Summary of Proposed Works - Gran Bahia Principe Expansion

Background

Hojapi Ltd., the hoteliers managing the Gran Bahia Principe resort located in Salt Coopers, Runaway Bay, St. Ann are currently desirous of expanding their existing facility. The proposed works (which are to be phased) will include additional rooms, a small power plant and a new beach. The new beach is deemed necessary to accommodate the expected increased number of guests.

The proposed works are shown in Figure 1 below. As the figure shows expansion is expected towards the east and south. The new beach will also be constructed to the east to accommodate the new guests there.

Additional Rooms

The existing facility at the Gran Bahia Principe resort currently boasts 920 rooms. The hotel had previously received permitting for a total of 1610 rooms. Of the remainder permitted, 435 are being built now during the current works and another 235 will be built in the third phase. The breakdown of rooms are as follows:

Block	Number of Rooms	Phase / Status
11	36	Phase 1 - Existing
12	55	Phase 1 - Existing
13	61	Phase 1 - Existing
14	60	Phase 1 - Existing
15	60	Phase 1 - Existing
16	100	Phase 1 - Existing
17	100	Phase 1 - Existing
18	130	Phase 1 - Existing
21	36	Phase 1 - Existing
22	55	Phase 1 - Existing
23	157	Phase 1 - Existing
24	70	Phase 1 - Existing
25	189	Phase 2 - Being Constructed
26	224	Phase 2 - Being Constructed
27	42	Phase 2 - Being Constructed
	235	To be constructed in Phase 3
	1610	**Total number of rooms permitted**

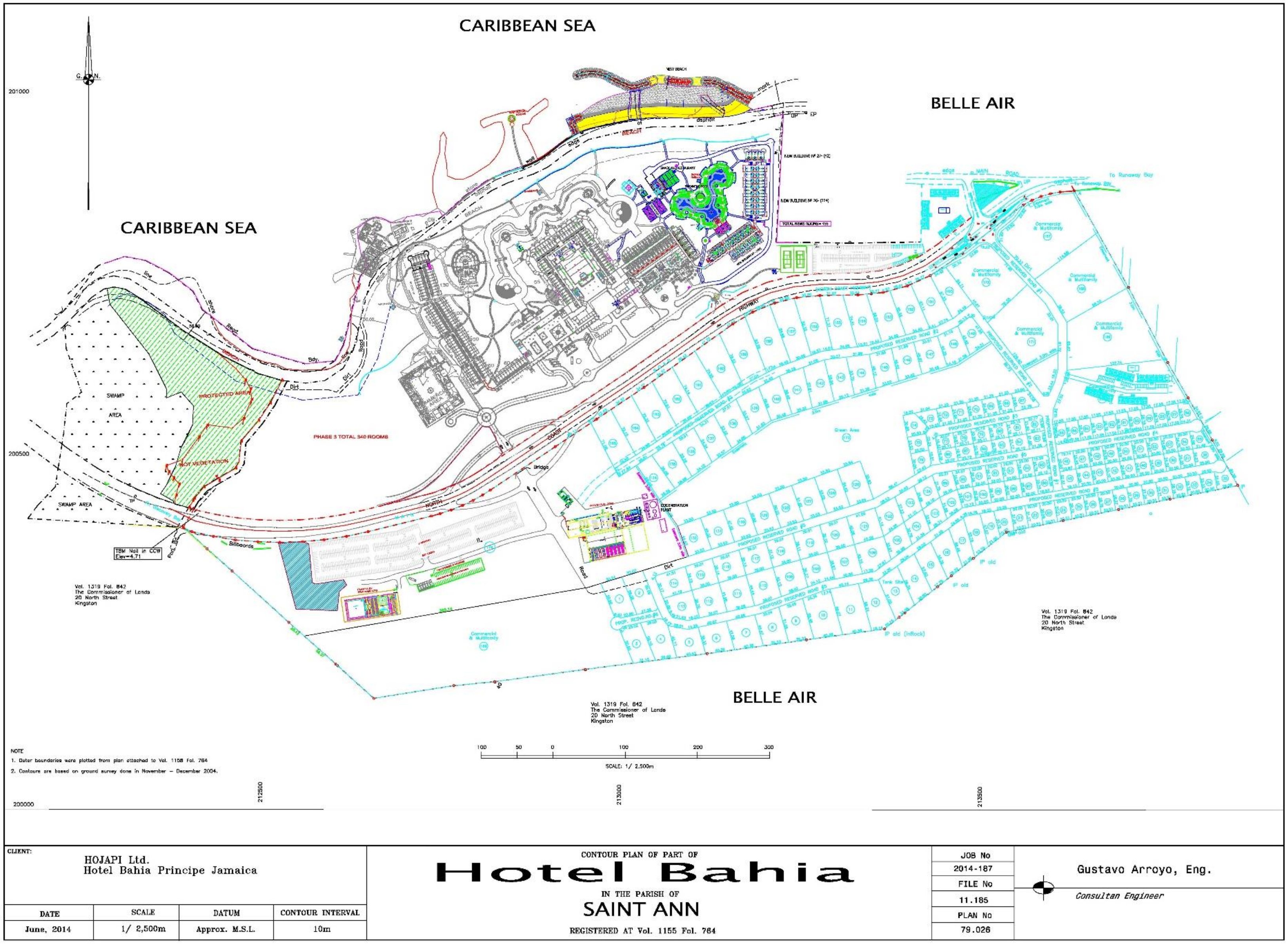

Figure 1 Master plan of the Gran Bahia Principe resort showing proposed additional rooms, proposed cogen plan and proposed lagoon beach.

Cogeneration Project

Cogeneration or combined heat and power (CHP) is the use of a heat engine or power station to generate electricity and useful heat at the same time. Hojapi Ltd. intends to construct a power plant for generation of power to supply the entire Gran Bahia Principe hotel.

The proposed system which is shown below in Figure 2 has the capacity to fulfil 100% of the energy needs for hot water, energy and steam.

The steam generated from the system will be used to run equipment in the laundry areas as well as in the kitchen, and the heat provided from the system generator will be reclaimed.

The harnessing of the system heat for use in the hotel will reduce the escape of heat into the atmosphere and also means that some existing equipment such as the broiler will work less.

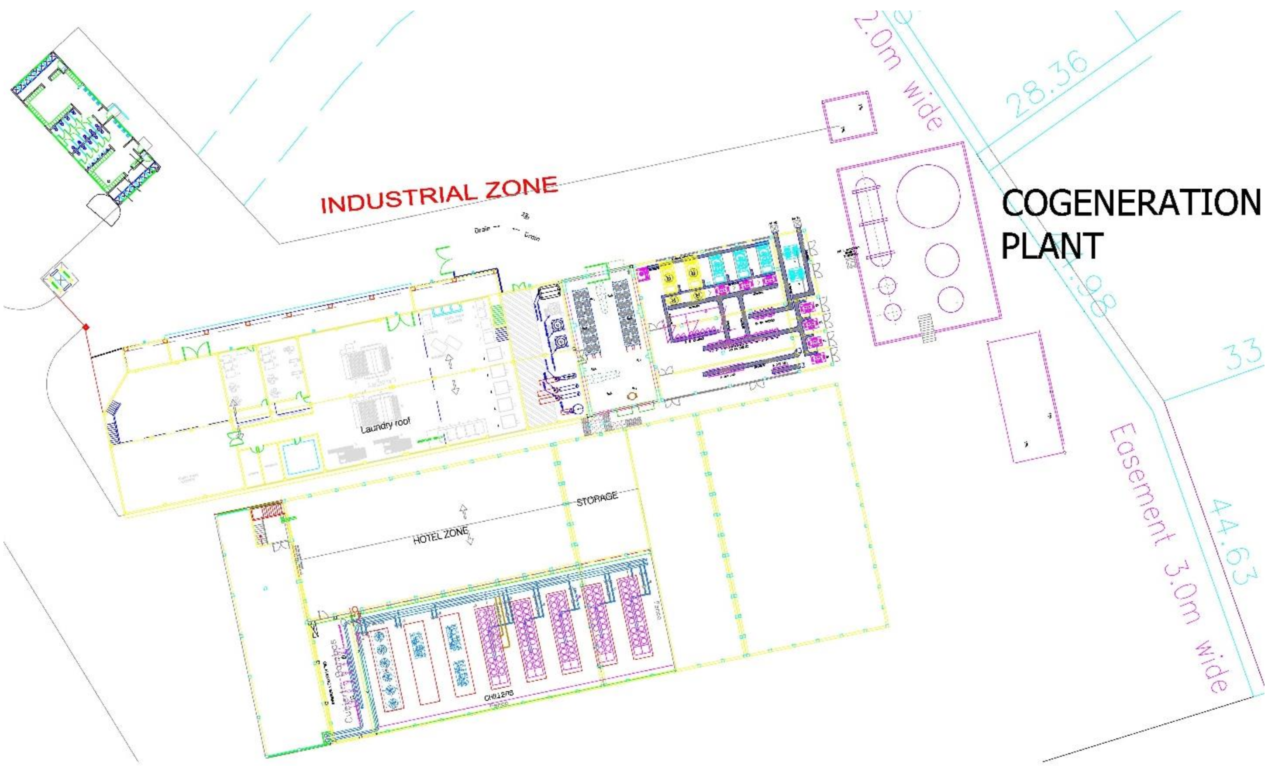

Figure 2 Schematic layout of proposed cogen plant

Proposed Beach

To accommodate the additional expected guests a suitable beach is required. The existing area is not suitable for the following reasons:

- There is insufficient sand on the beach to provide a comfortable beach experience for the expected increased number of guests;
- The nearshore area of the proposed beach has rocks that make wading uncomfortable;
- Unbroken wave energy is reaching the shoreline from the north-east direction;
- The existing structures were poorly constructed using stones too small to withstand major wave forces (such as those due to hurricanes); as a result they have been damaged throughout the hotel's history. It is believed that these structures are currently providing only very limited protection to the nearshore area. Further, their configuration and small stone size are also hampering circulation and contributing to poor water quality in the nearshore.

In order to address these issues, and in general create a proper beach to accommodate the increased number of guests, the following actions would have to be taken:

- Remove small rocks from the nearshore area by hand/shovel and place sand to improve the wading experience;
- Remove that portion of the T-groyne that is currently perpendicular to the shoreline and remove the existing groyne structure towards the east;
- Place approximately 4000m^3 of sand of appropriate quality on the beach. This sand would be used to increase the beach width as well as to cover the rocky substrate in the swimming area;
- Construct a new cut stone walkway boardwalk. which will join the proposed beach to the existing sandy beach;
- Repack the existing breakwater (that portion which is parallel to the shoreline) to be tied in to the proposed structures;
- Extend existing breakwater westward and seaward of its current western end;
- Construct a new submerged breakwater to the east of the existing structure to be tied in when complete;
- Construct a new emergent groyne stretching from the eastern end, forming a right angle and headland to be tied in with the new proposed submerged breakwater; and
- Construct a new spur groyne to the west of the new proposed beach area to retain the sand nourishment placed.

The proposed 'lagoon' beach is shown below in Figure 3. As the image shows and as outlined above, it is proposed that the beach area be nourished with sediment. That sediment is to be retained through the use of connected breakwaters and groynes tying into some existing structures as well as a small spur groyne to the west.

The "Preliminary Engineering Report" attached details the methodology undertaken to determine the aforementioned solution as well as to determine the appropriate stone sizes and layouts. Additionally the "Benthic Relocation Plan" also attached identifies any benthos which will be disturbed by the construction works and suitable relocation sites.

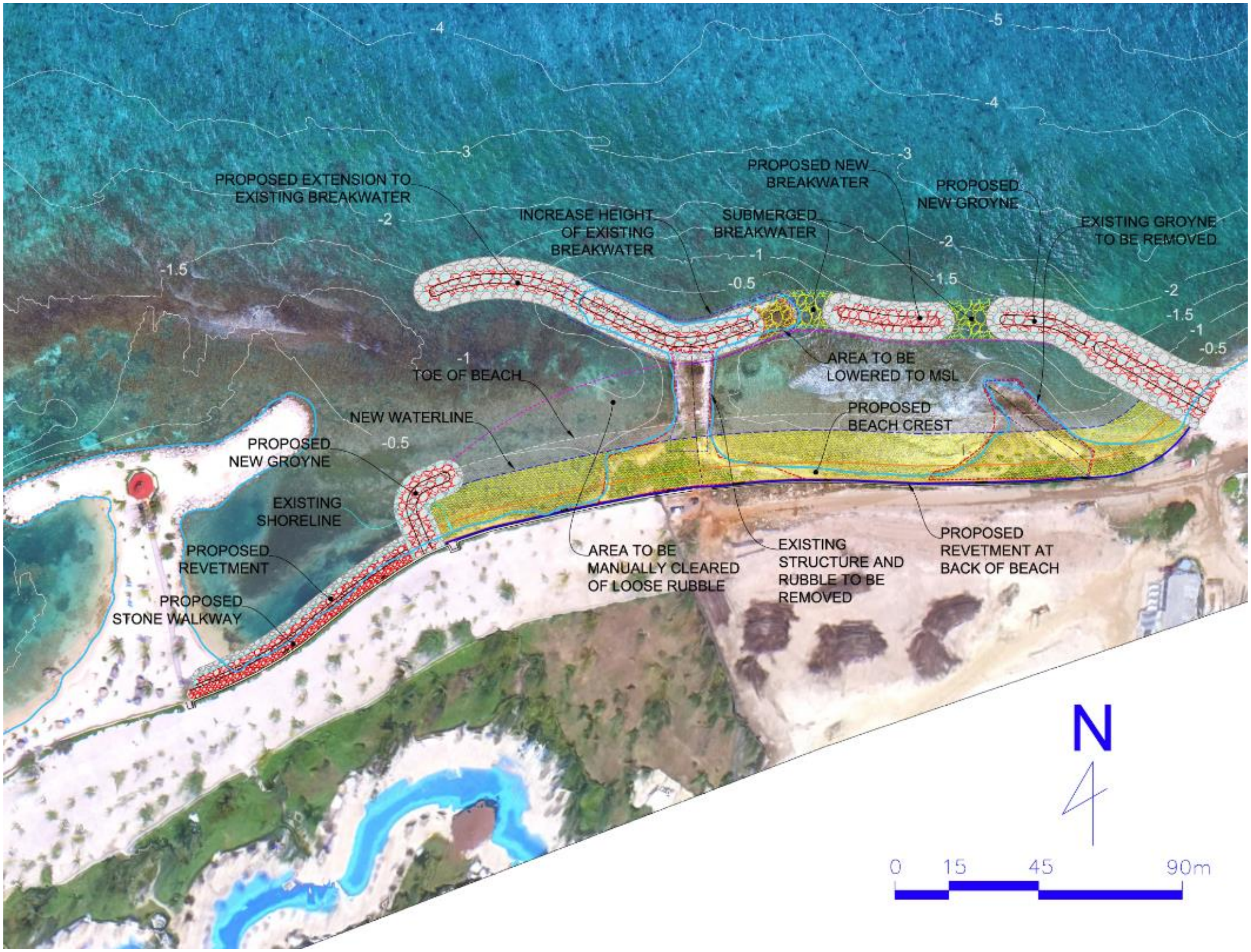

Figure 3 Proposed new beach development showing proposed structures as well as structures to be removed

APPENDIX ONE

Preliminary Engineering Report

Prepared for

Gran Bahia Principe Jamaica

by

Smith Warner International

July 2015

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Appendix A Description of the Models

1. Introduction and Background

Gran Bahia Principe Jamaica, a subsidiary of the Bahia Principe Spas and Resorts Group, is a beachfront resort located in Runaway Bay, Jamaica. The hotel is one of the newer all-inclusive resorts in Jamaica, having only opened its doors in February 2007. The hoteliers now wish to expand the hotel by constructing some additional rooms to the east of the existing facility (Figure 1.1). To accommodate the increased number of guests, they also wish to expand the beach area.

This report serves as a project brief as part of the Beach Licence Application for the proposed beach works at the Gran Bahia Principe Jamaica. The purpose of this report is therefore to furnish the National Environment and Planning Agency (NEPA) with the necessary and relevant information regarding the proposed works.

Figure 1.1 Location map showing Runaway Bay in relation to the rest of Jamaica (left) Google© image overview of project site, highlighting proposed new beach area (right)

The Gran Bahia Principe property spreads along approximately 1 km of shoreline. The main beach is located to the west of the main building; it is separated from the other beaches by a restaurant on the shoreline and is approximately 470m long. As it is the largest beach, it is currently the most used of the three (Plate 1.1). There are remnants of a coral reef directly offshore of this beach. This reef skeleton acts as a natural sheltering agent for the beach, minimally protecting the area from incoming wave energy and negating the necessity for additional structures on this beach. The main bathing beach lacks sand along its western boundary, which limits the usability of this portion of the beach and limits the beach extents as a whole.

The area directly in front of the hotel is heavily constructed, featuring a beach wall, an old road, a breakwater and a groyne. This area is partially enclosed between the groyne and the breakwater, and is referred to as Half Moon Beach (Plate 1.2).

Plate 1.1 Main Bathing Beach looking west (left) and Main Beach looking east (right)

Plate 1.2 Half Moon Beach looking west (left) and looking east (right)

The beach area to the east of the large breakwater is the area currently proposed for further development and enhancement. This beach currently has limited sand and will have to be widened to beyond the eastern boundary if it is to reasonably accommodate the additional guests expected after the expansion.

2. Field Data Collection

2.1 Bathymetric and Aerial Survey

Detailed bathymetric and beach profile surveys were carried out. The bathymetric surveys were conducted by a licensed, contracted surveyor, using an echo-sounder (Odom Echotrac sounding system) mounted over the side of a small boat, while spatial positions were recorded with a Trimble DGPS.

Figure 2.1 shows the bathymetry, with contour lines indicating water depths. The bathymetric survey points are highlighted in a different colour. The contours are generated not only from the bathymetric survey but from available nautical chart depth data as well.

Beach profiles were also surveyed approximately every 30m perpendicular to the shorelines of both beaches. Figure 2.1 also shows the beach profile survey points along with the water depth points that were collected. This data was used to assist in the computer modelling of waves from deep water into the nearshore regions, and in evaluating the degree of sheltering of any proposed option.

Analysis of the bathymetric data superimposed on satellite imagery (Figure 2.1) revealed that the nearshore seafloor has a relatively gentle slope of approximately 4% to the 20m contour line, which lies approximately 0.5km offshore. The shelf ends just beyond that point, as depths drop dramatically with an approximately 40% slope to the -200m contour.

An aerial drone survey was also conducted at the project site. The purpose of this survey was to collect high resolution images of the nearshore area from which an estimate could be made as to the best possible alignment of structures as well as the location of offshore sand deposits that could be used in sand nourishment. An example of the aerial imagery is shown in Figure 2.2.

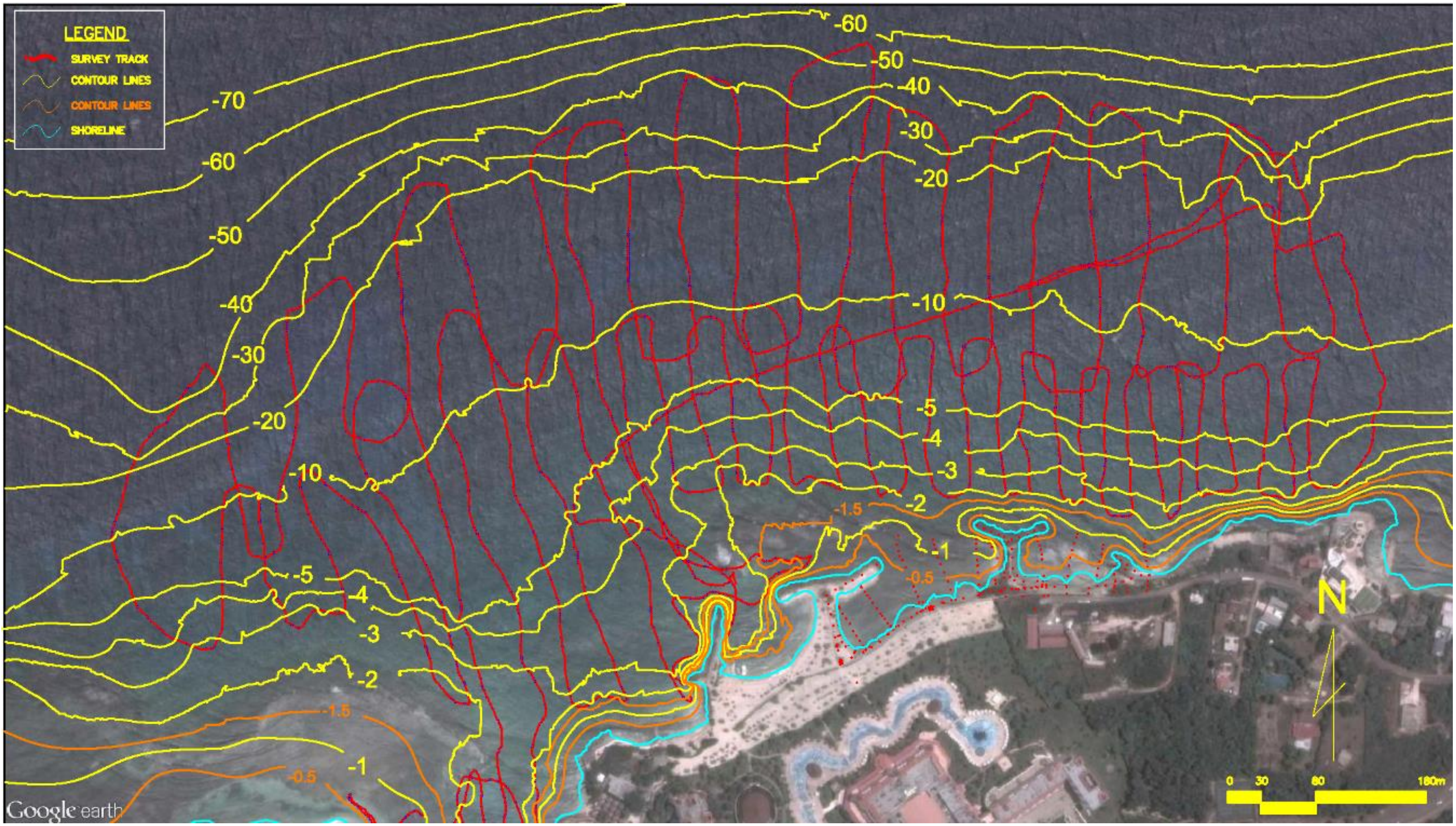


Figure 2.1 Results of bathymetric and beach profile survey overlaid on satellite imagery. Contours generated from the data collected are also shown.

Figure 2.2 Aerial imagery captured in drone survey of project site

2.2 Water Quality

During the site visit to the Gran Bahia Principe on May 1st 2015 there were algal blooms occurring in the shallower areas of the proposed beach. These algae are shown in Plate 2.1 and Plate 2.2 below.

Plate 2.1 Algal bloom in nearshore of project area

Plate 2.2 Algae on rocks in the nearshore of project site

These observations caused some concern regarding the water quality at the beaches. As a result of the concerns arising from the observations, two samples were collected for water quality testing, both in the lee of the existing structures as shown in Figure 2.3. The results of the lab tests are shown in Table 2.1.

Figure 2.3 Location of water quality samples (WQ1 & WQ2) taken from the project area

Table 2.1 Results of water quality sample analysis

Parameters	Method	Water Quality 1	Water Quality 2	NRCA Marine Water Standard
pH	DR	8.20	8.22	8.0 - 8.4
Phosphate (mg/l)	H-8048	<0.02	<0.02	0.001 – 0.003
Nitrate (mg/l)	H-8192	<0.01	0.01	0.007 – 0.0014
Biochemical Oxygen Demand (BOD) (mg/l)	H-10099	0.9	1.1	0.0 – 1.16
Faecal Coliform (MPN/100ml)	SM-9221	<1.8	13	<2 - 13

All the results outlined in Table 2.1 fall within the marine water standard for the parameters tested. However the tests for faecal coliform and biochemical oxygen demand for water quality for Sample 2 are just on the boundary of the acceptable standard. Both parameters are dangerously close to being unhealthy for swimming.

It is believed that this sample, WQ2, is too sheltered by the existing structure to allow for adequate water circulation. The stone sizes in the existing T-groyne are thought to be too small and therefore there are no voids in the structure to keep water circulating in the area.

2.3 Benthic Survey

The GPS coordinates for eight transects were established using the preliminary proposed structural layout (which has been subsequently revised) in conjunction with satellite imagery (Table 2.2 and Figure 2.4).

Table 2.2 GPS coordinates for survey transects

Transect No.	Latitude	Longitude
1W	18°27'47.23"N	77°20'58.89"W
2W	18°27'46.90"N	77°21'00.05"W
3W	18°27'46.14"N	77°21'01.19"W
1E	18°27'47.76"N	77°20'56.31"W
2E	18°27'47.75"N	77°20'55.21"W
TG1	18°27'49.31"N	77°20'54.11"W
TG2	18°27'49.76"N	77°20'54.91"W
TG3	18°27'49.40"N	77°20'58.92"W

Five transects (yellow arrows - up to 40m long where possible) were spaced at approximately 40m intervals along the beach and oriented at right angles to the shoreline [1W, 2W, 3W, 1E & 2E]. Sublittoral areas to be impacted by the newly proposed groynes were assigned 50m long transects (black arrows) that were set in line with the main axis of each portion of the proposed structure [TG1, TG2 & TG3]. Photographs covering $1m^2$ of the substrate were taken at 4m intervals along each transect line and analysed with Coral Point Count with Excel extensions (CPCe) software to determine percent substrate composition. The CPCe[1] program is a Windows-based software that provides a tool for the determination of coral cover using transect photographs. A specified number of spatially random points are distributed on a transect image and the features underlying the points are user-identified. Coverage statistics are then calculated and the results sent to Excel spreadsheets automatically. Additionally, CPCe can be used for image calibration and area analysis of benthic features. Excel sheets are automatically generated to summarize the area calculations for each image.

