No.

Independent Public Business Corporation

The Independent State of Papua New Guinea

DETAILED DESIGN (PHASE 2) ON PORT MORESBY SEWERAGE SYSTEM UPGRADING PROJECT IN THE INDEPENDENT STATE OF PAPUA NEW GUINEA

FINAL REPORT

PART I: Design Report

Volume III – Result of Natural Condition Surveys

December 2011

JAPAN INTERNATIONAL COOPERATION AGENCY

NJS CONSULTANTS CO., LTD.

GED
CR(3)
11-206

DETAIL DESIGN ON
PORT MORESBY SEWERAGE SYSTEM UPGRADING PROJECT

FINAL REPORT

Part I: Design Report
Volume III: Result of Natural Condition Surveys

TABLE OF CONTENTS

1. Topographic Survey

SURVEY REPORT

FOR

JICA – PORT MORESBY SEWERAGE UPGRADING PROJECT

TOPOGRAPHICAL SURVEY

PREPARED BY ARMAN LARMER SURVEYS LTD
OCTOBER 2011.

Table of Contents

1.0 INTRODUCTION

This Survey report has been produced for JICA Study Team engaged in Port Moresby Sewerage Upgrading Project

Arman Larmer Surveys Limited (ALSL) was awarded contract to carry out Topographic Survey whilst the second contract was awarded to Joint Venture formed by Arman Larmer Surveys Limited and Mapping & Hydrographic Surveys (HMS) to carry out Ocean Outfall Topographic Survey for JICA Study Team under Port Moresby Sewerage Upgrading Project.

Both Topographic Survey and Ocean Outfall Survey contracts were awarded on the 3rd February 2011.

The commencement of the Field Survey subsequently followed after issuance of Notice to Proceed by JICA Study Team after receiving the Inception Report as per contract clause 1.4. The survey commenced on 17th February 2011.

Under the Topographic Survey Contract following are the survey items:

1. Main Trunk
2. Sub Raising
3. Proposed Gravity Sewer
4. 17 Pumping Stations
5. Morata Sewer Treatment Plant & Access Road
6. Kilakila Sewer Treatment Plant & Access Road

2.0 Table 2.1 Survey items and Quantity, and Specification for the Deliverables

Table 2.1 Survey items and Quantity, and Specification for the Deliverables

Item	Target and Description	Unit	Quantity
1. Route Survey	Alignment along the existing/proposed sewer pipelines and a part of ocean outfall of Kila Kila STP proposed on the ground Trunk sewer 17.3km Branch sewer 17.7km Ocean outfall 1.0km Plane Survey (Scale: S=1:500, Width: Trunk sewer 50m Ave., Branch sewer and ocean outfall 30m Ave. ROW shall be covered by the width) Centre line survey (H:S=1:500, V:S=1:200) Cross section survey (S:1:100, Width=Trunk sewer 50m Ave., Branch sewer and ocean outfall 30m Ave.) Note: *Plan drawings should include the information of Manhole, crossing drainage, canal, and other facilities of roads. *ROW shall be covered by the survey width	Km Section	(Total) 36.0 720 (1 section /50m)
2.Plane Survey	Proposed construction site of Kila Kila sewage treatment Plant, Proposed construction site of Morata sludge drying bed, and access roads to each STP (1) Kila Kila STP Plane survey (Scale=1:500) Cross section survey (Width=200m Ave.) (Scale=1:100, Interval 50m for X and Y direction both) (2) Morata STP Plane Survey (Scale=1:500) Cross section survey (Width=600m Ave.) (Scale=1:100, Interval 50m for X and Y direction both) (3) Access road to each STP Plane Survey (Scale=1:500, Width=50m Ave.) Centre line survey (H:Scale=1:500, V:Scale=1:200) Note; * Plan drawings shall include the cadastral information. * Plan drawings should include the contour line with 1m interval	m^2 Section m^2 Section km	75,000 12 38,000 24 (Total) 3.0 approx.

3.0 Survey Control

3.1 Primary Control

Primary Control Survey was executed by GPS, 4X Sokkia GSR2700 units plus two Leica Viva GPS units were used on this project. With Paga Grid original Origin Point destroyed due to recent development at Paga Hill we decided to re-occupy three old Paga Grid Survey Monuments.

With two of these Paga Grid Survey Monuments occupied as our Base Stations we established and coordinated recently established GPS stations along the main trunk from Kanudi to Kilakila and at various selected locations where we saw fit to provide enough survey coordination in and around Proposed Gravity Sewer areas.

Similarly, we established Three GPS Stations at Morata treatment plant and two at start chainage of the Access Road at Talapia Street.

Pair of GPS stations established at end of Main Sub Raising at Joyce Bay facilitated control for both Kilakila Sewer Treatment Plant and Ocean Outfall survey.

On the same campaign we located and re-occupied two Old Cement Pegs (OCP), one OCP at each plant site, to tie in the DCDB data provided by the client and Cadastral Survey Plans.

For other locations as per proposed Gravity Sewer routes, we established two pairs at each end of the survey route and also in cooperated recent GPS Stations established by Asia Pacific Surveys (APS), another survey firm who were also engaged on same project but on a separate contract.

All GPS control data observed for this project were validated by Richard Stanaway of Quickclose based in Melbourne, Australia.

3.2 Secondary Control

3.2.1 Main Trunk

The Secondary Control traverse was executed using Wild Leica Total Station theodolites. The traverse for Main Sub Raising Sewer commenced from recently established GPS Station; GPS PS001 and existing BM 191 at Kanudi and terminated at two recently established GPS Stations; GPS PS 010 and PS011 at Kilakila Sewer Treatment Plan at Joyce Bay.

3.2.2 Kilakila Sewer Treatment Plant Access Road

The secondary traverse for Kilakila Sewer Treatment Plant Access Road commenced from GPS Stations; PS011 and PS 010 at Joyce Bay and was closed onto two GPS stations; SW 39 AND SW 40 along the Main Trunk, Scratchely Road

3.2.3 Morata Sewer Treatment Plant and Access Road

The secondary traverse for Morata Sewer Treatment Plant started and closed on to three GPS Stations, GPS PS016, PS017 and OCP07, whilst Access Road secondary traverse commenced from same three GPS Stations and was closed onto two GPS Stations at Talapia Road, GPS PS028 and GPS PS029.

3.2.4 Proposed Gravity Sewer

The secondary control traverses for Proposed Gravity Routes that did not joined the Main Sub Raising Sewer were executed independently, the loops started from recently established GPS stations and similarly ended on recently established GPS stations established either by our firm or APS.

Whilst adjoining Proposed Gravity Routes to the Main Sub Raising Sewer were tied onto Main Raising Sewer control and recently established GPS Stations at various locations.

4.0 Digital Terrain Modeling (DTM) SURVEY

Digital Terrain Modeling (DTM) SURVEY

DTM survey was carried out using Wild Lieca Total Stations and Leica RTK GPS. Data collected was downloaded on GEOCOMP, a survey and engineering software, for data reduction, processing, editing.

The DTM data was reduced using the adjusted secondary control

The DTM Survey for the following site were not completed or not executed primarily due to access:

1. Pandora Crest
2. D'Albertis Street – Hanuabada
3. Onno Street – Horse Camp Settlement

Route Survey between Badili Pump Stations and Koki Pump Stations was cancelled by the client.

Extra Survey DTM were carried out

1. At Hanuabada Village at three jetties towards southern end of the village for a pilot project
2. Route Survey between Sabama Junction and Sebea Rd Junction, Pari Road.

5.0 Survey Datum:

Survey Datum

In consultation with Eda Ranu and the JICA study team agreed project Survey Datum is Paga Grid as Horitonal Datum and CDW as Vertical Datum.

Both Paga Grid and CDW were established by Common Wealth Department of Works in early days when Port Moresby was emerging as the City of Papua New Guinea.

Paga Grid is a Plane Datum with its Origin Point for this survey is BM 164 at the junction of Waigani Drive and Sir John Guise Drive, with BM 198, next to Habours Board Port is the CDW point of Origin as per CDW report.

PNG 94 been the datum for Port Moresby Digital Cadastral Data Base (DCDB)

Following Parameters were used in this project:

Horizontal Datum - PNG94 - origin -PSM15382 NMB Base Station	
Plane Datum - PAGA Grid - origin - BM164	
Vertical Datum (MSL) - BM 198 from CSIRO Tidal Observations	
Vertical Datum (CDW) - BM 198 from CDW report	
Geoid Model used - EGM2008 2.5'	
MSL = EGM2008 - 0.928 metres	
CDW = MSL -1.073 metres (close to Highest Astro Tide)	

6.0 BOUNDARY OR RIGHT OF WAY (ROW)

ROW information for the following survey items were taken from the Registered Cadastral Survey Plans

1. Main Trunk
2. Kilakila Sewerage Treatment Plan & Access Road
3. Morata Sewerage Treatment Plan & Access Road

Port Moresby Cadastral Data Base, also referred to as DCDB, provided the client did not compare well against our actual survey connections to property boundary corners, hence have accepted our survey comparison and connections to property boundary corners.

ROW information for ALL Sub Raising survey areas adjacent to the Main Trunk were taken from BDCB, hence survey accuracies are within plotting accuracies only. Please see the note above.

7.0 GPS SURVEY STATIONS CORDINATE LISTING

See appendix 1

Appendix 1

JICA Port Moresby Sewerage Project - Geodetic Control - 29th April 2011

Station	Station Mark	Suburb	Location	PNG94			MSL CSIRO POM TG	PAGA GRID (Plane)		
				PNGMG94 (UTM) Zone 55		Ellipsoid Height		Easting	Northing	CDW RL
				Easting	Northing					
PS038	Star Picket	2 Mile	Pruth St (at end)	520015.452	8952070.951	151.862	76.389	108365.361	104633.127	75.316
PS039	Nail in kerb	2 Mile	Pruth St. (N of Pacific View Apts)	520121.990	8952247.573	162.147	96.647	108471.868	104809.867	95.574
PS040	Iron Pin	3 Mile	Settlement	519967.023	8952383.614	111.193	35.695	108316.779	104945.899	34.622
PS041	Iron Pin	3 Mile	Settlement	519902.641	8952326.905	106.939	31.453	108252.394	104889.139	30.380
SW33	Nail in kerb	3 Mile	Hubert Murray Rd / Korobosea Dr	520293.000	8952469.797	165.414	89.877	108642.854	105032.256	88.804
SW34	Nail in kerb	3 Mile	Hubert Murray Rd W of Korobosea	520142.247	8952490.721	157.169	81.644	108492.030	105053.125	80.571
ALS BASE	Nail in bit.	Badili	Arman Larmer Car Park	519547.416	8952407.350	98.353	22.893	107896.988	104969.466	21.820
PM007	IP in conc.	Badili	Scratchley Rd (Moore Printing)	519395.364	8952219.031	85.421	9.993	107744.953	104781.005	8.920
PS021	Nail in conc.	Badili	Hides St	519220.356	8952045.946	78.436	3.041	107569.946	104607.774	1.968
PS031	Iron Pin	Badili	Goro-Be St (at end)	519608.569	8952802.725	173.876	98.373	107957.998	105365.031	97.300
PS133	Nail in road	Badili	Le Hunte Rd (opp. Primary School)	518436.570	8952122.164	89.329	14.002	106785.803	104683.690	12.929
PS134	?	Badili	Koke St (opp. Supermarket)	518560.979	8952275.156	86.931	11.578	106910.199	104836.798	10.505
PSM2139	Brass plaque	Badili	Cnr Scratchley Rd / Pascall Ave	519190.089	8952332.128	85.232	9.813	107539.545	104894.061	8.740
SW23	Nail in conc.	Badili	Hubert Murray Rd (median park)	518859.273	8952356.552	88.020	12.630	107208.582	104918.355	11.557
SW24	Nail in conc.	Badili	Hubert Murray Rd (median park)	518927.875	8952407.485	92.209	16.808	107277.191	104969.338	15.735
SW29	Nail in kerb	Badili	Hubert Murray Rd / cnr Muniogo	519142.711	8952650.847	101.257	25.813	107492.012	105212.892	24.740
SW30	Nail in kerb	Badili	Hubert Murray Rd / cnr Goro-Be St	519238.422	8952612.878	107.511	32.061	107587.779	105174.948	30.988
SW31	Nail in bit.	Badili	Muniogo Cr	519648.855	8952372.651	102.959	27.492	107998.484	104934.796	26.419
SW32	Nail in bit.	Badili	Muniogo Cr.	519566.564	8952424.804	100.832	25.368	107916.137	104986.936	24.295
BM?	?	Ela Beach	Lawes Rd (N of Ela-Makana St)	517732.281	8952717.233	138.791	63.478	106080.970	105278.706	62.405
PM012	Nail in bit.	Ela Beach	Cnr. Ela-Makana / Chester St	517907.227	8952662.76	159.016	83.691	106256.012	105224.285	82.618
PM013	Star Picket conc.	Ela Beach	Ela-Makana St (near end)	518012.519	8952733.762	192.975	117.632	106361.317	105295.361	116.559
PM014	Star Picket	Ela Beach	Chester St	518262.272	8952345.201	174.720	99.389	106611.339	104906.746	98.316
PM015	?	Ela Beach	Chester St (overlooking Badili)	518423.382	8952694.724	175.028	99.648	106772.367	105256.482	98.575
PS006	Star Picket conc.	Ela Beach	opp. Ela Beach Hotel	517039.225	8952132.781	78.010	2.824	105387.876	104693.718	1.751
SW11	Nail in bit.	Ela Beach	Ela-Makana St	517830.187	8952841.118	167.206	91.871	106178.864	105402.684	90.798
SW12	Nail in kerb	Ela Beach	Ela-Makana St	517853.883	8952880.103	169.298	93.957	106202.553	105441.695	92.884
SW15	Dot Manhole	Ela Beach	Lawes Rd (N of Ela-Makana St)	517749.225	8952728.285	140.135	64.819	106097.916	105289.770	63.746
SW16	Nail in kerb	Ela Beach	Lawes Rd / Ela-Makana St Jn	517767.025	8952660.542	135.991	60.680	106115.753	105222.007	59.607
SW21	Nail in bit.	Ela Beach	Jetty (North)	516449.994	8951755.343	77.555	2.465	104798.561	104315.873	1.392
SW22	Nail in bit.	Ela Beach	Jetty (Middle)	516474.912	8951666.309	77.728	2.644	104823.527	104226.813	1.571
PM003	Star Picket conc.	Gabi	Roundabout - Bypass / Boe Vagi Rd	516801.435	8955301.140	96.360	20.897	105148.641	107863.287	19.824
PS002	Star Picket	Gabi	Hagara Primary School (entrance)	516579.197	8955366.177	82.539	7.092	104926.283	107928.257	6.019
SW03	Texta mark	Gabi	Napa Napa Rd (nr school)	516457.425	8955409.628	80.120	4.681	104804.443	107971.674	3.608
SW04	Nail in bit.	Gabi	Napa Napa Rd (nr school)	516494.274	8955386.861	79.741	4.300	104841.316	107948.913	3.227
PS008	Star Picket conc.	Gabutu	Karius Rd (next to beach)	519798.525	8950798.017	79.855	4.521	108148.885	103359.574	3.448
PS009	Star Picket	Gabutu	Karius Rd (next to beach)	519936.804	8950667.913	78.922	3.586	108287.276	103229.475	2.513
SW41	Nail in kerb	Gabutu	Karius Rd (next to beach)	519757.862	8950844.323	80.479	5.144	108108.185	103405.882	4.071
PS021	Star picket	Horse Camp	Cnr Mataunage St / Kadea St	521707.743	8950460.788	81.637	6.148	110059.036	103023.016	5.075
PS022	Star Picket conc.	Horse Camp	Near Cnr Eava St / Kadea St	521741.540	8950367.421	78.260	2.776	110092.887	102929.625	1.703
PS023	Nail in conc.	Horse Camp	Cnr Rabura St / Hari St	521734.857	8950618.970	88.912	13.406	110086.094	103181.275	12.333
PS024	Star Picket conc.	Horse Camp	Cnr Rabura St / Mataunage St	521792.235	8950575.008	89.908	14.400	110143.515	103137.320	13.327
PS025	Star Picket conc.	Horse Camp	Cnr Rabura St / Sebea Rd	521659.571	8950657.481	87.403	11.901	110010.761	103219.770	10.828
BM193	Brass plaque	Idubada	Nr Fuel Farm entrance	516137.772	8955765.294	79.240	3.799	104484.506	108327.351	2.726
SW01	Nail in bit.	Idubada	POM Tech - Idubada Drive	515908.937	8955922.666	78.352	2.919	104255.510	108484.691	1.846
SW02	Nail in bit.	Idubada	POM Tech - Idubada Drive	515926.234	8955977.358	80.128	4.688	104272.790	108539.413	3.615
SW13	Nail in kerb	Kaevaga	Champion Pde (opp. Church)	517071.587	8954421.807	78.412	3.001	105419.278	106983.705	1.928

JICA Port Moresby Sewerage Project - Geodetic Control - 29th April 2011

Station	Station Mark	Suburb	Location	PNG94 PNGMG94 (UTM) Zone 55 Easting	PNG94 PNGMG94 (UTM) Zone 55 Northing	PNG94 Ellipsoid Height	MSL CSIRO POM TG	PAGA GRID (Plane) Easting	PAGA GRID (Plane) Northing	PAGA GRID (Plane) CDW RL
SW14	Nail in conc.	Kaevaga	Champion Pde (N of D'Albertis)	517179.150	8954283.277	83.992	8.584	105526.945	106845.164	7.511
BM191	Brass plaque	Kanudi	SE Cnr BP Compound	515452.796	8956600.160	78.422	2.971	103798.892	109162.272	1.898
PM001	Star Picket	Kanudi	SW Cnr Kanudi Compound	515227.063	8956739.086	78.642	3.199	103573.006	109301.160	2.126
SW35	Nail in kerb	Kaugere	Scratchley Rd / Karius Rd Inters.	519910.205	8951877.976	97.479	22.033	108260.152	104440.027	20.960
SW36	Nail in kerb	Kaugere	Scratchley Rd, N of Rabia Cr	519998.393	8951725.281	93.552	18.112	108348.442	104287.307	17.039
SW37	Nail in kerb	Kaugere	Scratchley Rd, Cnr Foster St	520340.587	8951322.960	97.804	22.368	108690.948	103884.964	21.295
SW38	Nail in bit.	Kaugere	Scratchley Rd, W of Foster St	520254.651	8951402.657	93.352	17.917	108604.943	103964.658	16.844
OCP11	OCP	Kila Kila	Horse Camp Hill	521176.097	8949744.821	97.741	22.371	109527.474	102306.527	21.298
PS010	Star Picket conc.	Kila Kila	Horse Camp Hill	521054.397	8950053.388	90.382	14.994	109405.593	102615.170	13.921
PS011	Star Picket conc.	Kila Kila	Horse Camp Hill	521173.817	8949766.248	100.465	25.093	109525.184	102327.962	24.020
SW39	Nail in conc.	Kila Kila	Scratchley Rd, Primary School Gate	520563.872	8951163.459	93.521	18.079	108914.393	103725.492	17.006
SW40	Nail in conc.	Kila Kila	Sebea Rd, High School Gate	520751.524	8951009.902	87.337	11.891	109102.188	103571.951	10.818
BM200	Brass plaque	Kok Point	Le Hunte Rd (corner)	518211.755	8951961.648	101.028	25.738	106560.964	104523.012	24.665
PS004	Nail in conc.	Kondedobu	Freeway median - Champion Pde	517347.208	8953942.140	86.700	11.308	105695.217	106503.957	10.235
PS005	Star Picket conc.	Kondedobu	Champion Pde - N. of Goodman F	517368.968	8953689.858	81.541	6.171	105717.094	106251.580	5.098
PS119	Star Picket	Kondedobu	Lawes Rd / Champion Pde Junc.	517365.587	8953512.419	78.269	2.917	105713.786	106074.066	1.844
SW25	Dot on conc.	Konedobu	Aviat St (end)	517180.892	8953278.281	99.164	23.853	105529.115	105839.752	22.780
SW26	Nail in bit.	Konedobu	Aviat St	517278.830	8953204.724	101.870	26.556	105627.124	105766.206	25.483
PS036	Iron Pin	Korobosea	Munikae Pl	520395.902	8952016.098	175.948	100.443	108745.992	104578.413	99.370
PS037	Iron Pin	Korobosea	Munikae Pl	520436.767	8951952.775	173.419	97.916	108786.900	104515.081	96.843
OCP7	OCP	Morata	Morata Swamp (N of suburb)	520152.426	8961604.787	108.444	32.148	108498.341	114170.967	31.075
PS026	Star picket	Morata	Morata Swamp (N of suburb)	520106.614	8961904.548	101.155	24.839	108452.382	114470.833	23.766
PS027	Star picket	Morata	Morata Swamp (N of suburb)	519917.690	8961759.286	103.695	27.406	108263.442	114325.430	26.333
PS028	Nail in kerb	Morata	Cnr Talapia St / Koka Pl	520425.077	8960739.718	99.400	23.148	108771.472	113305.656	22.075
PS029	Nail in Kerb	Morata	Talapia St NE of Vuvusai Pl	520597.175	8960893.106	108.875	32.596	108943.576	113459.181	31.523
SW43	Nail in kerb	Newtown	Cnr Elanese St / Tugini St	517893.634	8953196.299	91.682	16.307	106242.186	105758.039	15.234
SW44	Dumpy	Newtown	Elanese St W. of Tugini St	517789.248	8953216.130	88.728	13.362	106137.749	105777.834	12.289
PS018	Star Picket	Paga Hill	Bramell St (Ela Beach Foreshore)	516229.686	8951633.063	78.498	3.443	104578.214	104193.449	2.370
PS019	Nail in bit.	Paga Hill	Bramell St (Ela Beach Foreshore)	516098.256	8951531.119	76.867	1.835	104446.773	104091.407	0.762
PS020	Nail in kerb	Paga Hill	Bougainville Cr. (S of Hayes St Jn)	516246.615	8951934.516	145.194	70.108	104595.022	104495.034	69.035
SW19	Nail in bit.	Paga Hill	Bougainville Cr. (N of Hayes)	516096.183	8952196.571	122.405	47.308	104444.416	104757.134	46.235
SW20	Nail in bit.	Paga Hill	Bougainville Cr. (N of Hayes)	516152.651	8952135.341	127.877	52.781	104500.934	104695.902	51.708
PS032	Iron Pin	Sabama	Dodo St (nr Bagita St)	520562.023	8951611.606	136.179	60.695	108912.353	104173.824	59.622
PS033	Iron Pin	Sabama	Dodo St (nr Hidiha Rd)	520621.707	8951559.328	140.249	64.764	108972.084	104121.550	63.691
PS034	Iron Pin	Sabama	Dodo St (nr Kovegeva St)	520281.666	8951743.259	122.763	47.294	108631.824	104305.412	46.221
PS035	Nail in kerb	Sabama	Dodo St (nr Rabia Cr)	520203.400	8951865.861	116.690	41.217	108553.474	104428.032	40.144
PS030	Star Picket	Talai Settlemen	Flint Place (Gorobe Settlement)	518710.303	8952994.285	127.902	52.467	107059.279	105556.289	51.394
PS016	Nail in conc.	Touaguba Hill	N of Jn Airvos Ave / Konenamo Cr	516863.306	8952490.172	158.045	82.842	105211.732	105051.182	81.769
PS017	Nail in bit.	Touaguba Hill	Davatari Drive (top end)	517202.769	8953052.591	170.427	95.135	105551.096	105613.978	94.062
PSM16403	Brass plaque	Touaguba Hill	Lakosi Place (top end)	517220.242	8952935.263	202.584	127.302	105568.627	105496.609	126.229
PSM16712	Brass plaque	Touaguba Hill	Airvos Ave (above Aviat Club)	517284.711	8953134.922	128.708	53.400	105633.037	105696.378	52.327
PSM2773	Brass plaque	Touaguba Hill	Nr. junc. Davatari Dr / Lakosi Pl	517063.079	8952920.036	189.908	114.643	105411.405	105481.309	113.570
SW07	OIP in conc.	Touaguba Hill	McGregor St (top end)	516782.712	8952428.702	126.899	51.710	105131.131	104989.652	50.637
SW08	Nail in bit.	Touaguba Hill	Bernal St (nr McGregor)	516757.553	8952390.568	127.697	52.514	105105.977	104951.492	51.441
SW09	Nail in bit.	Touaguba Hill	Airvos Ave (nr Town)	516969.681	8952739.626	146.335	71.097	105318.045	105300.785	70.024
SW10	Nail in bit.	Touaguba Hill	Airvos Ave (nr Town)	516939.206	8952699.519	148.016	72.785	105287.574	105260.648	71.712
SW17	Nail in conc.	Touaguba Hill	Davatari Drive / Lakosi Pl junc	517096.478	8952834.887	187.469	112.209	105444.854	105396.139	111.136
SW18	Nail in bit.	Touaguba Hill	Davatari Dr (S of Lakosi Pl)	517072.355	8952921.352	190.229	114.963	105420.684	105482.629	113.890
BM198	Brass plaque	Town	Stanley Esplanade (NE of Fire Stn)	516634.949	8952530.457	78.206	3.022	104983.263	105091.387	1.949
BM199	Brass plaque	Town	Ela Beach Rd (opp. Hunter St)	516789.122	8952039.964	78.581	3.429	105137.708	104600.756	2.356
PSM15384	Brass plaque	Town	Wharf (NW of BM 198)	516450.023	8952651.104	77.854	2.677	104798.209	105212.005	1.604
PSM16569	Brass plaque	Town	Stanley Esplanade	516558.561	8952492.760	77.154	1.982	104906.860	105053.642	0.909
SW05	Nail in bit.	Town	Hunter St (nr Crowne Plaza)	516683.339	8952242.137	107.842	32.681	105031.796	104802.968	31.608
SW06	Nail in bit.	Town	Hunter St (nr Crowne Plaza)	516716.869	8952228.461	109.943	34.780	105065.346	104789.301	33.707
BM164	Brass plaque	Waigani	Waigani Drive (N of City Hall)	519780.240	8956572.035	141.082	65.228	108128.139	109135.973	64.155
PSM15382	Brass plaque	Waigani	NMB GPS Base Station (MORE)	520498.365	8957148.635	116.660	40.693	108846.316	109713.118	39.620

Stations in Bold - Coordinates amended, Stations in Red - coordinates and levels +/- 60 mm

Note: PAGA GRID and CDW should be used for Sewerage Project

Remarks:

Horizontal Datum - PNG94 - origin -PSM15382 NMB Base Station
Plane Datum - PAGA Grid - origin - BM164
Vertical Datum (MSL) - BM 198 from CSIRO Tidal Observations
Vertical Datum (CDW) - BM 198 from CDW report
Geoid Model used - EGM2008 2.5'
MSL = EGM2008 - 0.928 metres
CDW = MSL -1.073 metres (close to Highest Astro Tide)

8.0 SURVEY DELIVERABLES

See attached Data Transmittal Sheet, all Drawings shown on Data Transmittal Sheet have been copied onto CD as part of this report.

Appendix 2

Arman Larmer Surveys Limited
Consulting Surveyors and Planners
PNG Survey Haus, Scratchley Road, Badili
P.O.Box 372, Port Moresby
Ph:3215925, 3215979, 3217025, 3217061

	DATA TRANSMITAL FORM			
Date:	**26-Sep-11**			
Transmital No.	**20110926**			
FOLDER	**DETAILS**	**FORMAT**	**No.of DWGS**	**FILE No.**
AIRVOS AVE	DETAIL SURVEY	3D DXF,TXT,ASC	5	101105
BARETO ST.KOKI	DETAIL SURVEY	3D DXF,TXT,ASC	2	51104
BYPASS	HANUABADA BYPASS ROAD	3D DXF,TXT,ASC	4	53111
BOUGAINVILLE CRES	DETAIL SURVEY	3D DXF,TXT,ASC	1	40511
CHESTER	DETAIL SURVEY	3D DXF,TXT,ASC	4	112804
D ALBERTIS	DETAIL SURVEY	3D DXF,TXT,ASC	3	50511
DAVARA-PAGA PS	DETAIL SURVEY	3D DXF,TXT,ASC	8	181105
DAVETARI&LAKOSI	DETAIL SURVEY	3D DXF,TXT,ASC	5	201180
ELA MAKANA	DETAIL SURVEY	3D DXF,TXT,ASC	2	271104
FLINT ST	DETAIL SURVEY	3D DXF,TXT,ASC	4	301104
GABUTU	DETAIL SURVEY	3D DXF,TXT,ASC	22	231104
GAVAMAIN RD	DETAIL SURVEY	3D DXF,TXT,ASC	2	60511
GOROBE ST.	DETAIL SURVEY	3D DXF,TXT,ASC	7	230411
HORSE CAMP	DETAIL SURVEY	3D DXF,TXT,ASC	13	150411
HUBERT MURRAY	DETAIL SURVEY	3D DXF,TXT,ASC	11	112004
KAUGERE	DETAIL SURVEY	3D DXF,TXT,ASC	12	170411
KILA BARRACKS	DETAIL SURVEY	3D DXF,TXT,ASC	3	211104
KILA KILA STP	DETAIL SURVEY	3D DXF,TXT,ASC	40	191104
KOHOKA ST.	DETAIL SURVEY	3D DXF,TXT,ASC	2	110380
KOKI HTS	DETAIL SURVEY	3D DXF,TXT,ASC	4	280411
KOURABAD	DETAIL SURVEY	3D DXF,TXT,ASC	2	310411
LAMDEN ST	DETAIL SURVEY	3D DXF,TXT,ASC	4	261104
LAWES ROAD	DETAIL SURVEY	3D DXF,TXT,ASC	1	251104
MACGREGOR	DETAIL SURVEY	3D DXF,TXT,ASC	1	281104
MORATA STP	DETAIL SURVEY	3D DXF,TXT,ASC	15	902152
MUSGARVE	DETAIL SURVEY	3D DXF,TXT,ASC	4	221104
PARI ROAD	DETAIL SURVEY	3D DXF,TXT,ASC	4	10611
PASCAL AVE	DETAIL SURVEY	3D DXF,TXT,ASC	4	41118
PRUTH ST	DETAIL SURVEY	3D DXF,TXT,ASC	2	21105
PUMP STATIONS	PUMP STATIONS		13	
RABIAGINI SETTLEMT	MUNIOGO CRESCENT	3D DXF,TXT,ASC	2	311105
SALVATION ARMY	DETAIL SURVEY	3D DXF,TXT,ASC	1	291104
TALAI SETTLEMT	DETAIL SURVEY	3D DXF,TXT,ASC	13	20511
TUNIGI ST	DETAIL SURVEY	3D DXF,TXT,ASC	1	110436
VANAME	DETAIL SURVEY	3D DXF,TXT,ASC	1	112704
TRUNK SEWER	KANUDI - KILAKILA STP	3D DXF,TXT,ASC	91	902046
TOTAL	**TRUNK & BRANCH SEWER,STP & PS**		**313**	

…………………………………………………….

