MILLET INTAKE

FINAL GEOTECHNICAL REPORT

ST. LUCIA

AMARNA

CONSULT • DESIGN • BUILD

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Executive Summary

R.J. Burnside engaged Amarna Consult Ltd to conduct a geological survey for the Millet Intake Project on behalf of the Water and Sewage Authority. This report deals with foundation parameters for proposed structures as well as geotechnical parameters for a proposed new pipeline and associated infrastructure. The purpose of the study was to confirm geological conditions and determine the geotechnical properties of the soil to inform the design of the proposed infrastructure. This report presents key design parameters and foundations options based on results from field exploration, laboratory testing and review of other relevant literature.

The recommendations coming out of the investigation for the various sites are as follows:

	Geotechnical Recommendation
T-Junction (0+00)	Shallow Mat foundation on weathered rock at 2.1m depth
Intake Site (2+300)	Shallow foundation base tying into existing structures
Pipeline Route	Soil has very low shear strength and highly unstable slopes. Consider relocation of route to minimize steep slopes.

Table 1 showing Design summary

1. Site Characteristics

1.1. Location and Topography

The Millet intake is located near the center of St. Lucia approximately 2.3km West South west of the John Compton Dam. The Millet Intake is a small Dam-like structure consisting of stone masonry within the Millet River at an elevation of 188.5m above sea level. The structure was compromised after the passage of Tropical Storms and Hurricanes within the last fifteen years. The existing pipeline carries water down from the intake by gravity to a T-junction at elevation 110m above sea level. The proposed pipeline route traverses land with very steep terrain with several water crossings.

***Figure 1:** Map location of Millet Intake & Pipe Route*

- Proposed New Pipe Route

- Millet River

1.1. Geology & Soil Type

The site of the Millet Intake and proposed pipe route consists of surficial deposits of residual soil which range in depth from 0.2m to 10m. The shallowest deposits occur within the Millet River channel with gravelly sands and transition to silty sands and clayey sands away from the river. Beneath the residual soil lies highly weathered rock of andesite origin on the northern half of the pipe route and pumice flow deposits on the southern half. The figures below illustrate the general geology map of St. Lucia overlain with the project site.

Figure 2: *Excerpt from Dominica Geological Map showing section 2*

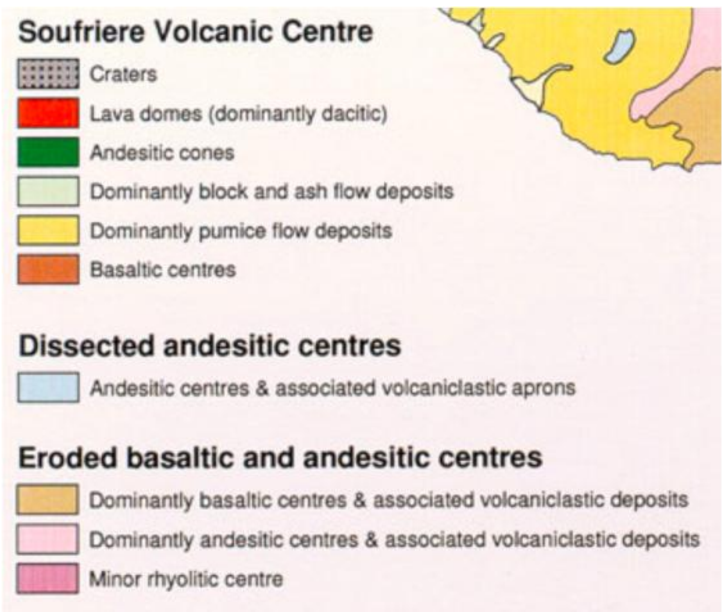


Figure 3: *Excerpt from St.Lucia Geology Map showing Legend*

2. Field and Laboratory Investigation

2.1. Test Pits

One Test pits was dug using a mini-excavator near the point 0+00 (T-Junction) along the pipe route. The operator excavated until the bucket hit a refusal zone where no further excavation was possible due to the hardness of the material. Bulk Samples were collected from material retrieved in the test pit and these were transported to the soils laboratory. Initially, the intent was to continue using the excavator along the pipe route but this could not done due to constraints from landowners not wanting their land to be damaged. Therefore only the one test pit was dug using a backhoe.

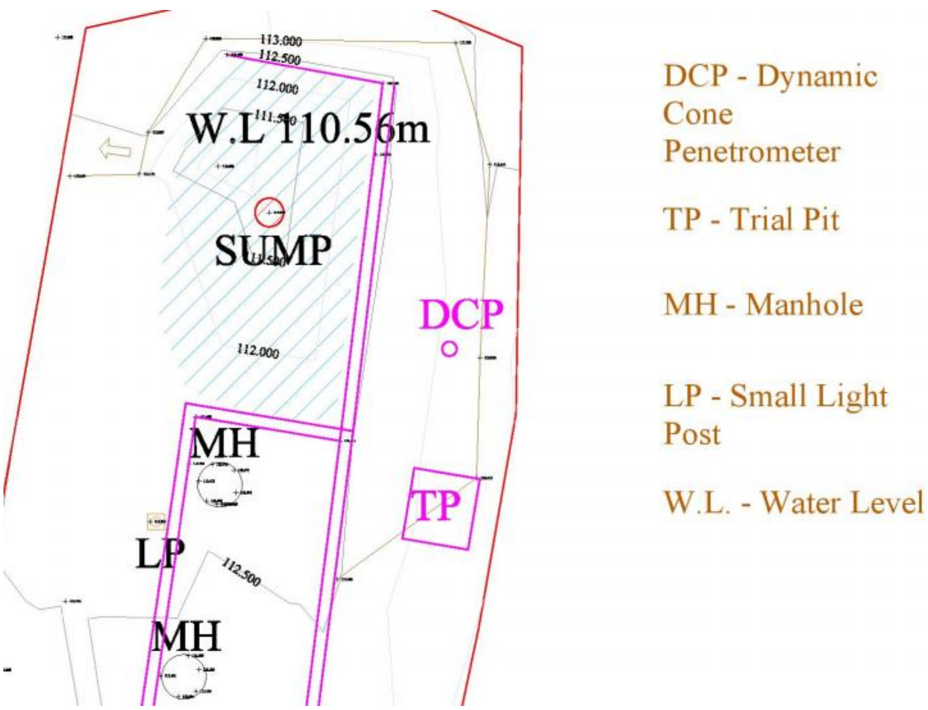


Figure 4: *Location of test pit near 0+00*

2.2. Manual Sampling

At the existing Millet Intake structure, manual excavation into the riverbed material was performed both due to the constraints of mechanical machinery not being allowed and due to the shallow depth of the soil. A shovel was used to extract material at three locations upstream of the existing structure. In addition to soil sampling, a geological hammer test was performed on exposed rock on each of the river banks to estimate the rock strength and degree of weathering.

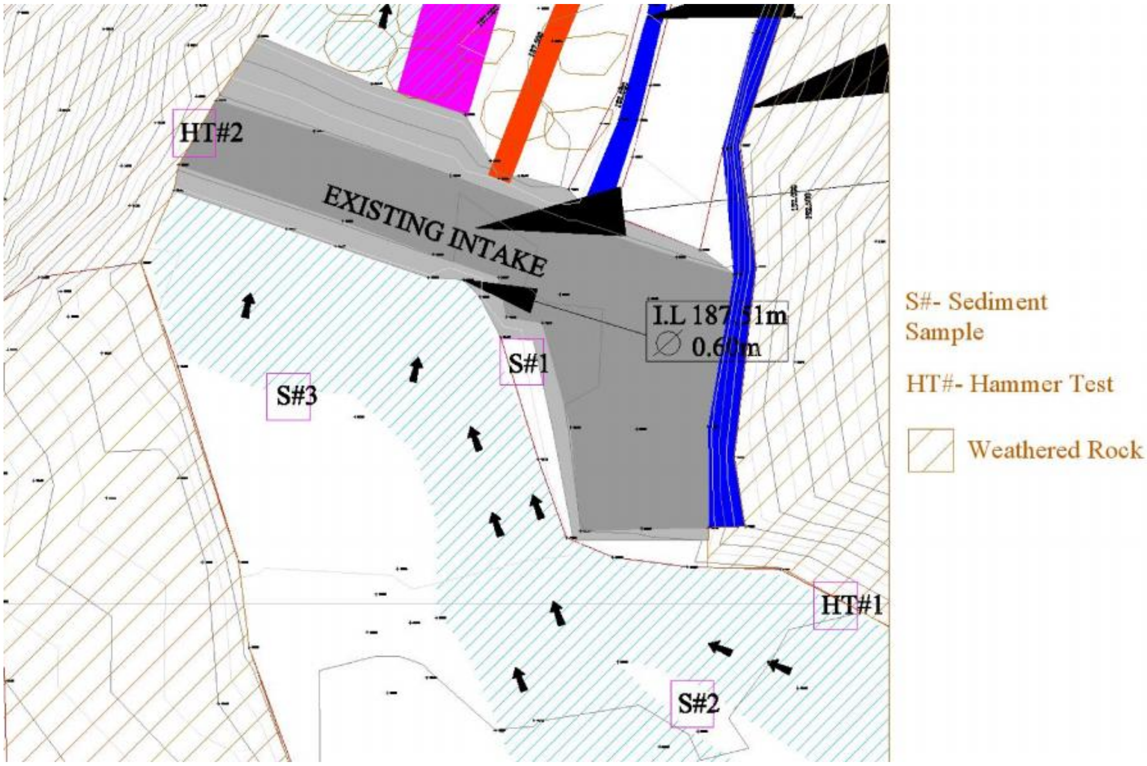


Figure 5: *Location of soil samples and hammer tests*

Along the proposed pipe route, a manual auger was used to collect both disturbed and undisturbed soil samples at selected points along the route. The soil collected was sent to the laboratory for testing.

2.3. Dynamic Cone Penetrometer Tests

Along the pipe route, dynamic cone penetrometer (DCP) tests were performed at approximately 100m intervals starting from the T-Junction (0+00) where the terrain permitted. In some cases it was not possible to conduct the test at the proposed intervals to steepness of the slopes in which case the location was moved. The dynamic penetrometer gives an estimate of the level of density of the soil which can be correlated to California Bearing Ratio values or bearing capacity. The test can be performed to a maximum depth of 1m which is sufficient for design of shallow infrastructure such as roads and pipe anchor blocks. The figure below shows the locations of the DCP tests.

Figure 6: *Location of soil samples and hammer tests*

2.4. Laboratory Testing

Subsequent to the field exploration and test pit excavation, the geotechnical engineer selected several samples to be sent to the soils laboratory for testing. The following tests were performed on selected samples.

- Natural Moisture Content
- Atterberg Limits
- Particle Size Distribution (Sieve Analysis)
- Specific Gravity
- Direct Shear (Undisturbed Samples)

2.5. Field Observations

2.5.1. T-Junction (0+00)

One trial pit was dug about 1.5m to the East of the existing WASCO concrete structure which encloses the T connection between the Millet Intake pipe and the John Compton Dam pipe. The trial pit achieved maximum depth of 2.5m. The soil profile observed was as follows:

Layer 1: From surface to 0.5m, the soil consisted of Brown Loose Silty Sand which appeared to be colluvium material or landslide debris from the nearby hills.

Layer 2: From 0.5m to 2.1m, the soil consisted of Grey Loose Silty Sand which also appeared to be colluvium material. Based on laboratory testing, the fines content was 47% and the plasticity index was 27.

Layer 3: From 2.1m, moderately weathered rock probably of andesitic origin was observed. The bucket of the mini-excavator was able to break the rock and the pit was ended at 2.5m. Water was observed in the hole at 2.1m. A field hammer test was conducted on a rock sample and the rock was subsequently classified as moderately weathered according to classification guidelines by Moye & Hosking (1990). The ultimate bearing strength is estimated at 0.9MPa (20ksf) according to AASHTO table C10.6.2.6.1-1.

2.5.2. Existing Intake site (2+300)

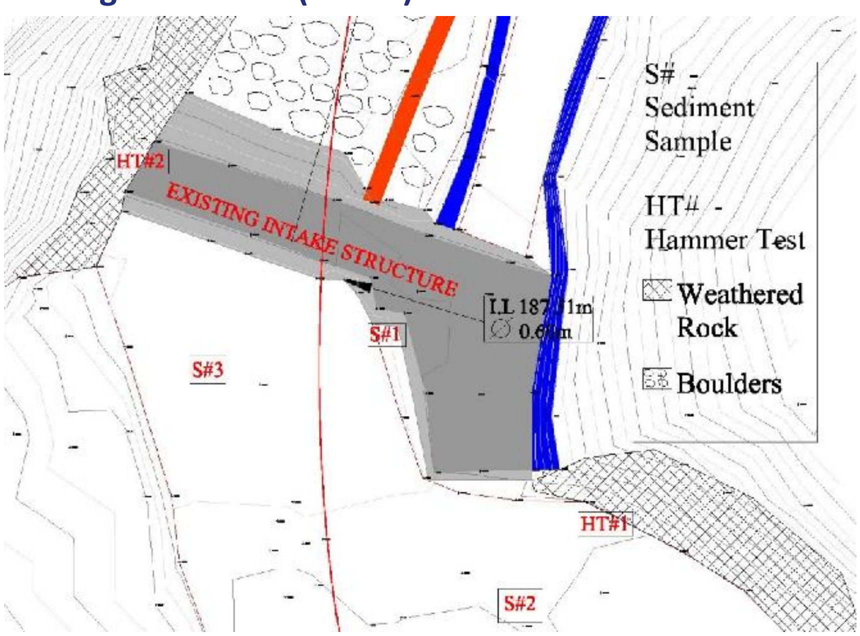


Figure 7: *Observations at Intake Site*

The figure above illustrates the layout of the existing intake structure. The banks of the river in that location are very steep and consist of weathered rock outcrops. Based on field observations and hammer tests, the exposed rock can be classified as highly weathered as the rock is highly discoloured and can be broken by hand but does not readily disintegrate with water. Downstream of the intake, the rock outcrops appear to be less weathered and would be classified as moderately weathered.