The numbers of urchins were recorded in these quadrats and counts of seagrass shoot density were taken from 25cm x 25cm area subsets of the larger quadrats placed at 4m intervals on alternating sides of the transect line. Specific note was made of:

- Any sensitive fauna (as well as signs of eutrophication/recent disturbance, e.g. presence of *Lyngbia*, *Enteromorpha* algae);
- Presence/absence of fish or other indicator, sensitive fauna, e.g. urchins;
- Immediate surroundings of existing structures to describe associated benthos and any other significant/general features of importance or sensitive fauna; and
- The benthos seaward of existing structures (brown arrow) for any other significant/general features of importance and make note of any sensitive flora/fauna onsite.

[1] Kohler, K.E. and S.M. Gill, 2006. Coral Point Count with Excel extensions (CPCe): A Visual Basic program for the determination of coral and substrate coverage using random point count methodology. Computers and Geosciences, Vol. 32, No. 9, pp. 1259-1269, DOI:10.1016/j.cageo.2005.11.009.

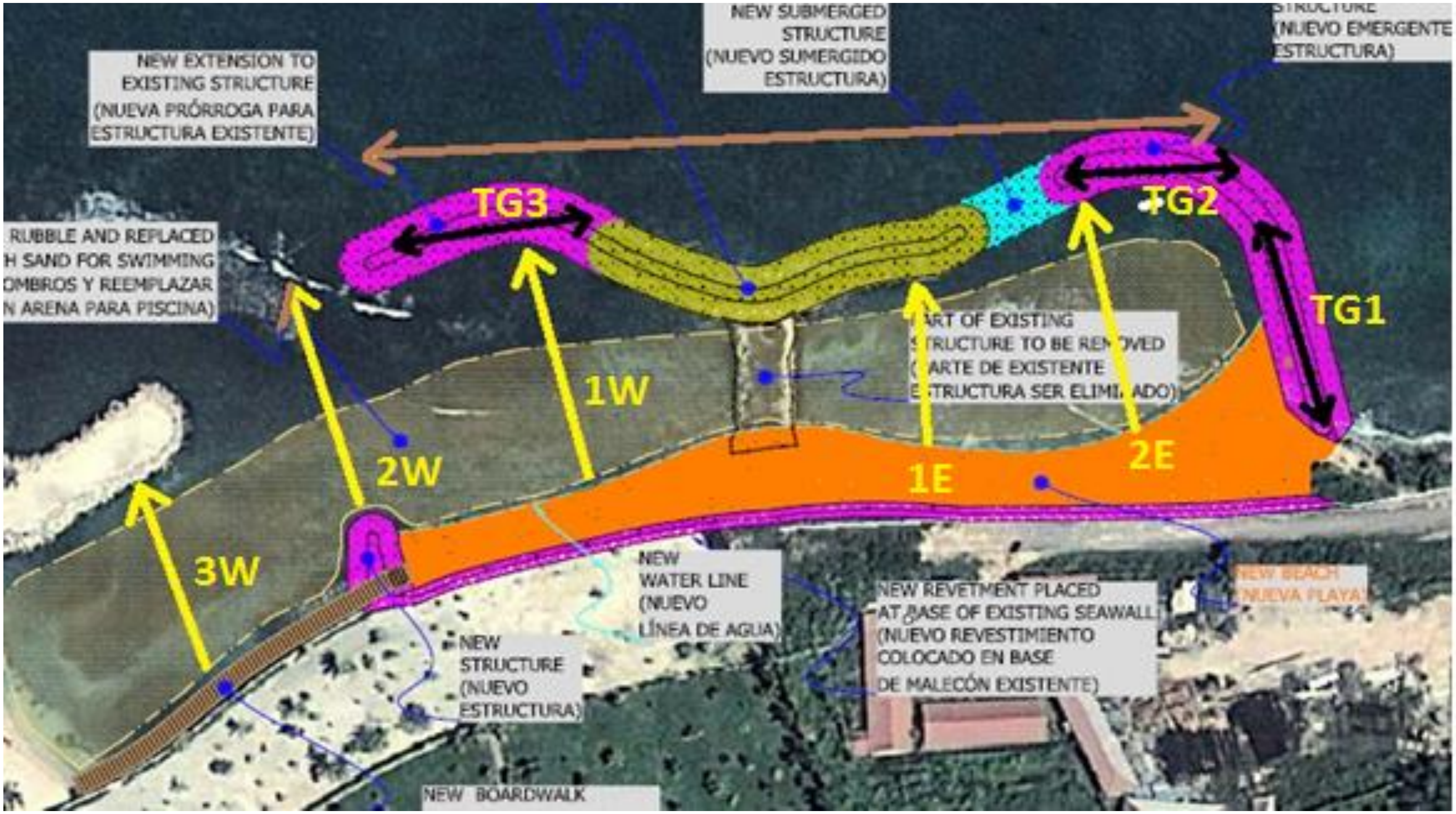


Figure 2.4 Survey transects at study site

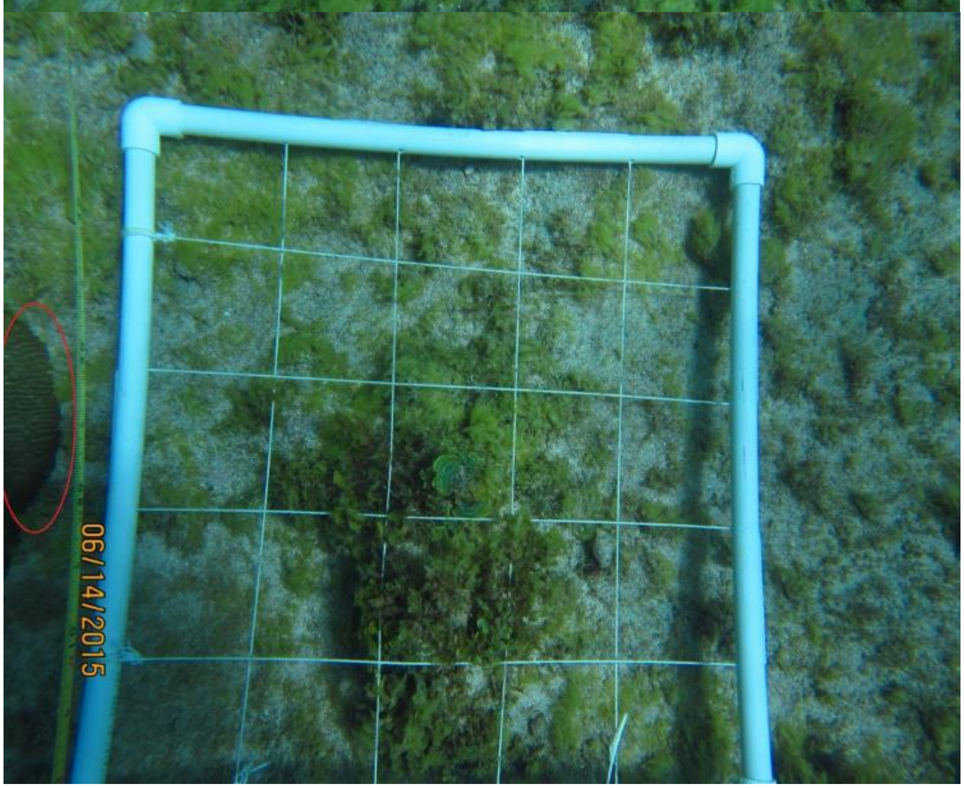
The following photographs show some of the species found in and around the swimming area.

Heavy seagrass cover at the seaward end of the western transects

Nearshore western transects with medium density seagrass cover atop silt & mud

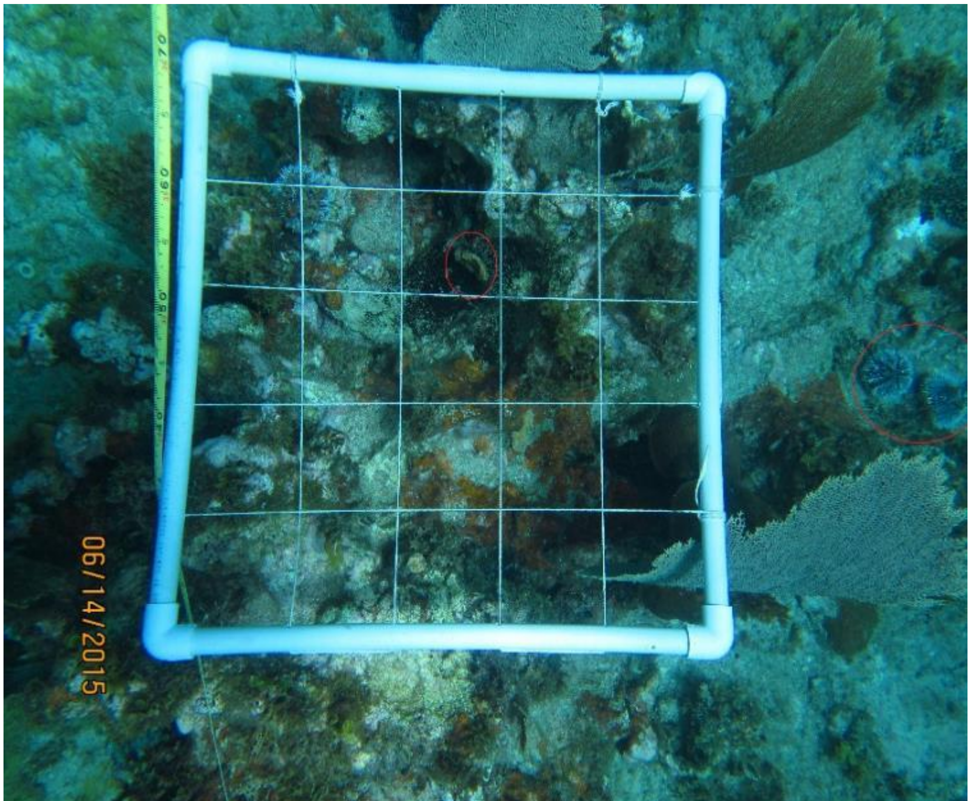
Figure 2.5 Photos of substrate near and around western transects (1W, 2W, 3W)

Hard pavement on eastern side of beach area supporting high % cover of *Lyngbia* spp. algae suggestive of eutrophic (nutrient enriched) waters

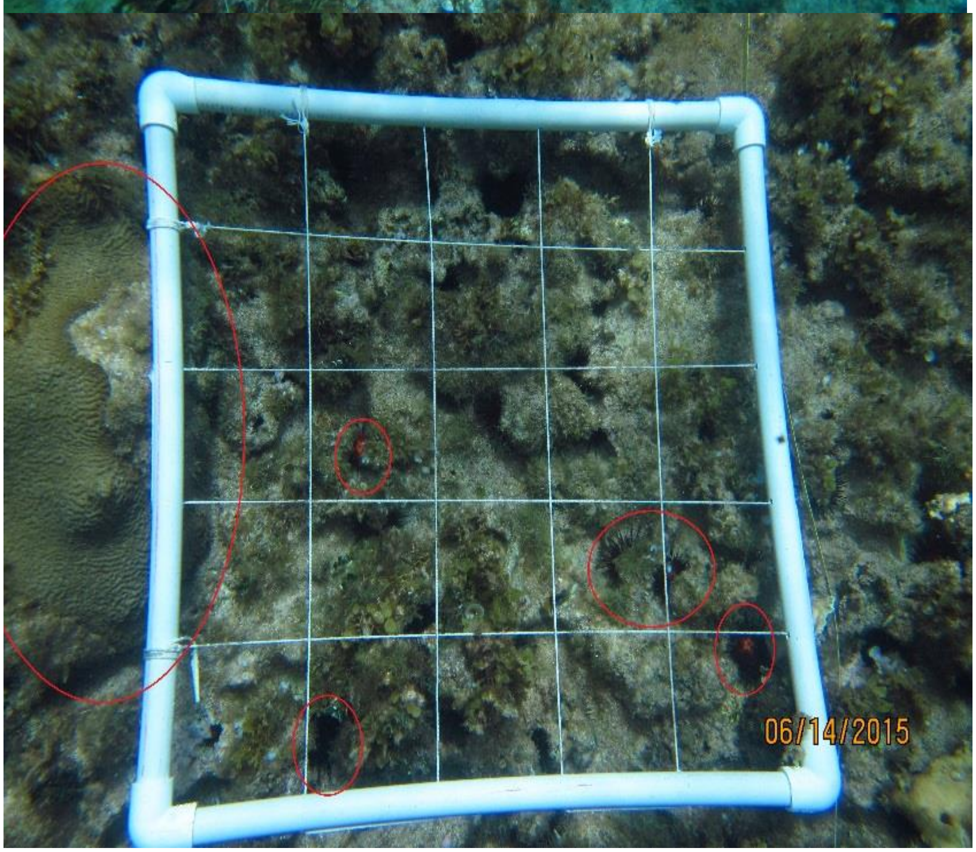


Hard pavement supporting encrusting *Diploria* spp. coral. Evidence of *Lyngbia* spp. algae indicative of increased local nutrient levels in the water (eutrophic conditions)

Figure 2.6 Photos of hard pavement on substrate covered with varying levels of algae



Agaricia spp. coral and *Tripneustes* spp. urchins with high % cover of sea fans



Encrusting corals (*Diploria* spp.) on hard pavement with reduced algal cover due to the presence of urchins (*Echinometra* spp.)

Figure 2.7 Photos of corals found near and around that area seaward of the proposed groynes (brown arrow in figure)

Hard pavement immediately seaward of proposed groyne area supporting variable spp. of corals including branching *Acropora palmata* (an endangered spp) and boulder / encrusting corals which would require protection from sedimentation effects during construction

Hard pavement seaward of proposed groyne area supporting extensive sea fan coverage

Figure 2.8 Photos of hard pavement substrate found near and around that area seaward of the proposed groynes (brown arrow in figure)

Table 2.3 below summarizes the results of observations made from photo quadrats and direct counts along the transects defined above. The western transects contained dense seagrass cover (mean shoot density > 460 shoots/m^2) in which the first 15m were supported by soft, silty sediments. The seaward portions of these transects contained particularly dense seagrass with a well developed root system. Very little coral (~4% mean), from 7 different species, was found on these transects. Most of the coral at this location was observed along transects 1W, 2E and TG3. The urchin *D. antillarum* was notably absent from all transects though *Echinometra* spp. (~10/m^2) were the most common species recorded. The substrate under the most seaward swim transect (brown arrow) contained hard pavement supporting scattered sea fans and small coral heads.

Table 2.3 Summary of photo/quadrat transect results

Transect	Depth (m)	% *Thalassia* cover/m²	Shoot density/m²	% coral cover/m²	*Diadema* /m²	*Tripneus-tes* /m2	*Echinom-etra* /m²	Conch /m²	Other Info.
T3W	0.5 - 2	78	698	0.5	0	0	0	0	*P. divaricata*
T2W	0.5 - 2	10	229	0.3	0	0	0	0	*P. divaricata; S. radians;*
T1W	0.3	0	0	7	0	0	0	0	*P. divaricata*
T1E	1 - 1.5	0	0	1	0	0.4	18.8	0	*D. clivosa; A. agracites; S. radians; A. palmata*
T2E	1.5 - 2.5	0	0	11	0	0.4	0	1.2	*D. clivosa; A. agracites; S. radians;* ~ 15cm dia
TG1	1.5 - 2.5	0	0	3	0	0	6.8	0	*S. radians; D. clivosa; Agaricia* spp; ~ 8cm dia; juvenile Parrotfish & Grunt
TG2	2 - 2.5	0	0	2	0	1.6	52	0	*S. radians; D. clivosa; Agaricia* spp; ~ 8cm dia; juvenile Parrotfish, Grunt & Damselfish
TG3	0.3	0	0	7	0	0	0	0	*S. radians; D. clivosa; Agaricia* spp; ~ 5-8cm dia
MEAN #/m²		**44**	**463.5**	**3.9**	**0**	**0.3**	**9.7**	**0.15**	

2.4 Sediment Analysis

Three sediment samples were collected on the existing shoreline stretching from the main beach to the two smaller coves on the eastern side of the property. The samples were visually inspected, air dried and subjected to a standard dry sieve analysis to determine the grain size distribution as well as other characteristic parameters. Table 2.4 summarizes the results of the sieve analysis. The three sand samples contain sediment that could be described as poorly graded with some gravel content, while the grain sizes range from coarse sand to fine gravel.

Table 2.4 Grain Size Results for sediment samples collected from existing beach areas

Area	Sample Number	Grain Sizes (mm)		Description	
		D50	D10	Classification	Grading
Beach A - onshore	SS1	0.58	0.20	Coarse sand	Poorly graded
Beach B - onshore	SS2	1.54	0.48	Very coarse sand	Poorly graded
Beach C - onshore	SS3	3.54	1.29	Very fine gravel	Poorly graded with gravel

3. Wave Climate Analysis

After the field data was collected, the next step in the analysis involved a determination of the prevailing coastal conditions at the site. These analyses were conducted using the MIKE 21 suite of numerical models, which allow detailed assessment of waves and currents at specific locations (described in greater detail in Appendix A).

MIKE 21 uses process-based complex mathematical expressions to determine the interaction of waves and currents and requires a detailed computation grid to represent the water and land at the site under investigation. It also requires input boundary values that are derived from long-term global or regional databases. MIKE 21 uses these input boundary values, which are valid for large areas, and determines the resulting conditions at the specific site.

An example of input boundary values would be a wave climate, which is valid over a large area, but only in unsheltered deep water. MIKE 21 then computes the wave conditions at a specific site by considering the localized effects including wave sheltering, wave breaking and tide levels.

The MIKE 21 model was used to investigate the local conditions at the coastline along the Gran Bahia Principe property corresponding to the input boundary values consisting of binned operational wave data for over a decade.

It is vital that a detailed understanding of the operational hydrodynamic climate be established to understand how the proposed works will affect the coastal environment on a day-to-day basis. However, it is to be expected that the impact of the structures on the surrounding shoreline will be more pronounced during storm events when the wave action, in conjunction with currents, are typically far more significant. For these reasons the wave and hydrodynamic modelling investigated the existing and proposed response of surrounding lands during both an operational scenario as well as during the high wave energy associated with a 1903 hurricane (Not Named 2, 1903) which is representative of a hurricane with a return period of 50 years. The model results helped in determining the likely impacts of the construction and nourishment activities on the shoreline of the Gran Bahia Principe as well as surrounding coastal lands.

3.1 Modelling with MIKE 21

Both the operational waves and the extreme waves were developed and transformed to the nearshore using coupled hydrodynamic and spectral wave modules. The MIKE 21 model can use various modules to simulate, hydrodynamic variances in current velocities and surface elevation (HD) as well as spectral waves (SW).

The basic starting point of the model is the creation of a computational mesh where waves and currents are determined at each simulation time step. The MIKE 21 model uses a flexible mesh that represents the seabed using a series of connected triangular elements.

The results of the bathymetric survey as well as the shoreline profile results were all input and used in the model mesh development. Offshore depths were established through the incorporation of nautical chart data and other available map data, such as previous surveys of the site. The model domain encompassed the entire island of Jamaica, extending out to water depths of roughly 6000m, and extending more than 130km from the coastline. The MIKE 21 mesh used in the modelling exercises is shown in Figure 3.1. The figure shows the entire domain as well as a close-up of the Gran Bahia Principe project area.

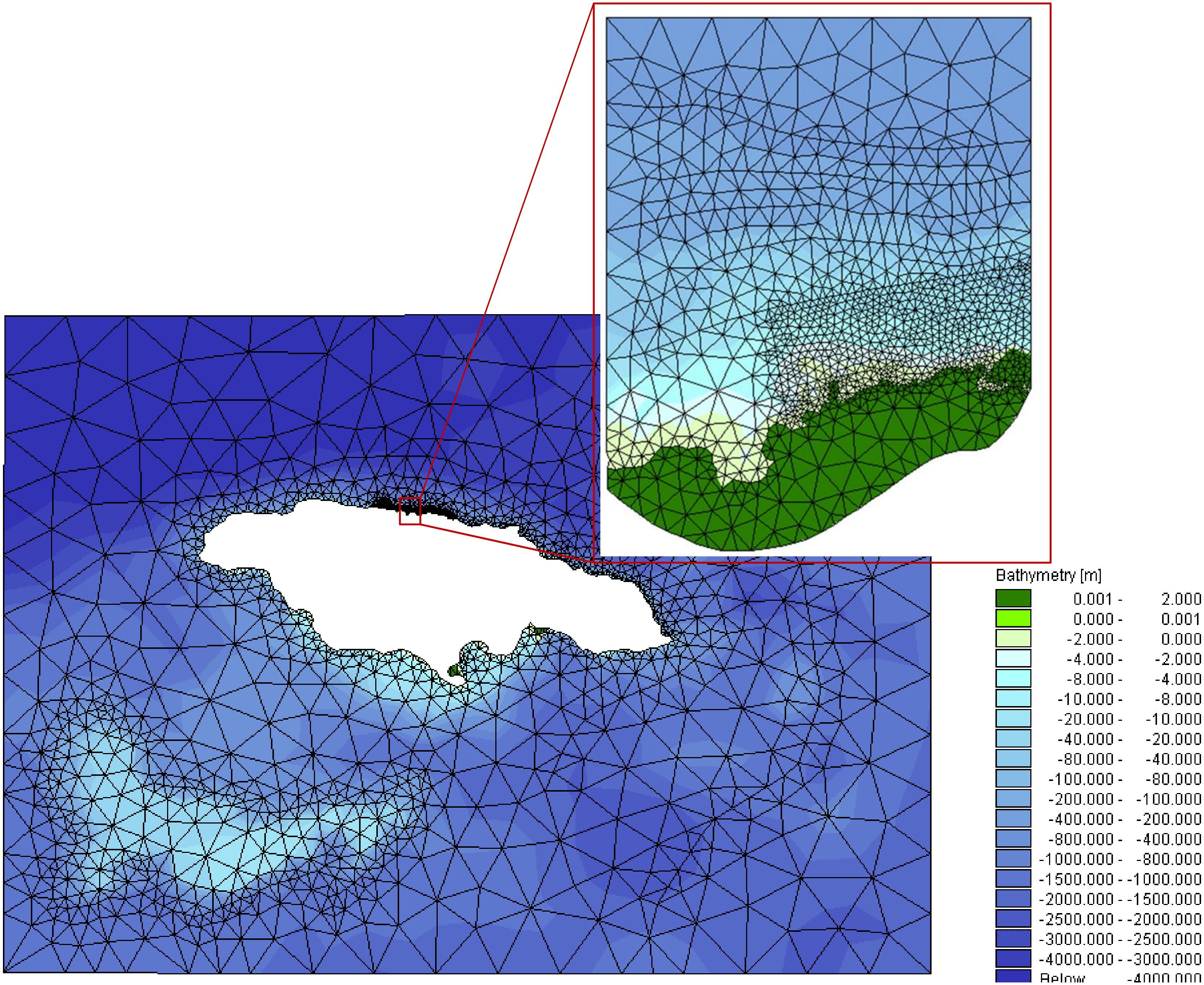


Figure 3.1 Nearshore bathymetry and flexible element mesh details used in MIKE 21 modelling

3.1.1. Extraction Points

All of the modelling concentrated on the nearshore and, as such, specific points were established in the nearshore where modelling data would be extracted from (Figure 3.2). The coordinates of the points are as follows:

Name	Easting	Northing
Point t1	251835	2043067
Point t2	251869	2043070
Point t3	251937	2043078
Point t4	251983	2043077
Point t5	251800	2043050

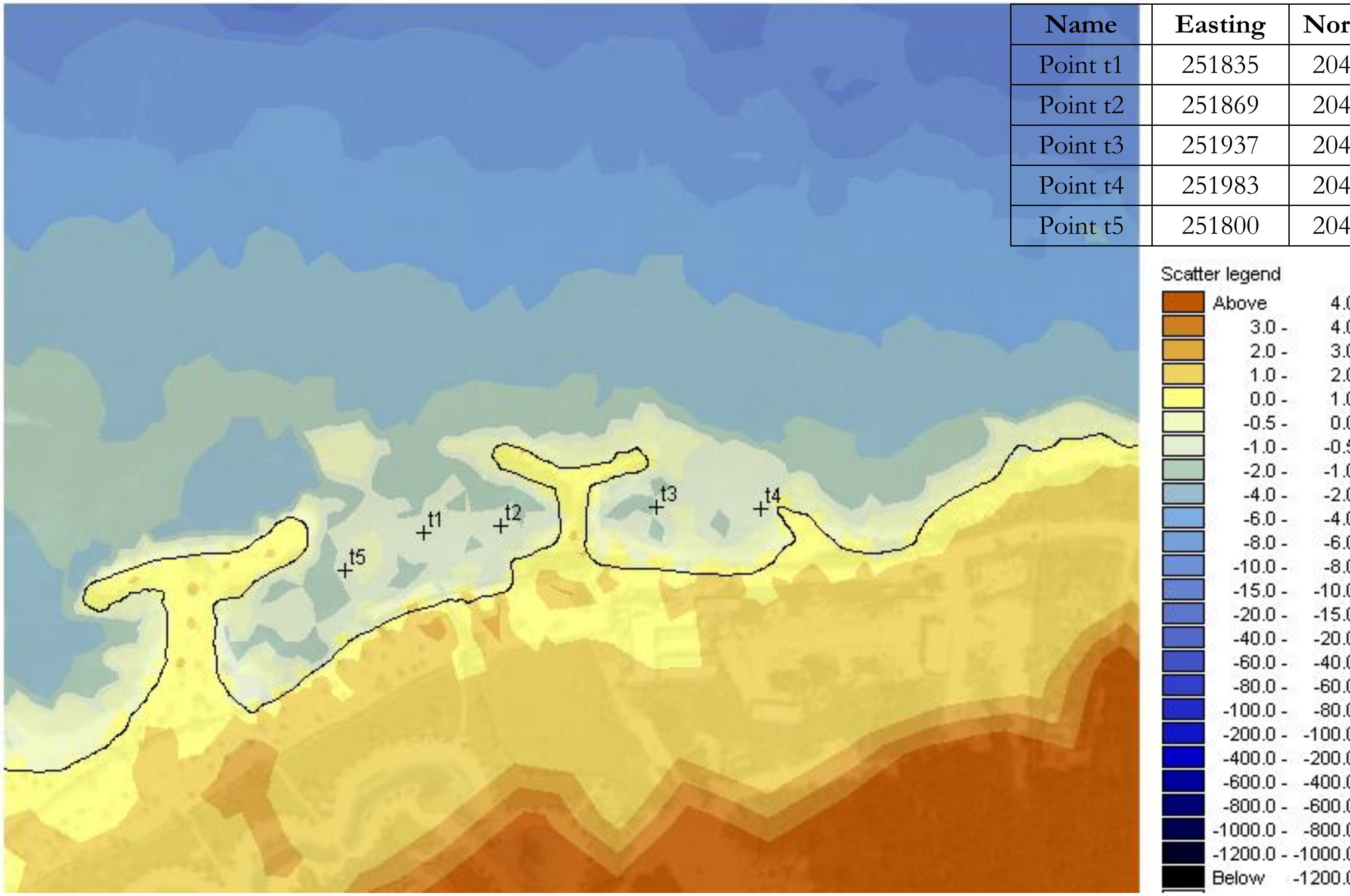


Figure 3.2 Location of extraction points

3.2 Operational (Day to Day) Climate

3.2.1. Operational Waves

The operational wave climate at the project site is characterized by (a) day-to-day, relatively calm conditions and (b) by seasonal winter swells (December to May). The day-to-day conditions are created by the north-east Trade Winds. The north coast of Jamaica is especially vulnerable to these wave conditions because of its location. The swells, on the other hand, are generated by north Atlantic cold fronts and these waves can approach from the north to north-west sector.