Gairo WARI
Arman Larmer Surveys Limited

2. Topographic Survey of Ocean outfall

BIOLOGICAL SURVEY AND MARINE IMPACT ASSESSMENT OF STP PIPELINE OCEAN OUTFALL AT JOYCE BAY

OCEAN OUTFALL FINAL SURVEY REPORT

JICA – PORT MORESBY SEWERAGE UPGRADING PROJECT

SURVEY

PREPARED BY: ARMAN LARMER SURVEYS & STOCKS
& PARTNERS JOINT VENTURE (JV)

OCT 2011

List of Figures and Tables

BIOLOGICAL SURVEY AND MARINE IMPACT ASSESSMENT OF STP PIPELINE OCEAN OUTFALL AT JOYCE BAY.

1. INTRODUCTION

1.1 Background

This report provides the result of a rapid biological survey of the site of pipeline outfall in Joyce Bay. The purpose of the survey is to assess the state of the coral reef and marine habitats and to evaluate the possible impacts of the construction of a sewage system on the marine environment. The biggest impact will be to dig up trenches along the pipeline route and removing coral boulders to make way pipeline laying. There is a wide range of marine zones of considerable natural habitats including traditional resource use by the local population. However, these habitats have been subjected to increasing environmental stress due to urban encroachment and commercial development as well as increased usage associated increasing population pressure coming from the villages and settlements.

For the coastal communities, uncontrolled sewage discharges can cause serious health problems and sewage contains pathogenic organisms which are a health risk. To avoid this, sewage should be treated and the effluents to be discharged offshore. The risk of an adverse impact would be minimized if the outfall is located well beyond the reef edge where oceanic circulation is strong and the effluents are treated before being discharged.

However, the Joyce Bay area like the main Port Moresby harbor receives raw sewage from several different outfalls, including raw sewerage directly from the large villages and settlements along the coast. The severity of the discharges depends on the sea current circulation for flushing which have at times not been fully cleared out. The cholera outbreak in recent months in Port Moresby coastal villages have been attributed to the presence of raw sewerage in the coastal areas and very little improvement may take place, unless all the localized sewage discharges are connected to the main city system. This will require linking the coastal villages to the sewerage pipeline having only one discharge point through the Kila Kila STP and to be discharged undersea about 1 km from the coastline.

The coastal villages and the city surrounding generally are the sources of anthropogenic stress on the marine environment and unless these are addressed immediately, the effectiveness of any carefully-planned waste disposal scheme in mitigating adverse effects on the marine environment would be minimal.

A marine monitoring scheme to evaluate water quality should be an integral part of the Waste Management Plan.

There will be physical disturbances to the coral, fish and benthic communities during construction especially along the route of the pipeline. The coral reefs provide sanctuary to many fish species including those of high economic value and any disturbances will have drastic effects on the marine species to change the biodiversity of the ecosystem and may bring in undesirable species into the area. The extent of the disturbance is likely to have drastic impact on many reef species and biological assemblages in this marine environment.

Results from the recent rapid biological survey show that the ecosystems in Joyce Bay area are heavily polluted along the coastline because of improper waste disposal practices and increasing human activities. Despite the anthropogenic stresses, the marine environment still maintains a moderate level of biodiversity. But, for how long?

The net effect of a modern designed sewerage system for the coastal communities should result in reduction in the level of contamination, as and when there is a proper sewage disposal facility and all the villages are connected to the proposed system. The proposed POMSSUP is being planned and designed to do just that.

1.2 Project Description

The Japanese International Cooperation Agency (JICA) on behalf of the Japanese Government and the Independent Public Business Corporation (IPBC) on behalf of the PNG Government commenced the Detailed Design Phase of the Port Moresby Sewerage System Upgrading Project (POMSSUP) in November 2010.

This project concerns improving the sanitation and hygiene conditions of the coastal areas utilizing the new technology and improvement of terrestrial and marine environmental quality.

The sewerage services have remained a challenge especially in the coastal communities around the National Capital District and after initial approval of Environment Permit in 2007 the project design has since been modified to include the Kila Kila STP, an access road and installation of the marine outfall.

The pilot study will look at sewerage from the coastal villages to feed into the trunk line through Paga Point linking Le Hunte and Gabutu and finally into the Kila Kila STP for oxidation ditch treatment before liquid effluent is disposed off at Joyce Bay outfall some 1 km offshore.

This survey was conducted to obtain the necessary environmental and biological data to assist the project planners for a modified design that will conform with the legal systems, standards and government guidelines pertaining to the POMSSUP project.

1.2.1 Project Objectives

The immediate objectives of POMSSUP are:

- to improve the sanitation and hygiene conditions of the coastal areas by utilizing the latest sewerage technology;
- to improve seawater quality for sound marine ecosystem ensuring better sanitation, alleviation of poverty, potential for fisheries development and tourism opportunities;
- for the pilot project to improve traditional lifestyle in coastal villages; and
- capacity building in GoPNG and personnel pertaining to this project.

This consultancy work is part of other surveys including a topographical (hydrographic) survey of the ocean sewerage outfall which includes:

- topographical survey and environmental condition of corals along the route of the pipeline to the ocean outfall.
- collection of topographical and environmental data.
- topographical contour of the seafloor and marine habitat map necessary for the design of the project.

1.3 Requirements of the Detailed Design (Phase 2) of POMSSUP

The consultant was required to study the area within the 120 m wide corridor of the pipeline route which runs from north (E109465.582/N101941.651) to south (E108771.048/N101165.792) direction in Joyce Bay. This will be the main area of influence which the project designers have set and the study of possible impacts to be confined to the immediate vicinity of the pipeline route. The 70 cm diameter pipeline will require precise excavation and pipeline laying work to affect only the 30 m corridor along the route.

The contractor is required to minimize disturbance by strictly observing the area of influence as determined by the designed route being determined in the marine survey.

The pipeline will pass through seagrass habitats and coral reef to become dug up and excavated for a trench for pipeline laying. It is expected that disturbance will be localized and temporary whilst the digging is in progress.

Corals and similar assemblages along this route will be removed and transplanted elsewhere within the corridor.

1.4 Purpose of this Document

This report summarizes existing biological characteristics of the nearshore marine environment of Joyce Bay to be traversed by the proposed STP pipeline sewerage outflow into the ocean. The constructions and laying of pipeline will require excavations of reefs and sediments to the reef edge. There will be construction of the Sewerage Treatment Plant (STP) at Kila Kila from where the pipeline will lead out to the ocean outfall.
Potential environmental and biological issues associated with the constructions and laying of the pipeline are described and assessed. Recommendations for

measures and options are given towards mitigation and effective control of the issues.

This survey is limited to the nearshore marine environment including the shallow reef habitats and fringing reef slope down to the outfall to 26 m depth. Much of the environmental concerns are about trenching and excavation work along the pipeline route to the reef edge that are expected to cause temporary disturbance during constructions and of the need to remove corals from the corridor to be transplanted elsewhere within the project area.

This being the final report, it contains data and appropriate conclusions concerning the possible impacts and mitigation measures necessary to meet government regulatory requirements for this project. The assessments herein are being discussed with accompanying recommendations to reduce impacts from construction and laying of outfall pipeline on the marine environment of Joyce Bay.

1.5 Methods and Sources of Information

The methods and sources of information used to describe the marine environment are summarized as follows:

- Bathymetric data from the hydrographer through the surveyors Pro-Mak Ltd providing detailed bathymetry of the pipeline corridor in Joyce Bay delineating the pipeline route to the outfall.

- Previous studies and survey of the marine characteristics of Joyce Bay, which included coral reef surveys, underwater photography and general biological description of the marine environment.

2. EXISTING BIOLOGICAL ENVIRONMENT

During 13 – 15 July 2011, the consultant conducted a thorough survey of the biological characteristics of the marine environment along the pipeline route within Joyce Bay. The survey was to identify marine habitats, assess the general condition and their potential impacts posed by the POMSSUP project. The three days of study focused on corals on the reef flats and coral bommies at the reef edge and reef slope. The hydrographer provided the markings indicating the pipeline corridor using GPS coordinates.

A continuous survey line was strung along the proposed pipeline route with use of long connecting ropes from the starting point on land to the reef slope some 800m from the shoreline. The consultant accompanied by a professional

SCUBA diver snorkeled and dived along the rope line and took underwater photographs of the different marine habitats. During the low tide, the same was repeated by wading through water along the same line and photographs also taken of the habitats which became visible over the larger area of the corridor. Four line transects of 25 m lengths each were made from the reef edge and the corals counted and identified to the types (species) present and sizes of the boulder corals.

2.1 Survey Methods

2.1.1 Study Timing and Personnel

The survey was conducted under fine weather, sunny days, slight SE breeze and no choppy seas, making ideal conditions for the consultant to carry out the study uninterrupted. The survey was conducted using a 6m banana boat. The consultant was assisted by a scuba diver and the boat operator along with three other helpers. The tide for the southern region was low water 0500 hrs of 1.1m and high water 0931 of 1.5m over the three days.

The first day was spent working with the hydrographer marking out the pipeline corridor (alignment) who operated from another boat using the hydrographic instruments and GPS to pinpoint the spots demarcating the corridor. The points were marked by buoys with flagging tape tied with a string and weighted down to the seafloor. From this, a central line was determined clearly giving a visual of the proposed pipeline route. The consultant worked along side the hydrographer to delineate the pipeline corridor and within which to assess the marine habitats (zones), assess the diversity of coral reef, invertebrates, fish and seagrass. The pipeline route was clearly marked out and surveyed over the subsequent two days.

Visual counts of the corals along the 120 m wide corridor which were necessary to account for the number and sizes of the corals that will be removed and transplanted elsewhere. This data is necessary to provide the prudent information for engineers to plan the pipeline laying work.

There was one dive down to the discharge point at 26 m depth. Underwater photographs taken of the bottom seafloor and substrates were noted of these depths. A sample of the bottom sediment was also taken.

2.1.2 Survey Location

Satellite images were used to provide a wider scope of Joyce Bay area and more specifically the area of concern to the survey. The pipeline route had been pre-determined by the project designers as shown in Figure 1. The total area of the 120m-wide pipeline corridor is some 124,920 sq. metres and is located in the area demarcated by the points E109510.264 - N101901.608 and E109420.900 - N101981.695 from the shoreline to E108802.613 - N101111.069 and E108713.249 - N101191.156 to the discharge point at 1,041.31m offshore.

2.1.3 Coral Census

Four coral transect sites were established inside the pipeline corridor to characterize the existing pre-impact conditions of the fringing reef. The transect locations were selected where there was a reasonably extensive coral cover, in order to extend comparisons into the future. Line transects were deliberately located in the 120 m corridor of the pipeline route to measure the coral boulders (bommies) with visual count of their numbers. The approximate locations of the transect lines 1 - 4 are shown in Figure 1.

At each transect location, a start marker with pink highlight flag tape wrapped around the boulder coral and ran the 25 m length of the transect line. Each transect ran along the reef edge and oriented parallel with the reef slope to enable comparisons between different locations. The depths of transects were 5 - 6m during the high tide.

Only one method was used to quantify coral distribution and this is described below.

Figure 1. Proposed Alignment for the Pipeline Ocean Outfall

Locations of the pipeline route (blue) and transect lines (yellow) are approximated.

Visual Census

The coral surveys were conducted by visual observations along each transect line using the line intercept method and then recorded the distance along the line where the key features were intersected for each individual coral type.

The corals were recorded under the following criteria:

- Hard coral families and growth forms (e.g., massive boulder Porites, digitate Acropora, encrusting Faviids).
- Other biota (e.g., soft corals, sponges, algae and Halimeda).
- Abiota (e.g., dead coral, rubble and sand)

Photographs at the coral transects were obtained using high-definition digital camera in an underwater housing. The diver took photographs at approximately 5 m intervals along the 25 m transect with the camera held 1 to 2 m above the substrate and with the line rope in the centre of each photograph. Plates 1 - 3.

		
Plate 1. Line transect across coral rubble	**Plate 2. Line transect across boulder corals**	**Plate 3. Line transect across corals**

Data Analysis

Data collected from the line intercept method was converted to percentage cover for each of the 25 m coral transect sites. Similarly, the data collected from the pipeline route (alignment) indicated by the line rope was also converted to percentage cover over entire length of the pipeline corridor to the reef slope.

Underwater visual census methods was used to record fish (identified to families) at each of the coral transect locations.

2.1.4 Seagrass and Algae

Underwater photographs of the seagrass and algae types for abundance were taken.

2.1.5 Invertebrates

Several invertebrate types (e.g., seastars, sea cucumber, crinoids, sea urchins) were photographed along with the corals during the survey. Plates 4 – 7.

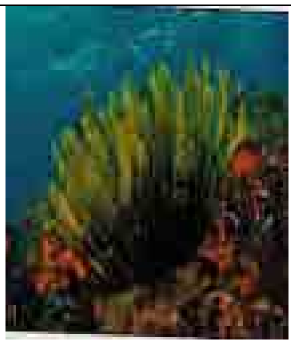
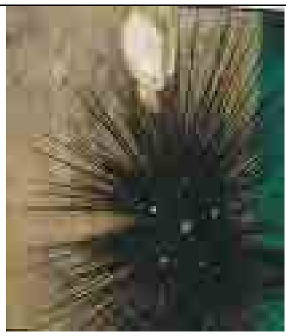
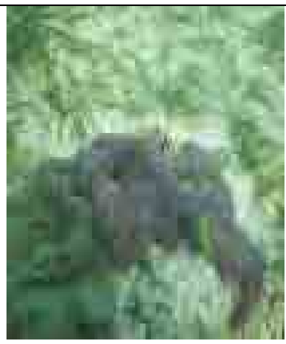
2.1.6 Habitat Map

This survey along the pipeline corridor also provided data necessary for habitat assessment of the marine environment. Still photographs and observations were taken whilst snorkeling or scuba diving. The photographs and notes were reviewed to describe the fauna and flora inhabiting the area of the pipeline corridor. The field information was used to interpret satellite imagery of the area necessary to construct the habitat map. The description and approximate locations of the habitats and the visual assessments are depicted in Figure 2 and further elaborated in Figures 3, 4 and 5.

2.2 Results and Discussion

2.2.1 Overview

Joyce Bay is a rather large enclosed bay area that includes the coastal villages of Pari, Kila Kila and Vabukori, about 10 km east of Port Moresby. At the periphery of the bay and along the coastline is an extensive shallow fringing reef and lagoons. The pipeline corridor is located to the west of the deeper waters of the bay and is to run across the shallow reef for about 80m into the deeper waters outside the bay to about 26m depth, see Figure 1. The coastal reef provides protection from ocean swells as there no natural openings in the reef to allow small vessels into the area of the pipeline corridor especially during low tide.

			
Plate 4. Seastar	**Plate 5. Feather star**	**Plate 6. Sea urchin**	**Plate 7. Sea anemone**

There are a number of large coral boulders (bommies) to depths of 5 m, whereas at the shallower end of the corridor, this is characterized by areas supporting patches of corals and seagrass. Here the boulder corals are flattened (table-top type) with coral growth around the boulder periphery. These are remnants of luxuriant coral community that once thrived at this section of the reef.

The survey work identifies four main marine habitats (coral reef, coastal silty seashore, seagrass and submerged sand patches) along the coastal region of Joyce Bay where the pipeline is to be laid. The seafloor between the coastline and the reef exhibits distinct zonation including large patches of seagrass, sand, rubble and sargassum. The coastline at the landfall is of solid boulders and loose rocks and slightly to the west is sandier and does not display extensive coral formations.

The distribution of the fringing reef within Joyce Bay is shown in Figure 2. Comparisons of diversity of taxa counts across the transect sites as shown in Table 1.

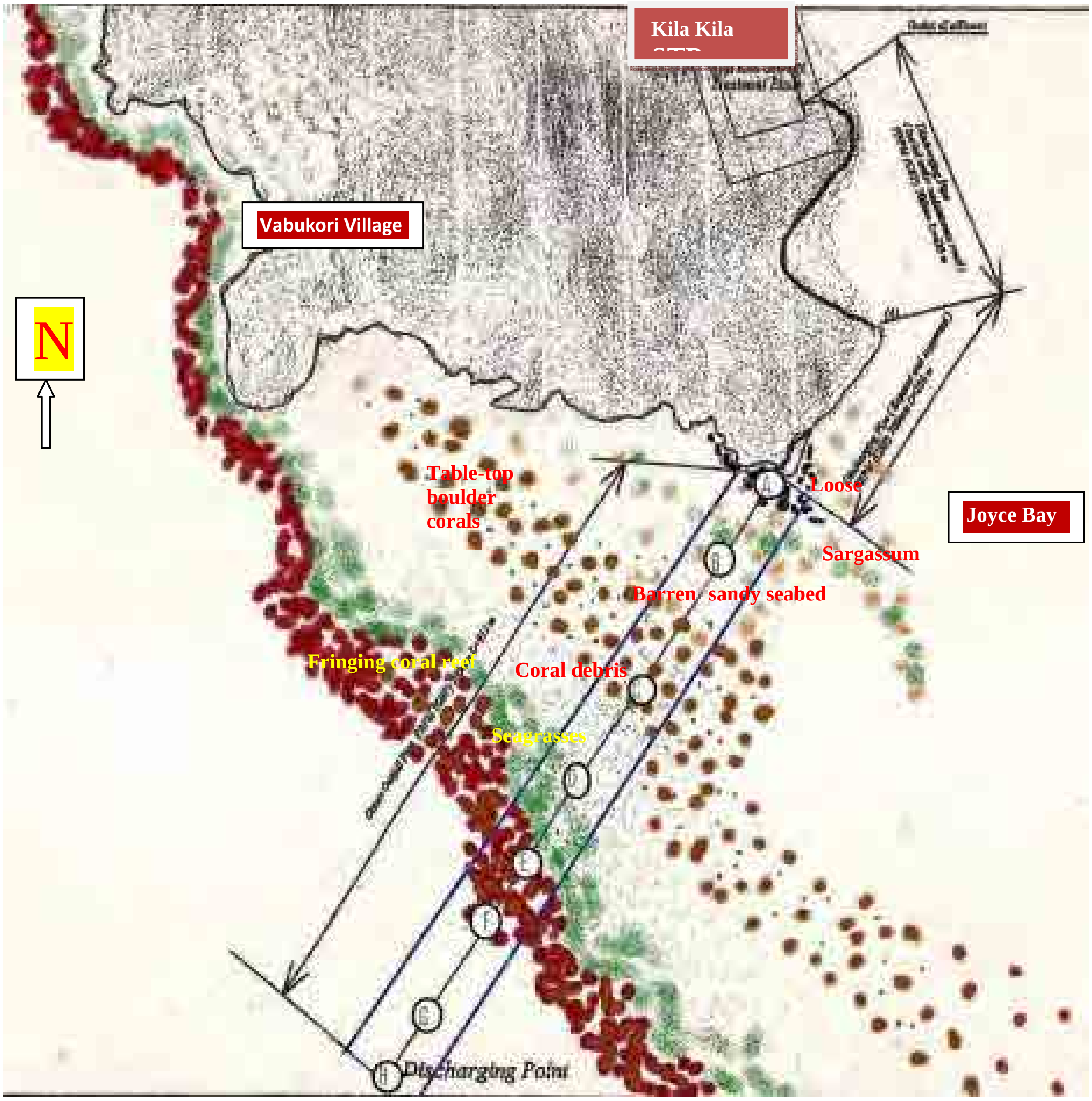
Table 1. Coral Taxa recorded from Transect Lines

Coral Type	Coral Species	Line Transect 1	Line Transect 2	Line Transect 3	Line Transect 4
Boulder coral (brown)	*Porties sp*	15	18	18	13

Boulder coral (purple)	*Porites sp*	3	3	5	3
Cylinder coral	*Porites cylindrica*	1	0	1	0
Faviid coral	*Favia sp*	1	0	1	1
Moon coral	*Favia sp*	0	1	0	1
Branching coral	*Acropora grandis*	2	3	0	3
Green acropora	*Acropora sp*	1	0	1	0
Bushy staghorn coral	*Acropora millepora*	0	0	0	2
Palm lettuce coral	*Pectinia paeonia*	0	0	2	1
Leather coral	*Sacrophyton sp*	2	0	0	0
Finger leather coral	*Sinularia sp*	2	0	0	0
Fungiid coral	*Fungia sp*	0	2	0	0
Sea anemone	*Heteractis magnifica*	1	0	0	1
Coral rubble	Assorted coral skeletons	3	2	3	4

The people from coastal villages rely on the nearshore marine environment as a source of food and income from selling excess fish at local markets. During the survey, there were crowds of people fishing and frolicking on the reefs at low tide, evidence of the significance of the marine environment to their livelihood.

Figure 2. Map of Marine Zones and Pipeline Corridor. (Location of 120 m wide pipeline corridor inside the blue lines is only approximate)



2.2.2 Marine Zones

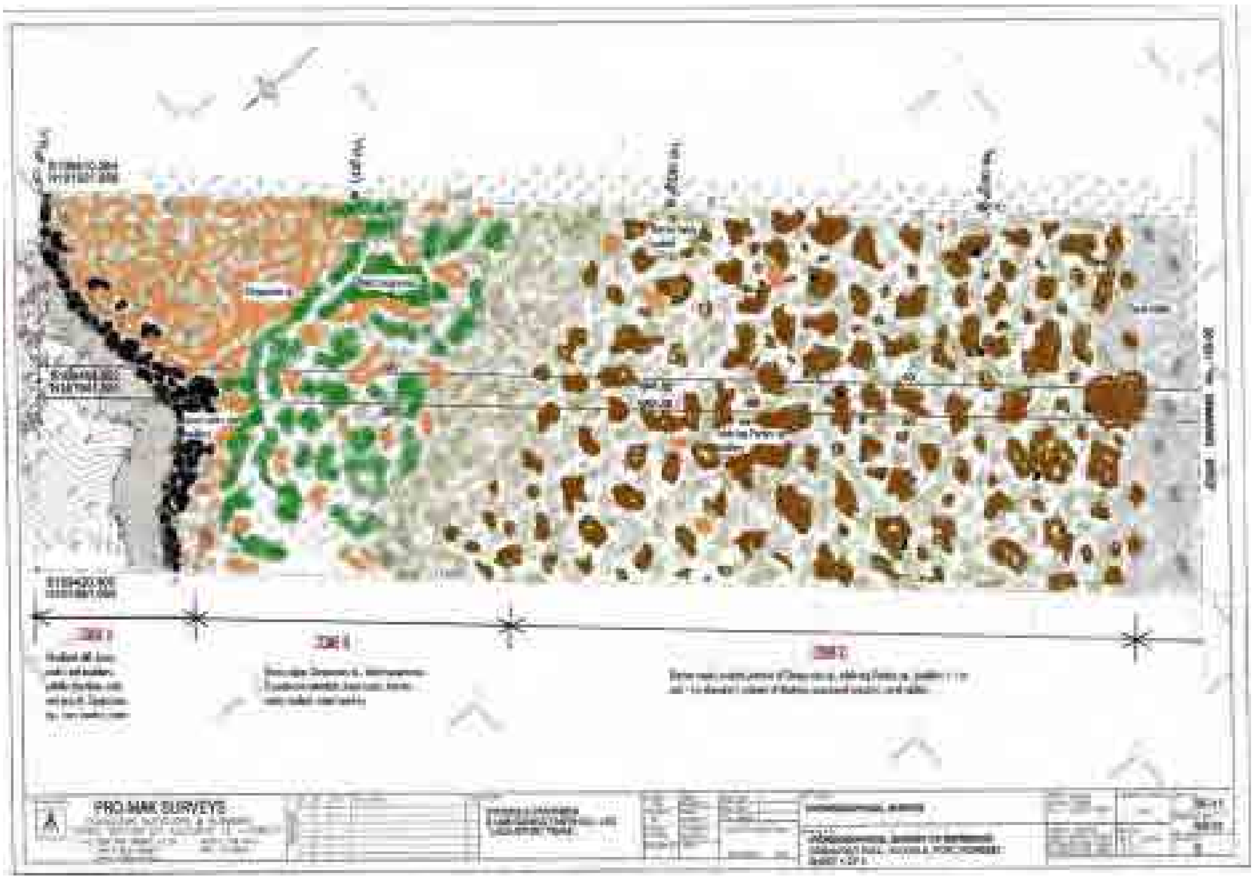
For this study, the survey area is divided into eight zones (**Zones A to H**) reported at the respective depths and delineated by distances from the starting point on the land and along the pipeline route to the outfall some 1 km offshore. These zones coincide with assemblages of the biota including seagrass, brown algae, corals as well as the barren sandy seafloor and rubble substrates which are described throughout this report.

There are no distinct cutoff boundaries in the marine zones that can be clearly delineated by the measurements of distances given below as they overlap into another, but nonetheless, there are certain patterns of biological assemblages found there. Details of the marine zones are given in Figures 3, 4 and 5. See also Plates 8 – 39.

Table 2. Marine Zones surveyed along Pipeline Corridor

Zone	Distance from Shoreline	Habitat, Biological Assemblages and Substrate Type
A	0 - 50 m Depth 0.00 to -1.11m	Headland cliff, loose rocks, pebbles shoreline. Very murky water.
B	50 – 150 m Depth -1.11 to -1.53m	Short seagrass patches, strands of brown algae *Sargassum sp* to the east, barren sandy seabed. Murky water.
C	150 – 350 m Depth -1.53 to -1.58m	Barren sandy seabed, *Sargassum* patches, scattering of table-top boulder *Porites sp* coral both large (> 1 m diameter) and small, *Diadema sp* in small crevices of boulder corals. Water clear.
D	350 – 500 m Depth -1.58 to -1.58m	Coral rubble prominent, remains of dead boulder corals, coarse substrates. Dense short seagrass, some long seagrass mixed in, numerous seastars. Boulder coral (< 1 m diameter) appearing at the seaward fringes.
E	500 – 650 m Depth -1.58 to -1.62m	Reef crest area with dense boulder Porites and Faviid corals appearing as single (< 1 m diameter) or colonies (> I m diameter). Anemones and crinoids present and few types of seastars occurring. Branching corals and soft corals very few. Pockets of coral rubble and dead boulder corals. Several fish species common here.
F	650 – 750 m Depth -1.62 to -2.78m	Reef edge with isolated large bommies of Porites and Faviid corals (2-4 m diameter and standing 3m tall), fish species concentrating over or around the bommies.
G	750 – 950 m Depth -2.78 to -24.38m	Reef slope, coral rubble, little visible coral growths, coarse sand, occasional sponges.
H	950 – 1041 m Depth -24.38 to -26.33m	Pipeline discharge point at 26 m depth. Fine light grey silt and sand. One sponge found growing here. Water murky.

Figure 3: Marine Zones A – C within Pipeline Corridor.


PRO-MAK SURVEYS

Example Photographs of Marine Zones

Zone A: Headland cliff, loose rock and pebble shoreline, murky water.

Plate 8: Headland and starting point.

Plate 9. Cliff, loose rocks, rocky shoreline.

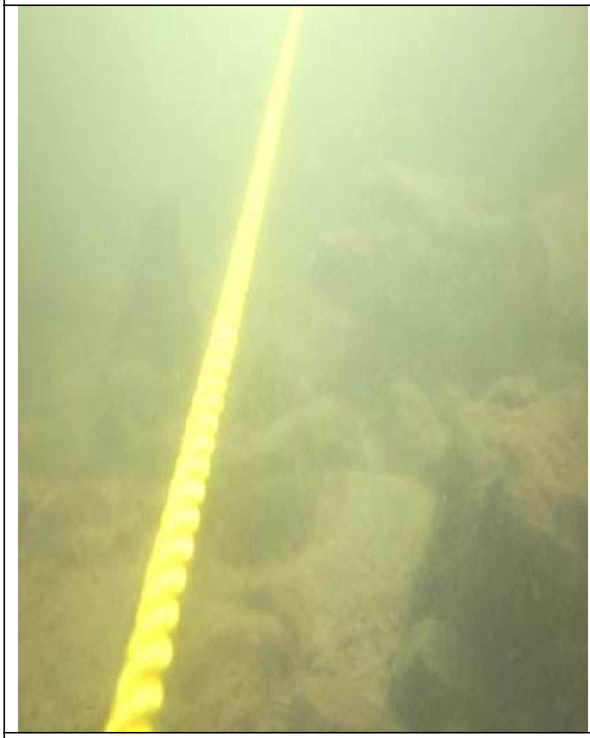


Plate 10. Rocky shoreline, murky water.

