Metropolis Pacific

Telios Corporate and Consultancy Services

Mamara New Capital City Development Phase 1

Environment Impact Statement

Chapter 4: Climate Change and Disaster Risk Assessments

Combined report

August 2020

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Abbreviations

ARI – Annual Return Interval

CSIRO – Commonwealth Scientific and Industrial Research

DEM – Digital Elevation Model

ENSO - El Nino Southern Oscillation

GCM – Global Climate Models

GIS – Geography Information System

LDA – Land Development Authority

LiDAR – Light Detecting and Ranging

MECDM – Ministry of Environment, Climate Change, Disaster Management and Meteorology

MS – Microsoft

PACC – Pacific Adaptation to Climate Change

PCCSP – Pacific Climate Change Science Program

PCRAFI -Pacific Catastrophe Risk Assessment and Financing Initiative

RCP – Representative Concentration Pathways

RH – Relative Humidity

SI – Solomon Islands

USD – United States Dollar

WACOP – Wave and Coast of Pacific

Figures and Tables

1 SITE DESCRIPTION

The Mamara new capital city development is located west of Honiara city in the Tandai ward of Guadalcanal province. The current development covers an area of approximately 698,761 square metres and lies between Poha Bridge and Mamara stream. The site was bounded by Mamara stream in the west, LDA in the east, the main road in the north and the settlements of Borosughu and Vatuluma in the south. The map below shows the propose site of the development (Figure 1).

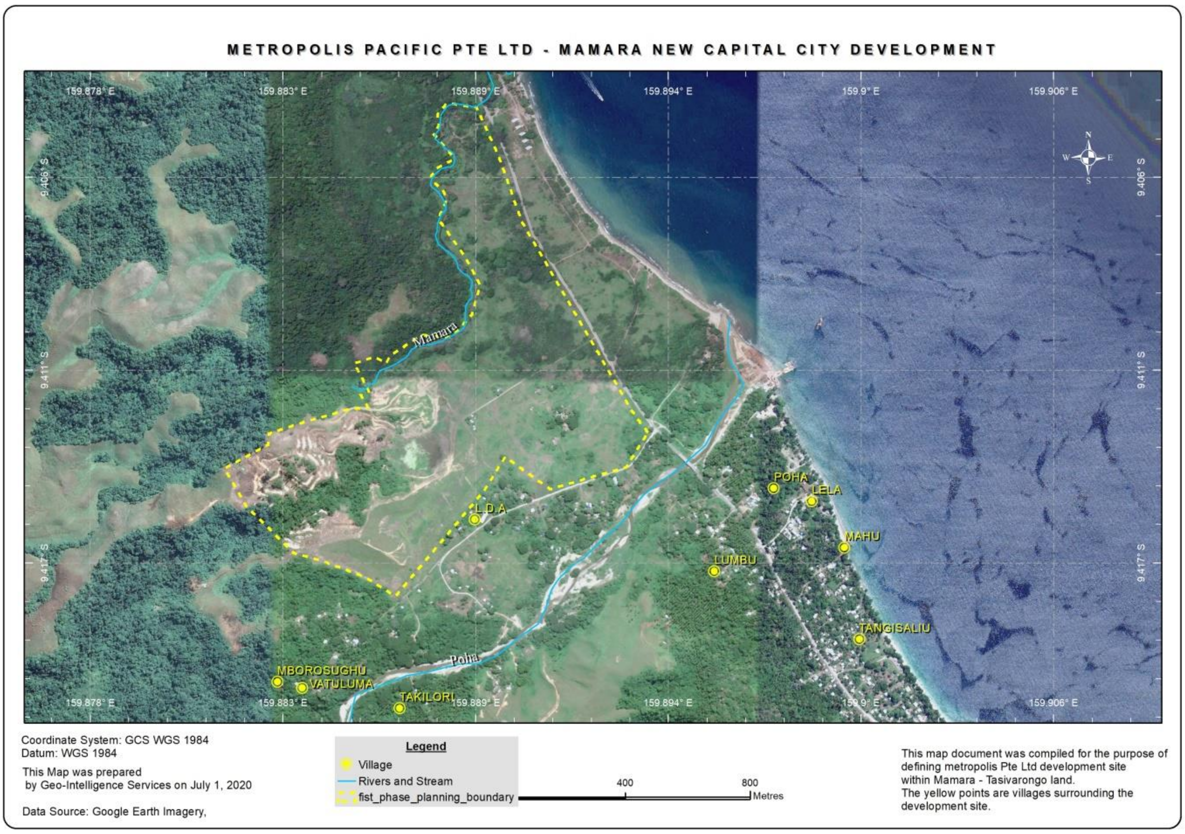


Figure 1: Map showing the general boundary of the development site

1.1. Geology and Bio-physical Environment

Poha valley and coastal region lies within the Central geological province according to Coleman's classification (Coleman, 1965). Inland geology is dominated by the Poha diorite formations bounded by outcrops of the Miocene Mboneghe limestone (Hackman, 1980). In the Northern ridges of Poha catchment, the limestone exposed into steep ridges and outcrops to a greater or lesser extent to the eastern and western ridges. Towards the coast, the limestone are fronted by grass escarpment set on the Pleistocene Honiara beds, 'a group of calcareous sediments of varied lithology which rise from the sea as series of three or four terraces'(Hackman, 1980). In some areas, these sediments rest on a poorly know

Lungga beds. Alluvial deposition is generally restricted within the Poha valley with sediments being largely confined to small fans at river mouth.

General topography of this area consists of dissected terrain with narrow ridge tops and steep ridge slopes. Narrow valley as seen in the Poha catchment, is prone to flash flooding during extreme rainfall events. These topographic features influence settlement and subsistence pattern within the study area. Villages are generally restricted to ridge tops and subsistence gardens utilise flood plains and steep hill side slopes.

Guadalcanal has a general pattern of uplift in the north-west and south-east and subsidence in the north-east and south-west. The low coastal terraces running from the north-west cape to Honiara is Holocene in age and represents the only formation of this type to have emerged in the past 50,000 years (Sherwood and Howorth, 1996). This phenomenon also contributes to the general topography and geomorphology of the Poha – Mamara area.

Bio-physical environment is characterized by grassland of *Themeda Australis* and *Imperata cylindrica* and small patches of lowland and swamp forests. A detail vegetation history reveals that massive grassland extensions occur at the expense of forest taxa are the results of burning events consistent with forest clearance (Haberle, 1996).

Past human activities such as farming, settlement and road works had altered the bio-physical environment within the development site.

1.2. Natural Hazards and Disasters

Meteorological, hydrological, and geologic hazards had significantly impacted the Solomon Islands since the 1900s causing significant economic losses as well as loss of lives. Over the past 90 years, the Solomon Islands were struck by more than 70 natural disasters affecting more than 430,000 inhabitants (Committee for Development Policy, 2018). Solomon Islands is expected to incur, over the long term, average annual loss of USD 20 million due to Earthquake or Tropical Cyclone (PCRAFI, 2015). In the next 50 years, the Solomon Islands has a 50 percent chance of experiencing a single event loss exceeding USD 240 million and a 10 percent chance of experiencing a single event loss exceeding USD 520 million (PCRAFI, 2015).

The positions of individual Islands and geographical regions of larger islands, in relation to plate tectonic boundaries, latitude and longitude as well as their size and topography, determines the incidence to natural hazards (Radford and Blong, 1992). As a result of these variability, each islands and separate geographic areas within larger islands have to be studied individually to determine their exposure to determine their vulnerability to hazards.

In the case of Guadalcanal, incidences to natural hazards impacting the north-west geographic region include Tropical Cyclone associated with heavy rain and strong wind, flash flooding due to heavy rainfall, landslide, drought, storm surge, earthquake, tsunami, and volcanoes.

Meteorological hazards cause considerable damage and loss to livelihood, wellbeing, and infrastructures in north-west Guadalcanal. The local communities had suffered widespread damage to housing and food gardens including loss of life. An estimated 52,000 people were affected, 2000 people being displaced and 13 people killed or drowned during the heavy rainfall following a Tropical Cyclone in 2009 (Lal and Thurairajah, 2011b). The main road west of Honiara was overtopped with water leading to major damage on existing bridges, wet crossings, fords, causeways, extended bridge slabs and bridge wing walls.

1.3. General Objectives

The general objectives of this study are:

i. To provide descriptions of the development site in relation to hydro-meteorological and geophysical hazards
ii. To provide information on projected climate scenarios and the expected impacts onto Mamara new capital city development site.
iii. To provide adaptation and mitigation options to reduce the chances of hydro-meteorological and geophysical hazards incurring damage to the development.

1.4. Rationale and Justification

The need to harmonized development activities with natural occurring hazards provides guidance on analyzing disaster risk-related consequences of developmental activities as a result of their environmental impacts, as well as the potential threat posed by natural hazards to the project.

Guadalcanal is located in an area known for frequent Tropical Cyclone as well as active seismic activities. It is exposed to hydro-meteorological and geophysical hazards. Previous hazard events incurred the loss in millions of dollars to the National Government and aid donor's budget.

Assessment on climate and disaster is important for the purpose of mitigating the expected impacts posed by Hydro-meteorological and geophysical hazards at different phases of development within Mamara New Capital City.

2. CLIMATE AND METEOROLOGICAL DESCRIPTIONS OF DEVELOPMENT SITE

2.1. Brief overview of Solomon Islands and local climate and weather

The climate of Solomon Islands is hot and humid all year round, with an average temperature of 27 degrees Celsius. There are two distinct seasons; a wet season from November to April and a dry season from May to October. The temperatures are strongly tied to changes in the surrounding ocean temperature. Warmest months are January, February, March, April, May, October, November, and December (31°C). Months with the lowest average temperature are July and August (29°C).

The weather and climate is determined by the seasonal movement and development of the equatorial trough; a belt of low pressure that migrates between hemispheres following the apparent movement of the sun, and the subtropical ridge of the southern hemisphere (a belt of high pressure typically located at about latitude 30 to 35 degrees south). During January to March the equatorial trough is usually found close to, or south of the Solomon Islands, and this is a period of West to North-westerly monsoonal winds (National Meteorological Services, 2018). The heaviest rainfall at most places occurs at this time. The equatorial trough is in the Northern hemisphere from May to October and the Islands in the north experience stronger and more persistent Southeast trade wind blowing from the subtropical ridge towards the equatorial trough. These winds are moisture bearing resulting in heavy rainfalls during the South-easterlies on the windward side of most large islands.

The average annual rainfall ranges from 3000 to 5000 mm with the majority of monthly rainfall exceeding 200 mm. The wettest months are during the Northwest monsoon season, with a tendency for reduced amounts during February when the equatorial trough is normally furthest south. Places on the southern sides of the larger islands also tend to have a rainfall maximum between June and September.

Orography plays an important role in rainfall distribution within and among islands. Depending on the local topography, rainfall could be expected to increase with elevation with a maximum at about 600-1000 metres above sea level on windward slopes. The heaviest average yearly rainfall could reach 9000mm at some elevated sites. The extreme falls often occur between the months of December to April when the equatorial trough migrates across the islands. Heavy daily falls can also occur during the South-easterly season at places well exposed to the prevailing wind.

