Our Ref: CE1013/RAC/03
Date: 16 May 2016

Suite 5a, Rossett Business Village
Llyndir Lane
Rossett, Wrexham
LL12 0AY
Tel: 01244 571358

www.stratus-environmental.co.uk

Mr Ian Oakes
Natural Resources Wales
Chester Road
Buckley
Flintshire
CH7 3AJ

Dear Ian

HAFOD QUARRY LANDFILL SITE
Inspection of Secondary Containment to New Leachate Storage Tank

We have been asked by Cory Environmental to assess the provision of secondary containment to the new leachate storage tank recently constructed at the site. The secondary containment is provided by an engineered clay liner to the base and sidewalls of the storage tank area, the permeability of which is to be at or below that applicable to cell engineering at the site.

Material

The secondary containment liner was sourced from on-site materials that were being processed for use in the Cell 4 construction works, undertaken at the end of last year. The excavated marl was conditioned by the addition of water to increase its moisture content, in the same manner as utilised for the liner construction, using a tractor and bowser combination.

Placement Methodology

The processed clay was placed loosely in 300mm layers and compacted by eight passes with a padfoot roller; for the bulk of the works, this was the Hamm 3412 roller utilised for the cell construction works. For the recent completion of the access route into the containment area, a Bomag BW213 DH padfoot roller was used, for which the mass per metre width was 3,474 kg; this is a marginally-heavier roller than the Hamm 3412 (3,180 kg per metre width).

Inspection

Inspection of the works was provided by Kay Adedotun on a part-time basis whilst he was supervising the construction of Cell 4. He took hand shear vane readings to confirm that the minimum shear strength of the emplaced clay was 50kPa or above. He also maintained observation to ensure that the clay did not contain excessive tile or brick fragments.

Sampling and Testing

Samples of the compacted clay liner being placed to the access closure area were obtained by a Stratus Environmental engineer who attended site on 24 February 2016. These samples were despatched to Celtest Ltd for analysis.

Laboratory Results

Triaxial Permeability:

Sample Ref	Certificate Ref	Bulk Density (Mg/m^3)	Moisture Content (%)	Dry Density (Mg/m^3)	Permeability (m/s)
P1	STR 453315	2.191	10.1%	1.990	1.6×10^{-10}
P2	STR 453316	2.216	11.1%	1.995	1.2×10^{-10}

Characterisation:

Sample Ref	Certificate Ref	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index	Particle Density (Mg/m^3)	Clay Content (%)
B1	STR 453317	15	27	12		
	STR 453318				2.74	
	STR 453319					14.1
B2	STR 453321	15	28	13		
	STR 453323				2.75	
	STR 453324					15.2

Comparison With Cell Engineered Clay Liner

For the recent Cell 4 works, a total of 40 bulk samples and 34 permeability samples were taken as part of the CQA validation process. The laboratory analyses of these samples yielded the following data:

Cell 4	Plastic Limit (%)	Liquid Limit (%)	Plasticity Index	Particle Density (Mg/m^3)	Clay Content (%)	Permeability (m/s)
Min	14	26	12	2.71	11.2	2.70×10^{-11}
Mean	15	29	14	2.75	19.2	8.76×10^{-11}
Max	16	37	16	2.77	28.0	4.50×10^{-10}

Comparison of the results obtained for the leachate storage tank works with the larger Cell 4 data-set demonstrates that the clay used for the former works is comparable in both its intrinsic properties and also in its permeability performance.

Summary

The clay selected for use within the secondary containment works meets the required permeability specification ($k \leq 1 \times 10^{-9}$ m/s), and has been shown to be of the same quality of material as that used for the recent cell construction works. It has been compacted using the same methodology, and employing the same or greater compactive effort, as that used in the cell construction works. From observation of the material, its placement and the finished installation, we believe that the secondary containment system has been constructed in general accordance with the requirements of the cell containment CQA Plan, and that it is fit for purpose.

We trust that you find the above report acceptable, and look forward to your comments in due course. Should you have any queries or require further details, please do not hesitate to contact the undersigned.