Plate 11. Boulder rock and tape seagrass *Enhalus acoriodes.*

Zone B: Short seagrass, brown algae, loose rock, barren sandy seabed, murky water.

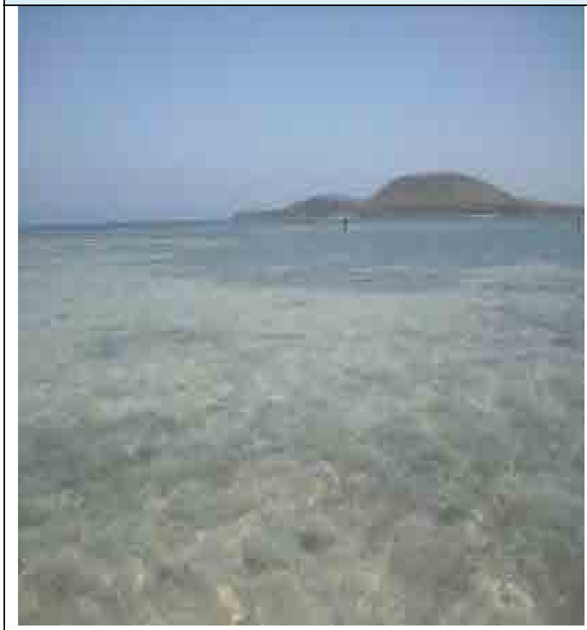


Plate 12. Rocks scattered over barren sandy reef bed.

Plate 13. Brown algae *Sargassum sp.*

Plate 14. Seagrass *Cymodocea rotundat.* Seastar *Protoreaster nodosus.*

Plate 15. Dead boulder rock on sandy reef bed.

Zone C: Brown algae, coral growth, seagrass, barren sandy areas, murky water.

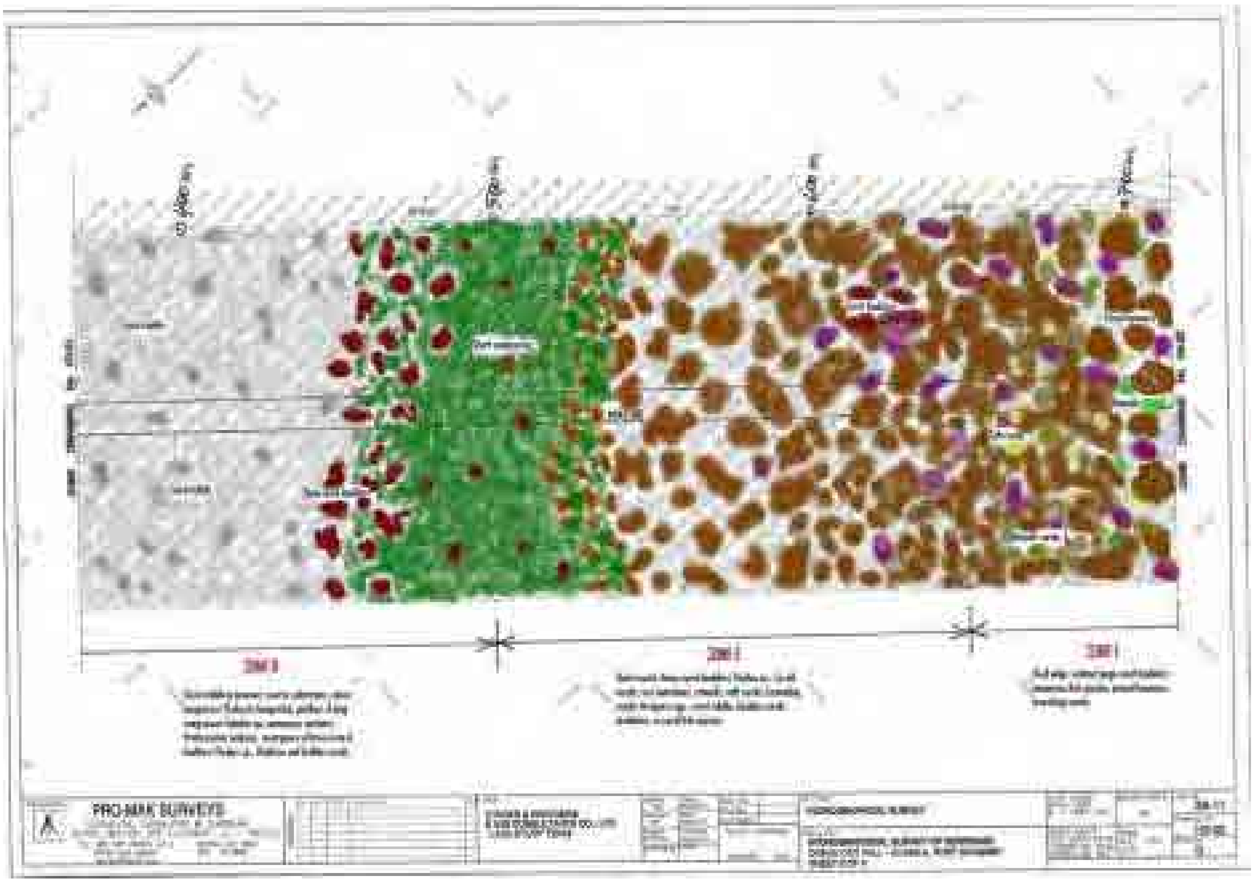
Olate 16. Sea urchin *Diadema savignyi*

Plate 17. Sargassum weed *Sargassum sp*

Plate 18. Short seagrass *Cymodocea rotundata.*
Paddle grass *Halophila ovalis*

Plate 19. Table–top brown boulder coral *Porites sp*

Figure 4: Marine Zones D – F within Pipeline Corridor



Example Photographs of Marine Zones

Zone D: Coral growth, sandy reef bed, seagrass.

Plate 20. Brown boulder coral *Porites sp*

Plate 21. Seagrass *Thalassia hemprichii.* Sea star *Protoreaster nodosus*

Plate 22. Leather coral *Sarcophyton sp*Magnificent sea anemone

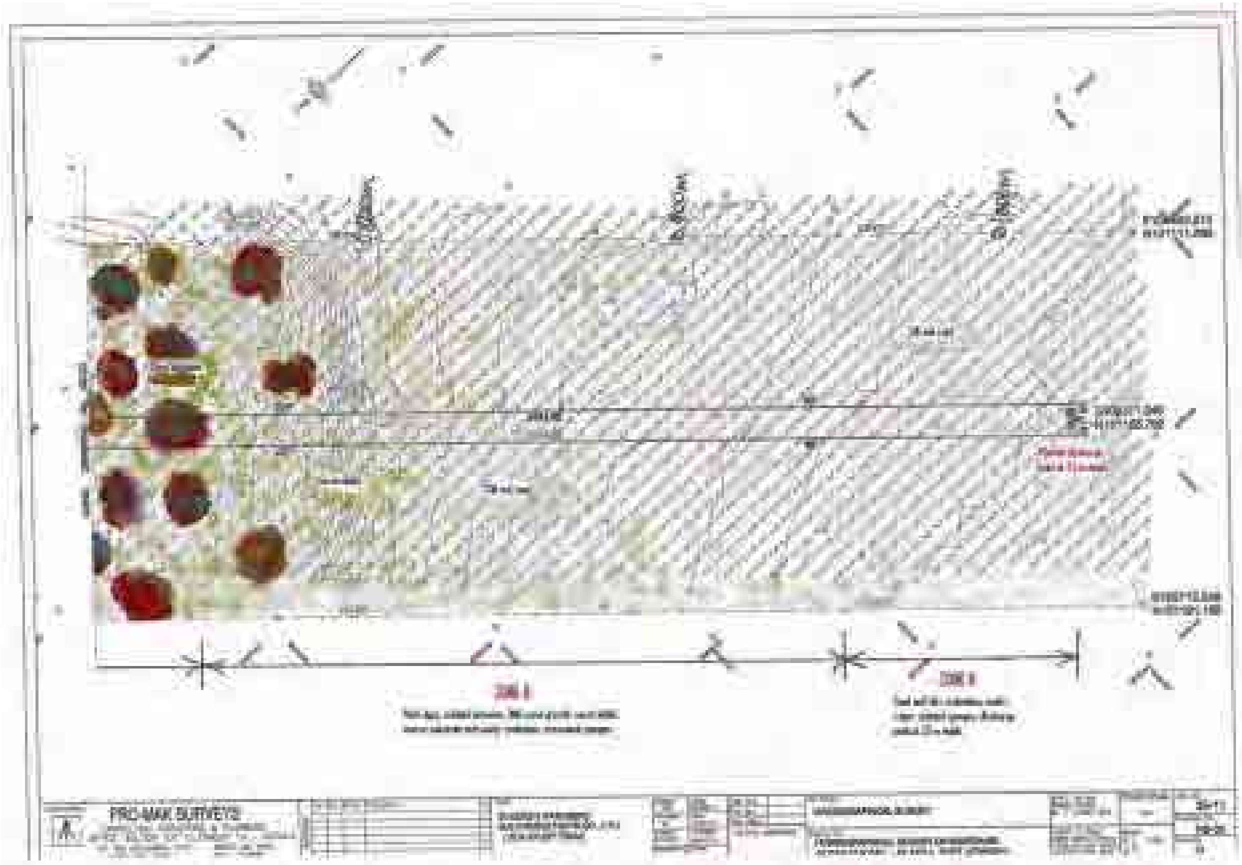
Plate 23. Aggregations of needle spined sea urchin *Diadema setosum*

Zone F: Coral boulders, branching corals, bommies

Zone E: Coral rubbles, seagrass, boulder coral, branching corals, soft corals.	
	
Plate 24. Branching coral *Acropora tenuis.*	**Plate 25. Branching coral *Acropora grandis.***
	
Plate 26. Boulder coral and leather coral.	**Plate 27. Boulder coral in the rubble.**

	
Plate 28. Boulder coral *Porites sp*	*Plate 29. Porites sp*
	
Plate 30. Branching coral *Acropora grandis*	Plate 31. Boulder coral and large carpet shark *Eucrossorhinus dasypogon*

Figure 5: Marine Zones G – H within Pipeline Corridor



Example Photographs of Marine Zones

Zone G: Reef slope, boulder coral bommies, coral rubble.

Plate 32. Boulder coral bommies *Porites sp*

Plate 33. *Porites sp*

Plate 34. *Porites sp*

Plate 35. Large Faviid coral bommie *Favia sp*

Zone H: Pipeline outfall, sand and fine silt, broken coral skeletons.

Plate 36. Lone sponge growing at outfall point

Plate 37. Fine sand and silt in murky water

Plate 38. Boat anchor at outfall spot

Plate 39. Confirmed depth at outfall

2.2.2 Coral Census

Visual Census

As outlined in methods, the selection of transect sites had to be inside the pipeline alignment which is a 120 m corridor, that is 60 m on each side of the pipeline route to the edge of the reef.

There were abiotic life forms of loose rocks and dead corals and sand in the murky zones A, B and C. Large areas of bare sandy substrate here also may be attributed to impacts associated with local villages traversing the area at low tide and exposure of the reef top during low tide and sedimentation from wave and current action.

The fringing reefs in Joyce Bay are exposed to sediment mobilization from wind- induced waves especially across from the nearby open waters of the bay and extended periods of SE trade winds. The high abundance of abiotic features on the reef is not unusual but indicates the poor overall condition of this fringing reef system.

Poor visibility was experienced for zones A and B which account for less descriptive features of the sections concerned.

The lowest abundance of coral cover (10 -20 %) was the mid-zones (Zones C and D). This was the area of bare sandy coral beds.

Remnants of *Porites sp* table-top coral boulders were observed from zones B to C. The corals are growing at the rim of the boulder and around the dead calcified centre or core of the colony. It was estimated that 10 or more of the large (> I m diameter) coral boulders and small boulders (30 cm – 80 cm diameter) could be counted in a box of 10m x 10m square.

Plate 40. Coral growth mainly around rim of boulder coral

Plate 41. Boulder coral being exposed at low tide

In some sections of the corridor (Zone C) there had been 5 or more boulder corals in the square box. The distances between the boulders were any where between 1 – 5 m apart. The larger corals are found as one continuous coral assemblage, that is, several colonies having encrusted or grown into another forming a large colony notably at the shallower reef beds. Plates 40 – 43.

Plate 42. Distribution of table-top boulder corals

Plate 43. Scattered patches of boulder corals *Porites sp*

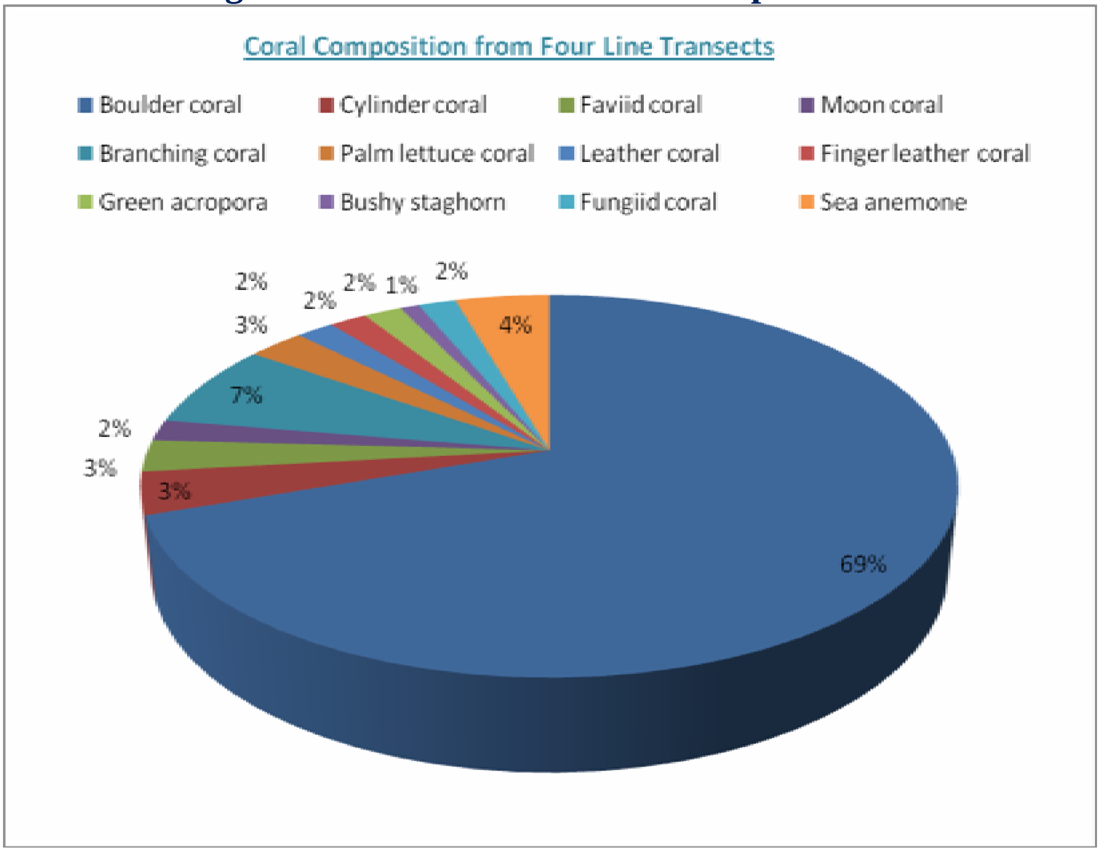
From zones E to F, there is a large area of coral rubble and bare substrate which support no visible biota. These are probably the remnants of once thriving branching coral assemblages in the Joyce Bay area in the past.
Hard coral cover is dense about 60 - 80 % coverage at the reef edge (zones F and G). These zones had the highest diversity of hard and soft corals. Here also were the hard Porites and Faviid corals, soft corals *Sarcophyton spp*, staghorn corals *Acropora grandis*, and *Acropora muricatap*, bushy staghorn coral *Acropora millepora*, Fungia corals *Fungia sp*, *Ctenactis achinata* and crinoids. Two boulder corals *Porites* spp accounted for 80 - 90 % of the hard coral cover, see Table 1. The branching corals *Acropora* spp were very few and isolated and found to be regenerative growths, unlike the usually dominant branching corals of typical tropical coral reefs. Very few massive *Porites sp and Faviid sp* of corals dominate the reef edge and the coral bommies into zones F and G.
The major substrate types across the reef sites of the abiotic life forms such as dead coral, rubble and sand attributed to about 10 - 20 % of total substrate cover in zones F to G.
From zone G was the barren substrate of broken corals and coarse substrates. Plates 44- 45.

Plate 44. Coral rubble just below the reef crest

Plate 45. Branching coral rubble at reef edge

From zones G to H, there was little or no sign of coral life although sponges were found in very isolated patches.
Further down in zone H was the featureless sand and fine silt ocean bottom. Plates 36 - 38.
The coral reef community composition recorded from the visual census is shown below in Figure 6.

Figure 6. Coral Communities Represented



2.2.4 <u>Coral Removal and Transplantation</u>

The coral counts were made inside the pipeline corridor to get an estimate of the extent of coral cover that will become removed and transplanted elsewhere. The corals in the shallower sections of the route are growing around the rim (periphery) of the large table-top shaped coral assemblages. The smaller size boulders are regenerated stand alone boulders growing in the interstices (spaces) between the larger boulders. Plates 46 -47.

	
Plate 46. Visual of percentage coverage of boulder coral.	**Plate 47. Less densed coral coverage from another section.**

The POMSSUP project design requires that corals found to be inside the 30m corridor on either side must be removed and transplanted to other locations within sections of this 120 m wide corridor. The sections of the corridor up to about 650 m (our estimate) from the coastline will need to be dug up or excavated for a trench to bury the 70 cm diameter pipeline.

The corals inside the 30 m corridor were estimated for the coverage over the area of zones B and C, or 150m to 360 m from the shoreline. Extrapolations made from 60 boxes (each box 10 m x 10m) needed to arrive at the total number of corals required to be removed.

The POMSSUP design requires that the corals found beyond 600 m mark and further to the reef crest will not need to be removed as these will be submerged during the low tide. This finding is based on work done previously by others for this area and given in a consultancy report commissioned by Eda Ranu in 2006.

However, from this survey we found that even at 650 m from the shoreline, the corals are exposed at low tide. The survey team was at the site during the time of low tide and observed wading through the water which was above the knee to the waist. This is supported also by the hydrographic survey of the pipeline alignment where the reef bed is relatively flat at 1.11m depth (50 m from shoreline) to 1.62 m depth (650 m from shoreline), where the corals are exposed at low tide. This is a 50 cm gradient from the shoreline, which suggests that as the pipeline is laid on top of the reef bed at 650 m distance from the shoreline, it will become exposed during low tide. This will become a physical barrier to smaller crafts and dinghy and may result also in sedimentation build up along the pipeline corridor.

In the shallower corridor sections from zones B to C, coral counts of 5 – 10 small boulder corals (< 1m diameter) and large boulder corals (> 1m diameter) in the box (10m x 10m) will have to be removed from the 30 m corridor. The smaller corals numbering 80% more than the larger coral boulders.

There is need for removal of corals that are found right on the alignment of the pipeline to the 700 m mark (1.69m depth). The coral boulders (individual coral as well as extensive coral assemblages) here which number around 30 boulder corals along the centre line will need to be removed and transplanted elsewhere.

From our estimation, approximately **240 coral boulders** consisting of the individual boulder corals and the large coral assemblages will need to be removed from the pipeline corridor. This is a total area of 6,000 sq. metres that will be disturbed directly requiring removals from the 30m wide pipeline corridor.

Estimated Coral Removal from Pipeline Corridor

Zones covered	Coral Count	Total Boulder Corals
Zones B – C Approx. 6,000 sq. meters of coral area. Depths -1.11 to -1.58 m	10 coral boulders per box (10m x 10 m) x 30 along the western alignment of pipeline.	140
	5 coral boulders per box (10m x 10 m) x 30 along the eastern alignment of pipeline.	70
Zones E – F Coverage along the pipeline route. Depths -1.58 to -2.78	Coral counts along 100 m line.	30
	Total	**240**

Methods for Coral Removals and Transplantation

Coral removals will be done by digging trenches for the pipeline to dislodge the boulders and lifted out for transplanting elsewhere. For the areas not trenched, this will require digging around the rock base to be dislodged and removed.
Coral transplantation will involve digging up shallow depressions at the new location. It is suggested that replanting occurs only inside the pipeline corridor so as to minimize silt plumes and deposits over a wider area.
Removing corals and transplanting will result in plumes of silt along the corridor and sedimentation. In both instances, silt curtains will be necessary to reduce such impacts on the marine environment. Constant daily monitoring during construction will be necessary to ensure silt dispersals and dispositions into other areas are minimized.

Summary

The fringing reef of this area of Joyce Bay is very much degraded with very low coral and fish abundance. The damage has been caused by local dynamite fishing (pers. comm.) in the past and subsequent storm events and other fishing practices. A number of fishing boats and canoes were observed in Joyce Bay during the survey where locals had been fishing using spears, fishing line and nets.

Two types of coral assemblages are found; in zones E and F being the luxuriant and dense round coral boulder colonies of the reef edge and the other in zones B and C being the degraded table-top coral colonies in the shallower waters.

On the shallow reef beds contain several large aggregations of sea urchin *Diadema sp* indicating damage to the reef and overfishing of predatory fish such as trigger fish and octopus which are known to naturally control the populations of sea urchins. Grazing by *Diadema sp* in turn adds to the reduction of coral settlement and recovery. Large amounts of broken coral heads and coral rubble were commonly observed all the way to the seafloor to depths of 26m at the pipeline outfall.

2.2.5 Fish

The fish observed were mostly from zones F and G where the coral associated species of damselfish, butterfly fish, blennies and tang are found in numbers. A list of fish species found is in Table 3. Fish numbers and types were surprisingly low and mostly congregating on and around corals at the reef edge.

Table 3. Fish Species Observed at Transect Sites

Fish Family	Species	Common Name	Abundance
Serranidae	*Epinephalus merra* *Epinephalus maculatus*	Honeycomb cod Marbled rockcod	Single specimens
Nemipteridae	*Scolopsis margaritifer* *Pentapodus trivittatus*	Pearly monocle bream Three-striped whiptail	Single specimens
Lutjanidae	*Lutjanus fulvus*	Black tail snapper	Single specimen
Mullidae	*Parapeneus multifasciatus*	Manybar goatfish	Single specimen
Zanclidae	*Zanclus cornutus*	Moorish idol	Several specimens
Chaetodontidae	*Chaetodon ornatissimus* *Chaetodon rafflesi* *Heniochus chrysostomus*	Ornate butterflyfish Latticed butterflyfish Pennant bannerfish	Not common
Pomacanthidae	*Apolemichthys trimaculatus* *Pygoplites diacanthus*	Three spot angelfish Royal angelfish	Single specimens
Ephippidae	*Platax teira*	Tail-fin batfish	
Pomacentridae	*Amblyglyphidodon curacao* *Chromis amboinensis* *Chromis atripes* *Chromis viridis* *Premnas biaculeatus* *Plectroglyphidodon lacrymatus*	Stahorn damselfish Ambon chromis Darkfin chromis Blue green damselfish Spinecheek anemonefish Jewel damselfish	Common in large numbers
Labridae	*Helichoeres hortulanus* *Labroides dimitiatus*	Checkerboard wrasse Blue streak cleaner wrasse	Not common
Scaridae	*Chlorurus sordidus*	Bullet-head parrotfish	In large aggregations
Blennidae	*Plagiotremus laudanus*	Bicolor fangblenny	Common
Acanthuridae	*Zebrasoma scopas*	Twotone tang	In small aggregations
Gobiidae	*Amblyeleotris arcupinna* *Amblygobius phalaena*	Red banded shrimp goby Banded goby	Several specimens
Siganidae	*Siganus canaliculatus*	White-spotted rabbitfish	Single

			specimen
Tetraodontidae	*Arothron manilensis*	Narrow-line pufferfish	Single specimen
Scorpaenidae	*Pterois volitans*	Common lionfish	Single specimen

2.2.6 Seagrass and Algae

Zones D and E had extensive meadows of short grass *Thalassia hemprichii*, and lesser counts of tape seagrass *Enhalus acoroides*, ribbon seagrass *Cymodocea rotundata* on reef bed between the shoreline and reef crest. Patchy or isolated strands of algae *Sargassum sp* were most found in zones B and C. The cactus algae *Halimeda sp* were observed in rock crevices and bottom substrate in zones C and D. No seagrasses were observed in deeper waters of the reef slope.

2.2.7 Invertebrates

The sea stars *Protoreaster nodosus* were found in abundance at zones D and E where there was abundant seagrass cover. Other species of seastars *Linkia laevigata* and *Nardoa tuberculata* were found in zone F.

The sea cucumbers *Bohadschia argus* and *Holothuria atra* were rarely seen from all the zones.

Several sea anemones *Heteractis magnifica* and *Stichodactylus giganteum* were found in zones E and F.

2.2.8 Nearshore Habitat Map

The survey work identified four main marine habitats of major benthic features (coral reefs, barren sandy seabeds, seagrass and subtidal shoreline) in assessing the relative importance of the different habitats within the project site. There were no mudflats at this site and the silt that deposit there during high tides become dispersed upon the receding tide and thinning out the sediments. The habitat map showing the locations of the four habitats are presented in Figure 2, 3, 4 and 5. The habitats were clearly visible from the photographs and the area extensively surveyed providing delineations of the habitat boundaries. For the purpose of this project the habitats are divided into seven zones where each one is identified by the types and descriptions made of the biological assemblages there.

Subtidal Shoreline

The shoreline is rocky and of loose sharp edge rocks fallen off the cliff on the headland. This area is not known to support any biota that would live on the rough rocky substrates having little mudflat or deposited silts to be able to hold back anything. The immediate beach front is of loose rocks and pebbles while a sandy beach is some 300 – 500 m west towards Vabukori village.

Seabeds

The sandy seabeds extend subtidally, including the inner region of the coastal fringing reef. On the barren seabeds are remnants of table-top shape *Porites* boulders which are found scattered throughout the shallow inner reef area toward the shoreline.

Fringing Reef

As outlined in section 2.2.2, the condition of the fringing reef was poor, probably as a result of fishing use and damages during periods of strong winds and waves. It would appear that the absence of branching corals growing in the area is probably due to past coral bleaching where a large stretch of the fringing reef has been affected as evidenced by the rubbles largely of broken branch corals.

The reef flat inward from the reef crest is punctuated by the presence of dead coral boulders and rubbles. Further inward from this is the zone of lush seagrass cover. The patches of *Sargassum sp* being the dominant algal species found here are found closer to the shoreline and thick *Sargassum* communities also occur toward the lagoon of Joyce Bay.

3. PRE-MITIGATION IMPACT ISSUES

3.1 Introduction

Within the impacted areas along the pipeline alignment, the subsistence fisheries are expected to be lost along the 120m-wide corridor where the corals will be removed and therefore the refuge and local habitats will become decimated. Fish, shellfish and other marine resources will be similarly affected. During the pipeline construction, vessels associated with the pipeline construction and trench dredging, tugs and barges will interfere with local fishing activities within the 500m radius. This may prevent local people adjacent to the area from fishing during the construction phase if access to and from the reefs is restricted. Fishing or harvesting will be limited and a reduction in the size of available fish and shellfish stocks. Significant reductions in yields of fish and shellfish are predicted.

The local people of Vabukori who traditionally fish on the coastal fringing reefs will be most affected by the constructions and laying of the pipeline. There will be hazards to local communities and users from project constructions and safety implications for the people fishing on the reefs.

3.2 Direct Loss to Marine Habitats

3.2.1 Issue

The marine habitats along the pipeline route will be removed or buried during construction activities. Adjacent areas will be affected by construction-induced increases in sedimentation. This will mainly affect marine habitats between the shore and 26m water depth. Where the pipeline is to be constructed and laid, seafloor and shoreline habitats along and immediately adjacent will be disturbed immediately. The types of the nearshore habitats to be affected include submerged and intertidal sandy or silty shoreline.

3.2.2 Pre-Mitigation Impact Assessment

Magnitude of Impact

The extent of loss of marine habitats due to construction and laying of the pipeline will be limited to the 120m width of the corridor and its immediate vicinity. The pipeline laying requires excavation and removal of corals across the sand and silt seafloor with seagrass macrobenthic communities associated with it. The magnitude of impact is assessed as HIGH (local impact generally up to 500m from impact site).

Sensitivity of Resource or Receptor

The narrow subtidal shoreline and seagrass and coral environments provide nursery habitat for many juvenile fish species and marine invertebrates. All of the corals and seagrass will be removed from the pipeline corridor, affecting the source of subsistence to the local villagers. For these reasons, the sensitivity of the resource/receptor of marine habitats for the pipeline development is considered as HIGH.

Assessment of Significance

Based on the criteria set out in the matrix of significance, the significance of this potential impact to the marine habitats in the vicinity of the pipeline alignment is assessed as HIGH.

3.3 Impact Categories

The impact categories given are:

Table 4. Impact Categories

Category	Description
Very high	Effect likely to have large impact on population, community or ecosystem survival and health, possibly even leading to local extinction or system collapse. Impact is widespread, affecting 10 to 25% of a regional population (e.g., within all of Joyce Bay). Recovery, if possible, is likely to take more than 10 years.
High	Effect likely to have severe negative impact on population, community or ecosystem survival or health. Impact is regional, affecting up to 10% of a regional population. Recovery, if possible, is likely to take from 5 to 10 years.
Medium	Effect will be detectable but not severe; populations or the areal extent of communities may be reduced but unlikely to lead to major changes to population, community or ecosystem survival or health. Impact is local, generally occurring up to 2 km from impact site. Recovery is likely to take from 2 to 5 years.
Low	Effect may be detectable but is small and unlikely to have any material impact. Impact affects immediate surrounds of area of activity and extends for less than 1 km radius. Recovery is rapid - up to 2 years.
Minimal	Effect unlikely to be detectable.
Positive	Effect is likely to benefit the population, community or ecosystem.