2.5.3. Proposed Pipeline Route

The ground conditions along the pipeline route were predominantly soft clayey sands and Silt of varying depths ranging from 1m to 7m from observed excavation cuts. Where river crossings occurred, the residual soil was very thin within the channel and got thicker moving away from the banks. The river channels also had more gravel based deposits and there were signs of exposed outcrops of soft highly weathered rock. The slopes along some of the banks of river crossings were as steep as 120% and seemed to be kept stable only by roots of vegetation.

2.5.4. Summary of Laboratory Results

		Pt.1	Pt.2	Pt. 8	Pt. 15	Pt. 18	Pt. 19	Pt. 20	Intake #1	Intake #2	Intake #3	T-Junction
Sample Depth /m		1	0.6	1	1	1	1	0.2	0.3	0.3	0.3	0.5
Natural Moisture Content (%)		26.6	55.3	55.1	46	51.8		41.9	32.7	28.8	34.5	63.7
Atterberg Limits	PL	NP	52	44	37	47		NP	NP	NP	NP	37
	LL	NV	72	74	67	98		NV	NV	NV	NV	64
	P.I.	NP	20	30	30	51		NP	NP	NP	NP	27
Particle Size Distribution	% Gravel	15	0	5	11	7		21	19	41	7	15
	% Sand	39	8	24	40	48		75	80	41	83	34
	%passing #200 (fines)	3	92	71	49	45		4	1	1	1	47
	D50	10.7837			0.1139	0.0958		1.4507	1.2857	6.7866	0.6021	0.1062
	Uniformity, Cu	70.32						12.86	6.19	19.32	3.35	
Specific Gravity		2.55		1.85		1.84						
Classification (USC)		GP	MH	MH	SM	SM		SP	SP		SP	SM
Direct Shear Test	Friction Angle (Deg.)				11	16	11					
	Cohesion (KPa)				2.18	3.33	2.68					
	Bulk Unit Weight (KN/m3)				13.7	13	13.6					

N.P. – Non Plastic **N.V.** – No Value **N.A.** – Not Available **SP-SM** – Poorly Graded Sand with silt **SM** – Silty Sand **SP**-Poorly Graded Sand **MH**- Elastic Silt **SW-SM** – Well Graded Sand with silt **CH** – Fat Clay **ML** – Silt **GP**- Poorly Graded Gravel **CL**- Lean Clay **GW-GM**- well graded gravel with silt

Table 2 showing summary of laboratory results

2.5.5. DCP Results

Location: Point 1 (0+131)		**Hammer Weight**: 8kg		**Soil Type**:Poorly Graded Gravel (GP)		**Moisture** (%):26
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	380					
5	530	150	30	30	6.5	3
5	700	170	34	34	5.6	2.7
5	920	220	44	44	4.2	2.1

Location: Point 2 (0+381)		**Hammer Weight**: 8kg		**Soil Type**: Elastic Silt (MH)		**Moisture** (%):55
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		Note:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	0					
5	460	460	92	92	1.8	1
5	595	135	27	27	7.3	3
5	640	45	9	9	24.9	10
5	745	105	21	21	9.6	4
5	960	215	43	43	4.3	2

Location: Point 3 (0+563)		**Hammer Weight**: 8kg		**Soil Type**: Road Base; Silty clay		**Moisture** (%):
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**: Existing Road
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	220					
5	300	80	16	16	13.1	6
5	325	25	5	5	48.1	18
5	365	40	8	8	28.4	11
5	385	20	4	4	61.8	23

5	430	45	9	9	24.9	10
5	500	70	14	14	15.2	7
5	590	90	18	18	11.5	5
5	685	95	19	19	10.8	5
5	785	100	20	20	10.2	5
5	890	105	21	21	9.6	4

Location: Point 4 (0+703)		**Hammer Weight**: 8kg		**Soil Type**: Clayey Sand		**Moisture** (%):
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**: Bank of ravine
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	290					
5	590	300	60	60	3	2
5	720	130	26	26	7.6	4
5	785	65	13	13	16.5	7
5	840	55	11	11	19.9	8
5	875	35	7	7	33	13

Location: Point 5 (0+850)		**Hammer Weight**: 8kg		**Soil Type**: Clayey Sand		**Moisture** (%):
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	255					
5	625	370	74	74	2.4	1
5	705	80	16	16	13.1	6
5	785	80	16	16	13.1	6
5	890	105	21	21	9.6	4
3	960	70	23.3	23.3	8.6	4

Location: Point 6 (1+100)		**Hammer Weight**: 8kg		**Soil Type**: MH		**Moisture** (%):
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	310					
5	560	250	50	50	3.7	2
5	860	300	60	60	3	2
2	960	100	20	20	10.2	5

Location: Point 7 (1+190)		**Hammer Weight**: 8kg		**Soil Type**: Silty Sand		**Moisture** (%):
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	380					
5	615	235	47	47	3.9	2
5	745	130	26	26	7.6	4
5	860	115	23	23	8.7	4
2	925	65	13	13	16.5	7

Location: Point 8(1+290)		**Hammer Weight**: 8kg		**Soil Type**: MH		**Moisture** (%):55
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	235					
5	575	340	68	68	2.6	1
5	865	290	58	58	3.1	2
4	960	95	19	19	10.8	5

Location: Point 9 (1+500)		Hammer Weight: 8kg		Soil Type: MH		Moisture (%):
Weather: Sunny		Hammer Factor: 1		Cone Angle: 60 degrees		Note:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	320					
5	605	285	57	57	3.2	2
5	960	355	71	71	2.5	1

Location: Point 10(1+610)		Hammer Weight: 8kg		Soil Type: MH		Moisture (%):
Weather: Sunny		Hammer Factor: 1		Cone Angle: 60 degrees		Note:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	235					
5	575	340	68	68	2.6	1
5	865	290	58	58	3.1	2
4	960	95	23.75	23.75	8.4	4

Location: Point 11(1+680)		Hammer Weight: 8kg		Soil Type: SM		Moisture (%):
Weather: Sunny		Hammer Factor: 1		Cone Angle: 60 degrees		Note:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	240					
5	525	285	57	57	3.2	2
5	855	330	66	66	2.7	1
4	960	105	26.25	26.25	7.5	4

Location: Point 12(1+740)		Hammer Weight: 8kg		Soil Type: SM		Moisture (%):
Weather: Sunny		Hammer Factor: 1		Cone Angle: 60 degrees		Note:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)

0	240					
5	525	285	57	57	3.2	2
5	855	330	66	66	2.7	1
4	960	105	26.25	26.25	7.5	4

Location: Point 13(1+800)		**Hammer Weight**: 8kg		**Soil Type**: MH; Weathered Rock		**Moisture** (%):
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	525					
5	565	40	8	8	28.4	12
5	670	105	21	21	9.6	4
5	790	120	24	24	8.3	4
5	820	30	6	3	39.3	15
5	830	10	2	2	134.3	46

Location: Point 14(1+870)		**Hammer Weight**: 8kg		**Soil Type**: SM		**Moisture** (%):
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	420					
5	510	90	18	18	11.5	5
5	625	115	23	23	8.7	4
5	750	125	25	25	7.9	4
5	835	85	17	17	12.2	5
5	960	125	25	25	7.9	4

Location: Point 15(1+950)	**Hammer Weight**: 8kg	**Soil Type**: SM	**Moisture** (%):
Weather: Sunny	**Hammer Factor**: 1	**Cone Angle**: 60 degrees	**Note**:

Blows	Penetration Depth (mm)	Penetration bet. Readings (mm)	Penetration Rate (mm/blow)	DCP Index(mm/blow)	CBR (%)	SPT Correlation (Livneh and Ishai 1988)
0	310					
5	960	650	130	130	1.3	1

Location: Point 16(2+000)		**Hammer Weight**: 8kg		**Soil Type**: SM		**Moisture** (%):
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	295					
5	785	490	98	98	1.7	1
2	960	175	87.5	87.5	2	1

Location: Point 17(2+050)		**Hammer Weight**: 8kg		**Soil Type**: SM		**Moisture** (%):
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	320					
5	725	405	81	81	2.1	1
2	960	235	117.5	117.5	1.4	1

Location: Point 18 (2+110)		**Hammer Weight**: 8kg		**Soil Type**: SM		**Moisture** (%): 52
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	425					
5	960	535	107	107	1.6	1

Location: Point 19 (2+160)		**Hammer Weight**: 8kg		**Soil Type**: SM		**Moisture** (%):
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	345					
5	715	370	74	74	2.4	1
5	960	245	49	49	3.7	2

Location: Point 20 (2+200)		**Hammer Weight**: 8kg		**Soil Type**: SP		**Moisture** (%):
Weather: Sunny		**Hammer Factor**: 1		**Cone Angle**: 60 degrees		**Note**:
Blows	**Penetration Depth (mm)**	**Penetration bet. Readings (mm)**	**Penetration Rate (mm/blow)**	**DCP Index(mm/blow)**	**CBR (%)**	**SPT Correlation** (Livneh and Ishai 1988)
0	310					
5	670	360	72	72	2.4	1
5	960	290	58	58	3.1	2

***Table 3** showing DCP results*

3. Analysis

3.1. Seismicity

Monitoring of seismic activity in the Eastern Caribbean islands falls under the jurisdiction of the UWI Seismic Research Unit. Today, there are seismic hazard maps established for the Eastern Caribbean based on peak ground acceleration (pga), 0.2second and 1 second acceleration as illustrated in the map below.

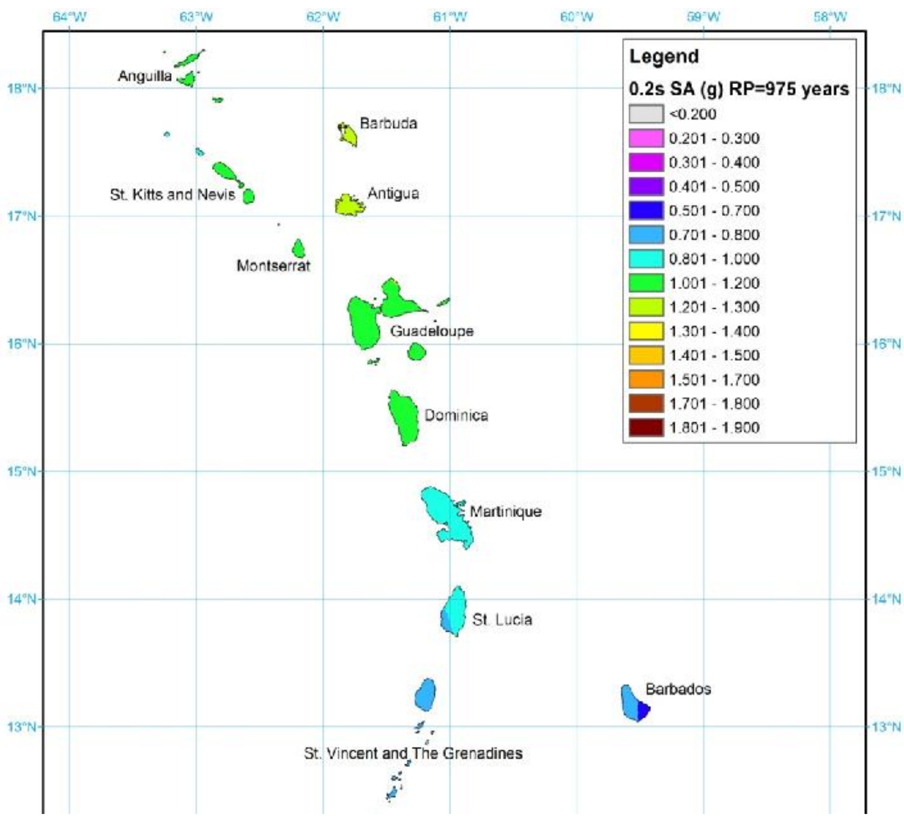


***Figure 8**: Seismic Hazard Map for 0.2s Acceleration and return period of 975 years*

(PGA) RP=95 year	(PGA) RP= 475 year	(PGA) RP= 975 year	(PGA) RP= 2475 year	1s SA RP=95	1s SA RP= 475	1s SA RP= 975	1s SA RP= 2475	0.2s SA RP=95	0.2s SA RP= 475	0.2s SA RP= 975	0.2s SA RP= 2475
0.101-0.150 (g)	0.201-0.250 (g)	0.301-0.350 (g)	0.451-0.500 (g)	0.051-0.100 (g)	0.151-0.200 (g)	0.301-0.350 (g)	0.351-0.400 (g)	0.201-0.300 (g)	0.501-0.700 (g)	0.801-1.00 (g)	0.101-0.150 (g)

***Table 4**: Seismic Spectral Acceleration for St. Lucia*

3.2. Liquefaction Potential

Saturated loose sands and some gravels tend to decrease in volume when subjected to ground vibrations as with earthquakes. When drainage is not possible, this decrease results in an increase in pore pressure in the soil until the pore pressure equalises the overburden pressure resulting in a complete loss of strength. This is referred to as liquefaction. The potential for liquefaction is based soil type, relative density, earthquake intensity and earthquake duration. The figure below illustrates the range of grain size curves for soils susceptible to liquefaction.

