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HATFORD QUARRY STABILITY RISK ASSESSMENT TO SUPPORT ENVIRONMENTAL PERMIT APPLICATION - LANDFILL FOR INERT WASTE

For

HATFORD QUARRY LIMITED

May 2021

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Appendix 3	Stability analyses – waste mass

HATFORD QUARRY STABILITY RISK ASSESSMENT TO SUPPORT ENVIRONMENTAL PERMIT APPLICATION - LANDFILL FOR INERT WASTE

1. Introduction

1.1 Report Context

Hatford Quarry currently operates under extant Planning Permissions HAT/11163/89, MW.0153/12, and MW.0066/19 which variously provide for mineral extraction (sand and limestone) and restoration of the excavation void with imported inert waste material and indigenous soils (overburden, interburden and crushing/screening fines).

This report presents a Stability Risk Assessment (SRA) and has been prepared to support an EPR Permit application to provide for landfilling with imported inert waste to achieve the restoration landform.

1.2 Operator of the proposed installation

Hatford Quarry Limited, The Upper Lime Kiln Works, Bytham Road, Ogbourne St. George, Marlborough, Wiltshire, SN8 1TD.

1.3 Agent who completed this report

GWP Consultants LLP, Upton House, Market Street, Charlbury, Oxfordshire, OX7 3PJ.

1.4 Outline of the proposed installation

The EPR Permit application is to provide for landfilling with imported inert waste of the existing and approved future quarry excavations at Hatford Quarry.

Drawing No. HATFEXT2104-1 shows the site location and Drawing No. HATFEXT2104-2 shows the EPR Permit application area.

The EPR Permit application area is *c.* 45.7ha. The inert landfill capacity to be provided for by the EPR Permit is *c.* 1.13Mm^3.

Details of the site setting and installation design are presented in the Environmental Setting and Site Design (ESSD) report prepared by GWP Consultants LLP (GWP Report No. 210423) which accompanies the EPR Permit variation application (Appendix Iii) and which should be read in conjunction with this report.

2. SITE SETTING

2.1 Physical Setting

The application site is located at Hatford Quarry, Fernham Road, Hatford, Faringdon, Oxfordshire, SN7 8QJ (National Grid Reference SU 32930 95600).

Drawing No. HATFEXT2104-1 shows the site location and Drawing No. HATFEXT2104-2 shows the EPR Permit application area.

Hatford Quarry is located *c.* 0.5km northwest of the village of Hatford and *c.* 1.5km northwest of the village of Stanford in the Vale. The town of Faringdon is located *c.* 2.5km to the west of the quarry.

The quarry is excavated in Jurassic strata belonging to the Corralian Group and comprising principally the Highworth Grit Member (sand) and underlying Highworth Limestone Member (limestone) of the Kingston Formation. The quarry is excavated to levels ranging from *c.* 96mAOD in the north to *c.* 76mAOD in the south.

The site is accessed from the B4508 (Fernham Road) located to the south.

2.2 Geological Setting

The geological setting of the site has been determined based on a review of published information, site investigation information and observations made in the existing quarry excavation.

The general geological setting of the site is shown on Drawing No. HATFEXT2104-9.

The quarry is excavated in Jurassic strata belonging to the Corallian Group and comprising principally

the Highworth Grit Member (sand) and underlying Highworth Limestone Member (limestone) of the Kingston Formation.

More specifically, within the vicinity of the site the strata comprise:

- Calne Member (Stanford Formation) – rubbly oolitic and clayey limestones (0.0m to *c.* 2.0m thick locally); overlying
- Highworth Grit Member (Kingston Formation) – fine and medium grained sands, rippled and cross bedded with thin limestone bands and clay lenses, increasingly silty to the base (0.0m to *c.* 5m thick locally); overlying
- Highworth Clay Member (Kingston Formation) – grey sandy and silty clay, often thin or absent (0.0m to *c.* 1.5m thick locally); overlying
- Highworth Limestone Member (Kingston Formation) – oolitic and bioclastic limestones with thin sandy clay bands, becoming a sandy limestone to the base (*c.* 2m to *c.* 7m thick locally); overlying
- Lower Calcareous Grit Formation (Corallian Group) – silty and clayey fine to medium sands (*c.* 0m to *c.* 9m thick locally – not worked); overlying
- Oxford Clay Formation (Ancholme Group) – clay (greater than 30m thick – not worked).

The general overall strata dip within and near the site is *c.* 1v : 60h (vertical : horizontal) to the south-southeast. However, strata dip varies locally from *c.* 1v : 25h to *c.* 1v : 100h and there are lateral variations in strata character and thickness.

The quarry is not excavated below the base of the Highworth Limestone Member *i.e.* no excavation into the underlying Lower Calcareous Grit Formation.

3. CONCEPTUAL STABILITY SITE MODEL

Details of the components of the conceptual stability site model are presented in the following sub-sections, are summarised on Table 1 and are illustrated on Drawing No. HATFEXT2104-7.

3.1 Basal Sub-Grade Model

The basal sub-grade of the landfill will comprise the base of the Highworth Limestone Member/top of the Lower Calcareous Grit Formation which forms the floor of the mineral excavation.

3.2 Side Slopes Sub-Grade Model

The side slopes sub-grade of the landfill will comprise the perimeter slopes of the mineral excavation formed in the Kingston Formation.

3.3 Basal Artificial Geological Barrier Model

A basal artificial geological barrier will be constructed on a phased basis across the floor of the excavation. The artificial geological barrier will comprise a compacted layer of indigenous quarry material (overburden, interburden and crushing/screening fines) and/or suitable selected imported inert waste material and will have a minimum thickness of 1m and a permeability no greater than 1 x 10^{-7}m/s.

The basal AGB will be constructed in accordance with a Construction Quality Assurance Plan approved by the Environment Agency.

3.4 Side Slopes Artificial Geological Barrier Model

A side slopes AGB will be formed on a phased basis using suitable indigenous quarry material (overburden, interburden and crushing/screening fines) and/or suitable selected imported inert waste.

The suitable material will be compacted in layers and brought up in lifts up to *c.* 5m high against the side slopes sub-grade formed in the Kingston Formation as the general placement of waste progresses.

Following the completion of each side slopes AGB lift, imported inert waste material will be graded against the compacted material in order to provide buttress support and to establish a stable platform for the placement and compaction of the next side slopes AGB lift. Excavated perimeter slopes in the Kingston Formation will have a maximum height of *c.* 12m and the maximum unsupported height

of the side slopes AGB will be *c.* 5m. The side slopes AGB will have a minimum thickness of 1m and a permeability no greater than 1 x 10^{-7}m/s.

The side slopes AGB will be constructed in accordance with a Construction Quality Assurance Plan approved by the Environment Agency.

3.5 Waste Mass Model

The site will receive inert waste.

The waste will be placed in layers *c.* 1m thick in lifts *c.* 5m thick. The maximum total thickness of waste will be *c.* 10m. Active advancing slopes in waste material will be formed no steeper than 1v : 2h. Temporary inter-phase slopes in waste material will be formed no steeper than 1v : 3h. An intermediate bench with a minimum width of 10m will be maintained between lifts. The final restoration surface of the waste mass will be formed at gradients shallower than *c.* 1v : 20h.

No daily cover material will be placed.

3.6 Capping System Model

No engineered low permeability capping system will be placed (see Section 2.2.4 of the ESSD report which accompanies the EPR Permit variation application (Appendix Iii)). The waste will be capped in a progressive manner with restoration soils following landfilling.

Site restoration will be in accordance with the requirements of extant Planning Permissions HAT/1163/89, MW.0153/12, and MW.0066/19.

Restoration surface contours are shown on Drawing No. HATFEXT2104-4.

4. STABILITY RISK ASSESSMENT

4.1 Risk Screening

A risk screening of the geotechnical issues relating to the stability and integrity of the components of the landfill development is presented in Table 1.

4.2 Modelling Approach and Software

Assessment of the geotechnical stability and integrity of the landfill development has principally involved the completion of a series of 2D limit equilibrium slope stability analyses. This modelling and analytical approach is considered appropriate given the simplicity of the geotechnical setting of the development.

Industry standard computer software (SLIDE – supplied by Rocscience Inc.) has been used to complete the slope stability analyses.

4.3 Geotechnical Parameters Selected for Analyses

Geotechnical parameters selected for analysis purposes are presented in the following sub-sections:

4.3.1 Artificial Geological Barrier

Drained shear strength: c′ = 4kPa ø′ = 23°

(conservative estimate)

Bulk density: 1.8Mg/m^3

4.3.2 Waste Mass

Drained shear strength: c′ = 4kPa ø′ = 23°

(conservative estimate)

Bulk density: 1.8Mg/m^3

4.4 Selection of Appropriate Factor of Safety

A benchmark minimum Factor of Safety (FoS) value of 1.30 has been adopted for the purpose of assessing the stability of the landfill development. It is considered that this benchmark value is appropriate given that:

- the geotechnical setting of the site is simple and is adequately defined;
- the geotechnical input parameters selected for analysis are known or have been conservatively estimated with reasonable confidence;
- the geotechnical stability and safety risks associated with the landfill development at the site are considered to be very low.

