Preliminary Coastal Processes Assessment: Nananu-I-Cake Resort Development

Prepared for:

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Executive Summary

- This report provides a preliminary assessment of coastal processes and metocean conditions at Nananu-I-Cake Island based on available information (i.e., a desktop review).
- Nananu-I-Cake Island is located on the northern side of Viti Levu, about ~1 km from the mainland in the Rakiraki Province.
- The nearshore bathymetry is characterised by a fringing reef (~0.2 – 0.6 m), which surrounds the entire island. Beyond the fringing reef, the depths increase to ~10-17 m on the western and southern sides of the island and ~20-30 m on the northern and western sides of the island. The island is mostly protected from larger wave events from all sides due to protection by offshore reefs and islands, as well as Viti Levu.
- The predicted tidal range is ~2.05 m with an LAT of -1.04 and an HAT of 1.01 m, and it is likely that there are strong tidal currents through the passes (out-going to the north, incoming to the south), especially during spring and King tide events.
- Wind climate data from near Nananu-I-Cake demonstrates that the predominate winds are from the ESE (trade winds) with wind speeds generally lower in the summer/wet-season with a component of northerly winds during this season also.
- The wave climate data from near Nananu-I-Cake indicates that waves are predominantly from the north-west through to the north-east (which is open to the north Pacific Ocean), with a secondary ESE trade wind-generated wave component. Significant wave height (Hs) and peak period (Tp) range are typically less 2.0 m and between 8-16 s, respectively.
- Seasonally, Hs are greater during summer months (max ~8.5 m) compared to winter months (max ~5.9 m) with longer wave periods for summer (6-16 seconds) compared to winter (7-12 second). The largest swells come from the northern quarter during the summer, with the largest swells derived from the south-east in the winter.
- These seasonal wave patterns represent both the local seasonal changes – that is, winter dominated by the ESE tradewinds and short period waves, and the s tropical cyclone (TC) and tropical depression (TD) events – and Pacific Ocean seasonal changes – that is, the quiescent northern hemisphere wave climate during its summer (Fiji's winter), and the northern hemisphere winter producing consistent long period ground swell in Fiji's summer.
- Heavy rainfall and flooding in Fiji is a regular occurrence during the summer wet season (November to April) and occasionally in the dry season during La Niña years.

The larger floods that have occurred are associated with episodes of severe weather phenomena, such as TCs and TDs.

- Storm surge when combined with extreme events will likely cause wave overtopping and inundation in low-lying areas. Sea Level Rise (SLR) will exacerbate these effects.
- 62 tropical cyclones (TCs) have passed within 300 km of Nananu-I-Cake Island, and 10 TCs have passed within 50 km of the Island since 1969.
- Preliminary estimates of extreme water levels during extreme metocean events and with 100-years of sea level rise (SLR) indicate an extreme water level of 3.95 m above mean sea level (MSL). However, this is likely to be reduced with field data collection, numerical modelling and Monte Carlo simulation better representing the coastal processes around the island.
- Recommendations with respect to investigations for the design and construction of proposed marina, jetties, artificial islands and beaches and over-water bures with respect to coastal processes and hazards are also included.

Contents

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1 Site Description

The Island of Nananu-I-Cake is located on the northern side of Viti Levu, Fiji, less than 1 km from mainland near the Rakiraki district in the Province of Ra (Figure 1.1). The island is ~600 acres, which includes the small island Nambua Island. Most of the Island still maintains the natural tropical vegetation (although possibly regenerated), including some mango trees lining some of the trails, pine forest for potential harvest, and extensive landscaped gardens, which have been developed over a generation. A deep-water jetty provides access to the island on the western shore. To the north and east of the island is a series of fringing coral reefs (Figure 1.2). The island retains evidence of Moka, stone formations built in tidal areas to trap fish at low tide, and ring-wall fortifications built with volcanic rocks. It is proposed to develop the Island into a resort, which will be known as Cryptoland (Figure 1.3).

Figure 1.1 Nananu-I-Cake Island on the northern side of Viti Levu, Fiji (Images sourced from Google Earth, 2021).

Figure 1.2. The northern and eastern sides of Nananu-I-Cake are characterised by a series of fringing reefs; Cakau Levu is the large reef structure to the southeast of the island.

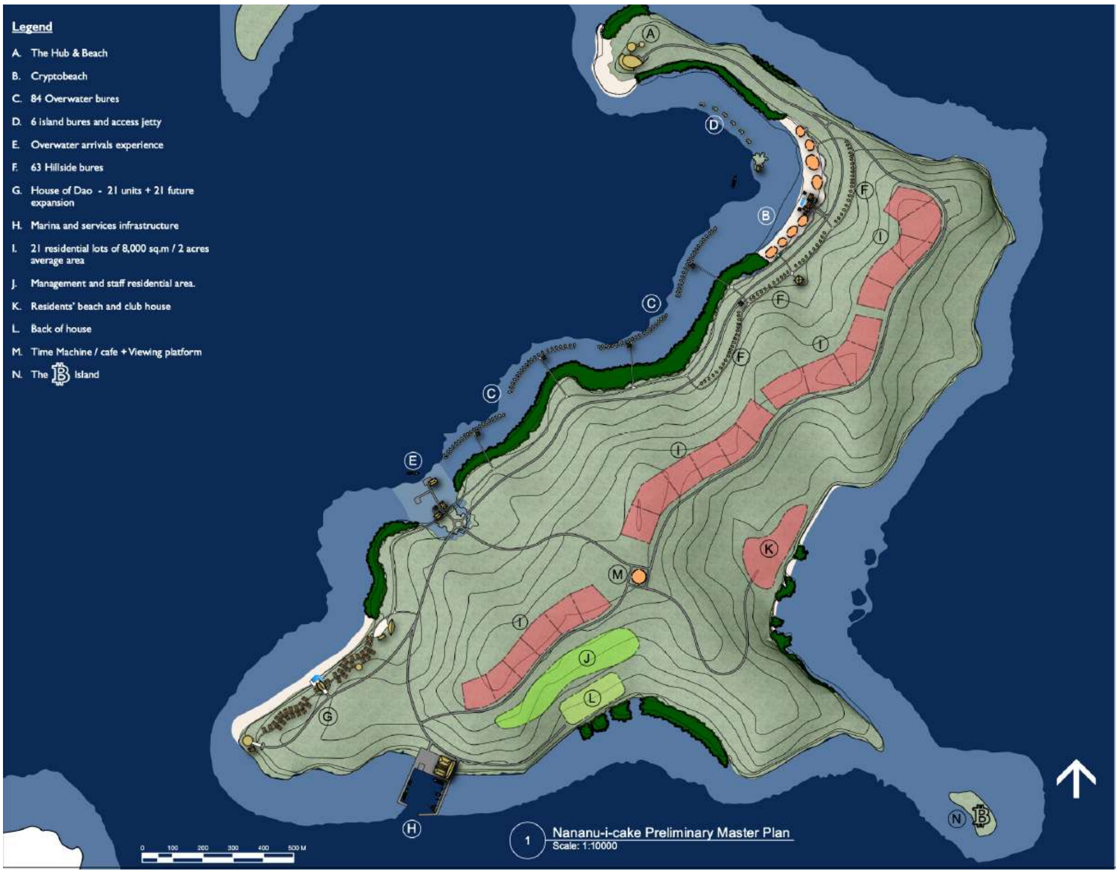

Figure 1.3 Proposed resort development on Nananu-I-Cake Island, Fiji (Plans provided by Pacific Architects).

This report provides a preliminary assessment of coastal processes and hazards associated with the site for input into the Master Plan and Screening Application for the Environmental Impact Assessment. Coastal developments and considerations for the proposed Cryptoland development include (see Figure 1.3):

- Creation of a beach and a small island on the fringing reef on the northwestern side of the island;
- Coastal structures;
- Overwater structures (jetties and bures);
- Marina development on the southern side of the island and Reception area on the northern side of the island, and;
- Water intake and disposal.

Preliminary considerations for these aspects are also included.

2 Nearshore Bathymetry and Coastline

The nearshore bathymetry of Nananu-I-Cake Island is characterised by a shallow (~0.2 – 0.6 m) coralline fringing reef around the entire island. Beyond the fringing reef, the depths increase to ~10-17 m on the western and southern sides of the island and ~20-30 m on the northern and western sides of the island (Figure 2.1), before dropping into depths of >800 m beyond the fringing reefs in the Bligh Water between Viti Levu and Vanua Levu (Figure 1.1). As noted above, to the north and east of the island is a series of fringing coral reefs (Figure 1.2). There are small mangrove stands are situated on the southern and western sides of the island with a larger connected stand fringing the northern 2/3rd of the western side. The presence of the large stand of fringing mangroves is due the western side of the island being protected from the dominant ESE tradewinds (especially in the dry season) as well as offshore reefs and islands to the north and Viti Levu to the west, making it a low energy environments (and so a good anchorage). Due to the sheltered nature of the island, sediment transport rates are relatively low, and very low on the western lagoon-side.

