Metropolis Pacific

Telios Corporate and Consultancy Services

Mamara New Capital City Development Phase 1 Environment Impact Statement (EIS)

Chapter 5: Geo-technical Engineering Assessment

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1 INTRODUCTION

1.1 General

The Mamara-Tasivarongo-Mavo Development Agreement Act 1997 was passed by the National Parliament of Solomon Islands on the 27th May 1997. This was to ratify and protect the development agreement made between the Government of Solomon Islands, Commissioner of Lands and Metropolis Pacific PTE Limited (Developer) on the 20th November 1995.

1.2 The Project

The project, under the Act is to develop a designated site between the Poha River and Mamara River. The site will be developed by the developer Metropolis Pacific PTE Limited.

1.3 Objective of this Report

Telios Consulting (TC) was engaged by the developer to undertake Environmental Impact Statement (EIS) study. This report is the soil/geology and engineering assessment of the proposed development site. Specific tasks are outlined in the Scope of Works section of this report.

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2 SCOPE OF WORKS

The scope of work is listed below.

(a) Undertake Geotechnical investigation of the proposed site which includes;
   (i) Four borehole (BH) drilling with piezometric readings;
   (ii) Laboratory testing of the retrieved soil samples; and
   (iii) Groundwater monitoring.

(b) Factual Reporting – comment on proposed development with recommendation and mitigations where applicable

3 DESKTOP STUDY

3.1 Allotment and Zoning

The allotment and zoning of the propose development site is as pictured in Figure 4.1. The zoning is categorised as below.

3.1.1 Residential

There are a total of 1234 residential properties proposed to be constructed as part of the development.

3.1.2 Industrial/Commercial Warehouses

The development of the township has two dedicated industrial and commercial zones as shown on Figure 4.1. These are areas of high commercial production of goods.

3.1.3 Business Centre

As seen in Figure 4.1, there is a town centre where business houses and commercial activities are designated.

3.1.4 Community Facilities

A school, a clinic and a football field will be constructed to the west of the development site next to Mamara River. The school will be from early childhood education to secondary school level. Flood levels will need to be confirmed and the facilities built accordingly.

3.1.5 Utilities Facilities

At the time of writing, the water reservoir and the sewage treatment plant have been designated. The town’s water supply will be located on top of the hill to the east of Mamara River. Inspections of the site to accommodate the water reservoir indicate the site is generally flat at the crest with steeply sloping flanks. Heavy vegetation exists on the flanks. It is recommended that clearing should be kept to a minimum, only where required. Vegetation should be encouraged on the slopes as it assists in stability via root binding effects and controls moisture via evapotranspiration.

The sewage and wastewater treatment plant are proposed to be located just north west of Poha River, approximately 50m from the riverbank. The client must satisfy itself that the proposed sewage plant is not at risk from flood inundation for a 1 in 100 flood events.

3.2 Regional & Local Geology

The geomorphology of Guadalcanal has been classified (Hackman 1980) as consisting of three broad terrain zones. These comprise the alluvial plains, the foothills, and the mountains. The foothill zone is further divided into two belts, the lower foothills, and the upper foothills. The Guadalcanal alluvial plains are at their widest between Honiara and Aola bay. The alluvial plains are flanked inland by foothill zones, which comprise a dissected and northward sloping eroded plateau which narrows eastward.

The lower and upper foothill zones are divided by a distinct change in angle of slope. The angle is steeper, and the surface more deeply incised in the upper belt. The upper foothills pass on upwards and southwards into the true mountain zones of Guadalcanal which are characterized by a pattern of very close dissection with deep narrow ravines, steep slopes, and razor back ridges. The mountain zones occupy most of the southern half of Guadalcanal. The oldest rocks in this area are predominantly basaltic lavas, metamorphosed lavas, ultrabasic serpentine, and crystalline intrusive rocks, and are essentially restricted in outcrop to the mountain and upper foothill terrain zones.

The three main rock types that were found in Poha-Mbonege area were the Umasani Volcanics, Poha Diorite complex and the Mbonege Limestone (Hackman, 1980). It was determined that the oldest type of rock known in the area was the Umasani volcanics, they were basically tholeiitic basaltic andesite formed during the Oligocene age and were rarely exposed. This is because most of its outcrop was being intruded by the Poha-mbonege complex believed to be at the pre-Miocene age. It was a polyphase intrusion which was dominated by Microdiorite/Porphyrite followed by Leucodiorite, Melanocratic augite-microdiorite and the late phase microdite dykes and veins. The deposition and formation of the Mbonege limestone was the latest process that took place at the lower Miocene to middle Miocene age. The deposition of the sediments was mostly concentrated on the edges of the Poha Diorite main body and therefore directly responsible for the typical "cockpit Karst" topography seen along the area.

3.3 Seismic Data

Solomon Islands is located along the Ring of Fire in the South Pacific Ocean which is well known for having high seismic activity. The data received from the Ministry of Mines, Energy, and Rural Electrification in 2019 (MMERE) for Guadalcanal Province shows that the magnitude produced by the earthquake ranges from 4.0 to 6.4 on the Richter Scale. The figure below summarizes the earthquake events near Guadalcanal in the past 10 years which is relevant for the site location.

Ministry of Mines, Energy and Rural Electrification
P O Box G37
Honiara
Solomon Islands
Tel: (+677) 21522, 21523 **Fax (+677) 25811**

SEISMOLOGY/VOLCANOLOGY SECTION - EARTHQUAKE DATA (2009-2019).

Date	Time	Lat	Long	Depth	Mag	Epicentre
10/12/2019	21:08:25.366Z	-10.026	160.344	22.24	4.8	78km SSE of Honiara, Solomon Islands
28/10/2019	08:01:37.656Z	-9.7833	159.67	13.39	5.1	49km SW of Honiara, Solomon Islands
04/10/2019	16:58:58.494Z	-9.815	160.665	11.93	4.4	89km ESE of Honiara, Solomon Islands
26/09/2019	19:07:40.838Z	-9.882	159.631	10	5.1	60km SW of Honiara, Solomon Islands
09/08/2019	22:01:13.661Z	-9.8708	160.19	38.21	4.4	55km SSE of Honiara, Solomon Islands
04/08/2019	13:54:48.843Z	-9.9269	160.276	42.84	4.7	65km SSE of Honiara, Solomon Islands
08/02/2019	18:40:14.700Z	-9.7756	160.22	37.7	4.7	48km SE of Honiara, Solomon Islands
18/07/2018	15:29:47.470Z	-9.76	160.313	37.56	4.3	53km SE of Honiara, Solomon Islands
20/06/2018	00:29:40.530Z	-9.8148	159.745	27.53	4.5	47km SSW of Honiara, Solomon Islands
18/05/2018	02:22:20.640Z	-9.7482	160.354	13.02	4.5	56km SE of Honiara, Solomon Islands
29/04/2018	07:55:15.760Z	-9.8334	159.567	10	4.5	61km SW of Honiara, Solomon Islands
29/03/2018	18:51:12.290Z	-9.4211	159.579	32	5.8	40km W of Honiara, Solomon Islands
19/11/2017	17:53:00.300Z	-9.8515	160.448	10	4.7	71km SE of Honiara, Solomon Islands
28/08/2017	12:06:34.430Z	-9.7476	159.806	31.76	4.9	38km SSW of Honiara, Solomon Islands
13/08/2017	03:47:49.850Z	-10.05	160.868	28.58	5	121km SE of Honiara, Solomon Islands
10/07/2017	00:40:45.070Z	-9.5532	160.537	29.52	4.2	65km ESE of Honiara, Solomon Islands
02/05/2017	05:22:01.880Z	-9.7907	160.043	25.31	4.6	40km SSE of Honiara, Solomon Islands
02/05/2017	04:38:48.410Z	-9.7396	159.625	13.09	5.1	49km SW of Honiara, Solomon Islands
24/02/2017	09:44:18.630Z	-9.6565	159.786	27.47	4.9	30km SW of Honiara, Solomon Islands
20/12/2016	23:22:03.180Z	-10.036	160.748	35.39	5.1	110km SE of Honiara, Solomon Islands
20/12/2016	20:07:52.550Z	-10.155	160.782	10.38	5.5	121km SE of Honiara, Solomon Islands
16/12/2016	09:17:16.120Z	-9.9433	160.755	10	4.7	104km ESE of Honiara, Solomon Islands
15/12/2016	23:32:22.900Z	-9.9785	160.611	10	4.9	94km SE of Honiara, Solomon Islands
15/12/2016	22:23:26.510Z	-9.9092	160.519	16.15	5.4	81km SE of Honiara, Solomon Islands
08/12/2016	22:15:14.590Z	-10.068	160.672	35	4.4	105km SE of Honiara, Solomon Islands
02/12/2016	01:00:36.990Z	-10.055	160.427	42.01	5	86km SE of Honiara, Solomon Islands

Figure 3.1 Earthquake Data for Honiara from 2009 -2019 (Source: Ministry of Mines, Energy and Rural Electrification, 2019).

