# 3 BASELINE ENVIRONMENT

## 3.1 Site Description and Context

The Baie du Tombeau site lies along the north-western coast of Mauritius in the district of Pamplemousses. It is located to the north of the Port Louis Container Terminal and the estuary of River Terre Rouge (Figure 3-).

The site, which is approx 310m long is part of a 5km long NW facing convex coastline that backs an approx. 500m wide lagoon. MPA has dredged areas off the shoreline for their Mer Rouge Container Terminal.

There are two off-shore sand bars/islands within the lagoon W and NW of the site respectively.


**Figure 3- Site location within the bay**

The location plan of the site is enclosed as drawing M190//BDT/DD/01 in Appendix C.

The limits of the site as shown in Figure 3-2 are:

- on the north at the wall of a private property
- on the south at the abutment of Avenue des Dorades at the coastline
- on the east by property boundary walls
- on the west by the open sea.


**Figure 3- Site Limits**

### 3.1.1 Jurisdiction over Waterfront

Mauritius Port Authority (MPA) is the responsible authority with planning jurisdiction over the shoreline and water area from Albion to Pointe aux Piments, which includes the Baie du Tombeau site.

### 3.1.2 Waterfront Features

The Baie du Tombeau site overlooks the Mer Rouge Container Terminal (Figure 3-). The site waterfront has an approx. 500m wide lagoon with two offshore sand bars/ islands. There are about 18 residential plots along the site waterfront with an assortment of hard seawalls built right along the shoreline. Wave action has eroded the shoreline and undermined boundary walls in places. Some trees along the shore have had their roots undermined by waves (Figure 3-).

Facing Mer Rouge Container Terminal

Offshore sand bars in satellite image

Existing Site Waterfront to SE

Existing Site Waterfront to NW

**Figure 3- Existing site waterfront**

At the northern end of the site waterfront, there is only a very narrow strip of sandy beach exposed at low water because property boundary walls (Figure 3-) now lie right upon and in some places to seaward of the high-water mark. There is a wider sandy beach at the SE end of the site, where sand has accreted (Figure 3-).

The boundary walls, of assorted masonry and concrete construction, vary in height with top levels ranging from 1m to 2.5m MSL.

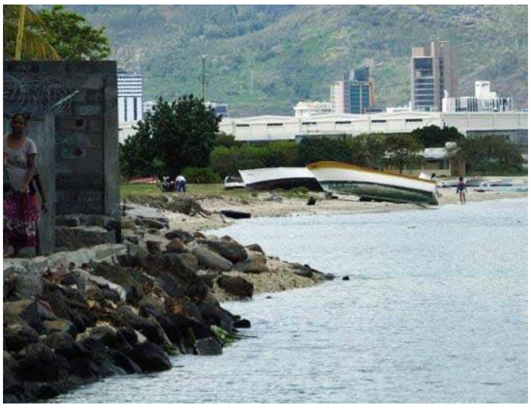
The coastline at the site has suffered severe erosion as shown in Figure 3-.

**Figure 3- Eroded Coastline and Boundary Walls**

**Figure 3- Existing boundary wall types**

The northern part of this waterfront is eroding, whereas there is accretion at the SE end (Figure 3-).

Eroded narrow beach at N end



Accreted beach at SE end

**Figure 3- Erosion and accretion along site waterfront**

### 3.1.3 Land and Water Use

High value residences occupy the entire waterfront of the site, which faces MPA's Mer Rouge Container Terminal to the South. Fishing boats moor off the waterfront, mostly at the SE end. The boats draw up on the beach beyond the SE end of the site, and according to information obtained on site, are removed from the water at the onset of a cyclone. One private waterfront property has a rudimentary boat ramp leading to the water, and stores boats on the premises (Figure 3-).

High value residences

Beached fishing boats at SE end

Fishing boats moored off site N end

Fishing boats at SE end of site

Boat inside property

Boat ramp serving private property

**Figure 3- Land and water use**

### 3.1.4 Landside Access to Waterfront

The site can be accessed directly from Baie du Tombeau Road through two tarred roads, namely Rue des Capitaines to the NW and Rue des Dorades to the SE. Towards the NW end of the site, there are two narrow unsurfaced public access tracks (Figure 3-) leading from Rue des Carandines, a tarred road that runs almost parallel to the shoreline about 125m inland. These tracks end abruptly at the shoreline and do not at present offer easy pedestrian access to the sea because of an almost vertical drop of 1.2m between track level (circa +1.7m MSL) and the shore (+0.5m MSL).

Rue des Capitaines and Rue des Dorades offer easier access to the waterside for vehicles and pedestrians.

Access track No 1 (near NW end of waterfront)

Rue des Dorades

Access track No 2 (from Survey Station 1)

Rue des Capitaines (from Simla Way)

**Figure 3- Landside access to waterfront**

### 3.1.5 Pedestrian Access along Waterfront

Damaged gabion walls, dumped mass concrete and rock, concrete platforms and a boat ramp run at levels between +0.5m MSL and +1.0m MSL along the seaward side of the property boundaries. Pedestrian access for the public along these is hazardous and discontinuous (Figure 3-).

Doorways in some of the boundary walls with steps leading down to the sea provide access to the water for property owners. One property also has a boat ramp, with boats parked within the property (Figure 3-).

### 3.1.6 Historical Features

No historical features were identified on the site. Also, during preliminary consultations with stakeholders, the National Heritage Fund has not reported any national heritage at the site.

The Schedule in the National Heritage Fund Act quotes two national heritage sites in the district of Pamplemousses at Biae du Tombeau, namely Fort Albert and Old Fort, which are located at some 500 m to the north of the project site.

Damaged gabion walls

Dumped mass concrete and rock

Doorways

Gates with steps to beach

Hazardous pedestrian access

Underpinned wall

**Figure 3- Pedestrian access along waterfront**

### 3.1.7 Rivulet Terre Rouge Estuary Bird Sanctuary

The Rivulet Terre Rouge Estuary Bird Sanctuary, a RAMSAR site, is located some 400m to the south east of the project site.

## 3.2 Site Topography

The site has been topographically surveyed within the project limits along the waterfront strip.

Drawing M190/BDT/DD/02 shows the principal topographical features surveyed.

### 3.2.1 Elevation Datum

Levels and elevations for site surveys and engineering design of the works have been related to Mean Sea Level (MSL) Datum.

BMG 45058 established by the Ministry of Housing and Lands and forming part of the primary levelling network of Mauritius was used as reference benchmark. This benchmark is located on the roundabout along Quay D Approach Road (B 30 Road) off Motorway M2.

The reduced level of BMG 45058 is 3.17m above MSL.

### 3.2.2 Horizontal Datum

The surveys carried out at this site have been tied to the Mauritius geodetic network named 'Local Grid Mauritius' (LGM2012), as established by the Ministry of Housing and Lands.

## 3.3 Bathymetry

The lagoon has been bathymetrically surveyed and mapped up to the -2.0m MSL contour along the seafront of the site. The -1.5m MSL seabed contour lies between 40m and 60m off the property boundaries. Chart 711 suggests depths of up to -2m MSL within the lagoon.

Drawing M190/BDT/DD/02 in Appendix C shows the seabed contours.

## 3.4 Utilities and General Infrastructure

### 3.4.1 Power, Potable Water and Sewers

Power, potable water and sewer lines were not observed along the shoreline during the site visits and surveys.

### 3.4.2 Stormwater Drainage

No stormwater drainage outlets were identified along the waterfront to the site.

## 3.5 Geology and Geomorphology

From an environmental perspective, geology and geomorphology interests cover the scientific and educational value of geological exposures on the site, including landforms and features such as sea cliffs and sand dune systems.

### 3.5.1 Geology

The geological map of Mauritius describes Baie du Tombeau area as being formed from sedimentary rocks and alluvial deposits along the coast as shown in Figure 3-.