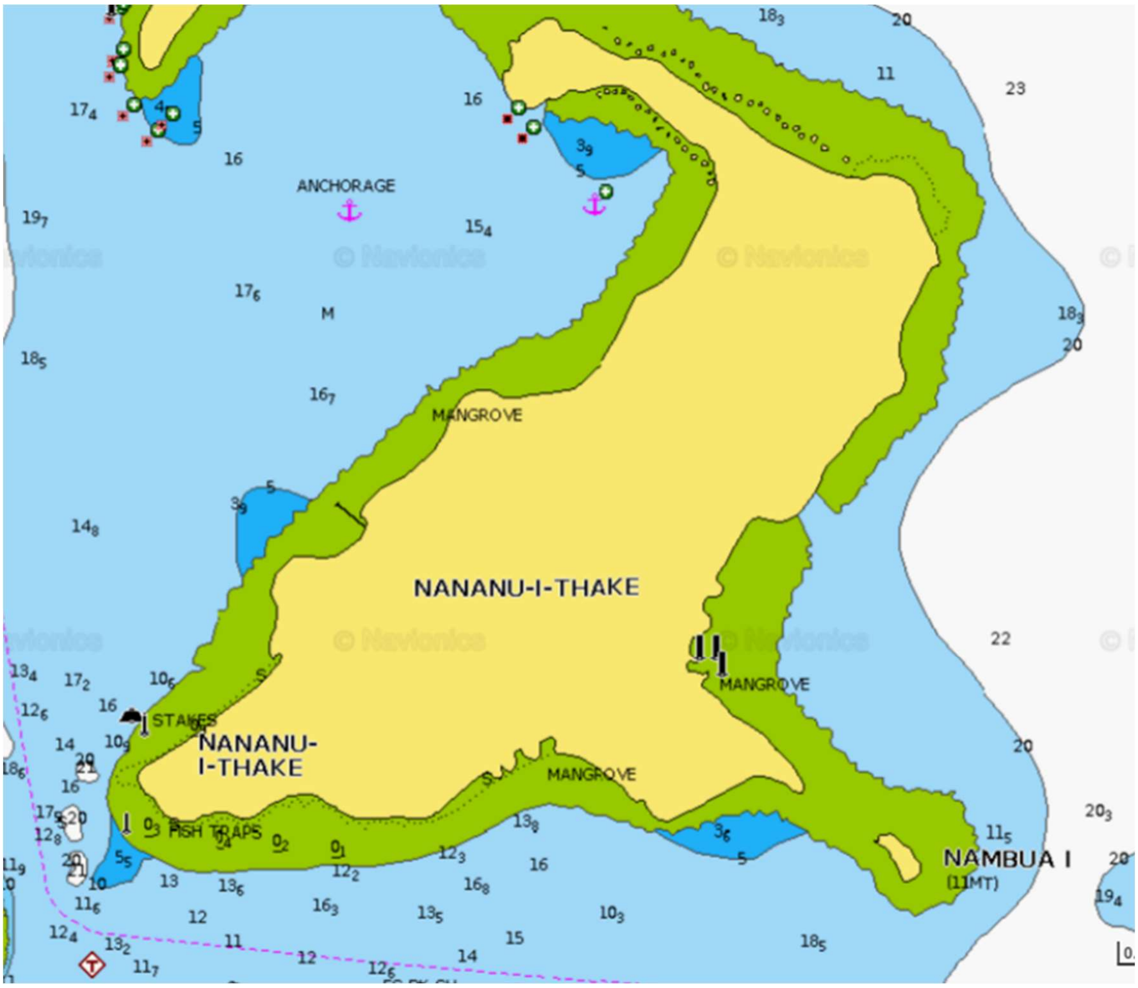

Figure 2.1 Nearshore bathymetry of Nananu-I-Cake (Image sourced from Navionics, 2021). These bathymetry data are mostly derived from British Admiralty charts and are relatively coarse.

3 Tide

Tidal boundary conditions on the open ocean boundaries of the model were extracted from the TPXO wave atlas (Egbert and Erofeeva, 2002). This model was developed by the Oregon State University which created global model of ocean tides which uses along track averaged altimeter data from the TOPEX/Poseidon and Jason satellites since 2002. The methodology applied in the global tide models has been refined to create regional models at higher resolution. For this project, we used the Pacific Ocean model with a resolution of 1/12 degree. The model provided the 11 most influential constituents, as well as two long period (Mf, Mm) harmonic constituents. Each constituent is a sinusoid, which represents the gravitational influence of a particular aspect of a planetary body or of several bodies. Each sinusoid was described at each node in the model by a phase and amplitude of the sinusoid and these were extracted at regular intervals along the model boundary.

Using the Matalb function tmd_tide_pred, 30 years of tidal data was extracted from the coordinates -17.3196 (lat), 178.235 (lon); just north of Nananu-I-Cake Island (Figure 1.2). The maximum tidal range over this period at Nananu-I-Cake Island is predicted to be ~2.05 m with a LAT of -1.04 m and a HAT of 1.01 m. This tidal range is similar to that at Lautoka. It is likely that there are strong tidal currents through the passes (out-going to the north, incoming to the south), especially during spring and King tide events.

The tidal range and currents will be further refined with the deployment of wave/current/water level meters at Nananu-I-Cake Island during field data collection for the EIA, where 28 days of measured data can be used for harmonic analysis to determine accurate tides for the site, as well as to calibrate a hydrodynamic numerical model. The tidal range has implications to recommended finished ground levels for areas of coastal development, floor levels of coastal structures, over-water structures, marina revetment heights, etc., etc.

4 Wind Climate

A long-term offshore record of wave statistics was taken from a 0.5-degree by 0.5-degree global model of wave characteristics maintained by NOAA (National Oceanic and Atmospheric Administration). A 40-year record running from 1979 until 2019 was extracted from the model from a point corresponding to -17° latitude and 178° longitude (Figure 4.1).

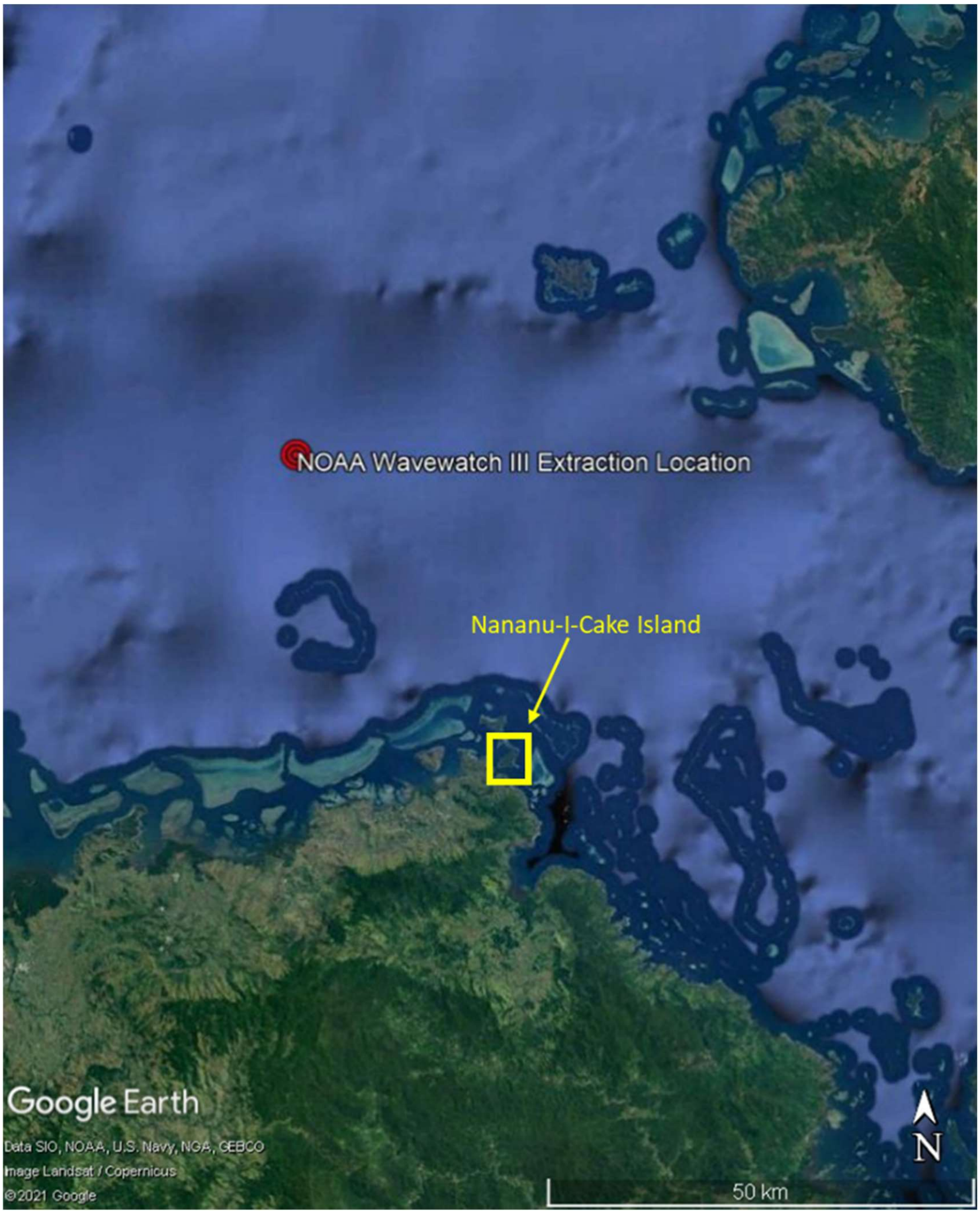

Figure 4.1 Extraction location of the NOAA wind and wave climate data (Image sourced from Google Earth, 2021).

Trade winds are the predominant broad scale winds affecting Fiji and occur in all seasons with varying duration and intensity. The trade winds blow from the south-east towards the north-west, and as a result there is a strong windward – leeward component to the microclimate of Viti Levu and Vanua Levu, the two largest and most populated islands of Fiji.

The wind climate for the area is summarised in Figure 4.2 to Figure 4.4, and illustrates the prevailing south-east trade winds with speeds typically less than 11 m/s. The seasonal wind climate is summarised in Figure 4.3, which also shows the dominant south-east trade winds, which are stronger during the months of winter (<11 s) compared to summer (<9 s), and a higher occurrence of northerly quarter winds in the summer/wet season.

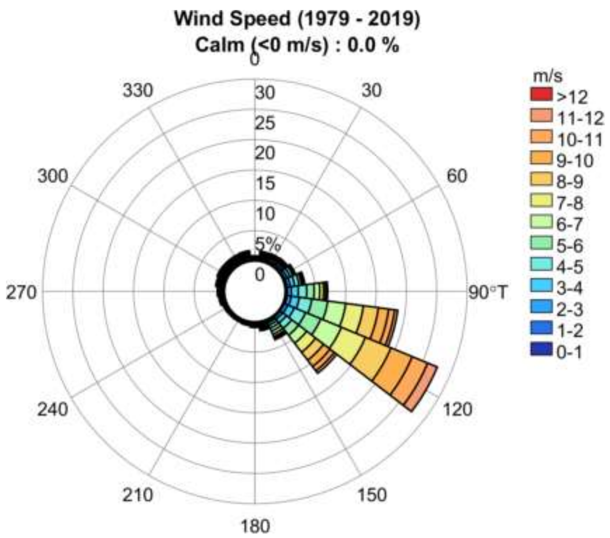

Figure 4.2 Wind rose of long term (1979-2019) climate at NOAA extraction location.