01/08/2016	21:24:19.600Z	-9.3859	159.425	19.64	5	57km W of Honiara, Solomon Islands
10/07/2016	21:53:06.390Z	-9.8715	159.933	28.1	4.4	48km S of Honiara, Solomon Islands
07/03/2016	14:33:01.350Z	-9.7709	160.15	28.28	4.3	43km SSE of Honiara, Solomon Islands
19/01/2016	10:30:53.570Z	-9.7151	159.931	25.79	4.1	31km S of Honiara, Solomon Islands
30/11/2015	00:28:47.430Z	-9.9981	159.714	10	4.4	67km SSW of Honiara, Solomon Islands
24/09/2015	15:56:56.170Z	-10.192	160.52	25.54	5.8	104km SE of Honiara, Solomon Islands
07/09/2015	04:23:02.130Z	-9.7758	160.348	22.34	5.1	57km SE of Honiara, Solomon Islands
24/07/2015	07:42:22.390Z	-9.6694	159.937	39.05	4.4	26km S of Honiara, Solomon Islands
21/05/2015	19:57:19.810Z	-9.9429	160.364	10	4.5	72km SE of Honiara, Solomon Islands
21/05/2015	19:32:57.730Z	-9.8042	160.334	5	5.7	58km SE of Honiara, Solomon Islands
19/05/2015	10:04:28.260Z	-9.9624	160.805	80.31	4.2	110km ESE of Honiara, Solomon Islands
10/05/2015	11:57:19.470Z	-9.7666	160.084	35	4.8	39km SSE of Honiara, Solomon Islands
03/04/2015	11:09:10.380Z	-10.09	160.716	10	4.2	111km SE of Honiara, Solomon Islands
05/01/2015	00:59:47.360Z	-10.147	160.61	35	4.5	107km SE of Honiara, Solomon Islands
26/11/2014	14:21:26.560Z	-9.8799	159.738	10	4.2	54km SSW of Honiara, Solomon Islands
01/11/2014	22:44:50.550Z	-9.809	159.621	21.75	4.3	55km SW of Honiara, Solomon Islands
01/11/2014	22:13:14.550Z	-9.7822	159.758	24.48	5.3	43km SSW of Honiara, Solomon Islands
20/10/2014	03:35:26.480Z	-9.4594	159.498	19.52	4.3	49km W of Honiara, Solomon Islands
07/10/2014	08:55:43.490Z	-9.8829	160.909	121.68	4.7	116km ESE of Honiara, Solomon Islands
24/07/2014	16:21:47.290Z	-10.147	160.653	16.95	4.7	110km SE of Honiara, Solomon Islands
16/07/2014	18:24:20.000Z	-10.044	160.87	21.2	5.2	121km SE of Honiara, Solomon Islands
16/07/2014	16:56:11.740Z	-10.034	160.838	26.78	5.2	117km SE of Honiara, Solomon Islands
15/07/2014	20:42:52.570Z	-9.5061	159.43	17.91	4.2	57km W of Honiara, Solomon Islands
06/05/2014	05:47:05.720Z	-10.022	160.878	35.43	4.5	120km ESE of Honiara, Solomon Islands
05/05/2014	02:24:52.610Z	-9.75	159.835	35.39	5.3	37km SSW of Honiara, Solomon Islands
08/02/2014	05:40:13.360Z	-9.6785	159.665	40.92	5.1	41km SW of Honiara, Solomon Islands
07/02/2014	19:52:04.490Z	-9.7818	159.661	27.04	4.4	49km SW of Honiara, Solomon Islands
01/02/2014	10:27:54.980Z	-9.7819	159.65	30.68	4.5	50km SW of Honiara, Solomon Islands
06/12/2013	01:42:15.650Z	-9.9462	160.169	48.13	4.2	61km SSE of Honiara, Solomon Islands
06/10/2013	16:37:02.330Z	-10.089	160.562	46.54	4.7	98km SE of Honiara, Solomon Islands
27/09/2013	21:52:49.260Z	-10.179	160.71	47.46	5	117km SE of Honiara, Solomon Islands
27/06/2013	23:28:16.320Z	-9.8	160.516	40	4.6	69km SE of Honiara, Solomon Islands
11/10/2012	03:05:00.580Z	-10.008	160.798	14.5	4.8	Solomon Islands
25/09/2012	19:42:33.080Z	-9.748	159.746	30.9	5.2	Solomon Islands
08/09/2012	21:24:02.570Z	-9.874	160.486	35.4	4	Solomon Islands
08/09/2012	04:11:48.480Z	-9.849	160.404	47.8	5.2	Solomon Islands

25/07/2012	21:43:28.950Z	-9.725	159.699	26	5	Solomon Islands
25/07/2012	20:01:35.780Z	-9.795	159.826	22.8	4.8	Solomon Islands
25/07/2012	12:35:46.580Z	-9.7	159.765	30	4.5	Solomon Islands
25/07/2012	11:20:27.030Z	-9.694	159.727	20	6.4	Solomon Islands
11/07/2012	04:09:58.290Z	-9.776	159.524	31.8	4.7	Solomon Islands
19/03/2012	16:03:12.690Z	-9.534	159.482	26.7	4.8	Solomon Islands
11/02/2012	15:23:07.900Z	-9.954	160.274	47	5.1	Solomon Islands
22/01/2012	08:24:19.160Z	-10.098	160.97	62.6	4.3	Solomon Islands
18/12/2011	15:48:38.880Z	-9.927	160.449	51.2	4.1	Solomon Islands
11/09/2011	23:57:25.240Z	-9.492	159.469	21.3	4.2	Solomon Islands
10/08/2011	06:47:12.360Z	-9.401	159.534	35	4.4	Solomon Islands
26/05/2011	20:36:17.320Z	-9.719	159.582	16.2	4.8	Solomon Islands
21/05/2011	04:35:36.930Z	-10.017	160.944	41.3	4.8	Solomon Islands
02/05/2011	16:41:46.490Z	-10.041	160.456	17.9	5	Solomon Islands
28/04/2011	07:42:34.860Z	-9.973	160.492	11	5.7	Solomon Islands
26/04/2011	22:20:28.790Z	-9.996	160.359	32.3	4.9	Solomon Islands
05/04/2011	09:57:13.730Z	-9.594	159.733	25.9	5.1	Solomon Islands
22/01/2011	05:04:49.750Z	-9.977	160.842	10	4.6	Solomon Islands
21/08/2010	02:55:15.300Z	-9.618	159.548	22.5	4.4	Solomon Islands
22/06/2010	04:44:08.180Z	-9.823	160.053	13.5	4.7	Solomon Islands
04/05/2010	08:29:16.010Z	-9.68	159.679	39	4.6	Solomon Islands
02/03/2010	18:01:06.590Z	-9.673	159.424	548.7	4.6	Solomon Islands
13/10/2009	11:14:45.260Z	-9.691	159.595	30.1	4.3	Solomon Islands
28/08/2009	20:05:19.780Z	-10.01	160.862	42.9	4.5	Solomon Islands
09/07/2009	07:43:29.710Z	-10.118	160.551	35	4.5	Solomon Islands
31/05/2009	05:31:28.060Z	-10.054	160.975	32.9	4.6	Solomon Islands
12/05/2009	17:24:27.980Z	-9.979	160.507	37.3	4.5	Solomon Islands
12/03/2009	15:13:24.240Z	-9.807	159.817	35	5	Solomon Islands
13/02/2009	07:47:14.160Z	-9.747	159.815	42	4.3	Solomon Islands
26/01/2009	00:07:40.880Z	-9.52	159.791	32.5	4.3	Solomon Islands
12/01/2009	20:10:54.020Z	-9.864	160.385	53.8	4.5	Solomon Islands

A major sub-duction trench is located immediately south of Guadalcanal trending NW-SE (Fig 3.2a & 3.2b).

Data from USGS show earthquakes along this trench (Fig 3.2b). The data revealed 22 earthquakes equalling M6 and greater occurred in the last 50 yrs on or in close proximity to Guadalcanal, on which Honiara is located.

Work undertaken by the Solomon Islands National Disaster Office suggests Guadalcanal has a High to Very High exposure to earthquakes (Fig 3.2c).

For future buildings that are multi-level and/or structures that are of significant functions (e.g., hospitals, schools, churches…etc…) will require seismic assessment as part of the building design.