2.2. Aim and objective of climate and meteorological data analysis and reporting

The objective of the climate, meteorological data analysis and reporting is to understand the climatic conditions of the development site so that a better plan, design and approach is taken to minimise the impact of daily, monthly, seasonal and annual weather and climate variations from rainfall, humidity, wind velocity and temperature.

2.3. Brief description on data collection, processing, and analysis

The climate and meteorological data for Honiara Met Station is being used towards the analysis of the weather and climate conditions of the development site. The Honiara Met Station is the closest to the development site and is located at latitude -9.434800 and longitude 159.954200, at Vavaya Ridge in Central Honiara, approximately 7Km to the east of the development site. There is no historic climate data collected in the past for the exact development site, and hence available climate data from the Honiara Met Station is been used as the best proxy. Existing literature and analyses by scholars and the climatology section of the Solomon Islands Meteorology Service are used. For this section, most of the information and analysis done by Mr Milton Galokale Keremama towards his Master's Degree in 2013, entitled; "Solomon Islands: Historical and projected Rainfall and Temperature Trends and Variability" has been used.

2.4. Rainfall analysis for Honiara

The digitised daily rainfall recorded from 1955 to 2011 are used to calculate the monthly and annual climatological values of rainfall indices (variables) for 1981 to 2010 period.

Table 1 Climatological normal of rainfall indicators for Honiara based on 1981 - 2010

Variables	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Average rainfall (mm)	230.9	275.8	280.9	174.3	136.3	78.7	96.6	96.6	91.3	125.5	152.6	207.8	1947.4

Highest monthly rain (mm) (Byrne *et al.*)	569.4 (Environment Reguation 2008)	600.8 (1999)	582.7 (1997)	547.7 (Environment Reguation 2008)	428.9 (2000)	201.1 (1994)	232 (2002)	272.6 (1998)	181.2 (2002)	268.9 (2004)	453.4 (1988)	549.4 (1988)	2725.2 (Environment Reguation 2008)
Lowest monthly rain (mm) (Byrne *et al.*)	35.9 (2007)	71.4 (1990)	66 (1981)	56.3 (1998)	24 (1981)	0 (1987)	4.6 (1997)	30 (1987)	19.1 (1994)	9 (1985)	15.4 (1995)	16.4 (1991)	1264.4 (1993)
No. of wet days ≥10mm	188	228	215	144	110	80	82	83	82	98	125	140	1575
No. of high rainfall events (61.4 - 99.9 mm)	14	20	13	10	7	0	2	2	3	4	11	12	98
No. of rainfall events (≥100 mm)	2	4	12	1	1	1	0	1	0	1	4	6	33

Source: Milton Galokale Keremama, 2013

As shown in table 1, the rainfall in Honiara is highly variable. The average annual rainfall climatological normal is for the period 1981-2010 shows that Honiara received an average annual total of rainfall of 1947.3 mm, with March recorded with the highest rainfall of at 280.9 mm, while June was recorded with the lowest rainfall on average at 78.7 mm (Figure 2).

Most (approximately 2/3) of the annual rainfall fell during the wet season (Nov-Apr) and the remaining rainfall (approximately 1/3) fell during the dry season (Figure 2).

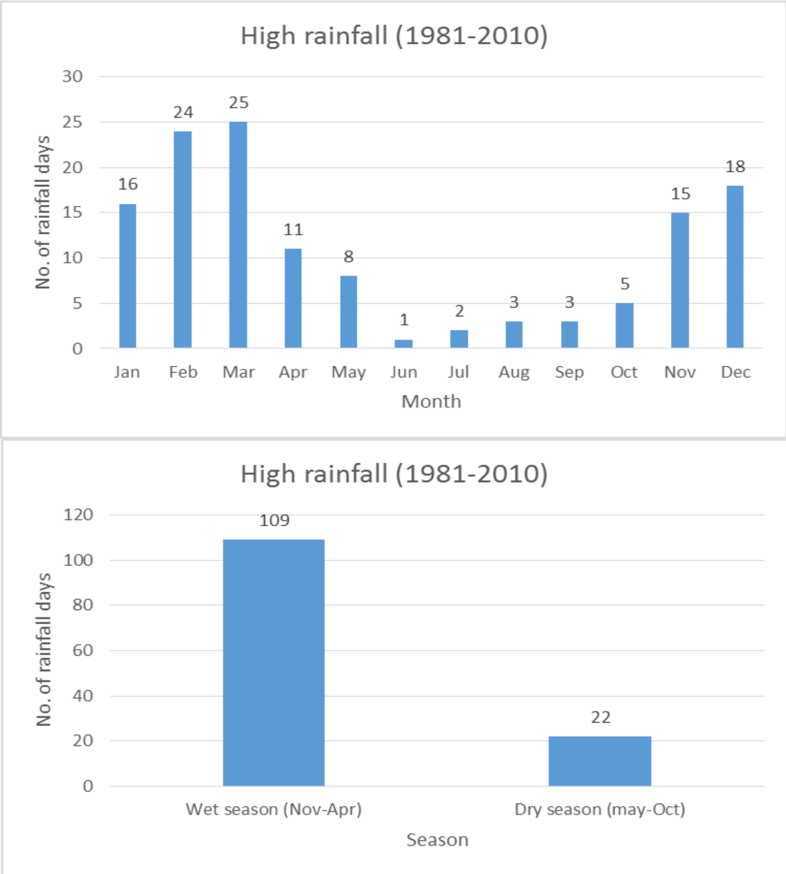


Figure 2: Average rainfall per month including wet and dry seasons for Honiara from 1981 – 2010

2.4.1. Average annual rainfall

Over the period 1955-2011 (57 years), there has been substantive variation in annual rainfall for Honiara. The rainfall anomalies fluctuated between the highest rainfall anomaly that peaked above normal of 1947.3 mm (+49.8%) in 1967 and the lowest rainfall anomaly below the normal (-35.1%) in 1993. The average annual rainfall has decreased by 1.7%/annum at Honiara from 1955 to 2011.

2.4.2. Rainfall anomalies of Wet and Dry Season

The average rainfall anomalies during the wet season (Nov-Apr) peaked above the wet season average of 1322.3 mm at 55.5% in 2008, with the lowest anomaly at -37.7% in 1993. The 2008 anomaly was affected by the La Nina event of that year. 1993 anomaly was affected by the El Nino event of that year. It is found that ENSO has greater impact on the wet season (Nov-Apr) than the dry season.

The decadal variability is also more pronounced on the wet season rainfall than on the dry season rainfall for Honiara from 1955 to 2011.

The mean temperature anomalies during the dry season (May-Oct) peaked above the dry season average of 625.0 mm at almost 60% in 1967, with the lowest anomaly at -60.3% in 1966. Note that 1967 was an ENSO neutral year. The negative and positive anomalies of 1966 and 1967 respectively are largely associated with the natural inter-annual variability.

2.4.3. Wet days at Honiara

For the period of 30 years (1981-2010) February and March were observed to have the highest occurrence of wet days with 228 and 215 wet days respectively, whilst June through September were observed with the least occurrence of wet days with an average of 82 wet days. Most wet days clearly fall within the wet season while least wet days fall within the dry season.

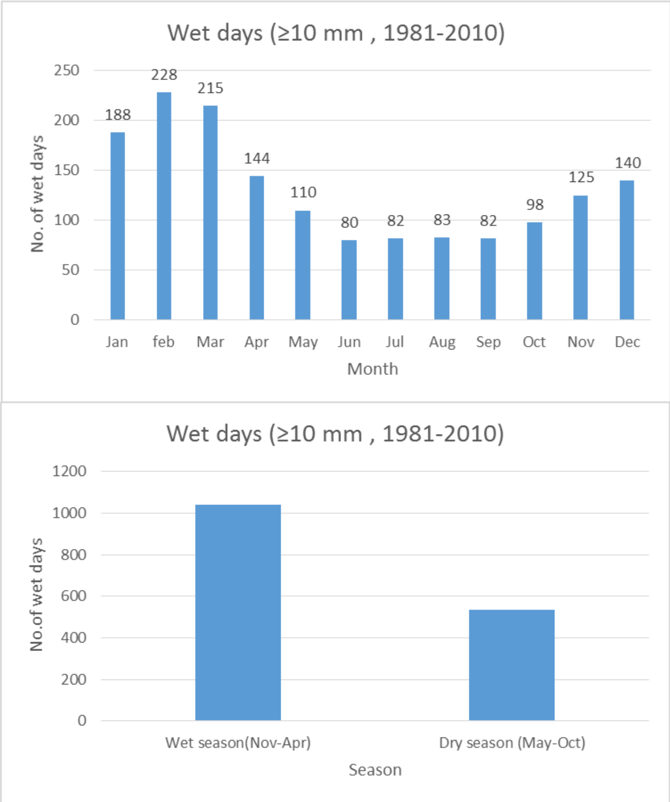


Figure 3: The number of wet days (≥10 mm) per month and seasons in Honiara from 1981 to 2010

2.4.4. High rainfall events

From 1955 to 2011, Honiara Met Station recorded its highest daily rainfall of 251.8 mm over a 12-hour period on 30 January 2009. This record was later broken on 4 April 2014 when Honiara Met Station recorded over the same period 317.6 mm of rainfall. The highest monthly total rainfall for the period 1955 to 2011 was 955.8 mm in January 1972, whilst the lowest monthly rainfall was at 0mm in June 1987. The highest annual total rainfall was 2916.4 mm in 1967, whilst the lowest annual total rainfall was 1264.4mm in 1993 (Figure 4).

A total of 131 high-rainfall events (61.4 to 99.9 mm) were observed at Honiara from 1981 to 2010 period. February and March were observed with the highest occurrence of high rainfalls, whilst June and July were observed with the least high rainfalls (Figure 4).

On seasonal basis, of the total of 131, 83% of high rainfall occurred during the wet season and 17% occurred during the dry season at Honiara from 1981 to 2010 (Figure 4).

On annual basis, 1999 had the most occurrences of high rainfalls (11 events), whilst no high rainfall events were recorded in 1993 at Honiara from 1981 to 2010. There is an increasing trend in the annual number of high rainfall events at Honiara during the period 1981 to 2010.