Yours sincerely

Richard Clarke
for and on behalf of
Stratus Environmental Limited

Enc: Appendix 1 : Construction Photographs (8 pages)
Appendix 2 : Laboratory Analysis Reports (12 pages)

Cc: Dr Ewan Thomas, NRW/Geotechnology Ltd
Ian Craven, Cory Environmental

APPENDIX 1
CONSTRUCTION PHOTOGRAPHS

PHOTOGRAPHS

Plate 1

Basal formwork, waterstop and reinforcement prior to casting

Plate 2

Basal slab being cast

stratus environmental	Job Title: Hafod - Leachate Storage Tank		Client: Cory Environmental Ltd	
	Approved: RAC	Signature: RA Chandler	Date: May-16	Appendix 1

PHOTOGRAPHS

Plate 3

Cube samples after preparation (taken by others)

Plate 4

Completed tank construction; clay containment incomplete

stratus environmental	Job Title: Hafod - Leachate Storage Tank		Client: Cory Environmental Ltd	
	Approved: RAC	Signature: RA Chesher	Date: May-16	Appendix 1

PHOTOGRAPHS

Plate 5

Padfoot roller utilised for cell construction (Hamm 3412)

Plate 6

Padfoot roller utilised for construction of tank containment (Bomag BW213 DH)

stratus environmental	Job Title: Hafod - Leachate Storage Tank		Client: Cory Environmental Ltd	
	Approved: RAC	Signature: RA Clarke	Date: May-16	Appendix 1

PHOTOGRAPHS

Plate 7

Installation of leak detection pipework to base of tank sidewall

Plate 8

Gravel surround and separation geotextile to leak detection drain

stratus environmental	Job Title: Hafod - Leachate Storage Tank		Client: Cory Environmental Ltd	
	Approved: RAC	Signature: RA Chamberlain	Date: May-16	Appendix 1

PHOTOGRAPHS

Plate 9

Compaction of engineering clay to apron around tank

Plate 10

Leak detection chamber visible against tank sidewall

stratus environmental	Job Title: Hafod - Leachate Storage Tank		Client: Cory Environmental Ltd	
	Approved: RAC	Signature: RA Chamberlain	Date: May-16	Appendix 1

PHOTOGRAPHS

Plate 11

Leak detection drain installation completed; clay compaction under way

Plate 12

Hand shear vane and undisturbed core samples taken to confirm clay suitability

stratus environmental	Job Title: Hafod - Leachate Storage Tank		Client: Cory Environmental Ltd	
	Approved: RAC	Signature: RA Chandler	Date: May-16	Appendix 1

PHOTOGRAPHS

Plate 13

Clay placement and compaction completed, prior to concrete apron casting

Plate 14

Leak detection chamber now flush with top of containment clay, prior to casting of apron

stratus environmental	Job Title: Hafod - Leachate Storage Tank		Client: Cory Environmental Ltd	
	Approved: RAC	Signature: RA Chamberlain	Date: May-16	Appendix 1

PHOTOGRAPHS

Plate 15

Clay containment bund and concrete apron completed

View of leachate storage tank prior to placement of engineerde clay to access route

stratus environmental	Job Title: Hafod - Leachate Storage Tank		Client: Cory Environmental Ltd	
	Approved: RAC	Signature: RA Chamberlain	Date: May-16	Appendix 1

APPENDIX 2
LABORATORY ANALYSIS REPORTS

celtest
INDEPENDENT MATERIALS TESTING | DIAMOND DRILLING & SAWING

Stratus Environmental Limited
4245 Park Approach
Thorpe Park
Leeds
LS15 8GB

Date: 24 March 2016
Test Report Ref: STR 453315

Order No: 1107/CE1013/RC

Contract: Hafod Landfill - Leachate Storage Tank

LABORATORY TEST REPORT

TEST REQUIREMENTS: To determine the Coefficient of Permeability under constant head conditions in a Triaxial Cell in accordance with **BS 1377: Part 6 : 1990 : Clause 6.**

SAMPLE DETAILS:

Certificate of sampling received:	**No**
Laboratory Ref. No:	**S57217**
Client Ref. No:	**P1**
Date and Time of Sampling:	**24/02/2016**
Date of Receipt at Lab:	**26/02/2016**
Date of Start of Test:	**08/03/2016**
Sampling Location:	**Unknown**
Name of Source:	**Site Won**
Method of Sampling:	**Core Cutter**
Sampled By:	**Client**
Material Description:	**Red/brown very sandy silty CLAY**
Target Specification:	**N/A**