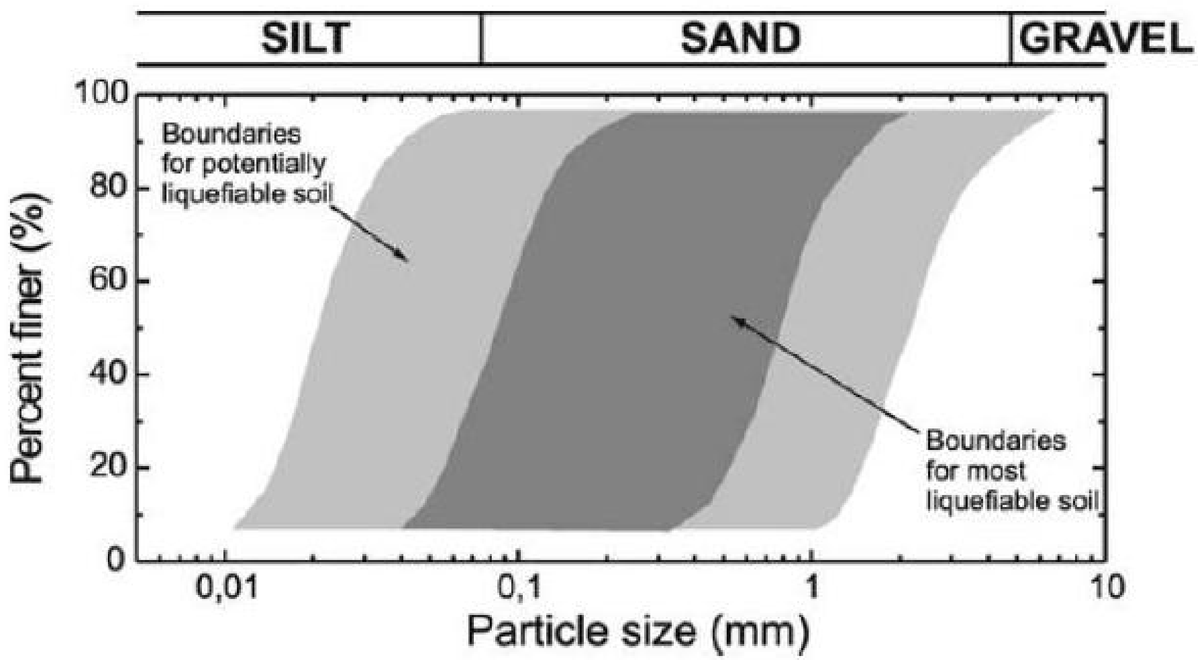


***Figure 9**: Grain Size of liquefiable soil (Tsuchida 1970)*

Although St. Lucia sits within an active seismic zone, none of the sites examined exhibited soils which fit the criteria for high liquefaction risk. As illustrated in the figure above, the highest risk of liquefaction occurs with clean uniformly graded sands. None of the soils examined either by visual inspection or laboratory testing could be considered uniformly graded sands. Considering those soil type factors, no further liquefaction analysis was necessary.

3.3. Dynamic Soil Response

The intensity of ground shaking and the associated damage to structures are influenced by local soil conditions. The site conditions influence ground motion by the soil acting as a filter for the seismic waves, amplification of ground motion and duration of motion. A medium stiff sand will generate a reduced surface acceleration after transmitting a wave from the initial seismic source as opposed to a stiffer soil and deeper soil which would increase the surface acceleration. The soil conditions influence structural response in that a structure with a similar frequency to the soil that supports it will promote amplification of the shear waves from an earthquake. Therefore a stiff structure which is founded on a stiff soil may produce undesirable amplification effects.

The range of travel speed for P (compression) and S (shear) waves for various soil types is given in the table below:

Medium	P-Wave Velocity (ft/s)	S wave velocity (ft/s)
Water	5,000	0
Soft Clay	1,600-2,400	250 -500
Medium Sand	3,000 – 4,500	800 -1,200
Dense Sand	4,500 – 6,000	1,200 – 1,800
Soft Rock	8000+	2,500+
Hard Rock	18,000+	12,000+

***Table 5**. Source: M.Aggour, ENCE 743 Class Notes, University of Maryland, 2009*

Chapter 7 of ASCE-07 Minimum Design Loads for Buildings and Structures describes the process of evaluating the seismic design criteria for structures. The impact of geological characteristics of the site is captured by determination of the site class and mapped acceleration parameters.

3.3.1. Site Class Determination

Site class may be determined according to ASCE-07 20.4.2 by shear wave velocity, Standard penetration Resistance or Undrained Shear strength. The soil properties are evaluated for the top 30m (100ft) and the average conditions estimated. In the absence of SPT values the following table can be used to guide site class.

Site Class	$\bar{v}_s$	$\bar{N}$ or $\bar{N}_{ch}$	$\bar{s}_u$
A. Hard rock	>5,000 ft/s	NA	NA
B. Rock	2,500 to 5,000 ft/s	NA	NA
C. Very dense soil and soft rock	1,200 to 2,500 ft/s	>50	>2,000 psf
D. Stiff soil	600 to 1,200 ft/s	15 to 50	1,000 to 2,000 psf
E. Soft clay soil	<600 ft/s	<15	<1,000 psf
	Any profile with more than 10 ft of soil having the following characteristics: - Plasticity index PI > 20, - Moisture content $w \geq 40\%$, and - Undrained shear strength $\bar{s}_u$ < 500 psf		
F. Soils requiring site response analysis in accordance with Section 21.1	See Section 20.3.1		

For SI: 1 ft/s = 0.3048 m/s 1 lb/ft^2 = 0.0479 kN/m^2

***Table 6** showing site class criteria(ASCE-07)*

Based on the Engineer's assessment of the site the following site classes are to be used;

Location	**Observations**	**Recommended Site Class**
T-Junction	Weathered Rock observed at 2.1m	Site Class C if excavated to 2.1m.
New Intake Site	Weathered Rock at surface	Site Class C
Pipe Route	Soft Clayey soils dominant	Site Class E

***Table 7** showing recommended site class for Millet sites.*

4. Design Recommendations

4.1. T-Junction (0+00)

It is recommended that a shallow footing be used at a depth of 2.1m. No additional support measures are required.

4.1.1. Bearing Capacity

The bearing capacity of the soil bearing layer was determined using correlations to the field observations and taken from recommended values from the AASHTO table C10.6.2.6.1-1.

Type of Bearing Material	Consistency in Place	Bearing Resistance (ksf)	
		Ordinary Range	Recommended Value of Use
Massive crystalline igneous and metamorphic rock: granite, diorite, basalt, gneiss, thoroughly cemented conglomerate (sound condition allows minor cracks)	Very hard, sound rock	120–200	160
Foliated metamorphic rock: slate, schist (sound condition allows minor cracks)	Hard sound rock	60–80	70
Sedimentary rock: hard cemented shales, siltstone, sandstone, limestone without cavities	Hard sound rock	30–50	40
Weathered or broken bedrock of any kind, except highly argillaceous rock (shale)	Medium hard rock	16–24	20
Compaction shale or other highly argillaceous rock in sound condition	Medium hard rock	16–24	20
Well-graded mixture of fine- and coarse-grained soil: glacial till, hardpan, boulder clay (GW-GC, GC, SC)	Very dense	16–24	20
Gravel, gravel-sand mixture, boulder-gravel mixtures (GW, GP, SW, SP)	Very dense Medium dense to dense Loose	12–20 8–14 4–12	14 10 6
Coarse to medium sand, and with little gravel (SW, SP)	Very dense Medium dense to dense Loose	8–12 4–8 2–6	8 6 3
Fine to medium sand, silty or clayey medium to coarse sand (SW, SM, SC)	Very dense Medium dense to dense Loose	6–10 4–8 2–4	6 5 3
Fine sand, silty or clayey medium to fine sand (SP, SM, SC)	Very dense Medium dense to dense Loose	6–10 4–8 2–4	6 5 3
Homogeneous inorganic clay, sandy or silty clay (CL, CH)	Very dense Medium dense to dense Loose	6–12 2–6 1–2	8 4 1
Inorganic silt, sandy or clayey silt, varved silt-clay-fine sand (ML, MH)	Very stiff to hard Medium stiff to stiff Soft	4–8 2–6 1–2	6 3 1

***Table 8** showing presumptive bearing values for different soil/rock types*

Based on the table 8 above, we consider the weathered rock from the test pit which corresponds to a recommended value of 20Ksf (957 KPa). By applying the recommended factor of safety of 3 for bearing capacity, the allowable bearing pressure would be 319 KPa. It is likely that any settlement will be negligible.

4.2. Existing Intake site (2+300)

For the proposed intake site, as with the T-junction site, the bearing layer will be weathered rock and an allowable bearing capacity of 300KPa is recommended for a shallow foundation structure. Settlement is also likely to be negligible. Provisions should be made however to deal with potential scour of the foundation base. A shear key may be excavated into the rock along the full width of the proposed new intake structure which may also act as a cut-off trench.

Alternatively, the existing intake structure can be used as additional scour protection if the new structure is constructed on the downstream side of the existing structure.

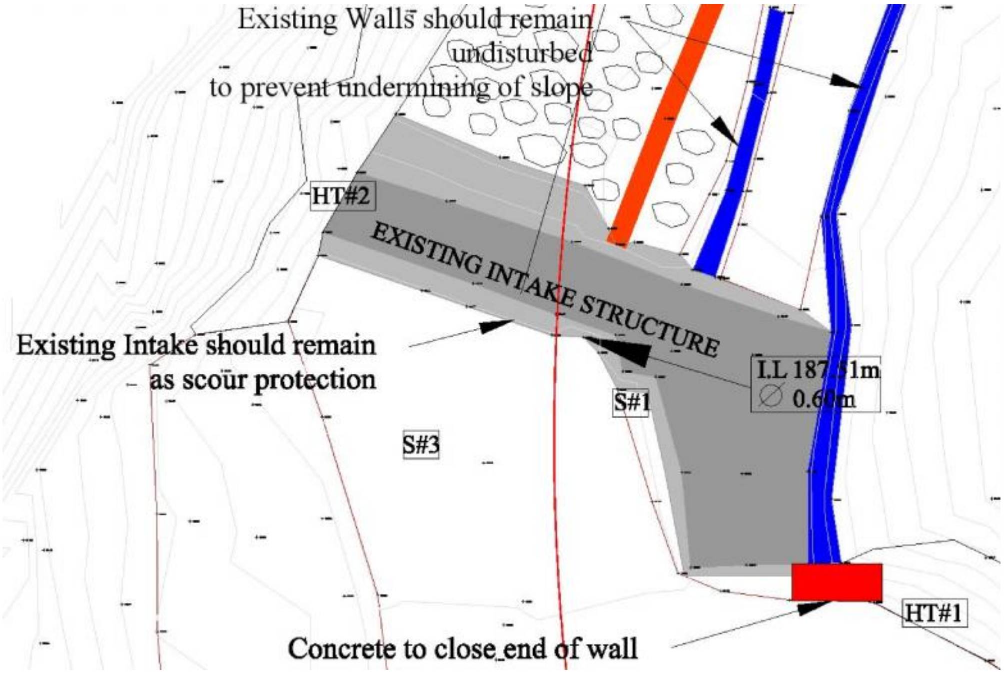


Figure 10 *showing recommendations for existing intake structure.*

The existing wall structures which protect the slope on the eastern bank should not be disturbed unless a new retaining structure is to be built. The end of the stone wall on the upstream end is susceptible to erosion and should be closed off with a concrete structure. For construction of new structure, any material or boulder which can be moved by an excavator should be removed prior to construction of the foundation. Dowels should also be considered through the existing weathered rock or large boulders to tie the new structure to the existing structure and base.

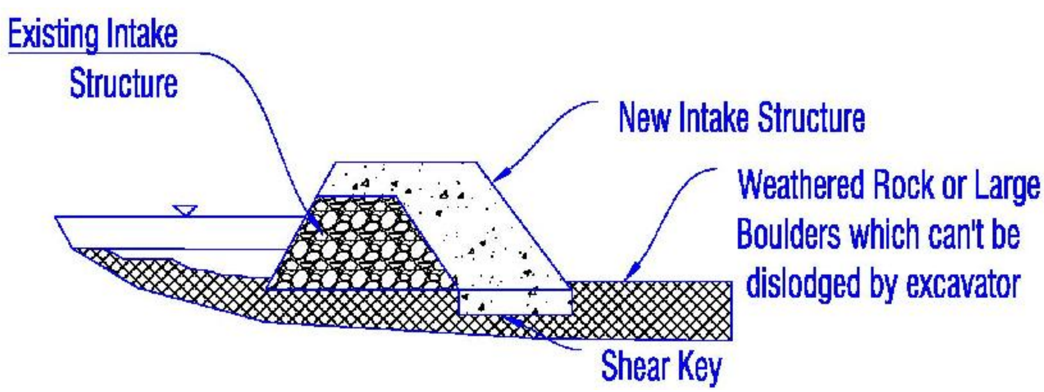


Figure 11 *showing section of proposed new intake structure integrated into existing*

4.3. Pipeline Route

The pipeline route proposed features significant changes in grade and several deep river crossings. The dominant soil types present were Elastic Silt (MH) and Silty Sand (SM). Based on the observation and the geology, the depth to weathered rock varies from 1m to 7m. The likely features to be designed for the pipeline route include trenching, pipe junction supports, access road pavements and associated retaining walls.