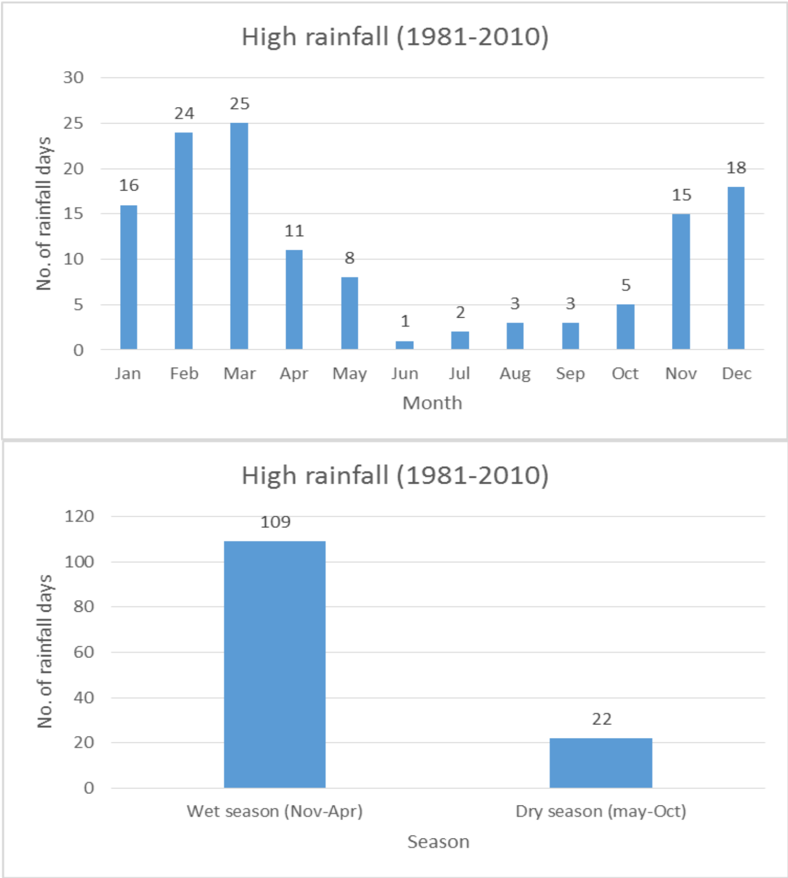


Figure 4: The number of high rainfall events (daily rainfall of 61.4mm - 99.9mm) per month and seasons for Honiara from 1981 to 2010

2.5. Surface Air Temperature Analysis for Honiara Met Station

The digitised daily temperature recorded from 1951 to 2011 is being used to calculate the monthly and annual climatological values of temperature indices (variables) for 1981 to 2010 period (Table 2).

Table 2: Climatological average for surface temperature in Honiara from 1981 to 2010

Variables	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tmean (ºC)	27.6	27.5	27.5	27.6	27.5	27.2	26.9	26.9	27.2	27.3	27.6	27.7	27.4
Tmax (ºC)	31.3	31.2	31.1	31.3	31.2	31.1	30.8	30.9	31.2	31.2	31.5	31.4	31.2
Tmin (ºC)	24.0	23.8	23.9	23.8	23.8	23.3	23.0	23.0	23.2	23.3	23.6	23.9	23.6
Warm days	17	14	7	3	7	2	4	6	7	14	13	21	115
Cool days	6	17	4	10	7	12	16	11	11	4	2	7	107
Warm nights	22	17	6	7	11	3	2	2	6	9	12	21	118
Cool nights	0	0	4	5	1	7	23	33	12	18	10	2	115

Source: Milton Galokale Keremama, 2013.

The mean surface temperature (Tmean) at Honiara during the 30-year period from 1981 to 2010 was 27.4ºC, with December and January being the warmest months with daily average temperatures of 27.7ºC and 27.6 ºC respectably. July and August were the coldest months with mean surface temperatures of 26.9ºC. The average annual mean temperature during the wet season (Nov- Apr) was 27.6ºC and the average mean temperature during the dry season (May-Oct) was 27.2ºC.

The average annual maximum surface air temperature (Tmax) was 31.2^{o}C, with November at 31.5^{o}C as the highest average daytime temperature whilst July and August being the months with the lowest average daytime temperature at 30.9^{o}C (Figure 5). The average annual maximum temperature during the wet season (Nov-Apr) was 31.3^{o}C and the average annual maximum temperature during the dry season (May-Oct) was 31.1^{o}C.

The average annual minimum surface temperature (Tmin) was 23.6^{o}C, with 24.0^{o}C in January as the highest night-time on average whilst the months of July and August being the coldest on average with 23.0^{o}C (Figure 5).

The average minimum temperature during the wet season (Nov-Apr) was 23.9^{o}C and the average annual minimum temperature during the dry season (May-Oct) was 23.3^{o}C (Figure 6).

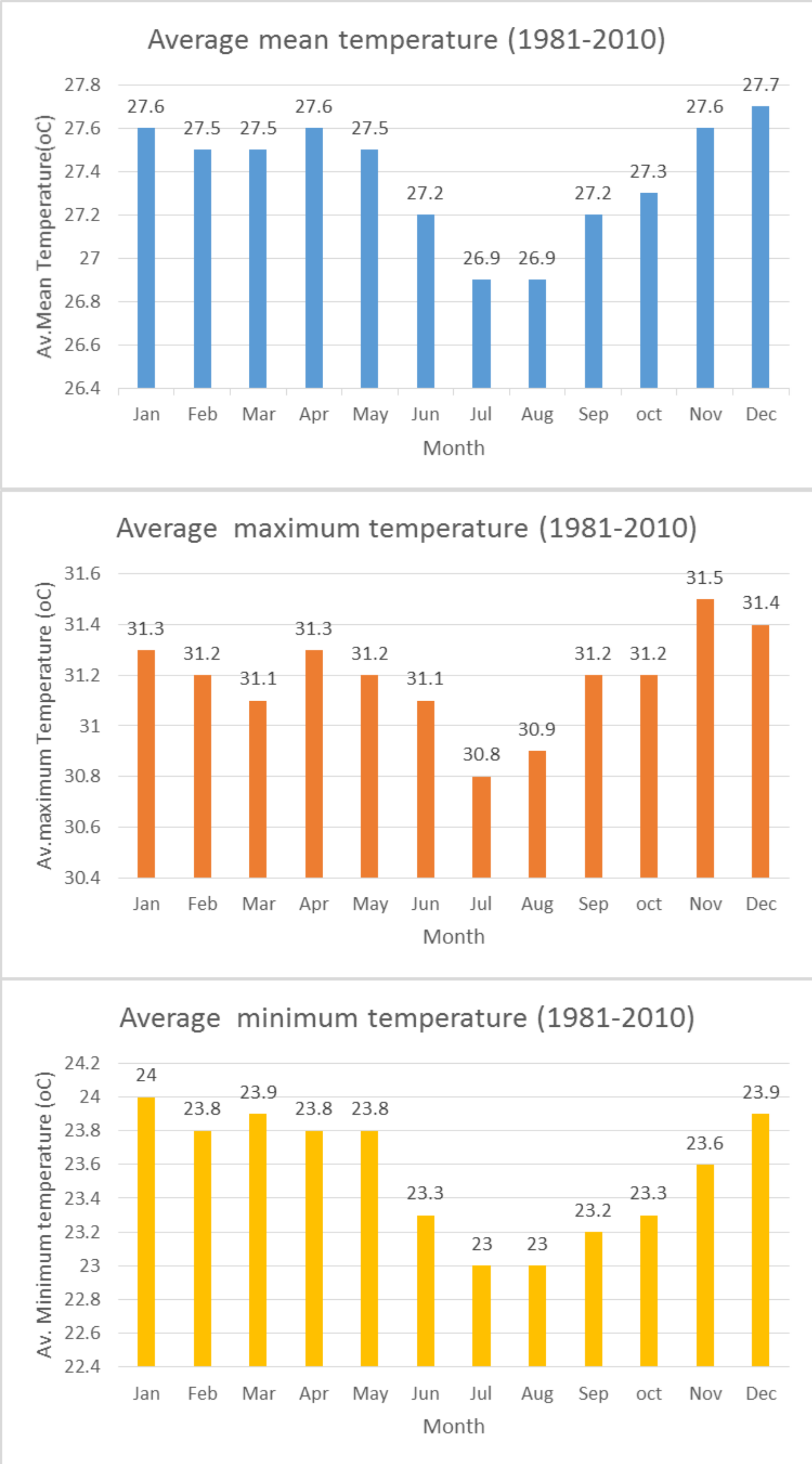


Figure 5: Monthly averages for mean, maximum and minimum temperatures for Honiara from 1981 to 2010

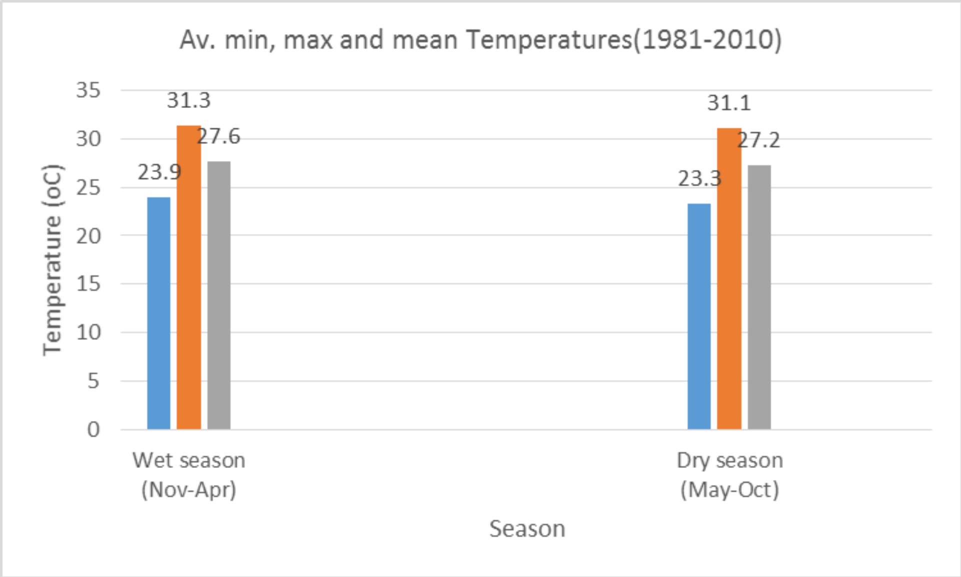


Figure 6: Seasonal averages for minimum, maximum, and mean temperature for Honiara from 1981 to 2010