The deep water operational wave climate was established using the global wave model Wave Watch 3 (WW3) developed by NOAA. The WW3 model archives wave parameters including wave height, period and direction as well as the wind speed and direction. Data is available for every three hours covering the period from July 1999 to April 2015, giving a total of over 46,000 data points per parameter and covering almost 16 years. This time series of wave conditions was extracted for a node located north of Jamaica. Figure 3.3 shows the wave height distribution and the location of the node (Node 5) that was selected for the project. Note the majority of the waves come from the east sector, as dictated by the Trade Wind patterns.

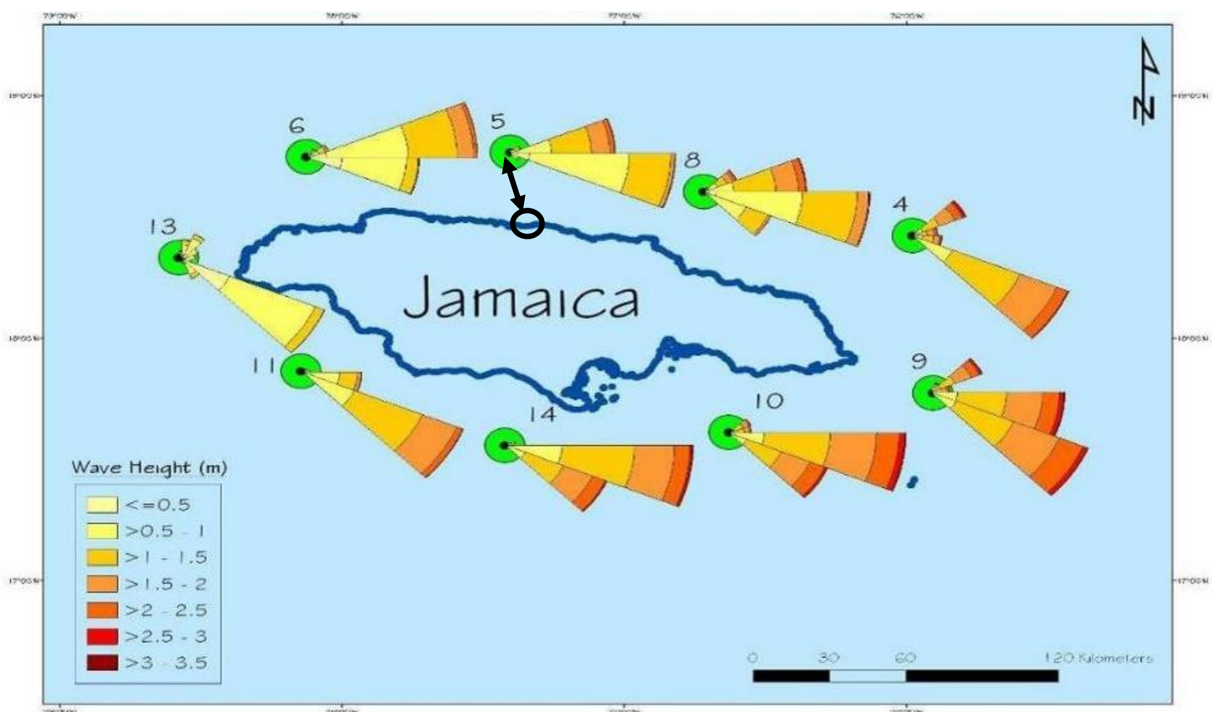


Figure 3.3 NOAA Wave Watch 3 nodes in the vicinity of Jamaica

The WW3 model is usually applied on spatial scales (grid increments) larger than 1-10km and outside the surf zone. As a result, the model is not at a sufficiently detailed scale to provide accurate nearshore wave data. The nearshore wave climate for this project was therefore developed using a spectral wave model MIKE 21 SW (described above) to simulate waves as they approach the nearshore of the project site.

The 16 years of wave data (1999-2015) obtained from Node 5 were categorized using a tri-variate frequency analysis of wave height, period and direction, also known as "binning". This frequency analysis resulted in 470 different conditions or "events" representing a combination of wave height, peak period and direction, each with a specific duration related to the number of occurrences in the eight year period. The MIKE 21 SW spectral wave model was then run in a semi-stationary mode with inputs of the wave heights, periods and directions along the boundaries of the model domain. As mentioned, the model was set up on a flexible mesh to represent seabed depths from offshore to nearshore of the project site at a sufficient degree of detail.

The resulting annual wave rose distributions at the location of the five selected nearshore nodes are shown in Figure 3.4. Results indicate that wave heights at the site are very low and typically do not exceed 0.4m throughout the year with occasional maximums up to 0.5m. Results further indicate that the predominant approach was from the north-north-east. The only exception was Profile 2, which is located in the shadow of the existing structure and thus is only exposed to those which wrap around the T-groyne and approach from the west.

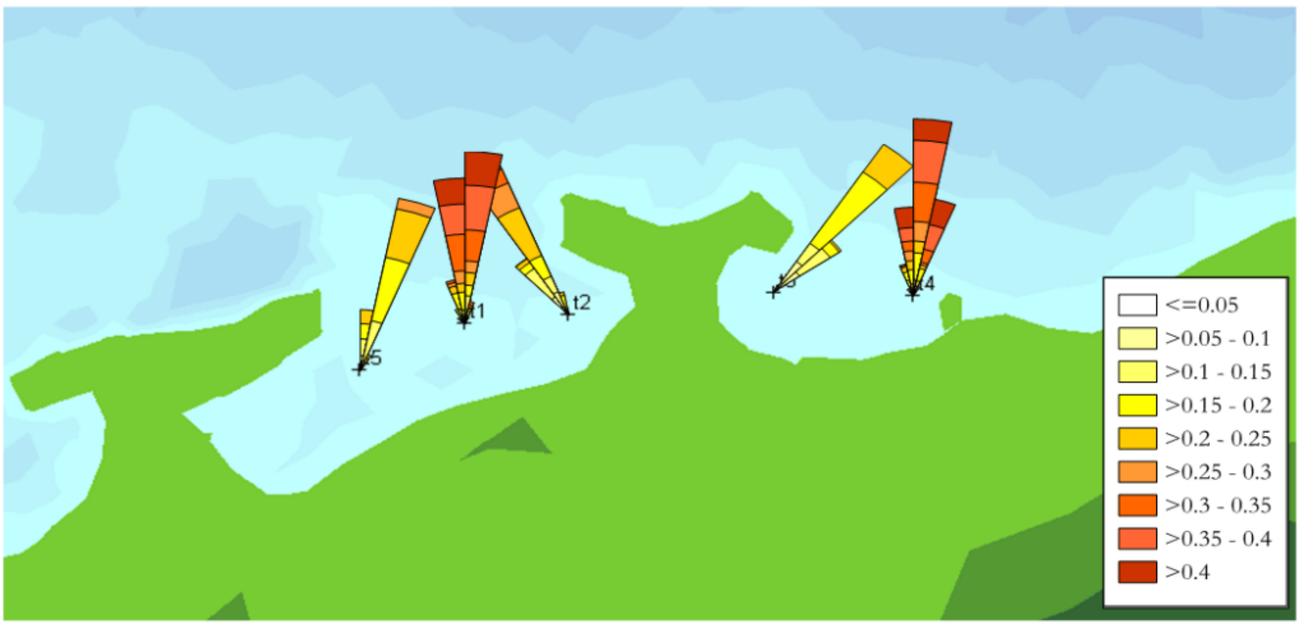


Figure 3.4 Wave Rose plots of typical conditions (binned operational waves) at the site

The results of the modelling also indicated the following percentage breakdown of the annual wave climate at Point 4, which is in the most exposed area of the project site:

- Waves remain below 0.1m in height 1.15% of the time or approximately 4 days per year;
- Waves range between 0.1m and 0.25m in height 46.5% of the time or approximately 170 days per year;
- Waves range between 0.25m and 0.4m in height 48.1% of the time or approximately 176 days per year;
- Waves exceed 0.4m in height 4.17% of the time or approximately 15 days per year.

In binning the WaveWatch III data, it was discovered that the most common condition (Hs=0.5m, Tp=4s, Dir=95°) occurred 11.91% of the time. This condition, when transformed to the nearshore, tends to refract and bend and approaches onsite more from a north-easterly direction than straight easterly. The plot of the condition is shown in Figure 3.5.

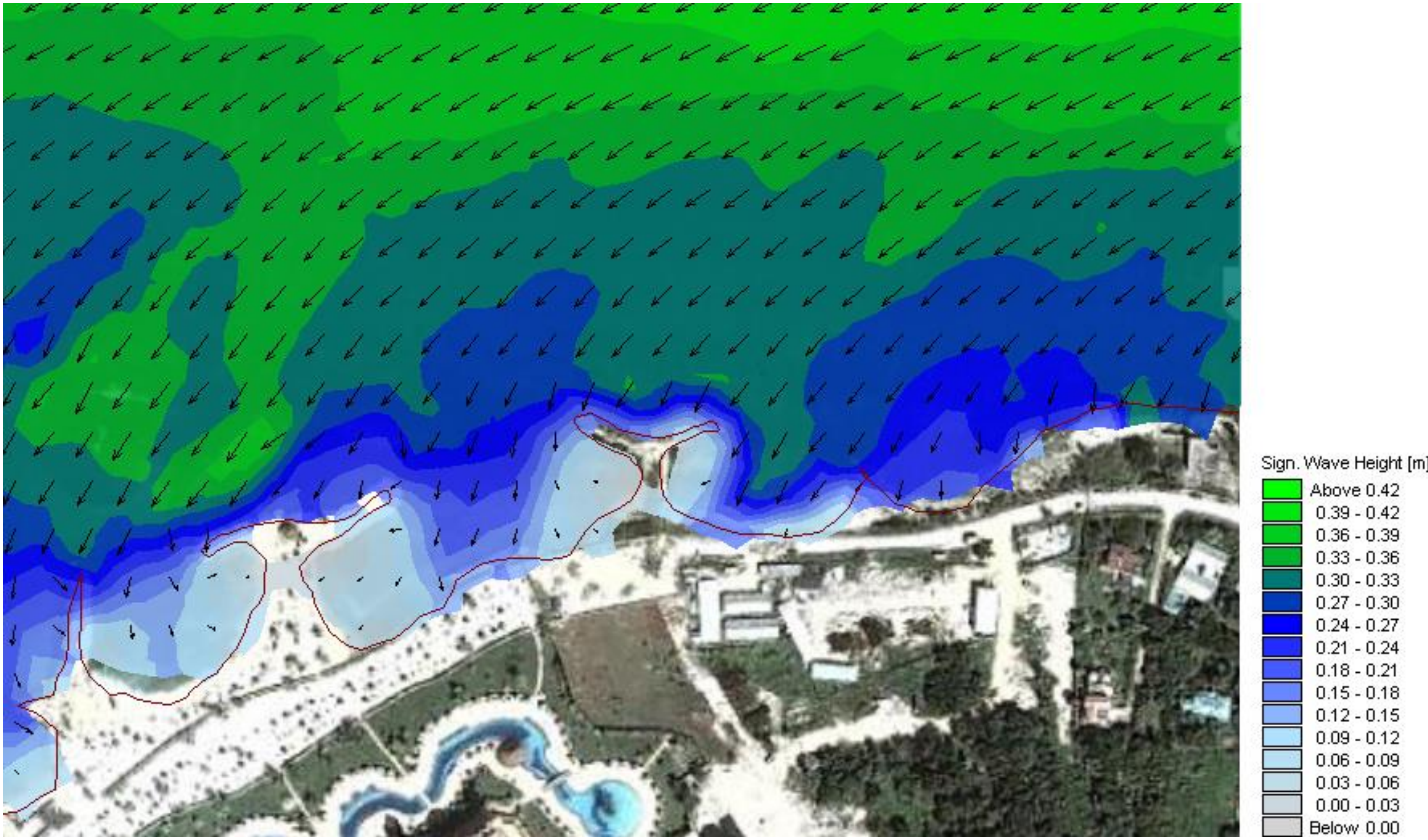


Figure 3.5 Most common operational wave condition transformed to the nearshore

Variations in the water surface elevation caused by tidal influences were also examined and plotted (Figure 3.6). The results show that during a typical year (2014), the tidal levels vary from -0.24m to 0.23m. A typical tidal range of 0.46m is thus expected on an annual basis; the value associated with the highest astronomical tide value (HAT) is 0.2m.

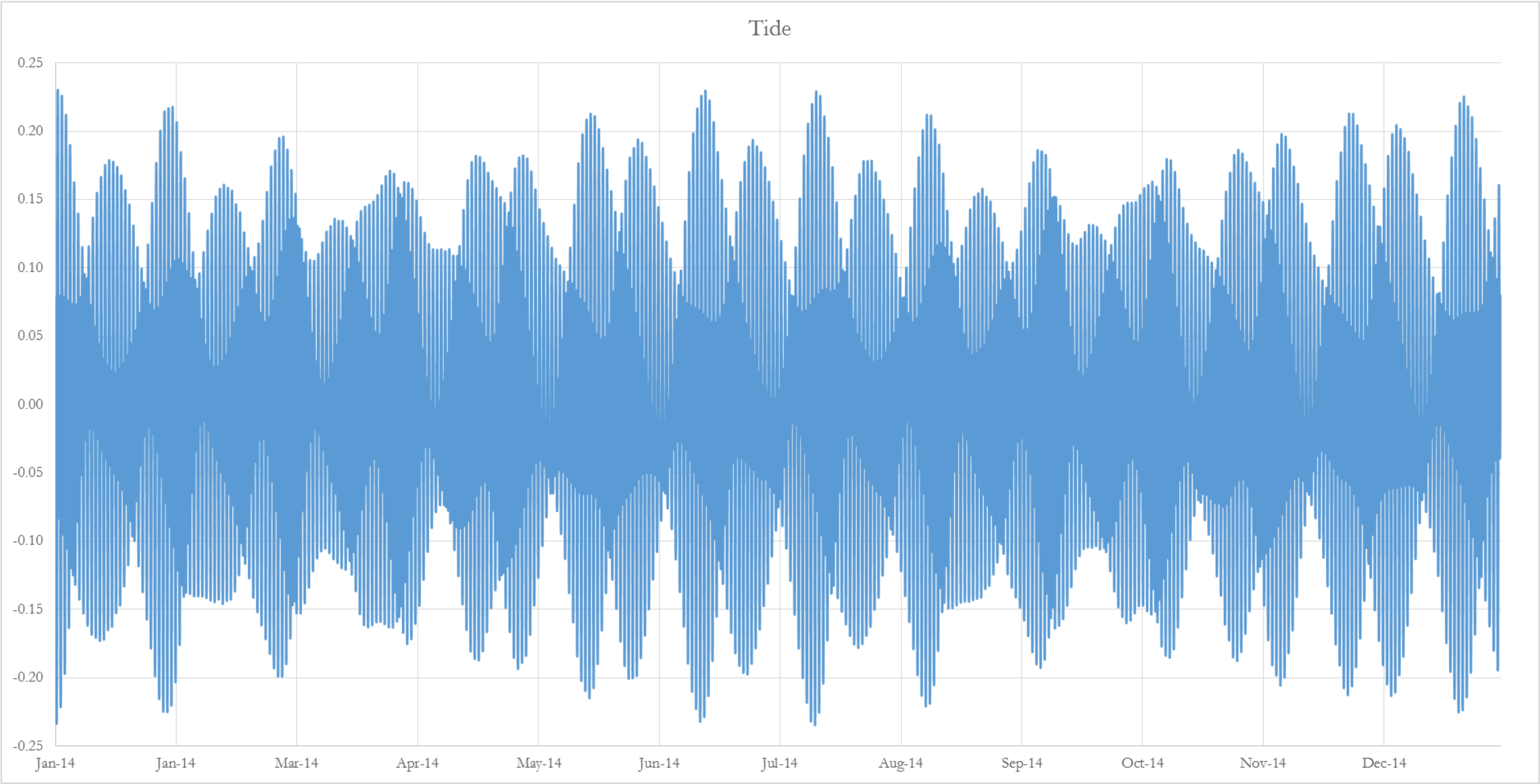


Figure 3.6 Tidal variation at project site over a typical year (2014)

3.2.2. Operational Hydrodynamics

It was recognized from the onset that the hydrodynamics in the project area would be of vital importance to the design of the new beach considering that the proper circulation is necessary to achieve bathing standard water quality.

A hydrodynamic model was therefore developed to simulate the surface elevation and currents in the project area. This model was developed with tidal input on the boundaries being the main forcing processes. The water level input was obtained from a global tide prediction model, which is based on the superposition of numerous sinusoidal tidal constituents, each with an amplitude and phase lag that varies depending on time and position (DHI, 2009b). It is to be expected, however, that the tidal influence on currents would not be very significant given that the tidal range is so limited (approximately 0.45m), and so other forcings are required. The second step therefore was the application of wind forcing to the numerical model. The wind data was derived from the WW3 Node 5 as described above in Section 3.2.1. This node provided both wind speed and wind direction, and this data was applied as a forcing across the domain. The forcings were applied across the hydrodynamic model for the month of August 2014, a "typical" month that has both spring and neap tide as it was necessary to capture those variations.

The hydrodynamic results revealed what was expected, that currents in the area are very low averaging 12mm/s (0.123m/s) across all four extraction points. Extraction Point #2 (see Figure 3.2 for reference) is in the approximate location of the water sample collected with parameter values just within the range of acceptable standards, and so was chosen for further analysis. The time series of depth-averaged currents throughout the month of August 2014 is shown below in Figure 3.7.

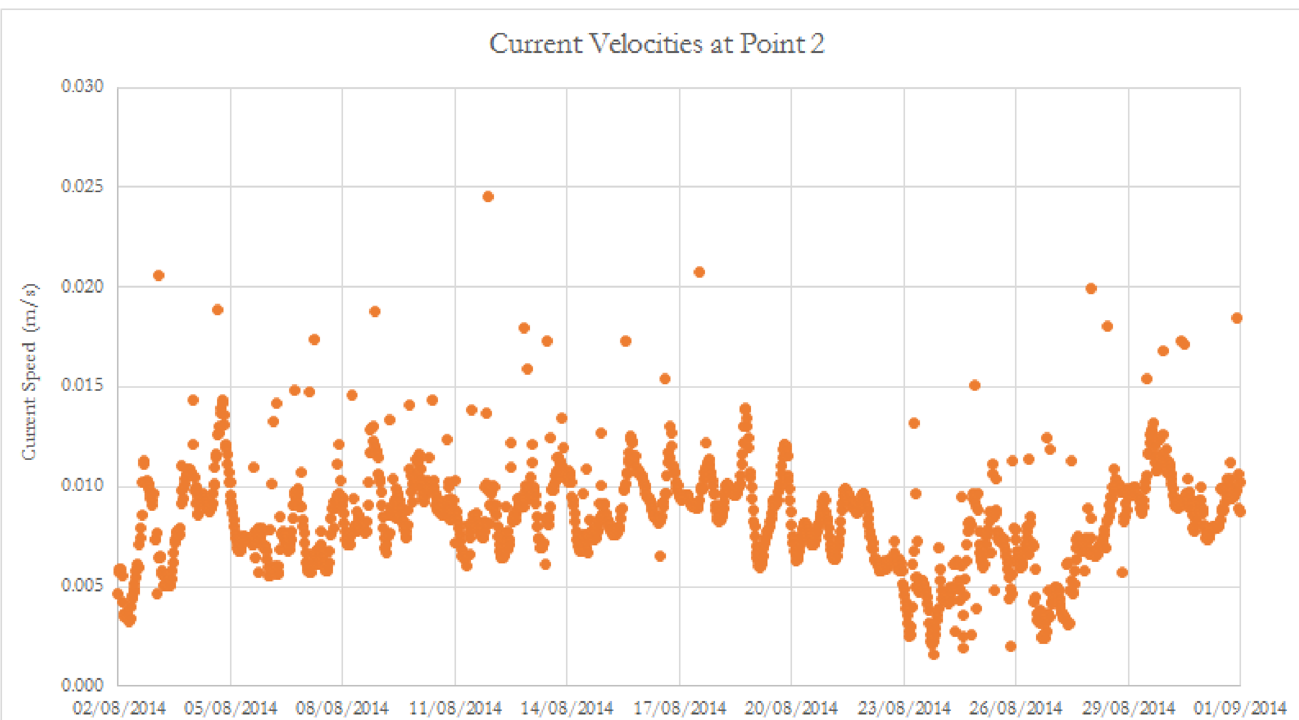


Figure 3.7 Values of Current Speeds at Point #2 throughout the month of August-2014

As shown, the values tend to oscillate in between 0.015 m/s and 0.005 m/s corresponding to tidal oscillations. Additionally the first three weeks of the month, which corresponds to the spring tide, tends to be higher than the remaining three weeks, which corresponds to neap tide. It should also be noted that there are some higher values that appear to fall outside of the pattern. These are likely corresponding to higher gusts of wind at these points.

A representative time step, in between the spring and neap tides, where there was no obvious irregularity such as those due to wind gusts was selected. This time step is shown below in Figure 3.8. In the figure the colour gradients represents bands of current speeds whereas the arrows indicate direction. As shown, the dominant direction for current movement is towards the west.