4.5 Stability Analyses

4.5.1 Basal Sub-Grade

No specific stability analyses have been deemed necessary. Relevant geotechnical issues are discussed below in Section 4.6.1.

4.5.2 Side Slopes Sub-Grade

No specific stability analyses have been deemed necessary. Relevant geotechnical issues are discussed below in Section 4.6.2.

4.5.3 Basal Artificial Geological Barrier

See Appendix 1 and Section 4.6.3 below.

4.5.4 Side Slopes Artificial Geological Barrier

See Appendix 2 and Section 4.6.4 below.

4.5.5 Waste Mass

See Appendix 3 and Section 4.6.5 below.

4.5.6 Capping

No specific stability analyses have been deemed necessary. Relevant geotechnical issues are discussed below in Section 4.6.6.

4.6 Stability Analyses Results

The following sub-sections summarise the results of the stability analyses performed and discuss relevant geotechnical issues associated with the various landfill components. Reference should be made as appropriate to the relevant Appendices for full details of the analyses performed and the associated results.

4.6.1 Basal Sub-Grade

- Basal Sub-Grade Stability

  Based on evidence from geotechnical site inspection, site investigation borehole logs and published information relating to the lithological character of the base of the Highworth Limestone Member/top of the Lower Calcareous Grit Formation, it is considered that no compressible material or cavities will be present beneath the site.

  Accordingly, it is considered that the stability and integrity of the basal sub-grade will not be compromised by compressibility or the presence of cavities.

- Basal Heave

  The basal sub-grade of the landfill will comprise the base of the Highworth Limestone Member/top of the Lower Calcareous Grit Formation which forms the floor of the mineral excavation.

Groundwater is present in the lower part of the Highworth Limestone Member and the underlying Lower Calcareous Grit Formation.

The inferred saturated thickness of the Highworth Limestone Member across the site ranges from *c.* 0m in the north to *c.* 2.5m in the south.

Excavation dewatering occurs and will continue to allow mineral excavation, engineered artificial geological barrier (AGB) construction and restoration infilling to be undertaken in dry condition.

There will be no groundwater pressures acting which have the potential to promote basal heave. Accordingly, it is considered that the stability and integrity of the basal sub-grade will not be compromised by basal heave.

4.6.2 Side Slopes Sub-Grade

- Compressibility

  Based on evidence from geotechnical site inspection, site investigation borehole logs and published information relating to the lithological character of the Kingston Formation, it is considered that no compressible material or cavities will be present in the excavated perimeter slopes. Accordingly, it is considered that the stability and integrity of the excavated perimeter side slopes sub-grade will not be compromised by compressibility or the presence of cavities.

- Slope Stability

  Excavated perimeter slopes in the Kingston Formation will generally be formed at overall design gradients of *c.* 2v : 1h (vertical : horizontal) in limestone and *c.* 1v : 1h in sand. The maximum height of the excavated perimeter slopes will be *c.* 12m.

  Based on the findings of geotechnical inspections undertaken most recently by Consultants LLP in May 2020, it is considered that the excavated slopes will remain adequately stable at the design gradients. Any minor face dressing or re-grading of the side slopes sub-grade will be undertaken on a phased basis in advance of the construction of the side slopes AGB.

  In accordance with the requirements of the Quarries Regulations 1999, the quarry operator is responsible for ensuring that the excavated faces are designed, constructed, operated and maintained so as to ensure that instability or movement which is likely to give rise to a risk to the health and safety of any person is avoided. Accordingly, it is considered that the stability and integrity of the side slopes sub-grade will not be compromised by slope instability.

4.6.3 Basal Artificial Geological Barrier (see Appendix 1)

- Basal Sub-Grade Stability

  Based on evidence from geotechnical site inspection, site investigation borehole logs and published information relating to the lithological character of the base of the Highworth Limestone Member/top of the Lower Calcareous Grit Formation, it is considered that no compressible material or cavities will be present beneath the site.

  Accordingly, it is considered that the stability and integrity of the basal AGB will not be compromised by compressibility or the presence of cavities in the basal sub-grade.

- Basal Heave

  The basal sub-grade of the landfill will comprise the base of the Highworth Limestone Member/top of the Lower Calcareous Grit Formation which will form the floor of the mineral excavation.

  Groundwater is present in the lower part of the Highworth Limestone Member and the underlying Lower Calcareous Grit Formation.

  The inferred saturated thickness of the Highworth Limestone Member across the site ranges from *c.* 0m in the north to *c.* 2.5m in the south.

  Excavation dewatering occurs and will continue to allow mineral excavation, AGB construction and restoration infilling to be undertaken in dry condition.

There will be no groundwater pressures acting which have the potential to promote basal heave. Accordingly, it is considered that the stability and integrity of the basal AGB will not be compromised by basal heave.

- Slope Instability involving Side Slopes and Basal Artificial Geological Barriers

  Using the input parameters detailed in Appendix 1, a satisfactory minimum FoS value of 1.46 is indicated by the analysis results for a circular slope failure involving the side slope and basal AGBs. Accordingly, it is considered that the stability and integrity of the basal AGB will not be compromised by slope instability involving the side slopes AGB.

- Slope Instability involving Waste Mass and Basal Artificial Geological Barrier

  Using the input parameters detailed in Appendix 1, a satisfactory minimum FoS value of 1.48 is indicated by the analysis results for circular slope failure involving the waste mass and the basal AGB. Accordingly, it is considered that the stability and integrity of the basal AGB will not be compromised by slope instability involving the waste mass.

*4.6.4 **Side Slopes Artificial Geological Barrier*** (see Appendix 2)

- Side Slopes Sub-Grade Stability

  Based on evidence from geotechnical site inspection, site investigation borehole logs and published information relating to the lithological character of the Kingston Formation, it is considered that no compressible material or cavities will be present in the excavated perimeter slopes. Accordingly, it is considered that the stability and integrity of the side slopes AGB will not be compromised by compressibility or the presence of cavities associated with the excavated perimeter side slopes sub-grade.

  Excavated perimeter slopes in the Kingston Formation will generally be formed at overall design gradients of *c.* 2v : 1h (vertical : horizontal) in limestone and *c.* 1v : 1h in sand. The maximum height of the excavated perimeter slopes will be *c.* 12m.

  Based on the findings of geotechnical inspections undertaken most recently by Consultants LLP in May 2020, it is considered that the excavated slopes will remain adequately stable at the design gradients. Any minor face dressing or re-grading of the side slopes sub-grade will be undertaken on a phased basis in advance of the construction of the side slopes AGB.

  In accordance with the requirements of the Quarries Regulations 1999, the quarry operator is responsible for ensuring that the excavated faces are designed, constructed, operated and maintained so as to ensure that instability or movement which is likely to give rise to a risk to the health and safety of any person is avoided. Accordingly, it is considered that the stability and integrity of the side slopes AGB will note be compromised by slope instability associated with the excavated perimeter side slopes sub-grade.

- Side Slopes Artificial Geological Barrier Slope Stability

  Using the input parameters detailed in Appendix 2, a satisfactory minimum FoS value of 1.46 is indicated by the analysis results for circular slope failure involving the side slopes AGB. Accordingly, it is considered that the stability and integrity of the side slopes AGB will not be compromised by slope instability.

*4.6.5 **Waste Mass*** (see Appendix 3)

Using the input parameters detailed in Appendix 3, a satisfactory minimum FoS value of 1.48 is indicated by the analysis results for circular slope failure involving the waste mass. Accordingly, it is considered that the stability and integrity of the waste mass will not be compromised by slope instability.

*4.6.6 **Capping***

- Slope Stability

  Site restoration will be in accordance with the requirements of extant Planning Permissions HAT/1163/89, MW.0153/12, and MW.0066/19.

  Restoration surface contours are shown on Drawing No. HATFEXT2104-4.

  The final restoration surface of the landfill will be formed at gradients shallower than *c.* 1v : 20h

Given the shallow restoration gradients, it is considered that the stability of the final restoration surface of the landfill will not be compromised by slope instability.

- Deformation Due to Landfill Settlement

  No engineered low permeability capping system will be placed and therefore the potential for the integrity of such a system to be compromised by settlement of the waste mass does not exist.

  Given:

  - the character of the inert waste which will be placed into the landfill (mainly clayey soil and stone);
  - that site operational procedures, consistent with principles of best practice, will be employed to ensure that the waste is placed in layers *c.* 1m thick and is adequately compacted

  it is considered that the potential for landfill settlement will be low (less than *c.* 2% of waste thickness). Re-grading of the restored landfill surface will be undertaken if landfill settlement results in the formation of localised shallow depressions. Whilst it is considered that such depressions would not adversely affect landfill stability, they may cause localised ponding and therefore affect the afteruse of the site.

5. MONITORING

5.1 Basal Sub-Grade

The basal sub-grade will be inspected prior to the construction of the basal AGB, in order to ensure that no compressible or unsuitable material is present, and that no ponded surface water is present.

5.2 Side Slopes Sub-Grade

The side slopes sub-grade will be inspected prior to the construction of the side slopes AGB in order to ensure that no compressible or unsuitable material is present and that the sub-grade slopes exhibit adequate stability.

