GHALLIS LANDFILL

Revised Restoration Design Report

Prepared for: WasteServ Malta Limited

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DRAWINGS

1.0 Introduction

SLR Consulting Limited (SLR) has been instructed by WasteServ Malta Limited (WasteServ) to undertake a review of the proposed raising of the pre-settlement levels at Ghallis Landfill. It is proposed that the current maximum elevation of the pre-settlement contours is to be raised from 65mAMSL to optimise the available waste void.

This report presents part of the work defined under WasteServ Contract WSM 073/2020 dated 10th June 2020 following submittal of the SLR proposal P403/4168 dated 24th April 2020. Specifically, the report looks at how the void space at the site could be modified considering the following:

- Maximum allowable depth of waste which does not impact of the existing infrastructure, namely; lining system, leachate collection pipework and leachate risers;
- Stability analysis to determine the maximum allowable gradient of the restoration profile;
- Increase in waste void based on the findings maximum waste depth and gradient;

and

- Proposed capping system, with supporting Specification, CQA Plan and construction details.

The proposed restoration levels are presented to give an indication as to how the maximum height of the landfill may be achieved to ensure the integrity of the lining system, slope stability and safe access, in line with the constraints determined within this report. Ultimately the final profile of the landfill may change to take account of future for operational needs.

2.0 Background

WasteServ has been operating the facility since December 2006 and the objective of the work is to assess options on how the void space can be increased from the scheme currently planned. Drawing No.1 presents the most recent topographic survey of the landfill area.

The landfill development has followed the principals set out in the Environmental Impact Assessment for the site[1] with the landfill void created by the phased extraction of in-situ limestone deposits. The lining system design incorporates a 500mm thick foundation layer on the base and side slopes of the disposal area overlain by a Geosynthetic Clay Liner (GCL) and a 2.0mm thick High Density Polyethylene (HDPE) geomembrane. For each constructed landfill cell a gravel drainage blanket placed on a protection geotextile allows the free drainage of leachate to a sump and vertical chamber from where it can be extracted. Details of the materials used in the construction of the basal lining system are presented in Appendix 01.

It should be noted that Phases are numbered from 1 to 9, however, Phases 3 and 4 do not exist due to the Phase 1 and 2 being subdivided into numerous sub-phases and extension areas. Drawing No. 2 shows the layout out of the base of Ghallis Landfill identifying each of the phases and sub-phases of construction.

Following completion of waste infilling at the site a capping and restoration system will be installed. To date no areas have been capped and restored. The detailed design for the system is yet to be finalised. The concept presented in the Environmental Impact Assessment assumed the capping and restoration system to comprise (bottom to top) of a 250mm thick stabilisation layer overlain by a 1mm thick geomembrane, geogrid, geocomposite drainage layer and 1000mm of restoration soils (300mm topsoil and 700mm subsoil).

[1] WasteServ Malta Limited. Waste Management Facility at Ghallis Ta Gewwa, Naxxar. Environmental Statement. SLR Consulting Limited, December 2005

3.0 Determine Maximum Elevation of Landfill

3.1 Waste Load

By raising the restoration levels, the maximum load experienced by the lining and leachate collection systems at the base of the landfill will increase. When calculating the increase in the load at the base of the landfill it is important that as accurate as possible estimation of the waste density is made. In order to calculate the waste density WasteServ provided SLR with the most recent topographic survey of the landfill and waste input tonnages.

The topographic survey was provided to SLR in a 3D format, dated 21 April 2020, which indicated that the volume of waste placed at that point in time was 3,182,000m^3.

Table 3-1 below sets out the input of waste into the landfill in tonnes per annum, starting in December 2006 up to 21 April 2020, in line with the date of the survey.

Table 3-1
Waste Input Tonnages

Year	Quantity (t)	Year	Quantity (kt)
2006	23,000	2014	244,000
2007	286,000	2015	278,000
2008	303,000	2016	258,000
2009	270,000	2017	291,000
2010	224,000	2018	298,000
2011	208,000	2019	315,000
2012	235,000	Jan - 21 April 20	92,000
2013	230,000	**TOTAL**	**3,555,000**

In addition to the waste that has been placed within the landfill, daily cover will also have been used to prevent windblown waste from leaving the site, minimise odours and discourage vectors (birds and rats). The tonnages of daily cover is not usually recorded over the weighbridge, particularly when the materials are sourced from excavations on site. At Ghallis a fine-grained limestone material is used as daily cover, which is a by-product of crushing and screening operations on site.

Based on the volume of waste and the total tonnage the density of the waste calculated as detailed below:

Total tonnage of waste placed =	3,555,000 tonnes
Volume of waste (top of waste - base) =	3,182,000 m^3
Daily cover volume (quarry Fines) 5% =	159,100 m^3
Daily cover tonnage (assume 1.3t/m^3) =	206,830 tonnes
Total Tonnage =	3,761,830 tonnes
Average density of waste and daily cover =	1.18t/m3 or 11.6kPa

The maximum elevation for the current approved restoration contours is 65mAMSL, which lies in Phases 7 and 8 with a basal elevation of 13mAMSL, giving a maximum depth of 52m. Based on this depth the load at the base of the landfill (P_{actual})is calculated as set out in Table 3-2, below:

Table 3-2
Maximum Load on Base of Landfill

Material	Approved Restoration Levels		
	Depth	Unit Weight (kN/m3)	P_{actual} (kPa)
Topsoil	0.2	14	2.80
Lightly placed soil	0.4	16	6.40
Moderately compacted soil	0.4	18	7.2
Intermediate cover	0.3	16	5.04
Waste	50.2	12.2	614.2
Drainage Gravel	0.5	18	6.00
	Total		644.4

3.2 Lining System Integrity

One of the main factors when designing a landfill is ensuring that adequate protection is provided above the geomembrane liner to prevent the overlying drainage stone from damaging the integrity of the lining system. The load at the base of the landfill is calculated based on the pre-settlement levels and the proposed capping system, as set out above. Based on this load and on the grading of the leachate drainage stone, the grade of geotextile protector can be selected Subsequently, any increases in the load which the lining system will be subjected to, as a result of raising the restoration levels, must be reviewed to ensure that the integrity of the lining system is not affected.

It is common practice in Europe to use the cylinder test to replicate the basal lining system and demonstrate that the proposed geotextile provides sufficient protection to the underlying geomembrane liner. In the test apparatus a lead sheet is installed beneath the geomembrane liner, which deforms permanently as it is loaded, allowing the dimensions of any indentations to be measured and the strain in the geomembrane calculated. The allowable level of strain for a HDPE geomembrane liner is 0.25%.

However, cylinder testing was not undertaken for any of the phases of construction at Ghallis. When undertaking a cylinder test it is important to use the same combination of stone geotextile and geomembrane to give defendable results. To retrospectively undertake cylinder testing is considered unpractical, since many of the materials used in the construction have been discontinued and extracting samples from the site is not possible.

Hence, in reviewing the impact of the increased restoration levels on the integrity of the lining system, the empirical method proposed by Robert Koerner has been used (see Section 5.6.7 of "Designing with Geosynthetic", 5th Edition 2005). This method was based on a series of laboratory tests which relate the mass per unit area of a geotextile protector with the applied pressure required to puncture the underlying geomembrane.

$$P_{allow} = \left(50 + 0.00045\frac{M}{H^2}\right)\left[\frac{1}{MF_S \times MF_{PD} \times MF_A}\right]\left[\frac{1}{RF_{CR} \times RF_{CBD}}\right]$$

Where

P_{allow} = Allowable Pressure

M = Mass per unit area of Geotextile

H = Maximum Protrusion Height

Modification Factors

- Modification factor for protrusion shape (MF_S)
- Modification factor for packing density (MF_{PD})
- Modification factor for arching in solids (MF_A)

Reduction Factors

- Reduction factor for long term creep (RF_{CR})
- Reduction factor for long chemical/biological (RF_{CBD})

Using this equation the maximum allowable pressure can be calculated for each product and therefore determine whether or not the restoration levels may be increased to 75mAMSL or higher. However, Koerner also recommended that a minimum factor of safety of greater than 3 should also be applied, hence 4 adopted i.e.

$$Factor\ of\ Safety = \frac{P_{allow}}{P_{actual}} = 4$$

During the development of Ghallis a number of different products were used as the geotextile protector above the geomembrane liner with different mass per unit areas, as detailed in Table 3-3 below:

Table 3-3
Mass per unit Area of Geotextile Products Used

Manufacturer	Product	Mass Per Unit Area (g/m^2)	Phase of Construction
Polyfelt/Tencate	XP1000	1000	1A, 1A Ext., 1B, 1B Ext., 2A, 2B, 5A, 5D, 6A
Manifattura Fontana	Defron S 1000	1000	5C,
Naue	Secutex R1201	1200	5B, 6B
Geofabrics	HPS 12	1200	7
VIGANO PAVITEX	TECNOGEO FG65	1000	8
ATRARFIL	GTX NWH 1000	1000	9

As can be seen whilst there were 6 different products used at Ghallis, with respect to the mass per unit area was either 1000g/m^2 or 1200g/m^2. The following sets out the calculations to determine the maximum allowable pressure and from this determine the maximum depth of waste.

Assumptions

1. It has been assumed that the maximum protrusion height is assumed to be 2/3 of d_{50} Particle Size. The d50 is the particle size at which 50% of the sample would pass through a sieve. From the attached laboratory grading results for the 10-20mm drainage stone (Appendix 02) used in the leachate drainage blanket, the d_{50} is 15mm and hence the protrusion height is 10mm.

2. Modification Factors are taken from Table 5.18 of "Designing with Geosynthetic" by Robert Koerner, 5th Edition (2005).

MF_s		MF_{pd}		MF_a	
Angular	1	Isolated	1	Hydrostatic	1
Subrounded	0.5	Dense, 38mm	0.83	Geostatic, shallow	0.75
Rounded	0.25	Dense 25 mm	0.67	Geostatic, mod.	0.5
		Dense 12mm	0.5	Geostatic, deep	0.25

3. Reduction Factors are taken from Table 5.18 of "Designing with Geosynthetic" by Robert Koerner, 5th Edition (2005), reproduced below:

RF_{CBD}		RF_{CR}			
		Mass Per Unit Area (g/m^2)	Protrusion		
			38	25	12
Mild Leachate	1.1	Geomembrane Alone	N/R	N/R	N/R
Moderate Leachate	1.3	270	N/R	N/R	>1.5
Harsh Leachate	1.5	550	N/R	1.5	1.3
		1100	1.3	1.2	1.1
		>1100	1.2	1.1	1

Maximum Waste Depth 1000g/m2 Geotextile Protector

M = 1000g/m^2
H = 10mm

Modification Factors

MF_S	= 1	(assumed Angular)
MF_{PD}	= 0.67	(assumed dense max stone size <25mm)
MF_A	= 1	(assumed Hydrostatic)

Reduction Factors

RF_{CR} = 1.5 (assumed Harsh Leachate)
RF_{CBD} = 1.1 (mass per unit area <1100 and protrusion <12mm)

$$P_{allow} = \left(50 + 0.00045\frac{1000}{0.01^2}\right)\left[\frac{1}{1 \times 0.67 \times 1}\right]\left[\frac{1}{1.5 \times 1.1}\right] = 4116\text{kPa}$$

$$\text{Maximum Waste Depth} = \frac{P_{allow}/_{FoS} - Engineering\ Materials}{11.6} = \frac{4116/_{4} - 30}{11.6} = \underline{\mathbf{84\ m}}$$

Maximum Waste Depth 1200g/m2 Geotextile Protector

M = 1200g/m^2
H = 10mm

Modification Factors

MF_S	= 1	(assumed Angular)
MF_{PD}	= 0.67	(assumed dense max stone size <25mm)
MF_A	= 1	(assumed Hydrostatic)

Reduction Factors

RF_{CR}	= 1.5 (assumed Harsh Leachate)
RF_{CBD}	= 1.0 (mass per unit area >1100 and protrusion <12mm)

$$P_{allow} = \left(50 + 0.00045\frac{1200}{0.01^2}\right)\left[\frac{1}{1 \times 0.67 \times 1}\right]\left[\frac{1}{1.5 \times 1}\right] = 5423\text{Pa}$$

$$\text{Maximum Waste Depth Above Liner} = \frac{P_{allow}/_{FoS} - Engineering\ Materials}{11.6} = \frac{5423/_{4} - 30}{11.6} = \underline{\mathbf{114\ m}}$$

The calculations indicate that the 1200g/m^2 geotextile is capable of resisting puncture at waste depth of 114m, the area of the landfill which has been covered with this weight of material is relatively small, namely; Phases 5B, 6B and 7. The majority of the base of the landfill is covered by 1000g/m^2 material, hence, the limiting waste depth is 84m, hence with respect to the lining system integrity the limiting depth of waste is 84m.

3.3 Leachate Collection System

The basal leachate collection system is installed above the lining system within the leachate drainage blanket of each phase of the landfill, comprising the leachate drainage blanket and collection pipework. The collection pipework system comprises 200mm diameter PE80 SDR11 perforated pipes laid on 100mm of pipe bedding and covered with a minimum of 400mm of gravel haunching, see Figure 3-1.

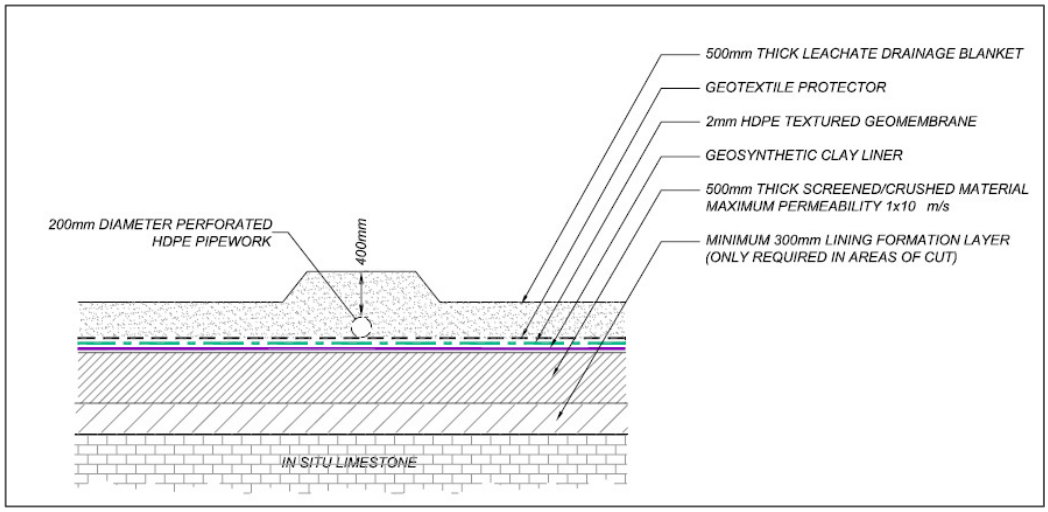

Figure 3-1
Leachate Drainage Pipework Construction Detail

The purpose of the pipework is to allow leachate to flow to the leachate collection sump, rapidly drawing down leachate levels in the drainage blanket to minimise leachate heads on the base of the landfill. At the design stage the pipework is checked to ensure that it will not crush when loaded to the full depth of waste, such that flow through the pipework is not compromised.

To check the deflection of the pipework under the anticipated loads the Modified Iowa Formula is used to calculate the deflection of the pipe (ΔX). Originally the pipes were checked to ensure that the deflection did not exceed 5% in both the long and short term. However, due to the proposed increase in the depth of waste the deflection of the pipework has been reviewed. The calculations set out below are based on a waste depth of 84m plus the engineering material (1005kPA).

Modified Iowa Formula

$$\Delta X = \frac{k(D_L W_c - K_o W_{c)}}{\left({EI}/{r^3}\right) + 0.061E'}$$

Where

ΔX = Change in diameter of the pipe	
DL = Lag Factor	= 1 (UK Environment Agency Guidance)
k = Bedding Constant	= 0.1 (UK Environment Agency Guidance)
W_c = Prism Load per unit length of pipe	= 1005kPa
Ko = Coefficient of Horizontal Earth Pressure	= 0.4 (UK Environment Agency Guidance)
E = Modulus of elasticity of pipe	= 1.6×10^5 kN/m^2
I = Moment of inertia	= 4.3×10^{-5}m^4/m
r = Radius of pipe	= 0.1m
E' = Modulus of soil reaction	= 3000kN/m^2

$$\Delta X = \frac{0.1(1 \times 1005 - 0.4 \times 690)}{\left({1.6 \times 10^5 \times 4.3 \times 10^{-5}}/{0.1^3}\right) + (0.061 \times 3000)} = 0.008478\text{m}$$

Percentage Deflection = 0.008478/0.2 = 4.24%

If the calculations are repeated for the areas of the site where the 1200g/m^2 material has been installed and where the maximum load is 1364kPa, then the deflection is 5.75% which is a failure. By repeating the calculation with varying loads, the limiting depth of waste where a deflection of 5% is found to be 99m.

Given limiting depth of waste based on the lining system integrity is 84 m, the deflection calculations for the leachate pipework have demonstrated that the increased loads will not result in pipes becoming unserviceable and will not influence the final restoration levels.

3.4 Leachate Extraction Risers

The leachate extraction system is installed in the base of the landfill at the lowest point in each of the phases. The risers comprise a 1m diameter concrete rings with a lower perforated section, founded on a 4m x 4m reinforced concrete pad, see Figure 3-2 below. The concrete rings are raised in line with the waste inputs up to the final restoration levels.

As the waste around the leachate riser compresses and consolidates, under self-weight, a frictional drag-down load is applied around the circumference of the concrete ring that forms the riser. This load is transferred downwards to the reinforced concrete foundation slab upon which the riser sits. To ensure the integrity of the lining system at the base of the landfill, the stability of the foundations need to be checked to determine that the forces acting on the foundation do not cause a failure of the underlying geology.

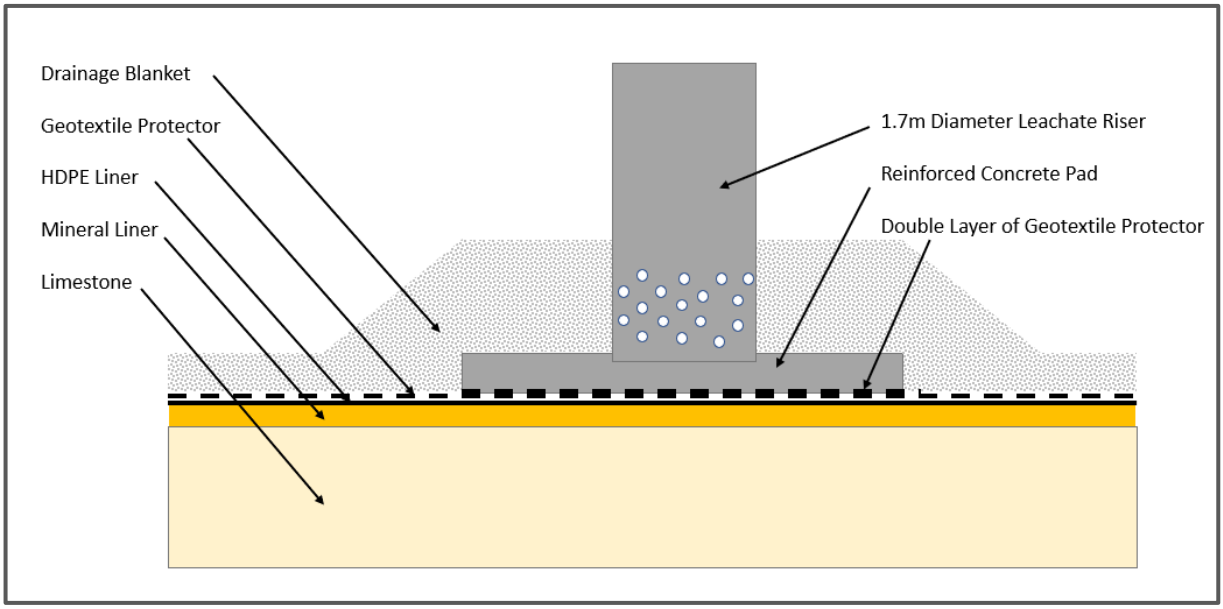

Figure 3-2
Riser Construction Detail

Appendix 03 presents the calculation of the maximum depth of waste to ensure that the bearing capacity of the underlying limestone foundation is capable of supporting the leachate riser. These calculations show that the allowable maximum waste depth, assuming a factor of safety of 1.5, is 66m.

3.5 Conclusions

Based on the above investigation and calculations, the following conclusions have been made which have been used in developing the proposed restoration profile:

- Maximum depth of waste above the lining system should not exceed 84m;

and

- Maximum depth of waste at a leachate riser should not exceed 66m.

4.0 Stability

A stability risk assessment has been undertaken for the increase in the restoration levels at Ghallis Landfill, a copy of which is presented in Appendix 04. The following summarises the findings of the assessment.

4.1 Factors of Safety

The factor of safety is the numerical expression of the degree of confidence that exists, for a given set of conditions, against a particular failure mechanism occurring. It is commonly expressed as the ratio of the load or action which would cause failure against the actual load or actions likely to be applied during service. This is readily determined by limit equilibrium slope stability analyses, which are the only type of analyses required for the current study.

For the stability of the waste mass a factor of safety of 1.3 is considered appropriate when adopting peak shear strength parameters under normal loading conditions i.e. no earthquake loading. When considering the worst-case scenario and applying a seismic load to allow for the additional loading imparted during an earthquake event a Factor of Safety in excess of 1.1 is considered appropriate.

A minimum factor of safety for the capping system of 1.3 for peak and 1.0 for residual shear strength parameters are considered appropriate for the pre-settlement slopes.

4.2 Modelling Approach and Software

The analytical methods used in this Stability Risk Assessment include:

- Limit equilibrium stability analyses for the derivation of factors of safety for the side slope geological barrier and temporary waste slopes.
- Closed-form analyses for the capping liner stability and integrity analyses.

The limit equilibrium analyses have been undertaken using the package Slope/W 2018, version 9.1.0 (Geo-Slope International). The Morgenstern-Price[2] non-circular methods of analysis have been used.

The capping stability assessment was undertaken using the methods proposed by Jones and Dixon[3]. The equations developed by these authors were input into Microsoft Excel spreadsheets for processing.

4.3 Geotechnical Parameters Selected for Analysis

Parameters used in the stability analyses based on the following criteria:

- An assessment of the suitability of non-site-specific data, where used;
- Methods for the derivation of the parameters adopted.

A summary of the geotechnical parameters used in the design and analysis of the development are presented in tabular form for each component of the site in Table 4-1.

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[2] Morgenstern, N.R and Price, V.E. (1965), 'The analysis of stability of general slip surfaces' Geotechnique.

3 Jones, D.R.V. & Dixon, N, 'The stability of geosynthetic landfill lining systems' Geotechnical Engineering of Landfills, Thomas Telford, London, 1998.

Table 4-1
Geotechnical Design Parameters Waste Mass Stability

Material	Unit Weight, γ (kN/m3)	Effective cohesion, c′ (kPa)	Angle of Shearing Resistance, ø' (°)	Typical Description
Bedrock - Limestone				Assumed impenetrable
Existing non-hazardous waste	11	5	28	Inert and similar non-reactive non-hazardous waste.
Mineral Liner - Steepwall	18	0	21.3	
Proposed non-hazardous waste	11	5	28	Inert and similar non-reactive non-hazardous waste.
Reinforced non-hazardous waste	11	0	24	Engineered waste in accordance with the Frisoli design
Vegetation Layer Steepwall				

*Shear strengths in parenthesis indicate post peak parameters

A summary of the geotechnical parameters used in the design and analysis of the development are presented in tabular form for each component of the site in Table 4-2.

Table 4-2
Geotechnical Design Parameters Capping Stability

Material	Unit Weight, γ (kN/m3)	Peak		Residual	
		Effective cohesion, c′ (kPa)	Angle of Shearing Resistance, ø' (°)	Effective cohesion, c′ (kPa)	Angle of Shearing Resistance, ø' (°)
Restoration soils	18	1	32	1	30
Interface Soils to Geogrid		0	34	0	34
Interface Granular to protection geotextile		0	29	0	24
Interface protection geotextile to geomembrane		6.7	26	3.6	13.1
Interface geomembrane to subgrade		1	31	1	25

4.4 Waste Mass Stability

A worst-case scenario has been considered in the stability risk assessment, this section of the landfill is located around the eastern and southern boundaries of Ghallis. The slope comprises, from the toe up, the steepwall

capping system constructed using waste reinforced with geogrids, a gently sloping plateau and benched waste slope with an overall gradient of 1V:3H, which rises to a maximum elevation of 82mAMSL.

The model considers partial saturation of the waste mass through the application of pore water ratio, r_u = 0.2, within the waste mass. For the worst-case scenario , i.e. during an earth quake, seismic loads have were applied both horizontally (0.035g) and vertically (0.018g) has been applied.

Analyses have been dealt with in terms of circular and non-circular 2-D limit equilibrium using the computer program Slope/W.

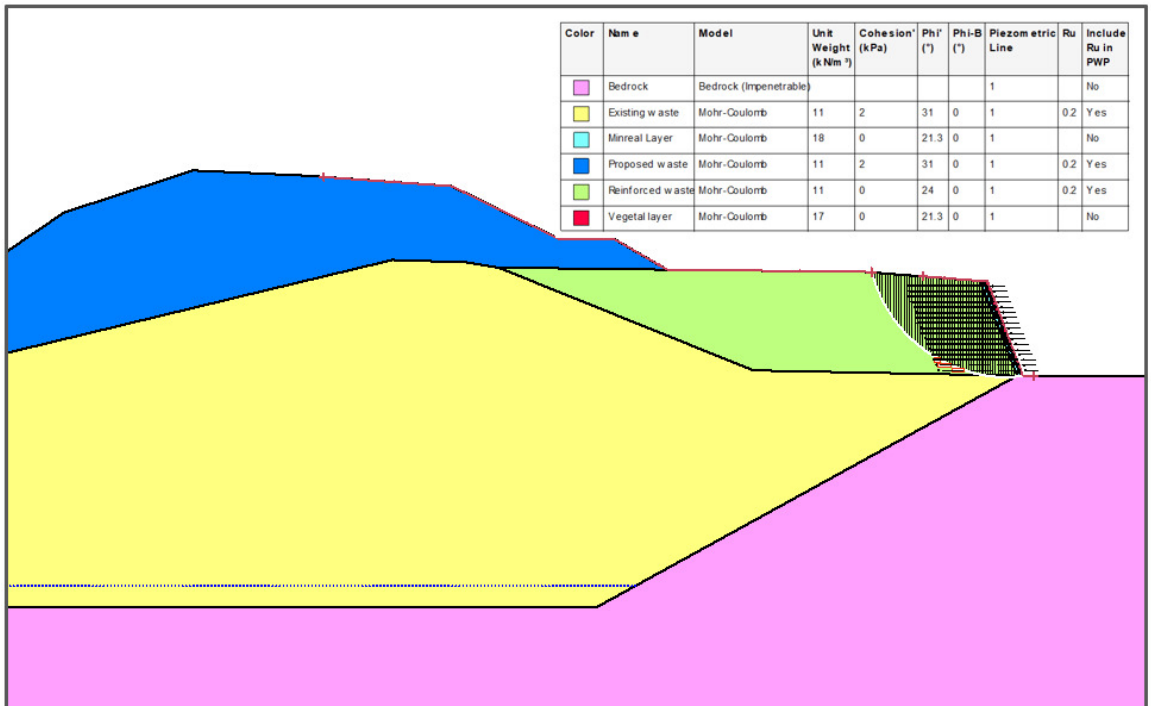


Figure 4-1
Section through the revised restoration levels indicating the critical slip plane

A sensitivity analysis was undertaken under normal conditions to establish the distance of the toe of the initial 1V:2H slope above the plateau from the crest of the reinforced waste slope, such that the stability of the steepwall is not affected by the placement of additional waste to achieve the revised restoration levels. The sensitivity analysis established that a stand-off of 35m would be required, the subsequent stability analyse allow for this stand-off.

A second analysis was then undertaken that considers the same geometry slope as above, however, this includes an earthquake loading.

The results from the analyses are presented within Table 4-3 below:

Table 4-3
Summary of Waste Mass Stability Analysis

Figure	Method	Factor of Safety	r_u	Horizontal Seismic load	Vertical Seismic load	Comments
SRA2-1	Drained Circular	1.259	0.2	0	0	Acceptable FoS
SRA2-2	Drained	1.124	0.2	0.035	0.018	Acceptable FoS

Figure	Method	Factor of Safety	r_u	Horizontal Seismic load	Vertical Seismic load	Comments
	Circular					

The stability assessment demonstrated that the waste slopes maintain an adequate factor of safety in all modelled conditions. Notwithstanding this, should a failure occur, the nature of the waste will result in a slow-moving slip. The waste mass will generally stay intact as a series of blocks, moving a relatively short distance and therefore will be remain within the confines of the site. However, a slip may allow perched leachate to be released, which will be intercepted by the surface water drainage system and fed to the pond adjacent to the entrance of the site off the coastal road. To mitigate the risk of potential release of contaminated water into the coastal environment, in the event of a slope failure discharges from the pond should be stopped immediately. Water quality testing should then be undertaken to demonstrate that the water meets the requirements of the site permit, prior to allowing water to discharge off site again. Should testing demonstrate that the water is contaminated then the pond should be pumped out and contaminated water treated.