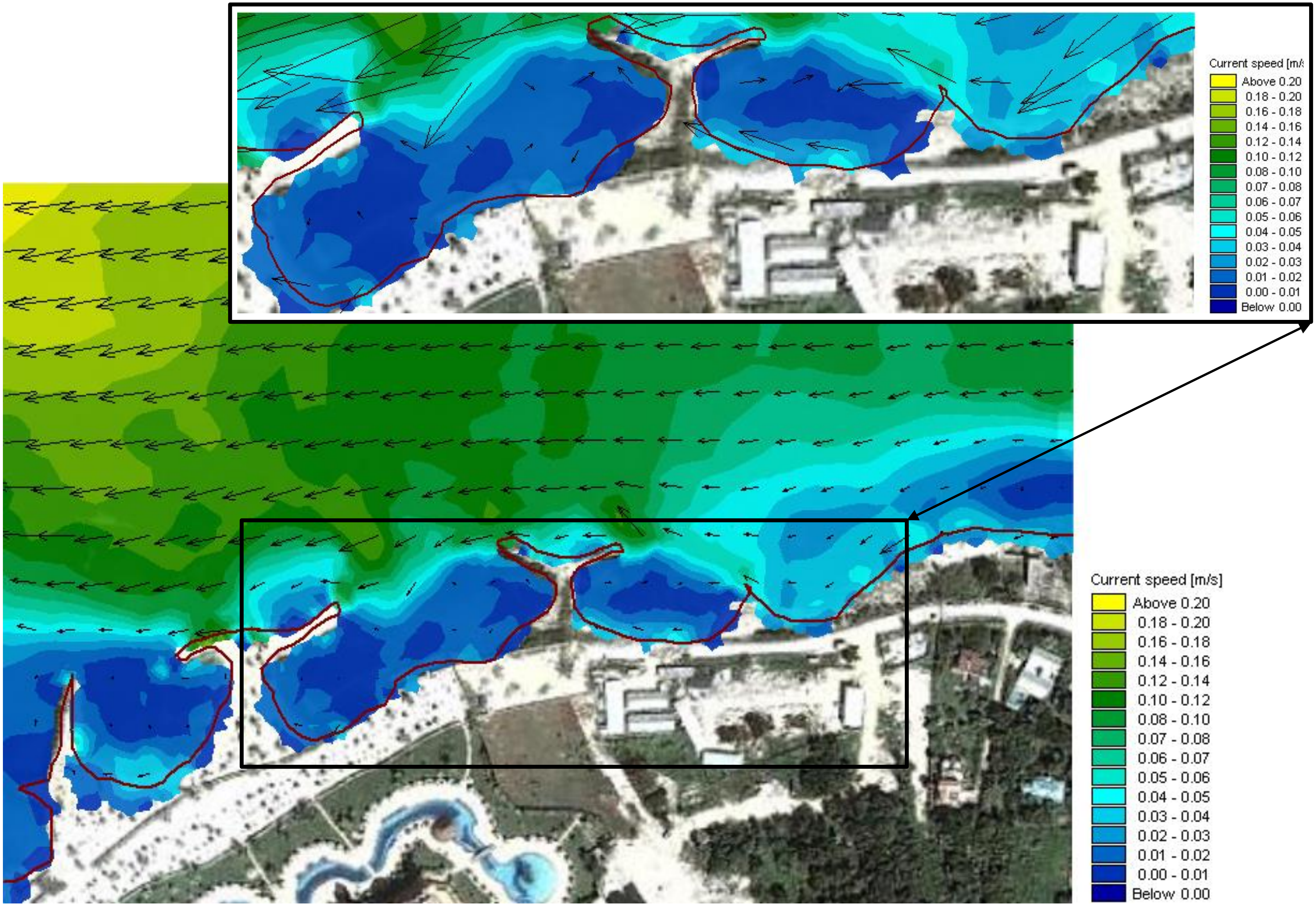


Figure 3.8 Current speed and direction at midnight on August 20th 2014

3.3 Hurricane Wave Climate

Every year between the months of June and November, the coastal areas of Jamaica are vulnerable to tropical cyclones. They are typically formed between latitudes 5° and 25° north of the Equator and usually move on a westerly track across the northern Atlantic. The most intense of these tropical cyclones are known as hurricanes, which have the most damaging effects on both inland and coastal regions. A tropical cyclone is classified as a hurricane only after it has attained one-minute maximum sustained near-surface (10m above ground level) winds of 33m/s or more. Below this, these cyclones are referred to as tropical storms. The Saffir-Simpson Scale is commonly used to classify hurricanes into five different ranges based on the maximum wind speed attained.

Hurricane winds increase in speed to a maximum near the centre (or eye) of the hurricane, while inversely, atmospheric pressure decreases to a low point at the centre. These high velocity winds are able to generate waves of considerable height, while the low pressure at the centre is able to raise the sea level underneath the centre (an effect known as Inverse Barometric Rise or IBR). This combination can be devastating to coastal areas, often leading to the partial or complete destruction of coastal structures, inundation of low-lying lands adjacent to the coastline and severe erosion of beaches. It is important, therefore, that all developments in coastal areas be designed to withstand these natural hazards. In order to achieve this objective, reliable predictions of wave heights and storm surges are necessary.

The elevated water levels that accompany hurricanes and create flooding and cause damage to coastal infrastructure is known as storm surge. A storm surge is the rise in the water surface elevation of the sea above its mean level. The static storm surge is made up of five major components, namely:

1. The Inverse Barometric Rise (IBR), (caused by low pressure)
2. Highest Astronomical Tide (HAT),
3. Global Sea Level Rise (GSLR),
4. Wind Setup (when winds push water up onto the land), and
5. Wave Setup (caused by wave breaking).

In addition, when waves break at the shoreline they run up the beach slope, further elevating the water level (wave run-up). When this component is added to the static surge, it results in a dynamic surge component. The run-up can be intense along sloping structures such as breakwaters.

The occurrence of tropical cyclones is difficult to predict based on short-term analysis, but the accuracy of predictions can be markedly improved by taking into consideration the history of occurrences of tropical cyclones over a longer period of time. The method of using past tropical storm and hurricane occurrences to predict the intensities of future ones is called hind-casting. Within this context, wave conditions are often described in terms of a return period, a statistical term expressing a low probability of occurrence that represents the average time period between successive occurrences of an event being equalled or exceeded.

An in-house computer program, HurWave, was used for the hind-casting analysis (described in more detail in Appendix A). HurWave calculates deep-water wave parameters for different return periods and locations within the Caribbean. The workflow of the program is as follows:

- Scan the NOAA-NHC (National Oceanographic and Atmospheric Administration – National Hurricane Center) database for all storms and hurricanes that passed within a 300 km radius of the project site, from the year 1850 to the present;

- Calculate offshore wave conditions for each storm using widely established and calibrated parametric models;
- Define the wave heights levels for various return period events based on the statistical analysis of the calculated extreme waves. The wave conditions are determined separately for each directional sector.

3.3.1. Storm Occurrence

Since 1850, a total of 138 tropical cyclones have passed within 300km of the project site. Table 3.1 summarizes the distribution of these tropical cyclones as well as the wind speed ranges that characterise the Saffir-Simpson Scale. The table shows that the area is more frequently hit by tropical storms and is rarely affected by major hurricanes. Of all the storms, only 21 storms (≈15%) Category 3 or stronger have passed within 300km of the islands. Figure 3.9 shows the temporal distribution of these cyclones since 1850. The number of cyclones affecting the area has been relatively constant throughout the years, with some notably active years such as 1886, 1909, 1933, 1979 and 2008. Figure 3.10 shows the tracks of the worst five storms to hit Runaway Bay since 1850; these are: NotNamed4 1944, Gilbert 1988, Charlie 1951, Dean 2007 and NotNamed2 1903. All of these storms, which all passed the project site as a Category 3 or higher, were reported to have caused widespread erosion on the beaches and dunes, and buildings were also damaged.

Table 3.1 Summary of tropical cyclone events within 300 km of the project site over the past 110 years

Cyclone Category	Wind Speed (m/s)	Wind Speed (km/h)	No. of Events
Tropical Storm (0)	18 – 33	64 – 118	79
1	33 – 43	119 – 154	26
2	44 – 49	155 – 178	12
3	50 – 58	179 – 210	13
4	59 – 70	211 – 250	5
5	> 70	> 250	3

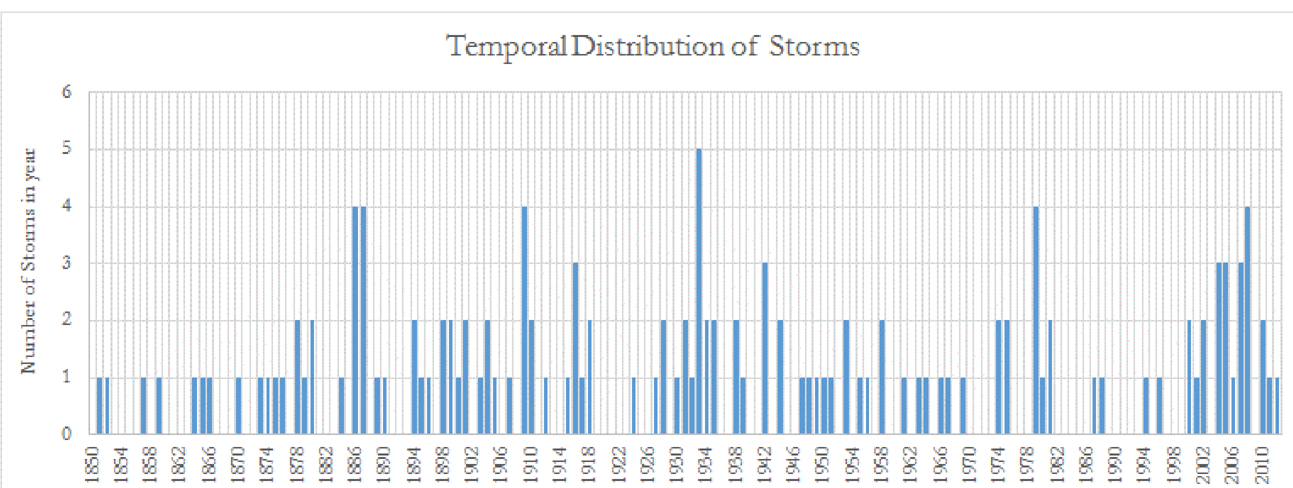


Figure 3.9 Temporal distribution of tropical cyclones since 1850

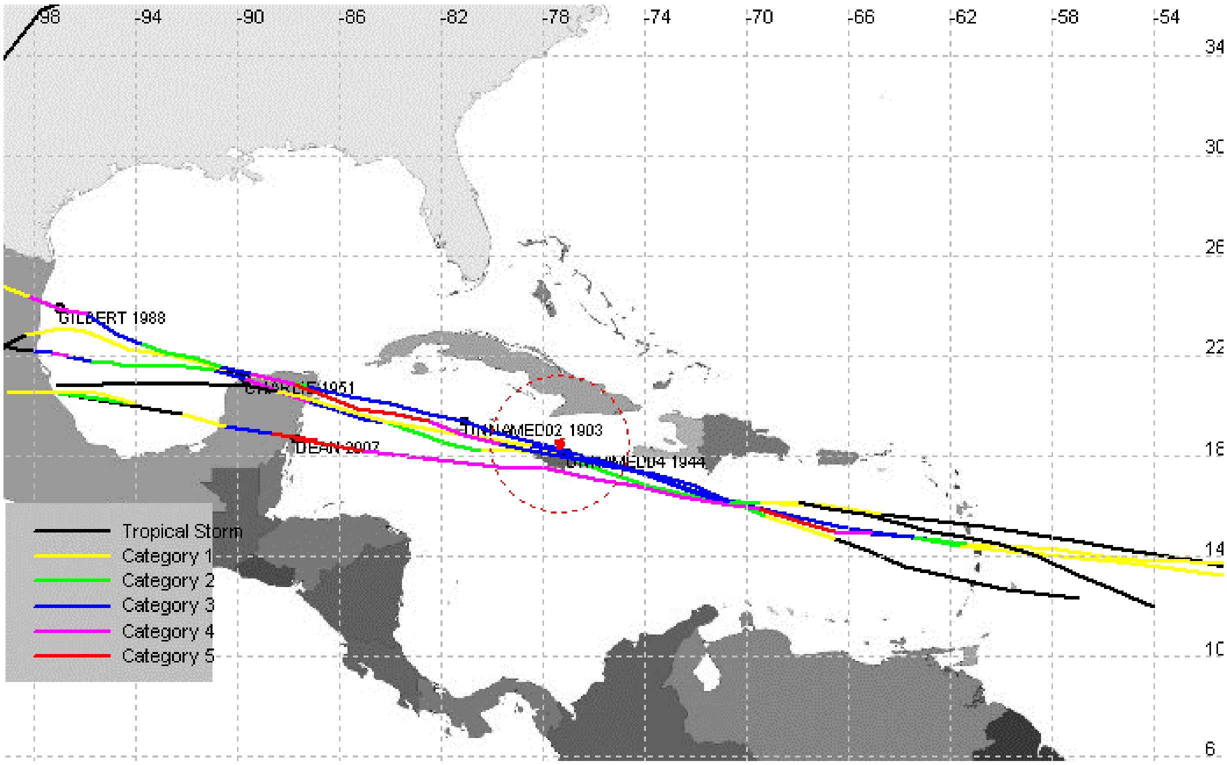


Figure 3.10 Storm tracks of five hurricanes that passed within the 300 km search radius causing damage

3.3.2. Hindcasting hurricane waves and surge levels

The deep-water wave parameters were calculated for each selected tropical cyclone using parametric models (Cooper, 1988; Young and Burchell, 1996). The resulting wave conditions were segmented into directional sectors and fit to a statistical function describing their exceedance probability. The wave parameter values for 50 and 100-year return periods were determined from the best-fit statistical distribution. The computed values of deep-water wave parameters for return periods of 50 and 100 years are listed in Table 3.2. Hurricane waves coming from the east had the largest wave heights and longest wave periods, however interestingly the highest winds came from the north-east direction.

In order to compute the total static storm surge level in deep-water, the Global Sea Level Rise (GSLR) for the projected year and the highest astronomical tide were added to the IBR values. The results for the 50-year and 100-year surface level values are listed in Table 3.3.

Table 3.2 Values of deep-water wave height and wave period for return periods of 50 and 100 years

Return Period (years)		50	100
West	Hs (m)	5.48	6.65
	Tp (s)	9.64	10.88
	U10 (m/s)	23.53	26.47
North-west	Hs (m)	5.32	5.94
	Tp (s)	9.46	10.14
	U10 (m/s)	21.17	24.66
North	Hs (m)	5.64	6.71
	Tp (s)	9.82	10.94
	U10 (m/s)	26.01	29.05
North-east	Hs (m)	7.69	9.09
	Tp (s)	11.93	13.26
	U10 (m/s)	39.08	43.19
East	Hs (m)	11.37	13.08
	Tp (s)	15.26	16.67
	U10 (m/s)	25.56	29.29

Hs = Significant wave height; Tp = peak wave period; U_{10} = wind speed (m/s)

Table 3.3 IBR and design deep water surface level (m) for return periods of 50 and 100 years

Parameter	Return Period (years)		Notes
	50	100	
IBR (m)	0.34	0.40	Determined through statistical hind-casting analysis
Highest Astronomical Tide (m)	0.2		Determined through historical analysis
Rate of Sea Level Rise (mm/year)	5		B2 Scenario value from IPCC research
Design Life (years)	50		How long structure is to last (not related to design storm)
Design Deep Water Surface Level (m)	0.79	0.85	

3.3.3. Nearshore wave transformation of hurricane waves

The 50 and 100-year return period waves outlined in the previous section were used as input boundary conditions in the nearshore wave model, MIKE 21. The numerical modelling results revealed the parameters listed in Table 3.4 at the various nearshore locations described above in Section 3.1.1.

Table 3.4 Values of nearshore wave height, period, direction and surface elevation for return periods of 50 and 100 years at selected five (5) extraction points (as previously outlined in section 3.1.1)

		EAST_50	NORTH-EAST_50	NORTH_50	NORTH-WEST_50	WEST_50		EAST_100	NORTH-EAST_100	NORTH_100	NORTH-WEST_100	WEST_100
Significant Wave Height	Point 1	1.484	1.430	1.339	1.233	1.186		1.562	1.606	1.471	1.323	1.307
	Point 2	1.231	1.157	1.105	1.055	1.019		1.302	1.368	1.277	1.137	1.131
	Point 3	1.437	1.353	1.162	1.023	0.875		1.512	1.550	1.363	1.138	1.048
	Point 4	1.881	1.786	1.571	1.445	1.357		1.979	1.975	1.727	1.557	1.526
	Point 5	1.313	1.234	1.116	1.005	0.906		1.384	1.413	1.275	1.103	1.050
Mean Wave Period	Point 1	13.2	10.7	8.9	8.6	9.1		13.2	11.7	9.9	9.2	10.3
	Point 2	13.3	10.8	9.0	8.6	9.0		13.2	11.8	9.9	9.2	10.2
	Point 3	12.8	10.6	8.9	8.7	9.1		12.8	11.5	9.9	9.3	10.3
	Point 4	12.7	10.4	8.9	8.7	9.0		12.7	11.3	9.9	9.3	10.2
	Point 5	13.3	10.8	8.9	8.7	9.2		13.2	11.8	9.9	9.2	10.4
Mean Wave Direction	Point 1	6.5	5.5	358.6	349.2	343.5		6.8	5.6	358.8	349.4	344.6
	Point 2	352.9	352.9	344.8	335.4	329.0		353.9	354.2	347.4	336.4	330.8
	Point 3	28.5	28.0	18.5	11.5	9.1		28.3	26.2	16.1	10.6	7.6
	Point 4	14.5	15.3	7.1	359.2	352.9		14.6	14.8	7.6	359.7	354.6
	Point 5	9.0	7.4	0.3	351.2	347.7		9.2	6.9	359.1	350.8	347.3
Surface Elevation	Point 1	1.256	1.247	1.198	1.092	1.000		1.354	1.430	1.360	1.189	1.113
	Point 2	1.287	1.273	1.262	1.108	1.017		1.389	1.467	1.430	1.205	1.133
	Point 3	1.376	1.373	1.258	1.117	0.999		1.477	1.547	1.422	1.212	1.124
	Point 4	1.319	1.327	1.198	1.090	0.972		1.421	1.494	1.358	1.184	1.089
	Point 5	1.268	1.262	1.226	1.116	1.026		1.363	1.439	1.388	1.211	1.138

Generally the nearshore wave transformation revealed the following:

- The waves approaching from the east and north-east are comparable in magnitude and far exceed the waves approaching from the other directions. The nearshore waves for the 50-year return period from the east are shown in Figure 3.11.
- As waves propagate from deep water to the inshore regions they shoal, refract and lose energy. Wave energy is significantly reduced at the step offshore cliff as well as the numerous reefs offshore where enhanced breaking occurs. As a result, wave heights reaching the project shoreline range from 1-2m.

Figure 3.11 Resulting values of significant wave height and surface elevation extracted from the nearshore point

- Due to the wave refraction process and a depth-limiting constraint, the differences in wave height and direction between different deep-water wave directions and between the 50 and 100-year waves are not very significant.
- Waves coming from the east and north-east also produced the largest surge elevation.
- Generally, surge levels expected at the project shoreline during the 50-year storm will be less than 1.38m and less than 1.55m during the 100-year storm.

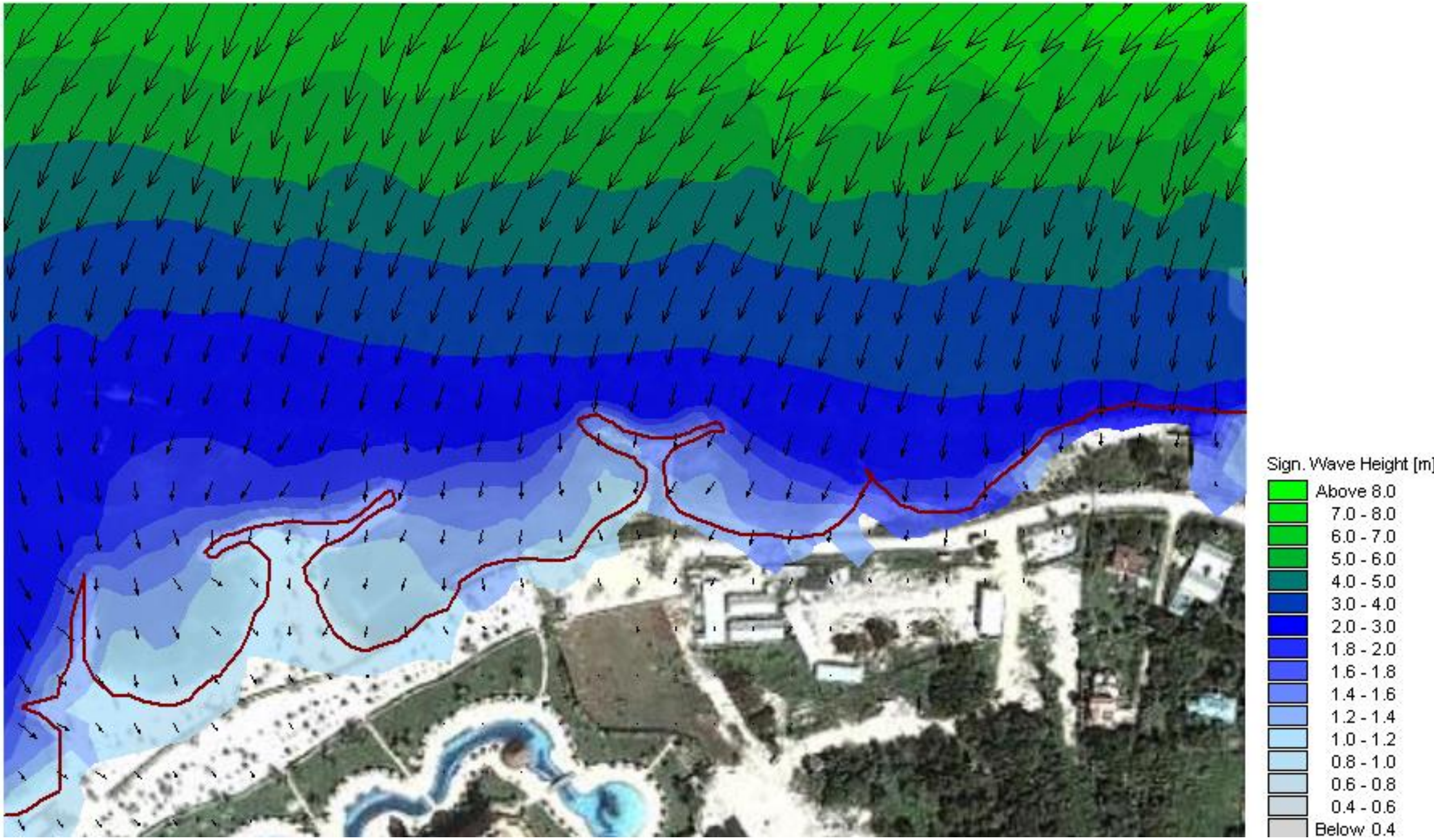


Figure 3.12 Significant wave heights (m) from hurricane waves from the east representative of a 50-year return period

4. Design of Coastal Structures

The primary issues for the proposed beach are as follows:

- There is insufficient sand on the beach to provide a comfortable beach experience for the expected increased number of guests;
- The nearshore area of the proposed beach has rocks that make wading uncomfortable;
- Unbroken wave energy is reaching the shoreline from the north-east direction;
- The existing structures were poorly constructed using stones too small to withstand major wave forces (such as those due to hurricanes); as a result they have been damaged throughout the hotel's history. It is believed that these structures are currently providing only very limited protection to the nearshore area. Further, their configuration and small stone size are also hampering circulation and contributing to poor water quality in the nearshore.

In order to address these issues, and in general create a suitable beach to accommodate the increased number of guests, the following actions would have to be taken:

- Remove small rocks from the nearshore area by hand/shovel and place sand to improve the wading experience;
- Remove that portion of the T-groyne that is currently perpendicular to the shoreline and remove the existing groyne structure towards the east;
- Place approximately 4000m^3 of sand of appropriate quality on the beach. This sand would be used to increase the beach width as well as to cover the rocky substrate in the swimming area;
- Construct a new cut stone walkway boardwalk. which will join the proposed beach to the existing sandy beach;
- Repack the existing breakwater (that portion which is parallel to the shoreline) to be tied in to proposed structures;
- Extend existing breakwater westward and seaward of its current western end;
- Construct a new submerged breakwater to the east of the existing structure to be tied in when complete;
- Construct a new emergent groyne stretching from the eastern end, forming a right angle and headland to be tied in with the new proposed submerged breakwater; and
- Construct a new spur groyne to the west of the new proposed beach area to retain the sand nourishment placed.

This section of the report describes the design of the coastal structures proposed for the beach enhancement concept. Preliminary designs have been prepared, including footprints and cross-sections for the considered option.

The environmental impacts will be considered and addressed in a separate report "Coral and Seagrass Relocation Plan," which will be submitted once the secondary benthic plan has been completed. .

4.1 Design Specifications

A preliminary concept design was developed based on existing literature, collected field data, as well as on an understanding of the waves, tides and currents.

To ensure the stability of the beach at the site the wave forces must be reduced. The design of any protective structure is highly dependent on the day-to-day (operational) wave climate experienced in the nearshore. Given the incident wave climate, a preliminary option was developed. Hurricane wave conditions were used to assess the structural stability requirements. It must be noted that hurricane wave conditions could have a significant and unpredictable impact on the sediment and nearshore beach conditions.

To improve the circulation of currents in the nearshore area, the structures were reconfigured to allow for a wider swimming space. Additionally the larger stone sizes will allow for transmission of water through the voids, whereas currently the small stone sizes allow for no or limited transmission.

The proposed option therefore consists of removal of rocks in the nearshore area along with the removal of that portion of the existing groyne which is currently perpendicular to the shoreline as well as the removal of the existing groyne headland to the eastern end of the proposed swimming area.

Sand nourishment of approximately 4000m^3 of sand is to be placed in the nearshore after existing rocks and stones have been removed. This is necessary to create a beach area that additional guests can enjoy.

In order to protect this nourished sand there will be a long breakwater/groyne, created through the connection of seven groynes of various heights. Portions of the breakwater will be emergent to more effectively break oncoming waves, while some portions will be submerged to allow for some water into the system to aid in circulation. Additional considerations of the structure are:

- The groyne at the eastern most end of the property will be tied in with the existing ground level there, and will thus be the highest portion of the breakwater. The structure will then "step down" to a lower height, which will be more consistent with the additional emergent portions of the structure.
- The emergent portions of the structure, except the initial portion closest to land, will therefore be the same height.
- The submerged portions of the structure, of which there are two, will be built so it is just visible at low tide. It is intended to not impact the view to the ocean.
- A spur groyne to the western end will also be constructed to retain the sand in the lagoon beach by preventing it from being moved to the west by the predominant winds and waves.
- All structures in the plan will be armoured with a neatly placed boulders sloped gently.
- The proposed stone walkway is necessary to connect the existing beach area to the newly proposed beach.

All the boulders will be appropriately sized and packed so that the structures are stable under hurricane conditions. The design calculations used the 1 in 50-year hurricane condition for the site, and will determine the required boulder sizes under those conditions.