4.3.1. Trenching

Excavation of trenches will be relatively easy as the residual soil is very soft and can be easily worked by mechanical means. A typical trench for water pipes is shown below:

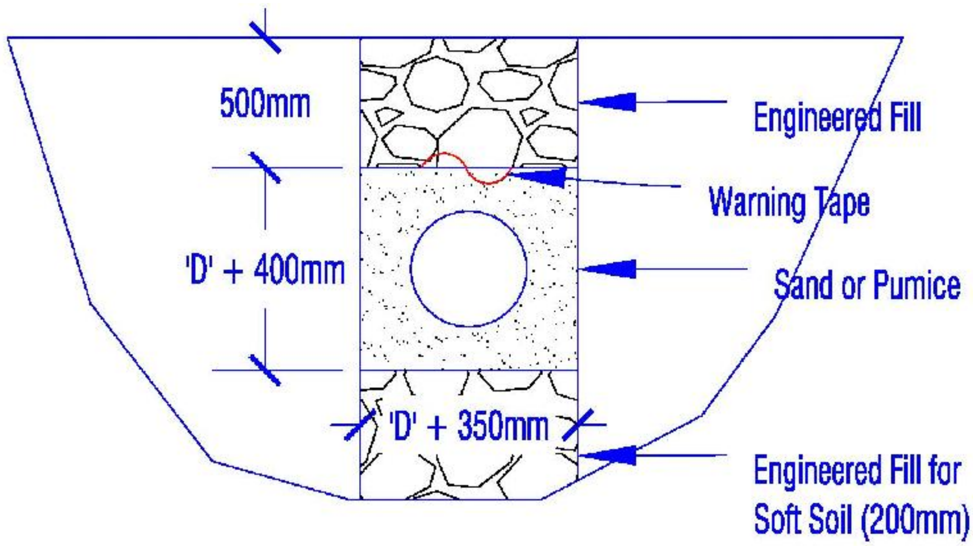


***Figure 12** showing typical pipeline trench*

Where soft clayey or silty soil is encountered at the bottom of the trench, a 200mm thick layer of compacted granular fill (95% Proctor) should be placed for improved bearing resistance.

4.3.2. Pipe Junction supports

In areas where the pipeline will have to be above ground du to topography, the pipe will be supported by blocks typically of concrete. Based on the results of the DCP tests, the SPT values were estimated for the residual soil using the table below.

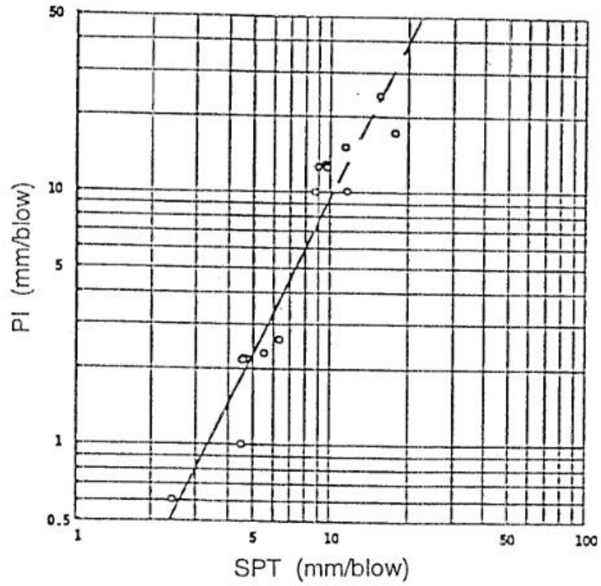


***Figure 13** showing correlation between DCP Penetration Index and SPT (Livneh & Ishai, 1988)*

The SPT values estimated along the pipeline route were generally in the range of 1-5 which represent a soft material with low bearing capacity. The few exceptions occurred where stones or rock fill was encountered within the soil.

It is therefore recommended that any block concrete supports are founded on a 250mm thick compacted granular fill layer and the depth of embedment should be no less than 900mm. The allowable bearing capacity recommended is 50KPa.

4.3.3. Road Pavement Design

For road pavement design, the key Parameter is the resilient modulus of the soil which is calculated from the CBR value by the equation: M_r (MPa)= 10.342xCBR.

Station	Ave. CBR (%)	Resilient Modulus (MPA)
0+131	5.4	55.85
0+381	9.58	99.1
0+563	23.36	242
0+703	16	166
0+850	9.36	97

1+100	5.6	58
1+190	9.18	94
1+290	5.5	57
1+500	2.85	30
1+610	4.7	49
1+680	4.5	47
1+740	4.5	47
1+800	43.98	455
1+870	9.64	100
1+950	1.3	13
2+000	1.85	19
2+050	1.75	18
2+110	1.6	17
2+160	3.1	32
2+200	2.75	28

***Table 9** showing calculated Resilient modulus values for the subgrade*

The results in the above table suggest a wide range of values for CBR for the sub-grade. It should be noted that some of the higher values may be influenced by individual coarse fragments being intercepted by the DCP cone. Such isolated high values may give an abnormally high reading. It should also be noted that the moisture conditions during the investigation would not have represented saturated conditions in the sub-grade during extreme rain events. It is therefore recommended that the design subgrade CBR for the proposed access road not exceed **5%** which is equivalent to a resilient modulus of 51.71 MPa for sections where weathered rock is not found during excavation. Where a road cut has exposed weathered rock, the design CBR can be taken as 20% or a resilient modulus of 207 Mpa.

4.3.4. Stability of Slopes

The slopes encountered along the proposed pipeline route range from as flat as 5% to as steep 120%. A significant portion of the route involves slopes greater 40%. This creates significant challenges for construction and long term stability of excavated cuts for access. The residual soil which occurs is of low shear strength as deduced from the laboratory results. The records from the DCP tests suggest that the SPT values generally range from 1-6. Based on the equation by Hara et al. (1971), the undrained shear strength on the higher end would be calculated as:

$C_u = 29\ (6)^{0.72} = 105$ KPa

This value is very low and is likely to result in significant active pressure and thus potentially unstable slopes.

Direct shear tests performed on three samples suggest the following average parameters for the residual soil:

Internal Friction Angle (degrees)	Cohesion (KPa)	Bulk Unit weight (KN/m3) @45% M.C.
13	2.73	13.4

Table 10

These parameters suggest that the slopes are not very stable and likely to be restrained mainly by the roots of existing vegetation. The soil also has a significant amount of organic content likely from those same roots which explains the low bulk unit weights.

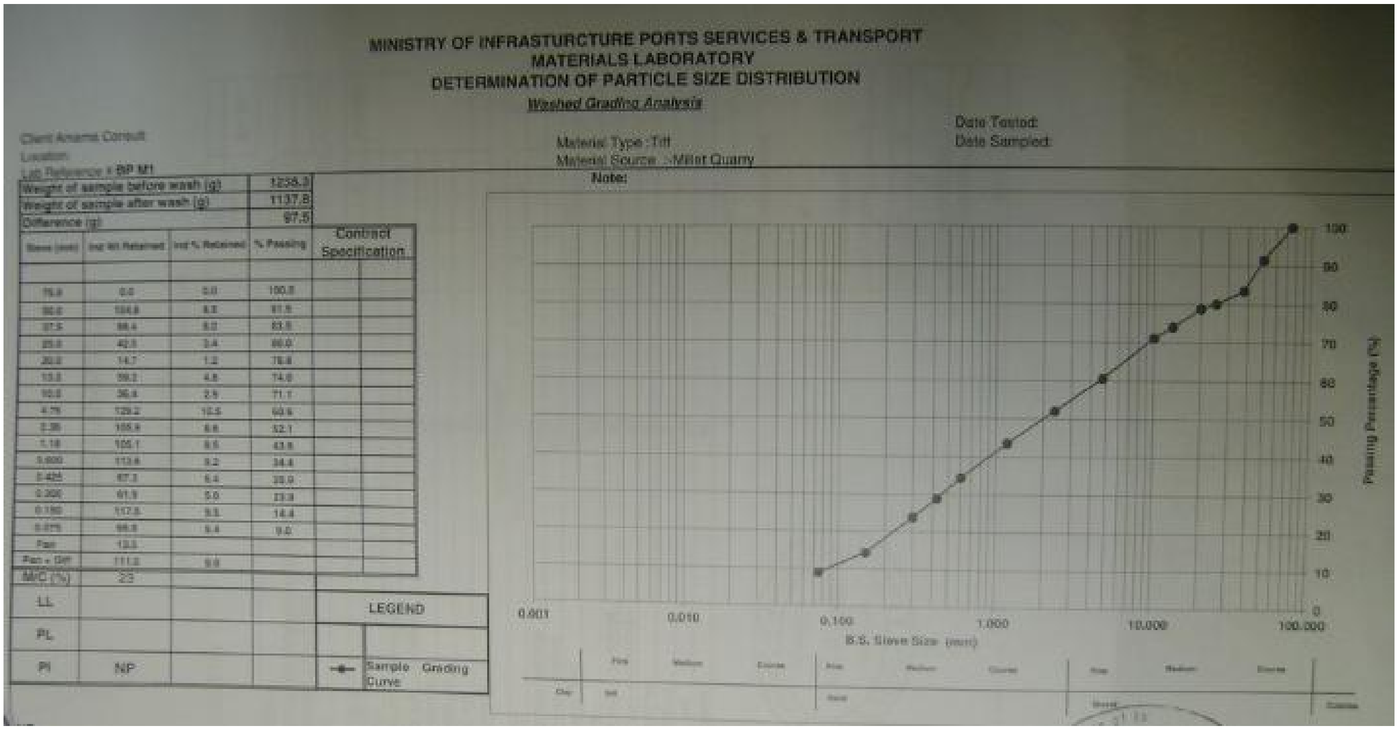
Any major excavation to allow for road access would likely require slope stabilisation measures and the low shear strength of the soil will result in uneconomical designs. It is therefore recommended that the proposed route be revisited to avoid steep slopes as much as possible thereby reducing the need for slope stabilisation measures.

5. Aggressiveness of Soil Conditions

Based on previous studies of the corrosive potential of the ground conditions, it was showed that the Millet Intake site to the T-junction along the existing pipeline route had conditions considered corrosive and in a few cases highly corrosive. The study used electrical resistivity measurements which ranged from 9.4 to 20 ohm/m. Protective measures such as coatings from the pipe manufacturers and the use of less corrosive materials in trenches such as washed sand or pumice can provide some mitigation of pipe corrosion. Concrete structures should de designed to include the appropriate cover to reinforcing bars under severe environments.

6. Borrow Pits

Borrow pits for importation of materials for road construction and trench backfilling are located relatively close to the proposed site. There is a quarry at Millet which is within a few kilometers of the site. Based on previous test results of their fill material, they provide fill which achieve CBR values in excess of 50 and have a well graded particle distribution.



MINISTRY OF INFRASTURCTURE PORTS SERVICES & TRANSPORT
MATERIALS LABORATORY
DETERMINATION OF PARTICLE SIZE DISTRIBUTION
Washed Grading Analysis

Client Amarna Consult
Location
Lab Reference = BP M1

Material Type : Tiff
Material Source :-Millet Quarry
Note:

Date Tested:
Date Sampled:

Weight of sample before wash (g)	1235.3
Weight of sample after wash (g)	1137.8
Difference (g)	97.5

Sieve (mm)	Ind Wt Retained	Ind % Retained	% Passing	Contract Specification	
75.0	0.0	0.0	100.0		
50.0	104.8	8.5	91.5		
37.5	98.4	8.0	83.5		
28.0	42.5	3.4	80.0		
20.0	14.7	1.2	78.8		
14.0	59.2	4.8	74.0		
10.0	36.4	2.9	71.1		
4.75	129.2	10.5	60.6		
2.36	105.9	8.6	52.1		
1.18	105.1	8.5	43.6		
0.600	113.6	9.2	34.4		
0.425	67.3	5.4	28.9		
0.300	61.5	5.0	23.9		
0.150	117.5	9.5	14.4		
0.075	66.8	5.4	9.0		
Pan	13.5				
Pan + Diff	111.0	9.0			
M/C (%)	23				
LL					
PL					
PI	NP				

Figure 14 *showing Sieve Analysis for Fill from Millet Quarry*

7. Limitations of Report

Geotechnical studies generate information on the soil properties only in the areas where samples are taken which are then extrapolated by the Geotechnical Engineer with applied judgment to give an opinion on the overall project site. Actual soil properties may vary in areas not sampled and therefore it is recommended that the Geotechnical Engineer be retained to examine any changes in observed subsurface materials during construction.

8. References

- AASHTO LRFD Bridge Design Specifications, 6th Edition, 2012
- Bowles, J.E. (1996). Foundation Analysis and Design, 5th Edition, Mc Graw Hill
- Coduto D.P. (1999). Geotechnical Engineering Principles and Practices, Prentice-Hall
- Das, B.M. (2004). Principles of Foundation Engineering, 5th Edition, Brooks/Cole
- Johnson D. & Burnham T. (1993). Insitu Foundation Characterization Using the Dynamic Cone Penetrometer, Minnesota Depatment of Transportation, 93-05
- Northmore K.J. et al (1992). Engineering Geology of Tropical Red Clay Soil. British Geological Survey
- Water and Sewage Authority Geophysical Survey of Potential Corrosion on the Millet Water System (1987). Wimpey Laboratories
- Water and Sewage Authority, Roseau Basin Water Development, Program Stage 1 (1988) ; Working Papers, WP23; Stanley Associates Engineering Ltd; Klohn Leonoff Ltd

9. Appendix

9.1. Photos

Photo 1: Test Pit Excavation at T-Junction

Photo2: Sample Collection at Existing Intake

Photo 3: Auger Sampling along piperoute

Photo 4:DCP Testing along Piperoute

Photo 5: Undisturbed Sampler

Photo 6: Undisturbed Sampler with Hammer

Photo 7: End of Existing Retaining Wall to be Protected.