4.5 Capping Stability Analysis

The proposed capping systems from the top down, comprise:

Geosynthetic Capping

- 300mm topsoil forming materials
- 700mm subsoil forming material
- Geogrid
- Geocomposite drainage / protection layer.
- 1mm double-textured geomembrane.
- 250mm waste regulation layer.

In considering the stability of the capping system, the methodology used considered the factor of safety at each of the geosynthetic interfaces within the slope profile. The analyses use a limit equilibrium method based on a passive wedge at the toe of the slope resisting an active wedge pushing down the slope. Figure 4-2 presents the forces acting on the passive and active wedges.

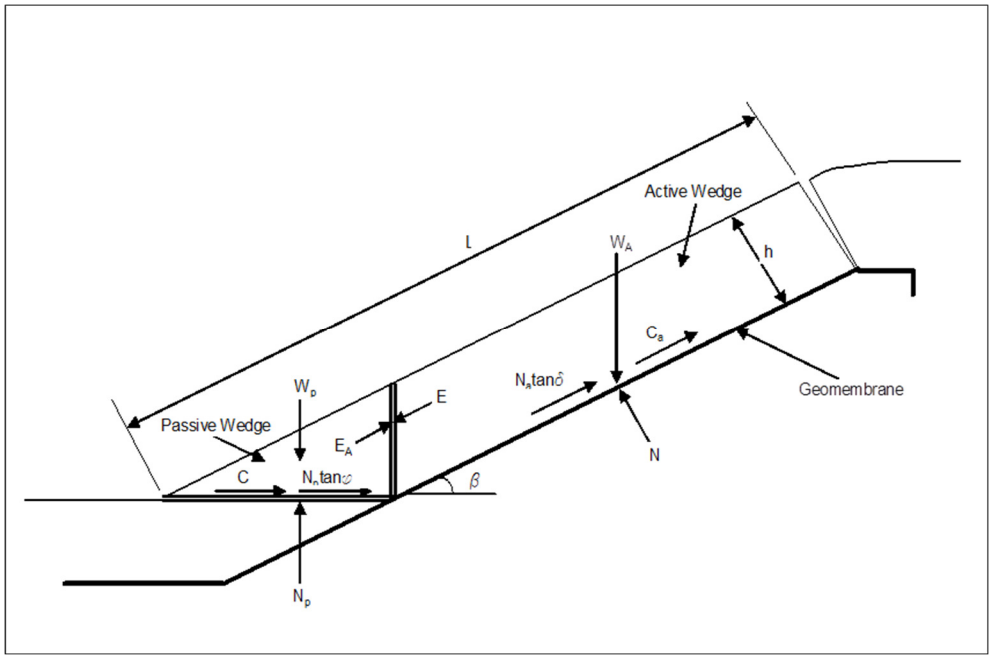


Figure 4-2
Schematic Section Showing Forces Acting on Active and Passive Wedges

By resolving the forces acting on the wedges, the factor of safety is calculated using the following quadratic equation:

$$aF^2+bF=c=0$$

where:

$$a = \frac{\gamma H L}{2} \sin^2(2\beta)$$

$$b = -[\gamma HL \cos^2\beta \tan\delta_u \sin(2\beta) + \alpha_u L\cos(2)\beta + \gamma HL\sin^2\beta \tan\phi \sin(2\beta) + 2cH \cos\beta + H^2 \tan\phi]$$

$$c= (\gamma HL \cos\beta \tan\delta_u + \alpha_u)(\tan\phi \sin\beta \sin(2\beta)$$

and

γ = unit weight,

H = thickness of cover soil,

L = slope length,

β = slope angle,

ϕ = angle of internal friction of cover soil,

c = cohesion of cover soil,

δ_u = interface friction angle at the upper interface,

α_u = apparent cohesion at upper interface

The method used also calculates tension within the geosynthetics elements by comparing the imbalance of forces between the upper and lower interfaces of a geosynthetic material, using the following equation:

$$T = \{(\alpha_u - \alpha_l) + \gamma H\cos\beta (\tan\delta_u - \tan\delta_l)] L$$

Where

α_l = interface friction angle at the lower surface

α_l = apparent cohesion at the lower interface

These equations are input into Microsoft Excel spreadsheets for processing.

Following a review of the proposed pre-settlement contours the pre-settlement waste slope – 10m high, 1V:2H (~25°) was identified for further consideration. The analysis undertaken demonstrates an acceptable factor of safety for 1V:2H inclination slopes (26.5°) for all 4 of the interfaces.

4.6 Monitoring

Based upon the Stability Risk Assessment, a simple risk-based monitoring scheme is considered appropriate for the future development of the landfill. The monitoring is limited to ensuring compliance with the tipping rules and monitoring of groundwater levels.

- Tip faces and surrounding areas should be inspected daily for signs of failure.
- No other specific monitoring is required for the waste other than to record waste elevations across the site.
- Monitoring during construction of the capping system will comprise construction quality assurance to ensure compliance with the construction specification.
- No additional instrumentation is deemed as being required during construction or post closure.

5.0 Proposed Revised Restoration Design

5.1 Restoration Profile

The proposed restoration profile is presented on Drawing No. 3 (Top of Waste) and Drawing 4 (top of Restoration), it has been developed based on the maximum waste depths calculated (Section 3) and the allowable slope geometry determined in the stability analysis (Section 4), as summarised below:

- Maximum depth from the top of restoration to base of landfill 84m;
- Maximum waste depth at leachate risers 66m;
- Benched profile with inter-bench slopes 10m high with a gradient of 1V in 2H and bench width of 10m, giving an overall gradient of 1V:3H; and
- Minimum offset from the crest of the Frisoli Steepwall Capping System of 35m.

In addition to this, the design has also been influenced by safety considerations for vehicles accessing the landfill to tip waste, namely:

- Area of the top plateau designed to allow for a safe working platform for vehicles to manoeuvre and tip waste at the top of the landfill;
- Access up to the top plateau has been included with a gradient of 1V in 10H; and
- Access roads have been modelled as 10m wide to allow a 7m wide carriageway for 2-way traffic and safety bund along the outside edge during operation of the landfill.

The restrictions on the geometry of the landfill has resulted in a maximum depth from the top of restoration to the base of the landfill of 66m.

The restoration levels indicated on the drawings are provided to give an indication as to how the maximum height of the landfill may be achieved using the constraints in respect of bench width, slope gradient and maximum height of steep capping system, as considered in the stability risk assessment. Ultimately the location of the benches may be altered in the final profile of the landfill for operational requirements, such as access for landfill traffic.

The waste void available due to the Frisoli design and the revised restoration profile, using the topographic survey from April 2020, are set out below:

- Frisoli Steep Wall Capping System: 365,000m^3
- Revised Restoration Profile: 1,022,000m^3
- Total Available 1,387,000m^3

The post-settlement contours are shown on Drawing No. 5, which are based on 20% settlement of the pre-settlement waste contours, which is industry standard for municipal solid waste. Drawing No. 6 presents a series of cross sections through the revised restoration scheme, outlining the current topography, basal levels, Frisoli steep wall system and the revised restoration profile, both pre and post settlement. Drawing No. 7 presents an isopachyte drawing of the waste thickness between the April 2020 topographic survey and the revised restoration profile.

Drawing No. 9 confirms that the maximum depth of the leachate risers occurs at LCP 8 which is 65.24m.

6.0 Final Cover System Design

The capping system forms the final component in the construction of a containment landfill and comprises the engineered cap and the restoration layer. The principal objectives of the final cover are to:

- Contain the waste;
- Manage leachate production by controlling the ingress of rain and surface water into the underlying waste;
- Prevent uncontrolled escape of landfill gas or the entry of air into the waste;
- Accommodate the environmental control measures; and
- Provide a physical separation between the waste and overlying restoration layer and ultimately the wider environment.

The geosynthetic capping system design has been developed in line with the capping design that was originally assumed for the hydrogeological risk assessment for Ghallis in 2004, which comprised 1000m restoration soils, geocomposite drainage layer, geomembrane, 300mm thick waste regulating layer. The following provides a description of each element of the capping system (from top down):

- **Restoration Soils:** In line with the Landfill Directive a 1000mm thick layer of soils and or soil-forming materials (comprising 300mm topsoil and 700mm subsoil) shall be sourced from onsite stockpiles, or shall be imported to site, to provide a growth medium to establish vegetation and therefore enable the planned after use to be achieved. Due to the gradient of the inter-bench slopes additional support to the soils in the form of geocells will be required, to prevent erosion until such time that vegetation has been able to establish a deep root system which will ultimately reinforce the soils in the long-term.
- **Geogrid layer:** Due to the gradient of the inter-bench slopes a geogrid reinforcing layer will be required to ensure the stability of the capping system. The geogrid provides an additional resistance to gravitational forces acting down the slope, due to its high tensile strength. The geogrid will be installed above the geocomposite drainage layer and will be anchored on each bench.
- **Geocomposite Drainage Layer:** The geocomposite drainage layer lies beneath the restoration soils and above the geomembrane cap. The objective of the layer is to facilitate the drainage of rainwater and surface water that percolate through the restoration layer. Draining the water away from the base of the restoration soils not only reduces the infiltration of water through the engineered cap but also improves stability.

  The directive requires a minimum 500mm thick layer of drainage material to be installed above the impermeable layer, however, it does not specify the permeability of the drainage material. It is accepted that the thickness of this layer may be reduced as long as the flow capacity of the drainage layer is capable of accommodating the volume of water infiltrating to the base of the restoration soils. The use of primary aggregates and the carbon footprint associated with truck movements is not considered best practise, hence a geocomposite drainage layer is proposed.

  To determine the required in plane flow capacity for the geocomposite drainage layer, the maximum discharge of seepage water at the toe of each inter-bench slope needs to be calculated.

  Malta has an arid climate with an annual rainfall of c.600mm, with the majority of rain falling in the winter months. Precipitation characteristically falls as heavy intense showers, rather than prolonged periods of light rain, leading to a high degree of runoff rather than infiltration. Based on rainfall data Preliminary Flood Risk Assessment for the Malta River Basin District, published by The Energy and Water Agency (2019) the intensity duration frequency curves are based on the equations below and are presented graphically in Figure 6-1.

- 5-years return period time $i = 21.58 \cdot t^{-0.667}$
- 50-years return period time $i = 36.53 \cdot t^{-0.667}$
- 200-years return period time $i = 45.21 \cdot t^{-0.667}$

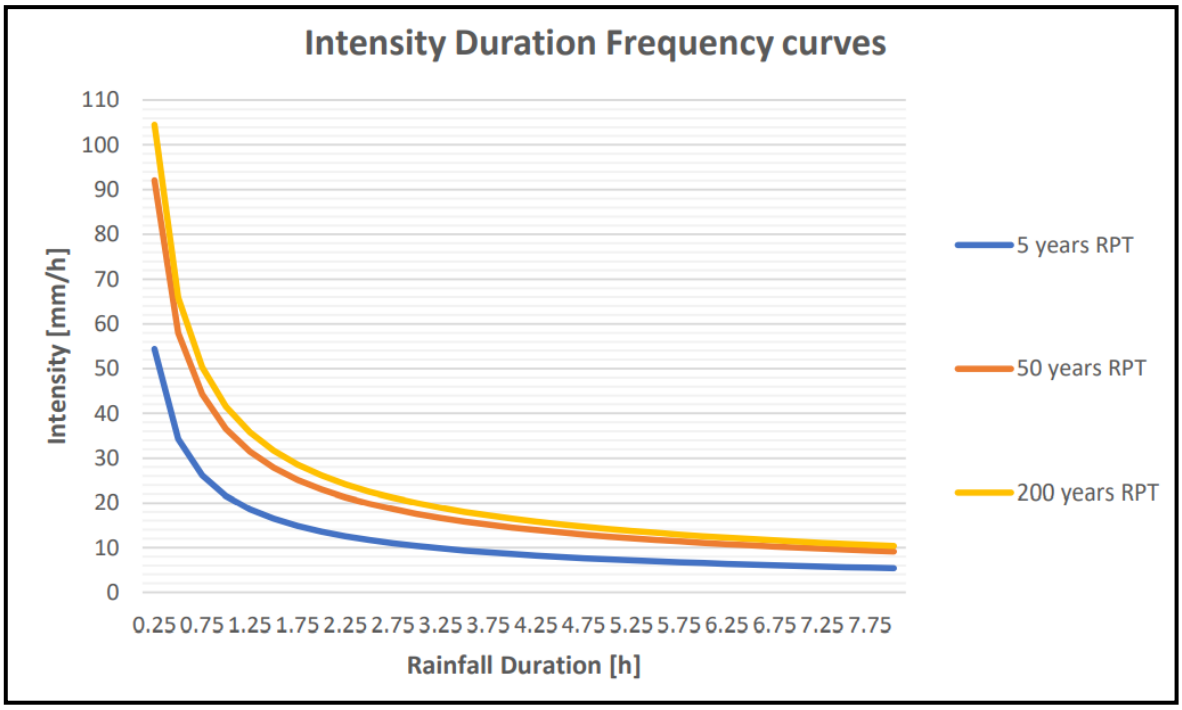


Figure 6-1 IDF Curves for the Malta RBD reproduced from Preliminary Flood Risk Assessment for the Malta River Basin District, published by The Energy and Water Agency (2019)

Based on the above, a 1 in 200-year storm event with a duration of 1 hour would result in a rainfall intensity of 45.2mm.

The nomograph presented in Figure 6-2 was used to estimate the run- off coefficient. Given the 1V in 2H (0.5) gradient of the inter bench slopes of the restored profile, semi vegetated surface and a sandy loam soil, a runoff rate of 0.5 would be considered conservative.

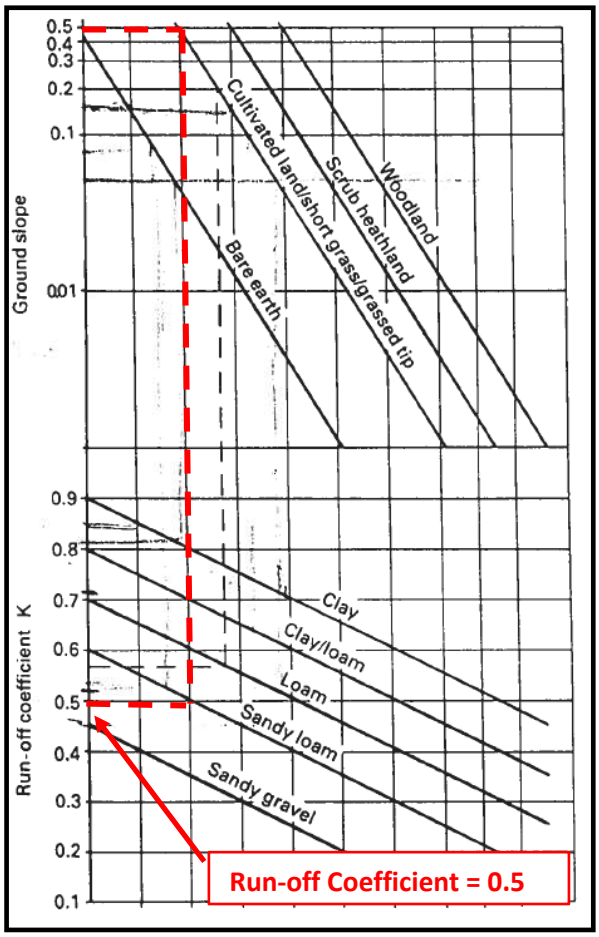


Figure 6-2: Nomogram to determine run-off coefficient (NCB (1982) "Water in the Coal Industry")

Assuming a worst-case scenario where all of the water that infiltrates the surface of the soil is able to drain to the base of the restoration soils, i.e. there is no unsaturated zone within the soils profile, the capacity of the drainage layer will need to be able to accommodate this volume of water.

Based on the worst-case scenario the longest section of slope between benches, i.e. a 10m high slope at a gradient of 1V in 2H, hence, the plan length of slope to be drained is 20m. The maximum required flow capacity of the drainage layer will be at the toe of the slope, where water drain into a piped system. Given the infiltration into the soils is 22.6mm (i.e. 0.5 x 45.2mm) over 1 hour, and assuming all water reports to the drainage layer, the required flow capacity at the toe of the slope will be 452l/hr (0.000125m^3/s).

When specifying a suitable geocomposite material, which is capable of achieving the required flow rate in the long term, a number if reduction factors must be applied to the in-plane flow capacity of the proposed product. The following equation (8.10) has been taken from R. M. Keoner "Designing With Geosynthetics" (1997):

$$q_{allow} = \frac{q_{ult}}{(RF_{IN} \times RF_{CR} \times RF_{CC} \times RF_{BC})}$$

Where

q_{allow} = allowable flow rate to be used in design

q_{ult} = ultimate flow rate (asdetermined by ASTM D4716) for the short term tests

RF_{IN} = reduection factor for elastic deformation of the drainage core itself

RF_{CR} = reduction factor for creep deformation of the drainage core

RF_{CC} = reduction factor for chemical clogging and/or precipitation of chemicals

RF_{BC} = reduction factor for biological clogging of the geotextile or within the drainage core

Reduction factors are taken from Table 8.5 of Keoner (1997), see below:

TABLE 8.5 RECOMMENDED REDUCTION FACTORS FOR eq(8.10) TO DETERMINE ALLOWABLE FLOW RATE OF DRAINAGE GEOCOMPOSITES (WICK DRAINS, SHEET DRAINS AND EDGE DRAINS)

Application Area	RF_{IN}	RF_{CR}	RF_{CC}	RF_{BC}
Sports fields	1.0 to 1.2	1.0 to 1.2	1.0 to 1.2	1.1 to 1.3
Capillary break	1.1 to 1.3	1.0 to 1.2	1.1 to 1.5	1.1 to 1.3
Roof and plaza decks	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2	1.1 to 1.3
Retaining walls, seeping rock and soil slopes	1.3 to 1.5	1.2 to 1.4		1.0 to 1.5
Drainage blankets	1.3 to 1.5	1.2 to 1.4	1.0 to 1.2	1.0 to 1.2
Surface water drains for landfill caps	1.3 to 1.5	1.2 to 1.4	1.0 to 1.2	1.2 to 1.5
Secondary leachate collection (landfill)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 2.0
Primary leachate collections (landfill)	1.5 to 2.0	1.4 to 2.0	1.5 to 2.0	1.5 to 10
Wick drains	1.5 to 2.5	1.0 to 2.0	1.0 to 1.2	1.0 to 1.2
Highway edge drains	1.2 to 1.8	1.5 to 3.0	1.1 to 5.0	1.0 to 1.2

Using the highest factors associated with surface water drains for landfill caps, indicated in red box, the minimum in plane flow requirement for the geocomposite drainage blanket can be calculated, as follows:

- $q_{ult} = (RF_{IN} \times RF_{CR} \times RF_{CC} \times RF_{BC}) \times q_{allow}$
- $q_{ult} = (1.5 \times 1.4 \times 1.2 \times 1.5) \times 0.000125$
- $q_{ult} = 3.78 \times 0.000125 = 0.0004725$ m³/s/m width

Assuming required Factor of Safety =2, then

- $q_{ult} = 0.0009450$ m³/s/m width
- $q_{ult} = 0.001$m³/s/m width or 1 l/s/m width

This value has been taken forward into Table 6-1 of the Specification presented in Appendix 05.

- **Capping Layer:** The capping layer provides a low permeability barrier controlling both the generation of leachate by minimising the infiltration of water and uncontrolled release of landfill gases. In the absence of suitable low permeability soils the capping layer over the waste will be formed by a geomembrane, manufactured from Linear Low Density PolyEthylene (LLDPE). LLDPE is considered to be the most appropriate material for capping as it has a better stress crack resistance and is more flexible than a High Density PolyEthylene (HDPE). In addition to this LLDPE geomembranes are not susceptible to desiccation and root penetration, as is the case for low permeability soil layers, allowing a reduction in the thickness of the restoration soils. The geomembrane cap will tie into the basal geomembrane liner around the perimeter of the landfill.

- **Waste Regulating Layer:** A minimum 250mm thick layer of soils will be placed to provide a firm even surface over the waste fill upon which to install the barrier layer. The regulating layer will comprise soils excavated from onsite sources or stockpiles of imported soils.
- **Landfill Gas:** The landfill gas management system shall comprise a series of deep gas extraction wells located on a nominally 40m grid, allowing well locations to be moved to suit actual conditions on site at the time of installation. The wells are connected to manifolds via using small-bore connecting pipes (typically 63mm or 90mm diameter), which connects into two ring mains, high and low percentage methane land gas. A system of valves allows the extraction of gas from to be managed, enabling wells to connect into either high or low gas ring main, or alternatively be turned off.

A Specification and CQA Plan for the construction of the capping system are presented in Appendix B and C, respectively. It should be noted that the specification only covers the construction of the capping system to the benched profile of the landfill and does not relate to the construction of the Frisoli Steepwall cap design.

Typical construction details for the proposed capping design and the layout of the landfill gas management system are presented on Drawing No. 8. The construction details and gas management system layout are presented to present the conceptual design and will need to be confirmed as part of the detailed design process, as conditions on site may alter in the future.

APPENDIX 01

Details of materials used in basal lining system

Annex 1: Summary of materials used in the construction of Ghallis Landfill

Cell / Phase	GCL		HDPE Geomembrane		Geotextile Protector		Leachate Collection		
	Manufacturer	Product Name	Manufacturer	Type	Manufacturer	Product Name	Drainage Material		
							Supplier	Size	Layer Thickness
Phase 1A	CETCO	AS100	Agru	2mm Double Textured	Polyfelt/Tencate	XP 1000	Local	10-20mm	500mm
Phase 1A Extension	WasteServ	Maccaferri	Agru	2mm Double Textured	Polyfelt/Tencate	XP 1000			
Phase 1B	CETCO	NSP 4900	Agru	2mm Double Textured	Polyfelt/Tencate	XP 1000	Local	10-20mm	500mm
Phase 1B Basal Extension	CETCO	Bentomat AS100	Agru	2mm Double Textured	Polyfelt/Tencate	XP 1000	Local	10-20mm	500mm
Phase 2A	WasteServ	Maccaferri	Agru	2mm Double Textured	Polyfelt/Tencate	XP 1000			
Phase 2B	WasteServ	Maccaferri	Agru	2mm Double Textured	Polyfelt/Tencate	XP 1000	Local	10-20mm	500mm
Phase 5A	CETCO	Bentomat AS4500 / AS4600	Agru NAUE	2mm Textured (side slope) 2mm Smooth	Manifattura Fontana Polyfelt/Tencate	Drefon S 1000 XP 1000	Local	10-20mm	500mm
Phase 5B	NAUE	Bentofix NSP4900	NAUE	2mm Textured	NAUE	SECUTEX R1201	Local	10-20mm	500mm
Phase 5C	Laviosa Modulo	Geoben XP5/330	NAUE / Atarfil	2mm Textured	Manifattura Fontana	Drefon S 1200	Local	10-20mm	500mm
Phase 5D	CETCO	Bentomat AS5000	Agru	2mm Textured	Polyfelt/Tencate	XP 1000	Local	10-20mm	500mm
Phase 6A	CETCO	BENTOMAT AS 5000-1	Agru	2mm Textured	Polyfelt/Tencate	XP 1000	Local	10-20mm	500mm
Phase 6B	NAUE	Bentofix NSP4900	NAUE	2mm Textured	NAUE	SECUTEX R1201	Local	10-20mm	500mm
Cell 7	GEOMAS	Bentoshield 5000 SS	Atarfil	2mm Textured	GEOFabrics	HPS12	Local	10-20mm	500mm
Cell 8	THRACE	Euroben 4700	NAUE	2mm Textured	VIGANO PAVITEX	TECNOGEO F65	Local	10-20mm	500mm
Cell 9	GEOMAS	Bentoshield 5500 AS	Atarfil	2mm Double Textured	ATARFIL	GTX NWH 1000	Local	10-20mm	500mm

APPENDIX 02

Grading analysis of leachate drainage stone

solidbase LABORATORY LTD.

TEST REPORT

Wasteserv Malta Ltd
Phoenix Building
Old Railway Track
Santa Venera HMR 16
Tel: 23858000
Fax: 21441930
Attn: Mr Charles Zerafa

Date: 4 April 2013

Job No: J042

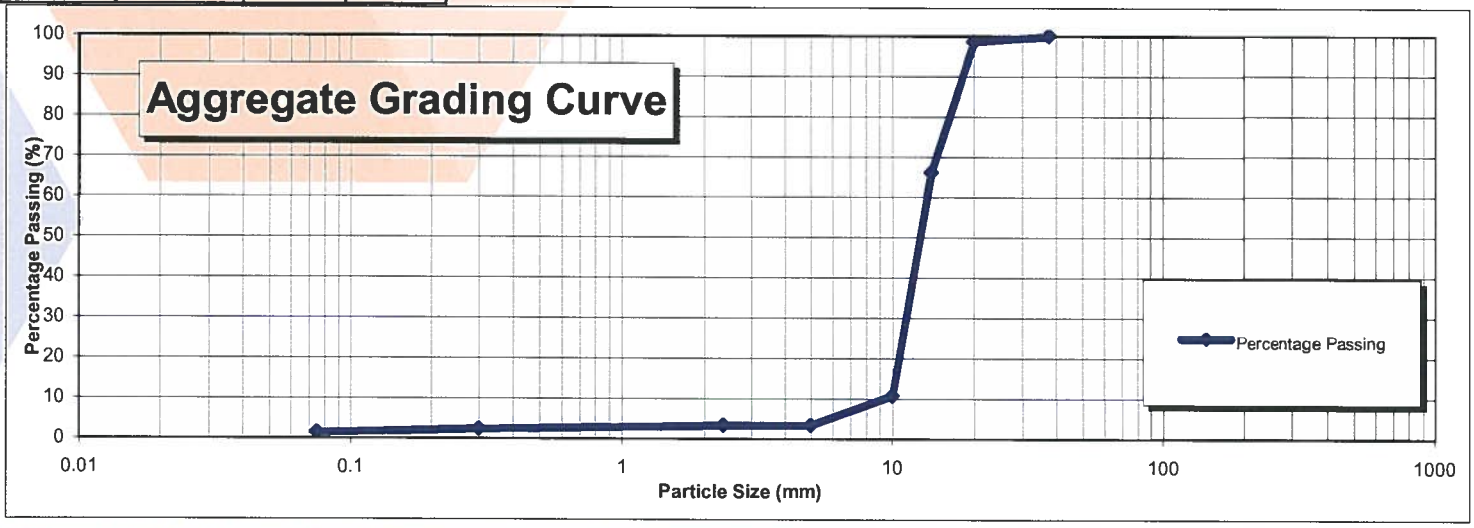
10% Fines Value, Silt content, Moisture content & Grading

Client	Location of sampling		Aggregate type	
Wasteserv Malta Ltd	**As Supplied, Sample 1**		**Aggregate mix**	
Date received	Source	Sampled by	Date test completed	Tested by
26/03/2013	**Supplier 1**	**Client**	**02/04/2013**	**S.Mangion**

Sample No	**A13/0004**

Sieve Size mm	Percentage Passing	Overall Limits Lower	Overall Limits Upper
37.5	100		
20.0	99		
14.0	66		
10.0	11		
5.00	3		
2.36	3		
0.300	2		
0.075	1		

Type of test	Result
Moisture content %	0.3
Silt Content %	1.4
10% Fines Value kN	86.8



Description of material: **A mixture 10-20mm aggregate & little sand.**
Comments: **None**

Report No : **170**

Kenneth Spiteri
Laboratory Manager

solidbase LABORATORY LTD.