The proposed option is shown below in Figure 4.1.

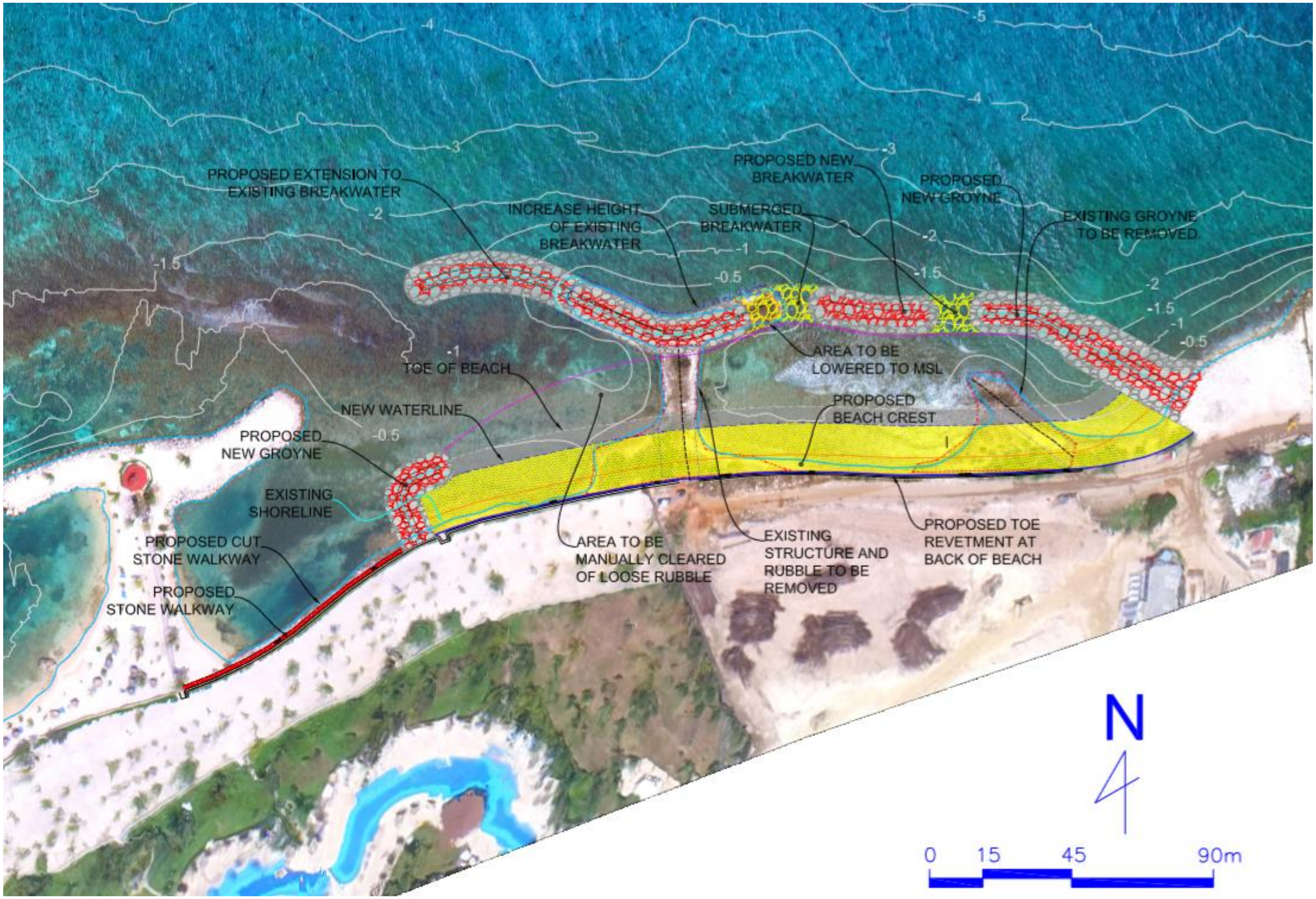


Figure 4.1 Proposed layout of structures to form "lagoon" beach

4.2 Beach Response and Structure Performance

4.2.1. Operational Waves

The method and model set up previously to develop an understanding of the existing conditions was adopted to evaluate the effectiveness of the proposed breakwater/groyne system. The spectral wave and hydrodynamic modelling investigated the existing and proposed shoreline responses and the variations between the two.

The 470 different conditions representing a combination of wave height, peak period and direction, each with a specific duration related to the number of occurrences in the 16-year period, which had then been used as a year of operational waves, was again input to the model mesh domain. The resulting annual wave rose distributions at the location of the five selected nearshore nodes (as described in Section 3.1.1) are shown in Figure 3.4 for the existing conditions. Additionally the minimum, average, median and maximum values of each node under existing conditions and with the proposed structure configuration in place is shown in Table 4.1 below.

Table 4.1 Statistical values of significant wave heights in the nearshore, with and without proposed structures

Without Proposed Structures	Point 1	Point 2	Point 3	Point 4	Point 5
Minimum	0.006	0.002	0.005	0.006	0.005
Average	0.270	0.170	0.137	0.280	0.160
Median	0.298	0.174	0.150	0.306	0.180
Maximum	0.488	0.372	0.245	0.514	0.287
With Proposed Structures	**Point 1**	**Point 2**	**Point 3**	**Point 4**	**Point 5**
Minimum	0.000	0.000	0.000	0.000	0.000
Average	0.105	0.053	0.005	0.004	0.119
Median	0.104	0.057	0.005	0.004	0.129
Maximum	0.230	0.109	0.010	0.008	0.214
Average reduction	0.166	0.117	0.132	0.276	0.041
Median reduction	0.194	0.117	0.144	0.302	0.052
Average percentage reduction	61.3%	68.7%	96.4%	98.6%	25.6%
Median percentage reduction	65.0%	67.2%	96.4%	98.6%	28.6%

Results indicate that at Point 1 and Point 2 (towards the western end of the proposed structure) there was roughly 65% reduction in wave heights. Predictably the direction of approach was affected and waves at these points typically approached from the west as waves wrap around the western end of the structure. Point 3 and Point 4, which are completely sheltered, saw a 99% reduction in wave heights. Point 4 (which was previously the most exposed point) was reduced from a median wave height of 0.3m to a new median wave height of 0.004m. Point 5, which is the point closest to the existing beach, recorded the least difference as it is not directly sheltered by the structure based on its location and is receiving predominantly shadow effects.

As mentioned previously the most common operational condition (Hs=0.5m, Tp=4s, Dir=95°) occurred 11.91% of the time. Plots of this condition before and after the structures were incorporated are shown in Figure 4.2.

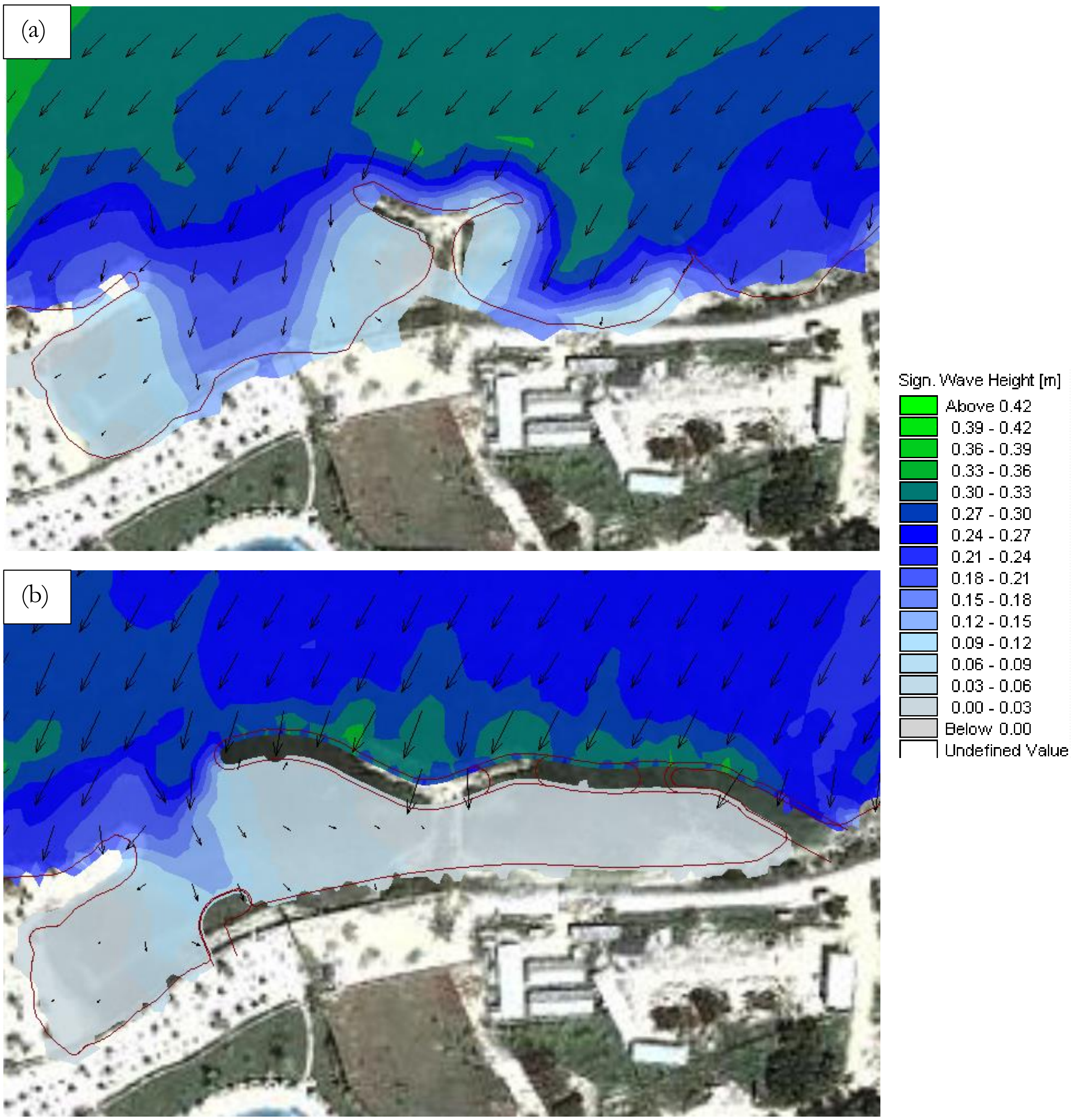


Figure 4.2 Most common operational wave condition transformed to the nearshore showing (a) existing configuration and (b) proposed configuration

4.2.1. Hurricane Waves

The hurricane analysis completed previously (Section 3.3) revealed that the waves coming from the east produced the highest waves in the nearshore. This condition was therefore modelled with the structures in place to note any difference. As expected, the presence of the structures served to significantly reduce the wave heights in the nearshore. A percentage reduction of approximately 54% on average was noted across the nearshore extraction points. This is shown below in Table 4.2. The significant wave heights under the *East 50* storm with the proposed structures in place are shown in Figure 4.3.

Table 4.2 Significant wave height (m) under existing conditions and with the proposed structures in place. Table also shows percentage reduction.

	Point 1	Point 2	Point 3	Point 4	Point 5
Existing	1.48	1.23	1.44	1.88	1.31
Proposed	0.76	0.53	0.74	0.73	1.11
Reduction	0.72	0.70	0.70	1.15	0.21
% Reduction	48.6%	56.7%	48.8%	61.1%	15.8%

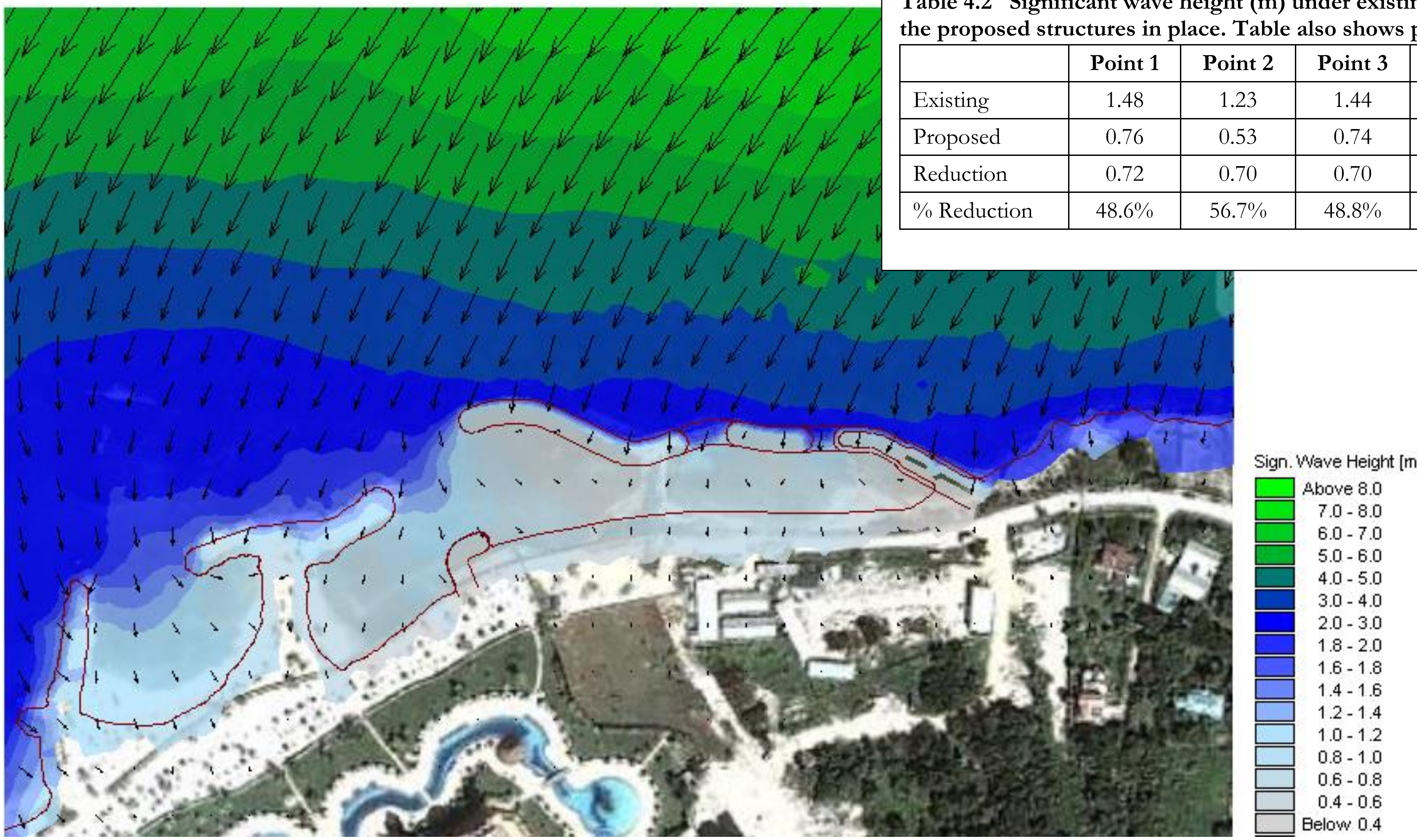


Figure 4.3 Significant wave heights (m) from hurricane waves from the East representative of a 50-year return period under proposed beach configuration

4.2.2. Current circulation

Certain elements, such as the submerged breakwaters, in the proposed configuration were included particularly to increase circulation in the proposed swimming area where the water quality is very close to exceeding the standard.

The current velocities that were compared at the selected extraction points (Table 4.3) before and after the structures were in place showed that currents are increased in the swimming area. Further, the current variation was far more regular with the structures in place, i.e. there were less spikes in current velocities than without the structures.

Table 4.3 Values of current velocity (mm/s) before and after structures incorporated in model

	Point 1	Point 2	Point 3	Point 4	Point 5
Existing Beach Configuration	11.9	8.4	8.1	7.7	9.7
Proposed Beach Configuration	14.1	12.7	11.7	9.2	13.7
Difference (Proposed – Existing)	2.2	4.4	3.6	1.5	4.0
Percentage Increase	18.2%	52.2%	45.0%	18.8%	41.6%

The results showed that currents in the area are very low, typically less than 30mm/s (0.3m/s). Extraction Point #2 (see Figure 3.2 for reference) is in the approximate location of the water sample collected with parameter values just within the range of acceptable standards, and so was chosen for further analysis. The time series of depth-averaged currents throughout the month of August 2014 under both the existing and proposed configurations is shown below in Figure 4.4.

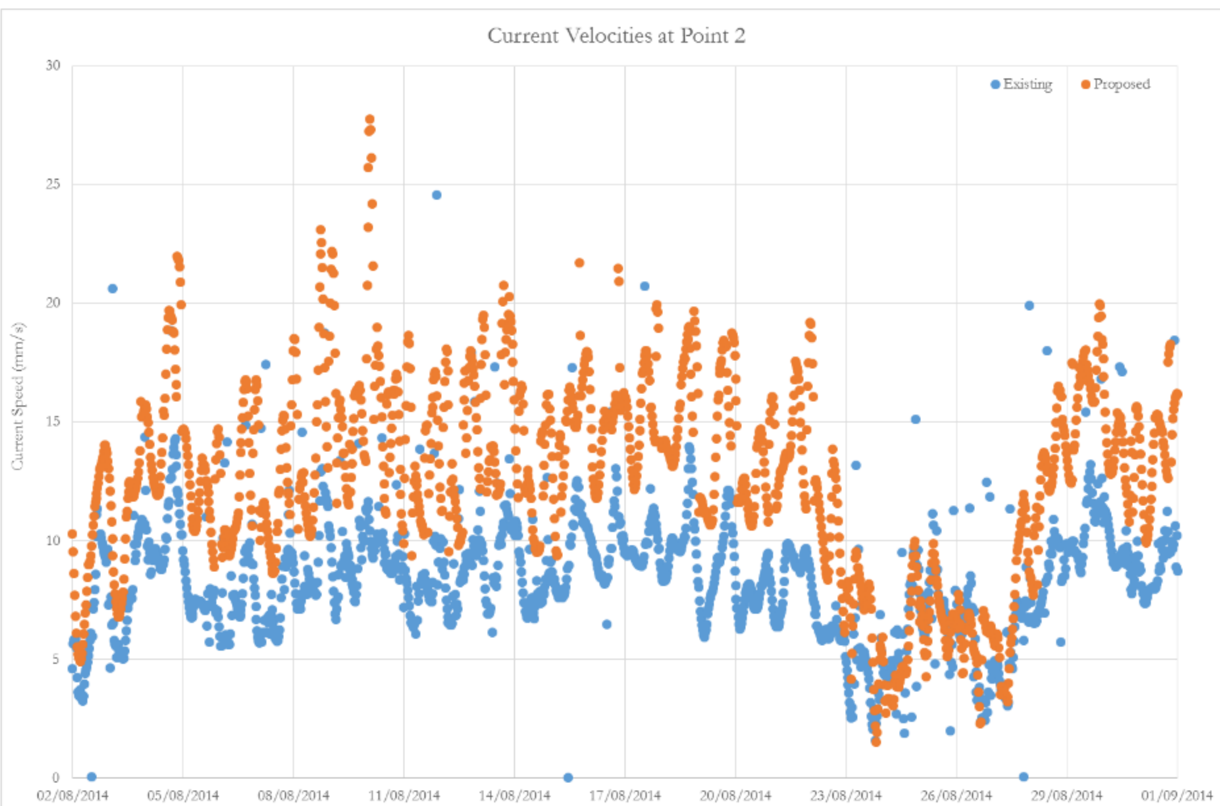


Figure 4.4 Current velocities at Point 2 under the existing beach configuration (blue) and the proposed beach configuration (orange)

As was done before, a representative time step, in between the spring and neap tides, where there was no obvious irregularity such as those due to wind gusts was selected. This time step is shown below in Figure 4.5 both with and without the proposed structures in place.

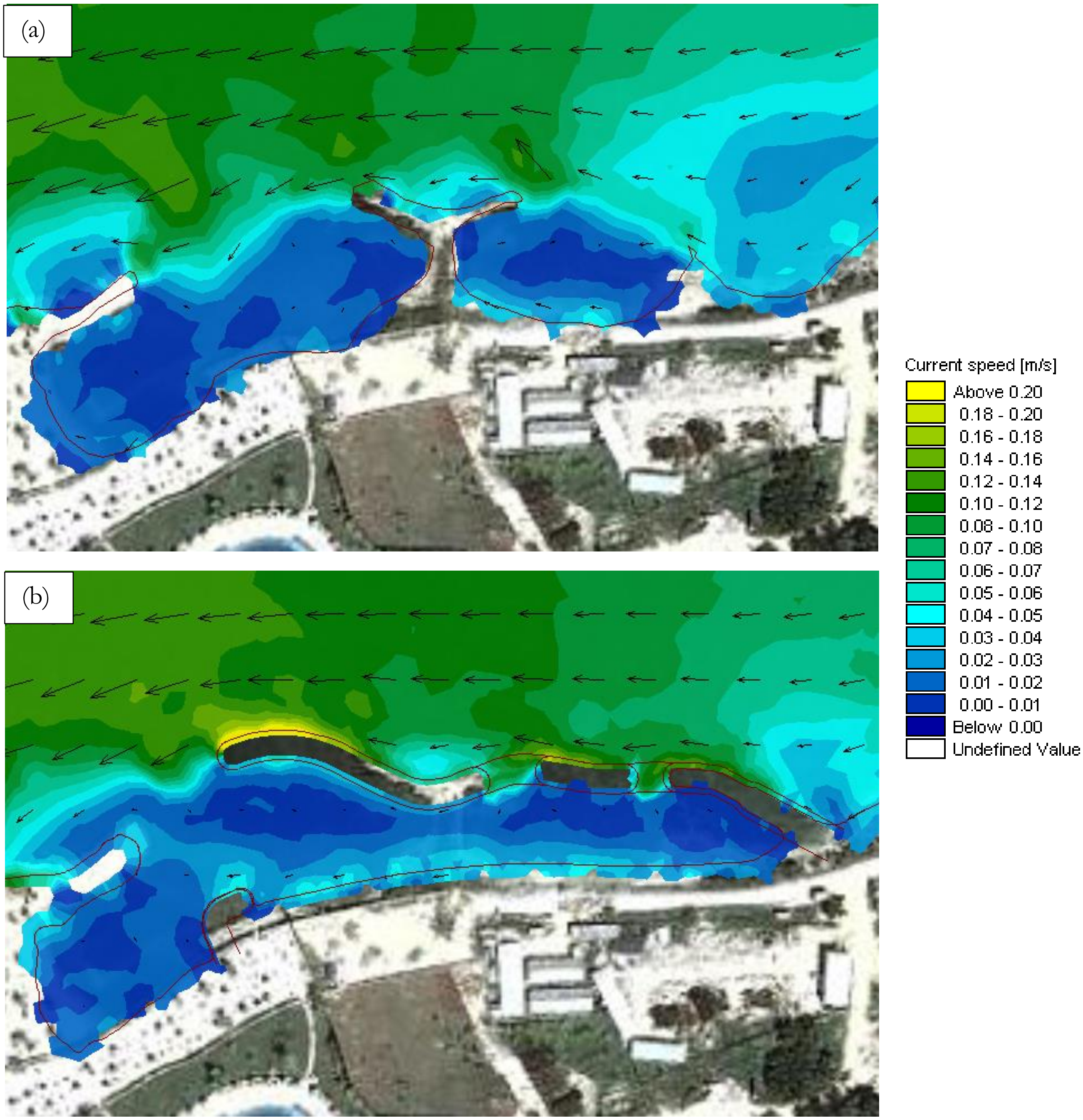


Figure 4.5 Current speed and direction at midnight on August 20th 2014 showing (a) existing configuration and (b) proposed configuration

The numerical modelling results have indicated that the proposed beach configuration has met two of the initial objectives. It has effectively created lower wave heights which will enhance the wading experience for guests as well as protect the nourished sediment. The new layout has also increased the circulation in the nearshore of the area which will serve to improve water quality.

4.3 Structural Stability

This section describes the analysis carried out to determine the stability of the proposed structures using proper stone sizes and, if necessary, core and armour layer thickness. Using the results of the wave modelling, the structures were designed to enhance the swimming area in the nearshore by creating a suitable area in the nearshore and to further retain sand placed on the shoreline. The use of boulders is proposed to provide protection against wave forces for the structures, which have been designed to withstand the 1 in 50-year hurricane condition.

4.3.1. Stone Size for Emergent Sub-Sections of Structure

The wave height for the 1 in 50-year event was found to be 2.3m at the toe of the proposed structures. The emergent groyne was designed based on an in-house program used to determine armour stone sizes from the design wave conditions. The computations of the Van der Meer formula for Static Stability of Rocks (Table 4.4) with the assumption that stone density was 2500 kg/m^3, showed that stones of 1500kg to 3500kg in mass (D50 of 0.9 to 1.1m) are required to sustain only minimal damage during the 50-year storm event.