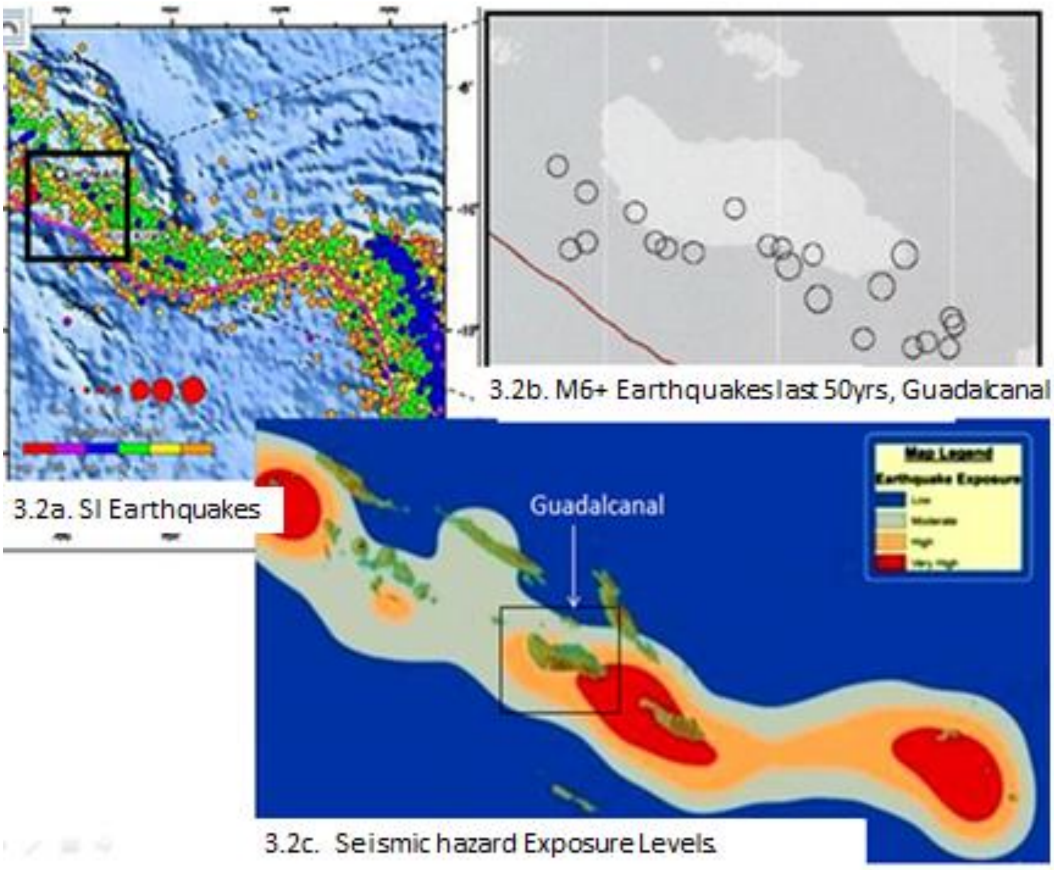

Fig 3.2 Seismic Characterisation of Guadalcanal & the Solomons.

3.4 Rainfall and Hydrogeology

Many climates feature influence rainfall in the Solomon Islands. Rainfall in the Solomon Islands is affected by the movement of the South Pacific Convergence Zone and the Intertropical Convergence Zone. (Ref: Solomon Islands Provincial Airfields, Basis of Design MFAT 16 May 2019.).

3.4.1 Rainfall

As per the rainfall data collected by SIMS for Honiara over the last 10 years (2010 to 2019), Honiara has a clear wet season from November to April with an average almost 70% of the yearly total rainfall occurs. In the dry season (May-October) on average about 600 mm rainfall compared with upwards of 1800 mm in the wet season. The Figure below shows on average, the precipitation is 185.44mm in June (the driest month) and reaches its peak on an average of 420mm in January and March. It should be noted that this is the closest recorded data for the site.

It is anticipated that groundwater recharge is highest during the wet months. The underlying sands and gravels are highly permeable allowing for easy water transport.

Earthworks should be planned during the drier months to avoid/minimise disruptions to work or provisions made to in terms of water pumps and pipes to deal with inflows and high groundwater levels.

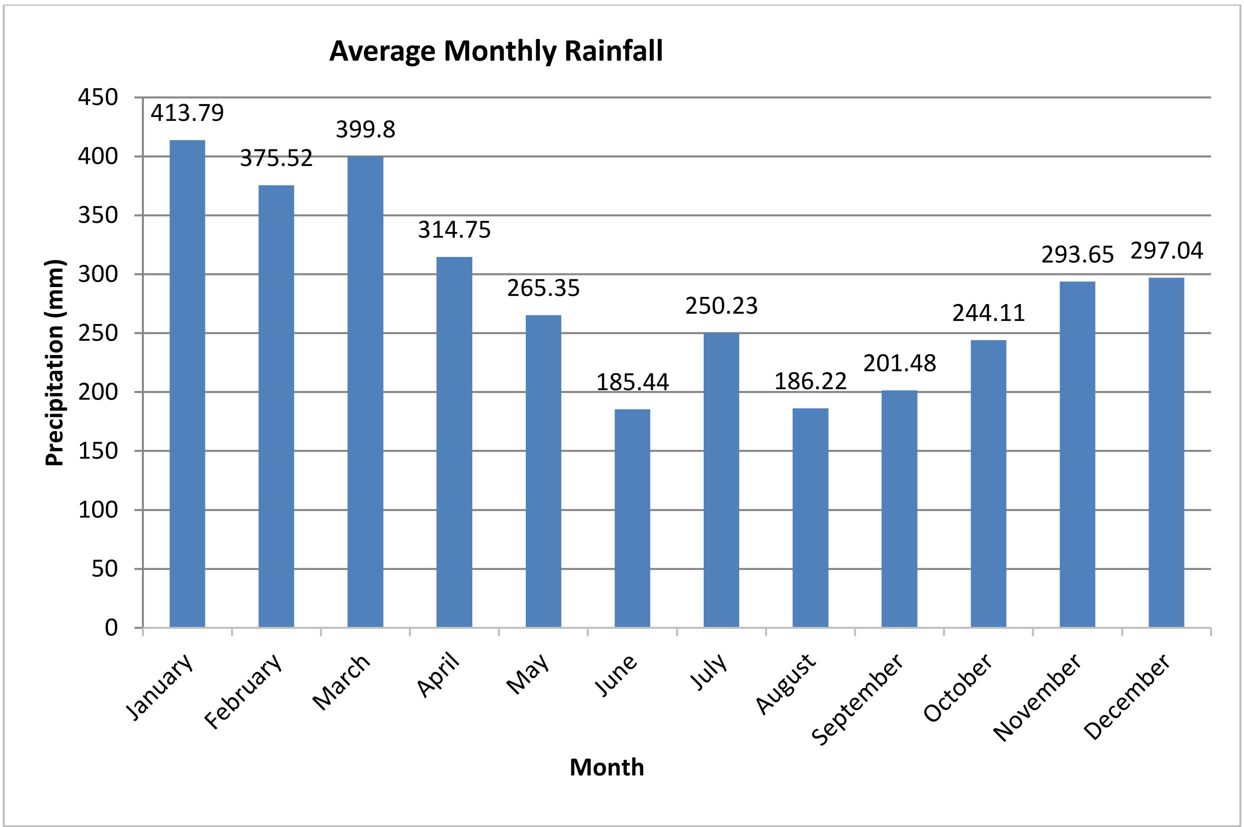

Figure 3.3 Average monthly total rainfall from 2010 to 2019 (Source: Solomon Islands MET Services).

3.4.2 Relative Humidity and Temperature

Air temperatures in Honiara and the rest of the Solomon Islands are consistent throughout the year. The average daytime temperatures for the last 10 years are in the 30.0^{o}C range, while in the evenings it drops just below 23^{o}C. A record high was 33.5°C in January of 2016, while the record low was 22.7°C in September of 2015 as seen in Figure 3.1.

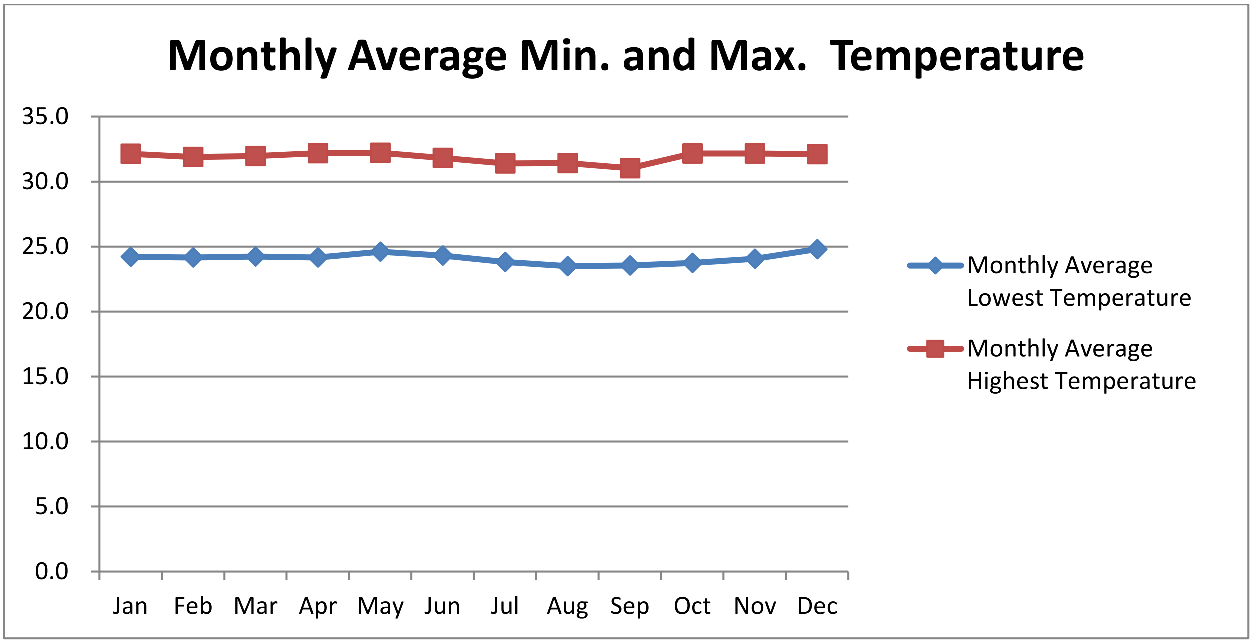

Figure 3.4 Average temperature of Honiara over the last 10 years, 2010 – 2019 (Source: MET Services, Honiara).