5.3 Basal Artificial Geological Barrier

Construction Quality Assurance procedures, consistent with a Construction Quality Assurance Plan approved by the Environment Agency and involving construction supervision and testing, will be adopted in order to ensure that the basal AGB meets required specifications.

5.4 Side Slopes Artificial Geological Barrier

Construction Quality Assurance procedures, consistent with a Construction Quality Assurance Plan approved by the Environment Agency and involving construction supervision and testing, will be adopted in order to ensure that the side slopes AGB meets required specifications.

5.5 Waste Mass

Placement of the waste will be routinely monitored in order to ensure that the waste is placed in layers *c.* 1m thick and is adequately compacted and that waste slopes are formed at appropriate gradients and remain stable.

5.6 Capping

A topographic survey of the restored landfill surface will be undertaken at intervals in accordance with the requirements of the EPR Permit in order to monitor landfill settlement.

6. SUMMARY AND CONCLUSIONS

This report presents a Stability Risk Assessment and has been prepared to support an EPR Permit application to accommodate landfilling with imported inert waste of the existing and approved future quarry excavations at Hatford Quarry.

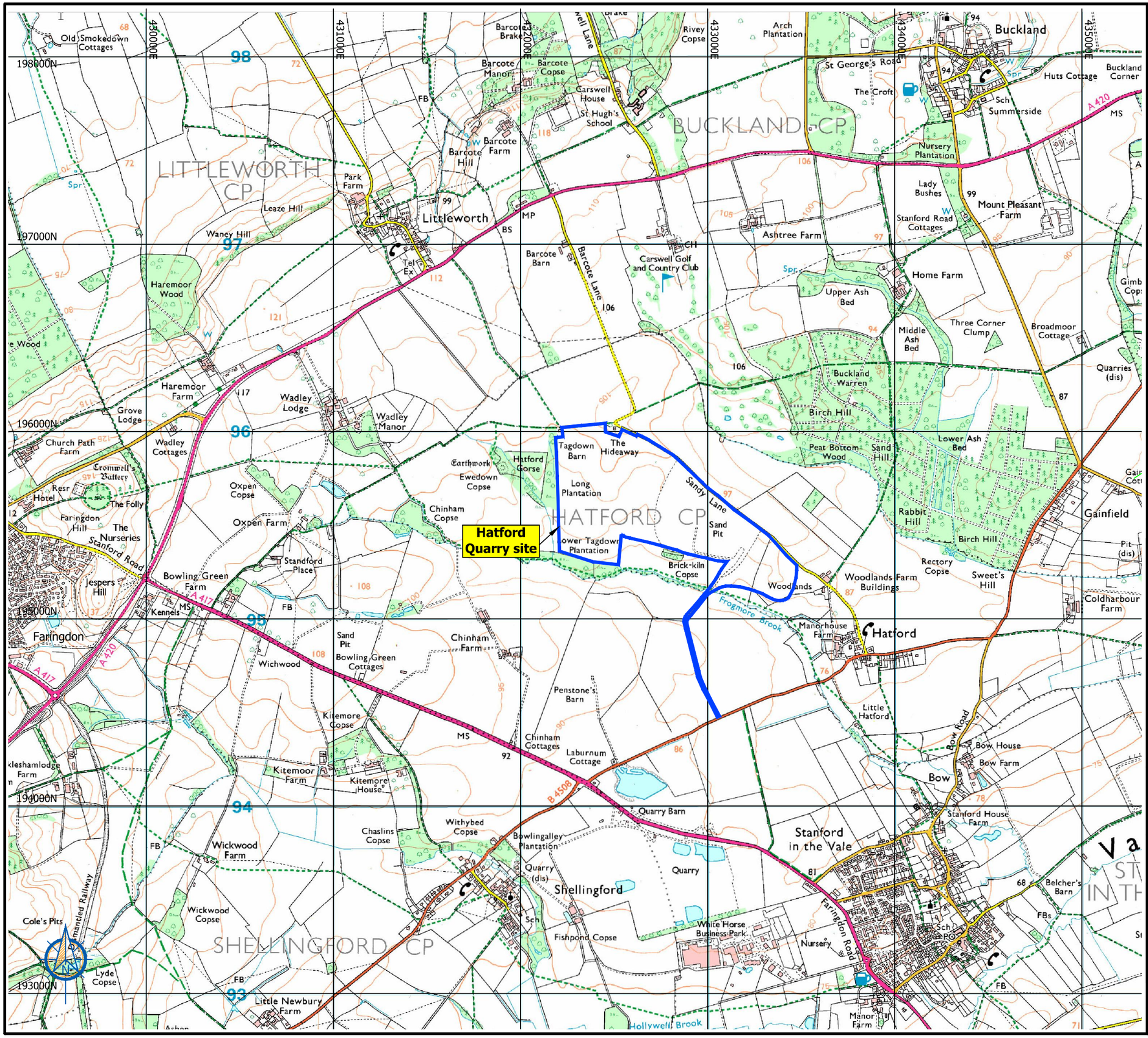
It is considered that the geotechnical setting of the site is adequately defined and that the geotechnical stability and safety risks associated with the development are very low.

The geotechnical stability and integrity of the components of the landfill development have been assessed and it is considered that adequate factor of safety values will be obtained during site development and following completion.

GWP CONSULTANTS
MAY 2021

Table 1 – Stability risk screening of landfill components

Landfill C component	Geotechnical issue	Classification of geotechnical issue	Justification		
			Is stability/integrity of landfill component at significant risk?	Principal reason(s)	Supporting analyses
Basal Sub-grade	Compressibility of sub-grade	Simple	No	No compressible material in basal sub-grade	See Section 4.6.1
	Cavities in sub-grade	Simple	No	No cavities in basal sub-grade	See Section 4.6.1
	Basal heave	Simple	No	No groundwater pressures acting to promote basal heave.	See Section 4.6.1
Side slopes sub-grade	Compressibility of sub-grade	Simple	No	No compressible material in side slopes sub-grade	See Section 4.6.2
	Cavities in sub-grade	Simple	No	No cavities in side slopes sub-grade	See Section 4.6.2
	Slope stability	Simple	No	Adequate stability of side slopes sub-grade	See Section 4.6.2
Basal artificial geological barrier	Compressibility of sub-grade	Simple	No	No compressible material in basal sub-grade	See Section 4.6.3
	Cavities in sub-grade	Simple	No	No cavities in basal sub-grade	See Section 4.6.3
	Basal heave	Simple	No	No groundwater pressures acting to promote basal heave	See Section 4.6.3
	Stability of sides slopes artificial geological barrier or waste mass and basal artificial geological barrier	Simple	No	Shallow gradient drained slopes in adequately strong side slopes artificial geological barrier and waste mass material	See Section 4.6.3
Side slopes artificial geological barrier	Compressibility and slope stability of side slopes sub-grade	Simple	No	No compressible material in side slopes sub-grade and adequate stability of side slopes sub-grade	See Section 4.6.4
	Cavities in sub-grade	Simple	No	No cavities in side slopes sub-grade	See Section 4.6.4
	Slope stability	Simple	No	Shallow gradient slopes in adequately strong side slopes artificial geological barrier material	See Section 4.6.4
Waste mass	Stability of waste mass	Simple	No	Shallow gradient slopes in adequately strong waste mass material	See Section 4.6.5
Capping system	Slope stability	Simple	No	Shallow gradient restored landfill surface	See Section 4.6.6
	Deformation due to waste settlement	Simple	No	No engineered capping system - limited landfill settlement	See Section 4.6.6



LEGEND

Hatford Quarry site

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a	Issued	27.05.2021

Client
Hatford Quarry Limited

Project
Hatford Quarry - Environmental Permit application (inert landfill) EPR/KB3009XM/A001

Hatford Quarry site location context plan

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Date	Drawn	Checked	Scale
27.05.2021	EB/EMB	*MP*	1:20,000 at A3