Table 4.4 Design table used to determine armour stone size for the emergent sections of the proposed structure

SMITH WARNER INTERNATIONAL
COASTAL & ENVIRONMENTAL ENGINEERING

Breakwater Design Worksheet

Client:	Hojapi Limited
Project:	Gran Bahia Principe
Designer:	DDG
Date:	2015-07-16

Design Parameters (Structure)			Design Parameters (Wave)			Notes	
armour unit density (phor)	2500	kg/m3	design wave height (Hs)	2.30	m		
water density (phow)	1025	kg/m3	design wave period (Tp)	13.00	s	1	Rounded rock is less stable than equant rocks
buoyant density (s)	1.44		mean wave period (Tm)	10.83	s	2	Damage generally greater than predicted by
structure slope (cot alpha)	2	>=1.5	duration of storm	4	hrs		van der Meer for widely graded armouring
stability coefficient (Kd)	2	-	no. of waves (N)	1329	no	3	Narrow graded armour typically : D85/D15 = 1.25-1.5
damage number (Sd)	2	-	wave steepness	0.013	-	4	Widely graded armour typically : D85/D15 = 2 - 5
no. of units displaced per Dn, Nod	0.5	-	iribarren no.	4.5		5	Widely graded rip rap typically : D85/D15 = 2.25-2.5
perm of structure (P)	0.4	-	critical iribarren no.	3.77			
					wave is surging		

filter and core layer specifications	
User specified ratio? *(yes/no)*	yes
User specified value :	2
D50A/D50F	2
D50F/D50C	2

Rock Sizing Table
Van der Meer - Rock (Static Stability)

Primary Armour			Rock Gradation factor 1.31 Range Lower	Upper	Filter Layer			Filter Gradation factor 1.5 Range Lower	Upper	Core Material for Rock			Core Grad Ra Lower
Dn50	0.99	m	0.86	1.12	D50F	0.49	m	0.39	0.59	D50F	0.25	m	0.10
M50	2406	kg	1567	3500	M50F	301	kg	154	520	M50F	38	kg	2.7
D5n0 max	*1.07*	m	*0.92*	*1.21*	*D 50F max*	*0.53*	m	*0.43*	*0.64*				
M50 max	*3035*	kg	*1977*	*4416*	*M 50F max*	*379*	kg	*194*	*656*				
Layer thickness	2.2	m											

That portion of the structure which abuts the land will be slightly larger and feature a core with smaller stone sizes.

The small spur groyne will also feature smaller stones as these structures are not subjected to waves higher than 1m in the 50-year design condition.

Details of all the emergent structures are listed in the summary specifications in this chapter.

4.3.2. Stone Size for Emergent Sub-Sections of Structure

The design worksheet used to calculate the armour stone size for the submerged portions of the breakwater shows that stones with a density of 2500 kg/m3, a mass of 1500kg (approximately one and a half ton) and an approximate diameter of 0.85m would be required to sustain minimal to no damage during the 50-year storm event (Table 4.5).

Table 4.5 Design table used to determine stone size for the submerged portions of the proposed breakwater

STATICALLY STABLE SUBMERGED BREAKWATERS								
Wave Conditions	Symbol		units					
Wave Height	Hs*	2.57	m	Results from Kamphuis Formula:				
Wave Period	Tp	13	s	Kamphuis, J.W., 1991. Incipient Wave Breaking, Coastal Eng., 15: 185-203				
Wave Length	Lp	40.54	m					
Stone Parameters					Rock Gradation factor			
Stone Density	rho a	2500	kg/m^3			1.3		
Water Density	rho w	1025	kg/m^3		Range			
Damage Level	S	0	-		Lower	Upper		
Stone Size	Dn50	0.84	m		0.73	0.95	m	
Stone Weight	W50	1498	kg		986	2167	kg	
Structure								
Water Depth	h	1	m					
Crest height	h'c	1	m					
Submergence		0		measured positive down from Water Line to Crest				
				Emergent struct has a Negative Submergence				
Calc's								
Stability Number	Ns*	5.30	-	van der Meer and Pilarczyk, 1990, "Stability of Low Crested and Reef				
				Breakwaters", Proceed 22nd Coastal Conference, Vol.2, pp.1375-1388, 1990				

4.4 Sand Characteristics

The mean grain size along the existing Gran Bahia Principe beach ranged from 0.58mm on the western end of the property to 1.54mm in the middle of the property, to 3.54mm on the eastern end of the existing beach closest to the proposed structure. As this larger grain size is uncomfortable underfoot for guests, a smaller grain size akin to that on the western end of the beach would be considered more appropriate. However, it is important that the grain sizes not be too small as this sediment can be easily washed off the beach and out to sea.

To strike an appropriate balance, it is therefore recommended that the sand used to enhance the beach at the Gran Bahia Principe have a mean grain size ranging from 0.5-0.8mm. In addition, the silt content should be low, ideally less than 0.5%. Higher silt content will result in cloudy water as the waves gradually clean the sand, and can create a hardened surface over time.

Other characteristics, such as carbonate content and colour are generally aesthetic, and are subject to preference. In this case, however, the existing beach sand is white/yellow in colour, and it is recommended that the sand placed for beach enhancement be selected to match this.

To predict cross-shore sediment transport on the proposed "lagoon" beach, wave parameters on the lee side of the proposed submerged breakwater were used. These were the 99th percentile condition: Hs = 0.11m, Tp = 2.6s as well as the 90th percentile condition: Hs = 0.08m, Tp = 1.7s. Further the grain sizes of the proposed sediment nourishment was varied between 0.4mm and 0.6mm.

Table 4.6 Spreadsheet showing input values and beach stability numbers derived from Ahrens and Hands

Beach Erosion / Accretion					
Parameters	**Units**	**99th - dia0.6**	**99th - dia0.4**	**90th - dia0.6**	**90th - dia0.4**
Hso	m	0.11	0.11	0.08	0.08
Tp	s	2.6	2.6	1.7	1.7
d50	mm	0.6	0.4	0.6	0.4
p sand	kg/m^3	1922	1922	1922	1922
p water	kg/m^3	1025	1025	1025	1025
rel pho		0.88	0.88	0.88	0.88
Lo	m	10	10	5	5
Hso/Lo		**0.0103**	**0.0103**	**0.0175**	**0.0175**
Hb	m	0.18	0.18	0.11	0.11
db		0.2	0.2	0.1	0.1
Ns (Ahrens)		**341**	**511**	**217**	**326**
Ns - Upper Transition		4578	4578	3131	3131
Ns - Middle Transition		3425	3425	2342	2342
Ns - Lower Transition		1699	1699	1162	1162
John P. Ahrens and Edward B. Hands					
Paper # 75 ICCE 1998					

When the values for wave steepness and stability number were plotted on the graph shown below, the position on the graph places the proposed Gran Bahia lagoon beach firmly within the *Accretion Region* of sediment movement regions as highlighted by the blue (99th percentile) and green (90th percentile) dots on the graph. It further shows that both grain sizes, (0.4mm and 0.6mm) are acceptable for the proposed nourishment.

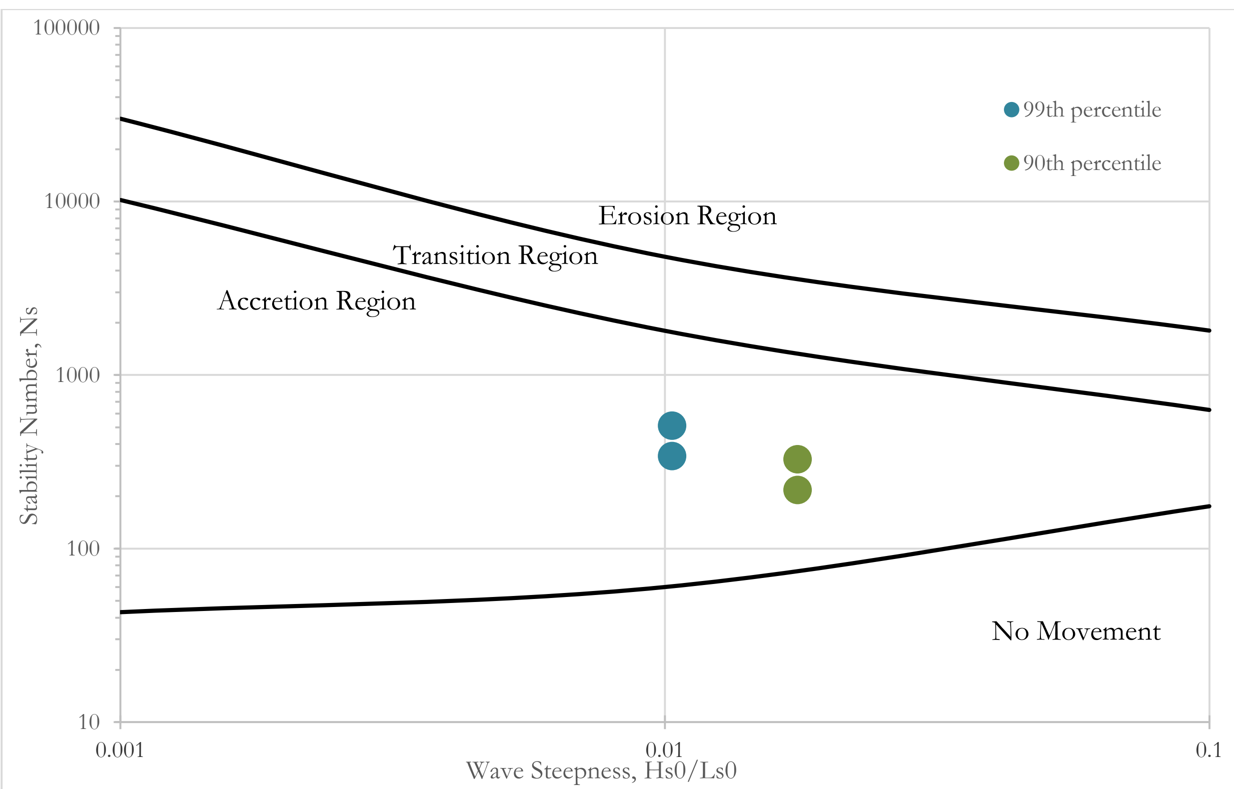


Figure 4.6 Graph of Beach Stability regions developed by Ahrens and Hands. Position of proposed beach depicted by dots.

4.5 Structural Specifications

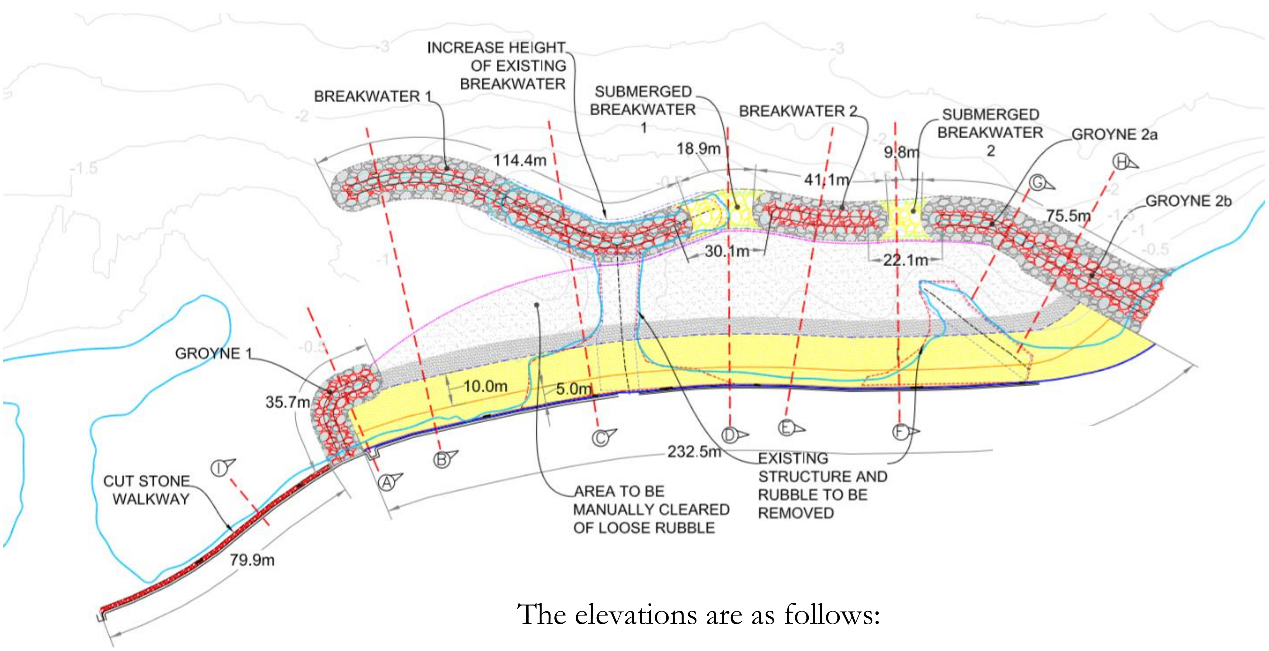
For the preliminary design of the proposed structures, the placement, length and crest elevation of each of the protective structures was determined using the operational wave conditions to optimize the protection capacity of the main beach in order to create the suitable wading area required for the additional guests.

The results from the coastal process investigations showed that the impact on the adjacent shorelines would be minimal due to the existing structural headlands already encompassing the project site.

It should be noted that increasing the crest elevation of any structure above mean sea level significantly improves its effectiveness in blocking the waves and reducing wave energy in its lee, however, this creates a greater visual impact. For this project, therefore, varying heights were adopted for the breakwater. The submerged portions of the structure also aided in increasing water flow into the "lagoon" and thereby increasing circulation and improving water quality.

The design specification of the final recommendation is as follows:

- One large breakwater/groyne system encircling the proposed wading area to create a feeling of a lagoon. Another small spur groyne to the west to retain the sand.
- The proposed structures features both emerging and submerging portions, and are generally of varying heights. The structures can be broken into seven sub-sections as shown in Figure 4.7.



The elevations are as follows:

- o Groyne 1 – emergent at +1.5m
- o Breakwater 1, Breakwater 2 and Groyne 2a – emergent at +1.0m
- o Submerged Breakwaters 1 and 2 – submerged at MSL (0m)
- o Groyne 2b - emergent at +2.0m

Figure 4.7 Proposed structures

- All emerged portions 1(V):2(H). The arm specifications are:

  - D50 =1m (acceptable range of 0.8 – 1m)
  - M50=2400kg (acceptable range of 1500 – 3500kg).

- That emerged portion closer to land will feature a greater width and a core layer. The thickness of the armour layer will be 2m and the armour stone size specifications are those outlined above. The core layer of this portion of the structure will feature stones with an M50 of 800kg (500 – 1500kg acceptable) and a D50 of 0.7m (0.55 – 0.8m acceptable).
- The small spur groyne to the west of the proposed beach are to be composed of armour stone with a slope of 1(V):1.5(H). The armour stone density should have a density of 2500 kg/m^3. The size specifications are:
  - D50 =0.3m (acceptable range of 0.25 – 0.35m)
  - M50=450kg (acceptable range of 300 – 650kg).
- All submerged portions of the breakwater are to be composed of armour stone with a slope of 1(V):1.5(H). The armour stone density should have a density of 2500 kg/m^3. The size specifications are:
  - D50 =0.8m (acceptable range of 0.75 – 0.95m)
  - M50=1500kg (acceptable range of 1000 – 2000kg).
- The nourishment of the existing beach with 4500 m^3 of sand with a mean grain size ranging from 0.5mm to 0.8mm and a silt content less than 0.5%. The finished elevation of the beach was set to +1m above MSL with a slope of 1 in 10.
- The entire shoreline and nearshore is to be cleared of existing rock rubble and debris. This includes two elements:
  - Breakup and removal from the seafloor of existing structures and hard surfaces
    - portion of existing T-groyne (293 m^3 of rock to be broken up and cleared)
    - existing headland to the east (237 m^3 of rock to be broken up and cleared)
  - Removal from the seafloor of any loose rubble or debris currently in proposed swimming area, an approximate area of 3388 m^2 will be cleared.

Cross-sections through the various structures are shown in Figure 4.9 and Figure 4.10.

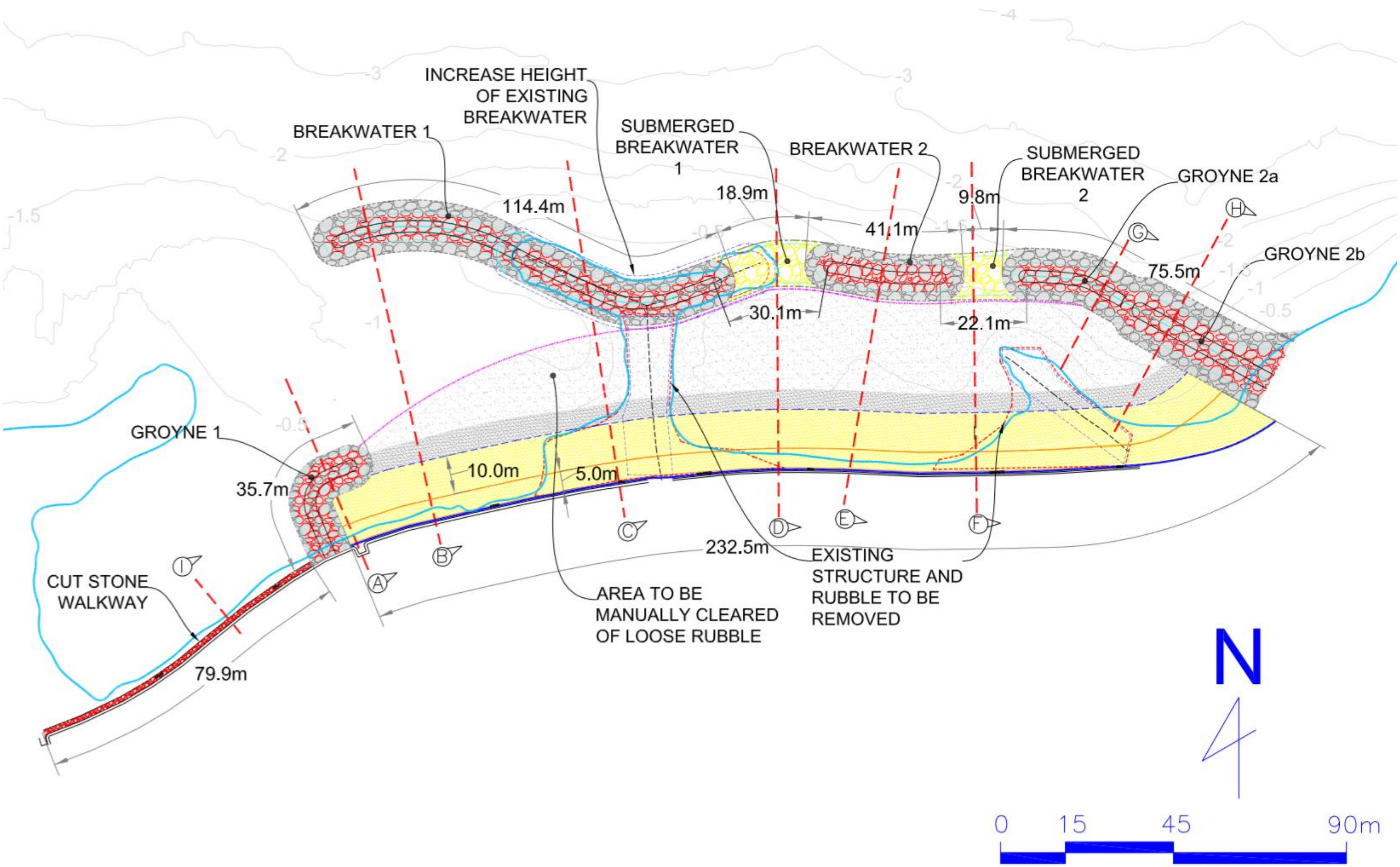


Figure 4.8 Plan of proposed structure layout including cut lines where cross-sections were drawn

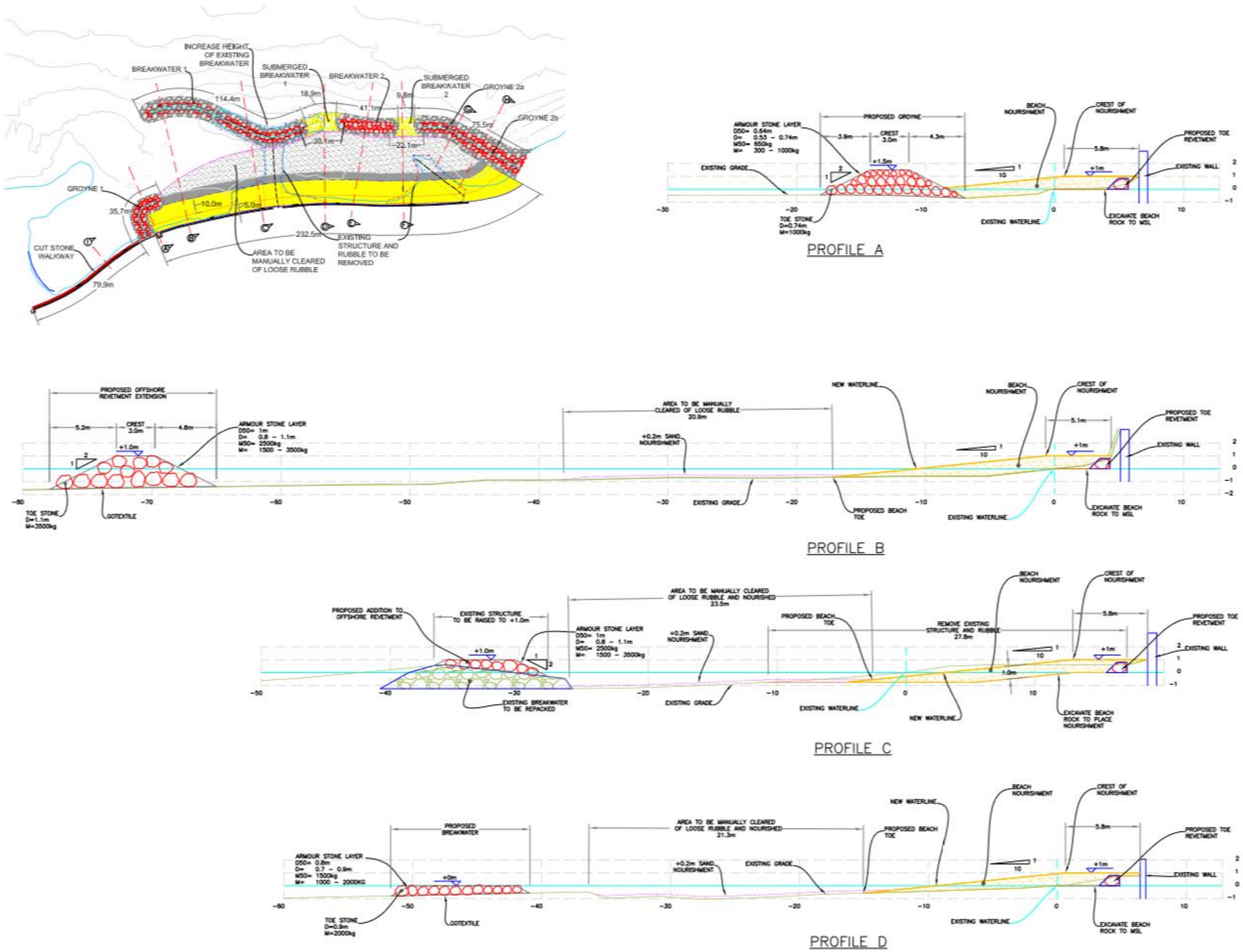


Figure 4.9 Cross-sections of the proposed breakwater system and beach nourishment; plan of proposed structures shown in left window

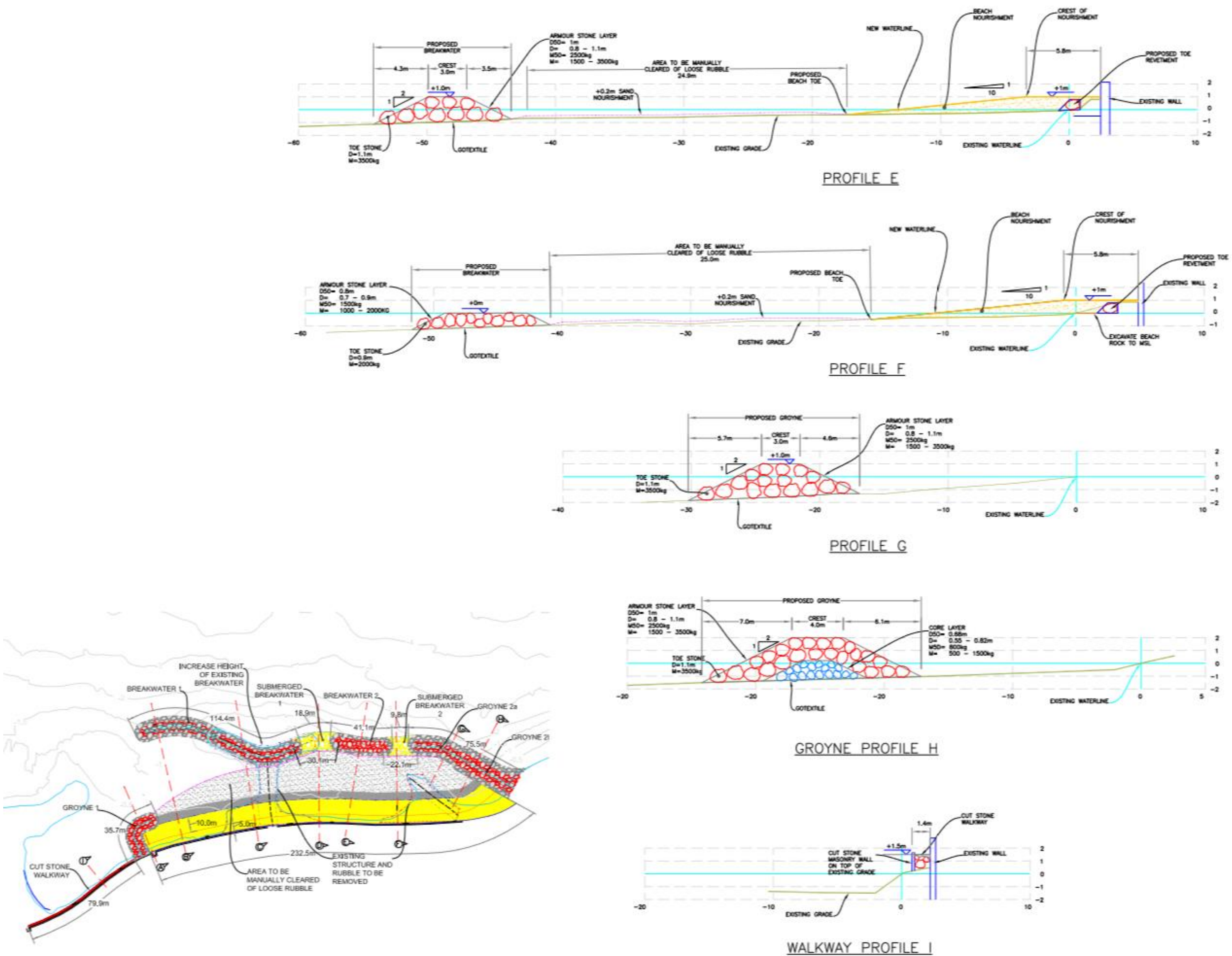


Figure 4.10 Cross-sections of the proposed breakwater system and beach nourishment; plan of proposed structures shown in left window

4.1 Estimated Quantities

Estimates of the material volumes (whether the material involved is boulders or sediment) required to implement the proposed works are summarized below in Table 4.7. The corresponding areas of seafloor in the foreshore which will be affected by the construction are summarized in Table 4.8. The relevant quantities for NEPA licensing are highlighted.