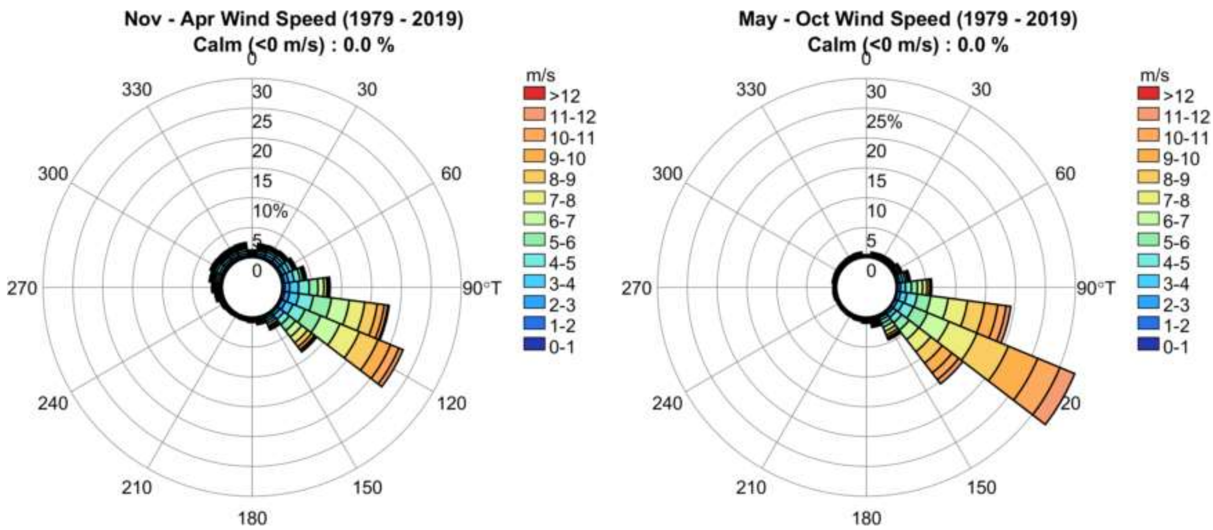

Figure 4.3 Seasonal wind rose of long term (1979-2019) climate at NOAA extraction location.

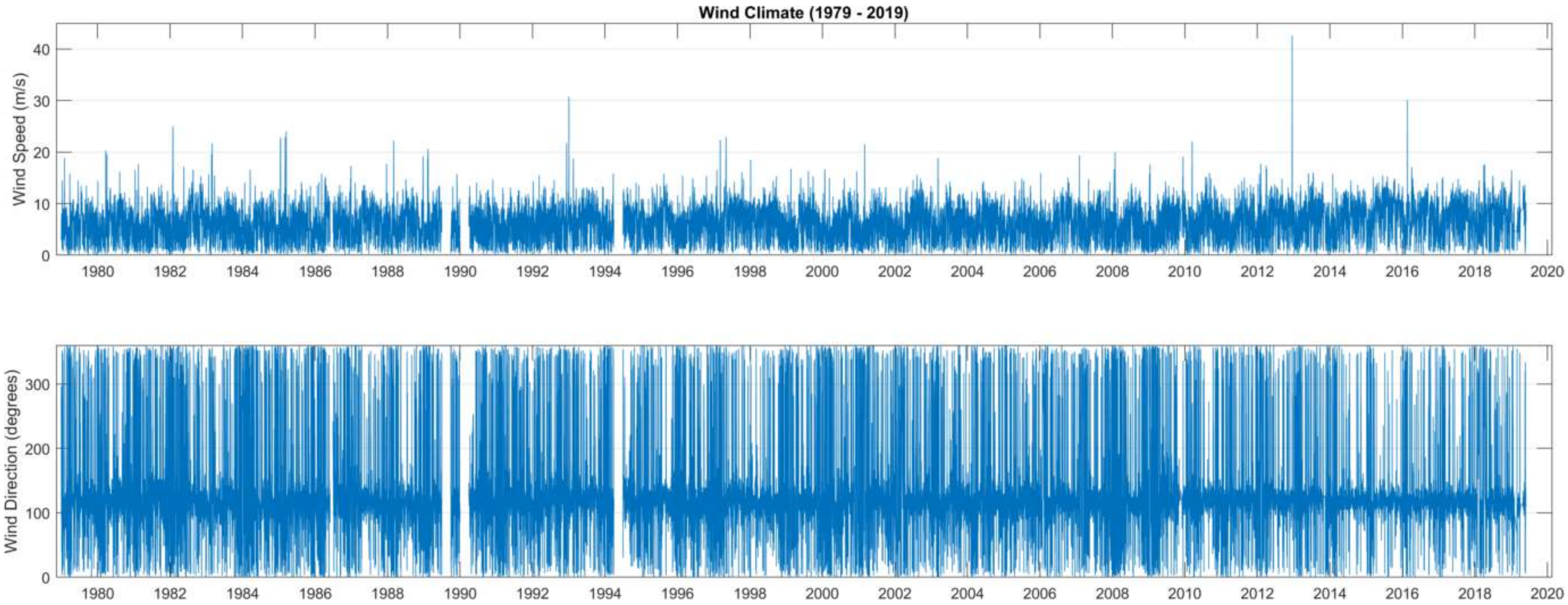

Figure 4.4 40-year wind climate from 1979 to 2019 at the extraction location sourced from NOAA Wavewatch III.

5 Wave Climate

The wave climate at the extraction location (Figure 4.1) is summarised in the wave roses shown in Figure 5.1, which show that the majority of swell waves (i.e., long period) come from the north with short-period waves arriving from the south-east, the latter of which is dominated by peak periods of 8 seconds or less (i.e. trade wind-generated waves). Furthermore, most values for significant wave heights (Hs) are less than 2.0 m with peak periods (Tp) typically between 8 and 16 seconds.

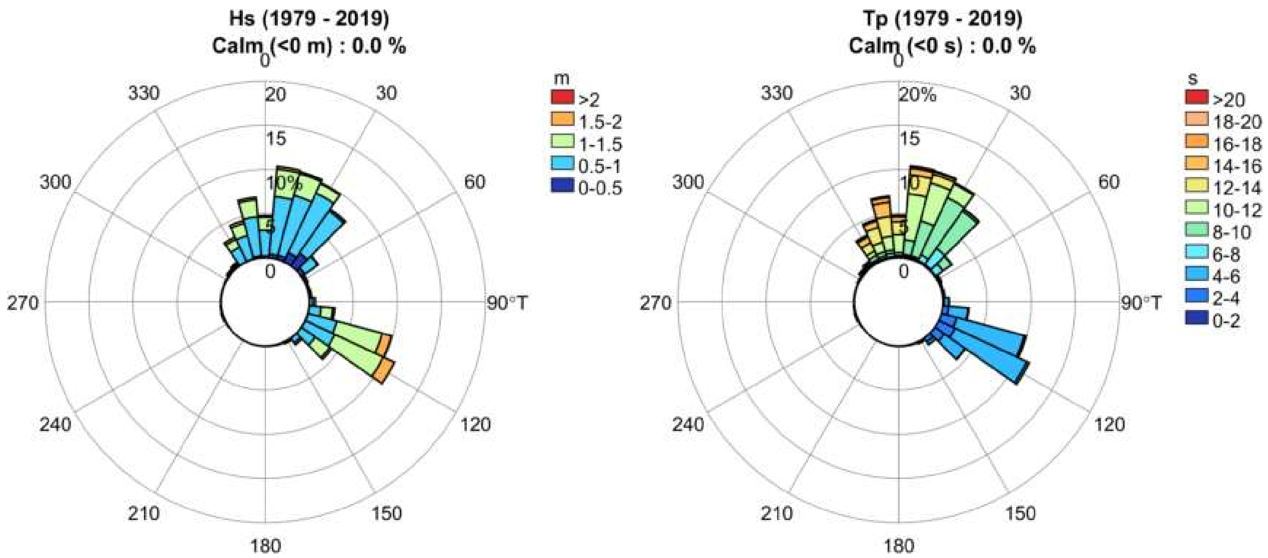

Figure 5.1 Wave roses of long-term (1979-2019) Hs (significant wave height) and Tp (peak period) extracted from NOAA Wavewatch III

Plotting Hs (significant wave height) against Tp (peak period) (Figure 5.2) shows that for low values of Hs there is a large range of values for Tp. However, for extreme events (>6 m), Tp is limited to being between 8 and 14 s. Plotting Hs against peak wave direction (Dp) (Figure 5.3) shows that the largest records mostly come from between the north-west to north-east (between 300 and 50 degrees), with a secondary peak from the south-east (between 70 and 170 degrees). These northerly quarter events are associated with tropical cyclones and depressions.

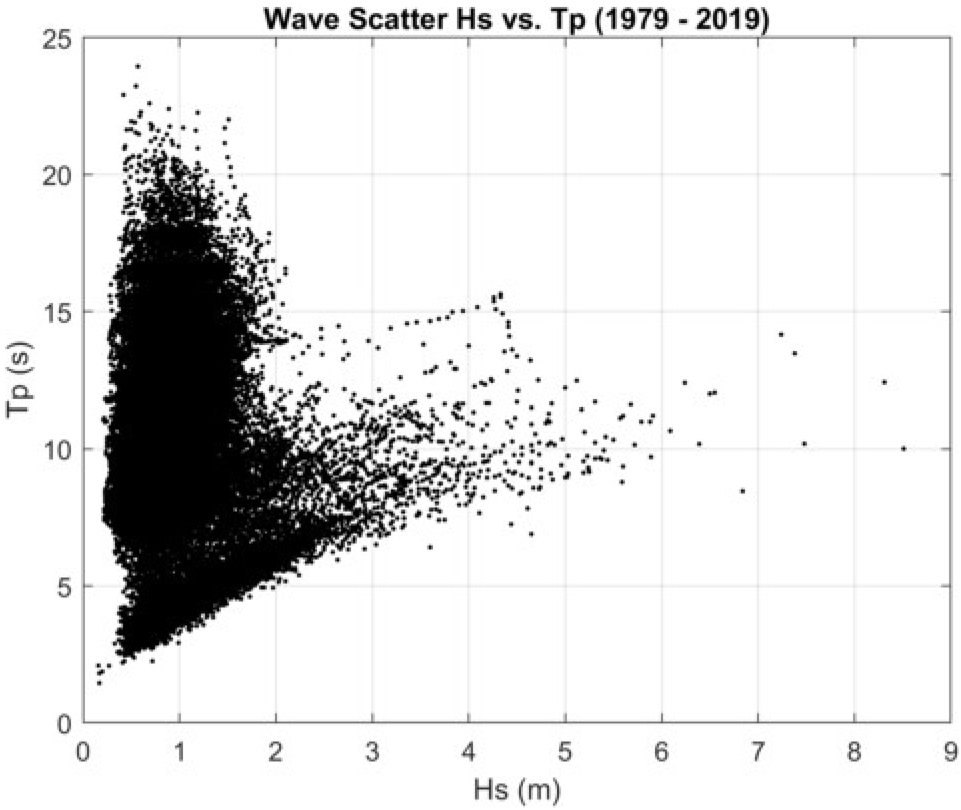

Figure 5.2 Hs versus Tp of the long-term offshore wave record.