Drawing Ref	Drawing No	Version
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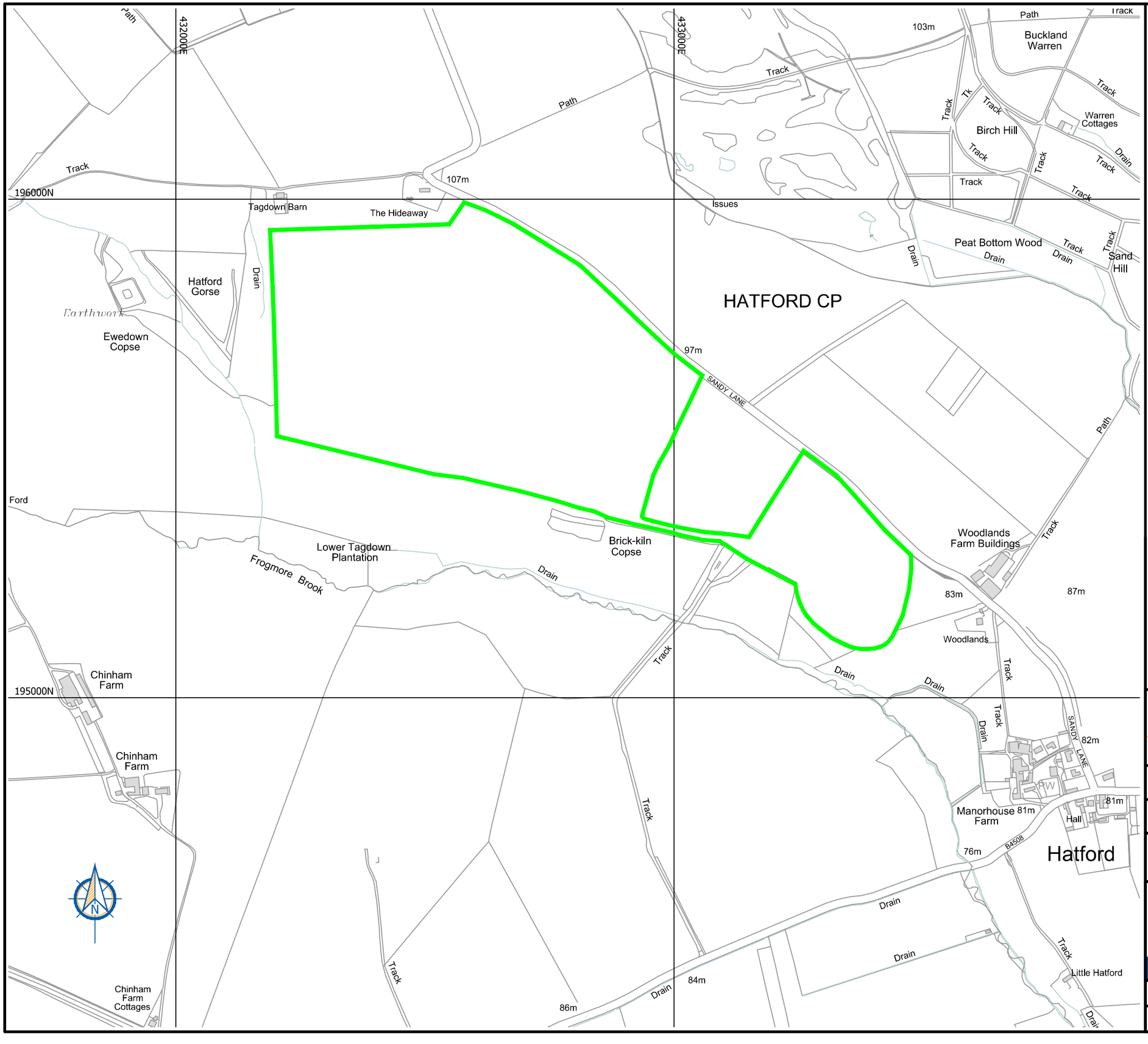

LEGEND

Environmental Permit application boundary

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Client
Hatford Quarry Limited

Project
Hatford Quarry - Environmental Permit application (inert landfill) EPR/KB3009XM/A001

Site plan

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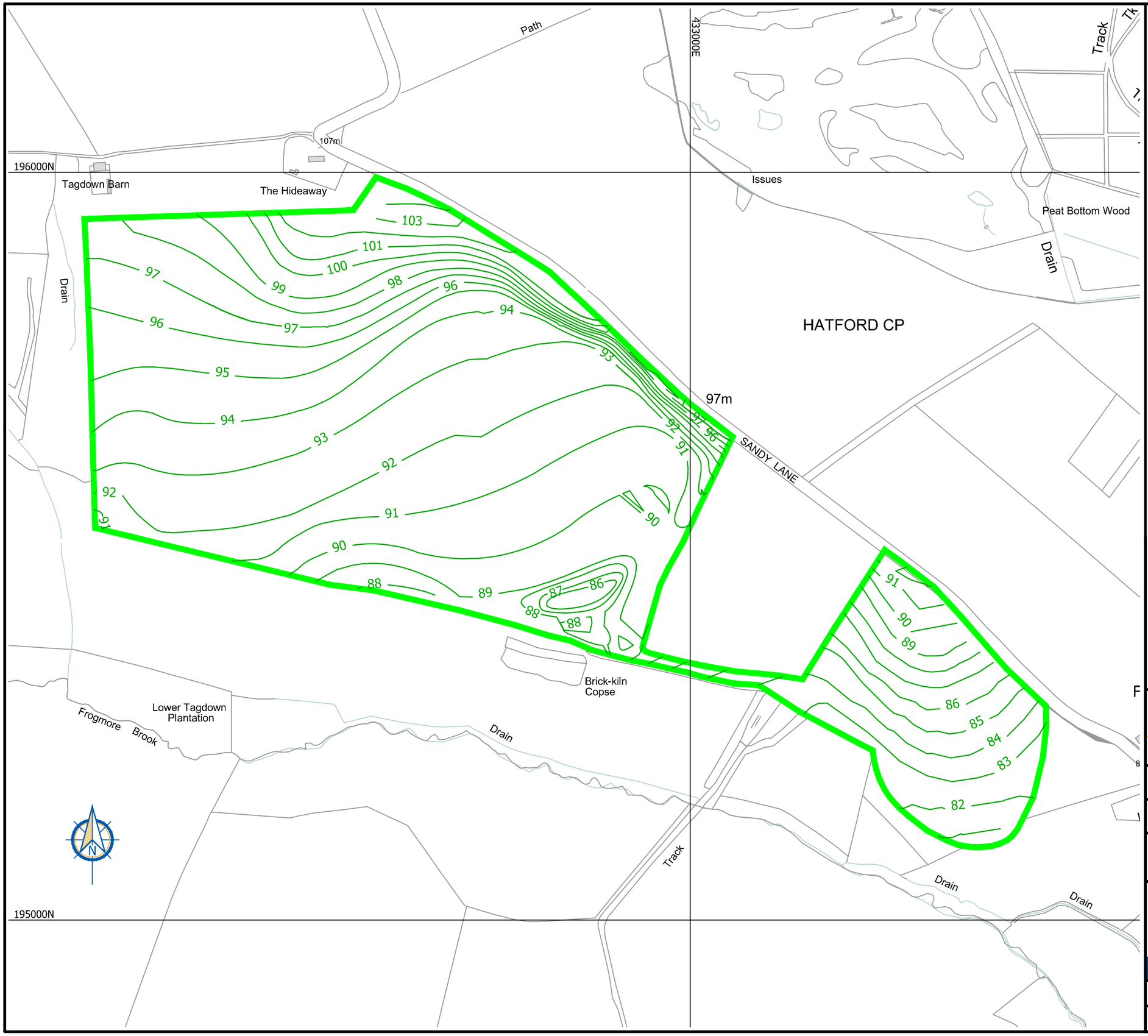
Date	Drawn	Checked	Scale
27.05.2021	EB/EMB	*MP*	1:7,500 at A3

Drawing Ref	Drawing No	Version
HATFEXT2104	2	a



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Environmental Permit application boundary

86 — Restoration contour mAOD, 1m interval

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Version	Revision and compilation notes	Date
a	Issued	27.05.2021

Client: Hatford Quarry Limited

Project: Hatford Quarry - Environmental Permit application (inert landfill) EPR/KB3009XM/A001

Restoration contours

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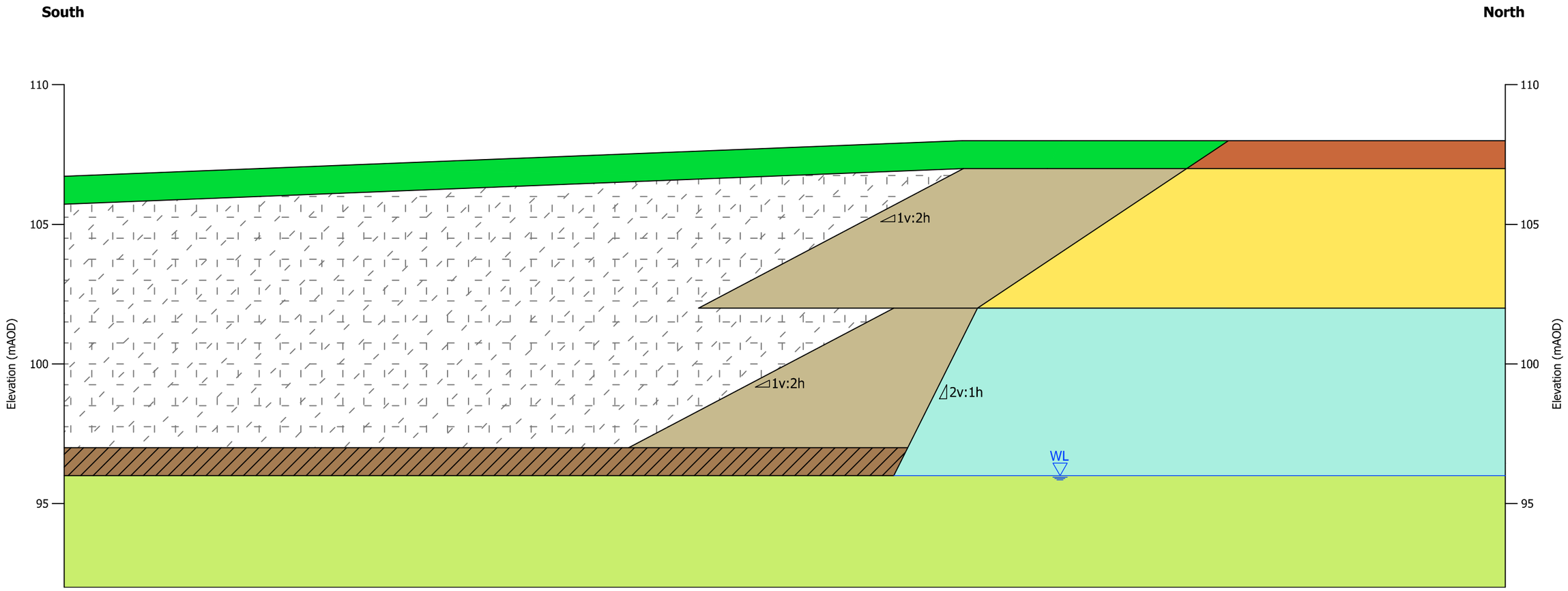
Date	Drawn	Checked	Scale
27.05.2021	EB/EMB	*MP*	1:5000 at A3