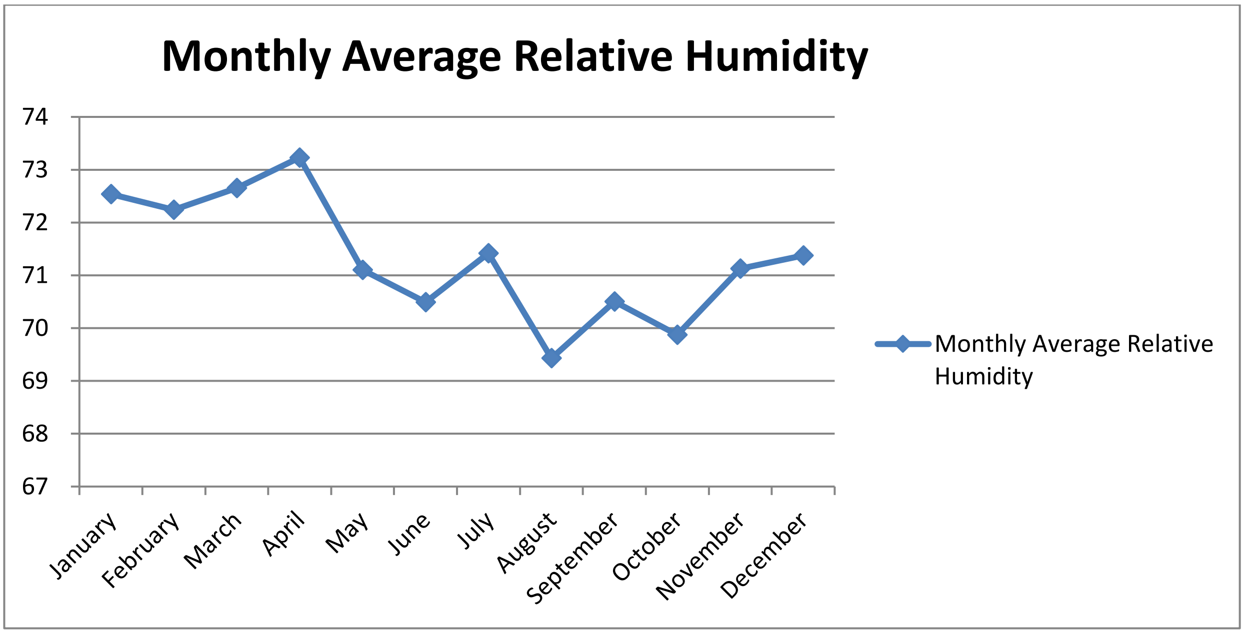

Figure 3.5 Monthly average relative humidity for Honiara, 2010 – 2019 (Source: MET Services, Solomon Islands).

4 PROPOSED DEVELOPMENT

The proposed development of the township is categorised into residential with community facilities, business centre and industrial zone. This is presented in Figure 4.1.

Figure 4.1 Ariel view of the Mamara site

5 SITE LOCATION AND DESCRIPTION

The site in consideration is located further west of Honiara. Mamara is located roughly about 7.5km from the Honiara Capital. The figure below shows the proposed location that will be developed.

The site is straddled between the Poha and Mamara watercourses. The demarcated area is parallel to the coastline forming an irregular oblong. The main highway intersects the development near the northern perimeter. This also defines the development phases, with the southern sector being Stage 1 and the northern sector Stage 2.

The general grade is due north. Section of land from the foreshore and extending some forty odd meters (40m+) is gently sloping seawards. The surface is covered in grass with a defined tree line parallel to the coastline some 5m south of the highwater mark.

Further west near the Mamara outlet, large trees and coconut palms exist. Thick vegetation also exists to the east of the site near Poha River. Much of the land between the foreshore and the highway is heavily grassed.

Beyond the highway to the south, the land has recently been cleared off raintrees, shrub, and undergrowth. Regenerating grass is taking over the cleared area. This area is a flat expanse of the site on which much of the dwellings will be constructed. Further south, the land rises up quite quickly where slope processes have carved into the landmass forming valleys and plunging ridgelines. A waterlogged low laying area is noted 50m north of the betelnut plantation.

Evidence of earthworks and logging is observed on the slopes. This is marked by contour tracks on ridge flanks and remnant logs on the valley floor. Only the ridgelines and valleys within the immediate vicinity of the Mamara Spring are spared from logging activities.

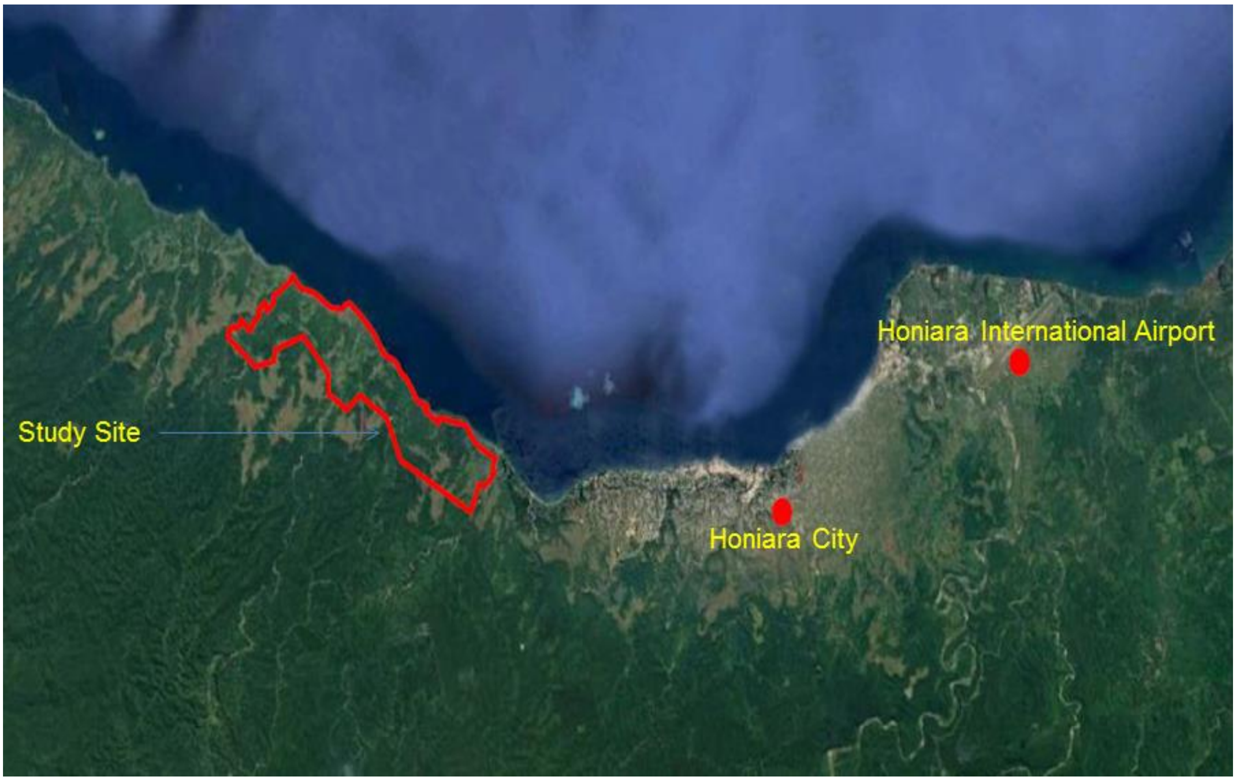

Figure 5.1Study site with respect to Honiara City & International Airport.

At the time of inspections and fieldwork, major clearing had occurred to the south of the main highway. Large, mature raintrees, undergrowth and shrubs were cleared to make way for accessway and buildings.

Significant Corraneous Fill was introduced along the central spine. This road will act as the vantage point from which the rest of the site will be filled including roads and building platforms.

6 METHODOLOGY AND APPROACH

The investigation approach is provided in detail in our proposal and summarised below. Preliminary work includes desktop study. This is undertaken to understand site history, appreciate site configuration and delineate areas that may need further work and identify potential constraints during sub-surface investigation.

Site walkover inspection was undertaken to appreciate geomorphology, topography, vegetation cover and surface water.