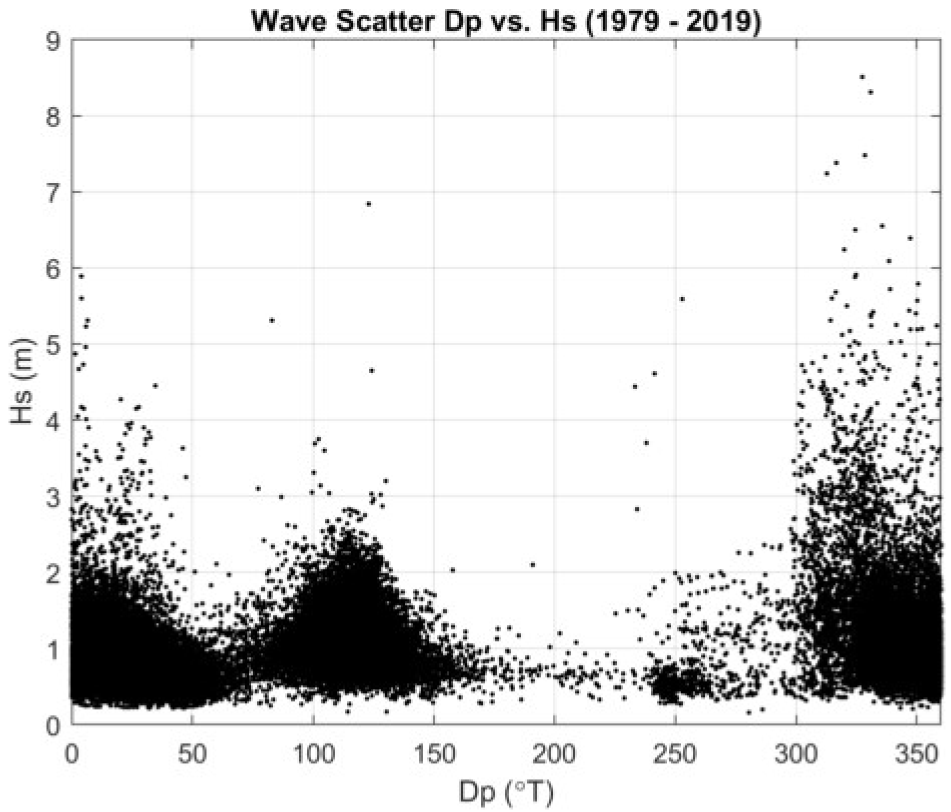

Figure 5.3 Hs versus Dp of the long-term offshore wave record.

5.1 Seasonal Breakdown

During the summer months, the swell waves are predominantly from the northern quarter with a small component derived from the south-eastern trade winds (Figure 5.4); the periods are long (mostly 12-20 seconds) and wave heights mostly 1-3 m. In contrast, during the winter months, the waves are predominantly from the south-east trade winds with smaller swell wave component from the north-east (Figure 5.5); the periods from the southeast are mostly small due to being locally-generated wind waves.

When plotting Hs against Tp, during the summer months the maximum Hs is greater (~8.5 m) compared winter months (5.9 m) with the Tp range also greater for larger waves (>3 m) with Tp ranges of 7-16 s and 7-12 s for summer and winter months, respectively (Figure 5.6 and Figure 5.7). When plotting Hs against Dp, during the summer and winter months, the largest records come from between the north-west to north-east (Figure 5.8 and Figure 5.9). During the winter months, however, a larger component of the record is derived from the south-east (trade winds) (Figure 5.9).

These patterns represent both the local seasonal changes – that is, winter dominated by the southeast tradewinds and short period waves, and the summer TC and TD events – and Pacific Ocean seasonal changes – that is, the quiescent northern hemisphere wave climate during its summer (Fiji's winter), and the northern hemisphere winter producing consistent long period ground swell in Fiji's summer.

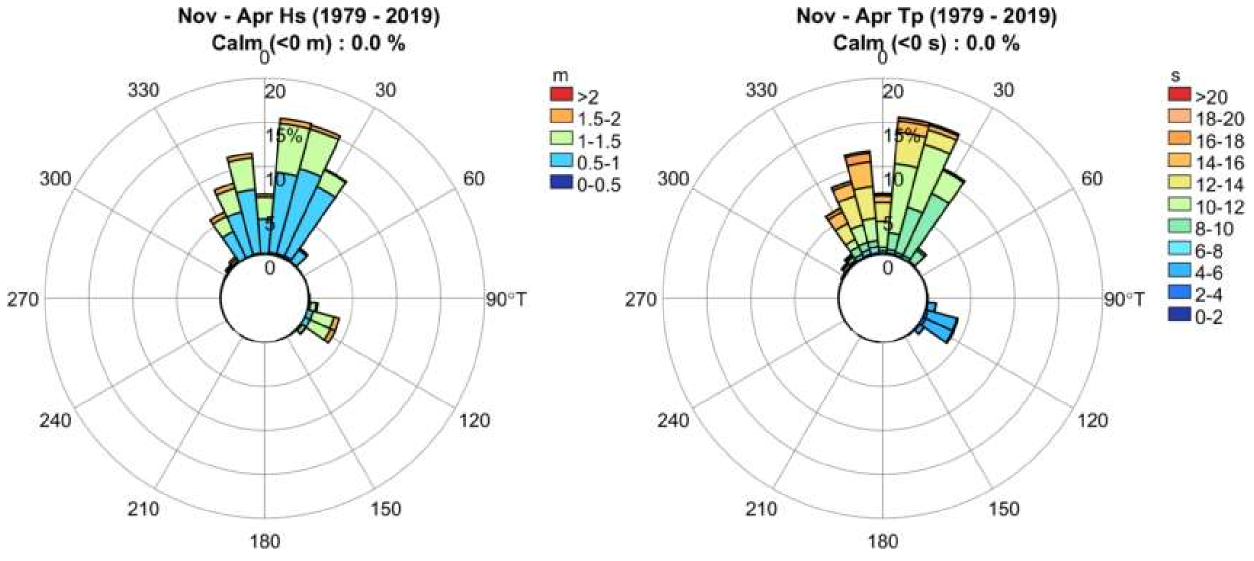

Figure 5.4 Summer wave roses of long-term (1979-2019) Hs and Tp extracted from NOAA Wavewatch III

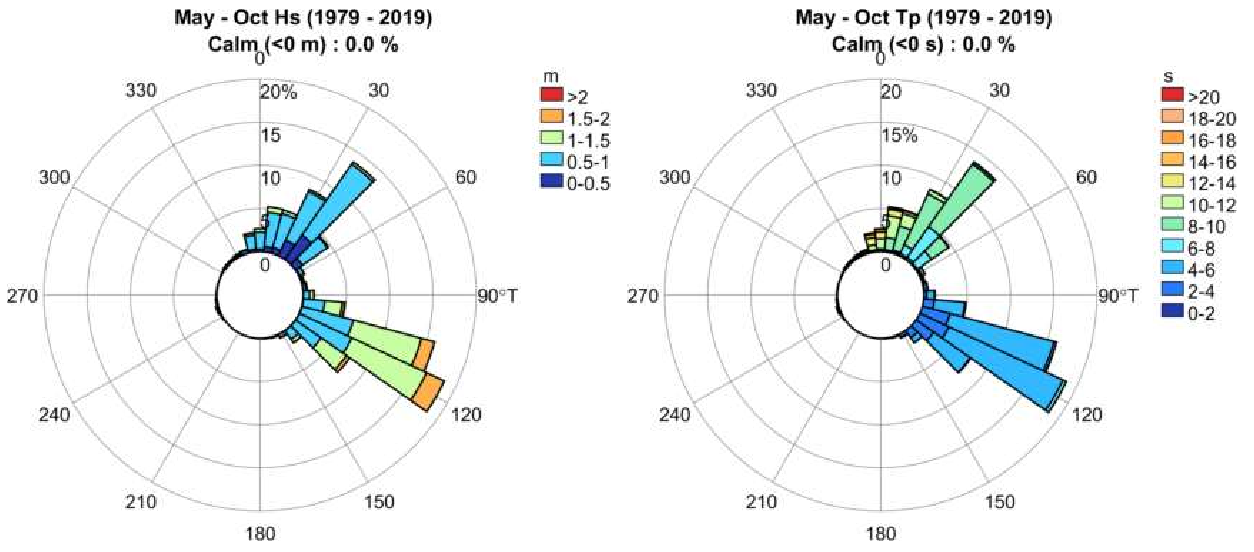

Figure 5.5 Winter wave roses of long-term (1979-2019) Hs and Tp extracted from NOAA Wavewatch III

