GEOTECHNICAL

ENVIRONMENTAL

WATLINGTON QUARRY

ENVIRONMENTAL PERMIT APPLICATION

Stability Risk Assessment Report

GEC NO: GE210280206

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Document History:

Reference: **GE20041/SRA/V1**		
Date of Issue	Document Description	Prepared
15/06/2021	Stability Risk Assessment	Dr David Fall CGEOL FGS
15/11/2021	Stability Risk Assessment V2	Dr David Fall CGEOL FGS

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1.0 INTRODUCTION

Report Context

1.1 The operator of the installation is Mick George Ltd. (MGL).

1.2 Watlington Quarry is an active site for the production of sand and gravel, since the first planning permission was issued in the mid 1960's and since then a number of planning permissions for extensions to the site have been granted. This SRA concerns the latest extraction and subsequent restoration in an area to the south of the existing quarry site.

1.3 On completion of the mineral extraction works MGL propose to utilise inert fill materials to create the restored profile of the site. The proposed filling operations will be completed under the terms of a Waste Recovery Environmental Permit.

1.4 Tetra Tech (TT) have instructed Geotechnical & Environmental Consulting Ltd. (GEC) to update the undertake Stability Risk Assessment (SRA) which will form part of an Environmental Permit Application for the waste recovery operation.

1.5 This environmental permit application is for the permanent placement of inert material within the void formed by the extraction of minerals to facilitate the restoration scheme outlined in the Planning Application.

1.6 The following documents and drawings have been supplied by the Client and referred to in the compilation of this Report:

- Non-Technical Summary Watlington Quarry Oak Field Extension – Mick George dated November 2021.
- Watlington Quarry Environmental Risk Assessment - Tetra Tech Report no. A117209 November 2021.
- Watlington Quarry: Environmental Permit Application – Environmental Setting and Site Design – Tetra Tech Report No. A117209 dated November 2021.
- Watlington Quarry Operating Techniques – Tetra Tech Report No. A117209 dated November 2021.
- Watlington Quarry: Environmental Permit Application-Hydrogeological Risk Assessment – Tetra Tech Report No. 784 A117209 dated November 2021.
- Groundwater Protection and Hydrogeological Impacts – Watlington Quarry, Oakfield. TerraConsult Report No. 10312-R04 dated September 2019.

1.7 This Report has been completed in conjunction with the Environmental Setting and Site Design Report (ESSD). It is not a standalone document and factual data related to the site, its setting and receiving environment are in the ESSD and referred to in this document. All drawings referred to in this SRA are to be found in the ESSD unless otherwise stated.

1.8 This document has been prepared to meet the requirements of the Application Part B, Stability Risk Assessment Report.

Conceptual Stability Site Model

Location

1.9 This Stability Risk Assessment refers to the area that is included within the Environmental Permit Application boundary shown on Drawing No MGL/A117209/PER/01.

1.10 The application site is located approximately 1.5km northeast from the village of Watlington. The site is centred at approximate National Grid Reference (NGR) 563427,311556.

1.11 Access to the site is achieved via an access road off Watlington Road located to the north of the site. Beyond the wider quarry site, the immediate surroundings are agricultural and the nearest residential property is considered to be Oak House which is located approximately 575m north of the application site.

1.12 The proposed facility will cover an area of approximately 11.1ha and lies on the crest of a local mound. Spot heights using the Magic website tool are shown to be gently sloping towards the west, with elevations 13mAOD in the east to approx. 7mAOD west towards the Hobbs drain.

Regional Geology

Solid Geology

1.13 With reference to British Geological Survey Sheet 159 Wisbech 1:50000 Sold & Drift, the application site is underlain by the Kimmeridge Clay Formation of the Ancholme Group. The Roxham Member and Runcton Member (undifferentiated) is shown to outcrop approximately 250m to the southeast of the site on the eastern side of Lynn Road.

1.14 The Lexicon of Named Rock Units describers the Kimmeridge Clay Formation as mudstone (calcareous or kerogen-rich or silty or sandy); thin siltstone and cementstone beds which can be locally sands and silts. Whilst the Roxham Member and Runcton Member (undifferentiated) are described as grey and yellow-green, pyritic, silty sands.

Superficial Geology

1.15 A superficial stratum comprising the Tottenhill Gravel Member is shown to outcrop across the site. The Tottenhill Gravel Member is described as a complex sequence of sands and gravels dominated by flint. Two units are recognised: a lower unit up to 5m thick of medium to coarse, poorly sorted, angular gravels: and the upper unit, 3.5m thick consisting of fine- and medium-grained well sorted gravels.

Structural Geology

1.16 No structural features are shown within the area of the permit application boundary.

Local Geology

1.17 RMC undertook a ground investigation in the area of the extension in which 8no. boreholes were undertaken. A precis of the stratigraphy encountered during these borehole works is presented as Table SRA1. A borehole location plan is included in the TerraConsult groundwater impact assessment.

Table SRA1 Local Stratigraphy of the Application Area

Borehole No.	Stratigraphy					
	Overburden		Tottenhill Gravel Member		Kimmeridge Clay Formation	
	From mbgl (mOD)	Thickness (m)	From mbgl (mOD)	Thickness (m)	From mbgl (mOD)	Thickness (m)
RMC Ground Investigation 1991 (only boreholes within or adjacent to the application area)						
BH1	Not Encountered		GL (10.52)	2.40	2.40 (8.12)	>6.40
BH2	GL (9.49)	0.50	0.50 (8.99)	5.40	5.90 (3.59)	>1.10
BH3	GL (9.46)	0.40	0.40 (9.06)	7.70	8.10 (1.36)	>0.90
BH4	GL (8.69)	0.30	0.30 (8.39)	3.50	3.80 (4.89)	>1.20
BH5	GL (9.86)	0.30	0.30 (9.56)	5.50	5.80 (4.06)	>1.20
BH6	Not Encountered		GL (10.00	.8.90	8.90 (1.10)	>1.10
BH11	Not Encountered		GL (11.00)	3.90	3.90 (7.10)	>1.10
BH12	GL (11.33)	0.40	0.40 (10.93)	3.30	3.70 (7.63)	>1.30

1.18 The borehole logs show a common stratigraphy across the application area comprising a discontinuous cover of overburden (Topsoil and Subsoil) up to 0.50m thick overlying the Tottenhill Gravel Member in turn over lying the Kimmeridge Clay Formation to the full depth of the ground investigation.

1.19 The Tottenhill Gravel Member was encountered beneath the overburden and generally increased in thickness from 2.40m in BH1 to 8.90m in BH3 which is consistent with the stratum thickness increasing towards the north.

1.20 The Kimmeridge Clay Formation was proven in all boreholes at between 2.40mbgl (8.12mOD) and 8.90mbgl (1.10mOD) and comprised 0.10 to 0.20m of brown-grey Clay over of firm grey Clay.

Hydrogeology

1.21 Groundwater was recorded during the installation of 7no. of the 8no. RMC ground investigation boreholes. (Table SRA2).

Table SRA2 Groundwater Strikes Recorded During the 1991 Ground Investigation

Borehole No.	Groundwater Strike		Stratum
	Depth (mbgl)	Elevation (mOD)	
BH1	Dry		
BH2	4.10	5.39	Tottenhill Gravel Member
BH3	7.40	2.06	
BH4	3.60	5.09	
BH5	4.70	5.16	
BH6	7.60	2.40	
BH11	3.50	7.50	
BH12	3.50	7.83	

1.22 Groundwater strikes were all within the granular Tottenhill Gravel Member suggesting the groundwater may be perched on the impermeable Kimmeridge Clay Formation.

1.23 The Kimmeridge Clay Formation is classified as an unproductive stratum; whilst the Tottenhill Gravel Member is classified as Secondary A Aquifer. The site is not located within a source protection zone (SPZ).

Hydrology

1.24 In accordance with information provided by TerraConsult (2019) and referred to in the site-specific Hydrological Risk Assessment (HRA) Watlington Quarry lies within the catchment of the River Nar, which is located approximately 1.4km north of the site’s boundary.

1.25 The surface water features and groundwater elevations surrounding the site are controlled by the artificial drainage channels which ultimately discharge into the Polver Drain, via the Hobbs Drain to the north. The final destination of these surface water flows is the River Great Ouse.

1.26 The site has been subjected to a flood risk assessment carried out by Amber Planning (report: Flood Risk Assessment September 2020, Extension of sand & gravel extraction area, Land at Watlington Quarry), which found the site is not in a flood warning area and is located in Flood Zone 1 (low risk).

Basal Subgrade Model

1.27 The void will be created by the extraction of the sands and gravels of the Tottenhill Gravel Member exposing the Kimmeridge Clay Formation which will form the basal subgrade of the extraction void.

1.28 The Kimmeridge Clay Formation is described in the RMC boreholes as consisting of a superficial layer (010 to 0.20m thick) brown-grey Clay overlying firm grey Clay.

1.29 Groundwater monitoring placed the groundwater within the Tottenhill Gravel at between 4.00 and 10mOD However, artificial dewatering will be undertaken during the extraction and inert waste placement such that the void will remain dry during these operations.

Basal Lining System

1.30 No geological basal liner is considered necessary as the basal subgrade will comprise low permeability Kimmeridge Clay Formation.

Side Slope Subgrade Model

1.31 The side slope subgrade will be exposed during the mineral extraction works and will comprise the mixed lithologies of any superficial deposits Known collectively as Overburden) in turn overlying the sandy gravels of the Tottenhill Gravel Member.

1.32 Cross section through the side slope subgrade is presented herein as Figure SRA1 overleaf. This section is based on the deepest excavation and the stratigraphy recorded in BH6 (Table SRA1).