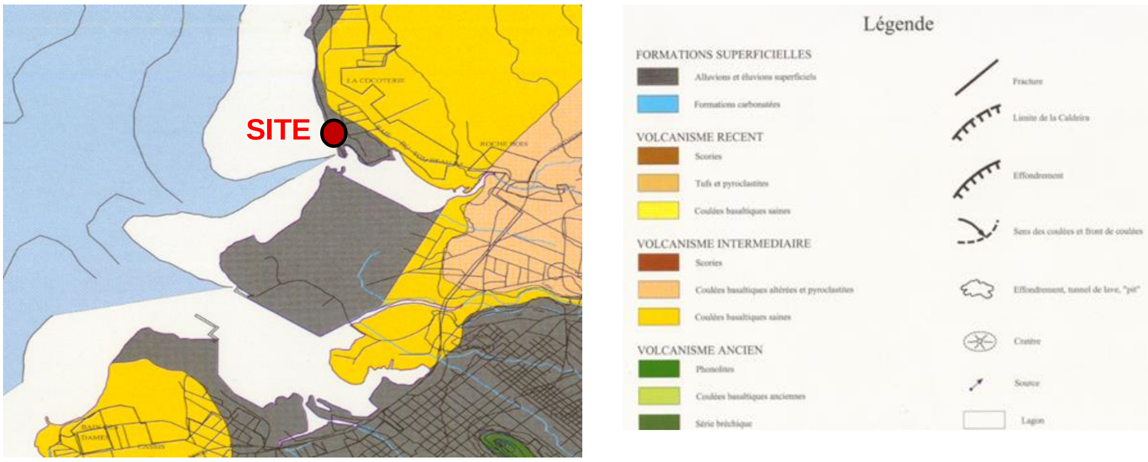



**Figure 3- Site Geology**

The natural strata of the site consist of Regosols (Coral Sand) that occur on deep unconsolidated coral around the coast line. Coral sand is a mixture of fragmented corals, shells and sand.

### 3.5.2 Site Observations

The site topography is plain and is located to the north of the Port area. Dredging activities were noted to be in progress near the site in front of the Container Terminal at Mer Rouge during the day the sampling exercise was carried out (Figure 3-).

Based on visual examination, the soil present on site can be described as pale yellow to greyish (in the vicinity of the -1m CD contour) coloured Sand to Sandy Silt, which consists of fragmented corals, shells and pebbles.

**Figure 3- Scattered rocks and construction debris**

### 3.5.3 Sediment Sampling and Test Results

Sediment sampling was carried out along the eroded coastline along five profiles at this site. Samples were collected at the High Water Mark, the Mean Sea Level, the

Low Water Mark and at the -1m CD contour. During the sampling exercise, particle sizes greater than 63 mm were discarded.

Drawing No M190/BDT/EV/02 shows the locations of the collected samples.

Twenty samples were collected and tested for grain size at the laboratory. Dry sieving was carried out in the range of 63mm to 63 micron particle sizes.

The detailed results of the sieve tests are enclosed in Appendix A.

Table 3- presents a summary of the soil classification at the site.

**Table 3- - Summary of Soil Classification**

| Location | Profile | | | | |
|---|---|---|---|---|---|
| | 1 (CH00) | 2 (CH60) | 3 (CH120) | 4 (CH180) | 5 (CH240) |
| High Water (H) | Sand | Sand | Sand | Gravelly Sand | Sandy Gravel |
| Mean Sea Level (M) | Gravelly Sand | Gravelly Sand | Gravelly Sand | Gravelly Sand | Gravelly Sand |
| Low (L) | Gravelly Sand | Gravelly Sand | Gravelly Sand | Gravelly Sand | Gravelly Sand |
| Chart Datum (CD) | Gravelly Sand | Gravelly Sand | Sandy Gravel | Sandy Gravel | Sandy Gravel |

Based on the laboratory test results, the upper stratum at the site comprises Gravelly Sand to Sandy Gravel of coral origin, which consists of fragmented corals, shells and sand. The sediment distribution from land to seaward varies from Gravelly Sand to Sandy Gravel i.e. distribution of particles from fine to coarse.

## 3.6 Sediment Transport and Morphology

Historically, before the formation of the sand bars offshore of the site, waves approached from a relatively normal angle to the shoreline due to transformation over the reef as shown in Figure 3-. This reduced significant longshore transport or gradients in longshore transport resulting in a historically uniform sandy beach along the entire site with a width of approximately 15m.


**Figure 3- Aerial Photograph of Baie du Tombeau, 1991**

As the offshore sand bar islands formed within the lagoon, the wave transformation over the reefs changed causing waves to approach the site at a more oblique angle resulting in significant southward longshore transport. Historical aerial imagery from Google Earth showed that in 2003 the sand bar had begun to form but was not fully developed as seen currently in Figure 3-.

The direction of the mean wave energy flux during operational conditions shown in Figure 3- reveals that there is a net southward longshore transport of sediment along the site.

The lower wave energy in the shadow zone behind the sandbar to the south of the site creates a gradient in the longshore transport along Baie du Tombeau resulting in the visible erosion of the beach along the site and accretion south of the site. The beach is almost non-existent width along the Northern part of the site due to the erosion whereas to the South, accretion has resulted in the formation of the salient behind the sandbar visible in Figure 3-.

Additionally, the construction of the container terminal quay causes wave reflection away from the quay which converges with the northerly waves shown in Figure 3- at the salient location, which further reduces the longshore transport south of the site and increases the rate of accretion.

A thin strip of sand is exposed at low tide at the NW end of the shore, and a wider beach exists at the SE end. Sediment budgets prepared by JICA in 2014 showed that the SE end of the beach was accreting, whereas erosion was occurring at the centre and to the NW. This is still the case.