Sub-surface investigation comprised drilling of 4no boreholes with associated Standard Penetration Testing (SPT). SPT was performed at 2.0m interval to termination depth of boreholes. Photography and sampling of test pits and boreholes were also undertaken.

Data from site observation and sub-surface investigation is used to assess general founding conditions and used in slope stability assessment.

7 FIELD INVESTIGATIONS

A drive-by and walkover inspection was undertaken of the site. Particular attention was given to geomorphology, topography, watercourses, springs, and exposed geology.

Visual inspections were supplemented by machine borehole drilling. This involved drilling of 4no boreholes. Boreholes 1 – 3 were drilled for a total of 6.0m below existing ground surface (begs). Borehole 4 was drilled to 10m begs. BH4 was the first to be drilled, taking it down to 10m was necessary to assess the phreatic surface under static conditions as well as sub-surface conditions. The depths of the rest of the boreholes were adjusted accordingly to achieve sufficient information and ensure cost effectiveness.

All the boreholes were inserted with a Casagrande type piezometer. This is required to assess groundwater levels and allow sampling of water for lab testing. The pipes were slotted from 2.0m begs to termination depth. This is an attempt at reducing likely surface infiltrations and consequent contamination.

Figure 7.1 Borehole locality plan.

8 ENGINEERING ASSESSMENT AND DISCUSSION

8.1 Sub-surface Conditions

Four boreholes were drilled at designated locations within the proposed site. Some of the test locations had to be adjusted to provide a fair coverage of site as well as accommodate the drill rig configuration.

The site is underlain by reworked materials in the form of Colluvium, Alluvium and Marine sediments.

Sections of land near the southern topographic highs are anticipated to have sliver of colluvium and scree. The site is predominantly underlain by Alluvium transported to site by both the Poha and Mamara Rivers and seasonal ephemeral watercourses that are formed during the wet season, running between valleys.

The boreholes revealed Sand and Gravel predominate. BH2 was an exception in that Clay was encountered to termination depth of 6.0m begs. This is due to its location proximal to a body of stagnant water. The fine sediments points to an environment of low energy flow (fine material settling last) with a pre-existing surface depression. BH1 closer to the ocean is underlain by Marine Sand. BH4 revealed Honiara Coral Reef Limestone at 10.0m begs.

The borehole results are summarised below. Details are presented in Appendix A.

Table 1. Borehole Lithological Summary.

Item	Depth (m)	BH1	BH2	BH3	BH4
1	2.0	Sand	Clay	Sandy Gravel	Clay
2	4.0	Sandy Gravel	Clay	Gravel	Sandy Gravel
3	6.0	Sandy Gravel (E.O.B.H@6.0m)	Clay (E.O.B.H@6.0m)	Sand (E.O.B.H@6.0m)	Sandy Gravel
4	8.0				Sandy Gravel
5	10.0				HCRL (E.O.B.H@10m)

Notes: E.O.B.H: End of borehole; HCRL: Honiara Coral Reef Limestone

The fine material is logged as CLAY, yellowish brown, soft, highly plastic, wet.

The Sand is logged as SAND, grey, uniform, loose, dense, wet.

Sandy Gravel is described as Sandy GRAVEL, trace silt/clay, grey, coarse sand, fine to medium gravel, well graded, very dense.

SPT data show the Clay material as observed in BH2 to be soft. The SAND and Sandy GRAVEL is Medium Dense to Very Dense. The result of SPT exercise is summarised on Fig 7.1.

Details of sub-surface conditions are presented on borehole logs in Appendix A.

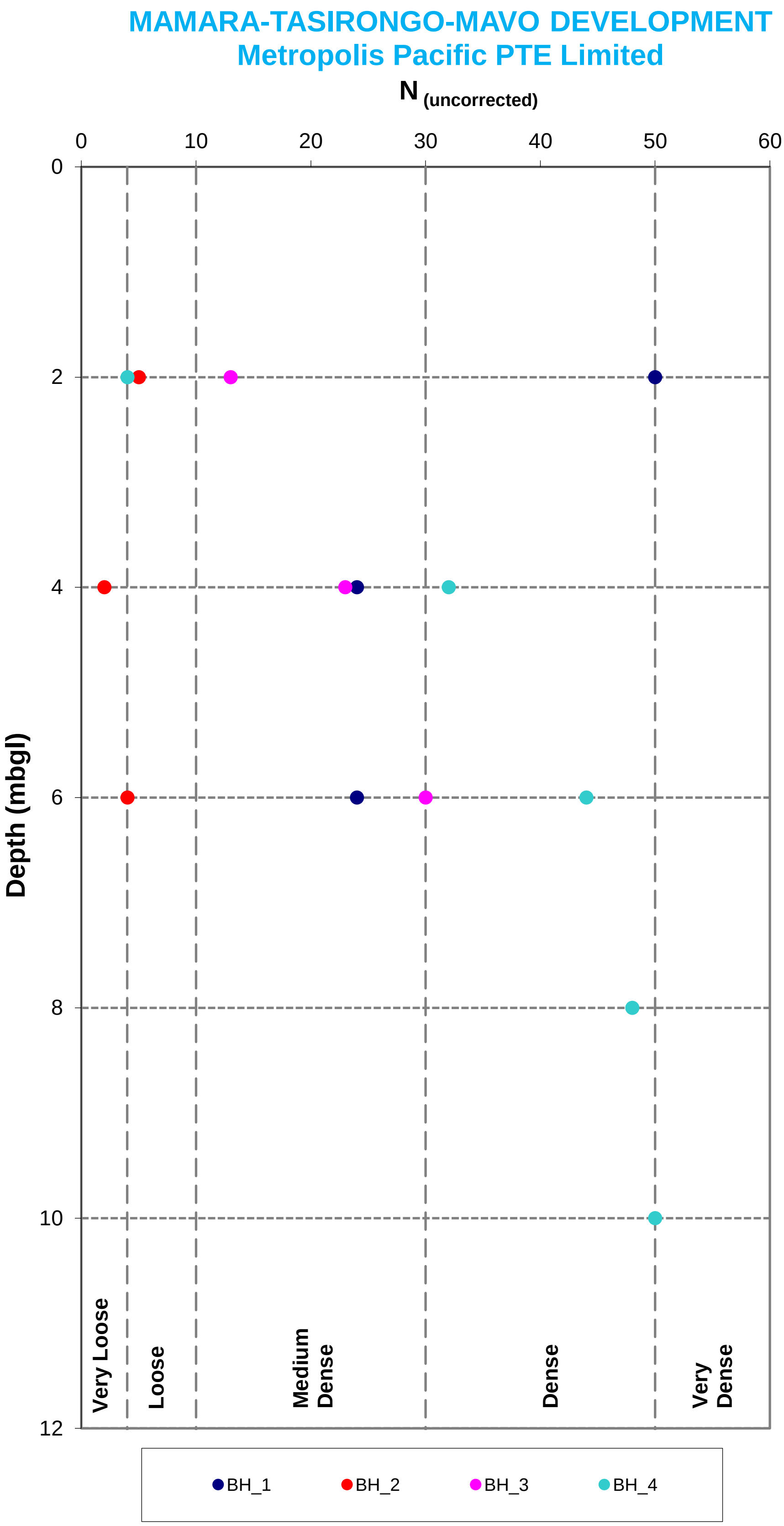

Figure 8.1 SPT-N, Depth-Density Summary.

8.2 Groundwater

During boring of all 4 boreholes, groundwater was encountered before the termination depth. This is summarised in the table below.

Table 2. Groundwater Depth Summary

BH No.	BH Depth (m)	Groundwater Depth (m)	Comments
BH01	6.0	1.95	Some 30m from to the ocean.
BH02	6.0	0.34	About 5.0m to a water pond.
BH03	6.0	0.20	About 30m the east of Mamara River.
BH04	10.0	2.03	Next to the main highway, low point.

Notes: 1). Collar of BH taken as datum. 2). WL measured on 11/07/2020.

8.2.1 Heavy Metal

At the time of writing, heavy metal testing is not possible as there are no accredited heavy metal testing facilities in the country. If testing is to be done, it is recommended samples are collected and sent overseas to an accredited testing facility to determine the heavy metal contents of the site. However, since the site is a greenfield site, contamination via heavy metals is considered negligible.

8.2.2 Acid Sulphate Soils

Similarly, testing of acid sulphate soils was not tested as part of this study because there are no testing facilities available in the country to carry out the required tests. There was very little by way of stagnant mudflats that are conducive to generating acid sulphate soils when disturbed. As such the risk to acid sulphate issues are low.

8.3 Engineering Options and Design Recommendations

The design options and recommendation are developed in this section.

8.3.1 Design Standards

For quality assurance, the following standards are recommended to be used when designing the road network and building foundations in detail.

8.3.2 Road

(i) MID Specification for Road and Bridge Works, October 2019.
(ii) Austroads Guide to Pavement Technology Part 2: Pavement Structural Design 2019.
(iii) Austroads Guide to Pavement Technology Part 4K: Selection and Design of Sprayed Seals 2019.
(iv) Road Pavement Design for the Pacific Region.
(v) Vanuatu Resilient Roads Manual.