Photo 8: Upstream of Existing Intake Structure

Photo 9: Downstream Existing Intake Structure

9.2. Test Pit Logs

TEST PIT LOG
Test Pit No.: T-Junction

PROJECT Millet Intake Geotechnical Survey	PROJECT NO.
CLIENT R.J. Burnside	DATE 20/12/2018
LOCATION WASCO T-Junction	ELEV. 110.56m
EXCAVATION METHOD Mini Excavator	LOGGER N. Jn Pierre

DEPTH TO - Water: 2.1m Caving: None

LATITUDE: 13.907175 LONGITUDE: -60.99752

ELEVATION/ DEPTH	USCS	DESCRIPTION	MOISTURE %	% Fines	% Sand	% Gravel
110.5 / 0	SM	Brown Loose Silty Sand w/some boulders. Colluvium				
110 / 0.5	SM	Grey Loose Clayey Sand w/some large boulders (>400mm).	63.7	47	34	
108.5 / 2		Moderately Weathered Rock				

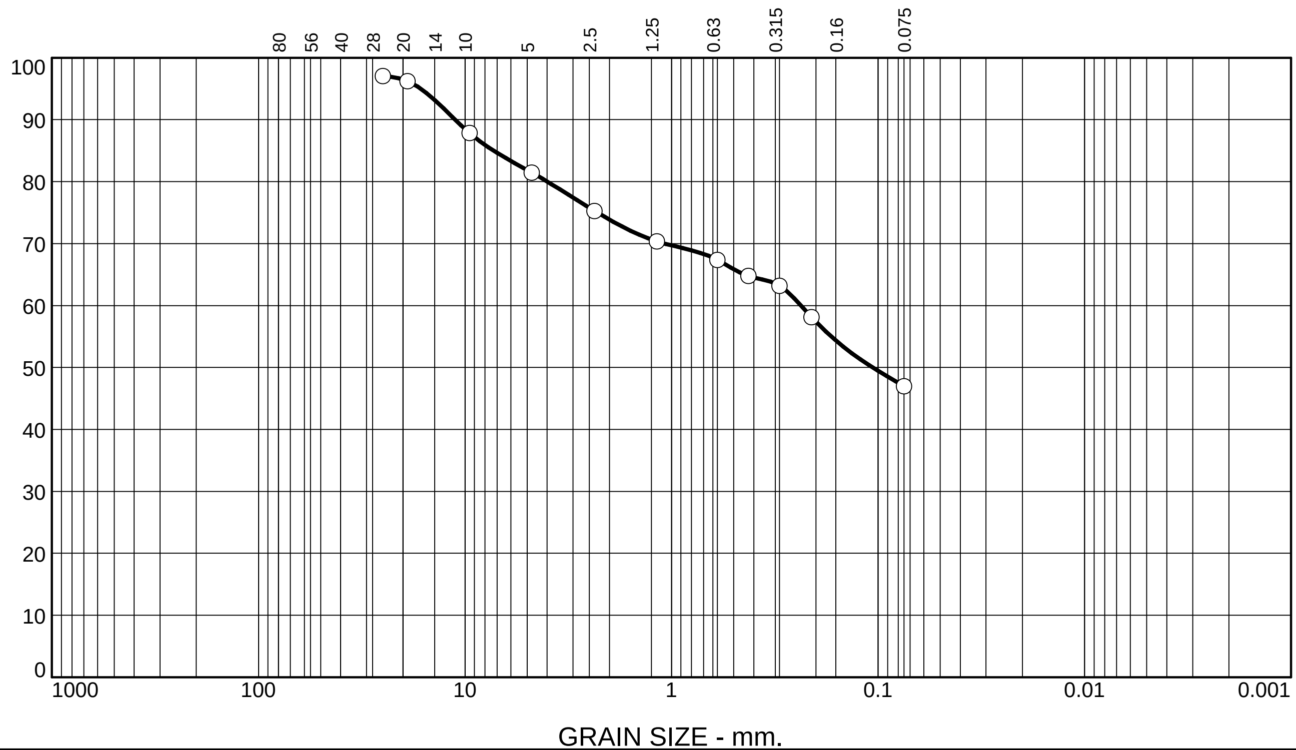
Elevation scale: 110.5, 110, 109.5, 109, 108.5, 108, 107.5, 107
Depth scale: 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5

Notes:

Amarna Consult Limited

9.3. Laboratory Results

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		15	7	9	18	47	

TEST RESULTS (ASTM D 422)			
Opening Size	**Percent Finer**	**Spec.* (Percent)**	**Pass? (X=Fail)**
25	97		
19	96		
9.5	88		
#4	81		
#8	75		
#16	70		
#30	67		
#40	65		
#50	63		
#70	58		
#200	47		

* (no specification provided)

Material Description

Grey Loose Clayey Sand w/some large boulders (>400mm).

Atterberg Limits (ASTM D 4318)

PL= 37 **LL=** 64 **PI=** 27

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-7-5(9)

Coefficients

D_{90}= 11.1626 D_{85}= 7.2710 D_{60}= 0.2361
D_{50}= 0.1062 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: 20/12/2018 **Date Tested:** 03/01/2019

Tested By: N. Jn Pierre

Checked By: M. Borges

Title:

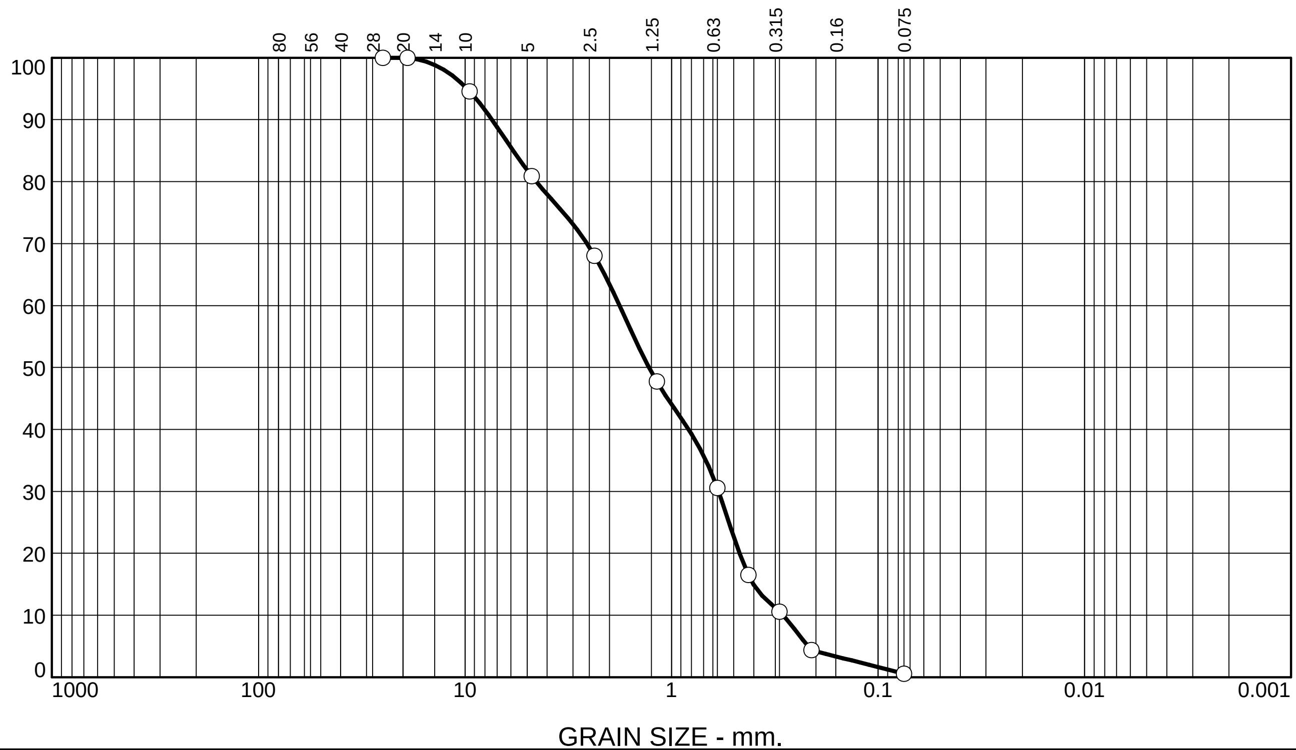
Source of Sample: T-Junction **Depth:** 0.5 **Date Sampled:** 20/12/2018

AMARNA

Castries, St. Lucia

Client: R.J. Burnside
Project: Millet Intake Geotechnical Survey
Project No: **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	19	18	47	15	1	

TEST RESULTS (ASTM D 422)			
Opening Size	**Percent Finer**	**Spec.* (Percent)**	**Pass? (X=Fail)**
25	100		
19	100		
9.5	95		
#4	81		
#8	68		
#16	48		
#30	31		
#40	16		
#50	11		
#70	4		
#200	0.6		

* (no specification provided)

Material Description

Light Brown Gravelly Sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= 7.4085 D_{85}= 5.8399 D_{60}= 1.7854
D_{50}= 1.2857 D_{30}= 0.5916 D_{15}= 0.4018
D_{10}= 0.2885 C_u= 6.19 C_c= 0.68

Remarks

Date Received: **Date Tested:** 21/12/2018

Tested By: N. Jn Pierre

Checked By: M. Borges

Title:

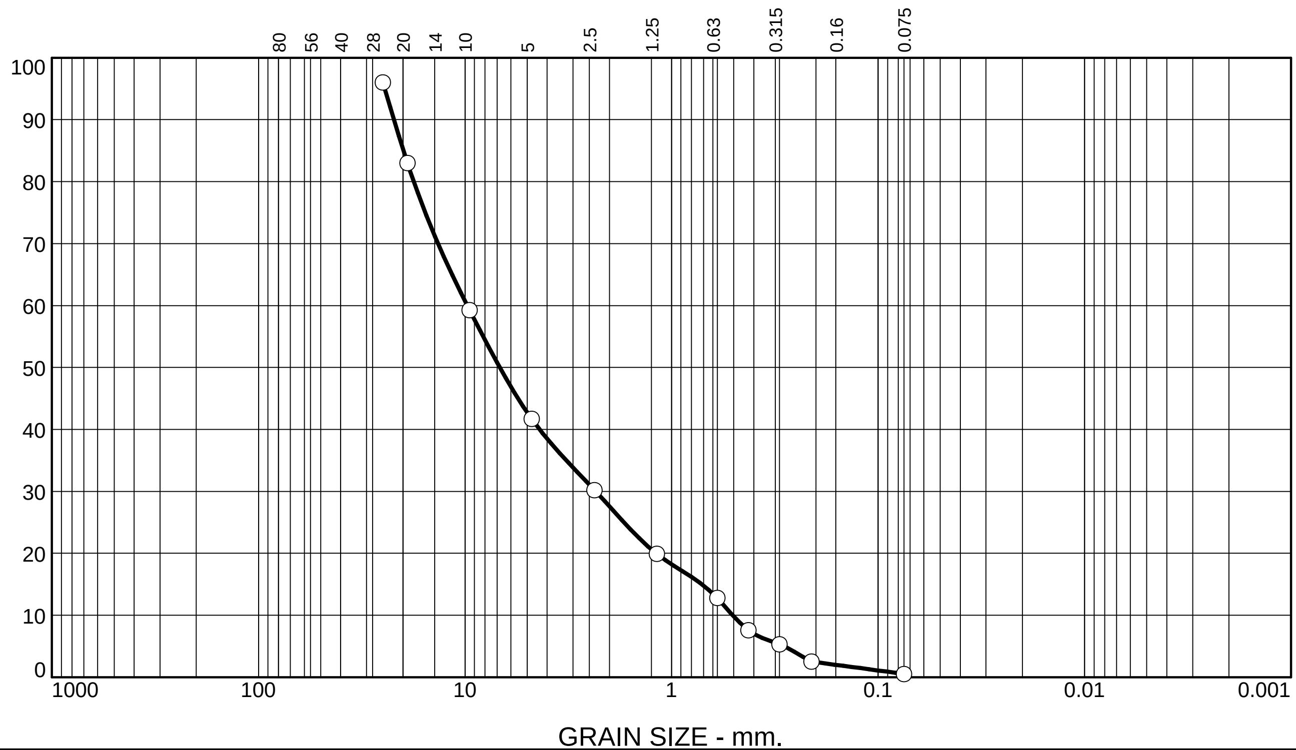
Source of Sample: Intake Pit 1 **Depth:** 0.3 **Date Sampled:** 20/12/2018

AMARNA

Castries, St. Lucia

Client: R.J. Burnside
Project: Millet Intake Geotechnical Survey
Project No: **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		41	14	20	7	1	

TEST RESULTS (ASTM D 422)			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
25	96		
19	83		
9.5	59		
#4	42		
#8	30		
#16	20		
#30	13		
#40	8		
#50	5		
#70	3		
#200	0.5		

* (no specification provided)

Material Description

Light Brown Gravelly Sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= GW **AASHTO (M 145)=** A-1-a

Coefficients

D_{90}= 22.1059 D_{85}= 19.8775 D_{60}= 9.7586
D_{50}= 6.7866 D_{30}= 2.3298 D_{15}= 0.7146
D_{10}= 0.5051 C_u= 19.32 C_c= 1.10

Remarks

Date Received: **Date Tested:** 21/12/2018

Tested By: N. Jn Pierre

Checked By: M. Borges

Title:

Source of Sample: Intake Pit 2 **Depth:** 0.3 **Date Sampled:** 20/12/2018

AMARNA

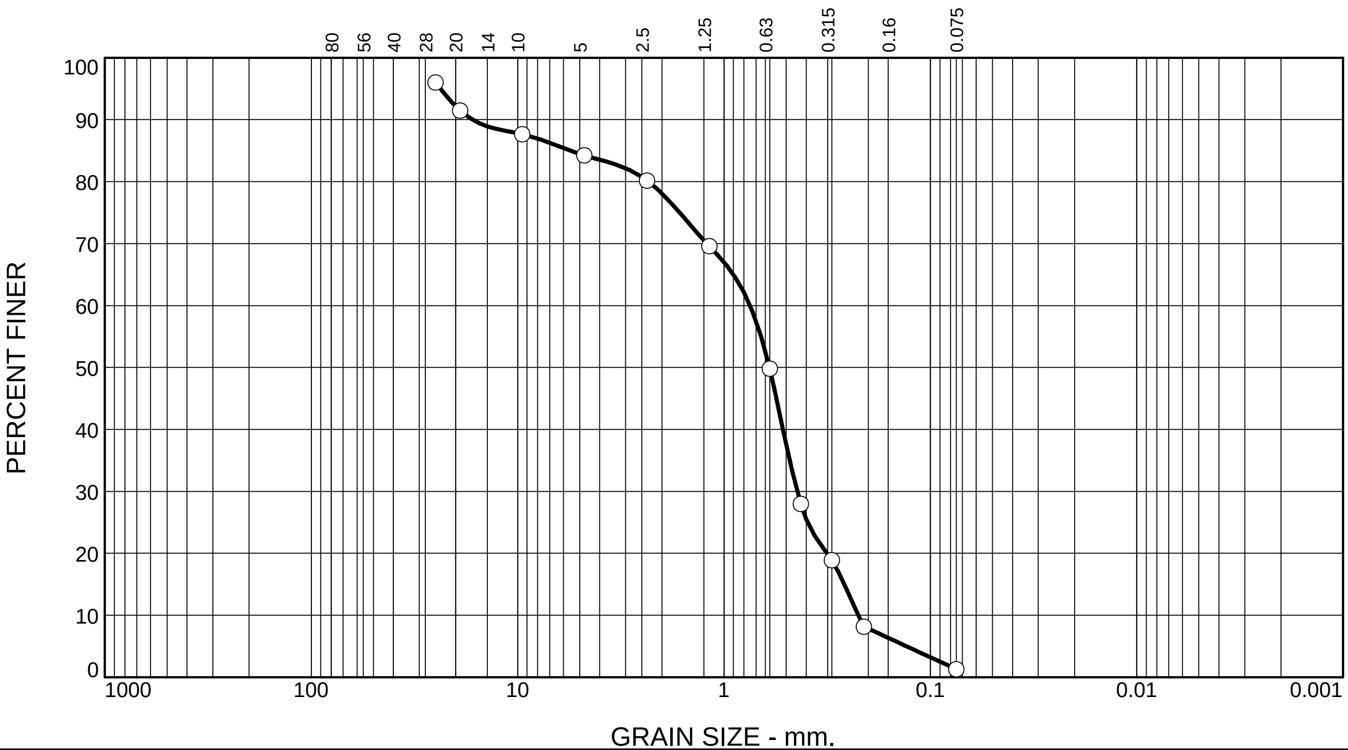
Castries, St. Lucia

Client: R.J. Burnside
Project: Millet Intake Geotechnical Survey
Project No: **Figure**

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicitive of apparently identical samples

These results are for the exclusive use of the client for whom they were obtained. They apply only to the samples tested and are not indicitive of apparently identical samples.

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		7	6	50	27	1	

TEST RESULTS (ASTM D 422)			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
25	96		
19	91		
9.5	88		
#4	84		
#8	80		
#16	70		
#30	50		
#40	28		
#50	19		
#70	8		
#200	1.3		

* (no specification provided)

Material Description

Light Brown Gravelly Sand

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= 16.5789 D_{85}= 5.5430 D_{60}= 0.7491
D_{50}= 0.6021 D_{30}= 0.4426 D_{15}= 0.2614
D_{10}= 0.2235 C_u= 3.35 C_c= 1.17

Remarks

Date Received: **Date Tested:** 21/12/2018

Tested By: N. Jn Pierre

Checked By: M. Borges

Title:

Source of Sample: Intake Pit 3 **Depth:** 0.3 **Date Sampled:** 20/12/2018

AMARNA

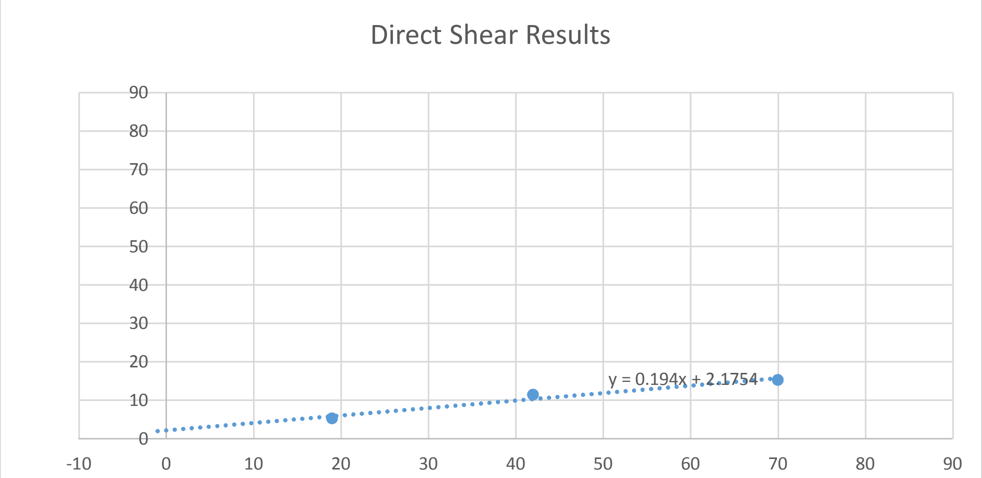
Castries, St. Lucia

Client: R.J. Burnside
Project: Millet Intake Geotechnical Survey
Project No: **Figure**

DIRECT SHEAR

Description of Soil:	Clayey sand	Sample No:	Pt. 15
Mass of Oven-Dry Specimen M (g):		Area of Sample	0.0036 m2
Location:	Millet Intake	Conditions:	Consol. drained
Tested By:	N. Jn Pierre	Date:	16/02/2019
Test Speed (mm/min):	0.6	Natural M/C (%)	

	Mass of specimen/g	Volume of Specimen/m3	Vertical Lc	Vertical stress KN/m2	Initial Vertical Dispacement /mm	Final Vertical Displacement	Horizontal Displacment/mm	Failure Shear Force/N	Failue Shear Stress/KN/m2	Notes
Test #1	112.56	0.0000792	4	19	4.1	4.7	10.13	19	5.277777778	
Test #2	113.52	0.0000828	8	42	2.4	3.45	9.95	41	11.38888889	
Test #3	111.21	0.0000792	16	70	4.8	5.2	9.55	55	15.27777778	



Bulk Density (kg/m3)

	1421.212121
	1371.014493
	1404.166667
ave	1398.79776
weight	13.71752006

Results

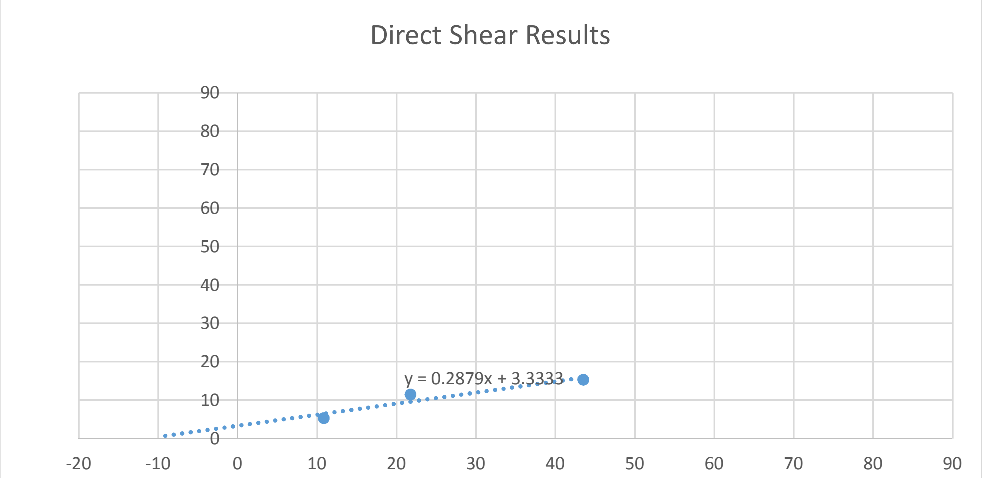
Slope	0.194032817	
bulk unit weight	13.7	
Angle of Internal Friction	0.191651355	radians
	11	degrees
Cohesion/KN/m2	2.18	Kn/m2

DIRECT SHEAR

Description of Soil: Clayey sand
Mass of Oven-Dry Specimen M (g):
Location: Millet Intake
Tested By: N. Jn Pierre
Test Speed (mm/min): 0.6

Sample No: Pt. 18
Area of Sample 0.0036 m2
Conditions: Consol. drained
Date: 15/02/2019
Natural M/C (%)

	Mass of specimen/g	Volume of Specimen/m3	Vertical Lc	Vertical stress KN/m2	Initial Vertical Dispacement /mm	Final Vertical Displacement	Horizontal Displacment/mm	Failure Shear Force/N	Failue Shear Stress/KN/m2	Notes
Test #1	119.92	0.00009	4	10.88889	3.12	3.61	16.12	19	5.277777778	
Test #2	120.35	0.00009	8	21.77778	5.3	5.6	11.32	41	11.38888889	
Test #3	120.54	0.00009	16	43.55556	6.5	6.85	10.289	55	15.27777778	



Bulk Density (kg/m3)

	1332.444444
	1337.222222
	1339.333333
ave	1336.333333
weight	13.10495328

Results

Slope	0.287900875	
bulk unit weight	13	
Angle of Internal Friction	0.280320053	radians
	16	degrees
Cohesion/KN/m2	3.33	Kn/m2

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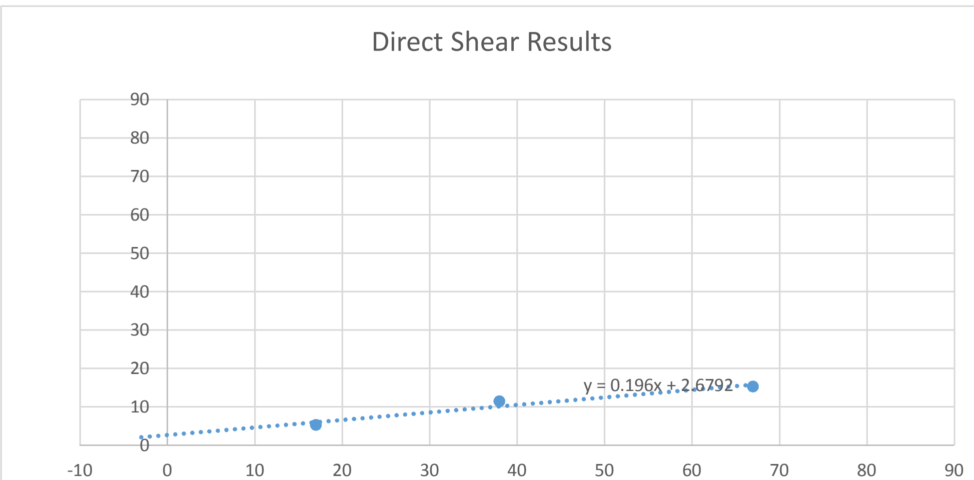
DIRECT SHEAR

Description of Soil:	Clayey sand	Sample No:	Pt. 19
Mass of Oven-Dry Specimen M (g):		Area of Sample	0.0036 m2
Location:	Millet Intake	Conditions:	Consol. drained
Tested By:	N. Jn Pierre	Date:	17/02/2019
Test Speed (mm/min):	0.6	Natural M/C (%)	

	Mass of specimen/g	Volume of Specimen/m3	Vertical Lc	Vertical stress KN/m2	Initial Vertical Dispacement /mm	Final Vertical Displacement	Horizontal Displacment/mm	Failure Shear Force/N	Failue Shear Stress/KN/m2	Notes
Test #1	114.23	0.0000828	4	17	3.1	3.3	6.8	19	5.277777778	
Test #2	114.89	0.0000828	8	38	5.7	6.1	8.2686	41	11.38888889	
Test #3	114.42	0.0000828	16	67	6.2	6.5	10.0935	55	15.27777778	



Bulk Density (kg/m3)

	1379.589372
	1387.560386
	1381.884058
ave	1383.011272
weight	13.56270749

Results

Slope	0.195957459	
bulk unit weight	13.6	
Angle of Internal Friction	0.193505497	radians
	11	degrees
Cohesion/KN/m2	2.68	Kn/m2

SPECIFIC GRAVITY OF SOIL SOLIDS

			Borehole/Test Pit No.:		Pt. 8
Description of soil:	Elastic Silt			Sample No.	1
Volume Of Flask At 20°C:	498.24	Temperature of Test:	30	A:	0.99744
Location:	Millet Intake				
Tested by:	N. Jn Pierre	Date:	14/02/2019		