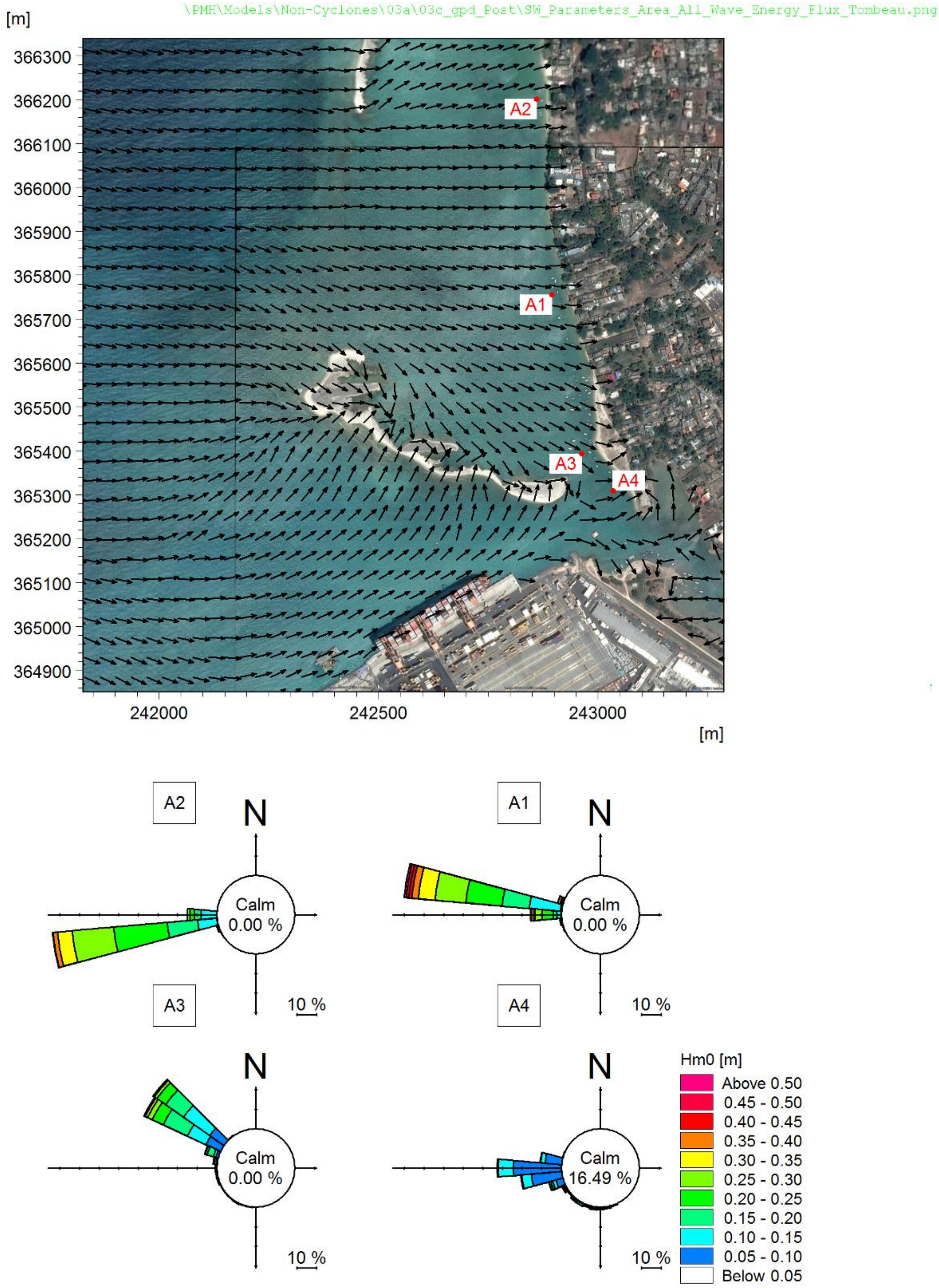



**Figure 3- Direction of mean wave energy flux (top) and wave roses (bottom)**

The mean wave energy flux parameter is the mean of $H_{m0}^{2.5}$ over the 4-month period modelled. The parameter is derived from sediment transport considerations, where the longshore transport according to the CERC equation is proportional to $H_{m0}^{2.5}$, evaluated at breaking (USACE, 2008).

Source: Figure A-12 of *Hydrodynamic and Wave Modelling Report - Lot 1*

## 3.7 Coastal Hydrodynamics – Baseline Modelling

The baseline scenarios, ie, the current layouts of the sites, were modelled as the present baseline condition without the proposed protection structures, except for the following:

1. At Baie du Tombeau, MPA has carried out dredging works at the English Channel and the area in front of the container terminal berths earlier this year. The planned changes have been incorporated into the numerical modelling by deepening these areas to a depth of 16.5m CD as envisaged in the dredging project
2. At Baie du Tombeau, sand bars have accumulated on the reef seaward of the project site. Since the sand bar levels are variable and are vulnerable to erosion during storm events, the levels of these features were reduced to that of the underlying reefs, I.e., 0.37m MSL (0m CD).

### 3.7.1 Model Calibration

The models were calibrated to available wave measurements offshore of Mauritius and nearshore wave and water level measurements in Grand Port.

For design, both cyclone and non-cyclone conditions were considered. The models were used to estimate the 1, 10 and 100-year return period design waves and water levels. This provides a complete range of design conditions to be used for the design of the coastal protection schemes.

### 3.7.2 Climate Change Effects

Due considerations for climate change were included, viz:

- The Project time frame is 3 years for implementation of the works. Therefore, the baseline date for the Project is 2020
- 20 and 50-year time horizons were considered for long-term climate change impacts

Thus the 1, 10 and 100-year annual return interval design waves and water levels were provided for each of the three climate change scenarios (Years 2020, 2040 and 2070).

### 3.7.3 Water Level

Water level data measured at Port Louis was available from the University of Hawaii Sea Level Center (Caldwell, et al., 2015). The dataset comprises measured water levels for a period of 31.2 years between 1986 and 2017. The vertical datum of the raw dataset is “Tide Staff Zero”, which is 1.321 m below Chart Datum (CD) (Mauritius Meteorological Services, 2016). At Port Louis, Chart Datum is 0.37 m below Land Levelling Datum (LLD), which is also commonly referred to as Mean Sea Level (MSL). The raw measured data is shown relative to MSL in Figure 3-.

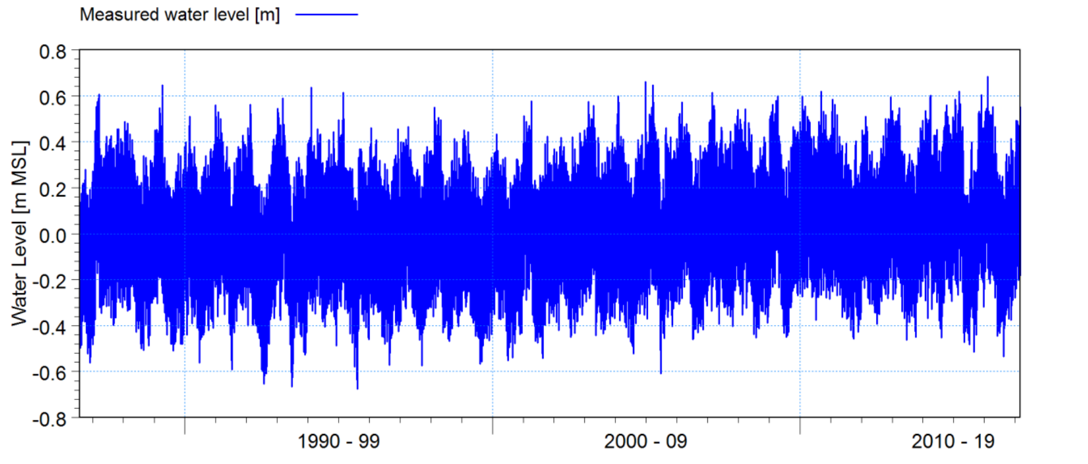



**Figure 3- Raw water level data measures at Port Louis (Caldwell, et al, 2015), shown relative to Mean Sea Level (MSL)**

### 3.7.4 Tide Levels

The measured water level data presented a notable long-term trend in the mean water level. Prior to conducting a tidal analysis of the measurements, the trend in the long-term data was removed. This was done applying a linearly-varying correction based on a trend line fitted through the data.

The correction was applied such that the mean level of the de-trended dataset is equal to the mean level of the original dataset at 1995, calculated as the average of the period of 1986-2005. This was done in order to have a baseline water level dataset which could be compared against the projections for sea level rise, which use 1995 as a baseline date.

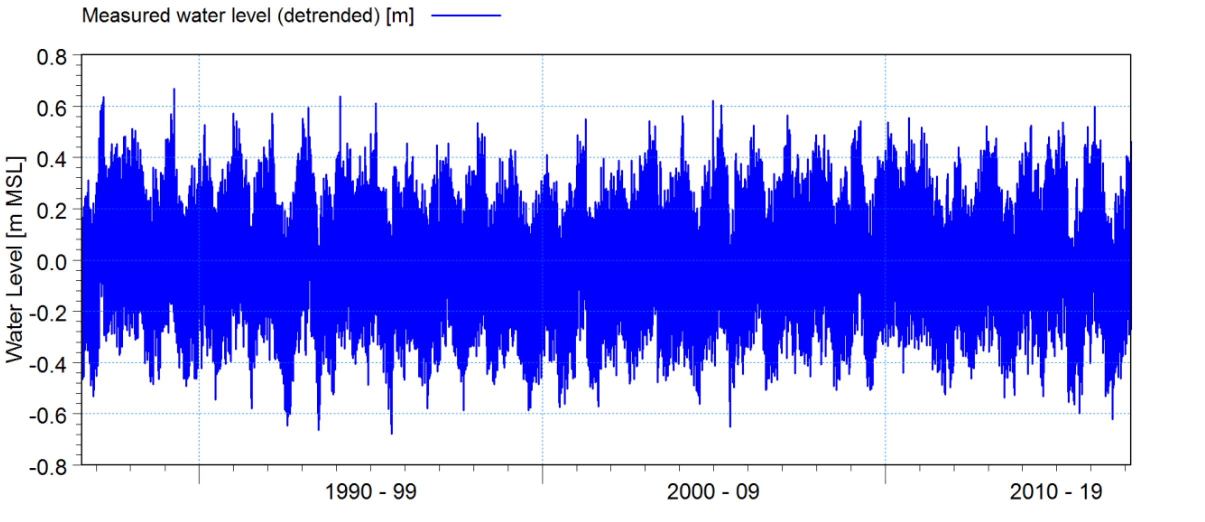



**Figure 3- Water level data measured at Port Louis (Caldwell, et al., 2015). The data shown was detrended, with a mean level equal to the measured mean level at 1995, calculated as the average over 1986-2005.**

A tidal harmonic analysis was carried out on the de-trended dataset, using the Tidal Analysis of Heights Tool in the MIKE 21 Toolbox (DHI, 2016e). The output of the tool is a set of tidal constituents for the site. Using the same tool, the tide at Port Louis was predicted using the constituents obtained from the analysis. The resulting predicted tidal water levels are presented in Table 3- relative to MSL and to CD.