Source: Coffey Natural Systems, 2008.

3.4 Other Assumptions

There are other likely potential impact issues during and after the construction phase of the project. The recent survey work did not cover these areas and their effects can only be measured as and when they occur. However, the general remarks below reflect the concerns that such issues should not be left unattended and future studies commissioned to address them and appropriate recommendations in their mitigation.

3.4.1 Changes to Coastal Processes and Sediment Transport

Issue

Potential changes to coastal processes and sediment transport will occur once the construction of the pipeline is complete and during the operational life of the project.

The construction and laying of the pipeline will not become fully buried and this will increase suspended sediments and turbidity in the areas of construction activity where the seafloor is directly disturbed, particularly that this is a rather shallow reef and degraded coastline area. The extent of sediment suspension in the water will also depend on the source and size characteristics of the material used for construction and the amount of fines contained. The existing patterns of tidal inundation will determine integrity and normal alongshore sediment transport processes which will need to be monitored constantly.

The Joyce Bay area is important for ecological processes and is also utilized by local communities for subsistence fishing, collection of shellfish and building supplies and there will be significant impact on the marine communities in the vicinity of the pipeline corridor. Continued monitoring will determine the need for mitigation action.

3.4.2 Increased Suspended Sediment and Sedimentation Rates

Issue

Sedimentation effects can lead to smothering of adjacent sensitive seafloor habitat and seagrass, and reduce light availability within the water column. Seagrass that rely on photosynthetic processes require adequate light penetration.

Several activities associated with project construction will cause increases in suspended sediment in the water column and sedimentation rates and these include the following:

- Dredging (Excavation). Dredging for trenching purposes will disturb the seafloor and stir up sediment leading to increased suspended sediment and turbidity in the water column within the immediate area and down current from the source.

- Marine traffic. Shipping traffic especially work boats and barges within project area will potentially cause re-suspension of seafloor sediments through the generation of currents from propeller action. Suspended sediments will disperse according to particle sizes and the strength of prevailing currents.
- Construction and laying of the pipeline. Activities associated with the construction of the pipeline will disturb the seafloor and stir up sediment leading to increased suspended sediment and turbidity in the water column.

3.4.3 Disposal of Dredged Material

Issue

Disposal of the spoil (dredged material) will cause temporary impacts from sediment plumes in the water column and deposition on the seafloor. The dredged material is likely to consist of sand, silts and clays and most probable will be disposed to very deep water off the continental shelf. Some of the dredged material will be used to fill in the trench.

3.4.4 Exclusion Zone

Issue

A 500m exclusion zone may be enforced around the marine facilities for safety and security purposes where only authorized personnel will be allowed to access this zone. Subsistence fishing is a major source of food and income for local villages situated along the coast of Joyce Bay. As such, fishing pressure on resources is relatively HIGH. The exclusion zone will act as a ‘no take zone’, and the local people will be excluded from fishing or travelling within the exclusion zones around the pipeline facility during construction. Without mitigation, given the ongoing nature of the exclusion, the magnitude of impact perceived as a HIGH impact by people whose fishing activities are directly affected.

3.5 Impact Assessment Method

A semi-quantitative, risk-ranking method can be applied to evaluate the risks to aquatic biota associated with the various potential impacts identified with definitions of consequence and likelihood to the aquatic environment and the nature of potential impacts likely to be associated with this project. The impact assessment method will provide the direction necessary for the decisions to arrive at an impact rating.

The risk rating categories defined in this impact assessment are:

Table 5. Risk Ratings

Insignificant	The risk associated with a potential impact is negligible and will not have an influence on any decision regarding the proposed activity/impact mechanism.
Very Low	The risk associated with the potential impact is very small and should not have any influence on any decision regarding the proposed activity/impact mechanism.
Low	The risk associated with the potential impact is small and may not have any influence on any decision regarding the proposed activity/impact mechanism.
Medium	The risk associated with the potential impact is moderate and should influence decisions regarding the proposed activity/impact mechanism.
High	The risk associated with the potential impact will be high and will influence decisions regarding the proposed activity/impact mechanism.
Very High	The risk associated with the potential impact is very high and will influence decisions regarding the proposed activity/impact mechanism.

4. POTENTIAL IMPACTS

4.1 Introduction

The quality of the environment especially the reefs and marine regime in the Joyce Bay area appear well preserved albeit with some stress and environmental threshold under the present system of land use and resource utilization. The narrow band of coastline carry little by way of opportunities for agriculture on a large scale. Land use is limited to the inhabited coastline fringes where houses and other dwellings are constructed for human habitation. The onshore areas and hills are of savannah type climate with typical *Eucalyptus* trees and grassland dominated vegetation. In some sense, the coastal stretches are typical of the coastal areas of the Central Province which remain vulnerable and indeed very fragile.

The pipeline constructions and laying will place further stress on the environment and may exceed the biological thresholds for the biodiversity in the area. Sound management measures are therefore very crucial to ensure that this fragile environment is sustained through mitigation means.

The descriptions provided below concern the physical and biological issues associated with this type and magnitude of construction and operation at the project site. These discussions are limited to assessing the immediate potential impacts to the environment and their significance, prior to any mitigation with regard to the effects of construction of access roads into Kila Kila/Horse Camp area and the pipeline construction work. This is a report on pre-mitigation impact assessment of the proposed sewage pipeline project in the Joyce Bay area.

4.2 Impact Categorization

The criteria and means to measure the magnitude of the impact and sensitivity of the receptor are applied in the pre-mitigation impact assessments in projects of this nature and magnitude.

The magnitude of the impact is expected to be assessed to reflect:

- the intensity or severity of the impact,
- how long it will last, and
- the extent of the impact on the area.

The sensitivity of resource is the sensitivity of the environmental receptor that will reflect:

- its formal status, whether by statutory or attributed conservation status, land use zoning or environmental quality standard,
- its vulnerability to material damage or loss by the impact in question, and
- its iconic or symbolic importance to cultural value systems.

Potential impacts associated with the project will differ between the construction phase and the operation phase. While this assessment has been based on field data collection in the receiving environment, the assessment of potential impacts necessarily involves understanding of the total project development.

The impact assessment involves five steps:

1. Characterization of the range of marine habitat types, fauna and flora likely to occur in the project area, the conservation significance of these and their sensitivities;
2. Identification of construction and operation activities to be carried out and assessment of how these may interact with marine ecosystems;
3. Identification of potential impacts associated with these activities;
4. Implementation of a procedure for rating risk that provides a consistent and transparent way of assessing the stresses associated with project activities and their potential effects on receptors; and
5. Recommendation of mitigation measures to address the potential impacts and predict the extent to which they are expected to reduce the impacts.

4.3 Construction Phase

The general activities of the construction phase that could potentially impact marine ecosystems are:

- Construction and laying of sewerage pipeline across the shallow water coastal fringing reefs and marine habitats;
- Construction of the pipeline and associated infrastructure; and
- Construction of the STP pipeline from Kila Kila landfall.

4.4 Operation Phase

The general activities of the operation phase (from our understanding of the project design) that could potentially impact marine ecosystems are:

- The management of sewage and treatment facilities through the secondary treatment plant utilizing the oxidation-ditch method requiring separation pits, sumps and retention ponds;
- Discharging of the treated liquid sewage from the STP via the pipeline to the ocean outfall at 25 m depth;
- Alterations to coastal hydrology and sedimentation processes due the presence of the pipeline which may lead to potential siltation of the coastline;
- The use and maintenance of pipeline infrastructure;
- The movement of support staff (and potentially non-support staff) into and out of the project area.

The placement of the pipeline (if it is not buried sufficiently) has the potential to disrupt coastal current flow, the influence of wave action and thus, coastal sediment transport and deposition. There is a risk of sedimentation and sediment build-up on the project site causing damage to the marine environment and the fishing grounds.

4.5 Summary of Potential Impacts

The potential impacts during construction and operation could fall into three broad categories:

- Potential impacts to physical aquatic habitat (direct impacts to habitats and indirect impact to fauna and flora);
- Potential impacts to water quality (indirect impact to fauna and flora); and
- Potential impacts to biological communities/processes (direct impact to fauna and flora).

5. MITIGATION MEASURES AND RECOMMENDATIONS

The following measures are recommended to assist with mitigation of the potential issues described in this report.

5.1 Direct Loss to Marine Habitat

(i) The project should undertake sedimentation and geomorphologic characterization studies of the pipeline alignment to collect baseline data so that any future changes can be compared to pre-construction conditions.

(ii) Limit Marine Habitat Disturbance. Limit marine habitat disturbance and coral removals to the area within the pipeline corridor. Prohibit works from exceeding the design disturbance width and enforce boundaries through use of markers/tape and worker awareness.

(iii) Development of Sedimentation, Erosion and Dredging Management Plan. Establish and enforce a sedimentation, erosion and dredging management plan that include validation monitoring during key activities such as dredging activities, construction of the pipeline with procedures to ameliorate impacts that exceed project license conditions. Consider use of silt curtains and other good industry practice management controls when working in the area, particularly near the seaward extent. Use gravel core and rock for construction of the cover material over the pipeline. Continue sediment monitoring.

(iv) Notification of Local People and Commercial Fishers about Construction and Operation Activities. A community awareness program should be carried out to inform inhabitants of villages situated along the coastline of Joyce Bay about the construction of pipeline landfall including likely timing and the dangers associated with approaching barges and work vessels.

Consultation should include issues such as:

- Project impacts to fishing and resources.
- Access issues and exclusion zones.
- Safety aspects (traffic dangers, approaching traffic too closely, fire/burning etc.).

5.2 Management

These assessments suggest that the impacts of the development of the pipeline area on marine habitats will be high. Construction of access road also has the potential to mobilize sediment to the system. Much of this potential materials could be avoided if such construction activities were completed during dry periods, when many of the drainages and runoffs in the project area are not flowing, thus minimizing the potential for sediment-related impacts.

.

The construction phase of the project is considered to have higher impacts on the marine environment which involves removing corals and benthic biota, large numbers of personnel and heavy use of machinery, whereas the operations phase will have low impact. During the operations phase, the main potential for impact may arise from accidental rupture in the pipeline resulting in sewerage leakage, which is easier to plan for and control.

5.3 Monitoring

It is recommended that monitoring take place during and after construction, during both wet and dry conditions. This monitoring exercise will aim to sample marine habitats, with the primary aim of maintaining current flow and allowing fish movement.

It is envisaged that water quality monitoring for a range of parameters will be necessary as part of the requirements of the project and monitoring will also serve to contain potential sediment/pollutant impacts and to be used to confirm the predictions of water quality impacts in this assessment.

________________*end*________________

REFERENCES

Allen, G.R and R. Swainston. 1993. Reef Fishes of New Guinea – A field guide for divers, anglers and naturalists. Publication No.8, Christensen Research Institute, PNG.

Baine, M and D. Harasti. 2007. *The Marine Life of Bootless Bay - Papua New Guinea,* Motupore Island Research Centre, School of Natural and Physical Sciences, Univ. of PNG. 143 pp.

Coffey Natural Systems. 2008. *Nearshore Marine Impact Assesment*. Report to Esso Highlands Limited: PNG LNG Project. 105 pp.

Maniwavie, T. 2006 *The Vabukori Sewerage Pipe Route Survey – Coral Reef Component April 2006*, Eda Ranu Consultancy Report, Port Moresby, Papua New Guinea. 39 pp.

Munro, I.S.R. 1967. *The Fishes of New Guinea*. DASF, Port Moresby. 650 pp.

APPENDICES

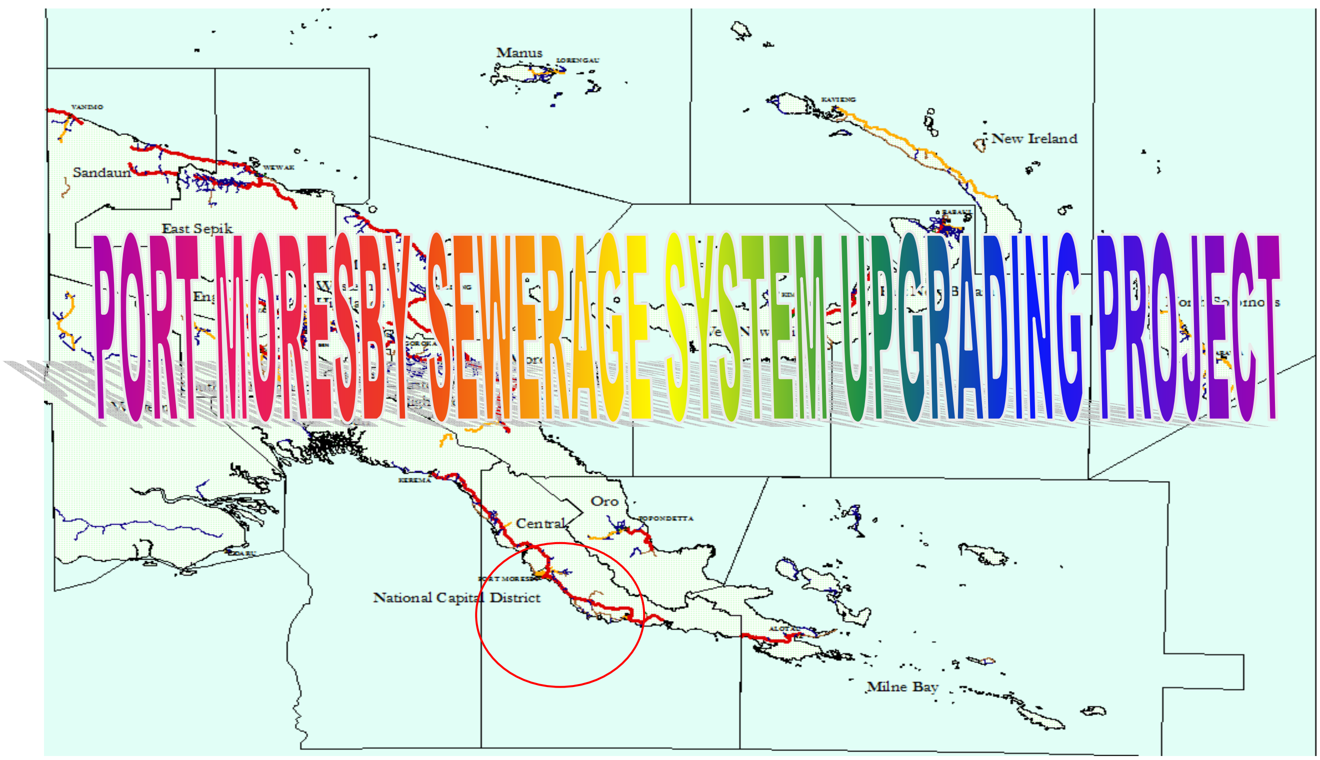
Appendix 1. The Common and not-so-common Biological Assemblages found inside the Pipeline Corridor.

Marine flora		
Seagrasses	Plants	*Halodule uninervis* Needle seagrass, *Enhanus acoroides* Tape seagrass, *Halophila ovalis* Paddle grass, *Thalassia hemprichii* Turtle grass.
Seaweeds/algae	Plants	*Halimeda sp.* Cactus algae, *Caulerpa racemosa* Sea grapes, *Chlorodesmis fastigiata* Turtle weed, *Hypnea pannosa* Tattered sea moss, *Peyssonnelia sp.* Red algae, *Dictyota sp.* Branched algae, *Padina sp.* Funnelweed, *Sargassum sp.* Sargassum weed, *Turbinaria decurrens* Triangular sea bell,
Marine fauna		
Corals	Cnidarians	*Macrorhynchia philipinus* Philippine hydroid, *Millepora sp.* Fire coral, *Lobophytum sp.* Lobed leather coral, *Sarcophyton sp.* Leather coral, *Sinularia flexibilis* Flexible leather coral, *Sinularia sp.* Finger leather coral, *Dendronephthya sp.* Tree coral, *Ellisella sp.* Sea whip, *Pteroeides sp.* Sea pen, *Acropora cf. caroliniana*, *Acropora grandis* Staghorn coral, *Acropora intermedia* Staghorn coral, *Acropora tenuis* Purple-tipped acropora, *Acropora millepora* Bushy staghorn coral, *Acropora sp.* Bottlebrush coral, *Astreopora myriophthalma* Moon coral, *Turbinaria frondens* Cup coral, *Diploastrea heliopora*, *Favia sp.* Moon coral, *Platygyra lamellina* Maze coral, *Ctenactis echinata* Fungiid coral, *Fungia sp.*, *Polyphyllia talpina* Slipper coral, *Symphyllia agaricia* Brain coral, *Pectinia paconia* Palm lettuce coral, *Stylophora pistillata* Cluster coral, *Porites cylindrica* Cylinder coral, *Porites sp* Boulder coral.
Sea urchins	Echinoderms	*Diadema savignyi* Savigny's sea urchin, *Echinometra mathaei* Mathaei's sea urchin, *Echinostrephus aciculatus* Needle spined sea urchin, *Salmacis sphaeroides* Bicolor urchin, *Holothuria leucospilota* Black fringed cucumber.
Sea stars	Echinoderms	*Protoreaster nodosus* Nodose seastar, Nardoa *novaecaledonia* Yellow mesh seastar, *Linckia laevigata* Blue sea star, *Comanthus alternans* Feather star, *Oxycomanthus bennetti* Bennett's feather star,
Sea cucumbers	Echinoderms	*Pearsonothuria graeffei* Flowerfish, *Synapta maculata* Spotted sea cucumber, *Bohadschia argus* Eyed sea cucumber, *Holothuria atra*.
Sea shells	Molluscs	Various species.
Marine worms	Polychetes	Burrowing species.
Sea anemones	Cnidarians	*Heteractis magnifica* Magnificent sea anemone, *Stichodactyla mertensii* Merten's carpet anemone
Fishes	Teleosts, elasmobranchs	Various teleost species, *Eucrossorhinus dasypogon* Carpet shark.
Others		
Sponges	Sponges	Various species
Ascidians	Ascidians	Various species

3. Soil Survey

PORT MORESBY SEWERAGE SYSTEM UPGRADING PROJECT, NATIONAL CAPITAL DISTRICT PAPUA NEW GUINEA

REPORT ON GEOTECHNICAL INVESTIGATION



Prepared for:

JICA STUDY TEAM
(NJS CONSULTANTS CO.. LTD)

Prepared by:

NIAWANG GEO-TECH SERVICES LTD

REPORT NO. 02 - 11 **JULY 2011**

Table of Contents

FIGURES

1 INTRODUCTION

Niawang Geotechnical & Consulting Services Limited (NGTS, hereafter termed the Consultant) was commissioned by NJS Consultants Co. Ltd (NJS), to undertake geotechnical investigation and reporting for the purpose of detailed engineering design of the Port Moresby Waigani Sewerage Upgrading System within the National Capital District. The detailed engineering design work is to be undertaken by NJS on behalf of the main Client Japanese International Corporation Agency (JICA).

This field investigation work was carried out at the request of the JICA STUDY TEAM (NJS CONSULTANTS CO., LTD.) There were two (2) separate components of geotechnical investigation work carried out at the time and includes the investigation of 10 Pump Station (PS) and 2 Sewerage Treatment Plant (STP) sites (Figure 1),.

This report presents the results of a geotechnical investigation work carried out for the proposed Pump Stations and the Sewerage Treatment Plant of the Port Moresby Sewerage System Upgrading Project.

2 SCOPE OF WORK

The objective of the geotechnical investigation is to:

- Explore the subsurface material composition of the individual sites by excavating trial pits, drilling boreholes and undertaking Dynamic Cone Penetrometer tests;
- Ascertain the soil profile, detail the composition and assign suitable engineering design parameters for the design of footings for the structure;
- Assess the soil conditions and recommend a suitable slope for cut banks and embankment protection work, drainages and consider options for retaining walls for fill embankments.
- Carryout appropriate field and laboratory tests to classify and determine the consistency, and strength of the soils.

Standard terms and symbols used in the investigation and reporting are contained in Appendix 1A.

The ten Pump Station sites to be investigated are:

1. Kanudi No.1;
2. Idubada No.2;
3. Elevala No.3;
4. Hanuabada No.4;
5. Davara Ela Beach No.5;
6. Ela Beach Lawes Road No.6;
7. Kila Police Barracks No.7;
8. Konebada No.8;
9. Gabutu No.9; and,
10. Kila Kila Horse Camp No.10.

The two STP sites to be investigated are:

1. Kila Kila; and,
2. Morata.

3 SITE DESCRIPTION AND GEOLOGY

3.1 SITE DESCRIPTION

All sites are within the National Capital District in Port Moresby. The Kanudi, Idubada, Elevala, Hanuabada, Davara, Lawes Road, Gabutu, Konebada and Kila Police Barrack PSS are located on the western and southern mainland shoreline fringes of the city and bound by the Fairfax Harbour, Ela Beach and Joyce Bay in Port Moresby. These sites are relatively flat hugging the shoreline, refer Figure 1.

Horse Camp pump station site is located on the southern side of the city and on the footslopes of the mountain range above which is sited the Korobosea Suburb. KilaKila STPS is located near to Horse Camp PSS. The Morata STPS is located further inland towards the northern fringes of the city boundary limits near 9 mile and Morata settlements on generally gentle sloping hilly terrain refer Figure 1.

The slopes on the natural ground surface along a longitudinal section of the sites are assumed to be 20 to 30 degrees. All the sites are generally free draining. Figure 1A shows the general landscape of the project sites.

3.2 GEOLOGY

Reference to the 1:250,000 scale Geological Map and associated memoir, entitled "Port Moresby Urban Geology" (Ref. 1), indicates the site to comprise a succession of inter-bedded alluvium and colluvium deposits underlain by the Port Moresby Beds (Figure 2). The Port Moresby Beds are of Palaeocene to Middle Eocene Age and are composed of three major units of which the Paga Beds dominate the project area. Colluvium and alluvium deposits mantle the hill slopes and the valleys in varying thickness. The most common superficial deposits in the Port Moresby area can be divided into three distinct material groups; namely, Hillslope, Footslope and Valley Floor deposits.

Hillslope deposits are formation of weathered bedrock from the Geological formation of the area. The material is usually derived directly from the weathering of the main bedrock and depth to bedrock is usual shallow. This material is generally referred to as Red Ridge Gravel and commonly used as fill material for building foundation and road pavement preparatory works.

Footslope Deposits are formed as a result of slope-wash and generally forms a ring around the base of hills, the deposit is more pronounced in tributary gullies formed from seasonal watercourse that run off from the hills to the valley floor. The deposit is characterised by grey/brown clays with variable sand and gravel content, sometimes are yellow or white where derived from weathered calcareous mudstone.

Valley Floor Deposits consists mainly of clay with some minor sand fragments. These are the original material formed at low areas. The deposit commonly grades from soft, greyish black clay near surface to stiff, yellowish grey at depth.

The Colluvial Deposits are subsequently underlain by Paleocene–Middle Eocene Port Moresby Beds. At the sites where encountered, the Paga Beds consist of light grey, yellow and buff brown calcareous and siliceous (chert) mudstone, mostly hard and strong with inter-bedded grey and khaki friable mudstone.

4 FIELD INVESTIGATION

4.1 INTRODUCTION

Based on the scope of works, the fieldwork exercise was executed on site by the geotechnical consultant, NGTS from early April to late May 2011. The investigation comprised; drilling, logging and sampling of borehole; excavation, logging and sampling of trial pits; and construction of Dynamic Cone Penetrometer (DCP) tests. Test locations are as summarized in Table 1 below and in Figure 1.

TABLE 1. FIELD INVESTIGATION TEST LOCATIONS AND TEST DEPTH RANGES

LOCATION	BH No. / (DEPTH RANGE)	TP No. / (DEPTH RANGE)	DCP No. / (DEPTH RANGE)
PUMP STATION SITE			
KANUDI **No.1**	**1** (0.00 to 7.00 m)	**1** (0.00 to 4.50 m)	**1** (0.30 to 4.30 m)
IDUBADA **No.2**		**2** (0.00 to 3.50 m)	**1** (0.00 to 3.40 m)
ELEVALA **No.3**		**3** (0.00 to 2.50 m)	**1** (0.00 to 2.40 m)
HANUABADA **No.4**		**4** (0.00 to 3.70 m)	**1** (0.00 to 3.70 m)
DAVARA ELA BEACH **No.5**	**9** (0.00 to 10.50 m)	**5** (0.00 to 3.00 m)	**9** (1.00 to 2.70 m)
ELA BEACH LAWES ROAD **No.6**	**10** (0.00 to 10.85 m)	**6** (0.00 to 2.00 m)	**10** (1.10 to 1.80 m)
KILA POLICE BARRACK **No.7**		**13** (0.00 to 1.40 m)	**1** (0.00 to 1.2 m)
KONEBADA **No.8**		**14** (0.00 to 3.50 m)	**1** (0.30 to 3.40 m)
GABUTU **No.9**		**15** (0.00 to 3.00 m)	**1** (0.00 to 3.00 m)
KILA KILA HORSE CAMP **No.10**	**16** (0.00 to 10.00 m)	**16** (0.00 to 3.50 m)	**1** (0.30 to 3.50 m)
SEWERAGE TREATMENT PLANT SITE			
KILA KILA		**1** (0.00 to 1.60 m) **2** (0.00 to 1.00 m) **3** (0.00 to 2.50 m) **4** (0.00 to 1.70 m) **5** (0.00 to 1.00 m) **6** (0.00 to 1.10 m)	**1** (0.00 to 0.70 m) **2** (0.00 to 0.80 m) **3** (0.00 to 1.70 m) **4** (0.00 to 1.00 m) **5** (0.00 to 0.30 m) **6** (0.00 to 0.90 m)

MORATA	**0.00 to 9.50m**	**1** (0.00 to 2.00 m) **2** (0.00 to 3.00 m) **3** (0.00 to 3.50 m) **4** (0.00 to 3.00 m) **5** (0.00 to 2.50 m)	**1** (0.00 to 1.10 m) **2** (0.00 to 2.00 m) **3** (0.00 to 2.40 m) **4** (0.00 to 2.20 m) **5** (0.00 to 1.60 m)

The fieldwork was organized and supervised on a full time basis by a Senior Geotechnical Technician under the guidance of a Senior Materials Engineer. The Senior Materials Engineer's responsibility included location of trial pits and boreholes and DCP test sites, nominated the sampling and testing regime and preparation of the engineering logs.

4.2 BOREHOLE (BH) INVESTIGATION & SAMPLING

A total of 5/6 No boreholes were mechanically drilling using a drill rig sub-contracted from SMEC PNG Ltd. Geotechnical drilling was programmed to be carried out at the following sites:

- Kanudi PS No. 1;
- Idubada PS No. 2;
- Davara Ela Beach PS No. 5;
- Ela Beach Lawes Road PS No. 6;
- Kila Kila Horse Camp PS No. 10 site; and,
- Morata STP site.

Drilling was only executed at Davara Ela Beach, Ela Beach Lawes Road, Kila Kila Horse Camp and Morata sites and completed successfully while Kanudi and Idubada sites were stopped by landowners. These two sites remain outstanding for further investigation subject to land issue negotiations between Eda Ranu and the local landowner. Borehole locations are as summarized in Table 1 above and each number and location presented in Figure 1.

Boreholes 1 and 2 were drilled on the foothills and reached maximum depths of 9.00 metres. Boreholes 5 and 6 were drilled on the hillslope and reached maximum depths of 10.50 metres. The boreholes were advanced using wash boring methods with the aid of fresh water as the drilling medium. Depth of drilling was controlled by the objective of the geotechnical study i.e., to determine thickness and properties of sub-surface materials for detail engineering design of PSS and STPS to be finalized.

Materials recovered from the boreholes were logged and sampled for further laboratory testing. Geotechnical log for the borehole (BHs 1,5,6,10 and Morata are presented as Appendix A together with Explanatory Notes defining the Terms and Symbols used in their preparation at the end of this report.

4.3 TRIAL PIT (TP) INVESTIGATION & SAMPLING

A total of 21 No. trial pits were mechanically excavated using a backhoe sub-contracted from L&A Contractors and Strength Construction Ltd. Trial pit locations are as summarized in Table 1 above and each number and location presented in Figure 1.

The trial pits were taken to the depths ranging from 3.50 metres (TP16) to 4.50 metres (TP1) from the existing surface. Backhoe refusal occurred in all trial pits on weathered mudstone, accept for trial pit 16 which extended further. Trial pit logs are presented in Appendix A together with Explanatory Notes defining the Terms and Symbols used in their preparation. Materials recovered from the trial pits were described and sampled for further laboratory testing. Geotechnical log for the trial pits (TPs 1 to 21).

4.4 DYNAMIC CONE PENETROMETER (DCP) TESTING

Twenty One (21) DCP tests were carried out according to test procedure AS1289 F3.2. The tests were located strategically to adequately cover the site. In addition, the positioning of DCP tests was to augment any variation in the sub-surface soil formation. The DCP tests were carried out from 1.0 metres in BH5 at KilaKila STP to 3.70 metres in BH4 at (PS 4) from the existing surface. Most of the DCP probes met with refusal due to the presence of very stiff cohesive soils or the presence of weathered bedrock restricting penetration of the DCP probe. Table 1 above presents a summary of DCP tests conducted on site at each particular location.