8.3.2.1 Building Structures

(vi) NBCSI National Building Code of Solomon Islands.
(vii) AS/NZS 1170.0 Structural Design Actions: General Principles.
(viii) AS/NZS 1170.1 Structural Design Actions: Permanent, Imposed and Other Actions.
(ix) AS/NZS 1170.2 Structural Design Actions: Wind Actions.
(x) NZS 1170.5 Structural Design Actions: Earthquake.

8.3.3 NZS 4219 Seismic Performance of Engineering Systems in Buildings.

(xi) NZS 3101 Concrete Structures Standard.

(xii) NZS 3104 Specification for Concrete Production.

(xiii) NZS 3109 Concrete Construction.

(xiv) NZS 4203 Code of practice for general structural design and design loadings for buildings.

8.3.4 Design Criteria

8.3.4.1 Buildings and Civil Structures

The design requirements for the founding material and depth for the buildings and other civil structures are listed below:

a) Groundwater level as high at least 0.34m below existing ground surface, noting some seasonal variation is likely;
b) Soil bearing capacity of at least 100kPa under ULS (Ultimate Limit State) load conditions;
c) Soil bulk density is 16kN/m^3;
d) Environmental exposure classification B2 (Ref.NZS3101 clause3.4) shall be adopted for the design of reinforced concrete for durability;
e) Specific engineering design for reinforced concrete slab to accommodate fire truck loading; and
f) The Contractor is required to undertake any additional subsurface investigations required to establish design parameters and the required footing configuration.

It should be noted that any specialised civil structures will require additional investigation and design development inputs by a specialist especially for buildings that are two-storey and above or large structures.

8.3.4.2 Road Network

The design criteria for the road network are as follows:

(a) Pavement Design Life;
(b) Design Traffic; and
(c) Road Safety.

Additionally, the design of the road network and material should be as per the recommended Design Standards.

8.3.5 Cut and Fill Material

The cutting of the hills on the southern fringes of the site has commenced. These coralline limestone (corronous) materials retrieved from the hills are then used as fill material for the road network and founding material of the building structures. It was observed that the slopes that will be cut have approximate 0.5m to 1.0m of topsoil. These must be removed before using the cut material as fill.

8.3.5.1 Fill Material Suitability

Corronous or Honiara Coral Reef Limestone (HCRL) has been used extensively as road base material in the pacific islands (PRIF, 2016). Therefore, the corronous material extracted from the hills at the southern end of the development site is suitable for road and foundation construction when proper compaction and drainage systems are in place. However, the MID Roads and Bridge Specifications (2019) and the Vanuatu Resilient Roads Manual (2018) should be used as the minimum standard for the road construction when using the fill material.

The total Fill thickness must consider the Base Flood Level (BSL) and Freeboard to guard against inundation of the buildings. It is assumed the client has confirmed this. In the event that this has not been done, it is highly recommended that assessment undertaken.

8.3.5.2 Grain Size

The materials observed at the spine road appear to have boulder sized grains as seen in Figure 8.1. Road base using corronous material should be crushed to granular sized material, i.e. 2mm to 200mm as described in New Zealand Geotechnical Society Soil and Rock Guidelines (NZGS Guidelines).

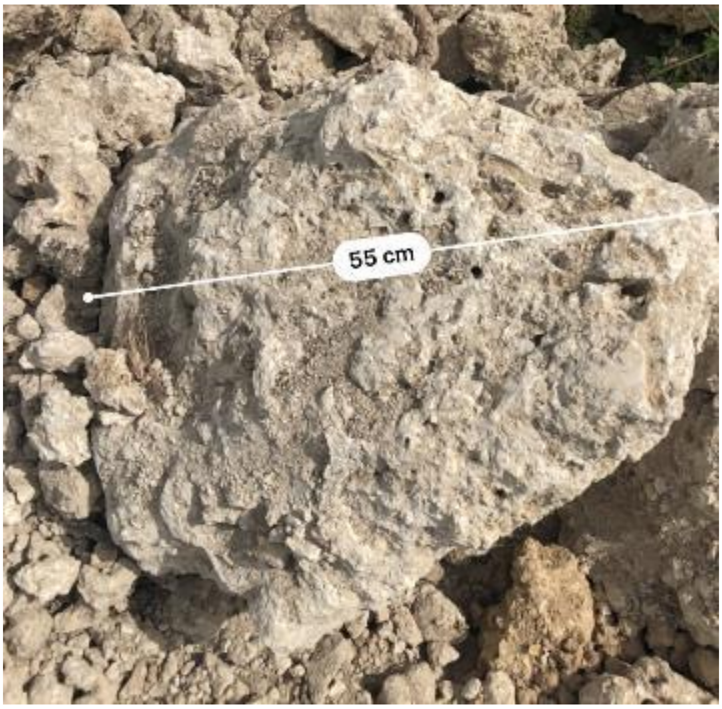

Figure 7.2 Boulder found on the Spine Road of the Development Area

Boulders are not recommended for road base material. It should be crushed to gravel sized material for durability and strength as large boulders do not interlock well. Crushing it to gravel sized material will allow for better interlocking between the different grain sizes as Average Least Dimension (ALD) of the granular material can be easily achieved during compaction.

8.3.6 Alternative Fill Materials

Other fill materials may be considered, particularly for the road network construction. These are listed in the following sub-sections below.

8.3.6.1 Natural Aggregates

Natural aggregate consists of manufactured crushed stone and sand created by crushing bedrock, or naturally occurring unconsolidated sand and gravel (i.e. colluvium, river run gravel, boulders). The main origin of natural aggregates is from bedrocks such as igneous rocks, sedimentary rocks, and metamorphic rocks.

It is preferred for use as base and subbase materials as it is produced to form dense-graded materials, has high resistance to crushing, not water sensitive, and provide long lasting pavement support.

The development area is situated between Poha River and Mamara River where aggregates of varying sizes and shapes are found. It is common engineering practice to use river gravel as road aggregates.

The Poha River aggregates are angular to sub-round as seen in the image below. The sizes vary from sandy to small boulders just greater than 200mm. Therefore, if these materials are considered to be used for the development, it is recommended they are tested for their suitability.

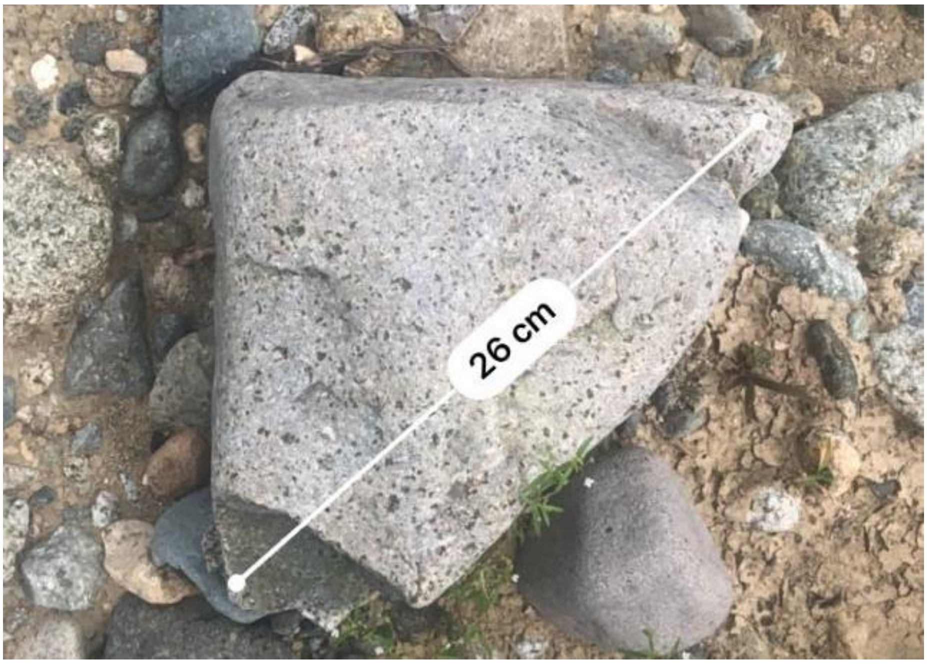

Figure 7.3 Poha River gravel and cobbles.

The Mamara River on the other hand appears to contain finer material and more rounded gravels. Similarly, if the Mamara River material is to be used for road base or building platform, it is recommended that its geo-mechanical properties are tested at MID Laboratory.

8.3.6.2 Quarried Volcanic Material

Citing the Road Pavement Design for the Pacific Region, volcanic rocks are naturally hard, well cemented, and massive rocks deposits. On Pacific islands where the central volcanic core remains, associated residual soils are silt and sand sized, of varying consistency. Alluvial soils (valley infill washed from the adjoining slopes) may well contain more organic material. High ground water levels, and water infiltration as a result of storm events, are prevalent. Such conditions influence the plasticity levels and water sensitivity in naturally occurring and processed road aggregate.