**Table 3- Predicted tidal water levels carried out through analusus of the de-trended water level measurements at Port-Louis. The ML of the de-trended ddataset corresponds to the mean level in 1995, calculated as the average over 1986-2005**

| Tide Level | Predicted from de-trended measurements (m MSL) | Predicted from de-trended measurements (m CD) |
|---|---|---|
| **Highest Astronomical Tide (HAT)** | 0.458 | 0.828 |
| **Mean High Water Springs (MHWS)** | 0.278 | 0.648 |
| **Mean High Water Neaps (MHWN)** | 0.072 | 0.442 |
| **Mean Level (ML)** | 0.004 | 0.374 |
| **Mean Low Water Neaps (MLWN)** | -0.062 | 0.308 |
| **Mean Low Water Springs (MLWS)** | -0.247 | 0.123 |
| **Lowest Astronomical Tide (LAT)** | -0.498 | -0.128 |

The maximum measured residual tide is approximately 0.5 m. The most of the residuals appear to be associated with cyclones.

### 3.7.5 Climate Change and Sea Level Rise

The measured tidal data was used to estimate the average sea level rise (SLR) for different time periods. Based on analysis of the Port Louis tidal measurements the following SLR trends have been determined (as shown in Figure 3-):

- +3.9 mm/yr for 1986 to 2016 (all 30 years)
- -3.2 mm/yr for 1986 to 2000 (first 15 years)
- +6.1 mm/yr for 2001 to 2016 (last 15 years).

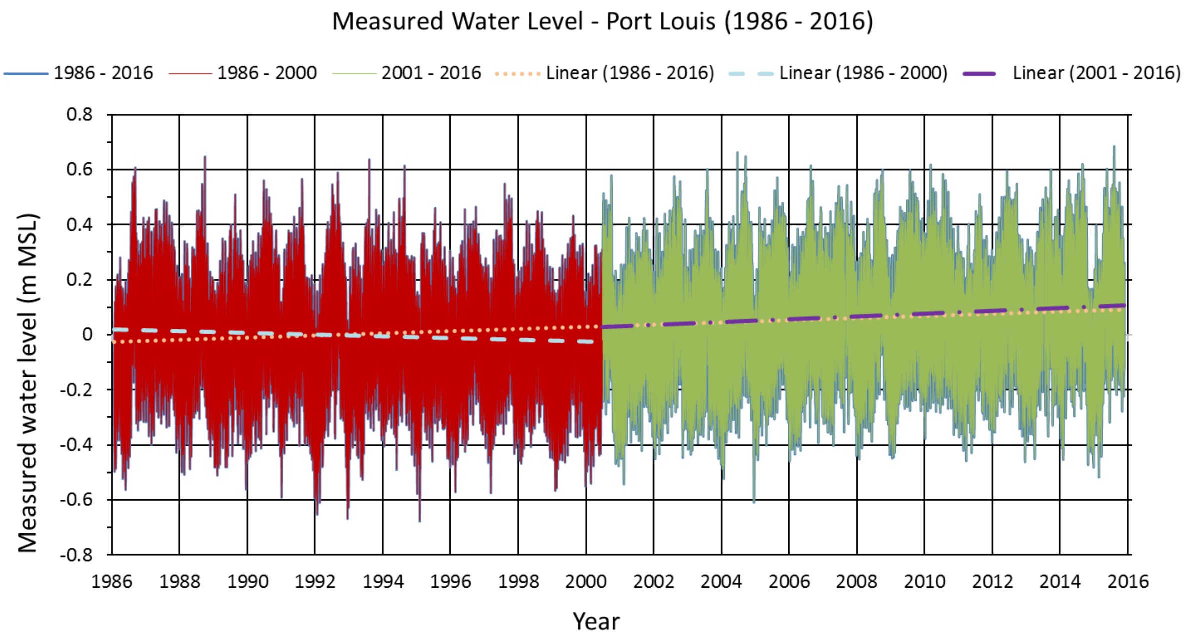



**Figure 3- Measured Water Level at Port Louis with SLR Trend Lines**

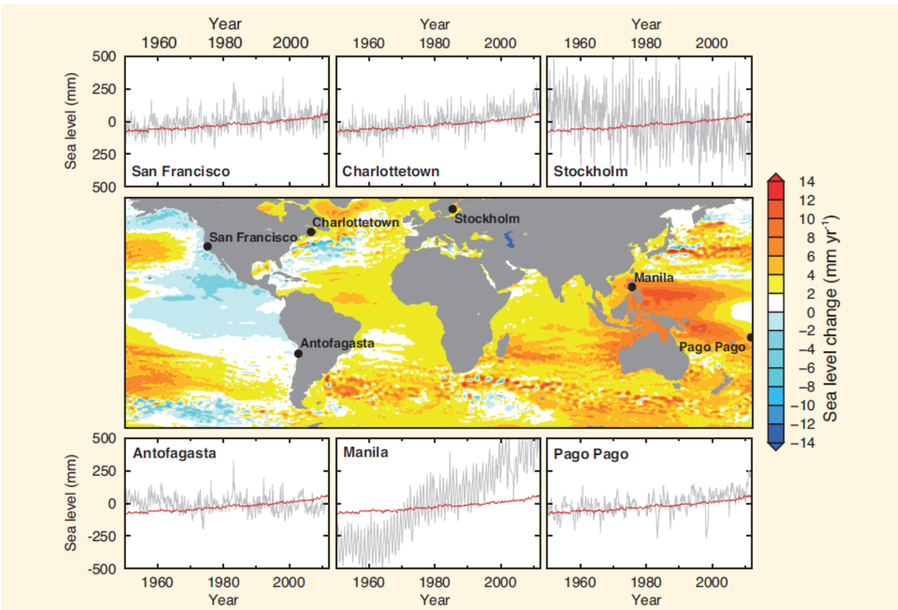
The data indicates that some variability is visible in the region’s water levels, but in general an increasing trend in the mean water level has been observed.

## 3.8 Climate

### 3.8.1 Water Levels

Various literature references were consulted, including the previous project studies. The key findings are summarised below:

- SLR dropped between 1986 and 2000 at Port Louis due to regional water level variability (Church,2006)
- +1.5 mm/yr at Port Louis including measurements in the 1950s and 1960s (Church, 2006)
- +2.1 mm/yr based on tidal data for 2003 to 2013 as sourced by Mauritius Meteorological Services (JICA, 2016)
- The IPCC (2013) estimates an average SLR between 1993-2010 of 3.2 mm/yr (ranging between 2.8 to 3.6 mm)
- +3.9 mm/yr for an analysis of the Port Louis tidal data 1986 to 2013 (JICA, 2016)
- +5.6 mm/yr has been predicted for the period 2003-2012 by the Sea Level Rise centre of the University of Hawaii (Thompson et al, 2016) as referenced by (JICA, 2016)
- +3.9 mm/yr for 1986 to 2016 (all 30 years) based on an analysis of the Port Louis data (discussed in Section 3.8 above)
- -3.2 mm/yr for 1986 to 2000 (first 15 years) based on an analysis of the Port Louis data (discussed in Section 3.8 above)
- +6.1 mm/yr for 2001 to 2016 (last 15 years) based on an analysis of the Port Louis data (discussed in Section 3.8 above)
- Mauritius is situated in a region which experienced ~6 mm/yr SLR in the period between 1993 – 2012, which is above the global average (IPCC, 2013) as shown in Figure 3-.




**FAQ13.1, Figure 1 |** Map of rates of change in sea surface height (geocentric sea level) for the period 1993–2012 from satellite altimetry. Also shown are relative sea level changes (grey lines) from selected tide gauge stations for the period 1950–2012. For comparison, an estimate of global mean sea level change is also shown (red lines) with each tide gauge time series. The relatively large, short-term oscillations in local sea level (grey lines) are due to the natural climate variability described in the main text. For example, the large, regular deviations at Pago Pago are associated with the El Niño-Southern Oscillation.