Drawing Ref	Drawing No	Version
HATFEXT2104	4	a



LEGEND

- Top/subsoil
- Highworth Grit Member
- Highworth Limestone Member
- Lower Calcareous Grit Formation
- Basal artificial geological barrier
- Side slopes artificial geological barrier
- Restoration cover soil
- Inert fill

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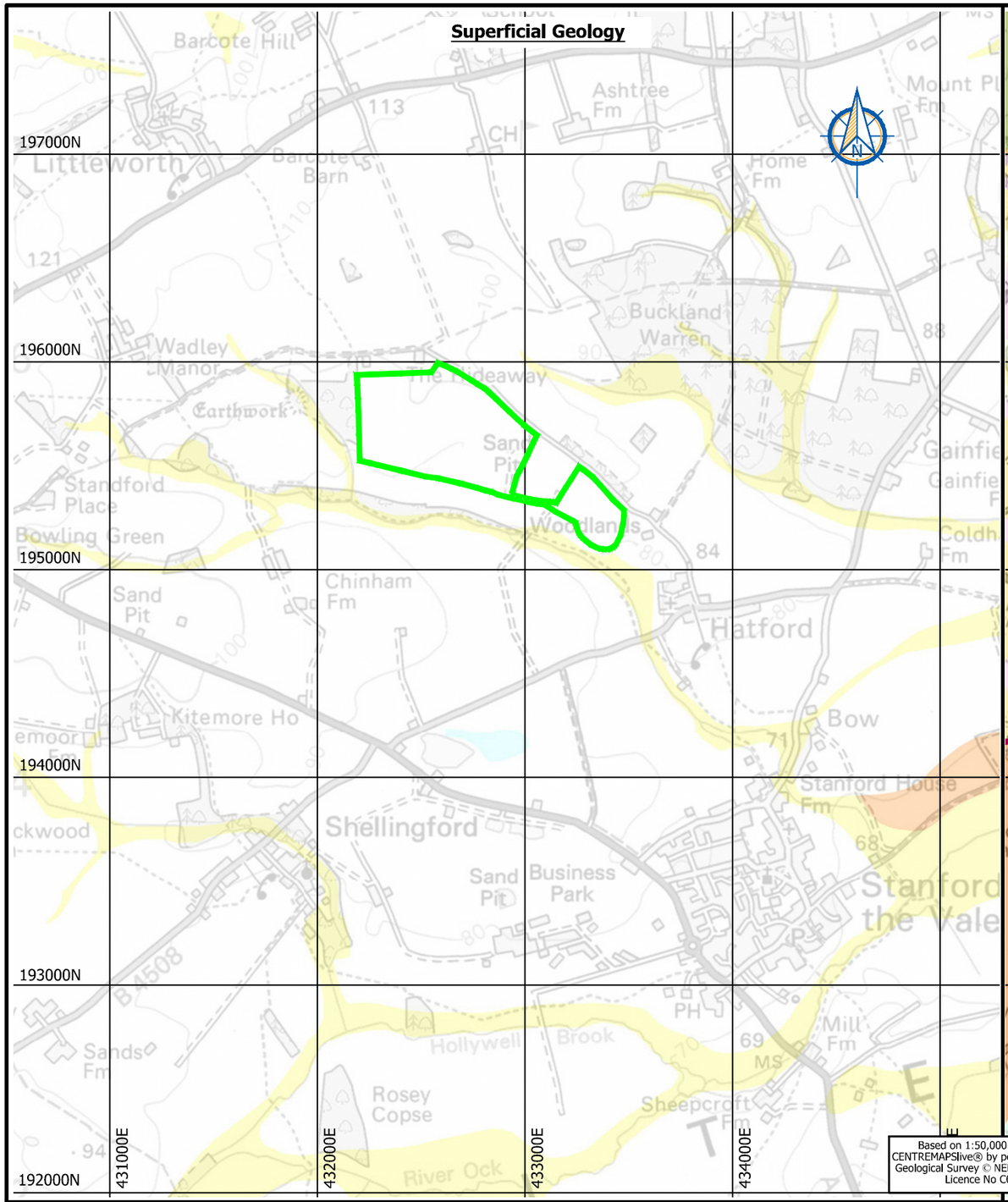
Components of the landfill installation

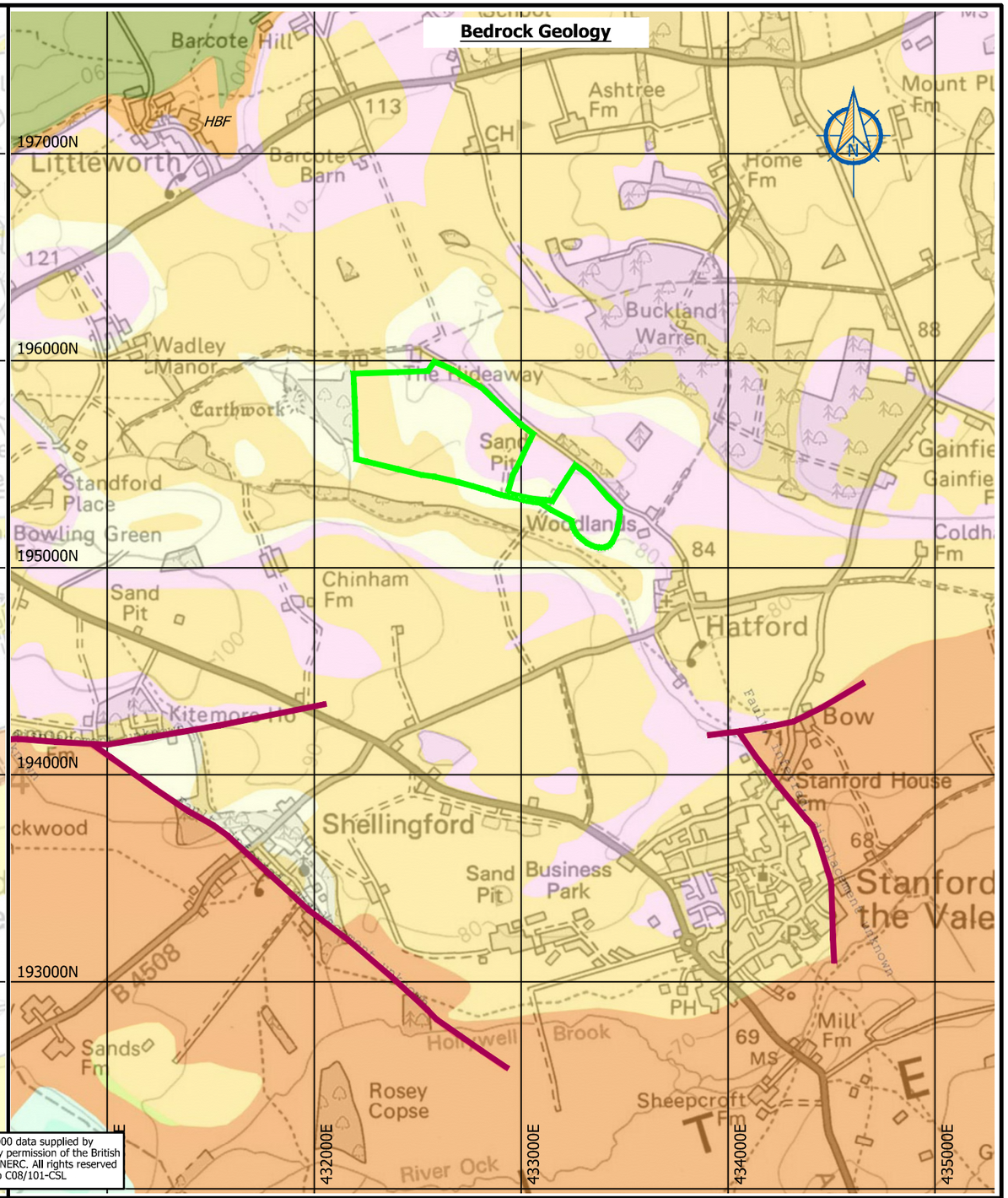
Date	Drawn	Checked	Scale
27.05.2021	EB/EMB	*MP*	1:150 at A3

Drawing Ref	Drawing No	Version
HATFEXT2104	7	a

Superficial Geology



Bedrock Geology



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LEGEND

Superficial geology

- Alluvium
- Till
- Northmoor Sand and Gravel Member

Bedrock geology

- Ampthill Clay Formation and Kimmeridge Clay Formation
- Stanford Formation
- Kingston Formation (Mudstone and Sandstone)
- Kingston Formation (Sandstone)
- *HBF* Hazelbury Bryan Formation
- Oxford Clay Formation

- Environmental Permit application boundary
- Fault

Version	Revision and compilation notes	Date
a	Issued	27.05.2021

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Geological setting

Date	Drawn	Checked	Scale
27.05.2021	EB/EMB	*MP*	1:25,000 at A3

Drawing Ref	Drawing No	Version
HATFEXT2104	9	a

APPENDIX 1

Stability analyses – basal artificial geological barrier

APPENDIX 1

STABILITY ANALYSES - BASAL ARTIFICIAL GEOLOGICAL BARRIER

1. Basal Artificial Geological Barrier Model

A basal artificial geological barrier will be constructed on a phased basis across the floor of the excavation. The artificial geological barrier will comprise a compacted layer of indigenous quarry material (overburden, interburden and crushing/screening fines) and/or suitable selected imported inert waste material and will have a minimum thickness of 1m and a permeability no greater than 1×10^{-7}m/s.