ITEM	TEST No.		
	1	2	
Pycnometer No.	3	2	
Mass Of Pycnometer + Water Filled To Mark, M1 (g)	605.94	632.35	
Mass Of Pycnometer + Soil + Water Filled To Mark, M2 (g)	630.12	654.85	
Mass of Dry Soil, Ms (g)	52.16	49.14	
Mass of Equal Volume Of Water and Soil Solids, Mw (g) = (M1+Ms)-M2	27.98	26.64	
Gs (at T1°C) = Ms/Mw	1.86	1.84	
Gs (at T1°C) = Gs (at T1°C)xA	1.86	1.84	
Average Gs =		1.85	

SPECIFIC GRAVITY OF SOIL SOLIDS

			Borehole/Test Pit No.:	Pt. 8
Description of soil:	Elastic Silt		Sample No.	1
Volume Of Flask At 20°C:	498.24	Temperature of Test: 30	A:	0.99744
Location:	Millet Intake			
Tested by:	N. Jn Pierre	Date: 14/02/2019		

ITEM	TEST No.		
	1	2	
Pycnometer No.	3	2	
Mass Of Pycnometer + Water Filled To Mark, M1 (g)	605.94	632.35	
Mass Of Pycnometer + Soil + Water Filled To Mark, M2 (g)	630.12	654.85	
Mass of Dry Soil, Ms (g)	52.16	49.14	
Mass of Equal Volume Of Water and Soil Solids, Mw (g) = (M1+Ms)-M2	27.98	26.64	
Gs (at T1°C) = Ms/Mw	1.86	1.84	
Gs (at T1°C) = Gs (at T1°C)xA	1.86	1.84	
Average Gs =		1.85	

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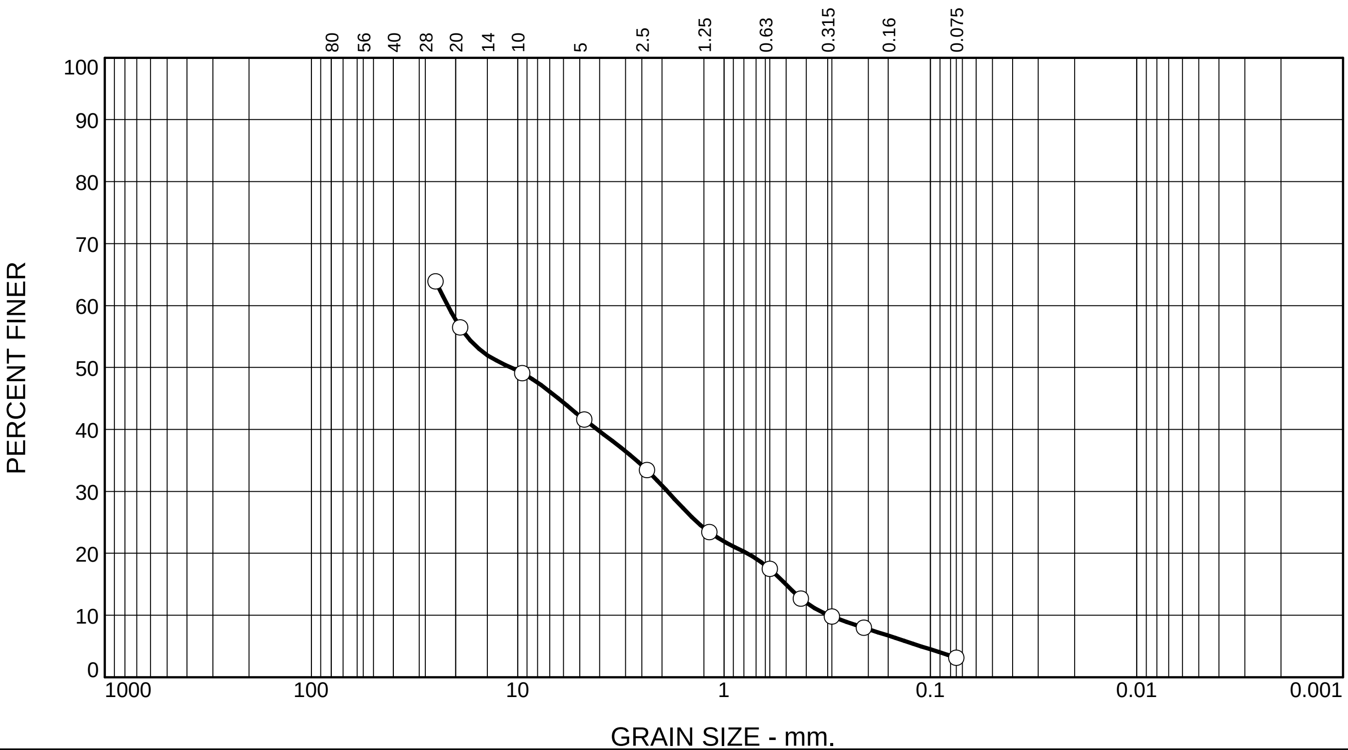
SPECIFIC GRAVITY OF SOIL SOLIDS

				Borehole/Test Pit No.:	Pt. 18
Description of soil:				Sample No.	1
Volume Of Flask At 20°C:	498.24	Temperature of Test:	30	A:	0.99744
Location:	Millet Intake				
Tested by:	N. Jn Pierre	Date:	14/02/2019		

ITEM	TEST No.		
	1	2	
Pycnometer No.	1	2	
Mass Of Pycnometer + Water Filled To Mark, M1 (g)	628.02	632.35	
Mass Of Pycnometer + Soil + Water Filled To Mark, M2 (g)	651.12	654.04	
Mass of Dry Soil, Ms (g)	50.62	47.41	
Mass of Equal Volume Of Water and Soil Solids, Mw (g) = (M1+Ms)-M2	27.52	25.72	
Gs (at T1°C) = Ms/Mw	1.84	1.84	
Gs (at T1°C) = Gs (at T1°C)xA	1.83	1.84	
Average Gs =		1.84	

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
		15	11	18	10	3	

TEST RESULTS (ASTM D 422)			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
25	64		
19	56		
9.5	49		
#4	42		
#8	33		
#16	23		
#30	18		
#40	13		
#50	10		
#70	8		
#200	3.1		

* (no specification provided)

Location

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= GP **AASHTO (M 145)=** A-1-a

Coefficients

D_{90}= D_{85}= D_{60}= 21.8549

D_{50}= 10.7837 D_{30}= 1.8806 D_{15}= 0.5016

D_{10}= 0.3108 C_u= 70.32 C_c= 0.52

Remarks

Date Received: ____________ **Date Tested:** 07/02/2019

Tested By: N. Jn Pierre

Checked By: M. Borges

Title: ____________

Source of Sample: Pt. 1 **Depth:** 1.0 **Date Sampled:** 16/01/2019

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Castries, St. Lucia

Client: R.J. Burnside

Project: Millet Intake Geotechnical Survey

Project No: **Figure**

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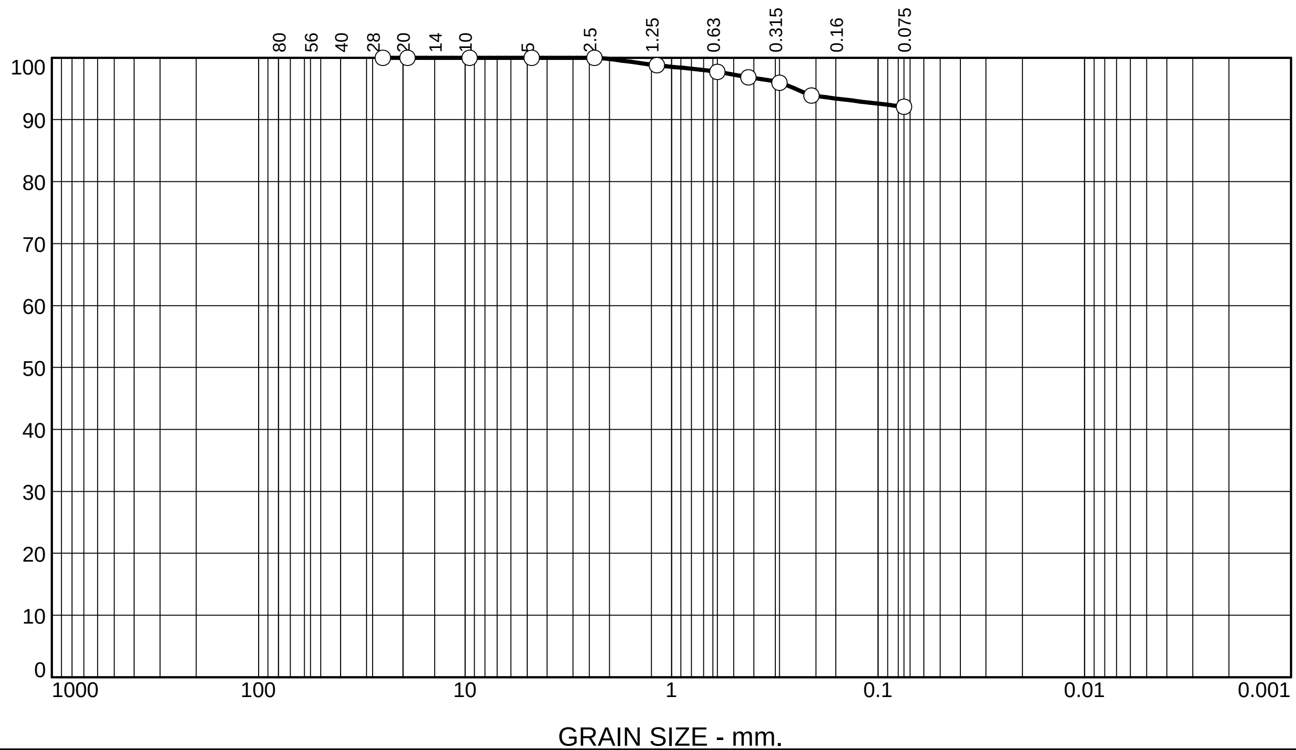
Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	0	0	3	5	92	

TEST RESULTS			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
25	100		
19	100		
9.5	100		
#4	100		
#8	100		
#16	99		
#30	98		
#40	97		
#50	96		
#70	94		
#200	92		

* (no specification provided)

Location

Atterberg Limits (ASTM D 4318)

PL= 52 **LL=** 72 **PI=** 20

Classification

USCS (D 2487)= MH **AASHTO (M 145)=** A-7-5(28)

Coefficients

D_{90}= D_{85}= D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: **Date Tested:** 07/02/2019

Tested By: N. Jn Pierre

Checked By: M. Borges

Title:

Source of Sample: Pt. 2 **Depth:** 0.6 **Date Sampled:** 16/01/2019
Sample Number: #2

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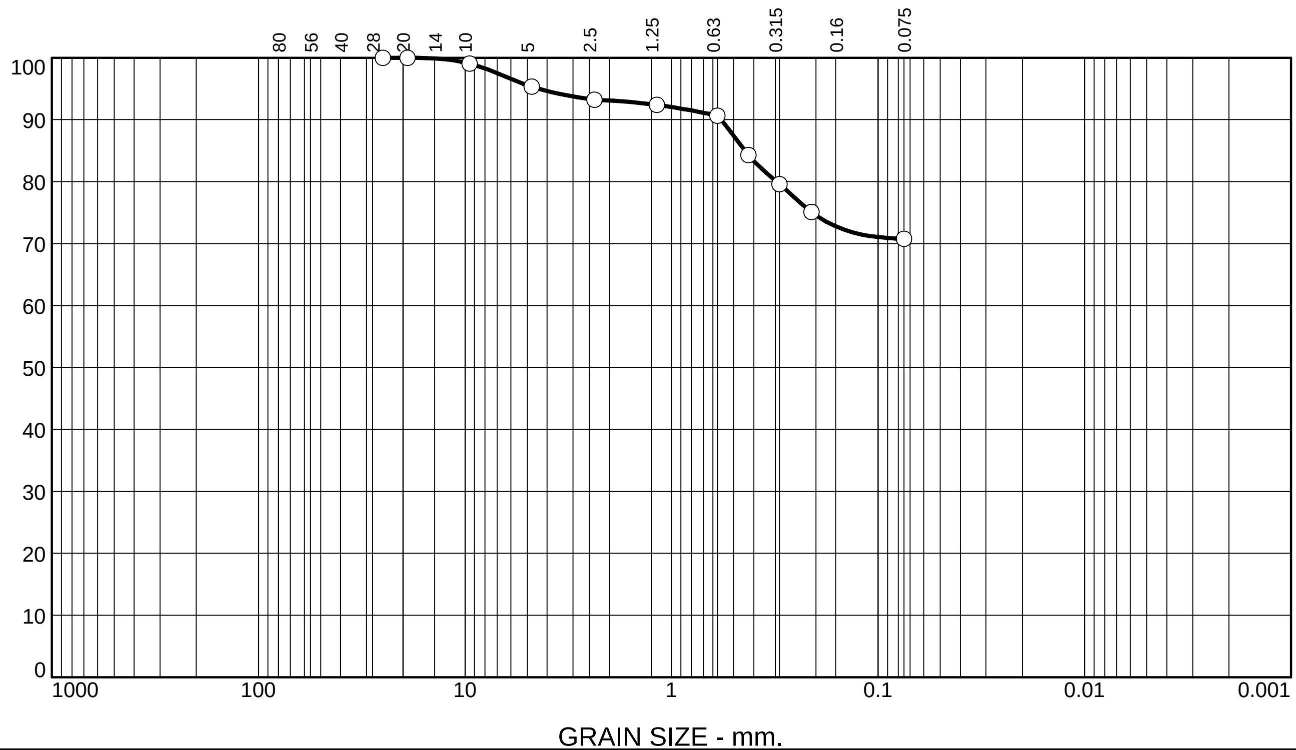
Castries, St. Lucia