**Figure 3- Extract from Chapter 13: Sea level change in the Fifth Assessment Report (IPCC,2013)**

Based upon the literature and the measured data for Port Louis, Mauritius appears to be near to the upper limit of the current global SLR observations.

The global mean sea level rise projections (IPCC, 2013) provide a basis for estimating the SLR for different years in the future. The recommended upper limit SLR can be predicted based upon the upper limit of the peer-reviewed climate models (as shown in Figure 3-). This translates to an SLR of 0.25 m for 2040 and 0.55 m for 2070.

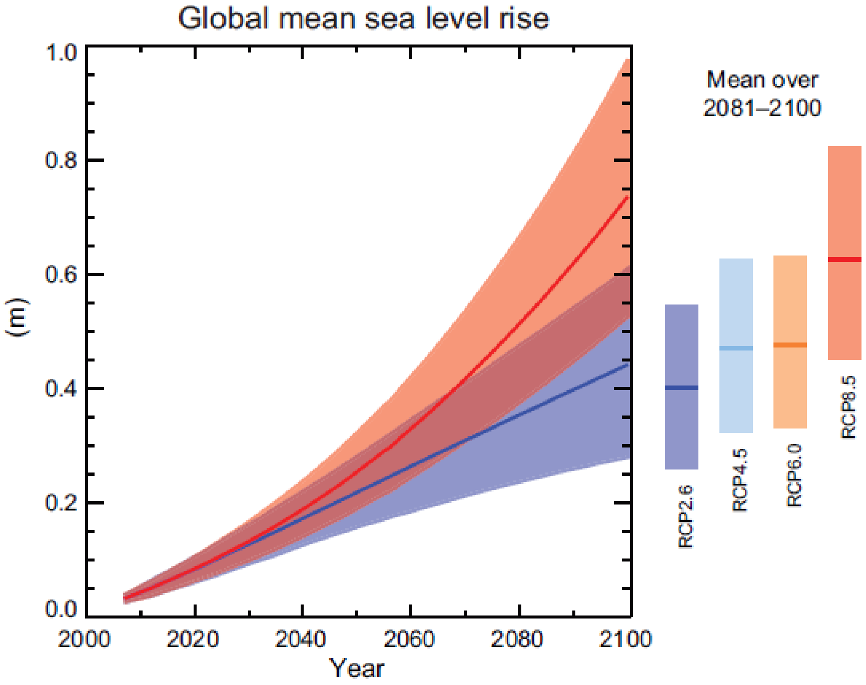



**Figure 3- SLR projections for this century, showing upper limit values for 2040 and 2070 (IPCC, 2013)**

The recommended design SLR for the three different design years are provided in Table 3-. The recommendation of 0.1 m SLR for 2020 is based upon the actual measured data: an average increase of 3.9 mm/yr increase for 25 years is approximately 100 mm by 2020.

**Table 3- Applied design SLR for 2020, 2040 and 2070 based on 1995 level**

| Design Year (yr) | SLR (m) | Average rise from 1995 (mm/yr) |
|---|---|---|
| **2020** | 0.10 | 3.9 |
| **2040** | 0.25 | 5.6 |
| **2070** | 0.55 | 7.3 |

### 3.8.2 Cyclones

Cyclone track data for this study has been sourced from the International Best Track Archive for Climate Stewardship (IBTrACS) from 1980 to 2015 (NOAA, 2016), as shown in Table 3-4 and Figure 3-.

**Table 3- Meteo France La reunion (MFR) storm classification system**

| Category | 10 min average $V_{max}$ | 10 min average $V_{max}$ |
|---|---|---|

| | (m/s) | (km/h) |
|---|---|---|
| **Tropical disturbance** | <14 | <50 |
| **Tropical depression** | 14 – 17 | 50 – 61 |
| **Moderate tropical storm** | 17 – 24 | 61 – 86 |
| **Severe tropical storm** | 24 – 32 | 86 – 115 |
| **Tropical cyclone** | 32 – 46 | 115 – 166 |
| **Intense tropical cyclone** | 46 – 59 | 166 – 212 |
| **Very intense tropical cyclone** | >59 | >212 |

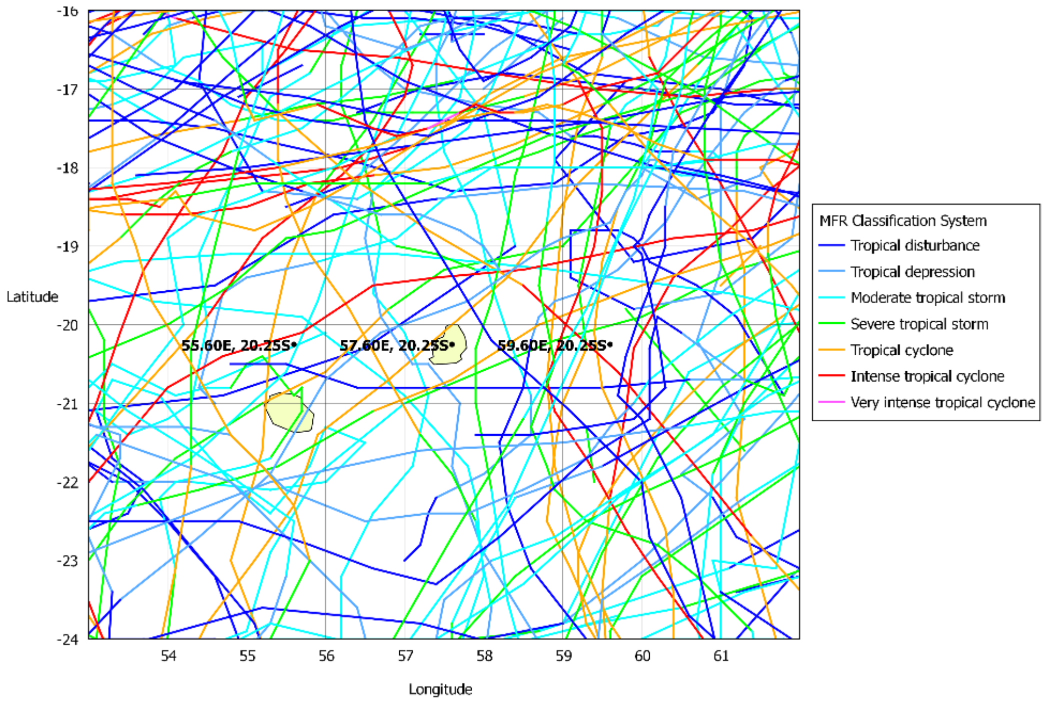



**Figure 3- MFR best track data for the years 1980 to 2015. Also indicated are the three locations used in the calculation of extreme wind speed.**

A parametric wind field model was run to determine time-series of wind speed at any location of interest. The time-series of modelled wind peaks for all available historical tropical cyclone events were extracted at three locations with 2° spacing in longitude for the Mauritius area (Figure 3-). The resulting time series (Figure 3-) shows scatter but no clear trend to support an increasing trend in cyclone wind speeds over the last 35 years.