For road aggregates prepared from volcanic source rock, or weathered inland corronous deposits, lime and cement stabilisation would help to mitigate the adverse effects of high plasticity, water sensitivity, and high natural water contents.

8.4 Impacts and Mitigating Options

Tabulated below are the anticipated activities, likely implication on the environment from a soil and hydrogeology perspective and available corrective options.

Table 3. Development Phases, likely Implications and Mitigating Options

Development Phase	Potential Impacts/Risk (respective fields) e.g. Climate change or water quality	Mitigation Measures (corrective actions that can be taken minimise or reduce impacts or risk)
Development phase 1 – Gravel Extraction and Reclamation Phase	(a) Cutting of ridgelines will change catchment area & may result in increased flood levels and siltation into waterways.	(a) Planting woodlands on unstable soils along the catchment and floodplain river corridors, use of silt traps near water bodies.

Table 3. Development Phases, likely Implications and Mitigating Options		
	(b) Underground water regime may also change; result in decrease storage. (c) Gravel extraction may result in aggradation	(b) A detail study of landform modification implication should be undertaken, in particular with respect to the Mamara Spring. (c) Harvest excess gravel to avoid elevated riverbed, bridge inundation & bank overtopping
Development phase 2 – Roads, Drainage and Building Construction	(a) Increase in paved surface, i.e. less water infiltration into the ground which will lead to decreased subsurface water levels. (b) Increased paved surfaces will lead to larger runoffs may in turn cause flooding through inundation.	(a) Use of injection wells to directly discharge water into water-bearing zones. (b) Tree roots increase water saturation. Proper stormwater drains to collect surface water & discharge at suitable locations.
Development phase – Operational Phase, Residential, Commercial and Supporting Utilities	(a) Commercial operations may introduce chemical waste. (b) Increase in human waste. The potential impact is the discharged effluents into natural water bodies.	Both solid and liquid waste need to be handled, treated, and disposed of appropriately.

9 CONCLUSION AND RECOMMODATIONS

Site inspection, site mapping and sub-surface investigation were undertaken in support of the proposed Mamara-Tasivarongo-Mavo development at Mamara, west Guadalcanal.

It is noted that the site is underlain by a veneer of Topsoil which is in turn underlain by Alluvium and Marine sediments, further underlain by the Honiara Coral Reef Limestone at depth.

We confirm from our assessment and analysis that the site is suitable for the proposed development not withstanding recommendations outlined in this report.

The following are recommendations to protect on-site works and minimise delays and provide some verification of ground conditions.

- Proposed phases of the project will have implications on the site. Refer Table 3 for Mitigating Options as far as hydrogeology and soils are concerned
- Seismic analysis should form part of future infrastructure design, in particular for high rise buildings and building with a high importance factor
- Flood assessment should be undertaken for proposed sites to accommodate the sewerage treatment plant and school so that floor levels have sufficient freeboard
- Minimal clearance should be undertaken at the site for the water reservoir and the reservoir constructed not less than 10m from the edge of the slope. Slope stability assessment should also be undertaken at the design stage
- Aggregate selection (size) and treatment (crushing) is required for the subgrade formation to ensure the long-term performance of the roads
- Filling of site for roads and building platforms should consider compaction parameters for a given material type (lab testing to verify)
- Fill thickness must consider Flood base Level and Freeboard
- All earthworks should be independently verified to ensure the minimum design intent is achieved
- Sub-section 7.3 lists some Standards and Design Criteria that can be adopted for this development
- Trenching and excavation work on site should be undertaken during dry season, refer Fig 3.1. Should works be intended to occur at other times, arrangement of water pump should be made for pumping out potential surface infiltration
- Provision should be made to shore side of excavations in the case of elevated water level
- The bottom layer of the foundation should be compacted; there should be no soft spots in foundation due to roots etc. Any soft/ defective spots should be dug out and filled with granular material and compacted
- Bottom of footing excavation should be inspected by a qualified Engineer prior to placement of reinforcement steel and pouring of concrete to confirm design intent has been achieved.
- Structural loads to be transferred to Marine Sand/Gravel or HCRL at depth or satisfactory compacted Fill platform
- Foundation depth and footing dimensions will need to be confirmed by Structural Engineer once structural loads become available
- A suitably experienced Engineer should be present during foundation excavation to confirm minimum design intent has been achieved
- Stormwater runoff from roofs and paved areas should be collected and piped to safe disposal points such as tanks and existing drains away from building foundation
- Relevant expertise should be notified immediately, should ground conditions differ from reported observations on which this report is based

10 LIMITATION

This report has been prepared solely for the benefit of the developer and the parties under the Mamara-Tasivarongo-Mavo Agreement (1995). The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such parties' sole risk.

Recommendations and opinions in this report are based on data from limited test positions. The nature and continuity of subsoil conditions away from the test positions are inferred and it must be appreciated that actual conditions could vary considerably from the assumed model.

During excavation and construction, the site should be examined by an Engineer or Engineering Geologist competent to judge whether the exposed subsoils are compatible with the inferred conditions on which the report has been based. It is possible that the nature of the exposed subsoils may require further investigation and the modification of the design based upon this report.

Telios would be pleased to provide this service to the Solomon Islands Government and believe that the project would benefit from such continuity. In an event, it is essential Telios is contacted if there is any variation in subsoil conditions from those described in the report as it may affect the design parameters recommended in the report.

REFERENCE

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Appendix A

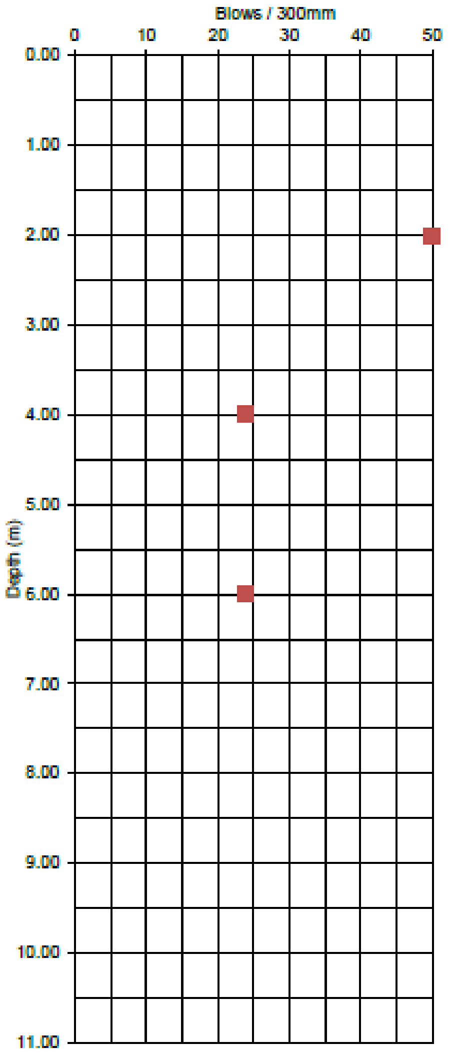
Test Pit Logs

BOREHOLE LOG

Project : Mamara-Tasirongo-Mawo
Location : See Site Plan
Client : Metropolis
Test number : BH1
Water level (m): As logged

Project No :	GI.MP0620.001
Lab Ref No :	N/A
Client Ref No :	N/A

SPT



Test Results

Depth (m)	SPT-N	Soil Description
0.0		TOPSOIL, dark brown, sandy, dry, roots.
0.20		SAND, grey, uniform, loose, wet.
		Phreatic surface at 1.95m, measured on 11/07/20.
2.00	15,22,28 N=50	Sandy GRAVEL, grey, fine to coarse sand, very dense, well graded, wet [ALLUVIUM].
4.00	9,10,14 N=24	
6.00	9,10,14 N=24	SANDY GRAVEL,minor clay, grey, dense, wet. E.O.B at 6.0m (Target Depth)

Test Methods

Field Descriptions of Soils and Rocks by NZ Geotechnical Society Dec 2005

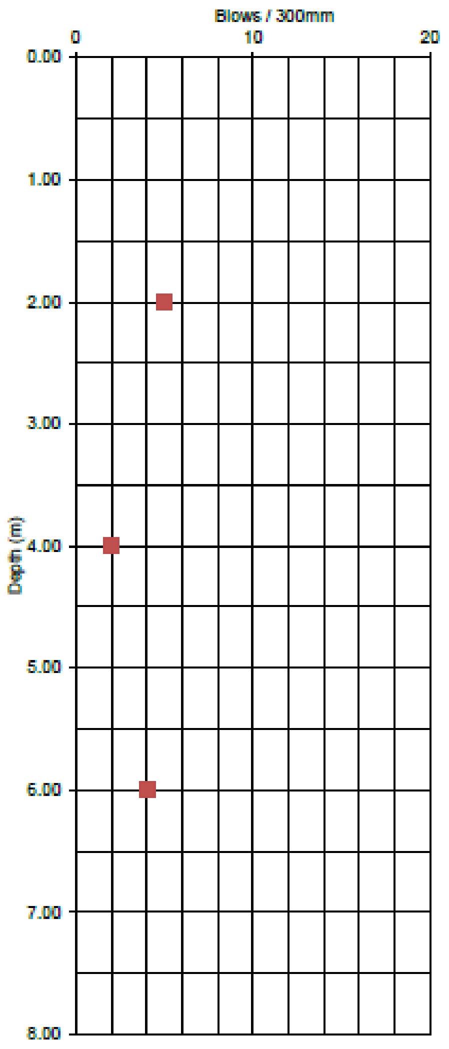
Note: Soil descriptions are based upon disturbed drilled samples.

