.9 |
| Legends Hotel | 54.3 | **56.3** | 55 | -9.1 |
| Mariner's Negril Beach Club | 52.8 | 54.8 | 55 | -8.8 |
| Mariposa | 51.2 | 53.2 | 55 | -8.3 |
| Merrils 1 Resort | 52.5 | 54.6 | 55 | -8.6 |
| Merrils 2 Resort | 51.8 | 53.8 | 55 | -8.6 |
| Merrils 3 Resort | 52.7 | 54.7 | 55 | -8.7 |
| Moon Dance Villas | 53.8 | **55.9** | 55 | -8.9 |
| Moonrise Villas | 54.4 | **56.4** | 55 | -9.3 |
| Native Son Villas | 55.8 | **57.8** | 55 | -9.4 |
| Negril Beach Villa | 53.2 | **55.3** | 55 | -8.8 |
| Negril Gardens Beach Resort | 54.7 | **56.8** | 55 | -9.2 |
| Negril Tree House Hotel | 47.8 | 49.9 | 55 | -7.2 |

| LOCATIONS | PROJECT Leq (24h) (dBA) | PROJECT 7 a.m. – 10 p.m. (dBA) | NEPA DAY TIME STD. (7 a.m. – 10 p.m.) (dBA) | DIFFERENCE IN NOISE LEVELS FROM EXISTING (7 a.m. – 10 p.m.) (dBA) |
|---|---|---|---|---|
| Nirvana | 54.2 | **56.3** | 55 | -9.0 |
| Palm Grove Manor Apartment and Rooms | 52.2 | 54.3 | 55 | -8.8 |
| Point Village | 29.2 | 31.3 | 55 | -7.8 |
| Rayon Hotel | 57.4 | **59.5** | 55 | -9.8 |
| Riu Hotel & Resorts Negril Club | 52.0 | 54.0 | 55 | -8.5 |
| Riu Hotel & Resorts Tropical Bay | 53.4 | **55.5** | 55 | -8.6 |
| Rondel Village | 54.1 | **56.1** | 55 | -9.0 |
| Rooms | 52.8 | 54.8 | 55 | -8.7 |
| Roots Bamboo Beach Resort | 53.3 | **55.4** | 55 | -8.8 |
| Sandals Negril Beach Resort & Spa | 51.2 | 53.3 | 55 | -8.3 |
| Sea Sand Eco Villas | 53.5 | 55.6 | 55 | -8.8 |
| Sea Scape Hotel | 52.8 | 54.8 | 55 | -9.0 |
| Sea Splash Resort | 52.8 | 54.8 | 55 | -8.8 |
| Seabreeze Apartments | 54.8 | **56.9** | 55 | -9.4 |
| Seascape Hotel | 59.9 | **62.0** | 55 | -9.5 |
| Seawind Resort | 52.7 | 54.7 | 55 | -8.7 |
| Shield's Negril Villas | 51.7 | 53.7 | 55 | -8.4 |
| Sunquest Cottages | 53.0 | 55.0 | 55 | -8.8 |
| Sunrise Club Hotel | 57.7 | **59.8** | 55 | -9.7 |
| Sunset at the Palms Resort and Spa | 57.4 | **59.4** | 55 | -9.8 |
| Sunset on the Beach Resort (Coral Seas B | 57.4 | **59.5** | 55 | -9.5 |
| Sunset Palm Resort | 56.6 | **58.7** | 55 | -9.6 |
| Superclubs Hedonism II | 38.0 | 40.1 | 55 | -6.6 |
| The Palms | 53.6 | **55.6** | 55 | -8.9 |
| Travellers Beach Resort | 52.5 | 54.6 | 55 | -8.6 |
| Villa Mora Rooms & Cottages | 60.1 | **62.2** | 55 | -9.6 |
| Wavz | 53.5 | **55.5** | 55 | -8.9 |
| Whistling Bird | 52.7 | 54.8 | 55 | -8.7 |
| White Sands | 52.1 | 54.2 | 55 | -8.6 |
| Yellow Bird Rooms & Cottages | 50.8 | 52.9 | 55 | -8.1 |

The noise emission contours for Project related traffic along the Negril round-a-bout to Sheffield main road and the Norman Manley Boulevard are depicted in Figure 7-1 and Figure 7-2 respectively.

The potential for noise generated from project related traffic to be a nuisance on both transportation routes is small.

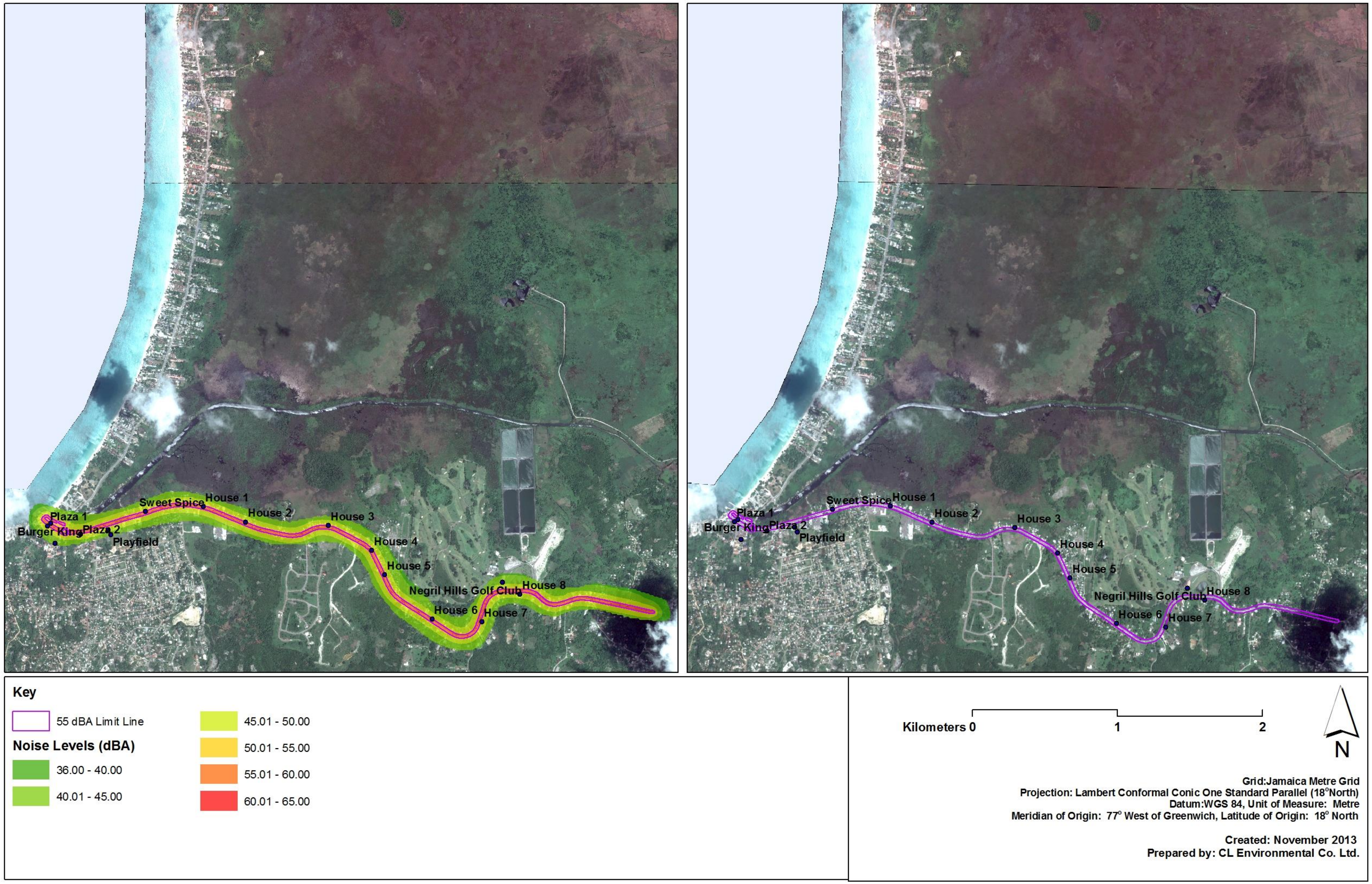



*Figure 7-1 Noise contours from the proposed Project traffic along the Negril round-a-bout to Sheffield main road*

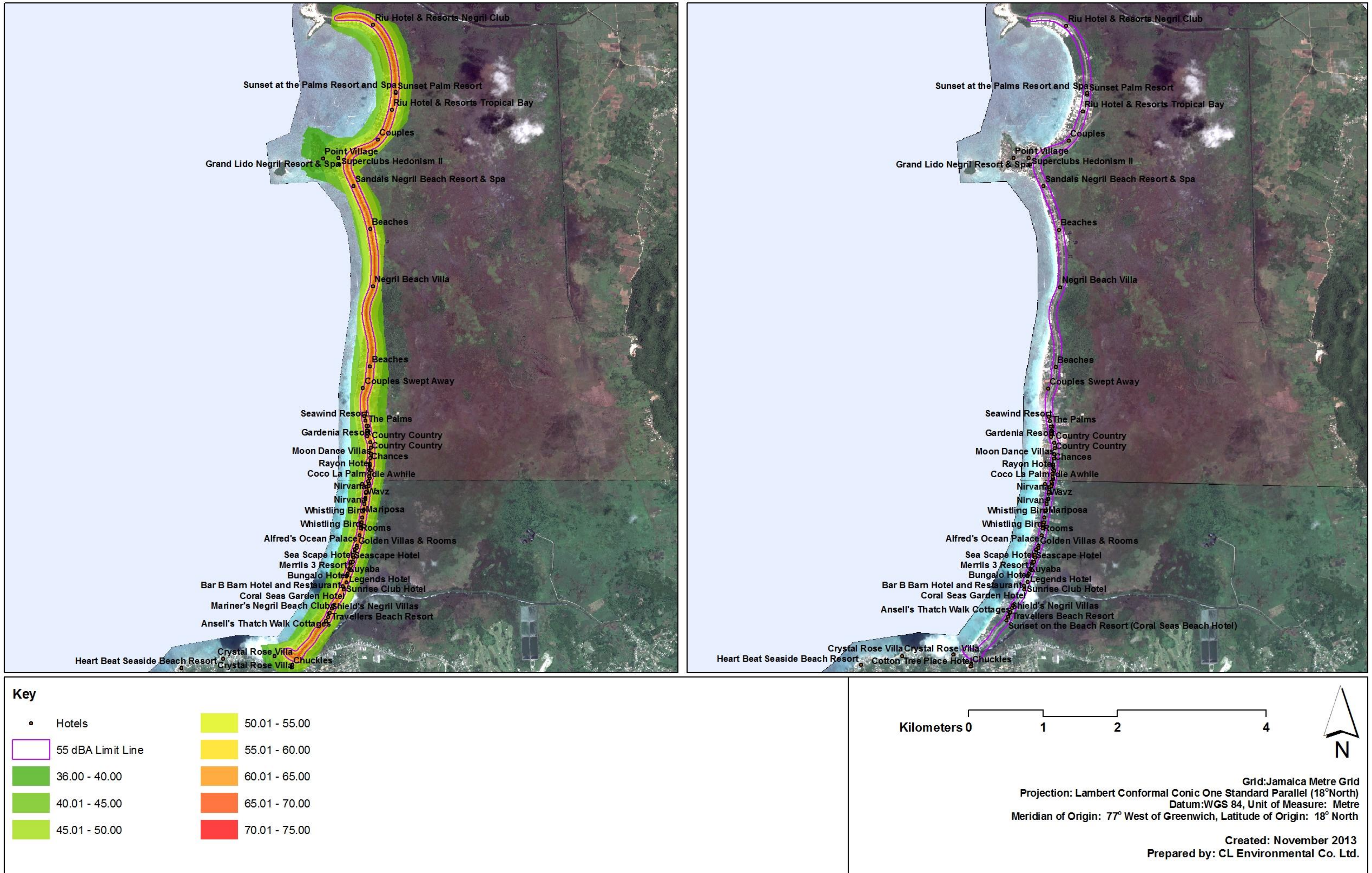



*Figure 7-2 Noise contours from the proposed Project traffic along the Norman Manley Boulevard*

**Predicted Noise Emissions from Construction of the Stockpile Area**

The construction of the stockpile area requires sheet metals to be used to stabilize the seaward edges. These sheet metals will be driven into the substrate which has the potential to create a noise nuisance. SoundPlan 7.3 was used to model the potential noise emissions from this activity, looking at noise generated from the extreme locations where piling will be done (areas having the most noise effect on the population). These are piling to the extreme north, south and west of the area. The results of the highest ten noise level locations are outlined in Table 7-6 and Table 7-7, and the overall results depicted in Figure 7-3 to Figure 7-8. The influence of wind direction was also examined where it was established that the greatest impact occurred when the wind was blowing from the north.

The Lmax gives the highest noise levels expected (worst case scenario). Piling at the north is expected to cause the widest noise nuisance impact evidenced by the tables and figures. With the wind from the north the noise levels increase by 2 – 3 dBA (not significant to be perceived).

The most impacted locations are in the commercial centre of the town of Negril. A NEPA day time standard for commercial areas is 65 dBA. Of the top ten highest noise levels at the locations investigated for the north, south and northwest piling, 6 locations and 4 locations each for the north, south and northwest piling respectively would not be compliant with this standard.

The potential noise nuisance from the piling operation will be short term (1 to 2 weeks) but the annoyance factor might be high due to the intermittent noise generated from piling.

*Table 7-6 Predicted average noise levels during piling for the day and the maximum noise levels to be experienced (ten highest)*

| PILING TO THE NORTH | | | PILING TO THE SOUTH | | | PILING TO THE NORTHWEST | | |
|---|---|---|---|---|---|---|---|---|
| **Receiver** | **Day Noise Level, dB(A)** | **Lmax, dB(A)** | **Receiver** | **Day Noise Level, dB(A)** | **Lmax, dB(A)** | **Receiver** | **Day Noise Level, dB(A)** | **Lmax, dB(A)** |
| Building 6 Close | 84.1 | 100.9 | Building 6 Close | 83.4 | 100.9 | Building 6 Close | 74.8 | 92.2 |
| Plaza 2 | 77.1 | 93.1 | Plaza 2 | 75.6 | 93.1 | Plaza 2 | 69.7 | 87.2 |
| Closest Building | 75.3 | 89.8 | Closest Building | 72.4 | 89.8 | Closest Building | 68.7 | 86.2 |
| Building 3 | 69.8 | 83.9 | Plaza 1 | 66.8 | 84.3 | Building 3 | 66.4 | 83.9 |
| Cotton Tree Place Hotel | 67.5 | 81.2 | Building 3 | 65.0 | 82.5 | Cotton Tree Place Hotel | 63.7 | 81.2 |
| Plaza 1 | 67.2 | 84.3 | Cotton Tree Place Hotel | 62.4 | 79.9 | Building 4 | 59.7 | 77.2 |
| Building 4 | 63.9 | 79.2 | Craft Village | 58.0 | 75.5 | Craft Village | 57.8 | 75.3 |
| Craft Village | 63.5 | 77.5 | Chuckles | 56.8 | 74.3 | Chuckles | 55.8 | 73.3 |
| Burger King | 62.9 | 79.6 | Burger King | 53.7 | 71.2 | Fishers Loc 2 | 52.8 | 70.3 |
| Fishers Loc 1 | 60.6 | 77.8 | Building 4 | 47.3 | 64.7 | Plaza 1 | 50.9 | 68.4 |

*Table 7-7 Predicted average noise levels during piling with the wind from the north for the day and the maximum noise levels to be experienced (ten highest)*

| PILING TO THE NORTH | | | PILING TO THE SOUTH | | | PILING TO THE NORTHWEST | | |
|---|---|---|---|---|---|---|---|---|
| **Receiver** | **Day Noise Level, dB(A)** | **Lmax, dB(A)** | **Receiver** | **Day Noise Level, dB(A)** | **Lmax, dB(A)** | **Receiver** | **Day Noise Level, dB(A)** | **Lmax, dB(A)** |
| Building 6 Close | 85.4 | 102.2 | Building 6 Close | 84.7 | 102.2 | Building 6 Close | 75.4 | 92.9 |
| Plaza 2 | 79.6 | 95.7 | Plaza 2 | 78.2 | 95.7 | Plaza 2 | 71.6 | 89.1 |
| Closest Building | 78.1 | 92.8 | Closest Building | 75.3 | 92.8 | Closest Building | 70.9 | 88.4 |
| Plaza 1 | 72.7 | 89.7 | Plaza 1 | 72.2 | 89.7 | Building 3 | 68.6 | 86.1 |
| Building 3 | 72.3 | 86.1 | Building 3 | 67.9 | 85.3 | Cotton Tree Place Hotel | 65 | 82.5 |
| Cotton Tree Place Hotel | 69.0 | 82.5 | Cotton Tree Place Hotel | 66.2 | 83.6 | Building 4 | 61.2 | 78.7 |
| Burger King | 68.2 | 82.8 | Burger King | 65.3 | 82.8 | Chuckles | 58.2 | 75.7 |
| Building 4 | 65.6 | 81 | Cotton Tree Place Hotel | 64.1 | 81.6 | Craft Village | 57.4 | 74.9 |
| Craft Village | 63.3 | 77.6 | Chuckles | 58.6 | 76.1 | Caribbean Sunset Resort | 56.2 | 73.6 |
| Fishers Loc 1 | 63.2 | 80.5 | Craft Village | 57.4 | 74.9 | Plaza 1 | 54.5 | 72.0 |

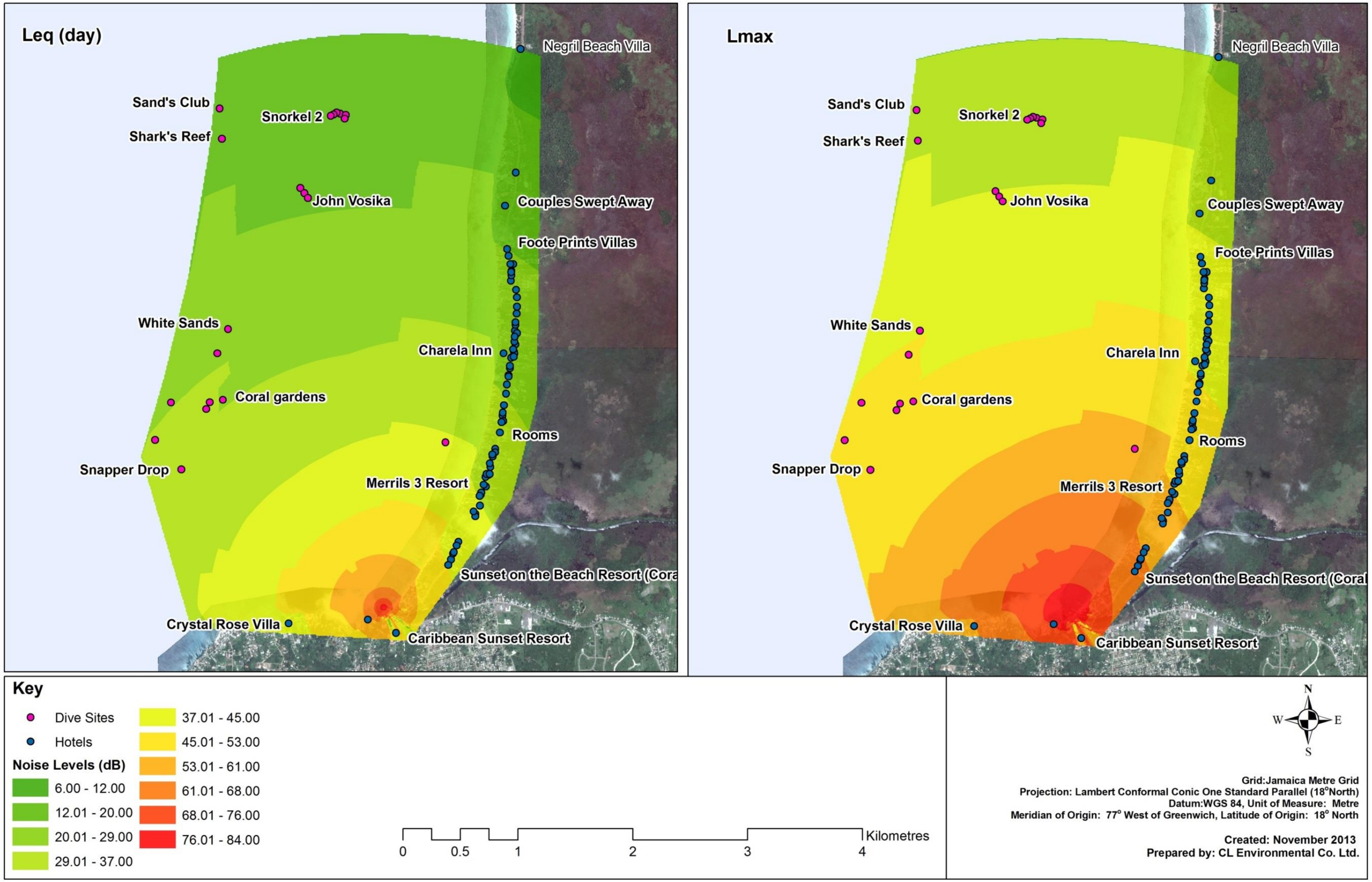



*Figure 7-3 Average noise levels over the day (Leq) and the highest noise level (Lmax) while piling is conducted to the north*

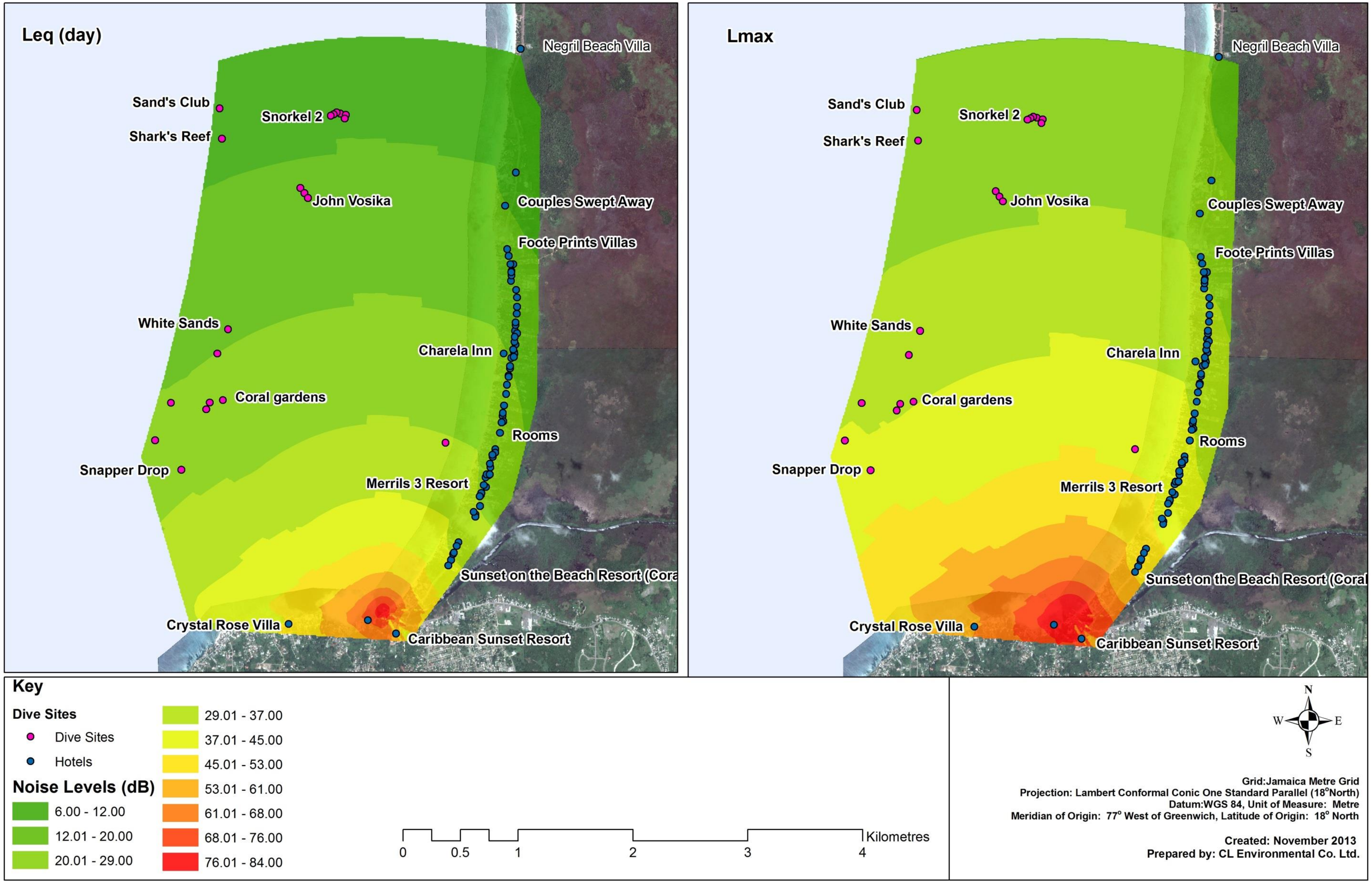



*Figure 7-4 Average noise levels over the day (Leq) and the highest noise level (Lmax) while piling is conducted to the north when the wind direction is from the north*

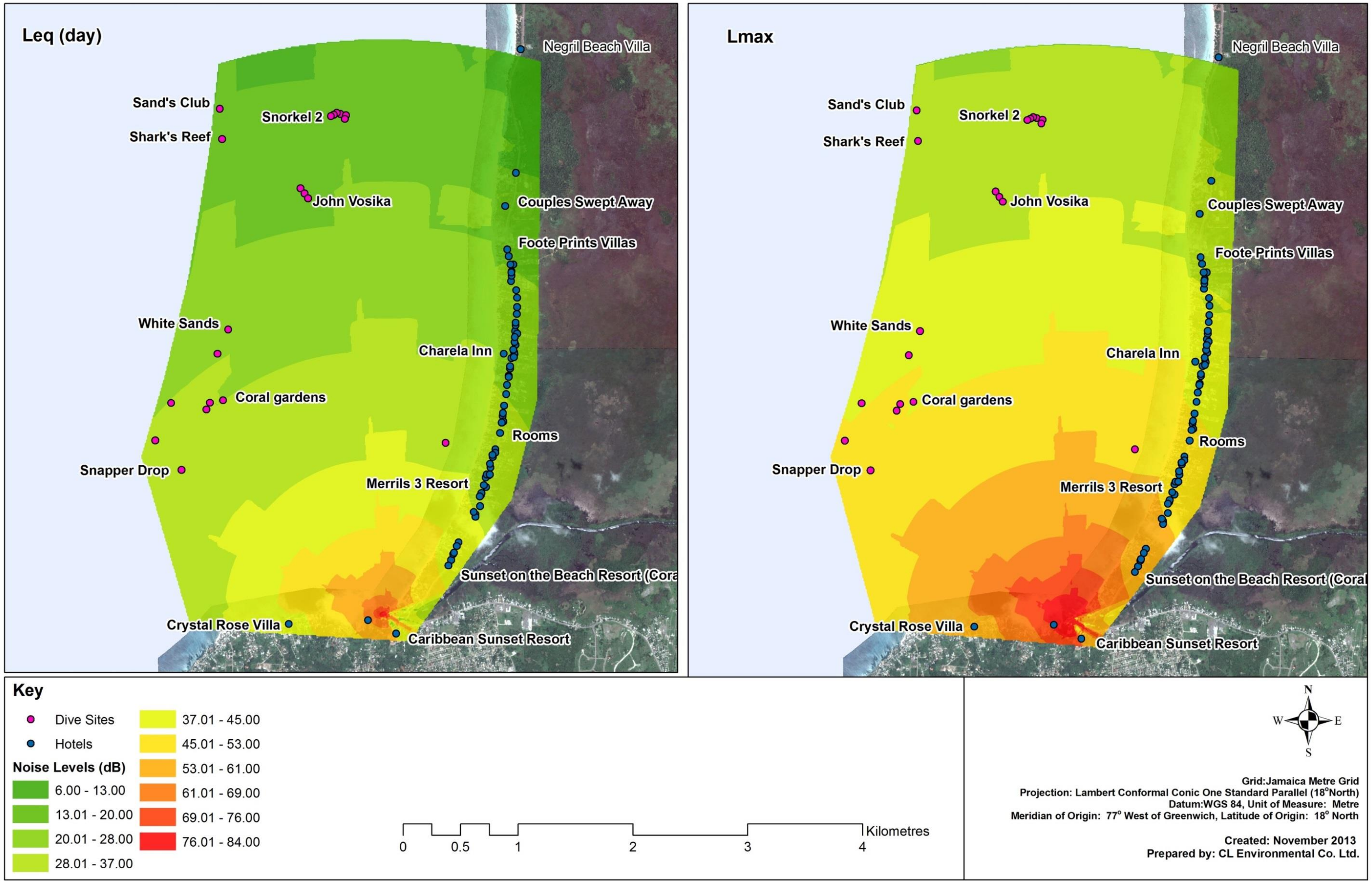



*Figure 7-5 Average noise levels over the day (Leq) and the highest noise level (Lmax) while piling is conducted to the south*

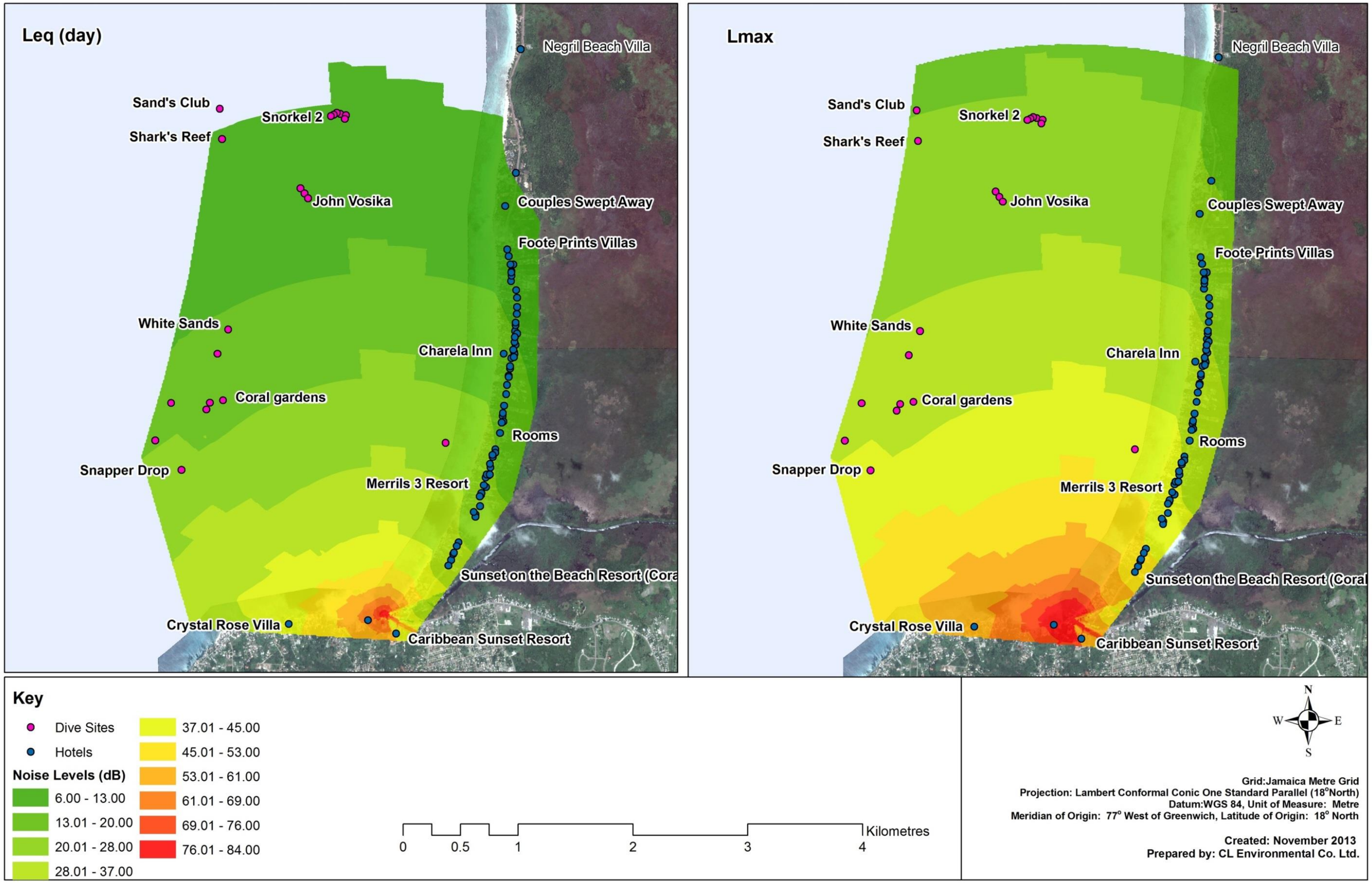



*Figure 7-6 Average noise levels over the day (Leq) and the highest noise level (Lmax) while piling is conducted to the south when the wind direction is from the north*

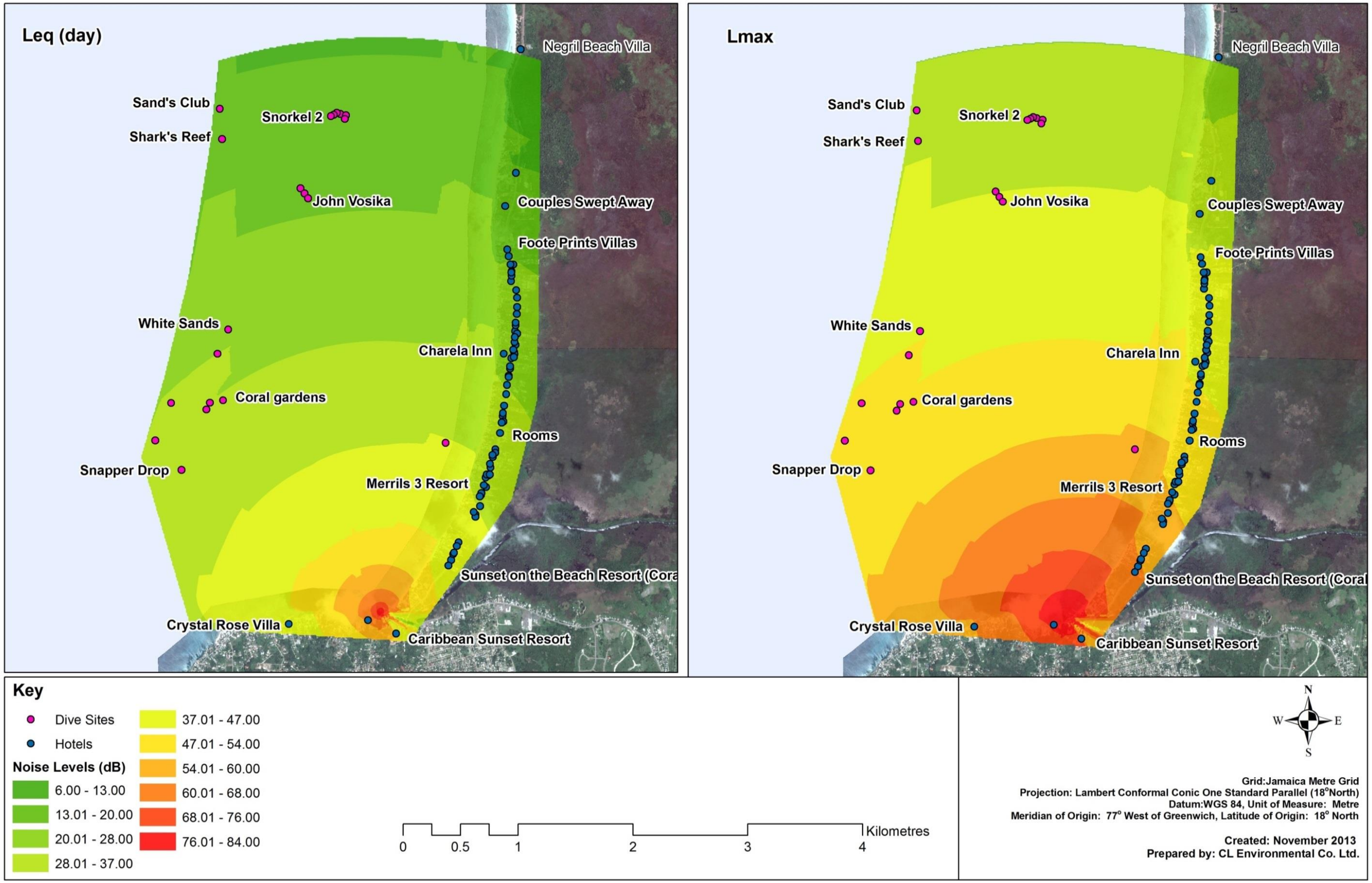



*Figure 7-7 Average noise levels over the day (Leq) and the highest noise level (Lmax) while piling is conducted to the northwest*

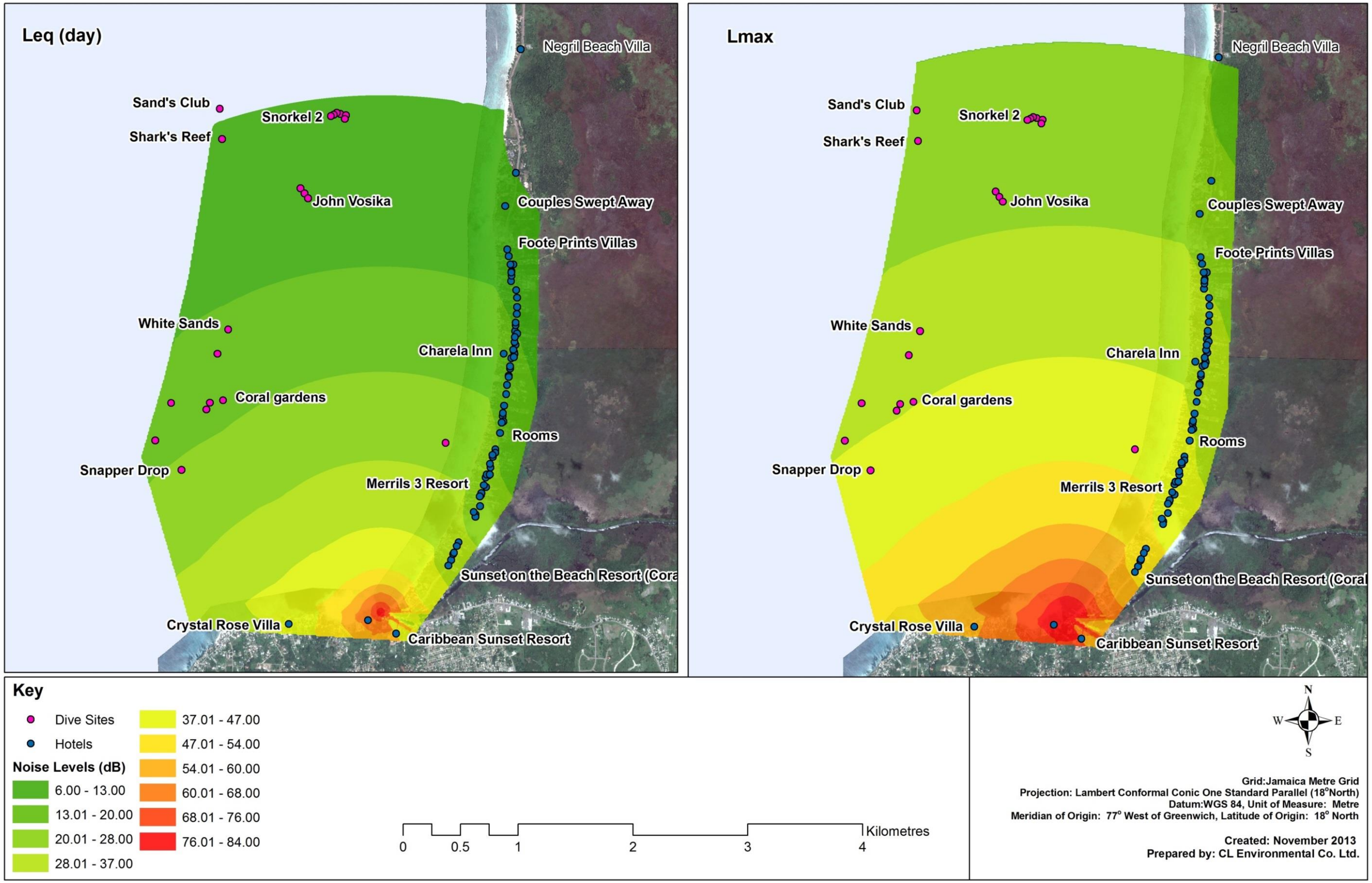



*Figure 7-8 Average noise levels over the day (Leq) and the highest noise level (Lmax) while piling is conducted to the northwest when the wind direction is from the north*

**Predicted Noise Emissions from Stockpile Operations**

The operations at the stockpile area will involve the offloading of boulders from the trucks that carry the boulders for the breakwaters construction and the loading of these boulders on the barge to be transported to the breakwater sites.

SoundPlan 7.3 was used to model a frontend loader moving over the entire stockpile area and two trucks being onsite. The major noise impacts are expected to be confined in close proximity to the stockpile site (Figure 7-9 - purple line). Only buildings close to the stockpile area would experience noise levels over the 65 dBA NEPA day time standard. The model also shows that no hotel will experience day time noise levels above the NEPA 55 dBA noise standard.

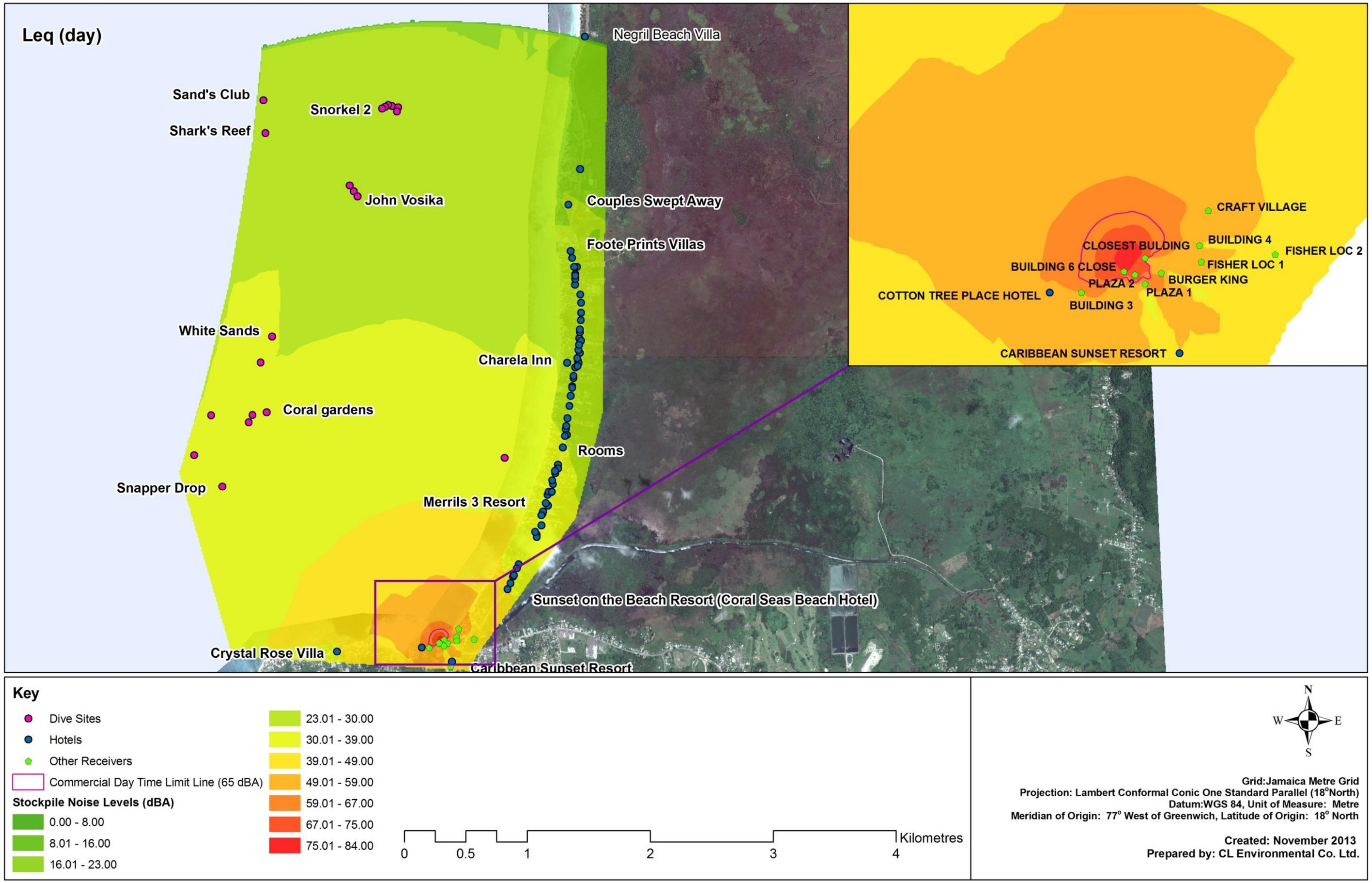



*Figure 7-9 Predicted average day time noise levels (dBA) during operations at the stockpile area*

**Predicted Noise Emissions from Boulder Transportation**

The noise emissions from the operation of the barge to carry boulders to the breakwater sites were investigated using SoundPlan 7.3 noise software. It was assumed that the barge will travel at approximately 5 knots. The noise emissions were modeled with (Concawe model) or without wind (General Prediction model). Wind from the north was used as the worst case scenario with an average wind speed of 4 m/s (≈ 7.8 knots).

The results of the modelling looking at either the average day time noise levels or the Lmax has shown that the areas most affected are close to the stockpile area.

The only hotel predicted to experience average day time noise levels above 35 dBA is Cotton Tree Place Hotel (42.9 dBA). This level is compliant with the NEPA day time standard of 55 dBA. Also importantly, this noise level is on the outside of the buildings and it is expected that the noise will be attenuated (reduction) by 10 – 15 dBA with transmission from outdoor to indoor (through doors, windows and walls) resulting in lower levels. At these levels the noise generated from the barge transportation of the boulders to the breakwater sites won't be a nuisance to the hotel guests. Predicted average noise levels in proximity will be compliant with NEPA's commercial day time standard and will not create a noise nuisance.

As it relates to the dive and snorkeling sites, the highest number of sites impacted by noise from the barge operation will occur when the northern breakwaters are being constructed with the predicted highest noise level to be experienced being 58.7 dBA at Aqua Moon. This potential impact is expected to me negligible as there will be an exclusion zone during construction, therefore no one should be there.

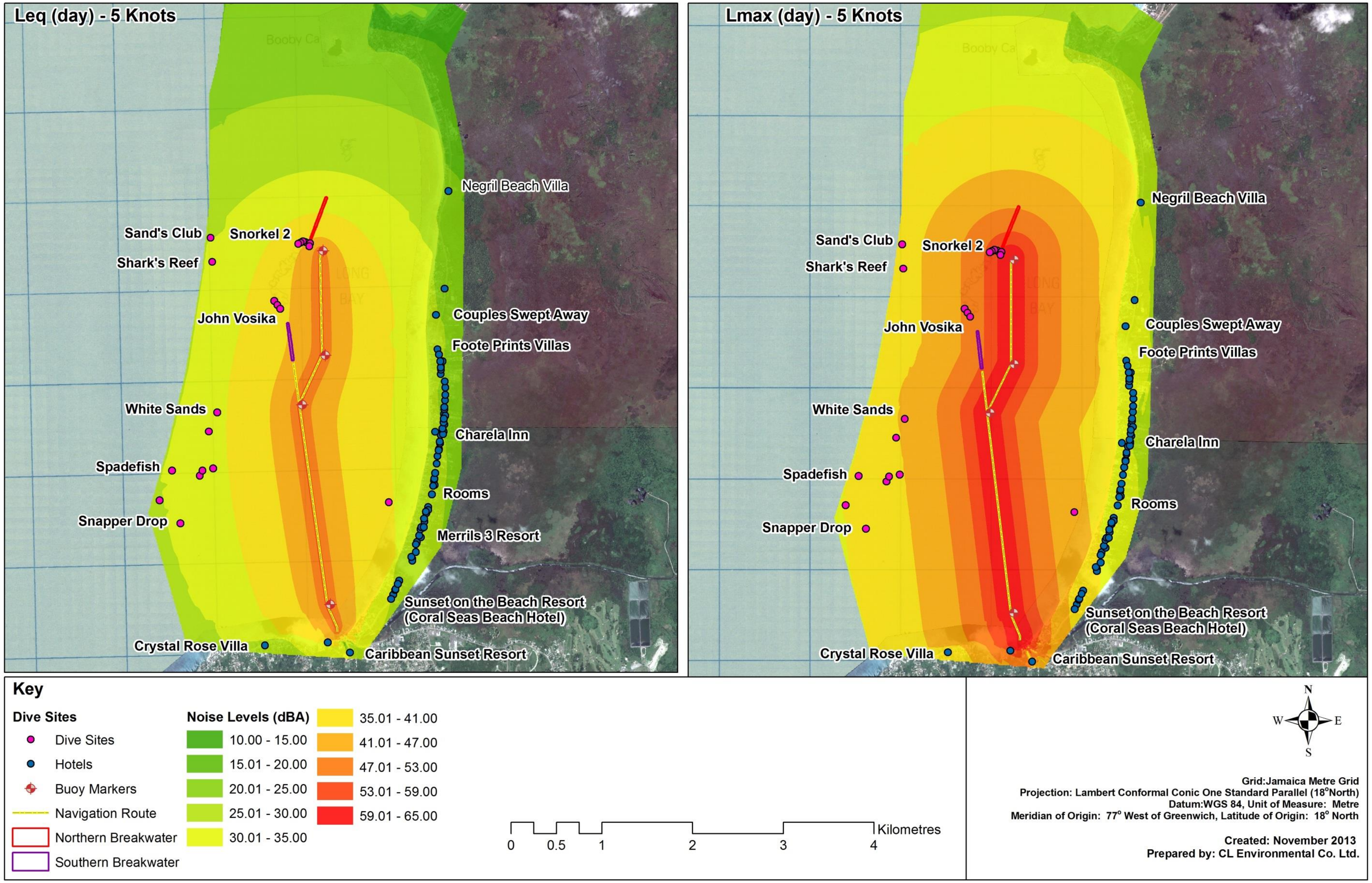



*Figure 7-10 Predicted average noise and Lmax levels (day) for barge operations to the northern breakwater*

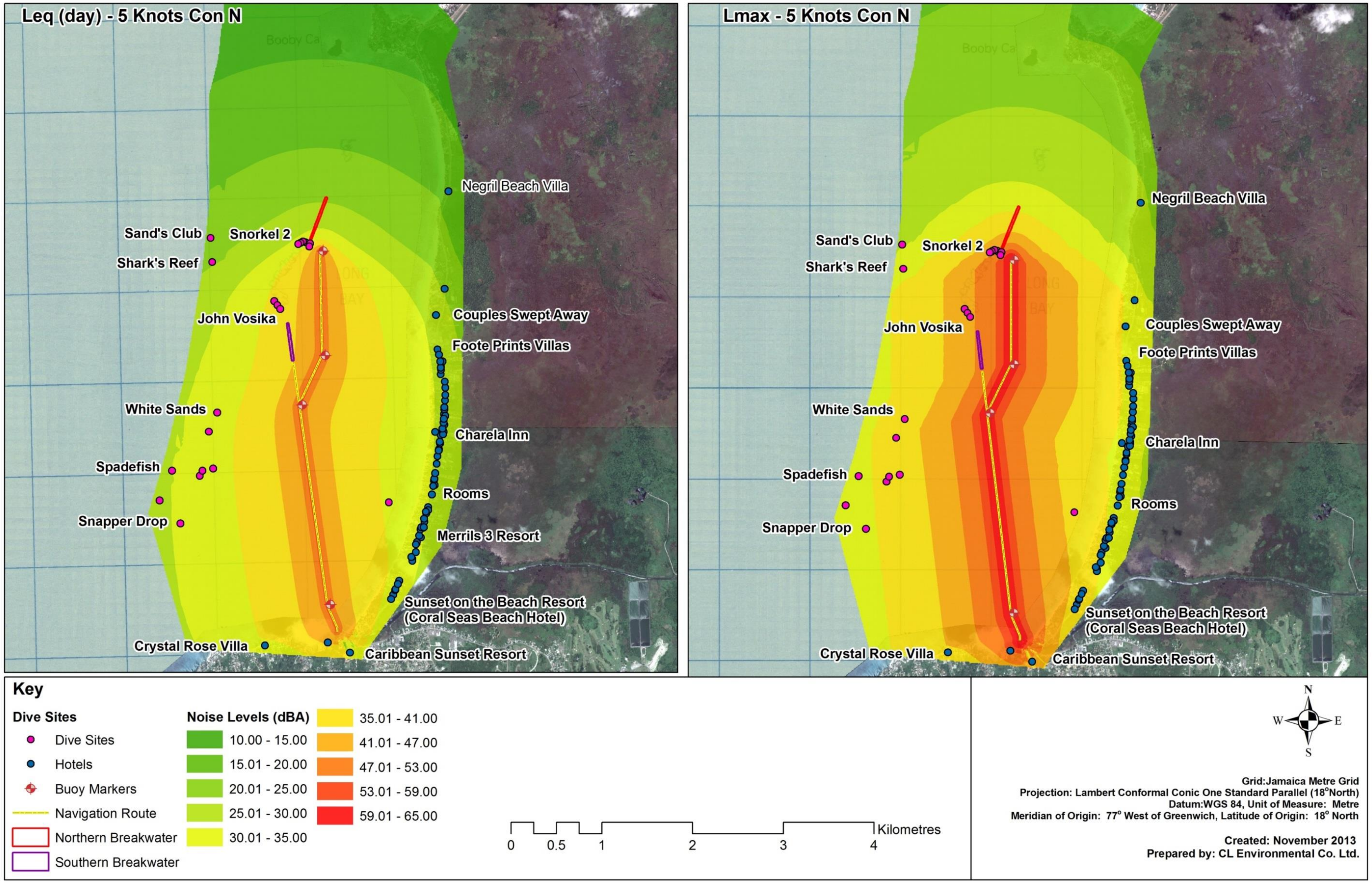



*Figure 7-11 Predicted average noise and Lmax levels (day) for barge operations to the northern breakwater with wind from the north*

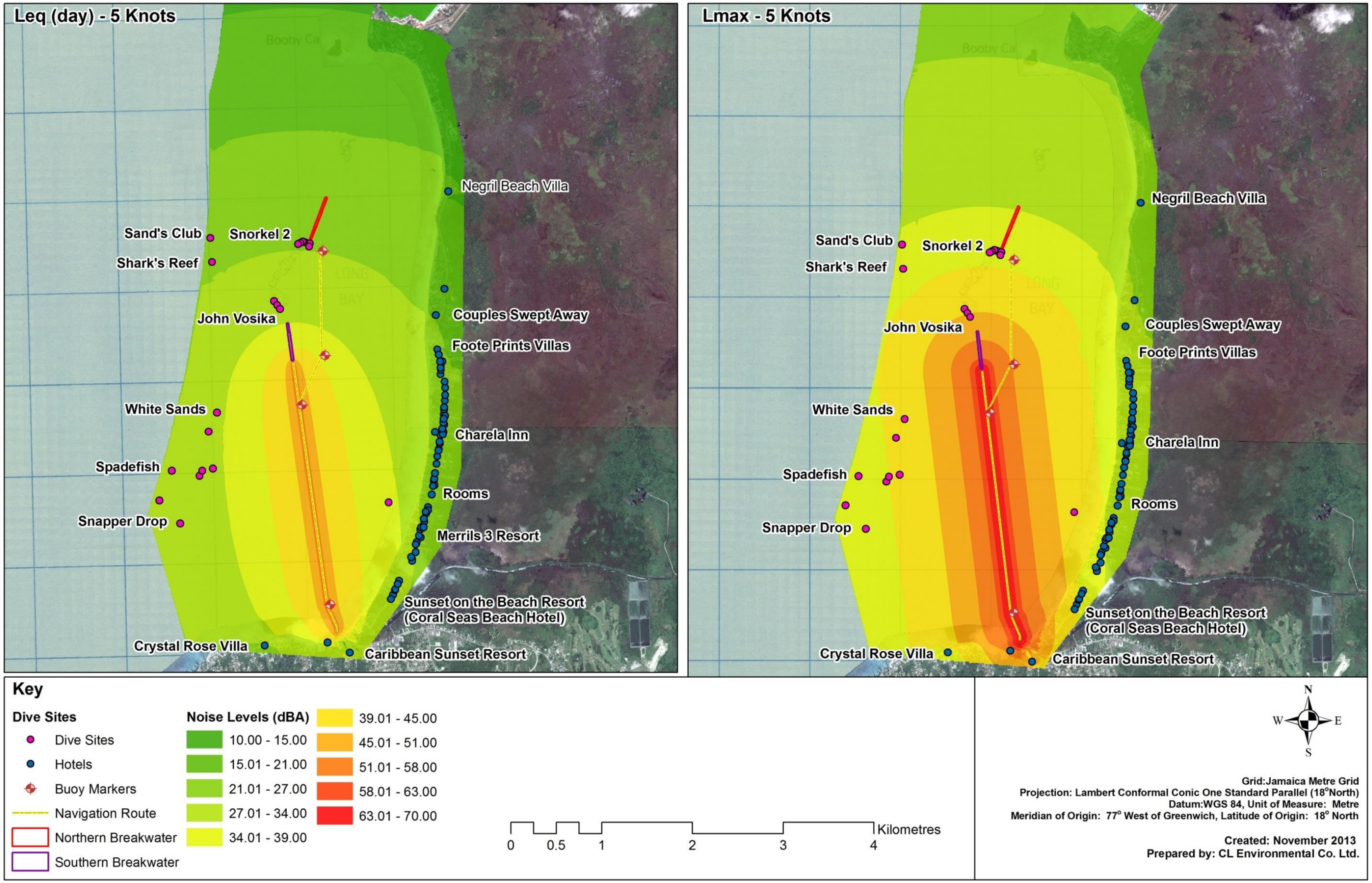



*Figure 7-12 Predicted average noise and Lmax levels (day) for barge operations to the southern breakwater*

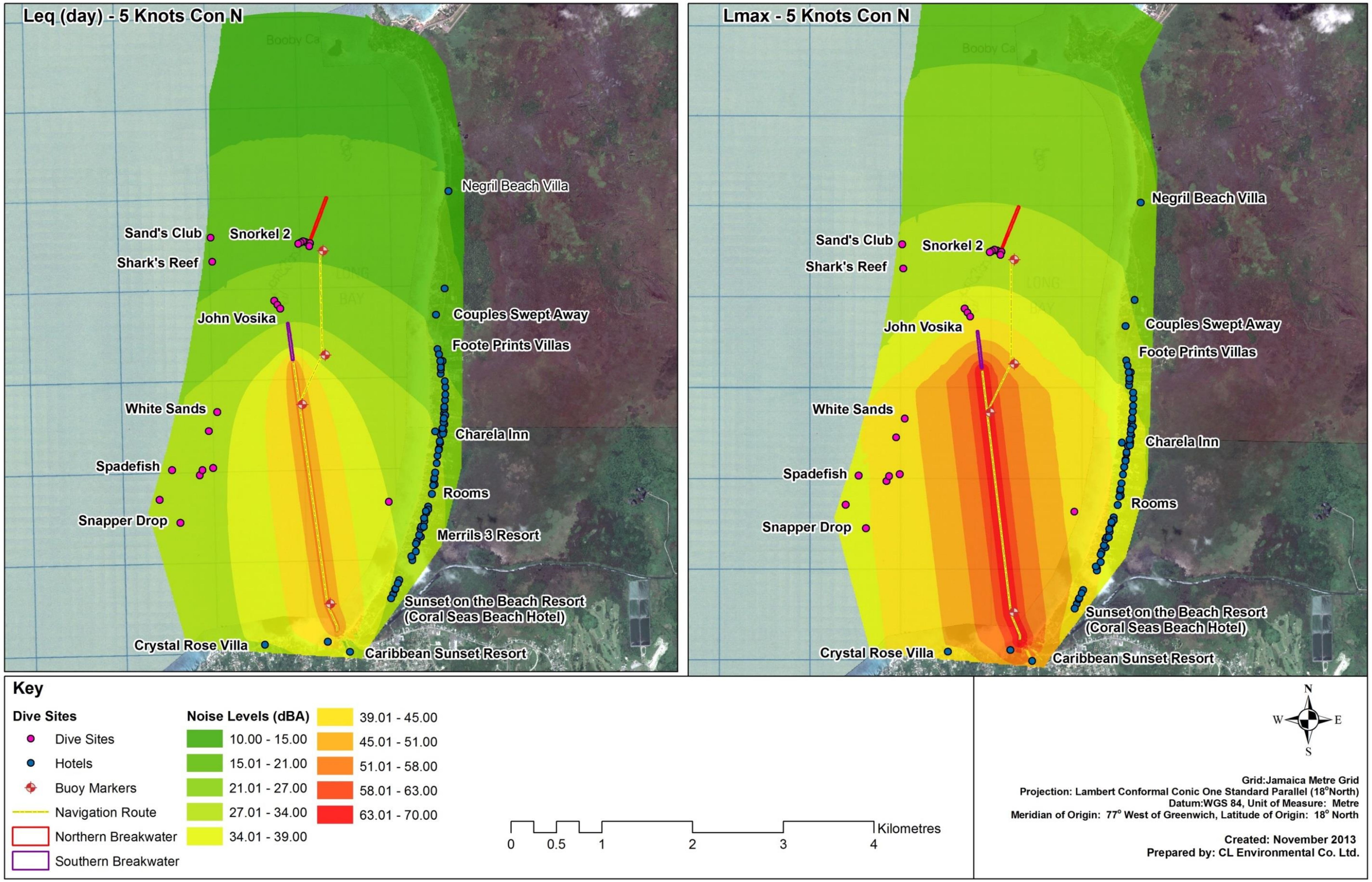



*Figure 7-13 Predicted average noise and Lmax levels (day) for barge operations to the southern breakwater with wind from the north*

#### *7.1.1.4 Water Quality*

During construction, the immediate areas around the staging area and breakwaters will have the potential to have reduced water quality. The storage of material and docking of the barge will have the potential to generate turbidity, sedimentation and possible run-off from land. Similarly, the placement of geotextile, armour stones, toe stones and filter stones at the breakwater sites could potentially result in the generation of turbidity and sedimentation in the water. Additionally, these areas could be affected by wave action and currents resulting in the transportation of turbidity and silt down current.

**Sediment Dispersion Assessment**

*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 and Kenworthy (1996) suggest a value of 15 mg/l for both tropical and freshwater lake settings, and Devlin and 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 of up to 15 mg/l.

*Description of Placement Operations Source of Sediments*

Boulders will be sourced from quarries from a process of drilling and blasting. It is very likely that during the sorting of the boulders in the quarry that naturally occurring soil and other debris will be encountered. The specification requires washing of the boulders before being brought to site. It is therefore unlikely that dirt and silt will be brought to the site in significant quantities. Other potential sources of silt exist, including the material placed in the bottom of the trucks in the transportation of the boulders. Whilst this practice will not be facilitated it is likely that some truckers, in an attempt to protect the bed of the truck will attempt to do this from time to time.

*Plate 7-1 Clean quarried rocks washed and sorted on quarry floor*


*Plate 7-2 Washing plant/pump at quarry*

*Plate 7-3 Quarry with debris on flat bed and dirt on stone*

*Plate 7-4 Sediment plume from red mud used to pad truck beds to carry armour stone*

An attempt was made to rationalize the likely silt load on the boulders. An upper estimate of 3 kilograms of debris per boulder of silt was assumed and discharged into the water column with the volume of the stone being placed in the water. This rate was applied uniformly over the 24 hours of each day to account for the possibility of the barges being cleaned after working hours of any debris that may accumulate on the barge. Whilst this is not a sanctioned activity it was modelled to estimate the potential impacts of a worst case scenario. Both north and south breakwaters were modelled independently.