2.6. Wind analysis for the development site

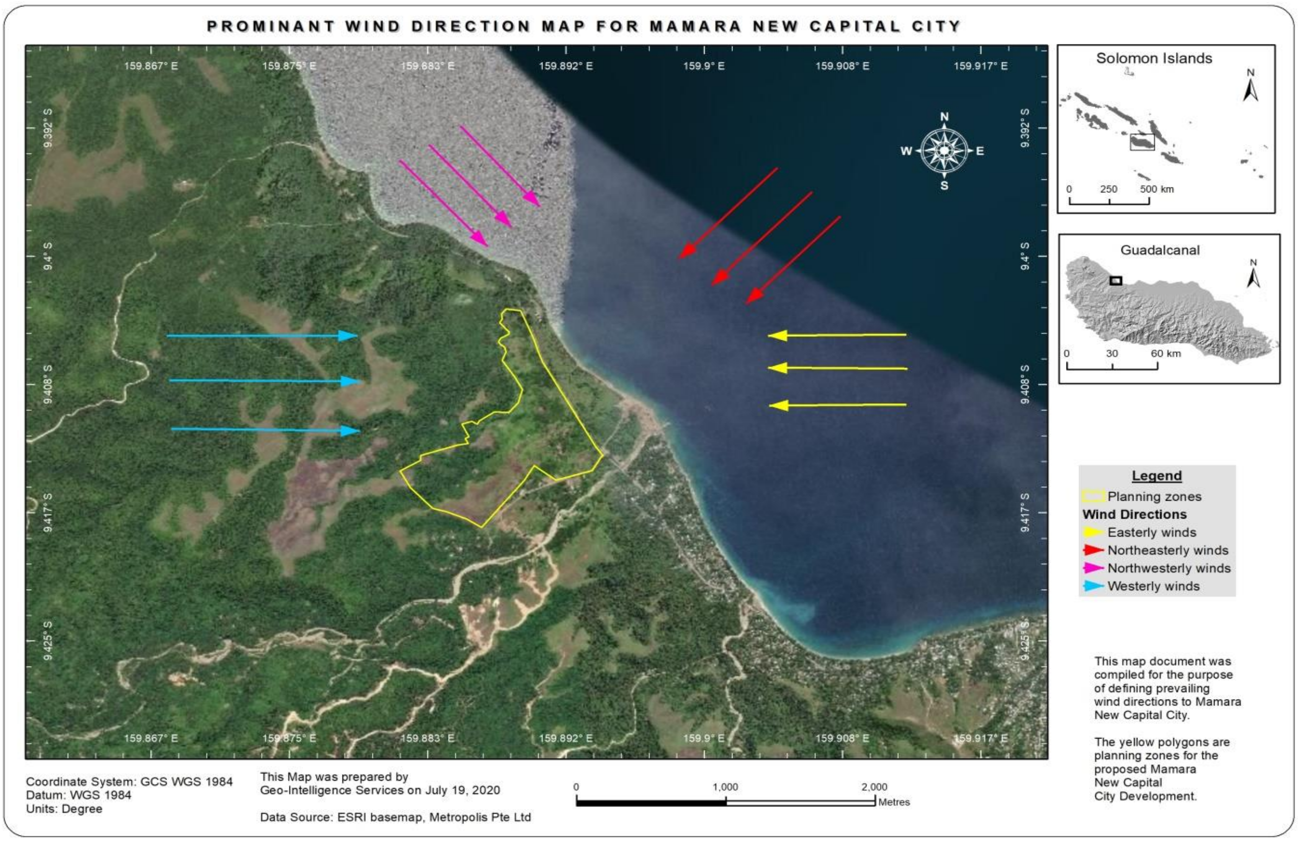


Figure 7: Wind direction map for the development site.

There is no consistent historical daily wind data record for Honiara Met Station. However, the wind analysis is based on the map above (Figure 7) which merely shows what direction of wind will have greater impact on the actual development site. From the actual geographical location of the development site as shown above and from onsite investigation, the actual site is vulnerable mostly to easterly and north-easterly winds. Persistent strong easterly winds normally occur during the dry season (May-Oct). Any coastal planning to protect or minimise the impact on the coastal area of the site should consider winds and accompanied waves coming from the easterly directions. Westerly winds should have lesser coastal impact on the site as wind velocity should be reduced by the hills and land points to the west of the site. Also, the site should not have major impacts from any southerly winds as the site should be protected by the hills and mountains to the south.

2.6.1. Relative Humidity analysis for Honiara

Daily Relative Humidity (RH) for Honiara Met Station is recorded twice daily – 9am in the morning and 2pm in the afternoon. Digitised daily RH data that is available from the Climatology Section of the SI Met Service for 9am is only available from 1 January 1966 to 1 December 1973. Digitised daily RH data that is available from the Climatology Section of the SI Met Service for 2pm is only available from 1 June 1987 to 1 January 2019. Given the two different periods for daily RH for 9 am and 2pm, it is not possible to calculate the mean daily RH for both periods. What is shown in the table below (Table 3) is the daily average RH for 9am for the period 1966 to 1973, and the daily average RH for 2pm for the period 1987 to 2019.

Table 3: Daily average Relative Humidity for Honiara

Period	Av. Daily RH for 9am (%)	Av. Daily RH for 2 pm (%)
1966-1973	72.75	Not available
1987 -2019	Not available	72.35

From Table 3 above, it is safe to say that the average daily RH for Honiara is between 72 % and 73 %. Also, monthly, seasonal, and annual mean RH cannot really be distinguished. However, further analysis is required to verify this statement.

2.6.2. Historical extreme climatic events

Table 4: Historical Tropical Cyclone Events for Solomon Islands from 1966 to 2020

Year	Name	Duration	Mean maximum wind speed (knots)
1966	Angela	14 to 19 November	73
1967	Dinah	23 January to 02 February	ND
1967	Barbara	16 to 22 February	ND
1967	Glenda	26 March to 08 April	63
1967	Annie	10 to 16 November	63

1968	Giselle	3 to 9 April	35
1968	Becky	10 to 15 November	ND
1969	Collen	27 January to 05 February	ND
1969	Esther	26 April to 02 May	ND
1970	Isa	13 to 18 April	34
1971	Ursula	02 to 16 December	100
1971	Althea	20 to 30 December	ND
1972	Carlotta	5 to 21 January	71
1972	Wendy	30 January to 09 February	ND
1972	Emily	25 March to 01 April	69
1972	Hannah	8 to 11 May	ND
1972	Ida	30 May to 03 June	52
1973	Madge	1 to 18 April	ND
1976	Alan	30 January to 02 February	ND
1976	Colin	26 February to 04 March	ND
1977	Norman	Date Unknown	ND
1979	Kerry	13 to 28 February	70
1982	Bernie	1 to 7 April	43
1985	Hina	12 to 17 March	95
1986	Namu	15 to 22 May	63
1987	Blanch	22 to 23 May	45
1988	Anne	09 to 14 January	6518
1989	Lili	06 to 12 April	75
1989	Meena	04 to 09 May	45
1991	Tia	14 to 21 November	72 to 93
1992	Betsy	06 to 08 January	45 to 55
1992	Esau	27 February to 04 March	80
1992	Innis	23 to 30 April	35 to 55
1992	Kina	26 to 28 December	30 to 50
1992/1993	Nina	30 December to 03 January	75 to 100
1993	Roger	12 to 13 March	34 to 47
1993	Rewa	28 to 30 December	45 to 65
1994	Tomas	23 To25 March	45 to 55
1994	Usha	24 to 26 March	40 to 50
1994	Vania	13 to 14 November	30 to 40
1996	Beti	22 to 28 March	ND
1996	Fergus	23 to 30 December	80
1997	Drena	3 to 6 January	90
1997	Justin	15 to 19 March	80
1998	Susan	2 to 5 January	125

1998	Katrina	6 to 8 January	60
1998	Yali	18 to 20 March	45 to 50
1999	Dani	18 to 20 January	85
1999	Ella	10 to 12 February	45
2001	Paula	04 February to 06 March	94
2002/2003	Zoe	31 December to 01 January	130
2003	Beni	25 to 31 January	111
2003	Gina	5 to 9 June	81
2006	Xavier	21 to 26 October	94
2006	Yani	16 to 26 November	76
2007	Daman	3 to 10 December	100
2010	Ului	09 to 14 March	116
2011	Yasi	26 to 31 January	84
2017	Donna	1 to 10 May	110
2018	Iris	20-24 March	53
2018	Liua	26-28 Sept	40
2019	Ann	7-18 May	51
2019	Rita	22-26 November	64
2020	Tino	11-20 January	64
2020	Harold	2-10 April	124

Source: Solomon Islands Met Service, MECDM

Information on cyclone events from the period 2012 to 2016 is still missing. The duration of each cyclone reflects the lifetime period of each cyclone and not necessarily the period when the cyclone is within Solomon Islands boundary.

From Table 4 above, most cyclones occurred in Solomon Islands in the month of January, followed by March, February, and April. Two obvious off-season cyclones occurred in Solomon Islands during this period; Cyclone Gina in 2003 and Cyclone Liua in September 2018.

2.7. Projection for Temperature and Rainfall

Rainfall and Temperature projections have been documented for Solomon Islands (Mimura et al, 2007; PCCSP Country Report, 2014). 18 GCMs (Global Climate Models) were carefully selected by PCCSP to generate temperature and rainfall projections for Pacific Island countries including Solomon Islands. Possible absolute annual temperature and rainfall were determined for 2030, 2055 and 2090 (Table 5).

Table 5 shows Projected change in annual mean temperature and total annual rainfall for Solomon Islands for three emission scenarios (A2, A1B and B1) at three future time periods (2030, 2055 and 2090).The range given represents changes in the average climate relative to 1981-2000 average (referred to as the 1990 baseline). The upper limits of the ranges (in yellow) under the high emission (A2) scenarios for the three future periods were considered for the calculation for possible magnitude of the average annual temperature and rainfall. Source: Australia Bureau of Meteorology & CSIRO 2011c, p213).

Table 5: Projected change in annual mean temperature and total annual rainfall for Solomon Islands for the three emission scenarios (A2, A1B and B1) for 2030, 2055 and 2090

Variable	Scenario	2030	2055	2090
Annual mean Temperature (°C)	Low emission (B1)	0.2-1.0	0.7-1.5	0.9-2.1
	Medium emission (A1B)	0.4-1.2	0.9-1.9	1.5-3.1
	High emission (A2)	0.4-1.0	1.0-1.8	2.1-3.3
Annual total rain (%)	Low emission (B1)	-8-10	-4-12	-3-15
	Medium emission (A1B)	-7-11	-5-15	-2-20
	High emission (A2)	-4-8	-5-13	-3-21

2.7.1. Temperature

The surface air temperature will continue to rise and Figure 8 shows the likely magnitude of the average minimum, maximum and mean temperatures under the high emission (A2) upper limit range at 1.0°C, 1.8°C and 3.3°C for 2030, 2055 and 2090 respectively. The upper range selected portrays the worst-case scenario possible by presenting the likely magnitude of average temperatures in the 21st century for Solomon Islands. This means the average annual maximum air surface temperature could possibly increase to 34.5°C by 2090 compared to 31.2°C, the 1981-2010 average (Figure 8).

Figure 8: Historic and possible future temperature for Honiara under high emission scenario (A2) with projected temperature change of 1°C by 2030, 1.8°C by 2055 and 3.3°C by 2090 based on 1990 baseline

2.7.2. Rainfall

The likely magnitude for the future average annual rainfalls under the high emission scenario (A2) is shown in Figure 9 below. From the upper limit range of 8, 13 and 21% for 2030, 2055 and 2090 respectively that are projected by PCCSP, the average annual rainfall at Honiara may increase to a value as high as 2356 mm by 2090 compared to 1947 mm (1981-2010). Do take note that there could be limitations (substantial margin of error) to the projections from the climate models used. The results herein should be treated with caution.

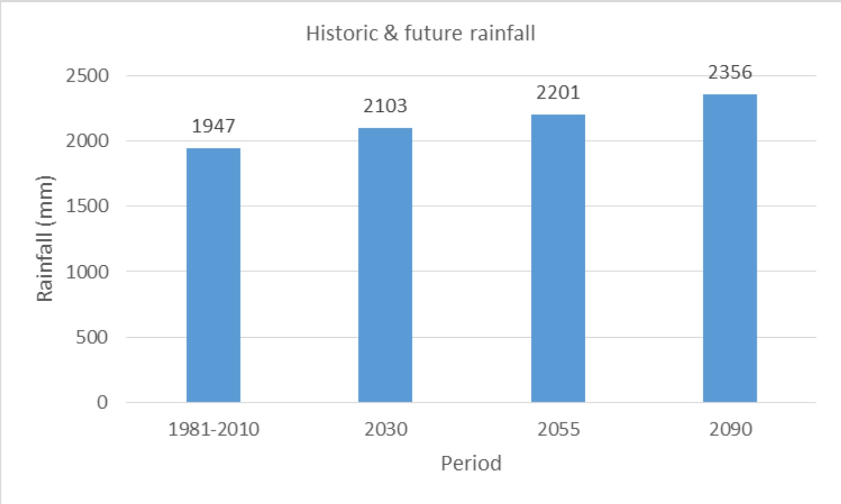


Figure 9: Historic and projected rainfall for Honiara Met Station under High emission scenario (A2) with projected rainfall change at 8% by 2030, 13% by 2055 and 21% by 2090 based on 1990 baseline

3. GEO-PHYSICAL DESCRIPTION

Northwest Guadalcanal is vulnerable to geologic hazards with various degrees of exposure and damages recorded from historical events. Geologic hazards such as earthquake, landslide, tsunami, and volcano are common and had historical records of their occurrence in Guadalcanal. This section of the report discusses some of the geological hazards that had occurred within close proximity to the Mamara New Capital City development sites.