Client: R.J. Burnside
Project: Millet Intake Geotechnical Survey

Project No: **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	5	2	9	13	71	

TEST RESULTS (ASTM D 422)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
25	100		
19	100		
9.5	99		
#4	95		
#8	93		
#16	92		
#30	91		
#40	84		
#50	80		
#70	75		
#200	71		

* (no specification provided)

Location

Atterberg Limits (ASTM D 4318)

PL= 44 **LL=** 74 **PI=** 30

Classification

USCS (D 2487)= MH **AASHTO (M 145)=** A-7-5(25)

Coefficients

D_{90}= 0.5752 D_{85}= 0.4417 D_{60}=
D_{50}= D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: **Date Tested:** 07/02/19

Tested By: N. Jn Pierre

Checked By: M. Borges

Title:

Source of Sample: Pt.8 **Depth:** 1 **Date Sampled:** 16/01/19

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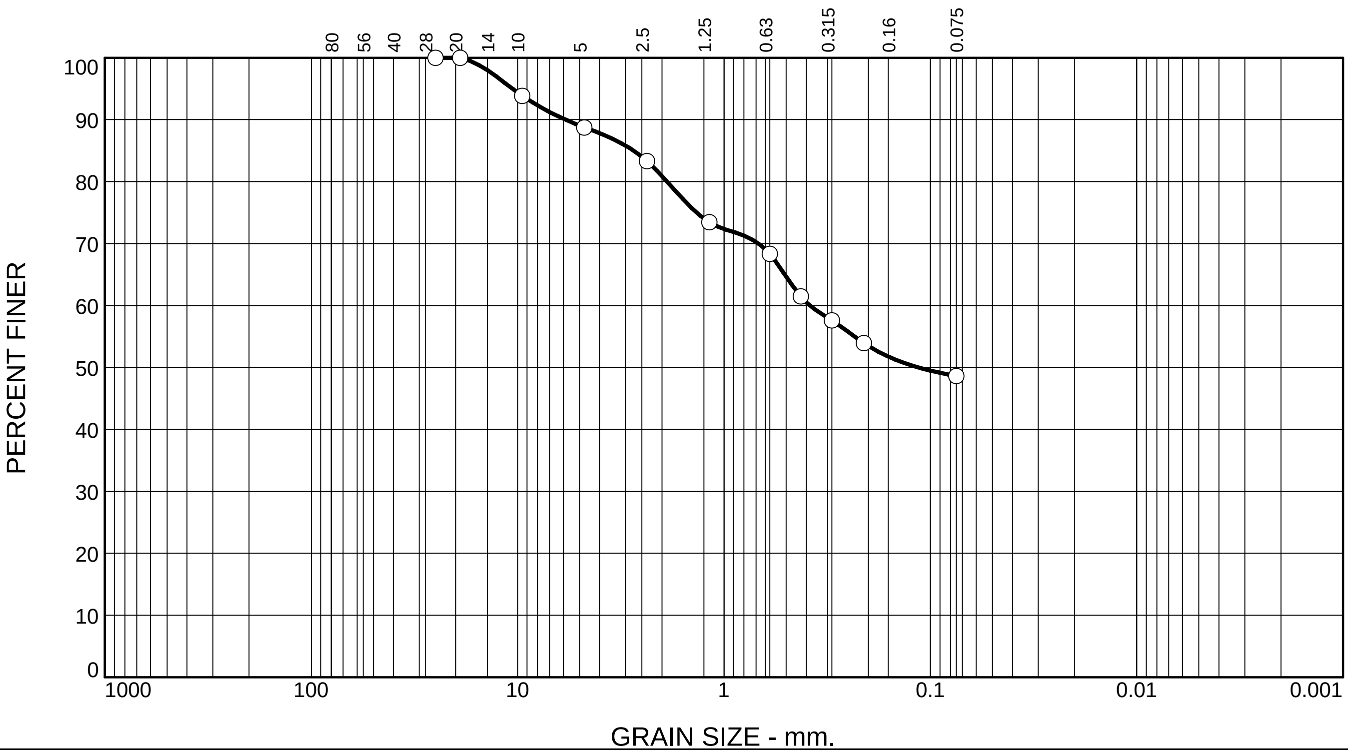
Castries, St. Lucia

Client: R.J. Burnside
Project: Millet Intake Geotechnical Survey
Project No: **Figure**

Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	11	8	20	12	49	

TEST RESULTS (ASTM D 422)			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
25	100		
19	100		
9.5	94		
#4	89		
#8	83		
#16	73		
#30	68		
#40	61		
#50	58		
#70	54		
#200	49		

* (no specification provided)

Location

Atterberg Limits (ASTM D 4318)

PL= 37 **LL=** 67 **PI=** 30

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-7-5(11)

Coefficients

D_{90}= 5.8551 D_{85}= 2.7421 D_{60}= 0.3840
D_{50}= 0.1139 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: ____________ **Date Tested:** 07/02/2019

Tested By: N. Jn Pierre

Checked By: M. Borges

Title:

Source of Sample: Pt.15 **Depth:** 1 **Date Sampled:** 16/01/2019

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Castries, St. Lucia

Client: R.J. Burnside
Project: Millet Intake Geotechnical Survey
Project No: **Figure**

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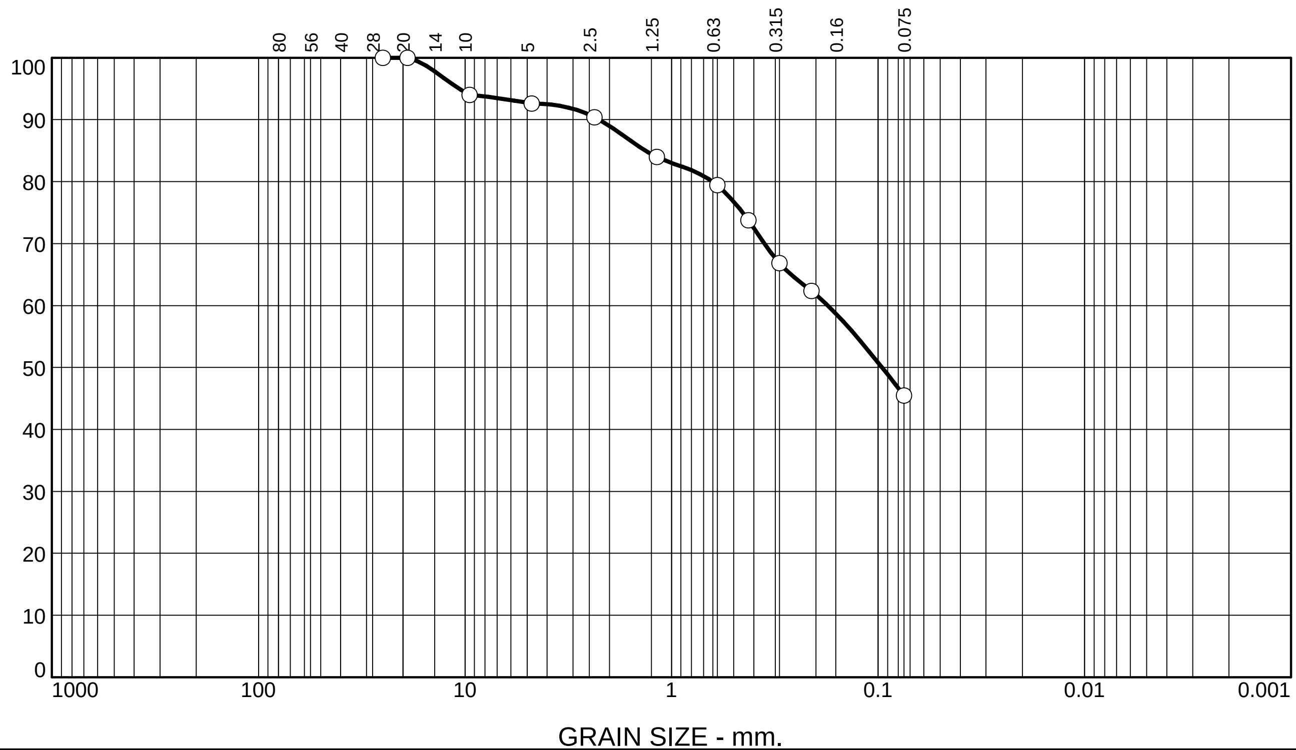
Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	0	7	4	15	29	45	

TEST RESULTS (ASTM D 422)

Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
25	100		
19	100		
9.5	94		
#4	93		
#8	90		
#16	84		
#30	79		
#40	74		
#50	67		
#70	62		
#200	45		

* (no specification provided)

Location

Atterberg Limits (ASTM D 4318)

PL= 47 **LL=** 98 **PI=** 51

Classification

USCS (D 2487)= SM **AASHTO (M 145)=** A-7-5(17)

Coefficients

D_{90}= 2.2427 D_{85}= 1.3344 D_{60}= 0.1753
D_{50}= 0.0958 D_{30}= D_{15}=
D_{10}= C_u= C_c=

Remarks

Date Received: **Date Tested:** 07/02/19

Tested By: N. Jn Pierre

Checked By: M. Borges

Title:

Source of Sample: Pt. 18 **Depth:** 1 **Date Sampled:** 17/01/19

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Castries, St. Lucia

Client: R.J. Burnside
Project: Millet Intake Geotechnical Survey
Project No: **Figure**

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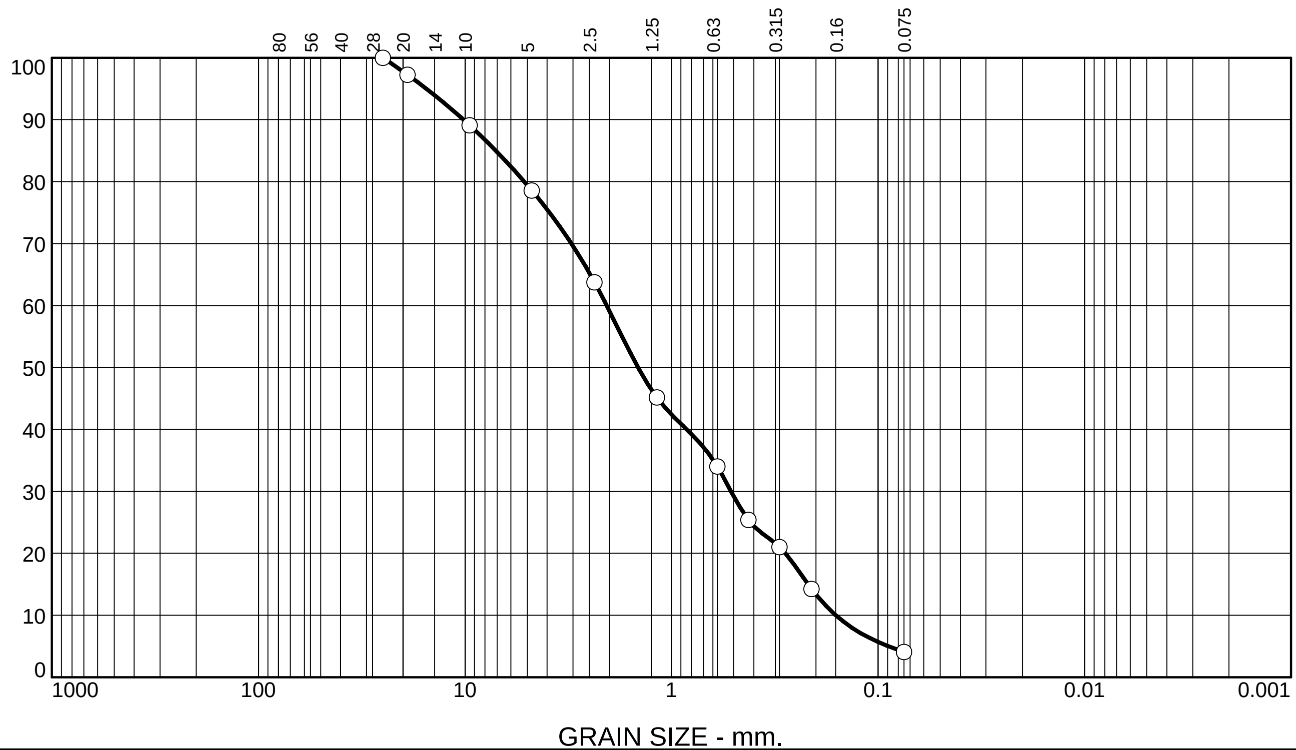
Particle Size Distribution Report



% +3"	% Gravel		% Sand			% Fines	
	Coarse	Fine	Coarse	Medium	Fine	Silt	Clay
0	3	18	20	34	21	4	

TEST RESULTS			
Opening Size	Percent Finer	Spec.* (Percent)	Pass? (X=Fail)
25	100		
19	97		
9.5	89		
#4	79		
#8	64		
#16	45		
#30	34		
#40	25		
#50	21		
#70	14		
#200	4.1		

* (no specification provided)

Location

Atterberg Limits (ASTM D 4318)

PL= NP **LL=** NV **PI=** NP

Classification

USCS (D 2487)= SP **AASHTO (M 145)=** A-1-b

Coefficients

D_{90}= 10.1744 D_{85}= 7.0968 D_{60}= 2.0624
D_{50}= 1.4507 D_{30}= 0.5147 D_{15}= 0.2183
D_{10}= 0.1604 C_u= 12.86 C_c= 0.80

Remarks

Date Received: **Date Tested:** 07/02/2019

Tested By: N. Jn Pierre

Checked By: M. Borges

Title:

Source of Sample: Pt. 20 **Depth:** 0.2 **Date Sampled:**

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Castries, St. Lucia

Client: R.J. Burnside
Project: Millet Intake Geotechnical Survey
Project No: **Figure**

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