*Table 7-8 – Estimation of sediment plume initial concentration from placement of boulders for Negril breakwaters*

| | | |
|---|---|---|
| Daily mass of boulders being delivered | 800 | T/day |
| Average mass of boulders | 7.5 | T |
| Number of boulders | 106.7 | |
| Average volume of boulders | 3.00 | m3 |
| Hours per day of placement | 24.00 | hours |
| Percentage of silt | 0.05% | |
| mass of sediments | 0.4 | T/day |
| Volume of water displaced | 320 | m3 |
| Average concentration | 1250 | mg/l |
| Average discharge | 0.0037 | m3/sec |

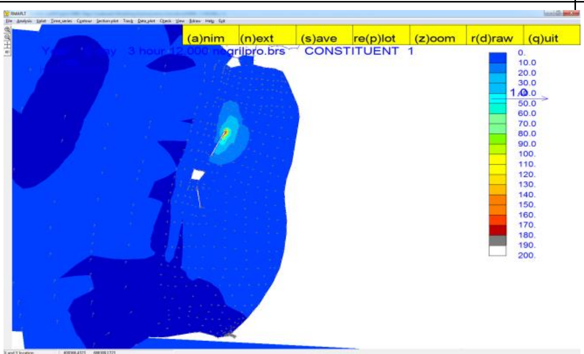
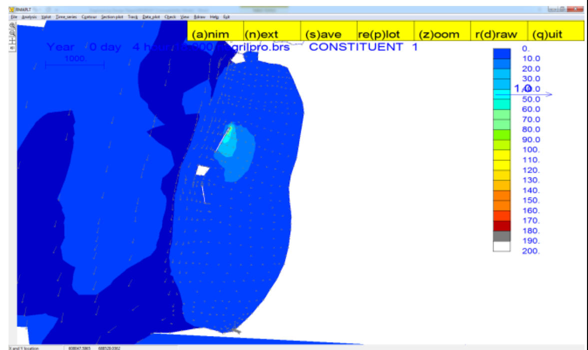
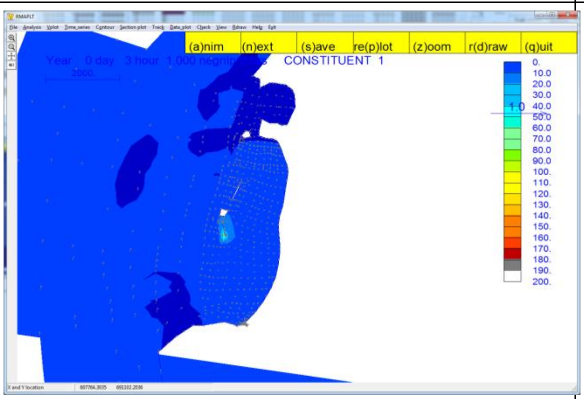
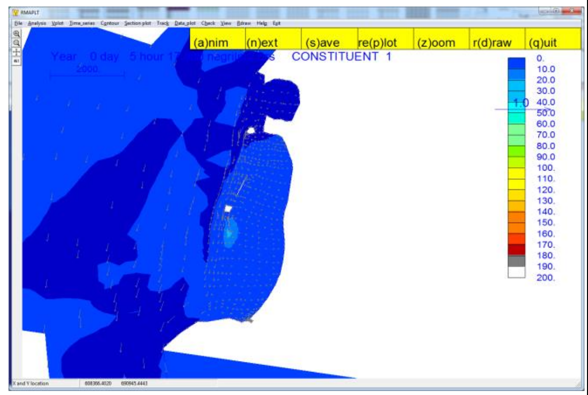
In order to reduce silt dispersion in the water column, management of source transport and stockpile locations must be in place so as to minimize the amount transported to site. Turbidity barriers should also be used in the immediate project area; this will also reduce silt dispersion.

*Results*

Plume modelling suggests that the extent of the north break water plume is in general larger than the southern breakwater. If construction is carried out without a turbidity barrier then the plume will extend approximately 400 to 500 metres north and south from the operation with an overall dimension of 800 to 1,000 metres. The expected concentration is 20 to 40 mg/l on average over the area of the plume. An area with high concentrations with levels of up to 120 to 170 mg/l some 20 to 50 metres in nominal dimensions can result from the operations, if the boulders are not properly washed. It does appear that the plume is more persistent within the bay and the bio-physical features on this side may be more at risk.

Plumes associated with the southern breakwater are in general much smaller and less concentrated than those for the northern breakwater. The plume takes on a circular shape with a radius of 200 metres with lower concentration of 20 to 30 mg/l. An increased risk of the plume contacting the sandy bank/main reef may exist if the turbidity is not adequately controlled.

*Table 7-9 Sediment plume modelling results for rising and falling tides for northern and southern breakwater construction for Negril*

| | Falling tide | Rising tide |
|---|---|---|
| North break water |   |   |
| South break water |   |   |

*Summary*

Sediment dispersion modelling underlines the importance of washing the boulders before delivery to site. Should the boulders not be washed and inadequate turbidity control measures are in place then a turbidity plume may result from the operations. This plume, however, is expected to remain offshore and will meet the NEPA guidelines for staying more than 400 to 500 metres away from the on shore operations in Negril.

#### 7.1.1.5 Desilting of the Mouth of South Negril River

The desilting the mouth of the South Negril River and Caribbean Sea to a depth of between 2 and 3 m to create the stockpile area has the potential for increasing turbidity and destroying aquatic vegetation and animals. It is recommended that the South Negril River be desilted in such a way that the width of the river's mouth remains the same and the hydraulics of the river is not affected. A detailed hydrological study is required to identify the effects of the desilting operation on the morass (outside the scope of this project).

The desilting of the mouth of South Negril River and a small channel will have a positive social impact in facilitating the fishermen's entry to the fishing beach.

It must be noted that river desilting and dredging is no longer a part of the project scope (though included in the original proposal). There will be no dredging of a section of the mouth of the river; material will be sourced from licenced quarries for the creation of the stockpile area.

#### *7.1.1.6 Roads Classification and Capacity*

The construction activities will have some impact on traffic in the area.

**Traffic Congestion**

The proposed staging area is located along a roadway that is prone to traffic congestion and the transportation of stones from the quarry via trucks can further aggravate the traffic situation. Construction traffic will be mostly trucks delivering equipment to the staging site. This will involve trucks laden with boulders, heading west from the Negril round-a-bout, entering the stockpile area and leaving eastwards behind Burger King up to Norman Manley Boulevard. There is a potential for traffic congestion caused from the transportation of the boulders however the anticipated 24 trucks per day should not have a significant impact on traffic.

**Safety**

The increase in traffic (extra-long and heavy vehicles) at the intersection during the construction phase will reduce the safety level for motorist's that traverse this route.

**Deterioration of Road Surface**

The increase in the number of heavy vehicles along the roadways has the potential to add significant stresses to the base and sub-base of the road. This has the potential to affect the structural integrity of the paved roads which may result in failure.

#### *7.1.1.7 Material Storage and Equipment Operation*

The improper storage and use of materials (boulders, fuel, hydraulic fluids and oils) have the potential to pollute the marine and riverine environment. The site will have both direct project workers (between 10 and 50 persons) on site plus transient workers (2 to 10 in an hour) during the delivery period, such as truckers and side men for short durations delivering boulders and other materials.

#### *7.1.1.8 Drainage*

The stockpiling of boulders on the site will potentially generate significant sediments that will accumulate on the site. Rainfall will create the opportunity for the sediments to be carried into the nearshore area.

#### *7.1.1.9 Solid Waste Generation*

To accommodate the expected workforce a contactors' office, a canteen and equipment yard need to be constructed. 50 workers will generate 300 kg or 6 cubic meters of solid waste, at 1 kg per worker day. During this construction phase of the proposed project, solid waste generation may occur mainly from four points:

i. From the construction campsite/staging area.
ii. From construction activities such as excavation and dredging of the river mouth (dredging is no longer in scope of work; instead, material will be sourced from licenced quarries).
iii. From the delivery of boulders to the staging area.
iv. Development of unauthorized vending areas

Improper collection, storage and disposal of solid waste will create an environment in which rodents and insects thrive which can become a health issue and cause a nuisance to local businesses and due to its proximity can enter the surrounding sea and river and affect marine wildlife and the livelihood of those who depend on the beach for their survival.

#### *7.1.1.10 Wastewater Generation and Disposal*

All construction sites generate wastewater from the workers. The collection and disposal of the wastewater generated at the campsite has the potential to have a minor negative impact on the marine and riverine environment due to its proximity.

### 7.1.2 Biological

#### *7.1.2.1 Phytoplankton*

Increased turbidity of the water column has the potential to reduce the quality of light received by the phytoplankton community resulting in a decrease in phytoplankton productivity as well as diversity due to loss of rare species and reduction of the abundance of the more common species. This can negatively impact organisms of higher trophic levels that depend on phytoplankton as a direct or indirect source of food (Jabusch, 2008, OSPAR, 2008). There is a risk of decreasing the diversity of the phytoplankton community through loss of rare species and other species with low abundance values as a result of the impact of changes in the physico-chemical parameters such as increased turbidity. This risk is considered to be moderate and the impact generally short term but this is dependent on the extent of the areas dredged (in terms of area and depth), the frequency and duration of dredging activities, the characteristics and the sensitivity of the areas dredged and their surroundings (in terms of distribution and importance of phytoplankton species), and the dredging techniques applied (OSPAR, 2008). It must be noted that dredging was included the original proposal; however this has been changed and there will no longer be dredging of any section of the river. Instead, material will be sourced from licenced quarries for the creation of the stockpile area.

Increased nutrient concentrations within the water column can result in blooms of various phytoplankton species which can reduce the light intercepted by other non-bloom phytoplankton species and larger marine plants and thus reduce the productivity of these species and species of higher trophic levels (Anderson et al., 2002). Decaying blooms can reduce the oxygen concentrations within the water column causing indiscriminate kills of fish and invertebrates due to oxygen depletion. Phytoplankton blooms can also reduce the recreational and aesthetic value of the area via reduced visibility, unpleasant odours and altered seawater colour (Anderson, 1996; Hallegraeff, 2004, OSPAR, 2008). Increased nutrient concentrations and changes of other physico-chemical parameters can also result in an increase in abundance and even blooms of potentially toxic phytoplankton species. These can negatively impact on marine organisms of higher trophic levels, restrict the exploitation of commercially important marine species in the area, lead to the loss of fishermen's livelihood and negatively impact on the tourist industry, through reduced aesthetic and recreational value of the area as well as via the possibility of human poisonings, through the consumption of fish and shellfish that have directly and indirectly ingested the potentially toxic species (Anderson, 1996; Anderson et al., 2001; Hallegraeff, 2004).

There is a risk of the creation of phytoplankton blooms through increased nutrient enrichment of the water column via sediment disturbance. This risk is considered to be moderate but short term and is dependent on the extent of the areas dredged (in terms of area and depth), the frequency and duration of dredging activities, the dredging techniques applied and most importantly the concentration of nutrients in the sediment that can stimulate the production of phytoplankton blooms (it should be kept in mind however that the project scope has changed and that dredging of the river will no longer be undertaken). Related to this, is the potential risk of the production of blooms of potentially toxic phytoplankton species. Disturbance of an area can lead to changes in physico-chemical parameters which can result in the concentration values of the potentially toxic species exceeding acceptable limits and even forming blooms (Anderson, 1989; Hallegraeff, 2004). These blooms can have long term impacts especially on the tourism industry of the area. The acceptable concentration limits for many of the potentially toxic species present in Jamaican waters have not yet been determined (Ranston, 2008). Concentration limits have been determined in other countries but these vary from country to country and even within single species primarily due to geographical variability in toxicity of the species and the environmental conditions (Anderson, 1996). These concentration limits can however be used as a general guideline for determination of acceptable limits for Jamaican species and on this basis the present concentration values are low and within acceptable concentration limits (Anderson, 1996). The level of the risk of potentially toxic phytoplankton concentrations exceeding acceptable limits or blooming is difficult to determine and dependent on the level of disturbance of the physico-chemical parameters of the area and the toxic potential of the Jamaican species which is presently unknown, however, as long as a species has the potential to be toxic then its presence alone must be taken into consideration as important and presenting a risk factor.

Reduction of the oxygen concentration of the water column through disturbance of the seafloor sediment and addition of chemicals to the water column via spillage or leakage from equipment may impact phytoplankton abundance and productivity. This can negatively impact organisms of higher trophic levels that depend on phytoplankton as a direct or indirect source of food (Jabusch, 2008, OSPAR, 2008).

#### *7.1.2.2 Fish Community, Marine Mammals and Reptiles*

Marine Mammals and reptiles observed in the project area include Porpoises, dolphins and hawksbill turtles. The increased maritime traffic during construction may result in an increased potential of accidents/harm to these species. Both during and after construction, the breakwaters may cause disruptions in their food supply or foraging grounds (in the case of turtles and access to the seagrass beds) as well as disturbing their typical travel routes. The activities could also potentially deter marine species (fish, dolphins, turtles).

There is a strong possibility that the activities could inundate fishing and tour areas with sediment and cover small fishes, eggs and other benthic organisms on which fish depend. The turbidity of the water may also be detrimental to marine plants and other organisms that depend on clear sunlit water for survival.

#### *7.1.2.3 Reef Community*

**Pavement Community**

The reef community within the footprint of the breakwaters is composed of several sensitive species which will need to be relocated. These include hard and soft corals and invertebrates such as lobster, *Diadema antillarum* and sea cucumbers.

**The Backreef and Reef Crest Community**

The backreef community is composed of several patch reefs and large seagrass beds. These communities are at risk of smothering and or excess sedimentation, ship groundings and other incidents during construction activities. Several colonies of *A.palmata* were identified in the natural reef between the breakwaters; these are both sensitive and endangered species and as a result require particular care during construction activities.

There is a potential for habitat fragmentation both during and after the construction phases. This may occur between the seagrass beds in the lagoon and surrounding reefs. This may affect larval distribution, migration of juveniles or other mobile invertebrates.

Seagrass beds and patch reefs located along the proposed transportation roots of ships and barges are also at risk. Accidental loss of material, sedimentation and ship grounding and other incidents may cause damage or harm to these communities/organisms in the area.

## 7.1.3 Human and Social

### *7.1.3.1 Employment*

There is the potential for increased employment; it is anticipated that approximately 50 persons will be employed directly and 75 indirectly during the project life span.

The activities associated with the delivery of boulders to the stockpile area will involve trucks laden with boulders, heading west from the Negril round-a-bout, entering the stockpile area and leaving eastwards behind Burger King up to Norman Manley Boulevard. There is a potential for traffic congestion caused from the transportation of the boulders which could have an impact on businesses in the immediate areas and West End. It should be noted that this exercise does not involve digging or trenching as was the case of the pipe laying activity carried out along West End. Therefore it is anticipated that the dislocation experienced during that project will not happen. The anticipated 24 trucks per day will not have a significant impact on traffic or cause any dislocation, therefore the impact on existing jobs or businesses will be limited.

### *7.1.3.2 Maritime Operations and Local Businesses*

Construction activity may have the potential to negatively impact watersports, fishing and other maritime activities taking place at sea. The locations of the proposed breakwater structures are close to snorkelling sites used by hotel and small business watersports operators as part of the services offered to clients (Figure 7-14). These sites will be inaccessible during construction of the breakwater structures. Dive, snorkel and glass-bottom boat tours operating outside of the construction zone may be impacted by low visibility and or noise as a result of construction activities.

Both during and after construction is complete, vessels will have to travel longer distances around the breakwater structures in order to access various dive/snorkel sites and island tours and cruises. This may cause additional expenses in the operational costs of watersports operators.

There are many activities during the construction process that can affect the livelihood of those who use the beach and the river to generate an income; this includes hotels, fishermen and divers.

- The South Negril River is used by fishermen to get access to the sea, when the river's entrance is being desilted this has the potential to interrupt the usual flow of marine traffic.
- Transporting the stones from the stockpile area to the construction area has the potential for destroying existing coastal structures which are used by divers to run organized scuba and dive tours.

#### *7.1.3.3 Visual Impact*

The staging area is located almost in the town centre (Negril) and as such the area will be seen by a lot of persons (locals, visitors and tourists) and has a potential negative visual impact on businesses operators and persons alike.

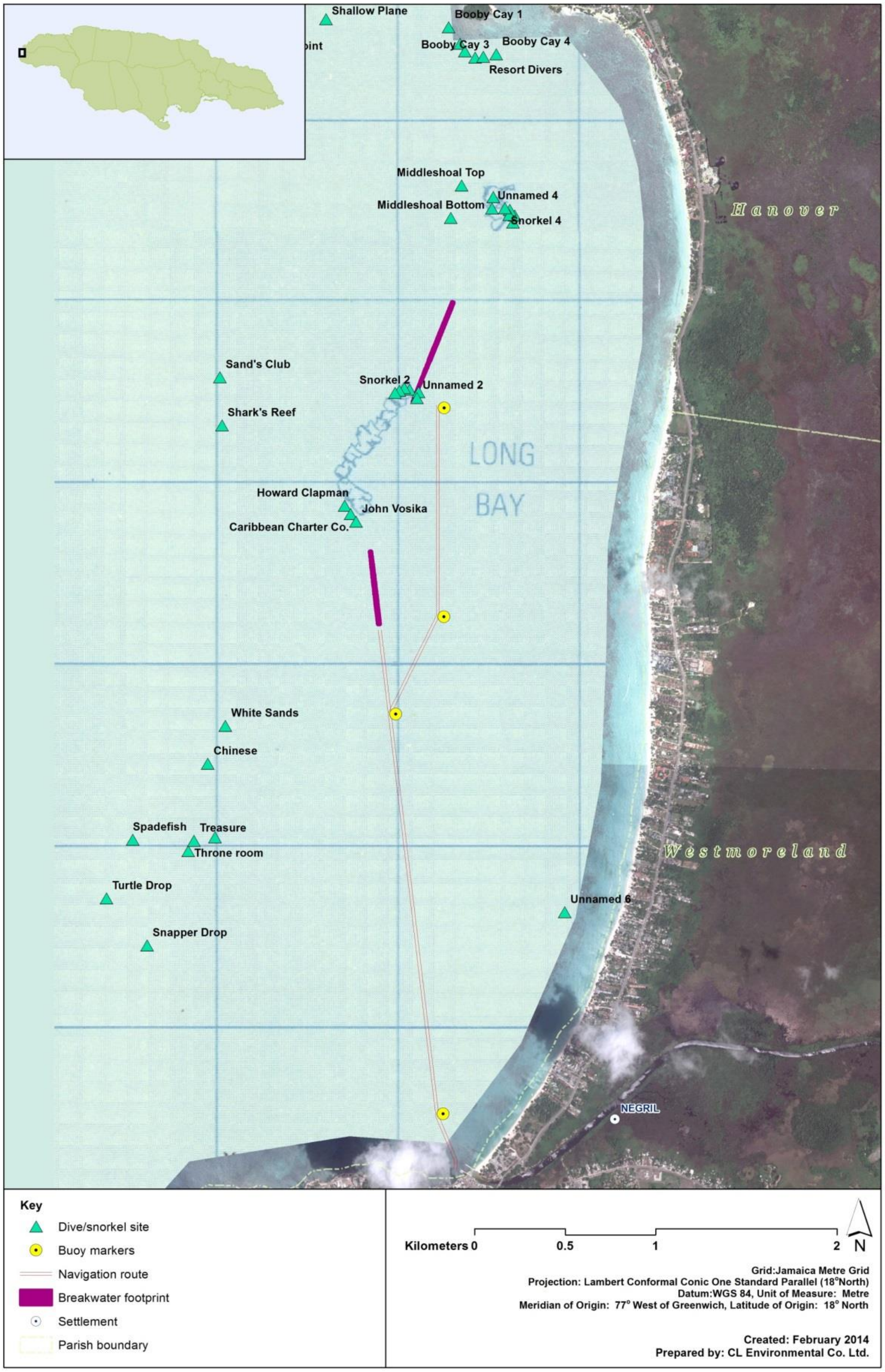



*Figure 7-14 Dive/snorkel sites and navigation routes within Long Bay*

# 7.2 OPERATION

## 7.2.1 Physical

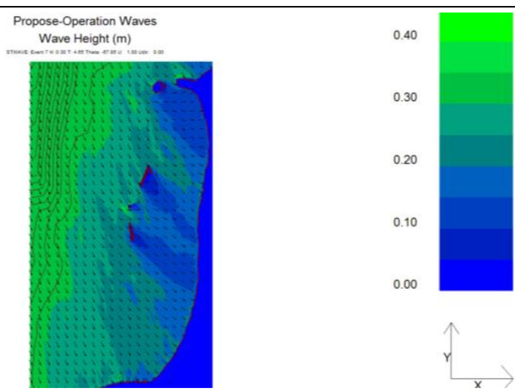
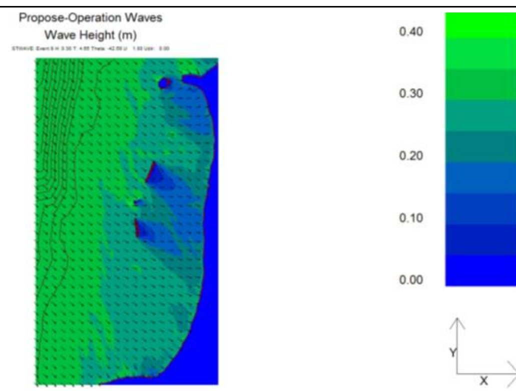
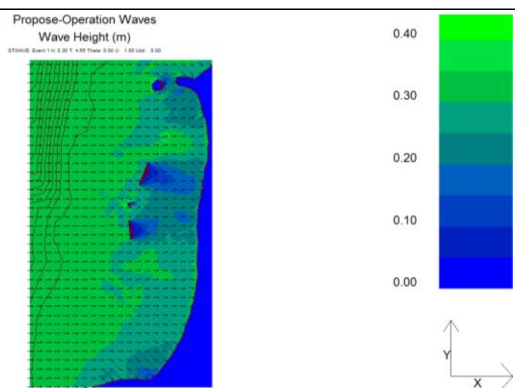
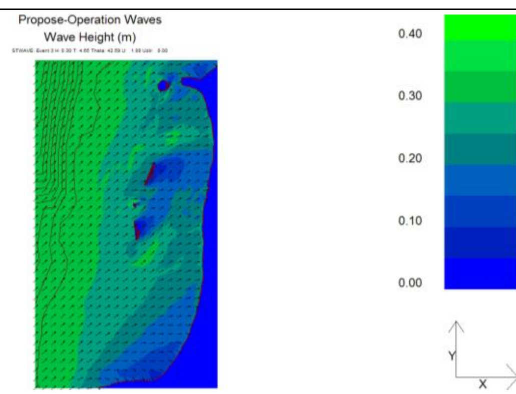
### *7.2.1.1 Waves and Storm Surge*

Implementation of two breakwaters 417 metres and 517 metres long placed approximately 1.5 km away from the shoreline. The structures will have crest elevations at mean sea level and will be placed on either side of the existing main reef. Their placement is aimed at minimizing the wave energies along the shoreline, which would result in stabilizing the Long Bay area; more specifically the central and northern sections of Long Bay which are historically the most vulnerable areas.

**Operational Waves**

Implementation of the breakwaters in the near shore wave model resulted in a reduction in the magnitude of waves reaching the shoreline from 0.15 to 0.4 metres (without breakwaters) to 0.1 to 0.3 metres (with breakwaters) for the directions models. Smallest waves height of 0.2m was observed reaching the northern and central section of the study area.

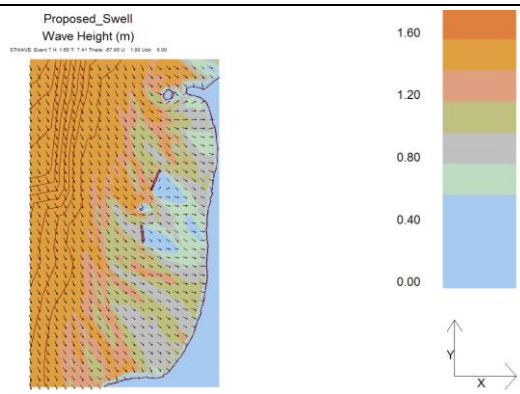
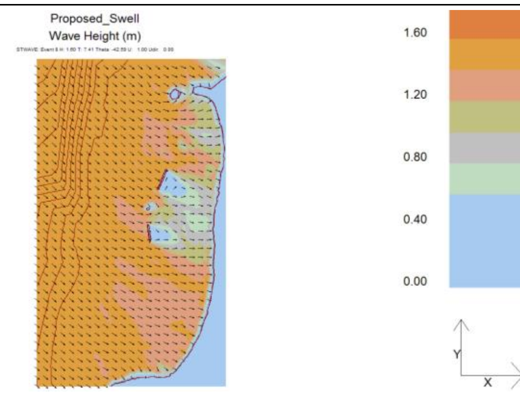
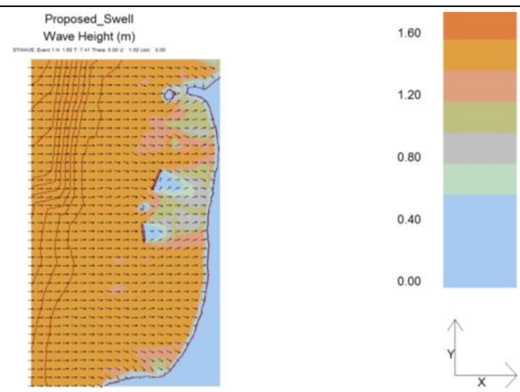
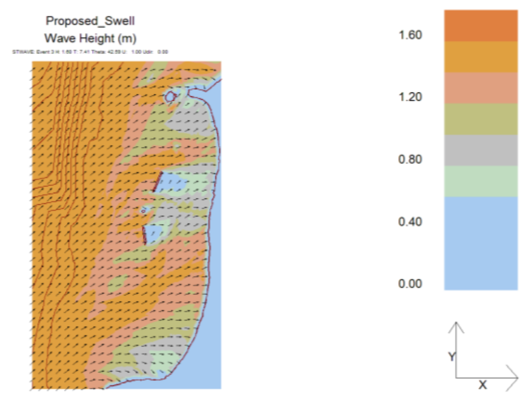
*Table 7-10 STWAVES resultant plots of operational waves for various directions (Post project)*

| | |
|---|---|
|  NNW |  NW |
|  W |  SW |

### Swell Waves

Pre-project scenario had wave heights of 1.2 to 1.4m reaching the shoreline from the south west and westerly direction during swell events. However, the post project solution resulted in a reduction in wave heights reaching the shoreline to 0.8 – 1.3m with the smallest wave height of 0.8m observed reaching the northern and central section of the study area.

*Table 7-11 STWAVES resultant plots of operational waves for various directions (Post Project)*

| | |
|---|---|
|   NNW |   NW |
|   W |   SW |

### Hurricane Waves

The NNW, NW, W and SW directions had wave heights ranging from 1.8 to 3.1m and 2.1 to 3.6m for the 50 and 100 year return periods reaching the shoreline. The implementation of the two breakwaters resulted in a reduction in the magnitude of waves reaching the shoreline to 1.5 to 2.5m and 1.6 to 2.8m for the 50 and 100 year return period respectively. The smallest wave heights observed reaching the central and northern section of the bay.

*Table 7-12 STWAVES resultant plots of Hurricane waves for various directions (Post Project)*

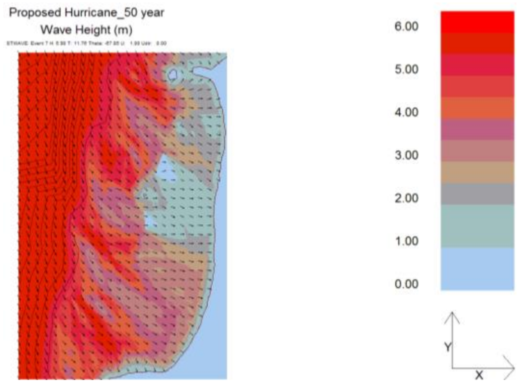
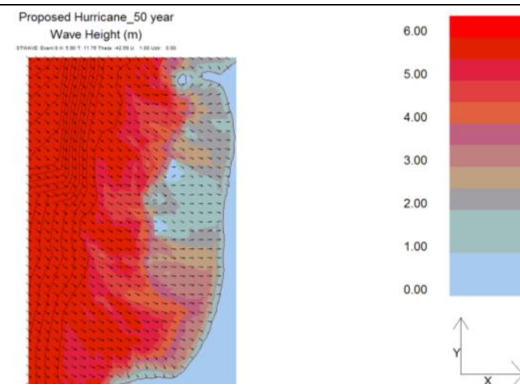
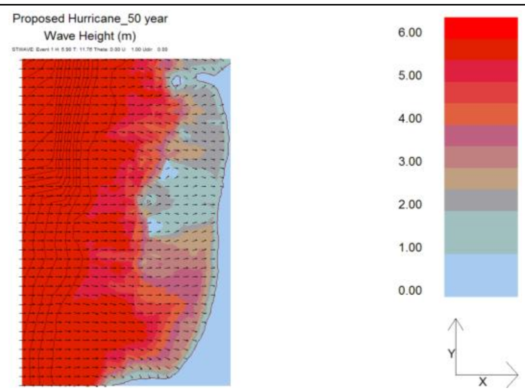
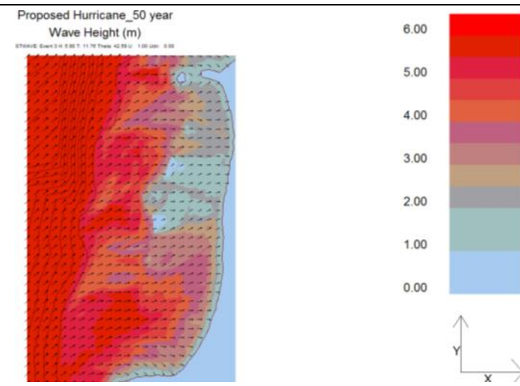
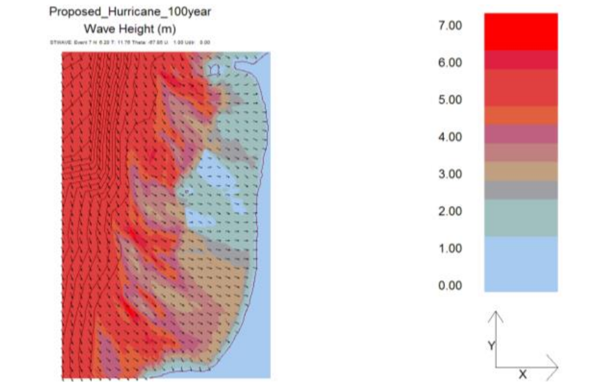
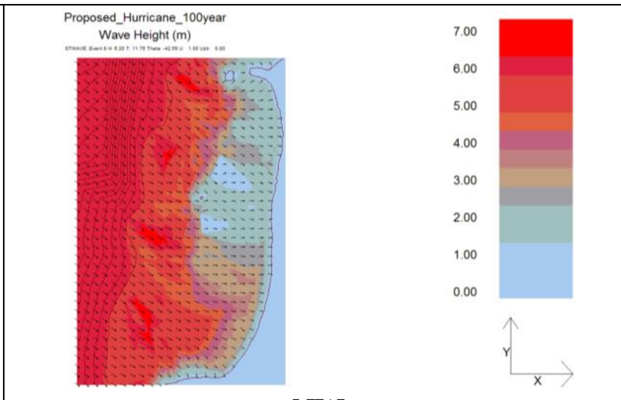
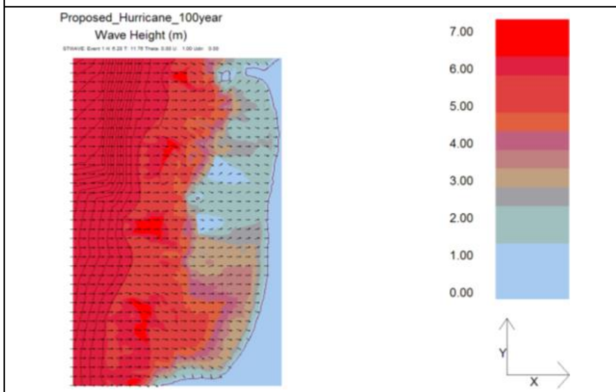
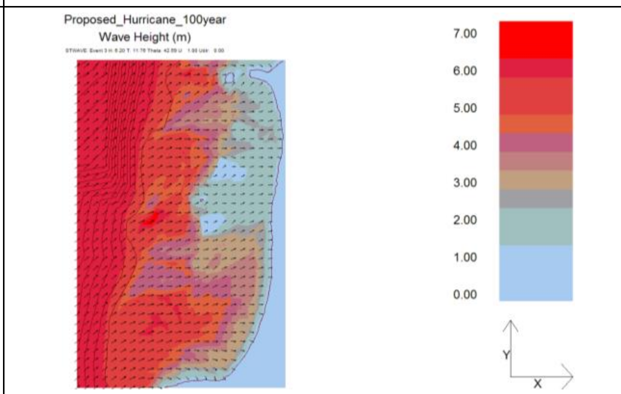
| | |
|---|---|
|   NNW |   NW |
|   W |   SW |

*Table 7-13 STWAVES resultant plots of Hurricane waves (100 Year) for various directions (Post Project)*

| | |
|---|---|
|  NNW |  NW |
|  W |  SW |



### Future Climate – Post Project

When considering climate change for the post project scenario the model showed that, the shoreline may experience wave heights ranging from 2 to 3.4 metres and 2.3 to 3.8 metres for the 50 and 100 year event respectively. Implementation of the breakwater (post project + Climate change) reduced the wave heights reaching the shoreline to 1.5-2.6 metres and 1.6 -3.1 metres for the 50 and 100 year return periods respectively.

Similar to the post project condition without climate change, the implication of the breakwater with the consideration of future climate change resulted in a reduction in the magnitude of waves reaching the shoreline. The 50 and 100 year event which had a range of 2 to 3.4 metres and 2.3 to 3.8 metres reduced to 1.5 to 2.6 and 1.6 to 3.1 metres respectively. The smallest waves observed at the central and northern section of the shoreline which is consistent with the design.

*Table 7-14 STWAVES resultant plots for future climate Hurricane waves (50 year) for various directions (Post Project)*

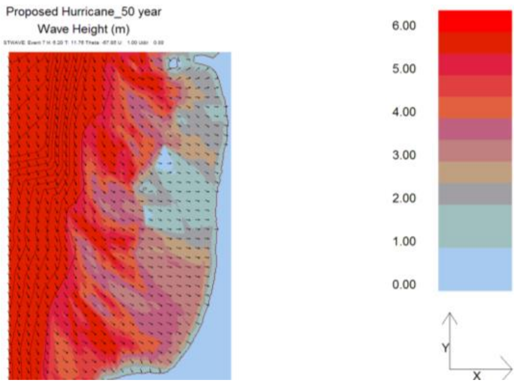
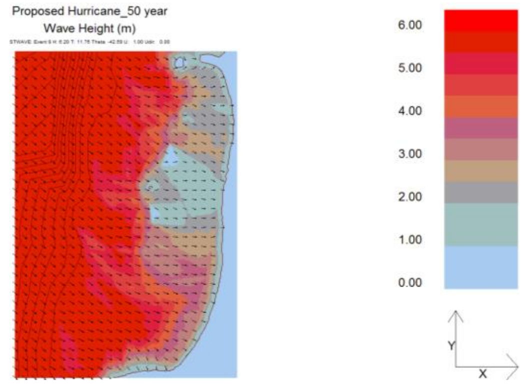
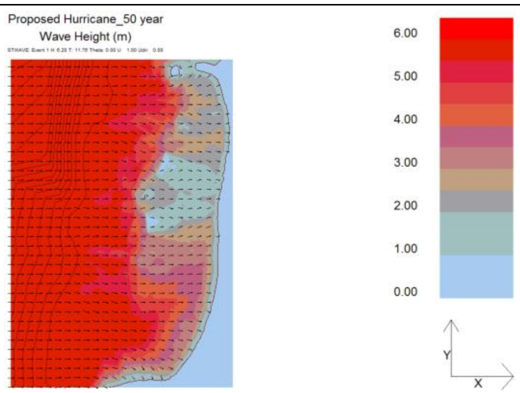
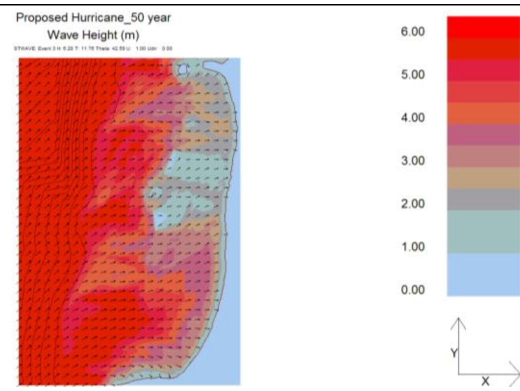
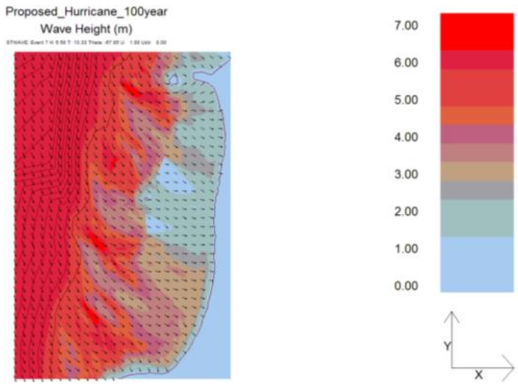
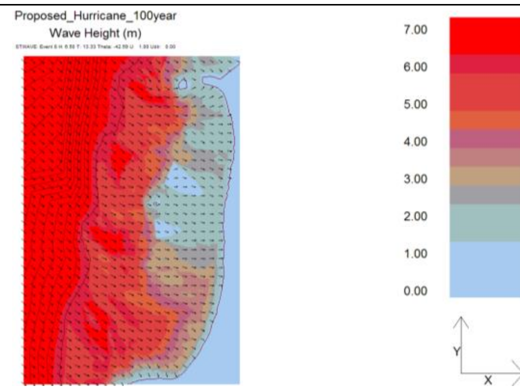
| | |
|---|---|
|   NNW |   NW |
|   W |   SW |

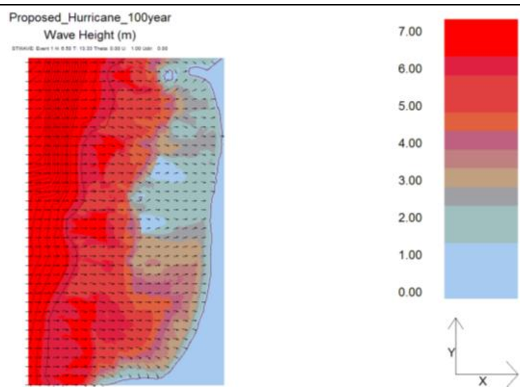
*Table 7-15 STWAVES resultant plots for future climate Hurricane waves (100 year) for various directions (Post Project)*



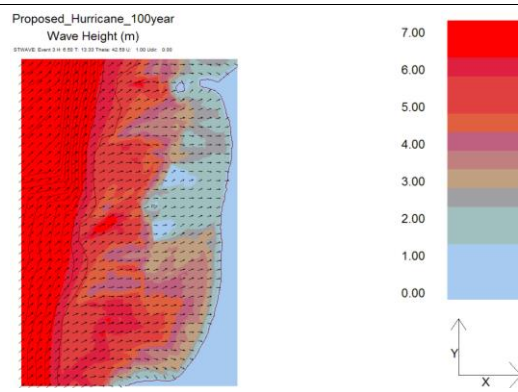

NNW




NW




W




SW

**Summary**

Operational waves are more frequent from the north-western directions which are among the least vulnerable directions in terms of waves approaching the shoreline. The placement of the breakwaters will further reduce the vulnerability of the shoreline to the mildly erosive forces of the operational waves. It should be noted that localized alongshore currents are generated at the shoreline when waves approach from an angle. These currents move suspended sediments along the shoreline in a southerly direction along the Long Bay beach. This confirms anecdotal data from several residents who have reported that the southern section of the beach has grown over the years whereas the north and central portions have eroded.

Swells occur less frequently but can occur from any direction facing the shoreline. Similarly, more of the shoreline and the central section in particular will be less vulnerable to these highly erosive waves. The wave heights are expected to be in the order of 0.4m arriving at the shoreline down from 1.6m in some areas.

The wave transformation modelling clearly indicates the vulnerability of the shoreline is greatest from hurricane waves approaching from the west and south west directions. For the pre and post-project scenarios, 4 to 5 metre waves are expected at the toe of the structures (some 1.5 kilometres offshore) and 2 to 3.8 metre waves are expected at the shoreline during 100yr and 50yr storm events. The bathymetry offshore between the continental shelf and the breakwater location is fairly long and shallow enough to reduce the wave heights to below 4 metres regardless of the deep water wave height.

The magnitudes of waves reaching the shoreline are predicted to range from 1.5 and 2.6 metres with the smallest waves reaching the central and northern section of the shoreline. The most vulnerable sections of the shoreline (central Long Bay) will accrue the most benefit from the implementation of the breakwaters in terms of storm waves. The benefits of the breakwaters are evident in the wave predictions and should be implemented as designed.

It should be added the breakwaters were designed to be stable in the design storm (100 year return period storm even), with a damage level of 2. This means that 1 or 2 stones may shift in the structure during the design event; however they will not roll towards the shoreline. Also, scale model testing was conducted and it showed that if 1 or 2 stones shift, the structure will settle into place and become even more stable. Finally if any shift, it will be along the seaward face of the structure and not the landward face, on the side of the shoreline.

*Table 7-16 Summary table for the wave climates resultant plots*

| Conditions | Location | Pre Project Wave Height (m) | | | | Post Project Wave Height (m) | | | | Pre Project + Climate Change - wave Height (m) | | | | Post Project + Climate Change - Wave Height (m) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NNW | NW | W | SW | NNW | NW | W | SW | NNW | NW | N | SW | NNW | NW | W | SW |
| Operational | Seaward of breakwater | | | | | 0.25 | 0.3 | 0.3 | 0.2 | | | | | 0.25 | 0.3 | 0.3 | 0.2 |
| | Leeward of breakwater | | | | | 0.15 | 0.15 | 0.15 | 0.15 | | | | | 0.15 | 0.15 | 0.15 | 0.15 |
| | Shoreline | 0.1 - 0.25 | 0.2 - 0.25 | 0.2 - 0.3 | 0.1-2.5 | 0.05 | 0.1 - 0.2 | 0.1 - 0.2 | 0.1 - 0.2 | 0.1 - 0.25 | 0.2 - 0.25 | 0.2 - 0.3 | 0.1-2.5 | 0.05 | 0.1 - 0.2 | 0.1 - 0.2 | 0.1 - 0.2 |
| Swell | Seaward of breakwater | | | | | 1.2 | 1.2 - 1.4 | 1.4 | 1.2 - 1.4 | | | | | 1.2 | 1.2 - 1.4 | 1.4 | 1.2 - 1.4 |
| | Leeward of breakwater | | | | | 0.4 | 0.4 | 0.4 | 0.4 | | | | | 0.4 | 0.4 | 0.4 | 0.4 |
| | Shoreline | 0.8 - 1 | 1 - 1.4 | 1 - 1.4 | 1 - 1.4 | 0.6 - 0.8 | 0.8 - 1.2 | 0.8 - 1.4 | 0.8 - 1.2 | 0.8 - 1 | 1 - 1.4 | 1 - 1.4 | 1.4 | 0.6 - 0.8 | 0.8 - 1.2 | 0.8 - 1.4 | 0.8 - 1.2 |
| Hurricane (50 year) | Seaward of breakwater | | | | | 3.5 | 3.5 | 3.5 | 3.5 | | | | | 4 | 4 | 4 | 4 |
| | Leeward of breakwater | | | | | 1 | 1 | 1 | 1 | | | | | 1 | 1 | 1 | 1 |
| | Shoreline | 2.0 - 3.0 | 2.0 - 3.0 | 2.0 - 3.0 | 2.0 - 3.0 | 1 - 2.5 | 1 - 2.5 | 1 - 2.5 | 1 - 2.5 | 2 - 3.4 | 2 - 3.4 | 2 - 3.4 | 2 - 3.4 | 1.5 - 2.6 | 1.5 - 2.6 | 1.5 - 2.6 | 1.5 - 2.6 |
| Hurricane (100 year) | Seaward of breakwater | | | | | 4 | 4 | 4 | 4 | | | | | 3.5 | 3.5 | 3.5 | 3.5 |
| | Leeward of breakwater | | | | | 1 | 1 | 1 | 1 | | | | | 1 | 1 | 1 | 1 |
| | Shoreline | 2.0 - 3.0 | 2.0 - 3.5 | 2.0 - 3.5 | 2.0 - 3.0 | 1.5 - 2.8 | 1.5 - 2.8 | 1.5 - 2.8 | 1.5 - 2.8 | 2.3 - 3.8 | 2.3 - 3.8 | 2.3 - 3.8 | 2.3 - 3.8 | 1.6 - 3.1 | 1.6 - 3.1 | 1.6 - 3.1 | 1.6 - 3.1 |

#### *7.2.1.2 Shoreline Vulnerability*

**Alongshore Sediment Transport Regime (GENESIS)**

*Proposed Breakwater Configurations (Options 1 and 2)*

As mentioned previously, two post-project options were investigated to maximize or evenly spread the area of stability and growth along the shoreline, they were:

- Option 1:the southern breakwater being 417m and northern breakwater 517m as per the initial design and,
- Option 2: the southern break water extended to 617m in a southerly direction and the northern breakwater shortened by 200m to 317m (on the northern end).

Option 1 resulted in 109,400 cubic metres of accretion over 80 percent (4.95km) of the shoreline within 7 years, with an average shoreline growth of 13.5 metres. Most of the growth occurred at the northern section of Long Bay with a maximum predicted growth of 41.7 metres. It should be noted that this is the average long-term estimated accretion for the seven year period with a similar wave climate to that considered in the modelling. The actual response of the shoreline to the many combinations of wave heights, directions and periodicity possible, relative to the shoreline will varying depending on the state of the beach at the time of the event and duration of the event. It is inherently assumed that no additional anthropogenic impacts are applied, such as but not limited to shoreline modifications and sand removal. The source of sand will be mobilized nearshore sediments previously eroded from the beach face and dune. The shoreline outside or marginal to the zone of influence of the breakwaters will continue to experience the underlying shoreline erosion trends.

Option 2 resulted in the 74,100 cubic metres of accretion in 7 years over 68 percent (4.23km) of the shoreline, with an average shoreline growth of 5.5 metres.

Although Option 2 resulted in a more evenly distributed growth along the shoreline, Option 1 resulted in more accretion along the shoreline and protection to the central and northern section consistent with erosion. Option 1 is therefore preferred, having more positive impact on the shoreline for the investment contemplated.

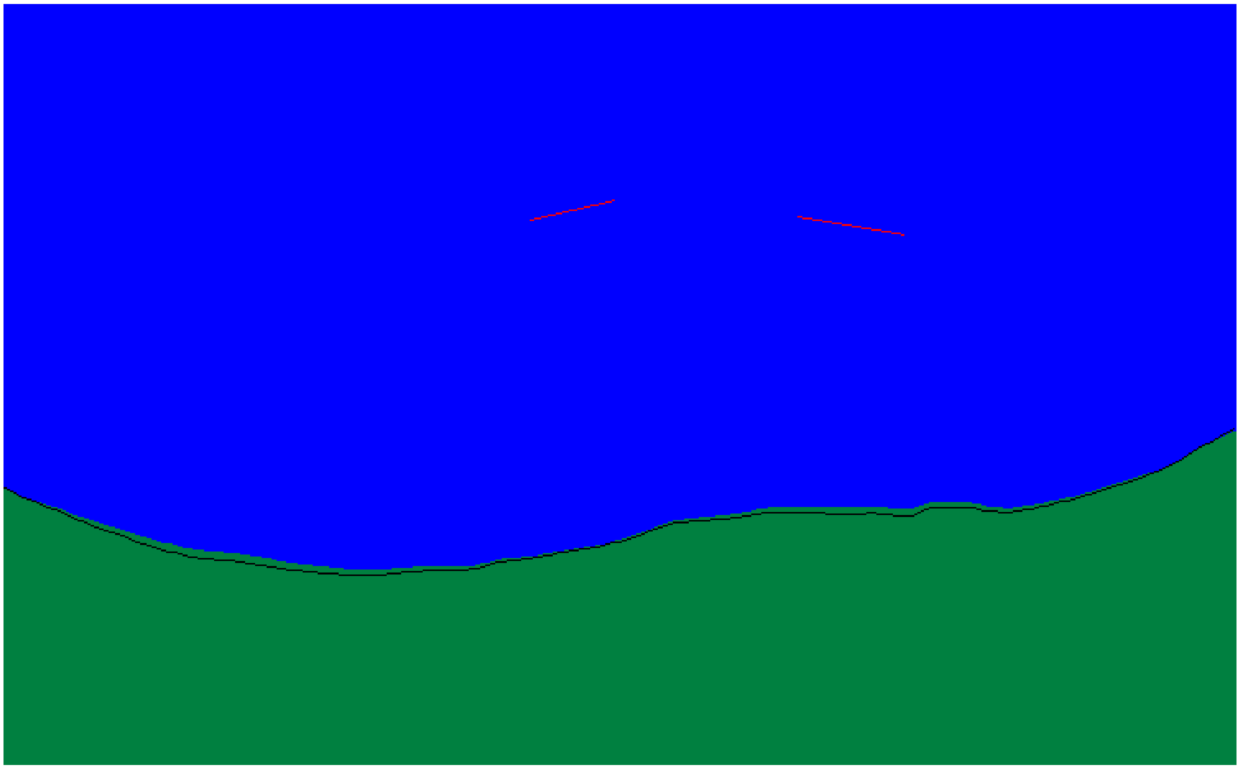


*Figure 7-15 Beach planform after 6 years of simulation for the post-project scenario with breakwaters for Long Bay*

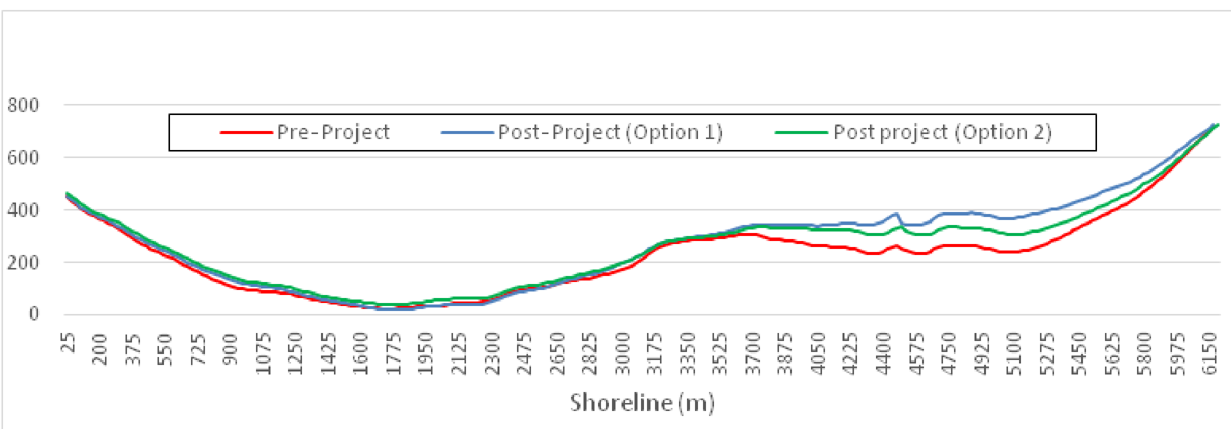



*Figure 7-16 Comparative analysis of pre-project post project option 1 and 2 shorelines for Long Bay*

*Existing and Climate Change Scenarios*

The effects of climate change inclusive of global sea level rise on the study area and the design life of the breakwaters was considered. A study by Stephnson (2013) indicated sea level rise predictions showing water levels rising to 0.14m by the year 2050. This scenario was investigated and the results indicated change will occur between that and the post project scenario. Sea level rise occurring as result of climate change will not have a noticeable impact on the shoreline up to 2050 if the structures are implemented as modelled in Option 1.

**Cross-shore Sediment Transport Modelling**

It is necessary to determine how the shoreline planform would respond to the proposed structures. Estimation of how the beach would accrete in the lee of the structures through the reduction of incident wave energy would serve as a benchmark for the monitoring phase as well. The approach adopted was as follows:

1. Calibrate and verify the planform model for records of past swell and hurricane events.
2. Examine the effect of the breakwater on the shoreline planform over a number of years of simulations

*Model Description*

SBEACH is an empirically based numerical model for estimating beach and dune erosion due to storm waves and water levels. The magnitude of cross-shore sand transport is related to wave energy dissipation per unit water volume in the main portion of the surf zone. The direction of transport is dependent on deep water wave steepness and sediment fall speed. SBEACH is a short-term storm processes model and is intended for the estimation of beach profile response to storm events. Typical simulation durations are limited to hours in comparison to the exposure times to historical storms.

*Wave Climate Input, Calibration and Verification*

Profiles were cut from deep water to land up to a maximum depth of 45 m at three locations spanning the entire shoreline (North, Central and South). The wave data corresponding to the 50 and 100 year storm events, to Hurricanes Ivan (2004) and Gilbert (1988), and to the November 2006 swell event provided by the deep water wave climate analysis and anecdotal information were utilized in this modelling exercise. Hurricane Ivan was used to calibrate the model and the November 2006 swell event was used to verify the model results.

*Table 7-17 SBEACH input parameters for each storm events*

| Storm | Hs (m) | Tp (s) | Wind Speed (m/s) |
|---|---|---|---|
| 50 YR | 5.9 | 12.1 | 34.7 |
| 100 YR | 6.2 | 12.4 | 38.4 |
| Ivan | 6 | 10.7 | 41.1 |
| Gilbert | 5.3 | 11.1 | 18.9 |
| Swell Event | 2.55 | 9.75 | 6 |

*Existing and Climate Change Scenarios*

The results of the model runs for erosion length and storm surge along the profiles are shown in Table 7-18and the locations of these profiles are shown in Figure 7-17. It should be noted that the profile directions at each node are limited by the shape of the shoreline. Waves approaching from the West, North West and South West are able to directly impact the Central and Northern nodes. Waves from the South West would not directly impact the Southern node because the land mass directly south blocks the waves from reaching the node.

*Table 7-18 SBEACH erosion results for the existing 50 year scenario and for the 50 year scenario with breakwaters and climate change*

| Profile (location of profile node, Direction of profile) | Erosion from 50 yr storm event (m) | | Level of Erosion halted (m) |
|---|---|---|---|
| | Existing Conditions | With Breakwaters and Climate Change | |
| South_W | 38 | 20 | 18 |
| South_NW | 33 | 18 | 15 |
| Central_NW | 37 | 0 | 37 |
| Central_W | 48 | 0 | 48 |
| Central_SW | 25 | 0 | 25 |
| North_NW | 16 | 18 | -2 |
| North_W | 0 | 0 | 0 |
| North_SW | 0 | 0 | 0 |

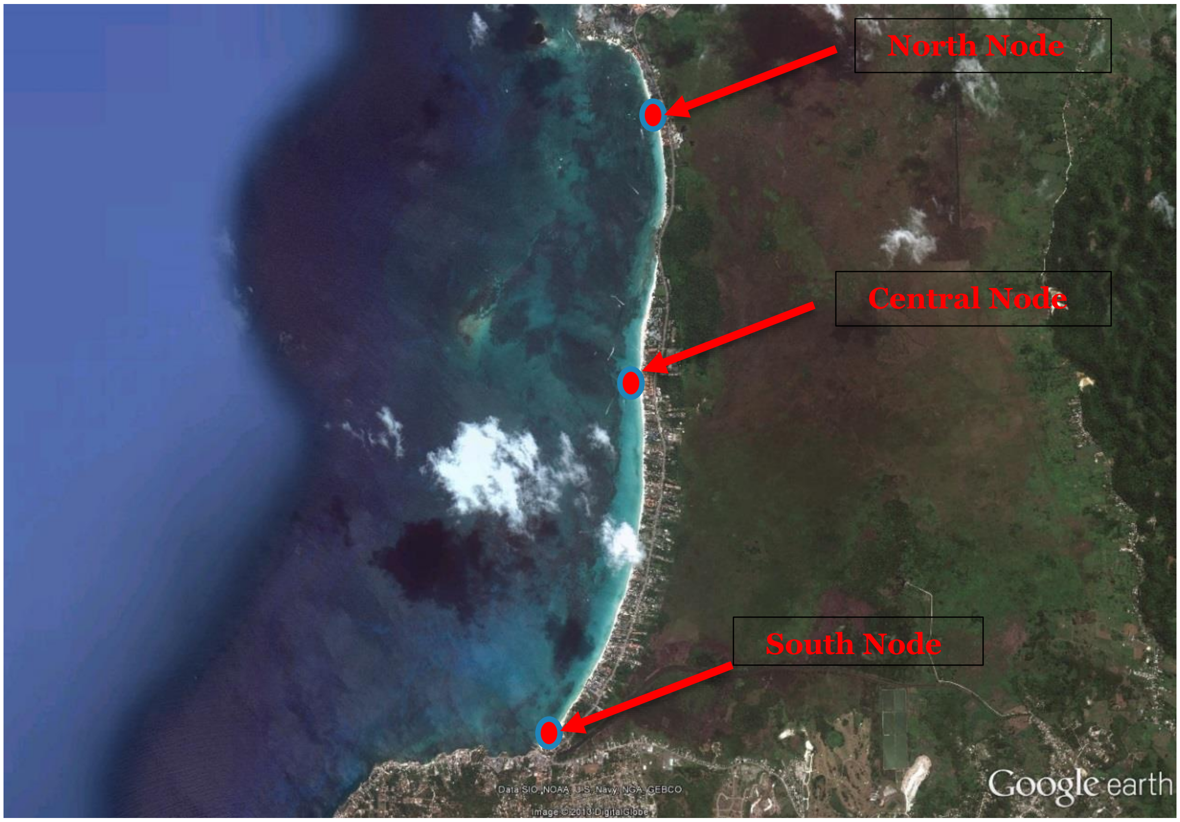



*Figure 7-17 Location of the profile nodes used in the storm surge model*

The following Figure 7-18to Figure 7-22 show the erosions that was predicted by SBEACH at the Southern, Central and Northern nodes based on current climate conditions for a 100 year return period storm event without the breakwaters. At the southern and central nodes erosion in the order of 0.5 m (vertical movement) occurs, while at the northern node there is no movement of sand.

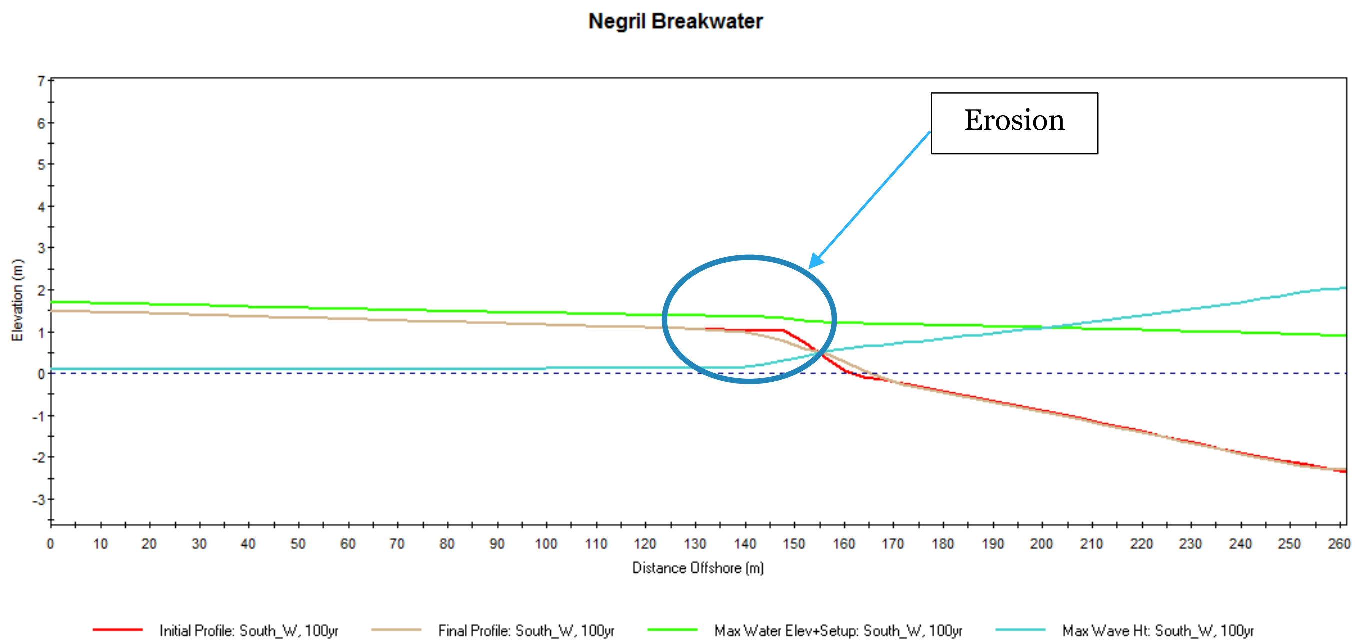



*Figure 7-18 BEACH results showing the southern node experiencing erosion along the shoreline for 100 return period storm event*

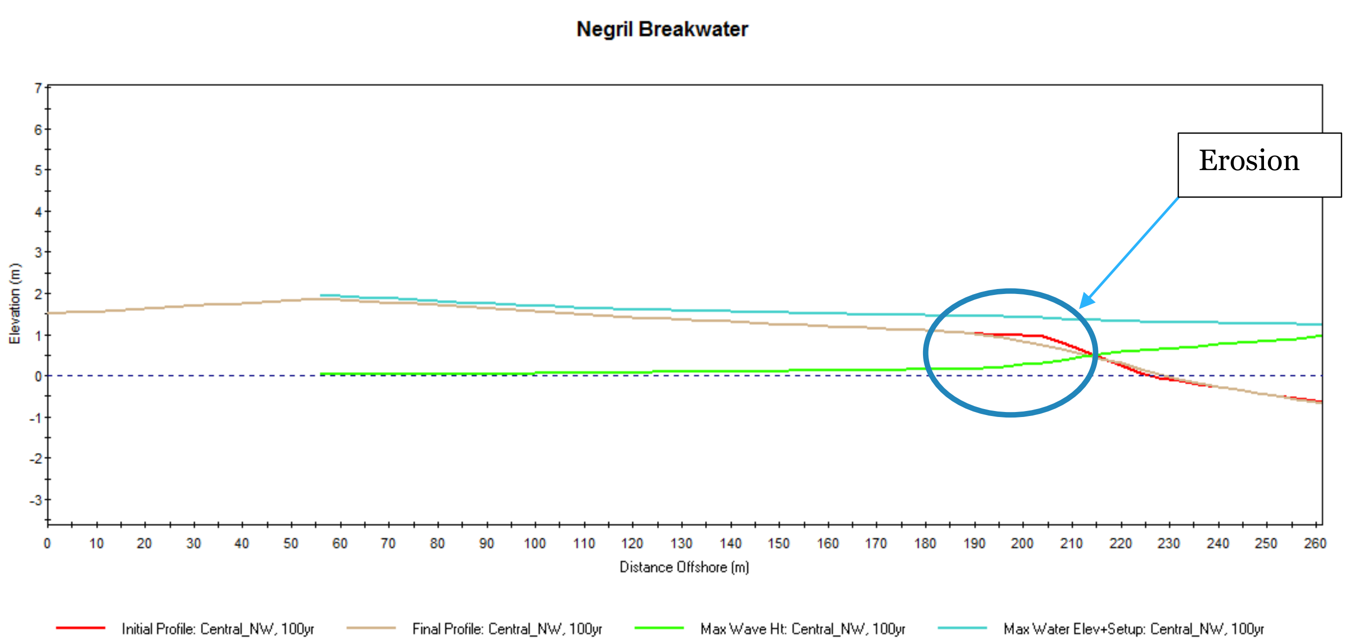



*Figure 7-19 SBEACH results showing the central node experiencing erosion along the shoreline for 100 return period storm event*

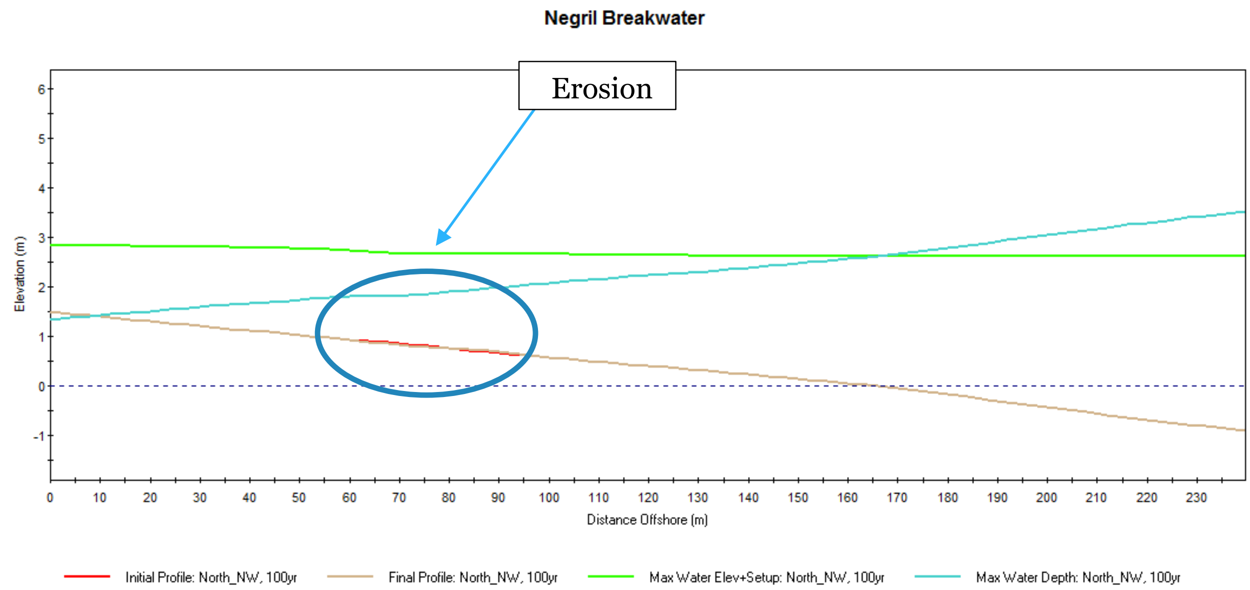



*Figure 7-20 SBEACH results showing the northern node experiencing minimal erosion along the shoreline for 100 return period storm event*

The figures below show the erosion along a profile from the central node for the projected 100 year return period storm event accounting for the breakwaters and climate change.