3.1. Geologic Hazards

In most cases, geologic hazards are naturally occurring hazards as a result of geo-physical processes happening within the earth's crust. Generally, seismic activities due to the under thrusting of the Australian and the Pacific plate boundaries is the main trigger of geologic hazards.

3.2. Aim and Objectives

The aim of this section of the report is to understand the context of geologic hazard in northwest Guadalcanal and surrounding the development site. The objects are:

i. To determine the spatial distribution of geologic hazard in northwest Guadalcanal
ii. To determine the local context of geologic hazard surrounding the development site
iii. To suggest mitigation options for geologic hazards to the proposed development.

3.3. Data collection and analysis

Data and information on geologic hazards were retrieved from literatures, reports, and online databases. Reports and publications on geologic hazards' occurrence and impact in the Solomon and on Guadalcanal were consulted and the data was collated into MS Excel sheet. Data on seismic activities were retrieved online from Geoscience Australia and PAGER-CAT websites. Data on seismic hazards in the Solomon Islands was obtained from Seismology department at the Ministry of Mines, Energy and Rural Electrification. The data were analyzed and mapped in GIS environment.

3.4. Volcanoes

Volcanoes can be described as mountains that opened downwards to a reservoir of molten rocks. Volcanic eruptions are one of the earth's most dramatic and violent agents of change on the earth's surface. Powerful large-scale eruptions are recorded in the past and could lead to catastrophic consequences to present developments within Solomon Islands.

Savo is a pelean type volcano and is about 30 kilometers northwest of Mamara new capital city development site. It is classified as quiescent volcano meaning neither active nor dormant. Historical records showed 5 eruptive events had taken place between 1500s to 1900s. The Toghavitu (1560 – 1570) and the 1847 eruptive events constitute a loss of lives of approximately 7000 and 500 people including properties (Petterson *et al.*, 2003). Most of the death are buried by ash and landslide (Radford *et al.*, 1991).

Savo has been dormant for more than a century but the important factor to consider is its eruptive style. Studies of recent tephra deposits reveal that Savo consistently erupts acid andesitic to dacitic block-rich ash flow with related pyroclastic air fall and surge activity. These eruptions are potentially highly dangerous to Mamara New City due to its close proximity to Savo.

The level of impact that can be attributed from volcanic hazards to the Mamara New City due to tephra fall depends on the directions of prevailing winds and the erupted volume of earth materials. A large scale eruption could affect a radius of up to 100 kilometers and a moderate scale eruption could affect a radius of 50 kilometers around the volcano (Petterson *et al.*, 2003). The given radius indicates that Mamara New Capital City development is within the potential risk area of tephra fall for moderate and large-scale eruptions. Map below (Figure 10) shows potential risk areas of tephra fall.

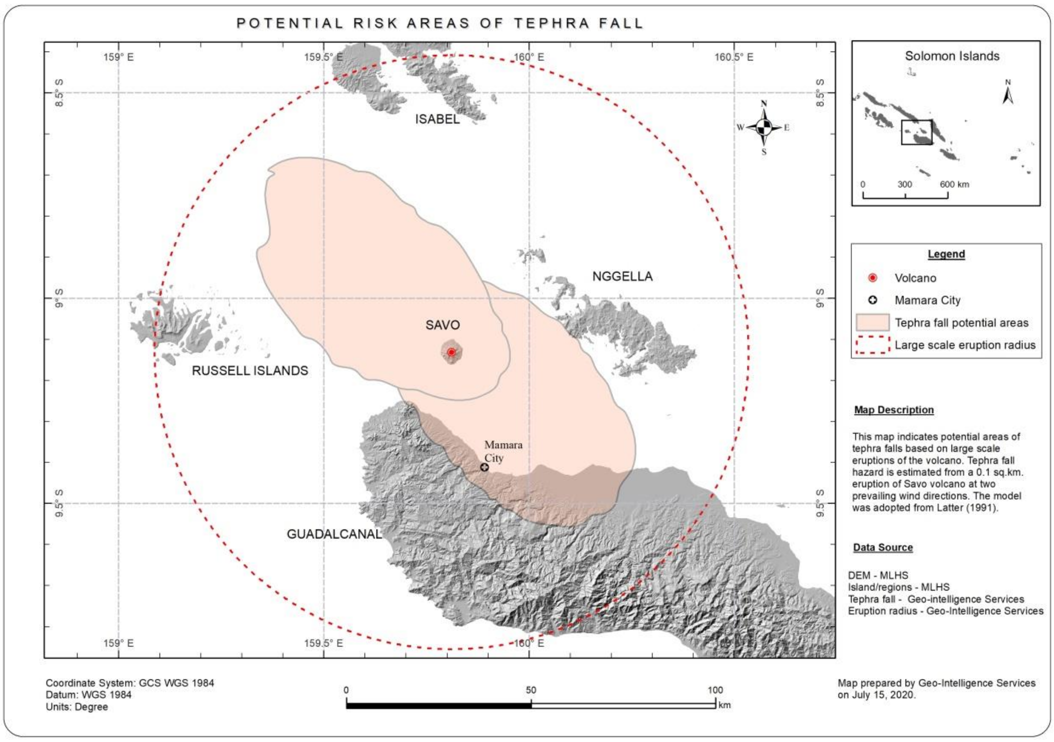


Figure 10: Map indicating the potential risk areas for tephra fall during moderate to large scale eruptions depending on the wind directions.

3.5. Earthquake, Landslide and Tsunami

Solomon Islands normally experience earthquake and tsunami since it is located above the collision zone where the Indo-Australian plate is subducted beneath the Pacific plate. Occurrences of destructive earthquakes have been documented on Guadalcanal and other large islands since the 1900s. There have been records of historical earthquakes that caused the destruction of land and properties including loss of lives as a result of landslide and tsunamis in northwest Guadalcanal. Figure 11 shows distribution of shallow earthquake with magnitude greater than 5 Mg.

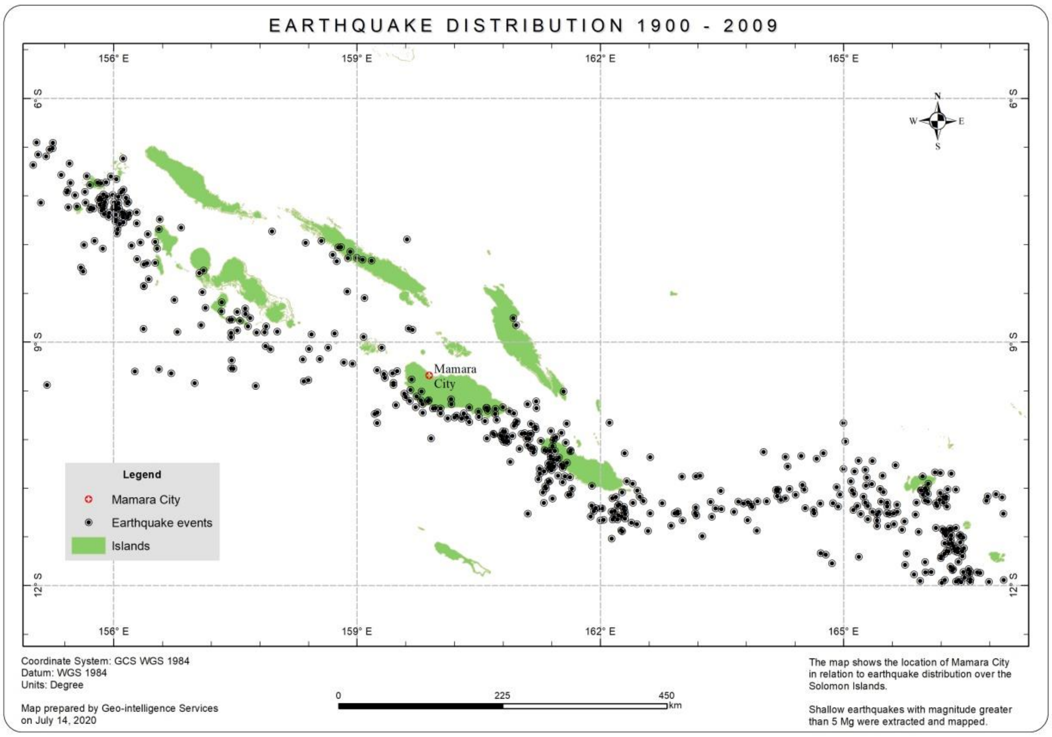


Figure 11: Distribution of shallow earthquakes with Magnitude greater than 5 Mg from 1900 to 2009

Earthquakes results in various degrees of damage have been recorded on Guadalcanal. Direct damages have resulted from ground shaking, ground subsidence and liquefaction while secondary damages result from landslides on steeper slopes and by tsunami along the coastline. The table in appendix 1 shows the impacts of earthquake and associated hazards within proximity to the Mamara New Capital City development site on Northwest Guadalcanal.

Mamara New Capital City development is approximately 40 kilometers northeast of the San Cristobal Trench. This distance indicates that the proposed city is exposed to damages from ground shaking, ground subsidence and liquefaction. Damages from landslide and local tsunami are expected to be minimal as the site is flat and sheltered from tsunami waves. Figure 12 shows Mamara new city in relation to the locations of previous earthquakes that generate tsunami waves and landslides impacting villages around Selwyn College and Visale in west Guadalcanal. Figure 13 determines areas that will be susceptible to landslide because of the ground shaking caused by shallow earthquakes with magnitude of 5 Mg and above.