RESULTS:

See attached

Comments
None

Certificate Prepared by:-
Meical Owen
Assistant Laboratory Manager

Approved by: -
Eric Goulden
Technical Manager

TEST RESULTS

Sample condition: **Undisturbed**

Method of Remoulding (If applicable): **N/A**

Specimen Details:	Initial:	Final:
Diameter:	99.5 mm	N/A
Height:	90.1 mm	N/A
Moisture Content:	10.1 %	12.2 %
Bulk density:	2.191 Mg/m^3	2.322 Mg/m^3
Dry density:	1.990 Mg/m^3	2.070 Mg/m^3

Saturation stage: **Performed in accordance with clause 5.4.3 - Saturation by increments of cell pressure and back pressure.**

Initial pore pressure coefficient,B:	0.28
Final pore pressure coefficient,B:	0.96
Duration of stage:	7 days

Consolidation stage:

Effective pressure:	100 kPa
Duration of stage:	5 days

Permeability stage:

Pressure difference across specimen:	20 kPa
Mean effective stress:	90 kPa
Duration of stage	2 days
Coefficient of Permeability (k_v) at 20°C =	**1.6 x 10^{-10} m/s**

celtest
INDEPENDENT MATERIALS TESTING I DIAMOND DRILLING & SAWING

Stratus Environmental Limited
4245 Park Approach
Thorpe Park
Leeds
LS15 8GB

Date: 24 March 2016
Test Report Ref: STR 453316

Order No: 1107/CE1013/RC

Contract: Hafod Landfill - Leachate Storage Tank

LABORATORY TEST REPORT

TEST REQUIREMENTS: To determine the Coefficient of Permeability under constant head conditions in a Triaxial Cell in accordance with **BS 1377: Part 6 : 1990 : Clause 6.**

SAMPLE DETAILS:

Certificate of sampling received:	**No**
Laboratory Ref. No:	**S57217**
Client Ref. No:	**P2**
Date and Time of Sampling:	**24/02/2016**
Date of Receipt at Lab:	**26/02/2016**
Date of Start of Test:	**09/03/2016**
Sampling Location:	**Unknown**
Name of Source:	**Site Won**
Method of Sampling:	**Core Cutter**
Sampled By:	**Client**
Material Description:	**Red/brown very sandy silty CLAY**
Target Specification:	**N/A**

RESULTS:

See attached

Comments
None

Certificate Prepared by:-
Meical Owen
Assistant Laboratory Manager

Approved by: -
Eric Goulden
Technical Manager

TEST RESULTS

Sample condition: **Undisturbed**

Method of Remoulding (If applicable): **N/A**

Specimen Details:	Initial:	Final:
Diameter:	101.1 mm	N/A
Height:	98.7 mm	N/A
Moisture Content:	11.1 %	12.9 %
Bulk density:	2.216 Mg/m^3	2.328 Mg/m^3
Dry density:	1.995 Mg/m^3	2.062 Mg/m^3

Saturation stage: **Performed in accordance with clause 5.4.3 - Saturation by increments of cell pressure and back pressure.**

Initial pore pressure coefficient,B:	0.30
Final pore pressure coefficient,B:	0.96
Duration of stage:	7 days

Consolidation stage:

Effective pressure:	100 kPa
Duration of stage:	5 days

Permeability stage:

Pressure difference across specimen:	20 kPa
Mean effective stress:	90 kPa
Duration of stage	2 days

Coefficient of Permeability (k_v) at 20°C = 1.2×10^{-10} m/s

Stratus Environmental Limited
4245 Park Approach
Thorpe Park
Leeds

LS15 8GB

Date: 24 March 2016
Test Report Ref: STR 453317

Order No: 1107/CE1013/RC
Page 1 of 1

Contract: Hafod Landfill - Leachate Storage Tank

LABORATORY TEST REPORT

TEST REQUIREMENTS: To determine the Plastic Limit, Liquid Limit, and Plasticity Index of sample in accordance with **BS 1377:Part 2:1990 Clause 5.3, Clause 4.3, and Clause 5.4.**