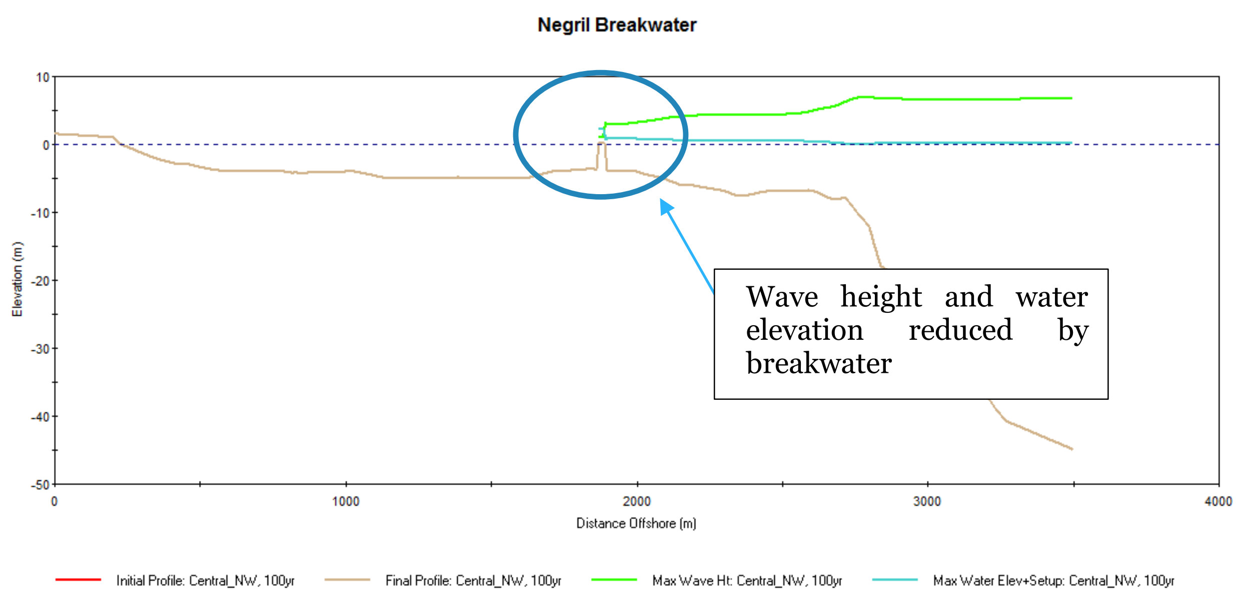



*Figure 7-21 SBEACH results showing that at the central node under the projected climate conditions with the breakwaters in place the breakwaters greatly reduced the amount of storm waves brought to the shoreline*

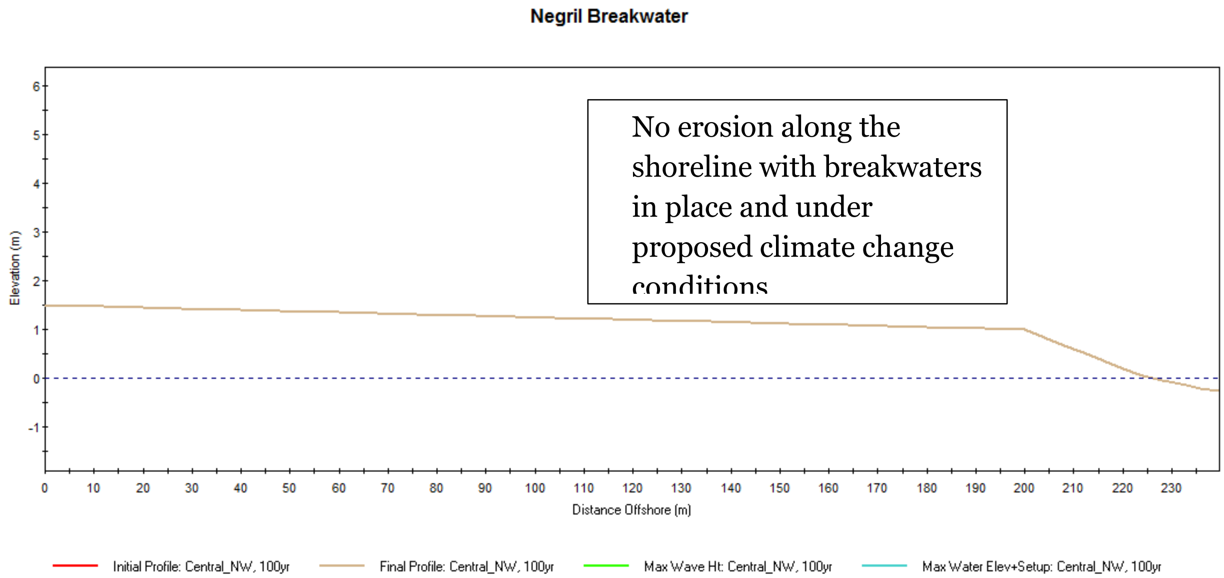



*Figure 7-22 SBEACH results showing that at the central node under the projected climate conditions with the breakwaters in place the breakwaters no erosion takes place along the shoreline*

**Summary**

It is stated that erosion rates are between 0.5 metre and 1.0 metre per annum, with sections of the shoreline having lost between 20 and 55 metres of beach in this period, with some sections losing more than 70 metres. This has been a 40-year problem. The breakwaters are designed to provide effective sheltering of the shoreline and to provoke beach growth as much as possible in order to provide the maximum benefit. They will provide moderate wave protection for 2,000 to 2,500 meters of shoreline. It will provide accretion in some areas of potentially up to 48 metres in the long term. The source of sand will be mobilized nearshore sediments previously eroded from the beach face and dune. The shoreline outside of the zone of influence of the breakwaters will continue to experience the underlying shoreline erosion trends. Figure 7-23 illustrates the estimated future beach shoreline for 2050.

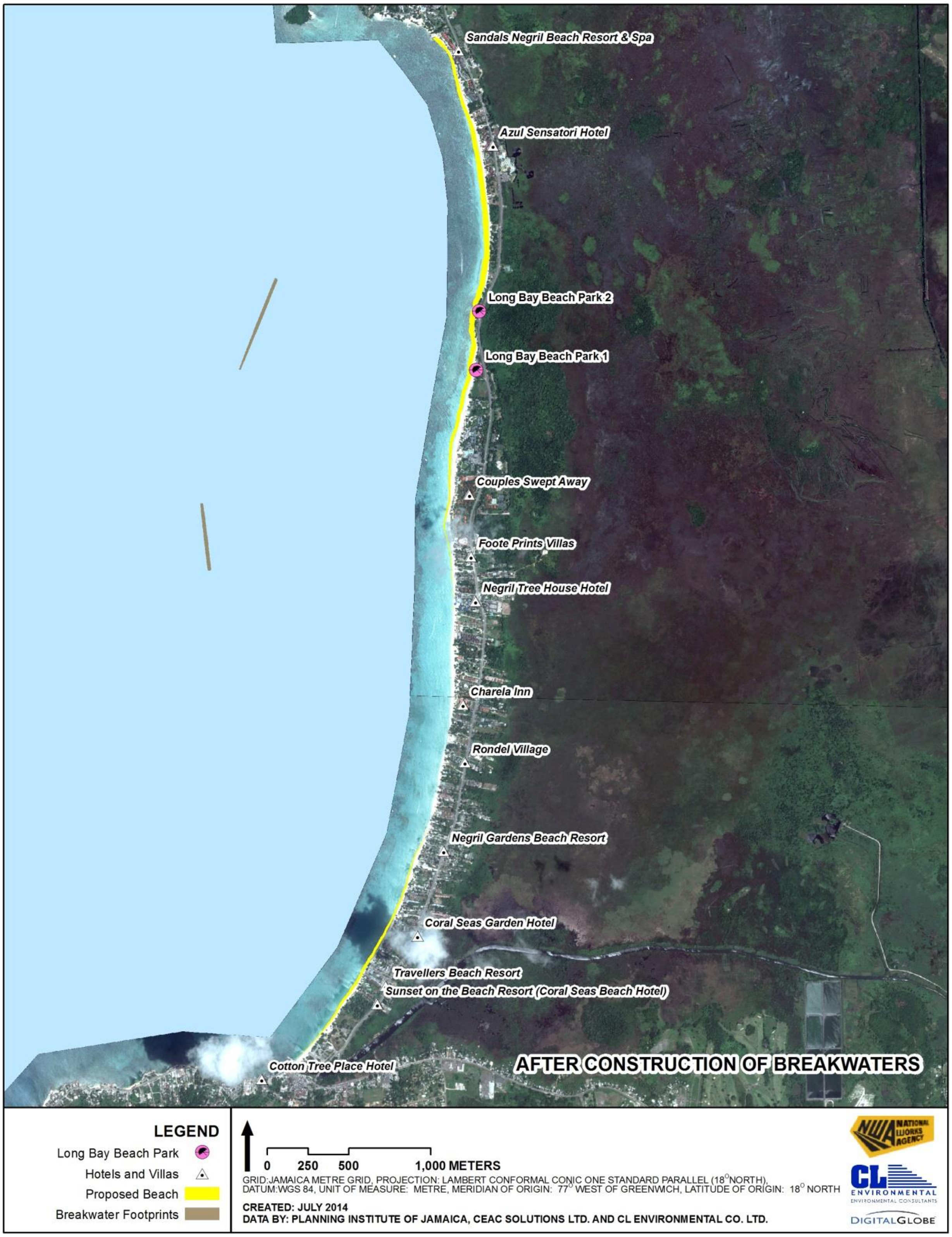



*Figure 7-23 Estimated future beach shoreline for 2050, Long Bay*

### *7.2.1.3 Hydrodynamic and Sediment Dispersion*

The current regime (i.e. patterns and speeds) in the coastal setting determines the ability of an area to flush and maintain 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 the falling tide that follows. This will result in some exchange of water between the outside and inside of the project area. This is dependent on the ratio of the water entering to the water leaving; the ratio is dependent on the tidal 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). If the fetch and duration are sufficient, the surface current speeds may approach 2-3% of the wind speeds.

Flushing rates and circulation patterns can be predicted by numerical, physical models and by field studies. Numerical models are most often used as it simply requires 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 Bay.

**Approach**

The approach to investigating the currents and sediment dispersion characteristics of the project involved current and circulation analysis and then analysis of sediment dispersion characteristics of the project area. Specifically the following was the approach:

1) Develop and calibrate a hydrodynamic model of the project area to achieve confidence in the model predictions.
2) Using the calibrated model, to investigate circulation and beach safety issues for the likely range of oceanographic and meteorological conditions the project area could experience
3) Using the calibrated hydrodynamic model for the range of oceanographic and meteorological conditions, investigate the importance and potential risks of sediment plumes being introduced into the water column from the placement of boulders to the nearby reefs and sea grass areas.

*Description of Models*

Analysis 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:

- 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 parameterisation of turbulent exchange or a Mellor-Yamada Level 2 turbulence sub-model.

#### RMA 11

The RMA 11 sediment transport model by King (1995) is a three dimensional finite element model that can also function as a two dimensional depth averaged model. The sediment transport component of RMA 11 is based on process representations from the STUDH sediment transport 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.

*Finite Element Mesh Development*

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 kilometres in a westerly direction. The outer deep water areas were gridded with large mesh which gradually decreases on approach to the project area.  The northern and southern boundaries were used as the open boundaries on which tides were applied.

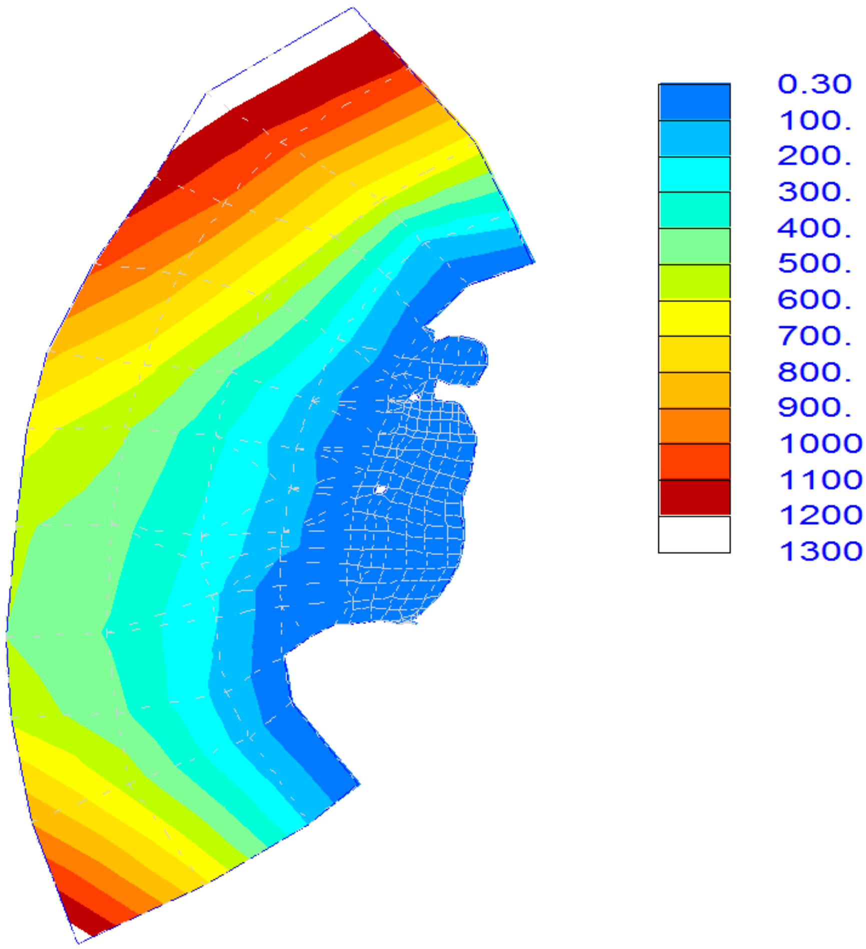



*Figure 7-24 Overview of entire Finite Element Mesh used for this project showing depth in metres*

*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.

The predicted current speeds and directions, versus the data from the drogue tracking sessions are summarized in Table 7-19. The model predictions were within the data ranges for the observed occurrences in most instances. The calibration data essentially indicates that there is reasonable agreement between the model and the data. The correlation coefficient and bias between the predicted and observed currents are outlined in Table 7-19 and Table 7-20.

*Table 7-19 Correlation coefficient and bias between the observed (drogues September 26 - 27 2013) and predicted (hydrodynamic model) currents*

| Drogue Session | Correlation | | Bias | |
|---|---|---|---|---|
| | Vx | Vy | Vx | Vy |
| Session 1 | 55% | 92% | -112% | -51% |
| Session 2 | -28% | 85% | -114% | -87% |
| Session 3 | 2% | -22% | 95% | -34% |

*Table 7-20 Correlation coefficient and bias between the observed (drogues October 16 and 17 2013) and predicted (hydrodynamic model) currents.*

| Drogue Session | Correlation | | Bias | |
|---|---|---|---|---|
| | Vx | Vy | Vx | Vy |
| Session 1 | -8% | 79% | -109% | -262% |
| Session 2 | 83% | 46% | -68% | -47% |
| Session 3 | -36% | 45% | -151% | -39% |
| Session 4 | 68% | 85% | -129% | -6% |

**Current Predictions**

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 ENE direction which is the overall dominant wind direction whereas the NW direction is the most dominant seaward direction. The wind speeds and directions used are outlined in Table 7-21. The results are summarized in the sections below as well as in Table 7-22 and Table 7-23.

*Table 7-21 Wind Speeds and Directions investigated in the Hydrodynamic model*

| Wind Speed | Wind Direction | |
|---|---|---|
| | ENE | NW |
| Slow | 1.0 | 1 |
| Average | 3.0 | 3 |
| Fast | 6.0 | 5 |

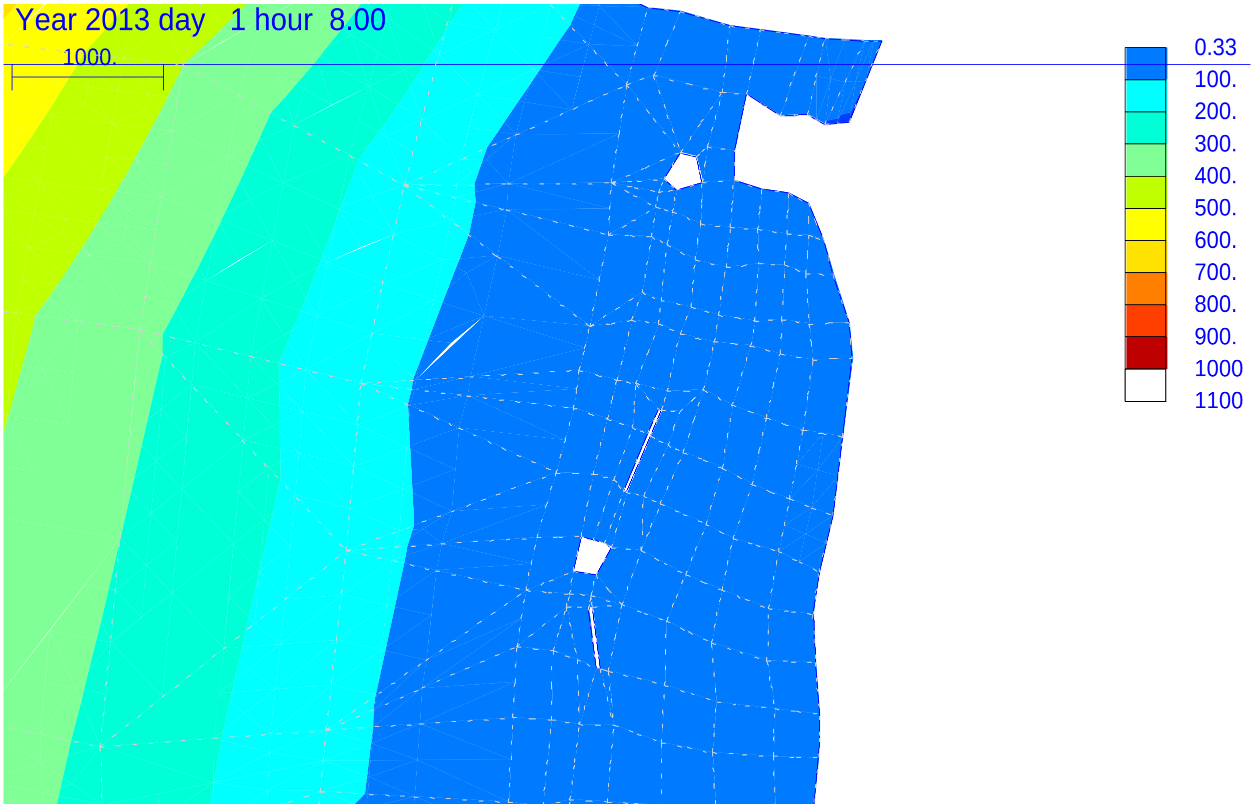



*Figure 7-25 Post Construction configuration of FEM used in post construction scenario*

*Slow Day*

For winds blowing from the ENE direction the currents are generally below 3cm/s for the north, central and southern sections of the bay during the existing and post construction rising tide scenarios. The falling tides scenario is generally the same except for the central to northern sections near the shore. In these areas, the predicted currents can be as high as 0.45 to 6.0 cm per second for the pre and post construction scenarios.

For days where the winds are predominantly out of the NW, the currents during rising tides are generally between 4.5 and 6cm/s for the central and southern sections of the bay during the existing condition. The northern sections have currents generally below 3cm/s. The post construction scenario has currents of 4.5-6cm/s in the southern sections only; all other areas are below 3cm/s.

During falling tides the pre and post construction scenarios are generally the same except in the vicinity of the proposed break waters where current are slower in the post construction scenario. The faster currents extend from the north to central sections of the bay and are in the order of 4.5-6cm/s. The slower areas are all below 3cm/s.

*Average Day*

Days when winds are predominantly from the ENE direction the currents are generally below 3cm/s for the north, central and southern sections of the bay during the existing and post construction rising tide scenarios. The post construction scenario however has a mixture of areas with faster currents (3.0-4.5 cm/s) extending out to the reef. The falling tides scenario is generally the same except for the central to northern sections near the shore. In these areas, the predicted currents can be as high as 0.45 to 6.0 cm per second for the pre and post construction scenarios.

Days when winds are predominantly out of the NW, the currents during rising tides are generally between 6.0 and 9.0cm/s for the central sections of the bay during the existing condition the northern and southern section varies from 0.0 to 6.0 cm/s. The post construction scenario has smaller areas of currents between 6.0 to 9.0 cm/s concentrated in the central section only; all other areas are below 6cm/s.

During falling tides the pre and post construction scenarios are similar. The currents generally in the bay are below 3cm/s, but there is a near shore area spanning from the northern to central section of the shoreline having currents between 4.5 and 6.0 cm/s.

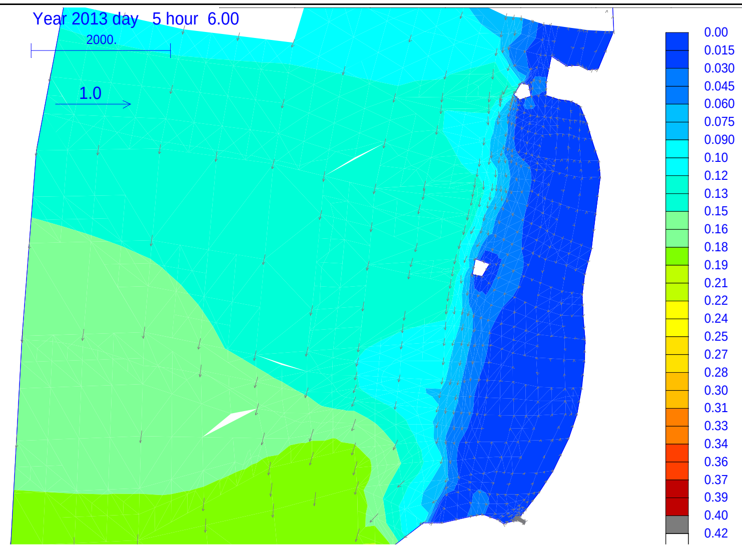
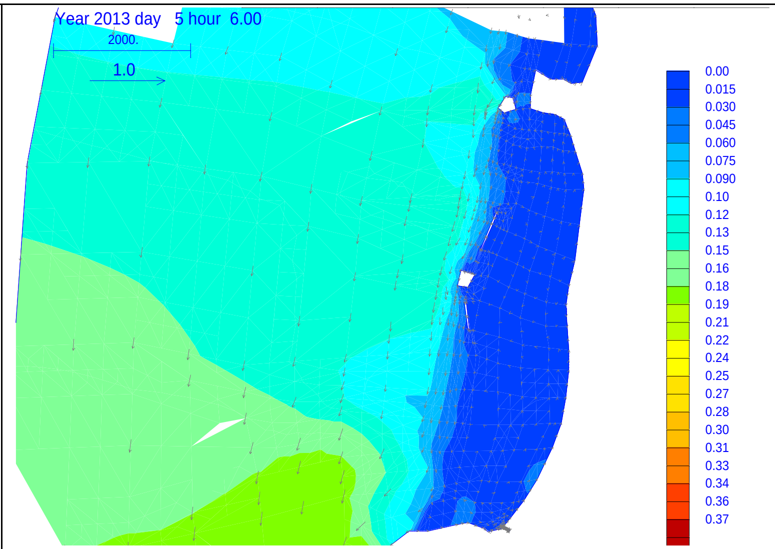
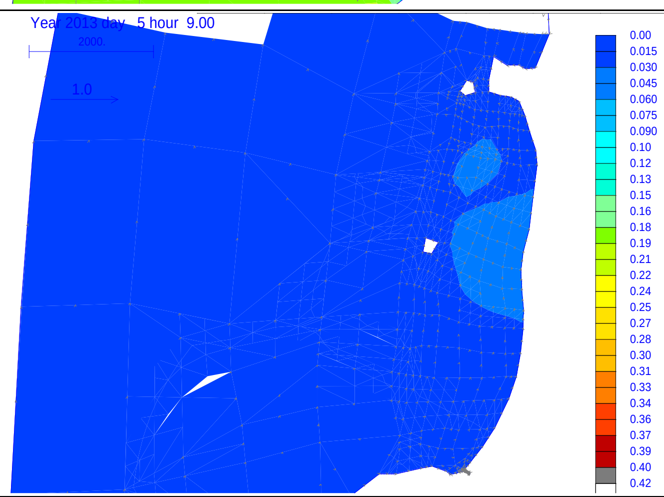
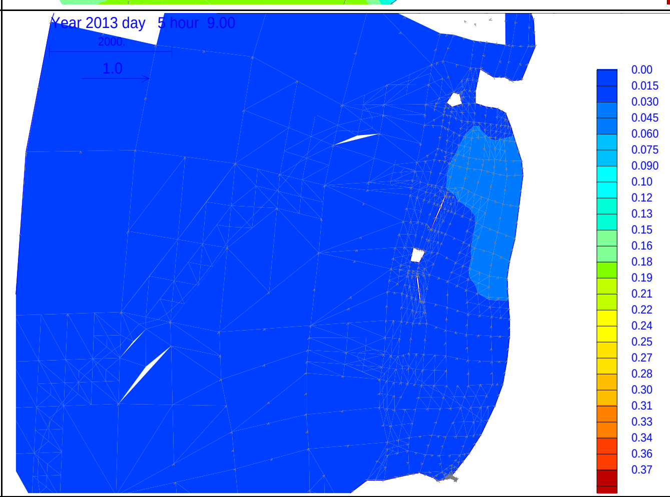
*Fast Day*

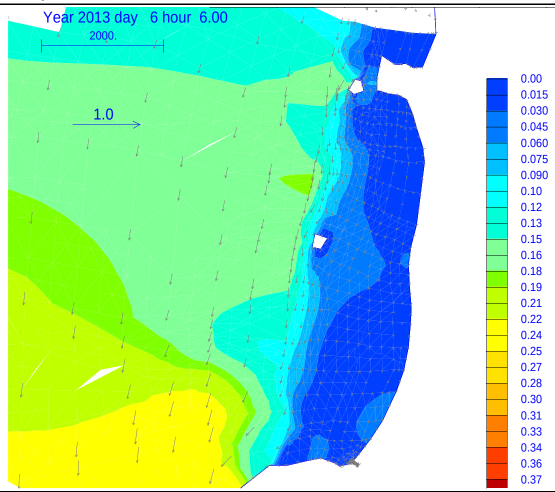
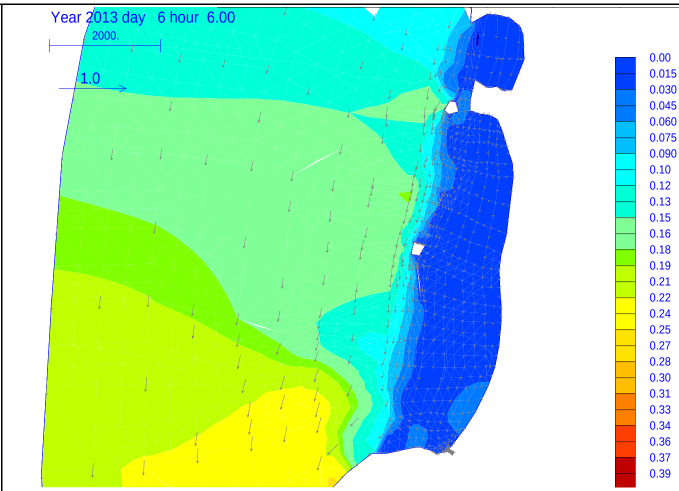
Days when winds are predominantly from the ENE direction the currents are generally below 3cm/s for the north and up to 6cm/s for the central and southern sections of the bay during the existing and post construction rising tide scenarios. Both conditions have similar geospatial spreads of the varying current speeds. The falling tides scenario is generally the same for the pre and post construction scenarios. The central section has the highest speeds which can go as fast as 12cm/s between the central and northern sections.

Days when the winds are predominantly out of the NW, the currents during rising tides are generally between 3.0 and 12cm/s in the bay, with the highest speeds in the central sections of the bay. Both the pre and post construction scenarios have the same speeds except the higher speeds are concentrated on a smaller area between the north and central section for the post construction scenario.

During falling tides the pre and post construction scenarios are similar. The currents in the bay are generally below 3cm/s, with small section experiencing up to 6cm/s.

*Table 7-22 Current speed predictions for the preconstruction and post-construction scenarios at Long Bay Negril for predominantly ENE winds*

| | Existing | Proposed |
|---|---|---|
| **Slow (1 m/s)** | | |
| **Rising** |  |  |
| **Falling** |  |  |

<table>
<tr><th></th><th>Existing</th><th>Proposed</th></tr>
<tr><td colspan="3">Average (3 m/s)</td></tr>
<tr><td>Rising</td><td>
</td><td>
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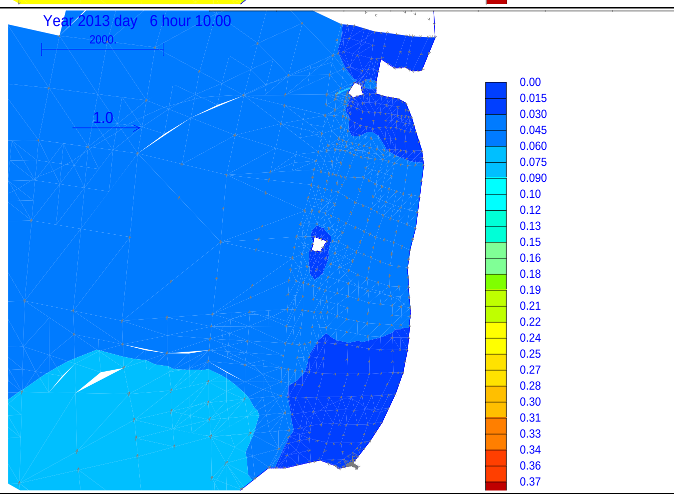
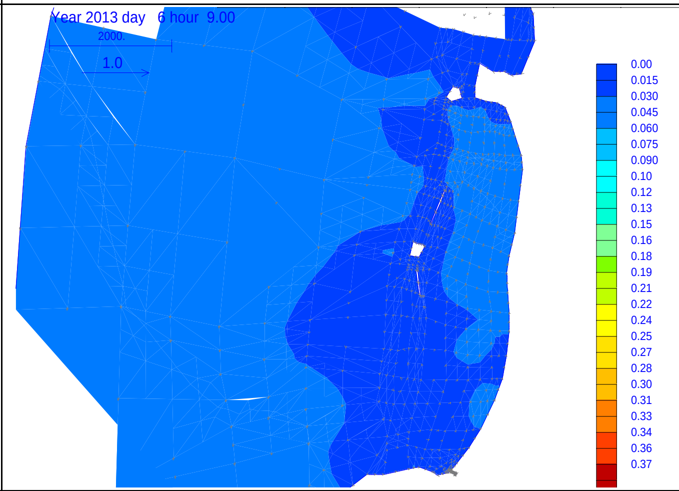
<tr><td>Falling</td><td>
</td><td>
</td></tr>
<tr><td colspan="2">Fast (6 m/s)</td><td></td></tr>
</table>

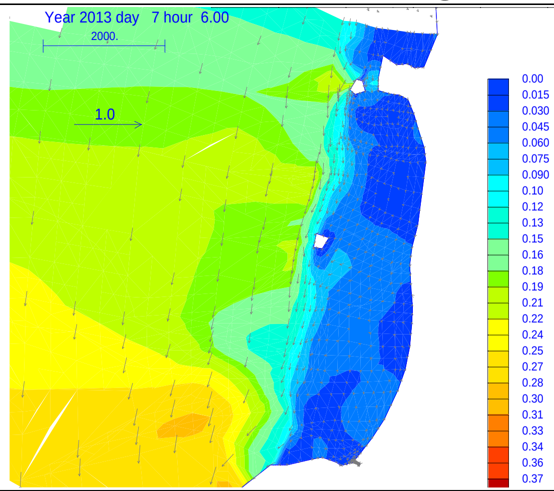
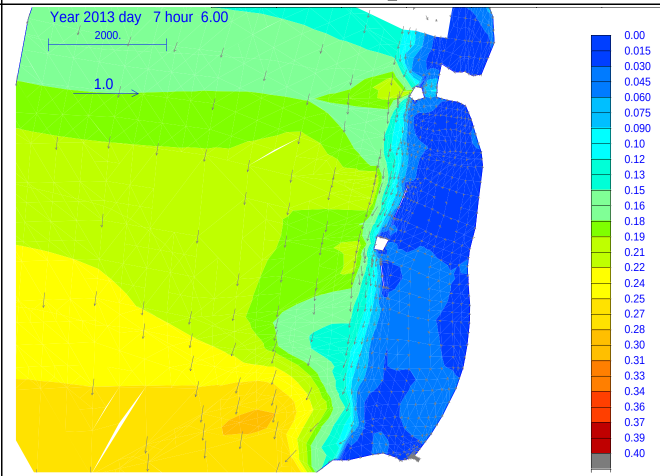
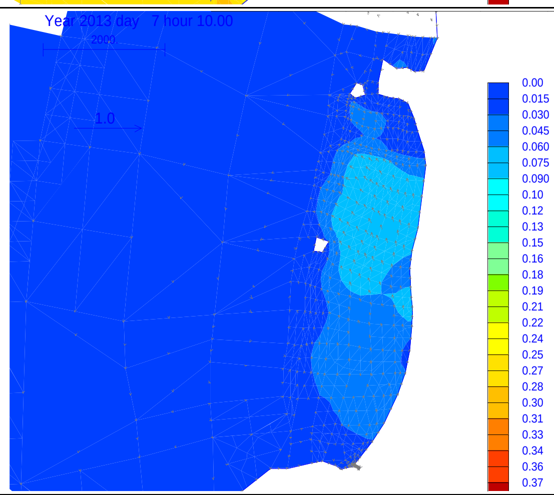
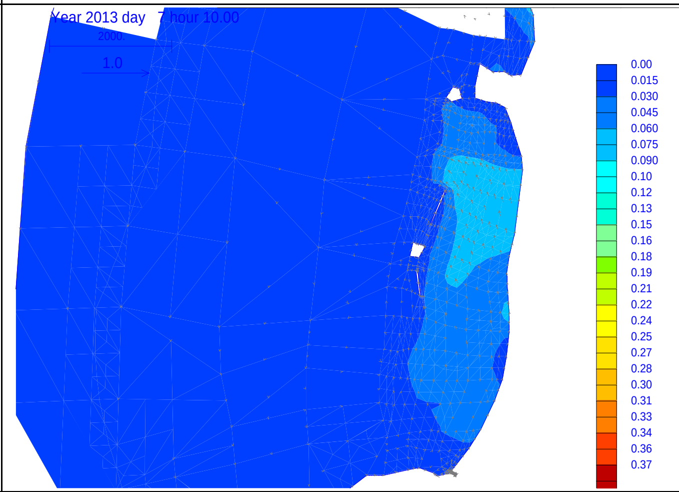
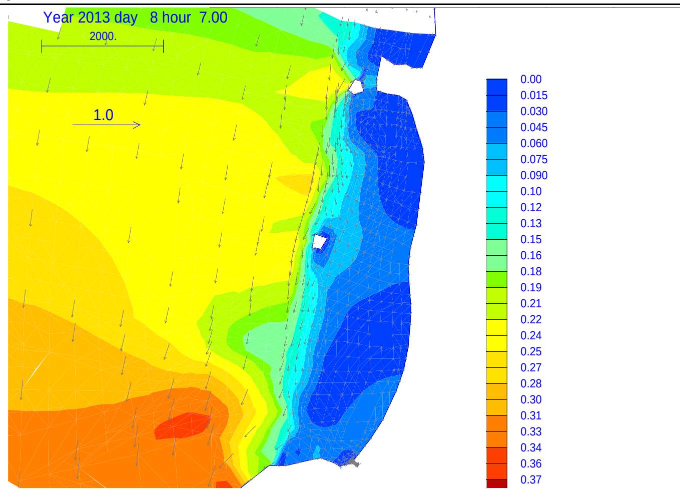
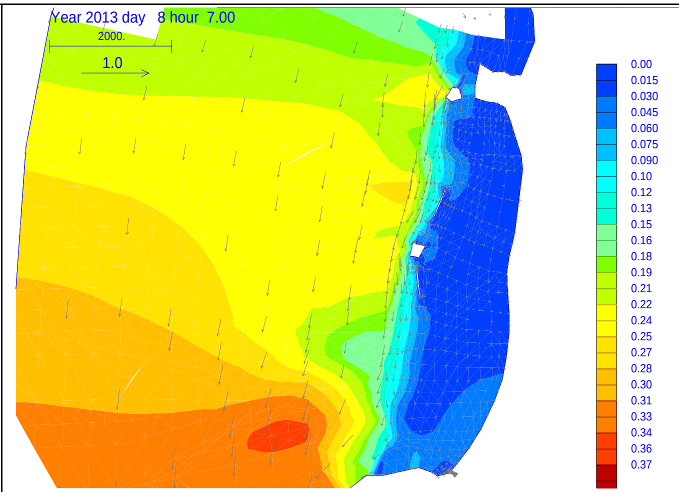
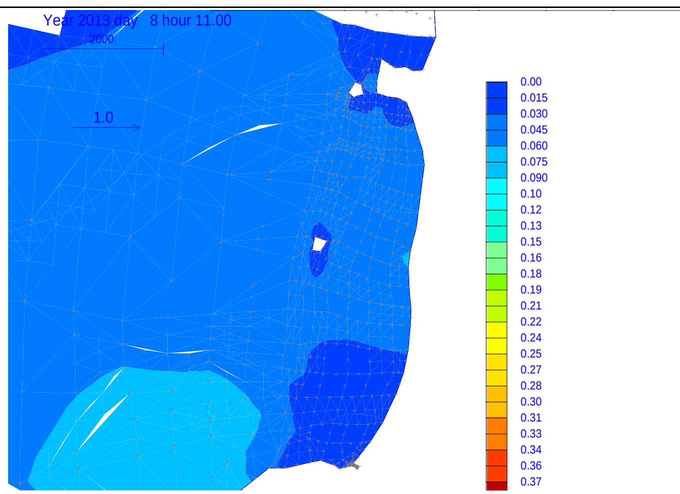
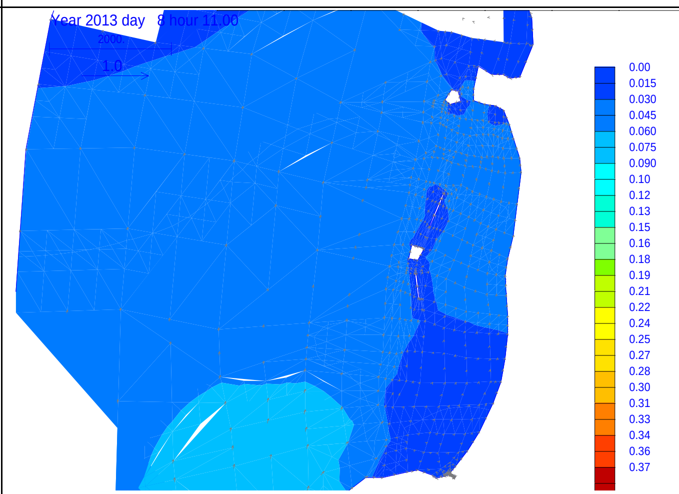
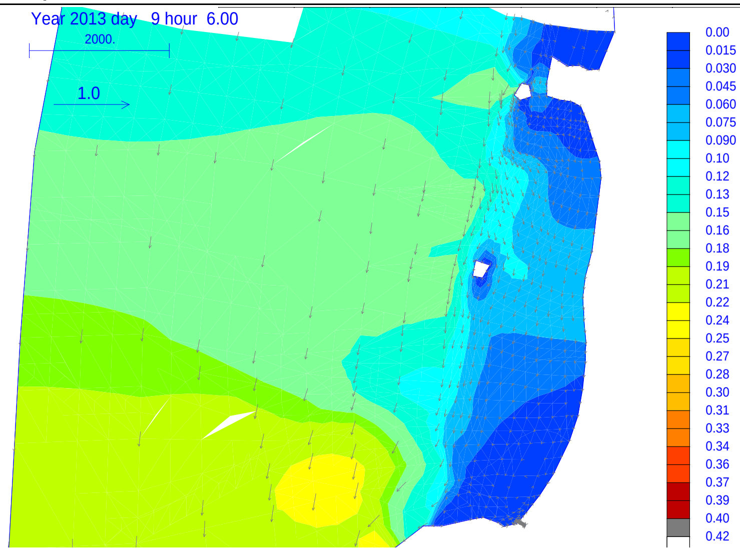
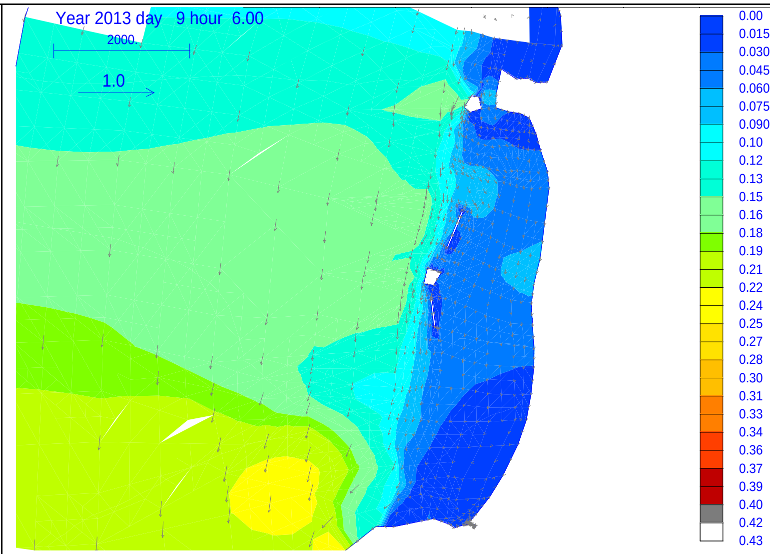
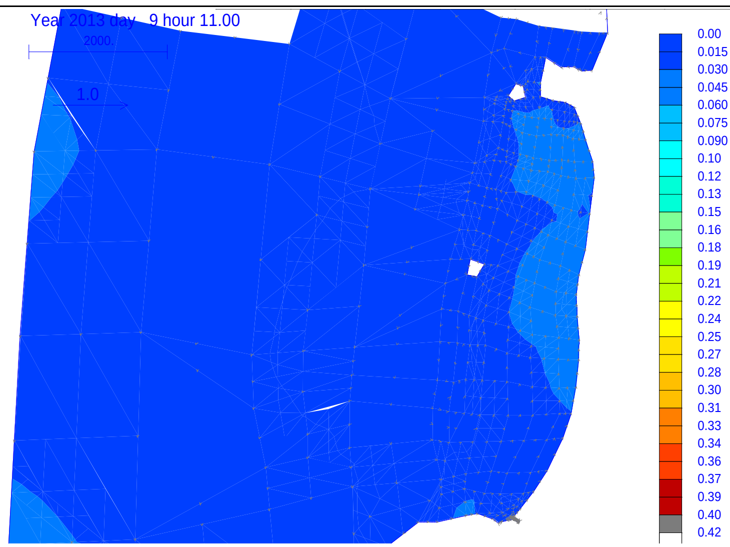
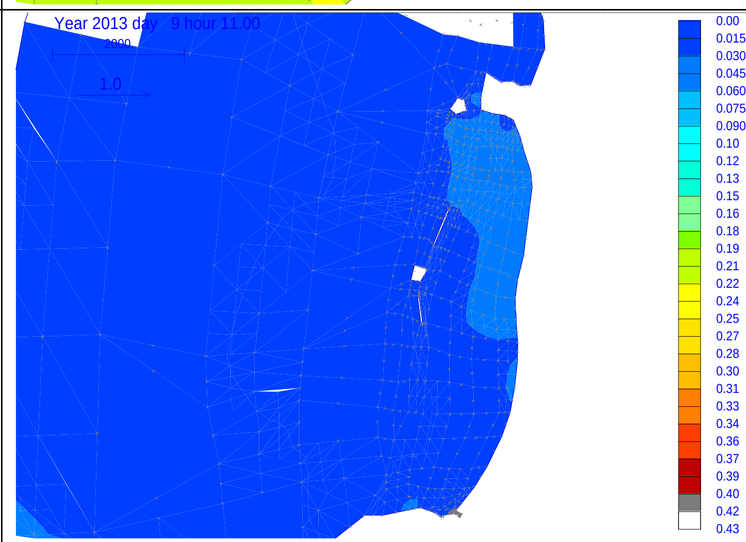
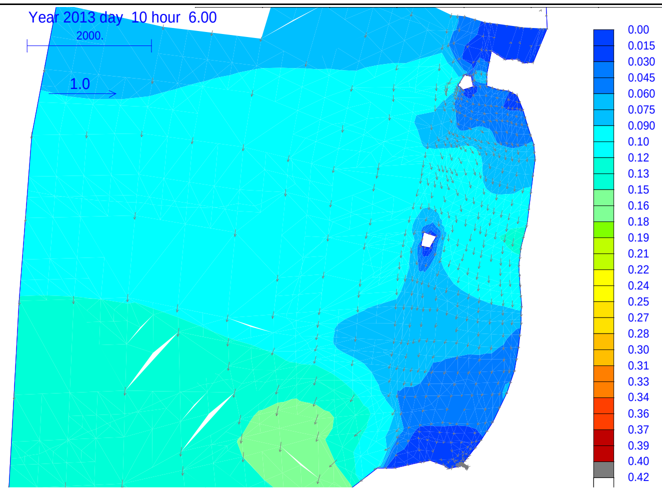
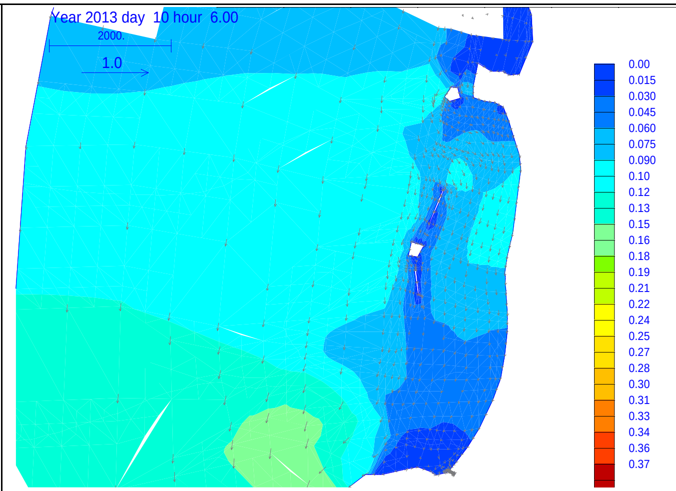
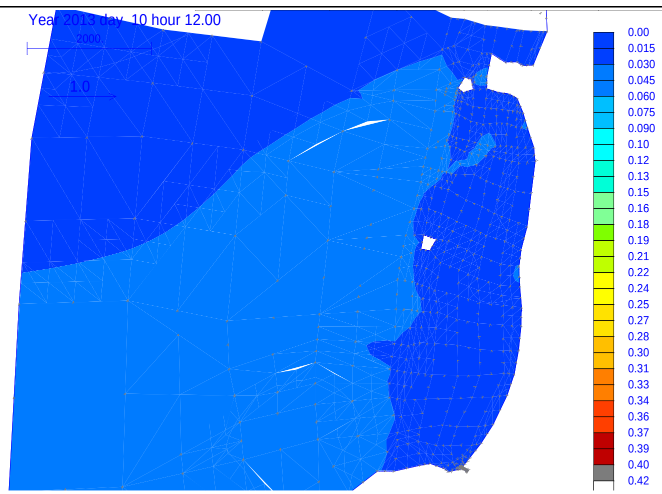
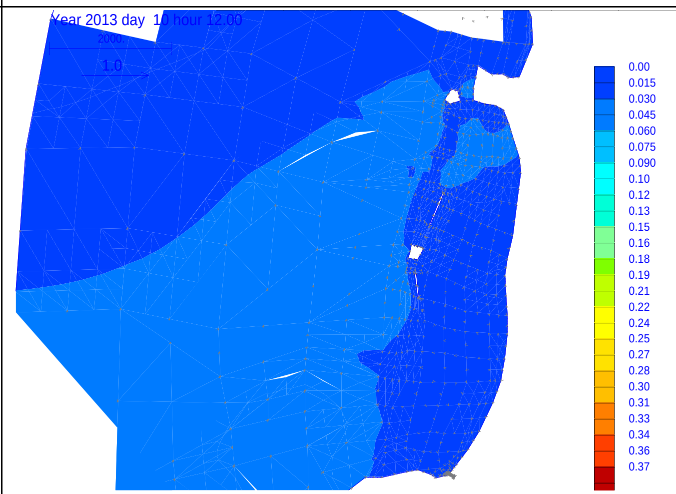
| | Existing | Proposed |
|---|---|---|
| **Rising** |  |  |
| **Falling** |  |  |

*Table 7-23 Current speed predictions for the preconstruction and post-construction scenarios at Long Bay Negril for predominantly NW winds*

<table>
<tr><th></th><th>Existing</th><th>Proposed</th></tr>
<tr><td colspan="3">Slow (1 m/s)</td></tr>
<tr><td>Rising</td><td>
</td><td>
</td></tr>
<tr><td>Falling</td><td>
</td><td>
</td></tr>
</table>

| | Existing | Proposed |
|---|---|---|
| **Average (3 m/s)** | | |
| **Rising** |  |  |
| **Falling** |  |  |

<table>
<tr><th></th><th>Existing</th><th>Proposed</th></tr>
<tr><td colspan="3">Fast (5 m/s)</td></tr>
<tr><td>Rising</td><td>
</td><td>
</td></tr>
<tr><td>Falling</td><td>
</td><td>
</td></tr>
</table>

The total current speeds were measured at several locations across the bay to determine or quantify the change in current speeds as a result of the implementation of the proposed breakwaters. The seven locations are shown in Figure 7-26. All sections showed a decrease in currents speeds except the southern station where the current there was a small increase of 2.8 percent. The decreases in current speeds for all the other points considered varied from 0.3 percent up to 51.4 percent, see Table 7-24.

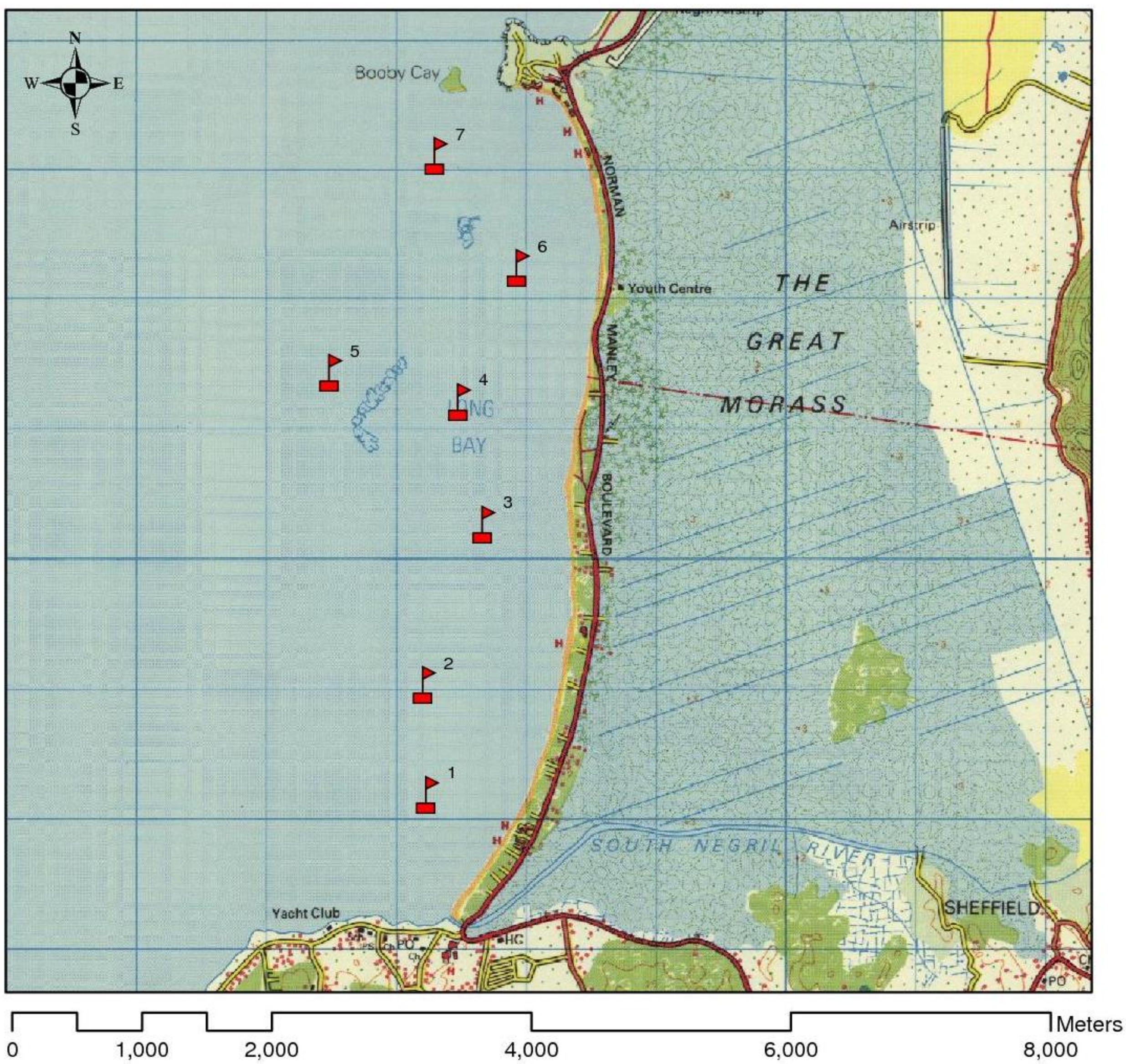
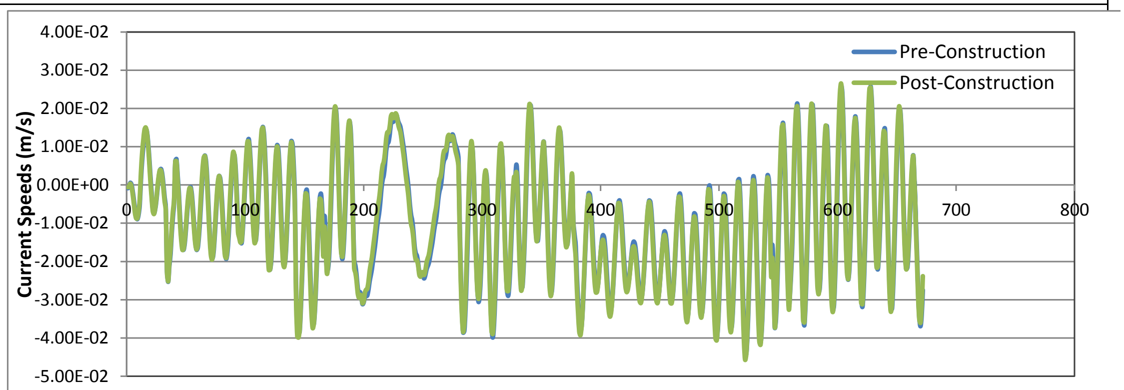



*Figure 7-26 Locations within Long Bay where the model predicted tides were checked for differences in curren speeds between pre and post construction scenarios*

*Table 7-24 Predicted changes in currents at selected locations across Long Bay*

| **Location** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **Average** |
|---|---|---|---|---|---|---|---|---|
| Change | 2.9% | -11.7% | -51.4% | -15.0% | -0.3% | -2.9% | -14.5% | -13.3% |

*Table 7-25 Current speeds by direction at the selected points*

<table>
<tr><th>Location</th><th>Total Current Speeds at Each Location</th></tr>
<tr><td>1</td><td>
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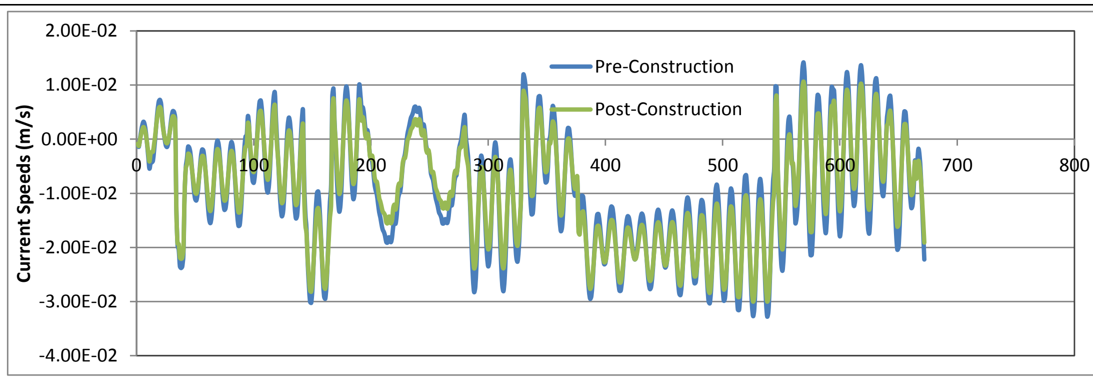
<tr><td>2</td><td>
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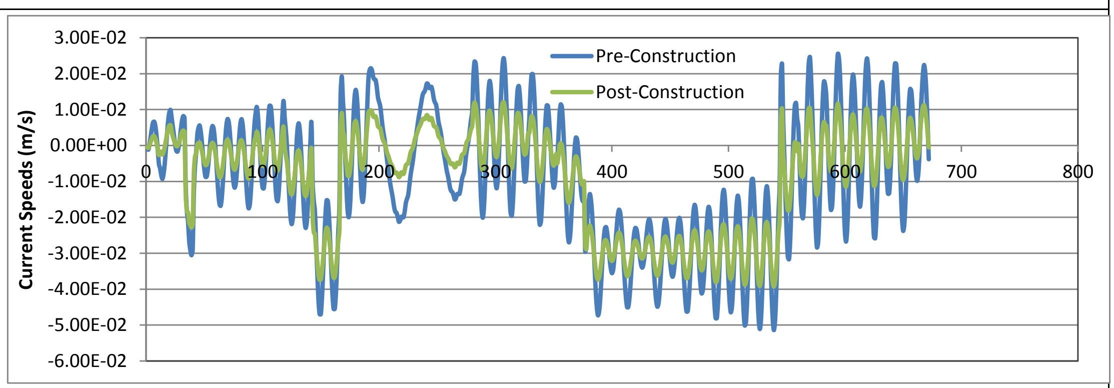
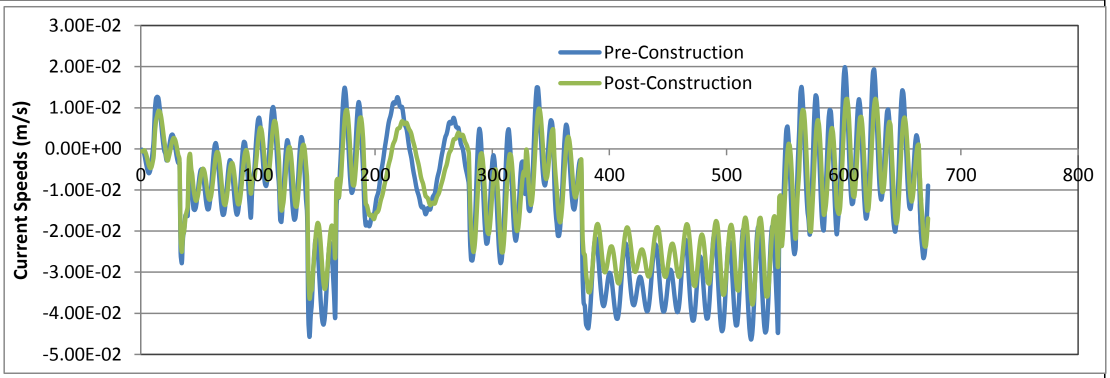
<tr><td>3</td><td>
</td></tr>
</table>

<table>
<tr><th>Location</th><th>Total Current Speeds at Each Location</th></tr>
<tr><td>4</td><td>
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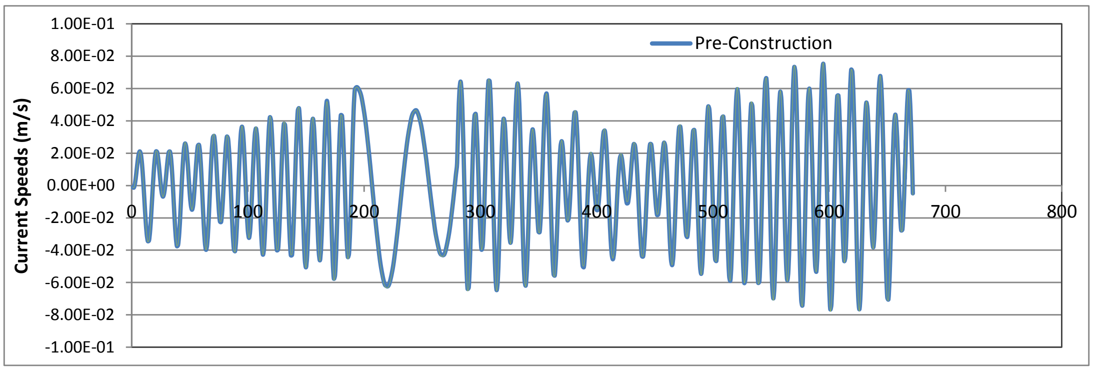
<tr><td>5</td><td>
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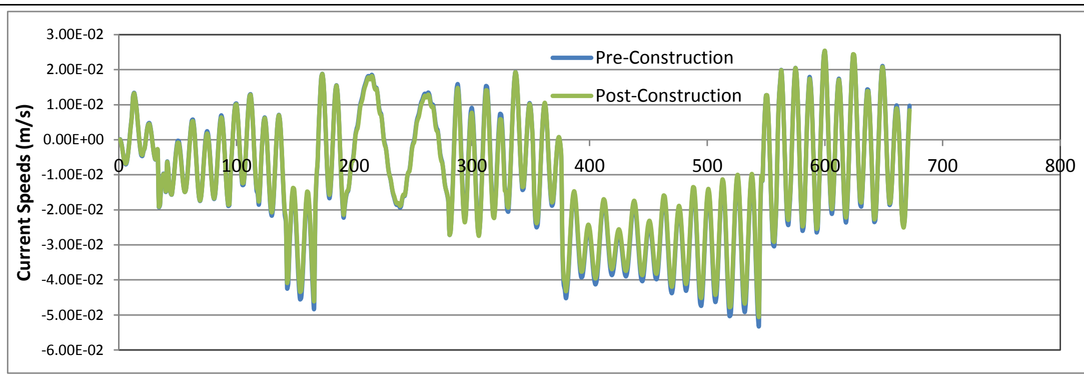
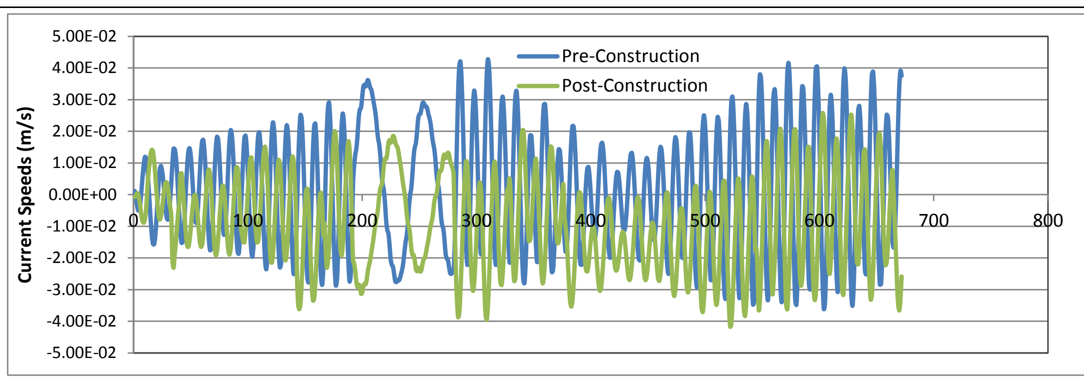
<tr><td>6</td><td>
</td></tr>
<tr><td>7</td><td>
</td></tr>
</table>

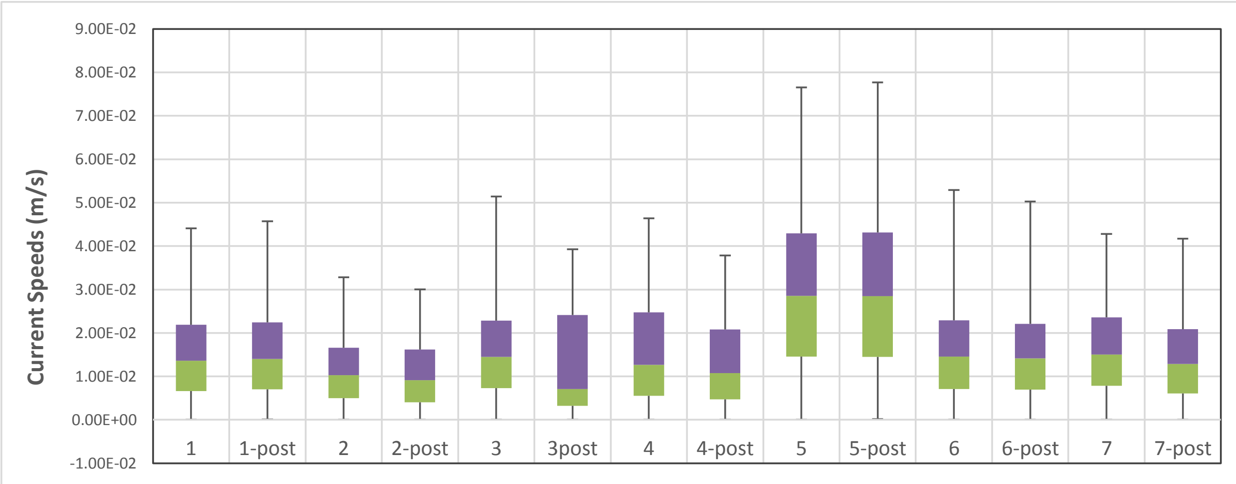



*Figure 7-27 Box plot of the predicted pre and post construction current speeds at selected locations in Long Bay, Negril*

**Beach Safety Assessment**

Beach safety is influenced by several factors including current regime, wave climate, and bathymetry. Given the proposed breakwater installation in the central area of the bay, it is anticipated that the currents and wave regime in the bay approaching the shoreline will change. It is therefore suggested that an assessment be done to identify if the installation of the breakwaters will worsen the conditions for swimming.