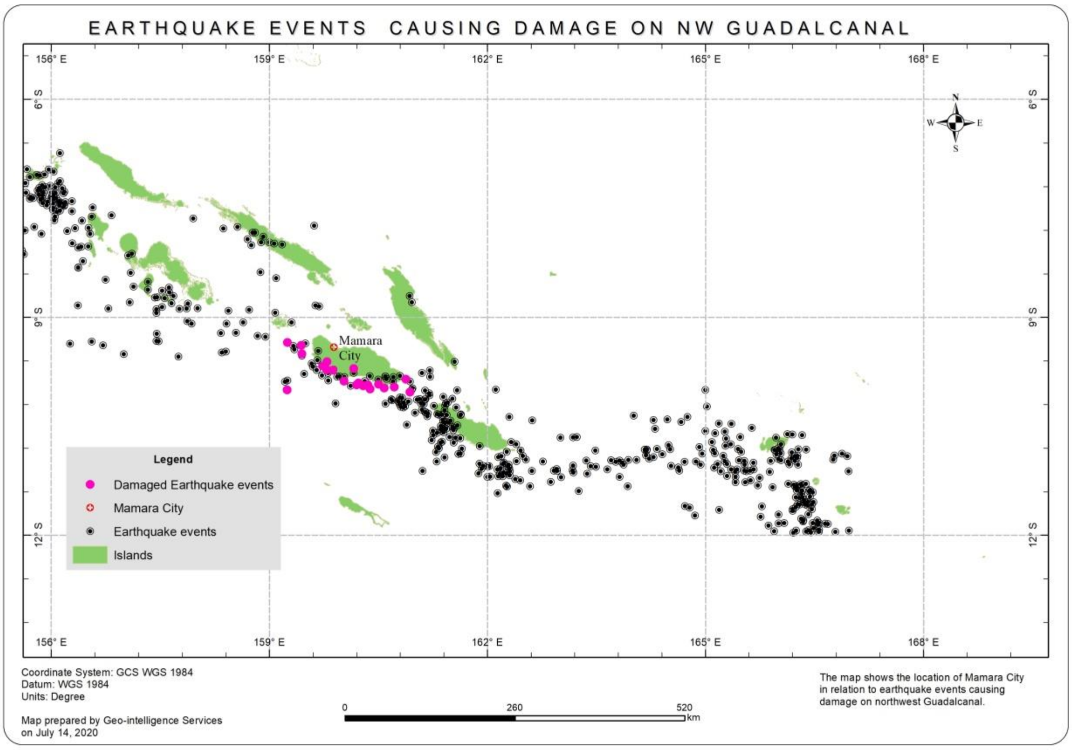


Figure 12: The map shows earthquake events that inflicted damages to West and Northwest Guadalcanal

Figure 13: The map shows slope steepness that is susceptible to landslide due to ground shaking caused by earthquakes

4. HYDROLOGICAL DESCRIPTIONS

Guadalcanal is regularly impacted by hydrological hazards brought about by natural climatic conditions. Common hydrological hazards experienced in northwest Guadalcanal includes heavy rain induce floods, landslide, storm surges, extreme tides, and sea level rise. Hydrological descriptions of Mamara new capital city discussed in this section focuses on the riverine and coastal characteristics of the site in relation to hydrological hazards.

4.1. Hydrological hazards

Northwest to west Guadalcanal is vulnerable to riverine floods and coastal hazards. Heavy rain induced flooding and storm surges had caused significant damage and losses to the community and the national Government. Between 29 January and 2 February 2009, heavy rainfall, landslide and storm surges caused considerable damages to roads, buildings and agricultural crops including food gardens in northwest Guadalcanal (Lal and Thurairajah, 2011a).

High intensity rainfall is the main mechanism that triggers severe flooding within the small and steep catchments of Poha River. This is due to the effects of rugged terrain which increases runoff which encourages rapid transfer of water into the channel, leading to a rapid hydrological response. The process is known as hydrological short-circuiting, displaying flashy behavior, give little lag times between the onset of intense rainfall and the rise in flood water (Lal and Thurairajah, 2011a). Appendix 2 shows the river catchment boundary for Poha.

On the other hand, coastal hazards posed significant threats to low-lying coastal areas in the Pacific Island Countries (Nurse *et al.*, 2014). This has become a challenge when coastal infrastructures are built without prior assessments on the severity of projected impacts of coastal hazards due to changes in coastal dynamics and processes.

Changes observed in the atmosphere and in the ocean as a result of Green House Gas emission are projected to exacerbate the severity of coastal erosion and inundation in certain areas, in addition to extreme hydro-meteorological events and inappropriate coastal developments (Albert *et al.*, 2016).

4.2. Aim and Objectives

The aim of this section of the report is to understand riverine and coastal characteristics of Mamara New Capital City in relations to floods, storm surges, coastal erosion, and projected sea level rise. The objectives are:

i. To determine riverine flood boundary in relation to Mamara new capital city development site.
ii. To determine coastal zones that will be impacted by the storm surges and projected sea level rise.

4.3. Data collection and Analysis

Satellite images and DEM of Mamara new capital city development site were collected from online image repositories and databases. Historical satellite images were downloaded from Google Earth Pro and corrected with recent LiDAR image dataset of the site. DEM generated from LiDAR survey was used to determine coastal areas that would be impacted by projected sea level rise including storm surges. The 2009 and 2014 satellite images taken after the flood events were used to determine the extent of flood waters for the Poha River. This was later, overlaid onto recent satellite image for analysis and mapping purposes.

4.4. Flood Hazards and Levels

Three major riverine flooding events have occurred in northwest Guadalcanal between 1984 to 2014. The 2009 flood causes more damage to northwest Guadalcanal in terms of lives lost and properties damaged. The 2014 flood caused more damages within north Guadalcanal including Honiara. The 1986 flooding event was also very destructive however, there is no aerial image available to determine the extent of the flood boundary.

Flood extent boundary analysis and mapping had indicated that the eastern section of Mamara new capital city development site is highly exposed to extreme flooding events. The area near the bridge is being flooded during the 2009 and 2014 flash flood events. The map (Figure 14) identifies these areas including the flood boundary of the two events. See Appendix 3 for the enlarge version of the flood hazard map.

Figure 14: Flood extent boundaries of 2009 and 2014 major flooding events

The 2014 flood event is related to the highest amount of rainfall recorded per day followed by the 2009 flood event. Previous studies and reports had calculated the return periods of daily rainfall extremes and threshold events including the 2014 and 2009 flood events. The table (Table 6) on next page provided the approximate return periods for a probable daily rainfall extremes events based on daily rainfall measurements from the 1951 to 2014.

Table 6: Probable daily rainfall with return period

Return period	Maximum rainfall (mm/day)	Daily rainfall intensity (mm/hr)
10	201	8.4
20	232	9.7
30	251	10.5
40	264	11
50	274	11.4
100	305	12.7
200	323	13.5

The maximum daily rainfall was recorded as 251.8mm in 2009 before the 2014 flood. The maximum daily rainfall was 318mm recorded on April 3, 2014. Table 6 indicates the return periods of probable maximum daily rainfall events for different return periods. The 2009 and 2014 flood events have a return period of 1-in-30 years and 1-in-150 years respectively based on table 6.

4.5. Coastal Hazards

Severe coastal erosion, coastal flooding, inundation and storm surges have been documented in Solomon Islands (Gillie, 1992; Hoeke et al., 2013; Mataki et al., 2013; PACC Technical Report 4, 2014; PCCSP Country Report, 2014; Albert et al., 2016). There is very high confidence in the direction of long-term changes in sea level in Solomon Islands with projected impacts on coastal areas (PCCSP Country Report, 2014).

4.5.1. Winds, waves, and tidal currents

Distant and local winds generate swells and local waves that impacted the coastline. The prevailing winds are dominated mainly by South Easterly Trade Winds with a mean wind speed of 2.66 meters per second blowing from 101 degrees (WACOP, 2014).

The coastline is sheltered from the South Easterly Trade Winds and exposed to the North East and North Westerly Winds. The graph (Figure 15) shows the monthly wind speed and direction for Honiara based on WACOP report for a 30-year period (1979 – 2012). Appendix 4 shows the wind rose for Honiara provided by WACOP report.

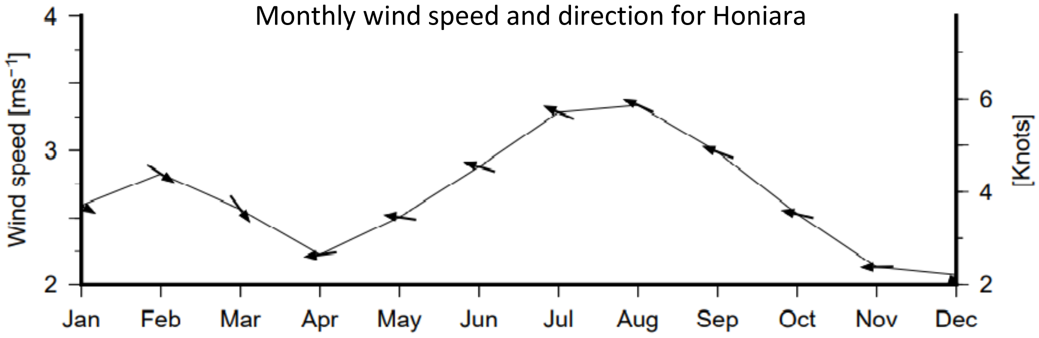


Figure 15: Shows monthly wind speed (black line) and wind direction (black arrow) for Honiara

The average sea state observes at the Mamara coastline is smooth and dominated by wind waves coming from the northeast. According to WACOP, the annual mean wave height for Honiara is 0.11 meters, the annual mean wave direction is 17 degrees and the annual mean wave period is 9.76 seconds (WACOP, 2014). The coastline is exposed to waves coming from many sources. However, the wave conditions are often calm. The waves usually come from the northeast propagating towards the coastline at 40 to 45 degrees. Figure 16 shows the wave height and direction for Honiara provided by WACOP report.

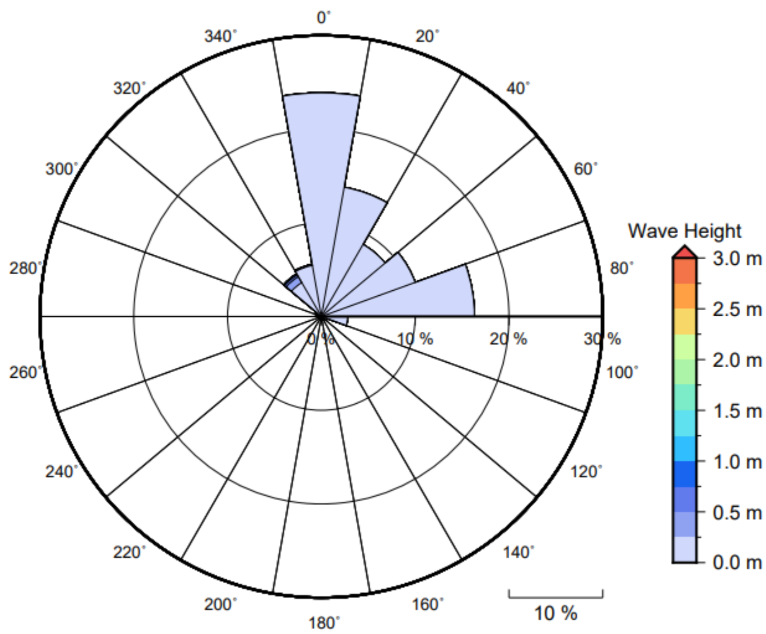


Figure 16: Wave rose representing wave height and direction for Honiara

Waves become larger from time to time to a point where they can cause erosion and inundation on the coastline. The threshold for large waves in Honiara is 0.2 meter. On the other hand, severe wave is not common and may occur only once in a year. Severe waves can cause erosion and inundation once they occur in coincidence with spring tides. The threshold for severe waves in Honiara is 0.6 meters (WACOP, 2014). Table 7 shows the Annual Return Intervals (ARI) of extreme wave events in Honiara based on WACOP report.

Table 7: Large and severe waves annual return interval (ARI) for Honiara

Large wave height (90th percentile)	0.20 m
Severe wave height (99th percentile)	0.57 m
1 year ARI wave height	NaN m
10 year ARI wave height	1.77 m
20 year ARI wave height	1.98 m
50 year ARI wave height	2.23 m
100 year ARI wave height	2.40 m

Onsite observation indicates that tidal current is most likely, the dominant inshore current within the assessed coastline. It is expected that spring tides will generate a stronger inshore current compare to neap tide due to large differences in water levels produced (very low and very high-water levels).