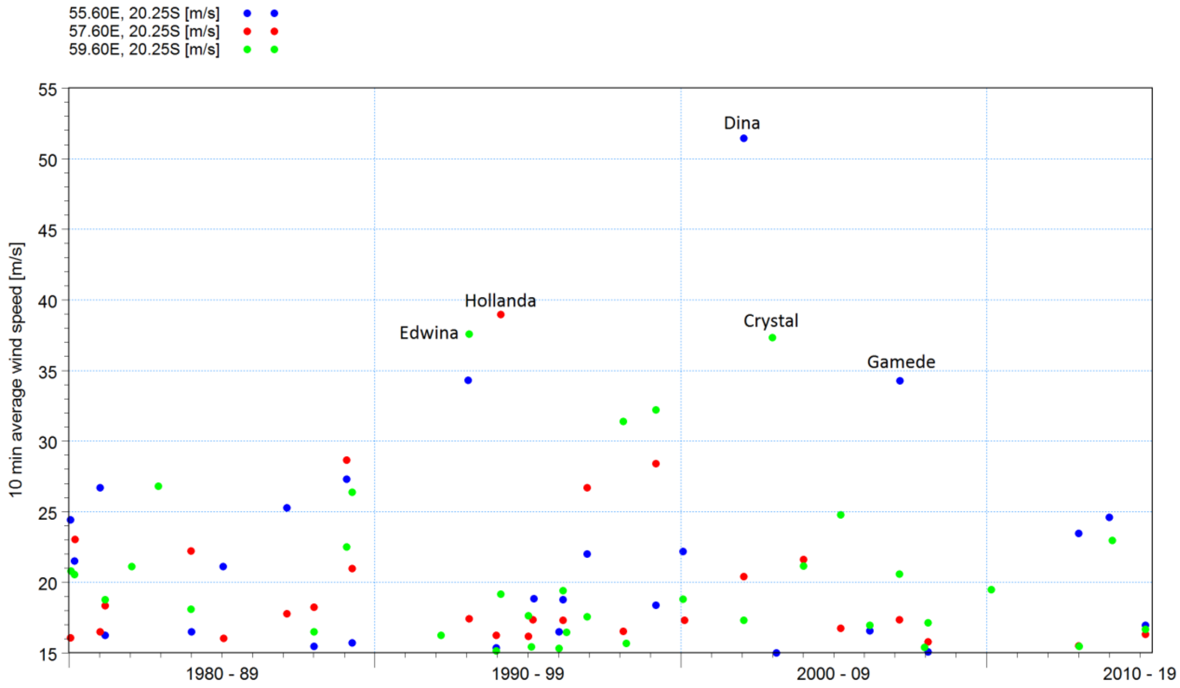



**Figure 3- Time-series of modelled peak wind speeds for all historical tropical cyclones from 1979 to 2015 at the three locations in Mauritius**

Based upon literature, cyclone frequency is expected to decrease or remain unchanged for 21st century (IPCC, 2013). However, on average an increase in cyclone intensity of approximately 10% is predicted for some basins. Additionally, mean cyclonic wind speeds are expected to increase between +2% and +11% (IPCC, 2013), with regional variation likely. There is low confidence in these projections at this stage.

Other sources cite the following findings:

- an increase in the frequency of intense storms in the Mauritius area from 1993 to 2008 (Fairhurst,2011)
- an increase in Category 3 storms and larger after 1997 in the region while no increase in total number of storms (Malan, 2013)
- the frequency and intensity of cyclones indicated overall increased activity during 1980 – 2007 (Mavume, 2009).

The IPCC (2013) predicts a 10% 'best estimate' increase in the lifetime maximum intensity of tropical cyclones for the South Indian Ocean, with a range of 0% to 15%.

**Based on the above, the values shown in**

Table 3- have been used in this study.

**Table 3- Applied increase in cyclone wind speed**

| Design year (yr) | Change in wind speed (%) |
|---|---|

| | |
|---|---|
| **2020** | 0 |
| **2040** | +5 |
| **2070** | +10 |

### 3.8.3 Wind

The potential increase in non-cyclonic winds have also been evaluated as this could impact upon the wind and swell wave design conditions, particularly for the operational case.

Various differing predictions for the change in extreme wind speeds have been sourced, i.e. (Young, 2012) estimated the trend in the 100-year wind speeds at 10 m elevation, which resulted in a decadal trend of 3.6 m/s per decade (if based upon a starting point of 44 m/s this results in approximately 8% increase per decade). (Bhaskaran, 2014) reports that an increase in the wind speeds (+3.2 m/s) and corresponding wave heights (+1.52 m in last 21 years) can be seen between the latitudinal belts of 40°S to 55°S (which would result in an increase of 3.5% per decade if 44 m/s was the starting point). A 100-year return wind speed of approximately 44 m/s can be estimated for the Roaring 40’s based upon research (Young, 2012).

Tokinaga et al (2011) predicts a trend of less than 0.1 m/s per decade for the average wind which corresponds to approximately 1.4% per decade for an average speed of 7 m/s (as shown in Figure 3-).

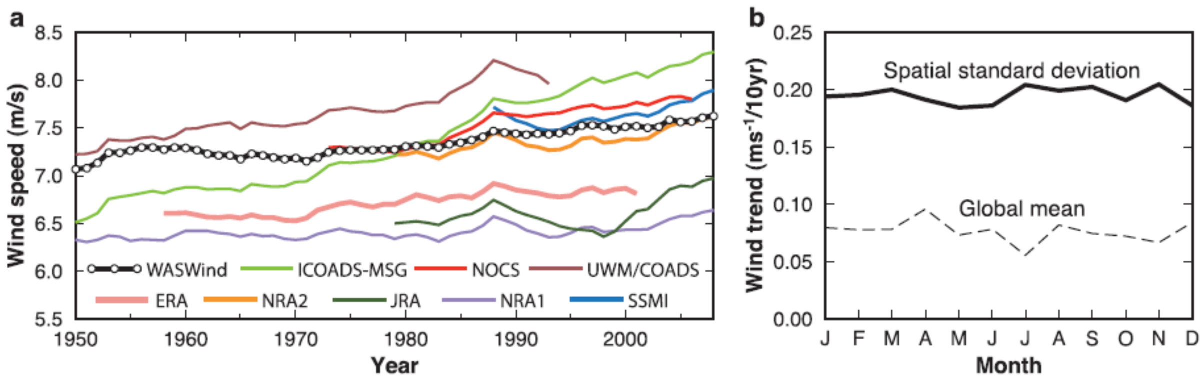



FIG. 14. (a) Time series of globally averaged annual scalar wind speed obtained from nine datasets. Each time series is smoothed with a 5-yr running average. (b) Spatial standard deviation of the scalar wind trend pattern (solid line in m $s^{-1}$ $decade^{-1}$) and the trend of global-mean scalar wind speed (dashed line in m $s^{-1}$ $decade^{-1}$) calculated from WASWind as a function of calendar month.

**Figure 3- trends in average wind speed based upon climate change (Tokinaga, 2011)**

The IPCC (2013) provided trends in the surface winds speeds (for 10 m elevation) between 1988 and 2010 for various climate models. Most models show an increase in the wind speeds in the area surrounding Mauritius; all show an increasing trend in the roaring 40’s, ranging between 0.1 and 0.5 m/s per decade (as shown in Figure 3-).

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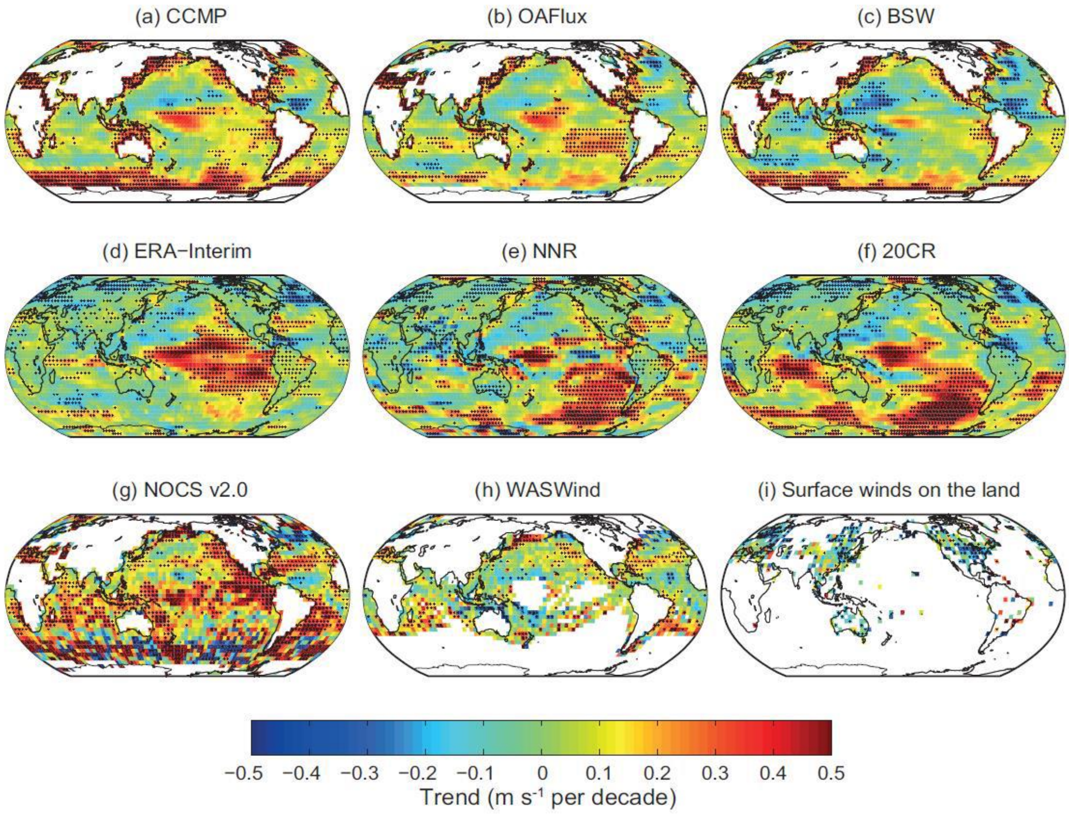