*Reported Drownings*

Reports of drownings in Jamaica and the Negril were obtained from The Gleaner and Jamaica Observer internet archives as well as a previous study done by CEAC Solutions in 2006. The 2006 report data was obtained from the same archives as well the Constabulary Communication Network (CCN).

Three incidences of drowning have been reported in Negril in 2013. Two of these are in West End and have been attributed to strong currents and waves. The third incident was of a 65 year old male tourist. There were no reported reasons for his death. Prior to this there have been no recent reports of accidental drowning along the Long Bay beach; only along the cliffs of West End.

The annual drownings across the island is estimated at 55 per year with the months of January and August having the highest numbers. Negril only accounts for approximately three or less per year, of which Long Bay only has 1 or less annually.

*Criteria and Methodology*

The Criteria utilized for the assessment was based on the Dr. Leatherman Criteria which has fifty criteria and five categories, all of which are not applicable to the Negril beach. The full complement can be viewed at Dr. Leatherman's website (http://www.drbeach.org/).

MICROBIAL ASPECTS OF SAFETY

Of these, some criteria are more important than others. For instance, water quality (criterion 19) is a very important criterion which could negate all the rest. Many studies have shown that microorganism content of recreational water has been directly linked to illnesses among bathers, predominantly gastroenteritis as well as other ailments such as rashes etc. Therefore it is important that beaches be monitored for fluctuations in numbers or even the sudden increase in numbers. If numbers of *Entercocci* were to exceed 40 organisms per 100ml steps would have to be taken to restrict use of such an area. Blue Flag regulation stipulates that if these standards are exceeded for more than 20% of samples then the beach should be closed for the remainder of the bathing season.

PHYSICAL ASPECTS

Due to the presence of water hazards the oceanographic conditions play an integral role in determining if a beach is safe for recreational use, especially in regards to recreational swimming. The presence of a rip current (criterion 12) makes an area very dangerous for swimming and depending of it periodicity should be one of the most important criterion in determining the suitability of a beach. A rip current is described as a fast moving offshore current perpendicular to the shore moving in excess of 70 cm/sec. This usually results in pulling bathers out of the near shore areas (comfort zones) and sending them offshore to deeper waters. Weak swimmers and strong swimmers to a lesser extent would experience some difficulties and can lead to drowning. Therefore if a rip current is a constant phenomenon in an area, swimming should be strongly discouraged as well as lifeguard services should also be encouraged. Other criteria that play an important role in beach safety are size of breaking waves and proximity to sewage outfalls especially in the cases where the beach form is a pocket.

This would result in an exaggeration of the effects of contamination because of a longer turn over time of the water body (retention time). All relevant criteria should be taken into consideration and a decision made accordingly with criteria 9 and 12 being of outmost importance.

*Proposed Beach Safety Criteria*

For the purposes of this study, the proposed set of criteria for Long Bay for wading and swimming use is outlined in Table 7-26 .

*Table 7-26 Physical parameters and the associated criteria used for assessing the beach safety*

| Physical Categories | Mild | Moderate | Strong | Unit |
|---|---|---|---|---|
| Current | <0.1 | 0.4-0.1 | >0.4 | m/s |
| Wave height | <0.3 | 0.3-0.5 | >0.5 | m |
| Depth | <1.2 | 1.2-1.8 | >1.8 | m |

The criterion wave height addresses the need for a safe beach bathing area to have relatively low (<0.3 m) wave heights. Smaller waves limit the potential for users being tossed or swept out further to sea by undertows. In comparison, wave heights greater than 0.5 m are considered too high for small crafts in marinas and most modern marinas are designed with 0.3 m wave height criterion for safe boat use.

High alongshore currents as a result of rip-currents can put swimmers in danger of drowning as a result of exhaustion. It is therefore important that the currents be sufficiently slow to allow for an average swimmer to reach to shore with relative ease before being swept far down stream and eventually out with the rip. Swimming with fins in current speeds of 50 to 100 cm/s water speeds can be exhaustive to the average swimmer going against such a current. A lower desirable limit of 10 cm/s was proposed to make due allowance for minors and geriatric users who might use the beach.

A water depth of 1.2m is typically sufficient for persons over 12 years to stand in safely. Persons normally begin to get into difficulties when the water depths exceed 1.5m. The proposed upper limit is 1.8m which is just about deeper than most persons are tall.

*Results*

The assessment revealed that the entire beach (north, south and central) can be classified as not dangerous for swimming. The most vulnerable swimming location was the central part of the bay on a fast wind day during the existing conditions; even this scenario can be classified as not dangerous.

The installation of the breakwaters will cause an average 20 percent reduction in the current the speeds in the bay, similarly the wave heights will be reduced primarily in the central section of the bay.

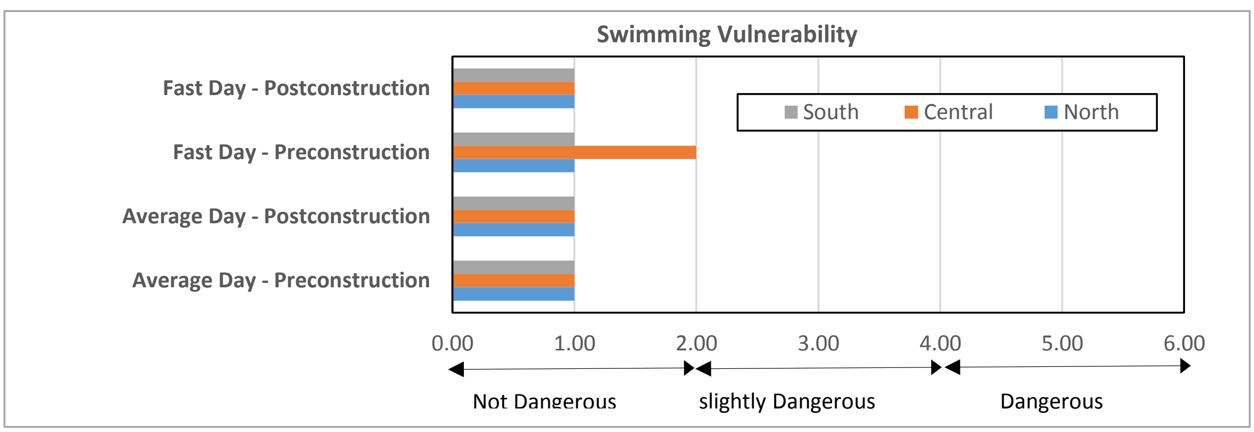



*Figure 7-28 Assessment of the vulnerability to drowning for Long Bay Negril. A rating of 0-2 meant the area is considered dangerous, 2.0 to 4.0 is considered slightly dangerous and 4.0-6.0 is considered dangerous*

**Current Flow and Flushing Analysis**

Tidal forcing and wind are the main drivers of currents in most bays. These currents have significant impacts on the biological systems that exist in the bays where they inhabit. Water quality and residence times are interdependent and changes with the water flux in the bay as a result of inflows from deep water or from rivers. These inflows and outflows bring organisms and nutrients into and out of the bay and maintain a balance for the ecosystem present. Physical changes to the bay, such as the installation of breakwaters will cause changes to the inflow/outflow patterns or flushing of the bay.

Any one or more of three basic time scales are commonly used to measure how well a bay is functioning in relation to the ecosystem, these are flushing time, age, and residence time. Processes such as salinity (or freshwater), nutrients, passive larvae/algae, and contaminants can be thought of as the markers for the estimate of the time scales related to advection and dispersion in the Bay.

Flushing time in this case defines the amount of time required to replace a certain water mass.

Accordingly, Fischer et al. (1979) expressed the flushing time in a reservoir system:

$$T_f = \frac{V}{Q}$$

Where, V is total volume of water in a coastal system and Q is volume exchange rate through the system.

Bays that flush rapidly (i.e., have a short residence time) will export nutrients more rapidly than those that flush more slowly, resulting in lower nutrient concentrations in the estuary. Bays with residence times shorter than the doubling time of algal cells will inhibit formation of algal blooms (rapid accumulation of phytoplankton). In order for algal blooms to occur, eutrophic conditions (increased nutrient levels) are necessary as well. Even though the nutrients (nitrogen and phosphorous) were present in quantities above the eutrophication limit, there were no observable signs of plankton blooms during the field missions conducted, nor are they known to have occurred. There are two possible reasons that could explain the absence of blooms in the bay, they are:

1) The typical half-life or doubling time for algae in this environment varies from 1.5 to 6.9 days. This should form a basis for the flushing criteria for the Bay; i.e. a minimum 14.4 percent of the bay should be flushed per day.
2) Generally, phytoplankton growth is limited by inorganic nutrients nitrogen, phosphorous and silicon. Four trace metals (zinc, copper, iron, and manganese) are also considered to be important to phytoplankton. Of these four, iron and manganese are thought to be in low enough concentrations to limit growth (Dawes 1998).

The hydrodynamic model used to determine the flushing time predictions (section 0) indicated the following flushing time averages:

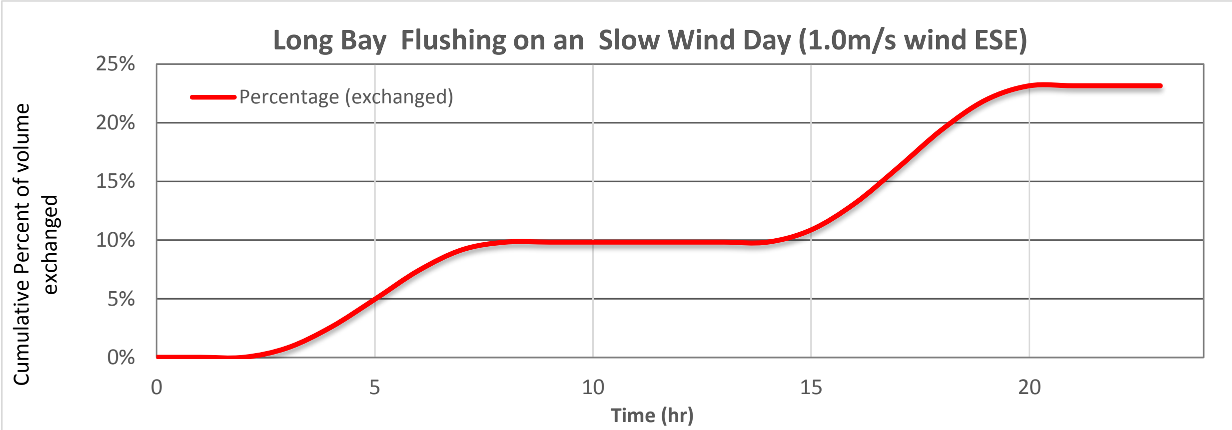
1) On slow days the flushing times average 3.72 days. This will increase by 10 percent on average during the post-construction scenario.
2) On average wind days the flushing times increase on average by 13 percent from 3.46 days.
3) On fast wind days the flushing times increase from 3.29 days by 4 percent on average from the preconstruction to the post construction scenario.

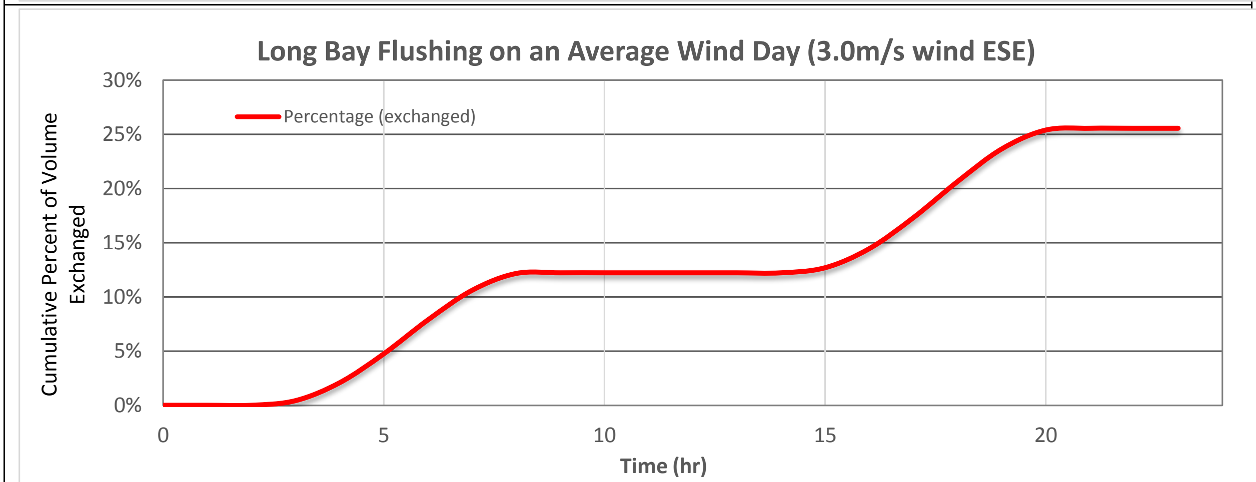
*Table 7-27 Comparison of the existing and post construction flushing times in Long Bay*

| Wind Day | Existing Flushing time (day) | Post-Construction Flushing time (day) | Increase |
|---|---|---|---|
| Slow | 3.72 | 4.09 | 10% |
| Average | 3.46 | 3.89 | 13% |
| Fast | 3.29 | 3.43 | 4% |

The flushing times of 3.29 up to 3.72 days appear to be sufficient to delay the onset of eutrophication in the Bay. These flushing times will not allow the formation of phytoplankton or algae to accumulate in numbers large enough to cause eutrophication. Similarly the predicted increases in flushing time as a result of the proposed structures are small enough to be negligible given that it is not applicable across the bay, but in some locations. A flushing time of 7 days is considered critical when it comes to eutrophication. Based on the anticipated flushing times as a result of the implementation of the breakwaters, there will be no impact on the water quality in the Bay.

*Table 7-28 Graphs of percent volume exchanged (flushing) over time on a slow average and fast wind days for winds from the ESE during the pre-construction scenario*



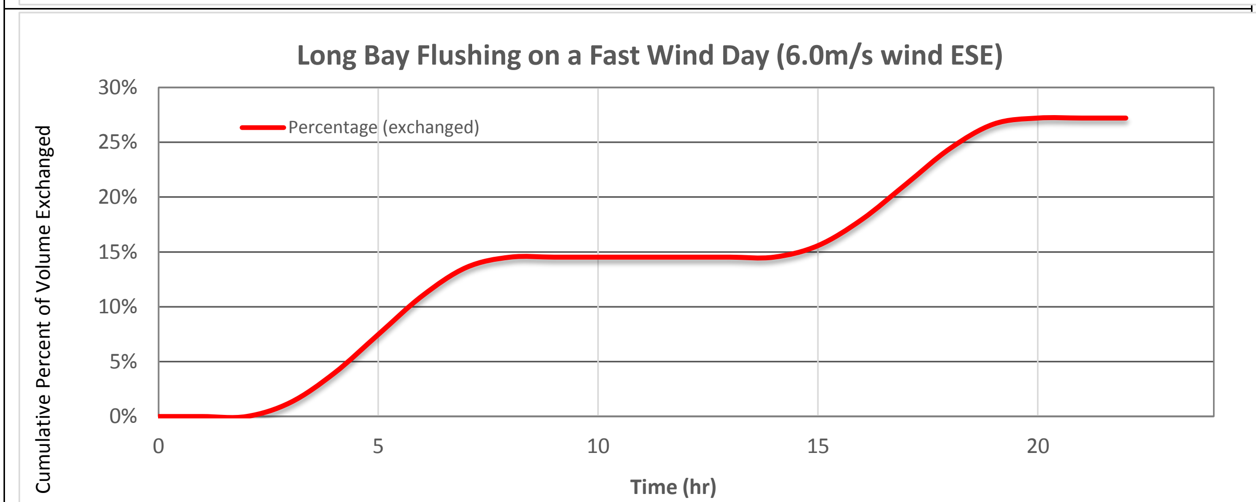
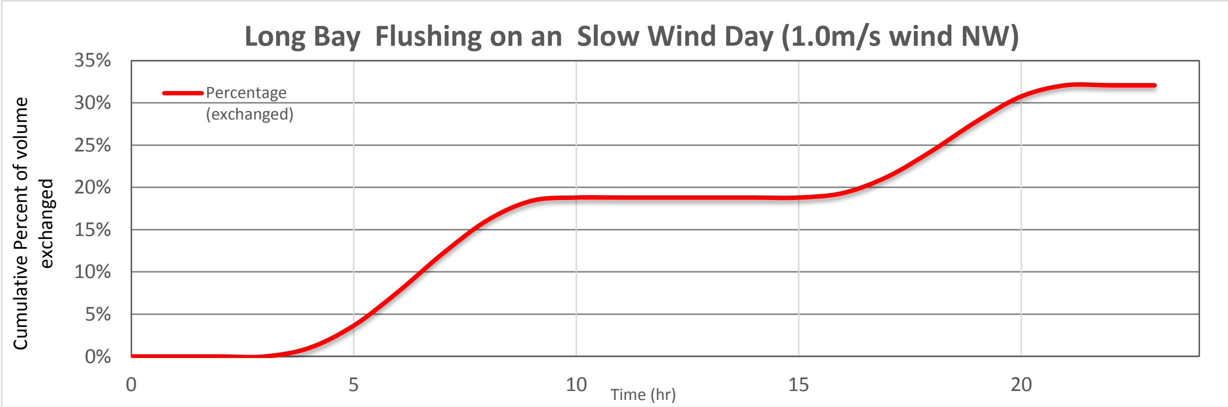
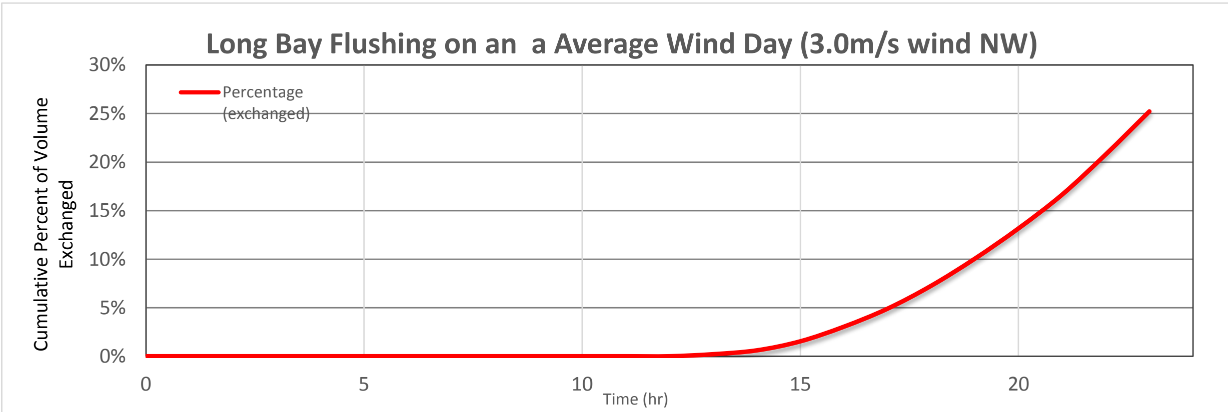



*Table 7-29 Graphs of percent volume exchanged (flushing) over time on a slow average and fast wind days for winds from the NW during the pre-construction scenario*



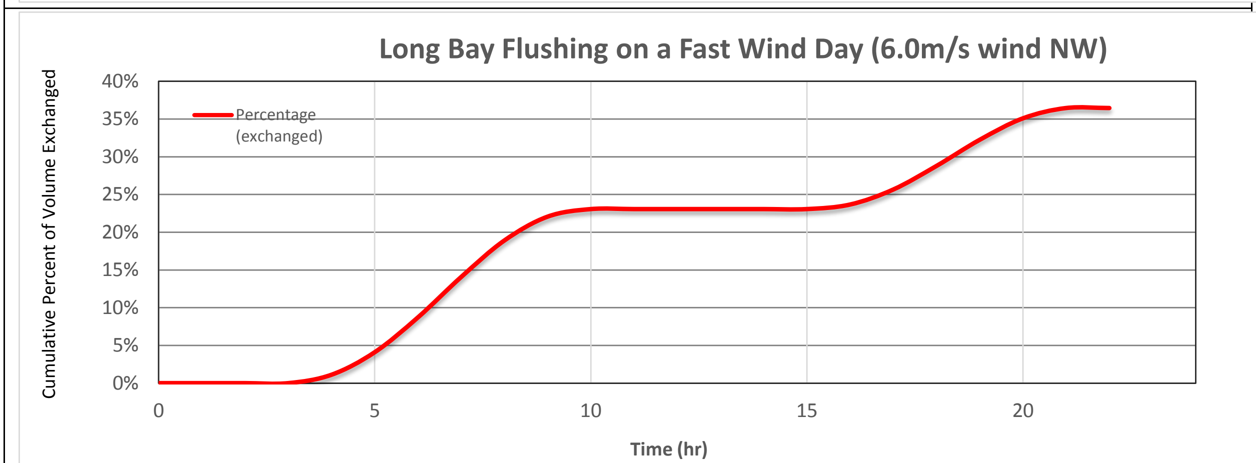
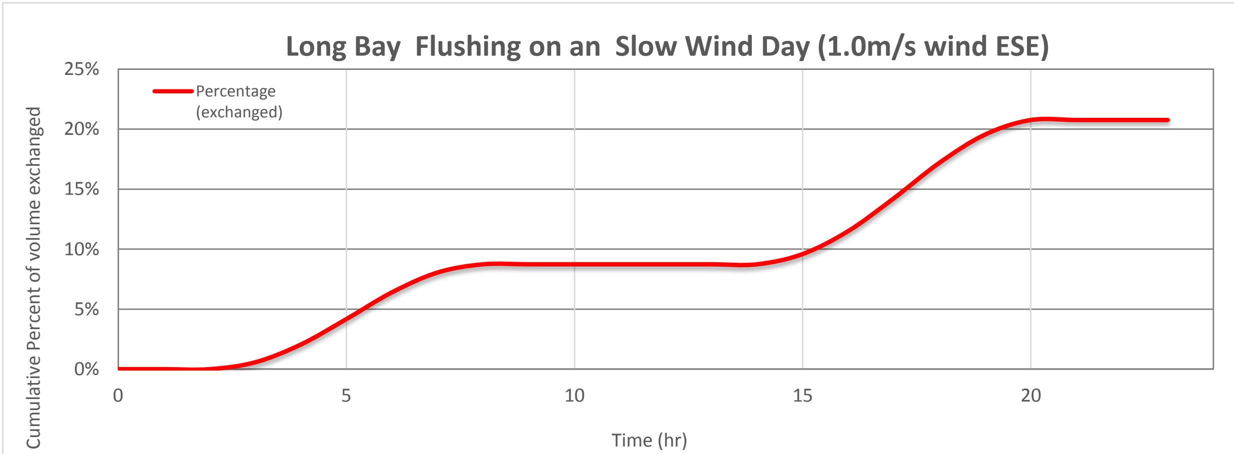
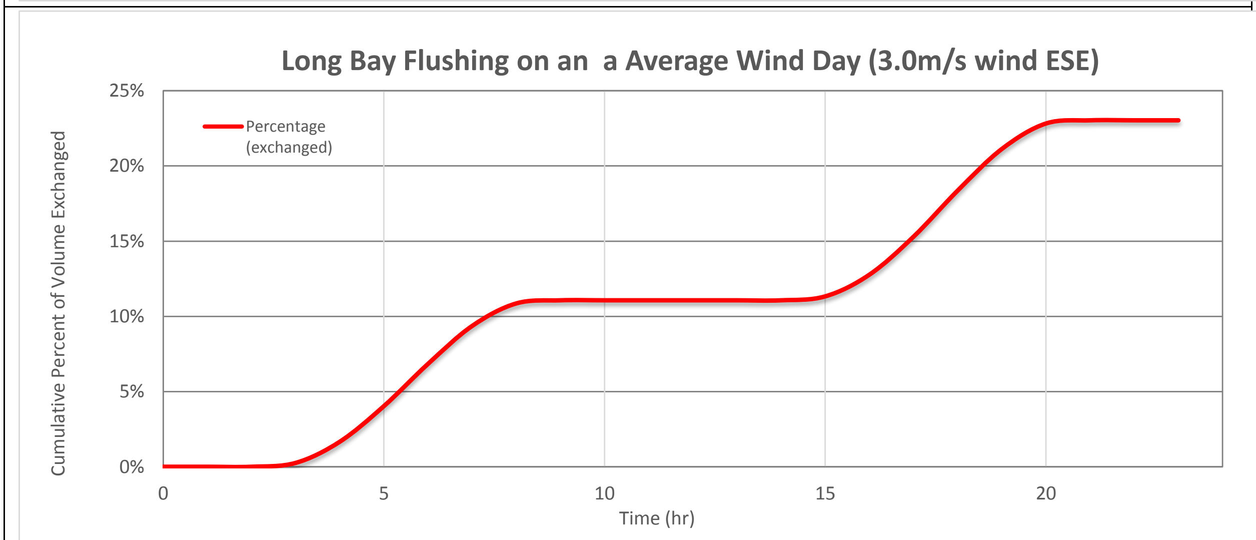



*Table 7-30 Graphs of percent volume exchanged (flushing) over time on a slow average and fast wind days for winds from the ESE during the post construction scenario*



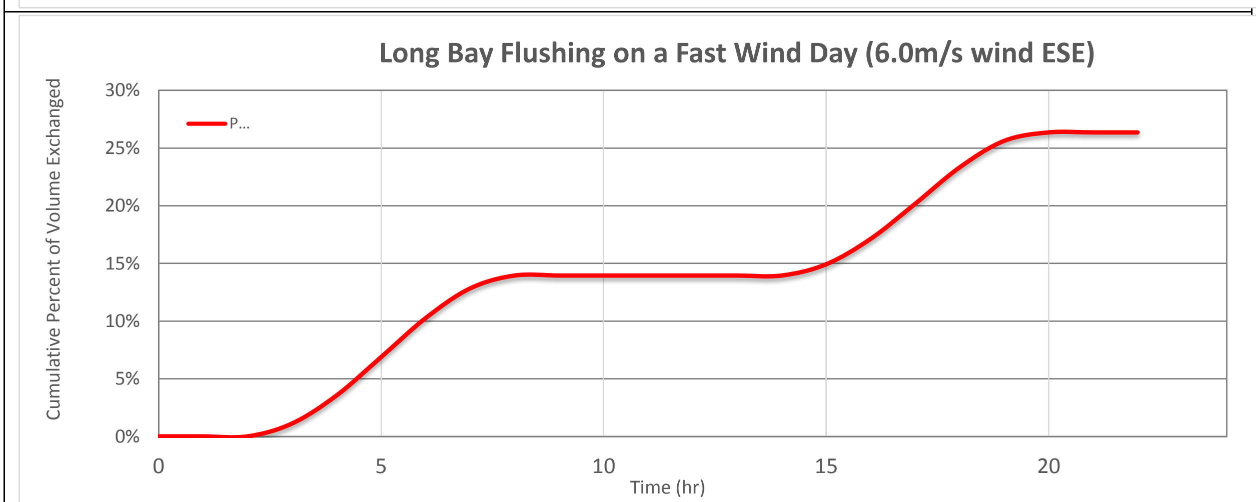
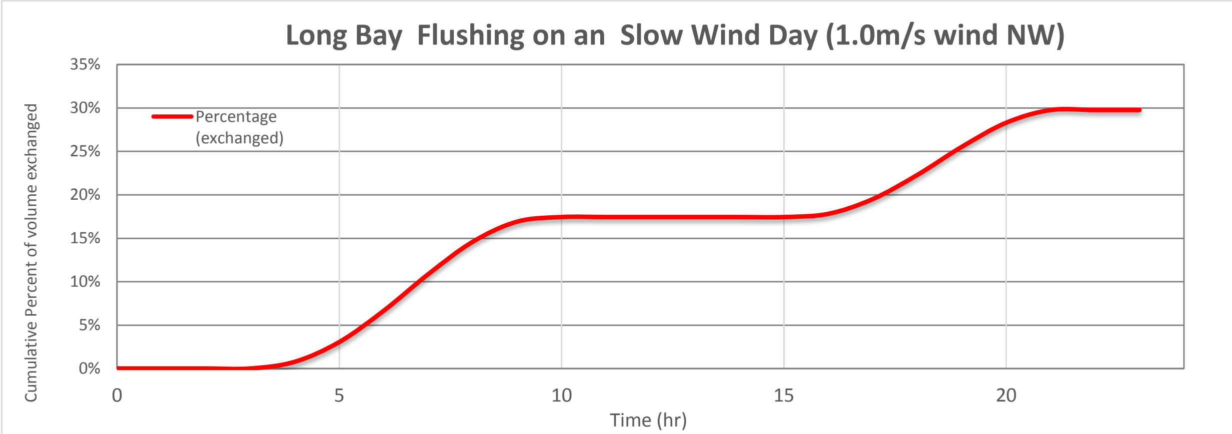
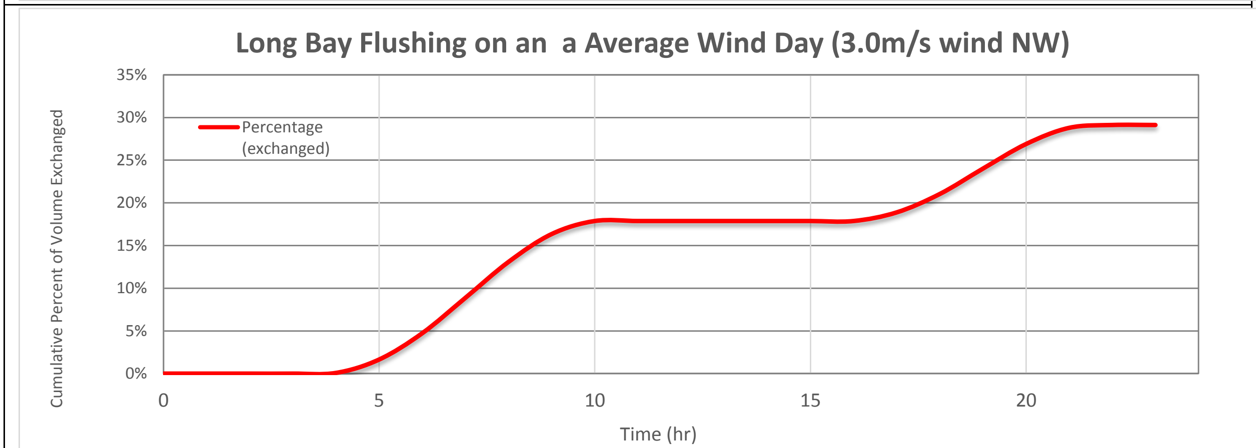
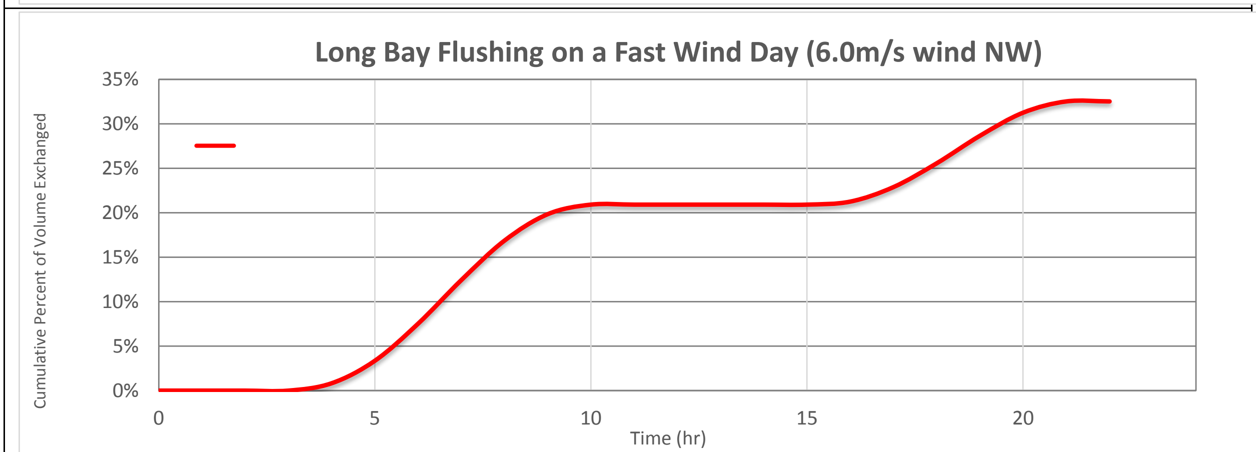



*Table 7-31 Graphs of percent volume exchanged (flushing) over time on a slow average and fast wind days for winds from the NW during the post construction scenario*



**Summary**

The construction of the breakwaters will cause a decrease in current speeds in some areas and an increase in others for an overall average decrease of around 13.3 percent on average. Flushing times will increase by 13 to 16% (to 3.4 to 4.1 days) owing to the placement of the breakwater structures; these durations are within the estimated required time limits (6 to 7 days) to prevent eutrophication.

Beach safety will not be jeopardized by the proposed structures. Currents are actually slowed marginally and this will improve beach safety during adverse wind conditions. With the current levels of nutrients measured and projected changes in flushing time, eutrophication is not an anticipated impact of the project. The potential for eutrophication exists with or without the presence of breakwaters however, if excess nutrients are introduced to bay or other factors encouraging eutrophication occur for example.

## 7.2.2 Biological

### *7.2.2.1 Phytoplankton*

As mentioned previously, the construction of the breakwaters will cause a decrease in current speeds in some areas and an increase in others for an overall average decrease of around 13.3 percent on average, and marginal increases in flushing times. As a result of this, changes in the physico-chemical environment are expected to be minimal. Nevertheless, the potential effects of changes in the physico-chemical environment discussed previously must be kept in mind throughout the operation phase (see section 7.1.2.1).

### *7.2.2.2 Fish Community, Marine Mammals and Reptiles*

Any structure placed in a reef environment and in particular one with very little relief as is the case in Negril, will act as a Fish Aggregation Device (FAD). As with other projects, both in Jamaica and around the world, this function alone is not sufficient in categorising the breakwaters as an artificial reef. In fact, the aggregation of fish in overfished, non-policed and unregulated waters can result in greater damage to the existing fish populations. Fishing around the breakwaters should therefore be limited or prevented. Preventing fishing in this area may also serve to improve fish stocks within the area, if managed and regulated sufficiently. The breakwaters will serve to increase ecological volume in the area as well as becoming colonised overtime.

***The breakwaters may also function as a snorkel site of interest if the fish aggregate around the structures and fishing (netting, spearfishing and fish pots) are not used in the area. This may be of particular importance due to the heavy usage of the area by local watersports operations and also reduced pressure on the surrounding natural reef dive sites (see Source: Dive/snorkel sites (NEPA), benthic habitats (Coastal Atlas, 1997)***

Figure 6-63) by providing an alternative dive sites for tourists.

As mentioned previously, marine mammals and reptiles observed in the project area include Porpoises, dolphins and hawksbill turtles. After construction, the breakwaters may cause disruptions in their food supply or foraging grounds (in the case of turtles and access to the seagrass beds) as well as disturbing their typical travel routes. The ends of the breakwater proximal to the reef have a 20 to 40 metres gap. The gaps between the breakwaters and the natural reef should allow for species migration and reduce the effects of habitat fragmentation.

#### *7.2.2.3 Reef and Seagrass Community*

There is a potential for habitat fragmentation after the construction phases. This may occur between the seagrass beds in the lagoon and surrounding reefs. This may affect larval distribution/dispersion, migration of juveniles or other mobile invertebrates. The use of the seagrass beds as a foraging ground may also be affected, that is, turtles and other animals may be hindered or their feeding patterns disrupted.

The rate of sand accretion in seagrass bed areas as a result of the breakwaters is not anticipated to have adverse effects on the beds. The rate of accretion should not exceed the rate of seagrass growth rate.

As mentioned previously, the construction of the breakwaters will cause a decrease in current speeds in some areas and an increase in others for an overall average decrease of around 13.3 percent on average, and marginal increases in flushing times. As a result of this, changes in the physico-chemical environment are expected to be minimal and the seagrass system as well as invertebrate community are not expected to be significantly impacted.

This is confirmed by experiments conducted by Cabaço, Santos and Duarte (2008) on the effects of sedimentation/burial of seagrass species. For the species analysed, the review indicated that some species did not experience 100% mortality (*Cymodocea serrulata*, *Enhalus acoroides*, *Halodule uninervis*, *Posidonia australis*, *Posidonia sinuosa*, *Syringodium isoetifolium*, *Thalassia hemprichii*, *Thalassia testudinum*) even at the highest burial levels applied (16–30 cm). Most species experienced 50% mortality within the 2–4 cm range of sediment burial (Table 7-32).

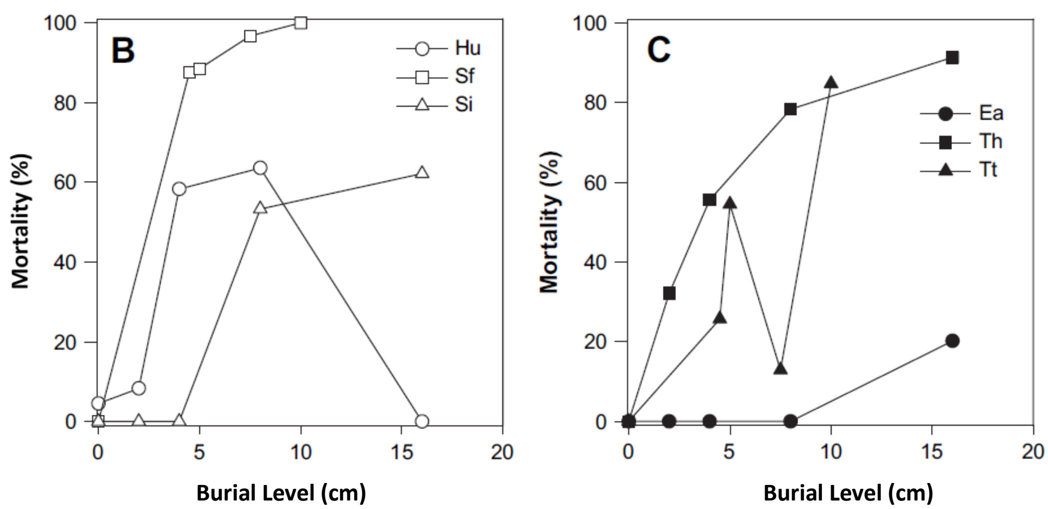
There are two main seagrasses in the Negril lagoon area; *Thalassia testudinum* and *Syringodium filiforme*. From the review the *Syringodium filiforme* would be affected most if there was sedimenatation problems with a 50% mortality at a sediment burial level of 4.5 cm and a 100% mortality at 10 cm for 60 days. On the other hand *Thalassia testudinum* shows a 50% mortality at 5 cm sediment burial and does not exhibit 100% up to 10 cm burial up to 60 days. The proposed project will not cause the build-up of sand in the lagoon area at the rate or level that would prevent these species from surviving (Table 7-32 and Figure 7-29).

*Table 7-32 Details of the experimental design to test the effects of burial on seagrasses (burial levels tested, the duration of the experiments, the size: burial ratio (SBR)) and the resulting effect on seagrass survival - burial levels causing 50% and 100% mortality*

| Species | Burial levels (cm) | Experimental period (days) | SBR | Burial level (cm) | |
|---|---|---|---|---|---|
| | | | | 50% Mort. | 100% Mort. |
| *C. nodosa* | 1, 2, 4, 7, 13, 16 | 35 | 0.6[c] | 4 | 13 |
| *C. rotundata* | 2, 4, 8, 16 | 60, 120, 300 | | 2 | 8 |
| *C. serrulata* | 2, 4, 8, 16 | 60, 120, 300 | | 2 | – |
| *E. acoroides* | 2, 4, 8, 16 | 60, 120, 300 | | 4 | – |
| *H. uninervis* | 2, 4, 8, 16 | 60, 120, 300 | | 4 | – |
| *H. ovalis* | 2, 4, 8, 16 | 60, 120, 300 | | 2 | 2 |
| *P. australis* | 10, 15, 20, 30 | 50 | 1.3 [d] | 19.5 | – |
| *P. oceanica*[a] | 5/7, 9/10, 13/14 | 250 | 1.4 | 14 | 14 |
| *P. oceanica*[b] | 3, 6, 9, 12, 15 | 45 | 1.3 [e] | 10.2 | 15 |
| *P. sinuosa* | 10, 15, 20, 30 | 50 | 1.3 [d] | 15.4 | – |
| *S. filiforme* | 3.5/4.5, 4/5, 6.5/7.5, 9/10 | 60 | 0.8 | 4.5 | 10 |
| *S. isoetifolium* | 2, 4, 8, 16 | 60, 120, 300 | | 8 | – |
| *T. hemprichii* | 2, 4, 8, 16 | 60, 120, 300 | | 4 | – |
| *T. testudinum* | 3.5/4.5, 4/5, 6.5/7.5, 9/10 | 60 | 1.2 | 5 | – |
| *Z. marina* | 4, 8, 12, 16 | 12, 24 | 1.0 | 4 | 12 |
| *Z. noltii* | 2, 4, 8, 16 | 7, 14, 28, 56 | < 1[f] | 2 | 8 |

[a] Manzanera et al. (1998).
[b] Ruiz (personal communication).
[c] N. Marbà (personal communication).
[d] Leaf length from Smith and Walker (2002) for the same area.
[e] Leaf length from Manzanera et al. (1998).
[f] Intertidal species, leaves are buried even at low burial levels.

***Adapted from Cabaço, Santos and Duarte (2008)***




*Key: Ea, Enhalus acoroides; Hu, Halodule uninervis; Sf, Syringodium filiforme; Si, Syringodium isoetifolium; Th, Thalassia hemprichii and Tt, Thalassia testudinum*

***Adapted from Cabaço, Santos and Duarte (2008)***

*Figure 7-29 The relationship between shoot mortality and burial levels in seagrasses subject to experimental burial*

The extent of the burial and erosion effects is species-specific and depends on the magnitude and on the frequency of disturbance. Large seagrass species are less susceptible to burial, whereas small, fast-growing species showed to be very sensitive to burial. *Posidonia australis* was the most tolerant seagrass species to burial, while *Thalassia testudinum* was the most tolerant species to erosion. The capacity of seagrasses to withstand sediment burial is strongly size-dependent. The leaf size and the rhizome diameter are the best predictors of the burial impact on seagrasses. Both natural and human-induced changes of the sediment level may seriously impact seagrasses.

#### *7.2.2.4 Creation of New Niches*

Once developed, the hard substrate (breakwaters) will create new niches (including intertidal zones). Maintenance and improvement of the surrounding fishery is essential for any ecosystem function; that is both the current and any future shifting dynamics as a result of the breakwater and the resultant increased ecological volume. Colonization of the breakwater should occur in various stages of succession with a variety of dynamic interactions. The increased ecological volume will encourage colonization of coral, coralline algae and other sessile invertebrates, however the extent of this colonization will be dependent on the colonization and proliferation of marcoalgae. The colonization of grazing invertebrates (such as sea urchins) as well grazing by fish (which should aggregate around the breakwater) should control the growth of macroalgae and allow for succession of colonization of the breakwater to result in some similar natural reef functions under ideal conditions.

### 7.2.3 Human/ Social

#### *7.2.3.1 Maritime Activities and Local Businesses*

After construction is complete, vessels will have to travel longer distances around the breakwater structures in order to access various dive/snorkel sites and island tours and cruises. This may cause additional expenses in the operational costs of watersports operators.

The proposed breakwaters will potentially provide an alternative dive/ snorkel site.

#### *7.2.3.2 Aesthetics and Visual Impact*

The breakwaters are approximately 1.5km from the shoreline. The random protrusion of the tips of the armour stone are beyond the limits of normal vision capabilities from the shoreline. Most of the structure will be placed with a crest elevation of MSL. This is critical in order to have the desired effects of stabilizing the beach and reducing the wave energy reaching the beach. The lower the structure crest is the less effective it will be. There are practicalities that must be borne in mind in the use of a gradation of sizes of quarried/irregular armour stone, on an uneven sea floor. The tips of the stones will be allowed to extend over a range of +0.43 to -0.43 meters relative to MSL based upon the pre-tender specification requirements. It must be noted that the occurrence of the projections is random and only expected to occur for approximately 10 to 22% of the total crest of the breakwaters. An observer with “eagle eye” vision will only be able to resolve the crest from 115 meters or closer.

Also, relative to the popular dive/snorkel sites, Shark and Throne, the breakwaters are over 1,000m away. This is well outside of the capacities of vision of both normal and "eagle eye" observers. It is therefore unlikely that the popular water sports activities will be visually affected by the random protrusions of the armour stones on the crest, placed at MSL.

A fisherman's boat was used to illustrate the potential for visual impacts from the placement of the breakwaters. The height of this boat is approximately 0.9 m (3 ft.) above the sea level. The breakwaters in sections (some boulders) during low tide will exceed the sea-level by 0.45 m. The boat was placed at various positions within the breakwaters footprint (South and North Breakwaters) and pictures taken from various points along the shoreline with and without (representing the normal human view) zoom. The illustration (Plate 7-5) shows that the breakwaters will not be visible to the normal human eye at that distance and height above sea level.

(a)


(b)


*Plate 7-5 View of fisherman's boat from Long Bay shoreline without camera zoom (a) and with zoom (b)*

# 8.0 CUMULATIVE ENVIRONMENTAL IMPACTS

## 8.1 NOISE POLLUTION AND VIBRATION NUISANCE

Cumulatively (Existing and Project traffic), the noise levels exceed the NEPA day time standards at the same locations as those of the existing traffic for both the Negril to Sheffield main road and the Norman Manley Boulevard. The increase in noise levels (over the existing) along both thoroughfares were less than 3 dBA which is the level at which persons will not perceived and increase in noise levels. The increases along the Norman Manley Boulevard (< 1dBA) are even much less than those along the Negril to Sheffield main road (< 2.2 dBA) (Table 8-1 and Table 8-2).

The locations that were non-compliant along the Negril to Sheffield main road were residences and as such during the day (when the trucks are delivering) most persons should not be at home coupled with the fact that the increase in noise levels being less than 3 dBA reduces the potential for a noise nuisance. The levels of increase (< 1dBA) along the Norman Manley Boulevard are small and will not be noticed.

*Table 8-1 Predicted noise emissions 24 hours and daytime levels from all traffic (existing plus project) travelling along the Negril to Sheffield main road*

| LOCATIONS | CUMULATIVE Leq $_{(24h)}$ (dBA) | CUMULATIVE 7 a.m. – 10 p.m. (dBA) | NEPA DAY TIME STD. (7 a.m. – 10 p.m.) (dBA) | DIFFERENCE IN NOISE LEVELS FROM EXISTING (7 a.m. – 10 p.m.) (dBA) |
|---|---|---|---|---|
| Burger King | 59.6 | 61.6 | 65 | 1.3 |
| Caribbean Sunset Resort | 44.2 | 46.3 | 55 | 2.2 |
| House 1 | 62.1 | **64.1** | 55 | 1.4 |
| House 2 | 59.3 | **61.3** | 55 | 1.3 |
| House 3 | 58.7 | **60.8** | 55 | 1.3 |
| House 4 | 62.7 | **64.8** | 55 | 1.4 |
| House 5 | 61.3 | **63.3** | 55 | 1.4 |
| House 6 | 60.7 | **62.8** | 55 | 1.4 |
| House 7 | 57.6 | **59.7** | 55 | 1.3 |
| House 8 | 55.8 | **57.8** | 55 | 1.4 |
| Negril Health Centre | 52.9 | **55.0** | 45 | 1.6 |
| Negril Hills Golf Club | 47.6 | 49.7 | 65 | 1.9 |
| Playfield | 46.6 | 48.7 | 65 | 2.1 |
| Plaza 1 | 58.7 | 60.7 | 65 | 1.3 |
| Plaza 2 | 59.0 | 61.1 | 65 | 1.3 |
| Sweet Spice | 59.8 | 61.9 | 65 | 1.4 |

*Table 8-2 Predicted noise emissions 24 hours and daytime levels from all traffic (existing plus project) travelling along the Norman Manley Boulevard*

| LOCATIONS | PROJECT Leq (24h) (dBA) | PROJECT 7 a.m. – 10 p.m. (dBA) | NEPA DAY TIME STD. (7 a.m. – 10 p.m.) (dBA) | DIFFERENCE IN NOISE LEVELS FROM EXISTING (7 a.m. – 10 p.m.) (dBA) |
|---|---|---|---|---|
| Alfred's Ocean Palace | 64.2 | **66.3** | 55 | 0.6 |
| Ansell's Thatch Walk Cottages | 62.4 | **64.4** | 55 | 0.5 |
| Aqua Negril Resort | 62.0 | **64.1** | 55 | 0.6 |
| Bar B Barn Hotel and Restaurant | 59.6 | **61.6** | 55 | 0.6 |
| Beachcomber Club Hotel and Spa | 62.6 | **64.6** | 55 | 0.5 |
| Beaches | 63.1 | **65.1** | 55 | 0.5 |
| Bungalo Hotel | 61.5 | **63.5** | 55 | 0.5 |
| Caribbean Sunset Resort | 47.2 | 49.3 | 55 | 0.7 |
| Chances | 60.9 | **62.9** | 55 | 0.6 |
| Charela Inn | 62.1 | **64.1** | 55 | 0.6 |
| Charela Inn | 47.4 | 49.4 | 55 | 0.7 |
| Chippewa Village Cafe Bar Lodging | 72.1 | **74.1** | 55 | 0.3 |
| Chuckles | 44.6 | 46.6 | 55 | 0.6 |
| Coco La Palm | 61.7 | **63.8** | 55 | 0.6 |
| Coral Seas Garden Hotel | 62.8 | **64.9** | 55 | 0.5 |
| Cotton Tree Place Hotel | 40.6 | 42.6 | 55 | 0.5 |
| Country Country | 62.5 | **64.6** | 55 | 0.6 |
| Couples | 60.4 | **62.4** | 55 | 0.5 |
| Couples Swept Away | 50.2 | 52.2 | 55 | 0.8 |
| Crystal Waters Villas | 61.6 | **63.7** | 55 | 0.6 |
| Errol's Sunset Cafe and Guest House | 62.5 | **64.6** | 55 | 0.6 |
| Firefly Cottages & Apartments | 61.7 | **63.7** | 55 | 0.5 |
| Foote Prints Villas | 61.3 | **63.3** | 55 | 0.5 |
| For Real Beach Resort | 61.3 | **63.3** | 55 | 0.5 |
| Fun Holiday Beach Resort | 61.6 | **63.7** | 55 | 0.6 |
| Gardenia Resort | 60.1 | **62.1** | 55 | 0.6 |
| Golden Villas & Rooms | 70.5 | **72.6** | 55 | 0.4 |
| Grand Lido Negril Resort & Spa | 43.5 | 45.5 | 55 | 0.7 |
| Grand Pineapple Beach Resort | 59.7 | **61.8** | 55 | 0.6 |
| Green Leaf Cabins | 72.0 | **74.1** | 55 | 0.4 |
| Hidden Paradise Garden Resort | 71.8 | **73.8** | 55 | 0.3 |
| Idle Awhile | 63.4 | **65.5** | 55 | 0.6 |
| Jamaican Tamboo | 62.7 | **64.8** | 55 | 0.6 |

| LOCATIONS | PROJECT Leq (24h) (dBA) | PROJECT 7 a.m. – 10 p.m. (dBA) | NEPA DAY TIME STD. (7 a.m. – 10 p.m.) (dBA) | DIFFERENCE IN NOISE LEVELS FROM EXISTING (7 a.m. – 10 p.m.) (dBA) |
|---|---|---|---|---|
| Kuyaba | 61.1 | **63.1** | 55 | 0.6 |
| Lazy Dayz | 62.5 | **64.5** | 55 | 0.5 |
| Legends Hotel | 63.9 | **65.9** | 55 | 0.5 |
| Mariner's Negril Beach Club | 62.1 | **64.1** | 55 | 0.5 |
| Mariposa | 60.0 | **62.1** | 55 | 0.6 |
| Merrils 1 Resort | 61.8 | **63.8** | 55 | 0.6 |
| Merrils 2 Resort | 60.9 | **62.9** | 55 | 0.5 |
| Merrils 3 Resort | 61.9 | **63.9** | 55 | 0.5 |
| Moon Dance Villas | 63.3 | **65.3** | 55 | 0.5 |
| Moonrise Villas | 64.2 | **66.2** | 55 | 0.5 |
| Native Son Villas | 65.6 | **67.7** | 55 | 0.5 |
| Negril Beach Villa | 62.6 | **64.6** | 55 | 0.5 |
| Negril Gardens Beach Resort | 64.4 | **66.5** | 55 | 0.5 |
| Negril Tree House Hotel | 55.8 | **57.8** | 55 | 0.7 |
| Nirvana | 63.8 | **65.8** | 55 | 0.5 |
| Palm Grove Manor Apartment and Rooms | 61.6 | **63.7** | 55 | 0.6 |
| Point Village | 37.7 | 39.7 | 55 | 0.6 |
| Rayon Hotel | 67.7 | **69.7** | 55 | 0.4 |
| Riu Hotel & Resorts Negril Club | 61.0 | **63.1** | 55 | 0.6 |
| Riu Hotel & Resorts Tropical Bay | 62.7 | **64.7** | 55 | 0.6 |
| Rondel Village | 63.6 | **65.6** | 55 | 0.5 |
| Rooms | 62.0 | **64.0** | 55 | 0.5 |
| Roots Bamboo Beach Resort | 62.7 | **64.8** | 55 | 0.6 |
| Sandals Negril Beach Resort & Spa | 60.1 | **62.1** | 55 | 0.5 |
| Sea Sand Eco Villas | 62.9 | **64.9** | 55 | 0.5 |
| Sea Scape Hotel | 62.3 | **64.4** | 55 | 0.6 |
| Sea Splash Resort | 62.1 | **64.1** | 55 | 0.5 |
| Seabreeze Apartments | 64.7 | **66.8** | 55 | 0.5 |
| Seascape Hotel | 70.0 | **72.0** | 55 | 0.5 |
| Seawind Resort | 61.9 | **64.0** | 55 | 0.6 |
| Shield's Negril Villas | 60.7 | **62.7** | 55 | 0.6 |
| Sunquest Cottages | 62.3 | **64.4** | 55 | 0.6 |
| Sunrise Club Hotel | 67.9 | **70.0** | 55 | 0.5 |
| Sunset at the Palms Resort and Spa | 67.6 | **69.7** | 55 | 0.5 |
| Sunset on the Beach Resort (Coral Seas B | 67.5 | **69.5** | 55 | 0.5 |
| Sunset Palm Resort | 66.7 | **68.8** | 55 | 0.5 |
| Superclubs Hedonism II | 45.4 | 47.4 | 55 | 0.7 |

| LOCATIONS | PROJECT Leq $_{(24h)}$ (dBA) | PROJECT 7 a.m. – 10 p.m. (dBA) | NEPA DAY TIME STD. (7 a.m. – 10 p.m.) (dBA) | DIFFERENCE IN NOISE LEVELS FROM EXISTING (7 a.m. – 10 p.m.) (dBA) |
|---|---|---|---|---|
| The Palms | 63.0 | **65.1** | 55 | 0.6 |
| Travellers Beach Resort | 61.7 | **63.7** | 55 | 0.5 |
| Villa Mora Rooms & Cottages | 70.2 | **72.3** | 55 | 0.5 |
| Wavz | 62.9 | **65.0** | 55 | 0.6 |
| Whistling Bird | 62.0 | **64.0** | 55 | 0.5 |
| White Sands | 61.3 | **63.4** | 55 | 0.6 |
| Yellow Bird Rooms & Cottages | 59.6 | **61.6** | 55 | 0.6 |

Noise emission contours for the existing traffic plus Project related traffic along the Negril round-a-bout to Sheffield main road and the Norman Manley Boulevard are depicted in Figure 8-1 and Figure 8-2 respectively.

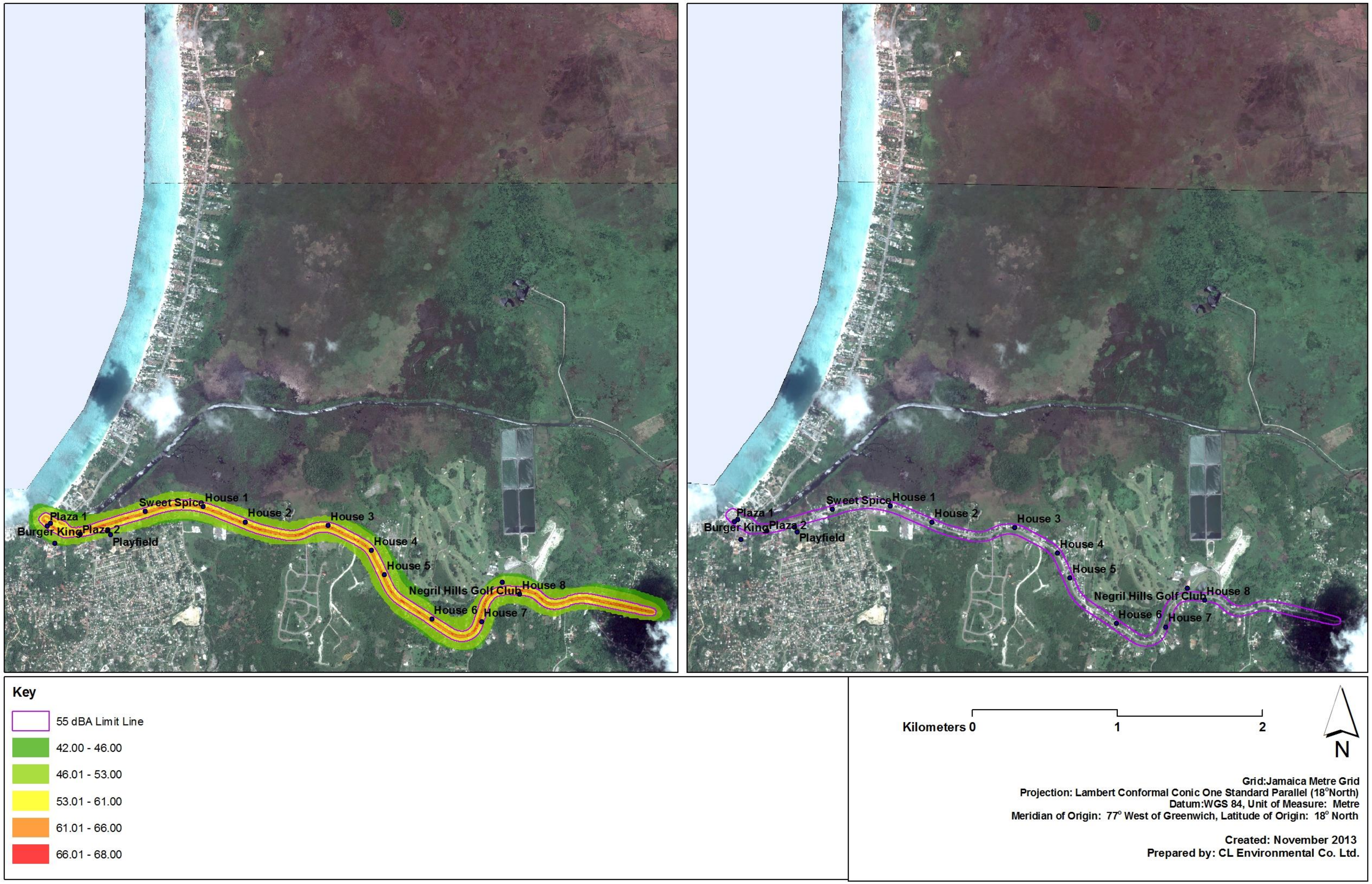



*Figure 8-1 Noise contours from existing plus proposed Project traffic along the Negril round-a-bout to Sheffield main road*

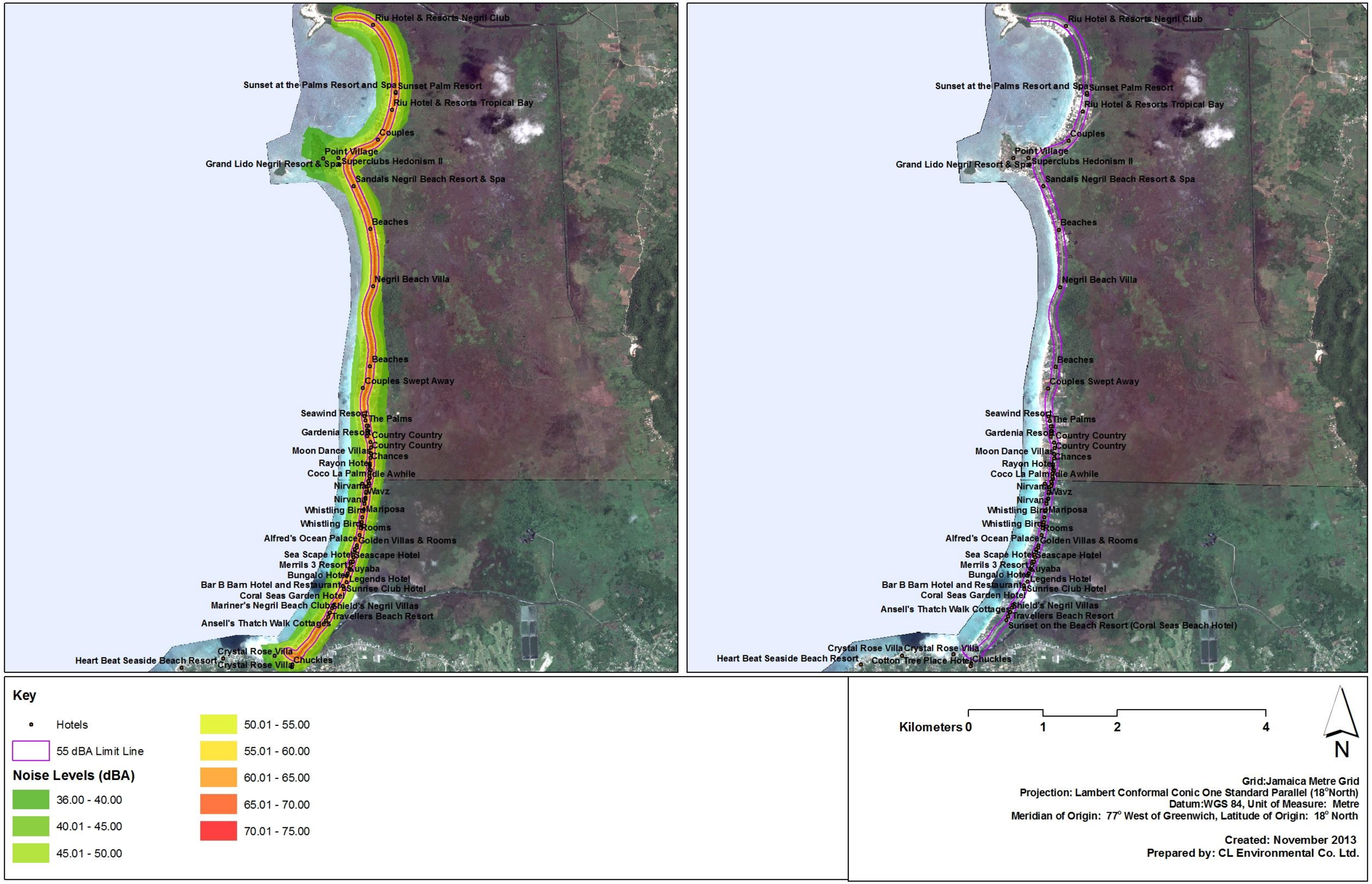



*Figure 8-2 Noise contours from existing plus proposed Project traffic along the Norman Manley Boulevard*

## 8.2 MARITIME OPERATIONS

There are many activities during the construction process that can affect the livelihood of those who use the beach and the river to generate an income; these users include hotels, fishermen and divers. The Port Authority of Jamaica is responsible for regulating safe navigation to ports of entry and for taking such measures as it regards in its interest, under the Port Authority Act (1972). Likewise, the Harbour Master of the Port Authority is the responsible officer for regulating all lighthouses and light beacons/markers for both harbours and ports, under the Harbour Lights and Lighthouse Act (1900).

