Banana Field, Meriden Quarry

Stability Risk Assessment (May 2026)

Prepared for NRS Meriden Aggregates Limited

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Document Information

Project name	Banana Field, Meriden Quarry
Project number	26-106
Report title	Stability Risk Assessment
Document number	26-106-R-01-0
Revision	0

	Name	**Position**	**Signature**	**Date**
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Rev.	**Date**	**Description**	**Prep.**	**Apr.**
0	11/05/26	First issue	VR	BD

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1 Contact Details and Report Context

Site Name	Banana Field, Meriden Quarry
Site Address	Meriden Quarry, Solihull
Proposed operator	NRS
Name and address of the agent who completed the risk assessment	Nova Geo Consulting Unit 7, 1 Lower Bar, Newport, Shropshire, TF10 7BE

1.1 Report context

Nova Geo Consulting (NGC) has been commissioned by NRS Meriden Aggregates Limited, the operators of Meriden Quarry, to undertake a Stability Risk Assessment to assess the stability of the proposed restoration of Banana Field to recreate approximate original ground levels by restoring the site with the importation of inert material as a waste recovery operation. The report follows the guidance provided in Technical Report P1-385/TR2 “Stability of Landfill Linings”.

The site is an active sand and gravel quarry and is part of the Meriden Quarry complex which has been extracting sand and gravel from the area since the late 1950s.

The following assumptions are made in the Stability Risk Assessment.

- The ground conditions at the site are as described in the Hydrogeological Risk Assessment report. These will be verified during construction.

1.2 Conceptual Site Model

The Conceptual Site Model is shown in Appendix 1.

1.3 Design Information

The following ground investigation and design information has been used in preparation of the Stability Risk Assessment:

- CQA Validation, January 2026, Nova Geo Consulting Ltd (ref. 25-273)
- Hydrogeological Risk Assessment, December 2025, Firth Consultants Ltd (ref. fc37351).

2 Conceptual Stability Site Model

2.1 Ground and Groundwater Conditions

This report deals with the proposed placement of a geological barrier within the Banana Field to allow backfilling with inert waste. The quarry is located approximately 5km south-east of Birmingham Airport and Meriden Borough of Solihull at National Grid Reference 422675mE, 281189mN.