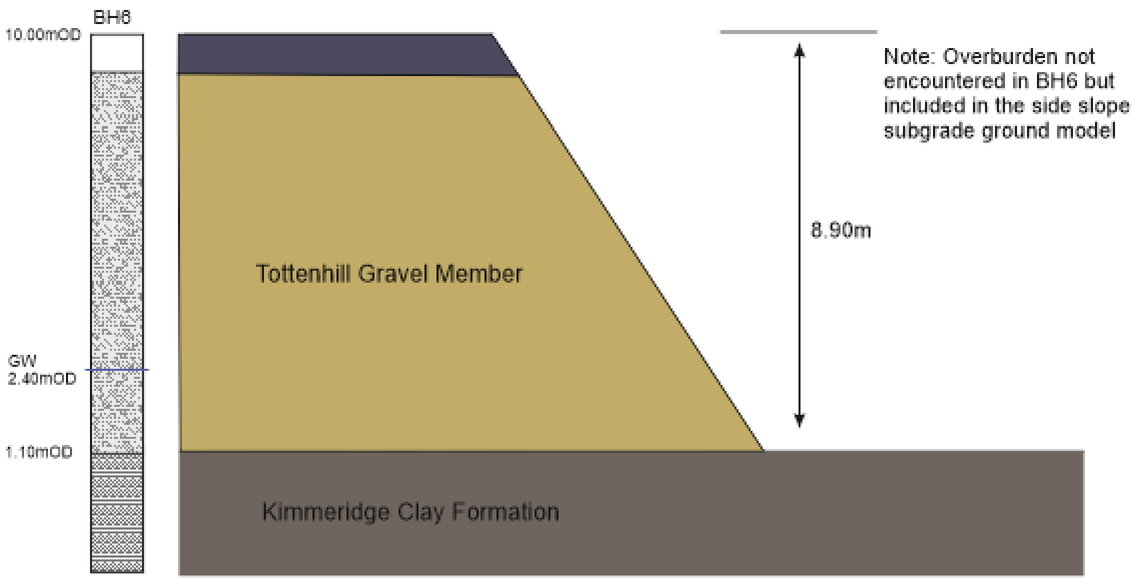


Figure SRA 1 Cross-Section Through Side Slope Subgrade

Side Slope Lining Model

1.33 A clay side-slope liner will be constructed from excavated site derived clay or suitable inert waste materials. The liner will have a horizontal crest width of 2m and be constructed at a maximum gradient of 1(v) : 3(h). The engineered clay side-slope liner will have a minimum thickness of 0.5m perpendicular to the side slope with a hydraulic conductivity of 5.0 x 10^{-8}m/s or the equivalent.

Inert Waste Mass Model

1.34 It is proposed that the Watlington Quarry extension will be restored using inert waste only.

1.35 The inert waste is liable to comprise locally derived arisings from earthworks, foundation construction works and demolition debris.

1.36 The geology of the local area is variable and comprises both coarse- and fine-grained materials. As most of the inert waste is likely to comprise locally derived materials, with respect to stability the worst case would be a waste mass comprised entirely of fine-grained materials. Therefore, the inert waste model will comprise a generic fine-grained material and the characteristic geotechnical parameters attributed to this material will be based on a number of sources.

Table SRA3 Bibliography of Published Sources used in the Determination of the Characteristic Geotechnical Parameters of the Inert Waste

Author	Date	Title
Carter M., & Bentley S.P.	2016	Soil Properties and Correlations 2nd. Ed.
Look B.	2007	Handbook of Geotechnical Investigation and Design Tables
Duncan J.M., & Wright, S.G.	2005	Soil Strength & Slope Stability
CIRIA C583	2004	Engineering in the Lambeth Group[1]
Hight D.W., McMillan, F., Powell, J.J.M., Jardine, R.J., & Allenou, C.P.	2003	Some Characteristics of the London Clay: IN Tan et al. (Eds.) Characterisation and Engineering Properties of Natural Soils.[1]

[1] *the inclusion of these two strata specific references should not be taken as a suggestion of the Inert Waste content.*

1.37 The maximum temporary waste slope during placement operations will be restricted to 1(v):3(h).

1.38 The waste will be compacted in horizontal layers across the base of the cell to the pre-settlement restoration level.

Capping System Model

1.39 In accordance with the requirements of the Landfill Directive, an engineered cap (clay or plastic) is not required. The site is to be restored in accordance with the approved restoration scheme (Mick George Drawing W8/1/19/04.

2.0 STABILITY RISK ASSESSMENT

Risk Screening

Basal Subgrade Screening

2.1 The basal subgrade will be formed of the in-situ Kimmeridge Clay Formation. As the void will be formed by the excavation and extraction of material there will be a net unloading of the basal subgrade. The replacement of the excavated material with inert waste will not fully reload the soil as there is a difference in the unit weight of the excavated material and the replaced inert waste this will cause only limited elastic recompression of the basal subgrade.

2.2 The Kimmeridge Clay Formation at basal void level will comprise firm Clays which are considered competent and medium compressibility and will not undergo large settlements. Although not considered a risk requiring stability analysis, it is recommended that careful inspection of the subgrade is undertaken prior to the placement of the inert waste. Further details and recommendations are presented in Section 3 of this SRA.

2.3 No stability analysis of this component is considered necessary.

Basal Lining System Screening

2.4 No basal liner is to be placed.

Side Slope Subgrade Screening

2.5 The side slopes will be formed as part of the mineral extraction process carried out by a suitably qualified and experienced specialists and subject to geotechnical appraisal under Regulation 33 of the Quarries Regulations. It can therefore be assumed that the void will have been designed to be stable during the extraction works. Given the stratigraphy and description of the side slope subgrade it is unlikely that the materials will become unstable during the inert waste placement phases of the works; however, a stability check of the side slope subgrade will be carried out for completeness and determine a long-term stable angle of repose.

Side Slope Lining System Screening

2.6 An artificially established side-lining system, comprising 2m of locally sourced clay material or suitable inert waste is to be placed against the side slope subgrade at a finished gradient of 1 (v) : 3(h). The side slope liner will have a minimum perpendicular thickness of 0.50m and a hydraulic conductivity of 5.0 x 10^{-8}m/s.

2.7 Groundwater outflows into the void are not expected as dewatering will continue until the side liner and inert waste level are above the standing groundwater level (ca 2.40mOD).

2.8 Analysis of this component is considered necessary to investigate the short-and long-term stability of this element prior to the placement of the inert waste.

Waste Mass Screening

2.9 This component will require a detailed geotechnical analysis in order to assess the stability of the waste mass.

Capping System Screening

2.10 Based on the proposed finished contours presented in Mick George Drawing No. W8/1/19/04 dated 25/08/2020 the site is to be restored to a mix of agriculture and species rich grassland with one area of surface water. The contours at the final restored level show a maximum difference in finished level of 3.00m over a length of ca 300m giving a gradient of 1(V) : 100 (H) and as such will remain stable under all foreseeable conditions.

2.11 Therefore, a stability assessment of the sloping areas of the Restoration Soils is not required.

Justification of Modelling Approach and Software

2.12 Two-dimensional limiting equilibrium stability analyses will be used in the assessment of the stability of the various components of the proposed inert landfill. The method of analysis used in each case was determined from an examination of the form of failure being considered.

2.13 The stability analyses were carried out using the Slope/W computer programme.

2.14 The Morgenstern and Price Method was used in the analyses to determine the degree of utilisation of the restoring forces under both total stress and effective stress conditions.

Justification of Geotechnical Parameters Selected for Analyses

Parameters Selected for Side Slope Subgrade Analyses

2.15 The side slope subgrade will comprise Overburden over Tottenhill Gravel Member. Based on the engineering descriptions of these materials recorded on the borehole logs typical characteristic geotechnical parameters have been developed and are presented in Table SRA4.

Table SRA4 Side Slope Subgrade Stability – Summary of Characteristic Geotechnical Data

Material	Description	Medium Sand	Total Stress		Effective Stress	
		γ (kN/m^3)	c_u (kN/m^2)	ϕ_u (°)	c′ (kN/m^2)	ϕ' (°)
Overburden	Topsoil / Subsoil	18	30	0	1	23
Tottenhill Gravel Member	Medium dense Sand and Gravel	19	Not Applicable Granular Material		0	36

Kimmeridge Clay Formation	Firm to stiff Clay	19	50	0	5	23

Parameters Selected for Side Slope Liner Analyses

2.16 The side slope liner is to be constructed using an appropriate fine-grained material. Typical values for clay materials have been used to define the characteristic geotechnical values of the side slope liner material (Table SRA5).

Table SRA5 Side Slope Liner Stability – Summary of Characteristic Geotechnical Data

Material	Unit Weigh	Total Stress		Effective Stress	
	γ (kN/m^3)	c_u (kN/m^2)	ϕ_u (°)	c′ (kN/m^2)	ϕ' (°)
Side Liner	19	50	0	2	25

Parameters Selected for Waste Analyses

2.17 The Parameters of the inert waste appropriate for this site were selected on the basis of the information presented in the various publications listed in Table SRA3. As stated previously the inclusion of stratum specific references should not be taken as guidance to what may be included within the Inert Waste but purely as another source to help define a generic fine-grained material. In reality, it is likely to comprise a mixture of fine- and coarse-grained materials and demolition materials. Therefore, the treatment of the inert waste as fine-grained will be the worst-case as the inclusion of any coarse-grained material will increase its characteristic angle of shearing resistance.

Table SRA6 Waste Mass Stability - Summary of Characteristic Geotechnical Data

Material	Bulk Unit Weight γ_k	Total Stress		Effective Stress	
	(kN/m^3)	c_{uk} (kN/m^2)	ϕ_{uk} (°)	c'_k (kN/m^2)	ϕ'_k (°)
Waste Mass	17	50	0	5	25

Selection of Appropriate Factors of Safety

2.18 The stability analyses have been carried out in accordance with EC7. The United Kingdom have adopted Design Approach 1 (DA1) Combination 1 & 2 (C 1 & 2) whereby partial factors are applied to either the actions or the material properties and a resultant degree of utilisation of less than 1.00 is required.

Table SRA7 Partial Factors used in Design in Accordance with the UK National Annex to EC7

Design Approach	Combination	Partial Factor Sets	Partial Factor Value			
1	1	A1 + M1 + R1	Actions A1			
			Permanent (G)	Unfavourable	$\gamma_{G;dst}$	1.35
				Favourable	$\gamma_{G;stb}$	1.00
			Variable (Q)	Unfavourable	$\gamma_{Q;dst}$	1.50
				Favourable	$\gamma_{G;dst}$	0
			Materials M1			
			Coefficient of shearing resistance (*tanϕ*)		$\gamma_{\phi'}$	1.00
			Effective cohesion (*c'*)		$\gamma_{c'}$	1.00
			Undrained shear strength (c_u)		γ_{cu}	1.00
			Resistance R1			
			Resistance		$\gamma_{R;e}$	1.00
	2	A2 + M2 + R1	Actions A2			
			Permanent (G)	Unfavourable	$\gamma_{G;dst}$	1.00
				Favourable	$\gamma_{G;stb}$	1.00
			Variable (Q)	Unfavourable	$\gamma_{Q;dst}$	1.30
				Favourable	$\gamma_{G;dst}$	0
			Materials M2			
			Coefficient of shearing resistance (*tanϕ*)		$\gamma_{\phi'}$	1.25
			Effective cohesion (*c'*)		$\gamma_{c'}$	1.25
			Undrained shear strength (c_u)		γ_{cu}	1.40
			Resistance R1			
			Resistance		$\gamma_{R;e}$	1.00

2.19 The values of the partial factors used are termed "nationally determined parameters" and EC7 (as published by CEN) allows these to be specified in National Annexes which recognise regional variations in design philosophy.