The number of blows required for each 100 mm penetration was recorded in accordance with the procedure derived by Stockwell (1977), (Ref. 2). DCP blow counts have been converted to 'e' values, measured in mm per blow. DCPs 1 to 3 tests are represented as graphical plots of 'e' values, Allowable Bearing Capacity (ABC) and California Bearing Ratio (CBR) versus Depth and assess the prevailing strength of the subgrade material on site. These plots are collectively presented in Appendix B.

5 LABORATORY TESTING

The Department of Works Materials Testing Laboratory in Port Moresby carried out the soil engineering characteristic tests on the soil samples obtained from the test pits.

As per the scope of works, tests requested to be performed by the laboratory only allowed for natural moisture content; Atterberg limits, linear shrinkage and particle size distribution. These tests were undertaken in accordance with internationally accepted Standards, AS 1289.E2.1 – 1991 (Ref. 4).

A summary of the laboratory test results obtained from the test pit samples are summarised in Appendix C.

6 SUBSOIL CONDITIONS AND ENGINEERING PROPERTIES

6.1 PUMPING STATION (PS) SITES

6.1.1 KANUDI PS NO. 1

The proposed Kanudi pumping station is located in front of Warner Shane Lawyers residential block, not far from the main road. The site is flat or level with some rain trees around the site. To the east is the access road leading to the InterOil Fuel Depot and the Kanudi Power Plant site. The waterfront is approximately 10 metres to the south from the nominated location and the road leading to Tatana and Baruni villages and the LNG project site runs in-between.

One (1) borehole was excavated and drilled to 7.5 metre depth. *In-situ* and laboratory tests include DCP, particle size distribution, Atterberg limits, linear shrinkage, specific gravity, unit weight, chloride ion (CL) and pH.

The subsoil material encountered here is of sandy clayey gravel to sandy silty gravel from the top surface to the maximum depth of the backhoe at 3.5 meters. Groundwater was encountered at 0.50 meters depth due to high tide at the time of the investigation. Material strength is expected to increase gradually with depth beyond the base of the hole, where weathered rock (siltstone or mudstone) is expected. The fines component of the materials recovered are of medium to high plasticity (Figure 3).

The site foundation consists of soft to medium fairly graded coarse grain gravel. The subsurface material is dense to very dense, becoming very dense at depth of 4.50 metre at which the hole was terminated with an N-value 37. The estimated bearing capacity of the soil at this depth is 500 kPa (qu).

Foundation design bearing strengths at various depth ranges are assessed as follows:

- >0.50 to <2.50 metres 170 to 205 kPa;
- >2.50 to <3.50 metres 205 to 315 kPa;
- >3.50 to 4.50 metres 315 to 570 kPa; and,
- >4.50 metres >570 kPa.

6.1.1.1 Liquefaction Potential

Liquefaction may occur in poorly graded, loose sands or silts (refer to PSD plot in Figure 4) as a result of severe vibration induced by seismic activity. However, grading analysis undertaken on samples from the trial pit indicates the mid-level and lower level consists of clayey sandy silts to be well graded. Where the profile may appear to be poorly graded, the sandy material contains significant proportions of clay and silty fines that further reduce the risk of liquefaction within these materials.

Furthermore, in consideration of SPT/DCP test results attained from site, the sandy silt material tend to be medium dense to dense such that overall liquefaction potential is considered to be low.

Test Pit and minor road cut confirm that this is due to the presence of thin beds or veneer of coarse sandy gravels and or weekly consolidated pyroclastic sediments within the dominantly silty clay and sandy profile. Minor limestone or calcareous sediments were also observed.

6.1.2 IDUBADA PS NO. 2

The proposed Idubada pumping station is located next to the main road near the boundary fence of the Port Moresby Technical College. Few meters away is the underground drain from the school flowing southwest in to the sea. The site is located at the shoulder of the road which was confirmed during our backhoe trial pit excavation. Red ridge gravel used as pavement material was encountered to 0.80 meters depth followed by black to grey, high plasticity clay material to the maximum excavation depth of 3.5 meters. Groundwater was encountered at 2.00 meters depth due to high tide at the time of the investigation.

One (1) borehole was excavated and drilled to 7.50 metre depth. *In-situ* and laboratory tests include DCP, particle size distribution, Atterberg limits, linear shrinkage, specific gravity, unit weight, chloride ion (CL) and pH.

The site foundation consist of gravelly silty clay to a depth of 2.00 metres and is stiff to very stiff, becoming very stiff to 3.50 metre depth with foundation bearing strength of <250 kPa. Material strength is expected to increase gradually with depth beyond the base of the hole, where weathered bedrock (siltstone or sandstone) is expected. The fines component of the materials recovered are of medium to high plasticity (Figure 5).

Foundation design bearing strengths at various depth ranges are assessed as follows:

- >0.50 to <2.50 metres 90 to 170 kPa;
- >2.50 to <3.00 metres 170 to 300 kPa;
- >3.00 to 4.50 metres 300 to 480 kPa; and,
- >4.50 metres >480 kPa.

6.1.2.1 Liquefaction Potential

Liquefaction may occur in poorly graded, loose sands or silts as a result of severe vibration induced by seismic activity (Figure 6). The SPT/DCP results also indicate the gravelly sandy clay to be firm to stiff at depth with estimated an unconfined compressive strength of 300 kPa (qu).

6.1.3 ELEVALA PS NO. 3

The proposed Elevala pumping station is located at the base of Gabi Hill next to the main road opposite Gabi Village. A water main sump is near to the proposed pumping station. Adjacent to a driveway for the residence on the hillside, an open concrete drain runs parallel with the main road and an InterOil pipe lies 3.00 meters away from the proposed location.

The backhoe trial pit encountered bedrock at a very shallow depth at 2.50 metre and is attributed to its proximity to the hill side. One (1) test pit was excavated to 3.50 metre depth. *In-situ* and laboratory tests include DCP, particle size distribution, Atterberg limits, linear shrinkage, specific gravity, unit weight, chloride ion (CL) and pH.

SPT/DCP test carried out encountered very dense strata of either well-graded sand or extremely weathered mudstone at depth. Refer test pit log in Appendix A. The site foundation consist of gravelly silty clay to a depth of 2.00 metres and is stiff to very stiff, becoming very stiff to hard at termination depth of 3.50 metres. Material strength is expected to increase gradually with depth beyond the base of the hole, where weathered bed rock (siltstone or mudstone) is expected. The fines component of the materials recovered are of high plasticity (Figure 7).

Foundation design bearing strengths at various depth ranges are assessed as follows:

- >0.50 to <2.00 metres 255 to 385 kPa;
- >2.00 to <2.50 metres 385 to 550 kPa; and,
- >2.50 metres >550 kPa.

6.1.3.1 Liquefaction Potential

Liquefaction may occur in poorly graded, loose sand or silt (refer to PSD plot in Figure 8) as a result of severe vibration induced by seismic activity.

The SPT/DCP results also indicate the gravelly clay material to be soft to firm at depth with estimated an unconfined compressive strength of 250 kPa (qu).

6.1.4 HANUABADA PS NO. 4

The proposed Hanuabada pumping station is located 4.00 meters away from the Hanuabada Catholic Church building next to the Hanuabada sewerage manhole. A big rain tree is not far away at the side of the main road to Hanuabada/Konedobu Road. An open drain runs off from the main road towards the west direction, flowing down to the sea near the proposed pumping station.

Backhoe trial pit material encountered here is of fill material from 0.00 to 8.00, than from 8.00 to 1.40 metres is silty clay of medium to high plasticity, dark brown or black material. Bedrock was encountered at 4.50 metre depth. One (1) trial pit was excavated to 3.70 metre depth. *In-situ* and laboratory tests include DCP, particle size distribution, Atterberg limits, linear shrinkage, specific gravity, unit weight, chloride ion (CL) and pH.

The site foundation is consists of soft to firm silty clay and firm to stiff, becoming stiff to very stiff at 2.50 metre depth. Extremely weathered bedrock was evident below this depth with the profile strength further increasing to very stiff to hard (dense) at 3.70 metre depth. Material strength is expected to increase further with depth beyond the base of the hole, where weathered bedrock (mudstone) is evident. The fines component of the materials recovered are of medium to high plasticity (Figure 9).

Foundation design bearing strengths at various depth ranges are assessed as follows:

- >0.50 to <3.50 metres 190 to 370 kPa;
- >3.50 to <3.70 metres 370 to 560 kPa; and,
- >3.70 metres >560 kPa.

6.1.4.1 Liquefaction Potential

Liquefaction is not considered to be a problem as a result of severe vibration induced by seismic activity due to presents of highly weathered bedrock near the surface. This is confirmed by the grading plot presented in Figure 10.

SPT/DCP result indicated the weathered tuffaceous sandy silts to be medium dense to dense such that liquefaction potential is considered to be low.

6.1.5 DAVARA ELA BEACH PS NO. 5

The proposed Davara (Ela Beach) pumping station is located next to the existing pumping station in the car parking area not far from the Ela beach shoreline. The site is 10.00 meters away from the beach front, 5.00 meters from the main road and 10 meters away from Ela Beach Hotel.

The backhoe trial pit ended at 3.00 meters depth after encountering a bitumen seal (20 mm), pavement base course (20 mm) and sub-base (500 mm) and, red ridge gravel subgrade replacement fill (500-800 mm) materials of the car park area;. After these materials, fine to medium size grain white sand was encountered to a depth of 7.50 meters, than coral reef sand to 9.50 meters and from 9.50 to 10.50 meters weathered bedrock of the Paga beds was encountered.

One (1) trial pit was excavated to 3.00 metres and a borehole drilled to 10.50 metres depth. *In-situ* and laboratory tests include DCP, particle size distribution, Atterberg limits, linear shrinkage, specific gravity, unit weight, chloride ion (CL) and pH.

The site foundation consists of medium dense to dense sandy gravelly clay to a depth of 2.50 metres and is dense to very dense from 3.00 to 9.50 metres depth than increases in consistency from very stiff to hard (dense) to 10.50 metres depth. Material strength is expected to increase gradually with depth beyond the base of the hole, where weathered bedrock (siltstone or sandstone) is expected. The fines component of the materials recovered are of non plasticity (Figure 11). Foundation may reach refusal level commencing at 10.5m due to high bearing capacity of the soil profile with values over >450 kPa (qu).

Foundation design bearing strengths at various depth ranges are assessed as follows:

- >0.50 to <2.00 metres 170 to 255 kPa;
- >2.00 to <2.70 metres 255 to 455 kPa; and,
- >2.70 metres >455 kPa.

6.1.5.1 Liquefaction Potential

Liquefaction may occur in poorly graded, loose sands or silts (refer to PSD plot in Figure 12) as a result of severe vibration induced by seismic activity.

Grading analysis undertaken on similar samples from similar subsurface profiles indicated the mid-level and lower level sandy silts to be well graded and containing significant proportions of clay and silty fine which further reduces the likelihood of soil liquefaction.

SPT results (N-value range of 18-20) indicate the sandy clayey silts to be very stiff to dense (>300 kPa) such that liquefaction potential is considered to be low.

6.1.6 ELA BEACH LAWES ROAD PS NO. 6

The Ela Beach (Roundabout) Lawes Road pumping station is located near the Ela Beach Mobil Service Station, next to the existing pumping station in the centre or middle of the roundabout island. The backhoe trial pit constructed encountered silty sandy gravel material overlying dark brown silty sand of medium grain size to 1.80 meters depth than weathered mudstone of the Port Moresby beds from 9.50 to 10.50 meters depth.

One (1) trial pit was excavated to 2.00 metres and a borehole drilled to 10.50 metres depth. *In-situ* and laboratory tests include DCP, particle size distribution, Atterberg limits, linear shrinkage, specific gravity, unit weight, chloride ion (CL) and pH.

The site foundation is similar to Davara Pump Station which consists of medium dense to dense sandy gravelly clay to a depth of 2.50 metres and becoming dense to very dense from 3.50 to 9.50 metres than, very stiff to hard (dense) from 9.50 to 10.50 metres depth. Material strength is expected to increase gradually with depth beyond the base of the hole, where weathered bedrock (siltstone or sandstone) is expected. The fines component of the materials recovered are of non plasticity (Figure 13).

Foundation may reach refusal level commencing at 10.5m due to high bearing capacity of the soil profile with values >250 kPa (qu).

Foundation design bearing strengths at various depth ranges are assessed as follows:

- >0.50 to <2.00 metres 470 kPa;
- >2.00 to <10.50 metres 470 to 560 kPa;
- >10.50 metres >560 kPa..

6.1.6.1 Liquefaction Potential

Liquefaction may occur in poorly graded, loose sands or silts (refer to PSD plot in Figure 14) as a result of severe vibration induced by seismic activity.

Grading analysis undertaken on similar samples from similar subsurface profiles indicates the mid-level and lower level sandy silts to be well graded and containing significant proportions of clay and silty fine which further reduces the likelihood of soil liquefaction.

SPT results (N-value range of 18-20) indicate the sandy clayey silts to be very stiff to dense (>300 kPa) such that liquefaction potential is considered to be low.

6.1.7 KILA POLICE BARRACKS PS NO. 7

The proposed Kila Police Barracks pump station is located within the Kila Police Barracks at the southwest end of the hill slope next to the sewerage outlet pipeline running towards the west direction at the Police Barracks beach front. The Backhoe trial pit encountered bedrock at a shallow depth of 1.40 meters comprising highly weathered calcareous and siliceous mudstone of the Port Moresby Beds. The site has a few mango trees, coconut palms and kunai grass growing around the area of the existing sewerage outlet. The proposed pump station is about 1.00 to 2.00 meters above high seawater mark and a few meters from the edge of the hill and sea front.

One (1) trial pit was excavated to 1.40 metre depth at this location. *In-situ* and laboratory tests include DCP, particle size distribution, Atterberg limits, linear shrinkage, specific gravity, unit weight, chloride ion (CL) and pH.

The site foundation consists of soft to firm gravelly sandy clay to 1.00 metre depth, firm to very stiff from 1.00 to 1.50 metre depth than, very stiff to hard (dense) at depths >1.40 metres. Material strength is expected to increase steadily with depth beyond the base of the hole, where weathered bedrock (siltstone or mudstone) is expected. The fines component of the materials recovered are of medium to high plasticity (Figure 15).
Indicative soil strengths from SPT values (N-values 9-36+) at 1.00 to 1.40 metres show bearing capacities of the subsoil material to be >300 kPa (qu).

Foundation design bearing strengths at various depth ranges are assessed as follows:

- >0.50 to <1.00 metres 205 kPa;
- >1.00 to <1.20 metres 205 to 560 kPa; and,
- >1.20 metres >560 kPa..

6.1.7.1 Liquefaction Potential

Liquefaction is not considered to be a problem as a result of severe vibration induced by seismic activity due to the presence of highly weathered bedrock near the surface.

Particle size analyses undertaken on samples indicate the lower level sandy silts to be well graded. The sand and silt components also contain significant proportions of clay and silty fines such that liquefaction potential is considered to be low (Figure 16).

SPT/DCP results indicate the clayey silts to be very stiff to hard (450 kPa) such that liquefaction potential is considered to be low.

6.1.8 KONEBADA PS NO. 8

The proposed Konebada pumping station is located at the recreational area of Konebada beach next to the small recreational shady huts. A small access road from the main road leads directly to the edge of the site at the car park area. The site is about 5.00 metres from the car park area. The backhoe trial pit encountered the bedrock of the Kaukana Hill at a depth of 3.50 meters from surface. Highly weathered mudstone or sandstone was encountered here with groundwater seeping from the hill slope at 1.5o metre depth.

One (1) trial pit was excavated to 3.50 metre depth. *In-situ* and laboratory tests include DCP, particle size distribution, Atterberg limits, linear shrinkage, specific gravity, unit weight, chloride ion (CL) and pH.

The site foundation consists of medium dense to dense silty sand from 2.00 to 3.00 metres, than becoming dense from 3.00 to 3.50 metres from surface. Subsurface soil consistency increases to very stiff to hard (dense) after 3.50 metres depth from surface. Material strength is expected to increase gradually with depth beyond the base of the hole, where weathered rock was evident (tuffaceous siltstone or sandstone). The fines component of the materials recovered are of medium to high plasticity (Figure 17).
Indicated soil strength parameter for weathered bedrock materials at 12m is 300 to 350 kPa (qu).

Foundation design bearing strengths at various depth ranges are assessed as follows:

- >0.50 to <1.50 metres 170 to 205 kPa;
- >1.50 to <2.50 metres 205 to 240 kPa;
- >2.50 to 3.50 metres 240 to 470 kPa; and,
- >3.50 metres >470 kPa.

6.1.8.1 Liquefaction Potential

Liquefaction may occur in poorly graded, loose sands or silts (refer to PSD plot in Figure 18) as a result of severe vibration induced by seismic activity.

SPT/DCP results indicate the silty sands to be medium dense to dense (450 kPa) such that liquefaction potential is considered to be low.

6.1.9 GABUTU PS NO. 9

The proposed Gabutu pumping station is located in front of the Don Bosco Technical High School adjacent to the Konebada/Vabukori Village main road. The proposed pumping station site is flat and clear. The backhoe trial pit investigation encountered fill material of silty sandy gravel overlying the silty sandy clay material from near surface to 3.00 meters depth and clayey sand material from 3.00 to 3.10 meter depth. Groundwater was encountered at 3.00 metre depth and bedrock material around 3.50 to 4.00 metre depth from surface.

One (1) borehole was excavated and drilled to 7.50 metre depth. *In-situ* and laboratory tests include DCP, particle size distribution, Atterberg limits, linear shrinkage, specific gravity, unit weight, chloride ion (CL) and pH.

The site foundation consists of soft to firm gravelly sandy clay to a depth of 0.50 metres, becoming stiff to very stiff than very stiff to hard (dense) at depths >3.00 metres.

Material strength is expected to increase gradually with depth beyond the base of the hole, where weathered rock (siltstone or sandstone) is expected. The fines component of the materials recovered are of medium to high plasticity (Figure 19). Indicated soil strength for the materials at 2.5 -3.0m indicates >300 kPa (qu).

Foundation design bearing strengths at various depth ranges are assessed as follows:

- >0.50 to <1.00 metres 170 to 255 kPa;
- >1.00 to <2.00 metres 255 to 385 kPa;
- >2.00 to 3.00 metres 385 to 560 kPa; and,
- >3.00 metres >560 kPa.

6.1.9.1 Liquefaction Potential

Liquefaction may occur in poorly graded, loose sands or silts (refer to PSD plot in Figure 20) as a result of severe vibration induced by seismic activity.

Particle size analyses undertaken on samples indicate the gravelly sandy clay to be well graded. The sand and silt also contain significant proportions of clay and silty fines such that liquefaction potential is considered to be low.

SPT/DCP results indicate the clayey silts to be medium dense (450 kPa) such that liquefaction potential is considered to be low.

6.1.10 KILA KILA HORSE CAMP PS NO. 10

The proposed site for the Horse Camp settlement pumping station is next to a creek or an open drain water channel from the settlement flowing south towards the sea at Joyce Bay. Settlement houses surround this proposed pumping station. Local information indicates that when the sea level or high tide rises, the seawater level is on the knee or about 0.5 to 1.0m above the existing ground level. Further, that the area was once vegetated by mangrove trees. The existing surface soil material of the site is fill material. People in the settlements placed general gravelly fill material on top of the silty clayey, peat soft (dead leaves/trees) of the mangrove deposits to improve the soil bearing strength. The mangrove trees were removed and used as building materials as well forewood.

The soil profile of the backhoe trial pit indicated that the proposed pumping station is located on a very soft soil area, this was confirmed with the backhoe excavation of trial pit and DCP tests encountering very soft silty sandy CLAY, dark brown to the depth of 3.50 and 4.50 metres respectively.

One (1) borehole was excavated and drilled to 10.00 metre depth. *In-situ* and laboratory tests include DCP, particle size distribution, Atterberg limits, linear shrinkage, specific gravity, unit weight, chloride ion (CL) and pH.

The site foundation consists of soft to very soft gravelly sandy clay to a depth of 2.00 metres from surface, than becoming firm to stiff after 2.00 metres from surface. Material strength is expected to increase gradually with depth beyond the base of the hole, where weathered rock (siltstone or sandstone) is expected. The fines component of the materials recovered are of medium to high plasticity (Figure 21). Soil strength for the materials at 3.00 metres is >200 kPa (qu).

Foundation design bearing strengths at various depth ranges are assessed as follows:

- >0.50 to <2.00 metres 65 to 130 kPa;
- >2.00 to <3.50 metres 130 to 150 kPa;
- >3.50 to 4.50 metres 150 to 425 kPa; and,
- >4.50 metres >425 kPa.

6.1.10.1 Liquefaction Potential

Liquefaction may occur in poorly graded, loose sands or silts (refer to PSD plot in Figure 22) as a result of severe vibration induced by seismic activity.

Particle size analyses undertaken on samples indicate the gravelly sandy clay to be well graded. The sand and silt also contain significant proportions of clay and silty fines such that liquefaction potential is considered to be low.

SPT/DCP results indicate the clayey silts to be medium dense (450 kPa) such that liquefaction potential is considered to be low.

6.2 SEWERAGE TREATMENT PLANT (STP) SITES

6.2.1 KILAKILA STP

The proposed KilaKila STP site is located at the foot slope of the Vabukori/Taikone hills, just past the Kilakila High school and Horse Camp settlement in the Joyce bay area. The site is overgrown with kunai grass with some few food gardens (e.g. kaukau) growing. The site is relatively gentle sloping from the toe of the slope and gets steeper towards the top of the undulating hilly terrain. The site is generally free draining with the site slopes on the natural ground surface along a longitudinal section of the site assessed between 20 to 30 degrees. Photo 1 shows the general landscape of the project site.

The site starts at the footslope of the hills and ascends towards the shoreline of Joyce bay. The proposed KilaKila STP site is underlain by highly weathered mudstone bedrock.

A total of six trial pits were dug by backhoe to their refused depths respectively to confirm the bedrock depths (refer pictures). DCP tests were first performed or carried out before the backhoe was used. The trial pit termination depths were constructed as follows:

- TP1 1.60 metres;

- TP2 1.00 metre;
- TP3 2.50 metres;
- TP4 1.70 metres;
- TP5 1.00 metre; and,
- TP6 1.10 metres.

All the trial pits dug by backhoe encountered their refusal on the bedrock of the Port Moresby Beds or Paga beds of highly weathered calcareous and siliceous mudstone. All the sites were located on the Hillslope.

In-situ and laboratory tests included DCP, particle size distribution, Atterberg limits, linear shrinkage, specific gravity, unit weight, chloride ions and pH. Trial Pits logs are as enclosed in Appendix B at the end of this report.

The site foundation consists of soft to firm gravelly sandy clay to 1.00 metre from surface; from 1.00 to 1.50 metres, the subsoil profile comprises firm to stiff gravelly sandy clay; becoming stiff to very stiff from 1.50 to 2.00 metres; than very stiff to hard (dense) after 2.00 metres from surface.

Material strength is expected to increase steadily with depth beyond the base of the hole, where weathered bedrock (siltstone or sandstone) is expected. The fines component of the materials recovered are of medium to high plasticity (Figure 23).
Soil strength from SPT N-values (30-36+) at 1.50 to 2.00 metres indicate values >300kPa (qu).

Foundation design bearing strengths at various depth ranges are assessed as follows:

- >0.50 to <1.00 metres 90 to 285 kPa;
- >1.00 to <2.00 metres 285 to 520 kPa; and,
- >2.00 metres 520 kPa.

6.2.1.1 Liquefaction Potential

Liquefaction is not considered to be a problem as a result of severe vibration induced by seismic activity due to presents of highly weathered bedrock near the surface.

Particle size analyses undertaken on samples indicate the lower level sandy silts to be well graded. The sand and silt also contain significant proportions of clay and silty fines such that liquefaction potential is considered to be low (Figure 24).

SPT/DCP results indicate the gravelly sandy clays to be stiff to very stiff such that liquefaction potential is considered to be low.

6.2.2 MORATA STP

The proposed Morata STP site is located northeast of the National Parliament House at the footslopes of the Morata hills, about 5 meters away from the proposed Gerehu Highway Bypass. The site is surrounded by peanut gardens, pit pits, kunai grass and some trees with a natural stormwater drainage channel flowing from the south to the west into the existing sewerage pond. The site is relatively gently sloping from the toe of the slopes and gets steeper towards the top of the undulating hilly terrain. The site is generally free draining with slopes on the natural ground surface along a longitudinal section of the site is assessed to be around 20 to 30 degrees. Photo 2 shows the general landscape of the project site.

A total of five trial pits and DCP tests were constructed to confirm the subsoil conditions prevalent on site (refer pictures). Trial pits were mechanically excavated using a hired backhoe. DCP tests were first performed or carried out before the backhoe was used. The trial pit termination depths were constructed as follows:

- TP1 2.00 metres;
- TP2 2.80 metre;
- TP3 3.50 metres;
- TP4 2.00 metres; and,
- TP5 3.00 metres.

TPs 2 and 3 encountered groundwater at 1.00 and 0.80 metre depths from surface respectively. This groundwater is believed to be natural occurring in this area and expected to be present especially alongside a natural drainage causeway.

Four trial pits were excavated to maximum depths of 3.50 metres from surface and one borehole drilled 9.50 metre depth from surface. *In-situ* and laboratory tests included DCP, particle size distribution, Atterberg limits, linear shrinkage, chloride ions and pH. Borehole and trial pit logs are as enclosed in Appendices A and B respectively at the end of this report.

The site foundation consists of soft to firm gravelly sandy clay to 1.00 metre; firm to stiff from 1.00 to 1.50 metres; than stiff to very stiff from 1.50 to 2.00 metres from surface. Material is very stiff to hard after 2.00 metres from surface.

Material strength is expected to increase steadily with depth beyond the base of the hole, where weathered bedrock (siltstone or sandstone) is expected. The fines component of the materials recovered are of medium to high plasticity (Figure 25).
Soil strength from SPT N-values (30-36+) at 1.50 to 2.00 metres and beyond indicate soil bearing pressures >300kPa (qu).

Foundation design bearing strengths at various depth ranges are assessed as follows:

- >0.50 to <1.00 metres 90 to 130 kPa;
- >1.00 to <2.00 metres 130 to 410 kPa;
- >2.00 metres >4180 kPa.

6.2.2.1 Liquefaction Potential

Liquefaction is not considered to be a problem as a result of severe vibration induced by seismic activity due to presents of highly weathered bedrock near the surface.

Particle size analyses undertaken on samples indicate the lower level sandy silts to be well graded. The sand and silt also contain significant proportions of clay and silty fines such that liquefaction potential is considered to be low (Figure 26).

SPT/DCP results indicate the gravelly sandy clays to be stiff to very stiff such that liquefaction potential is considered to be low.

7 RECOMMENDATIONS

7.1 SITE DESIGN ALLOWABLE BEARING PRESSURES

Based on information from the borehole logs (Appendix A), trial pits logs (Appendix B), DCP test logs (Appendix C) and laboratory test results (Appendix D), Table 2 below presents the recommended design Allowable Bearing Pressure values at various depths from surface for each of the 10 Pumping Station and 2 Sewerage Treatment Plant sites proposed for upgrading.

The information presented in Table 2 below recommends foundation design depths and foundation allowable bearing pressures prevalent at each site for the benefit of the structural design engineers to determine appropriate foundation design depths for the proposed construction/upgrading of the 10 Pumping Station and 2 Sewerage Treatment Plant site structures. These recommendations are proposed at each site investigated for upgrading purposes for the first 1.50 metre of subsoils including fill and subgrade materials.