Table 4.7 Volumes of material involved in construction of proposed structures

Volume of material in Breakwater 1	1138	m^3
Volume of material in Breakwater 2	492	m^3
Volume of material in Submerged Breakwater 1	60	m^3
Volume of material in Submerged Breakwater 2	118	m^3
Volume of material in Groyne 1	502	m^3
Volume of material in Groyne 2a	629	m^3
Volume of material in Groyne 2b	2121	m^3
Volume of material in Revetment	1075	m^3
Volume of rubble to be removed from swimming area	508	m^3
Volume of rubble to be removed from breakup of current structures	530	m^3
Volume of Sand nourishment	4500	m^3

Table 4.8 Areas of seafloor to be affected by proposed structures

Footprint of Breakwater 1	794	m^2
Footprint of Breakwater 2	482	m^2
Footprint of Submerged Breakwater 1	112	m^2
Footprint of Submerged Breakwater 2	118	m^2
Footprint of Groyne 1	409	m^2
Footprint of Groyne 2a	437	m^2
Footprint of Groyne 2b	777	m^2
Footprint of Revetment	719	m^2
Area to be nourished	137	m^2
Areas to be cleared :		
Remove rubble from swimming area	781	m^3
Remove rubble beach rock	1341	m^3
Break up and remove rubble currently part of structures	1765	m^3

5. Potential Impacts and Mitigation Measures

An impact is defined as any change to the existing condition of the environment arising from project implementation. Understanding the nature of the impact can be assisted by categorizing the effect of the potential impact as being either:

- Positive or negative,
- Reversible or irreversible,
- Of short or long duration,
- Of small or large magnitude, and
- Being local or wide in extent.

There are a number of potential negative impacts related to the construction and placement of the proposed structures and from the proposed nourishment activity.

Where the effect of an impact is negative, consideration should be given to implementing mitigation measures. It is important to design mitigation measures carefully so that potential negative impacts are minimized as much as possible, so that any damage to the environment is reduced. Mitigation measures are especially important when the nature of the impact has been identified as being irreversible, or being of long duration, or being of large magnitude, or where the expression is likely to be wide in extent.

A summary of potential negative impacts is presented in Table 5.1 following. Many of the impacts identified are of small magnitude and are likely to be expressed in the vicinity of the proposed works, however, there were some impacts identified to be irreversible and of long-lasting duration.

For all of the impacts identified, regardless of their nature, appropriate mitigation measures have been proposed. These mitigation measures involve known techniques related to relocating resources, the use of silt screens (turbidity barriers), and visual inspections. These mitigation measures are outlined below.

5.1.1. **Relocation of Ecosystem Resources**

The area of benthic resources that will be impacted during construction and operation are easily identified. Based on the existing environmental conditions it would be appropriate to relocate these resources (comprised mainly of seagrass and some coral).

Where the sediment type allows, harvesting of seagrass as mats/planting units can be done for the material to be relocated and used in re-turfing. Additionally and where the sediment characteristics are such that harvesting seagrass as mats/planting units is not practical (due to depth of sediment, presence of rubble, etc.), the apical meristems may be harvested allowing for the restoration of the seagrass bed in other areas. The combination of relocation and restoration will minimize the impact of this development proposal on the seagrass bed.

Table 5.1 Summary of assessment of the identified potential negative impacts

Potential Negative Impact	Impact Reversible?	Duration		Magnitude		Extent	
		Long	Short	Large	Small	Wide	Local
Physical damage: loss of the communities living on and in the footprint of the proposed structures and swimming area	No	X			X		X
Physical damage: toppling of undermined colonies.	No	X			X		X
Smothering: sensitive resources near to the construction zones can be affected by sediment.	No		X		X		X
Oil Pollution: fuel spills from boat engine and dredging equipment.	Yes	X		X		X	
Displacement of other uses: recreational swimming	Yes		X		X		X
Smothering: sedimentation leading to smothering of sensitive resources near to the nourishment sites.	No		X		X		X
Physical damage: heavy equipment impacting turtle nesting	No		X		X		X

5.1.2. Transplanting Methodology

A detailed *Benthic Relocation Plan* will be submitted to NEPA, which will discuss the seagrass and coral relocation in greater detail. That report will include the areas of seagrass to be relocated as well as the number and size of the coral that will be relocated. The characteristics of various relocation sites will also be examined and discussed within that report, to be submitted at a later time. Only the general approach to the proposed relocation is discussed herein.

Seagrass

The modified *Mat Method* will be used to harvest those seagrass beds marked for relocation. This entails using shovels and pitch forks to cut and extract the seagrass in mats. Each mat is referred to as a Planting Unit (PU), and each PU is expected to be approximately $0.15m^2$ in area. The sections will be removed with the rhizomes and soils attached. These sections will remain submerged at the harvesting site until they are needed for replanting. Keeping the sections submerged at the harvesting site ensures that the leaves are covered with water thereby preventing desiccation as well as maintaining the same osmotic potential and temperature. The quantities reaped per day will be limited to that which can be replanted within the same day.

The seagrass being transplanted will be transported via raft drawn by a boat from the donor site to the recipient site. At the recipient site the seagrass will be carefully removed so as to not disturb the sensitive root systems and sediment will be removed from the leaves of the plants. The unit will then be hand bundled with a twist tie to a stake or staple. The PU will then be inserted into the substrate at the recipient site allowing for a minimum spacing of 5cm between adjacent units. The planting units will further be anchored in the seabed substrate using the Staple Method. The planting units will be stabilized by "stapling" them into the seabed with the use of U-shaped rebars.

Coral

Any coral colonies identified to be relocated will be severed from the base to which it is attached with hammer and chisels. During the severing process divers will try to avoid touching live surfaces of the corals to prevent damaging or killing the sensitive coral polyps. When possible, the corals will be severed in such a way that they remain attached to their carbonate bases, which in turn will prevent direct contact of the polyps with the reef cement mixture. Once carefully removed, the coral will be placed on a large tray and guided by the divers to the transplant site, remaining below the water surface throughout. Colonies in the trays will be arranged so no live coral tissue will touch any other surface and no structural elements of the corals will be under pressure. Should any coral colonies be fragmented during the collection phase they shall be cemented to a suitable substrate prior to placement in the recipient site.

Within the recipient site, cement blocks will be cleaned/scrubbed with a wire brush and anchored to the sea bed using steel rebar. Once the recipient site has been readied in this manner, replanting activities can commence.

At the recipient site the divers will use gloved hands to remove sand particles and loose algae, prior to fitting a semi-cured cement ball to the base of the area for reattachment. The area for reattachment will be determined to get a close fit between the coral base and the area the cement is to be placed. Due to the use of additives and high rpm mixing, there will be an approximately 20-30 minute period while the reef cement mixture starts to cure, therefore corals will have to be placed at the donor site simultaneously with the mixing of the cement on shore. The curing cement will be placed in transparent plastic bags and divers will carefully and slowly remove the balls of cement from the bags to minimize localized sediment dispersal. The reef cement will then be placed on the flush surfaces between the transplanted coral and the block. By gently pressing the coral onto the semi-cured cement, divers will ensure that cement is evenly distributed under the coral colony. Strapping of corals to the blocks, while carefully handling, will also be done where appropriate.

Turbidity Control

The sites for relocation and replanting will be demarcated with a turbidity curtains (screens) encircling the areas of construction of activity to minimize leakage of turbid waters to adjacent areas. The barrier will serve as both demarcations for the areas of replanting as well as containment of any suspended silt in the water column.

Turbidity barriers will also be deployed and used during the nourishment activities to contain the suspended sediment to the nearshore where it is desired and prevent it from moving to adjacent areas where smothering could occur.

Schedule

Subsequent to receipt of the required licenses, the proposed schedule is as follows:

- Day 1 – One day training workshop inclusive of field and lecture sessions for all persons involved in this activity.
- Day 2 to 4– Preparation of recipient site for coral transplant. Coral removal and transplant.
- Days 4 to 7 – Seagrass removal and relocation.

Supervising Personnel

The replanting will be carried out under the supervision of Smith Warner International (SWI) Limited. The management team has carried out similar relocation activity successfully at Palmyra and Trident, and has overseen relocation activities at several other sits including Half Moon, Iberostar and Secrets.

In addition to the SWI personnel on site, Michelle McNaught, a marine biologist, with experience in Marine ecosystems mitigation (restoration, relocation and artificial systems), fisheries management, marine protected areas and environmental monitoring will provide oversight of all the relocation activities. As part of her duties she will be responsible for quality control in handling the sensitive species being relocated. She will also be responsible for logging and recording relocation activities

Mr. Huon (Dave) Guiness, an experienced SCUBA diver who has worked on other coral relocation projects such as those associated with the construction of the Falmouth pier, will be the lead individual in relocating the corals.

Any changes to these project personnel will be submitted to the Agency in writing.

Monitoring Report

A monitoring report will be submitted to NEPA within seven working days of completion of the transplanting period. This will include the following:

- Summary log of the daily transplanting operations. This is to include the location and total area of each seagrass planting unit harvested and stored/planted as well as the location and total number of each coral species harvested and anchored;
- Dated photographic evidence of all works;
- Sea and weather conditions during transplantation; and
- Any anthropogenic impacts during the transplantation.

Following completion of relocation, monthly monitoring will be carried out during the construction period.

APPENDIX TWO

Seagrass and Coral Relocation Plan

Background

The hoteliers of the Gran Bahia Principe located in Salt Coopers, Runaway Bay, St. Ann are currently desirous of expanding their beach area to the east of the property to accommodate the increased number of guests which will be using the beach in that area.

The proposed 'lagoon' beach is shown below in Figure 1. As the image shows, it is proposed that the beach area be nourished with sediment. That sediment is to be retained through the use of connected breakwaters and groynes tying into some existing structures as well as a small spur groyne to the west.

Two rounds of benthic mapping occurred, the first on July 18th and the second on July 25th. The exercises were undertaken to ground-truth and map the hard corals and seagrass beds within the footprint and construction impact zone of proposed beach development for Gran Bahia Principe Hotel.

The findings of the benthic ground truthing exercise are detailed below.

Methodology

Guided by the Proposed Development Plan, the area was divided into 3 sections. These are:

1. The Eastern Section – comprised of the Swim Area and Proposed structures (Groyne and Breakwater). Demarcated with points P8 to P18 as shown below in Figure 2.
2. The Western Section Swim Area. Demarcated with points P20 to P26 as shown below in Figure 2.
3. The Western Proposed Extension to the existing breakwater. Demarcated with points P1 to P7 as shown below in Figure 2.

Using the GPS Coordinates (P1 to P26 as shown below in Figure 2), the footprint of each section was identified and marked using 'shot lines'. The Eastern Section was Mapped on Day 1 (July 18, 2015) and the Western Section (Swim Area and Breakwater Extension) was mapped on Day 2 (July 25, 2015).

The entire area within each section was surveyed and corals larger than 5cm were marked using GPS and photographed. Seagrass beds were also marked and noted and the size estimated during the swim through and confirmed later using geo-referenced satellite imagery.

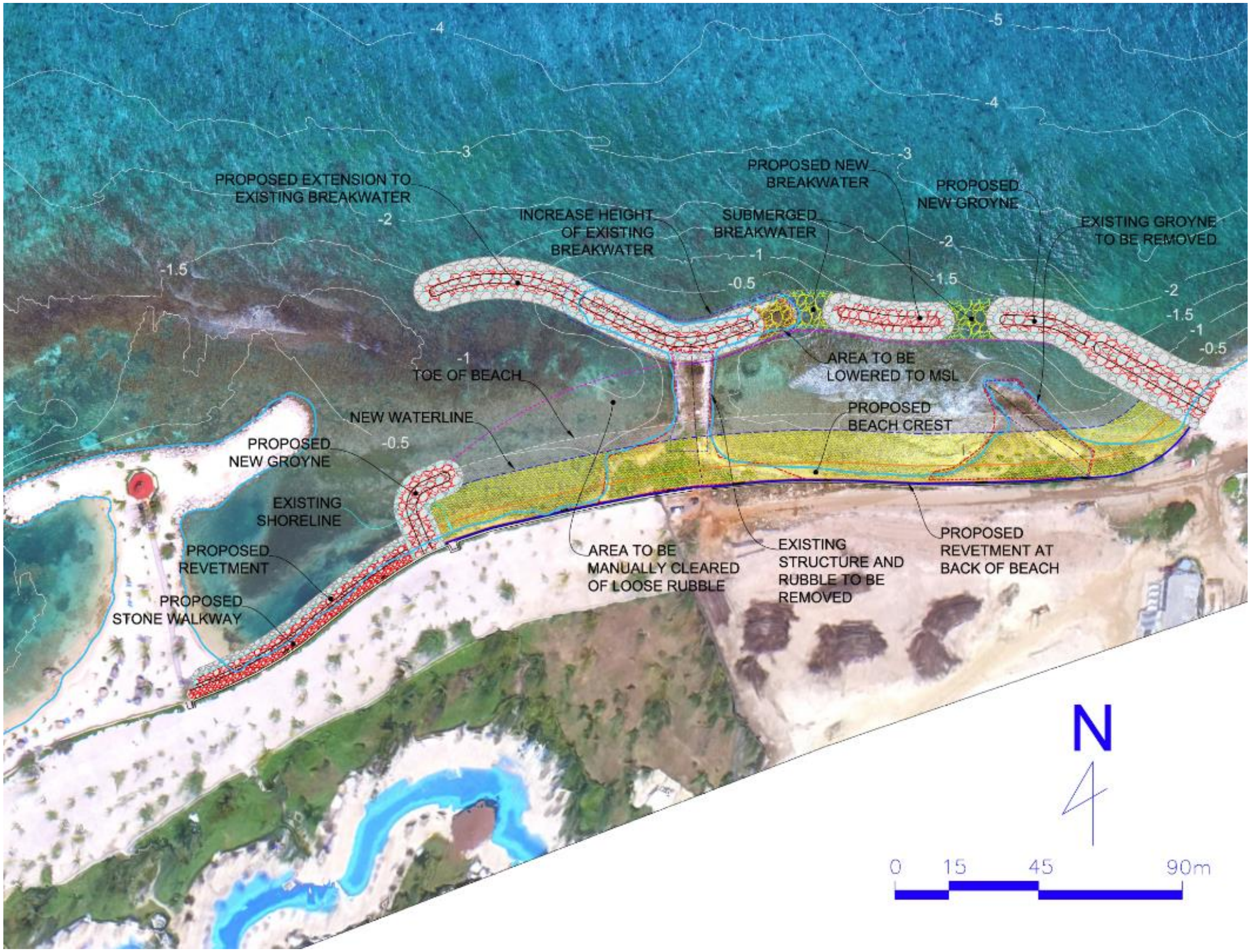


Figure 1 Proposed new beach development showing proposed structures as well as structures to be removed

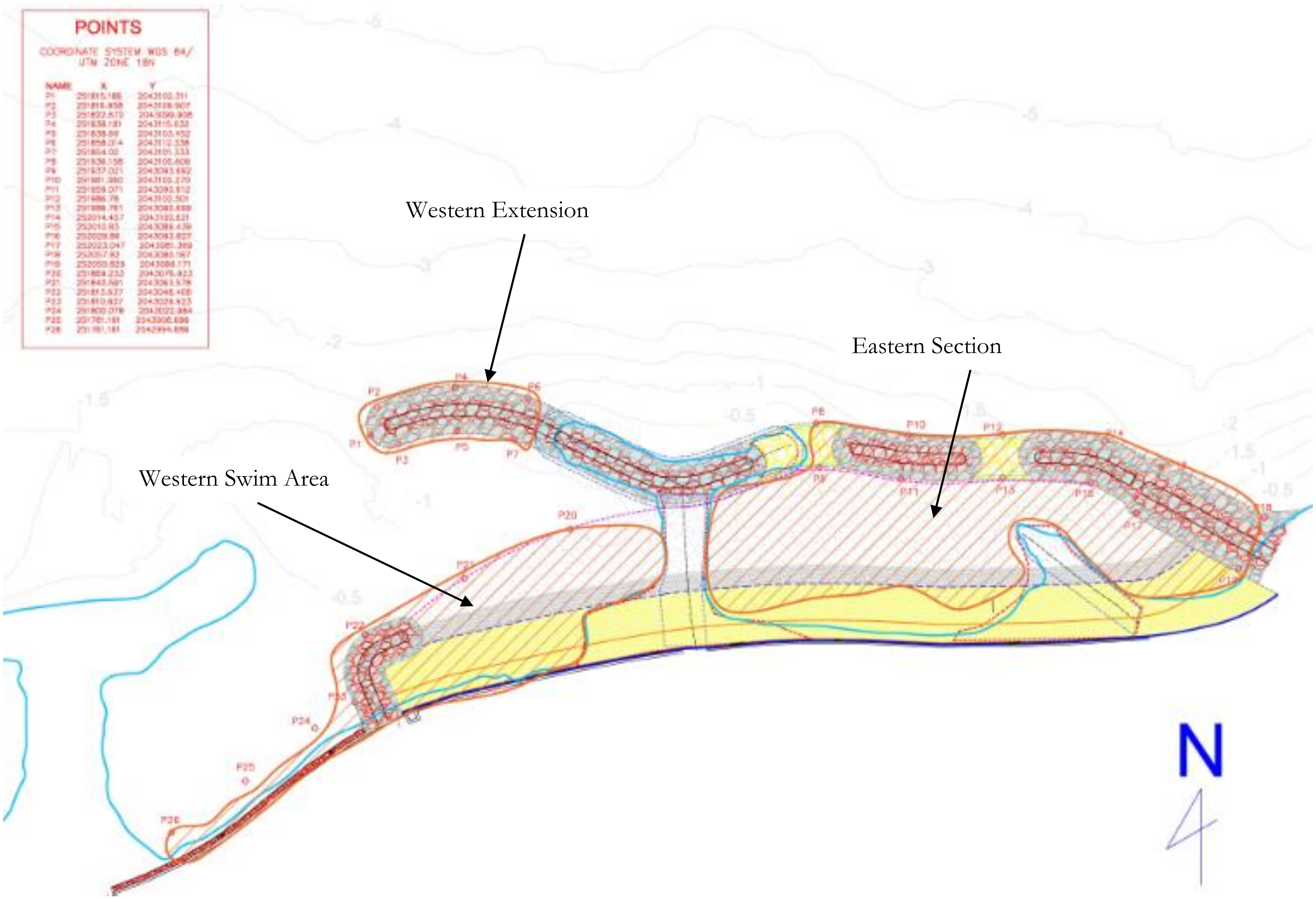


Figure 2 Surveyed area divided into three section (shown in orange hatch) which were then mapped in detail. (1) Eastern Section, (2) Western Section, (3) Western Extension.

Benthos within footprint of structures

Approximately **348 hard corals** greater than 5 cm were observed within the proposed footprint of this beach development. This amount could be more or less as some corals may have been missed due to rapid assessment and poor sea conditions at the time of sampling and some corals were close to edge of footprint. Numerous corals were noted next to the proposed footprint. The breakdown of the number of corals per section is as follows:

- Eastern Section – 251 corals
- Western Section
  - Western Swim Area – 6 corals
  - Western Breakwater Extension – 91 corals

Eastern Section (P 8 to P18 to shoreline)

- Approximately **251 hard corals** greater than 5 cm was observed.
- Overall species richness was low. Approximately 5 species of corals were observed. These are:
  - *Acropora palmata* – Few small colonies (Endangered and protected species)
  - *Diploria clivosa* – Dominant species of coral in area
  - *Montastrea cavernosa* – Single colony observed
  - *Orbicella annualris* – Few colonies present (most of which were large/boulder formation)
  - *Millepora complanata* - Many colonies present
- Rocky (iron shore) shoreline leads into seafloor and is therefore mostly pavement and rubble (hard bottom) overgrown with Marco algae interspersed with coral heads
- Eastern end of proposed swim area in the vicinity of the existing structure has numerous (very high density) **rock urchins** (Abundant)
- The area was dominated (Abundant) by **sea fans (soft corals)** especially towards the eastern end of proposed swim area
- This section had small patches of seagrass (*Thalassia testudinum)* confined to the lee of existing T-Structure which can be relocated. These smaller patchy areas of seagrass cover a total area of approximately 60 m^2.

(Single – 1; Few - 2 to 9 individuals, Many 10 – 100; Abundant - >100 AGRRA Methodology)

Photographs showing the general seascape of the *Eastern Section*: *Photo stick markings - 10cm*

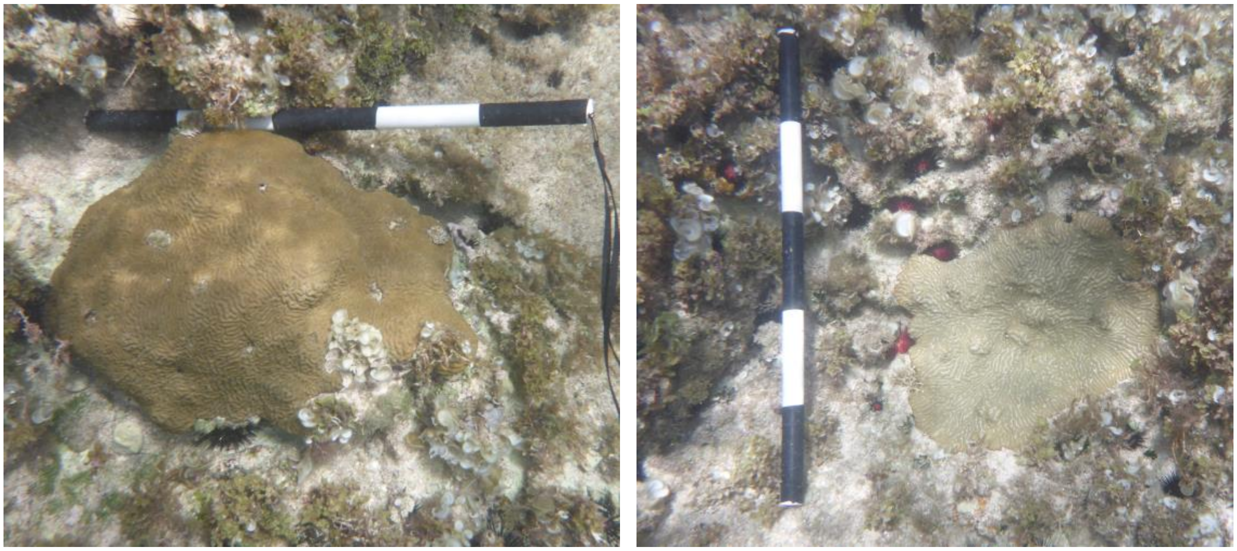


Photo 1a and 1b Dominant corals found in area – Knobby Brain Corals

Photo 2a and 2b Soft corals found in area – Gorgonians/Sea Fans

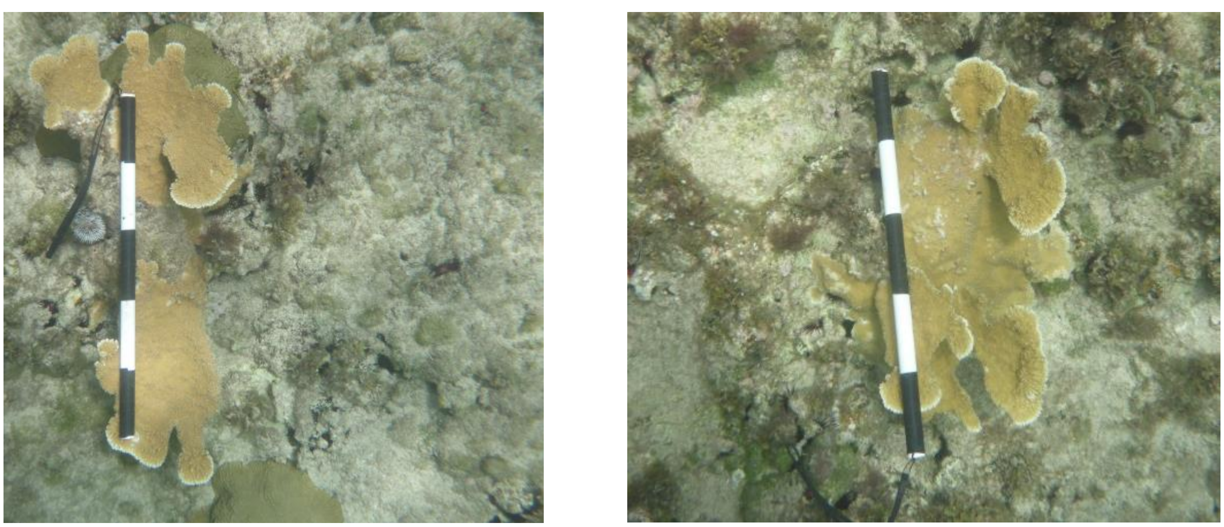


Photo 3a and 3b Elk Horn Coral *(Acropora palmate)*

Photo 4a and 4b Examples of seascape with dead Elk horn *(A. palmata)* Corals surrounded by sea fans