2.20 LFE4 – Earthworks in Landfill Engineering – Chapter 2 confirms the adoption of Design Approach 1 Combinations 1 and 2, and the nationally adopted partial factors.

Analyses

Side Slope Subgrade

2.21 The side slopes of the void will be formed during the mineral extraction phase of the works and will be subject to appraisal under Regulation 33 of the Quarries Regulations. However, for completeness a stability of the side slope subgrade has been carried out using the cross section presented as Figure SRA1.

2.22 Dewatering will keep the groundwater beneath the base of the void during the inert waste placement operations. However, consideration will be given to the effect of groundwater rising to its natural level of ca 7.6maOD.

2.23 The highest side slope subgrade will be ca 8.9m and will be formed at a gradient of 1(v):2(h).

2.24 The results of the side slope liner stability analyses are shown in Table SRA8 and the SlopeW worksheets presented in Appendix 1.

Table SRA8 Side Slope Subgrade Stability – Summary of Results

Run	File Name	Degree of Utilisation		Notes
		C1	C2	
01	SSG1	0.68		Short Term Stability Total Stress Analysis
02	SSG2		0.85	
03	SSG3	0.71		Effective Stress Analysis
04	SSG4		0.90	
05	SSG5		0.94	Groundwater at 3.00mOD

<u>Side Slope Liner Analyses</u>

2.25 A side slope liner will be placed against the side slope subgrade. Based on the results of the side slope subgrade analyses presented in Table SRA8 it is assumed that the side slopes are at (1(v) : 2(h)). The liner will be modelled with a 2m horizontal thickness at the top of the void and a maximum gradient of 1 (v) : 3 (h).

2.26 Continued dewatering of the site will ensure that hydrostatic pressures associated with the perched groundwater will not affect the side slope liner.

2.27 The results of the side slope liner stability analyses are shown in Table SRA9 and the SlopeW worksheets presented in Appendix 2.

Table SRA9 Side Slope Liner Stability – Summary of Results

Run	File Name	Characteristic Shear Strength		Degree of Utilisation		Liner Thickness (m)	Notes
		c	ϕ	C1	C2		
Side Slope Gradient 27 ° Side Slope Liner Gradient 18.3° Rotational Failure Entirely within Side Slope Liner							
01	SSL1	50	0	0.31		2.00	Total stress
02	SSL2				028		
03	SSL3	2	25	0.64		2.00	Full effective stress conditions- Liner fails under C2 Factoring
04	SSL4				0.74		

05	SSL5	0	25		0.89	2.00	Fully softened c′=0kN/m^2

Waste Mass Analyses

2.28 The post extraction void may be up to 9m deep; although it is unlikely that a temporary waste face 9.00m high will ever exist it will be considered in the inert waste stability analysis with waste faces during placement operations restricted to 1(v) : 3(h).

2.29 Leachate pore fluid pressures may develop in the waste mass during filling due to infiltration. It is noteworthy that the term leachate as applied refers to direct precipitation or groundwater present within the inert waste at time of placement.

2.30 Given the composition (inert materials), landfill gas pressures are unlikely to develop within the waste mass.

2.31 Waste stability must be assessed as part of the design process for the temporary waste slope configuration. A Stability assessment is required for failure modes wholly within the waste body. The analyses of the failures wholly within the waste were based on Table 3.43 “Failure Wholly within the Waste” of the Environmental Agency R&D Technical Report P1-385/TR2.

2.32 Slope/W has been used to undertake the investigation into failures wholly within the waste mass for both total and effective stress conditions.

2.33 The effects of variations in leachate pressure were modelled by investigating the effects of increased leachate levels on the factor of safety against instability within the waste body.

2.34 Results of the analyses are presented in Appendix 3 and are summarised in Table SRA10.

Table SRA10 Waste Mass Stability – Summary of Results

Run	File Name	Waste Strength	Leachate Level	Degree of Utilization		Notes
				C1	C2	
1	WASTE1	Total	Dry	0.36		Total Stress
2	WASTE2				0.30	
3	WASTE3	Effective	2.00m	0.41		Increasing leachate level measured from base of waste mass
4	WASTE4				0.40	
5	WASTE5		4.00m	0.47		
6	WASTE6				0.73	
07	WMass7		6.00m	0.69		
08	WMass8				0.82	
09	WMass9		Not Present		0.71	Cohesion = 0kN/m^2

Assessment

Basal Subgrade

2.35 The basal subgrade is to comprise the in-situ Kimmeridge Clay Formation which is considered competent and with no net increase in stress at basal subgrade level predicted, no settlement other than short term elastic recompression is expected.

2.36 Therefore, subject to careful inspection prior to the placement of the inert waste, the basal subgrade is considered appropriate without any significant re-engineering.

Side Slope Sub-Grade

2.37 The side slopes of the void will be formed as part of the mineral extraction works. It is appropriate to assume that the extraction works will be subject to Geotechnical Appraisal under Regulation 33 of the Quarries Regulations and as part of that appraisal it will be demonstrated that the side slope subgrade is stable at the planned angle of excavation.

2.38 However, a stability assessment of the side slope subgrade has been carried out at the proposed gradient of 1(v) : 2(h) (27°). The results of the stability assessments indicate the side slope subgrade is stable in the short term under total stress conditions with a degree of utilisation of 0.85 being achieved under Combination 2 factoring. In the long term, under effective stress conditions, the stability analysis indicates that the slope will remain stable with a slight increase in the degree of utilisation to 0.90 under Combination 2 factoring. The similarity in the results is due to the side slope subgrade materials being largely coarse-grained.

2.39 During the placement of the inert waste dewatering of the void will continue which will keep the base of the void dry. Slope Run SSG5 analyses the effect of the groundwater rising to a standing level of 3.00mbgl. The stability analysis demonstrates that this would increase the degree of utilisation to 0.94 under the more onerous Combination 2 factoring meaning the slope will remain stable.

2.40 Provided the side slope subgrade batter does not exceed 1(v) : 2 (h) the side slope subgrade will remain stable under all foreseeable conditions.

Side Slope Liner

2.41 The side slope liner with a horizontal thickness of 2.00m at the crest and a gradient of 1(v) : 3(h) has been analysed and shown to be stable in the short term under total stress conditions with a maximum degree of utilisation of 0.31 being returned under Combination 1 factoring.

2.42 If left unsupported in the long-term such that fully drained effective stress conditions are achieved the side slope liner is shown to remain stable with a maximum degree of utilisation of 0.74 under Combination 2 factoring.

2.43 Finally, the analyses show that even in the event of the side slope liner becoming fully saturated (c'=0kN/m^2) the degree of utilisation remains less than 1.00 (0.89).

2.44 It can be concluded that side liner will remain stable under all foreseeable conditions prior to the buttressing effect of the inert waste being applied.

Waste Mass

2.45 The stability of the temporary waste face was analysed using the computer programme SLOPE/W to calculate the degree of utilisation of the restoring forces to prevent failure through the waste body for a range of circular failure surfaces using Morgenstern and Price's method.

2.46 The importance of different leachate levels within the waste and their effect on overall stability was assessed. The effect of reduction of shear strength from peak to residual values has also been investigated.

2.47 The waste slope has a Degree of Utilisation of <1.00 (<100%) for all leachate levels up to 8.00m from the base of the waste body. A leachate level of 8.00m is considered extremely unlikely to occur under normal operating conditions and therefore represents a worst-case situation.

2.48 The waste slope has a degree of utilisation of 0.71 even if the value of the cohesion intercept of the waste reduces from 5kN/m^2 to 0kN/m^2

2.49 It is concluded that a 1(v) : 3(h) waste slope will be stable for the range of leachate levels anticipated.

Capping System

2.50 Not a consideration at this site.

3.0 MONITORING

The Risk-Based Monitoring Scheme

3.1 Monitoring of the stability of the site is proposed in the form set out below. The objectives are to identify any instances of overall settlement of the structure, identify instability of the waste mass itself and instability of the side slope subgrade and lining system at the earliest possible juncture.

Basal Subgrade Monitoring

3.2 Prior to the placement of the inert waste, it is recommended that the basal subgrade is carefully inspected. Special attention should be paid if any soft spots within the Kimmeridge Clay are identified.

3.3 If areas, 0f the basal subgrade, are considered to be soft or low strength it should be dealt with by the excavation of the softened area and replacement with properly compacted granular fill material to a minimum depth of 1.00m.

Side Slope Subgrade

3.4 The side slopes should be visually monitored for instability during the waste placement operations with special attention being paid to the upper slopes where the Superficial Deposits daylight. In the event of any instances of instability appropriate action should be taken which may include buttressing the toe of the slope using inert waste material.

3.5 Provided the side slope liner is placed at no more than 1(v) : 3(h) it should be stable under any foreseeable conditions. However, this does not preclude the need for regular inspection with particular attention being paid to separation between the liner and the side slope subgrade. If this, or any other instability is identified in the side slope liner, it should be buttressed with inert waste.

Waste Mass Monitoring

3.6 The temporary slopes in the waste should be visually monitored and appropriate actions taken on any sign of instability. This would typically include a reduction in slope angle of the temporary waste slopes.