The Harbour Master has been contacted and provided with the project details for relevant guidance on mitigating any potential impacts to navigation and for marking the channels for the breakwater. The number of markers to be used and colours and timing of the flashes for the beacons to mark the ends of the breakwaters will be discussed with the Harbour Master. Below is an excerpt from Section 8 of the Harbours Act, 1900:

> *"It shall be the duty of each Harbour Master, at the expense of the Island, to keep in good and sufficient order and repair, and in their proper places, and with all special distinctions of colouring and shape, all buoys, stakes, and marks for the time being of the harbour of which he is Harbour Master, and of all channels near or leading into or out of the same, and also, when directed by the Minister, to erect, float, and place other marks, stakes, or buoys in such places, and of such colours and shapes, and in such manner as the Minister shall direct, and to keep and render to the Accountant-General accounts of the expense thereof, in such manner as may be directed by the Minister."*

Construction activity may have the potential to negatively impact watersports, fishing and other maritime activities taking place at sea. The locations of the proposed breakwater structures are close to snorkelling sites used by hotel and small business watersports operators as part of the services offered to clients. These sites will be inaccessible during construction of the breakwater structures.

The use of marker buoys demarcating an exclusion zone should be used to keep out other marine traffic and recreational swimmers from the work area during construction. It is necessary to ensure that there is adequate presence of navigation aids for the barge operators to use when moving to and from breakwaters. After construction is completed, permanent market buoys should be placed at strategic points along (including at the start and end) of each breakwater structure, in particular in areas not clearly seen above water at low tide. Port Authority will also have to enforce and educate users in the area, including tourists and recreational users.

The Port Authority of Jamaica has no objections to the proposed Negril Breakwaters Project (Appendix 18).

# 9.0 RECOMMENDED MITIGATION

## 9.1 PHYSICAL

### 9.1.1 Air Quality

i. The staging area and immediate surrounding roadways should be dampened every 4-6 hours or within reason to prevent a dust nuisance and on hotter days, this frequency should be increased.
ii. Minimize cleared areas to those that are needed to be used.
iii. Cover equipment when not in use and/or wet construction materials to prevent a dust nuisance.
iv. Where unavoidable, construction workers working in dusty areas should be provided and fitted with N95 respirators.

### 9.1.2 Noise Pollution and Vibration Nuisance

i. Use equipment that has low noise emissions as stated by the manufacturers.
ii. Use equipment that is properly fitted with noise reduction devices such as mufflers, especially in areas with sensitive receptors such as the stockpile area.
iii. Operate noise-generating equipment during regular working hours (e.g. 7 am – 7 pm) to reduce the potential of creating a noise nuisance during the night.
iv. Construction workers operating equipment that generates noise should be equipped with noise protection. A guide is workers operating equipment generating noise of ≥ 80 dBA (decibels) continuously for 8 hours or more should use ear muffs. Workers experiencing prolonged noise levels 70 - 80 dBA should wear earplugs.

### 9.1.3 Water Quality

i. At source, the contractor is required to wash the stones, identify and remove unsuitable stones. At site, stones brought in are to be checked on site before they go in the water. Any stones that enter the water with these 'soft parts' that have escaped these checks will be a negligible source of fine sediments.
ii. All boulders should be properly washed before being loaded on the barge for transport to the breakwater site.
iii. A sediment basin should be constructed onsite at the staging area in order to intercept storm water before it is discharged to the sea. Typical EPA best management principles recommend the ponds be sized to hold the first flush which equates to 0.25 inches of runoff per impervious acre of contributing drainage area, with an absolute minimum of 0.1 inches per impervious acre. The runoff will then flow into an oil water separator and then discharged into the river/ sea.

iv. The use of silt screens/ turbidity barriers at the proposed breakwater site and staging site/ stockpile area is recommended so as to reduce the amount of suspended solids in the marine environment.
v. Monitoring of the water quality of the area should be conducted fortnightly during and after construction up to a period of one month after completion.

*Plate 9-1 Example of a turbidity barrier being used to mitigate against a declining water quality during construction*

### 9.1.4 South Negril River

It is recommended that the South Negril River be desilted in such a way that the width of the river's mouth remains the same and the hydraulics of the river is not affected. A detailed hydrological study is required to identify the effects of the desilting operation on the morass (outside the scope of this project).

It must be noted that river desilting and dredging is no longer a part of the project scope (though included in the original proposal). There will be no dredging of a section of the mouth of the river; material will be sourced from licenced quarries for the creation of the stockpile area.

### 9.1.5 Storage Facilities

i. All refuelling facilities within the camp should be situated on impermeable surfaces served by an oil trap, run-off collection system. As mentioned previously, a sediment basin should be constructed on the site to intercept storm water before it is discharged to the sea. The runoff will then flow into an oil water separator and then discharged into the river/ sea.

### 9.1.6 Solid Waste Generation

i. Skips and bins should be strategically placed within the staging area.
ii. The skips and bins should be adequately designed and covered to prevent access by vermin and minimise odour.
iii. The skips and bins should be emptied regularly to prevent overfilling.
iv. Disposal of the contents of the skips and bins should be done at an approved disposal site.
v. Waste boulders should be removed from site once rejected. Excavated material used in transport should be taken back to quarries etc.

### 9.1.7 Wastewater Generation and Disposal

i. Provide portable sanitary conveniences during construction for the workers for control of sewage waste. A ratio of approximately 25 workers per chemical toilet should be used. The specific layout will be a requirement of the contractor.

### 9.1.8 Road Traffic and Safety

i. Ensure that a traffic management and safety plan is developed prior to construction phase and implemented.
ii. Trucks should not be allowed to travel in a convoy.
iii. Trucks should not be parked along the public roadway.
iv. Schedule delivery during off peak as practical as possible.
v. Suitable traffic controls at the entrance to the site should be put in place.
vi. Ensure that a traffic management plan is developed and implemented.

Safety of motorist is of great concern and the following steps should be taken to mitigate or reduce accidents on the roads leading to the site:

- Appropriate traffic warning signs, informing road users of a construction site entrance ahead and instructing them to reduce speed, should be placed along the main road for the duration of the construction and operational 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 National Works Agency of Jamaica (NWA) has a standard for loads per axel that all trucks exert on roads (See Figure 9-1). It is further recommended that a maintenance plan be put in place to address the issue of road degradation over the construction period. This is needed because it is anticipated that even though the trucks may be within the weight limits, the roads in the unpaved areas especially will deteriorate with continued used by trucks from the quarries.

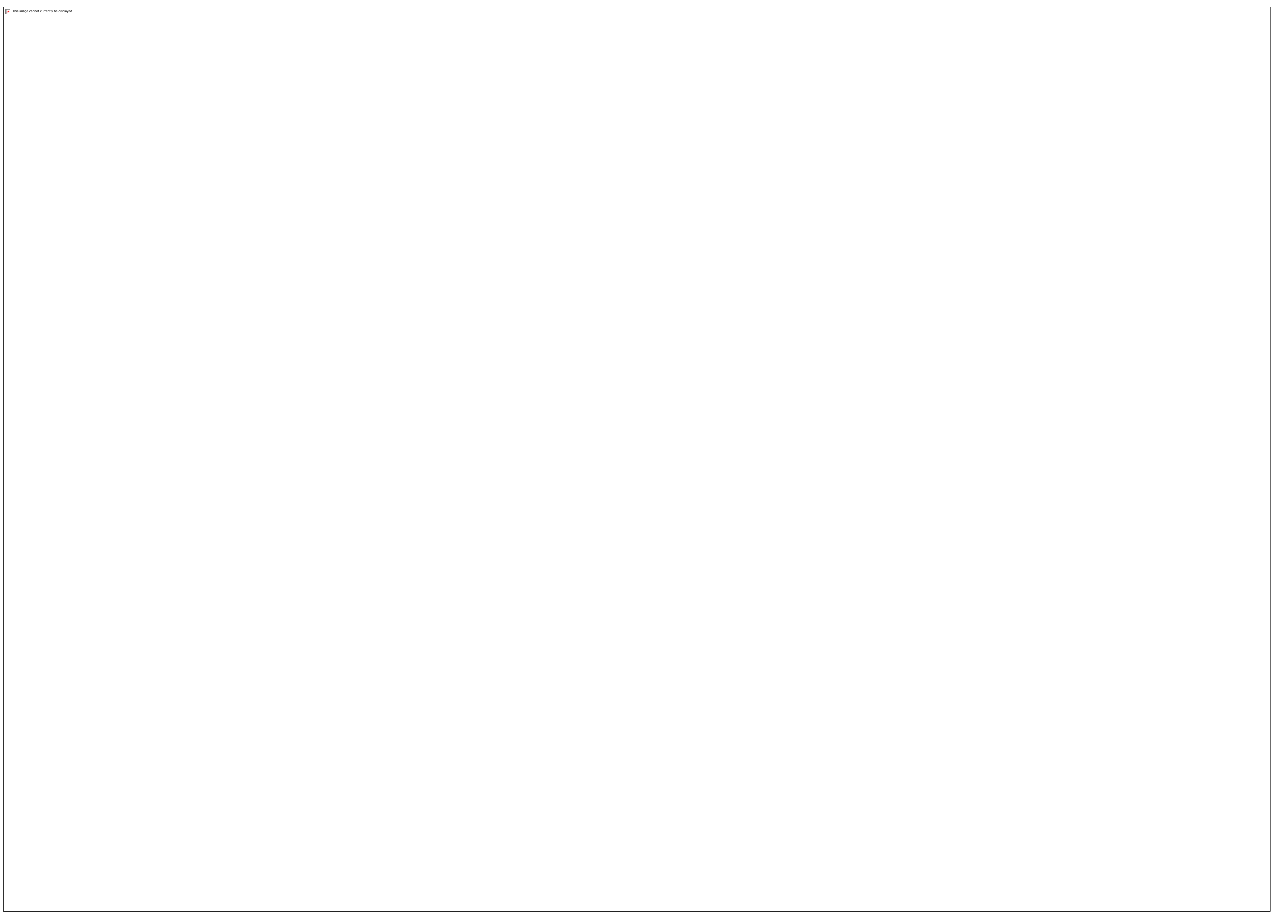


*Figure 9-1 National Works Agency of Jamaica weight limit requirements for heavy vehicles*

### 9.1.9 Maritime Operations

i. The use of marker buoys demarcating an exclusion zone should be used to keep out other marine traffic from the work area during construction.

ii. After construction is completed, permanent market buoys should be placed at strategic points along (including at the start and end) of each breakwater structure, in particular in areas not clearly seen above water at low tide.
iii. Port Authority will also have to enforce and educate users in the area, including tourists and recreational users.

The Harbour Master has been contacted and provided with the project details for relevant guidance on mitigating any potential impacts to navigation and for marking the channels for the breakwater. The number of markers to be used and colours and timing of the flashes for the beacons to mark the ends of the breakwaters will be discussed with the Harbour Master.

It is recommended that as a part of the engineering contract, the Contractor submit a detailed maritime traffic management and safety plan prior to construction phase.

## 9.2 BIOLOGICAL

### 9.2.1 Reef Community

#### *9.2.1.1 Pavement Community*

Typical relocation mitigation may not be suitable for all species present in the pavement community found within the breakwater footprint. As with typical reef flat/pavement areas, majority of the hard coral population is composed of small encrusting corals such as *Siderastrea sp*. and *Favia sp*, while soft corals and sponges are also often found with holdfasts encrusting on pavement as well. Sessile species found growing in/on pavement is unlikely to be relocated successfully. It will be difficult to remove these colonies without damage to the colonies themselves.

In the case of Negril, most of the substrate is pavement with little relief and as such, the majority of the coral population is composed of small, encrusting colonies. The tools needed to remove these colonies from the pavement will most likely result in more damage than good. Although these corals are small, they cannot be considered recruits or juveniles as many stay this size throughout their life. "Apparently environmental processes on reefs related to colony growth and mortality cause the greatest relative variation in colony size when corals are small" (Bak and Meesters 1998). It should also be noted that marine works and relocation in shallow, high wave energy environments is also problematic; relocated species are at a greater risk of dislodging or overturned in a high energy environment. A Natural Resource Valuation (NRV) is an essential component of the mitigation process; it is highly recommended that an NRV be used to guide project decisions.

As a result, hard and soft corals on suitable substrate (not growing on pavement) and mobile invertebrates within the footprint of the breakwater structures will have to be relocated to an area of similar conditions (light penetration, wave action and depth) where possible.

In order to reduce risks to the pavement community, the following are required:

i. Proper functioning of barge, silt screens and other equipment
ii. All material is properly washed and suitable for placement in the marine environment
iii. Proper safety and maritime regulations are adhered to at all times

#### *9.2.1.2 The Backreef and Reef Crest Community*

Excess siltation and reduction in water quality in the communities near the project site can be greatly reduced with the proper use of silt screens. Silt screens should be deployed correctly both to ensure they act as turbidity barriers and in such a way as to reduce the damage to the seafloor where they are placed. It should be noted that anchoring within pavement areas may require the use of temporary moorings or other suitable devices such as a mushroom anchor. Typical Lightweight or "Danforth" Anchors, Plow or "CQR/DELTA" Anchors, Kedge or Navy Anchors, Claw or "BRUCE" Anchors and Grapnels Anchors will not be suitable on pavement areas.

Construction activities, including the transport of material within the marine environment should be stopped when unfavourable weather conditions arise or are anticipated. The backreef community is composed of several patch reefs and large seagrass beds. These communities are at risk of smothering and or excess sedimentation during construction activities. Several colonies of *A.palmata* were identified in the natural reef between the breakwaters; these are both sensitive and endangered species and as a result require particular care during construction activities.

Reducing the risks to all environments and users by ensuring the following:

i. Proper functioning of barge doors, silt screens and other equipment
ii. All material is properly washed and suitable for placement in the marine environment
iii. Proper safety and maritime regulations are adhered to at all times

### 9.2.2 Phytoplankton

i. Monitoring of the water quality and phytoplankton community of the area should be conducted fortnightly during and after the construction phase of the proposed development, up to a period of one month after completion to detect any progressing unacceptable changes in the phytoplankton community. This will allow any increases or decreases in phytoplankton species concentrations to be detected early before reaching critical stages. If critical stages are exceeded mitigation measures would depend on the species that have exceeded the concentration limits as some are more harmful than others, as well as the extent of the increased concentration of the species over the limits. The extent of blooms of species would also be taken into consideration as some blooms can be isolated while others may travel with the currents and impact fishing areas and high human use areas. Mitigation in such cases can include closure of fishing and swimming areas and beaches. In very serious cases a stop work order may need to be issued on the construction site.

ii. Use of techniques or mechanisms such as silt screens or curtains to reduce impacts of suspended solids and increased turbidity.

### 9.2.3 Fish Community, Marine Mammals and Reptiles

i. Fishing around the breakwaters should be limited or prevented. Preventing fishing in this area may also serve to improve fish stocks within the area, if managed and regulated sufficiently.
ii. The breakwaters may also function as a snorkel site of interest if the fish aggregate around the structures and fishing (netting, spearfishing and fish pots) are not used in the area. This may be of particular importance due to the heavy usage of the area by local watersports operations and also reduced pressure on the surrounding natural reef dive sites by providing an alternative dive sites for tourists.
iii. 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 collisions both with marine life but also other users in the area.
iv. The fishing public and water sports personnel (dive operators, glass bottom boat tours *etc.*) should be kept informed as to the operation plans for the works and the times at which it will be operation within defined locations. This will ensure that users of the area have enough information to avoid being within the vicinity of the works, the staging area and the travel route of the barges.

## 9.3 HUMAN/ SOCIAL

### 9.3.1 Community Engagement

To keep the community and other stakeholders informed about the progress of the project and to create a mechanism to report grievances, it is recommended that a Stakeholders Engagement Committee be established and meet at an adequate frequency. This committee should be constituted of but not be limited to:

i. Representatives from the community (CBO or Community Associations).
ii. Representatives from the business community.
iii. Representatives of the Hotel/Villa associations.
iv. Representative of the fishing cooperation.
v. Representative of the water sport association.
vi. Representative of the craft vendors association.

vii. Representative of the local environmental group.
viii. Representative from NEPA.
ix. Representative of NGILAPA.
x. The Main Contractor.
xi. Representatives of the Implementation Agency and Project Team.

### 9.3.2 Local Maritime Businesses

To help the local business community that may be affected during the construction process the following provisions should be made:

i. Employing a fisheries liaison officer to ensure that the concerns of the fishermen are brought to the attention of the contractors and that the contractors take steps to address these concerns.
ii. Having the barge use a prescribed navigation route when moving to and from the breakwaters.
iii. Utilizing licensed and experienced barge operators to reduce the incidence of damage to existing coastal structures.
iv. Ensuring that there is adequate presence of navigation aids for the barge operators such as buoys.
v. Proper securing mechanisms in place on barges for boulders.
vi. Safety and emergency management plans (include fire etc.)

*Plate 9-2 Buoys being used as navigation aids*

### 9.3.3 Visual Impact

A construction screen should be erected to minimize visual intrusion of the staging area and loading works. Additional mitigation measures proposed include:

i. Ensure that the barges etc. are properly maintained and are not in a state of disrepair.
ii. Add signs to equipment in order to inform viewers.

# 10.0 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 – Different Breakwater Configurations
- Alternative 4 – The Project as Proposed, with Different Staging Area Locations
- Alternative 5 – The Project as Proposed, with Improved Aesthetics
- Alternative 6 – Reefball Breakwater Design
- Alterative 7 –Beach Nourishment
- Alternative 8 – Hybrid Alternative

In addition, the following alternatives to specific project components were deemed important considerations:

- Alternative 9 – South Negril River Desilting Options
- Alternative 10 – Coral and Sponge Relocation

## 10.1 ALTERNATIVE 1 - THE "NO-ACTION" ALTERNATIVE

As part of the EIA process, the No-Action Alternative has to be considered. This means that everything would remain as is. The main negative impact of this alternative would be the continued erosion along Long Bay beach; based on the modelled results, 37 m wide, along 6 km of beach will be eroded over the next 37 years (up to 2050). Various indirect negative impacts would potentially arise from this, including the potential decrease in tourists visiting Negril, potential loss in infrastructure and investments and increased unemployment in area.

## 10.2 ALTERNATIVE 2 - THE PROJECT AS PROPOSED

The breakwaters are designed to provide moderate wave protection for 2,000 to 2,500 meters of shoreline and accretion in some areas of potentially up to 48 metres in the long term. Negril's main tourist attraction will therefore be improved and this would potentially lead to increased visitor arrivals to Negril, and increased income in the area. The boulders used in breakwater construction would potentially create snorkelling sites due to fish aggregation and coral recruitment and improved boat access at the South Negril river mouth due to de-silting. Further, employment opportunities during the construction phase will arise.

On the other hand, the following negative impacts are anticipated:

- Destruction of natural marine habitats from the laying of boulders on the seafloor required during construction activity.
- Potential habitat fragmentation between the seagrass beds in the lagoon and surrounding reefs.
- Longer travelling distances for marine vessels in order to access various dive/snorkel sites and island tours and cruises.
- Visual impact of above-water portions of breakwater structures.
- Increased accident potential for marine vessels running aground the breakwaters.

The cost of breakwater construction for the project as proposed is US$6.9M.

## 10.3 ALTERNATIVE 3 – DIFFERENT BREAKWATER CONFIGURATIONS

Four (4) configurations of the breakwaters were developed for this project and they fall into 2 categories: Nearshore and Integrated Solution Phase 1 (reef extension). Smith Warner International Limited (SWIL) and CEAC developed a configuration for each category.

The Nearshore Category solutions were aimed at stabilizing the entire Long Bay shoreline with a series of nearshore breakwaters. The first option was developed by SWIL and it had 2 breakwaters both 400m long approximately 300m from the shoreline. The breakwaters were in 3.6 to 4.7m of water. The main concern however was the creation of rip currents that can affect marine life, swimmers and persons who derive their employment from the ocean.

The second option in this category was developed by CEAC and it comprised of 3 breakwaters using less material than the first option. The breakwaters were 264, 350 and 400m long approximately 240m from the shoreline in water 2.9 to 3.8m deep. This option could also create rip currents but it had more advantages than the SWIL option in that more of the shoreline was protected (an increase from 1,220 to 1,855m), and both the risk of rip currents and rock volume required for the breakwaters were reduced because the breakwaters were in shallower water.

The first option in the Integrated Solution Phase 1 (reef extension) category was again developed by SWIL and it had 4 breakwaters three of which were 400m long and the other 500m long approximately 1,500m from the shoreline. The breakwaters were in deep water between 4 – 6m depth as more armour stone is required with resulting additional costs.

The second option in this category was developed by CEAC and it had 2 breakwaters using less armour stone than the first option. The breakwaters were 480 and 600m long in 4 – 4.2m of water. The advantages of this option were that less armour stone was needed because the breakwaters were to be placed in shallower water, and the stability of the beach would increase in light of the reduced number of gaps in the breakwaters.

Table 10-1 summarises these results.

*Table 10-1 Summary of proposed hard structures solutions for the beach restoration of Negril*[27]

| | **Nearshore** | | **Integrated Solution Phase 1 (Reef Extension)** | |
|---|---|---|---|---|
| **Option** | **SWIL** | **CEAC** | **SWIL** | **CEAC** |
| Solution | 2 breakwaters 400m long 300m offshore | 3 breakwaters 264, 350 and 400m long 240m offshore | 4 breakwaters three of which are 400m long and one 500m long. All 1,500m offshore | 2 breakwaters 480 and 600m long approximately 1,500m offshore |
| *Total footprint area ($m^2$)* | 14,742 | 15,881 | 46,299 | 20,332 |
| *Length of shoreline impacted by wave climate (m)* | 1,220 | 1,855 | 4,472 | 2,009 |
| *Volume of armour stone ($m^3$)* | 30,798 | 28,007 | 113,155 | 44,432 |
| *Total length of structures (m)* | 800 | 1,014 | 2,200 | 1,055 |
| *Distance offshore (m)* | 300 | 280 | 1,500 | 1,500 |
| *Cost of armour stone (USD 100 per $m^3$) (2012 USD Millions)* | 3.1 | 2.8 | 11.3 | 4.4 |

Results indicate that the preferred solution is Integrated Solution Phase 1 developed by CEAC. It provides the most advantages, and these are listed below:

- It provides wave protection to the most vulnerable sections of Long Bay, the central and northern portions.
- The length of shoreline stabilized (2,009m) is proportional to the cost and effectiveness of the comparable solution, option 1.

The integrated solution (which is 1,500m offshore) is less visually obstructive in both the construction phase and the operational phase, in comparison to the nearshore solutions which are 280 to 300m offshore.

The Integrated Solution Phase 1 by CEAC was further evaluated in 2013 and modified. These modifications are as follows:

[27] CEAC Solutions Co. Ltd, Identification of Hard and Soft Engineering Structures for Negril, Jamaica, Planning Institute of Jamaica, 2012

- Option 1 (The Project as proposed), whereby southern breakwater is 417m and northern breakwater is 517m.
- Option 2 which had the southern breakwater extended to 617m in a southerly direction and the northern breakwater shortened by 200m to 317m (on the northern end).

Table 10-2 shows the benefits of each breakwater configuration.

*Table 10-2 Benefits of various breakwater configurations*

| | |
|---|---|
| **Option 1** | • 109,400 $m^3$ of accretion over 80% (4.95 km) of shoreline.<br>• Accretion 83,000 $m^2$<br>• Average shoreline growth of 13.5 metres. |
| **Option 2** | • 74,100 $m^3$ of accretion over 68% (4.23 km) of shoreline.<br>• Accretion 33,000 $m^2$<br>• Average shoreline growth of 5.5 metres. |

Option 2 resulted in a more evenly distributed growth along the entire shoreline whereas Option 1 resulted in more accretion along central and northern sections of shoreline that is consistent with the locations of greatest erosion. Therefore, Option 1 was estimated to have a more positive impact on the shoreline and is thus the preferred and proposed option for mitigating the erosion problem along Long Bay beach.

## 10.4 ALTERNATIVE 4 - THE PROJECT AS PROPOSED, WITH DIFFERENT STAGING AREA LOCATIONS

The advantages and disadvantages of various staging/stockpile area locations are shown in Table 10-3. The South Negril River is the preferred staging area location. Compared to using the North Negril River potential staging area, the cost savings are US$0.4 million.

*Table 10-3 Staging area location options*

| Staging Area Location | Advantage | Disadvantage |
|---|---|---|
| *South Negril River Mouth* | • Shorter travel distance to breakwater site by ≈1.7km (compared to North Negril River mouth).<br>• Convenient access for trucks transporting boulders due to presence of pier and roadway.<br>• Convenient access for barge. Minimal dredging needed to accommodate barge.<br>• Located on flat land with no rock outcrops.<br>• Less likely to encounter reef structures en route to breakwater site.<br>• Can be used as a monitoring station during and after construction due to close proximity to project area. | • Traffic impacts and potential congestion due to trucks transporting material in a busy section of the town.<br>• Cost of de-silting and land reclamation US$147,500<br>• Travel time and Cost of barge, crane and tugboat US$220,400 |
| *North Negril River Mouth* | • Less traffic impact from the trucks transporting material. | • Low utility lines thus problems accessing the area.<br>• Large rock outcrops therefore more effort needed to prepare the staging area.<br>• High vegetation cover.<br>• Longer travel distance to breakwater site by ≈1.7km (compared to South Negril River mouth).<br>• More likely to encounter reef structures en route to breakwater site |
| *Savanna-la-Mar* | • Established dock therefore reduction in site preparation impact.<br>• Shorter travel time for trucks. | • Longer time spent transporting boulders to breakwater site. Additional transportation cost and time required to complete the project is US$435,000.<br>• More traffic in a congested capital town.<br>• Increased transportation cost. |

# 10.5 ALTERNATIVE 5 - THE PROJECT AS PROPOSED, WITH IMPROVED AESTHETICS

Vegetating the sections of the breakwaters that are above water could make the breakwaters more aesthetically pleasing, giving them the appearance of "offshore island cays". This would however require sand/sediment to be placed atop the breakwater structures which could be easily washed away during severe wave climate conditions.

## 10.6 ALTERNATIVE 6 – REEFBALL BREAKWATER DESIGN

The typical reefball design would be entirely submerged, 1 m from the water's surface. They will therefore not be as effective as the proposed breakwaters in attenuating waves or in reducing the transmission of wave energy and are therefore not a preferred option for mitigating beach erosion. In addition, the reefballs are not heavy enough to withstand harsh wave climate.

## 10.7 ALTERNATIVE 7 – BEACH NOURISHMENT

Beach nourishment, or replenishment, is the process by which sand is placed along the beach to replenish and protect the shoreline from erosion. The sand is usually dredged from an offshore source and pumped on land. It may also be acquired from a third party. This alternative is popular in other parts of the world but has hardly been used in the Caribbean because it is an expensive undertaking and because hurricanes frequent the region and has the effect of 'eating away' the new beach. For example, a case study by UNESCO (http://www.unesco.org/csi/pub/source/ero19.htm) outlined that beach nourishment has been little used in the Caribbean. Similarly, a study by the Atlantic States Marine Fisheries Commission (http://w.asmfc.org/uploads/file/beachNourishment.pdf) also indicated that beach nourishment may not be cost-effective for beaches with high erosion rates, like Negril.

Beach nourishment is advantageous because it restores and widens the recreational beach. It also retains the natural appearance of the beach. This option however has many disadvantages including the fact that:

- The sand often erodes faster than the natural sand on the beach. Research suggests that nourished beaches erode two or three times faster than natural beaches, but this rate can vary for our project area in Negril. Nourished beaches are also susceptible to storm events and our study in climate change has shown that the frequency and magnitude of storm events impacting our project area is expected to increase over the next 50 years.
- This activity is expensive and must be repeated periodically.
- The beach turns into a construction zone during nourishment.

The sand used to nourish the beach must have similar sediment properties to the native sand. This limits the possible sources of sand.

Our analysis has revealed that 95% (5.9km) of the Long Bay beach is in erosion mode. The most vulnerable sections are the central and northern sections with erosion widths averaging 27m. If this area of the beach was to be replenished to an additional depth of 0.5m then 796,500 m3 of sand would be required. It costs approximately 25 – 40 USD per cubic metre to dredge nearshore for beach nourishment and costs approximately 120 – 150 USD per cubic metre to acquire the sand from a third party source such as the Bahamas. It will therefore cost approximately 19,900,000 – 31,900,000 USD for dredging nearshore and 95,600,000 – 119,500,000 USD from a third party source. This would be a one off nourishment cost; additional resources would be needed to replenish the beach following a severe storm event.

The material costs for the proposed project is approximately 4,400,000 USD. The beach nourishment alternative is not recommended for protecting and stabilising the Long Bay shoreline as it will cost at least four times the proposed project and will not be as stable (exposed to storms/hurricanes).

## 10.8 ALTERNATIVE 8 - HYBRID ALTERNATIVE

This alternative combines the Project as proposed (whereby the Southern breakwater is 417m and the Northern breakwater is 517m) with the South Negril River as the staging area, accompanied by the desilting of the mouth of the River and dredging of a small channel so that fisherfolk would still have access to the sea.

## 10.9 ALTERNATIVE 9 - SOUTH NEGRIL RIVER DESILTING OPTIONS

There are two options for this alternative:

1. Desilting the shallowest sections of the South Negril River mouth as opposed to the entire river mouth. This would decrease any potential likelihood of the desiccation of the morass. However, the area needed to accommodate the barge may not be enough if only the shallowest sections are dredged. This would result in having to source material elsewhere which would increase the overall cost of the Project.
2. Desilting the mouth of the South Negril River. In addition, a small channel will also be dredged so that fishermen still have access to the sea and the hydraulics of the river is minimally affected. This option is preferred because it will allow for the construction of the breakwaters to take place without any additional cost and without hindering the livelihood of the fisher folk.

It was subsequently decided by the client that there would be no desilting as the issues that may arise in this option were beyond the scope the engineering study and the alternative involving importing the material from land based sources would be pursued.

Dredging was included the original proposal; however this has been changed and there will no longer be dredging of any section of the river. Instead, material will be sourced from licenced quarries for the creation of the stockpile area.

## 10.10 ALTERNATIVE 10 – CORAL AND SPONGE RELOCATION

The nature of hardness of the substrate combined with the small size and fragility of the majority of coral colonies located in this area make these colonies less than suitable for relocation. The tools necessary; the potential negative impact to both the surrounding environment and the relocation site; the high wave energy in shallow water environments (which makes it easy to dislodge newly relocated colonies); the potential smothering of small colonies by rapidly growing macroalgae; the expense of relocation activities; all combine to suggest that not all corals potentially impacted by the project should be relocated. A Natural Resource Valuation (NRV) should be conducted in order to guide the process of what should be relocated and a cost benefit analysis provided. Instead of relocating all coral colonies we suggest that findings of the Natural Resource Valuation (NRV) be used to determine the value of this area and as such how much the client should put towards management of the area instead of the relocation activities. By funding the management of the area, there should be an overall improvement in the remaining natural environment, which is unlikely if left unmanaged.

It is our opinion that coral and sponge colonies growing on the pavement should not be relocated.

# 11.0 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) Traffic
5) Maritime Operations
6) Solid Waste Generation and Disposal
7) Sewage Generation and Disposal
8) Equipment Maintenance
9) Health and Safety

## 11.1 PHASED RECOMMENDATIONS

### 11.1.1 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.

### 11.1.2 Construction Phase

- Daily inspection of site preparation activities to ensure that they are following the proposed plan. Check and balance can be provided by NEPA.
  Person(s) appointed by NWA may perform this exercise.
- Undertake weekly water quality monitoring or a frequency agreed to with NEPA to ensure that the construction works 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.
- 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 cleared areas, 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 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 an d 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.
- Any relocated coral colony should be monitored weekly or a frequency agreed to with NEPA, using several different methods, including the establishment of permanent transects both within relocation sites and in a control reef area:

  1) Permanent Transects:
     a. Steel pegs should be used as permanent markers at the start and end of each 50m transect line, and should also be mapped with a GPS.
     b. 1x1m photo quadrats should be used along the line.
  c. Each photo should be analysed using Coral Point Count (CPCe).
  2) Photo Inventory and Roving Surveys:

3) Fish Surveys:
    - The fish component of the AGRRA survey should be conducted.
4) General Parameters:
   Physicochemical water quality parameters, including but not limited to Temperature, pH, Light Irradiance, Salinity and Turbidity should be obtained both within and outside of each relocation site using a Hydrolab DS-5 water quality multiprobe.
6) To monitor the potential sediment impact from construction activities on the marine environment, one sediment trap should be deployed at each of the relocated 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.

### 11.1.3 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.
- Any relocated coral colony should continue to be monitored, using the different methods. At the end of the construction phase and during operation, coral and fish assessments should be conducted quarterly for a minimum of five years.
- Beach profile monitoring should be done at least quarterly after construction. In order to have a baseline, pre-construction summer and winter profiles should be undertaken as well. IN order to facilitate this monitoring, permanent markers should be put in place. Grain size and constituent monitoring should also be done at least annually, at the target areas and areas immediately outside the target areas.

## 11.2 REPORTING REQUIREMENTS

### 11.2.1 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 two (2) 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.

### 11.2.2 Relocated Coral (if any)

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
3) Where possible Algae will be identified and categorised (fleshy, calcareous and cyanobacteria.
4) General Substrate Composition
5) The substrate type will also be identified (sand, pavement rock etc.)
6) *Diadema sp.* Counts
7) Fish counts, species and size classes
8) Presence of fish nets, pots, spearfishers, invasive and rare species.
9) 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 two (2) weeks of testing being completed to NEPA.

Reports will be maintained on file for a minimum of three years.Public Participation and Consultation

In order to facilitate consultation with the public, assistance in coordinating the review of the EIA by constantly communicating with NEPA and in distribution of the report to relevant government agencies and stakeholders, will be provided as required by NEPA.

One (1) Public Presentation will be 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 EIS report.

Regular contact with the Client and the National Environmental Planning Agency (NEPA), and other involved regulatory agencies will be maintained so as to ensure that all problems are rectified as quickly as possible in an environmentally sound manner. Additionally, CL Environmental will represent the Client at meetings with NEPA and other relevant Government bodies as necessary.

To date, public consultation has included a perception survey (community, watersports operators, fishers, tourists and shops/stalls/ mobile), stakeholder meeting and focus group meetings (see section 6.3.5).

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# 13.0 APPENDICES

# Appendix 1 – Terms of Reference

**Terms of Reference for Environmental Impact Assessment for the Construction of Two Breakwaters at Long Bay, Negril 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) Project Rationale
4) Description of the proposed project in detail
5) Complete description of the existing sites proposed for deployment
6) Policies, Legislation and Regulations relevant to the project
7) Identification and assessment of the potential direct, indirect, cumulative, positive and negative environmental impacts
8) Identification of proposed mitigation measures
9) Assessment of public perception of the proposed development
10) Conclusions
11) List of References
12) Glossary of Technical Terms
13) Appendices (should include reference documents, maps, photographs, data tables, the composition [i.e. the name and qualification] of team that undertook the assessment, notes of public consultation sessions, sample of instruments used in community surveys, etc.)

**1.0 Introduction**

The Introduction should give a background; explain the need for, and the context of the project. It should also seek to clearly indicate why these sites were chosen, referencing any previous studies done to inform the selected site.

**2.0 Project Brief**

The Project Brief should give a summary of the project activities, including site location maps and project timelines.

**3.0 Project Description**

This section should provide:

- 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)
- Site maps with GPS coordinates, where appropriate, illustrating areas to be developed and areas to be preserved in their existing state
- A comprehensive description of all aspects of the project noting areas for modification (construction, 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

modified sediment transport, current speed, wave and current patterns and the expected impact on the Negril coastline; seagrass, coral and invertebrate relocation

- Details of the breakwaters to be constructed, including proposed layout, detailed engineering drawings showing dimensions, cross sections, weight or size of the boulders and other material required for the breakwater construction
- Proposed source(s) of the material to be used in the works (Identification of potential source of suitable material for the construction of the breakwaters including quarry sites and transportation methods and routes)
- Details of the methods and equipment to be employed to undertake each aspect of the project including mobilization, construction, transportation of construction materials, disposal of leftover materials, storage of material and secondary activities such as refueling of vessels/equipment
- Details of any required decommissioning and abandonment of the works and/or facilities

## 4.0 Description of the 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:

### 4.1 Physical Environment

- Baseline water quality data which should include but not be limited to Photosynthetically Active Radiation (PAR), temperature, faecal coliform, chlorophyll A, pH, turbidity, Total Suspended Solids (TSS), salinity, hydrocarbons, Biological Oxygen Demand (BOD) and Dissolved Oxygen (DO).
- Bathymetry of the proposed project site and surrounding areas
- Obvious sources of existing pollution and extent of contamination
- Current circulatory patterns
- Existing sedimentary deposition patterns and forces

### 4.2 Biological Environment

- Detailed description of the flora and fauna present at the impact site with special emphasis on rare, threatened, endangered, endemic, protected, invasive and economically important species
- Identification and description of the different ecosystem types and structure including species dominance, dependence and diversity, habitat specificity and community structure
- Possible loss of biological resources or habitat fragmentation
- Quantifying the types and amount of species that may require relocation

### 4.3 Socio-Economic

- Assessment of the public's perception of the project
- Assessment of the present and proposed uses at site and areas expected to be impacted by the work
- Assessment of the expected impacts on current users – including fishermen, hoteliers, water sports operators, beach goers, etc – of the areas identified above, during and post development

- Assessment of all dislocation occasioned by the works and the projected duration of each

**5.0 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, Natural Resources (Marine Parks) Regulations, Wild Life Protection Act, Town and Country Planning Act, Harbours Act and the Fishing Industry Act and appropriate international conventions/protocols/treaties, where applicable.

**6.0 Identification and Assessment/Analysis of Potential Impacts**

This section should detail all significant potential environmental, health, safety and socio-economic impacts that may arise as a result of the development (during construction and post construction). 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:

- Results of physical modeling to support the design (inclusive of proposed tolerances) and placement of the proposed structures
- Loss of biodiversity at all proposed impacted sites
- Quantifying the types and amount of species that may require relocation
- Loss of ecosystem functions as a result of habitat loss and fragmentation
- Pollution and disturbance of the marine environment as a result of incidents with equipment or vessels, etc.; increased turbidity; removal and relocation of marine resources including seagrass or corals; and contamination or clearance of storage sites
- Changes in the sediment transport, wave patterns and coastline dynamics – including flushing/water exchange in the area and erosion, and accretion of sediments along the coast
- Loss of naturally significant features
- Socio-economic and cultural impacts including impacts on existing activities at the site and the surrounding areas
- Social impacts such as the possible impacts on public health and safety, workers health and welfare

**7.0 Mitigation**

This section should provide practical solutions for avoiding, reducing and compensating (eg. Restoration, rehabilitation and relocation) for any identified impacts, including the proposed timeline for the implementation 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, diagrams and GPS coordinates should be used to illustrate areas where mitigation measures are proposed to be implemented.

**8.0 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:

- Conducted at an appropriate location agreed to by the National Environment and Planning Agency (NEPA)
- Held in accordance with the NEPA's Guidelines for Conducting Public Presentations available on the Agency's website (www.nepa.gov.jm)

***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 appendices 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, Ph.D. , CIEC (Project Manager/Team Leader & Noise)
  - Matthew Lee, M.Sc. (Noise, Dust, Social Survey, Water Quality)
  - Kristoffer Lue, M.Phil. (Water Quality, Benthic Survey)
  - Rachel D'Silva, M.Sc. pending (Benthic Survey, Social Survey, Water Quality)
  - Karen McIntyre, M.Sc. pending (GIS, Legislation, Human/Social Environment)
  - Tamia Harker, M.Phil. (Benthic Survey, Literature Review-Biological Environment)
  - Glen Patrick, Field Technician (Social Survey)
  - Errol Harrison, Field Technician (Noise and Dust)

- **CEAC Solutions Ltd. (Project Description, Oceanography and Coastal Geomorphology)**
  - Christopher Burgess, Team Leader, MSc. Environmental Engineering and BSc. Civil Engineering
  - Carlnenus Johnson, Coastal/ Oceanographic Engineer Assistant Support Staff, and Hydrologic Surveyor Assistant, and Certified Diver Assistant, B Eng. Civil Engineering
  - Kristoffer Freeman, Coastal/ Oceanographic Engineer Assistant Support Staff, BSc. Civil Engineering
  - Jessica Stewart, Coastal/ Oceanographic Engineer Assistant Support Staff, and Hydrologic Surveyor Assistant, BSc. Civil Engineering
  - Marc Henry, CAD Technician, Hydrologic Surveyor Assistant, and Certified Diver Assistant, Certificate, Advance AutoCAD

- **Associates/ Consultants**
  - Marlene Attzs, Ph.D (Focus Groups and Socio-economic Questionnaires)
  - Myrna Ellis, M.Sc. (Focus Groups)
  - Emma Ranston, Ph.D (Phytoplankton Assessment)
  - University Interns (Social Survey): Kimani Kitson-Walters, Achsah Mitchell, Tamarah Campbell, Kevin White, Jordon Levy, Randel Wilson, Amanda Channer, Naomi Ramsey
  - Edward Downer (Benthic Survey, Water Quality)

## *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 – Public Presentation Attendance List

**PUBLIC PRESENTATION**
**ENVIRONMENTAL IMPACT ASSESSMENT**
**NEGRIL BREAKWATER**
**JULY 29, 2014**
**NEGRIL COMMUNITY CENTRE**
**COMMENCING AT 3:30PM**

| NAME | ORGANIZATION | CONTACT NO./EMAIL |
|---|---|---|
| Leonard Shaw | P.DC DAC CDC | 364-7166 4463064 |
| D R Foote | Foote Print | 9574300 |
| HARTLEY PERRIN | CUSTOS | 372-4070 |
| SEAN TOWNSEND | U.D.C (Kingston) | 420-3868 |
| [illegible] Clayton | NEPT/NCRPS | 4245503 |
| Sean Renford | N.C.R.P.S | 408 0758 |
| Sasha-Gae Nichols-Johnson | Couples Negril | 484-9542 |
| Christopher Hamilton | Port Authority of Ja | 322-4676 |
| BARRY J. HUGHES | NEGRIL TRAIL GUIDE | 383-5996 |
| ADRIAN HARRISON | JAMAICA TOURIST BOARD | 564-0919 aharrison@visitjamaica.co |
| Elecia Myers | Ministry of Tourism & Ente. | elecia.myers@mot.gov.jm |
| Rose Perrin Greenwood | NRCA | 2763657 |
| Patrice Gilpin | NEPA | patrice.gilpin@nepa.gov.jm |
| Teisha Rattham | PIOJ | tsrattham@pioj.gov.jm |
| Allan Hamilton | NEPA | allan.hamilton@nepa.gov.jm |
| DAVID Clarke | NWA Westmoreland | davidClarke@nwa.gov.jm |
| [illegible] Vaughan | NEPA | 379-1049 |
| H C ENTWISTLE | OUR PASTIME | 392 4127 |
| K ENTWISTLE | — | — " — |
| Alexander Mann | Hanover Parish Council | 564 0716 |
| CHERRON BAGGOO | Resident | 4529139 |
| Allecia James | Craft Market | 416-9328 |
| Aisha Bedasse | NEPA | 754-7540 ext 2162 |
| Donna Malahoo | DIAC | malahoo-donna@yahoo.com 573-5846 |
| FORMIER BRUNO | BRUNO'S DENTAL LAB | 2239271 |
| Carey Green | Bruno's Dental Lab | 3670471 |
| Konrad MALCOLM | COUPLES RESORTS | 845-4297 |
| Evangeline Clee | | 842-8143 |
| NATALIE SMITH | TPDCo | 297-1484 |
| Winnifred Grant | TPDCo | 440 8786 |
| Renelle Aarons-Morgan | MoFP | 932-5453 |
| Karl Chin | MOFP | 9325465 |
| Edward Thompson | Resident | |
| Coswell Leroy | | |
| Thelma Titus | Resident | 482-8717 |
| Answord Titus | Farmer | |

| | | |
|---|---|---|
| Ben Lanigan | Couples Swept Away | csa.gm@couples.com |
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GOJ Adaptation Fund Programme Component 1- Enhancing the Resilience of the Negril Coastline
EIA Consultation
Negril Community Centre
29 July 2014

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EIA Consultation
Negril Community Centre
29 July 2014

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| Linda Williams | | 346-0333 | | Linda Williams |
| Gerry Montgomery | Resident | 295-4939 | | [signature] |
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GOJ Adaptation Fund Programme Component 1- Enhancing the Resilience of the Negril Coastline
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Negril Community Centre
29 July 2014

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| ANTHONY DAVIS | CITIZEN | 440-2890 | see above | A DAVIS |
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| Roland Hayle | ODPEM | 844-4792 | rashayle-1@yahoo.com | [signature] |
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Negril Community Centre
29 July 2014

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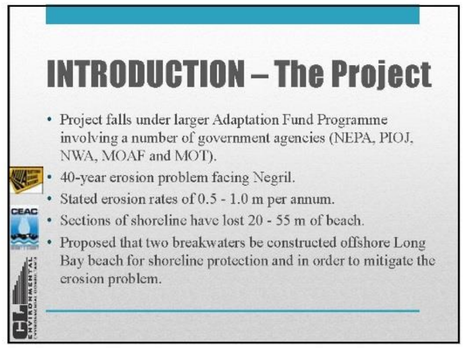
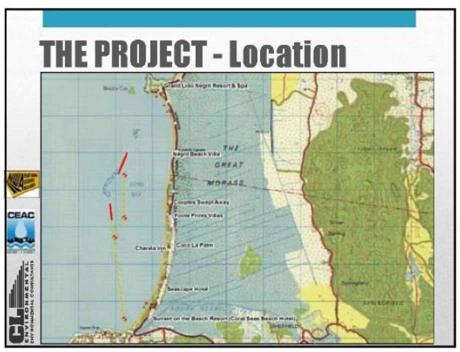
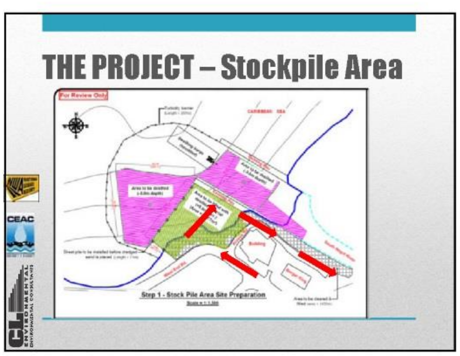
# *Appendix 5 –Presentation given at Public Meeting*

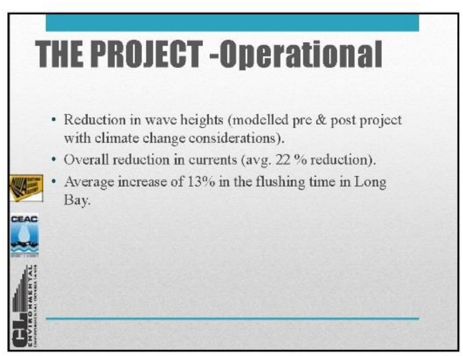
28/07/2014



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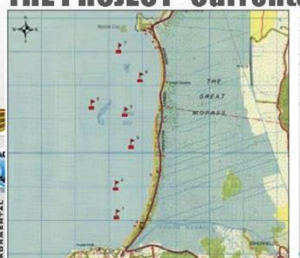
28/07/2014

## THE PROJECT -Currents



Locations within Long Bay where model predicted tides were checked for differences in current speeds between pre and post construction scenarios

| Location | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Average |
|---|---|---|---|---|---|---|---|---|
| Change | 2.8% | -13.2% | -105.8% | -17.6% | -0.3% | -3.0% | -17.0% | -22.0% |

## WATER QUALITY

- 18 locations sampled in Long Bay on three (3) occasions.
- *In situ* measurements and whole water samples collected.
  - Temperature, SpC., salinity, pH, DO, TDS, turbidity
- Water samples analysed for BOD, COD, TSS, $NO_3$, $PO_4$, FOG and F. coliform.

## WATER QUALITY STATIONS

## WATER QUALITY - Observations

- Temp., salinity, SpC, pH and TDS showed little variation.
- South Negril River appears to be a source of freshwater bringing nutrients and organic material into the Bay
- Nutrient levels generally above standards with elevated pockets at the extremes (SNR area, the northern end) and middle of the Bay.
- F. coliform levels were within standards at most areas (<13MPN/100ml). However, high levels observed near the extremes and middle of the Bay.

## PHYTOPLANKTON COMMUNITY - Method

- Whole water samples collected at 18 stations using a Niskin bottle at different depths.
- Analysis of the samples included:
  - Counting and identification using a microscope
  - Calculation of species densities
  - Assessing chlorophyll *a* concentration

## PHYTOPLANKTON COMMUNITY - Observations

- Diverse (124 species) but dominated by small diatom species (78 species).
- Abundance ($\leq 2.26 \times 10^4$ $L^{-1}$) and biomass ($\leq$ 0.7 mgChl.a $m^3$) are low.
- Suggests water quality is mesotrophic (moderate nutrient levels).

28/07/2014

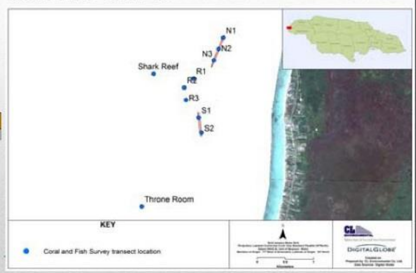
## THE BENTHIC COMMUNITY

- Breakwater footprints are located in the pavement zone.
- Area dominated by macroalgae.
- Hard coral size, diversity and numbers are very low.
- Area affected by overfishing.

## BENTHIC SURVEY - Methods

- Sampled along100m long transect line using a 0.5m² photo quadrat.
- Pictures were taken every metre along the line and analysed using CPCE.
- Manual hard coral counts were also done for transects in the breakwater footprint.
- Transect line surveys conducted:
  - 3 in the Northern Breakwater
  - 2 in the Southern Breakwater
  - 3 along the Forereef (between the breakwaters)
  - 1 at each dive site (Shark reef and Throne room)

## SURVEY SITES




## BREAKWATER FOOTPRINT

### Pavement Community

- A Pavement community is flat, with low-relief, solid carbonate rock with little or no fine-scale rugosity.
- Covered with a thin sand veneer and also colonized with algae, hard coral, gorgonians or other sessile organisms; dense enough to partially obscure the underlying surface.

## PAVEMENT COMMUNITY

- Negril's has a typical pavement.
- Hard coral community dominated by small encrusting colonies of *Siderastrea sp.* and *Favid sp.*
- Most sessile species have an encrusting growth form or holdfast (sponges, soft and hard coral).

**Estimated Total Hard Coral Colonies in the Footprint**

| SIZE CLASS (cm) | NORTH BW | SOUTH BW |
|---|---|---|
| <5 | 123,120 | 60,648 |
| 5<Coral<10 | 19,440 | 2,016 |
| >10 | 10,320 | 1,512 |

## CORAL COMMUNITY

- Screen shot of a typical transect photo.
- No readily visible coral colonies.

Magnified view
- 4 colonies identified.
- *Siderastrea sp.*
- Encrusting growth form

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## CORAL COMMUNITY

- The CPCE analysis indicates a coral community with a ≤1% hard coral cover in both breakwater footprints.
- Manual counts were needed to clearly illustrate the hard coral community.
- The Forereef has low relief and is dominated by macroalgae.
- Shark Reef and Throne Room, both have more structure and coral diversity but are also dominated by macroalgae.
- Both dive sites are also deeper than the breakwater and Forereef areas.

## CORAL COMMUNITY

- Conditions for relocation not ideal.
  - Relocation of encrusting morphologies is unlikely to be effective.
  - Relocating corals in shallow water/high wave climate makes detachment likely.
  - Relocation can be expensive.
- Management of the area and fishery will offer greater benefits to the benthic community.

## CORAL COMMUNITY – Sharks Reef and Throne Room



## Coral Community - Reef crest and Forereef

- Coral community is slightly more diverse.
- Endangered *A.palmata* colonies observed.
- Bordered by dense healthy seagrass beds.
- Slightly more structure than breakwater areas but relief, diversity and coral cover are still low.
- Area dominated by macroalgae.


## REEF CREST/FOREREEF



## REEF CREST, BACKREEF AND LAGOON

- Reef area appears to be typical of shallow crest reefs on the North Coast.
  - Dominated by turfs and macroalgae.
  - Patch reefs.
  - Larger colonies and more diverse than areas outside.
- Lagoon –behind the natural reef.
  - Large healthy beds.
  - Dominated by *Thalassia* but several sections of the larger beds are mixed with *Syringodium.*

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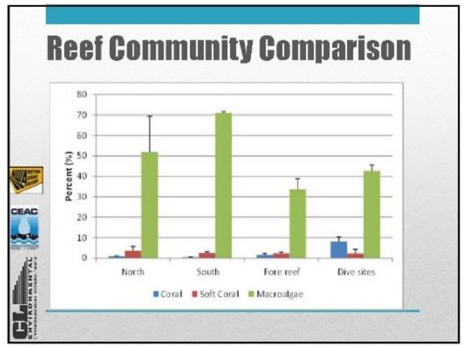
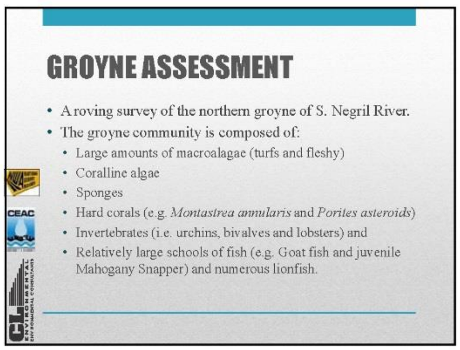
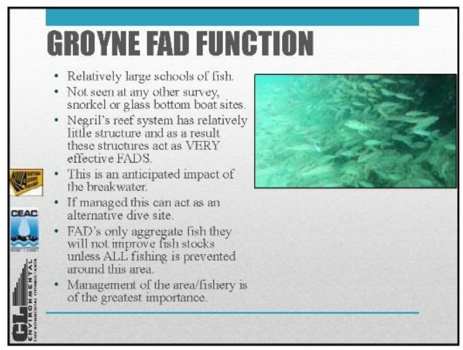
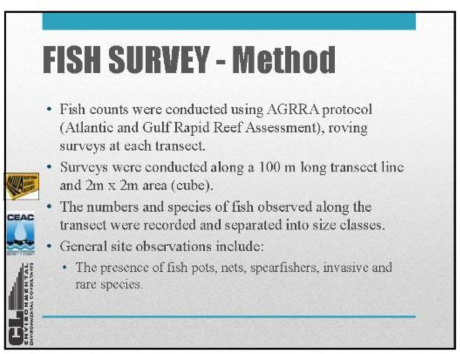
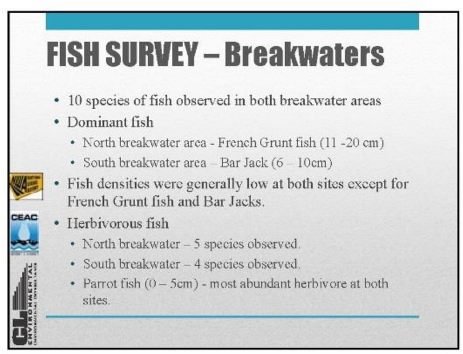
SEAGRASS BEDS- Backreef


Reef Community Comparison
Percent (%)
0
10
20
30
40
50
60
70
80
North
South
Fore reef
Dive sites
Coral
Soft Coral
Macroalgae


GROYNE ASSESSMENT
• A roving survey of the northern groyne of S. Negril River.
• The groyne community is composed of:
• Large amounts of macroalagae (turfs and fleshy)
• Coralline algae
• Sponges
• Hard corals (e.g. Montastrea annularis and Porites asteroids)
• Invertebrates (i.e. urchins, bivalves and lobsters) and
• Relatively large schools of fish (e.g. Goat fish and juvenile Mahogany Snapper) and numerous lionfish.


GROYNE FAD FUNCTION
• Relatively large schools of fish.
• Not seen at any other survey, snorkel or glass bottom boat sites.
• Negril's reef system has relatively little structure and as a result these structures act as VERY effective FADS.
• This is an anticipated impact of the breakwater.
• If managed this can act as an alternative dive site.
• FAD's only aggregate fish they will not improve fish stocks unless ALL fishing is prevented around this area.
• Management of the area/fishery is of the greatest importance.


FISH SURVEY - Method
• Fish counts were conducted using AGRRA protocol (Atlantic and Gulf Rapid Reef Assessment), roving surveys at each transect.
• Surveys were conducted along a 100 m long transect line and 2m x 2m area (cube).
• The numbers and species of fish observed along the transect were recorded and separated into size classes.
• General site observations include:
• The presence of fish pots, nets, spearfishers, invasive and rare species.


FISH SURVEY – Breakwaters
• 10 species of fish observed in both breakwater areas
• Dominant fish
• North breakwater area - French Grunt fish (11 -20 cm)
• South breakwater area – Bar Jack (6 – 10cm)
• Fish densities were generally low at both sites except for French Grunt fish and Bar Jacks.
• Herbivorous fish
• North breakwater – 5 species observed.
• South breakwater – 4 species observed.
• Parrot fish (0 – 5cm) - most abundant herbivore at both sites.

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## FISH SURVEY – Forereef

- Herbivorous fish – 5 species observed.
  - Parrotfish (0-5 cm) – dominant species.
- Lionfish (6-10 cm) were observed, but in low numbers.
- Species richness of the forereef was higher than the breakwater areas.
- Moderate species diversity with 17 species observed.

## FISH SURVEY – Dive sites

- The recreational dive sites, Throne Room and Shark Reef, showed highest density and diversity.
- Dominated by Parrotfish, Damselfish and *Chromis spp*.
- Majority of fish were found within the smaller size classes with very few being larger than 11-20 cm.
- Herbivorous fish
  - Throne room – 7 species observed: Parrot fish most abundant.
  - Sharkreef – 8 species observed: Damsel fish most dominant.

## Social Survey Summary

## MAP OF SOCIAL SURVEY AREA

- SIA 4 km buffer

## HUMAN AND SOCIAL SURVEY

- The SIA traverses two parishes: Hanover in the northern section and Westmoreland in the southern.
- Encompasses sections of communities:
  - Orange Bay.
  - Negril.
  - Sheffield.
  - Whitehall; and
  - Westland (colloquially known as "West End").

## HUMAN AND SOCIAL SURVEY

- Approx. 3,674 persons within SIA (2001).
- Approx.4,509 persons within SIA (2011).
- Based growth rate (2.07% per annum - 2001 - 2011) at the time of this study (2013), the population was approximately 4,698 persons.
- Expected to reach 7,840 persons over the next twenty five years.

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## TOURISM

- Negril accounted for 20.9% of the stopover arrivals for 2012.
- The third most visited resort area in the island.
- Negril has a total of 5,350 rooms, which represents 25.5% of all rooms in Jamaica.
- Hotel room occupancy was 61.3% in 2012, which shows an increase of 2.8% from 2011.
- Negril with 9,365 direct jobs, accounted for 26.6% of employment in the accommodation sector.
- It is estimated that 18,730 jobs were indirectly generated or induced in 2012 in Negril from tourism.

## SOCIAL SURVEY

- Two techniques were used:
- Survey instrument (questionnaires)
  - 355 questionnaires administered (Jan 30 -31 and Feb 1, 2014)
    - 224 Community
    - 22 Watersports Operators
    - 18 Fishers
    - 65 Tourists
    - 26 Retail and other services
- Focus Groups

## COMMUNITY SURVEY

- Approx. 66.2% of persons stated that they had not noticed any environmental changes within their community.
- The others observed:
  - Temperatures changes (cooler and hotter )
  - Changes in rainfall (more as well as drought)
  - Changes in flooding (more as well as less)
  - Less burning
  - Beach erosion
  - Cutting of trees
  - Mosquito infestation
  - Polluted river from sewage and subsequent destruction of reef
  - Urbanization
  - Littering

## COMMUNITY SURVEY

- Specific to Long Bay, some of the problems stated to affect Long Bay include:
  - Odour problems
  - Garbage on roads, in river and on beach
  - Destruction of marine life
  - Removal of mangroves
  - Poor road conditions
  - Blockage of river with sand
  - Seaweed on beach
  - Burning of garbage in sink holes
  - Problems with sewage system
  - Building of hotels on beachfront
  - Beach erosion and flooding

## COMMUNITY SURVEY

- Most persons (89.7%) were not aware of the plans to construct a breakwater.
- The majority (81.8%) did not have any concerns regarding the project.
- Those that had concerns (18.2%) expressed:
  - The effect on recreational activity of children at breakwater site
  - Effect on businesses and possible work opportunities
  - Effect on fishing activities and possible harm to fish populations and reefs
  - Effects on appearance of beach during construction
  - Effects on tax
  - Duration of construction phase and maintenance programme during operation
  - Safety
  - Effect on tourism, beach use and boat traffic.
  - Breakwaters wouldn't work and that the project is a waste of time and money.

## COMMUNITY SURVEY

- 94.5% of residents interviewed believed that the breakwaters are needed in Long Bay.
- When asked about the construction possibly causing negative impact on businesses, the majority (82.7%) believed that there would be no affect.
- 72% expressed that the construction activity will not affect their income earning capacity.

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## WATERSPORT OPERATORS SURVEY

- Approx. 70% of respondents indicated that they have noticed changes in the water or environment.
- Responses given for the most significant changes varied, however beach erosion was the most stated.
- 55.6% stated that the observed changes had effects on their business.
- When asked if any of their customers indicated that they noticed similar changes, 59.1% responded in the affirmative.

## WATERSPORT OPERATORS SURVEY

- 68.2% of respondents stated that they had not lost customers as a result of the changes observed.
- 68.4% believed that the breakwaters would alleviate some of the problems in the bay.
- 47.4% had other opinions on how to protect the bay:
  - Mentioned the movement of hotels landward.
  - Fixing the sewage problem.
  - Cleaning up the communities.
  - Implementing mooring restrictions.
  - Building an artificial reef; or
  - Leaving it to natural mechanisms.

## FISHERS SURVEY

- 88.2% were aware of environmental problems.
- Changes in the environment in the past 10 years and causes for these included:
  - River pollution resulting from sewage discharged from the treatment plant.
  - Blocking of river channel owing to build up of sand,
  - Beach erosion.
  - Unhealthy appearance of reef and the reduction in fish numbers potentially caused from pollution and eggs not being laid by adults.

## TOURISM SURVEY

- 80% had visited Long Bay, Negril previously.
- 5 main activities
  - Sun bathing (60.0%)
  - Restaurants (53.8%)
  - Jogging/ walking (50.8%)
  - Swimming (46.2%)
  - Glass bottom boat tours (38.5%)
- 89.3% of tourists said that environmental quality plays an important role in choosing tourism destination.

## TOURISM SURVEY

- When asked to rate the environmental quality of Long Bay beach:
  - 54.7% rated it as "good".
  - 28.3% as "excellent".
  - 11.3% as "satisfactory".
  - 3.8% as "fair"; and
  - 1.9% as "poor".
- Problems described include:
  - Beach erosion.
  - Garbage pollution on beach and in the water.
  - Noise nuisance from jet skis.
  - Visually unpleasant beach vegetation.
  - Presence of oil in the water and reef deterioration.

## TOURISM SURVEY

- 75% were of the opinion that constructing the two breakwaters would assist in protecting the beach from erosion and its tourism products.
- 23.8% of those interviewed thought that other means could protect the bay.
- 55.6% said that they would be willing to pay additional amounts to use Long Bay beach if it is to be used for conservation efforts.

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## RETAIL AND OTHER SERVICES SURVEY

- 70.8% noticed changes in the water or the environment.
- The most significant of these were:
  - Beach erosion
  - Hotel development on the beach; and
  - Smaller fish populations.

## RETAIL AND OTHER SERVICES SURVEY ALONG LONG BAY

- 86.4% believed that the breakwaters were needed in Long Bay.
- 85.0% believed that the construction would not cause their business to have to relocate.
- 70% believed that the breakwater construction would not affect their core business.
- 50% believed that construction activities would impact their income/ livelihood.

## FOCUS GROUP DISCUSSIONS

- Four groups of stakeholders during the period March 12 and 13, 2014.
- Total of fifty-two (52) persons participated.
- The stakeholders represented among the focus groups were:
  - Environmental groups (NEPT, NEPA), one hotelier and one representative from the Negril craft-market (8 pers.)
  - Fisher folk and water sport operators (13 pers.)
  - Planning and law enforcement agencies in Negril such as the police, fire services and health department (8 pers.); and
  - Hoteliers and key personnel from the tourism industry (23 pers.)
- In addition to the above an initial meeting was held on Feb 6, 2014 with the Negril Resort Board.

## FOCUS GROUP DISCUSSIONS – TECHNICAL ISSUES

- Participants suggested the following:
  - The monitoring period proposed was insufficient.
  - Review of technical specifications; appropriateness of the location and design of the breakwater.
  - Disagreement with the major points of erosion identified in the proposed project.
  - The negative effects of dredging the river.
  - Effect of the structure on the natural flow of the ocean and sea life.
  - Aesthetics of breakwater both during construction (boulders transportation) and post construction (visual impact of boulders).

## FOCUS GROUP DISCUSSIONS – LOGISTICS ISSUES

- Concern about the ability of the trucks to manoeuvre within the designated stockpile area.
- Identified the need for indicators on or near the breakwaters to alert boaters of the physical structure.
- The appropriateness of the season - Construction of the breakwaters could indirectly interrupt the tourist season.
- Emergency procedures in case of accidents (particularly fire).
- Justification for the route chosen for transport of material and the choice of location for stockpiling area.