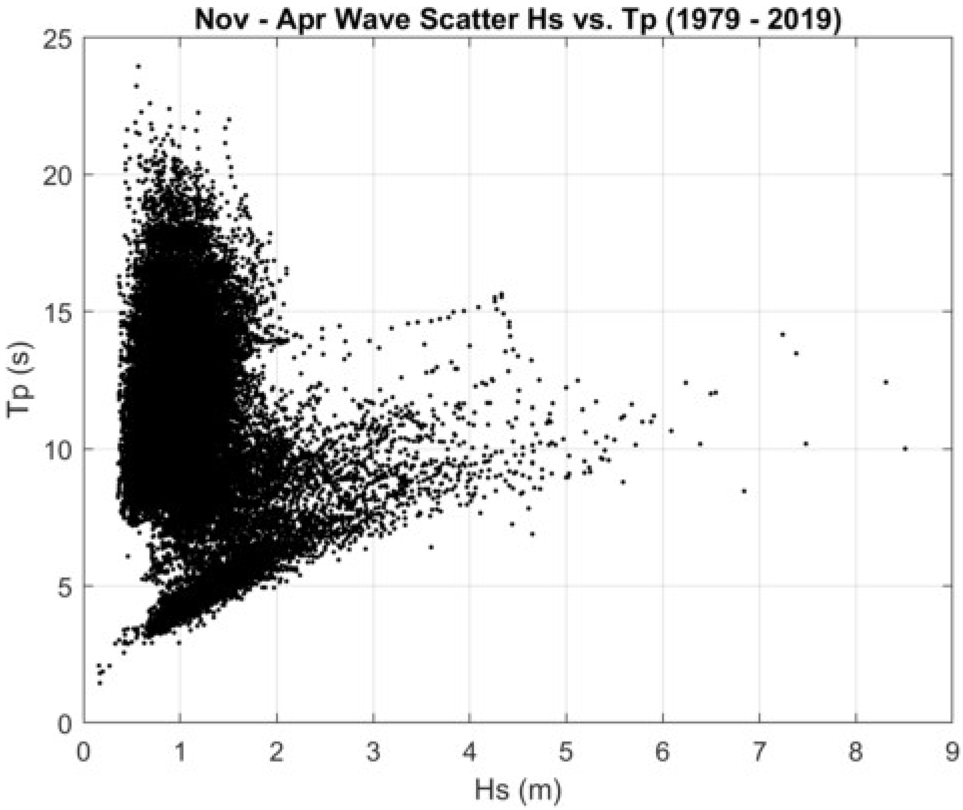

Figure 5.6 Summer Hs versus Tp of the long-term offshore wave record.

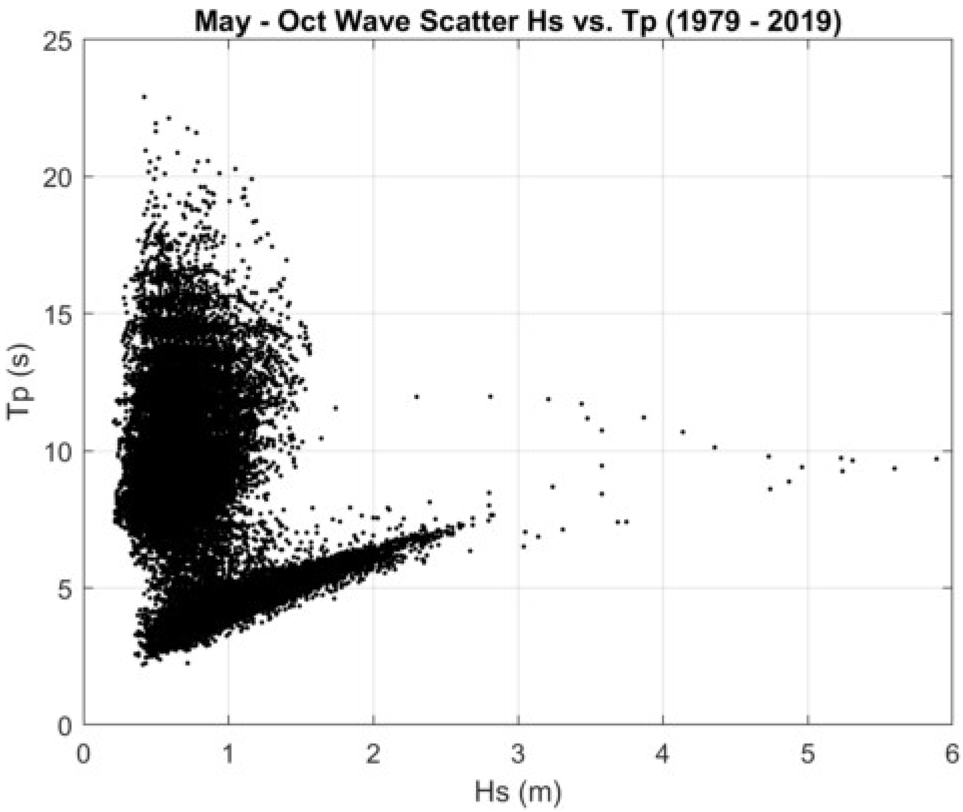

Figure 5.7 Winter Hs versus Tp of the long-term offshore wave record.

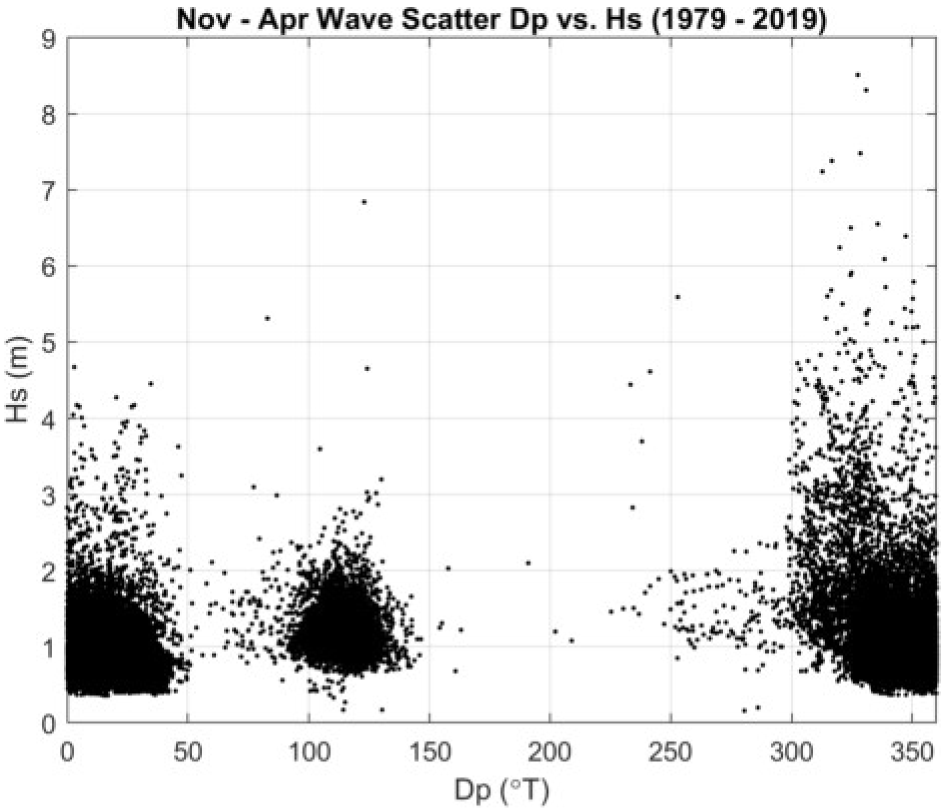

Figure 5.8 Summer Hs versus Dp of the long-term offshore wave record.

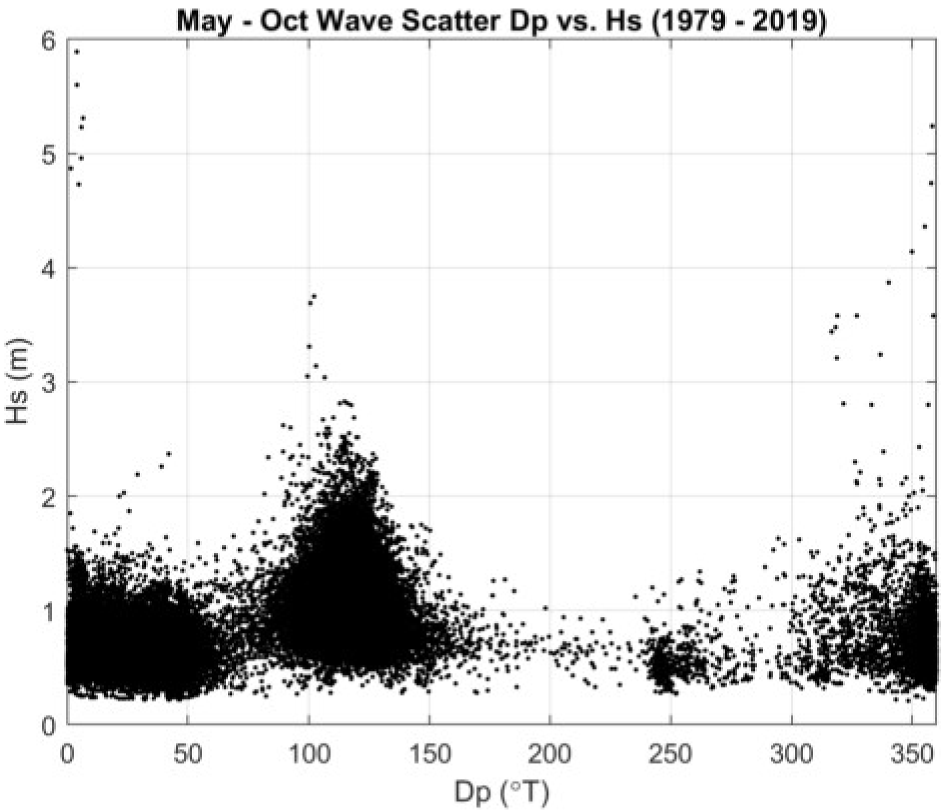

Figure 5.9 Winer Hs versus Dp of the long-term offshore wave record.