TEST REPORT

Wasteserv Malta Ltd
Phoenix Building
Old Railway Track
Santa Venera HMR 16
Tel: 23858000
Fax: 21441930
Attn: Mr Charles Zerafa

Date: 4 April 2013

Job No: J042

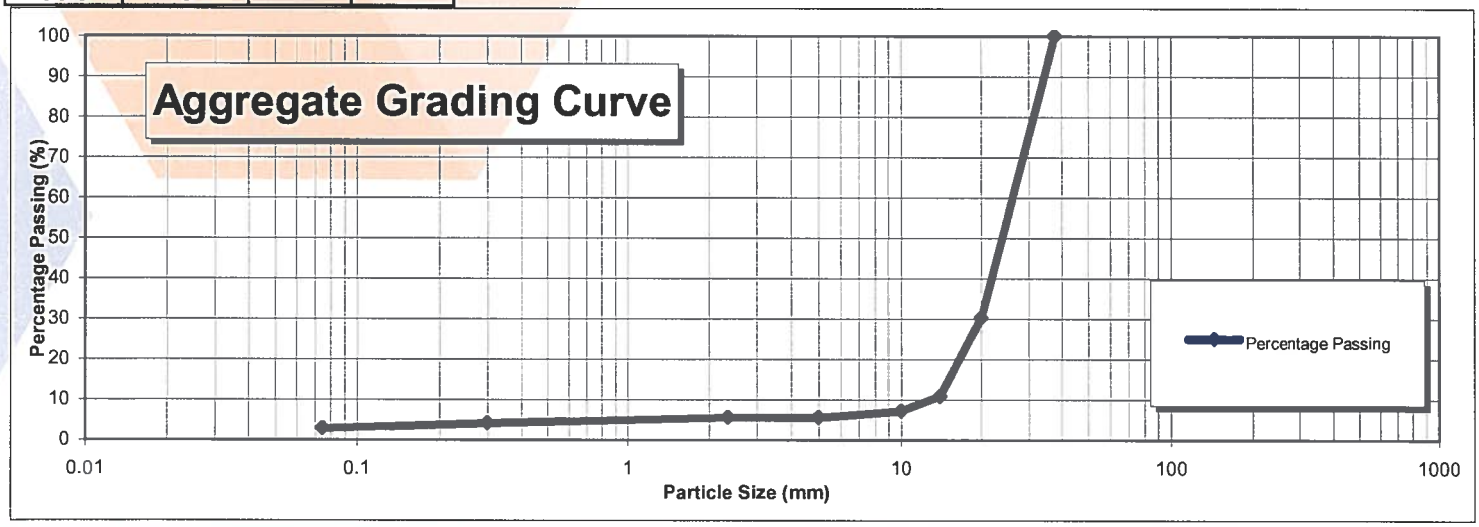
10% Fines Value, Silt content, Moisture content & Grading

Client	Location of sampling		Aggregate type	
Wasteserv Malta Ltd	**As Supplied, Sample 2**		**Aggregate mix**	
Date received	Source	Sampled by	Date test completed	Tested by
26/03/2013	**Supplier 2**	**Client**	**02/04/2013**	**S.Mangion**

Sample No	**A13/0005**

Sieve Size mm	Percentage Passing	Overall Limits Lower	Overall Limits Upper
37.5	100		
20.0	30		
14.0	11		
10.0	7		
5.00	6		
2.36	6		
0.300	4		
0.075	3		

Type of test	Result
Moisture content %	1.6
Silt Content %	2.5
10% Fines Value kN	49.6*



Description of material: **A mixture of 10 to 37.5mm aggregate & 6% sand.**
Comments: *** 10% Fines value was conducted on a non standard size 28/20mm sieve due to aggregate size.**

Report No : **171**

Kenneth Spiteri
Laboratory Manager

solidbase LABORATORY LTD.

TEST REPORT

Wasteserv Malta Ltd
Phoenix Building
Old Railway Track
Santa Venera HMR 16
Tel: 23858000
Fax: 21441930
Attn: Mr Charles Zerafa

Date: 4 April 2013

Job No: J042

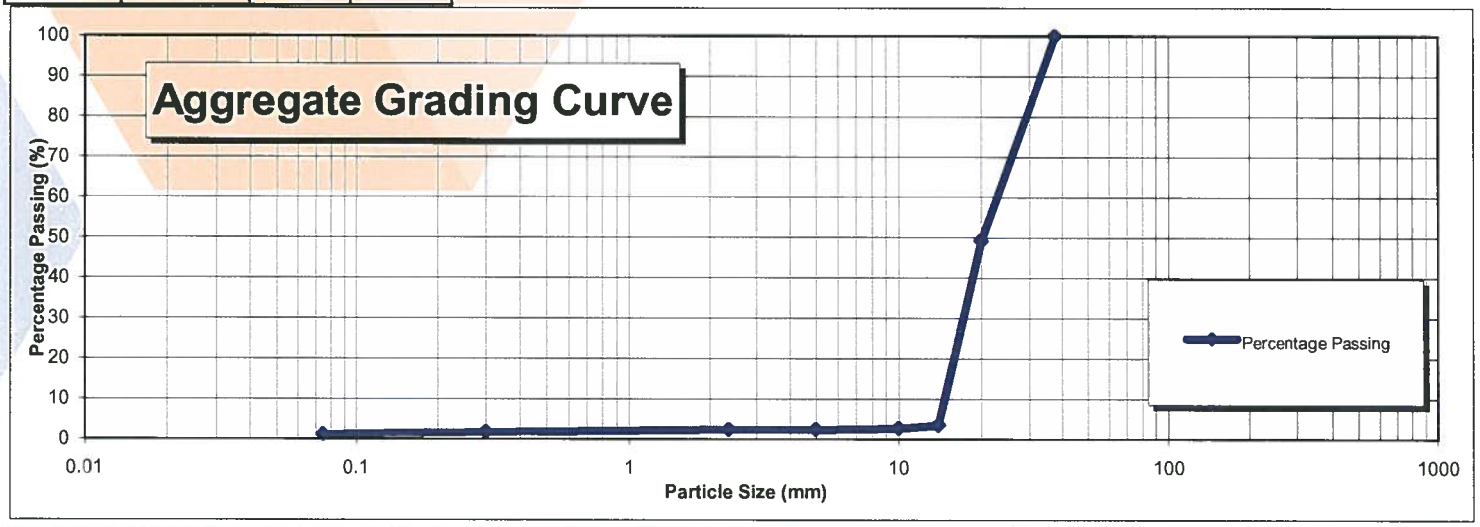
10% Fines Value, Silt content, Moisture content & Grading

Client	Location of sampling		Aggregate type	
Wasteserv Malta Ltd	**As Supplied, Sample 3**		**Aggregate mix**	
Date received	Source	Sampled by	Date test completed	Tested by
26/03/2013	**Supplier 3**	**Client**	**02/04/2013**	**S.Mangion**

Sample No	**A13/0006**

Sieve Size mm	Percentage Passing	Overall Limits Lower	Overall Limits Upper
37.5	100		
20.0	49		
14.0	3		
10.0	3		
5.00	2		
2.36	2		
0.300	2		
0.075	1		

Type of test	Result
Moisture content %	2.6
Silt Content %	1.1
10% Fines Value kN	64.8*



Description of material: **A mixture of 14 to 37.5mm aggregate & 6% sand.**
Comments: *** 10% Fines value was conducted on a non standard size 28/20mm sieve due to aggregate size.**

Report No : **172**

Kenneth Spiteri
Laboratory Manager

APPENDIX 03

Assessment of maximum height of leachate extraction risers

Calculations For Riser Stability 4m x 4m reinforced Concrete Pad

Coefficient of Earth Pressure at Rest, Ko = 0.4

Angle of Friction Pipe to Waste = 20 tan 20 = 0.3639702

Internal Diameter of concrete Shaft =	1.4 m	Radius =	0.7 m	Area =	1.54 m^2
External Diamter of Concrete Shaft =	1.7 m	Radius =	0.85 m	Area =	2.27 m^2

Total Area of Concrete =	0.73 m^2	Mass per m of Concrete =	17.20 KN

Width of Concrete pad =	4 m	4 m	4 m	4 m
Length of Concrete Pad =	4 m	4 m	4 m	4 m
Depth of Concrete Pad =	0.3 m	0.3 m	0.3 m	0.3 m
Waste - Gravel & Concrete (X - Y) =	84 m	74 m	70 m	66 m
Undrained Shear Strength (Su) =	300 KN	300 KN	300 KN	300 KN
				0
Load per m of Riser =	17.20 KN/m	17.20 KN/m	17.20 KN/m	17.20 KN/m
Total Load at Base of Riser =	1444.55 KN	1272.58 KN	1203.79 KN	1135.00 KN
Density of Waste =	11.60 KN/m3	11.60 KN/m3	11.60 KN/m3	11.60 KN/m3
Verical Stress at Base of Shaft =	974.40 KN/m2	858.40 KN/m2	812.00 KN/m2	765.60 KN/m2
Horizontal Pressure on Pipe =	141.86 KN/m2	124.97 KN/m2	118.22 KN/m2	111.46 KN/m2
Total Skin Friction =	31804.68 KN	24682.88 KN	22086.58 KN	19634.52 KN
Area at the Base of Landfill =	16.00 m2	16.00 m2	16.00 m2	16.00 m2
Total Load =	46629.05 KN	37742.45 KN	34440.23 KN	31282.24 KN
Bearing Stress Load distribution =	2914.32 KN/m2	2358.90 KN/m2	2152.51 KN/m2	1955.14 KN/m2
Factor of Safety =	0.97	1.26	1.41	1.58

APPENDIX 04

Stability Risk Assessment

GHALLIS LANDFILL

REVISED RESTORATION LEVELS

Stability Risk Assessment

Prepared for: W**asteServ Malta**

SLR Ref: 403.00585.00035
Version No: 1
July 2020

BASIS OF REPORT

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CONTENTS

DOCUMENT REFERENCES

TABLES

APPENDICES

1.0 Introduction

SLR Consulting Limited (SLR) has been retained by Wasteserv Malta (Wasteserv) to prepare a revised restoration scheme for Ghallis landfill, located within the Maghtab waste management complex (the site).

As part of the preparing the revised scheme, SLR has undertaken a Geotechnical Stability Risk Assessment (SRA). This document describes the manner in which the assessment has been carried out and presents the overall findings of the work.

The methodology adopted for this Stability Risk Assessment generally follows the principles outlined in the Environment Agency R&D Technical Report P-385, volumes TR1 and TR2[1] (from here on referred to as the guidance). Where additional analytical techniques have been used, these are described within the text.

1.1 Conceptual Stability Site Model

The conceptual stability site model has been developed from information contained in the Frisoli Stability Risk Assessment[2] and review of relevant publicly available and site specific data.

The site has been developed through the construction of engineered cells, formed within a former limestone excavation. The existing restoration contours allow for the placement of waste to a maximum height of 65m aOD (above Ordnance Datum).

To increase the capacity of the landfill, an alternative scheme was developed by Frisoli, which involves the use of compacted waste, and engineered geogrid reinforcement to form a restraining structure to allow waste to be placed an inclination of 70°.

The SRA considers the global stability of the existing waste mass including the reinforced waste once the overall restoration levels are increased through the importation of inert and non-reactive non-hazardous waste to a maximum height of 82m AMSL.

The assessment has allowed for a stand-off from where the reinforced waste has been constructed to ensure that no additional load is placed on to this structure which could reduce the stability of the waste mass in this area.

The following sections provide further details of the principal components of the landfill development.

1.1.1 Basal Subgrade Model

The basal subgrade of Ghallis landfill is formed of in-situ limestone at the base of former limestone extraction.

1.1.2 Side Slope Subgrade Model

The basal subgrade of Ghallis landfill is formed of in-situ limestone at the base of former limestone extraction.

1.1.3 Basal Lining System Model

The basal geological lining system at Ghallis has been fully developed and is understood to typically comprise (from the top down):

- 500mm sand protection layer;
- geotextile protector;

[1] Environment Agency R&D Technical Report P1-385/ TR1 and TR2, 'Stability of Landfill Liner Systems', March 2003.
[2] Frisoli stability Risk Assessment

- textured HDPE geomembrane;
- Geosynthetic Clay Liner (GCL); and
- geological barrier (maximum permeability $1x10^{-9}$m/s)

1.1.4 Side Slope Lining System Model

The side slope lining system model is complete across the footprint of the site and comprises the same materials as the basal lining system.

1.1.5 Waste Mass Model

The site will be continued to be developed on the principle of engineered containment and is permitted to receive non-hazardous municipal, commercial and industrial wastes, together with inert wastes.

The design for temporary waste slopes has assumed a maximum inclination of 1V:2H.

Above the rim of the void, the waste shall be placed in line with the revised pre-settlement restoration contours to a maximum elevation of 82mAMSL at a maximum gradient of 1V:3H.

1.1.6 Capping System Model

The capping system is understood to comprise, from the top down:

- 1000mm restoration soils (comprising 300mm topsoil and 700mm subsoil)
- Geogrid
- Geocomposite drainage / protection layer.
- 1mm double-textured geomembrane.
- 250mm waste regulation layer.

The capping system will be placed against the maximum inclination pre-settlement waste slopes as discussed in Section 1.1.5 above.

2.0 STABILITY RISK ASSESSMENT

Each of the six principal components of the conceptual stability site model has been considered and the various elements of that component have been assessed with regard to stability.

The principal components considered are:

- The basal subgrade.
- The side slope subgrade.
- The basal geological barrier.
- The side slope geological barrier.
- The waste.
- The capping system.

2.1 Risk Screening

Issues relating to stability and integrity for each principal component of the proposed development have been subject to a preliminary review to determine the need to undertake further detailed geotechnical analyses. The following sections present the results of this screening exercise.

2.1.1 Basal Subgrade Screening

The base of the site is formed of the in-situ chalk formation at an elevation of between 115m and 130m AOD.

Table 2-1
Stability Components for Basal Subgrade

Excessive Deformation	Compressible subgrade	The basal subgrade is formed by the in-situ limestone. The limestone is considered effectively incompressible under the limited weight imparted by the waste mass. This does not require further consideration.
	Basal heave	Historic groundwater monitoring data indicates that groundwater is located below the basal levels of the landfill and is not confined by any impermeable strata therefore this component does not require further consideration.
	Cavities in subgrade	It is possible that cavities will exist within the limestone formation; but any cavities would have been observed and recorded during the development of the landfill but there are no evidence of this. This does not require further consideration
Filling on Waste	Compressible waste	Not applicable.
	Cavities in waste	Not applicable.

Given the foregoing, it is considered that the basal subgrade system does not require further assessment.

2.1.2 Side Slope Subgrade Screening

The controlling factors that will affect the stability and deformability of the side slope subgrade are detailed in Table 2-2 below.

Table 2-2
Stability/Integrity Components of Side Slope Subgrade

Cut slope	Rock	Stability	The side slope subgrade is formed by the in-situ limestone. The limestone is considered effectively incompressible under the limited weight imparted by the waste mass. This does not require further consideration.
		Cavities in subgrade	It is possible that cavities will exist within the limestone formation; but any cavities would have been observed and recorded during the development of the landfill but there isn't any evidence of this. This does not require further consideration
		Deformability	The side slope subgrade is formed by the in-situ limestone. The limestone is considered effectively incompressible under the limited weight imparted by the waste mass. This does not require further consideration.
	Cohesive soils	Stability	Not applicable
		Deformability	Not applicable
		Time dependent stability	Not applicable.
		Groundwater	Not applicable
	Granular soils	Stability	Not applicable
		Deformability	Not applicable
		Groundwater	Not applicable
Fill Slope	Cohesive soils	Stability	Not applicable.
		Time dependent stability	Not applicable.
		Groundwater	Not applicable.
	Granular soils	Stability	Not applicable.
		Deformability	Not applicable.
		Groundwater	Not applicable.

Given the foregoing, it is considered that the side slope subgrade does not require further assessment.

2.1.3 Basal Lining System Screening

The controlling factors that influence the stability and integrity of the basal geological barrier system are given in Table 2-3 below.

Table 2-3
Stability/Integrity Components of Basal Lining System

Mineral only	Stability and Integrity	The basal geological barrier system comprises engineered low permeability material. In terms of potential for movements along the basal geological barrier, the increase in the restoration levels of the site will result in the generation of temporary waste slopes. However, as the additional waste placement is taking place above the previously placed waste and which is above the crest of the side-slope, the presence of temporary slopes cannot result in instability within the waste and the along basal geological barrier system. This component does not require further consideration.
	Compressible subgrade	The basal geological barrier comprises engineered low permeability material which is considered to be effectively incompressible under the stresses imposed by the waste height proposed. This component does not require further consideration.
	Cavities	It is possible that cavities will exist within the limestone formation; but any cavities would have been observed and recorded during the development of the landfill but there isn't any evidence of this. This does not require further consideration.
	Basal heave	Historic groundwater monitoring data indicates that groundwater is located below the basal levels of the landfill and is not confined by any impermeable strata therefore this component does not require further consideration.
Geosynthetic / clay geological barrier	Stability and Integrity	Stability of the leachate collection system and the integrity of the lining system are addressed in Design Report[3]
	Compressible subgrade	Not applicable.
	Cavities	Not applicable.
	Basal heave	Not applicable.

Given the foregoing, it is considered that the basal geological barrier does not require further assessment.

2.1.4 Side Slope Lining System Screening

The controlling factors that influence the stability and integrity of the side slope geological barrier system are given in Table 2-4 below.

[3] SLR Consulting Ltd. "Ghallis Landfill – Revised Restoration Design Report" File Ref 200904 403.00585.00035 Restoration Report, Sept 2020

Table 2-4
Stability/Integrity Components of Side Slope Lining System

Unconfined	Mineral only	Stability	The future filling will take place above the crest of the side slope and therefore this does not require further consideration.
		Integrity	The future filling will take place above the crest of the side slope and therefore this does not require further consideration.
	Geosynthetic / mineral	Stability	The future filling will take place above the crest of the side slope and therefore this does not require further consideration.
		Integrity	The future filling will take place above the crest of the side slope and therefore this does not require further consideration.
Confined	Mineral only	Stability	The future filling will take place above the crest of the side slope and therefore this does not require further consideration.
		Integrity	The future filling will take place above the crest of the side slope and therefore this does not require further consideration.
	Geosynthetic / mineral	Stability	The future filling will take place above the crest of the side slope and therefore this does not require further consideration.
		Integrity	The future filling will take place above the crest of the side slope and therefore this does not require further consideration.

2.1.5 Waste Mass Screening

The controlling factors that influence the stability of the waste mass are presented in Table 2-5 below.

Table 2-5
Stability Components of Waste Slopes

Failure wholly in waste	Stability		Inert and non-reactive non-hazardous waste will be placed in phases. Temporary waste slopes will be generated through progressive filling. Temporary waste slopes will require further assessment.
Failure involving lining system and waste	Mineral only	Stability	The future filling will take place above the crest of the side slope and therefore this does not require further consideration.
		Integrity	The future filling will take place above the crest of the side slope and therefore this does not require further consideration.

	Geosynthetic / Mineral	Stability	The future filling will take place above the crest of the side slope and therefore this does not require further consideration.
		Integrity	The future filling will take place above the crest of the side slope and therefore this does not require further consideration.

Given the foregoing, it is considered that the waste mass requires further assessment.

Leachate Collection System

Leachate recirculation will only be undertaken within capped and restored phases of the site. No leachate recirculation will be undertaken in active phases of the landfill.

Leachate extraction will be via vertical and/or side slope risers that will be extended as waste levels increase.

Gas Collection System

Active gas extraction will be provided by gas extraction wells installed within the waste mass and connected to gas carrier mains. The effectiveness of the extraction system will be affected by differential settlement of the waste leading to low spots along the gas carrier mains across previously filled areas. These low spots can lead to collection of condensate which in turn will lead to blockages in the collection system.

To minimise the effect of waste settlement on the effectiveness of the gas collection system, gas extraction mains will be installed to suitable gradients across filled areas and condensate sumps will be installed at strategic locations. These measures will ensure that the effectiveness of the collection system will not be affected by settlement of the waste mass.

2.1.6 Capping System Screening

The controlling factors that influence the stability of the capping system are presented in Table 2-5 below.

Table 2-6
Stability Components of Capping System

Mineral Cap	Stability	Pre-settlement slope gradient	Not applicable
	Integrity	Compressible waste	Not applicable
		Slope deformation	Not applicable
		Construction	Not applicable
		Cavities in waste	Not applicable
	Stability	Pre-settlement slope gradient	Stability of the proposed capping lining system on the pre-settlement slopes requires assessment.
		Compressible waste	No external factors will be present to cause anything other than deformations normally associated with waste settlement. Further investigation is not considered to be required.

		Slope deformation	No external factors will be present to cause anything other than deformations normally associated with waste settlement. This aspect is therefore not considered to require further assessment.
		Construction	The potential effects of construction plant activity on the cap during placement of restoration soils should be considered as geosynthetics are to be used in the capping system.
		Cavities in waste	It is proposed that the final waste surface be graded and inspected prior to placement of the regulation layer. This practice will eliminate the potential for near-surface cavities to be present, and this issue does not therefore require further assessment.

2.2 Lifecycle Phases

This aspect of the assessment identifies the critical phases during the development of the site.

To ensure the Stability Risk Assessment fully addresses the key issues throughout the life of the landfill, the following lifecycle phases are considered:

- The condition during waste filling when temporary waste slopes are formed.
- The end-of-filling condition when the capping system is placed upon the pre-settled waste slopes.

To ensure the SRA fully addresses the key issues throughout the life of the site, the temporary waste slope stability and capping stability are considered.

2.3 Data Summary

The following data are required as input for the analyses undertaken for this Stability Risk Assessment

- Material unit weight.
- Drained and undrained shear strength of soils and waste.

Previous site investigations have been completed at the site. However, it is not considered that direct measurement of geotechnical parameters applicable to this assessment has been undertaken. As no direct measurements of geotechnical properties are available, reference has been made to the borehole logs, published data and relevant experience from within SLR in the same or similar materials. The geotechnical parameter values adopted are discussed in more detail in Section 2.6.

2.4 Selection of Appropriate Factors of Safety

The factor of safety is the numerical expression of the degree of confidence that exists, for a given set of conditions, against a particular failure mechanism occurring. It is commonly expressed as the ratio of the load or action which would cause failure against the actual load or actions likely to be applied during service. This is

readily determined by limit equilibrium slope stability analyses, which are the only type of analyses required for the current study.

Prior to determining appropriate factors of safety for the various components of the model, it is necessary to identify key 'receptors' and evaluate the consequences in the event of a failure (relating to both stability and integrity). Consideration of the following receptors is required:

- Groundwater
- Property - relating to site infrastructure, third party property
- Human beings (i.e. direct risk)

The factor of safety adopted for each component of the model would be related to the consequences of a failure.

2.4.1 Factor of Safety for Basal Subgrade

An assessment is not required on this component as it has been screened out in Section 2.1.1.

2.4.2 Factor of Safety for Side Slope Subgrade

An assessment is not required on this component as it has been screened out in Section 2.1.2.

2.4.3 Factor of Safety for Basal Lining System

An assessment is not required on this component as it has been screened out in Section 2.1.3.

2.4.4 Factor of Safety for Side Slope Lining System

An assessment is not required on this component as it has been screened out in Section 2.1.3.

2.4.5 Factor of Safety for Waste Mass

There are no waste shear strength parameters available in the published guidance, therefore effective stress shear strength parameters have been used, based on the likely materials accepted at the site. In this case a factor of safety of 1.3 is considered appropriate when adopting peak shear strength parameters under normal loading conditions i.e. no earthquake loading. When considering the worst-case scenario and applying a seismic load to allow for the additional loading imparted during an earthquake event a Factor of Safety in excess of 1.1 is considered appropriate.

2.4.6 Factor of Safety for Capping System

A minimum factor of safety of 1.3 is considered appropriate and has been adopted where peak shear strength conditions are applied for the pre-settlement slopes. A factor of safety greater than unity is considered appropriate where residual shear strengths are applied.

2.5 Justification for Modelling Approach and Software

In order to perform a comprehensive Stability Risk Assessment, the components of the site development, as previously described in Section 1.2 of this document, must be considered not only individually but also in conjunction with one another where relevant. Any analytical techniques adopted for such an assessment should adequately represent all the considered scenarios, i.e. the different modelled phases of the lifecycle, for both confined and unconfined conditions (where appropriate). The methodology and the software should also achieve the desired output parameters for the assessment, e.g. determination of limit equilibrium factor of safety or calculation of strains within geological barrier components.

The analytical methods used in this Stability Risk Assessment include:

- Limit equilibrium stability analyses for the derivation of factors of safety for the side slope geological barrier and temporary waste slopes.
- Closed-form analyses for the capping liner stability and integrity analyses.

The limit equilibrium analyses have been undertaken using the package Slope/W 2018, version 9.1.0 (Geo-Slope International). The Morgenstern-Price[4] non-circular methods of analysis have been used.

The capping stability assessment was undertaken using the methods proposed by Jones and Dixon5. The equations developed by these authors were input into Microsoft Excel spreadsheets for processing.

2.6 Justification of Geotechnical Parameters Selected for Analysis

The following sections present a justification for the various parameters used in the stability analyses based on the following criteria:

- An assessment of the suitability of non-site-specific data, where used;
- Methods for the derivation of the parameters adopted.

A summary of the geotechnical parameters used in the design and analysis of the development are presented in tabular form for each component of the site in In summary, the geotechnical parameters selected for the waste mass stability analysis are presented in Table 2-7.

Table 2-7.

The parameters used in the analysis have been:

- Adapted from similar work undertaken by SLR;
- Inferred from site specific data or other relevant published data.

It should be noted that the geotechnical parameters for limit equilibrium analysis include the shear strength and unit weight of each material within the model, plus pore water or gas pressure assumptions. Shear strength has been defined using total or undrained (s_u), and effective shear strength parameters of cohesion, (c′), and the angle of shearing resistance, (ø′).

2.6.1 Parameters Selected for Basal Subgrade Analysis

Analysis of the basal subgrade is not necessary as it has been screened out in Section 2.1.1.

2.6.2 Parameters Selected for Side Slopes Subgrade Analysis

Analysis of the Side Slope subgrade is not necessary as it has been screened out in Section 2.1.2.

2.6.3 Parameters Selected for Basal Lining System Analysis

Analysis of the Side Slope subgrade is not necessary as it has been screened out in Section 2.1.3.

2.6.4 Parameters Selected for Side Slope Lining System Analyses

Analysis of the Side Slope subgrade is not necessary as it has been screened out in Section 2.1.4.

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[4] Morgenstern, N.R and Price, V.E. (1965), 'The analysis of stability of general slip surfaces' Geotechnique.

5 Jones, D.R.V. & Dixon, N, 'The stability of geosynthetic landfill lining systems' Geotechnical Engineering of Landfills, Thomas Telford, London, 1998.

2.6.5 Parameters Selected for Waste Analyses

In terms of waste strength, SLR adopts conservative values of effective shear strength parameters as derived from a study of geotechnical properties of municipal waste by Van Impe and Bouazza[6], these values being backed up in later work by Kavazanjian et al[7] and later confirmed in a research summary by Jotisankasa[8] along with further research by Stark et al[9] .

The values for c' and ø' adopted throughout the modelling were 28kPa and 0°, respectively. The unit weight of the waste was taken as 11kN/m3, a value slightly higher than that generally adopted (10kN/m3). This is based upon experience gained from some of SLR's most recent modelling and stability work.

In summary, the geotechnical parameters selected for the waste mass stability analysis are presented in Table 2-7.

Table 2-7
Geotechnical Design Parameters Waste Mass Stability

Material	Unit Weight, γ (kN/m3)	Effective cohesion, c′ (kPa)	Angle of Shearing Resistance, ø' (°)	Typical Description
Bedrock - Limestone				Assumed impenetrable
Existing non-hazardous waste	11	5	28	Inert and similar non-reactive non-hazardous waste.
Mineral Liner - Steepwall	18	0	21.3	
Proposed non-hazardous waste	11	5	28	Inert and similar non-reactive non-hazardous waste.
Reinforced non-hazardous waste	11	2	32	Engineered waste in accordance with the Frissoli design
Vegetation Layer Steepwall				

2.6.6 Parameters Selected for Capping Analyses

The shear strength values for the interfaces present within the capping system are conservatively adapted from experience gained from some of SLR's most recent modelling and stability work.

In summary, the geotechnical parameters selected for the interface stability analysis are presented in Table 2-8.

6 Van Impe, W. F. and Bouazza, A., "Geotechnical properties of MSW", draft version of keynote lecture, Osaka, 1996.

7 Kavazanjia, E., Matasovic, N., Bonaparte, R. & Schmertmann, G.R. (1995), "Evaluation of MSW properties for seismic analysis". Proc. Geo-environment 2000, ASCE Special Geotechnical Publication, pp 1126-1141.

8 Jotisankasa, A., "Evaluating the Parameters that Control the Stability of Municipal Solid Waste Landfills", Master of Science Dissertation, University of London, September 2001.

9 Timothy D. Stark Æ Nejan Huvaj-Sarihan ÆGuocheng Li. Shear strength of municipal solid waste for stability analyses. Environmental Geology June 2008

Table 2-8
Geotechnical Design Parameters Capping Stability

Material	Unit Weight, γ (kN/m3)	Peak		Residual	
		Effective cohesion, c′ (kPa)	Angle of Shearing Resistance, ø' (°)	Effective cohesion, c′ (kPa)	Angle of Shearing Resistance, ø' (°)
Restoration soils	18	1	32	1	30
Interface Soils to Geogrid		0	34	0	34
Interface Granular to protection geotextile		0	29	0	24
Interface protection geotextile to geomembrane		6.7	26	3.6	13.1
Interface geomembrane to subgrade		1	31	1	25

2.7 Analyses

Details of the various Stability Risk Assessment analyses undertaken for the site are presented in the following sections.