SAMPLE DETAILS:

Certificate of sampling received:	**No**
Laboratory Ref. No:	**S57217**
Client Ref. :	**B1**
Date and Time of Sampling:	**24/02/2016**
Date of Receipt at Lab:	**26/02/2016**
Date of Start of Test:	**03/03/2016**
Sampling Location:	**Unknown**
Name of Source:	**Site Won**
Method of Sampling:	**Disturbed Bulk Sample**
Sampled By:	**Client**
Soil Description:	**Red/brown very sandy silty CLAY**
Target Specification:	**N/A**

RESULTS:

History of sample:	:	**After wet sieving**
% Materials passing 425µm	=	**72**
Plastic Limit	=	**15**
Liquid Limit	=	**27**
Plasticity Index	=	**12**

Comments
None

Certificate Prepared by:-
Meical Owen
Assistant Laboratory Manager

Approved by:
Eric Goulden
Technical Manager

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INDEPENDENT MATERIALS TESTING I DIAMOND DRILLING & SAWING

Stratus Environmental Limited
4245 Park Approach
Thorpe Park
Leeds

LS15 8GB

Date: 24 March 2016
Test Report Ref: STR 453318

Order No: 1107/CE1013/RC

Contract: Hafod Landfill - Leachate Storage Tank

LABORATORY TEST REPORT

TEST REQUIREMENTS: To determine the Particle Density of Soil – Gas Jar method, in accordance with **BS 1377 : Part 2 : 1990 : Clause 8.2.**

SAMPLE DETAILS:

Certificate of sampling received:	**No**
Laboratory Ref. No:	**S57217**
Client Ref. No:	**B1**
Date and Time of Sampling:	**24/02/2016**
Date of Receipt at Lab:	**26/02/2016**
Date of Start of Test:	**03/03/2016**
Sampling Location:	**Unknown**
Name of Source:	**Site Won**
Method of Sampling:	**Disturbed Bulk Sample**
Sampled By:	**Client**
Material Description:	**Red/brown very sandy silty CLAY**
Target Specification	**N/A**

RESULTS:

Particle Density = 2.74 Mg/m^3

Comments
None

Certificate Prepared by:- Meical Owen
Assistant Laboratory Manager

Approved by: - Eric Goulden
Technical Manager

celtest
INDEPENDENT MATERIALS TESTING I DIAMOND DRILLING & SAWING

Stratus Environmental Limited
4245 Park Approach
Thorpe Park
Leeds

LS15 8GB

Date: 24 March 2016
Test Report Ref: STR 453319

Order No: 1107/CE1013/RC

Contract: Hafod Landfill - Leachate Storage Tank

LABORATORY TEST REPORT

TEST REQUIREMENTS: To determine the Particle Size Distribution (PSD) of a soil sample- washing and sieving method in accordance with **BS1377-Part2-1990 Clause 9.2** Sedimentation by pipette method to **BS 1377: Part 2: 1990: clause 9.4.**

SAMPLE DETAILS:

Certificate of sampling received:	**No**
Laboratory Ref. No:	**S57217**
Client Ref. No:	**B1**
Date and Time of Sampling:	**24/02/2016**
Date of Receipt at Lab:	**26/02/2016**
Date of Start of Test:	**08/03/2016**
Sampling Location:	**Unknown**
Name of Source:	**Site Won**
Method of Sampling:	**Disturbed Bulk Sample**
Sampled By:	**Client**
Material Description:	**Red/brown very sandy silty CLAY**
Target Specification:	**N/A**

RESULTS:

SEE ATTACHED

Comments
None

Certificate Prepared by:- Meical Owen
Assistant Laboratory Manager

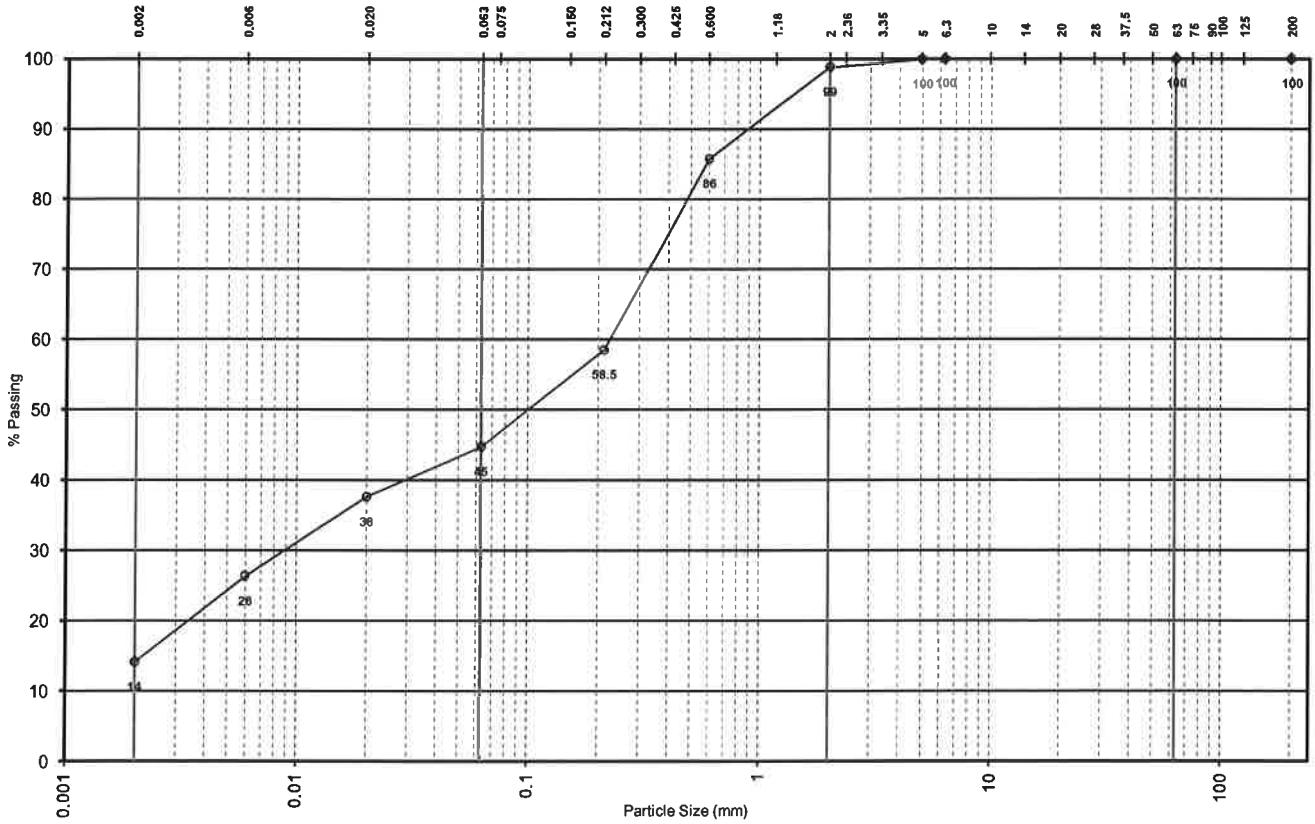
Approved by: - Eric Goulden
Technical Manager

MATERIAL DESCRIPTION

Red/brown very sandy silty CLAY

Method of pre-treatment:		N/A	
Sieve Size mm	% Passing	Sieve Size mm	% Passing
200	100.0	3.35	
125		2.36	
100		2.0	98.8
90		1.18	
75		0.600	85.7
63	100.0	0.425	
50		0.300	
37.5		0.212	58.5
28		0.150	
20		0.075	
14		0.063	44.7
10		0.020	37.6
6.3	100.0	0.006	26.3
5.0	99.9	0.002	14.1

Cobbles	0.0
Gravel	1.2
Sand	54.1
Silt	30.6
Clay	14.1



CLAY	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	COBBLES
	0.002	0.006	0.02	0.063		0.63	2.0	6.3	20	63 200
	SILT			0.2 SAND			GRAVEL			

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Stratus Environmental Limited
4245 Park Approach
Thorpe Park
Leeds

LS15 8GB

Date: 24 March 2016
Test Report Ref: STR 453321

Order No: 1107/CE1013/RC

Contract: Hafod Landfill - Leachate Storage Tank

LABORATORY TEST REPORT

TEST REQUIREMENTS: To determine the Plastic Limit, Liquid Limit, and Plasticity Index of sample in accordance with **BS 1377:Part 2:1990 Clause 5.3, Clause 4.3, and Clause 5.4.**