5.2 Extreme Wave Analysis

A non-directional extreme value analysis (i.e. all directions, 0° - 359°) was carried out using the WAFO (2011) toolbox developed by the faculty of Engineering, Mathematical Statistics, Lund University, Sweden, which is a commonly used statistical toolbox for carrying out univariate extreme value analysis. The routines in WAFO were used for fitting a statistical distribution to the occurrence of wave heights. The analysis was carried out using a Peaks over Threshold (PoT) method and fitting the resultant data to a generalised Pareto distribution using a threshold of 3.0 m to define what constitutes an extreme event. The fitted distributions were then used to estimate the magnitude of a 1, 5, 10, 30, 50 and 100-year return period event (Table 1). The extreme wave analysis revealed that for a 100-year return period, wave hights of up 9.86 m could be expected at the NOAA extraction location (Figure 4.1).

Table 1. Extreme wave analysis for the NOAA extraction location.

Return Period (yrs)	Hs (m)
1	3.09
5	5.47
10	6.5
30	8.1
50	8.85
100	9.86

6 Flooding

Heavy rainfall and flooding in Fiji is a regular occurrence during the wet season (November to April) and occasionally in the dry season during La Niña years. Most of the flooding occurs during the months of January, February, and March at the peak of the wet season with few having occurred during the drier months. The larger floods that have occurred are associated with episodes of severe weather phenomena such as tropical cyclones and tropical depressions, which create high intensity rainfall (McGree *et al.,* 2010). The rivers and streams in Fiji tend to be relatively small and stem from the mountains. When intense rainfall combines with the small and steep watercourses this leads to rapidly rising water levels. Flash floods can occur in just a few hours post rainfall initiating. While benefits from flooding exists, such as increasing the floodplain fertility, implications associated with flooding far outweigh the benefits. Flooding in Fiji has caused a great deal of damage to agriculture, infrastructure, buildings, and livelihoods (McGree *et al.,* 2010).

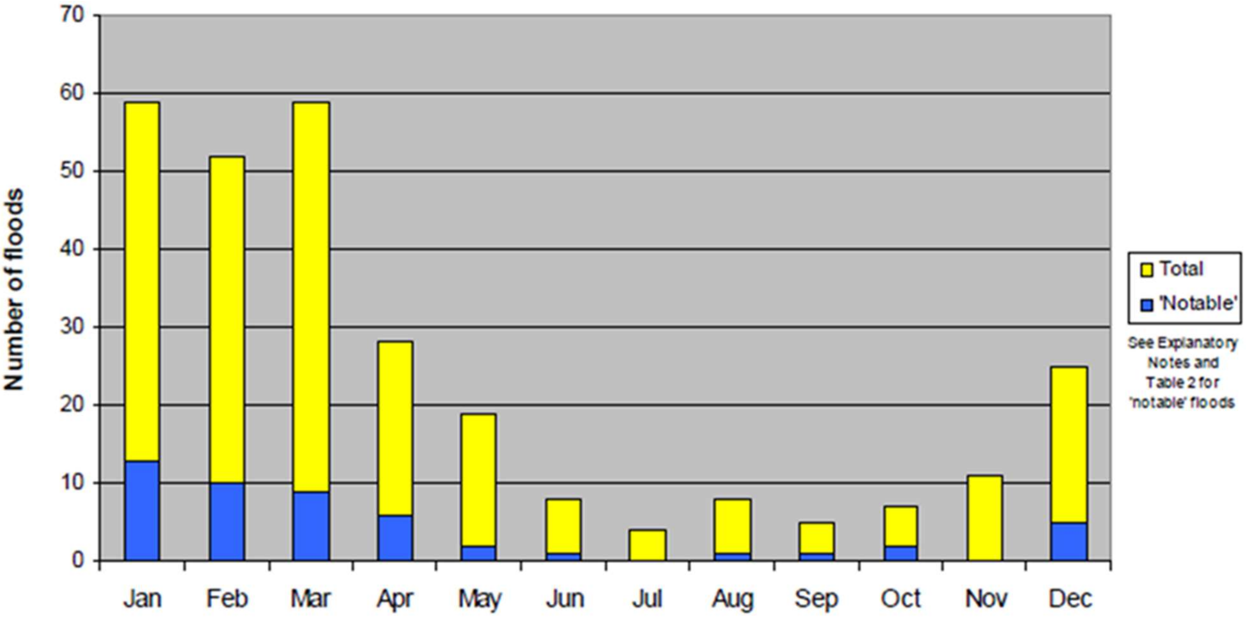

Figure 2.1. Shows the monthly distribution of floods in Fiji from 1840 to 2009 (McGree *et al.,* 2010).

McGree *et al.* (2010) report that the major floods in Fiji have results from several different meteorological phenomena and or combinations of meteorological phenomena, which include but not limited to; tropical disturbances (tropical cyclones and depressions); a south-west displaced South Pacific Convergence Zone (SPCZ); embedded tropical depressions in a trough or the SPCZ; merging synoptic systems over FIJI e.g. SPCZ and cold front, of trough and cold front; and synoptic systems retrogressing over the country (McGree *et al..,* 2010).

High magnitude short duration floods are typically the result of tropical disturbances quickly passing over, or very close to, the country (in the absence of moving nearby synoptic systems). These high magnitude floods are devastating and prolonged and are associated with prolonged soil saturations caused by looping or slow-moving tropical disturbances near Fiji, successive tropical disturbances passing close over Fiji for a short period of time, or tropical depressions passing over Fiji after prolonged south-westward SPCZ displacement. In delta regions, when high tides, especially spring high tides, coincide with passages of tropical disturbance, flooding is exacerbated. Complication is added during La Niña when sea levels are higher than normal (Chand & Walsh, 2009, cited in McGree *et al.,* 2010).

7 Coastal Hazards

7.1 Climate Change (CC) Projections and Sea Level Rise (SLR)

As shown in Figure 7.1, the total water level at any time is a combination of several factors. The primary component is of course the astronomical tide level. To this can be added any 'storm surge' which may affect the site, as well as wave setup and wave runup. The storm surge component in this context is assumed to contain both the effect of wind (wind setup), as well as the inverse barometer effect (pressure setup). When combined during extreme events, wave over-topping and inundation can occur, which will be exacerbated by SLR.

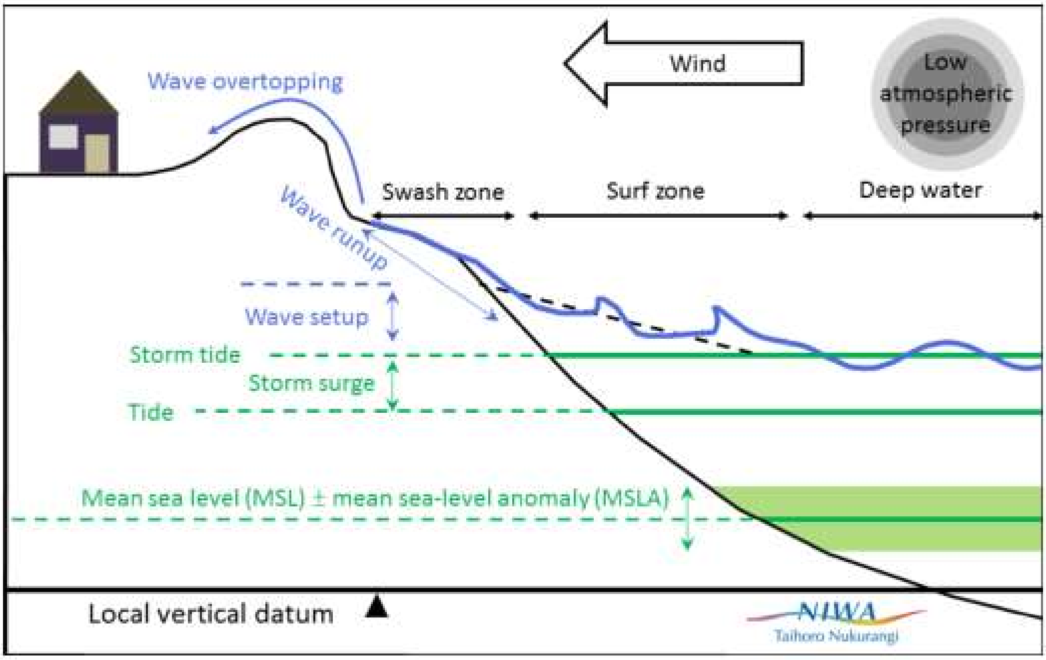

Figure 7.1. Components of the total water level.

Figure 7.2 illustrates four scenarios of New Zealand-wide regional sea level rise to the year 2150 from the IPCC AR5 cited in MfE (2017). The most extreme scenario (NZ RCP8.5 H+) indicates that in 100 years the sea level will rise by 1.34 m with the medium projections indicating SLR values in 100 years of 0.55 m, 0.67 m, 1.06 m for RCP2.6 m, RCP4.5 m, and RCP8.5 m, respectively. The projections include a New Zealand-wide regional offset, with a small additional SLR above the global mean projections. Note: RCP refers to representative concentration pathways.

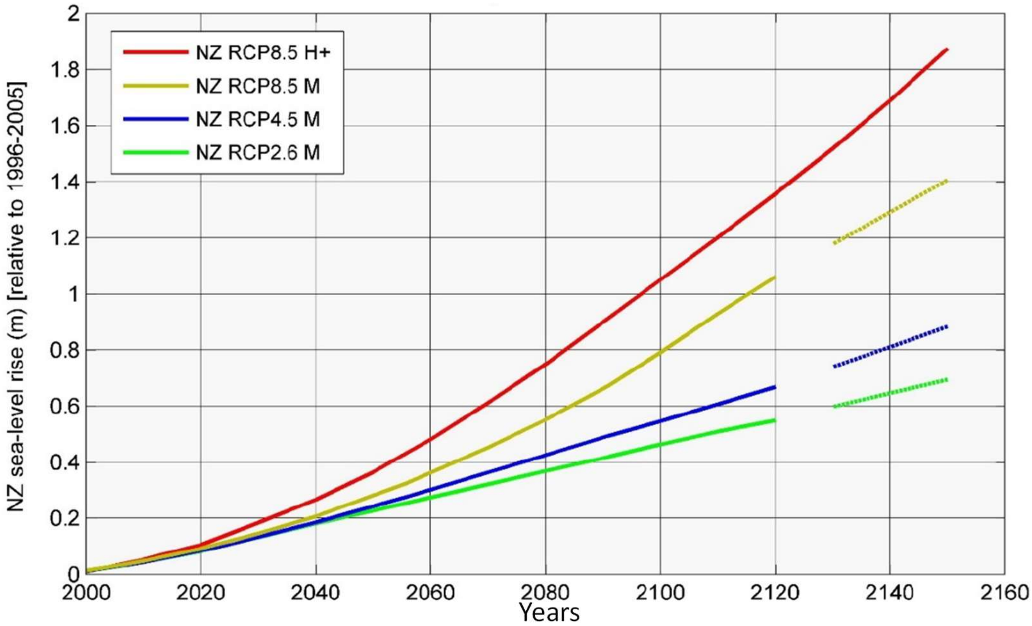

Figure 7.2. Four scenarios of New Zealand-wide regional sea level rise projections to 2150 based on Kopp *et al.* (2014) cited in MfE (2017).