2.7.1 Basal Subgrade Analysis

Analysis of the basal subgrade is not necessary, as it has been screened out in Section 2.1.1.

2.7.2 Side Slope Subgrade Analysis

Analysis of the basal subgrade is not necessary, as it has been screened out in Section 2.1.2.

2.7.3 Basal Lining System Analysis

Analysis of the basal lining system is not necessary as it has been screened out in Section 2.1.3.

2.7.4 Side Slope Lining Analysis

Analysis of the basal lining system is not necessary as it has been screened out in Section 2.1.4

2.7.5 Waste Analysis

In considering the stability of the waste mass, the stability and integrity of the geological barrier system would normally be considered as they are intrinsically linked. However, given that waste has already been placed to the crest of the side slope, only the stability of the waste mass needs to be considered.

Analyses have been dealt with in terms of circular and non-circular 2-D limit equilibrium using the computer program Slope/W. Stability analysis outputs are presented in Appendix SRA2.

Pore fluid pressure is the combined effect of water and gas pressures. The distribution of pore fluid pressure varies within the waste mass due to a number of factors, including the nature and variability of the waste and the presence of perched water tables.

In order to model the pore fluid pressures in the waste mass a pore water pressure ratio (r_u) of 0.2 will be applied to the waste mass to represent a worst-case condition.

A worst-case situation will be used by placing waste to a maximum height of 82mAMSL, including the reinforced waste present outside the footprint of the side slope area.

In order to consider the stability of the waste mass during earthquake scenario a horizontal seismic load of 0.035G and a vertical load of 0.018 has been applied in certain scenarios.

A sensitivity analysis was undertaken to establish the distance from the crest of the reinforced waste slope where there would be no impact on the stability of the waste mass in this area when additional waste is placed to the revised restoration levels. The sensitivity analysis established that a stand-off of 35m would be required, the subsequent stability analyse allow for this stand-off.

An analysis has been carried out on 26m high waste slope with an overall gradient of 1V:3H, although it will be constructed with slopes formed at 1V:2H, with 10m wide intermediate benches at 10m intervals (vertical). The model considers partial saturation of the waste mass through the application of pore water ratio (r_u) within the waste mass. No earthquake loading has been applied in this scenario.

A second analysis considers the same geometry slope as above, however, this includes an earthquake loading as described previously.

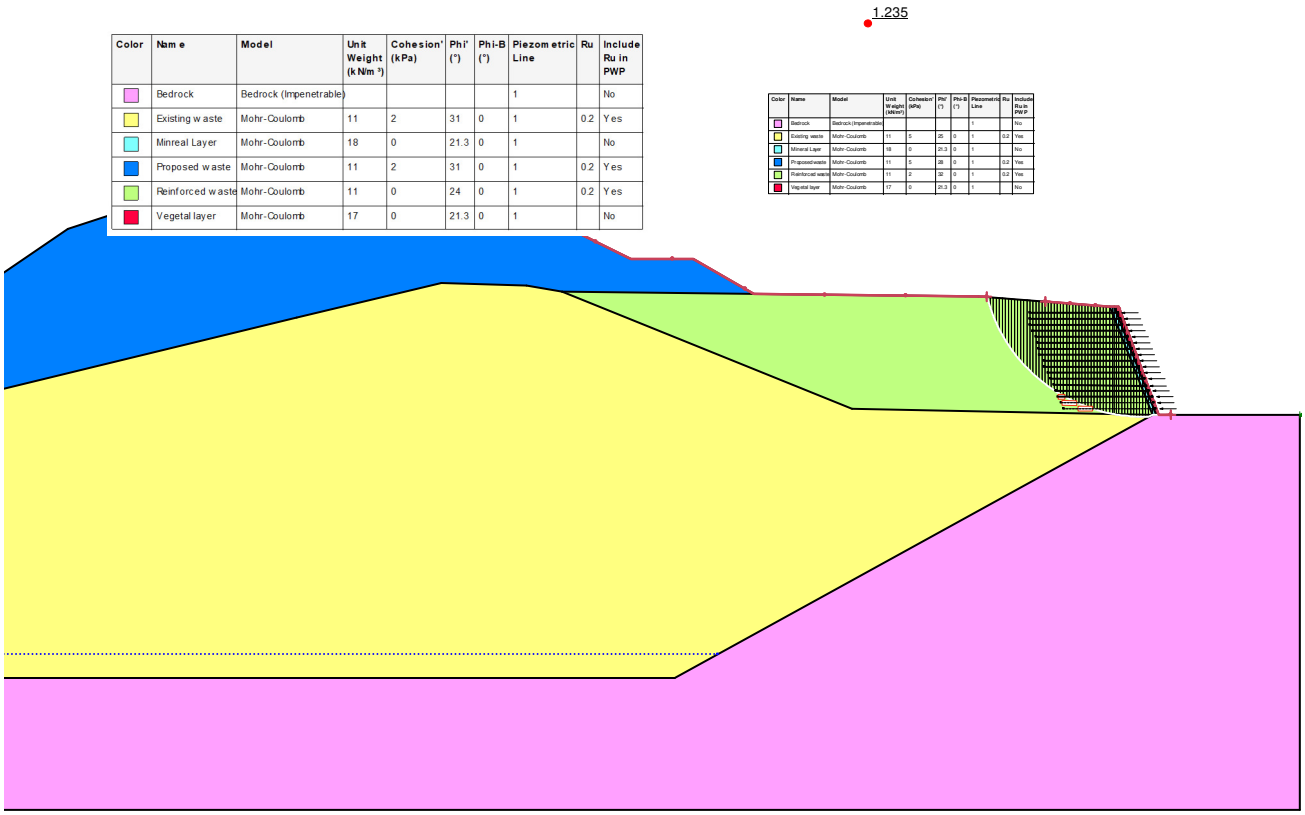


Figure 2-1 Section through the revised restoration levels indicating the critical slip plane

The results from the analyses are presented within Table 2-1 below

Table 2-1
Summary of Waste Stability Analysis for Mode 1

Figure	Method	Factor of Safety	r_u	Horizontal Seismic load	Vertical Seismic load	Comments
SRA2-1	Drained Circular	1.319	0.2	0	0	Acceptable FoS
SRA2-2	Drained Circular	1.235	0..2	0.035	0.018	Acceptable FoS

2.7.6 Capping Stability Analysis

Following a review of the proposed pre-settlement contours the pre-settlement waste slope – 10m high, 1V:2H (~25°) was identified for further consideration:

The proposed capping system from the top down, the following capping system comprises; 1000mm restoration soils.

- 1000mm restoration soils (comprising 300mm topsoil and 700mm subsoil)
- Geogrid
- Geocomposite drainage / protection layer.
- 1mm double-textured geomembrane.
- 250mm waste regulation layer.

In considering the stability of the capping system, the methodology used considered the factor of safety at each of the geosynthetic interfaces within the slope profile. The analyses use a limit equilibrium method based on a passive wedge at the toe of the slope resisting an active wedge pushing down the slope. Figure 4-2 presents the forces acting on the passive and active wedges.

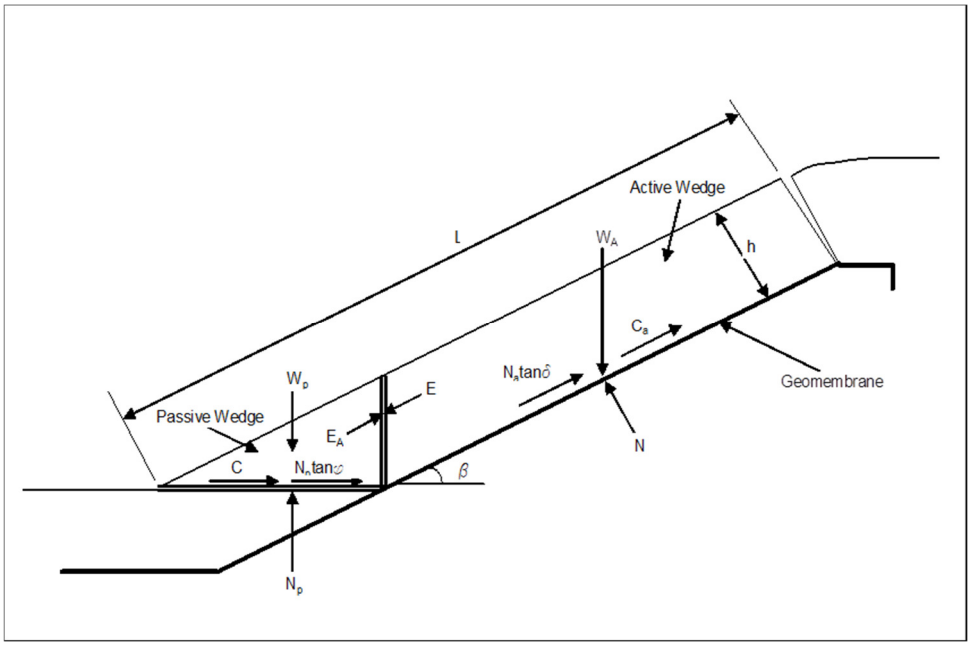


Figure 2-2: Schematic Section Showing Forces Acting on Active and Passive Wedges

By resolving the forces acting on the wedges, the factor of safety is calculated using the following quadratic equation:

$$aF^2+bF=c=0$$

where:

$$a = \frac{\gamma H L}{2} \sin^2(2\beta)$$

$$b = -[\gamma HL \cos^2\beta \tan\delta_u \sin(2\beta) + \alpha_u L\cos(2)\beta + \gamma HL\sin^2\beta \tan\phi \sin(2\beta) + 2cH \cos\beta + H^2 \tan\phi]$$

$$c= (\gamma HL \cos\beta \tan\delta_u + \alpha_u)(\tan\phi \sin\beta \sin(2\beta)$$

and

γ = unit weight,

H = thickness of cover soil,

L = slope length,

β = slope angle,

ϕ = angle of internal friction of cover soil,

c = cohesion of cover soil,

δ_u = interface friction angle at the upper interface,

α_u = apparent cohesion at upper interface

The method used also calculates tension within the geosynthetics elements by comparing the imbalance of forces between the upper and lower interfaces of a geosynthetic material, using the following equation:

$$T = \{(\alpha_u - \alpha_l) + \gamma H\cos\beta (\tan\delta_u - \tan\delta_l)] L$$

Where

α_l = interface friction angle at the lower surface

α_l = apparent cohesion at the lower interface

These equations are input into Microsoft Excel spreadsheets for processing.

Following a review of the proposed pre-settlement contours the pre-settlement waste slope – 10m high, 1V:2H (~25°) was identified for further consideration. The analysis undertaken demonstrates an acceptable factor of safety for 1V:2H inclination slopes (26.5°) for all 4 of the interfaces.

In considering the stability of the restoration soils overlying the geosynthetics of the capping system, the influence of possible partial saturation of the soil is typically investigated by adopting a Parallel Submerged Ratio (PSR). In the analysis the soils are assumed to be placed in a uniform layer over the slope and the phreatic surface of the water within the soil is assumed to be parallel to the slope. The PSR is the ratio of the saturated depth of soils versus the full depth of the soils. However, given the location of the site and the low annual rainfall, the inclination of the slope and that the restoration soils directly overlying the geosynthetics will be free draining, the slope will not become partially saturated and therefore it is not considered necessary to include a PSR value in this instance.

The modelled slope configuration, together with all input parameters, is presented as Figure A4-1 within Appendix SRA 4.

The analysis undertaken demonstrates an acceptable factor of safety for 1V:2H inclination slopes (26.5°) for all 4 of the interfaces. It suggested that due to the steep slopes that when the granular material is placed and spread

out over the geosynthetics they are done so from the bottom of the slope and pushed upwards rather than from the top of the slope down. This should be considered further during the detailed design stage when the construction methodology is being developed.

2.8 Assessment

2.8.1 Basal Subgrade Assessment

Assessment of this component is not required as it was eliminated from consideration by the screening process (Section 2.1.1).

2.8.2 Side Slope Subgrade Assessment

Assessment of this component is not required as it was eliminated from consideration by the screening process (Section 2.1.2).

2.8.3 Basal Lining System Assessment

Assessment of this component is not required as it was eliminated from consideration by the screening process (Section 2.1.3).

2.8.4 Side Slope Lining System Assessment

Assessment of this component is not required as it was eliminated from consideration by the screening process (Section 2.1.4).

2.8.5 Waste Assessment

The stability assessment demonstrated that the waste slopes maintain an adequate factor of safety in all modelled conditions.

2.8.6 Capping Assessment

The assessment demonstrated that the capping slopes maintain an adequate factor of safety in all modelled conditions.

3.0 MONITORING

3.1 The Risk Based Monitoring Scheme

Based upon the foregoing Stability Risk Assessment, a simple risk-based monitoring scheme is considered appropriate for the future development of the landfill. The monitoring is limited to ensuring compliance with the tipping rules and monitoring of groundwater levels.

3.2 Basal Subgrade Monitoring

No additional monitoring is deemed as being required during the operational or post closure phases of the landfill.

3.3 Side Slope Subgrade Monitoring

No additional monitoring is deemed as being required during the operational or post closure phases of the landfill.

3.4 Basal Lining System Monitoring

No additional monitoring is deemed as being required during the operational or post closure phases of the landfill.

3.5 Side Slope Lining System Monitoring

No additional monitoring is deemed as being required during the operational or post closure phases of the landfill.

3.6 Waste Mass Monitoring

Tip faces and surrounding areas should be inspected daily for signs of failure.

No other specific monitoring is required for the waste other than to record waste elevations across the site.

3.7 Capping Monitoring

Monitoring during construction will comprise construction quality assurance to ensure compliance with the construction specification.

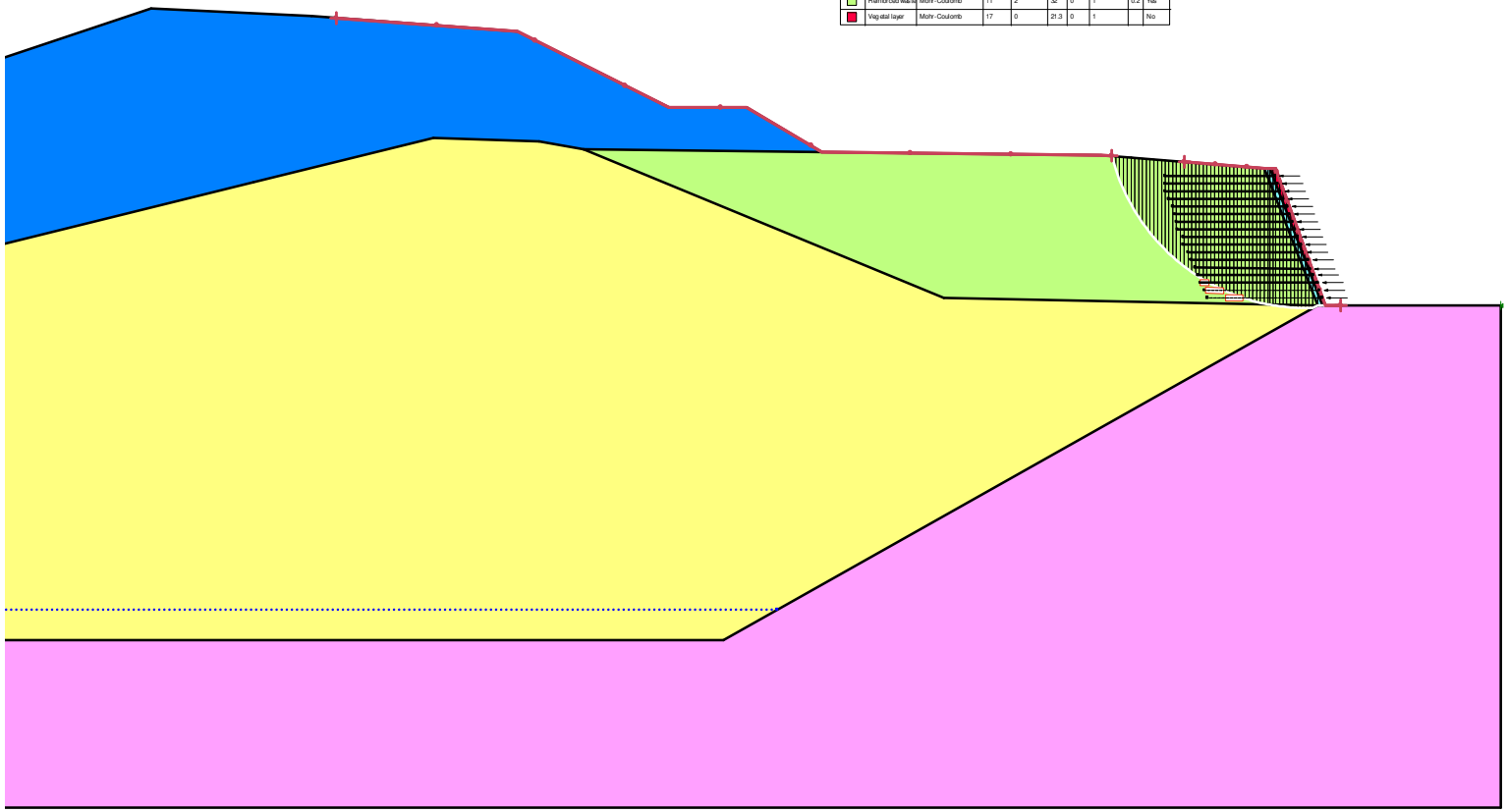
No additional instrumentation is deemed as being required during construction or post closure.

APPENDIX SRA1

Waste Mass Analysis

1.319

Color	Name	Model	Unit Weight (kN/m³)	Cohesion' (kPa)	Phi' (°)	Phi-B (°)	Piezometric Line	Ru	Include Ru in PWP
	Bedrock	Bedrock (Impenetrable)					1		No
	Existing waste	Mohr-Coulomb	11	5	25	0	1	0.2	Yes
	Mineral Layer	Mohr-Coulomb	18	0	21.3	0	1		No
	Proposed waste	Mohr-Coulomb	11	5	28	0	1	0.2	Yes
	Reinforced waste	Mohr-Coulomb	11	2	32	0	1	0.2	Yes
	Vegetal layer	Mohr-Coulomb	17	0	21.3	0	1		No



Notes:

SLR

Rev. 0 - 150626 4120100900119 Allens Bank SRA App

Site: GHALLIS LANDFILL

Project: STABILITY RISK ASSESSMENT

Date: SEPTEMBER 2020 SCALE: NTS

Drawing: **SRA 1-1**

Appendix **1**

APPENDIX SRA2

Capping Analysis

Table 1-1 - Capping System Stability/Integrity Analyses

Input Parameters				**Peak**	**Residual**
β	Slope Angle		°	25.60	25.60
H	Slope height		m	10.00	10.00
h	Thickness of cover soils		m	1.00	1.00
ϕ	Friction angle of cover soil		°	32.00	30.00
c	Cohesion of cover soil		kPa	1.00	1.00
δtg	Interface friction granular layer / geogrid		°	34.00	30.00
αtg	Apparent cohesion granular layer /geogrid		kPa	0.00	0.00
δgs	Interface friction granular layerr/ geotextile protector		°	29.00	24.00
αgs	Apparent cohesion granular layer / geotextile protector		kPa	0.00	0.00
δtg	Interface friction geotextile protector / double textured geomembrane		°	26.00	13.10
αtg	Apparent cohesion geotextile protector / double textured geomembrane		kPa	6.70	3.60
δgs	Interface friction double textured geomembrane / subgrade		°	31.00	25.00
αgs	Apparent cohesion double textured geomembrane / subgrade		kPa	1.00	1.00
PRS	Parallel Submerged Ratio			0.00	0.00
γ_d	Dry unit weight of cover soil		kN	18.00	18.00
γ_{sat}	Saturated weight of cover soil		kN	19.00	20.00
h_w	Thickness of saturated cover soil		m	**0.00**	**0.00**
W_A	Weight of active wedge		kN	**393.49**	**393.49**
W_P	Weight of passive wedge		kN	**23.10**	**23.10**
U_n	Resultant pore water pressure perpendicular to slope		kN	**0.00**	**0.00**
U_h	Resultant pore water pressure on interwedge surface		kN	**0.00**	**0.00**
N_{Aab}	Effective force normal to failure plane of active wedge above impermeable layer		kN	**354.86**	**354.86**
N_{Abb}	Effective force normal to failure plane of active wedge below impermeable layer		kN	**354.86**	**354.86**
U_v	Resultant vertical pore water pressure acting on passive wedge		kN	**0.00**	**0.00**
L	Slope Length		m	**23.14**	**23.14**
A/B interface					
	Quadratic Equation Parameters		a	153.33	153.33
			b	-278.51	-242.83
			c	64.63	51.11
	Factor of Safety Against Failure			**1.54**	**1.33**
	Tension in geomembrane		**kN**	**-44.05**	**-4.65**
				No Tension	**No Tension**
B/C interface					
	Quadratic Equation Parameters		a	153.33	153.33
			b	-240.04	-200.55
			c	53.11	39.41
	Factor of Safety Against Failure			**1.30**	**1.07**
	Tension in geomembrane		**kN**	**-6.70**	**-3.60**
				No Tension	**No Tension**
C/D interface					
	Quadratic Equation Parameters	a		153.33	153.33
		b		-358.58	-207.67
		c		88.60	41.39
	Factor of Safety Against Failure			**2.06**	**1.11**
	Tension in geomembrane		**kN**	**-0.87**	**-0.91**
				No Tension	**No Tension**
D/E interface					
	Quadratic Equation Parameters	a		153.33	153.33
		b		-275.81	-228.16
		c		63.82	47.05
	Factor of Safety Against Failure			**1.53**	**1.24**

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APPENDIX 05

Construction Specification

GHALLIS LANDFILL

Capping Specification

Prepared for: **WasteServ Malta Limited**

SLR Ref: 403.00585.00035
Version No: D0
July 2020

BASIS OF REPORT

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DOCUMENT REFERENCES

TABLES

1.0 INTRODUCTION

This document is an Engineering Specification and presents details for the capping and restoration works at Staple Quarry Landfill Site. It is intended to provide information necessary for the preparation of the Construction Quality Assurance (CQA) Plan, which will need to be approved by the Environment Agency (EA).

This document describes the detailed scope of works and covers all project-specific testing requirements with additional supporting technical information being provided in the Appendices. The capping and restoration works are due to be undertaken in 2009.

1.1 Site Location and Access

Zwejra Landfill site is operated by WasteServ Malta Limited (WasteServ) and is located near the village of Maghtab. A location plan is presented on Drawing No. 1.

Access to the site is via the dedicated entrance off the main coast road which leads into the wider Maghtab waste management complex.

1.2 Scope

This Engineering Specification relates to the capping and restoration of Ghallis Landfill and describes the associated works to be undertaken including the deployment, handling & installation of materials. This document also identifies the relevant responsibilities of the parties being involved and outlines all the necessary testing requirements

The geosynthetic capping works will comprise of:

- Placement of the 250mm regulation layer;
- Installation of a 1mm thick LLDPE Geomembrane Cap (textured on both sides) with welded seams;
- Placement of a geocomposite drainage layer;
- Installation of a reinforcing geogrid layer;
- Placement of minimum 1000mm thick restoration soils (300mm topsoil and 700mm subsoil);
- Installation of geocells to prevent erosion of the restoration soils;
- Planting with suitable seed mix;
- Construction of a surface water ditch; and
- Provision of adjustable boots around all protrusions in the capping area.

The capping and restoration works will cover approximately 110,000m^2. The site layout is presented on Drawing No. 2.

2.0 GENERAL CONDITIONS

2.1 Materials

Goods and materials used in the execution of this Contract shall, where possible, have been produced in Malta or the European Economic Community. The Contractor shall name all sources of materials to be supplied to site for approval of the CQA Engineer. Any material condemned or rejected by the CQA Engineer will be removed immediately from the site at the Contractor's expense. All materials will be stored and transported in such a manner as to preserve their quality and integrity. All materials used in the construction of the Works, which can be detrimentally affected by the weather, are to be removed, covered or sealed at the end of every working period.

2.2 Personnel and Relevant Experience

Prior to commencement of the Works, the Contractor shall provide a list of key personnel he proposes to employ together with a resume of their experience and qualification. The list of key personnel shall include the name of the full-time Contractors Agent. The list will be accompanied with a chart showing the key personnel on the project and who / what they are responsible for.

2.3 Hours of Work

The hours of work shall be within those allowed by the Planning Permission, as indicated below:

Monday to Friday	07:00 - 17:00*
Saturday	07:00 - 12:00*
Sunday, Bank Holidays and Public Holidays	Not without permission of WasteServ

* Working hours may be increased outside of those indicated above upon agreement of WasteServ.

2.4 Plant and Equipment

The Contractor shall use plant of suitable and appropriate capacity to carry out the work in accordance with the Specification. Each item of plant will be maintained and operated in a safe manner. A chart detailing the plant required to excavate the works, time required on site, forecasted earthmoving capability of tonnes per day, etc shall be submitted to the CQA Engineer prior to commencement of the works. No claim will be entertained for mechanical breakdown, theft, vandalism or punctures. Plant operators are to be trained and certified by an approved body for the plant they are operating. The Contractor will consider the potential safety hazards of his proposed works and adapt plant and vehicles accordingly.

2.5 Contractors Superintendence

The Contractor shall give or provide all necessary superintendence during the execution of the Works and as long thereafter as the CQA Engineer may consider necessary. Such superintendence shall be given by an experienced person having adequate knowledge of the operations to be carried out (including the methods and techniques required, the hazards likely to be encountered and the methods of preventing accidents) as may be requisite for the satisfactory construction of the Works.

2.6 Contractors Agent and Personnel

The Contractor or a competent and authorised agent or representative, approved of in writing by the CQA Engineer (for which approval may at any time be withdrawn) is to be constantly present during the Works and shall give his whole time to the superintendence of the same if required by the CQA Engineer. The Contractor

will only employ staff competent to undertake the required works. At all times during the contract a trained First Aider must be present on site.

2.7 Site Facilities

The Contractor shall provide, maintain and remove on completion of the works, suitable site offices for the sole use of the Contractors Agent and the CQA Engineer, and furniture appropriate to their functions. All buildings, sheds and other temporary structures that the Contractor may erect for his own or the CQA Engineer's purpose shall (in respect of location, design and sanitary arrangements) meet with the approval of the CQA Engineer. Immediately on completion of the Works, or at such other times as the CQA Engineer may determine that they are no longer required, all temporary buildings, offices, sheds, huts, stores and other accommodations put up by the Contractor shall be removed by him.

2.8 Site Cleanliness

The Contractor shall confine his operations to the minimum area of ground required for correct execution of the Works and access thereto. The Contractor shall at all times keep the working area and area surrounding all site temporary buildings clean and tidy. The Contractor shall be responsible for the disposal of all mud, water, chippings, soil or other waste products resulting directly or indirectly from the works. The Contractor shall take all precautions necessary to prevent pollution or contamination of streams, waterways and watercourses. Provision must be made to ensure that the metalled roads to and within the site remain clear of mud, soil and debris.

The Contractor shall take all reasonable steps to minimise dust nuisance during the Construction of the Works. The CQA Engineer may direct that water bowsers are permanently on the site during the Contract period to hose down areas of the Works causing a dust nuisance.

Upon instruction from the CQA Engineer, when the Works have been satisfactorily completed, the Contractor shall leave the working area and the access thereto in a clean and tidy condition; this will require occasional road sweeper hire. The Contractor shall repair any damage he may have caused whether in the vicinity of the works or on the access route thereto to the satisfaction of the CQA Engineer. The Contractor shall indemnify and keep indemnified the Employer against all claims arising from any such pollution, contamination, loss or damage.

2.9 Site Electricity Supply

The Contractor shall be required to provide a suitable electricity supply to suit his own requirements.

2.10 Site Water Supply

The Contractor shall be responsible for locating a suitable water supply and for providing and paying for all temporary plumbing and connection of the water supply to site. Where a suitable water supply is not available in the locality, the Contractor shall make arrangements for carrying and storing water in quantities as necessary for the Works. All costs incurred in this respect shall be borne by the Contractor. The Contractor is responsible for its sensible use and for the care and the maintenance of his pipework from the supply point.

2.11 Existing Structures and Services

The Employer may provide the CQA Engineer and Contractor with details of any such services known or likely to affect or be affected by the works. The supply of this information to the Contractor does not absolve the Contractor from his responsibilities to ascertain more accurately the location of any service apparatus within the site using all reasonable care and attention.