## FOCUS GROUP DISCUSSIONS – LOGISTICS ISSUES

- Air and noise pollution during construction (Mitigation strategies).
- Traffic congestion in the stock pile area.
- Safety concerns – particularly as trucks transport boulders in the Negril area.
- Impact of breakwater on livelihoods (snorkelling, diving, fishing, water sports).

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## DIVE SITES

## SOCIAL IMPACT ASSESSMENT – Summary Conclusions

- Main issues and concerns from survey results and focus group discussions:
  - Greater effort needs to be made by the relevant authorities to sensitize the public in Negril about the project.
  - There is a high level of awareness of the erosion problem facing the area.
  - General concerns regarding logistics and technical specifications.
  - Project alternatives or modifications were suggested.
  - The project is likely to yield benefits in terms of mitigating the erosion problem.

## PROJECT ALTERNATIVES

1. "No Action".
2. The Project as Proposed.
3. Different Breakwater Configuration.
4. Project as Proposed with different Staging Areas.
5. Proposed Project with improved aesthetics.
6. Reefball breakwater design.
7. Proposed Project with South Negril River desilting options.
8. Proposed Project with the relocation of corals and sponges.
9. Beach Nourishment.
10. Hybrid Alternative.

## IMPACT AND MITIGATION - Site Preparation & Construction

| | |
|---|---|
| **Material Storage and Equipment Operation** | • Prevent direct runoff to the marine environment and bermed.<br>• Any refuelling or repair facilities onsite should be situated on impermeable surfaces served by an oil trap, run-off collection system. |
| **Air Quality** | • Wetting of staging area and immediate surrounding roadways. Increased frequency when needed.<br>• Minimize cleared areas.<br>• Cover equipment when not in use.<br>• Wet construction materials.<br>• Use N95 respirators where necessary. |
| **Noise Pollution and Vibration Nuisance** | • Use equipment that has low noise emissions as stated by the manufacturers.<br>• Use noise reduction devices such as mufflers.<br>• Operate noise-generating equipment during regular working hours (e.g. 7 am – 7 pm).<br>• Construction workers operating equipment that generates noise should be equipped with noise protection. |

## IMPACT AND MITIGATION - Site Preparation & Construction

| | |
|---|---|
| **Water Quality /Drainage** | • A sediment basin with an oily water separator should be constructed onsite and then discharged into the river/ sea.<br>• All boulders should be properly washed.<br>• The use of silt screens/ turbidity barriers at the proposed breakwater site and staging site/ stockpile area is recommended.<br>• Monitoring of the water quality of the area should be conducted fortnightly during and after construction monthly. |

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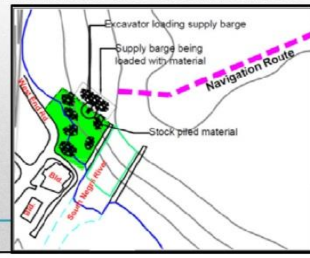
## IMPACT AND MITIGATION - Site Preparation & Construction

| | |
|---|---|
| **South Negril River** | • Desilting activities should be done in such a way so as to reduce impacts on the hydraulic dynamics of the river.<br>• A detailed hydrological study is required to identify the effects of the desilting operation on the morass (outside the scope of this project). |
| **Wastewater Generation and Disposal** | • Provide portable sanitary conveniences during construction for the workers.<br>• A ratio of approximately 25 workers per chemical toilet should be used. |
| **Road Traffic and Safety** | • Appropriate traffic management including: signage and flagmen.<br>• Ensure that the heavy vehicles traversing the roads are within the appropriate weight limits as prescribed by the NWA.<br>• A maintenance plan must be put in place to address the issue of road degradation over the construction period.<br>• Materials should be brought from the quarries during off-peak periods as much as possible. |

## IMPACT AND MITIGATION - Site Preparation & Construction




## IMPACT AND MITIGATION - Site Preparation & Construction

| | |
|---|---|
| **Maritime Operations** | • The use of marker buoys demarcating an exclusion zone.<br>• Port Authority will also have to enforce and educate users in the area, including tourists and recreational users.<br>• The Contractor must submit a detailed maritime traffic management and safety plan prior to construction phase. |
| **Pavement, Backreef and Reef Crest Communities** | • Hard and soft corals on suitable substrate (not growing on pavement) and mobile invertebrates within the footprint of the breakwater structures will have to be relocated to an area of similar conditions (light penetration, wave action and depth) where possible.<br>• In order to reduce risks to the pavement community, the following are required:<br>• Proper functioning of barge, silt screens and other equipment.<br>• All material is properly washed and suitable for placement in the marine environment.<br>• Proper safety and maritime regulations are adhered to at all times. |

## IMPACT AND MITIGATION - Site Preparation & Construction

| | |
|---|---|
| **Fish Community, Marine Mammals and Reptiles** | • Sensitisation and education of construction personnel about marine animals and reptiles including, proper procedures in the event of an interaction/incident.<br>• A spotter should be used<br>• The maritime users should be kept informed as to the operation plans for the works, times and locations. |
| **Employment** | • 50 persons will be employed directly and 75 indirectly .<br>• No mitigation required. |
| **Aesthetics** | Staging area<br>• Construction screen should be placed around the staging area.<br>Breakwaters<br>• Ensure that the barges and other equipment etc. are properly maintained.<br>• Adequate signage. |

## IMPACT AND MITIGATION - Site Preparation & Construction

| | |
|---|---|
| **Local Maritime Businesses** | • Employing a fisheries liaison officer to ensure that the concerns of the fishermen are brought to the attention of the contractors and steps are take to address these concerns.<br>• Having the barge use prescribed navigation routes.<br>• Utilizing licensed and experienced barge operators to reduce the incidence of damage to existing coastal structures.<br>• Ensuring that there is adequate presence of navigation aids for the barge operators.<br>• Proper securing mechanisms for boulder transportation.<br>• Safety and emergency management plans (include fire and oil spill contingency plans). |

## IMPACT AND MITIGATION - Site Preparation & Construction

| | |
|---|---|
| **Community Engagement** | • It is recommended that a Stakeholders Engagement Committee be established and meet at an adequate frequency.<br>• This committee should be constituted of but not be limited to:<br>1. Representatives from the community (CBO or Community Associations).<br>2. Representatives from the business community.<br>3. Representatives of the Hotel/Villa associations.<br>4. Representative of the fishing cooperation.<br>5. Representative of the water sport association.<br>6. Representative of the craft vendors association.<br>7. Representative of the local environmental group.<br>8. Representative from NEPA.<br>9. Representative of NGILAPA.<br>10. The Main Contractor.<br>11. Representatives of the Implementation Agency and Project Team. |

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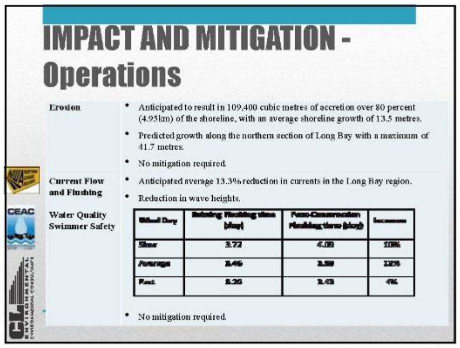
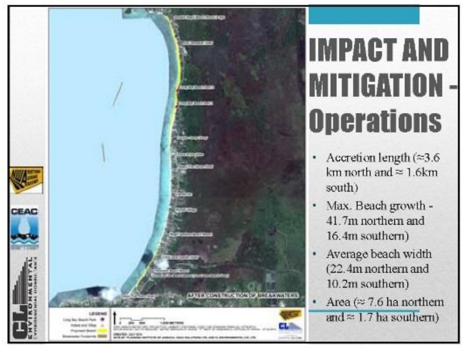
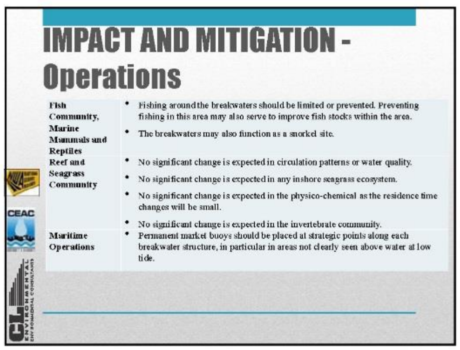
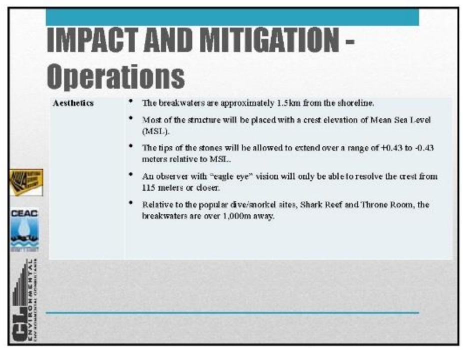
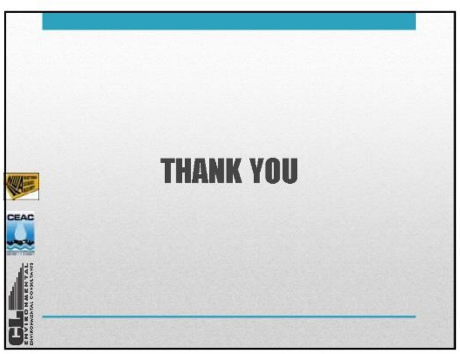

IMPACT AND MITIGATION - Operations
Erosion
• Anticipated to result in 109,400 cubic metres of accretion over 80 percent (4.95km) of the shoreline, with an average shoreline growth of 13.5 metres.
• Predicted growth along the northern section of Long Bay with a maximum of 41.7 metres.
• No mitigation required.
Current Flow and Flushing
• Anticipated average 13.3% reduction in currents in the Long Bay region.
• Reduction in wave heights.
Water Quality Swimmer Safety
• No mitigation required.
CEAC


IMPACT AND MITIGATION - Operations
• Accretion length (≈3.6 km north and ≈ 1.6km south)
• Max. Beach growth - 41.7m northern and 16.4m southern)
• Average beach width (22.4m northern and 10.2m southern)
• Area (≈ 7.6 ha northern and ≈ 1.7 ha southern)
CEAC

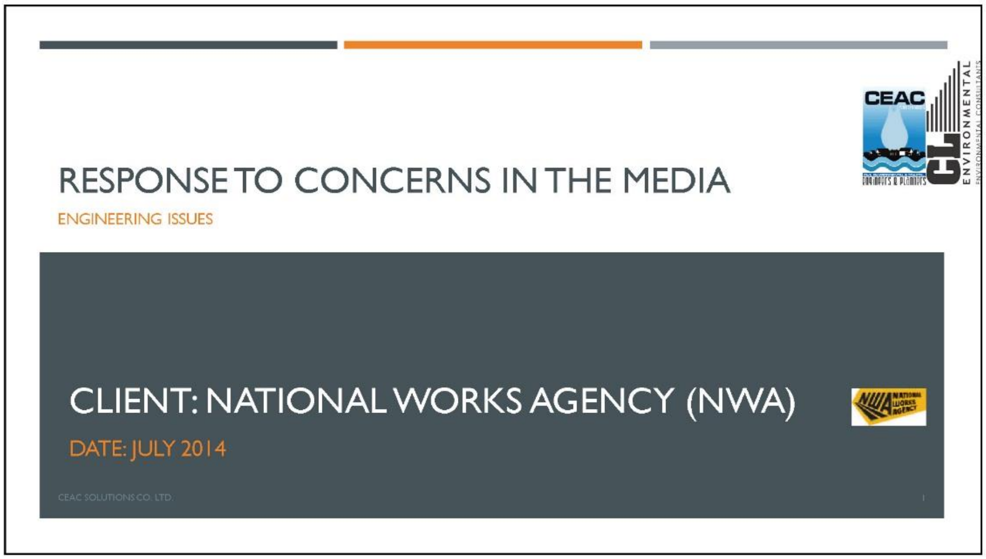

IMPACT AND MITIGATION - Operations
Fish Community, Marine Mammals and Reptiles
• Fishing around the breakwaters should be limited or prevented. Preventing fishing in this area may also serve to improve fish stocks within the area.
• The breakwaters may also function as a snorkel site.
Reef and Seagrass Community
• No significant change is expected in circulation patterns or water quality.
• No significant change is expected in any inshore seagrass ecosystem.
• No significant change is expected in the physico-chemical as the residence time changes will be small.
• No significant change is expected in the invertebrate community.
Maritime Operations
• Permanent market buoys should be placed at strategic points along each breakwater structure, in particular in areas not clearly seen above water at low tide.
CEAC

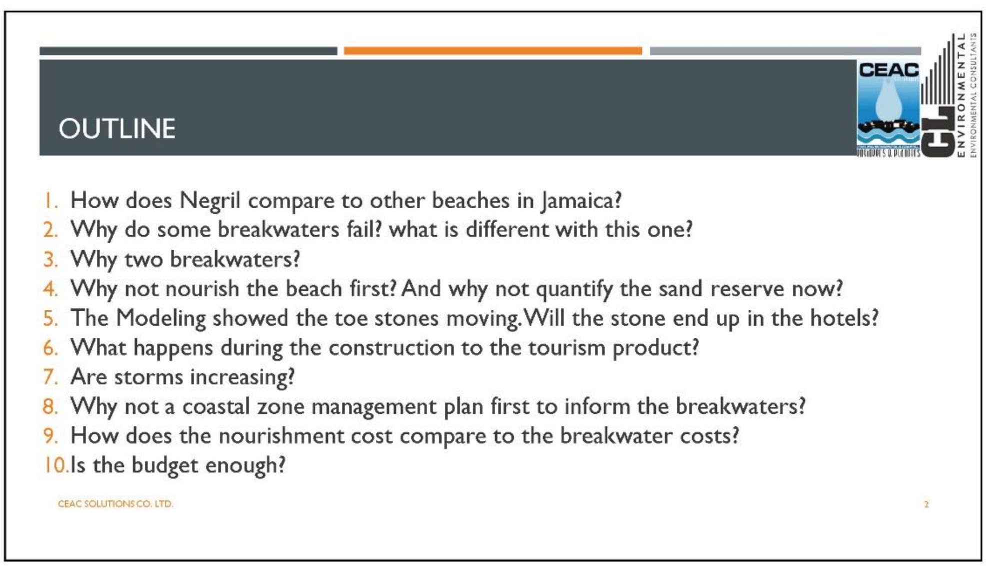

IMPACT AND MITIGATION - Operations
Aesthetics
• The breakwaters are approximately 1.5km from the shoreline.
• Most of the structure will be placed with a crest elevation of Mean Sea Level (MSL).
• The tips of the stones will be allowed to extend over a range of +0.43 to -0.43 meters relative to MSL.
• An observer with "eagle eye" vision will only be able to resolve the crest from 115 meters or closer.
• Relative to the popular dive/snorkel sites, Shark Reef and Throne Room, the breakwaters are over 1,000m away.
CEAC


THANK YOU
CEAC

## *Appendix 6 – Response to Concerns*

16/11/2014

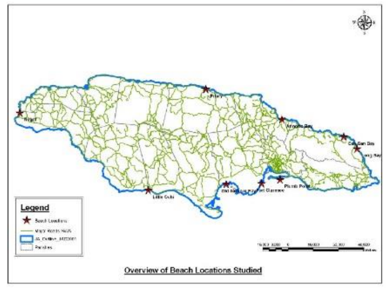


16/11/2014

## HOW DOES NEGRIL COMPARE TO OTHER BEACHES?

1. Negril is the fastest eroding beach in Jamaica at 0.6 to 0.8 meters per annum (1968 to 2010)
2. Next fast eroding beaches are:
   - Old Harbour Bay (fishing beach with 8,000 persons) at 0.74 meter per annum
   - Fort Clarence/Hellshire 0.42 meter per annum

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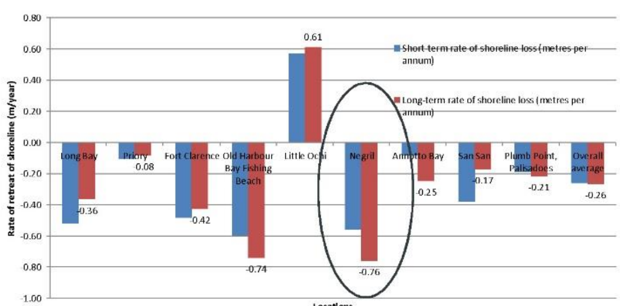
## HOW DOES NEGRIL COMPARE TO OTHER BEACHES?

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16/11/2014

## WHY SOME BREAKWATERS FAIL

Failure in most instances in the literature is defined by:

- Erosion on ends of the beach from localized current patterns
- Disruption of alongshore transport starving beach down drift
- Disruption of offshore transport starving bars and troughs that lead to more wave energy onshore.

References:

Thomalla, F., and C. E.Vincent. "Beach response to shore-parallel breakwaters at Sea Palling, Norfolk, UK." Estuarine, coastal and shelf science 56, no. 2 (2003): 203-212.

Browder, Albert E., Robert G. Dean, and Renjie Chen. "Performance of a submerged breakwater for shore protection." Coastal Engineering Proceedings 1, no. 25 (1996).

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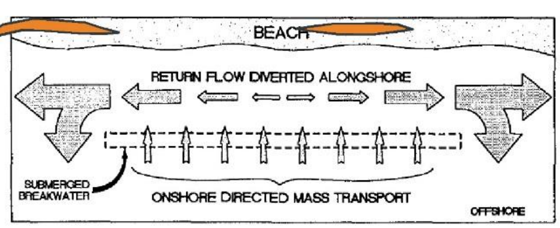
## WHY SOME BREAKWATERS FAIL

**NEARSHORE BREAKWATERS**

- Fast alongshore currents erode beach sand
- Tombolo blocks alongshore transport

**OFFSHORE BREAKWATERS**

- Negril's currents are relatively slow.
- Breakwaters far offshore (1 mile) and won't create rip currents

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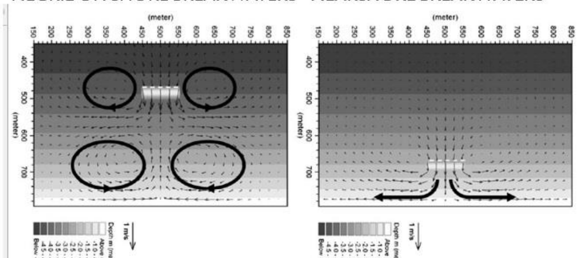
16/11/2014

## WHY SOME BREAKWATERS SUCCEED

| LATEST RESEARCH | NEGRIL |
| --- | --- |
| Two cell circulation leads to erosion. Four cell leads to accretion | ✔ |
| Wide width of water between breakwater and shoreline | ✔ |

NEGRIL OFFSHORE BREAKWATERS NEARSHORE BREAKWATERS



References:
Ranasinghe, R., Magnus Larson, and J. Savioli. "Shoreline response to a single shore-parallel submerged breakwater." Coastal Engineering 57, no. 11 (2010): 1006-1017.
Villani, Mara, Judith Bosboom, Marcel Zijlema, and Marcel JF Stive. "Circulation patterns and shoreline response induced by submerged breakwaters." Coastal Engineering Proceedings 1, no. 33 (2012): structures-25.
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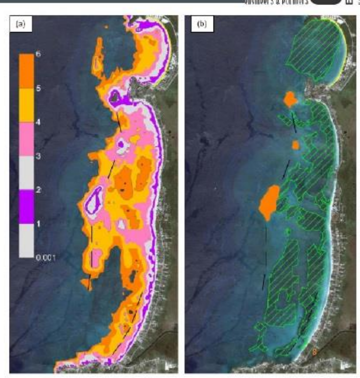
## WHY TWO BREAKWATERS?

SWIL (2007) INTERGRATED SOLUTIONS

1. Offshore breakwaters/reef extension x 5
2. Near shore breakwaters x 4
   } 9 breakwaters
3. Beach nourishment ~500,000 cubic meters
   - 30 meters in Long Bay and 20 meters in Bloody Bay



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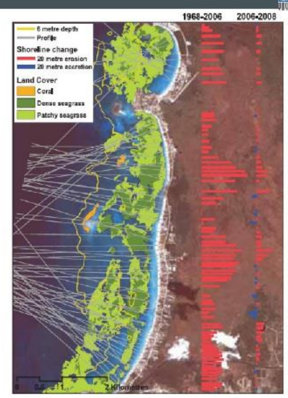
## WHY TWO BREAKWATERS?

1. Efficiency of investment: cost versus hazard x vulnerability
   - North and central more venerable and exposed (RIVAMP)
   - Reef extension focus on north and central areas is cheaper and more effective
   - North reef extension is 3 times more effective than south reef extension
2. Phasing of implementation
3. Availability of funds (~6 million USD)
4. Near shore breakwaters are not acceptable

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## WHY TWO BREAKWATERS?

1. Efficiency of investment: cost versus hazard x vulnerability
2. Phasing of implementation (SWIL 2007, Chp. 10 pg. 110)
   - ~~Phase 1 - Nearshore Breakwaters in Southern Long Bay~~ — CONSULTATIONS INDICATED THAT THIS WOULD JEAPORDIZE THE TOURISM PRODUCT AND EROSION LIKELY
   - Phase 2 - Reef Extension Structures in Central Long Bay
   - Phase 3 - Reef Extension Structures in Northern Long Bay — 50% ADDRESSED BY THIS PROJECT (Phases 2 and 3)
   - Phase 4 - Beach Nourishment in Long Bay and Bloody Bay — AFTER
3. Availability of funds (~5.2 million USD)
4. Near shore breakwaters are not acceptable

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## WHY TWO BREAKWATERS?

1. Efficiency/priorities of investment
2. Phasing of implementation
3. Availability of funds (~5 million USD)
4. Near shore breakwaters are not acceptable

| COMPONENTS OF INTEGRATED SOLUTION | SWIL COSTS (USD) | CURRENT COSTS (USD) |
|---|---|---|
| Reef extension breakwaters | ~10 million | ~ 6.8 million |
| Nearshore breakwaters | ~8 million | Not acceptable and likely to fail |
| Beach nourishment | ~6 million | no budget space |
| TOTAL | ~24 million | |

1. Project is being done in phases based on priorities and affordability
2. This is why what appears to be a USD40 million project is being done for USD 6.8 million

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## WHY NOT NOURISH THE BEACH (FIRST)?

**Because after considering best available science, previous recommendations and financial implications in a logical framework, the beach nourishment should be done after stabilization**

1. Empirical evidence: Sand is eroding gradually
2. Sediment Transport Simulations: says nourishment is unstable
3. Climate change:
   - Sea level rise of responsible for 63 to 73% of the erosion
   - Increase in wave intensity (4%) and frequency (5.2%) for hurricanes in future climate
4. Consistent with recommendations of Preliminary Engineering Report
5. Costs favour stabilization first
6. Environmental impacts of dredging and placement of nourishment

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## WHY NOT NOURISH THE BEACH (FIRST)?

1. Empirical evidence:
   - exposed conditions will erode any nourishment if near shore wave climate is not modified
   - Eroding trends of **6 to 14 meters every decade** dominant over the last 40 years (Robinson 2012, McKenzie 2012, SWIL 2007, RIVAMP 2010)
2. Sediment Transport Simulations
3. Climate change:
   - Sea level rise of responsible for 63 to 73% of the erosion
   - Increase in wave intensity (4%) and frequency (5.2%) for hurricanes in future climate
4. Consistent with recommendations of Preliminary Engineering Report
5. Long term costs higher than stabilization
6. Environmental impacts of dredging and placement

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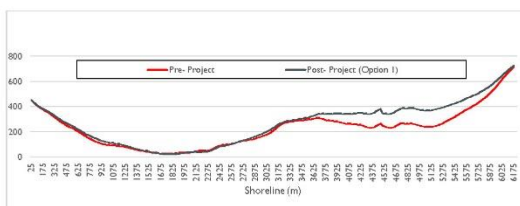
## WHY NOT NOURISH THE BEACH (FIRST)?

1. Empirical evidence:
2. Sediment Transport Simulations
   - 20 to 30 meter fill erodes within 7 to 10 years with typical storm climate.




3. Climate change:
4. Consistent with recommendations of Preliminary Engineering Report
5. Long term costs higher than stabilization
6. Environmental impacts of dredging and placement

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## WHY NOT NOURISH THE BEACH (FIRST)?

1. Empirical evidence:
2. Sediment Transport Simulations (25 to 35 meters of nourish and 7 years simulation 2006 to 2013)
   - Fill adjusts and moves south
   - Rondel to South Negril River would adjust to 40 to 60 meters wide
   - Continued erosion in north would narrow beach to 0 to 10 meters of present widths
   - Could smoother sea grass beds in south Long Bay
   - Clog South Negril river with 75 meter long groin being by-passed

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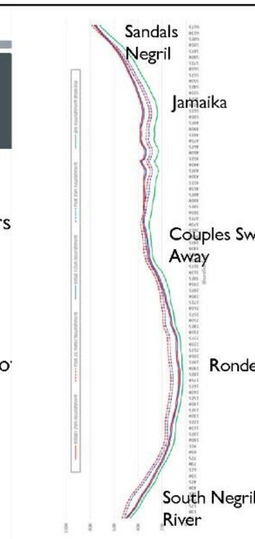


## WHY NOT NOURISH THE BEACH (FIRST)?

1. Empirical evidence:
2. Sediment Transport Simulations
3. Climate change:
   - Sea level rise of responsible for 63 to 73% of the erosion
   - Increase in wave intensity (4%) and frequency (5.2%) for hurricanes in future climate
   - Accelerating observe SLR
4. Consistent with recommendations of Preliminary Engineering Report
5. Long term costs higher than stabilization
6. Environmental impacts of dredging and placement

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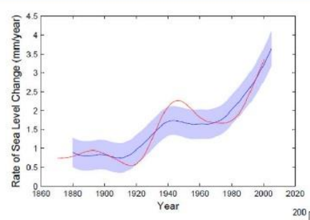
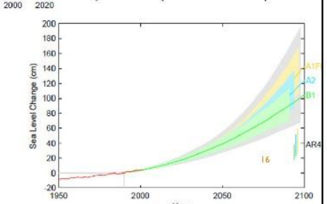



Past sea level rise rates (1880 to 2010)

Projections (2000 to 2100)



16/11/2014

## WHY NOT NOURISH THE BEACH (FIRST)?

1. Empirical evidence:
2. Sediment Transport Simulations
3. Climate change:
4. Consistent with recommendations of Preliminary Engineering Report. (Chap. 11. pg 114 )
5. Long term costs higher than stabilization
6. Environmental impacts of dredging and placement

*…Given that maintenance costs were not included in the analysis, and it is anticipated that* ***beach nourishment will require the most maintenance, the value of this alternative may be diminished.***

*….beach nourishment alone does not actually target the cause of the erosion problem. Therefore,* ***one big storm event could completely wipe out the replenished and, as wave action along the shoreline is not reduced****.*

*Therefore,* ***the integrated solution was recommended*** *for this project.*

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## WHY NOT NOURISH THE BEACH (FIRST)?

1. Empirical evidence:
2. Sediment Transport Simulations
3. Climate change:
4. Consistent with recommendations of Preliminary Engineering Report. (Chap. 11. pg 114 )
5. Long term costs higher than stabilization (SWIL estimate versus current estimate for breakwater)
6. Environmental impacts of dredging and placement

| Year | Nourishment only | Breakwaters and Nourishment |
|---|---|---|
| 2014 | 7,000,000 | 6,700,000 + 3,500,000 |
| 2021 | 7,000,000 | 6,000,000 + 2,000,000 |
| 2028 | 7,000,000 | 2,000,000 |
| 2035 | 7,000,000 | 2,000,000 |
| TOTAL | 28,000,000 | 22,200,000 |

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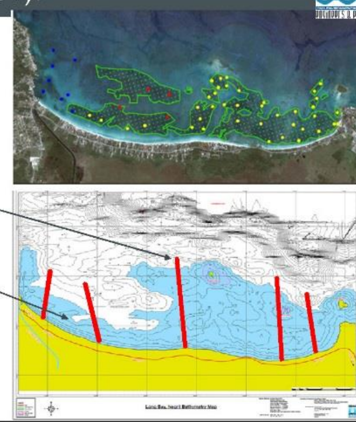
## WHY NOT NOURISH THE BEACH (FIRST)?

6. Environmental impacts of dredging and placement: Discharge pipes over sea grass beds and reef has to be carefully planned.

- Dredge pipes will have to be floated and over 800 to 1500 meters long and anchored in sea grass bed
- Shallow bathymetry will restrict loaded dredge to draft of 5 meter (very shallow for industry)
- North will be harder to nourish because of access



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## WHY NOT NOURISH THE BEACH (FIRST)?


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## WHY NOT A COASTAL ZONE MANAGEMENT PLAN FIRST

BECAUSE:

1. There is an immediate challenge (erosion) and a possible solution (ADAPTATION FUND)
2. NEPT/NEPA is working on a plan
3. The study is holistic and the breakwaters do not jeopardize an ICZM

**Integrated coastal zone management** (ICZM) is a process for the management of the coastal area using an integrated approach, in an attempt to achieve sustainability.

(Rio de Janeiro, 3-14 June 1992)
Chapter 17: Protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources.

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## WHY NOT A COASTAL ZONE MANAGEMENT PLAN FIRST?

BECAUSE:

1. There is an immediate challenge (erosion) and a possible solution (ADAPTATION FUND)
2. NEPT/NEPA is working on a plan
3. The study is holistic and the breakwaters do not prejudice an ICZM

| Dimensions of a ICZM | This Study | |
|---|---|---|
| Spatial | From Booby Cay/Bloody Bay to West End | ✔ |
| Functional | • Fisheries and water sports<br>• Water circulation, shoreline and wave climate<br>• Livelihoods | ✔ |
| Legal | All regulations considered in process.<br>Application under Beach Licence Act | ✔ |
| Policy | | |
| Knowledge | Local knowledge from: 300 interviews, ENGO, Water sports and fishermen<br>Local expert knowledge (Goreau, McKenzie, Robinson, Mondon and Warner, SWIL) | ✔ |
| Participation | One pre-EIA consultation, four stakeholder/focus group meeting, 355 surveys/questionnaires, plus public consultation | ✔ |

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## IS THE FREQUENCY OF STORMS INCREASING?

1. YES.. Strong storms
2. PRESENT:
   - CEAC observations: Both categories 4 and 5 are increasing and the south and west coast are more vulnerable.
   - Holland and Buryere (2014): proportion of Category 4 and 5 hurricanes has increased at a rate of ~25–30 % per °C of global warming
3. FUTURE:
   - Gleixner et al (2014): Frequency of strongest storms increase and weakest storms decrease
   - Consistent with present climate

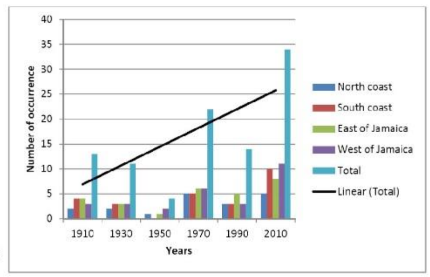


Figure 5 - Occurrences of Category 4 and 5 hurricanes that have passed within 300 kilometres of Jamaica's shoreline since 1890 to 2010, in twenty years intervals

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## WILL THE STONES MOVE (1)? WILL THEY END UP IN THE HOTELS (2)

1. Some:
   - 1 in 200 of the toe stones and 1 in 930 of the armour stone
   - Engineering guidelines applied to Negril recommend less than 1 in 14 for this structure
     - Van der Meer, et al. (1987), Vidal, C.et al. (1992).
2. No. The stones that move, will move seaward

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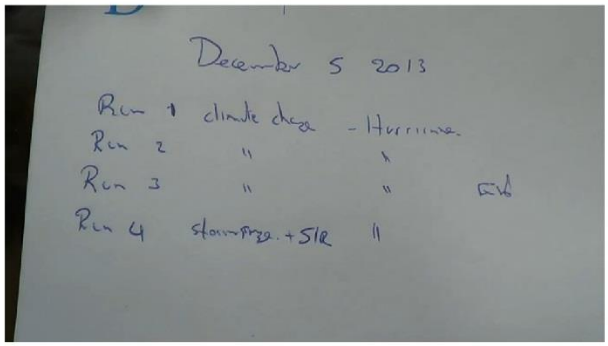
## WILL THE STONES MOVE (1)? WILL THEY END UP IN THE HOTELS (2)

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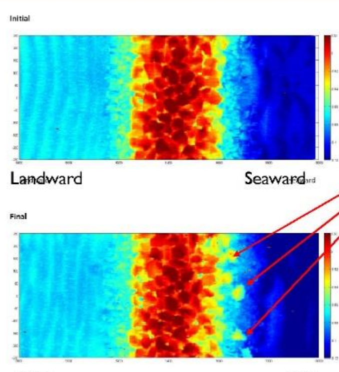
## WILL THE STONES MOVE (1)? WILL THEY END UP IN THE HOTELS (2)

Pre and post scale model measurements using lazer scan of damage after design hurricane




Seaward Movement Due To Wave Dynamics And Well Broken Waves

Packing Of Stone Critical To Ensure Success

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## HOW DOES THE NOURISHMENT COST COMPARE TO THE BREAKWATER COSTS?

1. Cost of breakwater = **USD6.7** million for phase 1
2. Cost of Nourishment @ **USD20** per cubic meters
   - 35 meters width - Comparable resilience over 7 years = **909,000** cubic meters = **USD18.2** million
   - 25 meters width – less resilience over 7 years = **695,000** cubic meters = **USD 13.9** million
3. Based on November **2013** surveys and volumetric surface analysis of **DEM**
4. NOT **USD7** million as in Preliminary Engineering report

| Year | Nourishment only | Breakwaters and Nourishment |
|---|---|---|
| 2014 | 13,900,000 | 6,700,000 + 6,000,000 |
| 2021 | 6,000,000 | 6,000,000 |
| 2028 | 6,000,000 | 3,000,000 |
| 2035 | 6,000,000 | |
| TOTAL | 31,900,000 | 21,700,000 |

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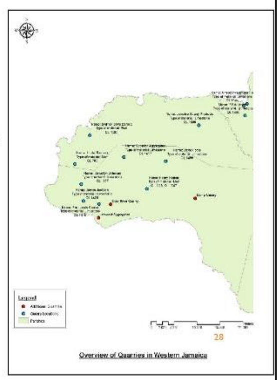
## IS THE ESTIMATE FOR THIS PHASE ENOUGH?

1. Yes
2. Estimate based on high accuracy and best practice in surveying, engineering, quantity surveying and construction engineering
   - CEAC 2013 Hydrographic survey determined a 0.4 to 0.6 meters error between previous information (2007) and professional grade surveying (2013) ~ USD0.5 million in construction cost.
   - Over ten quarries surveyed for prices and distances to transport material to site
   - Motion studies of marine equipment
   - Professionals involved the largest marine projects (USD 2 to 65 million) in Jamaica in recent times.

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## TRAFFIC DISRUPTION TO TOWN

- 28 trucks will carry stones to the stockpile site per day for nine months
- Less than 1% of the existing traffic in Negril
- Number of trucks limited by barge capacity and placement

Ref.: NWA traffic count data from 2012 and 2014

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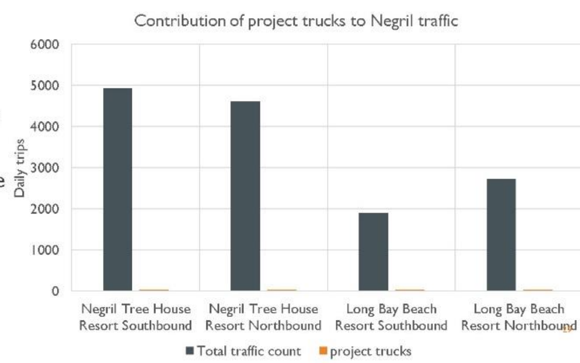


## TRAFFIC DISRUPTION TO TOWN

- Deliveries can be timed to between:
  - 11 am and 3 pm
  - 6 am to 8 am
- Outside of the
  - 8 to 9 am peaks
  - 5 to 7 pm peaks

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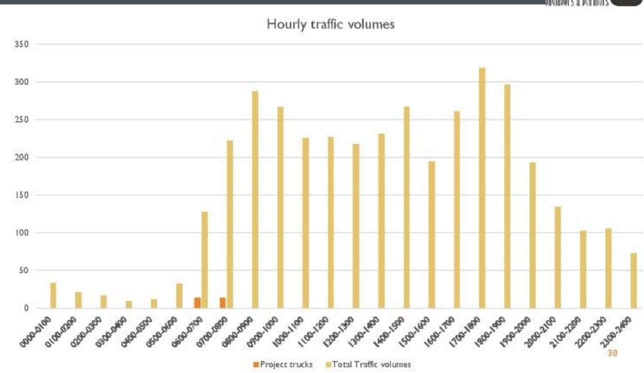

# *Appendix 7 – Letters to Land Owners affected by Stockpile Area*

NATIONAL WORKS AGENCY

140 Maxfield Avenue, Kingston 10, Jamaica Tel: (876) 926-3210-9 · Fax: (876) 926-2572

ANY REPLY OR SUBSEQUENT REFERENCE SHOULD BE ADDRESSED TO THE CHIEF EXECUTIVE OFFICER AND THE FOLLOWING REFERENCE NUMBER QUOTED:-

Ref. No.:

KMR Regional Office
15 Hagley Park Road
Kingston 10
Tel: 926-6499
929-7328, 968-1576
Fax: 929-7327

Central Regional Office
33 Caledonia Road
Mandeville, Manchester
Tel: 962-2258
Fax: 961-6172

Western Regional Office
Flankers Main Road
Flankers, St. James
Tel: 940-7387
940-4466, 979-3166
Fax: 940-7973

North Eastern Regional Office
West Street
Port Antonio
Portland
Tel: 993-2531
Fax: 993-9565

March 24, 2014.

**REF. No.: 035.01**

Mrs. Elizabeth Stair
Commissioner of Lands
National Land Agency
8 Ardenne Road,
Kingston 10.

Dear Mrs. Stair,

**NEGRIL BREAKWATERS CONTRUCTION – POTENTIAL STOCKPILE LOCATION AND ACCESS ROUTE**

With reference to the subject matter, the National Works Agency in conjunction with National Environmental and Planning Agency (NEPA) and Civil, Environmental and Coastal Engineers and Planners (CEAC) formally acknowledge and advise that we require access to enter your property for the construction of the Negril Breakwater. The prospective commencement date will be July 2014.

The property is identified as Green Island, valuation number 05505001090 approximately 2830 square metres located off Westend Road, Negril Westmoreland.

We are requesting your continued support in our efforts to complete the Negril breakwaters construction by giving us the opportunity to use this property for approximately two (2) years starting June 2014.

Thank you in advance for your attention in this matter.

Sincerely,
**NATIONAL WORKS AGENCY**

Paul Clarke (Mr.)
Property/Estate Manager

*'Developing Safe, Reliable and Quality Roads'*

NATIONAL WORKS AGENCY

140 Maxfield Avenue, Kingston 10, Jamaica Tel: (876) 926-3210-9 · Fax: (876) 926-2572

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Fax: 940-7973

North Eastern Regional Office
West Street
Port Antonio
Portland
Tel: 993-2531
Fax: 993-9665

March 24, 2014.

**REF. No.: 035.01**

Nunes Scholefield Deleon & Company
C/O John Dehmiller & Walter Byles
Westend Road,
Negril P.O.,
Westmoreland

Dear Sir/Madam,

**NEGRIL BREAKWATERS CONTRUCTION – POTENTIAL STOCKPILE LOCATION AND ACCESS ROUTE**

With reference to the subject matter, the National Works Agency in conjunction with National Environmental and Planning Agency (NEPA) and Civil, Environmental and Coastal Engineers and Planners (CEAC) formally acknowledge and advise that we require access to enter your property for the construction of the Negril Breakwater. The prospective commencement date will be July 2014.

It is against this background that a compensation package will be initiated to lease a part/whole of your property (volume 964 folio 3) once we establish that you are the rightful owner of the property.

We therefore request the following from you:

1. A copy of the Property Title or
2. Any document that will indicate ownership or rightful operation of the property.

A member of our team will contact you shortly to carry out the process of verification and negotiation.

In the Interim, we are requesting your support in our efforts to complete the Negril breakwaters construction.

Sincerely,
**NATIONAL WORKS AGENCY**

Paul Clarke (Mr.)
Property/Estate Manager (Acting)

*'Developing Safe, Reliable and Quality Roads'*

NATIONAL WORKS AGENCY

140 Maxfield Avenue, Kingston 10, Jamaica Tel: (876) 926-3210-9 · Fax: (876) 926-2572

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940-4466, 979-3166
Fax: 940-7973

North Eastern Regional Office
West Street
Port Antonio
Portland
Tel: 993-2531
Fax: 993-9665

March 24, 2014.

**REF. No.: 035.01**

Ms. Valda Ormsby
General Manager
Restaurant Associates Limited
C/O Burger King Negril,
18 Hope Road,
Kingston 10.

Dear Ms. Ormsby,

**NEGRIL BREAKWATERS CONTRUCTION – POTENTIAL STOCKPILE LOCATION AND ACCESS ROUTE**

With reference to the subject matter, the National Works Agency in conjunction with National Environmental and Planning Agency (NEPA) and Civil, Environmental and Coastal Engineers and Planners (CEAC) formally acknowledge and advise that we require access to enter your property for the construction of the Negril Breakwater. The prospective commencement date will be July 2014.

It is against this background that a compensation package will be initiated to lease a part/whole of your property (volume 1401 folio 171) once we establish that you are the rightful owner of the property.

We therefore request the following from you:

1. A copy of the Property Title or
2. Any document that will indicate ownership or rightful operation of the property.

A member of our team will contact you shortly to carry out the process of verification and negotiation.

In the Interim, we are requesting your support in our efforts to complete the Negril breakwaters construction.

Sincerely,
**NATIONAL WORKS AGENCY**

Paul Clarke (Mr.)
Property/Estate Manager (Acting)

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North Eastern
Regional Office
West Street
Port Antonio
Portland
Tel: 993-2531
Fax: 993-9665

March 24, 2014.

**REF. No.: 035.01**

East Sun Limited
First Choice Wholesale and Supermarket
Willie Belisser Boulevard,
Lucea P.O.,
Hanover.

Dear Sir/Madam,

**NEGRIL BREAKWATERS CONTRUCTION – POTENTIAL STOCKPILE LOCATION AND ACCESS ROUTE**

With reference to the subject matter, the National Works Agency in conjunction with National Environmental and Planning Agency (NEPA) and Civil, Environmental and Coastal Engineers and Planners (CEAC) formally acknowledge and advise that we require access to enter your property for the construction of the Negril Breakwater. The prospective commencement date will be July 2014.

It is against this background that a compensation package will be initiated to lease a part/whole of your property (volume 1325 folio 252) once we establish that you are the rightful owner of the property.

We therefore request the following from you:

1. A copy of the Property Title or
2. Any document that will indicate ownership or rightful operation of the property.

A member of our team will contact you shortly to carry out the process of verification and negotiation.

In the Interim, we are requesting your support in our efforts to complete the Negril breakwaters construction.

Sincerely,
**NATIONAL WORKS AGENCY**

Paul Clarke (Mr.)
Property/Estate Manager (Acting)

*'Developing Safe, Reliable and Quality Roads'*

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North Eastern
Regional Office
West Street
Port Antonio
Portland
Tel: 993-2531
Fax: 993-9665

March 24, 2014.

**REF. No.: 035.01**

Mr. Norval Dwyer
Chick Plus and Negril Spotlight Club
Housen Heights, Cedar Grove,
Mandeville P.O.,
Manchester.

Dear Mr. Dwyer,

**NEGRIL BREAKWATERS CONTRUCTION – POTENTIAL STOCKPILE LOCATION AND ACCESS ROUTE**

With reference to the subject matter, the National Works Agency in conjunction with National Environmental and Planning Agency (NEPA) and Civil, Environmental and Coastal Engineers and Planners (CEAC) formally acknowledge and advise that we require access to enter your property for the construction of the Negril Breakwater. The prospective commencement date will be July 2014.

It is against this background that a compensation package will be initiated to lease a part/whole of your property (volume 1367 folio 752) once we establish that you are the rightful owner of the property.

We therefore request the following from you:

1. A copy of the Property Title or
2. Any document that will indicate ownership or rightful operation of the property.

A member of our team will contact you shortly to carry out the process of verification and negotiation.

In the Interim, we are requesting your support in our efforts to complete the Negril breakwaters construction.

Sincerely,
**NATIONAL WORKS AGENCY**

Paul Clarke (Mr.)
Property/Estate Manager (Acting)

*'Developing Safe, Reliable and Quality Roads'*

# Appendix 8 - Hydrolab DS-5 Calibration Certificate

HACH
Hydromet

## Certificate of Instrument Performance

Agency Name: **CL Environmental**

Certification for Job# 1136954

| Part/Model Number: **DS5** | Serial Number: **100100048757** |
|---|---|

**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#): N.I.S.T. - traceable glass thermometer (H-B Thermometer, Serial **2Z9208**) and a Cole-Parmer "*PolyStat*" Constant Temperature Circulator

Environmental Conditions:

| Actual Temperature | Instrument Reading | Error |
|---|---|---|
| **10.00** °C | 10.03 °C | +**03** °C |
| **20.00** °C | 20.01 °C | +**0.01** °C |
| **30.00** °C | 29.97 °C | -**0.03** °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: J K Burton          Title: Instrument Service Technician

Certification Date: 3-14-13

5600 Lindbergh Drive • Loveland, CO 80538
(800) 227-4224 / FAX (970) 461-3924

## *Appendix 9 - Physical data for November 12th, 27th and December 10th for all the stations*

| Stn. | Run | Depth (m) | Temp. (C°) | SpC. (mS/cm) | Sal. (ppt) | pH | DO (mg/l) | Tur. (NTU) | TDS (mg/l) | PAR (uE/m2/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 29.8 | 52.85 | 34.89 | 8.36 | 5.96 | 1.6 | 33.79 | 256 |
| | 2 | 0 | 25.76 | 5.093 | 2.8 | 8.26 | 1.48 | 13.5 | 33.29 | 399 |
| | 3 | 0 | 27.45 | 40.05 | 25.73 | 8.28 | 4.67 | 1.9 | 26.63 | 439 |
| 2 | 1 | 0 | 29.8 | 52.84 | 34.89 | 8.32 | 5.12 | 2.6 | 33.82 | 218 |
| | 2 | 0 | 29.12 | 52.61 | 34.75 | 8.23 | 5.73 | 4.7 | 33.68 | 208 |
| | 3 | 0 | 28.7 | 52.82 | 34.93 | 8.18 | 5.56 | 2.6 | 33.79 | 677 |
| | 1 | 1 | 29.83 | 52.84 | 34.91 | 8.31 | 5.16 | 3.9 | 33.83 | 113 |
| | 2 | 1 | 29.14 | 52.65 | 34.78 | 8.23 | 4.98 | 4.4 | 33.72 | 81 |
| | 3 | 1 | 28.67 | 52.8 | 34.93 | 8.17 | 5.51 | 2.4 | 33.8 | 445 |
| | 1 | 2 | 29.84 | 52.85 | 34.93 | 8.31 | 5.32 | 3.5 | 33.82 | 80 |
| | 2 | 2 | 29.36 | 55.81 | 34.89 | 8.23 | 4.32 | 4.2 | 33.79 | 68 |
| | 3 | 2 | 28.63 | 52.85 | 34.92 | 8.17 | 5.13 | 2.5 | 33.85 | 246 |
| | 1 | 3 | 29.02 | 52.62 | 34.72 | 8.22 | 5.29 | 4 | 33.67 | 199 |
| | 2 | 3 | 28.63 | 52.88 | 34.93 | 8.17 | 5.12 | 4.7 | 33.83 | 253 |
| | 3 | 3 | 29.76 | 52.8 | 34.94 | 8.31 | 5.26 | 3.3 | 33.83 | 76 |
| 3 | 1 | 0 | 29.62 | 52.81 | 34.89 | 8.31 | 6.12 | 1.3 | 33.8 | 804 |
| | 2 | 0 | 29.38 | 52.83 | 34.91 | 8.21 | 6.02 | 1.7 | 33.81 | 1308 |
| | 3 | 0 | 28.7 | 52.92 | 34.97 | 8.19 | 6.03 | 1.6 | 33.89 | 1279 |
| | 1 | 1 | 29.66 | 52.8 | 34.9 | 8.3 | 6.01 | 1.5 | 33.8 | 281 |
| | 2 | 1 | 29.37 | 52.86 | 34.93 | 8.21 | 6.07 | 1.7 | 33.81 | 837 |
| | 3 | 1 | 28.71 | 52.92 | 34.98 | 8.18 | 6.02 | 1.5 | 33.87 | 698 |
| | 1 | 2 | 29.66 | 52.79 | 34.89 | 8.3 | 6.02 | 1.6 | 33.81 | 213 |
| | 2 | 2 | 29.39 | 52.87 | 34.93 | 8.21 | 6.08 | 1.8 | 33.84 | 782 |
| | 3 | 2 | 28.71 | 52.9 | 34.98 | 8.18 | 6.02 | 1.4 | 33.88 | 409 |
| | 1 | 3 | 29.66 | 52.81 | 34.9 | 8.3 | 6.03 | 1.7 | 33.79 | 197 |
| | 2 | 3 | 29.4 | 52.9 | 34.95 | 8.21 | 6.05 | 1.8 | 33.85 | 545 |
| | 3 | 3 | 28.72 | 52.92 | 34.99 | 8.17 | 6.02 | 1.5 | 33.9 | 455 |
| | 1 | 4 | 29.65 | 52.79 | 34.88 | 8.3 | 6 | 1.9 | 33.81 | 199 |
| | 2 | 4 | 29.39 | 52.9 | 34.96 | 8.21 | 5.93 | 2.1 | 33.85 | 440 |
| | 3 | 4 | 28.71 | 52.92 | 34.99 | 8.17 | 6.03 | 1.7 | 33.89 | 308 |
| | 1 | 5 | 29.65 | 52.8 | 34.88 | 8.3 | 6.02 | 2.2 | 33.82 | 184 |
| | 2 | 5 | 29.38 | 52.9 | 34.96 | 8.21 | 5.61 | 2.4 | 33.87 | 411 |
| | 3 | 5 | 28.7 | 52.97 | 35.01 | 8.17 | 6.04 | 1.7 | 33.88 | 334 |
| | 1 | 6 | 29.64 | 52.79 | 34.88 | 8.3 | 6.03 | 2.3 | 33.8 | 176 |
| | 2 | 6 | 29.38 | 52.92 | 34.98 | 8.21 | 5.34 | 2.4 | 33.88 | 294 |
| | 3 | 6 | 28.7 | 52.96 | 35.01 | 8.17 | 6.06 | 1.6 | 33.89 | 279 |
| | 1 | 7 | 29.65 | 52.79 | 34.88 | 8.3 | 6.01 | 2.4 | 33.8 | 159 |
| | 2 | 7 | 29.39 | 52.95 | 34.97 | 8.22 | 5.33 | 2.3 | 33.87 | 297 |
| | 3 | 7 | 28.7 | 52.94 | 35 | 8.17 | 6.02 | 2 | 33.87 | 245 |
| 4 | 1 | 0 | 29.71 | 52.88 | 34.94 | 8.3 | 5.9 | 1 | 33.85 | 1625 |
| | 2 | 0 | 28.79 | 52.7 | 34.81 | 8.19 | 6 | 1.6 | 33.72 | 1744 |
| | 3 | 0 | 28.39 | 52.92 | 34.97 | 8.18 | 5.95 | 3.9 | 33.87 | 918 |
| | 1 | 1 | 29.74 | 52.88 | 34.95 | 8.29 | 5.89 | 1 | 33.85 | 1076 |
| | 2 | 1 | 28.78 | 52.7 | 34.89 | 8.19 | 5.99 | 1.7 | 33.74 | 978 |
| | 3 | 1 | 28.41 | 52.9 | 34.96 | 8.17 | 5.93 | 3.7 | 33.87 | 352 |

| Stn. | Run | Depth (m) | Temp. (C°) | SpC. (mS/cm) | Sal. (ppt) | pH | DO (mg/l) | Tur. (NTU) | TDS (mg/l) | PAR (uE/m2/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 29.73 | 52.88 | 34.94 | 8.29 | 5.91 | 1 | 33.83 | 783 |
| | 2 | 2 | 28.78 | 52.67 | 34.8 | 8.19 | 6 | 1.8 | 33.7 | 933 |
| | 3 | 2 | 28.4 | 52.9 | 34.97 | 8.17 | 5.93 | 3.7 | 33.86 | 330 |
| | 1 | 3 | 29.73 | 52.87 | 34.94 | 8.29 | 5.93 | 1.1 | 33.86 | 566 |
| | 2 | 3 | 28.72 | 52.65 | 34.8 | 8.19 | 5.98 | 1.9 | 33.7 | 568 |
| | 3 | 3 | 28.39 | 52.9 | 34.97 | 8.17 | 5.94 | 3.8 | 33.85 | 326 |
| | 1 | 4 | 29.75 | 52.87 | 34.94 | 8.29 | 5.94 | 1.5 | 33.84 | 458 |
| | 2 | 4 | 28.62 | 52.68 | 34.8 | 8.2 | 5.93 | 2 | 33.7 | 437 |
| | 3 | 4 | 28.38 | 52.92 | 34.96 | 8.17 | 5.96 | 4.2 | 33.87 | 259 |
| | 1 | 0 | 29.64 | 52.87 | 34.91 | 8.29 | 6.1 | 0.9 | 33.79 | 1831 |
| | 2 | 0 | 29.15 | 52.9 | 34.96 | 8.2 | 5.76 | 4 | 33.84 | 702 |
| | 3 | 0 | 28.69 | 53.03 | 35.06 | 8.18 | 6.14 | 3.5 | 33.93 | 753 |
| | 1 | 1 | 29.65 | 52.81 | 34.9 | 8.28 | 6.13 | 0.9 | 33.79 | 1175 |
| | 2 | 1 | 29.15 | 52.88 | 34.96 | 8.2 | 5.75 | 3.7 | 33.84 | 231 |
| | 1 | 1 | 28.71 | 53.04 | 35.05 | 8.17 | 6.07 | 3.4 | 33.94 | 495 |
| | 1 | 2 | 29.65 | 52.78 | 34.88 | 8.28 | 6.16 | 1.2 | 33.8 | 992 |
| | 2 | 2 | 29.15 | 52.88 | 34.96 | 8.2 | 5.77 | 3.5 | 33.85 | 170 |
| | 3 | 2 | 28.72 | 53.01 | 35.04 | 8.17 | 6.06 | 3.4 | 33.94 | 635 |
| | 1 | 3 | 29.65 | 52.78 | 34.88 | 8.28 | 6.15 | 1.2 | 33.8 | 908 |
| | 2 | 3 | 29.15 | 52.89 | 34.96 | 8.2 | 5.78 | 3.5 | 33.85 | 167 |
| | 3 | 3 | 28.71 | 53 | 35.03 | 8.17 | 6.04 | 3.5 | 33.93 | 370 |
| | 1 | 4 | 29.65 | 52.79 | 34.88 | 8.28 | 6.15 | 1.3 | 33.79 | 647 |
| | 2 | 4 | 29.15 | 52.88 | 34.95 | 8.2 | 5.76 | 3.6 | 33.84 | 150 |
| 5 | 3 | 4 | 28.73 | 53.02 | 35.04 | 8.16 | 6.05 | 3.4 | 33.9 | 469 |
| | 1 | 5 | 29.65 | 52.78 | 34.87 | 8.29 | 6.14 | 1.8 | 33.8 | 677 |
| | 2 | 5 | 29.15 | 52.88 | 34.95 | 8.2 | 5.77 | 3.5 | 33.85 | 140 |
| | 3 | 5 | 28.72 | 53.03 | 35.05 | 8.17 | 6.08 | 3.5 | 33.93 | 522 |
| | 1 | 6 | 29.64 | 52.78 | 34.88 | 8.28 | 6.14 | 2 | 33.78 | 553 |
| | 2 | 6 | 29.15 | 52.88 | 34.94 | 8.2 | 5.77 | 3.6 | 33.82 | 131 |
| | 3 | 6 | 28.72 | 53.05 | 35.05 | 8.17 | 6.08 | 3.6 | 33.92 | 335 |
| | 1 | 7 | 29.65 | 52.76 | 34.87 | 8.29 | 6.15 | 2.2 | 33.78 | 461 |
| | 2 | 7 | 29.15 | 52.91 | 34.94 | 8.2 | 5.79 | 3.5 | 33.85 | 124 |
| | 3 | 7 | 28.72 | 53.02 | 35.04 | 8.17 | 6.02 | 3.4 | 33.94 | 375 |
| | 1 | 8 | 29.65 | 52.76 | 34.86 | 8.29 | 6.15 | 2.2 | 33.78 | 391 |
| | 2 | 8 | 29.15 | 52.89 | 34.94 | 8.2 | 5.78 | 3.4 | 33.84 | 119 |
| | 3 | 8 | 28.72 | 53.03 | 35.07 | 8.17 | 6.06 | 3.4 | 33.93 | 279 |
| | 1 | 9 | 29.65 | 52.79 | 34.86 | 8.29 | 6.15 | 2.3 | 33.77 | 395 |
| | 2 | 9 | 29.16 | 52.89 | 34.96 | 8.21 | 5.81 | 3.6 | 33.84 | 108 |
| | 3 | 9 | 28.73 | 53 | 35.05 | 8.17 | 6.09 | 3.7 | 33.93 | 279 |
| | 1 | 0 | 29.69 | 52.84 | 34.91 | 8.26 | 5.91 | 1.4 | 33.81 | 1774 |
| | 2 | 0 | 29.08 | 52.84 | 34.92 | 8.2 | 5.86 | 4.2 | 33.81 | 292 |
| | 3 | 0 | 28.58 | 53.01 | 35.04 | 8.18 | 6.03 | 4.6 | 33.92 | 1301 |
| | 1 | 1 | 29.71 | 52.83 | 34.91 | 8.26 | 5.93 | 1.4 | 33.81 | 1784 |
| | 2 | 1 | 29.12 | 52.84 | 34.91 | 8.2 | 5.8 | 4.2 | 33.81 | 171 |
| 6 | 3 | 1 | 28.59 | 52.99 | 35.02 | 8.17 | 5.98 | 4.4 | 33.9 | 775 |
| | 1 | 2 | 29.71 | 52.81 | 34.9 | 8.26 | 5.92 | 1.4 | 33.82 | 953 |
| | 2 | 2 | 29.12 | 52.85 | 34.92 | 8.2 | 5.82 | 4 | 33.81 | 172 |
| | 3 | 2 | 28.58 | 52.99 | 35.03 | 8.16 | 5.96 | 4 | 33.91 | 878 |
| | 1 | 3 | 29.71 | 52.8 | 34.89 | 8.7 | 5.92 | 1.5 | 33.75 | 822 |
| | 2 | 3 | 29.12 | 52.8 | 34.9 | 8.2 | 5.85 | 3.8 | 33.8 | 142 |
| | 3 | 3 | 28.59 | 53.02 | 35.01 | 8.16 | 5.97 | 3.4 | 33.91 | 407 |

| Stn. | Run | Depth (m) | Temp. (C$^o$) | SpC. (mS/cm) | Sal. (ppt) | pH | DO (mg/l) | Tur. (NTU) | TDS (mg/l) | PAR (uE/m2/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 4 | 29.63 | 52.76 | 34.85 | 8.27 | 6.22 | 1.8 | 33.79 | 852 |
| | 2 | 4 | 29.12 | 52.84 | 34.91 | 8.2 | 5.85 | 3.7 | 33.81 | 123 |
| | 3 | 4 | 28.59 | 52.99 | 35.03 | 8.17 | 5.97 | 3.2 | 33.91 | 459 |
| | 1 | 5 | 29.71 | 52.82 | 34.89 | 8.27 | 6.02 | 2 | 33.81 | 706 |
| | 2 | 5 | 29.12 | 52.84 | 34.92 | 8.2 | 5.85 | 3.6 | 33.82 | 101 |
| | 3 | 5 | 28.59 | 53 | 35.02 | 8.17 | 5.97 | 3 | 33.91 | 379 |
| | 1 | 6 | 29.71 | 52.8 | 34.9 | 8.27 | 5.91 | 2.1 | 33.79 | 707 |
| | 2 | 6 | 29.12 | 52.83 | 34.94 | 8.2 | 5.86 | 3.7 | 33.82 | 89 |
| | 3 | 6 | 28.6 | 52.99 | 35.03 | 8.17 | 5.97 | 2.4 | 33.91 | 346 |
| | 1 | 7 | 29.72 | 52.81 | 34.91 | 8.27 | 5.94 | 2.3 | 33.8 | 610 |
| | 2 | 7 | 29.12 | 52.84 | 34.91 | 8.2 | 5.88 | 3.8 | 33.81 | 83 |
| | 3 | 7 | - | - | - | - | - | - | - | - |
| 7 | 1 | 0 | 29.49 | 52.87 | 34.94 | 8.34 | 5.75 | 4.4 | 33.83 | 30 |
| | 2 | 0 | 28.93 | 52.75 | 34.85 | 8.48 | 5.99 | 4.9 | 33.78 | 428 |
| | 3 | 0 | 28.59 | 53.03 | 35.03 | 8.34 | 6.11 | 0.1 | 33.9 | 816 |
| | 1 | 1 | 29.49 | 52.87 | 34.96 | 8.34 | 5.76 | 3.6 | 33.85 | 24 |
| | 2 | 1 | 28.95 | 52.8 | 34.88 | 8.46 | 5.93 | 2.4 | 33.81 | 304 |
| | 3 | 1 | 28.62 | 53.05 | 35.07 | 8.33 | 6.1 | 0.4 | 33.95 | 348 |
| | 1 | 2 | 29.49 | 52.88 | 34.93 | 8.34 | 5.78 | 3.1 | 33.83 | 24 |
| | 2 | 2 | 28.94 | 52.81 | 34.92 | 8.45 | 5.94 | 2.1 | 33.79 | 232 |
| | 3 | 2 | 28.63 | 53.05 | 35.07 | 8.33 | 6.1 | 0.4 | 33.96 | 265 |
| | 1 | 3 | 29.49 | 52.88 | 34.94 | 8.34 | 5.79 | 1.8 | 33.85 | 22 |
| | 2 | 3 | 28.95 | 55.84 | 34.91 | 8.45 | 5.95 | 2 | 33.81 | 192 |
| | 3 | 3 | 28.62 | 53.07 | 35.09 | 8.33 | 6.11 | 0.4 | 33.98 | 221 |
| | 1 | 4 | 29.5 | 52.86 | 34.94 | 8.34 | 5.78 | 1.6 | 33.84 | 21 |
| | 2 | 4 | 28.95 | 52.82 | 34.9 | 8.45 | 5.95 | 2.3 | 33.83 | 178 |
| | 3 | 4 | 28.62 | 53.04 | 35.1 | 8.33 | 6.1 | 0.6 | 33.96 | 195 |
| | 1 | 5 | 29.5 | 52.87 | 34.94 | 8.34 | 5.79 | 1.7 | 33.83 | 18 |
| | 2 | 5 | 28.95 | 52.85 | 34.9 | 8.45 | 5.96 | 2.5 | 33.8 | 150 |
| | 3 | 5 | 28.63 | 53.07 | 35.09 | 8.33 | 6.09 | 1 | 33.95 | 182 |
| | 1 | 6 | 29.49 | 52.88 | 34.94 | 8.34 | 5.75 | 1.8 | 33.83 | 16 |
| | 2 | 6 | 28.94 | 52.83 | 34.9 | 8.45 | 5.93 | 2.5 | 33.81 | 118 |
| | 3 | 6 | 28.63 | 53.09 | 35.1 | 8.33 | 6.1 | 1.2 | 33.97 | 163 |
| | 1 | 7 | 29.49 | 52.87 | 34.93 | 8.34 | 5.7 | 1.7 | 33.84 | 14 |
| | 2 | 7 | 28.94 | 52.81 | 34.9 | 8.45 | 5.93 | 2.5 | 33.81 | 96 |
| | 3 | 7 | 28.64 | 53.06 | 35.08 | 8.33 | 6.06 | 1.5 | 33.97 | 144 |
| 8 | 1 | 0 | 29.5 | 52.77 | 34.86 | 8.28 | 5.78 | 4.2 | 33.77 | 1105 |
| | 2 | 0 | 28.96 | 52.96 | 35 | 8.21 | 5.8 | 12 | 33.9 | 245 |
| | 3 | 0 | 28.71 | 53.08 | 35.09 | 8.31 | 6.3 | 3.1 | 33.95 | 1275 |
| | 1 | 1 | 29.5 | 52.75 | 34.86 | 8.27 | 5.67 | 4.2 | 33.76 | 1049 |
| | 2 | 1 | 28.99 | 52.95 | 35 | 8.2 | 5.55 | 5 | 33.89 | 160 |
| | 3 | 1 | 28.72 | 53.05 | 35.07 | 8.25 | 6.12 | 3.2 | 33.96 | 583 |
| | 1 | 2 | 29.51 | 52.75 | 34.85 | 8.27 | 5.67 | 4.4 | 33.76 | 1124 |
| | 2 | 2 | 29 | 52.93 | 34.99 | 8.2 | 5.53 | 4.5 | 33.88 | 149 |
| | 3 | 2 | 28.72 | 53.06 | 35.05 | 8.25 | 6.13 | 3.2 | 33.94 | 876 |
| | 1 | 3 | 29.52 | 52.74 | 34.84 | 8.27 | 5.74 | 3.9 | 33.75 | 667 |
| | 2 | 3 | 29 | 52.94 | 34.99 | 8.2 | 5.53 | 4.3 | 33.89 | 113 |
| | 3 | 3 | 28.73 | 53.03 | 35.05 | 8.21 | 6.12 | 3.3 | 33.95 | 446 |
| | 1 | 4 | 29.54 | 52.74 | 34.84 | 8.27 | 5.82 | 3.3 | 33.75 | 544 |
| | 2 | 4 | 29 | 52.93 | 34.99 | 8.2 | 5.52 | 4.1 | 33.88 | 118 |
| | 3 | 4 | 28.73 | 53.05 | 35.04 | 8.17 | 6.13 | 3.3 | 33.94 | 661 |