TABLE 2. SUBSOIL DESIGN ALLOWABLE BEARING PRESSURES VS DEPTHS

SITE	DEPTH RANGE (M)	MATERIAL TYPE	ASSESSED SOIL BEARING PRESSURE	ALLOWABLE SOIL DESIGN BEARING PRESSURE
Kanudi Pump Station No.1	**>0.50 to <2.50**	**Subgrade**	**170 to 205 kPa**	**185 kPa**
	>2.50 to <3.50	**Subgrade**	**205 to 315 kPa**	**260 kPa**
	>3.50 to <4.50	**Subgrade**	**315 to 570 kPa**	**440 kPa**
	>4.50	**Subgrade**	**>570 kPa**	**570 kPa**
Idubada Pump Station No.2	**>0.50 to <2.50**	**Fill & Subgrade**	**90 to 170 kPa**	**130 kPa**
	>2.50 to <3.00	**Subgrade**	**170 to 300 kPa**	**235 kPa**
	>3.00 to <4.50	**Subgrade**	**300 to 480 kPa**	**390 kPa**
	>4.50	**Subgrade**	**>480 kPa**	**480 kPa**
Elevala Pump Station No.3	**>0.50 to <2.00**	**Subgrade**	**255 to 385 kPa**	**320 kPa**
	>2.00 to <2.50	**Subgrade**	**385 to 550 kPa**	**470 kPa**
	>2.50	**Subgrade**	**>550 kPa**	**550 kPa**
Hanuabada Pump Station No.4	**>0.50 to <3.50**	**Fill & Subgrade**	**255 to 385 kPa**	**320 kPa**
	>3.50 to <3.70	**Subgrade**	**385 to 550 kPa**	**465 kPa**
	>3.70	**Subgrade**	**>550 kPa**	**550 kPa**
Davara Ela Beach Pump Station No.5	**>0.50 to <2.00**	**Fill & Subgrade**	**170 to 255 kPa**	**210 kPa**
	>2.00 to <2.70	**Subgrade**	**255 to 455 kPa**	**340 kPa**
	>2.70	**Subgrade**	**>455 kPa**	**455 kPa**
Ela Beach Lawes Road	**>0.50 to <2.00**	**Subgrade**	**470 kPa**	**470 kPa**
	>2.00 to <10.50	**Subgrade**	**470 to 560 kPa**	**515 kPa**

Pump Station No.6	**>10.50**	**Subgrade**	**>560 kPa**	**560 kPa**
Kila Police Barracks Pump Station No.7	**>0.50 to <1.00**	**Subgrade**	**205 kPa**	**205 kPa**
	>1.00 to <1.20	**Subgrade**	**205 to 560 kPa**	**380 kPa**
	>1.20	**Subgrade**	**>560 kPa**	**560 kPa**
Konedobu Pump Station No.8	**>0.50 to <1.50**	**Subgrade**	**170 to 205 kPa**	**185 kPa**
	>1.50 to <2.50	**Subgrade**	**205 to 240 kPa**	**220 kPa**
	>2.50 to <3.50	**Subgrade**	**240 to 470 kPa**	**355 kPa**
	>3.50	**Subgrade**	**>470 kPa**	**470 kPa**
Gabutu Pump Station No.9	**>0.50 to <1.00**	**Subgrade**	**170 to 255 kPa**	**210 kPa**
	>1.00 to <2.00	**Subgrade**	**255 to 385 kPa**	**320 kPa**
	>2.00 to <3.00	**Subgrade**	**385 to 560 kPa**	**470 kPa**
	>3.00	**Subgrade**	**>560 kPa**	**560 kPa**
Kila Kila Horse Camp Pump Station No.10	**>0.50 to <2.00**	**Subgrade**	**65 to 130 kPa**	**105 kPa**
	>2.00 to <3.50	**Subgrade**	**130 to 150 kPa**	**140 kPa**
	>3.50 to <4.50	**Subgrade**	**150 to 425 kPa**	**285 kPa**
	>4.50	**Subgrade**	**>425 kPa**	**425 kPa**
Kila Kila Sewerage Treatment Plant	**>0.50 to <1.00**	**Subgrade**	**90 to 285 kPa**	**185 kPa**
	>1.00 to <2.00	**Subgrade**	**285 to 520 kPa**	**400 kPa**
	>2.00	**Subgrade**	**>520 kPa**	**520 kPa**
Morata Sewerage Treatment Plant	**>0.50 to <1.00**	**Subgrade**	**90 to 130 kPa**	**110 kPa**
	>1.00 to <2.00	**Subgrade**	**130 to 410 kPa**	**265 kPa**
	>2.00	**Subgrade**	**>410 kPa**	**410 kPa**

7.2 SUBSOIL ENGINEERING CLASSFICATIONS OF SITES

Recommended civil engineering site classification of each pump station and sewerage treatment plant site is summarised in Table 3 below. This recommendation is based on collective information assessed from the borehole data (Appenidx A), trial pit data (Appedix B) and laboratory test results (Appendix C) together with field observations and assessments.

Laboratory plasticity properties are used to gauge potential subsoil settlement conditions when subjected to extreme moisture fluctuations. In general, non-plastic to low plasticity sub-soils and medium to high to very high plasticity subs-oils indicate firm or medium to highly reactive site conditions respectively. This assessment is generally only appropriate for materials that exhibit the primary component of the material as cohesive. Soils exhibiting the primary component as granular are generally classified as firm.

TABLE 3. SUBSOIL ENGINEERING CLASSIFICATION OF SITES

SITE	DEPTH RANGE (M)	MATERIAL TYPE	SUBSOIL DESCRIPTION	SITE CLASSIFICATION
Kanudi Pump Station No.1	**>0.50 to <2.50**	**Subgrade**	**Sandy silty GRAVEL**	***"Firm"***
	>2.50 to <3.50	**Subgrade**		
	>3.50 to <4.50	**Subgrade**		
	>4.50	**Subgrade**		
Idubada Pump Station No.2	**>0.50 to <2.50**	**Fill & Subgrade**	**Gravelly CLAY & Gravelly sandy CLAY**	***"Soft"***
	>2.50 to <3.00	**Subgrade**	**Gravelly sandy CLAY**	
	>3.00 to <4.50	**Subgrade**		
	>4.50	**Subgrade**		
Elevala Pump Station No.3	**>0.50 to <2.00**	**Subgrade**	**Gravelly SILT**	***"Soft"***
	>2.00 to <2.50	**Subgrade**		
	>2.50	**Subgrade**		
Hanuabada Pump Station No.4	**>0.50 to <3.50**	**Fill & Subgrade**	**Silty CLAY, Silty GRAVEL &CLAY**	***"Soft"***
	>3.50 to <3.70	**Subgrade**		
	>3.70	**Subgrade**		
Davara Ela Beach Pump Station No.5	**>0.50 to <2.00**	**Fill & Subgrade**	**Fill & SAND**	***"Firm"***
	>2.00 to <2.70	**Subgrade**	**SAND**	
	>2.70	**Subgrade**		
Ela Beach Lawes Road Pump Station No.6	**>0.50 to <2.00**	**Subgrade**	**Silty sandy GRAVEL**	***"Firm"***
	>2.00 to <10.50	**Subgrade**	**Silty SAND**	
	>10.50	**Subgrade**		
Kila Police Barracks Pump Station No.7	**>0.50 to <1.00**	**Subgrade**	**Gravelly sandy CLAY**	***"Soft"***
	>1.00 to <1.20	**Subgrade**		
	>1.20	**Subgrade**		***"Firm"***
Konedobu Pump Station No.8	**>0.50 to <1.50**	**Subgrade**	**Sandy gravelly CLAY & Silty SAND**	***"Firm"***
	>1.50 to <2.50	**Subgrade**	**Silty SAND**	
	>2.50 to <3.50	**Subgrade**		
	>3.50	**Subgrade**		
Gabutu Pump Station No.9	**>0.50 to <1.00**	**Subgrade**	**Gravelly sandy CLAY**	***"Soft"***
	>1.00 to <2.00	**Subgrade**		
	>2.00 to <3.00	**Subgrade**		
	>3.00	**Subgrade**		
Kila Kila Horse Camp Pump Station No.10	**>0.50 to <2.00**	**Subgrade**	**Gravelly sandy CLAY & CLAY**	***"Soft"***
	>2.00 to <3.50	**Subgrade**	**CLAY**	
	>3.50 to <4.50	**Subgrade**		
	>4.50	**Subgrade**		
Kila Kila Sewerage Treatment Plant	**>0.50 to <1.00**	**Subgrade**	**Sandy gravelly CLAY**	***"Firm"***
	>1.00 to <2.00	**Subgrade**		
	>2.00	**Subgrade**	**Weathered Bedrock**	
Morata Sewerage Treatment Plant	**>0.50 to <1.00**	**Subgrade**	**Silty gravelly CLAY**	***"Firm"***
	>1.00 to <2.00	**Subgrade**		
	>2.00	**Subgrade**	**Weathered Bedrock**	

7.3 ASSESSMENT OF SUBSOIL LIQUEFACTION POTENTIAL AT SITES

The study area itself is located within Zone IV of the Earthquake Risk classification regions of PNG where potential for seismic activity is of the lowest risk in occurrence (Ref. 5). Based on PNGS 1001, Part 4, Clause 3.4.2 (Ref. 5), the founding subsoil deposits have allowable bearing pressures greater than 200 kPa at depths greater than 1.00 metre and less than 6 metres and therefore, the site is classified as "***firm***". In addition, these materials are cohesive in character and considered to have a low potential to liquefy under intense seismic conditions. Assessment of liquefaction potential is summarised in Table 4 below.

TABLE 4. SUBSOIL DESIGNALLOWABLE BEARING PRESSURES VS DEPTHS

SITE	DEPTH RANGE (M)	SOIL DESCRIPTION	ASSESSED SOIL BEARING PRESSURE	ASSESSED LIQUEFACTION POTENTIAL
Kanudi Pump Station No.1	**>0.50 to <2.50**	**Sandy silty GRAVEL**	**170 to 205 kPa**	**LOW TO MODERATE**
	>2.50 to <3.50		**205 to 315 kPa**	**LOW**
	>3.50 to <4.50		**315 to 570 kPa**	
	>4.50		**>570 kPa**	
Idubada Pump Station No.2	**>0.50 to <2.50**	**Gravelly CLAY & Gravelly sandy CLAY**	**90 to 170 kPa**	**MODERATE**
	>2.50 to <3.00	**Gravelly sandy CLAY**	**170 to 300 kPa**	
	>3.00 to <4.50		**300 to 480 kPa**	**LOW**
	>4.50		**>480 kPa**	
Elevala Pump Station No.3	**>0.50 to <2.00**	**Gravelly SILT**	**255 to 385 kPa**	**LOW TO MODERATE**
	>2.00 to <2.50		**385 to 550 kPa**	**LOW**
	>2.50		**>550 kPa**	
Hanuabada Pump Station No.4	**>0.50 to <3.50**	**Silty CLAY, Silty GRAVEL &CLAY**	**255 to 385 kPa**	**LOW**
	>3.50 to <3.70		**385 to 550 kPa**	
	>3.70		**>550 kPa**	
Davara Ela Beach Pump Station No.5	**>0.50 to <2.00**	**Fill & SAND**	**170 to 255 kPa**	**MODERATE TO HIGH**
	>2.00 to <2.70	**SAND**	**255 to 455 kPa**	**HIGH**
	>2.70		**>455 kPa**	
Ela Beach Lawes Road Pump Station No.6	**>0.50 to <2.00**	**Silty sandy GRAVEL**	**470 kPa**	**MODERATE**
	>2.00 to <10.50	**Silty SAND**	**470 to 560 kPa**	**HIGH**
	>10.50		**>560 kPa**	
Kila Police Barracks Pump Station No.7	**>0.50 to <1.00**	**Gravelly sandy CLAY**	**205 kPa**	**LOW**
	>1.00 to <1.20		**205 to 560 kPa**	
	>1.20		**>560 kPa**	
Konedobu Pump Station No.8	**>0.50 to <1.50**	**Sandy gravelly CLAY & Silty SAND**	**170 to 205 kPa**	**MODERATE**
	>1.50 to <2.50	**Silty SAND**	**205 to 240 kPa**	**LOW**

	>2.50 to <3.50 **>3.50**		**240 to 470 kPa** **>470 kPa**	
Gabutu Pump Station No.9	**>0.50 to <1.00**	**Gravelly sandy CLAY**	**170 to 255 kPa**	**MODERATE**
	>1.00 to <2.00 **>2.00 to <3.00** **>3.00**		**255 to 385 kPa** **385 to 560 kPa** **>560 kPa**	**LOW**
Kila Kila Horse Camp Pump Station No.10	**>0.50 to <2.00**	**Gravelly sandy CLAY & CLAY**	**65 to 130 kPa**	**MODERATE TO LOW**
	>2.00 to <3.50 **>3.50 to <4.50** **>4.50**	**CLAY**	**130 to 150 kPa** **150 to 425 kPa** **>425 kPa**	**LOW**
Kila Kila Sewerage Treatment Plant	**>0.50 to <1.00** **>1.00 to <2.00**	**Sandy gravelly CLAY**	**90 to 285 kPa** **285 to 520 kPa**	**MODERATE TO LOW**
	>2.00	**Weathered Bedrock**	**>520 kPa**	**LOW**
Morata Sewerage Treatment Plant	**>0.50 to <1.00** **>1.00 to <2.00**	**Silty gravelly CLAY**	**90 to 130 kPa** **130 to 410 kPa**	**MODERATE TO LOW**
	>2.00	**Weathered Bedrock**	**>410 kPa**	**LOW**

7.4 SITE EARTHWORKS PREPARATORY ISSUES

Topsoil and existing fill are considered not suitable for any foundation layer and should be stripped off and removed from the site completely before any surface treatment is applied. As part of the foundation for building, excavation may be necessary to approximately 3.0m. Exposed subgrade should be proof rolled to determine any soft spots. Should soft spots be dictated, due to the softness of the soil profile, the area should be excavated down by 3.5m depth and backfilled with selected granular or suitable fill and compacted. With the presence of high plasticity clay, minimum water is required to achieve better compaction. The choice of the type of roller will be determined by site condition prevalent. Tyre roller will give better roll in wet and muddy conditions were high plasticity is encountered.

It is anticipated that there should not be any groundwater inflows during excavation and construction. However, some groundwater inflow may be expected if the construction is carried out after heavy rainfall. It is anticipated that groundwater inflows may be controlled by conventional sump pumping arrangements. Alternatively, correct underwater concrete placement techniques should be adopted. However, the materials assumed to be highly plastic will be highly susceptible to shrinkage and cracking when exposed to drying and softening upon wetting. Therefore exposure time of these materials to the elements should be minimized, otherwise failure may occur. Likewise, construction delays in the construction of temporary and permanent retaining structures should also be minimized.

Proper drainage system incorporating free draining gravel drains behind all retaining structures should be incorporated to avoid the build-up of hydrostatic pressure. It is recommended that retaining walls be founded on and keyed into the natural hard clay at least 500mm below the level of any base excavation. An allowable bearing capacity of 150 kPa may be applied to such foundations. An active earth coefficient of 0.3 may be adopted for the design of retaining walls.

The material must be re-compacted in layers not exceeding 150mm thick layers in a approved manner that a minimum of 100% of Standard Maximum Dry Density at ± 2% of Standard Optimum Moisture Content is achieved in accordance with AS 1289.5.1.2 & 5.3.1.

It should be noted that any area of exposed subgrade which exhibits shrinkage and does not require re-compaction, should be watered and rolled until the shrinkage cracks do not reappear. It should be noted also that during this undertaking, care should be exercised to ensure the surface does not become soft.

7.5 SITE GROUNDWATER ISSUES

It is anticipated that there should not be any groundwater inflows during excavation and construction. However, some groundwater inflow may be expected if the construction is carried out after heavy rainfall. It is anticipated that groundwater inflows may be controlled by conventional sump pumping arrangements. Alternatively, correct underwater concrete placement techniques should be adopted. However, the materials assumed to be highly plastic will be highly susceptible to shrinkage and cracking when exposed to drying and softening upon wetting. Therefore exposure time of these materials to the elements should be minimized, otherwise failure may occur. Likewise, construction delays in the construction of temporary and permanent retaining structures should also be minimized.

Proper drainage system incorporating free draining gravel drains behind the all retaining structures should be incorporated to avoid the build-up of hydrostatic pressure. It is recommended that retaining walls be founded on and keyed into the natural hard clay at least 500mm below the level of any base excavation. An allowable bearing capacity of 150 kPa may be applied to such foundations. An active earth coefficient of 0.3 may be adopted for the design of retaining walls.

The material must be re-compacted in layers not exceeding 150mm thick layers in a approved manner that a minimum of 100% of Standard Maximum Dry Density at ± 2% of Standard Optimum Moisture Content is achieved in accordance with AS 1289.5.1.2 & 5.3.1.

It should be noted that any area of exposed sub-grade which exhibits shrinkage and does not require re-compaction, should be watered and rolled until the shrinkage cracks do not reappear. It should be noted also that during this undertaking, care should be exercised to ensure the surface does not become soft.

7.6 SITE SOIL & GROUNDWATER CHEMICAL REACTIVITY ISSUES

Information from previous studies show the Valley Floor Deposit material of alluvial origin is naturally a clean subsoil material free of natural chlorides or sulphates and with a pH between 6.5 and 7. It is therefore considered safe for any concrete structure to be placed on this fill material with minimal concern for chemical degradation.

8 REFERENCES

1. ACAD File 8019, Drawing No. C01 - 2008, Stocks & Partners, Port Moresby, NCD;
2. 1: 250,000 Geological Map Series and associated Memoir, Port Moresby Urban Geology, Geological Survey of Papua New Guinea;
3. Stockwell, M.J (1977), Determination of allowable bearing pressure under small structures;
4. Australian Standards Council (1997) – Methods of Testing Soils for Engineering Purposes. AS 1289; and,
5. PNG Standard 1001 – 1982, Part 4 Earthquake Loading.

FIGURES

APPENDIX A

Bore Hole Logs

APPENDIX B

Dynamic Cone Penetrometer Logs

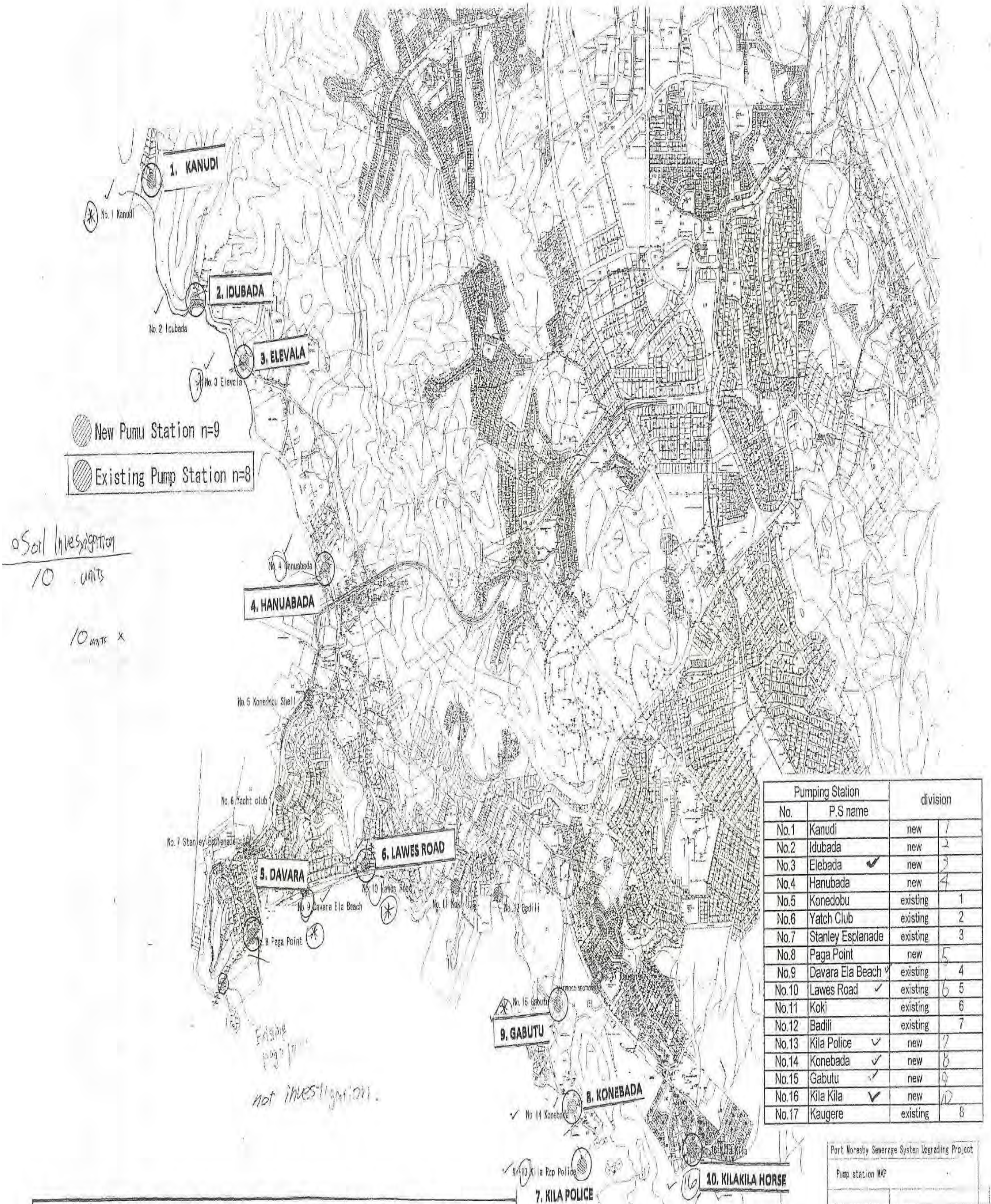
APPENDIX C

Laboratory Test Results

APPENDIX D

Site Photographs

Figure 1A : Locality Site Plan Showing 10 Pumping Stations Test



Pumping Station		division	
No.	P.S name		
No.1	Kanudi	new	1
No.2	Idubada	new	2
No.3	Elebada ✓	new	3
No.4	Hanubada	new	4
No.5	Konedobu	existing	1
No.6	Yatch Club	existing	2
No.7	Stanley Esplanade	existing	3
No.8	Paga Point	new	5
No.9	Davara Ela Beach ✓	existing	4
No.10	Lawes Road ✓	existing	6 5
No.11	Koki	existing	6
No.12	Badili	existing	7
No.13	Kila Police ✓	new	7
No.14	Konebada ✓	new	8
No.15	Gabutu ✓	new	9
No.16	Kila Kila ✓	new	10
No.17	Kaugere	existing	8

Figure 1 : Locality Site Plan Showing 10 Pumping Stations Test Locations

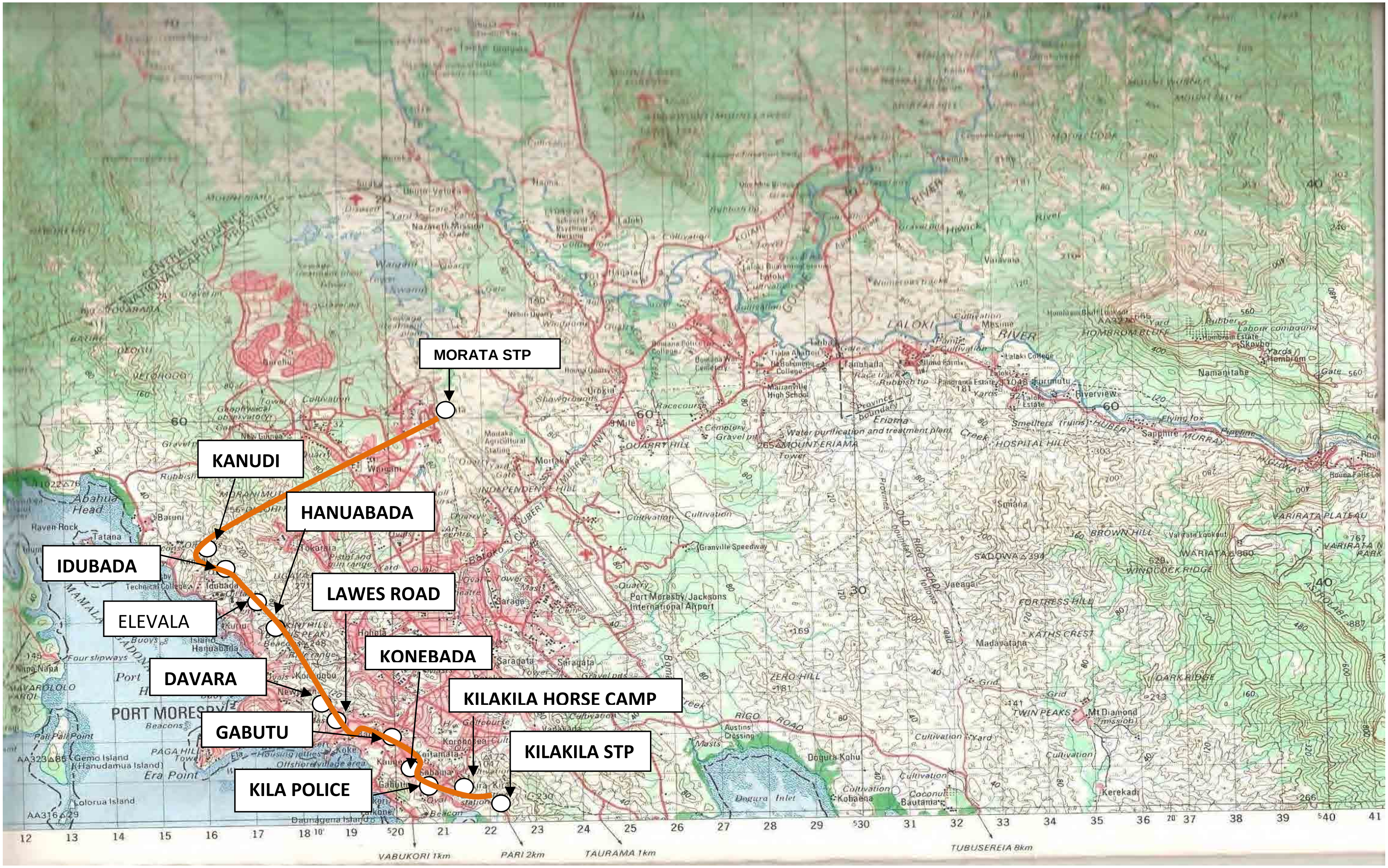
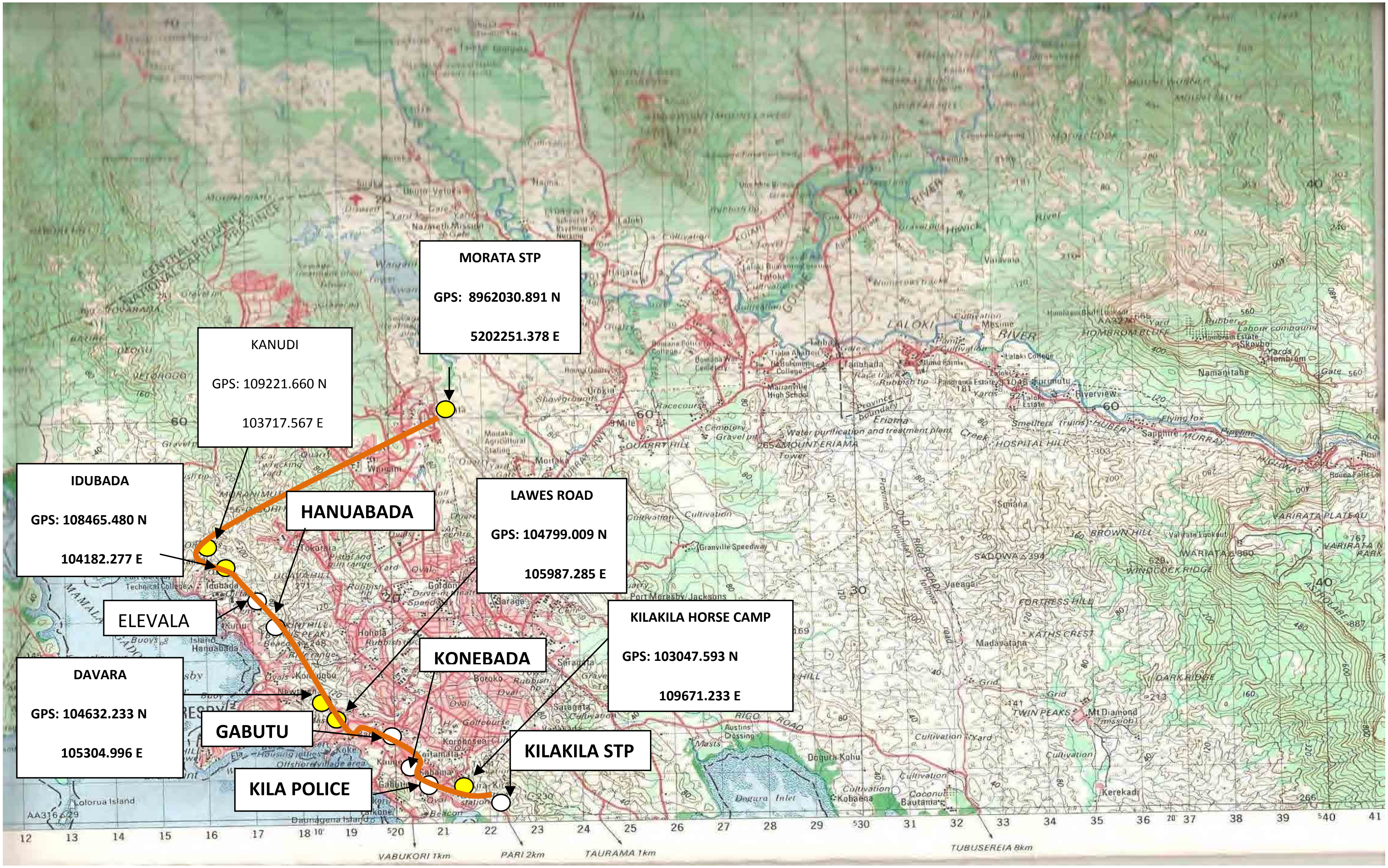


Figure 1: Locality Plan for10 Pumping Stations and 2 Sewerage Treatment Plant Sites, NCD