2.12 Health and Safety

The Contractor shall ensure that any incomplete or temporary works are covered and secure at the end of every working day. It is essential that the Works are covered at the end of each working period. The Contractor is responsible for provision of security for his works.

Contractors should note that smoking and naked flames are prohibited outside at all times. Smoking may be permitted inside the Contractors cabin or messing facilities, subject to the agreement of the Site Manager.

The following safety equipment is obligatory:

- A safety helmet;
- A reflective safety jacket;
- Safety footwear with steel toe caps and mid soles; and
- Personal protective clothing such as dust mask, goggles and gloves etc. will be worn when the appropriate works require it.

The Contractor will be required to liaise with the WasteServ Landfill Site Manager to ensure his operations do not conflict with the day to day landfilling operations. The Contractor must familiarise himself with any WasteServ site rules and will be required to comply with these rules. The Contractors attention is drawn to the presence of landfill gas close to the works area.

2.13 Inclement Weather

When weather conditions are such that the quality of the Works may be impaired or the conditions of the materials impaired then the Works will be stopped with the agreement of the CQA Engineer. Inclement weather may comprise high winds, rain, snow, freezing, excessive temperatures or a combination of the above.

Where, in the opinion of the CQA Engineer, any works carried out in inclement weather conditions that have been adversely affected, these works shall be removed and made good.

Following adverse weather conditions, any standing water on the surface of the works shall be removed at the earliest opportunity.

Earthworks placement operations following inclement weather conditions shall not proceed without the prior approval of the CQA Engineer.

2.14 Surface Water Control

The Contractor shall ensure that water does not accumulate on or adjacent to the surfaces of the Works. To ensure this temporary watercourses, ditches, drains, pumping or other means of maintaining the Works free from water, shall be provided by the Contractor. The Contractor will be deemed to have allowed for this in his rates.

On no account will any unauthorised discharge be permitted to leave the site without prior consent of the CQA Engineer in consultation with WasteServ.

2.15 Fuelling of Plant

Fuel tanks and drums used by the Contractor will be stored at a location approved by the WasteServ Landfill Site Manager. All such tanks and drums will be bunded in a containment bund capable of containing 110% of the total quantity of fuel present at any one time. The containment bund will have an impermeable base and sides. All fuel spillages within and outside the bund will be remediated in a safe and controlled manner by the Contractor. Empty oil and grease containers shall be disposed of properly.

2.16 Parking of Plant and Sitting of Ancillary Equipment

The Contractor shall be allowed to establish an area at a location to be agreed by WasteServ, for parking of plant overnight. WasteServ accepts no responsibility for damage or theft incurred as a result of the presence of the plant on site.

2.17 Daily Journal

The Contractor will be required to keep a detailed daily journal recording all plant and labour present, quantities of materials delivered and placed, dimensions and locations of materials placed, weather conditions, details of meetings and details of testing results, remedial works and any other relevant information. The Contractor will give the CQA Engineer reasonable access to the daily journal. The Contractor will forward copies of the daily journals on a weekly basis to the CQA Engineer.

2.18 Site Operations and Traffic Management

It is the responsibility of the Contractor not to interfere with the day to day routine of the site. The Contractor must liaise with the WasteServ Landfill Site Manager and must make all due provision for completing the works without interfering or detrimentally affecting site operations, and for complying with WasteServ's specific Site Rules.

No security fencing shall be removed, moved or altered without the written permission of the WasteServ Landfill Site Manager.

2.19 Disposal of Soil

All superfluous soil, subsoil, rubble, rock cuttings and waste or any other material accumulated on the surface or disturbed by contracting activities must be correctly and tidily disposed of. Any cost incurred in this respect will be borne by the Contractor.

2.20 Independent Construction Quality Assurance

WasteServ will appoint an Independent Consultant to supervise all aspects of quality assurance of the contract. The Consultant shall supply a CQA Engineer, who has suitable previous experience of supervising all aspects of the works. On site the CQA Engineer will ensure that all requirements of the Specification relating to quality are met.

The CQA Engineer's responsibilities are detailed below:

- Acts as the on-site (resident) representative of the Employer for quality issues;
- Attends all CQA related meetings (e.g. Pre-construction and Progress);
- Prepares or oversees the ongoing preparation of the Record Drawings;
- Assigns locations for testing and sampling in accordance with the Specification;
- Oversees the collection and shipping of all samples for laboratory testing;
- Reviews results of laboratory testing and makes appropriate recommendations;
- Reports any unresolved deviations from the Specification;
- Provides all logs and relevant data for the preparation of the final CQA report;

- Reviews all Certifications and Documentation from the Contractor and makes appropriate recommendations; and
- Notes and brings to the attention of the Contractor any on-site activities that could result in damage to the works.

2.21 Highways to be Kept Clean

No debris or material resulting from the Works shall be allowed to fall onto any public highway. It is the sole responsibility of the Contractor to ensure that all mud, soil, waste and other residual materials are not allowed to accumulate on the public highway or asphalted or concrete roads within the site. The Contractor will make due provision for the cleaning of roads.

2.22 Covering of Vehicles

The Contractor will ensure that any load being transported to or from the site which is capable of generating dust, ash, rubbish or other wind blown material is sheeted in an appropriate manner.

2.23 Noise and disturbance

All work shall be carried out without unreasonable noise and disturbance. The Contractor shall indemnify the Employer against any liability for damages on account of noise or any other disturbance created while or in carrying out the work and from and against all claim demands proceeding damages costs, charges and expenses whatsoever in regard or in relation to such liability.

2.24 Existing/Final Ground Levels

The Contractor will establish temporary benchmarks, referenced to Ordnance Datum, on or near the site to which all levels shall be referred. As soon as the Contractor takes possession of the site bench marks must be established at a ratio of one per hectare area of the site. Levels will be agreed with the CQA Engineer and a list supplied to him.

The Contractor should verify for himself the accuracy of all survey data. He will be required to agree original ground levels with the CQA Engineer prior to commencement of site works. The agreed original ground levels shall provide a basis for measurement purposes.

The Contractor shall carry out construction surveys to determine ground elevations at each of the following stages of earthworks and during construction and at other times as may be necessary to measure quantities for evaluation purposes:

i) Upon completion of the regulating layer placement;
ii) Upon completion of the geomembrane installation;
iii) Upon completion of restoration soils placement; and
iv) Upon completion of the surface water drainage ditches.

Each survey should be carried out on a fixed grid of points to facilitate this process. The Contractor shall undertake the survey using a fixed 20m grid, agreed with the CQA Engineer prior to the undertaking of any surveys. Further details such as crests and toes of slopes, in addition to the grid points, will be required for the production of as built drawings.

An onsite record of the formation levels shall be maintained and up dated, by the Contractor. Placement of fill materials above pipework shall not proceed without supporting survey information to demonstrate the location and invert levels have been recorded.

The Contractor shall give sufficient notice of the intention to survey to enable the CQA Engineer to conduct a joint survey or check the Contractor's survey.
The Contractor shall forward a paper and disc copy of each survey within one week of undertaking the survey, at a scale of 1:500. Proceeding with installation of an overlying layer prior to confirmation that the thickness requirements of the preceding layer has been attained as calculated by survey, is at the Contractor's own risk.

2.25 Tolerance Limits

The tolerance limits for the works shall be as follows;

i) Positions in plan shall be within 75mm of the true positions as shown on or calculated from the drawings;
ii) Slopes shall be sensibly plane and within 1% of the gradient shown on the Drawings;
iii) The prepared subgrade in the base shall be within –15 / +30mm of the required elevation; and
iv) Depths and thickness of the attenuation layers and leachate blankets shall be within –0/+50mm of the dimensions shown on the Drawings.

2.26 Method Statements

The Contractor shall produce method statements for each element of the works. Method statements shall detail how the works are to be undertaken, in a safe manner, in order to meet the Specification.

3.0 PREPARATORY WORKS

3.1 Final Waste Levels

Approved final waste levels are presented on Drawing No. 3.

The surface of the waste to be capped shall be trimmed and compacted by the passage of a tracked bulldozer, or similar approved plant, to produce an even and stable formation without any bumps, hollows or areas which may collect water.

Any any object which in the opinion of the CQA Engineer may potentially cause damage to the capping system through the regulating layer, visible in the final waste surface shall be removed. Any void or hollow created after removal of any object shall be filled with waste regulating material.

As part of the works the Contractor may be instructed by the CQA Engineer to place and compact additional waste regulating layer material to cover areas of exposed waste and to fill in any hollows and be tracked in by the passage of plant.

Where waste materials are required to be excavated from an area during the trimming process, they shall be disposed of within the Ghallis Landfill to fill any depressions or hollows within the final waste profile. Bulky items shall be buried within a hole excavated within the waste. Prior to the excavation of any waste WastServ shall be consulted with regards to any special precautions to be taken.

3.2 Leachate and Gas Extraction Systems

The Contractor shall be aware that the area to be permanently capped has gas extraction and leachate wells already installed. These wells will be constructed from HDPE pipework of varying diameters, and are connected to either the gas extraction system or leachate management system via surface laid pipes running across the area to be capped. All of the landfill gas and leachate well installations require access upon completion of the capping and restoration works, and therefore requires sealing at the point where they penetrate the geomembrane cap. The penetrations through the cap shall be in accordance with Drawing No. 5 and Section 5.13 of this Specification.

The Contractor shall provide a suitable means to prevent accidental damage occurring to any of the above installations during the course of the works, such as a temporary concrete manhole around the gas and leachate wells during the works.

4.0 WASTE REGULATING LAYER

The waste regulating layer shall be placed to a minimum thickness of 250mm and compacted to ensure that an even surface has been achieved, free of abnormalities that could result in ponding. The contours of the final cover system should be sufficient to prevent the development of local depressions due to post-construction settlement.

The regulating layer should be free of any objects that may puncture the membrane. The maximum particle size (in a material with a broad particle size distribution) in contact with the membrane will be no greater than 10mm if angular material and 20mm if rounded particles. The maximum particle size in the regulating layer (not in contact with the membrane or within 100mm of the membrane) shall be 150mm (in a material with a broad particle size distribution). Any stone that protrudes above the level of the surface of the regulating layer should be stone picked and any indentations remaining should be filled and compacted with suitable material.

4.1 Unsuitable Materials

Unsuitable materials shall include:

- Peat, materials from swamps, marshes and bogs;
- Materials in a frozen condition;
- Logs, stumps and perishable materials;
- Material susceptible to spontaneous combustion;
- Any industrial, commercial or domestic waste;
- Material with any dimensions greater than 150mm (in the bottom layer - not in contact with the membrane); and
- Any material with the potential to damage the overlying geomembrane Cap.

4.2 Regulating Layer Installation, Testing and Corrective Action

The waste regulating layer shall be placed and compacted to achieve a minimum thickness of 250mm. The surface of the regulating layer shall be smooth rolled to achieve a surface free of sudden sharp or abrupt changes in grade and free from track and roller marks. The surface shall be inspected by the CQA Engineer to ensure that there are no objects or irregularities within the waste regulating layer, which in their opinion may damage the overlying geomembrane cap.

Where necessary the Contractor shall also protect the regulating layer from desiccation, and flooding by installing a temporary impermeable cover prior to the installation of the geomembrane cap. Should the finished layer show any signs of desiccation cracks exceeding 12mm deep or exhibit any signs of swelling, the Contractor should take remedial action to the satisfaction of the CQA Engineer.

Should remedial works to achieve the specification be necessary, the Contractor shall scarify the top 50mm and subsequently re-compact with suitable compaction plant to the full satisfaction of the CQA Engineer.

5.0 GEOMEMBRANE CAP

The welded geomembrane cap shall consist of an un-laminated 1mm thick double textured Linear Low Density Polyethylene (LLDPE) geomembrane.

5.1 Material Specification

All material shall be new and manufactured by an extrusion process using pure (non-recycled) resin, entirely free of plasticizer or other filler materials and without prefabrication. The thickness of the geomembrane cap shall be 1mm.

The Contractor shall forward a statement detailing which manufacturer of material they propose to use including a schedule of results of independent laboratory testing which show that the minimum requirements set out in Table 5-1 can be met by typical materials of the type to be used.

5.2 Manufacturing Quality Control

The Contractor shall submit to the CQA Engineer a copy of the Manufacturer's Quality Control documentation for each roll of geomembrane delivered to site. Separate certificates shall be provided for tests conducted at a lesser frequency than 1 per roll. These certificates shall relate to the delivered rolls of material. The documentation shall be provided prior to installation of any material.

Should any of the certificates indicate that the material properties do not meet with the acceptance criteria outlined in Table 5-1, then the CQA Engineer may reject the relevant roll(s).

5.3 Conformance Testing

As soon as practicable after delivery of the geomembrane material to the site, and with the approval of the CQA Engineer, the Contractor shall cut a sample 1 metre wide across the entire width of the roll, after the first lap has been discarded.

The Contractor shall submit the sample for conformance testing in accordance with Table 5-1 to an independent geosynthetic testing laboratory with UKAS Accreditation (or similar) for the tests shown.

Conformance sampling shall be undertaken at the frequency shown in Table 5-1 or for every change in batch numbers, whichever is the greater.

Should any sample fail to meet the criteria shown in Table 5-1, the Contractor shall be informed and further conformance samples removed from other rolls for further testing. Where possible, these rolls shall be taken from rolls numerically either side of the failed roll. The roll from which the failed sample was removed shall not be used in the works, pending further conformance testing.

Table 5-1: Conformance Sampling and Testing Frequency for the Geomembrane

Parameter	Test Method	Minimum Required Value (All values minimum average) Textured*	Minimum Test Frequency
Thickness (mm)	D 5994	1.0	1 sample per 5000m² or 1per different resin source whichever is the greater number of tests
Density g/ml max.	D 1505	0.939	
Puncture Resistance	D4833	250N	
Tear Resistance	D 1004	100N	
Carbon Black Content (%)	D 1603	2.0 – 3.0%	
Carbon Black Dispersion	D5596	9 in categories 1 and 2 and 1 in category 3	
Asperity Height	D 7466	0.4mm	
Tensile Properties: Break Elongation Break Strength	D 6693 Type IV	800% 27N/mm	

5.4 Delivery, Handling and Storage

The geomembrane shall be delivered, handled and stored in accordance with the manufacturer's recommendations taking care to protect the material from damage and contamination. A copy of the manufacturer's recommendations shall be provided to the CQA Engineer for his information. The geomembrane shall be stored on a level, dry area at a location to be agreed on site and will not be stacked more than 2 rolls high with no materials being placed on top of the geomembrane.

The storage area shall be firm, clean and rolled flat to avoid damage to the geomembrane. The Contractor shall provide adequate and acceptable measures for protecting the materials at all stages of the work from all sources of potential damage, including adverse weather conditions until completion of the works.

Each roll should be identified with a unique roll number, the manufacturer's name, product name and type, batch number, date of manufacture and physical dimensions. Any protection coatings shall not be removed until the material is ready to be incorporated into the works.

The Contractor and CQA Engineer shall examine all rolls on delivery for damage in transportation and shall record the details of any damage together with the relevant manufacturer's reference numbers for each roll. Damaged rolls shall be set aside until the extent of damage and rejection of material can be determined.

5.5 Regulating Layer Surface Inspection

Prior to deployment of the geomembrane cap, the surface of the regulating layer must be inspected to ensure that there is a uniform surface free from sharp objects or any other materials that in the opinion of the CQA Engineer may cause damage to the overlying geomembrane cap.

5.6 Geomembrane Cap Deployment

The geomembrane cap shall be installed in accordance with the manufacturer's recommendations, either by hand or approved suitable plant, so as to not cause damage to the geomembrane cap or disturbances to the regulating layer. A copy of the manufacturer's recommendations shall be provided to the CQA Engineer for his information. Except in emergencies, plant shall not track directly on to the installed geomembrane cap.

Upon deployment, the geomembrane cap shall be free from cuts, holes, blisters, abrasions and other surface blemishes and defects.

A specialist Contractor with previous experience of geomembrane cap deployment shall install the geomembrane cap. The Contractor shall provide a proposed panel layout drawing prior to commencement of works for acceptance by the CQA Engineer. The drawing should show as a minimum:

- The location and alignment of panels; and
- The proposed direction of working.

The panel layout shall be agreed by the CQA Engineer prior to commencement of the capping works. The submitted panel layout drawing should show as a minimum the Contractor's proposed start point and direction of working. Any changes to the layout in panels shall be agreed with the CQA Engineer prior to the installation of any altered panels. The Contractor shall mark each panel placed with the original roll number.

The panel layout plan shall seek to minimise the number of welds required and wherever possible align the seams between panels so that they are normal to the contours.

Throughout deployment, the Contractor shall undertake a survey to pick up all panels, seams and repairs and provide an as-built drawing to the CQA Engineer for inclusion in the CQA Validation Report. This shall be fully referenced and show panel and roll reference numbers and any repair and sampling locations. The as-built drawings shall also include the locations and types of seam employed (fusion or extrusion – Section 5.8) throughout the works.

The method of installation of the geomembrane cap shall ensure that:

- Panels are deployed and seamed one at a time;
- Scratches or crimps do not occur as a result of deployment;
- Undulations in the installed geomembrane cap are minimised as far as practicable and do not exceed 150mm in height. In any case the installed geomembrane cap shall not be allowed to fold over, or have the potential to fold over once load is applied;
- Equipment does not cause excessive heat or leak hydrocarbons on the geomembrane cap; and
- Adequate and suitable temporary weighting, e.g. sandbags, is provided to ensure no movement occurs during deployment or seaming or at any subsequent time prior to approval by the CQA Engineer of the completed geomembrane cap installation.

Each deployed panel shall be assigned an individual number to record the order of deployment. The panels should also be marked with the date of deployment and the roll number from which the panel was taken. In order to provide an accurate panel layout drawing after completion of the works a survey should be carried out on every panel joint and repair position, the drawing shall also identify the types of seams employed and the welding method.

To avoid damage to the geomembrane cap all personnel working on the geomembrane cap shall wear suitable footwear and shall not smoke.

The free edges of each panel shall be adequately weighed down with sand bags, tyres or other means. Trafficking of plant directly on to the underlying regulating layer will be minimised, and any damage to the geomembrane cap subgrade shall be repaired prior to deployment. The Contractor shall deploy the geomembrane cap as close to its final position as practically possible to minimise the need for pulling the panel over the underlying regulating layer. If damage occurs to the regulating layer surface the Contractor will be required to carry out remedial work to ensure compliance. If the geomembrane cap is displaced due to wind (or suffers with damage) the material must be rejected due to the likelihood of overstressing. No materials will be used as weights if they pose a risk of damaging the geomembrane cap.

Seaming the sheets shall be carried out as soon as possible after the sheets have been laid.

5.7 Temporary Surcharge

The Contractor shall be responsible for the geomembrane cap at all times during the contract and shall adopt whatever measures are necessary to ensure its stability and protect it from damage. These measures shall include the use of sufficient temporary surcharge in the form of durable sandbags, tyres or similar weights, without sharp edges, to be placed on the geomembrane cap immediately after laying to prevent slipping and damage by wind or other agents prior to covering. In this regard the Contractors attention is drawn to the need to provide adequate restraint at free edges of sheet material before anchoring, in order to prevent damage by wind.

5.8 Seaming

Seaming of the geomembrane cap should be undertaken by either the dual hot wedge fusion or extrusion welding methods. The use of extrusion welding shall be limited, and shall only be undertaken with the agreement of the CQA Engineer. The overlap at the joint of the panels shall be a minimum of 100mm. The width of extrusion seams shall not be less than 30mm. The surfaces of the panels shall be adequately prepared before welding (e.g. grinding and cleaning) such that the surfaces are clean, dry and free from imperfections.

Seaming shall not be permitted under the following circumstances:

- Above saturated soils;
- During rain or snow unless proper precautions are taken which allow the seam to be made under dry conditions;
- Above frozen ground;
- During sheet temperatures below 5º C or above 35º C, unless it can be demonstrated to be of the same standard as that undertaken between 5ºC and 35ºC; and
- Over areas of standing water.

Seaming shall be made only by skilled and experienced operators using methods outlined in the document. The Contractor shall provide a supervisor and lead technician accredited to at least Level 1 of the BGA/TW1/CS WIP Welding Standard (or similar approved). Other welding operatives shall be accredited to at least Level 2. Relevant details shall be provided to the CQA Engineer of proposed personnel and their experience prior to any installation, for inclusion in the CQA Validation Report.

Geomembrane cap panels shall be aligned without significant wrinkles and shall be temporarily anchored using sandbags or other suitable means to prevent slippage or wind disturbance.

Before deployment of the geomembrane cap the Contractor should submit to the CQA Engineer a Method Statement outlining the proposed method of working. The Method Statement should include the following:

- Proposed seaming techniques and welding machine types;
- Proposed seam overlap and preparation prior to welding;
- Proposed acceptable temperature settings for hot wedge apparatus; and
- Proposed non-destructive testing methods.

5.9 Trial Seams

Prior to seaming of the geomembrane cap each day, trial seams shall be carried out to confirm the set-up of the seaming equipment for the ambient conditions and that the equipment is working satisfactorily. Trial seams shall be produced under the same conditions as the installation seams and shall be performed with the geomembrane cap in contact with the same formation type.

A trial seam of minimum length 3m shall be carried out for each piece of seaming equipment proposed for use at the beginning of each seaming period, every four hours of continuous welding, on the introduction of new welding equipment, on the introduction of a new welding technician, following a prolonged period of shut down and following any significant changes in weather conditions. All trial seams shall be carried out in the presence of the CQA Engineer.

From each trial seam, six tab samples of length 105mm by 25mm shall be extracted at random from the length of the seam. The tabs shall be examined by the CQA Engineer to confirm that the seam exhibits a homogenous fusing of the two sheets with no definable boundary or layer. The Contractor in the presence of the CQA Engineer shall test the tabs, three for peel failure and three for shear failure. The mode of failure shall be yield of the sheet material outside the seam. No samples shall fail in the seam.

If the field testing of the trial seams proves unsatisfactory further trial seams shall be performed and the procedure repeated until the CQA Engineer is satisfied with the set up of the particular item of seaming equipment. The CQA Engineer shall not allow seaming of the geomembrane cap to commence until successful trial seams are achieved.

Under no circumstances shall the cutting of test specimens, geomembrane cap material or any other materials be permitted above the installed geomembrane cap.

5.10 Seam Testing

5.10.1 Non-Destructive Seam Testing

Non –Destructive testing must be undertaken and witnessed by the CQA Engineer on all completed seams. The following non-destructive tests shall be employed in the works:

Air Pressure Testing

Air Pressure non-destructive testing (APT) shall be undertaken on all fusion weld seams generally in accordance with GRI Test Method GM6. The APT is carried out on the central hollow core between the two parallel seams created by the dual hot wedge fusion process. The test shall be undertaken by sealing both ends of the hollow core and inserting an air pressure gauge connected to a pump or air compressor. The seam shall be pressurised to a minimum air pressure of 140KPa (20 psi) and a maximum air pressure of 200KPa (30 psi) and the isolation valve shut off. The air pressure shall be allowed to stabilise in the channel for two minutes and the stabilised pressure recorded. The air pressure shall then be monitored for a further two minutes. The seam shall be deemed to have passed the test if the decrease in pressure is less than 27 KPa (4 psi) after the two-minute test. Following testing the air is to be released from the air channel from the opposite end of the seam to the air pressure gauge and the pressure drop to zero shall be witnessed by the CQA Engineer.

All APT results should be marked by the Contractor in indelible marker adjacent to the seam where the air pressure gauge was sited. The following information should be included:

- Date of test;
- Time of start of test and recorded air pressure;
- Time of completion of test and recorded air pressure; and
- Initials of test operative and CQA Engineer.

If a seam fails air pressure testing or indicates a channel blockage, the test length shall be incrementally reduced until the failure area has been clearly identified. In the case of identifiable points of failure, the seam shall be repaired and re-tested using the method described below. If specific points of failure cannot be identified or if the CQA Engineer is not satisfied with the integrity of the seam, the seam shall be repaired in accordance with Section 5.11.

Vacuum Box Testing

Vacuum box testing shall employ purpose made equipment that produces a vacuum over the tested area. A detergent/water solution shall be applied to the full test area prior to the application of the test equipment that will display any leaks by bubbling of the solution. The CQA Engineer shall confirm that no leaks are present under application of the vacuum.

The Contractor shall maintain full records of all non-destructive testing which shall be provided to the CQA Engineer on a regular basis.

If the seam fails vacuum box testing, repairs shall be undertaken in accordance with Section 5.11.

Spark Testing

Where vacuum box and air pressure testing is deemed inappropriate spark testing may be employed subject to site specific risk assessment). The equipment shall be adjustable in voltage between 0kV and 30kV and shall generally be operated at a voltage of 10kV per mm of geomembrane thickness. The spark tester shall be passed slowly in close proximity to the weld to test all points on the weld, the weld having been formed with a continues copper wire core placed at the centre of the weld. Any anomalies in the seam will be identified by the presence of a spark. The location of any sparks shall be marked and the seam repaired in accordance with Section 5.11 and retested until no sparking is evident.

5.10.2 Qualitative Destructive Seam Testing

The Contractor shall cut a 25mm wide tab from the beginning and end of each field seam and subject them to qualitative destructive testing in peel and shear modes using a tension-meter or similar method. The seam will be deemed to be acceptable if failure in the tab sample solely occurs in the parent material and does not enter the seam. Should a field tab fail the destructive test the Contractor shall:

- Reconstruct the seam between the two tab locations and re-test or; and
- Cut further tabs from each side of the failure point and undertake such destructive testing until a successful result is achieved. The seam shall then be repaired as necessary.

The CQA Engineer may request further tabs for destructive testing at any location on the seams.

5.10.3 Quantitative Destructive Seam Testing

The Contractor shall cut two 25mm wide seam tabs from a 1000mm long by 300mm panel. This will be undertaken for both fusion and extrusion welds for destructive testing by a geosynthetics testing laboratory. The testing laboratory shall have UKAS accreditation (or similar approved) for the tests being undertaken. One tab shall be retained by the CQA Engineer and the other sent for testing and both tabs shall be individually referenced for location of the tested seam within the works. One sample per welding equipment shall also be taken for destructive seam testing, which may be taken from extended trial welds. The frequency of testing shall be in accordance with Table 1-3 below. However, the CQA Engineer may increase this frequency of sampling if test results indicate problems or poor workmanship.

The Contractor shall arrange for the tabs to be tested to failure at the geosynthetics laboratory and shall be deemed to have passed destructive testing if:

- The failure occurs solely in the parent material and does not enter the seam;

- The peel strength and shear strengths are equal to or exceed that indicated in the manufacturer's specified limits (Table 5-2 below)

Table 5-2: Peel Strength and Shear Strength Parameters

Property	Test Method	Units	Required Values	Conformance Testing Frequency
Fusion:	ASTM 6392	N/mm	10.5 (min.)	1 suite per 200m of seam (with a minimum of 1 if total length of seam <200m) and 1 suite on every day in which 25m or more of seam is completed.
Shear strength		%	50 (min.)	
Shear elongation		N/mm	8.8 (min.)	
Peel strength		%	25 (max.)	
Peel seperation				
Extrusion:	ASTM 6392	N/mm	10.5 (min.)	
Shear strength		%	50 (min.)	
Shear elongation		N/mm	7.6 (min.)	
Peel strength		%	25 (max.)	
Peel separation				

Should any of the samples fail destructive testing, the Contractor shall investigate the seam at either side of the failed sample location. Further sample tabs shall be removed from the seam and tested in the laboratory until satisfactory tests are obtained. The Contractor shall then reconstruct the failed area of seam and re-test.

5.11 Defects and Repairs

Each deployed panel of the geomembrane cap shall be visually inspected by the CQA Engineer for defects or installation damage prior to installation of the geotextile protecting layer. Any defects shall be identified and given individual reference numbers, recorded and marked by the CQA Engineer. The defects shall be repaired by patching and/or extrusion welding as follows:

a) Minor point defects (including significant scratching and crimping) may be repaired by extrusion welding, or as agreed with the CQA Engineer.
b) Larger damaged areas may be overlain by a single piece of geomembrane cap material with a minimum overlap of 150mm in all directions, which will be seamed by extrusion welding. The size and shape of patches shall be such that re-heating of previously welded material is minimised.

All repairs shall be subject to non-destructive testing and if deemed necessary by the CQA Engineer, destructive testing. All associated repairs will be shown on the Panel Layout Drawing with the individual Repair Reference Number.

5.12 Edge Detail

Where the proposed geomembrane cap is to tie into a basal lining system, the existing geomembrane will be carefully exposed and the proposed geomembrane cap will be welded onto the existing geomembrane liner. When excavating overlying materials lying above the geomembrane, care shall be taken not to damage the underlying geosynthetics. Any damage to the basal lining system shall be repaired to the satisfaction of the CQA Engineer. The tie-in details around the perimeter of the site are shown on Drawing Nos. 6a and 6b.