| Stn. | Run | Depth (m) | Temp. (C°) | SpC. (mS/cm) | Sal. (ppt) | pH | DO (mg/l) | Tur. (NTU) | TDS (mg/l) | PAR (uE/m2/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 9 | 1 | 0 | 29.83 | 52.83 | 34.91 | 8.26 | 5.91 | 1.7 | 33.8 | 203 |
| | 2 | 0 | 28.98 | 52.77 | 34.87 | 8.21 | 5.57 | 6.4 | 33.78 | 1094 |
| | 3 | 0 | 28.5 | 52.96 | 35.01 | 8.16 | 6.15 | 3.4 | 33.89 | 1677 |
| | 1 | 1 | 29.82 | 52.82 | 34.9 | 8.27 | 5.93 | 1.4 | 33.79 | 1963 |
| | 2 | 1 | 28.97 | 52.77 | 34.86 | 8.21 | 5.47 | 6.1 | 33.78 | 841 |
| | 3 | 1 | 28.51 | 52.94 | 35 | 8.17 | 6.12 | 3.1 | 33.87 | 1291 |
| | 1 | 2 | 29.82 | 52.81 | 34.89 | 8.27 | 5.94 | 1.7 | 33.8 | 1096 |
| | 2 | 2 | 28.97 | 52.77 | 34.86 | 8.21 | 5.5 | 5.5 | 33.77 | 541 |
| | 3 | 2 | 28.51 | 52.94 | 34.99 | 8.16 | 6.09 | 3.2 | 33.88 | 739 |
| | 1 | 3 | 29.82 | 52.83 | 34.91 | 8.27 | 5.92 | 1.9 | 33.8 | 857 |
| | 2 | 3 | 28.98 | 52.76 | 34.85 | 8.21 | 5.51 | 4.7 | 33.77 | 369 |
| | 3 | 3 | 28.53 | 52.95 | 35 | 8.16 | 6.1 | 3.5 | 33.88 | 771 |
| 10 | 1 | 0 | 29.65 | 52.78 | 34.85 | 8.27 | 6.15 | 1.6 | 33.77 | 2411 |
| | 2 | 0 | 29.03 | 52.9 | 34.95 | 8.21 | 5.94 | 73.5 | 33.84 | 458 |
| | 3 | 0 | 28.51 | 53.04 | 35.06 | 8.18 | 5.77 | 3.5 | 33.93 | 278 |
| | 1 | 1 | 29.65 | 52.75 | 34.85 | 8.27 | 6.14 | 1.5 | 33.76 | 3087 |
| | 2 | 1 | 29.04 | 52.89 | 34.96 | 8.21 | 5.82 | 78.2 | 33.84 | 359 |
| | 3 | 1 | 28.51 | 52.99 | 35.03 | 8.17 | 5.77 | 11.5 | 33.92 | 270 |
| | 1 | 2 | 29.65 | 52.75 | 34.85 | 8.27 | 6.14 | 1.6 | 33.76 | 1317 |
| | 2 | 2 | 29.05 | 52.87 | 34.94 | 8.21 | 5.8 | 76.9 | 33.83 | 253 |
| | 3 | 2 | 28.52 | 52.98 | 35.06 | 8.17 | 5.77 | 8.9 | 33.92 | 380 |
| | 1 | 3 | 29.66 | 52.74 | 34.84 | 8.27 | 6.14 | 1.9 | 33.76 | 987 |
| | 2 | 3 | 29.05 | 52.87 | 34.93 | 8.21 | 5.81 | 58.1 | 33.83 | 212 |
| | 3 | 3 | 28.52 | 53 | 35.02 | 8.17 | 5.8 | 2 | 33.92 | 415 |
| | 1 | 4 | 29.67 | 52.76 | 34.85 | 8.27 | 6.14 | 2.1 | 33.74 | 1169 |
| | 2 | 4 | 28.53 | 53 | 35.03 | 8.17 | 5.85 | 4.4 | 33.91 | 576 |
| | 3 | 4 | 29.67 | 52.73 | 34.84 | 8.27 | 6.21 | 3 | 33.75 | 860 |
| 11 | 1 | 0 | 29.4 | 52.83 | 34.92 | 8.3 | 6.27 | 0.9 | 33.82 | 217 |
| | 2 | 0 | 29.05 | 52.85 | 34.93 | 8.42 | 6.25 | 5.3 | 33.82 | 990 |
| | 3 | 0 | 28.67 | 53.1 | 35.09 | 8.34 | 6.28 | 2.6 | 33.96 | 356 |
| | 1 | 1 | 29.48 | 52.83 | 34.91 | 8.3 | 6.27 | 0.6 | 33.83 | 144 |
| | 2 | 1 | 29.06 | 52.81 | 34.91 | 8.41 | 6.21 | 4.5 | 33.81 | 610 |
| | 3 | 1 | 28.69 | 53.06 | 35.08 | 8.33 | 6.29 | 2.6 | 33.95 | 452 |
| | 1 | 2 | 29.47 | 52.83 | 34.88 | 8.3 | 6.28 | 0.7 | 33.81 | 121 |
| | 2 | 2 | 29.07 | 52.82 | 34.9 | 8.41 | 6.25 | 3.9 | 33.8 | 535 |
| | 3 | 2 | 28.68 | 53.06 | 35.09 | 8.32 | 6.26 | 2.6 | 33.96 | 241 |
| | 1 | 3 | 29.49 | 52.83 | 34.93 | 8.3 | 6.27 | 0.9 | 33.81 | 104 |
| | 2 | 3 | 29.07 | 52.82 | 34.9 | 8.41 | 6.23 | 3.6 | 33.8 | 339 |
| | 3 | 3 | 28.71 | 53.05 | 35.07 | 8.32 | 6.3 | 2.7 | 33.96 | 259 |
| | 1 | 4 | 29.48 | 52.83 | 34.91 | 8.3 | 6.27 | 1.1 | 33.81 | 96 |
| | 2 | 4 | 29.08 | 52.81 | 34.89 | 8.41 | 6.23 | 3.5 | 33.8 | 312 |
| | 3 | 4 | 28.72 | 53.06 | 35.07 | 8.32 | 6.29 | 2.6 | 33.94 | 216 |
| | 1 | 5 | 29.49 | 52.82 | 34.91 | 8.29 | 6.26 | 1.1 | 33.81 | 95 |
| | 2 | 5 | 29.08 | 52.81 | 34.89 | 8.4 | 6.22 | 3.4 | 33.8 | 224 |
| | 3 | 5 | 28.72 | 53.04 | 35.07 | 8.32 | 6.29 | 2.7 | 33.95 | 180 |
| | 1 | 6 | 29.49 | 52.79 | 34.89 | 8.3 | 6.29 | 1.2 | 33.81 | 97 |
| | 2 | 6 | 29.08 | 52.8 | 34.88 | 8.4 | 6.24 | 3.5 | 33.79 | 217 |
| | 3 | 6 | 28.73 | 53.03 | 35.6 | 8.32 | 6.28 | 2.9 | 33.95 | 183 |
| | 1 | 7 | 29.49 | 52.82 | 34.9 | 8.3 | 6.25 | 1.5 | 33.82 | 89 |
| | 2 | 7 | 29.07 | 52.81 | 34.89 | 8.4 | 6.21 | 3.5 | 33.8 | 222 |
| | 3 | 7 | 28.73 | 53.02 | 35.05 | 8.32 | 6.21 | 3 | 33.96 | 175 |

| Stn. | Run | Depth (m) | Temp. (C°) | SpC. (mS/cm) | Sal. (ppt) | pH | DO (mg/l) | Tur. (NTU) | TDS (mg/l) | PAR (uE/m2/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 8 | 29.48 | 52.81 | 34.91 | 8.3 | 6.29 | 1.6 | 33.8 | 86 |
| | 2 | 8 | 29.07 | 52.82 | 34.9 | 8.4 | 6.23 | 3.7 | 33.8 | 212 |
| | 3 | 8 | 28.73 | 53.04 | 35.07 | 8.32 | 6.29 | 3 | 33.95 | 185 |
| | 1 | 9 | 29.49 | 52.82 | 34.9 | 8.3 | 6.25 | 1.8 | 33.81 | 80 |
| | 2 | 9 | 29.07 | 52.81 | 34.89 | 8.4 | 6.2 | 3.7 | 33.8 | 196 |
| | 3 | 9 | 28.72 | 53.04 | 35.05 | 8.32 | 6.3 | 2.9 | 33.92 | 163 |
| | 1 | 10 | 29.5 | 52.84 | 34.92 | 8.3 | 6.27 | 2.7 | 33.81 | 52 |
| | 2 | 10 | 29.07 | 52.81 | 34.9 | 8.4 | 6.22 | 3.6 | 33.79 | 185 |
| | 3 | 10 | 28.72 | 53.03 | 35.06 | 8.32 | 6.2 | 3.1 | 33.94 | 142 |
| | 1 | 15 | 29.52 | 52.86 | 34.94 | 8.3 | 6.23 | 2.5 | 33.87 | 44 |
| | 2 | 15 | 29.08 | 52.82 | 34.89 | 8.41 | 6.23 | 3.5 | 33.78 | 139 |
| | 3 | 15 | 28.74 | 53.03 | 35.1 | 8.32 | 6.3 | 3 | 33.94 | 122 |
| | 1 | 20 | 29.69 | 53.12 | 35.12 | 8.3 | 6.3 | 2.8 | 34 | 29 |
| | 2 | 20 | 29.07 | 52.79 | 34.87 | 8.4 | 6.2 | 3.5 | 33.78 | 50 |
| | 3 | 20 | 28.75 | 53.06 | 35.09 | 8.32 | 6.33 | 2.9 | 33.97 | 83 |
| 12 | 1 | 0 | 29.49 | 52.91 | 34.96 | 8.3 | 6 | 0.8 | 33.85 | 476 |
| | 2 | 0 | 29.03 | 52.85 | 34.92 | 8.38 | 6.23 | 2.4 | 33.82 | 1175 |
| | 3 | 0 | 28.58 | 53.14 | 35.13 | 8.33 | 5.98 | 1.2 | 34 | 951 |
| | 1 | 1 | 29.45 | 52.89 | 34.96 | 8.3 | 5.97 | 1.1 | 33.85 | 334 |
| | 2 | 1 | 29.07 | 52.82 | 34.9 | 8.38 | 6.22 | 2.1 | 33.8 | 445 |
| | 3 | 1 | 28.58 | 53.12 | 35.15 | 8.33 | 5.96 | 1 | 34 | 355 |
| | 1 | 2 | 29.45 | 52.89 | 34.95 | 8.3 | 5.96 | 1.2 | 33.85 | 273 |
| | 2 | 2 | 29.06 | 52.79 | 34.89 | 8.38 | 6.23 | 2 | 33.8 | 294 |
| | 3 | 2 | 28.6 | 53.5 | 35.14 | 8.32 | 5.98 | 1 | 34 | 337 |
| | 1 | 3 | 29.45 | 52.9 | 34.96 | 8.3 | 5.96 | 1.4 | 33.84 | 193 |
| | 2 | 3 | 29.07 | 52.8 | 34.89 | 8.38 | 6.21 | 1.9 | 33.8 | 507 |
| | 3 | 3 | 28.6 | 53.14 | 35.14 | 8.32 | 5.98 | 1.2 | 34 | 201 |
| | 1 | 4 | 29.45 | 52.88 | 34.95 | 8.29 | 5.95 | 1.6 | 33.84 | 196 |
| | 2 | 4 | 29.07 | 52.8 | 34.89 | 8.38 | 6.21 | 2 | 33.8 | 428 |
| | 3 | 4 | 28.6 | 53.11 | 35.11 | 8.32 | 5.95 | 1.2 | 34 | 249 |
| | 1 | 5 | 29.45 | 52.88 | 34.95 | 8.29 | 5.95 | 1.6 | 33.87 | 192 |
| | 2 | 5 | 29.07 | 52.79 | 34.88 | 8.38 | 6.21 | 1.9 | 33.79 | 327 |
| | 3 | 5 | 28.6 | 53.11 | 35.11 | 8.32 | 6 | 1.5 | 33.99 | 192 |
| | 1 | 6 | 29.46 | 52.85 | 34.93 | 8.29 | 5.95 | 1.8 | 33.83 | 178 |
| | 2 | 6 | 29.07 | 52.81 | 34.89 | 8.38 | 6.24 | 1.9 | 33.79 | 266 |
| | 3 | 6 | 28.61 | 53.09 | 35.1 | 8.32 | 6 | 1.8 | 33.99 | 161 |
| | 1 | 7 | 29.45 | 52.88 | 34.95 | 8.29 | 5.95 | 19 | 33.84 | 175 |
| | 2 | 7 | 29.08 | 52.81 | 34.89 | 8.38 | 6.23 | 2 | 33.79 | 131 |
| | 3 | 7 | 28.61 | 53.12 | 35.12 | 8.32 | 5.98 | 2 | 33.99 | 147 |
| 13 | 1 | 0 | 29.61 | 52.73 | 34.84 | 8.26 | 5.93 | 3.3 | 33.75 | 29.61 |
| | 2 | 0 | 29.13 | 52.94 | 35 | 8.21 | 6.13 | 5.3 | 33.87 | 29.13 |
| | 3 | 0 | 28.64 | 53.03 | 35.06 | 8.23 | 6.02 | 3.7 | 33.94 | 28.64 |
| | 1 | 1 | 29.62 | 52.72 | 34.83 | 8.26 | 5.96 | 3.5 | 33.75 | 29.62 |
| | 2 | 1 | 29.16 | 52.92 | 34.96 | 8.21 | 5.97 | 5 | 33.87 | 29.16 |
| | 3 | 1 | 28.65 | 53.02 | 35.05 | 8.18 | 6 | 3.4 | 33.92 | 28.65 |
| | 1 | 2 | 29.62 | 52.72 | 34.83 | 8.26 | 5.98 | 3.5 | 33.73 | 29.62 |
| | 2 | 2 | 29.13 | 52.93 | 34.96 | 8.21 | 6.01 | 4.6 | 33.86 | 29.13 |
| | 3 | 2 | 28.65 | 52.99 | 35.04 | 8.17 | 6.2 | 3.4 | 33.92 | 28.65 |
| | 1 | 3 | 29.62 | 52.72 | 34.82 | 8.26 | 6 | 3.4 | 33.75 | 29.62 |
| | 2 | 3 | 29.16 | 52.91 | 34.97 | 8.21 | 6.04 | 4 | 33.84 | 29.16 |
| | 3 | 3 | 28.66 | 53 | 35.02 | 8.17 | 6.04 | 3.4 | 33.91 | 28.66 |

| Stn. | Run | Depth (m) | Temp. (C°) | SpC. (mS/cm) | Sal. (ppt) | pH | DO (mg/l) | Tur. (NTU) | TDS (mg/l) | PAR (uE/m2/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 1 | 0 | 29.86 | 52.78 | 34.88 | 8.26 | 6.01 | 1.8 | 33.79 | 2207 |
| | 2 | 0 | 28.82 | 52.93 | 34.97 | 8.35 | 5.73 | 5.7 | 33.86 | 1370 |
| | 3 | 0 | 28.35 | 52.96 | 35.01 | 8.17 | 6.19 | 17 | 33.88 | 1593 |
| | 1 | 1 | 29.87 | 52.79 | 34.88 | 8.26 | 6.02 | 2 | 33.79 | 1411 |
| | 2 | 1 | 28.83 | 52.9 | 34.97 | 8.35 | 5.47 | 6.1 | 33.86 | 877 |
| | 3 | 1 | 28.33 | 52.93 | 34.99 | 8.17 | 6.17 | 15 | 33.88 | 683 |
| | 1 | 2 | 29.86 | 52.78 | 34.88 | 8.26 | 6.02 | 2.3 | 33.77 | 1421 |
| | 2 | 2 | 28.83 | 52.88 | 34.96 | 8.35 | 5.49 | 6.2 | 33.86 | 640 |
| | 3 | 2 | 28.34 | 52.94 | 35 | 8.17 | 6.25 | 15.7 | 33.86 | 743 |
| 15 | 1 | 0 | 29.66 | 52.83 | 34.89 | 8.29 | 5.27 | 38.1 | 33.82 | 1065 |
| | 2 | 0 | 28.77 | 52.95 | 35 | 8.36 | 5.59 | 5.9 | 33.88 | 495 |
| | 3 | 0 | 28.29 | 53.02 | 35.05 | 8.31 | 5.8 | 14.3 | 33.94 | 836 |
| | 1 | 1 | 29.67 | 52.84 | 34.92 | 8.29 | 5.71 | 31.1 | 33.81 | 597 |
| | 2 | 1 | 28.78 | 52.94 | 34.99 | 8.36 | 5.48 | 5.8 | 33.87 | 836 |
| | 3 | 1 | 28.29 | 53.03 | 35.06 | 8.3 | 5.72 | 13.3 | 33.94 | 537 |
| | 1 | 2 | 29.66 | 52.83 | 34.91 | 8.28 | 5.79 | 28.3 | 33.82 | 569 |
| | 2 | 2 | 28.76 | 52.93 | 34.98 | 8.36 | 5.52 | 5.6 | 33.87 | 753 |
| | 3 | 2 | 28.29 | 53 | 35.3 | 8.3 | 5.75 | 10.9 | 33.91 | 636 |
| | 1 | 3 | 29.56 | 52.81 | 34.88 | 8.28 | 5.57 | 17.9 | 33.8 | 404 |
| | 2 | 3 | 28.77 | 52.92 | 34.95 | 8.35 | 5.6 | 5.5 | 33.86 | 471 |
| | 3 | 3 | 28.31 | 52.99 | 35.03 | 8.3 | 5.78 | 9.5 | 33.91 | 352 |
| 16 | 1 | 0 | 29.6 | 52.79 | 34.89 | 8.3 | 5.76 | 0.9 | 33.79 | 940 |
| | 2 | 0 | 28.92 | 52.95 | 35 | 8.38 | 6.05 | 4.2 | 33.87 | 737 |
| | 3 | 0 | 28.47 | 53.06 | 35.07 | 8.32 | 5.73 | 3.3 | 33.93 | 914 |
| | 1 | 1 | 29.61 | 52.8 | 34.89 | 8.3 | 5.67 | 1.1 | 33.8 | 630 |
| | 2 | 1 | 28.94 | 52.92 | 34.97 | 8.37 | 5.91 | 4.4 | 33.87 | 636 |
| | 3 | 1 | 28.48 | 53.02 | 35.05 | 8.31 | 5.71 | 3.4 | 33.95 | 552 |
| | 1 | 2 | 29.58 | 52.79 | 34.86 | 8.29 | 5.62 | 1.4 | 33.78 | 486 |
| | 2 | 2 | 28.95 | 52.88 | 34.94 | 8.37 | 5.89 | 4.6 | 33.84 | 433 |
| | 3 | 2 | 28.48 | 53.03 | 35.08 | 8.31 | 5.73 | 3.5 | 33.94 | 422 |
| | 1 | 3 | 29.53 | 52.81 | 34.88 | 8.29 | 5.53 | 1.5 | 33.78 | 368 |
| | 2 | 3 | 28.95 | 52.87 | 34.95 | 8.37 | 5.91 | 4.9 | 33.84 | 401 |
| | 3 | 3 | 28.48 | 53.04 | 35.05 | 8.31 | 5.71 | 3.4 | 33.95 | 267 |
| | 1 | 4 | 28.96 | 52.87 | 34.95 | 8.37 | 5.91 | 4.9 | 33.83 | 335 |
| | 2 | 4 | 29.53 | 52.8 | 34.88 | 8.29 | 5.37 | 1.9 | 33.79 | 361 |
| | 3 | 4 | 28.48 | 53.02 | 35.05 | 8.31 | 5.75 | 3.8 | 33.92 | 306 |
| 17 | 1 | 0 | 29.53 | 52.93 | 34.94 | 8.3 | 6.06 | 28 | 33.88 | 855 |
| | 2 | 0 | 28.97 | 52.84 | 34.92 | 8.38 | 5.87 | 6 | 33.8 | 812 |
| | 3 | 0 | 28.63 | 53.16 | 35.16 | 8.33 | 6.26 | 115.7 | 34 | 1037 |
| | 1 | 1 | 29.55 | 52.91 | 34.97 | 8.3 | 6.04 | 1.6 | 33.85 | 422 |
| | 2 | 1 | 28.98 | 52.82 | 34.9 | 8.38 | 5.85 | 5.4 | 33.82 | 431 |
| | 3 | 1 | 28.67 | 53.1 | 35.13 | 8.32 | 6.2 | 21.1 | 34 | 247 |
| | 1 | 2 | 29.55 | 52.89 | 34.96 | 8.3 | 6 | 1.4 | 33.86 | 409 |
| | 2 | 2 | 28.98 | 52.82 | 34.89 | 8.38 | 5.88 | 4.8 | 33.8 | 416 |
| | 3 | 2 | 28.67 | 53.1 | 35.11 | 8.3 | 6.2 | 17.7 | 34 | 593 |
| | 1 | 3 | 29.56 | 52.9 | 34.96 | 8.29 | 6 | 1.7 | 33.87 | 461 |
| | 2 | 3 | 28.99 | 52.82 | 34.9 | 8.37 | 5.86 | 4.6 | 33.85 | 295 |
| | 3 | 3 | 28.67 | 53.14 | 35.14 | 8.31 | 6.22 | 17.2 | 33.99 | 370 |
| | 1 | 4 | 29.57 | 52.91 | 34.96 | 8.29 | 5.92 | 1.9 | 33.86 | 318 |
| | 2 | 4 | 28.99 | 52.82 | 34.9 | 8.37 | 5.87 | 4.5 | 33.8 | 251 |
| | 3 | 4 | 28.68 | 53.13 | 35.12 | 8.31 | 6.19 | 9.7 | 33.99 | 260 |

| Stn. | Run | Depth (m) | Temp. (Cº) | SpC. (mS/cm) | Sal. (ppt) | pH | DO (mg/l) | Tur. (NTU) | TDS (mg/l) | PAR (uE/m2/s) |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 5 | 29.56 | 52.9 | 34.97 | 8.29 | 5.94 | 1.9 | 33.87 | 258 |
| | 2 | 5 | 28.98 | 52.79 | 34.89 | 8.37 | 5.86 | 4.6 | 33.84 | 149 |
| | 3 | 5 | 28.66 | 53.11 | 35.11 | 8.31 | 6.2 | 8.3 | 33.99 | 317 |
| | 1 | 6 | 29.55 | 52.89 | 34.96 | 8.29 | 6.02 | 1.9 | 33.85 | 284 |
| | 2 | 6 | 29 | 52.81 | 34.9 | 8.37 | 5.86 | 4.8 | 33.81 | 79 |
| | 3 | 6 | 28.68 | 53.11 | 35.11 | 8.31 | 6.18 | 6.3 | 33.98 | 203 |
| | 1 | 7 | 29.55 | 52.89 | 34.96 | 8.29 | 6.01 | 2 | 33.85 | 248 |
| | 2 | 7 | 28.99 | 52.85 | 34.9 | 8.37 | 5.86 | 4.9 | 33.8 | 81 |
| | 3 | 7 | 28.67 | 53.1 | 35.11 | 8.31 | 6.18 | 5.2 | 33.99 | 226 |
| | 1 | 8 | 29.55 | 52.88 | 34.95 | 8.29 | 6.02 | 2.2 | 33.85 | 236 |
| | 2 | 8 | 28.99 | 52.82 | 34.9 | 8.37 | 5.88 | 4.4 | 33.81 | 29 |
| | 3 | 8 | 28.67 | 53.1 | 35.12 | 8.31 | 6.17 | 4.2 | 33.99 | 180 |
| | 1 | 9 | 29.5 | 52.88 | 34.95 | 8.29 | 5.98 | 2.3 | 33.85 | 214 |
| | 2 | 9 | 28.98 | 52.82 | 34.91 | 8.37 | 5.85 | 4.5 | 33.8 | 29 |
| | 3 | 9 | 28.68 | 53.1 | 35.11 | 8.31 | 6.2 | 3.6 | 33.99 | 185 |
| | 1 | 10 | 29.54 | 52.87 | 34.94 | 8.29 | 6.04 | 2.4 | 33.84 | 169 |
| | 2 | 10 | 28.98 | 52.84 | 34.9 | 8.37 | 5.85 | 4.5 | 33.81 | 38 |
| | 3 | 10 | 28.68 | 53.12 | 35.11 | 8.31 | 6.2 | 3.2 | 33.99 | 178 |
| | 1 | 13 | 29.53 | 52.88 | 34.95 | 8.29 | 6.04 | 3 | 33.83 | 133 |
| | 2 | 13 | 28.68 | 53.11 | 35.12 | 8.31 | 6.18 | 3.2 | 33.99 | 130 |
| | 3 | 13 | 28.98 | 52.82 | 34.91 | 8.37 | 5.82 | 4.5 | 33.8 | 37 |
| 18 | 1 | 0 | 29.49 | 52.75 | 34.87 | 8.3 | 5.13 | 17.7 | 33.75 | 502 |
| | 2 | 0 | 28.68 | 52.9 | 34.97 | 8.37 | 4.67 | 8.1 | 33.85 | 1532 |
| | 3 | 0 | 28.05 | 53.03 | 35.04 | 8.32 | 5.23 | 4.6 | 33.92 | 1350 |
| | 1 | 1 | 29.52 | 52.74 | 34.85 | 8.29 | 5 | 3.8 | 33.75 | 362 |
| | 2 | 1 | 28.62 | 52.87 | 34.94 | 8.37 | 4.78 | 8.2 | 33.84 | 646 |
| | 3 | 1 | 27.95 | 52.95 | 35.05 | 8.32 | 5.01 | 4.8 | 33.86 | 702 |
| | 1 | 2 | 29.54 | 52.77 | 34.85 | 8.29 | 5.07 | 3.8 | 33.76 | 296 |
| | 2 | 2 | 28.61 | 52.88 | 34.94 | 8.36 | 4.97 | 9.6 | 33.84 | 340 |
| | 3 | 2 | 27.79 | 52.95 | 35 | 8.32 | 4.61 | 5.6 | 33.89 | 602 |

## *Appendix 10 - Biophysical data for November 12th, 27th and December 10th for all stations*

| Stn. | Run | BOD (mg/l) | TSS (mg/l) | Nitrate (mg/l) | Phosphate (mg/l) | F. Coli (MPN/100ml) |
|---|---|---|---|---|---|---|
| 1 | 1 | 6 | 1 | 0.7 | 0.64 | <11 |
| | 2 | 19 | 11 | 0.1 | 1.28 | 230 |
| | 3 | 4 | 3 | 0.6 | 1.31 | 161 |
| 2 | 1 | 5 | 1 | 0.6 | 0.38 | <11 |
| | 2 | 10 | 55 | 0.2 | 0.25 | <11 |
| | 3 | 1 | 2 | 0.5 | 0.31 | <11 |
| 3 | 1 | 5 | 2 | 3.4 | 0.12 | <11 |
| | 2 | 11 | 2 | 0.5 | 0.16 | 230 |
| | 3 | 2 | 3 | 0.8 | 0.09 | 120 |
| 4 | 1 | 6 | 3 | 2.1 | 1.78 | <11 |
| | 2 | 10 | 1 | 0.1 | 0.09 | <11 |
| | 3 | 1 | 1 | 0.7 | 0.12 | <11 |
| 5 | 1 | 6 | 0 | 0.8 | 0.32 | <11 |
| | 2 | 10 | 1 | 1 | 2 | <11 |
| | 3 | 5 | 1 | 0.8 | 0.11 | <11 |
| 6 | 1 | 5 | 1 | 0.8 | 0.6 | <11 |
| | 2 | 5 | 1 | 0.9 | 0.08 | <11 |
| | 3 | 5 | 2 | 0.7 | 0.03 | <11 |
| 7 | 1 | 6 | 1 | 0.5 | 0.17 | <11 |
| | 2 | 5 | 2 | 0.2 | 0.69 | <11 |
| | 3 | 3 | 0 | 1.2 | 0.11 | <11 |
| 8 | 1 | 5 | 3 | 0.5 | 3.06 | <11 |
| | 2 | 9 | 1 | 1.2 | 0.04 | <11 |
| | 3 | 2 | 1 | 1 | 0.04 | <11 |
| 9 | 1 | 7 | 1 | 2.3 | 0.19 | <11 |
| | 2 | 12 | 1 | 0.7 | 0.04 | 51 |
| | 3 | 3 | 1 | 1.1 | 0.09 | 36 |
| 10 | 1 | 6 | 2 | 0.6 | 0.62 | <11 |
| | 2 | 11 | 1 | 0.2 | 0.96 | <11 |
| | 3 | 2 | 0 | 1 | 0.04 | <11 |
| 11 | 1 | 9 | 1 | 2.3 | 0.37 | <11 |
| | 2 | 4 | 2 | 1.5 | 0.12 | 120 |
| | 3 | 2 | 1 | 1.2 | 0.1 | 69 |
| 12 | 1 | 9 | 1 | 0.6 | 0.27 | <11 |
| | 2 | 4 | 2 | 3 | 0.27 | <11 |
| | 3 | 2 | 2 | 0.5 | 0.22 | <11 |
| 13 | 1 | 6 | 2 | 0.7 | 0.11 | <11 |
| | 2 | 9 | 1 | 1.4 | 0.07 | <11 |
| | 3 | 6 | 1 | 0.9 | 0.03 | <11 |
| 14 | 1 | 6 | 1 | 0.8 | 1.13 | <11 |
| | 2 | 13 | 2 | 0.1 | 0.17 | <11 |
| | 3 | 1 | 2 | 1.1 | 0.02 | <11 |
| 15 | 1 | 9 | 1 | 3.8 | 0.26 | <11 |
| | 2 | 5 | 3 | 1.1 | 0.99 | <11 |
| | 3 | 2 | 1 | 0.9 | 0.97 | <11 |
| 16 | 1 | 10 | 2 | 0.4 | 0.05 | <11 |
| | 2 | 4 | 1 | 0 | 0.2 | <11 |
| | 3 | 2 | 2 | 1.1 | 0.2 | <11 |

| Stn. | Run | BOD (mg/l) | TSS (mg/l) | Nitrate (mg/l) | Phosphate (mg/l) | F. Coli (MPN/100ml) |
|---|---|---|---|---|---|---|
| 17 | 1 | 10 | 2 | 0.5 | 0.26 | <11 |
| | 2 | 5 | 1 | 1.7 | 1.17 | <11 |
| | 3 | 2 | 0 | 0.9 | 1.13 | <11 |
| 18 | 1 | 6 | 0 | 5.8 | 0.04 | <11 |
| | 2 | 4 | 6 | 1 | 0.2 | 69 |
| | 3 | 2 | 1 | 1.1 | 0.19 | 36 |

## *Appendix 11 – QC-10 Noise Calibration Certificate*

3M Oconomowoc
Personal Safety Division

3M Detection Solutions
1060 Corporate Center Drive
Oconomowoc, WI 53066-4828
www.3M.com/detection
262 567 9157 800 245 0779
262 567 4047 Fax

Page 1 of 2

3M

# Certificate of Calibration

**Certificate No:** 5500556QII050083

**Submitted By:** C.L. ENVIRON. CO ITDA
22 FORT GEORGE HEIGHTS
KINGSTON, 9 JAMAICA

**Serial Number:** QII050083
**Customer ID:**
**Model:** QC-10 CALIBRATOR

**Date Received:** 8/12/2013
**Date Issued:** 8/17/2013
**Valid Until:** 8/17/2014

**Test Conditions:**

Temperature: 18°C to 29°C
Humidity: 20% to 80%
Barometric Pressure: 890 mbar to 1050 mbar

**Model Conditions:**

As Found: IN TOLERANCE
As Left: IN TOLERANCE

**SubAssemblies:**
**Description:**

**Serial Number:**

**Calibration Procedure:** 56V981

**Reference Standard(s):**

| I.D. Number | Device | Last Calibration Date | Calibration Due |
|---|---|---|---|
| ET0000556 | B&K ENSEMBLE | 10/13/2012 | 10/13/2013 |
| T00230 | FLUKE 45 MULTIMETER | 2/2/2012 | 2/2/2014 |

**Measurement Uncertainty:**

+/- 1.1% ACOUSTIC (0.1DB) +/- 1.4% VAC +/- 0.012% HZ
**Estimated at 95% Confidence Level (k=2)**

**Calibrated By:** SHAWN VANHEMERT, **Service Technician** 8/17/2013

**Reviewed/Approved By:** **Technical Manager/Deputy** 8/17/2013

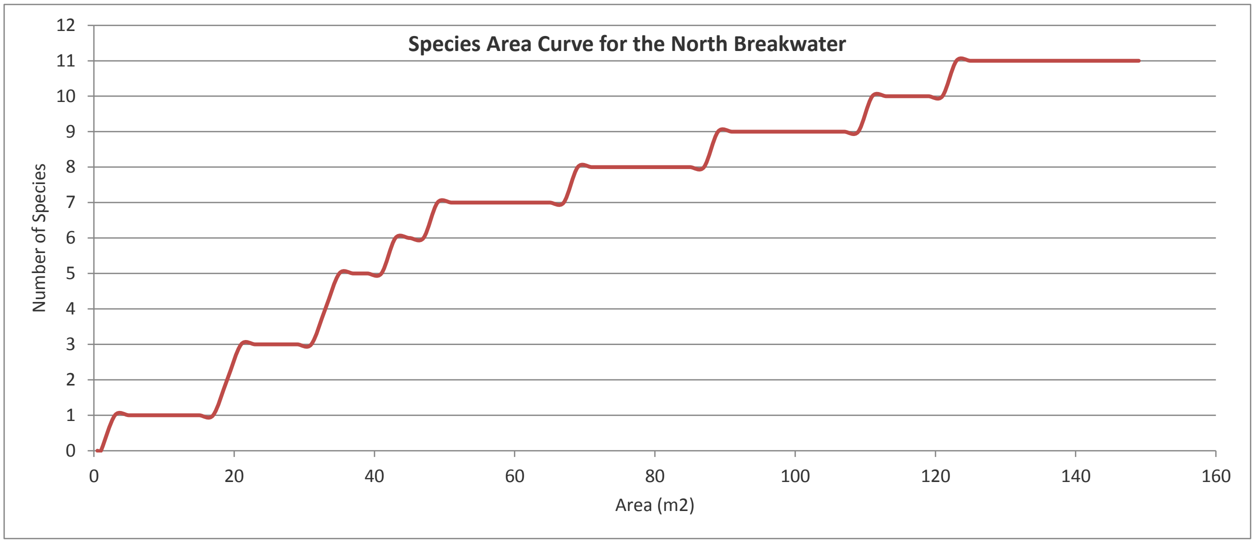
This report certifies that all calibration equipment used in the test is traceable to NIST or other NMI, and applies only to the unit identified under equipment above. This report must not be reproduced except in its entirety without the written approval of 3M Detection Solutions.

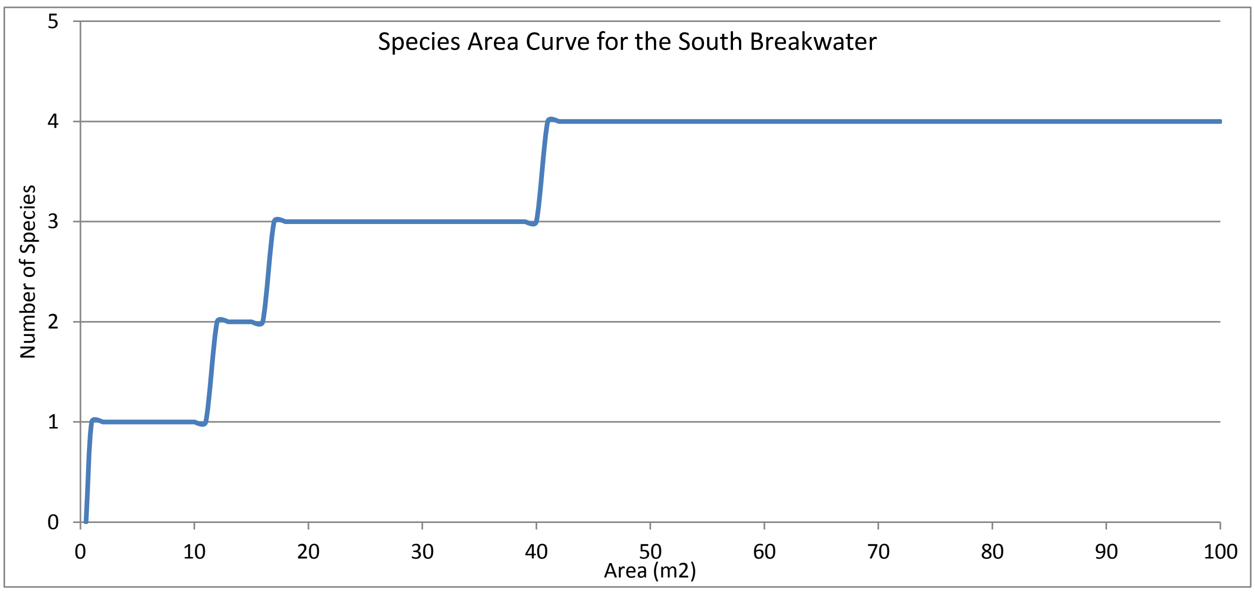
098-393 Rev. B

An ISO 9001 Registered Company
ISO 17025 Accredited Calibration Laboratory

ACCREDITED
Calibration Laboratory
CERT#1326.01

# *Appendix 12 – Species Area Curves for the North and South Breakwater Area*



## *Appendix 13 - Phytoplankton species identification and abundance (cells/litre) in seawater samples from Long Bay, Negril*

| SPECIES / STATIONS | N1 | N2 | N3 | N4 | N5 | N6 | N7 | N8 | N9 | N10 | N11 | N12 | N13 | N14 | N15 | N16 | N17 | N18 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bacillariophyta (diatoms)** | | | | | | | | | | | | | | | | | | | |
| *Achnanthes inflata* var. *elata* | 0 | 27 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27 | 0 | 0 | 0 | 58 |
| *Achnanthes longipes* | 0 | 13 | 2 | 3 | 3 | 0 | 123 | 10 | 0 | 7 | 3 | 3 | 7 | 13 | 20 | 950 | 0 | 950 | 2,108 |
| *Achnanthes mauiensis* | 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| *Achnanthes* sp. A | 0 | 33 | 13 | 3 | 5 | 2 | 153 | 20 | 7 | 13 | 3 | 0 | 7 | 7 | 117 | 2,840 | 53 | 977 | 4,253 |
| *Amphidinium carteri* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Amphiprora* sp. A | 0 | 5 | 0 | 10 | 0 | 0 | 200 | 10 | 0 | 5 | 0 | 0 | 0 | 5 | 110 | 1,420 | 80 | 1,420 | 3,265 |
| *Amphiprora* sp. B | 60 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 60 |
| *Amphora bigibba* | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| *Amphora cingulata* | 0 | 0 | 0 | 3 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 20 | 0 | 13 | 0 | 48 |
| *Amphora costata* | 27 | 13 | 0 | 10 | 7 | 33 | 120 | 0 | 10 | 0 | 0 | 0 | 10 | 33 | 60 | 947 | 47 | 957 | 2,273 |
| *Amphora marina* | 10 | 10 | 13 | 12 | 5 | 0 | 127 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 320 | 947 | 10 | 0 | 1,460 |
| *Amphora ostrearia* var. *vitrea* | 0 | 0 | 15 | 20 | 0 | 0 | 5 | 5 | 5 | 5 | 0 | 5 | 0 | 0 | 20 | 0 | 0 | 0 | 80 |
| *Amphora rhombica* | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 15 |
| *Amphora robusta* | 47 | 60 | 23 | 65 | 27 | 35 | 258 | 40 | 57 | 33 | 0 | 7 | 30 | 637 | 307 | 957 | 57 | 987 | 3,625 |
| *Amphora ventricosa* | 23 | 10 | 8 | 18 | 2 | 0 | 122 | 7 | 3 | 7 | 0 | 0 | 3 | 7 | 77 | 947 | 27 | 1,900 | 3,160 |
| *Amphora* sp. | 0 | 5 | 5 | 10 | 0 | 5 | 203 | 20 | 0 | 30 | 0 | 10 | 10 | 10 | 65 | 15 | 50 | 1,425 | 1,863 |
| *Asterionellopsis glacialis* | 17 | 3 | 13 | 20 | 15 | 52 | 147 | 523 | 50 | 510 | 0 | 10 | 333 | 217 | 423 | 1,927 | 153 | 997 | 5,410 |
| *Asterolampra* sp. | 0 | 0 | 0 | 0 | 0 | 5 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| *Attheya* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Bacteriastrum delicatulum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 30 |
| *Campylodiscus* sp. A | 0 | 0 | 0 | 0 | 0 | 0 | 355 | 0 | 0 | 10 | 0 | 0 | 0 | 20 | 20 | 2,840 | 40 | 2,840 | 6,125 |
| *Campylodiscus* sp. B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 40 | 2,840 | 20 | 2,840 | 5,750 |
| *Chaetoceros peruvianus* | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Chaetoceros similis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 |
| *Chaetoceros* sp. A | 10 | 5 | 0 | 5 | 0 | 3 | 0 | 0 | 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 48 |
| *Chaetoceros* sp. B | 7 | 0 | 3 | 3 | 0 | 7 | 0 | 7 | 0 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 37 |
| *Chaetoceros* sp. C | 0 | 0 | 0 | 10 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| *Chaetoceros* sp. E | 0 | 0 | 0 | 140 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 155 |

| SPECIES / STATIONS | N1 | N2 | N3 | N4 | N5 | N6 | N7 | N8 | N9 | N10 | N11 | N12 | N13 | N14 | N15 | N16 | N17 | N18 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Chaetoceros* sp. F | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Chaetoceros* sp. G | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Chaetoceros* sp. H | 10 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 15 |
| *Climacosphenia moniligera* | 0 | 3 | 0 | 2 | 0 | 8 | 128 | 10 | 10 | 3 | 0 | 3 | 7 | 7 | 167 | 2,843 | 20 | 950 | 4,162 |
| *Cocconeis disculoides* | 80 | 120 | 33 | 40 | 42 | 50 | 527 | 67 | 57 | 74 | 7 | 47 | 43 | 127 | 557 | 7 | 130 | 3,817 | 5,822 |
| *Cocconeis placentula* | 33 | 57 | 18 | 53 | 13 | 22 | 178 | 63 | 37 | 43 | 0 | 27 | 63 | 63 | 343 | 1,910 | 100 | 973 | 3,998 |
| *Cocconeis scutellum* | 0 | 23 | 8 | 25 | 8 | 28 | 157 | 17 | 3 | 7 | 0 | 10 | 27 | 50 | 140 | 1,903 | 100 | 980 | 3,487 |
| *Coscinodiscus radiatus* | 0 | 3 | 2 | 7 | 7 | 7 | 118 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 947 | 27 | 947 | 2,077 |
| *Cylindrotheca closterium* | 87 | 143 | 83 | 113 | 33 | 72 | 123 | 20 | 103 | 90 | 40 | 27 | 100 | 307 | 1,147 | 1,923 | 37 | 1,043 | 5,492 |
| *Cymatosira lorenziana* | 7 | 0 | 7 | 3 | 5 | 3 | 248 | 7 | 0 | 7 | 0 | 0 | 0 | 47 | 50 | 0 | 33 | 0 | 417 |
| *Donkinia recta* | 3 | 0 | 0 | 0 | 0 | 0 | 127 | 0 | 0 | 0 | 0 | 10 | 0 | 10 | 7 | 947 | 7 | 0 | 1,110 |
| *Donkinia sp.* | 0 | 5 | 0 | 0 | 0 | 0 | 183 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 1,420 | 0 | 0 | 1,613 |
| *Fragilaria crotonensis* | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 3 | 3 | 0 | 0 | 3 | 7 | 0 | 30 |
| *Fragilaria* sp. A | 3 | 7 | 0 | 13 | 0 | 17 | 125 | 67 | 17 | 43 | 0 | 7 | 70 | 63 | 280 | 957 | 43 | 970 | 2,682 |
| *Gephyria media* | 0 | 0 | 0 | 0 | 0 | 0 | 180 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 25 | 1,420 | 20 | 1,420 | 3,080 |
| *Gomphonema* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 80 | 0 | 0 | 0 | 80 |
| *Grammatophora undulata* | 33 | 0 | 0 | 0 | 0 | 5 | 0 | 130 | 7 | 60 | 3 | 0 | 53 | 3 | 3 | 0 | 0 | 0 | 298 |
| *Gyrosigma hippocampus* | 93 | 90 | 25 | 45 | 5 | 10 | 118 | 13 | 30 | 10 | 0 | 0 | 7 | 60 | 87 | 963 | 17 | 973 | 2,547 |
| *Gyrosigma prolongatum* var. *closterioides* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 20 | 20 | 0 | 10 | 0 | 55 |
| *Gyrosigma wansbeckii* | 10 | 3 | 2 | 2 | 0 | 3 | 120 | 7 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 947 | 7 | 953 | 2,057 |
| *Hemiaulus hauckii* | 0 | 0 | 3 | 0 | 0 | 2 | 125 | 0 | 0 | 3 | 7 | 7 | 17 | 0 | 0 | 947 | 0 | 947 | 2,057 |
| *Isthmia enervus* | 0 | 0 | 0 | 0 | 0 | 0 | 365 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,840 | 40 | 0 | 3,245 |
| *Leptocylindrus danicus* | 0 | 0 | 0 | 0 | 15 | 3 | 0 | 0 | 5 | 0 | 0 | 0 | 10 | 0 | 5 | 0 | 0 | 0 | 38 |
| *Licmophora flabellata* | 0 | 33 | 17 | 10 | 5 | 20 | 130 | 20 | 30 | 13 | 3 | 7 | 30 | 33 | 300 | 3 | 30 | 960 | 1,645 |
| *Melosira moniliformis* | 7 | 27 | 12 | 7 | 2 | 2 | 162 | 7 | 0 | 3 | 3 | 10 | 0 | 27 | 0 | 0 | 40 | 947 | 1,253 |
| *Navicula arenaria* | 10 | 30 | 7 | 3 | 0 | 20 | 8 | 0 | 0 | 17 | 0 | 0 | 23 | 7 | 67 | 947 | 13 | 3 | 1,155 |
| *Navicula cancellata* | 110 | 100 | 72 | 50 | 67 | 83 | 375 | 153 | 50 | 80 | 17 | 117 | 80 | 173 | 410 | 967 | 217 | 963 | 4,083 |
| *Navicula cincta* | 123 | 83 | 35 | 75 | 58 | 65 | 241 | 53 | 57 | 80 | 7 | 33 | 47 | 120 | 473 | 2,870 | 207 | 4,790 | 9,418 |

| SPECIES / STATIONS | N1 | N2 | N3 | N4 | N5 | N6 | N7 | N8 | N9 | N10 | N11 | N12 | N13 | N14 | N15 | N16 | N17 | N18 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Navicula cruciculoides* | 23 | 0 | 3 | 18 | 15 | 28 | 138 | 23 | 10 | 33 | 13 | 30 | 43 | 90 | 1,113 | 970 | 47 | 7 | 2,607 |
| *Navicula cuspidata* | 180 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 180 |
| *Navicula elegans* | 30 | 5 | 5 | 15 | 3 | 3 | 533 | 20 | 10 | 10 | 0 | 0 | 0 | 0 | 30 | 1,420 | 0 | 1,420 | 3,503 |
| *Navicula finmarchica* | 107 | 93 | 40 | 108 | 32 | 45 | 527 | 83 | 37 | 63 | 0 | 30 | 53 | 253 | 870 | 957 | 277 | 2,893 | 6,468 |
| *Navicula* sp. A | 7 | 13 | 0 | 3 | 5 | 0 | 120 | 0 | 7 | 0 | 0 | 7 | 3 | 0 | 27 | 950 | 20 | 947 | 2,108 |
| *Navicula* sp. B | 530 | 0 | 0 | 0 | 0 | 3 | 0 | 15 | 0 | 0 | 10 | 5 | 25 | 10 | 0 | 15 | 0 | 0 | 613 |
| *Navicula* sp. C | 13 | 50 | 17 | 22 | 25 | 23 | 177 | 20 | 33 | 7 | 7 | 10 | 17 | 63 | 150 | 960 | 33 | 980 | 2,607 |
| *Navicula* sp. D | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 50 | 0 | 10 | 0 | 0 | 100 |
| *Navicula* sp. E | 15 | 25 | 0 | 0 | 0 | 10 | 0 | 5 | 0 | 0 | 5 | 15 | 35 | 25 | 20 | 15 | 0 | 10 | 180 |
| *Navicula* sp. F | 77 | 20 | 20 | 15 | 7 | 28 | 125 | 30 | 50 | 60 | 0 | 7 | 50 | 40 | 47 | 963 | 17 | 3,790 | 5,345 |
| *Navicula* sp. G | 10 | 5 | 0 | 5 | 5 | 15 | 183 | 45 | 5 | 5 | 15 | 15 | 10 | 50 | 130 | 1,420 | 30 | 30 | 1,978 |
| *Navicula* sp. H | 0 | 5 | 0 | 5 | 0 | 3 | 3 | 5 | 0 | 0 | 0 | 0 | 0 | 5 | 25 | 1,420 | 0 | 0 | 1,470 |
| *Navicula* sp. I | 0 | 0 | 0 | 0 | 0 | 0 | 45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 45 |
| *Navicula* sp. J | 0 | 0 | 0 | 15 | 0 | 0 | 178 | 15 | 5 | 0 | 0 | 5 | 5 | 15 | 60 | 1,425 | 25 | 1,430 | 3,178 |
| *Nitzschia acuminata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Nitzschia bicapitata* | 300 | 0 | 0 | 5 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 310 |
| *Nitzschia bilobata* | 20 | 0 | 5 | 5 | 3 | 0 | 0 | 15 | 0 | 0 | 0 | 5 | 0 | 30 | 80 | 1,420 | 0 | 0 | 1,583 |
| *Nitzschia frequens* | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Nitzschia kerguelensis* | 3 | 17 | 2 | 20 | 3 | 0 | 0 | 10 | 13 | 13 | 3 | 0 | 30 | 27 | 7 | 20 | 3 | 10 | 182 |
| *Nitzschia laevis* | 70 | 37 | 15 | 47 | 28 | 55 | 318 | 60 | 40 | 43 | 0 | 23 | 77 | 67 | 380 | 3,807 | 1,003 | 1,927 | 7,997 |
| *Nitzschia linearis* | 0 | 0 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 35 |
| *Nitzschia longissima* | 7 | 7 | 5 | 7 | 10 | 2 | 122 | 3 | 0 | 3 | 0 | 0 | 3 | 30 | 53 | 947 | 17 | 0 | 1,215 |
| *Nitzschia macilenta* | 10 | 27 | 0 | 13 | 7 | 5 | 180 | 23 | 3 | 13 | 0 | 3 | 3 | 113 | 163 | 1,900 | 77 | 950 | 3,492 |
| *Nitzschia paleacea* | 133 | 120 | 72 | 83 | 57 | 110 | 427 | 93 | 123 | 107 | 10 | 27 | 180 | 420 | 1,317 | 1,943 | 113 | 1,043 | 6,378 |
| *Nitzschia sigma* | 17 | 10 | 0 | 18 | 5 | 5 | 138 | 17 | 3 | 10 | 0 | 0 | 10 | 13 | 110 | 950 | 67 | 963 | 2,337 |
| *Nitzschia ventricosa* | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 10 | 0 | 5 | 0 | 0 | 15 | 0 | 60 | 10 | 0 | 1,460 | 1,563 |
| *Nitzschia* sp. A | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 20 | 0 | 0 | 20 | 0 | 55 |
| *Nitzschia* sp. B | 0 | 0 | 0 | 7 | 12 | 3 | 128 | 0 | 20 | 7 | 3 | 17 | 20 | 183 | 1,133 | 957 | 20 | 3 | 2,513 |
| *Nitzschia* sp. D | 10 | 0 | 7 | 5 | 2 | 5 | 2 | 10 | 7 | 3 | 0 | 0 | 0 | 0 | 10 | 950 | 0 | 7 | 1,017 |
| *Nitzschia* sp. E | 10 | 0 | 3 | 18 | 2 | 0 | 3 | 7 | 7 | 3 | 3 | 7 | 3 | 37 | 30 | 950 | 0 | 3 | 1,087 |
| *Nitzschia* sp. F | 13 | 117 | 142 | 213 | 63 | 142 | 1,025 | 127 | 220 | 160 | 33 | 90 | 103 | 820 | 1,157 | 3,843 | 377 | 5,907 | 14,552 |
| *Nitzschia* sp. G | 0 | 0 | 0 | 3 | 0 | 0 | 195 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 1,420 | 0 | 0 | 1,623 |
| *Nitzschia* sp. H | 0 | 0 | 0 | 0 | 0 | 5 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| *Nitzschia* sp. I | 0 | 0 | 0 | 0 | 0 | 0 | 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 90 |
| *Nitzschia* sp. J | 0 | 0 | 0 | 0 | 0 | 0 | 45 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 45 |
| *Odontella aurita* | 0 | 10 | 0 | 20 | 0 | 0 | 180 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 1,420 | 0 | 0 | 1,640 |

| SPECIES / STATIONS | N1 | N2 | N3 | N4 | N5 | N6 | N7 | N8 | N9 | N10 | N11 | N12 | N13 | N14 | N15 | N16 | N17 | N18 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Odontella pulchella* | 0 | 3 | 0 | 0 | 0 | 7 | 120 | 3 | 3 | 0 | 0 | 0 | 0 | 73 | 47 | 947 | 0 | 0 | 1,203 |
| *Oestrupia* sp. | 0 | 5 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Pinnularia* sp. | 7 | 70 | 22 | 68 | 22 | 25 | 377 | 43 | 37 | 20 | 3 | 17 | 23 | 67 | 87 | 960 | 43 | 2,853 | 4,743 |
| *Plagiodiscus martensianus* | 0 | 3 | 0 | 0 | 0 | 13 | 0 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 947 | 0 | 0 | 970 |
| *Plagiogramma atomus* | 0 | 0 | 5 | 0 | 0 | 0 | 178 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 203 |
| *Plagiotropis lepidoptera* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 20 |
| *Plagiotropis* sp. | 13 | 0 | 0 | 20 | 7 | 0 | 0 | 17 | 7 | 0 | 10 | 7 | 3 | 43 | 100 | 947 | 73 | 947 | 2,193 |
| *Pleurosigma angulatum* | 0 | 7 | 0 | 5 | 2 | 2 | 118 | 0 | 3 | 0 | 0 | 0 | 0 | 3 | 27 | 953 | 7 | 950 | 2,077 |
| *Pleurosigma normanii* | 17 | 20 | 8 | 5 | 2 | 15 | 145 | 27 | 13 | 10 | 7 | 7 | 37 | 40 | 73 | 953 | 13 | 970 | 2,362 |
| *Podocystis perrinensis* | 3 | 13 | 8 | 3 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 13 | 947 | 27 | 947 | 1,982 |
| *Pseudoeunotia doliolus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 10 |
| *Pseudonitzschia* sp. A | 0 | 0 | 5 | 0 | 0 | 15 | 0 | 5 | 0 | 0 | 0 | 0 | 20 | 10 | 40 | 0 | 0 | 0 | 95 |
| *Rhizosolenia alata* | 3 | 10 | 18 | 0 | 22 | 0 | 137 | 13 | 13 | 7 | 43 | 47 | 13 | 3 | 0 | 947 | 17 | 3 | 1,297 |
| *Rhizosolenia calcar avis* | 7 | 3 | 8 | 18 | 0 | 13 | 120 | 13 | 30 | 7 | 7 | 20 | 47 | 30 | 33 | 3 | 7 | 0 | 367 |
| *Rhizosolenia setigera* | 0 | 3 | 7 | 5 | 12 | 8 | 8 | 0 | 3 | 10 | 47 | 20 | 7 | 10 | 0 | 0 | 10 | 0 | 150 |
| *Rhizosolenia stolterfothii* | 17 | 3 | 7 | 17 | 2 | 0 | 118 | 3 | 10 | 3 | 7 | 10 | 7 | 23 | 7 | 953 | 0 | 0 | 1,187 |
| *Rhopalodia musculus* | 0 | 3 | 3 | 3 | 0 | 10 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 43 | 947 | 37 | 0 | 1,052 |
| *Striatella unipunctata* | 0 | 3 | 2 | 33 | 2 | 53 | 125 | 17 | 23 | 7 | 0 | 3 | 13 | 150 | 140 | 947 | 7 | 950 | 2,475 |
| *Surirella striatula* | 0 | 7 | 0 | 3 | 0 | 5 | 133 | 3 | 3 | 3 | 0 | 0 | 0 | 7 | 20 | 950 | 13 | 953 | 2,102 |
| *Terpsinoe musica* | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 |
| *Thalassionema frauenfeldii* | 37 | 57 | 63 | 142 | 47 | 65 | 40 | 37 | 90 | 60 | 27 | 20 | 63 | 87 | 477 | 963 | 80 | 1,010 | 3,363 |
| *Thalassionema nitzschioides* | 33 | 93 | 63 | 47 | 48 | 55 | 175 | 47 | 73 | 53 | 7 | 33 | 30 | 137 | 683 | 963 | 173 | 4,783 | 7,498 |
| *Thalassiosira* sp. | 140 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 150 |
| *Toxarium undulatum* | 5 | 0 | 0 | 3 | 8 | 0 | 0 | 0 | 20 | 0 | 0 | 5 | 5 | 60 | 50 | 1,420 | 20 | 0 | 1,595 |
| *Trachyneis aspera* | 0 | 5 | 0 | 8 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 33 |
| *Trigonium formosum* | 0 | 0 | 0 | 5 | 0 | 0 | 178 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 1,420 | 1,608 |

| SPECIES / STATIONS | N1 | N2 | N3 | N4 | N5 | N6 | N7 | N8 | N9 | N10 | N11 | N12 | N13 | N14 | N15 | N16 | N17 | N18 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Tropidoneis* sp. A | 27 | 53 | 33 | 55 | 2 | 22 | 138 | 23 | 7 | 7 | 3 | 10 | 13 | 47 | 97 | 1,893 | 27 | 3 | 2,460 |
| *Tropidoneis* sp. B | 3 | 17 | 12 | 47 | 5 | 5 | 0 | 17 | 0 | 13 | 0 | 10 | 3 | 37 | 40 | 3 | 7 | 7 | 225 |
| **Dinophyta (dinoflagellates)** | | | | | | | | | | | | | | | | | | | |
| *Alexandrium* sp. A | 7 | 10 | 3 | 20 | 7 | 0 | 0 | 20 | 27 | 7 | 0 | 0 | 7 | 177 | 27 | 950 | 0 | 10 | 1,270 |
| *Ceratium furca* | 10 | 47 | 18 | 65 | 2 | 0 | 0 | 0 | 33 | 3 | 0 | 0 | 0 | 20 | 57 | 7 | 10 | 13 | 285 |
| *Ceratium fusus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 10 | 0 | 15 |
| *Ceratium lineatum* | 0 | 0 | 3 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 7 | 0 | 3 | 0 | 0 | 3 | 17 | 0 | 40 |
| *Ceratium teres* | 0 | 0 | 3 | 0 | 7 | 2 | 125 | 3 | 3 | 3 | 20 | 3 | 3 | 10 | 0 | 0 | 0 | 0 | 183 |
| *Ceratium trichoceros* | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Ceratium tripos* | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 8 |
| *Ceratocorys horrida* | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Cochlodinium brandti* | 3 | 0 | 13 | 0 | 0 | 0 | 3 | 7 | 0 | 3 | 3 | 0 | 3 | 0 | 13 | 0 | 0 | 0 | 50 |
| *Coolia areolata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Coolia monotis* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 20 |
| *Dinophysis acuminata* | 5 | 0 | 3 | 25 | 15 | 0 | 3 | 5 | 20 | 5 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 5 | 90 |
| *Dinophysis cf. rotundata* | 0 | 0 | 3 | 0 | 0 | 3 | 3 | 0 | 3 | 3 | 7 | 3 | 0 | 0 | 3 | 3 | 13 | 0 | 47 |
| *Dinophysis hastata* | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Gambierdiscus* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 20 |
| *Gonyaulax polygramma* | 0 | 0 | 0 | 5 | 8 | 0 | 183 | 0 | 5 | 5 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 210 |
| *Gonyaulax spinifera* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 90 | 0 | 40 | 0 | 0 | 60 | 190 |
| *Gonyaulax verior* | 0 | 0 | 5 | 5 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 20 | 15 | 0 | 0 | 0 | 53 |
| *Gonyaulax* sp. B | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 20 |
| *Gyrodinium adriaticum* | 13 | 17 | 13 | 37 | 50 | 35 | 123 | 7 | 77 | 23 | 33 | 20 | 13 | 33 | 40 | 0 | 37 | 17 | 588 |
| *Gyrodinium fusiforme* | 0 | 13 | 7 | 8 | 22 | 27 | 30 | 23 | 10 | 23 | 43 | 27 | 27 | 30 | 13 | 10 | 10 | 17 | 340 |
| *Gyrodinium* sp. B | 777 | 883 | 145 | 340 | 307 | 142 | 168 | 97 | 447 | 260 | 150 | 220 | 200 | 493 | 860 | 1,070 | 90 | 1,003 | 7,652 |
| *Gyrodinium* sp. C | 10 | 43 | 8 | 33 | 48 | 27 | 27 | 23 | 3 | 23 | 27 | 3 | 27 | 10 | 17 | 3 | 13 | 50 | 397 |
| *Gymnodinium splendens* | 0 | 0 | 15 | 7 | 7 | 0 | 5 | 0 | 3 | 10 | 3 | 7 | 7 | 0 | 10 | 0 | 7 | 3 | 83 |
| *Karenia* cf. *breviceps* | 30 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 43 |
| *Ostreopsis ovata* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 40 | 0 | 0 | 0 | 50 |
| *Oxytoxum gigas* | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Oxytoxum gladiolus* | 0 | 0 | 0 | 12 | 13 | 10 | 2 | 0 | 0 | 0 | 13 | 13 | 3 | 0 | 3 | 3 | 0 | 0 | 73 |
| *Oxytoxum laticeps* | 0 | 0 | 3 | 0 | 10 | 7 | 128 | 3 | 0 | 10 | 23 | 27 | 0 | 0 | 0 | 3 | 20 | 0 | 235 |

| SPECIES / STATIONS | N1 | N2 | N3 | N4 | N5 | N6 | N7 | N8 | N9 | N10 | N11 | N12 | N13 | N14 | N15 | N16 | N17 | N18 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Oxytoxum parvum* | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 5 | 10 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 25 |
| *Oxytoxum scolopax* | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 7 | 0 | 22 |
| *Oxytoxum tesselatum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 20 |
| *Oxytoxum viride* | 7 | 0 | 12 | 3 | 8 | 8 | 0 | 3 | 0 | 3 | 27 | 10 | 27 | 20 | 13 | 7 | 3 | 0 | 152 |
| *Podolampas palmipes* | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 3 | 0 | 7 | 7 | 0 | 7 | 0 | 0 | 0 | 30 |
| *Prorocentrum belizeanum* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 20 |
| *Prorocentrum emarginatum* | 5 | 0 | 0 | 0 | 3 | 5 | 8 | 10 | 0 | 0 | 0 | 0 | 5 | 0 | 20 | 0 | 0 | 0 | 55 |
| *Prorocentrum gracile* | 30 | 0 | 3 | 22 | 2 | 7 | 118 | 0 | 17 | 0 | 0 | 0 | 3 | 10 | 3 | 3 | 0 | 3 | 222 |
| *Prorocentrum lima* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,840 | 2,840 |
| *Prorocentrum rhathymum* | 13 | 40 | 7 | 48 | 0 | 5 | 123 | 30 | 3 | 10 | 0 | 0 | 7 | 33 | 180 | 973 | 73 | 1,893 | 3,440 |
| *Protoperidinium cerasus* | 3 | 7 | 3 | 10 | 0 | 17 | 122 | 0 | 10 | 7 | 3 | 3 | 3 | 3 | 7 | 0 | 7 | 0 | 205 |
| *Protoperidinium claudicans* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 90 | 0 | 30 | 0 | 0 | 120 |
| *Protoperidinium conicum* | 0 | 7 | 0 | 0 | 0 | 7 | 118 | 30 | 43 | 33 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 950 | 1,192 |
| *Protoperidinium pellucidum* | 5 | 5 | 0 | 28 | 0 | 3 | 0 | 0 | 45 | 0 | 0 | 0 | 0 | 10 | 35 | 5 | 5 | 0 | 140 |
| *Pyrodinium bahamense* var *bahamense* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 30 |
| *Scrippsiella trochoidea* | 0 | 0 | 8 | 5 | 7 | 22 | 0 | 3 | 47 | 47 | 13 | 0 | 27 | 57 | 47 | 10 | 27 | 3 | 322 |
| **Cyanophyta (blue-green algae)** | | | | | | | | | | | | | | | | | | | |
| *Anabaena confervoides* | 700 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 700 |
| *Anabaenopsis circularis* | 2,200 | 30 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,280 |
| *Aphanocapsa* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 2,840 | 2,870 |
| *Arthrospira jenneri* | 85,613 | 680 | 738 | 10 | 0 | 73 | 118 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 3 | 0 | 20 | 87,263 |
| *Chroococcus dispersus* | 3,500 | 70 | 40 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 280 | 80 | 0 | 0 | 0 | 0 | 0 | 3,980 |
| *Chroococcus minutus* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 30 | 0 | 0 | 10 | 10 | 40 | 20 | 0 | 0 | 110 |
| *Fisherella* sp. | 0 | 0 | 0 | 0 | 0 | 55 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 55 |

| SPECIES / STATIONS | N1 | N2 | N3 | N4 | N5 | N6 | N7 | N8 | N9 | N10 | N11 | N12 | N13 | N14 | N15 | N16 | N17 | N18 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Gloeocapsa conglomerata* | 7 | 0 | 5 | 40 | 27 | 43 | 0 | 133 | 77 | 38 | 1,007 | 100 | 313 | 323 | 507 | 947 | 240 | 1,893 | 5,700 |
| *Lyngbya* sp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 20 | 30 |
| *Merismopedia* sp. | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Oscillatoria limosa* | 30 | 7 | 5 | 10 | 22 | 32 | 125 | 17 | 13 | 13 | 273 | 10 | 10 | 147 | 63 | 950 | 0 | 1,900 | 3,627 |
| *Oscillatoria* sp. A | 1,243 | 3 | 47 | 57 | 2 | 7 | 135 | 3 | 7 | 7 | 0 | 17 | 10 | 60 | 107 | 953 | 13 | 953 | 3,623 |
| *Oscillatoria* sp. B | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 10 | 20 | 20 | 0 | 0 | 3 | 17 | 7 | 0 | 0 | 3 | 82 |
| *Oscillatoria* sp. C | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Phormidium favosum* | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 13 | 7 | 23 | 0 | 0 | 0 | 133 | 947 | 7 | 0 | 1,137 |
| *Pleurocapsa minor* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 40 | 0 | 0 | 40 |
| *Spirulina major* | 0 | 0 | 3 | 2 | 2 | 3 | 118 | 7 | 3 | 0 | 0 | 0 | 7 | 13 | 0 | 950 | 13 | 0 | 1,122 |
| *Spirulina subsalsa* | 0 | 0 | 7 | 8 | 3 | 0 | 125 | 3 | 0 | 3 | 13 | 0 | 7 | 3 | 47 | 0 | 7 | 947 | 1,173 |
| **Chlorophyta (green algae)** | | | | | | | | | | | | | | | | | | | |
| *Chlorella vulgaris* | 53 | 90 | 10 | 20 | 37 | 33 | 20 | 57 | 153 | 33 | 0 | 817 | 0 | 0 | 0 | 0 | 0 | 0 | 1,323 |
| *Closterium gracile* | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 10 | 10 | 80 | 0 | 0 | 5 | 30 | 50 | 1,420 | 60 | 0 | 1,670 |
| *Closterium* sp. | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 10 |
| *Micrasterias* sp. | 0 | 10 | 20 | 60 | 33 | 10 | 23 | 13 | 3 | 27 | 77 | 13 | 33 | 3 | 13 | 0 | 40 | 0 | 380 |
| *Radiofilum flavescens* | 0 | 30 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 35 |
| *Schroederia setigera* | 55,900 | 20 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 55,935 |
| **Euglenophyta (euglenoids)** | | | | | | | | | | | | | | | | | | | |
| *Euglena* sp. A | 500 | 0 | 20 | 0 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 525 |
| *Euglena* sp. B | 70 | 25 | 5 | 0 | 0 | 3 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 118 |
| **Phylum Chrysophyta (golden algae)** | | | | | | | | | | | | | | | | | | | |
| *Dictyocha fibula* | 0 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 10 | 10 | 0 | 0 | 30 | 0 | 0 | 0 | 0 | 0 | 60 |
| **Station Total** | 153,542 | 3,913 | 2,276 | 2,823 | 1,544 | 2,032 | 14,562 | 2,782 | 2,628 | 2,723 | 2,182 | 2,522 | 3,012 | 6,953 | 17,227 | 98,412 | 5,112 | 92,010 | |