The basal AGB will be constructed in accordance with a Construction Quality Assurance Plan approved by the Environment Agency.

2. Basal Sub-Grade

- **Basal Sub-Grade Stability**

  Based on evidence from geotechnical site inspection, site investigation borehole logs and published information relating to the lithological character of the base of the Highworth Limestone Member/top of the Lower Calcareous Grit Formation, it is considered that no compressible material or cavities will be present beneath the site.

  Accordingly, it is considered that the stability and integrity of the basal sub-grade will not be compromised by compressibility or the presence of cavities.

- **Basal Heave**

  The basal sub-grade of the landfill will comprise the base of the Highworth Limestone Member/top of the Lower Calcareous Grit Formation which forms the floor of the mineral excavation.

  Groundwater is present in the lower part of the Highworth Limestone Member and the underlying Lower Calcareous Grit Formation.

  The inferred saturated thickness of the Highworth Limestone Member across the site ranges from *c.* 0m in the north to *c.* 2.50m in the south.

  Excavation dewatering occurs and will continue to allow mineral excavation, engineered artificial geological barrier (AGB) construction and restoration infilling to be undertaken in dry condition.

  There will be no groundwater pressures acting which have the potential to promote basal heave. Accordingly, it is considered that the stability and integrity of the basal sub-grade will not be compromised by basal heave.

3. Slope Stability

- **Aim:** To assess the potential for instability of the basal AGB involving slope instability of the side slopes AGB or the waste mass.
- **Analytical approach:** Use of SLIDE computer software to investigate the potential for slope failure.
- **Slope geometry:** See Analyses A and B
- **Analysis input parameters:**
  - Shear strength and bulk density parameters:

    Artificial Geological Barrier

    Drained shear strength: c′ = 4kPa ø′ = 23°

    (conservative estimate)

    Bulk density: 1.8Mg/m^3

    Waste Mass

    Drained shear strength: c′ = 4kPa ø′ = 23°

    (Conservative estimate)

Bulk density: 1.8Mg/m^3

- Groundwater: Quarry floor level.
- Leachate: None.

- **Results**

  Slope Instability involving Side Slope and Basal Artificial Geological Barriers (Analysis A)

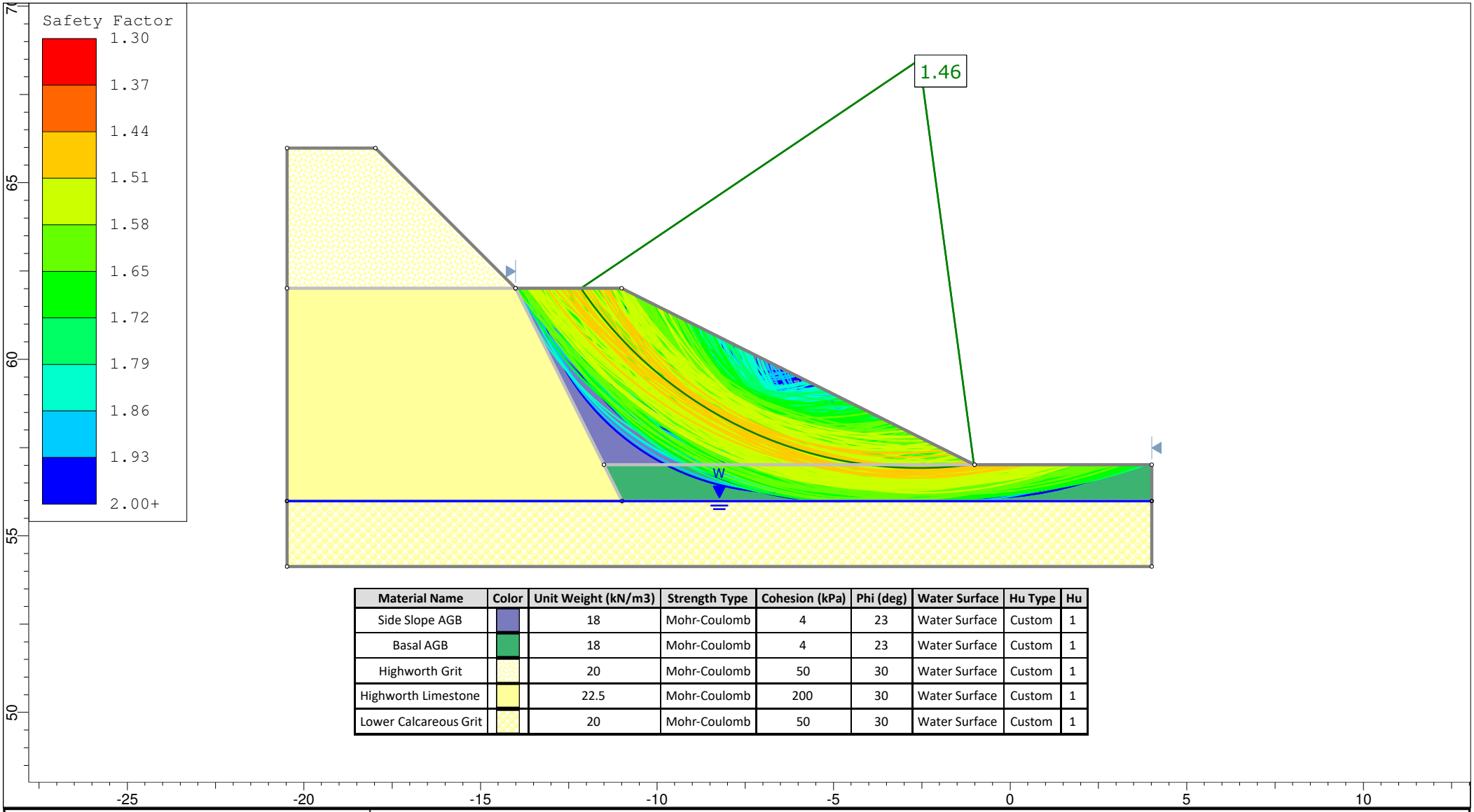
  Using the input parameters detailed above, a minimum FoS value of 1.46 is indicated by the analysis results for a circular slope failure involving the side slopes and basal AGBs.

  Slope Instability involving Waste Mass and Basal Artificial Geological Barrier (Analysis B)

  Using the input parameters detailed above, a minimum FoS value of 1.48 is indicated by the analysis results for a circular slope failure involving the waste mass and basal AGB.

- **Conclusions**

  The calculated FoS values of 1.46 and 1.48 are considered satisfactory. Accordingly, it is considered that the stability and integrity of the basal AGB will not be compromised by slope instability involving the side slopes AGB or the waste mass.



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Side Slope AGB		18	Mohr-Coulomb	4	23	Water Surface	Custom	1
Basal AGB		18	Mohr-Coulomb	4	23	Water Surface	Custom	1
Highworth Grit		20	Mohr-Coulomb	50	30	Water Surface	Custom	1
Highworth Limestone		22.5	Mohr-Coulomb	200	30	Water Surface	Custom	1
Lower Calcareous Grit		20	Mohr-Coulomb	50	30	Water Surface	Custom	1