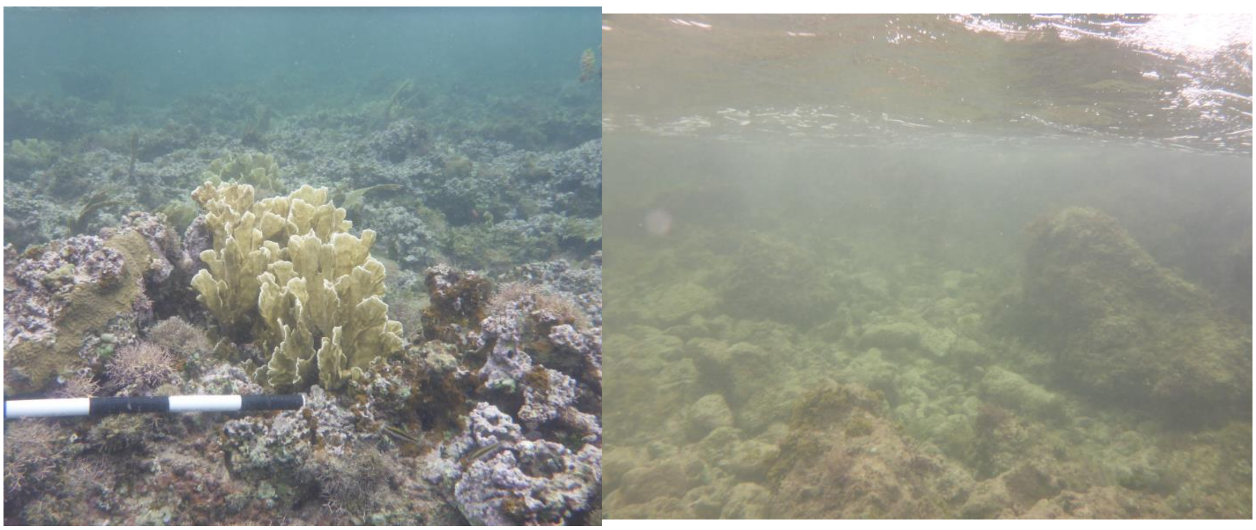


Photo 5a and 5b Example of seascape with fire corals (left) and rubble (right)

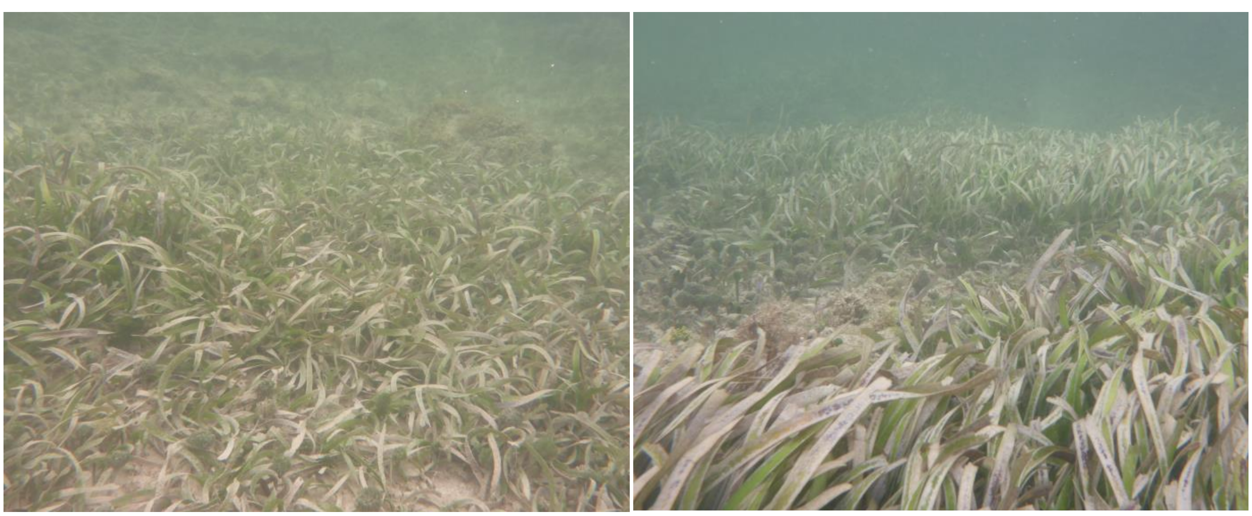


Photo 6a and 6b Seagrass in Eastern Section – lee of existing groyne

Western Swim Area (P20 to P26)

- Approximately **6 hard corals** greater than 5 cm was observed.
  - 3 of which was on the existing revetment structure (seawall – vicinity of P26)
  - Numerous coral recruits on revetment (seawall – vicinity of P25 to 24). Very low profile and <5cm. Difficult to remove
  - Species diversity of corals was also low with 3 species noted (*Porites sp, Diploria sp* and *Siderastrea sp*)
- Few species of reef fish observed, some of which were notably in the larger size class (along seawall/revetment)
- Area intruded with Sea Urchin (*Diadema antillarum*) which will be relocated before construction begins.
- Sparse Seagrass present in the vicinity of proposed groyne and revetment (P24 – P22). The seagrass is approximately 115m^2.
- There are also large dense seagrass patches to the west of the western swim area (shown on Figure 4). The area covered by this denser patch of seagrass is approximately 1000m^2. However these patches are significantly removed from the proposed footprint and therefore do not need to be relocated.
- Extensive macro –algae along existing groyne (western side) more than likely due to culvert with outlet.

Western Breakwater Extension (P1 – P7)

- **91 hard corals** greater than 5 cm was observed
- An additional **5 hard corals** with more than 70% mortality were noted close to the edge of the existing structure.
  - These may be considered for removal
- Coral species diversity was low and similar to the Eastern Section was dominated by boulder/massive corals (brain and knobby brain corals) with some fire and Elk horn corals
  - *Acropora palmata* – Few small colonies (Endangered and protected species)
  - *Diploria clivosa* – Dominant species of coral in area
  - *Diploria strigosa* - Many colonies present
  - *Montastrea cavernosa* – Single colony observed
  - *Millepora complanata* – Few colonies present
- Area is overgrown with marco-algae

(Single – 1; Few - 2 to 9 individuals, Many 10 – 100; Abundant - >100 AGRRA Methodology)

Photographs showing the general seascape of the *Western Swim Area*: *Photo stick markings - 10cm*

Photo 7 Branching coral – *Porites sp* (>10cm) – on revetment

Photo 8 Coral Recruits (< 5cm) on revetment

Photo 9 Urchins amidst rocky areas and sparse seagrass

Photo 10 Typical seascape with macro algae

Photo 11 Lee of groyne over grown with Nutrient indicating Algae

Photo 12 Seagrass in Western swim area

Photographs showing the general seascape of the <u>*Western Breakwater Extension*</u> : *Photo stick markings - 10cm*

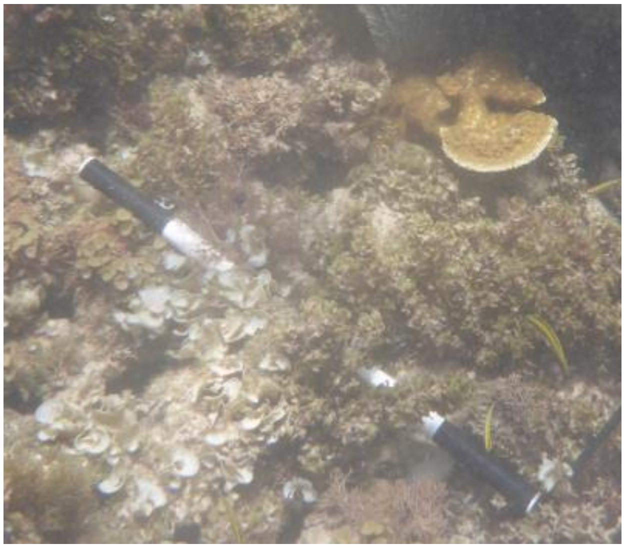
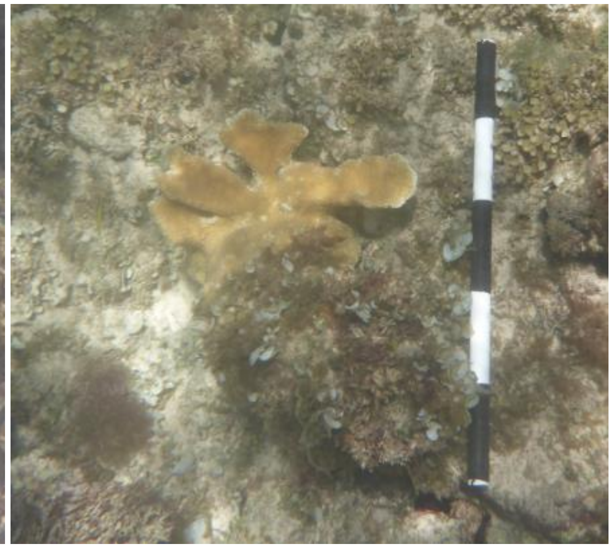



Photo 13a and 13b ***Acropora palmate*** **(Protected Species)**

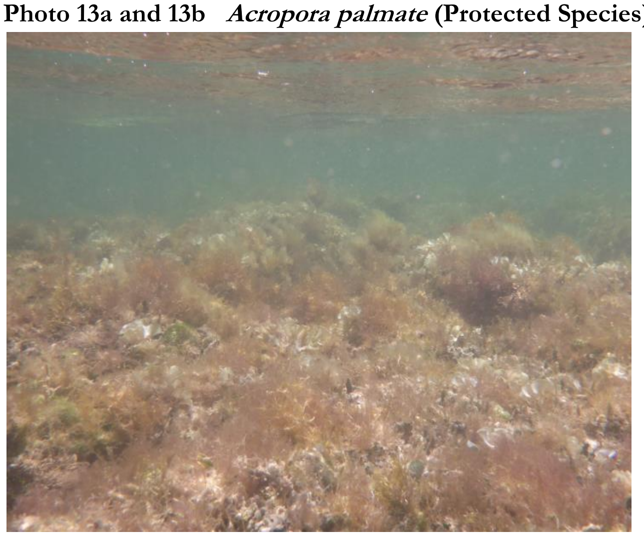


Photo 14 Typical seascape with macro algae

Photo 15 Example of seascape with dead *A. palmata (Elk horn) Corals*

Photo 16 Large brain corals (not within proposed footprint and therefore will not be disturbed)

Photo 17 Typical seascape with Knobby Brain corals and macro algae

Recommendations – Benthos to be removed / relocated

Corals

As hard corals were noted next to almost all of the proposed footprint areas, caution must be taken not disturb these during the construction phase. This general care during construction must incorporate the use of turbidity screens and constant monitoring of turbidity to ensure corals have a healthy environment throughout the entire construction phase. The monument corals in Western Section (seaward of the western breakwater extension) should not be removed and, in order to ensure no impact during construction, they should be marked as such.

All hard Corals (>5cm in size) within proposed footprint of beach development must be relocated to the north of proposed breakwater, outside of the proposed footprint and impact zone before construction begins. This proposed coral relocation site is identified as such in Figure 4 below. This site is ideal for coral relocation because of similarities in temperature, sunlight penetration etc. and it has suitable substrate and depth range of ~2 to 4 m, though deeper than footprint/reaping site.

Due to the number of corals identified identified it is recommended that the **Western Breakwater Extension** and **Eastern Section** be divided in to a grid system and corals of permitted size be relocated. The replanting area should also be gridded to ensure area outside of the impact zone and this will guided the replanting density of the reaped corals. Donor and Recipient site should be gridded (~10 x 10m) using colour coded rope and semi-permanent stakes/rebars.

As there are less corals in the Western Swim area, these can be tagged (using shot lines) and relocated to the above mentioned recipient area. See Table 1 with corals in the Western Swim Area to be tagged for relocation.

Table 1 Table of mapped corals within Western Swim Area.

Count	Way Points	Coordinates		No.	Coral			Photo ID
		North	West		Species	Growth form	Length (cm)	
1	158	18º 27'46.1"	077º 21'01.6"		*Porites sp*	Branch		
2	158	18º 27'46.1"	077º 21'01.6"		*Porites sp*	Branch		
3	P25	18º 27'46.3"	077º 21'01.5"		*Porites sp*	Branch		
4	166	18º 27'48.8"	077º 20'58.2"		*Diploria clivosa*	Boulder		
5	166	18º 27'48.8"	077º 20'58.2"		*Diploria clivosa*	Boulder		
6	162	18º 27'47.8"	077º 20'59.5"		*Cavernosa sp*	Boulder	20 cm	

Seagrass

There are some small patchy areas of seagrass inside the footprints of the proposed structures, ~ 60m^2 in the eastern section and ~ 115 m^2 in the western section. All of these smaller beds will have to be removed and relocated. The western end of the hotel has extensive seagrass beds next to the swim area there (in the vicinity of N 18º 27'40.42" W 077º 21'13.14", as shown below in Figure 3), which would be ideal as a sea-grass relocation site. It is located in approximately 2 to 3m water depth and is shown below in Photo 18.

Figure 3 Proposed seagrass relocation site in relation to proposed beach.

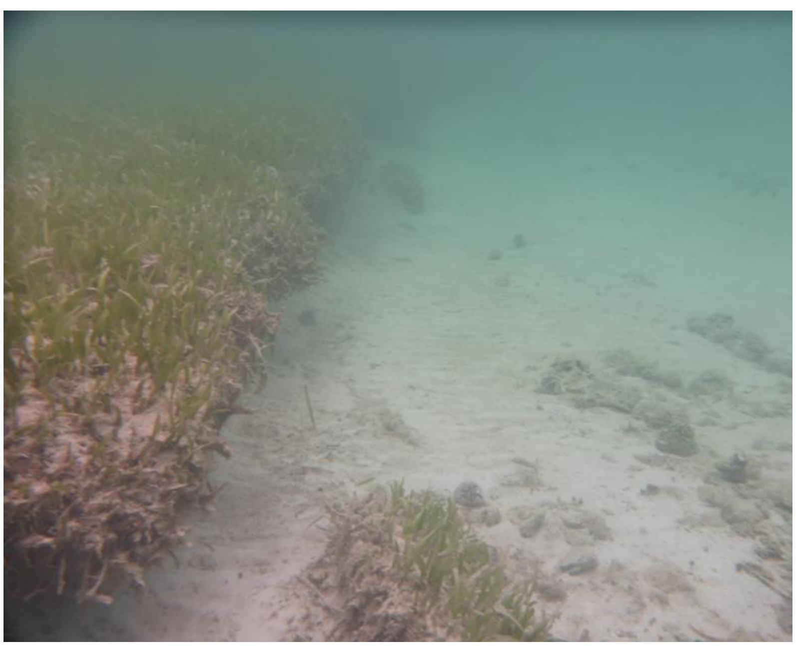


Photo 18 Proposed seagrass relocation area.

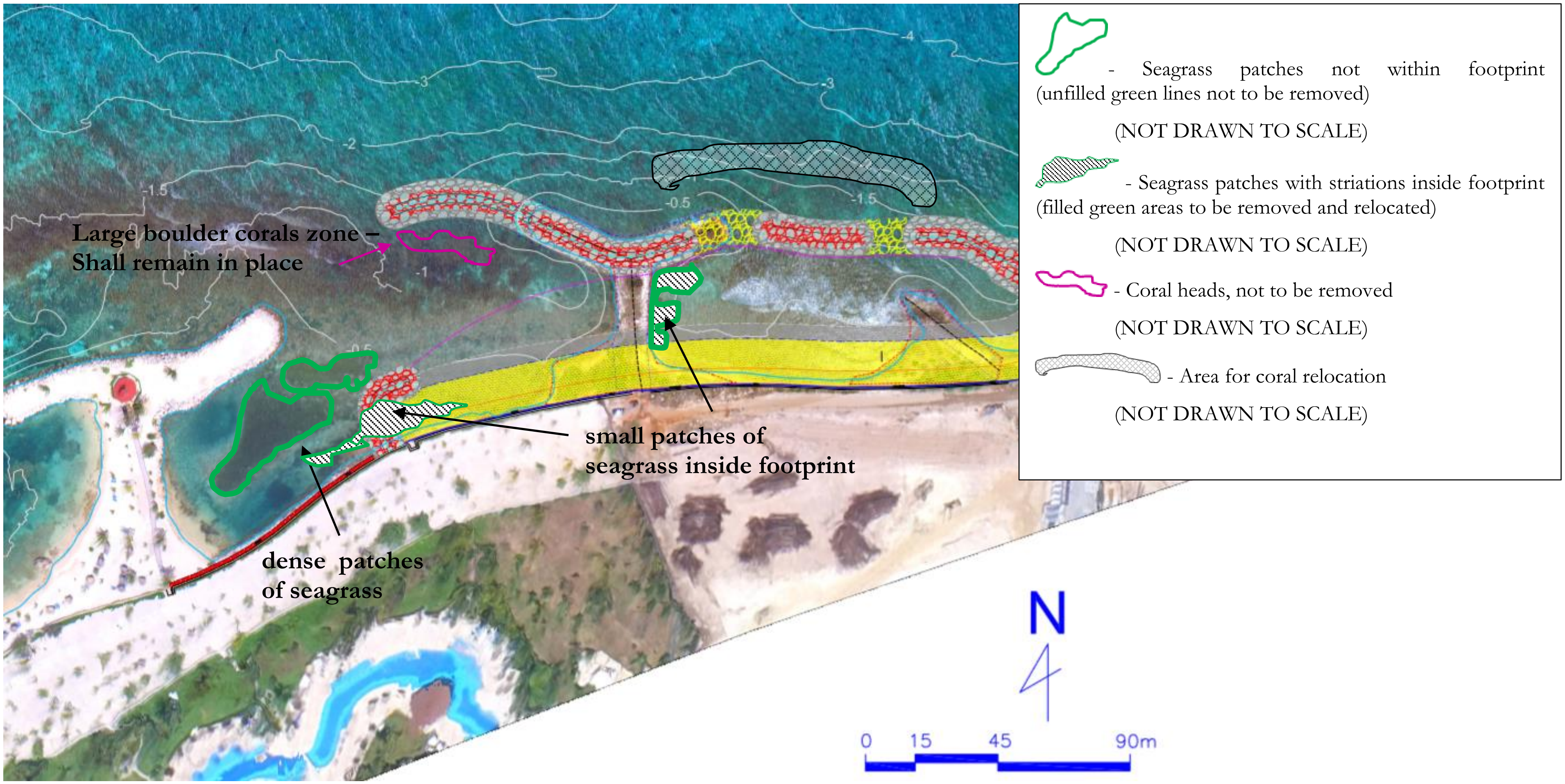


Figure 4 Image showing Benthos and proposed coral relocation areas

Transplanting Methodology

The relocation approach is discussed in detail in this section. The general plan is outlined following:

1. Relocate the corals larger than the permitted size within the footprint of the structures to the preferred relocation site just north of the proposed structure as shown in Figure 4.
2. Relocate the roughly 175 square meters of the seagrass beds located in the footprint of the proposed structures and swimming area to an area located roughly 50 metres offshore the existing beach on the western end of the hotel property.

Coral

The identified coral colonies will be removed from the substrate with hammer and chisels. During the removal process divers will try to avoid touching live surfaces of the corals to prevent damaging or killing the sensitive coral polyps. When possible, the corals will be removed in such a way that they remain attached to their carbonate bases, which in turn will prevent direct contact of the polyps with the adhesive (epoxy or cement) mixture. Once carefully removed, the coral will be placed in a large holding container/basket and guided by divers to the transplant site, remaining below the water surface throughout. Colonies in the baskets will be will be suitably spaced and arranged so no live coral tissue will touch any other surface and no structural elements of the corals will be under pressure. Should any coral colonies be fragmented during the collection phase they shall be cemented to a suitable substrate prior to placement in the recipient site.

At the recipient site the divers will use gloved hands to remove sand particles and loose algae, prior to fitting a semi-cured cement ball to the base of the area for reattachment. The area for reattachment will be determined to get a close fit between the coral base and the area the cement is to be placed. Due to the use of additives and high rpm mixing, there will be an approximately 20-30 minute period while the reef cement mixture starts to cure, therefore corals will have to be placed at the donor site simultaneously with the mixing of the cement on shore. The curing cement will be placed in transparent plastic bags and divers will carefully and slowly remove the balls of cement from the bags to minimize localized sediment dispersal. The reef cement will then be placed on the flush substrate. By gently pressing the coral onto the semi-cured cement, divers will ensure that cement is evenly distributed under the coral colony. Strapping and or pinning of corals in conjunction with cement or epoxy will be done if deemed necessary.

Seagrass

The modified Mat Method will be utilized to harvest those sea grass beds marked for relocation. This entails using shovels and pitch forks to cut and extract the sea grass in mats. Each mat is referred to as a Planting Unit (PU), and each PU is expected to be approximately 0.15m^2 in area. The sections will be removed with the rhizomes and sediment attached. These sections will remain submerged at the harvesting site until they are needed for replanting. Keeping the sections submerged at the harvesting site ensures that the leaves are covered with water thereby preventing desiccation as well as maintaining the same osmotic potential and temperature. The quantities reaped per day will be limited to that which can be replanted within the same day.

The seagrass PUs will then be placed on rafts until transferred to a boat which then take PUs to the recipient planting site. At the recipient site the seagrass will be carefully removed so as to not disturb the sensitive root systems and sediment will be removed from the leaves of the plants. The unit will then be hand bundled with a twist tie to a stake or staple. The PU will then be placed on seafloor and pinned (or stapled) into the substrate at the recipient site allowing for a minimum spacing of 5cm between adjacent units. The planting units will further be anchored in the seabed substrate using the Staple Method. The planting units will be stabilized by "stapling" them into the seabed with the use of U-shaped rebars.

Turbidity Control

The sites for relocation and replanting will be demarcated with a turbidity curtains (screens) encircling the areas of activity to minimize leakage of turbid waters to adjacent areas. The barrier will serve as both demarcations for the areas of replanting as well as containment of any suspended silt in the water column

Schedule

Subsequent to receipt of the required from your Agency, the proposed schedule is as follows:

- Day 1 – One day training workshop inclusive of field and lecture sessions for all persons involved in this activity
- Day 2 to 3 – Preparation of recipient site for coral transplant. Coral removal and transplant.
- Days 4 to 9 – Continued coral removal and transplant.
- Days 9 to 12 – Seagrass removal and relocation.

It should be noted that this schedule is highly weather dependent and so is subsequent to change.

Supervising Personnel

The replanting will be carried out under the supervision of Smith Warner International (SWI) Limited. The management team has carried out similar relocation activity successfully at Hyatt Ziva, Palmyra and Trident, and have overseen relocation activities at several other sits including Half Moon, Iberostar and Secrets.

In addition to the SWI personnel on site, Michelle McNaught, a marine biologist, with experience in Marine Ecosystems Mitigation (restoration, relocation and artificial systems) Fisheries Management, Marine Protected Areas and Environmental Monitoring will provide oversight of all the relocation activities. As part of her duties she will be responsible for quality control in handling the sensitive species being relocated. She will also be responsible for logging and recording relocation activities

Mr. Huon (Dave) Guiness, an experienced SCUBA diver who has worked on other coral relocation projects such as those associated with the construction of the Falmouth pier and the Rackham's Cay coral relocation (which pioneered this coral relocation as a mitigation measure), will be the lead individual in relocating the corals. The team will likely consist of additional divers (possibly up to five divers) who will take instruction from Ms. McNaught and Mr. Guiness

Any changes to these project personnel will be informed to the Agency in writing.

Monitoring Report

Given the relative short duration of the transplanting program (12 days if weather permits), a single monitoring report will be submitted to NEPA within 7 working days of completion of the transplanting period. This will include the following:

- Summary log of the daily transplanting operations. This is to include the location and total area of each seagrass planting unit harvested and stored/planted as well as the location and total number of each coral species harvested and anchored.
- Dated photographic evidence of all works
- Sea and weather conditions during transplantation
- Any anthropogenic impacts during the transplantation

A sample format for the daily log is attached.

Following completion of relocation, monthly monitoring will be carried out during the construction period.

Unit 13 - Seymour Park, 2 Seymour Avenue.
Kingston 10, Jamaica

Monitoring Form for Marine Construction

Project : GRAN BAHIA PRINCIPE, RUNAWAY BAY
NEPA Licence Numbers :
Date :
Name of Monitor :

Time of Collection	Construction Activity	Turbidity (NTUs)	Location	Notes
				Before start of construction
				Mid-morning sample
				Mid-afternoon sample

Sediment Plume? - Note direction of any plume and approximate size

Weather Conditions - Approximate wave height & direction, wind direction, other weather features:

Notes - Any incidents? Spills, damage, etc.

Signature : ______________________________