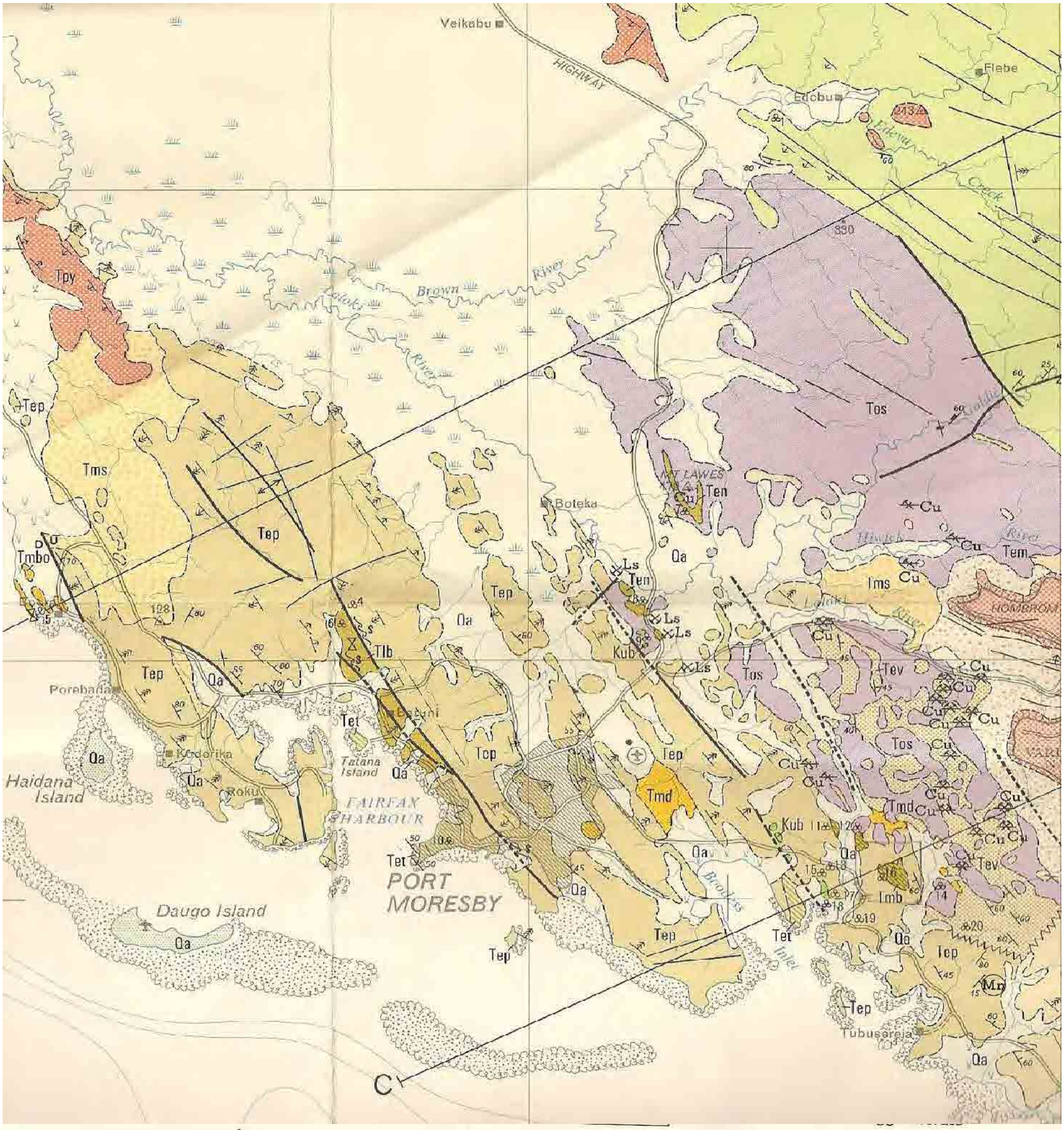


Keys : Boreholes, Trial Pits and DCP Tests Locations

Trial Pits and DCP Tests Locations

SEWERAGE ROUTE SOIL SURVEY TEST LOCATION BETWEEN KILAKILA AND MORATA

Figure 2 : Geology of the Project Site



LATE TO MIDDLE EOCENE Ta_2-Ta_3^*	Port Moresby Beds	Tem	Siliceous argillite, shale, calcilutite, minor chert, calcarenite; undivided
		Tev	Partly calcareous argillite and shale, calcilutite, minor tuff and slump breccia
		Tep	Partly calcareous, siliceous argillite and shale, calcilutite, chert, minor calcarenite and dolomite
		Ten	Massive argillaceous biomicrite
		Tet	Calcarenite, minor calcirudite; glauconitic

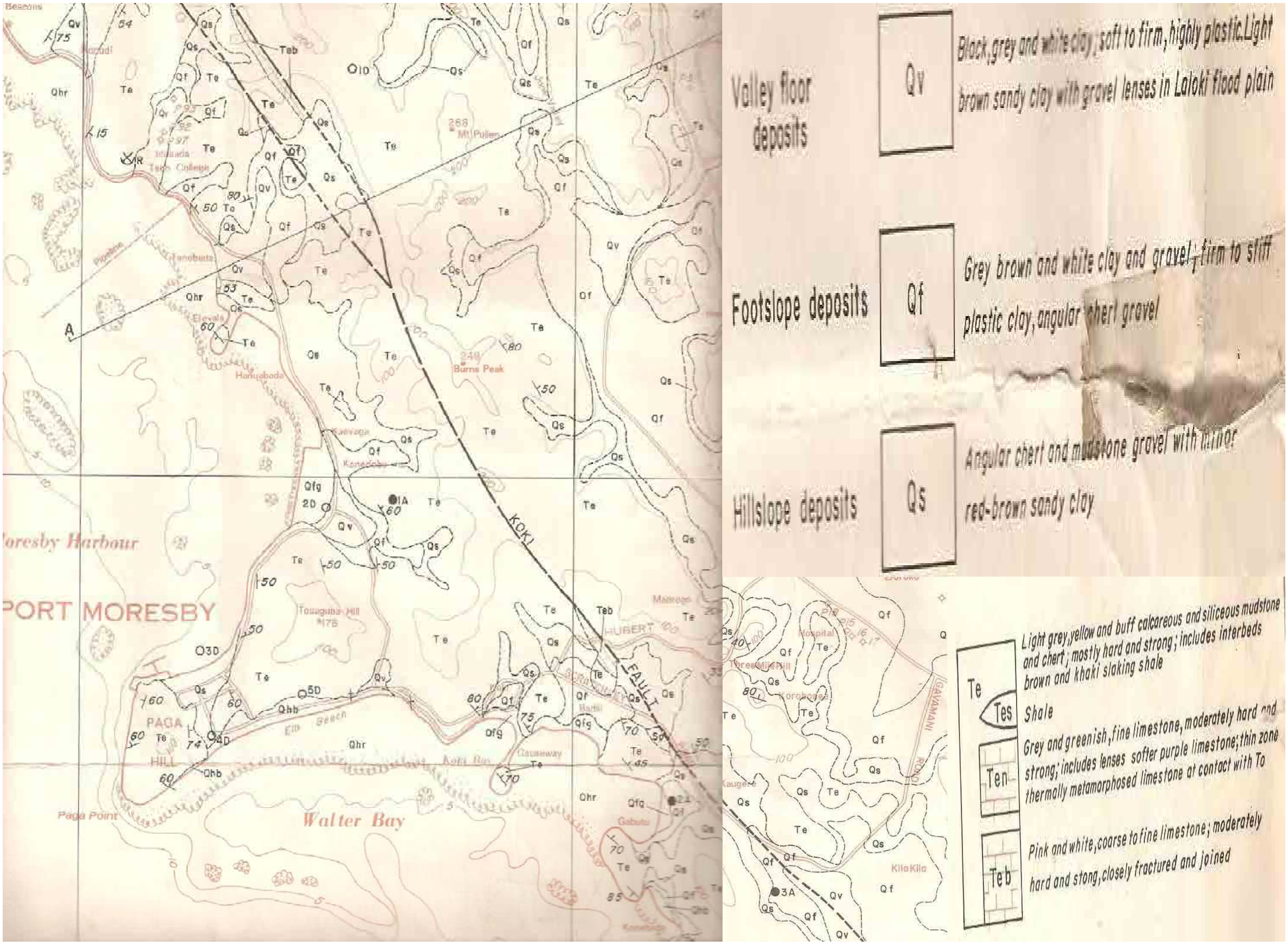
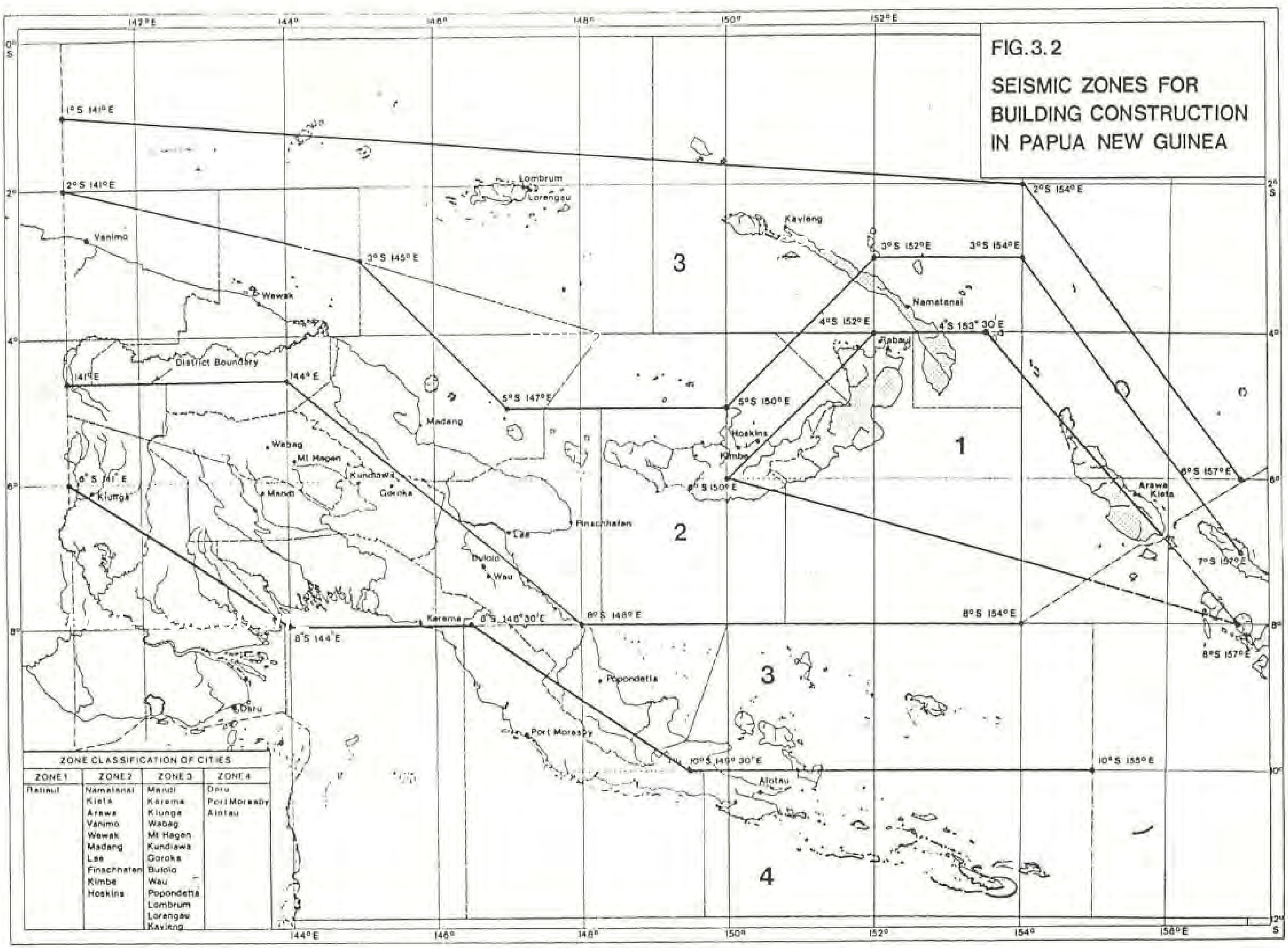


Figure 2A : Geology of the Project Site

Figure : 2B   Earthquake Seismic Risk Zone of Papua New Guinea



ZONE 1	ZONE 2	ZONE 3	ZONE 4
Rabaul	Namatanai	Mendi	Daru
	Kieta	Kerema	Port Moresby
	Arawa	Kiunga	Alotau
	Vanimo	Wabag	
	Wewak	Mt Hagen	
	Madang	Kundiawa	
	Lae	Goroka	
	Finschhafen	Bulolo	
	Kimbe	Wau	
	Hoskins	Popondetta	
		Lombrum	
		Lorengau	
		Kavieng	

Project: Port Moresby Sewerage System Upgrading

Location: Kanudi New Pump Station # 1 - Port Moresby **Job No:** NGTS01011

Client: njs - JICA **Date:** April, 2011

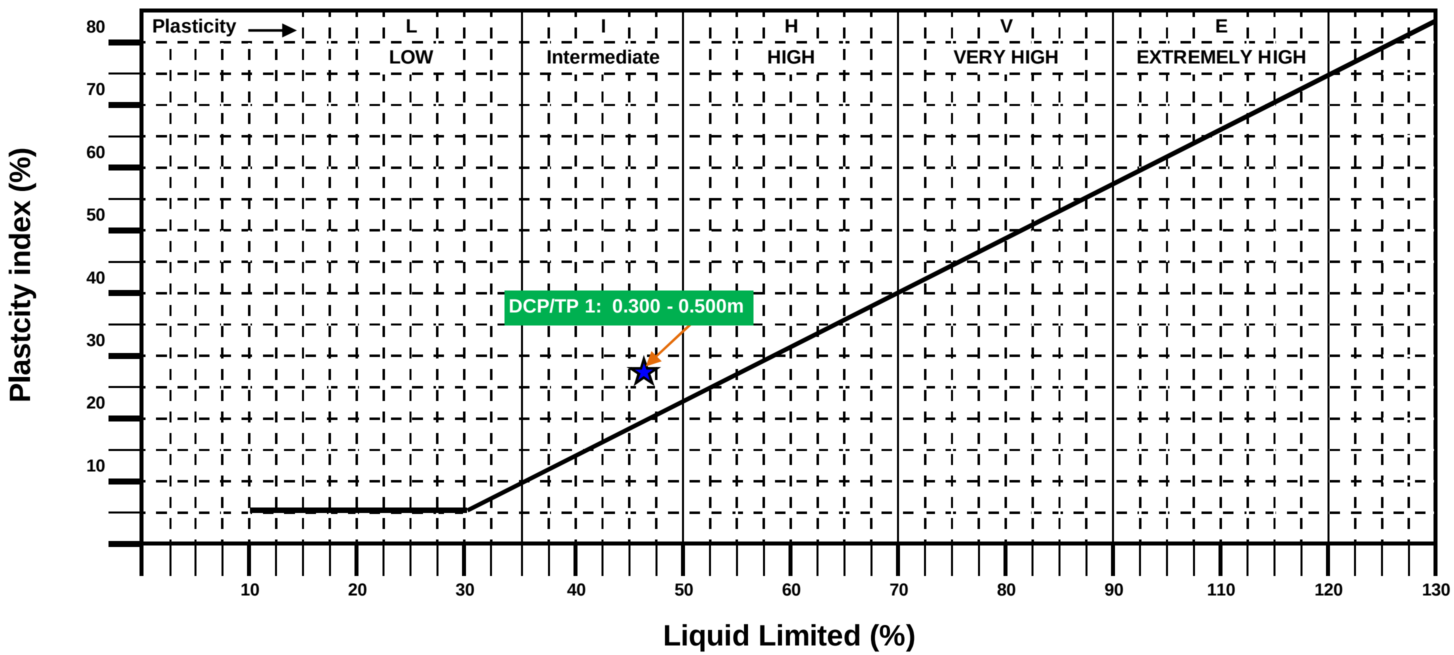


Figure 3. CASAGRANDE PLOT FOR SUBSOIL MATERIAL FROM TEST PIT # 1

Project: Port Moresby Sewerage System Upgrading
Location: Kanudi # 01 - Port Moresby, NCD
Client: njs - JICA

Job: NGTS01011
Date: April 2011

PARTICLE SIZE DISTRIBUTION & LIQUEFACTION POTENTIAL

Client: njs - JICA	**Project number:** NGTS01011
Project: Port Moresby Sewerage System Upgrading	**Location:** Kanudi # 01, Port Moresby - NCD

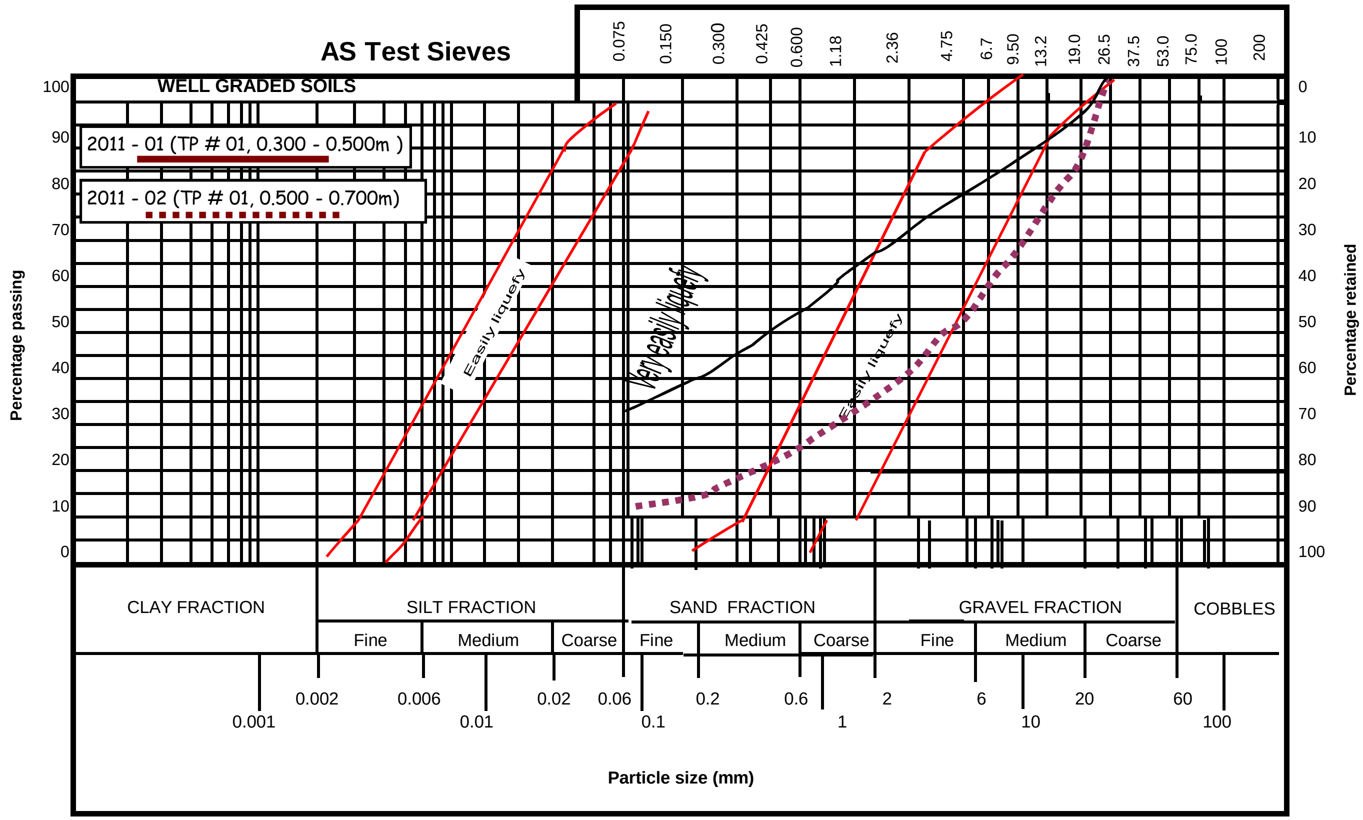


Figure 4 - GRADING CURVE FOR SAMPLES FROM TEST PIT # 01

NGTS

Project: Port Moresby Sewerage System Upgrading

Location: Idubada New Pump Station # 2 - Port Moresby **Job No:** NGTS01011

Client: njs - JICA **Date:** April, 2011

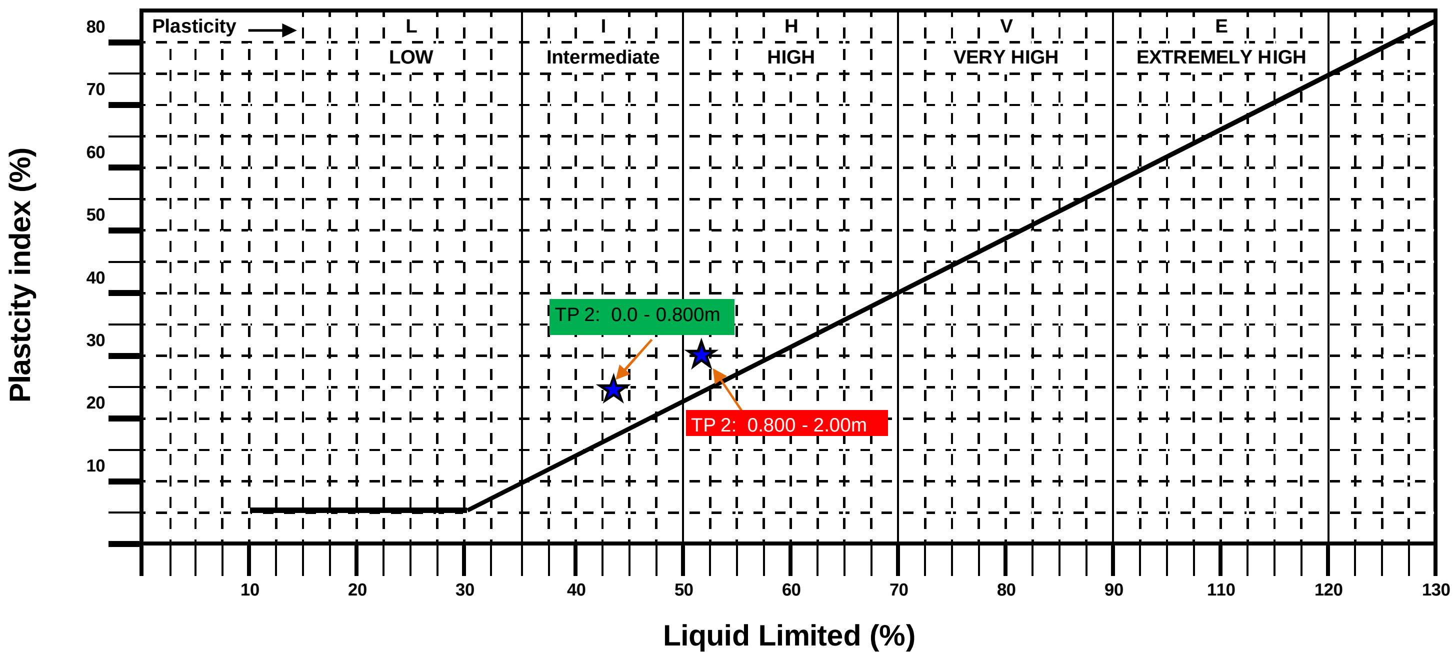


Figure 5. CASAGRANDE PLOT FOR SUBSOIL MATERIAL FROM TEST PIT # 2

Project: Port Moresby Sewerage System Upgrading
Location: Idubada # 2 - Port Moresby, NCD
Client: njs - JICA

Job: NGTS01011
Date: April 2011

PARTICLE SIZE DISTRIBUTION & LIQUEFACTION POTENTIAL

Client: njs - JICA	**Project number:** NGTS01011
Project: Port Moresby Sewerage System Upgrading	**Location:** Idubada # 02, Port Moresby - NCD

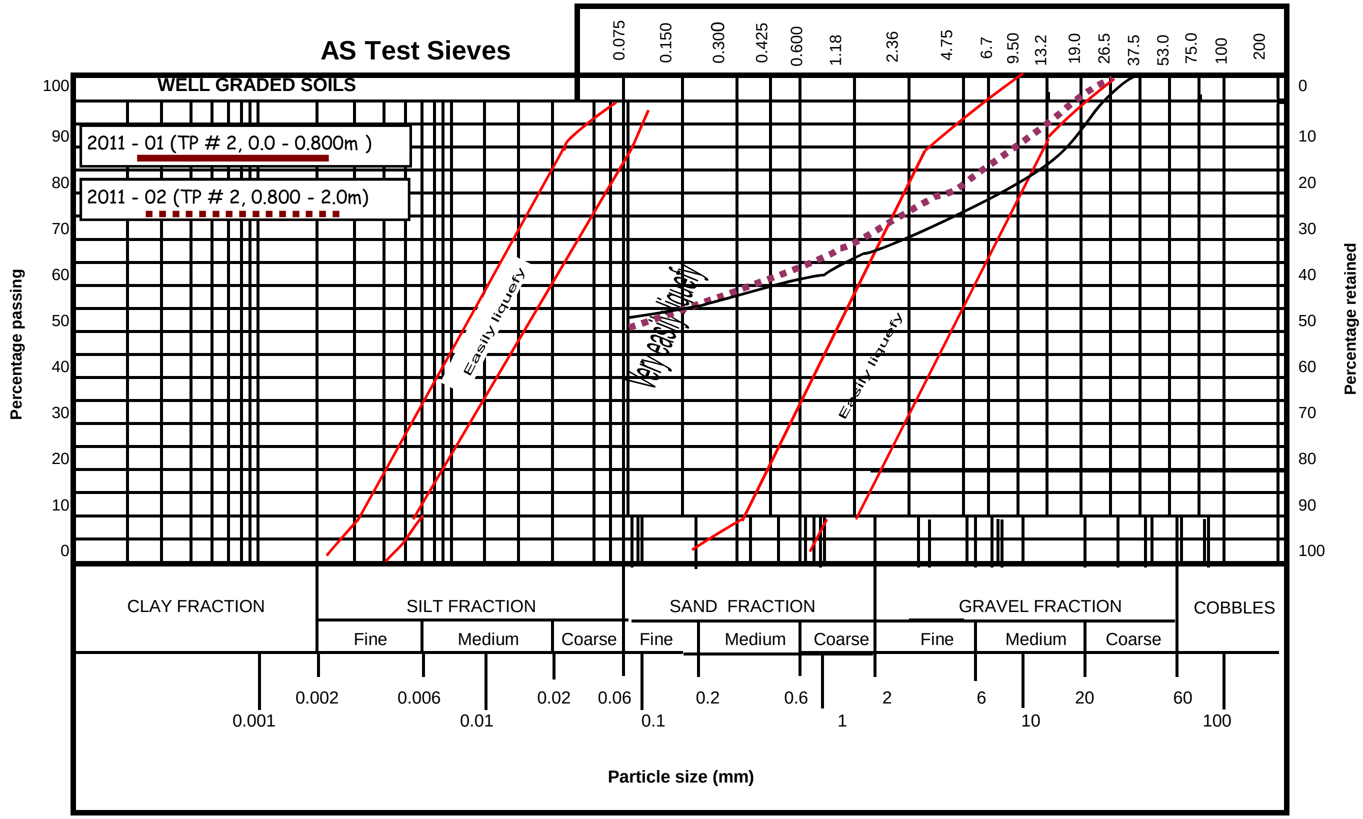


Figure 6 - GRADING CURVE FOR SAMPLES FROM TEST PIT # 02

Project: Port Moresby Sewerage System Upgrading

Location: Elevala New Pump Station # 03 - Port Moresby **Job No:** NGTS01011

Client: njs - JICA **Date:** April, 2011

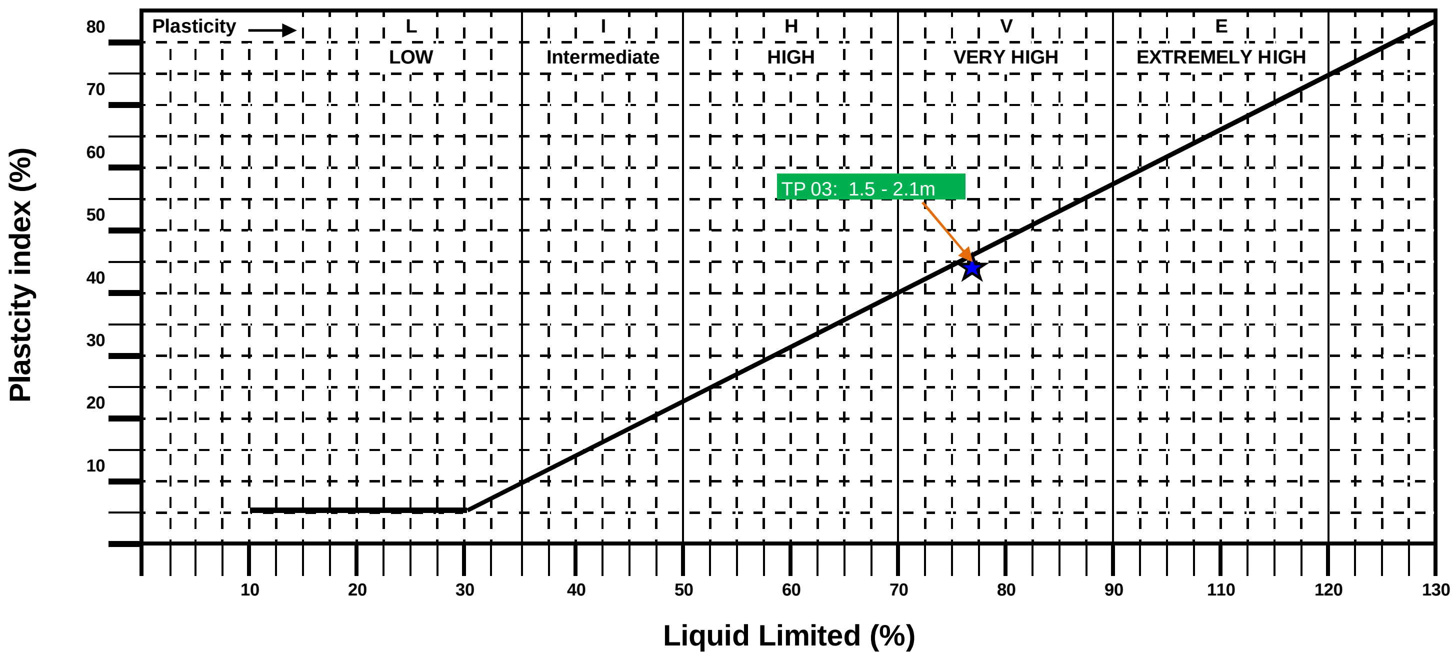


Figure 7. CASAGRANDE PLOT FOR SUBSOIL MATERIAL FROM TEST PIT # 03

Project: Port Moresby Sewerage System Upgrading
Location: Elevala # 03 - Port Moresby, NCD
Client: njs - JICA