**Figure 3- Trend in wind speeds per decade for 1998-2010 for different climate models (IPCC, 2013)**

This decadal increase translates to between 1% and 5% for an average wind of 10 per decade; or 0.5% and 2.5% for two decades for an average wind of 20 m/s. There is a significant variation in the percentage change for the different models. For this study a decadal increase of 0.4 m/s is applied (for an average wind of 20 m/s); which translates to +5% increase in the wind speed by 2040, double that is applied for 2070.

**Table 3- Applied increase in wind speed**

| Design year (yr) | Change in wind speed (%) |
|---|---|
| **2020** | 0 |
| **2040** | +5 |
| **2070** | +10 |

### 3.8.4 Wind Regime

The wind rose for Fort William located at about 1 km to the south of the site shows the prevailing winds to be easterly's. SE winds are moderately frequent while that from the NE are less frequent. The wind climate is expected to show seasonal characteristics with an increase in the frequency of NW winds in summer months.

Due to its coastal location, the site is expected to be subject to sea and land breeze during day and night respectively.

### 3.8.5 Waves and Surges

To estimate the expected increase in wind-generated waves resulting from increased wind speeds, the approach detailed in the Coastal Engineering Manual (US Army Corps of Engineers, 2002) was used for fetch and duration limited waves. The expected significant wave height was calculated for different wind speeds, durations and fetches. Wave heights increased more for duration than fetch-limited conditions for the same wind speed increment. Based on these analyses the applied design values are provided in Table 3-.

Note that when modelling the effect of climate change in this study, these increases in wave heights were only used to increase the waves on the boundary of the regional wave model. When modelling cyclone waves and locally-generated wind-waves, the approach was to adjust the applied wind speed in the model and allow the model to predict the corresponding increase in wave height.

**Table 3- Applied percentage increase in wave height corresponding to a change in wind speed**

| Design Year (yr) | Change in Wind Speed (m) | Change in Wave Height (mm/yr) |
|---|---|---|
| **2020** | 0 | 0 |
| **2040** | +5 | +6 |
| **2070** | +10 | +15 |

## 3.9 Hydrodynamic Modelling for Baie du Tombeau Site

The results of the hydrodynamic modelling exercise carried out for the site is detailed in Table 3- below.

**Table 3- Summary design waves and water levels**

| Climate change scenario | Return Period | Tide (incl. residual)* (m MSL) | Wind and wave setup (m) | SLR since 1995 (m) | Design SWL (m MSL) | Sea | | Swell | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Maximum $H_{m0}$ (m) | $T_p$ (s) | Maximum $H_{m0}$ (m) | $T_p$ (s) |
| 2020 | 1-year | 0.36 | 0.14 | 0.1 | 0.60 | - | - | 0.7 | 6-19 |
| 2040 | | 0.36 | 0.14 | 0.25 | 0.75 | - | - | 0.8 | 6-19 |
| 2070 | | 0.36 | 0.14 | 0.55 | 1.05 | - | - | 0.9 | 6-19 |
| 2020 | 10-year | 0.41 | 0.84 | 0.1 | 1.35 | 0.7 | 2 - 6 | 1.1 | 8 - 14 |
| 2040 | | 0.41 | 0.94 | 0.25 | 1.60 | 0.7 | 2 - 6 | 1.3 | 8 - 14 |
| 2070 | | 0.41 | 0.99 | 0.55 | 1.95 | 0.8 | 2 - 6 | 1.4 | 7 - 14 |
| 2020 | 100-year | 0.41 | 1.24 | 0.1 | 1.75 | 0.8 | 4 - 8 | 1.5 | 8 - 14 |
| 2040 | | 0.41 | 1.24 | 0.25 | 1.90 | 1.0 | 4 - 8 | 1.6 | 8 - 15 |
| 2070 | | 0.41 | 1.29 | 0.55 | 2.25 | 1.2 | 4 - 8 | 1.7 | 8 - 15 |

*1-year return period values calculated as the 90th percentile of high tide levels (including residuals) for all months over the period of 1986-2016.
*10-year and 100-year return period values calculated as the 90$^{th}$ percentile of high tide levels (including residuals) for cyclone months only (Dec-Apr) over the period of 1986-2016.
***SLR**: Sea Level Rise.

## 3.10 Water Quality

The water quality of the coastal water is given by the Guidelines for coastal Water Quality (Government Notice 620 of 1999).

A water sample was collected for testing to get a better indication of the water quality at the site. The sampling location is shown in Drawing M190/BDT/EV/02.

The sample was tested against the requirement of the Guidelines for Coastal Water Quality (Government Notice 620 of 1999) for Category B – Recreation. The test results are presented in Table 3-.

**Table 3- Water Quality Test Results at Baie du Tombeau Site**

| Parameters | Results | Limits Category B Recreation | Units |
|---|---|---|---|
| **Temperature** | 26 | | ºC |
| **Dissolved Oxygen** | 6.90 | | mg/l |
| **COD** | 2.0 | 3 | mg/l |
| **Cyanide** | Not detected | 0.01 | mg $CN^-$/l |
| **Nitrate as N** | 0.18 | 0.8 | mg $NO_3$-N/l |
| **Oil & Grease** | Not detected | Not detectable | mg/l |
| **pH** | 8.08 | 7.5-8.5 | no units |
| **Phenols** | Not detected | 0.05 | mg/l |
| **Orthophosphate as P** | <0.01 | 0.08 | mg $PO_4$-P/l |
| **Total Suspended Solids (TSS)** | 19 | 5 | mg/l |
| **Arsenic** | 0.001 | 0.05 | mg/l |
| **Cadmium** | <0.001 | 0.02 | mg/l |
| **Chromium** | <0.001 | 0.05 | mg/l |
| **Copper** | <0.001 | 0.05 | mg/l |
| **Lead** | 0.003 | 0.05 | mg/l |
| **Mercury** | <0.000 | 0.0005 | mg/l |
| **Total Coliform** | <10 | 1000 | Verified Coliform/100ml |
| **Faecal Coliform** | <10 | 200 | Verified Faecal Coliform/100ml |

It is to be noted that level of total suspended solids (TSS) is above the requirements of the Guidelines for Coastal Water Quality (General Notice No 620 of 1999).

## 3.11 Biodiversity

### 3.11.1 General

An ecological study was carried out by Diospyros Ltd to provide the baseline terrestrial and marine ecological information to assist in the successful planning of appropriate coastal protection measures in relation to the biodiversity and ecosystems present at the site and their relative sensitivities to impacts.

The surveys and assessment of the coastal and lagoon ecosystems were done in terms of:

- the flora, fauna and ecological compositions, diversity, state of health
- the biotopes, species composition, their relative abundance and state of health
- the ecological sensitivity of the different biotopes
- the geomorphological zonation of the affected lagoon area.