BOREHOLE LOG

Project :	**Mamara-Tasirongo-Mawo**
Location :	**See Site Plan**
Client :	**Metropolis**
Test number :	**BH2**
Water level (m):	**As logged**

Project No :	GLMP0620.001
Lab Ref No :	N/A
Client Ref No :	N/A

SPT



Test Results

Depth (m)	SPT-N	Soil Description
0.0		TOPSOIL, dark brown, friable, rootlets, dry. Phreatic Surface at 0.34m, measured on 11/07/20.
0.40		CLAY, yellowish brown, stiff, high plasticity, wet [ALLUVIUM].
2.00	1,2,3 N = 5	CLAY, dark brown, very soft, high plasticity, roots, wet.
4.00	1,1,1, N = 2	CLAY, dark brown, very soft, high plasticity, roots, wet.
	2,2,2 N=4	CLAY, black, stiff, medium plasticity.
		E.O.B @ 6.0m (Target Depth)

Test Methods

Field Descriptions of Soils and Rocks by NZ Geotechnical Society Dec 2005

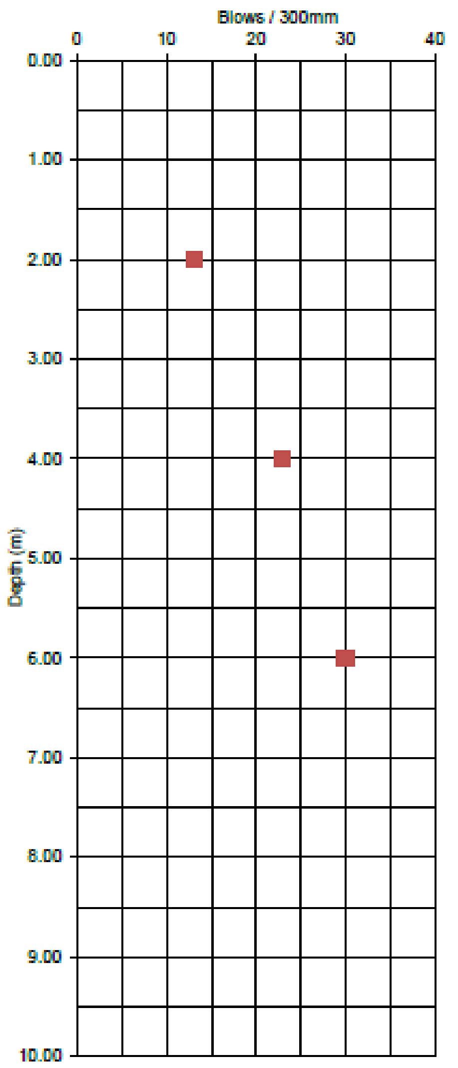
Note: Soil descriptions are based upon disturbed drilled samples.

BOREHOLE LOG

Project : Mamara-Tasirongo-Mavo
Location : See Site Map
Client : Metropolis
Test number : BH3
Water level (m): As logged

Project No : GLMP0620.001
Lab Ref No : N/A
Client Ref No : N/A

SPT



Test Results

Depth (m)	SPT-N	Soil Description
0.0		TOPSOIL, dark brown, very soft, highly plastic, rootlets, dry. Phreatic Surface at 0.20m, measured on 11/07/20.
0.40		Sandy GRAVEL, minor clay, brownish grey, fine to coarse sand, fresh, rounded river gravels, wet [ALLUVIUM].
2.00	6,6,7 N=13	
		SILTY SAND, grey, brown, fine to coarse sand with some fine to medium gravel, medium dense, moist.
4.00	11,12,11 N=23	grey, increasing gravels.
6.00	12,20,10 N=30	SAND, gravels, fine, trace gravels, wet.
		E.O.B @ 6.0m (Target Depth)

Test Methods

Field Descriptions of Soils and Rocks by NZ Geotechnical Society Dec 2005

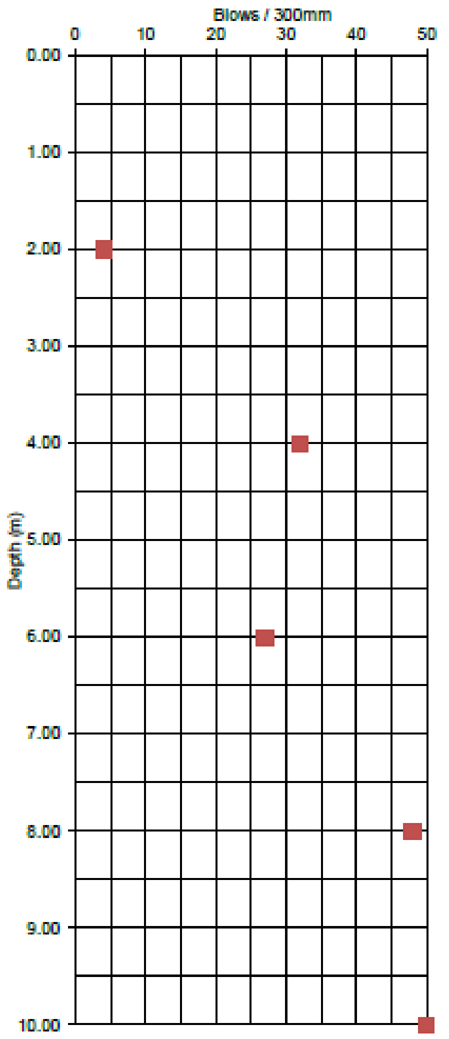
Note: Soil descriptions are based upon disturbed drilled samples.

BOREHOLE LOG

Project : Mamara-Tasirongo-Mawo
Location : See Site Plan
Client : Metropolis
Test number : BH4
Water level (m): As logged

Project No : GI.MP0620.001
Lab Ref No : N/A
Client Ref No : N/A

SPT



Test Results

Depth (m)	SPT-N	Soil Description
0.0		TOPSOIL, dark brown, friable, rootlets, dry.
0.30		CLAY, yellowish brown, soft, high plasticity, wet [ALLUVIUM].
2.03	1,1,3 N=4	Phreatic Surface at 2.03m, measured on 22/06/20.
	15,18,14 N=32	Sandy GRAVEL, trace silt, grey, coarse sand, fine to medium gravels, well graded, dense. grey, fine to
6.00	6,22,22 N=44	trace clay, dark grey, fine-coarse sand, sub-rounded clasts, gap graded.
	19,25,23 N=48	25mm clast inclusions.
10.00	13,20,18 N=50	Honiara Coral Reef Limestone, white, slightly weathered, medium strength. E.O.B @ 10.0m (Target Depth)

Test Methods

Field Descriptions of Soils and Rocks by NZ Geotechnical Society Dec 2005

Note: Soil descriptions are based upon disturbed drilled samples.

APPENDIX B

Site Photos

Plate 1. View NE ocean wards along central spine accessway.

Plate 2. View SW towards back of subdivision along SW perimeter, Poha River to the left.

. Plate 3. View NE along Mamara River.

Plate 4. View SW at logged ridges, Mamara River to the right, note pond in foreground.

Plate 5. View south towards Poha and LD, note formed accessway

.

Plate 6. View along formed access, note courageous boulders used to construct road basecourse.

Plate 7. View at waterlogged area (pond).

Plate 8. View from Mamara towards southern lot boundary.

Plate 9. View NW towards knoll proposed to support water reservoir.

Plate 10. Drilling of BH1 near the coat.

Plate 11. Drilling of BH4.

Plate 12. BH1 piezometer.

Plate 13. BH2 Piezometer.

Plate 14. BH3 Piezometer.

Plate 14. BH4 Piezometer.

BH1, SAND @ 2.0m. BH1, Sandy GRAVEL @4.0m. BH1, Sandy GRAVEL @6.0m.

BH2, CLAY, yellowish brown @ 2.0m. BH2, CLAY, dark grey@ 4.0m. BH2, CLAY, black@ 6.0m.

Plate 14. Samples from BH1 & 2 (see pen for scale).

BH3, Sandy GRAVEL, brownish grey @ 2.0m.

BH3, Sandy GRAVEL, grey @ 4.0m.

BH3, Sandy GRAVEL, grey @ 6.0m.

Plate 15. Samples from BH3 (see pen for scale).

BH4, CLAY, yellowish brown @ 2.0m.

BH4, Sandy GRAVEL, grey-brown @ 4.0m.

BH4, Sandy GRAVEL, grey @ 6.0m.

BH4, Sandy GRAVEL, grey @ 8.0m.

BH4, Sandy GRAVEL with HCRL, grey @ 10.0m.

Plate 16. Samples from BH4 (see pen for scale).