The likely impact from inshore tidal currents to the assessed coastline will be minimal under normal weather conditions. However, this might not be the case if the regular and predictable pattern of the tide is modified by meteorological disturbances such as atmospheric pressure and wind acting on the sea surface. The coincidence of meteorologically induce surges and spring or even neap tide, can increase water level to an exceptionally high total water levels causing disastrous coastal flooding. The implications of such occurrence to coastal infrastructures and other coastal developments should be considered in the designing phase and implementation phase of this project.

4.5.2. Observed sea level rise for Honiara

The earliest sea level monitoring gauge was installed at the Bokona Bay patrol boat jetty, Point Cruz Yacht Club since 1993, approximately 26 years ago. The average rate of sea level rise observed by the SI Met Service since then is approximately 8 mm per annum. This means the sea level has risen by approximately 208 mm (20.8 cm) since 1993. This rate is almost 3 times the global sea level rise rate of 2.8-3.6 mm per annum.

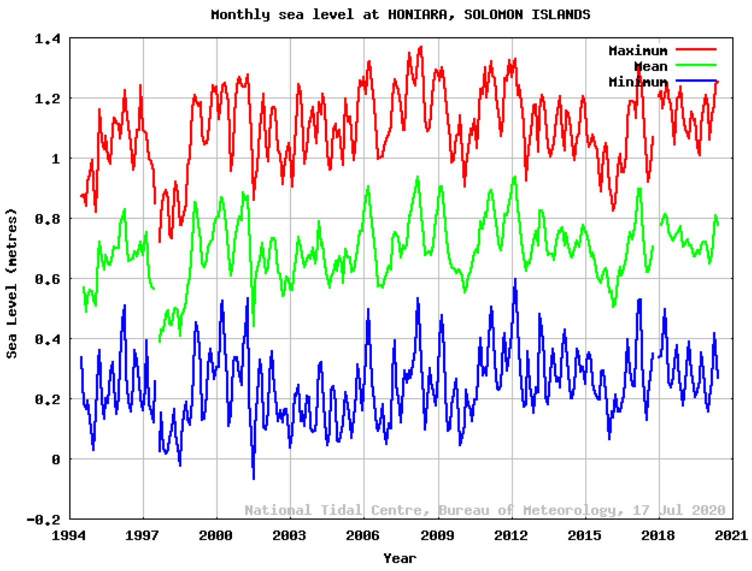


Figure 17: Monthly sea level for Honiara provided by Australian Bureau of Meteorology

4.5.3. Projected sea level rise for Solomon Islands

Projected sea level in the Solomon Islands will increase significantly in the longer term. This is due to the uncertainty regarding the contribution and speed of melting of the Antarctic ice sheet (PCCSP Country Report, 2014). Inter-annual variability has historically ranged 31 cm around the long-term average and is projected to maintain a similar range as the overall average of sea level increases. The table shows the projected Mean Sea Level Rise for the Solomon Islands based different emission scenarios.

Table 8: Projected sea level rise scenarios for the Solomon Islands

Projected Sea Levels	2030	2050	2070	2090
RCP 2.6	+13 cm (+8 to +18 cm)	+22 cm (+14 to +31 cm)	+32 cm (+21 to +48)	+42 cm (+29 to +67 cm)
RCP 4.5	+12 cm (+7 to +17 cm)	+22 cm (+14 to +31 cm	+35 cm (+21 to +48 cm)	+47 cm (+29 to +57 cm)
RCP 6	+12 cm (+7 to +17 cm)	+22 cm (+14 to +30 cm)	+34 cm (+21 to +47 cm)	+49 cm (+30 to +69 cm)
RCP 8.5	+13 cm (+8 to +18 cm)	+25 cm (+16 to 35 cm)	+42 cm (+28 to 58 cm)	+63 cm (+40 to +89 cm)

Impacts from projected sea level rise to Mamara new capital city development site is determined based on the emission scenarios or RCPs. The map (Figure 18) shows areas expected to be impacted by the projected sea level rise by 2100 based on RCP 8.5. Appendix 5 shows a large version of this map.

Figure 18: Map of projected sea level rise for the development site

5. RISK MANAGEMENT ACTIONS

The outcome of this study identifies climate, geologic and hydrological hazards surrounding the proposed development site. This section of the report provides adaptation and mitigation measures to reduce the impacts of hydro-meteorological and geophysical hazards for the three phases of development of Mamara new capital city.

5.1. Climate change mitigation and clean technology options

One of the policy directives of the government (National Climate Change Policy 2012-2017) is to reduce its own GHG emissions through use of renewable energy and other mitigation technologies that brings benefits to the country's economy, environment and improves the livelihoods of its people. Also, as a commitment of the country under the Paris Agreement, Solomon Islands in its Nationally Determined Contribution (NDC 2015) is committed to reduce its GHG emission by 45% by 2030 (conditional) and more than 50% by 2050. In the past few years, application of renewable energy technology especially through Solar PV has taken off at a faster speed. Solomon Power and the government is installing and planning to install various on-grid and off-grid solar hybrid systems around the country. These mitigation activities will help the country meet its target in its NDC.

There is no better opportunity to promote idea of green cities that uses green technology like solar and other green technologies than the Mamara new capital city development. Should we integrate green technologies into the design of the planned Mamara city, this will be one of the first in the region.

As an option, the planned 5,000 KVA diesel gen-set that is planned to generate power for Mamara City can be replaced by a hybrid (solar battery storage/ diesel gen-set). Also, methane that is generated through the waste treatment plan can be captured and used as a form of energy as well. Should the city be powered by green technologies that are mentioned above, it will be great to install an electric station within the city whereby electric vehicles can use to charge.

If the 5,000 KVA diesel gen-set is replaced by solar PV, approximately 3,650tCO_2e will be saved from emitting into the atmosphere annually. This will contribute towards the country's emission reduction targets as well as reduce noise pollution and other potential pollutions to the environment.

5.2. Potential Impacts/Risks and relevant mitigation measures to address these risks

This section of the report provides the summaries for potentials risks from climate and geophysical hazards through its various development phases and mitigation measures to address these risks. Refer to the table below (Table 9).

Table 9: Summaries of potential impacts and mitigation options for the development site

Development phase	Potential impacts/Risks to climate and disaster.	Mitigation Measures (corrective actions that can be taken to minimize or reduce impacts or risks
Development phase 1- Gravel Extraction and reclamation phase	a. Risk of landslide and mud flooding into the Mamara stream and when carrying out gravel extraction and reclamation activities during the rainy periods or rainy days. b. Risk of workers getting sick from very hot and humid conditions. c. Risk of changes to the landscape that will allow for potential water and vector borne diseases. E.g. breeding sites for	a. Gravel extraction and site reclamation should take place during the dry season (May-Oct). At least consult the daily weather forecast or the seasonal climate outlet for weather and climate conditions from the SI Met Service. b. Work procedures for hot and humid conditions. Also, provision of shading and air-condition for work areas and safety of critical

	mosquitoes are created where gravel extraction took place. d. Collapse of steep slopes as a result of gravel extraction on hillside.	equipment. c. Identification of landscape changes and climate conditions contributing to potential water and vector borne diseases. d. Determine the correct angle at which extraction should be done to avoid soil moving downhill.
Development phase 2- Roads, Drainage and building construction	a. Mean daily, monthly, or annual rainfall in Honiara is quite high. Hence, there is risk of drainage blockage or overflow as well erosion of the road especially during heavy rain periods. b. Tenants and occupants of buildings have a very high chance of discomfort if the buildings are not properly designed to allow good ventilation or if not fitted with proper cooling systems. c. There is risk of buildings and other	a. Design and construct surface water drainage and sediment control facilities that can cater for maximum daily rainfall. The highest records for Honiara in 2014 and 2009 should be used as minimum threshold. Proper drainage systems to be constructed along the roads and the roads must be properly tar sealed. b. Building designs and site plan should consider rainfall patterns, wind

	infrastructures being damaged due to strong winds and tropical cyclones. d. There is risk of damage/inundation to the east side of the development site and the proposed waste treatment site should the Poha River be flooded like in 2009 and 2014. e. There is high risk of the port and landing facilities being damaged by strong winds (mostly easterlies) and accompanied storm surges and high waves. Future sea level rise should be considered in the designs as well. f. Ground movement due to earthquake with magnitude greater than 8 Mg has a moderate to high impacts on the location of Mamara.	velocity, high relative humidity, and high temperature. c. All buildings and other infrastructures should be designed to withstand tropical cyclones, flooding, and storm surges. d. Shift the proposed wastewater treatment site to other safer sites. Engage surrounding communities to plant trees along Poha riverine as means of adaptation from flooding. Rehabilitate and protect the Mamara riverine to protect the site as well as existing ecosystems. e. Design ports and barge landing facilities based on coastal tides, maximum easterly and westerly winds with associated and waves. Also design these facilities considering 8mm rise of sea level rise per annum for at least the next 50 years. f. The design and constructions of roads, drainage systems and building should be

	g. Bursting of Poha Riverbank due to sediment build-up within the main channel can cause surface flooding.	engineered to withstand earthquake with magnitude greater than 8 Mg. g. The main channel of the Poha River should be continuously dredged to remove sediment deposits.
Development phase 3- Operational phase, Residential, commercial, and supporting utilities.	a. There is risk of damages to the site from flooding of Poha River, strong winds, storm surges, cyclones, and continuous sea level rise during the operational phase of the development should flooding and coastal dynamics not continuously monitored for timely actions. b. Ground movement due to earthquake with magnitude greater than 8 Mg has a moderate to high impacts on the location of Mamara. c. Bursting of Poha Riverbank due to sediment build-up within the main channel can cause surface flooding. d. Emission of GHGs into the atmosphere and related noise and other environment	a. Install AWSs to monitor daily weather variables such as rainfall, temperature, wind, and humidity. Install tide gauges on the coast for sea level and coastal monitoring. Install flood gauges especially at Poha River to monitor flooding. b. The design and constructions of roads, drainage systems and building should be engineered to withstand earthquake with magnitude greater than 8 Mg. c. The main channel of the Poha River should be continuously dredged to remove sediment deposits. d. Use of solar PV/genset hybrid system as the

	pollution from the diesel generator used for power and environmental pollutions from the sewage treatment plant.	source for power for the city. Capture of methane from the sewage treatment plant and use it as another energy source.

6. CONCLUSION

This study provides descriptions of Mamara new capital city development site in relation to climate, geologic and hydrological hazards. We found that the vulnerability of Mamara new capital city to the assessed hazards differs. The site is highly vulnerable to heavy rainfall associated with Tropical Cyclones. Flash floods and landslides are secondary hazards linked to heavy rainfall triggered by Tropical Cyclones.

Waves become larger from time to time to a point where they can cause erosion and inundation on the coastline once they occur in coincidence with spring tides. In addition, the coincidence of meteorologically induce surges and spring or even neap tide, can increase water level to an exceptionally high total water levels causing disastrous coastal flooding.

Geologic hazards from earthquakes and volcano would also impact the site but at a low to moderate impact levels. The difference can be attributed to the spatial distribution of hazards in relation to the geographic location of Mamara new capital city.