SAMPLE DETAILS:

Certificate of sampling received:	**No**
Laboratory Ref. No:	**S57217**
Client Ref. :	**B2**
Date and Time of Sampling:	**24/02/2016**
Date of Receipt at Lab:	**26/02/2016**
Date of Start of Test:	**03/03/2016**
Sampling Location:	**Unknown**
Name of Source:	**Site Won**
Method of Sampling:	**Disturbed Bulk Sample**
Sampled By:	**Client**
Soil Description:	**Red/brown very sandy silty CLAY**
Target Specification:	**N/A**

RESULTS:

History of sample:	:	**After wet sieving**
% Materials passing 425µm	=	**71**
Plastic Limit	=	**15**
Liquid Limit	=	**28**
Plasticity Index	=	**13**

Comments
None

Certificate Prepared by:- Meical Owen
Assistant Laboratory Manager

Approved by: Eric Goulden
Technical Manager

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INDEPENDENT MATERIALS TESTING I DIAMOND DRILLING & SAWING

Stratus Environmental Limited
4245 Park Approach
Thorpe Park
Leeds

LS15 8GB

Date: 24 March 2016
Test Report Ref: STR 453323

Order No: 1107/CE1013/RC

Contract: Hafod Landfill - Leachate Storage Tank

LABORATORY TEST REPORT

TEST REQUIREMENTS: To determine the Particle Density of Soil – Gas Jar method, in accordance with **BS 1377 : Part 2 : 1990 : Clause 8.2.**

SAMPLE DETAILS:

Certificate of sampling received:	**No**
Laboratory Ref. No:	**S57217**
Client Ref. No:	**B2**
Date and Time of Sampling:	**24/02/2016**
Date of Receipt at Lab:	**26/02/2016**
Date of Start of Test:	**03/03/2016**
Sampling Location:	**Unknown**
Name of Source:	**Site Won**
Method of Sampling:	**Disturbed Bulk Sample**
Sampled By:	**Client**
Material Description:	**Red/brown very sandy silty CLAY**
Target Specification	**N/A**

RESULTS:

Particle Density = 2.75 Mg/m^3

Comments
None

Certificate Prepared by:- Meical Owen
Assistant Laboratory Manager

Approved by: - Eric Goulden
Technical Manager

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INDEPENDENT MATERIALS TESTING I DIAMOND DRILLING & SAWING

Stratus Environmental Limited
4245 Park Approach
Thorpe Park
Leeds

LS15 8GB

Date: 24 March 2016
Test Report Ref: STR 453324

Order No: 1107/CE1013/RC

Contract: Hafod Landfill - Leachate Storage Tank

LABORATORY TEST REPORT

TEST REQUIREMENTS: To determine the Particle Size Distribution (PSD) of a soil sample- washing and sieving method in accordance with **BS1377-Part2-1990 Clause 9.2** Sedimentation by pipette method to **BS 1377: Part 2: 1990: clause 9.4.**

SAMPLE DETAILS:

Certificate of sampling received:	**No**
Laboratory Ref. No:	**S57217**
Client Ref. No:	**B2**
Date and Time of Sampling:	**24/02/2016**
Date of Receipt at Lab:	**26/02/2016**
Date of Start of Test:	**08/03/2016**
Sampling Location:	**Unknown**
Name of Source:	**Site Won**
Method of Sampling:	**Disturbed Bulk Sample**
Sampled By:	**Client**
Material Description:	**Red/brown very sandy silty CLAY**
Target Specification:	**N/A**

RESULTS:

SEE ATTACHED

Comments
None

Certificate Prepared by:- Meical Owen
Assistant Laboratory Manager

Approved by: - Eric Goulden
Technical Manager

Test Report Ref: STR 453324: Page 2 of 2

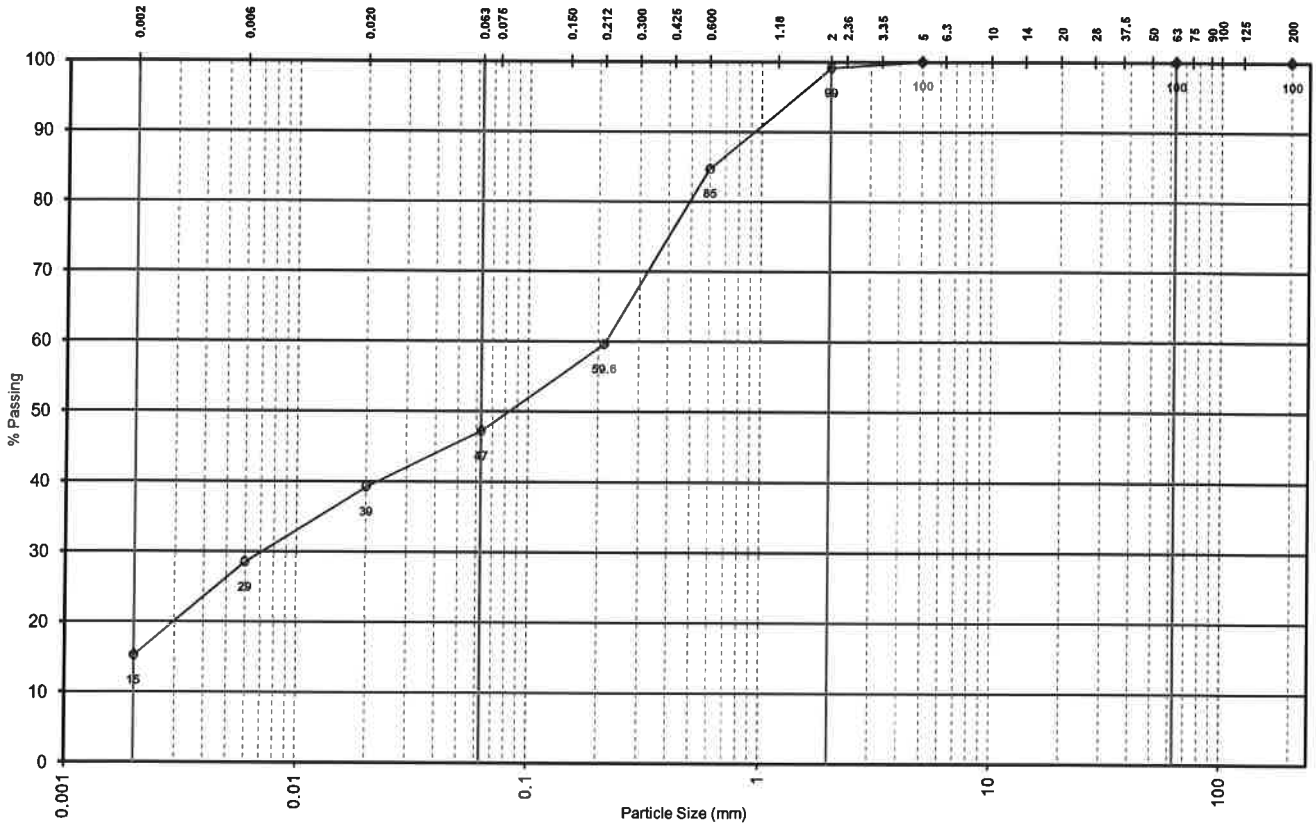
MATERIAL DESCRIPTION

Red/brown very sandy silty CLAY

Method of pre-treatment: N/A

Sieve Size mm	% Passing	Sieve Size mm	% Passing
200	100.0	3.35	
125		2.36	
100		2.0	99.1
90		1.18	
75		0.600	84.7
63	100.0	0.425	
50		0.300	
37.5		0.212	59.6
28		0.150	
20		0.075	
14		0.063	47.2
10		0.020	39.2
6.3		0.006	28.5
5.0	100.0	0.002	15.2

Cobbles	0.0
Gravel	0.9
Sand	51.9
Silt	32.0
Clay	15.2



CLAY	Fine	Medium	Coarse	Fine	Medium	Coarse	Fine	Medium	Coarse	COBBLES
	0.002	0.006	0.02	0.063		0.63	2.0	6.3	20	63 200
	SILT			0.2 SAND			GRAVEL			