Restoration Soils and Finished Surface Monitoring

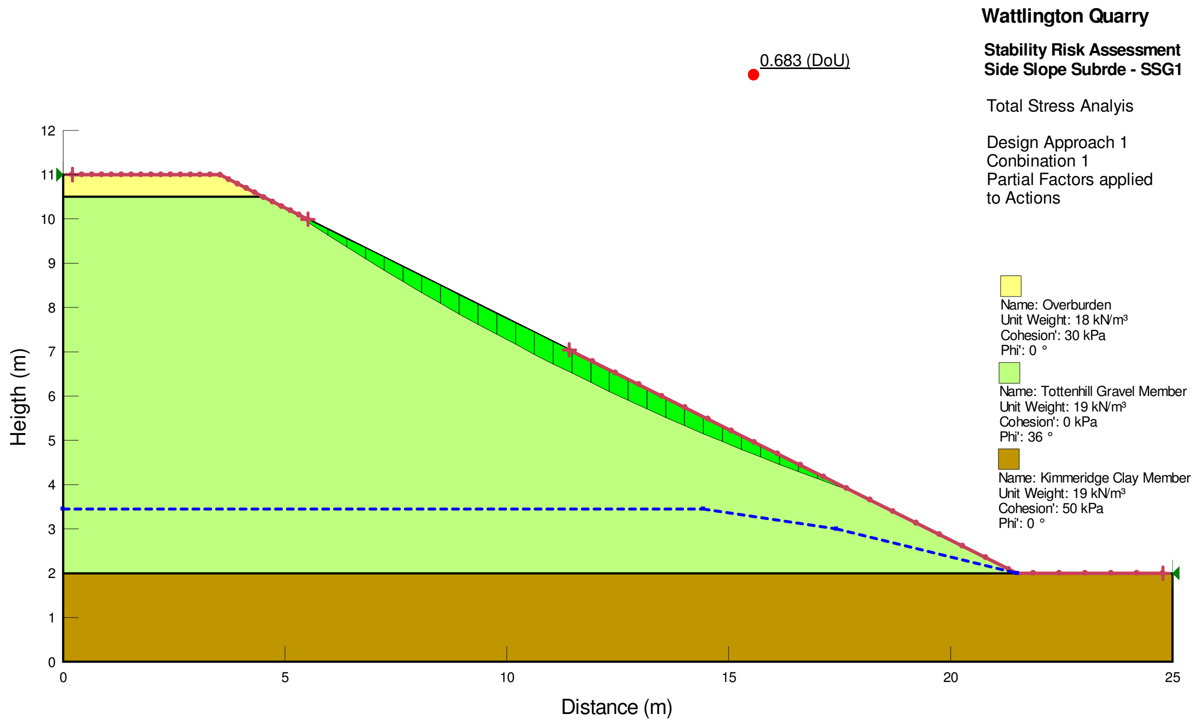
3.7 The condition of the ground surface of all restored areas will be monitored on a regular basis as part of the site inspection regimen.

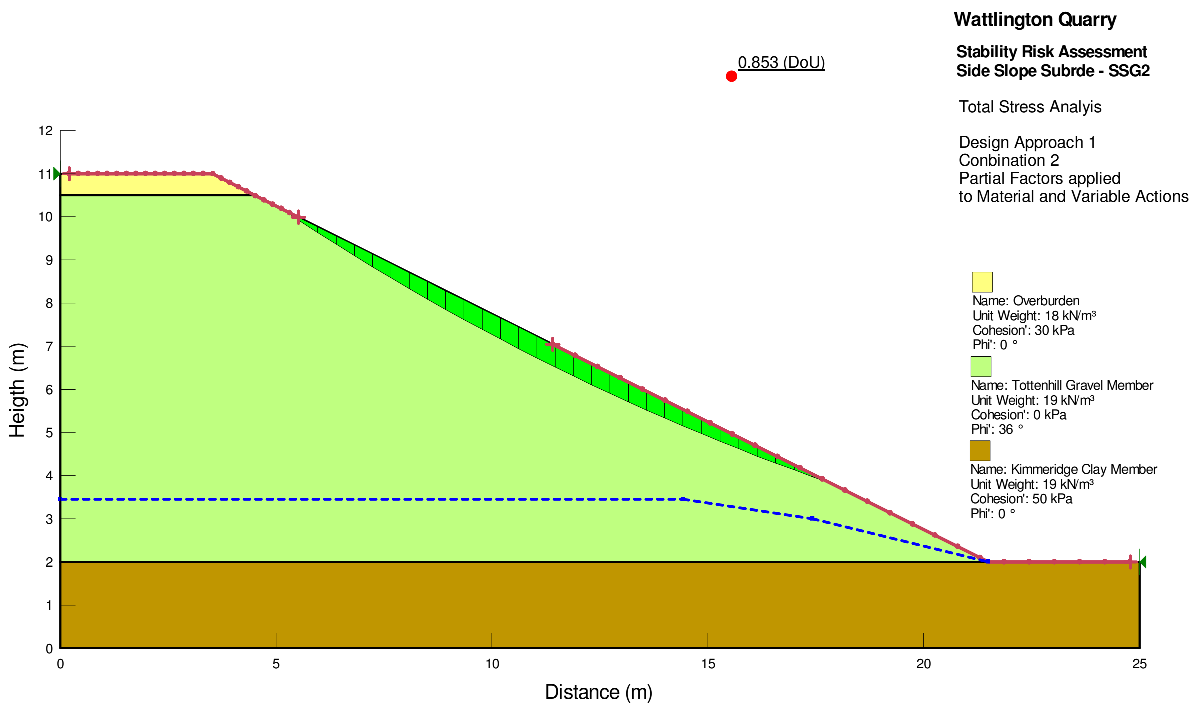
3.8 The surface will be checked for incipient signs of failure that might result from the occurrence of differential settlement within these deposits. These would include cracking, development of depressions or ponding and seepage of water. In the event that any symptom of incipient failure is detected the Environment Agency will be informed and a site action plan for remediation agreed.

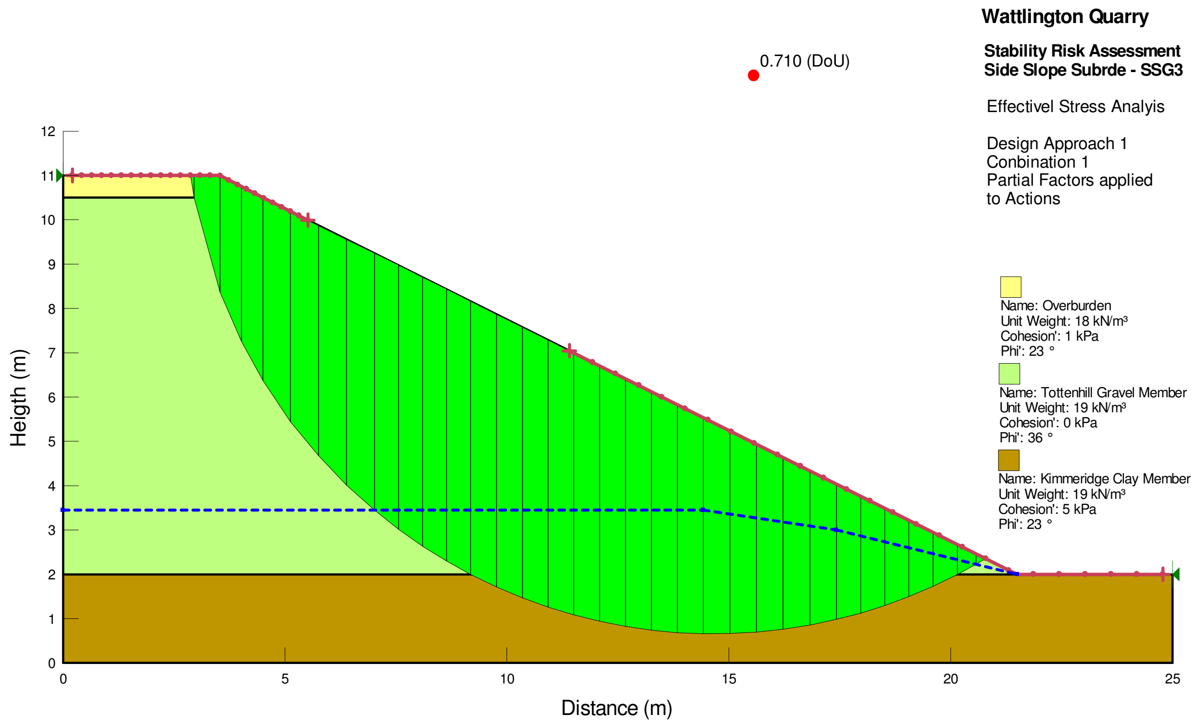
3.9 The Surface of the restored areas will be monitored by land survey techniques on a regular basis. These checks will be on a biannual basis for the first two years and then on an annual basis to the fifth year after restoration, when the periodicity reviewed with the Environment Agency.