5.13 Sealing Around Protruding Pipework

All penetrations through the geomembrane cap shall be sealed to prevent water infiltration and air ingress. The Contractor shall provide an appropriate sealing mechanism around the gas and leachate abstraction/monitoring pipework.

5.13.1 Installation of Pipe Boots

An adjustable "pipe boot" of suitable impermeable material will be installed, which will accommodate movement of the pipe relative to the geomembrane cap and sub-grade. The boot will need to be fitted with an adjustable collar which can be released to allow the boot to be lowered, in order to accommodate excess settlement in the underlying waste.

The protrusions present within the cap have various diameters, and the details shown in the drawings are indicative, and will be tailored on site to seal each protrusion.

Site fabricated pipe boots shall be in accordance to Drawing No.5 and the manufacturer's guidelines. All LLDPE sleeves will be a minimum of 1.4m in length in order to ensure a minimum of 0.4m is exposed above the final restoration level.

Prior to installing the sleeve, the Contractor shall ensure that there are no knuckles or discontinuities in the gas well which may cause the sleeve to jam. The Supervisor shall confirm the condition of the gas well prior to the installation of the sleeve.

Method Statements and Risk Assessments will be required for approval by the Supervisor, due to the presence of landfill gas. Gas levels shall be monitored, to demonstrate to the Supervisor that levels are sufficiently low to permit safe working. Where possible, the pipe-boot shall be pre-fabricated away from the working area.

5.13.2 Installation of Bentonite Seal

The following methodology shall be adopted when installing bentonite seals to leachate collection/monitoring points, around which it is not possible to install a pipe boot detail:

- All bentonite used shall be in the granule form. Pellets will not be permitted;
- A suitable form shall be used to maintain the annulus between the structure and the placed subsoil;
- Approximately 50mm of hydrated bentonite granules shall be placed in the annulus;
- Water shall then be added to ensure the granules form a seal and water no longer drains away; and
- Bentonite may then be added along with more water until the specified depth is achieved, ensuring that at all times the water level is maintained above the bentonite granules.

5.14 Installation Approval

The installed geomembrane cap shall be subject to the inspection and approval of the CQA Engineer prior to the placement of the overlying layers of the final cover. Approval shall be made on the basis of the following:

- Visual inspection to confirm that all stones, extrusion weld materials or any other potentially deleterious materials have been removed from the surface of the geomembrane cap; that there are no visible surface defects such as excessive scratching and no folds or excessive undulations; and that the appropriate overlap between adjacent panels has been achieved;
- All necessary repairs have been made and their locations recorded; and
- All tests to seams, patches and repairs have been completed and recorded by the CQA Engineer and the results of respective laboratory destructive seam testing have been received.

Following confirmation of approval, approved areas shall be covered with the Protective Geotextile at the earliest possible opportunity. Approved areas not covered in a timely manner will require re-approval.

6.0 DRAINAGE LAYER

A geocomposite drainage layer shall be installed immediately above the geomembrane cap as soon as practicable. The layer provides a free draining layer at the base of the restoration soils allowing water seeping through the restoration soils to flow off the cap, both improving stability and minimising the risk of water infiltrating into the waste.

The Geocomposite Drainage Layer (GDL) shall be installed immediately above the geomembrane cap, as shown on Drawing No. 6b.

6.1 Geocomposite Drainage / Protection Layer

6.1.1 Material Requirements

The GDL shall consist of a geonet drainage core or a cuspated HDPE bands with a non-woven needle punched geotextile bonded on either side of the core. The GDL shall meet the requirements of table below:

Table 6-1
Geocomposite Drainage / Protection Layer Requirements

Parameter	Test Method	Required Value
CBR Puncture Resistance (composite)	BS EN ISO 12236	>4kN
In-Plane flow capacity (i =1 with soft/hard platens @ 20kPa)	BS EN ISO 12958	1 l/s/m (min.)
Tensile Strength – MD/CD (kN/m)	BS EN ISO 10319	Within manufacturers published parameters

For the material proposed the manufacturer shall provide data sheets to demonstrate that the minimum values above are achieved and also provide minimum values for each of the parameters detailed in Tables 6-1. The Contractor shall also provide the Supervisor with a copy of the manufacturer's recommendations and installation instructions for the material.

Each roll of GDL material supplied shall be free of joints throughout and certified as needle free by the manufacturer

6.1.2 Delivery, Handling and Storage

The GDL material shall be delivered, handled and stored in accordance with the manufacturer's recommendations taking care to protect the material from damage and contamination. A copy of the manufacturer's recommendations shall be provided to the CQA Engineer for his information. The PG shall be stored on a level, dry area at a location to be agreed on site and will not be stacked more than 3 rolls high with no materials being placed on top of the GDL.

Each roll should be identified with a unique roll number, the manufacturer's name, product name and type, batch number, date of manufacture and physical dimensions. Any protection coatings shall not be removed until the material is ready to be incorporated into the works.

The Contractor and CQA Engineer shall examine all rolls on delivery for damage in transportation and shall record the details of any damage together with the relevant manufacturer's reference numbers for each roll. Damaged rolls shall be set aside until the extent of damage and rejection of material can be determined.

6.1.3 Manufacturing Quality Control

Each roll of GDL delivered to site should be marked by the manufacturer to indicate the following:

- Type of material;
- Material thickness;
- Roll and batch numbers; and
- Roll dimension.

Production Quality Assurance Certificates should be provided by the manufacturer for review and retention by the Contractor and shall be provided to the CQA Engineer at his request. These Certificates need to cover all the rolls deployed and the tests in Table 1-5.

6.1.4 Conformance Testing

Samples shall be taken from selected rolls of GDL as determined by the CQA Engineer at a frequency of 1 per 5000m2 and submitted for conformance testing to confirm that the properties of the material meet the requirements set out in table 6-1. Tests shall be undertaken by independent laboratories with UKAS accreditation for the required tests. Results of laboratory testing will be compared to the values provided by the manufacturer to ensure the material meets the minimum requirements. Any non-conforming material will be rejected and the two rolls with adjacent sequential numbers shall be conformance tested. Any additional testing required as a result of non-conforming material shall be carried out at the expense of the Contractor.

In addition to the above conformance procedure, if any material appears to be visually defective upon installation it shall be removed to an extent as directed by the CQA Engineer who may request additional conformance testing. This additional testing shall be carried out at the expense of the Contractor.

6.1.5 Installation

As with the geomembrane cap installation, a panel layout plan shall be provided and agreed by the CQA Engineer prior to any installation.

The GDL should be deployed in panels normal to the contours of the slope (in the same direction as the respective geomembrane cap panels) in accordance with details on Drawing No 4.

The GDL shall be laid with either adjacent panels of the HDPE core butt jointed together and the geotextile edge flap extended across the joint shiplap style or with adjacent panels overlapped by a minimum of 300mm as approved by the CQA Engineer.
Each panel shall be visually inspected by the CQA Engineer to confirm adequate overlap and seam bonding and that there is no damage or defects in the laid material. Any defects may be patched over with a minimum overlap of 500mm around the defect. Tack welding will be used to retain the patch in position.

The Contractors method of deployment shall be such that:

- equipment, plant and tools used will not damage the GDL by handling, trafficking, leakage of hydrocarbons or by other means;
- personnel working on the GDL will not smoke, wear footwear likely to cause damage, or otherwise engage in any activity that could damage the GDL;
- stresses and strains likely to cause damage to the GDL and underlying layers will be avoided;

- the GDL will be in continuous contact with the surface on which it is placed without stretching or bridging over humps and hollows;
- the method of deployment will minimise wrinkles;
- deployment will not take place in the presence wind likely to cause damage;
- GDL will not be placed over areas of ponded water;
- direct contact with the GDL is minimised, and;
- construction plant will not traverse over any area of GDL until sufficient depth of cover has been placed over it in accordance with the Contract.

GDL placement shall not take place during periods of excessive winds. Sandbags or other suitable means to prevent wind disturbance shall weight down the GDL to prevent wind disturbances prior to placement of the subsequent layers.

Throughout deployment, the Contractor shall undertake a survey to pick up all panels, joints and repairs and provide an as-built Drawing to the CQA Engineer for inclusion in the CQA Validation Report. This shall be fully referenced and show panel and roll reference numbers and any repair and sampling locations.

6.1.6 Damage, Defects and Repairs

The GDL installation shall be inspected visually by the CQA Engineer. Should there be any signs of damage, defects or contamination, these shall be clearly marked.

The CQA Engineer shall advise the Contractor of any panels, or portions of panels, which are to be replaced or repaired. Damaged panels or portions of damaged panels, which have been rejected, shall be removed from the works area and replaced with undamaged material.

Any damage to the GDL shall be repaired by placing a suitably sized patch of the same material and by overlapping of at least 500mm in all directions. Tack welding will be used to secure the geotextile repair patches in place. All repaired sections of the GDL shall be marked on the panel deployment drawings.

The CQA Engineer will record confirmation of approval on the appropriate record sheet.

6.1.7 Installation Approval

The installed GDL shall be subject to the inspection and approval of the CQA Engineer prior to the placement of the restoration soils. Approval shall be made on the basis of the following:

- Visual inspection to confirm that all large stones, or any other potentially deleterious materials have been removed from the surface of the GDL; that there are no visible surface defects; and that the appropriate overlap and seam bonding between adjacent panels has been achieved;
- All necessary repairs have been made and their locations recorded; and
- The results of laboratory destructive testing have been received by the CQA Engineer.

Following confirmation of approval, approved areas shall be covered with restoration soils at the earliest possible opportunity. Approved areas not covered in a timely manner will require re-approval.

6.2 Geogrid Layer

6.2.1 General

The Contractor shall install the geogrid in accordance with Drawing No. 3, the Contractor shall install the geogrid above the geocomposite drainage layer and install to the back of the anchor trench as shown on Drawing No. 3.

6.2.2 Material Specification

The material will be Naue Secugrid 40/40 or equivalent and must comply with the parameters set in Table 6-2 below.

Table 6-1: Geogrid Requirements

Properties	Test Method	Required Value
Mass per unit area	EN ISO 9864	285 g/m^2
Maximum tensile strength	EN ISO 10319	md ≥40kN/m md cmd ≥20kN/m
Elongation at nominal strength	EN ISO 10319	≤7%
Tensile strength at 2% elongation	EN ISO 10319	14kN/m
Tensile strength at 5% elongation	EN ISO 10319	28kN/m
Aperture size		approximately 73x31mm
UV-resistance (remaining tensile strength)	EN 12224	96.3%
Weather Resistance	FGSV	high
Production specific elongation		0%

Note: Values in the above table are typical and not minimum required values, however any proposed product must be approved by the CQA Engineer.

6.2.3 Geogrid Delivery, Storage and Protection

The geogrid material shall be delivered, stored and handled strictly in accordance with the manufacturer's requirements and recommendations. The Contractor should contact the manufacturer prior to shipment to ascertain the appropriateness of the proposed unloading methods and equipment.

The Contractor shall ensure that all geogrid rolls delivered to site conform to the requirements outlined above. To that end, prior to installation of any geogrid, the Contractor shall provide the CQA Engineer with the following information for each separate consignment of each material delivered to site:

- Product Name and Grade/No;
- Name and address of producer/supplier;
- Batch and code number;
- Manufacturing characteristics;
- Consignment number and delivery date; and
- Quality control certificates, signed by a representative party employed by the manufacturer. Each Quality Control certificate shall include roll identification numbers, testing procedures and results pf Quality Control tests.

The Contractor shall ensure that the rolls of geogrid are stored in such a manner that no damage occurs and that handling equipment used does not damage the product. The Contractor shall check the integrity of the rolls making note of all roll numbers received.

The Contractor shall provide adequate and acceptable measures for protecting the materials at all stages of the work from all sources of potential damage, including weather conditions, until completion of the contract.

All material shall be stored, prior to deployment, within a designated area adjacent to the works. The Contractor shall ensure that entry into this storage is by authorised personnel only. All stored geogrid materials must be covered using plastic sheet/tarpaulin until their installation.

A visual inspection of each roll should be made during unloading to identify if any packaging has been damaged. Rolls with damaged packaging should be marked and set aside for further inspection. The packaging should be repaired prior to being placed in storage.

6.2.4 Geogrid Deployment

The geogrid shall be installed in accordance with the Manufacturer's recommendations, the contract drawings and specifications. The geogrid is to be placed either by hand or by approved suitable plant.

Geogrid rolls shall be delivered to the working area of the site in their original packaging. Immediately prior to deployment, the packaging shall be carefully removed without damaging the geogrid. The orientation of the geogrid should be in accordance with the CQA Engineer's instructions or Manufacturer's recommendations.

Equipment which could damage the geogrid shall not be allowed to travel directly on it. If the installation equipment causes rutting of the sub-grade, the sub-grade must be restored to its originally accepted condition before placement continues.

During placement of the geogrid, the following procedures shall be adhered to:

- all geogrid panels shall lie flat on the underlying surface, with no wrinkles or folds;
- the geogrid must be temporarily anchored in anchor trenches as required until the complete liner system is installed and the trench backfilled with the specified material. Provision for temporary anchorage to prevent wind uplift should also be made (e.g. sandbags); and
- installation shall not take place during high winds or rain.

Joins in the geogrid shall be formed by overlapping a minimum of 300mm between adjacent panels, and tying with polypropylene tie-pulls or similar at 250mm intervals for horizontal overlaps and 1m intervals for vertical overlaps. This is to prevent movement during placement of restoration soils.

6.2.5 Product Damage

The Contractor shall demonstrate to the CQA Engineer that he can place the geogrid in such a way as to negate the potential for damage to the geogrid. If the geogrid is damaged (bent, torn, etc.) during installation, it may be repaired by cutting a patch to fit over the damaged area, subject to the approval of the CQA Engineer. The patch shall be obtained from a new geogrid roll and shall be cut to size such that a minimum overlap of 300mm is achieved around all of the damaged area. The patch will be connected to the main geogrid panel using plastic ties or equivalent at 250mm spacing.

7.0 RESTORATION SOILS

The contractor shall place restoration soils, as indicated on Drawing Nos. 6a and 6b, over the drainage layer. The restoration soils shall consist of material sourced from on-site stockpiles. A Geocell material shall be installed within the topsoil layer to provide erosion protection and ensure stability of the surface upper surface of the restored profile.

7.1 Soils Specification

Soils are limited in Malta, are highly alkaline and lack organic matter. As such, the revegetation of the landfill requires an artificial growing medium to be made, comprising a host soil mixed with an appropriate ameliorant. The precise specification of the growing media, Topsoils and Subsoil, will be derived from the results of trial mixes.

The host soils used to manufacture the topsoil and subsoil shall be obtained from a suitable source and shall be free from any deleterious materials.

No unsuitable material shall be incorporated within the subsoil or topsoil layers. Unsuitable materials shall include but not be limited to the following:

- Materials susceptible to spontaneous combustion;
- Domestic, commercial or industrial waste;

and

- Any material which in the opinion of the CQA Engineer has the potential to damage the Protective Geotextile or GDL, for example sharp objects.

7.2 Soil Making Trials

A minimum of four topsoil and four subsoil mixes shall be proposed and trialled by the Contractor. A typical mix for the topsoils and subsoils consists of air (incorporated by loose tipping of material), water (added by irrigation), recycled waste compost and reclaimed soils and organic matter. The topsoil and subsoil and its components shall be free from toxic pollutants and sourced locally. Details of the composition, origin and a 5kg sample of each mix proposed shall be submitted for approval to the CQA Engineer.

The mixes shall emulate the proportions which are noted for good plant growth, as detailed in the tables 7-1 and 7-2 below.

Table 7-1: General Soil Grading Requirements

Material	Quantity
Clay	8 – 17%
Silt	10 – 40%
Sand	43 – 78%
Gravel (d > 2mm)	< 30%
Fines (d< 2mm)	> 70%

Table 7-2: Specific Soil Requirements

Property	Topsoil	Subsoil
Humus Soil	2 – 4% (rottegrad 5)	0% (rottegrad 5)
Dry Density	1.45 – 1.65Mg/m^3	1.45 – 1.65Mg/m^3
nFC	> 21% by Volume	> 17.5% by Volume
Air Capacity	> 10% by Volume	> 8% by Volume
pH	6.0 – 7.5	6.0 – 8.0

Where it is not possible to achieve the soils requirements, alternatives are to be proposed by the Contractor and agreed with the CQA Engineer.

The organic matter content can be raised for increased moisture retention if necessary. These ratios are to be agreed between the Contractor and the CQA Engineer. For the trial mixes the air and water components are the "void" in the mix created by loose tipping and mixing of the materials and the mineral and organic components are the solids.

The trials shall use various ameliorants available in Malta. Possible sources include:

- Farm manure / animal husbandry wastes;
- Sewage sludge (digested); and
- Composted municipal solid waste.

Other sources of suitable ameliorants, which may be available in Malta include:

- Uncontaminated harbour dredging;
- Straw; and
- Bark / woodchips.

Any sewage supplied shall be treated and dehydrated before use. However, full laboratory testing of the treated sewage is required to ensure no unsuitable toxins are incorporated into the topsoil or subsoil. The extracted water is also to be tested and subsequently used for grey water irrigation. Grey water is recycled water, which can be acquired from domestic outflow or other similar uncontaminated sources.

The contractor shall prepare an area for the manufacture of topsoil and subsoil. The area of manufacture shall be located off of the landfill foot print and remote from any underground services or drainage, such as to avoid damage during the mixing and excavating of the soils. The area shall be flat and sufficiently large enough to be divided into quarters, such that each trial mix can be manufactured and stored without cross contamination.

Materials would be delivered / supplied by others / the contractor and spread in (nominally) 75-100mmm layers and mixed using conventional agricultural rotavator (or other method of mixing approved by the CQA Engineer) to produce a homogeneous product, where the constituent parts are evenly distributed throughout the soil.

The resulting topsoil and subsoil can be temporarily stored in situ before being transferred to site for placement.

7.3 Soil Production

On the basis of the selected topsoil and subsoil mix design approved for inclusion in the works, the contractor shall submit a method statements for each soil detailing the following:

- Equipment to be used;
- Proportions of each material to be used;
- Method of mixing, irrigation, handling and storing; and
- Protocols to be undertaken to ensure a consistent product is manufactured.

Topsoil and subsoil shall be stored, handled and placed in such a manner so as not to adversely affect its characteristics.

Topsoil and subsoil shall be stockpiled separately at an appropriate location agreed with the CQA Engineer.

7.4 Soils Placement

The restoration layer comprises in two layers, Subsoil and Topsoil, placed to provide a minimum depth of cover to the geosynthetic capping system of 1000mm, as detailed below for each option in Table 7-3:

Table 7-3: Restoration Profile

Option 2 Geocomposite Drainage Layer
300mm Topsoil with Geocell
700mm Subsoil
Geogrid
Geocomposite Drainage Layer
Geotextile Protector
1mm thick LLDPE Geomembrane
Waste Regulating Layer

A minimum of 1000mm thickness of restoration materials shall be maintained between the geosynthetic capping system and construction plant, (with the exception of a low ground pressure dozer which shall maintain a minimum of 300mm). This will be verified by visually assessing the thickness to ensure the dozer/excavator and haulage vehicles are not causing rutting or damage to the underlying materials. The restoration soils shall be graded using a low ground pressure dozer, which will be supervised such that any damage to the underlying materials are identified and repaired in accordance with this Specification.

Restoration soils shall be placed up-slope, with soils being placed at the lowest points of the capped area first. Soils shall be pushed out in a direction towards the highest point of the cap.

The thickness of restoration soils will be physically verified on a 25m alphanumeric grid basis. The Contractor shall agree the method of measurement with the CQA Engineer, but may include such measures as the placement of batter boards, trial pits or other means to ensure the required thickness is achieved. Any areas that fail to

meet the above thickness requirements will need to be remedied by the Contractor to the satisfaction of the CQA Engineer.

7.5 Geocells

7.5.1 General

A 200mm deep Geocell system (Neoweb PRS 660-200 or similar approved) shall be installed within the topsoil layer to provide erosion protection and ensure stability.

Geocell is a three dimensional cellular geotextile system that provides protection against slope erosion and a substrate suitable to support landscape planting. It is usually, but not always, supplied in flat panels that are extended across, and secured by pins to slopes to form a matrix of cells that restrain the surface fill material when placed

7.5.2 Delivery, Handling and Storage

The Geocell material shall be delivered, handled and stored in accordance with the manufacturer's recommendations taking care to protect the material from damage and contamination. A copy of the manufacturer's recommendations shall be provided to the CQA Engineer for his information. The Geocell shall be stored on a level, dry area at a location to be agreed on site and will not be stacked more than 3 rolls high with no materials being placed on top of the Geocell.

Each roll should be identified with a unique roll number, the manufacturer's name, product name and type, batch number, date of manufacture and physical dimensions. Any protection coatings shall not be removed until the material is ready to be incorporated into the works.

The Contractor and CQA Engineer shall examine all materials on delivery for damage in transportation and shall record the details of any damage together with the relevant manufacturer's reference numbers for each roll. Damaged rolls shall be set aside until the extent of damage and rejection of material can be determined.

7.5.3 Installation

A proposed layout plan for the Geocell shall be provided and agreed by the CQA Engineer prior to any installation.

Upon completion of the subsoil layer placement, a 125mm thick layer of topsoil shall be placed and trimmed ready to receive the Geocell material. The Geocell shall be installed and then filled to leave 25mm of the Geocell geotextile proud of the surface of the topsoil.

Placement and filling of the Geocell shall be carried out in such a manner as not to damage the underlying topsoil and subsoil layers. If in the opinion of the CQA Engineer, the construction equipment used to install the Geocell material and place the topsoil causes excessive rutting of the underlying soils, then the surface shall be repaired to the satisfaction of the CQA Engineer.

Prior to filling with topsoil the Geocell shall be securely fixed and anchored in place using anchor pins. Pins shall be located in accordance with the manufacturer's recommendations, such that the cell shape is maintained and downward forces resisted during and following filling. As a minimum, pins shall be placed at the corners of panels and every 2m in the perimeter of the Geocell panel. Restraint of the Geocell in the form of tendons, pins and proprietary fixings shall be installed within each panel to the manufacturer's requirements. Where no restraint is recommended within each panel, the extent of fixings shall be agreed with the CQA Engineer prior to installation.

The Geocell shall not be extended beyond the extent recommended by the manufacturer ti maintain structural integrity. If no pre-designated shapes and sizes are recommended, the Geocell shall be extended such that a

uniform shape and sized of cell is maintained throughout. Some variations in the cell size may be necessary to accommodate obstacles within the restoration profile.

Where a Geocell section is too long the Geocell shall be cut to size using a method recommended by the manufacturer.

Sections of Geocell shall be joined together by a method recommended by the manufacturer.

The Geocells are ot be filled with topsoil leaving 25mm of the cell proud of the surface of the topsoil. Topsoil shall be placed in the Geocells from the bottom of the slope upwards to ensure stability and to maintain the shape of the cells.

A placement trial shall be undertaken to demonstrate that the Contractor's method of construction meets the requirements of this specification.

7.6 Irrigation System

The contractor shall provide proposals for the irrigation system for the approval; of the CQA Engineer. The Contractor shall provide irrigation water from an offsite source, during the works (including the maintenance period) unless agreed with the Employer.

Irrigation shall be undertaken by hand with tankers until such time that the irrigation system has been installed to a point that it functions satisfactorily.

The irrigation system shall be installed without causing damage to the drainage and gas systems and shall be located so as not to interfere with the function of these systems.

The contractor shall prepare an irrigation programme. Optimally plants should be watered 2 times per day.

Water supply required for irrigation shall be provided by the Contractor.

7.7 Inclement Weather Conditions

No materials shall be imported or placed during inclement weather conditions, if in the opinion of the CQA Engineer, trafficking over compacted or un-compacted material would prove detrimental to the construction. Any such trafficking damage caused by the Contractor shall be repaired in accordance with the Specification. Inclement weather conditions may include rain, snow, freezing conditions or excessive heat indicated by the CQA Engineer on site.

Following wet weather conditions, any standing water on the surface of the construction must be removed. Earthworks placement operations following inclement weather conditions shall not proceed without the prior approval of the CQA Engineer.

Any material frozen in stockpiles shall be removed and put to one side until thawed.

The works may also be stopped if safety is compromised as a result of inclement weather conditions. Work resumption after interruptions due to inclement weather conditions shall be at the agreement of the CQA Engineer.

7.8 Seeding and Planting

The contractor shall submit a programme for the planting works for the approval of the Employer, which identifies the sequencing of planting in line with the construction capping system, placement of restoration soils and installation of the irrigation system.

Plants shall be selected from the list included in Table 7-1 below to create the habitats as outlined in Drawing No.9.

Table 7-4: Planting Varieties

Scientific Name	English Name / Maltese	Plant Type	Container/ Dimensions	Type of Soil	Water Logging Tolerance	Depth Of Soil (inc subsoil)	Litres per Week (Year 1)	Irrigation Type	Planting Season
Atriplex halimus	Shrubby Orache/ Bjanka	Shrub	18-20cm	Loam	Tolerant	55cm	12lt	Line	October - April
Helichrysum melitense	Maltese Everlasting/ S. ta' Ghawdex	Shrub	15-18cm	Loam	Tolerant	35cm	10lt	Line	October - April
Inula crithmoides	Golden Samphire / Xorbett	Shrub	15-18cm	Loam	Tolerant	35cm	10lt	Line	October - April
Nerium oleander	Oleander / Siġra tad-Difel	Shrub	18-20cm	Loam	Tolerant	55cm	12lt	Line	October - April -
Pistacia lentiscus	Lentisk / Deru	Small tree	18-20cm	Loam	Sensitive	55cm	12lt	Line	October - April
Rhamnus alaternus	Mediterranean Buckthorn / Alaternu	Small tree	18-20cm	Loam	Sensitive	55cm	12lt	Line	October - April
Senecio bicolor	Silvery Ragworth / Kromb il-Bahar Isfar	Shrub	15-18cm	Loam	Sensitive	35cm	10lt	Line	October - April
Spartium junceum	Spanish broom / Ġenista Safra	Shrub	15-18cm	Loam	Sensitive	35cm	10lt	Line	October - April
Tamarix africana	African Tamarisk / Siġra tal-Bruk	Small tree	18-20cm	Loam	Tolerant	55cm	12lt	Line	October - April
Teucrium fruticans	Teucrium fruticans Olive-leaved germander/ Zebbugija	Shrub	15-18cm	Loam	Sensitive	35cm	10lt	Line	October - April

8.0 SURFACE WATER SCHEME

The contractor shall install a surface water ditches around the perimeter of the landfill and along the benches within the restored profile, feeding into the existing surface water management drains which run along the adjacent access roads. The layout of the surface water ditches is shown on Drawing No. 7 and construction details are shown on Drawing No. 8.

Ditches around the perimeter of toe are formed at the point where the restored slope meets the perimeter retaining wall as shown Drawing No. 8. The ditch shall be lined with a layer of riprap, nominally 150mm, to minimise erosion of the base of the ditch.

At the locations indicated on Drawing No. 7 discharge points are to be constructed to allow water from the ditches to pass through the retaining wall and allow water to flow to the existing drains in the access road. Construction details for the discharge points are presented on Drawing No. 8.

Ditches running along the benches will be constructed to the details shown on Drawing No. 8, which in general show a triangular channel with sides to be constructed to 1(vertical):2(horizontal) slopes to a depth of 0.5m vertical.

Where benches on the landfill intersect culverts will be constructed in accordance with construction details pipework will comprise 2x200mm ID structured wall concrete pipes as shown on Drawing No. 8.

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APPENDIX 06

CQA Plan

GHALLIS LANDFILL

Capping and Restoration
Construction Quality Assurance Plan

Prepared for: **WasteServ Malta Limited**

SLR Ref: 403.00585.00035
Version No: V3
July 2020

BASIS OF REPORT

This document has been prepared by SLR with reasonable skill, care and diligence, and taking account of the manpower, timescales and resources devoted to it by agreement with WasteServ Malta Ltd. (the Client) as part or all of the services it has been appointed by the Client to carry out. It is subject to the terms and conditions of that appointment.

SLR shall not be liable for the use of or reliance on any information, advice, recommendations and opinions in this document for any purpose by any person other than the Client. Reliance may be granted to a third party only in the event that SLR and the third party have executed a reliance agreement or collateral warranty.

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Information, advice, recommendations and opinions in this document should only be relied upon in the context of the whole document and any documents referenced explicitly herein and should then only be used within the context of the appointment.

CONTENTS

1.0 General

1.1 Introduction

WasteServ Malta Limited (WasteServ) are in the process of appointing a Contractor to undertake the construction of the first non hazardous waste landfill cells at Ghallis Ta' Gewwa, following completion of an Environmental Impact Assessment (EIA) on the proposed facility and receipt of a permit from the Malta Environmental and Planning Authority (MEPA).