# *Appendix 14 - Calculation of Shannon-Weaver diversity index for phytoplankton*

| SPECIES | Ni | pi | lnpi | pi(lnpi) |
|---|---|---|---|---|
| *Achnanthes inflata* var. *elata* | 58 | 0.0001401 | -8.8728772 | -0.0012434 |
| *Achnanthes longipes* | 2108 | 0.005065 | -5.2853979 | -0.0267706 |
| *Achnanthes mauiensis* | 100 | 0.0002402 | -8.3338807 | -0.0020021 |
| *Achnanthes* sp. A | 4253 | 0.0102181 | -4.5835927 | -0.0468357 |
| *Amphidinium carteri* | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Amphiprora* sp. A | 3265 | 0.0078438 | -4.8480359 | -0.0380269 |
| *Amphiprora* sp. B | 60 | 0.0001441 | -8.8447064 | -0.0012749 |
| *Amphora bigibba* | 20 | 4.805E-05 | -9.9433187 | -0.0004778 |
| *Amphora cingulata* | 48 | 0.0001161 | -9.0609295 | -0.0010521 |
| *Amphora costata* | 2273 | 0.0054614 | -5.2100485 | -0.0284542 |
| *Amphora marina* | 1460 | 0.0035075 | -5.6528592 | -0.0198273 |
| *Amphora ostrearia* var. *vitrea* | 80 | 0.0001922 | -8.5570243 | -0.0016446 |
| *Amphora rhombica* | 15 | 3.604E-05 | -10.231001 | -0.0003687 |
| *Amphora robusta* | 3625 | 0.0087086 | -4.7434414 | -0.0413089 |
| *Amphora ventricosa* | 3160 | 0.0075915 | -4.8807236 | -0.0370521 |
| *Amphora* sp. | 1863 | 0.0044744 | -5.409376 | -0.0242039 |
| *Asterionellopsis glacialis* | 5410 | 0.0129969 | -4.3430466 | -0.056446 |
| *Asterolampra* sp. | 20 | 4.805E-05 | -9.9433187 | -0.0004778 |
| *Attheya* sp. | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Bacteriastrum delicatulum* | 30 | 7.207E-05 | -9.5378535 | -0.0006874 |
| *Campylodiscus* sp. A | 6125 | 0.0147146 | -4.2189169 | -0.0620796 |
| *Campylodiscus* sp. B | 5750 | 0.0138137 | -4.2820958 | -0.0591515 |
| *Chaetoceros peruvianus* | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Chaetoceros similis* | 30 | 7.207E-05 | -9.5378535 | -0.0006874 |
| *Chaetoceros* sp. A | 48 | 0.0001141 | -9.0783212 | -0.001036 |
| *Chaetoceros* sp. B | 37 | 8.809E-05 | -9.3371829 | -0.0008225 |
| *Chaetoceros* sp. C | 20 | 4.805E-05 | -9.9433187 | -0.0004778 |
| *Chaetoceros* sp. E | 155 | 0.0003724 | -7.8956258 | -0.0029401 |
| *Chaetoceros* sp. F | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Chaetoceros* sp. G | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Chaetoceros* sp. H | 15 | 3.604E-05 | -10.231001 | -0.0003687 |
| *Climacosphenia moniligera* | 4162 | 0.0099979 | -4.60538 | -0.0460441 |
| *Cocconeis disculoides* | 5822 | 0.0139867 | -4.2696518 | -0.0597181 |
| *Cocconeis placentula* | 3998 | 0.0096055 | -4.645418 | -0.0446216 |
| *Cocconeis scutellum* | 3487 | 0.0083763 | -4.7823495 | -0.0400584 |
| *Coscinodiscus radiatus* | 2077 | 0.0049889 | -5.3005316 | -0.026444 |
| *Cylindrotheca closterium* | 5492 | 0.0131931 | -4.3280639 | -0.0571004 |
| *Cymatosira lorenziana* | 417 | 0.001001 | -6.9067644 | -0.0069136 |
| *Donkinia recta* | 1110 | 0.0026666 | -5.9269356 | -0.015805 |
| *Donkinia sp.* | 1613 | 0.0038738 | -5.5535099 | -0.0215134 |
| *Fragilaria crotonensis* | 30 | 7.207E-05 | -9.5378535 | -0.0006874 |
| *Fragilaria* sp. A | 2682 | 0.0064424 | -5.0448572 | -0.0325009 |
| *Gephyria media* | 3080 | 0.0073993 | -4.9063661 | -0.0363038 |
| *Gomphonema* sp. | 80 | 0.0001922 | -8.5570243 | -0.0016446 |
| *Grammatophora undulata* | 298 | 0.0007167 | -7.2408395 | -0.0051896 |
| *Gyrosigma hippocampus* | 2547 | 0.0061181 | -5.0965103 | -0.0311808 |
| *Gyrosigma prolongatum* var. *closterioides* | 55 | 0.0001321 | -8.9317177 | -0.0011802 |
| *Gyrosigma wansbeckii* | 2057 | 0.0049409 | -5.3102091 | -0.0262372 |

| SPECIES | Ni | pi | lnpi | pi(lnpi) |
|---|---|---|---|---|
| *Hemiaulus hauckii* | 2057 | 0.0049409 | -5.3102091 | -0.0262372 |
| *Isthmia enervus* | 3245 | 0.0077957 | -4.8541803 | -0.0378418 |
| *Leptocylindrus danicus* | 38 | 9.009E-05 | -9.31471 | -0.0008392 |
| *Licmophora flabellata* | 1645 | 0.0039519 | -5.5335553 | -0.0218681 |
| *Melosira moniliformis* | 1253 | 0.003011 | -5.805489 | -0.0174802 |
| *Navicula arenaria* | 1155 | 0.0027747 | -5.8871953 | -0.0163355 |
| *Navicula cancellata* | 4083 | 0.0098097 | -4.624382 | -0.0453639 |
| *Navicula cincta* | 9418 | 0.0226248 | -3.7887083 | -0.0857188 |
| *Navicula cruciculoides* | 2607 | 0.0062622 | -5.0732234 | -0.0317696 |
| *Navicula cuspidata* | 180 | 0.0004324 | -7.7460941 | -0.0033496 |
| *Navicula elegans* | 3503 | 0.0084143 | -4.7778187 | -0.0402022 |
| *Navicula finmarchica* | 6468 | 0.0155394 | -4.1643772 | -0.0647119 |
| *Navicula* sp. A | 2108 | 0.005065 | -5.2853979 | -0.0267706 |
| *Navicula* sp. B | 613 | 0.0014715 | -6.521502 | -0.0095961 |
| *Navicula* sp. C | 2607 | 0.0062622 | -5.0732234 | -0.0317696 |
| *Navicula* sp. D | 100 | 0.0002402 | -8.3338807 | -0.0020021 |
| *Navicula* sp. E | 180 | 0.0004324 | -7.7460941 | -0.0033496 |
| *Navicula* sp. F | 5345 | 0.0128407 | -4.3551341 | -0.055923 |
| *Navicula* sp. G | 1978 | 0.0047507 | -5.3494622 | -0.0254137 |
| *Navicula* sp. H | 1470 | 0.0035315 | -5.6460333 | -0.019939 |
| *Navicula* sp. I | 45 | 0.0001081 | -9.1323884 | -0.0009873 |
| *Navicula* sp. J | 3178 | 0.0076336 | -4.8752009 | -0.0372151 |
| *Nitzschia acuminata* | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Nitzschia bicapitata* | 310 | 0.0007447 | -7.2024786 | -0.005364 |
| *Nitzschia bilobata* | 1583 | 0.0038018 | -5.5722898 | -0.0211845 |
| *Nitzschia frequens* | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Nitzschia kerguelensis* | 182 | 0.0004364 | -7.7368774 | -0.0033766 |
| *Nitzschia laevis* | 7997 | 0.019211 | -3.9522709 | -0.0759272 |
| *Nitzschia linearis* | 35 | 8.408E-05 | -9.3837029 | -0.000789 |
| *Nitzschia longissima* | 1215 | 0.0029189 | -5.8365516 | -0.0170363 |
| *Nitzschia macilenta* | 3492 | 0.0083883 | -4.7809165 | -0.0401038 |
| *Nitzschia paleacea* | 6378 | 0.0153232 | -4.1783888 | -0.0640262 |
| *Nitzschia sigma* | 2337 | 0.0056136 | -5.1825702 | -0.0290927 |
| *Nitzschia ventricosa* | 1563 | 0.0037537 | -5.5850085 | -0.0209645 |
| *Nitzschia* sp. A | 55 | 0.0001321 | -8.9317177 | -0.0011802 |
| *Nitzschia* sp. B | 2513 | 0.006038 | -5.1096858 | -0.0308522 |
| *Nitzschia* sp. D | 1017 | 0.0024424 | -6.0147663 | -0.0146906 |
| *Nitzschia* sp. E | 1087 | 0.0026106 | -5.9481807 | -0.0155282 |
| *Nitzschia* sp. F | 14552 | 0.0349586 | -3.3535901 | -0.1172369 |
| *Nitzschia* sp. G | 1623 | 0.0038979 | -5.5473275 | -0.0216227 |
| *Nitzschia* sp. H | 20 | 4.805E-05 | -9.9433187 | -0.0004778 |
| *Nitzschia* sp. I | 90 | 0.0002162 | -8.4392413 | -0.0018247 |
| *Nitzschia* sp. J | 45 | 0.0001081 | -9.1323884 | -0.0009873 |
| *Odontella aurita* | 1640 | 0.0039399 | -5.5365994 | -0.0218137 |
| *Odontella pulchella* | 1203 | 0.0028909 | -5.8462002 | -0.0169006 |
| *Oestrupia* sp. | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Pinnularia* sp. | 4743 | 0.0113953 | -4.4745555 | -0.0509888 |
| *Plagiodiscus martensianus* | 970 | 0.0023303 | -6.0617549 | -0.0141258 |
| *Plagiogramma atomus* | 203 | 0.0004865 | -7.628311 | -0.003711 |
| *Plagiotropis lepidoptera* | 20 | 4.805E-05 | -9.9433187 | -0.0004778 |
| *Plagiotropis* sp. | 2193 | 0.0052692 | -5.2458732 | -0.0276417 |
| *Pleurosigma angulatum* | 2077 | 0.0049889 | -5.3005316 | -0.026444 |

| SPECIES | Ni | pi | lnpi | pi(lnpi) |
|---|---|---|---|---|
| *Pleurosigma normanii* | 2362 | 0.0056736 | -5.1719281 | -0.0293436 |
| *Podocystis perrinensis* | 1982 | 0.0047607 | -5.3473574 | -0.0254572 |
| *Pseudoeunotia doliolus* | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Pseudonitzschia* sp. A | 95 | 0.0002282 | -8.385174 | -0.0019137 |
| *Rhizosolenia alata* | 1297 | 0.0031151 | -5.7714988 | -0.0179787 |
| *Rhizosolenia calcar avis* | 367 | 0.0008809 | -7.0345978 | -0.0061966 |
| *Rhizosolenia setigera* | 150 | 0.0003604 | -7.9284156 | -0.0028571 |
| *Rhizosolenia stolterfothii* | 1187 | 0.0028508 | -5.8601474 | -0.0167062 |
| *Rhopalodia musculus* | 1052 | 0.0025265 | -5.9809194 | -0.0151108 |
| *Striatella unipunctata* | 2475 | 0.0059459 | -5.1250553 | -0.030473 |
| *Surirella striatula* | 2102 | 0.005049 | -5.288565 | -0.026702 |
| *Terpsinoe musica* | 8 | 1.802E-05 | -10.924148 | -0.0001968 |
| *Thalassionema frauenfeldii* | 3363 | 0.00808 | -4.8183631 | -0.0389324 |
| *Thalassionema nitzschioides* | 7498 | 0.0180138 | -4.0166149 | -0.0723547 |
| *Thalassiosira* sp. | 150 | 0.0003604 | -7.9284156 | -0.0028571 |
| *Toxarium undulatum* | 1595 | 0.0038318 | -5.5644219 | -0.0213217 |
| *Trachyneis aspera* | 33 | 7.808E-05 | -9.4578108 | -0.0007384 |
| *Trigonium formosum* | 1608 | 0.0038618 | -5.5566155 | -0.0214587 |
| *Tropidoneis* sp. A | 2460 | 0.0059099 | -5.1311343 | -0.0303243 |
| *Tropidoneis* sp. B | 225 | 0.0005405 | -7.5229505 | -0.0040664 |
| *Alexandrium* sp. A | 1270 | 0.003051 | -5.7922788 | -0.0176724 |
| *Ceratium furca* | 285 | 0.0006847 | -7.2865617 | -0.0049889 |
| *Ceratium fusus* | 15 | 3.604E-05 | -10.231001 | -0.0003687 |
| *Ceratium lineatum* | 40 | 9.61E-05 | -9.2501715 | -0.0008889 |
| *Ceratium teres* | 183 | 0.0004404 | -7.7277449 | -0.0034036 |
| *Ceratium trichoceros* | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Ceratium tripos* | 8 | 1.802E-05 | -10.924148 | -0.0001968 |
| *Ceratocorys horrida* | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Cochlodinium brandti* | 50 | 0.0001201 | -9.0270279 | -0.0010843 |
| *Coolia areolata* | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Coolia monotis* | 20 | 4.805E-05 | -9.9433187 | -0.0004778 |
| *Dinophysis acuminata* | 90 | 0.0002162 | -8.4392413 | -0.0018247 |
| *Dinophysis cf. rotundata* | 47 | 0.0001121 | -9.0960208 | -0.0010198 |
| *Dinophysis hastata* | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Gambierdiscus* sp. | 20 | 4.805E-05 | -9.9433187 | -0.0004778 |
| *Gonyaulax polygramma* | 210 | 0.0005045 | -7.5919434 | -0.0038301 |
| *Gonyaulax spinifera* | 190 | 0.0004565 | -7.6920269 | -0.003511 |
| *Gonyaulax verior* | 53 | 0.0001261 | -8.9782378 | -0.0011324 |
| *Gonyaulax* sp. B | 20 | 4.805E-05 | -9.9433187 | -0.0004778 |
| *Gyrodinium adriaticum* | 588 | 0.0014134 | -6.5617572 | -0.0092744 |
| *Gyrodinium fusiforme* | 340 | 0.0008168 | -7.1101053 | -0.0058076 |
| *Gyrodinium* sp. B | 7652 | 0.0183822 | -3.9963722 | -0.0734621 |
| *Gyrodinium* sp. C | 397 | 0.0009529 | -6.9559546 | -0.0066286 |
| *Gymnodinium splendens* | 83 | 0.0002002 | -8.5162023 | -0.0017049 |
| *Karenia* cf. *breviceps* | 43 | 0.0001021 | -9.1895469 | -0.0009383 |
| *Ostreopsis ovata* | 50 | 0.0001201 | -9.0270279 | -0.0010843 |
| *Oxytoxum gigas* | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Oxytoxum gladiolus* | 73 | 0.0001762 | -8.6440357 | -0.0015229 |
| *Oxytoxum laticeps* | 235 | 0.0005646 | -7.4794654 | -0.0042226 |
| *Oxytoxum parvum* | 25 | 6.006E-05 | -9.7201751 | -0.0005838 |
| *Oxytoxum scolopax* | 22 | 5.205E-05 | -9.8632759 | -0.0005134 |
| *Oxytoxum tesselatum* | 20 | 4.805E-05 | -9.9433187 | -0.0004778 |

| SPECIES | Ni | pi | lnpi | pi(lnpi) |
|---|---|---|---|---|
| *Oxytoxum viride* | 152 | 0.0003644 | -7.9173658 | -0.0028848 |
| *Podolampas palmipes* | 30 | 7.207E-05 | -9.5378535 | -0.0006874 |
| *Prorocentrum belizeanum* | 20 | 4.805E-05 | -9.9433187 | -0.0004778 |
| *Prorocentrum emarginatum* | 55 | 0.0001321 | -8.9317177 | -0.0011802 |
| *Prorocentrum gracile* | 222 | 0.0005325 | -7.5378762 | -0.0040141 |
| *Prorocentrum lima* | 2840 | 0.0068228 | -4.9874916 | -0.0340284 |
| *Prorocentrum rhathymum* | 3440 | 0.0082642 | -4.7958242 | -0.0396336 |
| *Protoperidinium cerasus* | 205 | 0.0004925 | -7.616041 | -0.0037508 |
| *Protoperidinium claudicans* | 120 | 0.0002883 | -8.1515592 | -0.00235 |
| *Protoperidinium conicum* | 1192 | 0.0028628 | -5.8559428 | -0.0167646 |
| *Protoperidinium pellucidum* | 140 | 0.0003363 | -7.9974085 | -0.0026898 |
| *Pyrodinium bahamense* var *bahamense* | 30 | 7.207E-05 | -9.5378535 | -0.0006874 |
| *Scrippsiella trochoidea* | 322 | 0.0007728 | -7.1655351 | -0.0055373 |
| *Anabaena confervoides* | 700 | 0.0016817 | -6.3879706 | -0.0107424 |
| *Anabaenopsis circularis* | 2280 | 0.0054774 | -5.2071202 | -0.0285216 |
| *Aphanocapsa* sp. | 2870 | 0.0068948 | -4.9769836 | -0.0343154 |
| *Arthrospira jenneri* | 87263 | 0.2096396 | -1.5623653 | -0.3275337 |
| *Chroococcus dispersus* | 3980 | 0.0095615 | -4.6500138 | -0.044461 |
| *Chroococcus minutus* | 110 | 0.0002643 | -8.2385706 | -0.0021771 |
| *Fisherella* sp. | 55 | 0.0001321 | -8.9317177 | -0.0011802 |
| *Gloeocapsa conglomerata* | 5700 | 0.0136928 | -4.290888 | -0.0587541 |
| *Lyngbya* sp. | 30 | 7.207E-05 | -9.5378535 | -0.0006874 |
| *Merismopedia* sp. | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Oscillatoria limosa* | 3627 | 0.0087126 | -4.7429817 | -0.0413238 |
| *Oscillatoria* sp. A | 3623 | 0.0087046 | -4.7439012 | -0.0412939 |
| *Oscillatoria* sp. B | 82 | 0.0001962 | -8.536405 | -0.0016748 |
| *Oscillatoria* sp. C | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Phormidium favosum* | 1137 | 0.0027307 | -5.9031956 | -0.0161199 |
| *Pleurocapsa minor* | 40 | 9.61E-05 | -9.2501715 | -0.0008889 |
| *Spirulina major* | 1122 | 0.0026947 | -5.91648 | -0.015943 |
| *Spirulina subsalsa* | 1173 | 0.0028188 | -5.8714469 | -0.0165504 |
| *Chlorella vulgaris* | 1323 | 0.0031791 | -5.7511418 | -0.0182837 |
| *Closterium gracile* | 1670 | 0.004012 | -5.518472 | -0.02214 |
| *Closterium* sp. | 10 | 2.402E-05 | -10.636466 | -0.0002555 |
| *Micrasterias* sp. | 380 | 0.0009129 | -6.9988797 | -0.0063893 |
| *Radiofilum flavescens* | 35 | 8.408E-05 | -9.3837029 | -0.000789 |
| *Schroederia setigera* | 55935 | 0.1343771 | -2.0071053 | -0.269709 |
| *Euglena* sp. A | 525 | 0.0012612 | -6.6756527 | -0.0084197 |
| *Euglena* sp. B | 118 | 0.0002823 | -8.1726126 | -0.002307 |
| *Dictyocha fibula* | 60 | 0.0001441 | -8.8447064 | -0.0012749 |
| **Total** | **416254** | **1** | | **-3.76** |
| **Diversity Index** | | | | **3.76** |

## *Appendix 15 - Chlorophyll a levels for the size fractions for all stations*

| Station | Net (mg Chl.a m3) | Nano (mg Chl.a m3) | Pico (mg Chl.a m3) |
|---|---|---|---|
| 1b | 0.25 | 0.19 | 0.26 |
| 2b | 0.10 | 0.12 | 0.10 |
| 3t | 0.06 | 0.08 | 0.08 |
| 3b | 0.08 | 0.07 | 0.09 |
| 4t | 0.02 | 0.06 | 0.10 |
| 4b | 0.04 | 0.07 | 0.13 |
| 5t | 0.01 | 0.02 | 0.06 |
| 5b | 0.02 | 0.04 | 0.07 |
| 6t | 0.03 | 0.06 | 0.10 |
| 6b | 0.02 | 0.06 | 0.12 |
| 7t | 0.10 | 0.06 | 0.05 |
| 7b | 0.06 | 0.08 | 0.06 |
| 8b | 0.02 | 0.07 | 0.12 |
| 9b | 0.04 | 0.10 | 0.10 |
| 10b | 0.02 | 0.06 | 0.13 |
| 11t | 0.06 | 0.04 | 0.06 |
| 11m | 0.04 | 0.04 | 0.05 |
| 11b | 0.03 | 0.05 | 0.07 |
| 12t | 0.02 | 0.04 | 0.06 |
| 12b | 0.03 | 0.04 | 0.06 |
| 13b | 0.02 | 0.05 | 0.11 |
| 14b | 0.06 | 0.11 | 0.17 |
| 15b | 0.08 | 0.15 | 0.16 |
| 16b | 0.12 | 0.15 | 0.14 |
| 17t | 0.04 | 0.07 | 0.05 |
| 17m | 0.05 | 0.07 | 0.10 |
| 17b | 0.03 | 0.10 | 0.06 |
| 18b | 0.09 | 0.15 | 0.14 |

## *Appendix 16 – Questionnaires*

The following were covered with the socio team administering the questionnaires during a training meeting prior to the surveys:

(i) What is an EIA and why we do it, the process and legal requirements including the role of relevant organisations.
(ii) What a social survey entails and examples and experiences we have all had when conducting surveys.
(iii) Background on beach erosion and problems in Negril.
(iv) Background on Negril having a socially active community, that people may ask more questions than they can answer and that they should be directed to the company and website.
(v) What are breakwaters versus groynes.
(vi) Who CEAC is and explanation about a model to reduce the problem.
(vii) How the breakwaters would be built.
(viii) The kind of background work undertaken for the EIA.
(ix) The use of maps to explain placement of the breakwaters and staging area. Each team member was given a map depicting the Negril area showing both locations which they could use to help orientate the interviewee.
(x) They were each given a summary paragraph guiding them how to introduce themselves and what to say about the project. Summarized in the paragraph at the top of each survey instrument is the content below:

*"Hello, my name is ………………………………I am part of an environmental team from CL Environmental conducting a perception survey of the proposed Negril breakwater project. It is being proposed that two breakwaters will be constructed offshore Long Bay beach for shoreline protection and in order to mitigate the erosion problem. This project falls under a larger Adaptation Fund Programme involving a number of government agencies including NEPA, PIOJ, NWA, MOAF and MOT."*

*"You were randomly selected to take part in this survey and your participation in this interview is voluntary. You do not have to answer any questions that you are uncomfortable with. There are no right or wrong answers."*

*"I can assure you of full confidentiality in this survey. Your identity and responses will be kept confidential and your privacy*

*will be protected. I will not use your name, only a code number, to identify your information in my formal analysis and reports."*

(xi) They were told that alternatives were explored but this deemed the best. Alternatives were not discussed in detail.

(xii) Each question was discussed with the survey team to ensure that each person had the same understanding of what the question was getting at.

(xiii) There was a question and answer time at the end of the session to clarify any queries or concerns each person had.

## Community

**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 Negril breakwater project. It is being proposed that two breakwaters will be constructed offshore Long Bay beach for shoreline protection and in order to mitigate the erosion problem. This project falls under a larger Adaptation Fund Programme involving a number of government agencies including NEPA, PIOJ, NWA, MOAF and MOT. You were randomly selected to take part in this survey and your participation in this interview is voluntary. You do not have to answer any questions that you are not comfortable with. There are no right or wrong answers. I can assure you of full confidentiality in this survey. Your identity and responses will be kept confidential and your privacy will be protected. I will not use your name, only a code number, to identify your information in my formal analysis and reports.**

**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________
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 ____________

1

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 REGARDING BREAKWATER**

22. Since living in this community have you noticed any environmental changes
    Yes No
    If yes, specify
    ______________________________________________________________

23. Do you know what breakwaters are?
    Yes No (***if no provide a <u>brief non-technical</u> explanation***)

24. Are you aware of the proposal to build breakwaters at Long Bay, Negril
    Yes No (***if no provide a <u>brief non-technical</u> summary***)

25. Do you have any concerns about the project as proposed? (i) yes; (ii) no
    a. If yes what are they?
    ______________________________________________________________
    ______________________________________________________________

26. 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?
    ______________________________________________________________

27. Do you think that breakwaters are needed at Long Bay, Negril?
    _ Yes _ No

28. Do you think that the construction may cause any negative impact on business in the area?
    ¯ Yes ¯ No

29. Do you believe that construction activity will be good for the area ?
    _ Yes _ No
    If yes, please specify ________________________________________

30. Do you believe that construction activity will affect your income earning capacity?
    ¯ Yes ¯ No
    If yes, please specify ________________________________________

31. What do you think are some of the environmental problems occurring at Long Bay?
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________
__________________________________________________________________

32. Do you think that the construction of breakwaters will alleviate some of the problems occurring at Long Bay?
    ¯ Yes ¯ No

33. Can you think of any other measures that could be taken to alleviate these problems?
Yes No
If yes, please specify ________________________________________________

**EMPLOYMENT & INCOME**

34. Including yourself how many people in your household are employed?
__________________________

35. 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

36. 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 | |

37. What is the average weekly income of the household head? ____________________

38. What is your average weekly income? ___________________________

39. What is the average weekly income of the household? (All sources) _______________

40. Do you depend on the proposed location for business? (i) yes (ii) no
If yes what do you depend on it for?
______________________________________________________________________

**EDUCATION**

41. What is the highest level of education completed? (Which was the last school you attended)
_ None _ Primary _ Secondary _ Tertiary _ Technical Vocational (e.g. HEART)

42. 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.***

## Fishers

**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 Negril breakwater project. It is being proposed that two breakwaters will be constructed offshore Long Bay beach for shoreline protection and in order to mitigate the erosion problem. This project falls under a larger Adaptation Fund Programme involving a number of government agencies including NEPA, PIOJ, NWA, MOAF and MOT. You were randomly selected to take part in this survey and your participation in this interview is voluntary. You do not have to answer any questions that you are not comfortable with. There are no right or wrong answers. I can assure you of full confidentiality in this survey. Your identity and responses will be kept confidential and your privacy will be protected. I will not use your name, only a code number, to identify your information in my formal analysis and reports.**

**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 Negril area?
   ☐ <1 year ☐ 1 – 10 years ☐ 11 – 20 years ☐ > 20 years

**SECTION I: Perception of Environmental Quality**

5. Are you aware of any environmental problems within your community? ☐ Yes ☐ No

If yes, please state:

| |
|---|
| • |
| • |
| • |
| • |
| • |

6. What changes (either positive or negative) have occurred in the past 10 years that you have noticed in the environment? *E.g. beach erosion*

| |
|---|
| • |
| • |
| • |
| • |

7. What do you think have caused these changes? *E.g. increase in population, hotel development*

| |
|---|
| • |
| • |
| • |
| • |

8. What are the top three (3) environmental problems facing your community?

| |
|---|
| a) |
| b) |
| c) |

**SECTION II: Dependence on the Environment**

9. Do you rely on the environment as a source of income? ☐ Yes ☐ No

10. If yes, what current activities are you engaged in that are reliant on the environment?
   a. Agriculture
   b. Fishing
   c. Tourism Industry
   d. Craft Industry
   e. Other, please state ________________

11. Who are your main customers for your output? (Select where necessary)
   ☐ Locals
   ☐ Tourists
   ☐ Hotels
   ☐ Hostels
   ☐ Guesthouses
   ☐ Resort villas
   ☐ Apartments
   ☐ Other: ___________________________

12. What percentage of your total income is derived from the environment?
   a. >75%
   b. 51% - 75%
   c. 25% - 50%
   d. < 25%

13. 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

14. Do you rely on the environment for subsistence? ☐ Yes ☐ No

15. What % of your total activities is for subsistence?
   a. >75%
   b. 51% - 75%
   c. 25% - 50%
   d. < 25%

**SECTION III: Impact on the Environment**

16. Are you aware of any activities or practices which impact on the environment positively or negatively?
    ☐ Yes ☐ No
    If yes please specify: ______________________________

17. 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: ______________________________

18. 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: ______________________________

19. 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 ______________

20. What practice(s) do you think will be applicable in preserving the environment as well as sustaining it for the future?

| |
|---|
| • |
| • |
| • |
| • |
| • |

21. 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

22. If yes, would you be willing to pay for the full cost of these services? ☐ Yes ☐ No

23. If not the full cost, then how much would you be willing per month to pay to have?
    ______________________________

24. If no, to question 2, why?
    ______________________________
    ______________________________
    ______________________________

**SECTION IV: Constructing Two Breakwaters at Long Bay, Negril**

25. Are you aware of the proposal to construct two breakwaters at Long Bay, Negril? ☐ Yes ☐ No

26. Should they be constructed? ☐ Yes ☐ No

27. Do you think the constructing of the Breakwaters will affect your daily activities? ☐ Yes ☐ No
If Yes, how: ______________________________________________
______________________________________________
______________________________________________
______________________________________________

28. Do you believe construction activities will impact on your income/livelihood? ☐ Yes ☐ No
If Yes, how: ______________________________________________
______________________________________________
______________________________________________
______________________________________________

29. Do you think constructing the two breakwaters will assist in protecting the Bay? ☐ Yes ☐ No

30. Instead of constructing the breakwaters, do you think any other means can be used to protect the Bay from erosion? ☐ Yes ☐ No
If Yes, please specify:
______________________________________________
______________________________________________
______________________________________________
______________________________________________

**BACKGROUND**

31. Highest level of education:

☐ Primary ☐ Secondary ☐ Tertiary ☐ Technical Vocational

32. Do you own your own home? ☐ Yes ☐ No

33. Do you rent? ☐ Yes ☐ No

34. Do you own any land? ☐ Yes ☐ No

35. 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.***

## Watersports Operators

**WATERSPORTS OPERATORS** 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 Negril breakwater project. It is being proposed that two breakwaters will be constructed offshore Long Bay beach for shoreline protection and in order to mitigate the erosion problem. This project falls under a larger Adaptation Fund Programme involving a number of government agencies including NEPA, PIOJ, NWA, MOAF and MOT. You were randomly selected to take part in this survey and your participation in this interview is voluntary. You do not have to answer any questions that you are not comfortable with. There are no right or wrong answers. I can assure you of full confidentiality in this survey. Your identity and responses will be kept confidential and your privacy will be protected. I will not use your name, only a code number, to identify your information in my formal analysis and reports.**

**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 to which persons involved in the water-sport business are dependent on the environment for their livelihood as well as subsistence***
- ***To determine the extent to which persons involved in the water-sport business contribute to environmental preservation or degradation.***

1. Age: ☐ <25 ☐ 26-40 ☐ 41-60 ☐ >60
2. Gender: ☐ Male ☐ Female
3. How long have you been involved in watersports operation? ____________________

**SECTION I: Business Description**

4. What services do you provide?

| Service | Cost per person (USD/JMD) |
|---|---|
| | |
| | |
| | |
| | |
| | |

5. Could you identify your customers/clients by percentage?

Locals _____% Tourists ____ %

1

6. Approximately how many customers do you serve per day?
   ☐ <25 ☐26 – 50 ☐51- 75 ☐76 – 100 ☐>100

7. Do you use any equipment in your job? ☐ Yes ☐ No
If yes, please specify ____________________

8. Do your customers/clients have to be in the water at any time during the water-sport activity?
   ☐ Yes ☐ No

9. Approximately how far out do they go from the shore during this activity? ____________________

**SECTION II: Dependence on the Environment**

10. Do you depend on the environment for your business? ☐ Yes ☐ No
Please explain ____________________

11. Have you noticed any changes in the water or the environment since you have been in this business?
   ☐ Yes ☐ No

12. If yes, what have you noticed?

| |
|---|
| • |
| • |
| • |

13. What do you think has caused these changes?

| |
|---|
| • |
| • |
| • |

14. What would you say has been the most significant change?
____________________

15. Have the changes which you have observed affected your core business in any way? ☐ Yes ☐ No
If yes, please explain?
____________________
____________________

16. Have any of your customers indicated to you that they noticed similar changes? ☐ Yes ☐ No

17. Have any of your customers complained about these changes? ☐ Yes ☐ No

18. Have any of your customers experienced illnesses as a result of these changes? ☐ Yes ☐ No
If yes, please specify ____________________

19. Have you lost customers as a result of these changes? ☐ Yes ☐ No

20. Is there a particular time of day or season when these changes are most evident? ☐ Yes ☐ No
If yes, when? ____________________

21. What are your hours of operation? ______________________________

22. What percentage of your income is derived from the environment?
☐ >75% ☐ 51 – 75% ☐ 25 – 50% ☐ <25%

23. Would you be willing to state your weekly income (JMD/USD)? ☐ 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

**SECTION III: Environmental Impact**

24. Are you aware of any activities/practices that impact the environment positively or negatively?
☐ Yes ☐ No
If yes, please specify ______________________________

25. Do you think that any of your practices impact the environment positively? ☐ Yes ☐ No
If yes, please specify ______________________________

26. Do you think that any of your practices impact the environment negatively? ☐ Yes ☐ No
If yes, please specify ______________________________

27. Does the operation of your business contribute to any of the following?
☐ Noise pollution
☐ Air pollution
☐ Water pollution
☐ Land pollution
☐ Other: ______________________________

28. Do you educate you customers on positive environmental practices? ☐ Yes ☐ No
If not, why not? ______________________________

29. What challenges prevent you from engaging in positive environmental practices
☐ Cost
☐ Too little time
☐ Lack of know how
☐ Lack of technical assistance
☐ Lack of information about positive practices
☐ Do not see it as important to my business

30. If an environmental agency were providing you with information/technical assistance on ways to improve your environmental practices would you be willing to pay for these services? ☐ Yes ☐ No

31. If yes, will you be willing to pay the full cost? ☐ Yes ☐ No

32. If you are not willing to pay the full cost, can you say why?
______________________________
______________________________

33. What percentage of the cost will you be willing to pay per month?
☐ >75% ☐ 51 – 75% ☐ 25 – 50% ☐ <25%

3

**SECTION IV: Impact of Construction of Breakwaters**

34. Do you know what breakwaters are? ☐ Yes ☐ No

35. Do you think that breakwaters are needed at Long Bay, Negril? ☐ Yes ☐ No

36. Do you think that the construction may cause your business to have to relocate? ☐ Yes ☐ No

37. Do you believe that construction activity will affect your core business? ☐ Yes ☐ No
If yes, please specify ______________________________________________

______________________________________________

38. Do you believe that construction activity will affect your income earning capacity? ☐ Yes ☐ No
If yes, please specify ______________________________________________

39. What do you think are some of the environmental problems occurring at Long Bay?

______________________________________________

______________________________________________

______________________________________________

40. Do you think that the construction of breakwaters will alleviate some of the problems occurring at Long Bay? ☐ Yes ☐ No

41. Can you think of any other measures that could be taken to alleviate these problems? ☐ Yes ☐ No
If yes, please specify ______________________________

**BACKGROUND**

42. Highest level of education:

☐ Primary ☐ Secondary ☐ Tertiary ☐ Technical Vocational

43. Do you own your own home? ☐ Yes ☐ No

44. Do you rent? ☐ Yes ☐ No

45. Do you own any land? ☐ Yes ☐ No

46. 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.***

4

## Retail and Other Services

**SHOP/ STALL/ MOBILE OPERATORS** 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 Negril breakwater project. It is being proposed that two breakwaters will be constructed offshore Long Bay beach for shoreline protection and in order to mitigate the erosion problem. This project falls under a larger Adaptation Fund Programme involving a number of government agencies including NEPA, PIOJ, NWA, MOAF and MOT. You were randomly selected to take part in this survey and your participation in this interview is voluntary. You do not have to answer any questions that you are not comfortable with. There are no right or wrong answers. I can assure you of full confidentiality in this survey. Your identity and responses will be kept confidential and your privacy will be protected. I will not use your name, only a code number, to identify your information in my formal analysis and reports.**

**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 to which persons involved in the retail business are dependent on the environment for their livelihood as well as subsistence***
- ***To determine the extent to which persons involved in the retail business contribute to environmental preservation or degradation.***

1. Age: ☐ <25 ☐ 26-40 ☐ 41-60 ☐ >60
2. Gender: ☐ Male ☐ Female
3. How long have you been involved in this operation? ____________________
4. Where do you live? ____________________________________________________________

**SECTION I: Business Description**

5. Are you the sole owner of the shop/stall/mobile? ☐ Yes ☐ No
6. If no, how many other partners? ________________________
7. What time do you open for business ________ close for the day _________?
8. How many persons are employed at the shop/stall? ______________________

9. What services do you provide?

| Service | Cost per person (USD/JMD) |
|---|---|
| | |
| | |
| | |
| | |
| | |

10. Approximately how many customers do you serve per day?
☐ <25 ☐26 – 50 ☐51- 75 ☐76 – 100 ☐>100

11. Could you identify your customers/clients by percentage?
Locals _____% Tourists ____ %

12. Do you own any other stalls along the beach? ☐ Yes ☐ No

13. If yes where? ____________________________________________________________

**SECTION II: Dependence on the Environment**

14. Do you depend on the environment for your business? ☐ Yes ☐ No
Please explain ____________________________________________________________

15. Have you noticed any changes in the water or the environment since you have been in this business?
☐ Yes ☐ No

16. If yes, what have you noticed?

| |
|---|
| • |
| • |
| • |

17. What do you think has caused these changes?

| |
|---|
| • |
| • |
| • |

18. What would you say has been the most significant change?

____________________________________________________________

19. Have the changes which you have observed affected your core business in any way? ☐ Yes ☐ No
If yes, please explain?

____________________________________________________________

____________________________________________________________

20. Have any of your customers indicated to you that they noticed similar changes? ☐ Yes ☐ No

21. Have any of your customers complained about these changes? ☐ Yes ☐ No

22. Have any of your customers experienced illnesses as a result of these changes? ☐ Yes ☐ No
If yes, please specify ____________________

23. Have you lost customers as a result of these changes? ☐ Yes ☐ No

24. Is there a particular time of day or season when these changes are most evident? ☐ Yes ☐ No
If yes, when? ____________________

25. What percentage of your income is derived from the environment?
☐ >75% ☐ 51 – 75% ☐ 25 – 50% ☐ <25%

26. Would you be willing to state your weekly income (JMD/USD)? ☐ 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

27. 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

**SECTION III: Environmental Impact**

28. Are you aware of any activities/practices that impact the environment positively or negatively?
☐ Yes ☐ No
If yes, please specify ____________________

29. Do you think that any of your practices impact the environment positively? ☐ Yes ☐ No
If yes, please specify ____________________

30. Do you think that any of your practices impact the environment negatively? ☐ Yes ☐ No
If yes, please specify ____________________

31. Does the operation of your business contribute to any of the following?
☐ Noise pollution
☐ Air pollution
☐ Water pollution
☐ Land pollution
☐ Other: ____________________

32. Do you educate you customers on positive environmental practices? ☐ Yes ☐ No
If not, why not? ____________________

33. What challenges prevent you from engaging in positive environmental practices
☐ Cost
☐ Too little time
☐ Lack of know how
☐ Lack of technical assistance
☐ Lack of information about positive practices
☐ Do not see it as important to my business

34. If an environmental agency were providing you with information/technical assistance on ways to improve your environmental practices would you be willing to pay for these services? ☐ Yes ☐ No

**SECTION IV: Impact of Construction of Breakwaters**

35. Do you know what breakwaters are? ☐ Yes ☐ No

36. Do you think that breakwaters are needed at Long Bay, Negril? ☐ Yes ☐ No

37. Do you think that the construction may cause your business to have to relocate? ☐ Yes ☐ No

38. Do you believe that construction activity will affect your core business? ☐ Yes ☐ No

If yes, please specify ____________________________________________

____________________________________________

39. Do you believe that construction activity will affect your income earning capacity? ☐ Yes ☐ No

If yes, please specify ____________________________________________

40. What do you think are some of the environmental problems occurring at Long Bay?

____________________________________________

____________________________________________

____________________________________________

41. Do you think that the construction of breakwaters will alleviate some of the problems occurring at Long Bay? ☐ Yes ☐ No

42. Can you think of any other measures that could be taken to alleviate these problems? ☐ Yes ☐ No

If yes, please specify ______________________________

**BACKGROUND**

43. Highest level of education:

☐ Primary ☐ Secondary ☐ Tertiary ☐ Technical Vocational

44. Do you own your own home? ☐ Yes ☐ No

45. Do you rent? ☐ Yes ☐ No

46. Do you own any land? ☐ Yes ☐ No

**ANY OTHER COMMENTS**

____________________________________________

____________________________________________

____________________________________________

***THANK YOU FOR YOUR TIME TODAY. I APPRECIATE YOUR PARTICIPATION IN THIS SURVEY.***

## Tourists

**TOURISTS** 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 Negril breakwater project. It is being proposed that two breakwaters will be constructed offshore Long Bay beach for shoreline protection and in order to mitigate the erosion problem. This project falls under a larger Adaptation Fund Programme involving a number of government agencies including NEPA, PIOJ, NWA, MOAF and MOT. You were randomly selected to take part in this survey and your participation in this interview is voluntary. You do not have to answer any questions that you are not comfortable with. There are no right or wrong answers. I can assure you of full confidentiality in this survey. Your identity and responses will be kept confidential and your privacy will be protected. I will not use your name, only a code number, to identify your information in my formal analysis and reports.**

**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 how much value tourists place on tourism sites***
- ***To determine the impact of tourism on the environment (both positive and negative)***

1. Age: ☐ <25 ☐ 26-40 ☐ 41-60 ☐ >60
2. Gender: ☐ Male ☐ Female
3. Occupation: ________________________________

**SECTION I: Purpose of Visit**

4. What is the primary purpose of your visit to Negril?
   - ☐ Vacation
   - ☐ Business
   - ☐ Visit family/friends
   - ☐ Meeting/Conference
   - ☐ Other, please state ________________

5. How did you make your travel arrangements to Negril?
   - ☐ Independently
   - ☐ Travel Agency in Jamaica
   - ☐ Travel Agency (at home)
   - ☐ Other, please state ________________

6. Have you visited Long Bay beach previously? ☐ Yes ☐ No

If yes, number of times________________ Year of last visit________________

1

7. How did you find out about Long Bay beach?
   - ____ Travel Agency
   - ____ Internet Site
   - ____ Newspaper/Magazine
   - ____ Friend/Family
   - ____ Other, please state______________

8. How many days are you planning to be in and around Negril? ________________

9. Where was the last location you visited before coming to Negril? ______________________________

10. Where are you going after your visit to this tourism site? ______________________________________
    (List city or location)

11. Please check each activity that you have participated or intend to participate during your visit to Long Bay?
    - ____ Glass bottom boat tours
    - ____ Water sports
    - ____ Cruises
    - ____ Horseback riding
    - ____ Sun bathing
    - ____ Jogging/ walking
    - ____ Restaurants
    - ____ Nightlife
    - ____ Snorkelling/Diving
    - ____ Fishing
    - ____ Visiting Booby Cay
    - ____ Volleyball
    - ____ Swimming
    - ____ Massage
    - ____ Wedding
    - ____ Other, please state______________

12. Please check each activity that you have participated or intend to participate during your visit to Negril?
    - ____ Trails/hiking
    - ____ Museums
    - ____ Waterfall
    - ____ Cliff jumping
    - ____ Visiting cultural sites
    - ____ Other, please state______________

13. Do you perceive the activities you are taking part in (based on question 8) will impact on the environment negatively? ☐ Yes ☐ No

14. Does environmental quality play an important role in choosing the tourism destination you visit?
    ☐ Yes ☐ No

15. How will you rate the environmental quality of Long Bay beach as a tourism site?
a. Poor b. Fair c. Satisfactory d. Goode. Excellent

16. How will you rate the environmental quality of the general Negril area as a tourism site?
a. Poor b. Fair c. Satisfactory d. Goode. Excellent

**SECTION II: Perception of Tourism Site (Negril)**

17. How do you view the development of the tourism sector?
a. Long term b. Short term c. Both

18. Do you share the view that development of the tourism sector should include the environment?
    ☐ Yes ☐ No

19. Are you aware of any environmental problems within this tourism site? ☐ Yes ☐ No
If yes, please state:

| |
|---|
| • |
| • |
| • |
| • |
| • |

20. Do you believe that once contributions to the national GDP from the tourism sector are increasing, no emphasis should be placed on maintaining and preserving the environment? ☐ Yes ☐ No

21. Based on your experiences along Long Bay beach, 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 Long Bay beach 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**

22. 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 |

23. Do you know what breakwaters are? ☐ Yes ☐ No

24. There is a proposal to construct two breakwaters at Long Bay, Negril. Do you think they should be constructed? ☐ Yes ☐ No

25. Do you think constructing the two breakwaters will assist in protecting the beach from erosion, and its tourism products? ☐ Yes ☐ No

26. Instead of constructing the breakwaters, do you think any other means can be used to protect the beach from erosion? ☐ Yes ☐ No

If yes, please specify:

______________________________________________
______________________________________________
______________________________________________
______________________________________________
______________________________________________

**SECTION IV: Willingness to Pay**

27. On average, what costs (accommodation, meals, trips, souvenirs) have you incurred in **a DAY** in Negril?
USD/JMD ______________________

28. Do you know the cost of the Long Bay Beach Park fee? ☐ Yes, Cost (JMD/USD) ________ ☐ No

29. If yes to Question 2 above, how do you rate the fee?

a. Too much
b. Acceptable
c. Too little
d. Should not have to pay

Why?______________________________________________
______________________________________________

30. Would you be willing to pay any additional amount if it is to be used for conservation efforts?
☐ Yes ☐ No
How much? ______________________________________________

**BACKGROUND**

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 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.***

# *Appendix 17 –Focus Group Attendance and Discussions*

**DAY 1 SESSION 1**

*This group consisted of eight (8) persons representing Environmental groups (NEPT, NEPA), one hotelier and one representative from the Negril craft-market.*

STOCKPILE AREA

The first concern that was raised related to the proximity of the stockpile to the business community in Negril and the potential hazard that this poses. There were further concerns related to the dredging of the river. The views expressed suggested that this river was once a stream that widened over the years. It was the view of everyone that once dredged it was only a matter of time (4-5 months) before the sand was re-deposited at the mouth of the river due to wave action. It was pointed out that though this was not really part of the scope of work of the breakwater project, it was hoped that removing the sand from the river mouth would serve two purposes. Firstly it would help the fisher folk who needed to take their boats up the river and secondly the sand would be used in the stockpile area.

EROSION

It was the view of most present that the reasons for the erosion on the Negril beach were both natural and man-made. The man-made factor was directly related to the construction of hotels along the beach in breach of the building regulations for beachfront properties (150ft from the high water mark). It was the opinion of the group that these properties should be removed as an additional measure to stem the tide of beach erosion.

OTHER FACTORS

The group expressed the view that the construction of the breakwater should not be a 'one-stop-shop'. In addition, other factors that impact the entire Negril ecosystem need to be addressed, such as the 'health' of the morass which directly affects its ability to perform the function of nutrient and sediment filtration. This can have a negative effect on the life of the existing reef.

MONITORING PERIOD

The group suggested that the monitoring period of 12 months was too short and that a longer period would be more adequate.

EFFECT OF BEACH EROSION ON BUSINESS

When asked whether there was loss of business due to erosion of the beach, all present responded in the affirmative. One such example was the frequent flooding occurring in the craft market which seriously affected business there. It was pointed out that Negril beach was once ranked in the top two beaches in the world in the 1980's. By the 1990's it ranked among the top ten and today it is somewhere among the top fifty. This was attributed to the beach erosion.

BREAKWATER DESIGN AND LOCATION

In terms of prioritization of the measures to be taken to mitigate beach erosion, most agreed that the breakwater is the best measure to be put in place. However, there were concerns about the choice of location, the appropriateness of the design and the rationale for the choice.

WAVE ACTION & EROSION

On the issue of the effect of wave action on beach erosion, it was suggested that the large number of mechanized equipment plying their trade on the water further amplifies the natural wave action further exacerbating beach erosion. It was further pointed out that there are only 36 licensed motorized equipment operators but approximately 200 operate in the area presently.

EFFECT OF BREAKWATER ON BUSINESS

Most present expressed the view that in the long run the breakwater will help their business but had some concerns about the negative externalities in the short term such as noise from the dropping of boulders, turbidity of the water, traffic congestion etc.

KNOWLEDGE OF THE PROJECT

The group stated that there was not enough public awareness of the project as the cultural practice has been the top down approach to project implementation. It was the view of all present that stakeholders should be incorporated from inception.

TIMING OF THE PROJECT

The proposed commencement date of the project is June 2014. Concerns were expressed about the effect that the project would have on the holiday activities in Negril.

**DAY 1 SESSION 2**

*This group consisted of thirteen (13) persons representing fisher folk and water-sport personnel.*

LOCATION OF THE STOCKPILING AREA

Concerns were expressed about the stockpiling area being located in close proximity to the river mouth which is frequently used by the fishermen.

DREDGING OF THE RIVER

Further concerns were expressed about the dredging of the river and the cause and effect relationship of the moving sand from that area. While the dredging of the river would be helpful to the fishermen who ply their trade in this river, movement of the sand would cause the re-deposition of more sand over time which would work against them in the long run.

MONITORING PERIOD

It was unanimously agreed that the monitoring period was too short and a period of about 36 months was suggested.

INDICATORS IN THE WATER

The water-sport personnel indicated that it was necessary to position indicators in the area of the breakwater for unsuspecting users of the area such as boaters.

THE BREAKWATER (Location, workability, removal)

The view was that the breakwater in its present proposed location will not be protecting the area of the beach in which most erosion is occurring. The southern end of the beach was identified as that area and the breakwater's location is not targeted to protect the southern end. Further questions surfaced as to places in other parts of the world where this design has been successfully implemented. The group also wanted to know where liability would fall should the design fail and whether the structure could be removed should this be the case.

CAUSES OF BEACH EROSION

The group agreed that the beach was being eroded due to both natural and man-made occurrences. They identified structures that were built on the beach which do not conform to the requisite set back distance requirement as the reason. It was suggested that for the breakwater to be effective, these structures need to be removed and the requisite laws enforced.

SUPPORTIVE ROLE

When asked whether they see themselves playing a supportive role in the monitoring process, the initial answer was in the negative since they did not think that they possessed the technical 'know-how' to so do but agreed that if training were provided they would take up the challenge of partnering with the requisite body for the purpose of monitoring.

**DAY 2 SESSION 1**

*This group consisted of eight (8) persons representing the planning and law enforcement agencies in Negril such as the police, fire services and health department.*

REEF DAMAGE

Concerns were raised in relation to the potential damage that may be done to the reef as a result of barge and crane operations at sea and high levels of sediment in the water during the construction phase.

MONITORING

It was the view that the monitoring period of 12 months was inadequate and a five (5) year period should be considered.

AREAS OF EROSION

The group sought information as to whether studies were done to show whether the area identified was in fact the area where the greatest erosion occurred. They were duly informed that four studies were done along with the use of satellite imagery to arrive at those locations. The southern end of the beach was identified as the area which in their view was greatest affected by erosion.

EXTENSION OF BREAKWATER

The group enquired whether there were plans to extend the length of the breakwater structure in the future recognizing that funding may have been a limiting factor in determining the length of the design.

SAFETY AND SECURITY

Issues were raised as to whether there were procedures / systems in place in case of accidents on the badge out at sea and whether an emergency procedure would put in place on land. It was pointed out that at present there was only one operational fire boat for such a procedure.

TRAFFIC CONGESTION

The issue of traffic congestion due to the movement of the large trucks through the stockpiling area in the business community of Negril and the potential damage that may be done to the roadway was raised. It was also highlighted that this situation becomes more critical in light of the fact that this project is expected to commence during the season when there are many events taking place in Negril. It was suggested that transportation of material at night should be considered to eliminate congestion and potential accidents and that a schedule be worked out to stagger the dispatching of trucks. Further to this there should be a briefing session for the truckers.

AIR POLLUTION/DUST

The view was expressed that there is the potential for a public outcry / demonstrations as a result of high levels of dust and noise and this can be exacerbated if employment opportunities are not made available for the residents of Negril over the duration of the project.

**DAY 2 SESSION 2**

*This group consisted of twenty-three (23) persons representing the hoteliers and key personnel from the tourism industry including TPDCO and the Jamaica Tourist Board.*

APPROVAL OF THE BREAKWATER

This group raised concerns related to the approval for the design of the breakwater and enquired as to other locations in the world where this design has been successful. They also wanted to know what studies have been done to determine the feasibility of this design for Negril.

BENEFITS OF THE PROJECT

It was the view of most persons present that the project will do more harm than good in the long run.

EROSION OF THE BEACH

The group suggested that the area designated for protection by the breakwater was not the area in which the greatest erosion was occurring.

WATER FLOW THROUGH BREAKWATER

Questions and concerns were raised about the flow of water through the design and whether a dead zone would be created as a result of the structure.

MONITORING

Concerns were expressed as to the body that would be responsible for maintaining and monitoring the structure and their ability to so do. They paralleled the maintaining of the breakwater with the maintenance of the roads in Negril and were concerned about the authority's ability to take on additional responsibilities of maintenance and monitoring of a structure located in the sea.

CAUSE OF EROSION

They all agreed that the erosion taking place at Negril was as a result of natural causes in addition to man-made causes due to disregard for set-back distances along the beach. They suggested that if this situation is not dealt with and the laws were not enforced the breakwater will not be as effective.

THE MORASS

This group was very concerned about the morass and linked the health of the morass to the health of the reef and the beach. The activities in the construction phase such as dredging could lead to the morass being drained, which would result in fires. It was clearly expressed that the use of soft engineering measures such as beach nourishment and adding nutrients to help restore the health of the morass should be the first step toward saving the beach rather than the construction of the breakwater.

## DAY 1 SESSION 1

NEGRIL BREAK WATER FOCUS GROUP MEETING
MARCH 12, 2014

| NAME | ORGANIZATION/ GROUP | EMAIL | TELEPHONE CONTACT |
|---|---|---|---|
| William Hill | NEPA | William.Hill@nepa.gov.jm | 352-3463 |
| Cordia Chambers-Johnson | NEPA | cordia.johnson@nepa.gov.jm | 754-7590 |
| Joan Wallace 28@yahoo.com | Negril Craft Traders | jef Wallace 36@yahoo.com | |
| Keisha Spencer | NEPT | negrilepa@gmail.com | 957-3736 |
| SOPHIE GRIZZLE | CHARELA INN HOTEL | INFO@CHARELA.COM | 957 4648-50 |
| Peter D. Reid | JAM UK Charities | peternegril55@yahoo.com | 850 6800 |
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**DAY 1 SESSION 2**

NEGRIL BREAK WATER FOCUS GROUP MEETING

MARCH 12, 2014

| NAME | ORGANIZATION/ GROUP | EMAIL | TELEPHONE CONTACT |
|---|---|---|---|
| Ricardo Hylton | Orange Bay Fishers | | |
| Oscar Keckord. | Orange.Bay.fisherman | | 428-0458 |
| Kafel Williams | Fisheries Division | | 577-0596 |
| HOWARD BROMFIELD | M.A.F.D. | h_bromfield@yahoo.com | 963-5123 |
| VINTON KING | NEGRIL FISHERMAN | | 851-5388 |
| Granville Johnson | NEPT | | |
| Lenford King | NEGRIL FISHMAN | | 859-9464 |
| Wayne Salmon | Westmoreland Tourism Council | | ~~858-8426~~ |
| CECIL BROWN | Negril Water Sports Ass. | | 858-8426 |
| BRIAN PLUNKETT | Couples Swept Away | csa.wm@couples.com | 893-5519 |
| Dennis Evans | Fishing | | 4572879 |
| Calton Reynolds | Fishing | | 389 0386 |

## DAY 2 SESSION 1

NEGRIL BREAK WATER FOCUS GROUP MEETING
MARCH 13, 2014

| | NAME | ORGANIZATION/ GROUP | EMAIL | TELEPHONE CONTACT |
|---|---|---|---|---|
| 1. | Mercedes Currie | JCF | | |
| 2. | Charles Campbell | JCF | archie7192003@yahoo | 866-5637/312-8828 |
| 3. | Steve Morris | Westmoreland Health Dept | speckyes@gmail.com | 771-3484 |
| 4. | Donovan Loney | Negril Green Island Area Local | d.loney@yahoo.com | 872-7827 |
| 5. | Cordia Chambers-Johnson | NEPA | cordia.johnson@nepa.gov.jm | 9547540 |
| 6. | Donovan Bennett | JFB | dubennett@yahoo.com | (876)413-6823 |
| 7. | Dion Holgate | NEPT | | |
| 8. | | | | |
| 9. | | | | |
| 10. | | | | |
| 11. | | | | |
| 12. | | | | |

**DAY 2 SESSION 2**

NEGRIL BREAK WATER FOCUS GROUP MEETING
MARCH 13, 2014

| | NAME | ORGANIZATION/ GROUP | EMAIL | TELEPHONE CONTACT |
|---|---|---|---|---|
| 1. | Carlene Allwood | Hedonism II | Carlene Allwood@hedonism.com | 187629[illegible]-1616 |
| 2. | Andrew Ross | SEASCAPE CARIBBEAN | ROSS.ANDREW@MAC.COM | 363-8850 |
| 3. | [illegible] | CRYSTAL WATERS | [illegible]@cwjamaica.com | 524-285 |
| 4. | Elaine Allen-Bradley | WMNH Watch | [illegible]@hotmail.com | 829 2 |
| 5. | Rose Cousins | Little Ridge | rosalie.roachcousins@yahoo.com | |
| 6. | MARY VEIRA | COUPLES | mary@couples.com | 881-8698 |
| 7. | Clifton Ritchie | HEDONISM II | cliftonritchie@hedonism.com | 409-9340 |
| 8. | Lee [illegible] | Couples | lee@couples.com | 381-1122 |
| 9. | Garfield Grant | TPD CO | garfieldg@tpdco.org | 440-8786 |
| 10. | ADRIAN HARRISON | JAMAICA TOURIST BOARD | aharrison@visitjamaica.com | 564-0[illegible] |
| 11. | GERALDINE & RAY ARTHURS | GOLDEN SUNSET VILLAS | arthursr@cwjamaica.com. | 957-4241 |
| 12. | Suzette Wilson | Foote Prints Hotel | footeprints@cwjamaica.com | 957-4300 |
| 13. | AUDREY H. FOOTE | Foote Print Hotel | ✓ ✓ | ✓ |
| 14. | Dwane Austin | N.W.C | dwane.austin@nwc.com.jm | 429-7313 |
| 15. | Winthrope Wellington | Travellers Beach Resort | winthrope@tbresorts.com | 957-3039 |
| 16. | STACY-ANN Heslop | Burger King | Stacyannheslop@[illegible] | 440-1680 |
| 17. | Claudia Gardner | The Gleaner Company Ltd | claudia.gardner@gleanerjm.com | 952-2451 |
| 18. | Leonard [illegible] | Parish Development Committee | [illegible]@[illegible].com | 364-7166 |
| 19. | Anthony Lewis | Nationwide 90FM & Jamaica Observer | digicomchief@Yahoo.com | 859-5009 |
| 20. | Debra Boyle | SeaSand Eco Villas | organicdebra@gmail.com | 892 |
| 21. | Kevin Levee | Hedonism II | KevinLevee@hedonism.com | 957-5200 |
| 22. | ENRICO PEZZOLI | GRAND LIDO | [illegible]@grandlidonegril.com | 337-5010 |
| 23. | DANIEL Garzlu | CHARELA INN | | |

## *Appendix 18 – Port Authority of Jamaica Letter*

The Port Authority of Jamaica
15-17 Duke Street
Kingston, Jamaica, W.I.
Telephone: (876) 922-0290-9
(876) 922-0940-5
Fax: (876) 924-9437
E-mail: paj@portjam.com

April 11 2014

National Works Agency
140 Maxfield Avenue
Kingston 10

**Attention: Mr Andrew Sturridge**

Dear Sirs:

***Re: Negril Break Water Project, Westmoreland***

Having reviewed the drawings submitted with letter dated March 27 2014 in relation to the captioned, we hereby confirm our no objection to the project.

Our support also comes out of recognition of the need to take corrective action to stem the loss of shoreline as a result of continuous beach erosion in the Negril area.

We request that you keep us informed as to the status of the project.

Yours sincerely,

Captain Hopeton DeLisser
**VICE PRESIDENT**
**HARBOURS & PORT SERVICES**

RECEIVED
APR 14 2014
N.W.A.
RECORDS SERVICES UNIT

HD/sl.

c. Mr Earl Patterson, Senior Director, Project Implementation, NWA
Mr Roger Smith, Director, NWA