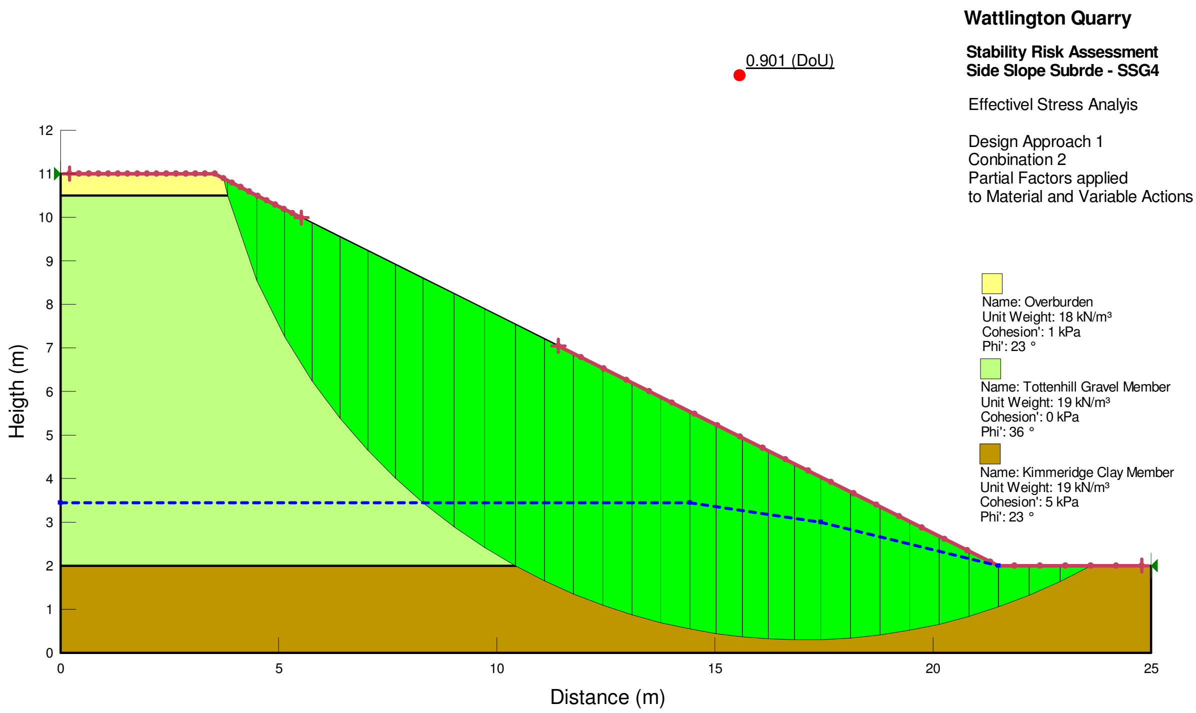
Appendix 1

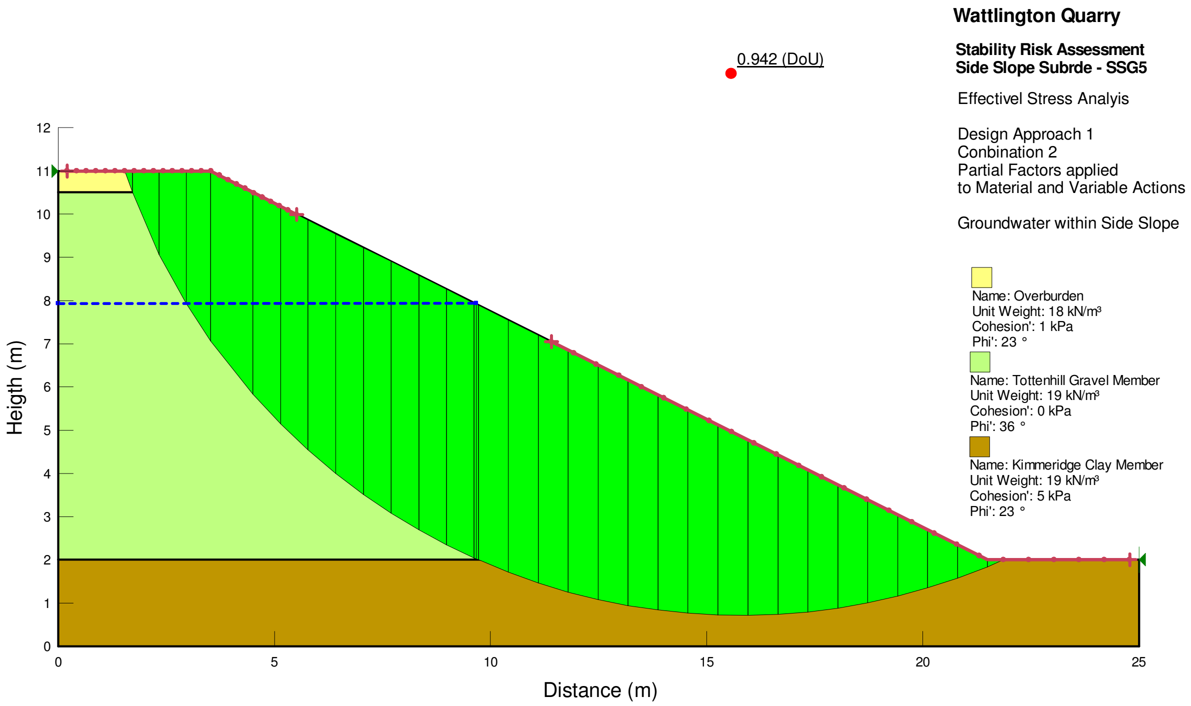
SlopeW Worksheets – Side Slope Subgrade


Wattlington Quarry
Stability Risk Assessment
Side Slope Subrde - SSG1
Total Stress Analyis
Design Approach 1
Conbination 1
Partial Factors applied
to Actions
0.683 (DoU)
Name: Overburden
Unit Weight: 18 kN/m³
Cohesion': 30 kPa
Phi': 0 °
Name: Tottenhill Gravel Member
Unit Weight: 19 kN/m³
Cohesion': 0 kPa
Phi': 36 °
Name: Kimmeridge Clay Member
Unit Weight: 19 kN/m³
Cohesion': 50 kPa
Phi': 0 °
Heigth (m)
Distance (m)


Wattlington Quarry
Stability Risk Assessment
Side Slope Subrde - SSG2
Total Stress Analyis
Design Approach 1
Conbination 2
Partial Factors applied
to Material and Variable Actions
0.853 (DoU)
Name: Overburden
Unit Weight: 18 kN/m³
Cohesion': 30 kPa
Phi': 0 °
Name: Tottenhill Gravel Member
Unit Weight: 19 kN/m³
Cohesion': 0 kPa
Phi': 36 °
Name: Kimmeridge Clay Member
Unit Weight: 19 kN/m³
Cohesion': 50 kPa
Phi': 0 °
Heigth (m)
Distance (m)


0.710 (DoU)
Wattlington Quarry
Stability Risk Assessment
Side Slope Subrde - SSG3
Effectivel Stress Analyis
Design Approach 1
Conbination 1
Partial Factors applied
to Actions
Name: Overburden
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 23 °
Name: Tottenhill Gravel Member
Unit Weight: 19 kN/m³
Cohesion': 0 kPa
Phi': 36 °
Name: Kimmeridge Clay Member
Unit Weight: 19 kN/m³
Cohesion': 5 kPa
Phi': 23 °
Heigth (m)
Distance (m)

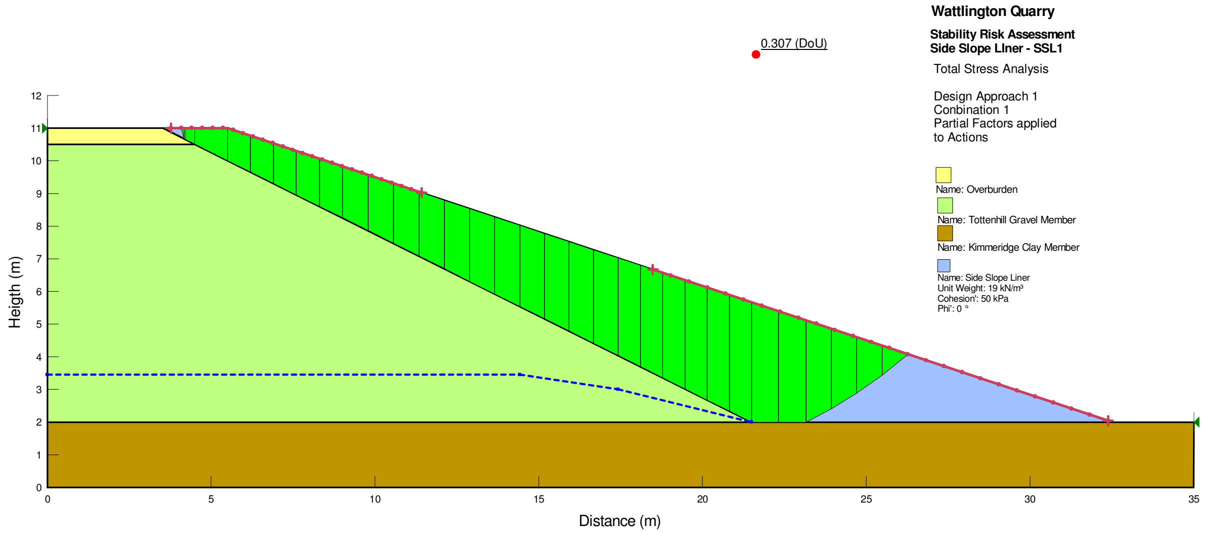

0.901 (DoU)
Wattlington Quarry
Stability Risk Assessment
Side Slope Subrde - SSG4
Effectivel Stress Analyis
Design Approach 1
Conbination 2
Partial Factors applied
to Material and Variable Actions
Name: Overburden
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 23 °
Name: Tottenhill Gravel Member
Unit Weight: 19 kN/m³
Cohesion': 0 kPa
Phi': 36 °
Name: Kimmeridge Clay Member
Unit Weight: 19 kN/m³
Cohesion': 5 kPa
Phi': 23 °
Heigth (m)
Distance (m)