SLR Consulting Limited (SLR) has been instructed to provide design services for the proposed construction works in accordance with the principals set out in the approved EIA and permit. The works entail the construction of a non hazardous lining and leachate collection system within the void created by extraction of in situ limestone deposits.

This CQA Plan has been prepared by SLR to detail the installation and testing quality control procedures that will be followed during the installation of the landfill lining and leachate collection system. A detailed installation specification for each element of the system is included in Appendix A.

1.2 Definitions

For the sake of clarification the following definitions are given:

Construction Quality Assurance (CQA) – A planned and systematic pattern of all means and actions designed to provide confidence that items or services meet contractual and regulatory requirements, and will perform satisfactorily in service.

Construction Quality Assurance refers to means and actions carried by parties (as appointed by WasteServ), to assure conformity with the landfill lining system design, as detailed in the Contract Drawings and Specifications. CQA is provided by SLR.

Construction Quality Control (CQC) – Those actions, which provide a means to measure and regulate the characteristics of an item or service to contractual requirements.

Construction Quality Control refers to those actions taken by Manufacturers, Installers, Contractors, or the Employer to ensure that the materials and the workmanship meet the requirements of the Contract Drawings and Specifications.

Employer – refers to the person or persons, firm or company or other body who owns and has responsibility for the facility. For the works undertaken at Ghallis, the Employer is WasteServ. The Employer has entered/will enter into a contract with a Contractor for the execution of the works detailed in the Specification and Contract Drawings. The Employer may be represented on site by personal representatives or other parties as appointed by the Employer.

Contractor - means the person or persons, firm, company or other body to whom the Contract has been/will be awarded by the Employer, and includes the Contractor's personal representatives or other parties, e.g. Sub-contractors, Manufacturer. The Contractor will undertake the execution of the Works under the terms of the Contract.

Specification - means that part of the Contract entered into between the Employer and the Contractor which sets out the Employer's detailed requirements as to how the works should be constructed, tested, measured and quality assured.

The Specification forms part of this CQA Plan and is included as Appendix A. It should be noted that the Specification and Construction Drawings presented in this CQA Plan are intended to set out the future construction of the capping works. However, the cap will be installed in a progressive manner and the design may have to be altered to accommodate the conditions encountered on site in the future.

1.3 Responsibilities

The CQA Project Team will comprise the following:

"CQA Project Manager" who will be based at the offices of SLR. The CQA Project Manger:

- attends selected progress or liaison meetings and is the key contact with regulatory officers;
- reviews all designs, plans and specifications;
- reviews other site-specific documentation, including proposed layouts, and Contractor's qualifications;
- administrates the CQA program;
- reviews all changes to the design, plans and specifications;
- oversees and reviews the CQA Certification Report.

"CQA Engineer" who is a representative of the Engineer/ Supervisor and is located full time at the site. The CQA Engineer:

- acts as the on-site (resident) representative of the Engineer/ Supervisor;
- familiarises all CQA Monitors with the site, and the CQA requirements for the project;
- manages the daily activities of the CQA Monitors;
- attends all CQA-related meetings (e.g. Pre-construction and Progress);
- prepares, or oversees the ongoing preparation of the Record Drawings;
- assigns locations for testing and sampling;
- reviews all CQA Monitors' daily reports and logs;
- reports to the CQA Project Manager, and logs in his daily report any relevant observations;
- oversees the collection and shipping of all samples for laboratory testing;
- reviews results of laboratory testing and makes appropriate recommendations;
- reports any unresolved deviations from this CQA Plan to the CQA Project Manager;
- provides all logs and relevant data to the CQA Project Manager for the preparation of the final report;
- reviews all Certifications and Documentation from the Contractor and makes appropriate recommendations; and
- notes and brings to the attention of the Contractor any on-site activities that could result in damage to the lining system.

2.0 Scope of Construction Works

This document is intended to provide a complete CQA Plan and Specification for the various aspects of work proposed at Ghallis Landfill Site (the Site).

The Site will undergo progressive capping and restoration as the final waste levels are achieved. The proposed capping, restoration and surface water works at the Site will incorporate the following main elements of works:

Geosynthetic Option

- Placement of the 250mm regulation layer;
- Installation of a 1mm thick LLDPE Geomembrane Cap (textured on both sides) with welded seams;
- Placement of a geocomposite drainage layer;
- Installation of a reinforcing geogrid layer;
- Placement of minimum 1000mm thick restoration soils;
- Installation of geocells to prevent erosion of the restoration soils;
- Planting with suitable seed mix;
- Construction of a surface water ditches; and
- Provision of adjustable boots around all protrusions in the capping area.

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3.0 As-Built Topographic Surveys

Prior to commencing the construction works and throughout the Construction Quality Assurance programme, a number of topographic surveys will be undertaken to confirm that construction is taking place in accordance with the Specification. Specifically, surveys shall be undertaken to provide details of the following for each phase of capping:

- prior to commencing earthworks;
- post waste re-grading;
- on completion of placement of the waste regulating layer (WRL);
- as-built geomembrane panel survey to include the location of tie-ins with existing phases of capping and the basal liner, and defect and repair locations;
- as-built geocomposite panel layout to include any defect and repair locations;
- on completion of restoration soils placement;
- on completion of surface water ditches; and
- total as built survey indicating the location of landfill gas and leachate infrastructure.

The above survey documentation shall be incorporated into the post construction Certification Report (Section 4).

4.0 Certification Report

Upon completion of each phase of the capping works the CQA Engineer will prepare Certification Reports summarising the works undertaken and including all CQA documentation prepared. As a minimum this shall include:

- Description of Works;
- Description of methods utilised to execute the works;
- Description of quality control procedures adopted;
- Description of materials used within the works;
- Manufactures quality control information for materials utilised in the works;
- Details of any non-conformances, including any remedial action taken;
- Daily Records and Completed Proformas;
- Contractor's Documentation;
- Test (Laboratory & Field) Reports;
- Photographic Records;
- As Built Drawings (see Section 3); and
- Engineer's daily diaries.

The above reports will confirm that the works have been carried out in accordance with the Specification as incorporated in this CQA Plan.

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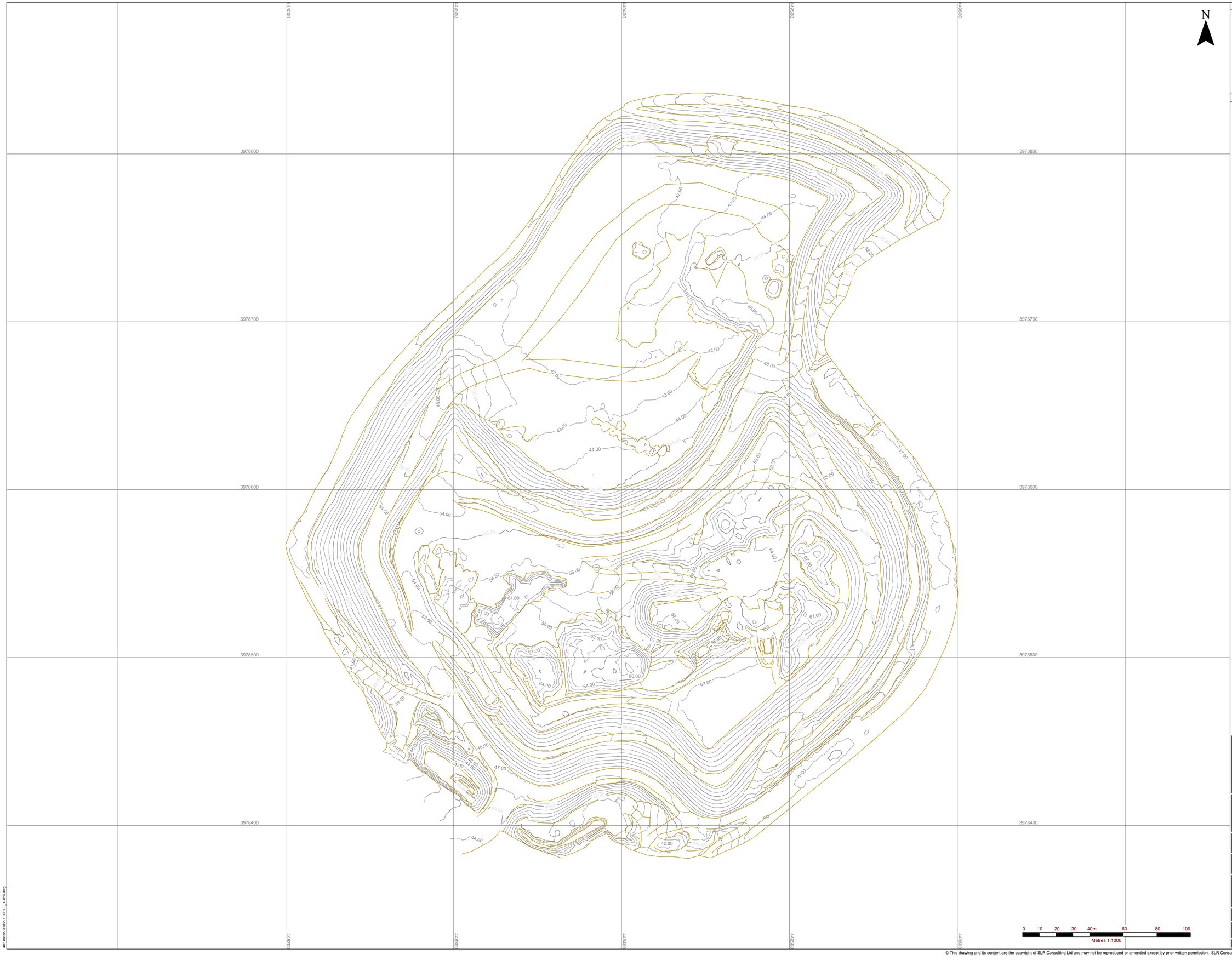
DRAWINGS



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1. TOPOGRAPHIC SURVEY INFORMATION SUPPLIED BY WASTESERVE MALTA LTD. REF: 200422 DTM FULL 2000.DXF, DATE RECEIVED: 11.06.2020.

LEGEND

50.00 TOPOGRAPHY LEVEL CONTOURS (mAMSC)

Revision	By	Chk'd By	Date	Comments
0	AB	JC	09/20	

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Site: GHALLIS LANDFILL SITE

Project: RESTORATION LEVELS

Drawing Title: **TOPOGRAPHIC SURVEY**

Scale: 1:1000 @ A1

Date: SEPTEMBER 2020

Drawing Number: **001**

Revision: **0**

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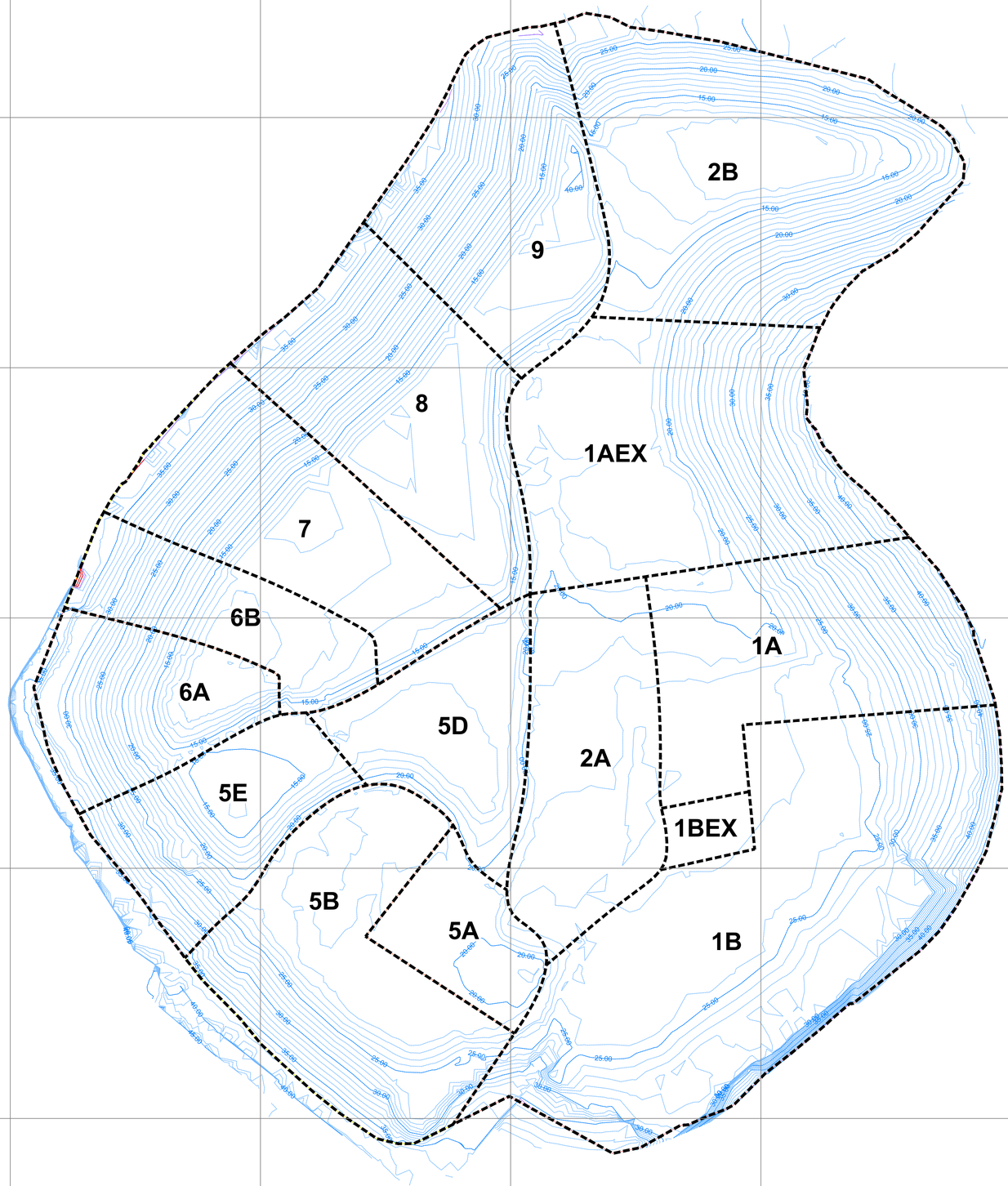

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LEGEND

PHASE BOUNDARY

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Metres 1:1000

Revision	By	Chk'd By	Date	Comments
0	KW	JC	09/20	

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Project: RESTORATION LEVELS

Drawing Title: **BASAL CELL LAYOUT**

Scale: 1:1000 @ A1

Date: SEPTEMBER 2020

Drawing Number: 002

Revision: 0

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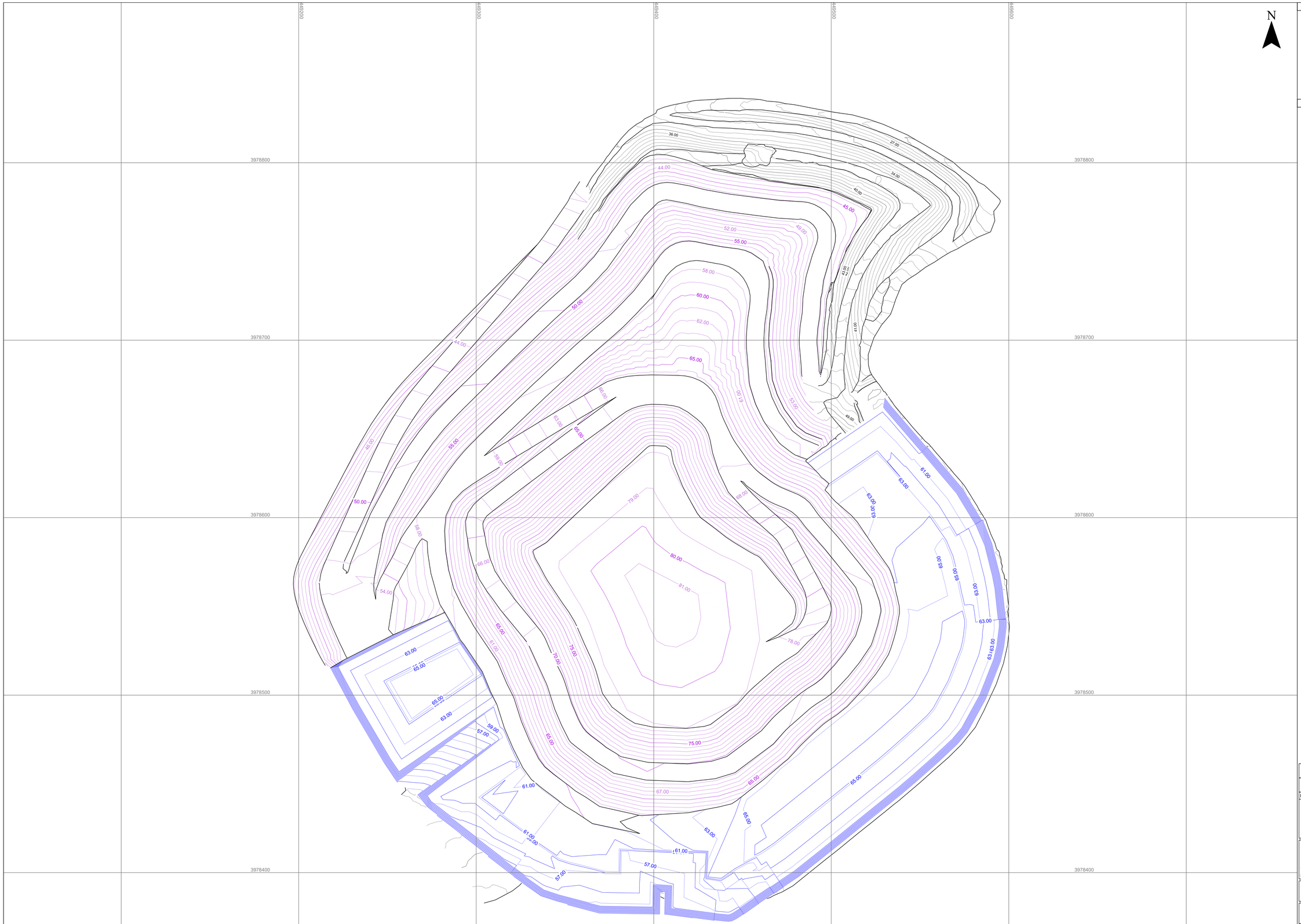

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1. TOPOGRAPHIC SURVEY INFORMATION SUPPLIED BY WASTESERVE MALTA LTD. REF: 200422 DTM FULL 2000.DXF, DATE RECEIVED: 11.06.2020.

LEGEND

- 40.00 — TOPOGRAPHIC SURVEY LEVEL CONTOURS (mAMSL)
- 50.00 — PROPOSED STEEP WALL LINER LEVEL CONTOURS (mAMSL)
- 60.00 — PROPOSED TOP OF PRE SETTLEMENT WASTE LEVEL CONTOURS (mAMSL)

Revision	By	Chk'd By	Date	Comments
1	AB	JC	12/20	Revised Landform
0	AB	JC	09/20	

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Project: RESTORATION LEVELS

Drawing Title: **PROPOSED RESTORATION SCHEME TOP OF WASTE LEVELS - PRE SETTLEMENT**

Scale: 1:1000 @ A1

Date: SEPTEMBER 2020

Drawing Number: 003

Revision: 0

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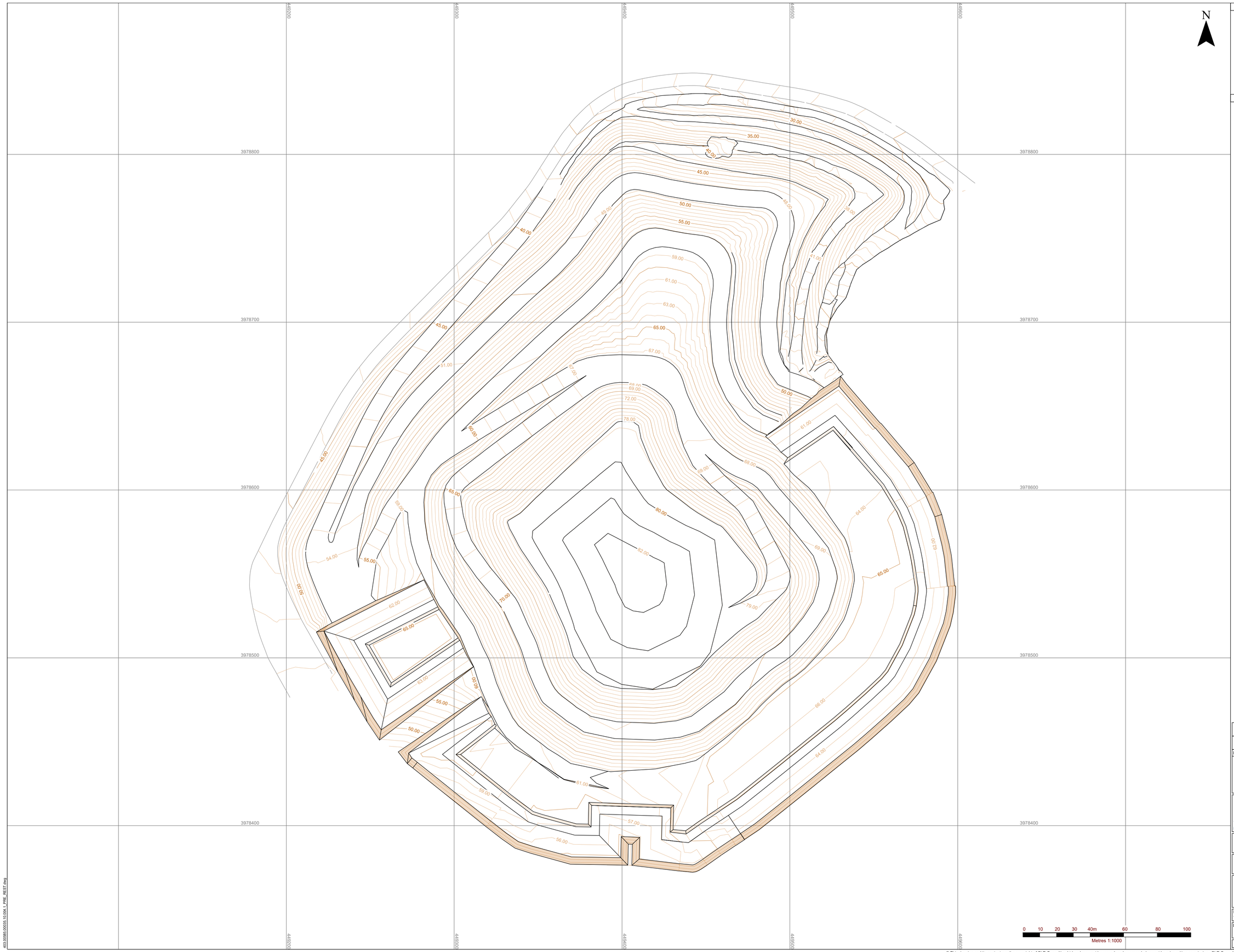

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1. TOPOGRAPHIC SURVEY INFORMATION SUPPLIED BY WASTESERVE MALTA LTD. REF: 200422 DTM FULL 2000.DXF, DATE RECEIVED: 11.06.2020.

LEGEND

70.00 — PROPOSED PRE SETTLEMENT RESTORATION LEVEL CONTOURS (mAMSL)

Revision	By	Chk'd By	Date	Comments
1	AB	JC	12/20	Revised Landform
0	KW	JC	09/20	

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Project: RESTORATION LEVELS

Drawing Title: **PROPOSED RESTORATION SCHEME TOP OF RESTORATION LEVELS - PRE SETTLEMENT**

Scale: 1:1000 @ A1

Date: SEPTEMBER 2020

Drawing Number: **004**

Revision: **0**

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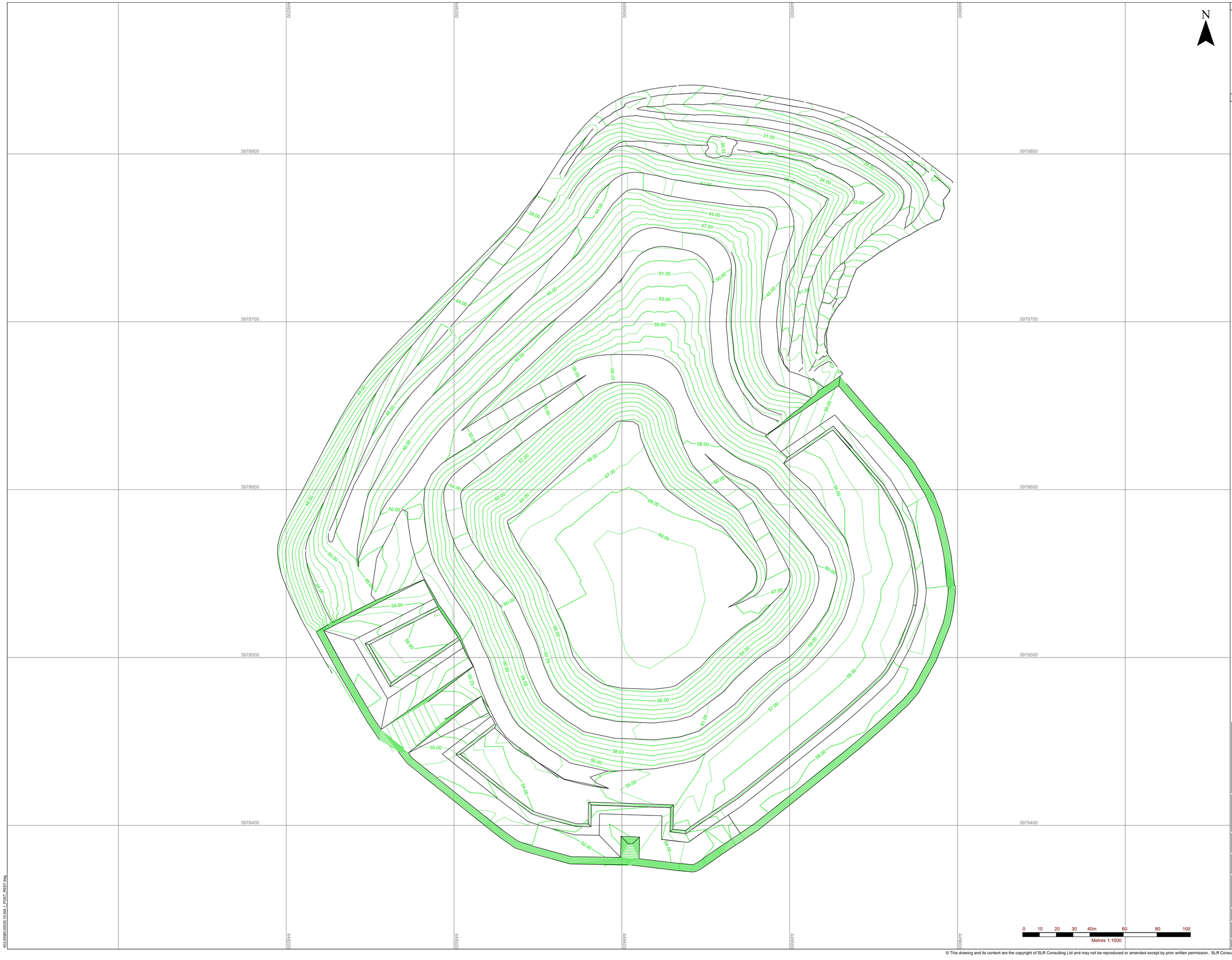

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1	AB	JC	12/20	Revised Landform
0	AB	JC	09/20	

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Project: RESTORATION LEVELS

Drawing Title: **PROPOSED RESTORATION SCHEME TOP OF RESTORATION LEVELS - POST SETTLEMENT**

Scale: 1:1000 @ A1

Date: SEPTEMBER 2020

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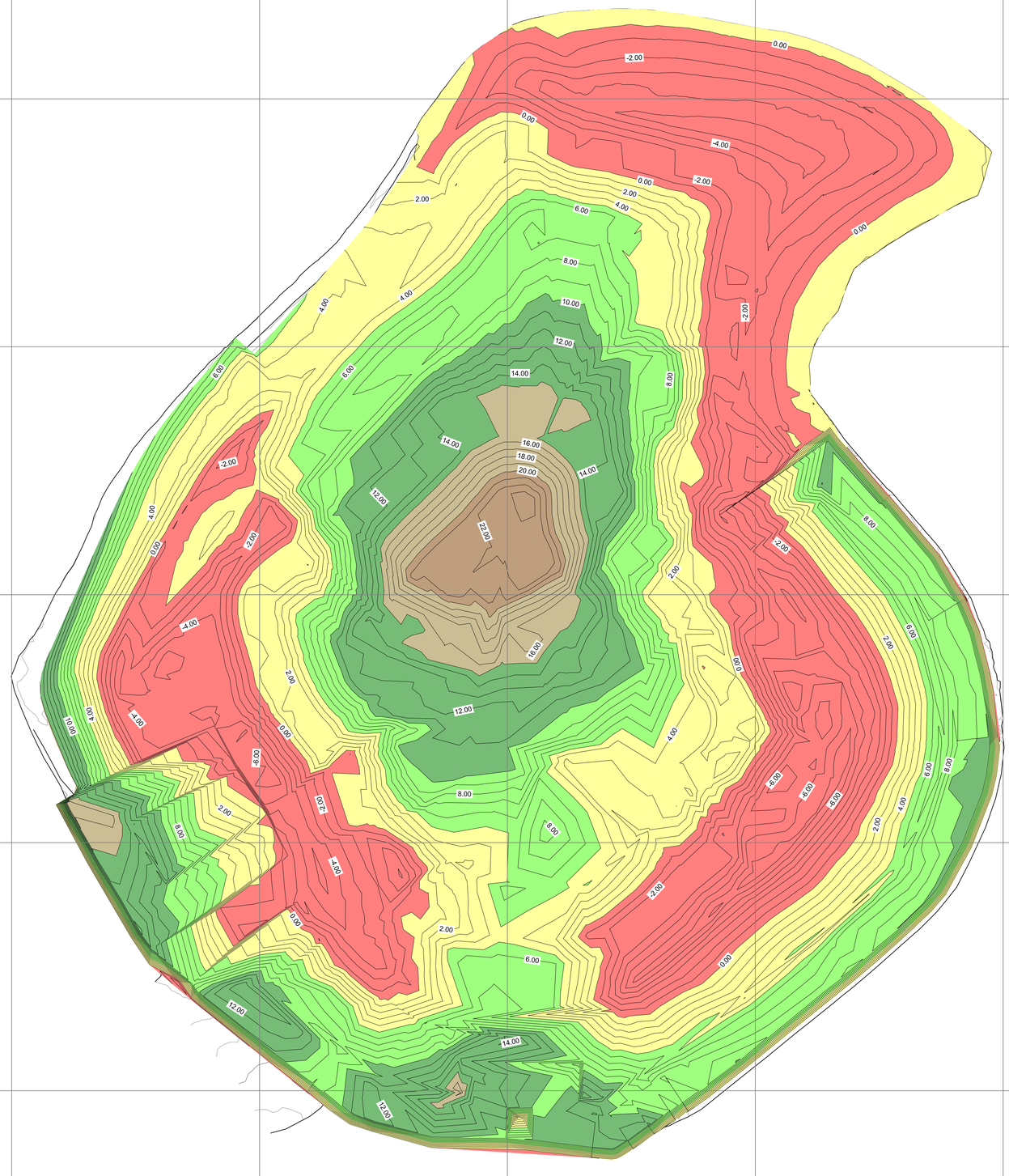

NOTES

1. TOPOGRAPHIC SURVEY INFORMATION SUPPLIED BY WASTESERVE MALTA LTD. REF: 200422 DTM FULL 2000.DXF, DATE RECEIVED: 11.06.2020.