The four sea-level rise scenarios are based around three RCPs (RCP2.6, RCP4.5, and RCP8.5). Three of the scenarios are derived from the median projections of global sea-level rise for the RCPs presented by the IPCC in its Fifth Assessment Report (AR5) (Church *et al.*, 2013). These have been extended to 2120, to meet the minimum requirement of assessing risk over at least 100 years, as required by the NZCPS 2010. A further extension to 2150, using the rates of rise from Kopp *et al*. (2014), provides a longer view over 130 years (with a gap shown in Figure 7.2 between the two sets of projections). It is also a reminder that sea level will keep rising after 100 years, irrespective of actual future greenhouse gas emissions (MfE, 2017). Figure 7.2 indicates that there is a large range of uncertainty with respect to what the magnitude of SLR will be as time progresses, mostly due to how human's respond to the challenge of CO_2 reduction and the uncertainties of ice-sheet mechanics. It is clear, however, that in low-lying areas (e.g. the proposed beach and coastal developments) the impacts of SLR will lead to coastal hazard issues in the short to medium term (i.e. 10 to 30 years) if not taken into account.

While the impacts of rising sea level can be envisaged, it is more difficult to determine what the combined impacts of climate change (CC) will be and how/when they will manifest. In general, the islands of Fiji are highly vulnerable to the impacts of climate change due to their geographical location and socio-economic characteristics. Fiji is susceptible to a wide range of climate change impacts in addition to SLR, including increasingly intense tropical cyclones, extreme rainfall events leading to flooding, coastal erosion, heat waves, drought, and ocean acidification.

7.2 Cyclone Frequency near Nananu-I-Cake Island

There has been a total of 62 tropical cyclones (TC's) in the period between 1969 – 2018 that have passed within 300 km of Nananu-I-Cake Island (Figure 7.3). This translates to an average of 1.27 TC's per year or season in this region. With respect to Nananu-I-Cake Island, 10 TC's have passed within a 50 km radius since 1969.

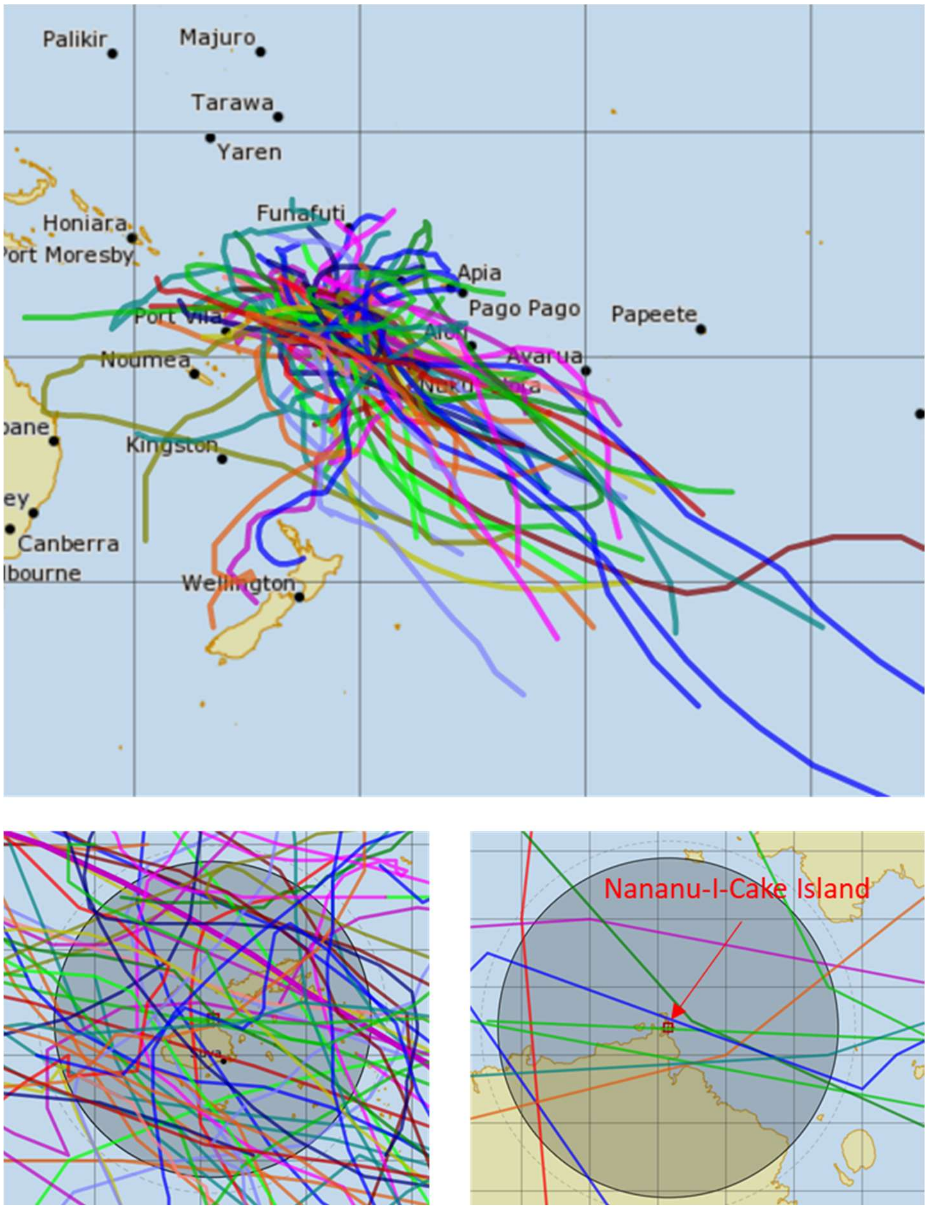

Figure 7.3. TC tracks that have passed within 300 km of Nananu-I-Cake Island, Fiji, in the period 1969 – 2018 (Australian Bureau of Meteorology).

Stephens and Ramsay (2014) used satellite observed TC tracks spanning the period 1969 – 2009 and constructed a spatial distribution of the average annual number of TC's by gridding the data into 3° x 3° cells (Figure 7.4). This was done for various phases of the El Nino Southern Oscillation (ENSO) cycle, however, for all ENSO phases, the Fiji region shows an average number of between 0.7 and 0.8 TC's annually.

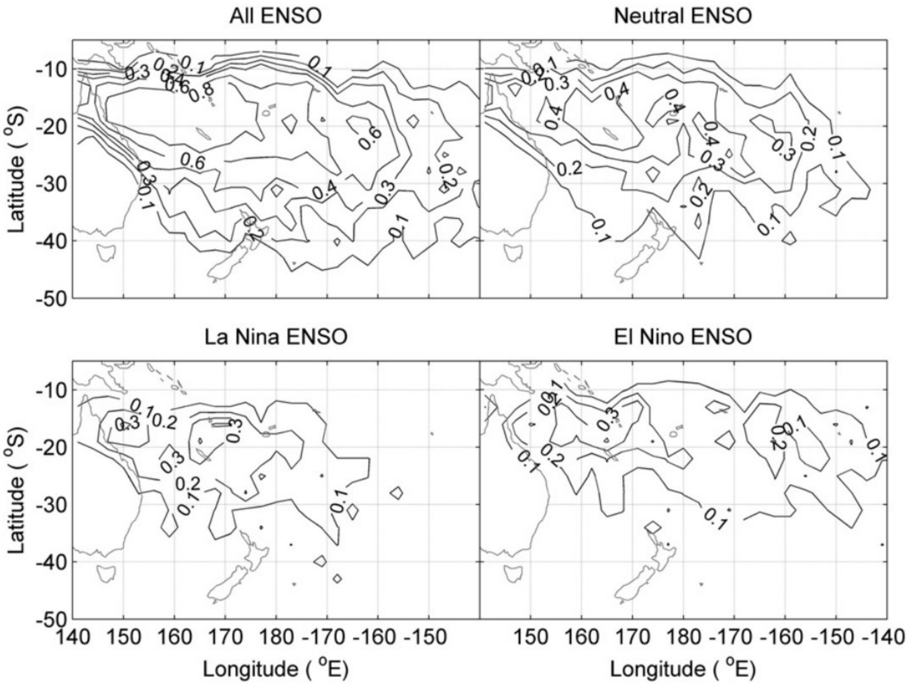

Figure 7.4 ENSO-dependant average annual number of TC's in the SW Pacific Ocean in 3° x 3° cells (Stephens and Ramsey, 2014).

7.3 Extreme Water Levels – Preliminary Estimate

A primary component of coastal hazard assessment is the extreme/maximum water levels for a particular return period (e.g. 50-years, 100-years, etc.) in order to determine the heights of coastal development (e.g. reclamation, revetments, finished floor levels (FFL's), etc.). In addition, these water levels can be used to determine the maximum wave heights that will impact on coastal structures such as revetments (and so can be used to calculate rock armour sizes). In this case, given the greenfield development of a resort, a 100-year return planning horizon has been considered for coastal hazards.

With the application of sea level rise (SLR) predictions estimated by the IPCC (Kopp *et al.*, 2014) MfE (2017) advise RCP 8.5H$^+$ (i.e., 1.4 m of SLR), the tidal estimate presented in Section 3 and useful calculations from previous coastal engineering reports for the area (e.g.

Grummett, 2009, Matarab, and Nakoro, 2007 and T&T, 2007 present recorded storm surge due to barometric pressure, wind and wave set-up, and recorded sea level variability for western Fiji), the 100-year return period extreme water level is calculated. These components and the total are shown in Table 7.1.