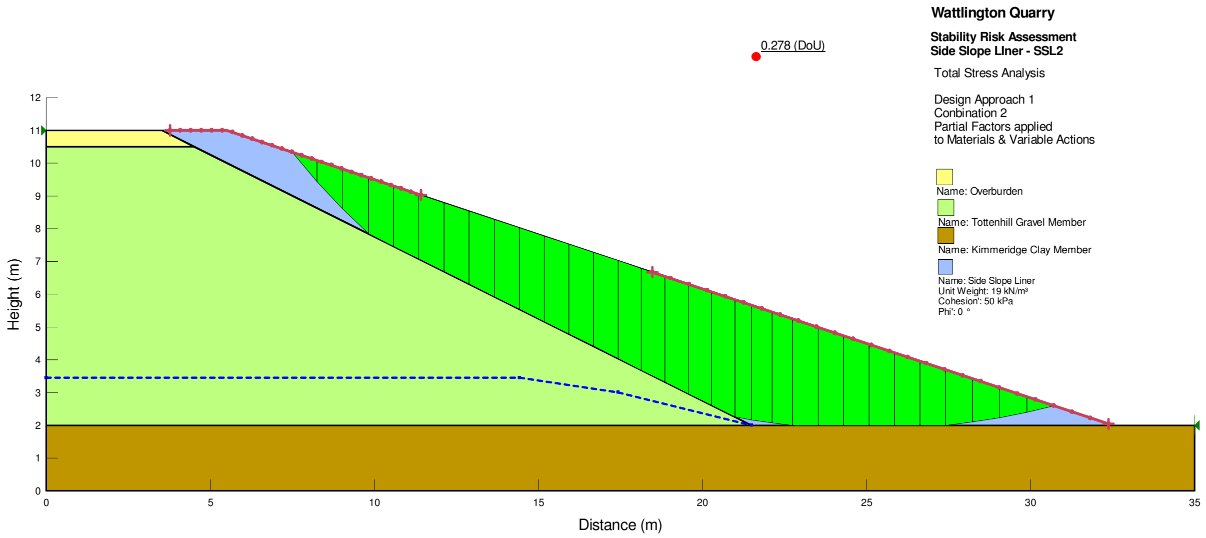


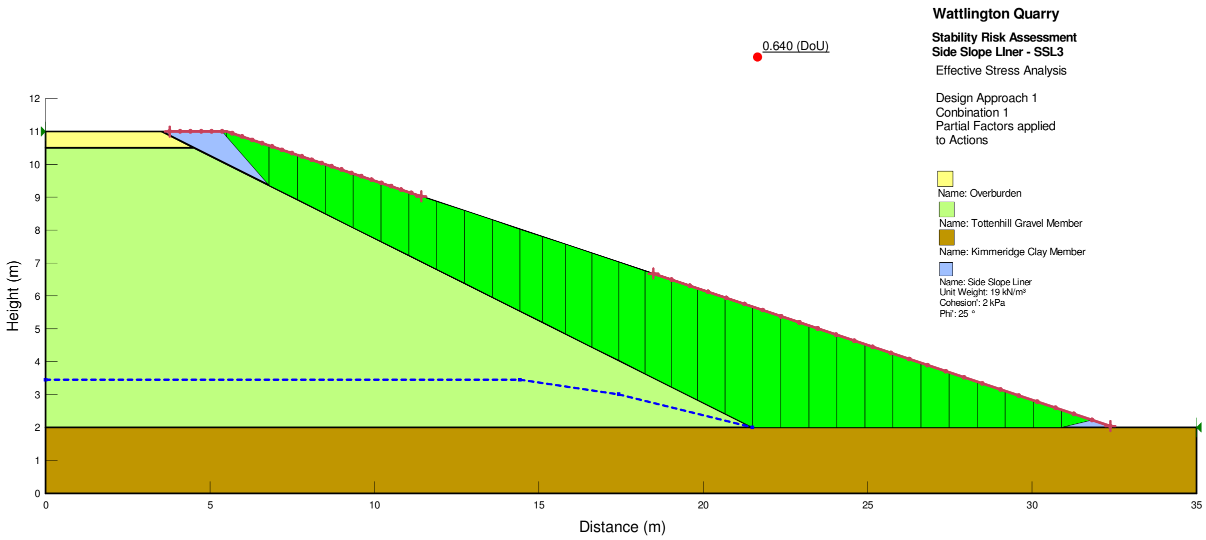
Wattlington Quarry
Stability Risk Assessment
Side Slope Subrde - SSG5
Effectivel Stress Analyis
Design Approach 1
Conbination 2
Partial Factors applied
to Material and Variable Actions
Groundwater within Side Slope
0.942 (DoU)
Name: Overburden
Unit Weight: 18 kN/m³
Cohesion': 1 kPa
Phi': 23 °
Name: Tottenhill Gravel Member
Unit Weight: 19 kN/m³
Cohesion': 0 kPa
Phi': 36 °
Name: Kimmeridge Clay Member
Unit Weight: 19 kN/m³
Cohesion': 5 kPa
Phi': 23 °
Heigth (m)
Distance (m)

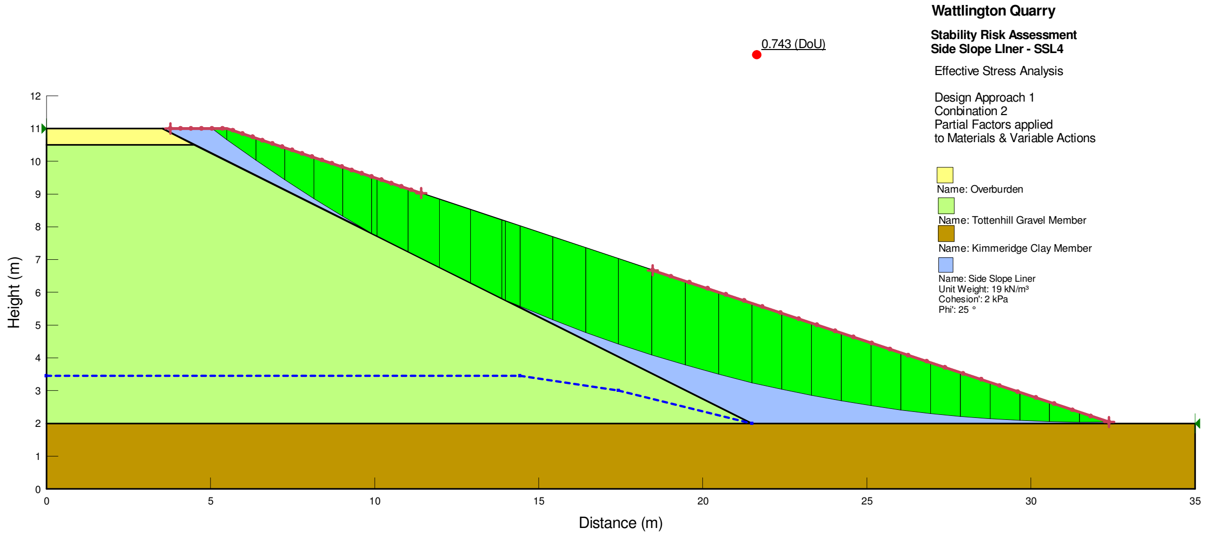
Appendix 2

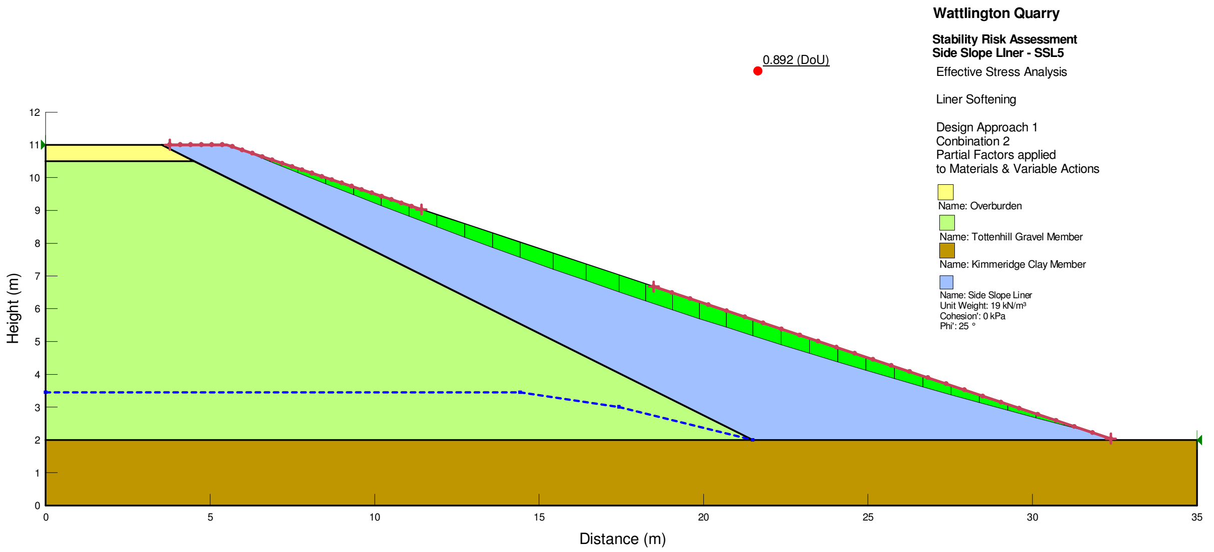
SlopeW Worksheets – Side Slope Liner


Wattlington Quarry
Stability Risk Assessment
Side Slope LIner - SSL1
Total Stress Analysis
Design Approach 1
Conbination 1
Partial Factors applied
to Actions
Name: Overburden
Name: Tottenhill Gravel Member
Name: Kimmeridge Clay Member
Name: Side Slope Liner
Unit Weight: 19 kN/m³
Cohesion': 50 kPa
Phi': 0 °
0.307 (DoU)
Heigth (m)
Distance (m)


Wattlington Quarry
Stability Risk Assessment
Side Slope LIner - SSL2
Total Stress Analysis
Design Approach 1
Conbination 2
Partial Factors applied
to Materials & Variable Actions
Name: Overburden
Name: Tottenhill Gravel Member
Name: Kimmeridge Clay Member
Name: Side Slope Liner
Unit Weight: 19 kN/m³
Cohesion': 50 kPa
Phi': 0 °
0.278 (DoU)
Height (m)
Distance (m)

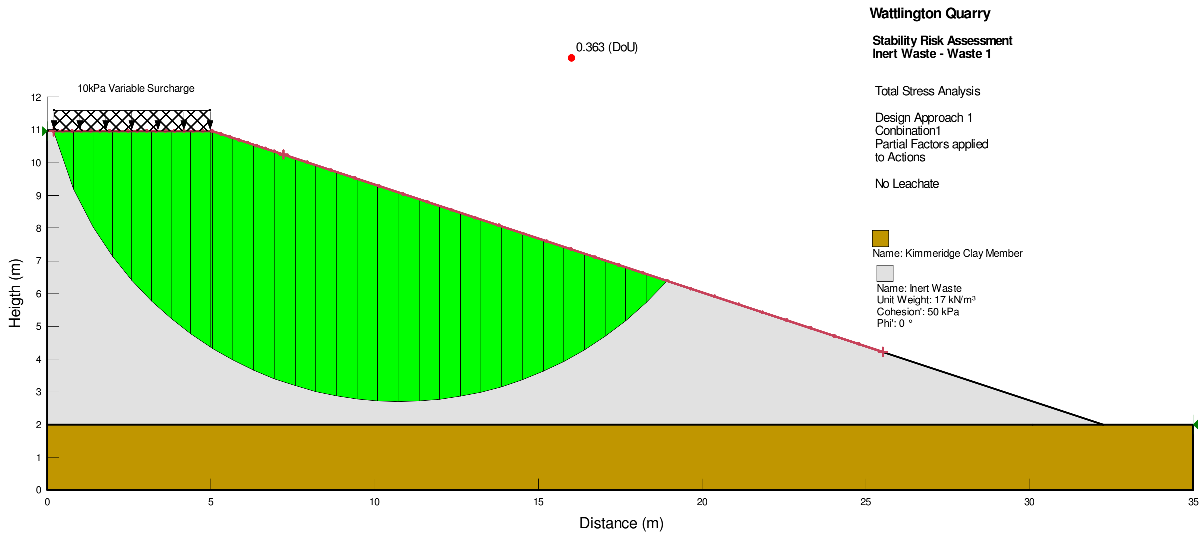

Wattlington Quarry
Stability Risk Assessment
Side Slope LIner - SSL3
Effective Stress Analysis
Design Approach 1
Conbination 1
Partial Factors applied
to Actions
Name: Overburden
Name: Tottenhill Gravel Member
Name: Kimmeridge Clay Member
Name: Side Slope Liner
Unit Weight: 19 kN/m³
Cohesion': 2 kPa
Phi': 25 °
0.640 (DoU)
Height (m)
Distance (m)