The severity of a natural hazard cannot necessarily be judged from its physical characteristics. For example, the relatively moderate intensity of Cyclone Namu would not, of itself, indicate the amount of damage incurred. However, its slow movement over Guadalcanal and the excessive rainfall were the main causes of damage. Cyclones of similar or greater magnitude than Namu can be expected in the future.

As the development will increase population and industrial expansion in area, the risk of damage from cyclones and earthquakes will also increase. Therefore, adaptation and mitigation measures outlined in section 5 of this report should be addressed at the different phases of development.

Reference

Albert, S., Leon, J. X., Grinham, A. R., Church, J. A., Gibbes, B. R. & Woodroffe, C. D. 2016. Interactions between Sea-Level Rise and Wave Exposure on Reef Island Dynamics in the Solomon Islands. *Environmental Research Letters,* 11**,** 1 - 9

Byrne, D., Horsburgh, K., Zachry, B. & Cipollini, P. 2017. Using Remotely Sensed Data to Modify Wind Forcing in Operational Storm Surge Forecasting. *Natural Hazards,* 89**,** 275-293.

Coleman, P. J. 1965. Stratigraphical and Structural Notes on the British Solomon Islands with Reference to Ffirst Geological Map, 1962. *British Solomon Islands Geological Review,* 2**,** 17 -31.

Committee for Development Policy 2018. Vulnerability Profile of the Solomon Islands. *Committee for Development Policy 20th Plenary Session* New York: United Nation.

Environment Reguation 2008 2008. The Environment Regulations 2008. *In:* Ministry of Environment, C. C., Disaster Management & Meteorology (ed.). Honiara: Solomon Island Government.

Haberle, S. 1996. Explanations for Palaeoecological Changes on the Northern Plains of Guadalcanal, Solomon Islands: The Last 3200 Years. *The Holocene,* 6**,** 333 - 338.

Hackman, B. D. 1980. *The Geology of Honiara Area,* Honiara, Solomon Islands Geological Survey Division.

Lal, N. P. & Thurairajah, V. 2011a. Making Informed Adaptation Choices: A Case Study of Climate Proofing Road Infrastructure in the Solomon Islands Suva: IUCN.

Lal, P. N. & Thurairajah, V. 2011b. Making Informed Adaptation Choices: A Case Study of Climate Proofing Road Infrastructure in the Solomon Islands Suva: IUCN.

Nurse, L. A., McLean, R. F., Agard, J., Briguglio, L. P., Duvat-Magnan, V., Pelesikoti, N., . . . Webb, A. 2014. Small Islands. *In:* Field, C. B., Barros, V. R., Dokken, D. J., Mastrandrea, M. D., Mach, K. J., Bilir, T. E., . . . White, L. L. (eds.) *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group Ii to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, United Kingdom and New York, USA: Cambridge University Press.

Ouma, Y. O. & Tateishi, R. 2014. Urban Flood Vulnerability and Risk Mapping Using Integrated Multi-Parametric Ahp and Gis: Methodological Overview and Case Study Assessment. *Water,* 6**,** 1515 - 1545.

PCCSP Country Report 2014. Climate Variability, Extremes and Change in Western Tropical Pacific: New Science and Updated Country Reports, Solomon Islands. Malbourne: Australian Bureau of Meteorology and CSIRO.

PCRAFI 2015. Country Note Solomon Islands: Disaster Risk Financing and Insurance. Washington: The World Bank.

Petterson, M., Cronin, S. J. & Toba, T. 2003. The Eruptive History and Volcanic Hazards of Savo, Solomon Island. *Bulletin of Volcanology,* 65**,** 165 - 181.

Radford, D. & Blong, R. 1992. Assessments of Natural Hazards in the Solomon Islands and the Implications for Other Pacific Island Countries *AODRO Newsletter,* 10**,** 1 - 8.

Radford, D. A., Blong, R. J. & Flood, N. R. 1991. Natural Disasters in the Solomon Islands. Sydney: School of Earth Sciences, Macquary University.

Sherwood, A. & Howorth, R. 1996. Report 222: Coasts of the Pacific Islands. Suva: SOPAC.

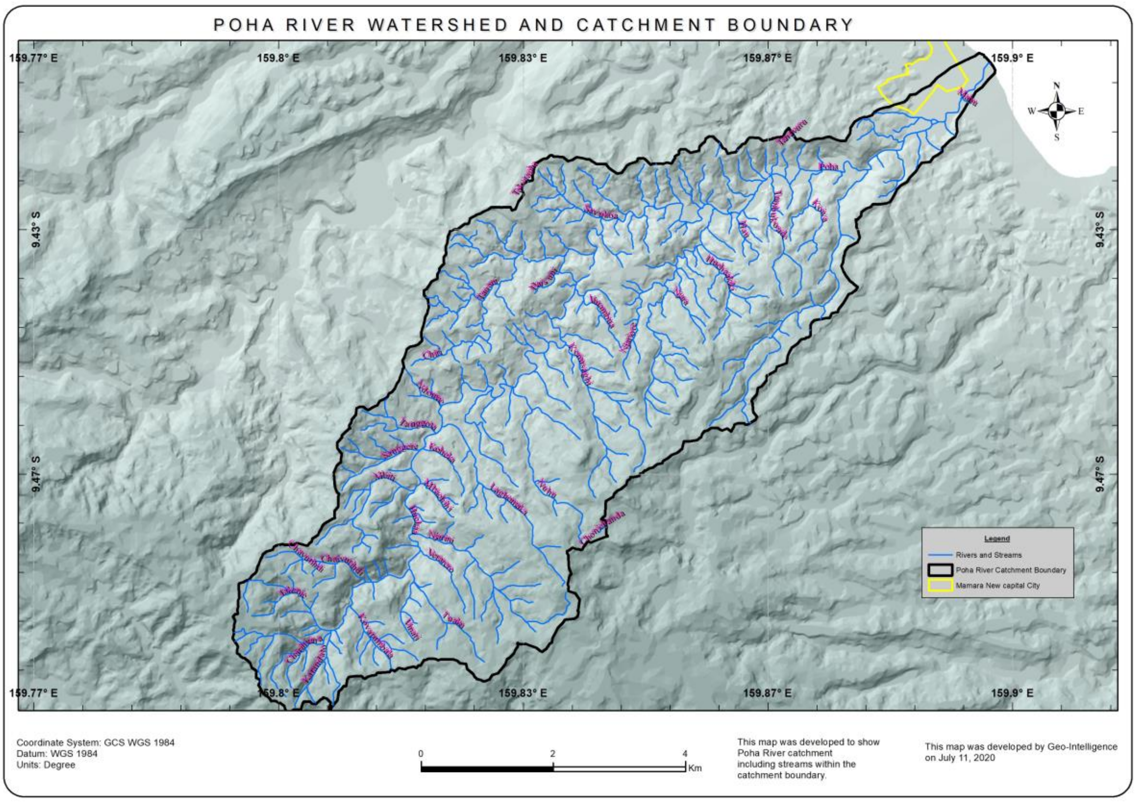
WACOP 2014. Wave Climate Report: Honiara. Suva: Secretariat of the Pacific Community.

APPENDICES

Appendix 1: Earthquake hazards impacting west and northwest Guadalcanal

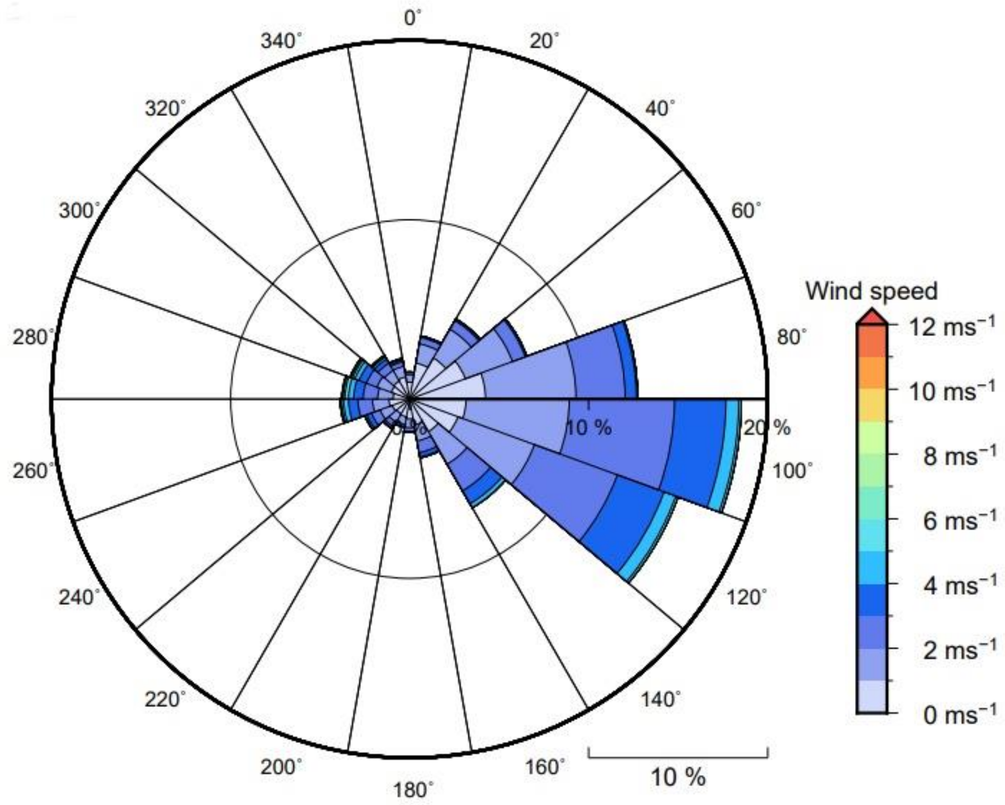
Hazards	Secondary Hazards	Year	Damages	Region	Province
Earthquake		1926	Church	Northwest Guadalcanal	Guadalcanal
Earthquake	Tsunami	1926	Houses	Northwest Guadalcanal	Guadalcanal, Central, Isabel
Earthquake	Landslide	1935	Gardens	East and southeast Guadalcanal	Guadalcanal, Central, Malaita
Earthquake	Tsunami	1936	Houses	Southwest - West Guadalcanal	Guadalcanal
Earthquake	Landslide, Tsunami	1939	Houses, Gardens, 12 deaths	Northwest Guadalcanal	Guadalcanal, Central
Earthquake	Landslide, Tsunami	1950	Gardens, houses	Central and South Guadalcanal	Guadalcanal
Earthquake		1965	Houses	North - Northwest Guadalcanal	Guadalcanal
Earthquake	Tsunami	1966	Material damage	North - Northwest Guadalcanal	Guadalcanal
Earthquake		1970	Material damage	North - Northwest Guadalcanal	Guadalcanal
Earthquake	Landslide, Tsunami	1977	Infrastructures, Houses, Materials	Guadalcanal	Guadalcanal
Earthquake	Landslide	1984	Infrastructures, Houses, Materials	North - Northwest - Northeast Guadalcanal	

Appendix 2: Poha river catchment Boundary



Appendix 3: Flood extent boundary

Appendix 4: Wind rose for Honiara based on WACOP report



Appendix 5: 1 metre Projected Sea level rise for 2100