The surveys were undertaken to identify the flora and the fauna and the main ecosystems present. The sites were walked through as required for ground-truthing and survey purposes. Aerial identification of the ecological zones and vegetation types was done with the help of Google Earth satellite imagery.

The study are comprises the coastal strip from the property boundaries along the shoreline to about 100 m into the lagoon.

The full Ecological Report is enclosed as Appendix B. The findings of the Report are presented in this subsection.

### 3.11.2 Terrestrial Environment

**Flora**

The terrestrial flora at the site is poor and comprises mainly one solitary badamier tree (*Terminalia catappa*) growing at the northern end of the site.

**Fauna**

No terrestrial fauna was seen except for a whimbrel *Numenius phaeopus,* which occasionally can be seen walking on the beach (Figure 3-).

**Figure 3- Whimbrel**

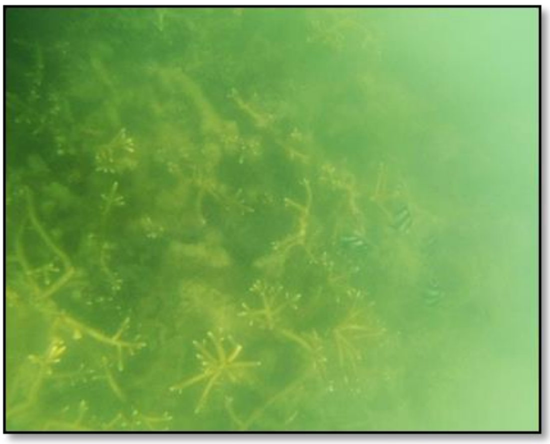
### 3.11.3 Marine Environment

**Flora & fauna**

The marine environment is similarly very poor. No life forms were visible for the first 50m into the lagoon.

Occasional live *Porites* massive coral heads (Figure 3-) could be seen here and there beyond the 50m limit from the shore.

Massive *Porites* boulder



Dead or partly recovering *Acropora*

**Figure 3- *Porites* and *Acropora***

Localised dead or partly recovering *Acropora* coral patches were noted in the lagoon. These can be seen as the dark areas next to the sea shore in Figure 3-. No other life forms were seen.

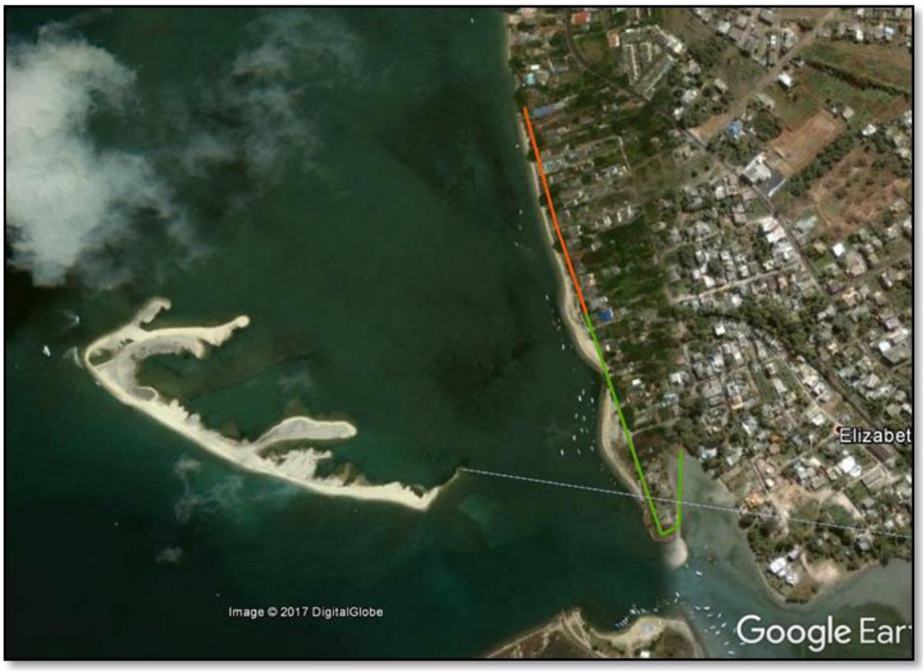



**Figure 3- Aerial view of site where darker ones in the sea shows coral patches**

The lagoon is particularly poor in biodiversity of which the only forms seen were dead or partly recovering *Acropora* and occasional *Porites* heads. The site can, therefore, be classed as being of very low sensitivity to impact. No particular care will be required for protection works on the site to prevent impacts on biodiversity.

## 3.12 Landscape and Aesthetics

Landscape and aesthetics cover all aspects of the environment that are considered to be of visual value.

The severely eroded coastline at the site has impacted negatively on the landscape. However, the coastal frontage and the beachfront view are considered to be of significant value, which need to be preserved. The following visual features are noted from the site:

- Sea and sand bars
- Harbour entrance
- Ships berthed and moored within the harbour area
- View of the container terminal.

## 3.13 Air Quality

The site is located immediately to the north of the port area, within and around which there are existing industrial activities that generate emissions to air. In this respect, the air quality at the site is not expected to be similar to the air quality at other coastal sites where no such industrial activities are present.

Therefore, it is expected that the air quality in the area where the site is located is influenced by emissions from the activities in the port area.

## 3.14 Traffic / Access to Site

The site is can be accessed from the Baie du Tombeau Road B 29 through Rue des Dorades and Rue des Capitaines. Two other untarred roads also give access to the site waterfront as shown in Figure 3-. Traffic along these internal roads is mainly generated by the residential area at the site and is quite low. Traffic level along B29 Road can be classified as medium to high during peak hours.

The access roads that lead to the site are quite narrow and are operated as two-way roads. These roads are about 3 to 4 m wide.

**Figure 3- Coastal road and access to site**

The coastal road is also a public bus route and is serviced by the United Bus Service and other private buses.

## 3.15 Noise

The noise level at the site reflects that of a small coastal village with local traffic being the main noise source. The noise level at the site, being located some 450 m from the Mer Rouge Container Terminal and Mauritius Freeport Development, is also expected to be influenced by the activities being carried out in the port area.

## 3.16 Land Ownership

According to information obtained on site and from stakeholders, land at the site is privately owned.

The waterfront is under the jurisdiction of the Mauritius Ports Authority.

## 3.17 Socio-economic Activities

### 3.17.1 Tourist Industry

No such activities have been identified at the site.

### 3.17.2 Fishing Activities

According to information obtained from the Ministry of Ocean Economy, Marine resources, Fisheries and Shipping, there are 175 registered fishermen at Baie du Tombeau and 103 registered boats.

Other than a rudimentary ramp in front of a private property, no facilities for the removal of boats from the sea is available at the site.

Fishing boats moor off the waterfront, mostly at the SE end. The boats draw up on the beach beyond the SE end of the site, and according to information obtained on site, are removed from the water at the onset of a cyclone.

During the site surveys, fishermen were seen to use Rue des Dorades for vehicular access the coastline.

### 3.17.3 Other Activities

Simla Way, a supermarket, is located along B29 Road at some 250 m to the ENE of the site.

## 3.18 Consultation with Stakeholders

### 3.18.1 Ministries and Authorities

Consultations were held with the relevant ministries and authorities at inception and preliminary design stages of the project to obtain more information about the site and to have a better appreciation of the functional requirements at this particular site.

The public bodies consulted include:

- Ministry of Housing and Lands
- Ministry of Public Infrastructure
- Ministry of Ocean Economy, Marine Resources, Fisheries and Shipping
- Ministry of Local Government
- Ministry of Tourism
- Mauritius Oceanography Institute
- Forestry Services
- National Coast Guard
- Traffic Management and Road Safety Unit
- Beach Authority
- District Council of Pamplemousses
- National Heritage Fund
- Mauritius Ports Authority.

The consultations were held on the following dates:

- 26 December 2016
- 16 January 2017
- 20 January 2017
- 28 February 2017
- 31 March 2017
- 4 July 2017.

### 3.18.2 Public Consultation

During the earlier stages of the project, the Consultant’s team has interacted with members of public met at the site. These interactions aimed at gathering existing information about the site specificities and were informal.

Consultations at community level at the site have not been carried out yet. The MSSESD intends to conduct public consultation at a later stage of the project.