Job: NGTS01011
Date: March 2011

PARTICLE SIZE DISTRIBUTION & LIQUEFACTION POTENTIAL

Client: njs - JICA	**Project number:** NGTS01011
Project: Port Moresby Sewerage System Upgrading	**Location:** Elevala # 03, Port Moresby - NCD

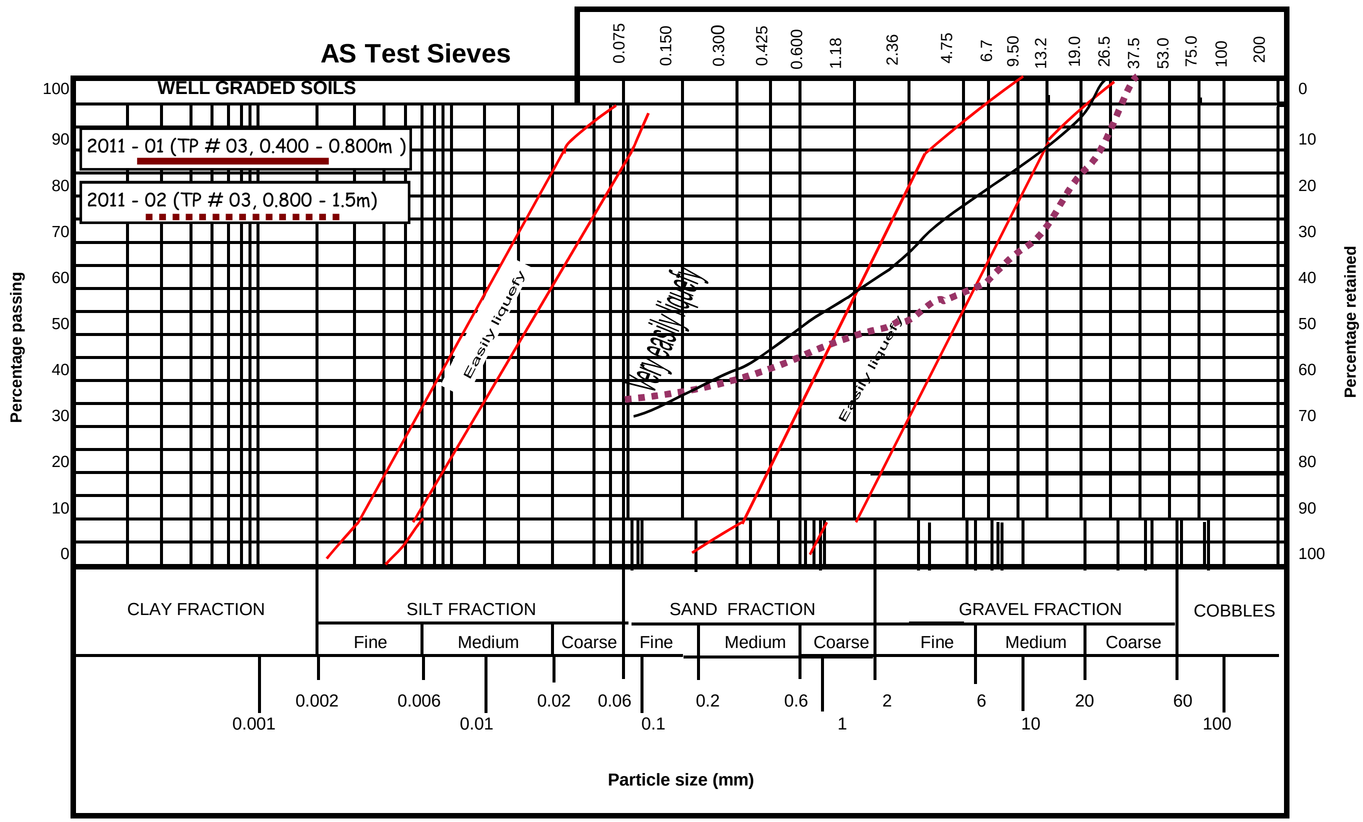


Figure 8 - GRADING CURVE FOR SAMPLES FROM TEST PIT # 03

Project: Port Moresby Sewerage System Upgrading

Location: Hanuabada New Pump Station # 4 - Port Moresby **Job No:** NGTS01011

Client: njs - JICA **Date:** April, 2011

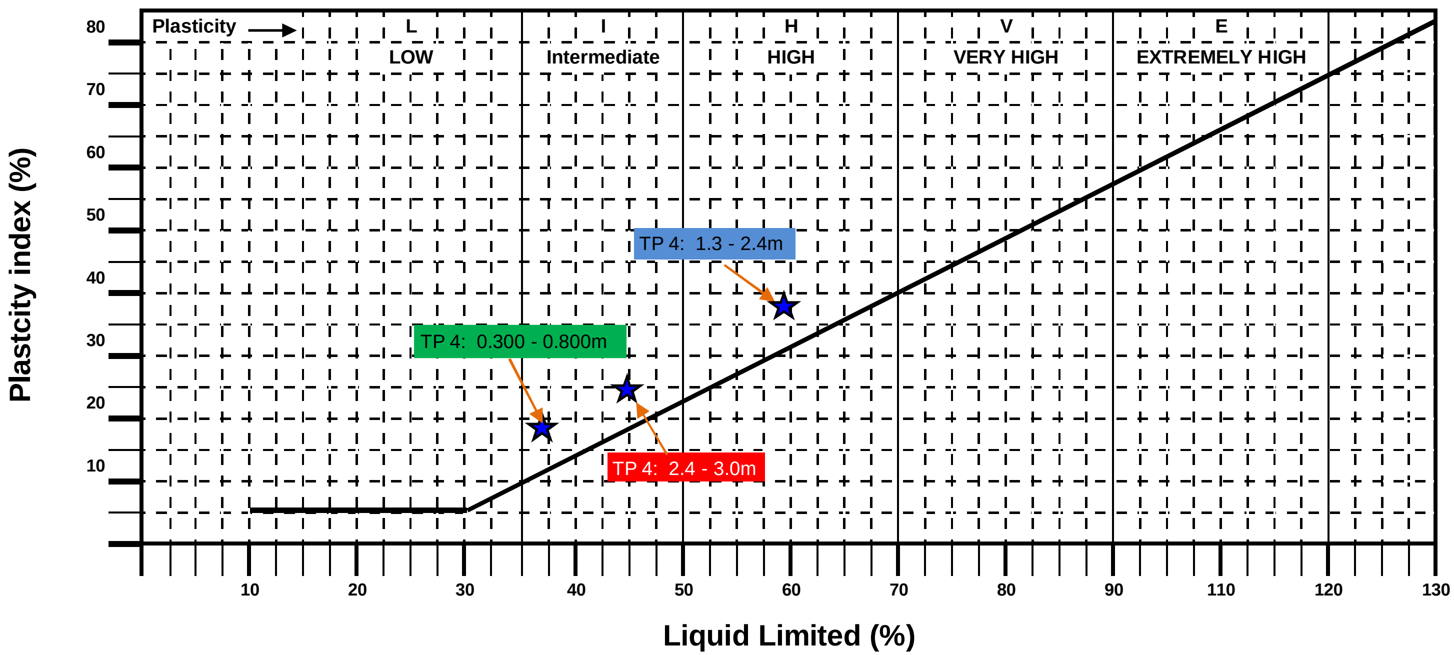


Figure 9. CASAGRANDE PLOT FOR SUBSOIL MATERIAL FROM TEST PIT # 4

Project: Port Moresby Sewerage System Upgrading
Location: Hanuabada # 4 - Port Moresby, NCD
Client: njs - JICA

Job: NGTS01011
Date: April 2011

PARTICLE SIZE DISTRIBUTION & LIQUEFACTION POTENTIAL

Client: njs - JICA	**Project number:** NGTS01011
Project: Port Moresby Sewerage System Upgrading	**Location:** Hanuabada # 4, Port Moresby - NCD

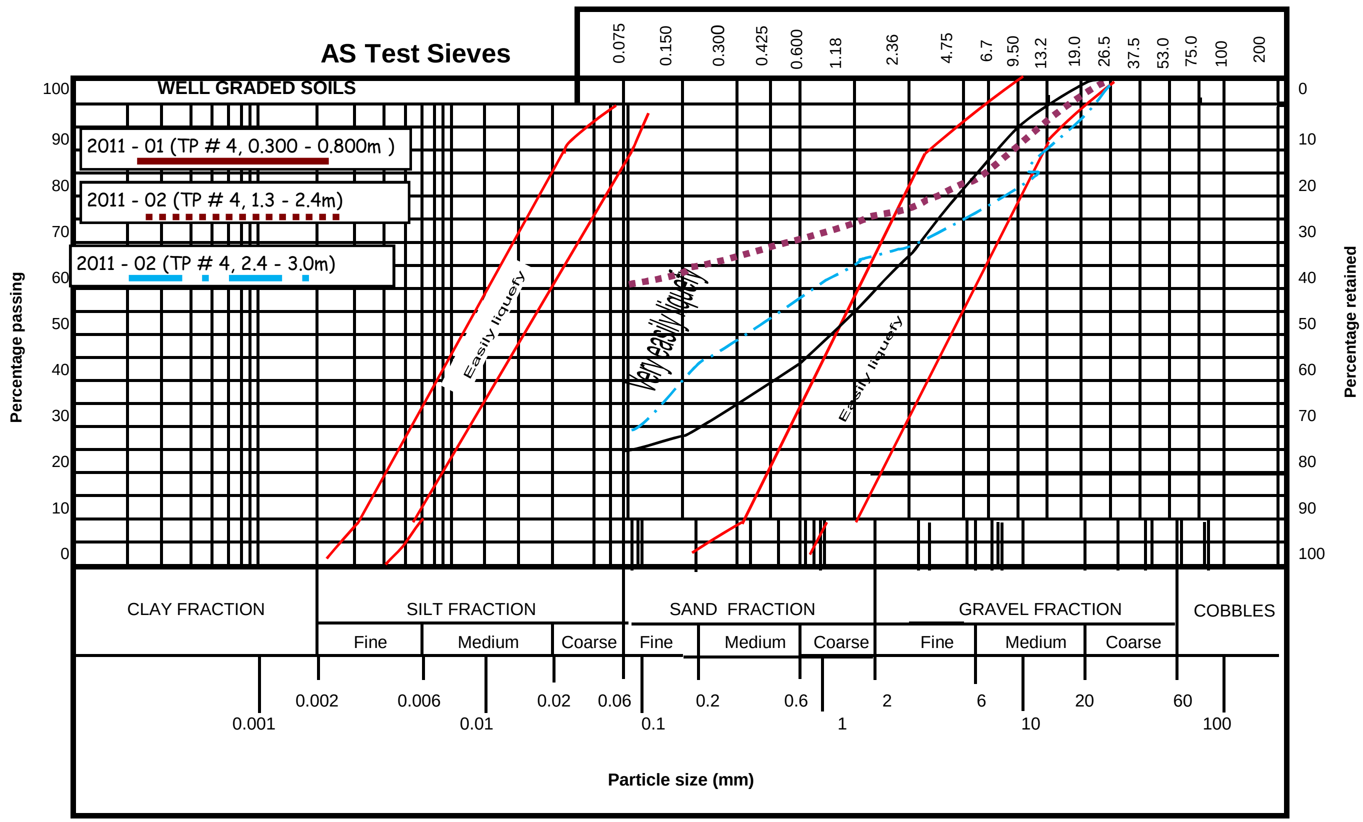


Figure 10 - GRADING CURVE FOR SAMPLES FROM TEST PIT # 4

Project: Port Moresby Sewerage System Upgrading

Location: Davara Pump Station # 5 - Port Moresby **Job No:** NGTS01011

Client: njs - JICA **Date:** April, 2011

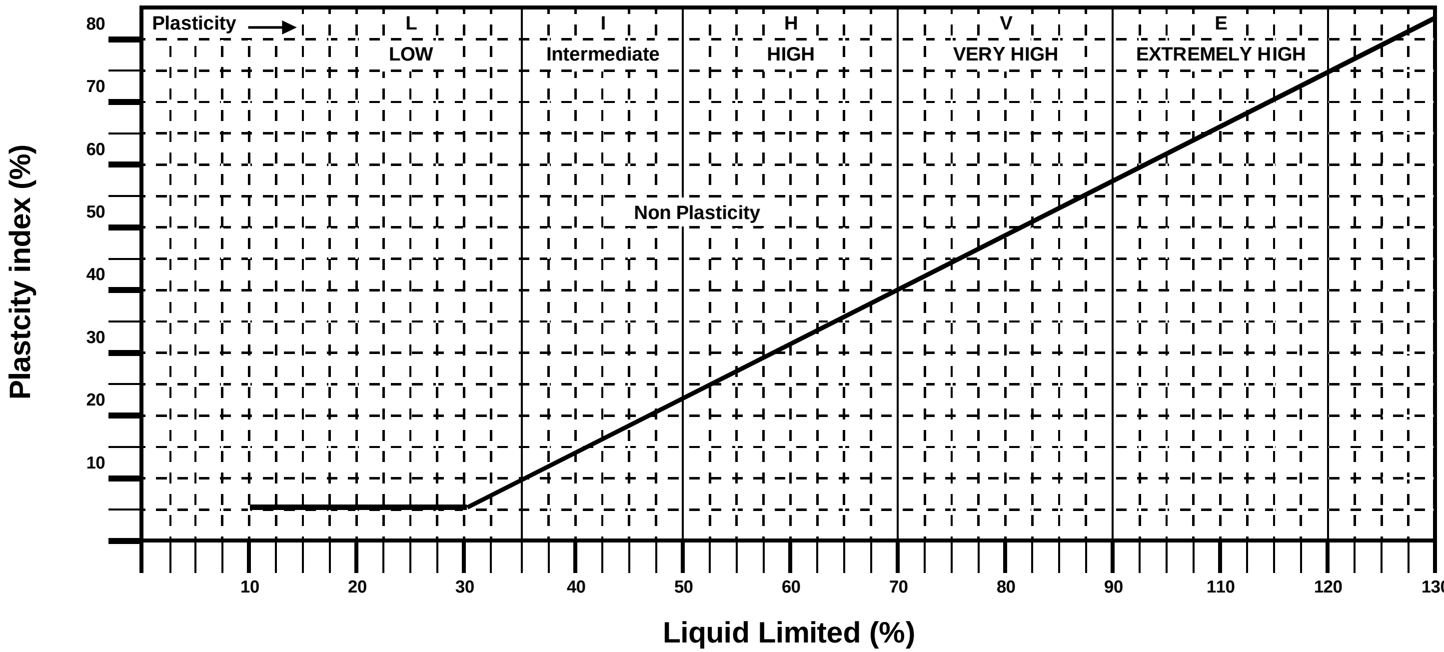


Figure 11. CASAGRANDE PLOT FOR SUBSOIL MATERIAL FROM TEST PIT # 5

Project: Port Moresby Sewerage System Upgrading
Location: Davara # 5 - Port Moresby, NCD
Client: njs - JICA

Job: NGTS01011
Date: March 2011

PARTICLE SIZE DISTRIBUTION & LIQUEFACTION POTENTIAL

Client: njs - JICA	**Project number:** NGTS01011
Project: Port Moresby Sewerage System Upgrading	**Location: Davara** # 05, Port Moresby - NCD

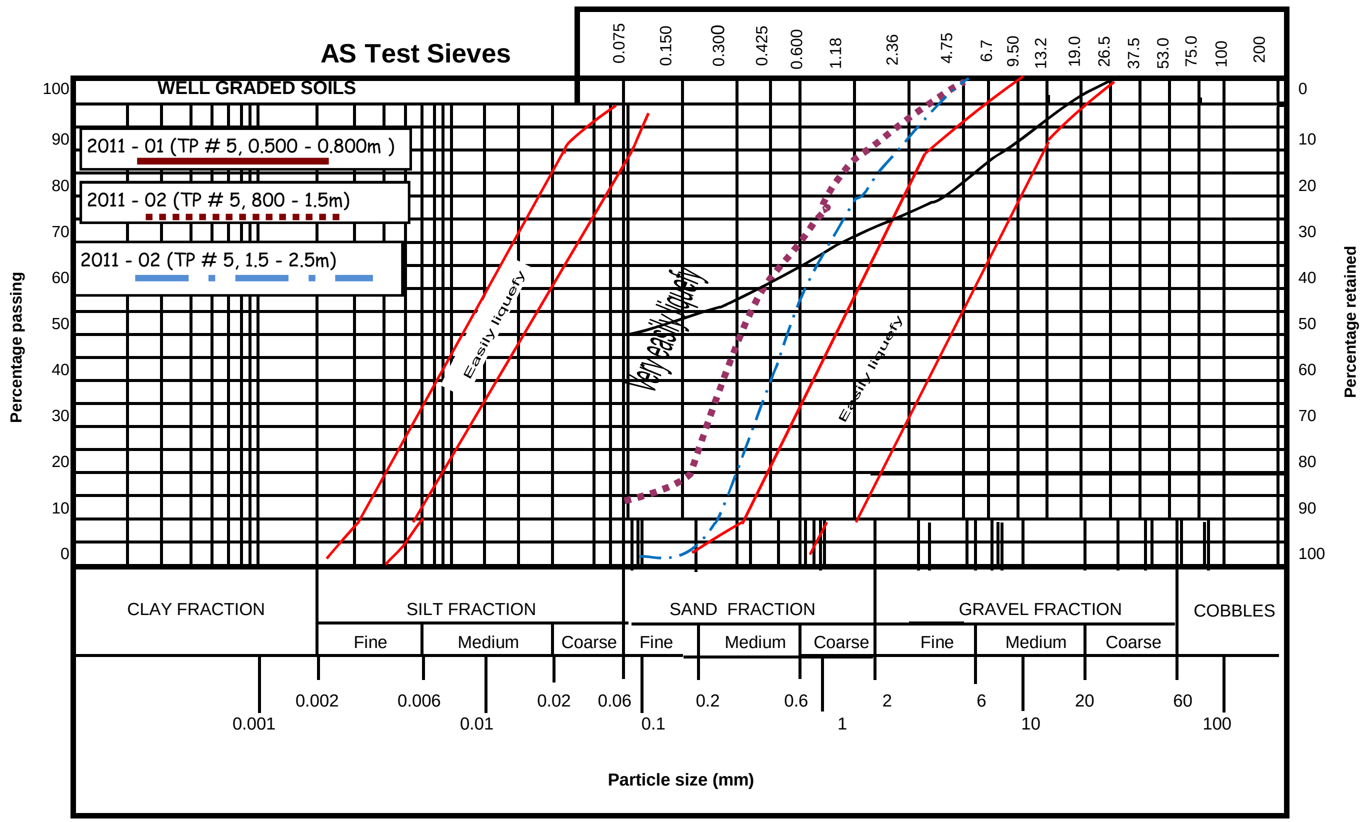


Figure 12 - GRADING CURVE FOR SAMPLES FROM TEST PIT # 5

Project: Port Moresby Sewerage System Upgrading

Location: Lawes Road (Ela Beach Round about) # 6 - Port Moresby **Job No:** NGTS01011

Client: njs - JICA **Date:** April, 2011

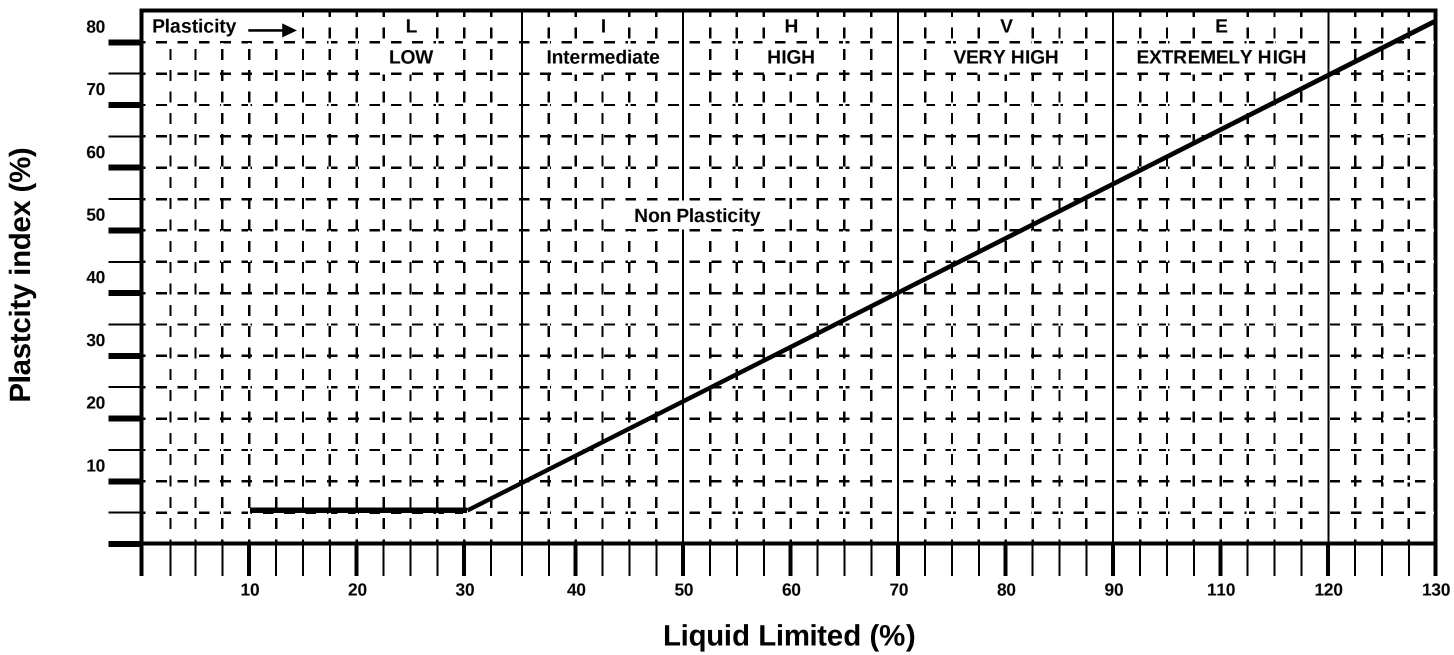


Figure 13. CASAGRANDE PLOT FOR SUBSOIL MATERIAL FROM TEST PIT # 6

Project: Port Moresby Sewerage System Upgrading
Location: Lawes Road # 6 - Port Moresby, NCD
Client: njs - JICA

Job: NGTS01011
Date: March 2011

PARTICLE SIZE DISTRIBUTION & LIQUEFACTION POTENTIAL

Client: njs - JICA	**Project number:** NGTS01011
Project: Port Moresby Sewerage System Upgrading	**Location: Lawes Road** # 6, Port Moresby - NCD

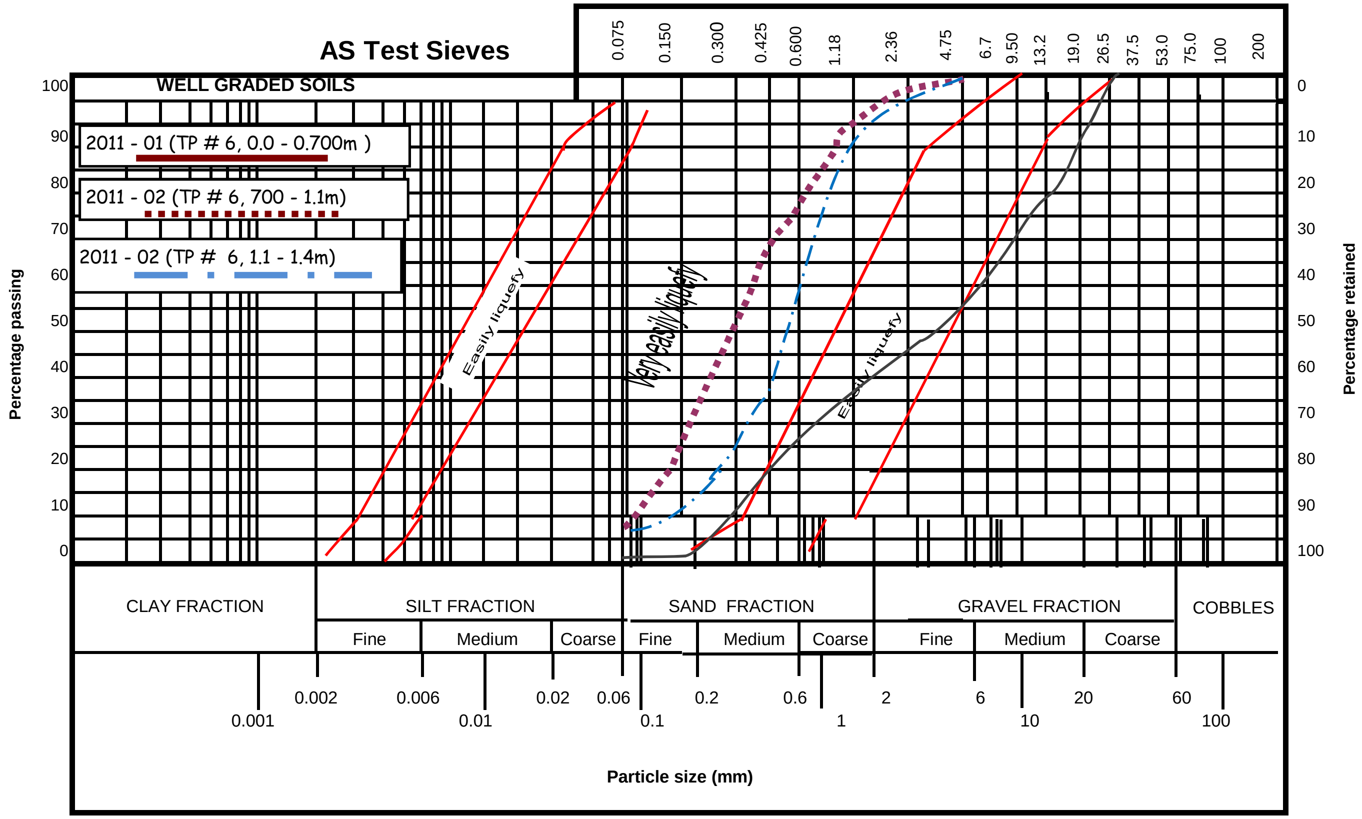


Figure 14 - GRADING CURVE FOR SAMPLES FROM TEST PIT # 6

NGTS

Project: Port Moresby Sewerage System Upgrading

Location: Kila Police Rep Pump Station # 7 - Port Moresby **Job No:** NGTS01011

Client: njs - JICA **Date:** April, 2011

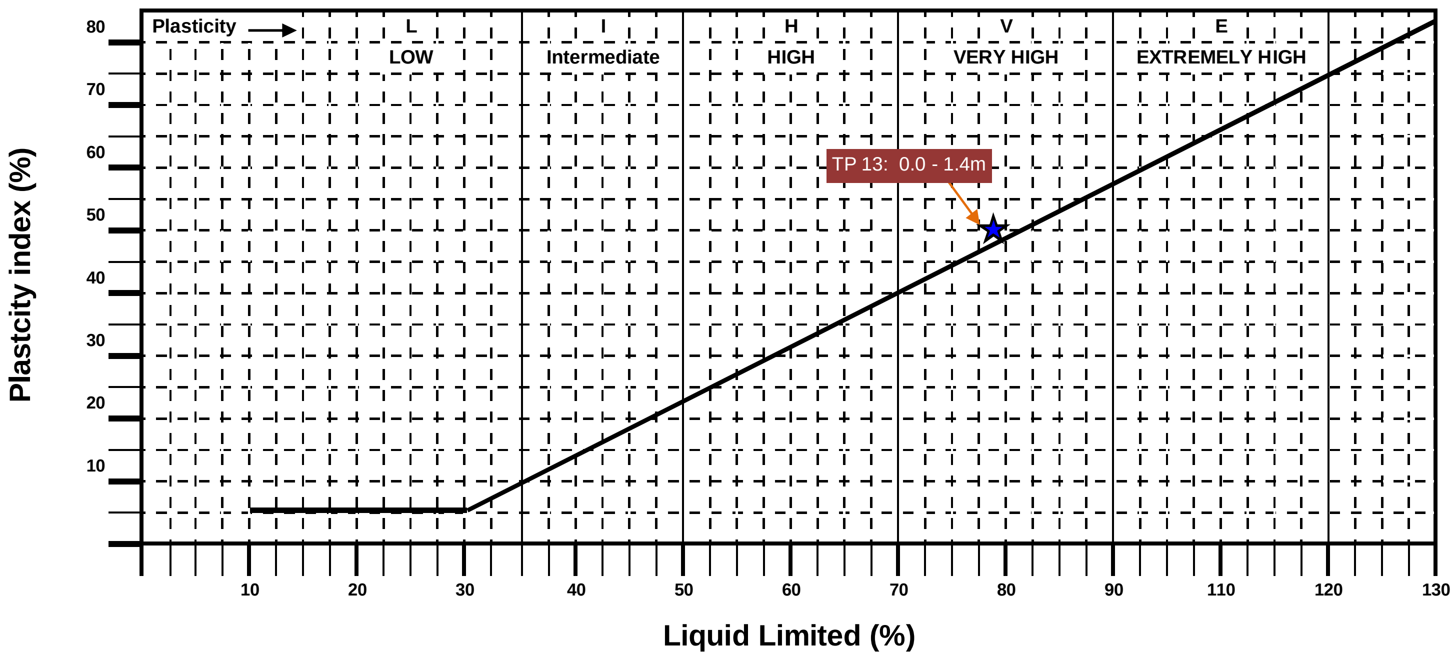


Figure 15. CASAGRANDE PLOT FOR SUBSOIL MATERIAL FROM TEST PIT # 7