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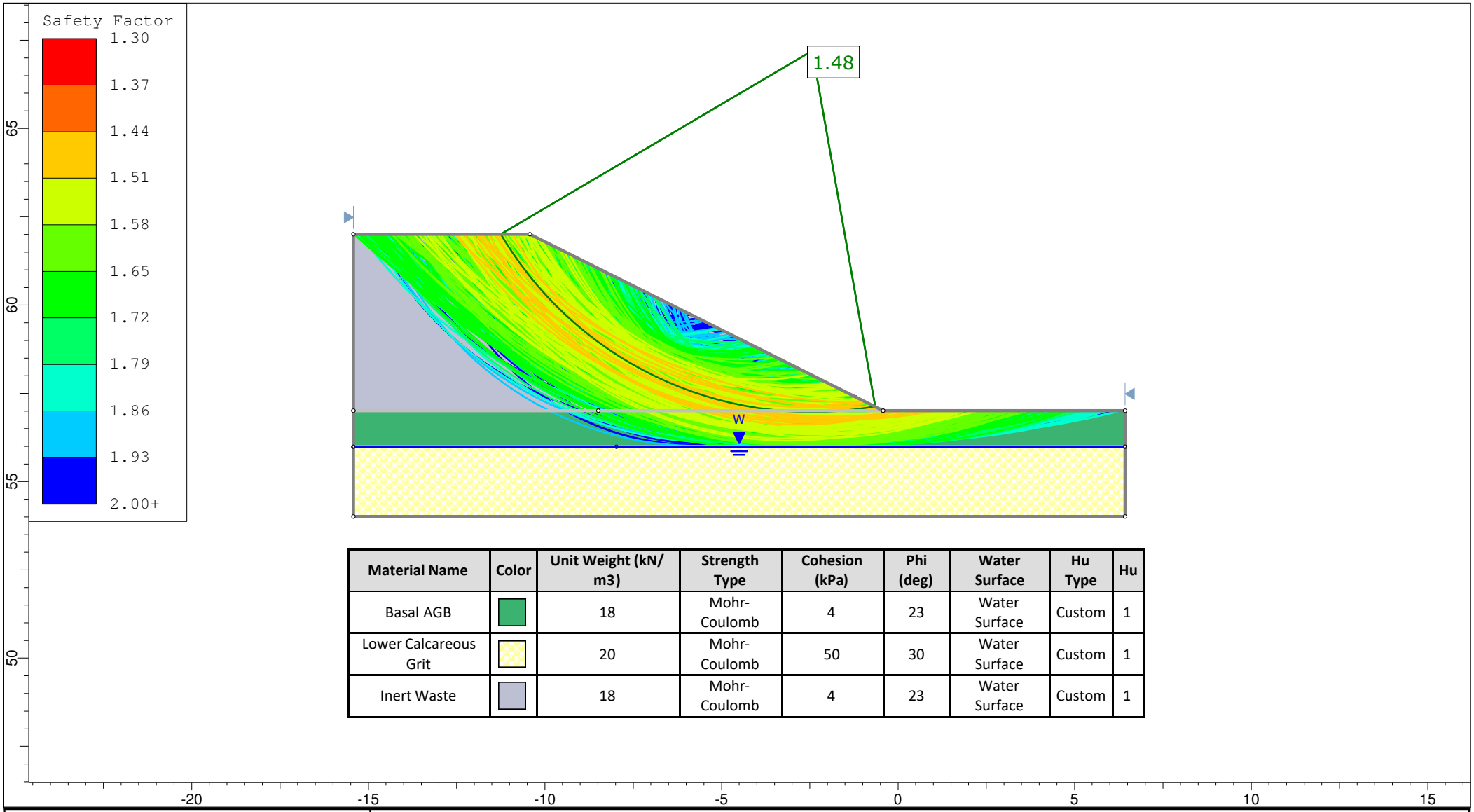
Project	Hatford Quarry - Stability Risk Assessment		
Analysis description	Side Slopes/Basal AGB - Analysis A		
Drawn By GWP Consultants LLP	*Scale* 1:150	*Company*	Hatford Quarry Limited
Date 07/07/2020		*File Name*	Hatford Quarry SRA Analysis A (Appendix 1).slim



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Basal AGB		18	Mohr-Coulomb	4	23	Water Surface	Custom	1
Lower Calcareous Grit		20	Mohr-Coulomb	50	30	Water Surface	Custom	1
Inert Waste		18	Mohr-Coulomb	4	23	Water Surface	Custom	1

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Project	Hatford Quarry - Stability Risk Assessment		
Analysis description	Waste Mass/Basal AGB Stability - Analysis B		
Drawn By GWP Consultants LLP	*Scale* 1:150	*Company* Hatford Quarry Limited	
Date 07/07/2020		*File Name* Hatford Quarry SRA Analysis B (Appendix 1).slim	

APPENDIX 2

Stability analyses – side slopes artificial geological barrier

APPENDIX 2

STABILITY ANALYSES – SIDE SLOPES ARTIFICIAL GEOLOGICAL BARRIER

1. Side Slopes Artificial Geological Barrier Model

A side slopes AGB will be formed on a phased basis using suitable indigenous quarry material (overburden, interburden and crushing/screening fines) and/or suitable selected imported inert waste.

The suitable material will be compacted in layers and brought up in lifts up to *c.* 5m high against the side slopes sub-grade formed in the Kingston Formation as the general placement of waste progresses.

Following the completion of each side slopes AGB lift, imported inert waste material will be graded against the compacted material in order to provide buttress support and to establish a stable platform for the placement and compaction of the next side slopes AGB lift. Excavated perimeter slopes in the Kingston Formation will have a maximum height of *c.* 12m and the maximum unsupported height of the side slopes AGB will be *c.* 5m. The side slopes AGB will have a minimum thickness of 1m and a permeability no greater than 1×10^{-7}m/s.

The side slopes AGB will be constructed in accordance with a Construction Quality Assurance Plan approved by the Environment Agency.

2. Side Slopes Sub-Grade

- **Compressibility of Side Slopes Sub-Grade**

  Based on evidence from geotechnical site inspection, site investigation borehole logs and published information relating to the lithological character of the Kingston Formation, it is considered that no compressible material or cavities will be present in the excavated perimeter slopes. Accordingly, it is considered that the stability and integrity of the side slopes AGB will not be compromised by compressibility or the presence of cavities associated with the excavated perimeter side slopes sub-grade.

- **Slope Stability of Side Slopes Sub-Grade**

  Excavated perimeter slopes in the Kingston Formation will generally be formed at overall design gradients of *c.* 2v : 1h (vertical : horizontal) in limestone and *c.* 1v : 1h in sand. The maximum height of the excavated perimeter slopes will be *c.* 12m.

  Based on the findings of geotechnical inspections undertaken most recently by GWP Consultants LLP in May 2020, it is considered that the excavated slopes will remain adequately stable at the design gradients. Any minor face dressing or re-grading of the side slopes sub-grade will be undertaken on a phased basis in advance of the construction of the side slopes AGB.

  In accordance with the requirements of the Quarries Regulations 1999, the quarry operator is responsible for ensuring that the excavated faces are designed, constructed, operated and maintained so as to ensure that instability or movement which is likely to give rise to a risk to the health and safety of any person is avoided. Accordingly, it is considered that the stability and integrity of the side slopes AGB will not be compromised by slope instability associated with the excavated perimeter side slopes sub-grade.

3. Slope Stability – Side Slopes Artificial Geological Barrier

- **Aim:** To assess the potential for instability involving the side slopes artificial geological barrier.
- **Analytical approach:** Use of SLIDE computer software to investigate the potential for slope failure.
- **Slope geometry:** See Analysis C
- **Analysis input parameters:**
- Shear strength and bulk density parameters:

  Artificial Geological Barrier

  Drained shear strength: c′ = 4kPa ø′ = 23°

  (Conservative estimate)

Bulk density: 1.8Mg/m^3

Waste Mass

Drained shear strength: c′ = 4kPa ø′ = 23°

(Conservative estimate)