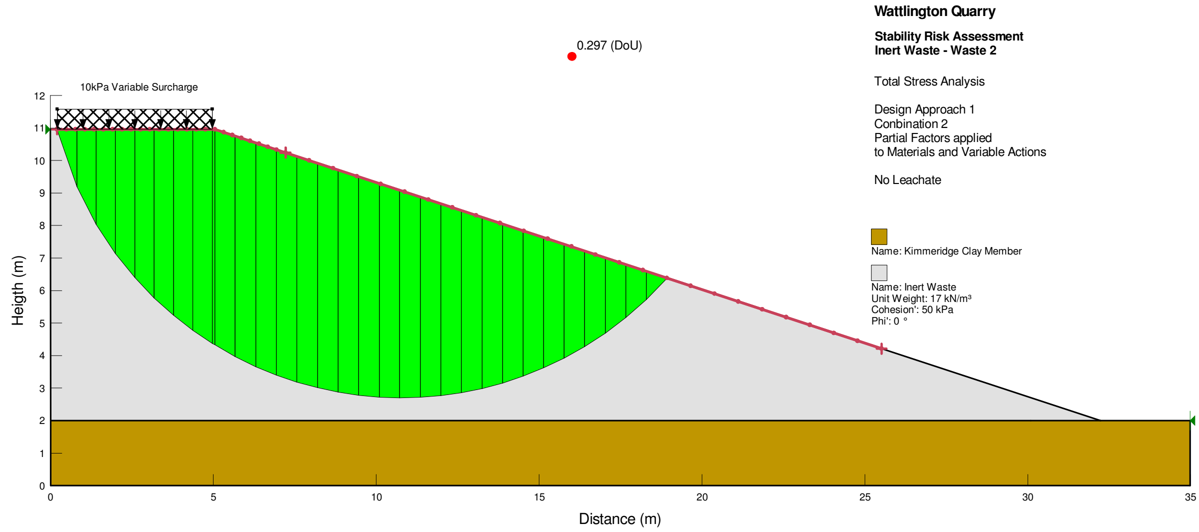

Wattlington Quarry
Stability Risk Assessment
Side Slope LIner - SSL4
Effective Stress Analysis
Design Approach 1
Conbination 2
Partial Factors applied
to Materials & Variable Actions
Name: Overburden
Name: Tottenhill Gravel Member
Name: Kimmeridge Clay Member
Name: Side Slope Liner
Unit Weight: 19 kN/m³
Cohesion': 2 kPa
Phi': 25 °
0.743 (DoU)
Height (m)
Distance (m)

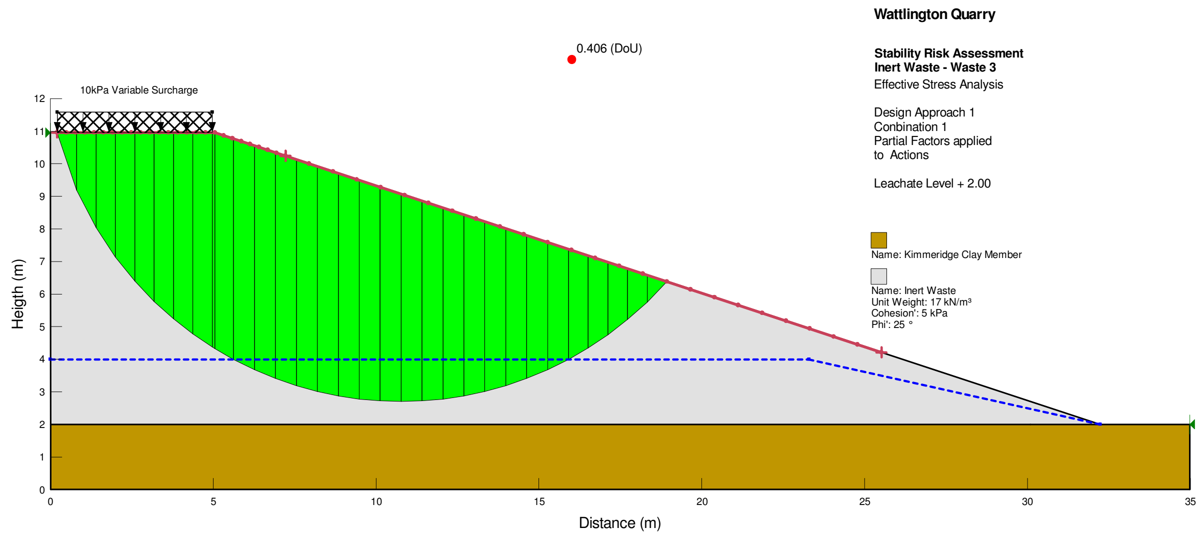

Wattlington Quarry
Stability Risk Assessment
Side Slope LIner - SSL5
Effective Stress Analysis
Liner Softening
Design Approach 1
Conbination 2
Partial Factors applied
to Materials & Variable Actions
Name: Overburden
Name: Tottenhill Gravel Member
Name: Kimmeridge Clay Member
Name: Side Slope Liner
Unit Weight: 19 kN/m³
Cohesion': 0 kPa
Phi': 25 °
0.892 (DoU)
Height (m)
Distance (m)

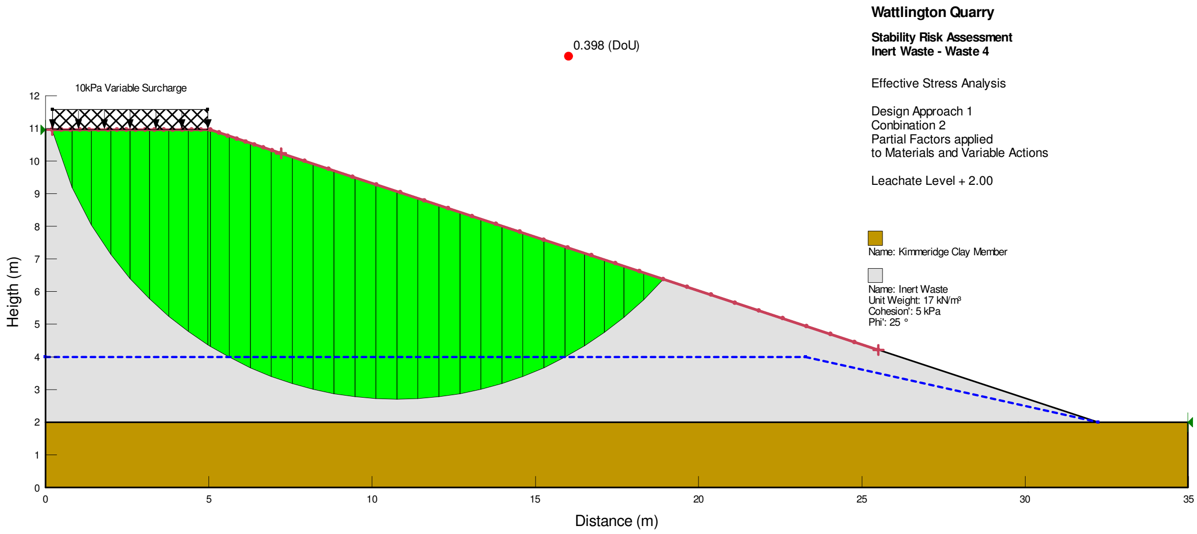
Appendix 3

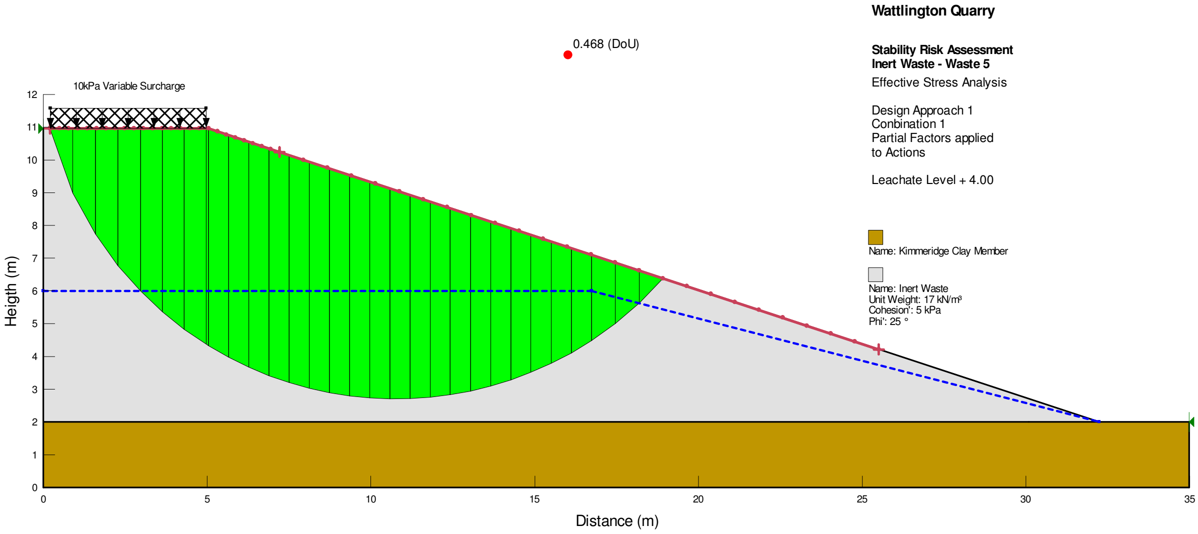
SlopeW Worksheets – Inert Waste

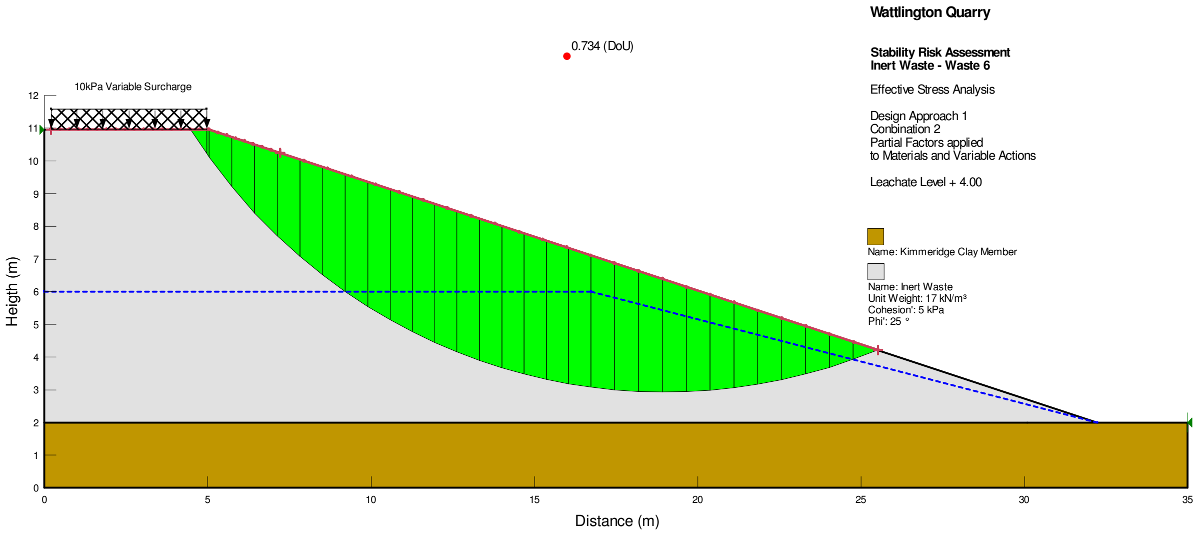

Wattlington Quarry
Stability Risk Assessment
Inert Waste - Waste 1
Total Stress Analysis
Design Approach 1
Conbination1
Partial Factors applied
to Actions
No Leachate
Name: Kimmeridge Clay Member
Name: Inert Waste
Unit Weight: 17 kN/m³
Cohesion': 50 kPa
Phi': 0 °
0.363 (DoU)
10kPa Variable Surcharge
Heigth (m)
Distance (m)