Table 7.1. 100-year return period sea level above MSL (0.0 m)

Component	**(m)**
MHWS	0.8
SLR	1.4
Inverse Barometric Pressure (storm surge)	1.0
Wind and Wave Set-Up	0.5
Sea Level Variability	0.25
Total	**3.95 m**

This results in a recommended finished ground level of 3.95 m for habitable areas, with a further 0.5 m of freeboard for finished floor levels; i.e., 4.45 m. These levels are well above the estimated 100-year return period tsunami for western Fiji, which is estimated at <2.5 m above MSL (e.g. T&T, 2007; Grummett, 2009).

These results are preliminary, and are likely to be reduced with field data (actual tides for the site, bathymetry for all the coastal area, wave/current data for model calibration, etc), numerical modelling (to determine return period extreme heights, periods and direction, wave set-up, etc.) and Monte Carlo simulation. Here we have applied the traditional method of extreme water level analysis, which is comprised of empirical model application and the results from the data and literature review above. The various parameters such as projected sea level rise (SLR), storm surge, wave set-up and run-up, sea level variability, etc., have been simply added to each other, which while providing increased conservatism, does not recognise interdependent parameters and so results is higher water levels that would likely occur in reality. A Monte Carlo simulation to develop the 100 year return event extreme water level is more realistic that the standard summative approach, and will likely reduce the recommended finished ground and floor levels significantly. This is important in terms of the volumes of fill required to raise the reclamations/beaches to the appropriate level, and especially important for over-water structures like the jetty and bures (Figure 1.3), resulting in cost-savings and better aesthetics (e.g. the over-water bures FFL's will be lower than if a summative approach was used). Extreme water levels will also vary around the island due to exposure and wind and wave set-up.

8 Summary and Recommendations

The preliminary assessment of the coastal processes and metocean conditions at and around Nananu-I-Cake are summarised as follows, and in Figure 8.1 and Figure 8.2:

- Wind is characterised by predominate winds from the ESE (trade winds), with wind speeds generally lower in the summer/wet-season with a component of northerly winds during this season also.
- The wave climate is dominated by long period swell from the north-west through to the north-east (which is open to the north Pacific Ocean), with a secondary ESE trade wind-generated wave component. Seasonally, significant wave heights are greater during summer/wet-season months compared to winter months, with longer wave periods for summer compared to winter. The largest swells come from the northern quarter during the summer, with the largest swells derived from the south-east in the winter.
- These seasonal wave patterns represent both the local seasonal changes – that is, winter dominated by the ESE tradewinds and short period waves, and the summer tropical cyclone (TC) and tropical depression (TD) events – and Pacific Ocean seasonal changes – that is, the quiescent northern hemisphere wave climate during its summer (Fiji's winter), and the northern hemisphere winter producing consistent long period ground swell in Fiji's summer along with TCs and TDs, which also usually cause strong winds and large wave events from the northern quarter.
- The nearshore bathymetry is characterised by a fringing reef (~0.2 – 0.6 m), which surrounds the entire island. The island is mostly protected from larger wave events from all sides due to protection by offshore reefs and islands, as well as Viti Levu. As a result, there is a very sheltered lagoon area on the leeward side of the island, and sediment transport rates are also very low on this side of the island. Sediment transport rates are low around the island where the coast is exposed to the ESE tradewinds, and is mostly SE to NW, with small amounts of seasonal reversal.
- The predicted tidal range is ~2.05 m, and it is likely that there are strong tidal currents through the passes (out-going to the north, incoming to the south), especially during spring and King tide events.

Field data collection and numerical modelling are required to quantify coastal processes (waves, tidal range, detailed bathymetry, sediment transport, etc.), and further considerations should are also required for the following components of the proposed development in relation to coastal processes:

Beach creation on the northern west coast of the island:

- Significant volumes of material will require removal where the mangrove belt is up to 100 m wide. A disposal area will be required on the island, noting that this material will consist of a large fraction of organic matter (i.e. it will be unsuitable material for constructing on without using novel techniques)
- A source of clean sand for the beach will need to be located (~20,000 m^3 is required). The western lagoon is 15-18 m deep, and so could potentially be a source for sand. However, given the protected nature of the western lagoon, there is potential that there is a large fraction of fine material meaning that it is unsuitable for use on the beach. The eastern side of the island may be a better source due to the exposure to SE winds. A sand resource investigation will be required during field data collection (i.e., depth probing and sediment collection for grain size analysis).
- The proposed beach site is relatively sheltered and so should be relatively stable. However, compartmentalisation and beach management may be required intermittently (i.e., terminal groynes at either end of the beach and transfer of sand from one end to the other). Numerical modelling will provide an assessment of sediment transport potential and beach monitoring will be designed to inform whether it is necessary or not and how often. The beach will be constructed with a hard core (e.g. soap stone or similar material available on the island) with a 500 mm layer of clean beach sand on top; i.e., it will require management.
- Similar considerations will be required for the development of small artificial islands on the fringing reef flats.

Overwater structures (bures and jetties):

- Underfloor forces due wave uplift are extreme in comparison to horizontal wave forces on piles.
- A Monte Carlo simulation is required to develop realistic 100 year return event extreme water level, which can be used to consider overwater structure heights. This will also be important in terms of the volumes of fill required to raise the reclamations/beaches to the appropriate level. Extreme water levels will also vary around the island due to exposure and wind and wave set-up.

Marina and Reception Area Design:

- The maximum vessel size for the marina will need to be specified for design (depth, entrance channel dimensions, etc.), and should include potential space for future expansion of the resort, noting the safe anchorage provided by the lagoon on the western side of the island which is 15-17 m deep.

- Bathymetry data, wave/current/water level measurements, the Monte Carlo simulation and numerical modelling will be required for rock armour sizing and revetment design, including crest/land heights, and overwater structures in the reception area.
- Wave penetration modelling (using a boussinesq model) and potentially iterative design modification to the marina entrance will be required to meet international marina standards.

Water Intakes and Discharges:

- Water intake for desalination and water discharge for hypersaline water and waste water (if required) will be determined through scenario modelling of the hydrodynamics in the vicinity of the infrastructure on land, and will be positioned to ensure that environmental impacts and mixing of water are minimised.

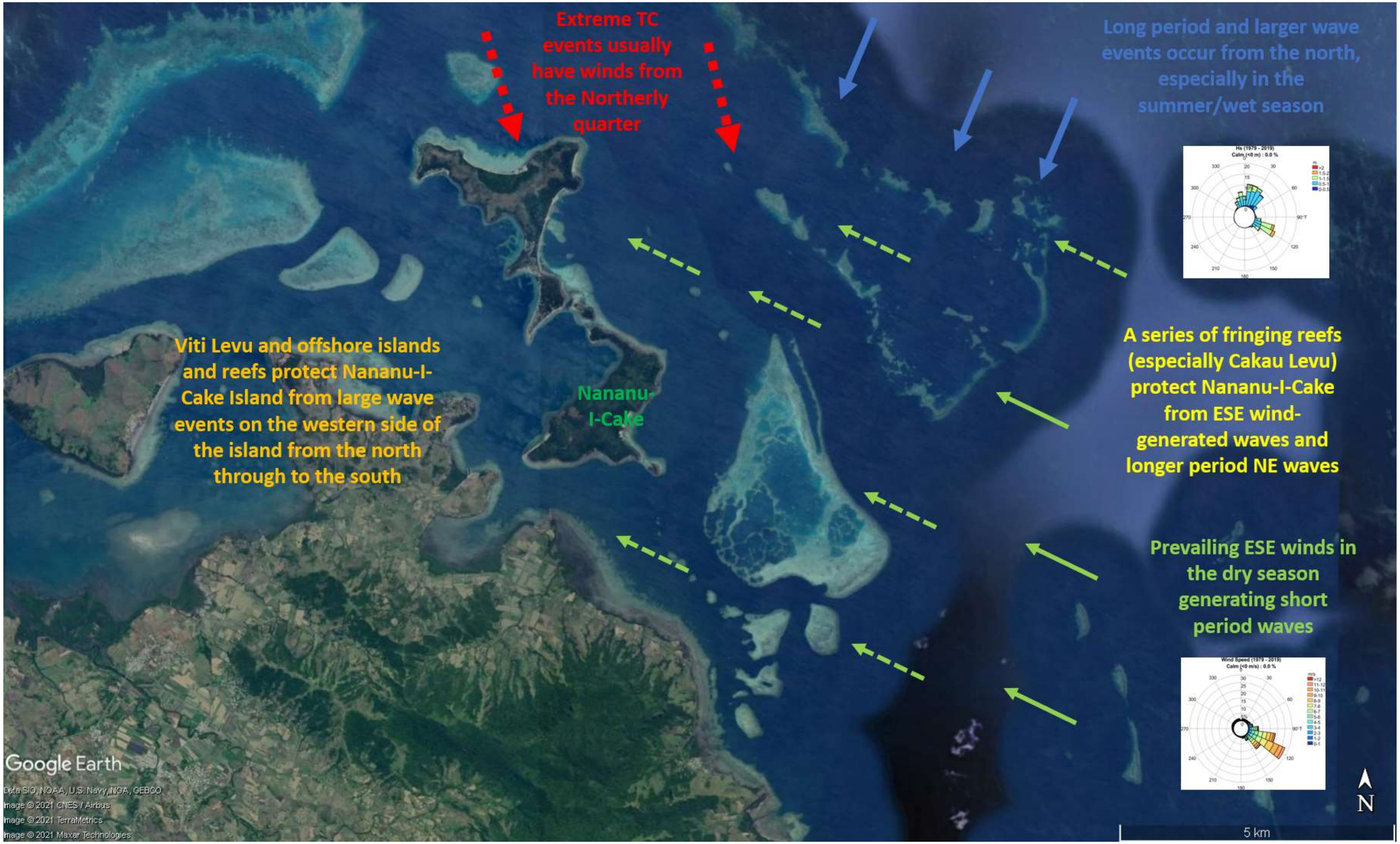

Figure 8.1. Summary of coastal processes and metocean conditions around Nananu-I-Cake Island.

Figure 8.2. Summary of coastal processes on and around Nananu-I-Cake

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