LEGEND

ISOPACHYTE CONTOURS

Elevations Table			
Number	Min Elevation	Max Elevation	Color
1	-7.98	0.00	
2	0.00	5.00	
3	5.00	10.00	
4	10.00	15.00	
5	15.00	20.00	
6	20.00	23.50	

0 10 20 30 40m 60 80 100
Metres 1:1000

Revision	By	Chk'd By	Date	Comments
1	AB	JC	12/20	Revised Landform
0	AB	JC	09/20	

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Site: GHALLIS LANDFILL SITE

Project: RESTORATION LEVELS

Drawing Title: **ISOPACHYTE OF WASTE THICKNESS BETWEEN TOPOGRAPHIC SURVEY AND PROPOSED RESTORATION SCHEME**

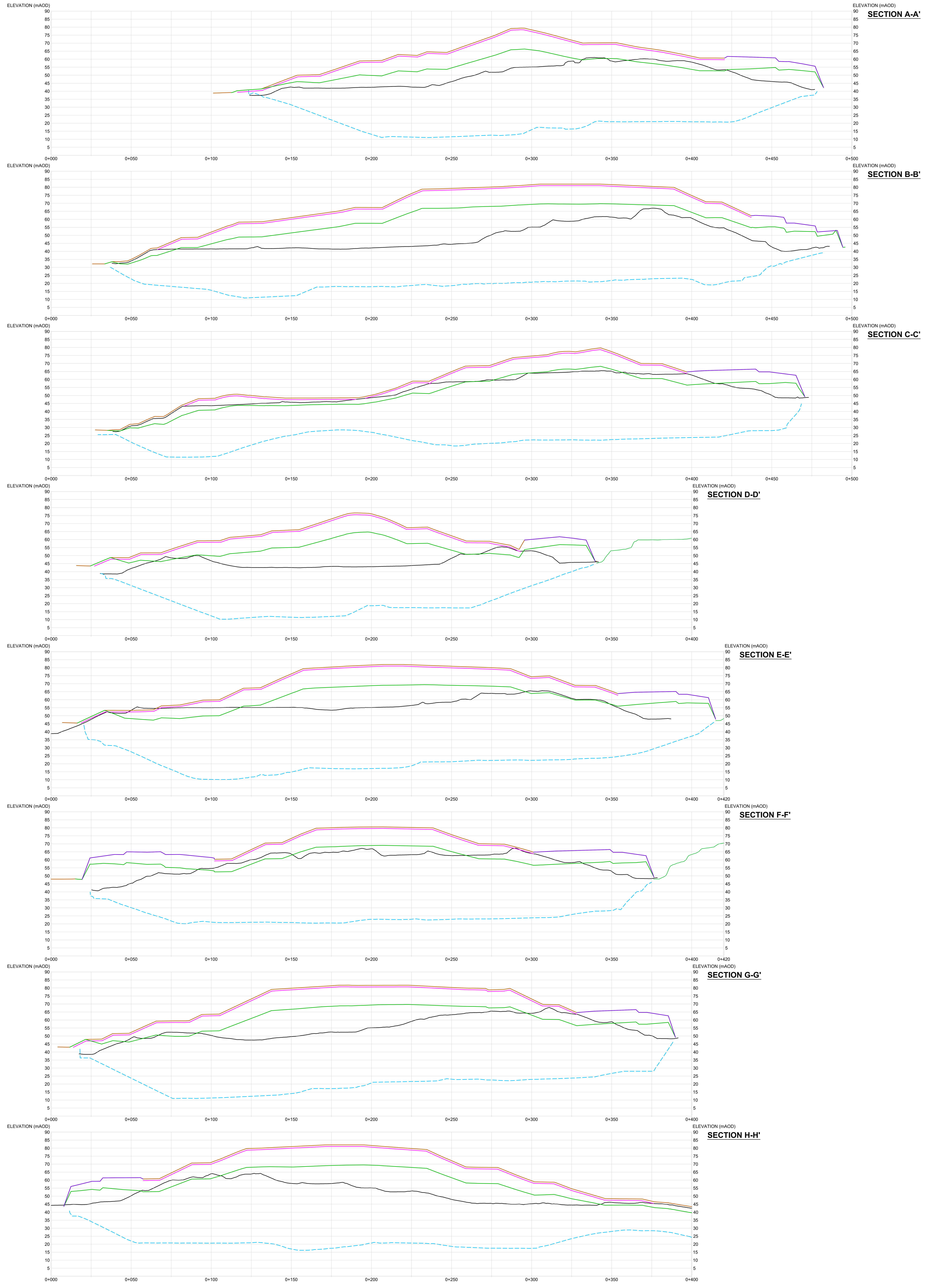
Scale: 1:1000 @ A1

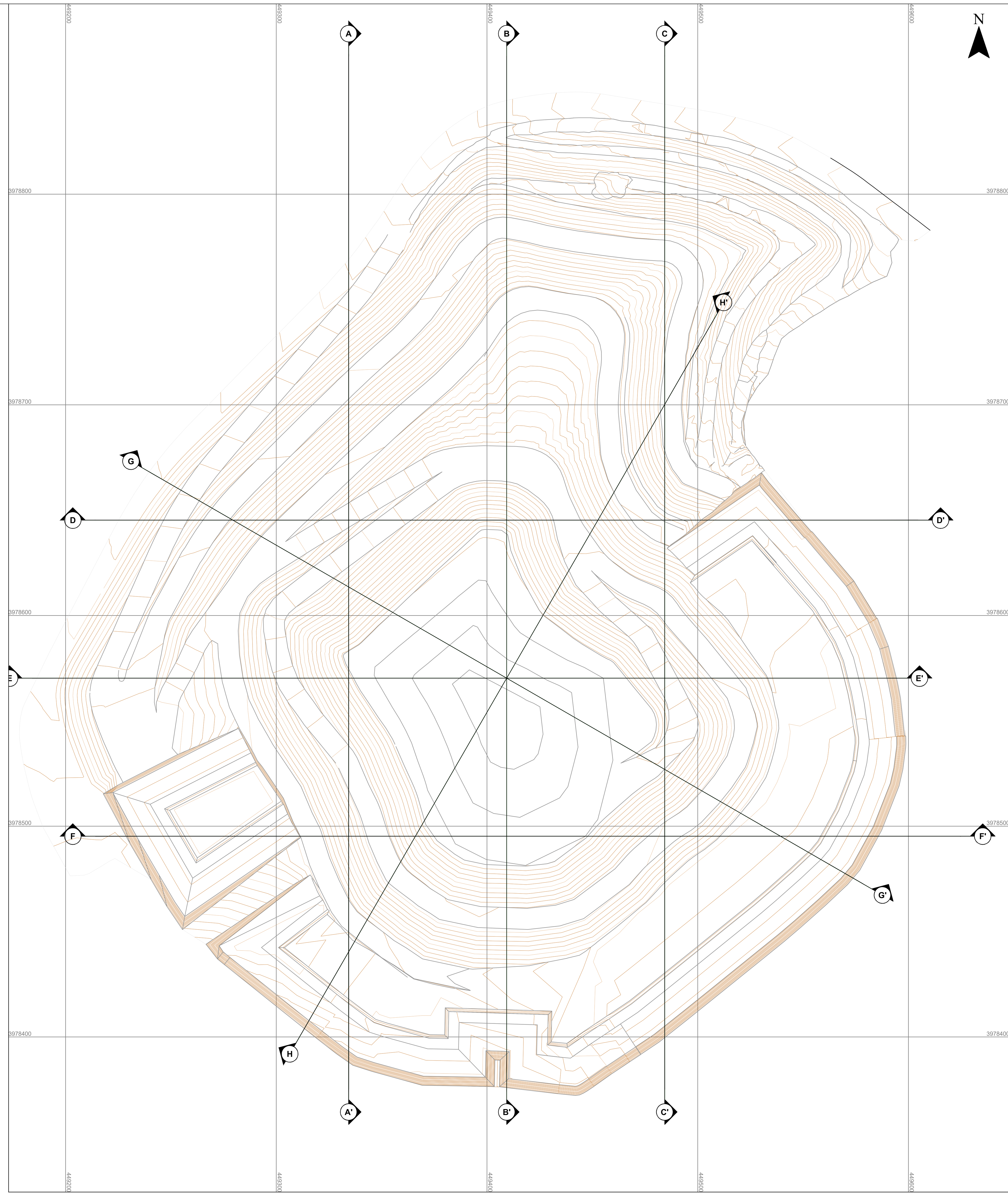
Date: SEPTEMBER 2020

Drawing Number: **005**

Revision: **0**

403.05088.00035.10.007.1-ISO_REST.dwg





PLAN SHOWING PROPOSED RESTORATION CONTOURS AND LOCATION OF CROSS SECTIONS

0 10 20 30 40m 60 80 100
Metres 1:1000

NOTES

1. TOPOGRAPHIC SURVEY INFORMATION SUPPLIED BY WASTESERVE MALTA LTD, REF: 200422 DTM FULL 2000.DXF, DATE RECEIVED: 11.06.2020.

LEGEND - PLAN

50.00 — PROPOSED PRE SETTLEMENT RESTORATION LEVEL CONTOURS (mAMSL)

LEGEND - SECTION

- CURRENT TOPOGRAPHIC SURVEY LEVEL PROFILE
- AS-BUILT BASAL LINER LEVEL PROFILE
- AS-BUILT MAGHTAB LANDFILL PROFILE
- PROPOSED STEEP WALL LINER LEVEL PROFILE
- PROPOSED TOP OF WASTE LEVEL PROFILE
- PROPOSED PRE SETTLEMENT RESTORATION LEVEL PROFILE
- PROPOSED POST SETTLEMENT RESTORATION LEVEL PROFILE

Revision	By	Chk'd By	Date	Comments
1	AB	JC	12/20	Revised Landform
0	AB	JC	09/20	

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Site
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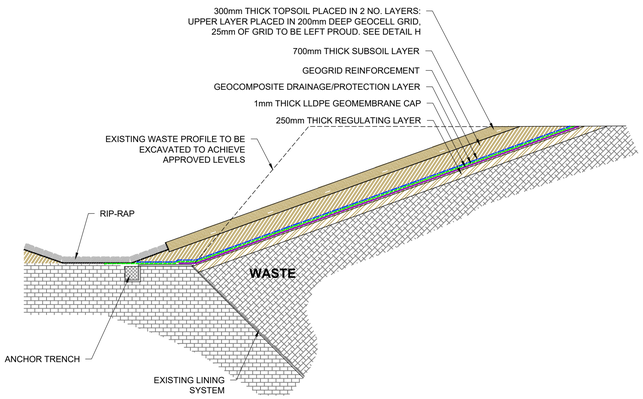
Project
RESTORATION LEVELS

Drawing Title
CROSS SECTIONS THROUGH THE PROPOSED RESTORATION SCHEME

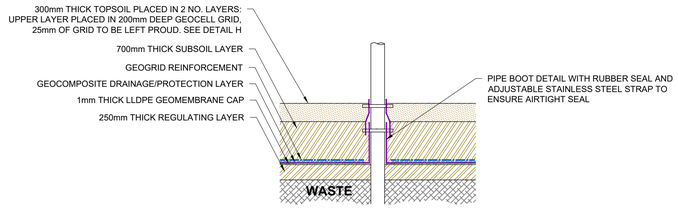
Scale	Date
1:1000 @ A0	SEPTEMBER 2020

Drawing Number	Revision
006	0



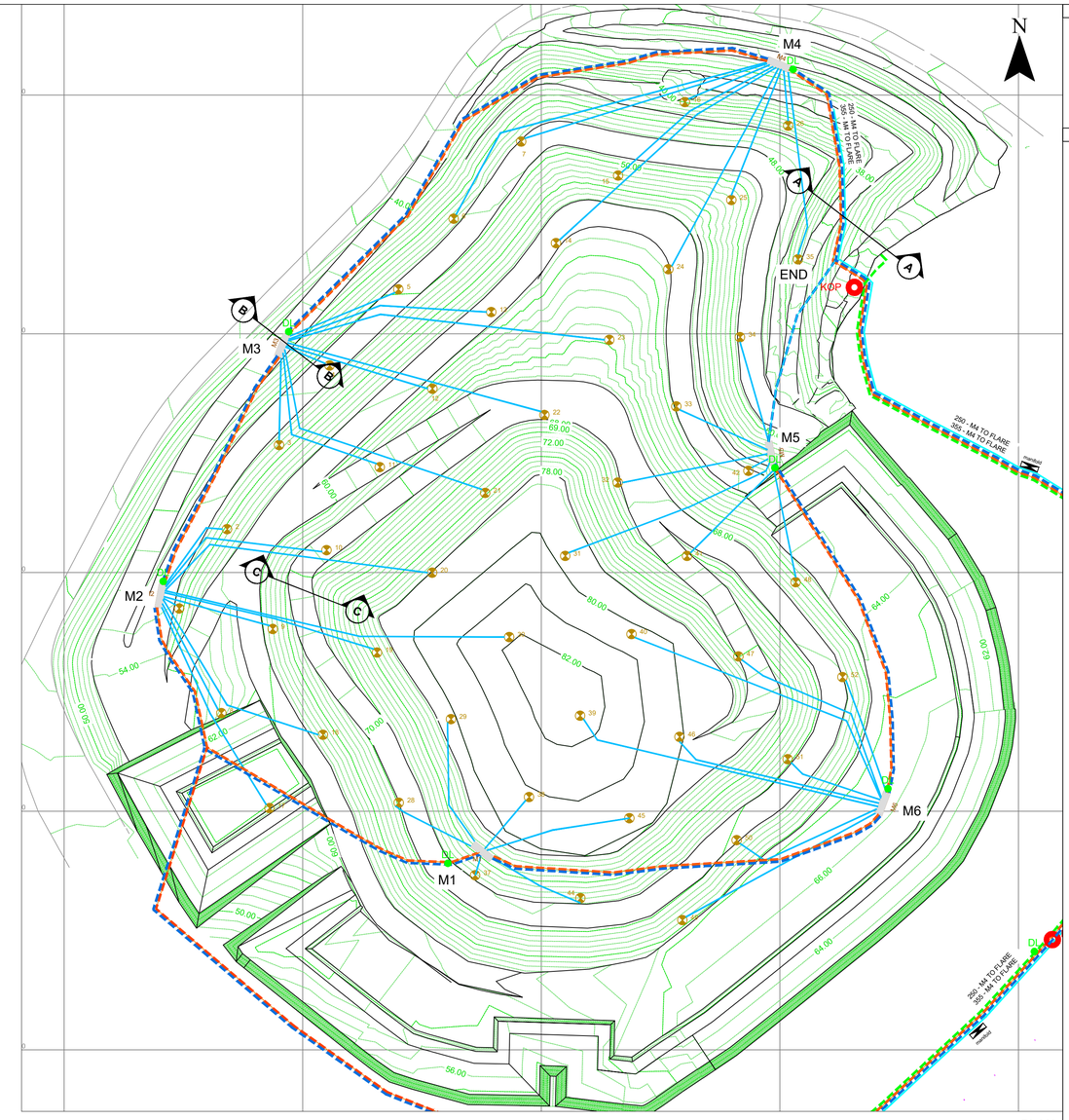
SECTION AA - THROUGH TIE-IN ALONG WESTERN BOUNDARY ADJACENT TO LANDFILL GAS PLANT

SCALE NTS



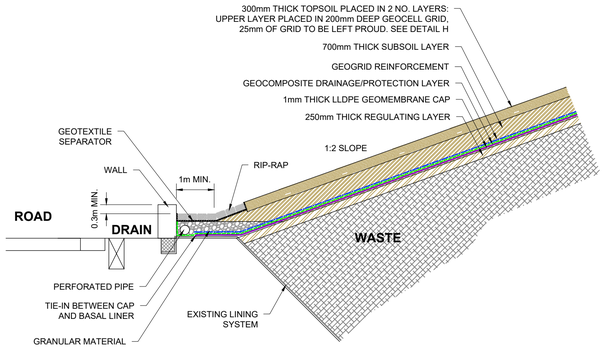
DETAIL A: SECTION THROUGH LANDFILL GAS AND LEACHATE EXTRACTION PIPEWORK

SCALE 1:50



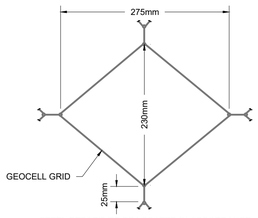
PLAN

SCALE 1:1250



SECTION BB - THROUGH TIE-IN IMMEDIATELY EITHER SIDE OF ACCESS ROADS AT TOE OF WASTE SLOPE

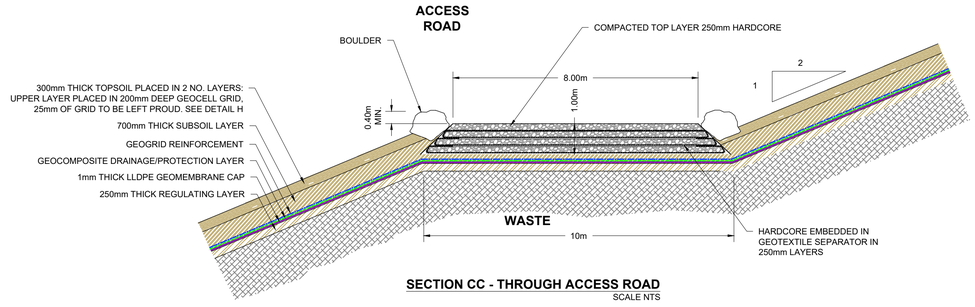
SCALE NTS



STEEL REBAR'S TO BE LOCATED IN ACCORDANCE WITH MANUFACTURERS RECOMMENDATIONS

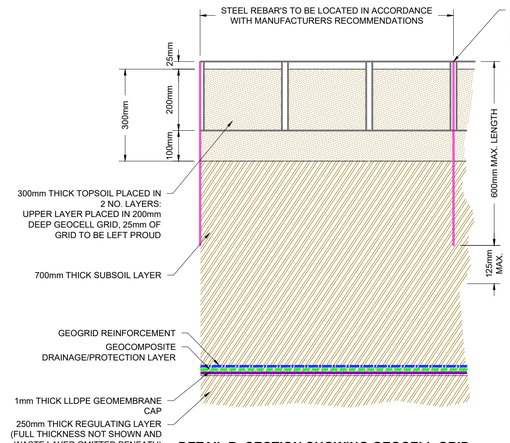
DETAIL C: PLAN SHOWING GEOCELL GRID ARRANGEMENT

SCALE 1:5



SECTION CC - THROUGH ACCESS ROAD

SCALE NTS



DETAIL B: SECTION SHOWING GEOCELL GRID ARRANGEMENT

SCALE 1:10

NOTES

1. TOPOGRAPHIC SURVEY INFORMATION SUPPLIED BY WASTESERVE MALTA LTD, REF: 200422 DTM FULL 2000.DXF, DATE RECEIVED: 11.06.2020.
2. ALL DIMENSIONS ARE IN METERS UNLESS STATED OTHERWISE.
3. GEOCELL GRID SPECIFIED SHALL BE BASED UPON TERRAM GEOCELLS SPECIFICATION SHEET FOR 22/20 PANEL GRADE OR SIMILAR APPROVED.

LEGEND

FEATURES - PLAN

- PROPOSED PRE SETTLEMENT RESTORATION LEVEL CONTOURS (mAMSL)
- PERMANENT DRILL LOCATIONS
- MANIFOLD
- SERVICE CORRIDOR
- PERMANENT 250mm Ø LEAN GAS LINE
- PERMANENT 355mm Ø GAS LINE
- NEW PERMANENT 250mm Ø GAS LINE
- DRAIN LEG
- KNOCKOUT POT
- MANIFOLD

EXISTING FEATURES - SECTIONS

- EXISTING INSITU BEDROCK
- EXISTING GEOMEMBRANE
- EXISTING GEOTEXTILE
- EXISTING GEOSYNTHETIC CLAY LINER
- WASTE
- EXISTING ANCHOR TRENCH

PROPOSED FEATURES - SECTIONS

- PROPOSED GEOMEMBRANE
- PROPOSED GEOTEXTILE SEPARATOR
- PROPOSED GEOCOMPOSITE DRAINAGE/PROTECTION LAYER
- PROPOSED GEOTEXTILE PROTECTOR
- PROPOSED GRANULAR DRAINAGE STONE
- PROPOSED TOPSOIL
- PROPOSED SUBSOIL
- PROPOSED REGULATING LAYER
- PROPOSED HYDRATED BENTONITE PASTE
- PROPOSED HARDCORE TO ACCESS ROADS
- PROPOSED ANCHOR TRENCH
- RIP-RAP
- GENERAL FILL

Revision	By	Chk'd By	Date	Comments
3	AB	JC	11/21	Revised details subsoil thicker, drainage removed
2	AB	JC	04/21	Gas layout added
1	AB	JC	12/20	Revised Landform
0	AB	JC	09/20	

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Site: GHALLIS LANDFILL SITE

Project: RESTORATION LEVELS

Drawing Title: **TYPICAL CONSTRUCTION DETAILS**

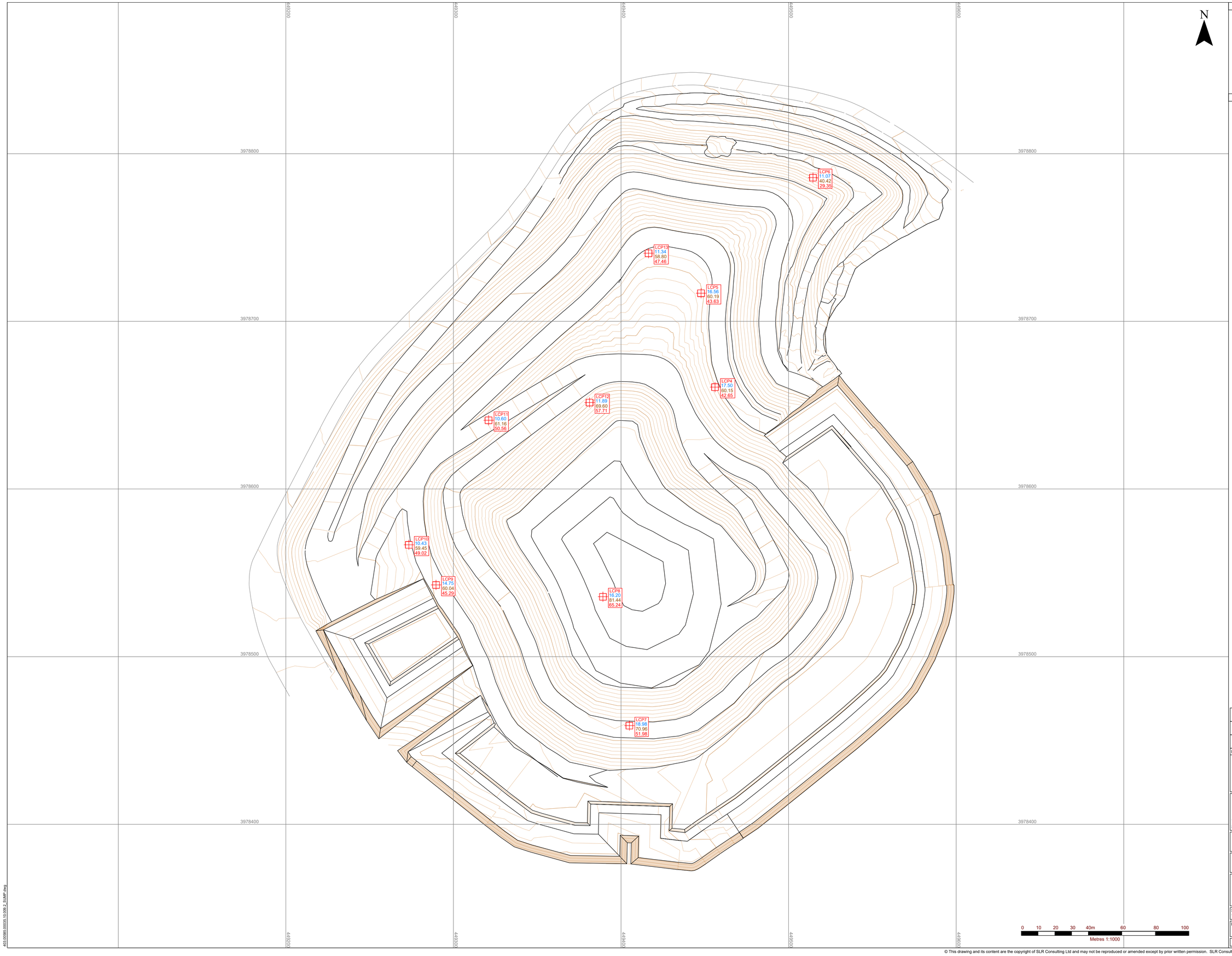
Scale: AS SHOWN @ A1

Date: SEPTEMBER 2020

Drawing Number: **008**

Revision: **0**

403.00085.00035.10.008.3_DETAILS.dwg



NOTES

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LEGEND

- 70.00 — PROPOSED PRE SETTLEMENT RESTORATION LEVEL CONTOURS (mAMSL)
- LCP — EXISTING LEACHATE EXTRACTION SUMP LOCATION
- 70.00 — EXISTING BASE SUMP LEVEL (mAMSL)
- 70.00 — PROPOSED PRE SETTLEMENT RESTORATION SUMP LEVEL (mAMSL)
- 70.00 — PROPOSED SUMP DEPTH (m)

Revision	By	Chk'd By	Date	Comments
2	AB	JC	03/21	Additional sump locations
1	AB	JC	12/20	Revised Landform
0	KW	JC	09/20	

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Site: GHALLIS LANDFILL SITE

Project: RESTORATION LEVELS

Drawing Title: **PROPOSED RESTORATION SCHEME - PRE SETTLEMENT SUMP LEVELS**

Scale: 1:1000 @ A1

Date: SEPTEMBER 2020

Drawing Number: **009**

Revision: **0**

403.00585.00035.10.009_2_SUMP.dwg

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