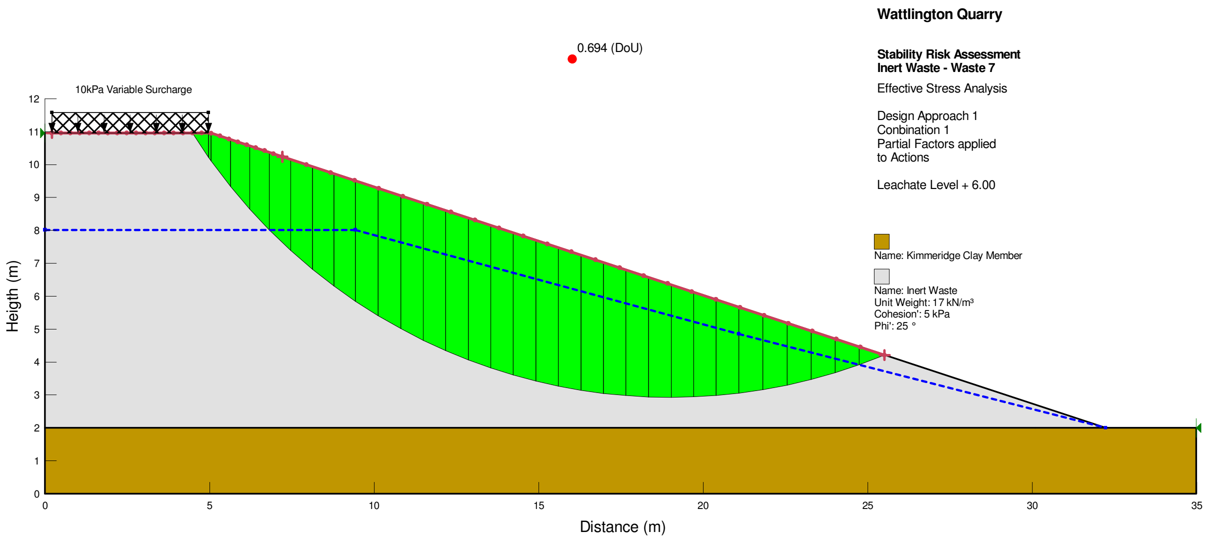

Wattlington Quarry
Stability Risk Assessment
Inert Waste - Waste 2
Total Stress Analysis
Design Approach 1
Conbination 2
Partial Factors applied
to Materials and Variable Actions
No Leachate
Name: Kimmeridge Clay Member
Name: Inert Waste
Unit Weight: 17 kN/m³
Cohesion': 50 kPa
Phi': 0 °
0.297 (DoU)
10kPa Variable Surcharge
Heigth (m)
Distance (m)

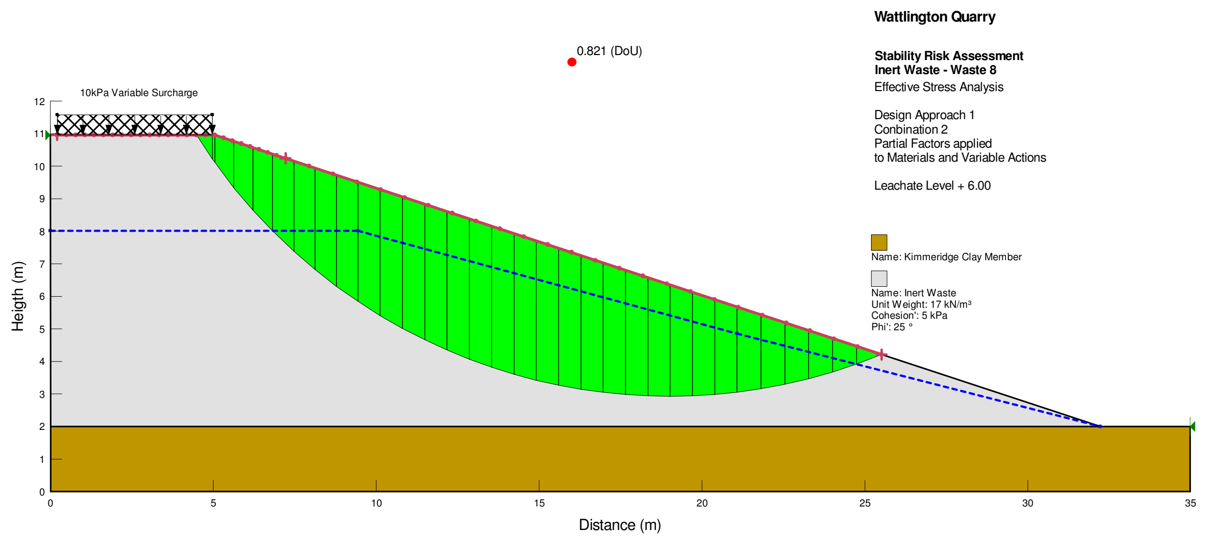

Wattlington Quarry
Stability Risk Assessment
Inert Waste - Waste 3
Effective Stress Analysis
Design Approach 1
Conbination 1
Partial Factors applied
to Actions
Leachate Level + 2.00
Name: Kimmeridge Clay Member
Name: Inert Waste
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 25 °
0.406 (DoU)
10kPa Variable Surcharge
Heigth (m)
Distance (m)

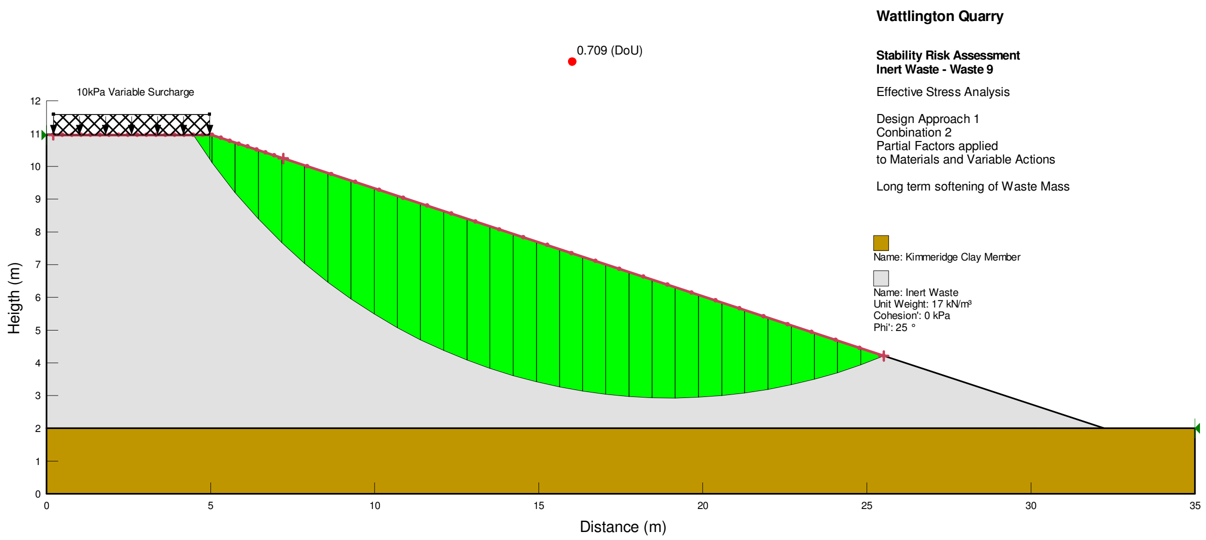

Wattlington Quarry
Stability Risk Assessment
Inert Waste - Waste 4
Effective Stress Analysis
Design Approach 1
Conbination 2
Partial Factors applied
to Materials and Variable Actions
Leachate Level + 2.00
Name: Kimmeridge Clay Member
Name: Inert Waste
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 25 °
0.398 (DoU)
10kPa Variable Surcharge
Heigth (m)
Distance (m)


Wattlington Quarry
Stability Risk Assessment
Inert Waste - Waste 5
Effective Stress Analysis
Design Approach 1
Conbination 1
Partial Factors applied
to Actions
Leachate Level + 4.00
Name: Kimmeridge Clay Member
Name: Inert Waste
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 25 °
0.468 (DoU)
10kPa Variable Surcharge
Heigth (m)
Distance (m)


Wattlington Quarry
Stability Risk Assessment
Inert Waste - Waste 6
Effective Stress Analysis
Design Approach 1
Conbination 2
Partial Factors applied
to Materials and Variable Actions
Leachate Level + 4.00
Name: Kimmeridge Clay Member
Name: Inert Waste
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 25 °
0.734 (DoU)
10kPa Variable Surcharge
Heigth (m)
Distance (m)


Wattlington Quarry
Stability Risk Assessment
Inert Waste - Waste 7
Effective Stress Analysis
Design Approach 1
Conbination 1
Partial Factors applied
to Actions
Leachate Level + 6.00
Name: Kimmeridge Clay Member
Name: Inert Waste
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 25 °
0.694 (DoU)
10kPa Variable Surcharge
Heigth (m)
Distance (m)


Wattlington Quarry
Stability Risk Assessment
Inert Waste - Waste 8
Effective Stress Analysis
Design Approach 1
Conbination 2
Partial Factors applied
to Materials and Variable Actions
Leachate Level + 6.00
Name: Kimmeridge Clay Member
Name: Inert Waste
Unit Weight: 17 kN/m³
Cohesion': 5 kPa
Phi': 25 °
0.821 (DoU)
10kPa Variable Surcharge
Heigth (m)
Distance (m)


Wattlington Quarry
Stability Risk Assessment
Inert Waste - Waste 9
Effective Stress Analysis
Design Approach 1
Conbination 2
Partial Factors applied
to Materials and Variable Actions
Long term softening of Waste Mass
Name: Kimmeridge Clay Member
Name: Inert Waste
Unit Weight: 17 kN/m³
Cohesion': 0 kPa
Phi': 25 °
0.709 (DoU)
10kPa Variable Surcharge
Heigth (m)
Distance (m)