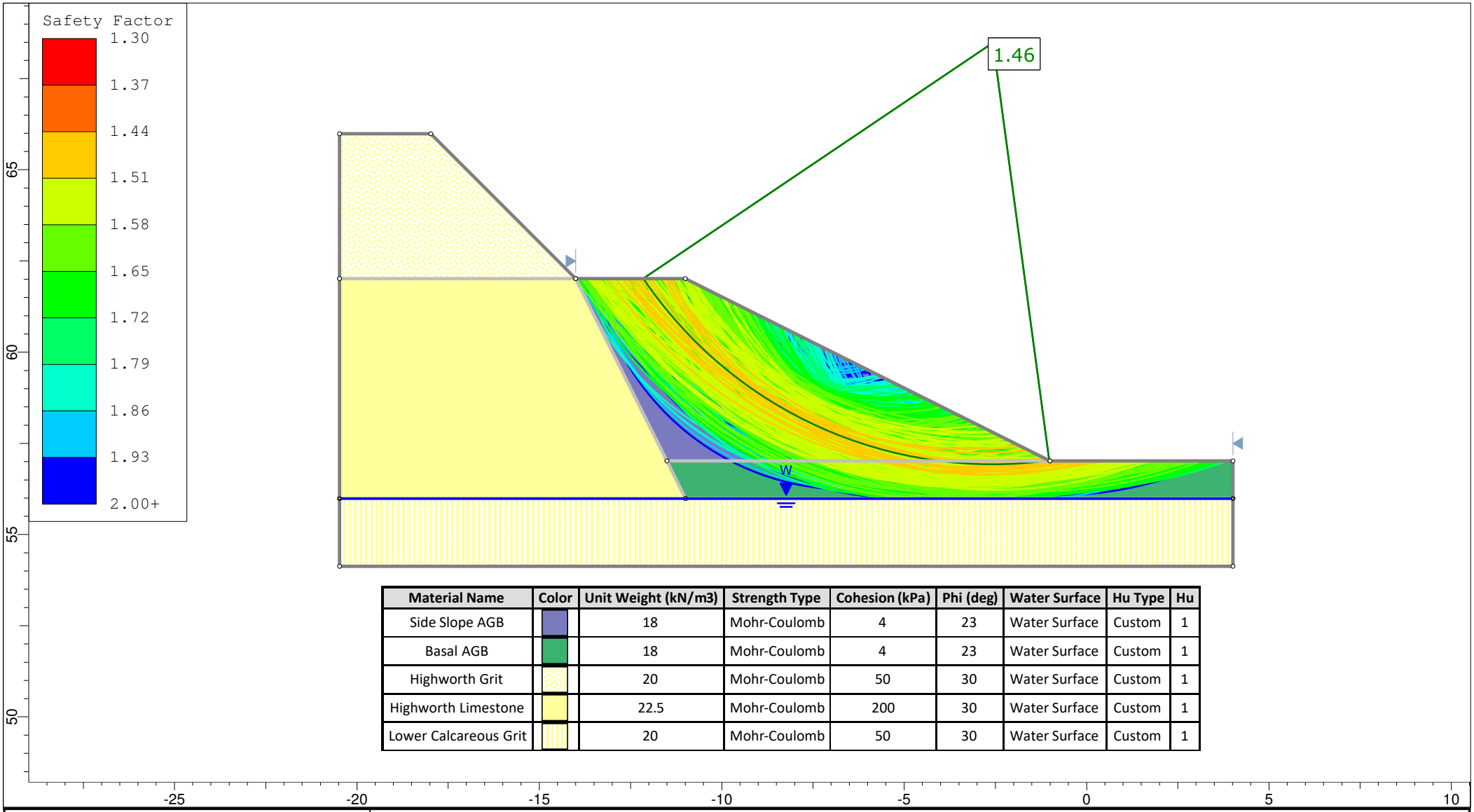
Bulk density: 1.8Mg/m^3

- Groundwater: Quarry floor level.
- Leachate: None.
- **Results** (Analysis C)

  Using the input parameters detailed above, a minimum FoS value of 1.46 is indicated by the analysis results for circular failure involving the side slopes AGB.

- **Conclusions**

  The calculated FoS value of 1.46 calculated is considered satisfactory. Accordingly, it is considered that the stability and integrity of the side slopes AGB will not be compromised by slope instability.



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
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Highworth Grit		20	Mohr-Coulomb	50	30	Water Surface	Custom	1
Highworth Limestone		22.5	Mohr-Coulomb	200	30	Water Surface	Custom	1
Lower Calcareous Grit		20	Mohr-Coulomb	50	30	Water Surface	Custom	1

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Project	Hatford Quarry - Stability Risk Assessment				
Analysis description	Side Slopes AGB - Analysis C				
Drawn By	GWP Consultants LLP	*Scale*	1:145	*Company*	Hatford Quarry Limited
Date	07/07/2020			*File Name*	Hatford Quarry SRA Analysis C (Appendix 2).slim

APPENDIX 3

Stability analyses – waste mass

APPENDIX 3

STABILITY ANALYSES – WASTE MASS

1. Waste Mass Model

The site will receive inert waste.

The waste will be placed in layers *c.* 1m thick in lifts *c.* 5m thick. The maximum total thickness of waste will be *c.* 10m. Active advancing slopes in waste material will be formed no steeper than 1v : 2h. Temporary inter-phase slopes in waste material will be formed no steeper than 1v : 3h. An intermediate bench with a minimum width of 10m will be maintained between lifts. The final restoration surface of the waste mass will be formed at gradients shallower than *c.* 1v : 20h.

No daily cover material will be placed.

2. Slope Stability – Waste Mass

- **Aim:** To assess the potential for instability involving the waste mass.
- **Analytical approach:** Use of SLIDE computer software to investigate the potential for slope failure.
- **Slope geometry:** See Analysis D
- **Analysis input parameters:**
  - Shear strength and bulk density parameters:

    Artificial Geological Barrier

    Drained shear strength: c′ = 4kPa ø′ = 23°

    (conservative estimate)

    Bulk density: 1.8Mg/m^3

    Waste Mass

    Drained shear strength: c′ = 4kPa ø′ = 23°

    (conservative estimate)

    Bulk density: 1.8Mg/m^3
  - Groundwater: Quarry floor level.
  - Leachate: None.
- **Results** (Analysis D)

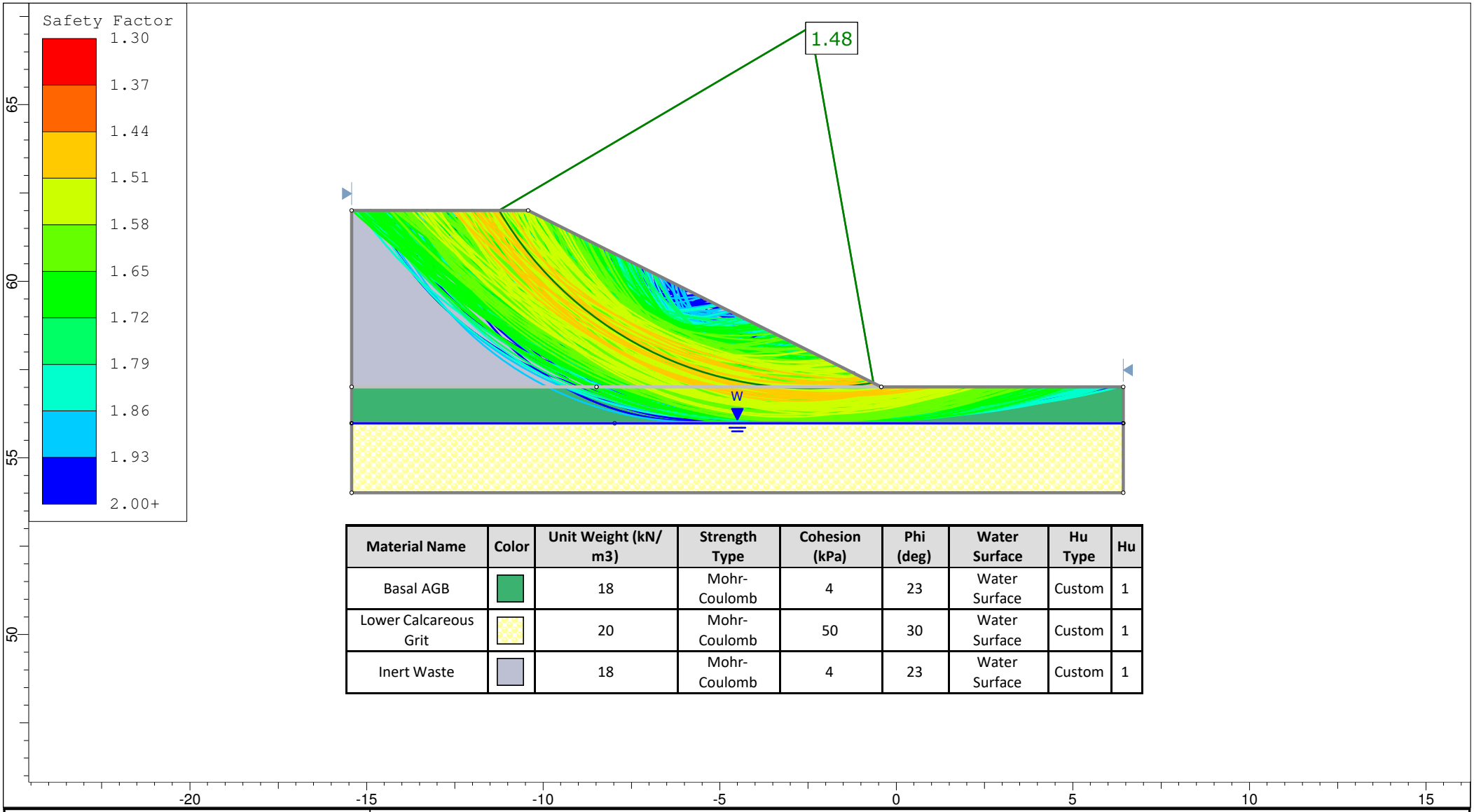
  Advancing waste slope

  Using the input parameters detailed above, a minimum FoS value of 1.48 is indicated by the analysis results for circular failure involving an advancing waste slope.

  Temporary inter-phase waste slope

  Temporary inter-phase slopes in waste material will be formed at a shallower gradient than active advancing waste slopes. FoS values for circular slope failure involving the waste mass will be higher for temporary inter-phase waste slopes than for advancing waste slopes.
- **Conclusions**

  The calculated FoS value of 1.48 for an advancing waste slope is considered satisfactory. Accordingly, it is considered that the stability and integrity of an advancing or temporary inter-phase waste slope will not be compromised by slope instability.



Material Name	Color	Unit Weight (kN/m3)	Strength Type	Cohesion (kPa)	Phi (deg)	Water Surface	Hu Type	Hu
Basal AGB		18	Mohr-Coulomb	4	23	Water Surface	Custom	1
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Inert Waste		18	Mohr-Coulomb	4	23	Water Surface	Custom	1

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Project	Hatford Quarry - Stability Risk Assessment		
Analysis description	Waste Mass Stability - Analysis D		
Drawn By	GWP Consultants LLP	*Scale* 1:150	*Company* Hatford Quarry Limited
Date	07/07/2020		*File Name* Hatford Quarry SRA Analysis D (Appendix 3).slim