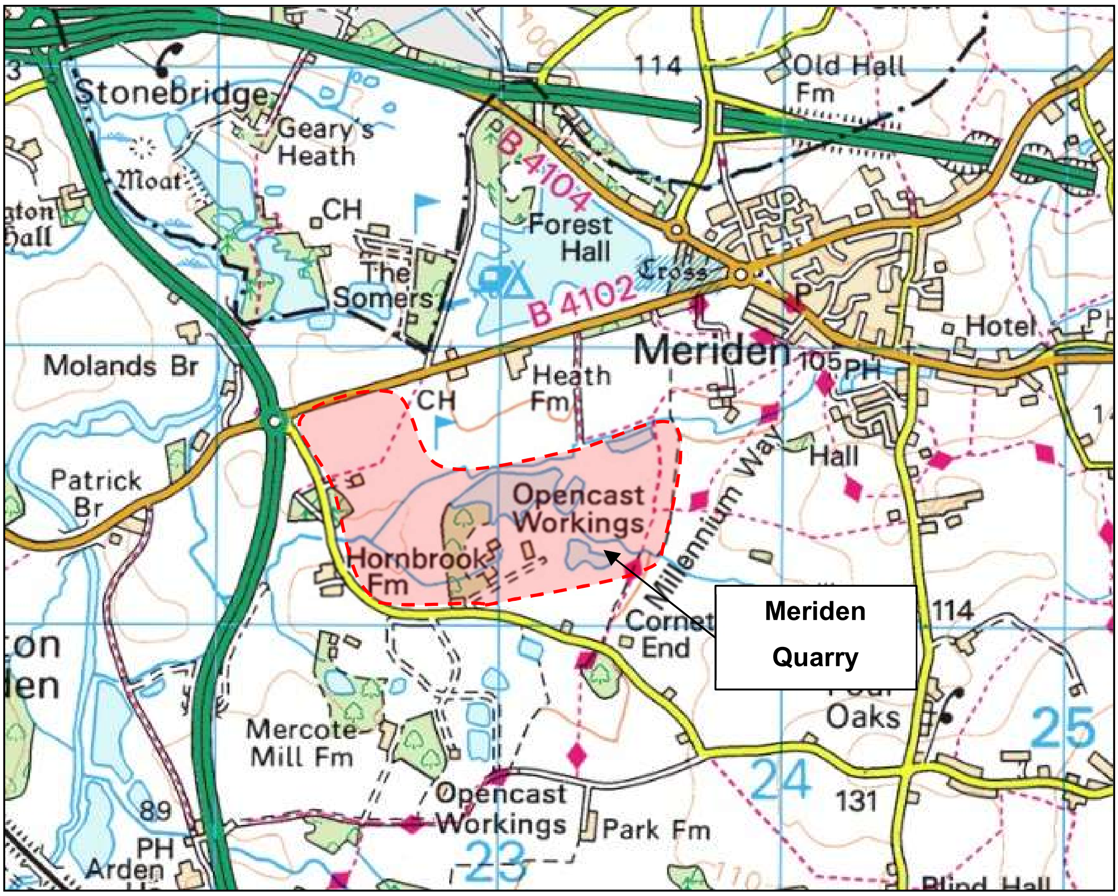


Figure 2.1-1: Site Location (Reproduced by permission of Ordnance Survey all rights reserved)

The mapped geology is shown on BGS 1:50,000 Sheet No. 168 Birmingham, which shows the site to be underlain by the Sidmouth Mudstone Formation of the Mercia Mudstone Group. As explained in the Hydrogeological Risk Assessment, this strata comprises of mudstone and siltstone. The Sidmouth Mudstone Formation is overlain by Glaciofluvial deposits described as sand and gravel.

The Hydrogeological Risk Assessment indicates that the Glaciofluvial deposits were historically present across the site, with Alluvium associated with Cornets End Brook and Horn Brook recorded to the north. Borehole information reviewed within that assessment indicates that the base of the Glaciofluvial deposits lies at approximately 84.1mAOD to 85.5mAOD, equivalent to around 4.5m to 11.9m thickness of sands and gravels overlying the mudstone. Quarrying activities have, however, removed the alluvium and the majority of the sand and gravel deposits across much of the site, with limited deposits understood to remain within the batter slopes at the western, eastern and southern margins of the excavation.

The site-specific geology is described on the basis of boreholes BH3, BH4, BH4D and BH5 positioned around the site perimeter. These indicate red/orange clay with gravels to depths of approximately 4.8m below ground level in the west to about 10m below ground level in the east, overlying between 0.3m and 3.7m of red stiff sandy clay, interpreted as weathered bedrock, with red/orange mudstone beneath. The mudstone was proven to at least 25m depth in borehole BH4D and is described as firm to very stiff red/brown clay with green/grey clay marbling.

The Sidmouth Mudstone Formation is identified as a Secondary B Aquifer, while the overlying Glaciofluvial deposits and Alluvium are classified as Secondary A Aquifers. The mudstone beneath the site is represented by firm to very stiff clay strata with no evidence of significant sandstone or siltstone horizons to the depth explored and is therefore considered to behave as a low permeability aquitard rather than a significant groundwater-bearing unit in the vicinity of the site.

Groundwater is identified within the Glaciofluvial deposits. The Hydrogeological Risk Assessment states that baseline groundwater monitoring, undertaken prior to dewatering associated with quarry operations, indicated groundwater flow within these superficial deposits towards the west to north-west, with an average saturated thickness of approximately 6m. Groundwater levels reportedly declined as a result of quarry dewatering, although these are expected to recover towards baseline conditions following restoration.

A minimum 3m thick geological barrier has been constructed over the side of the excavation prior to the placement of inert waste. The side slopes of the void have been formed at 1v:2h.

2.2 Primary Components of Conceptual Site Model

A Stability Risk Assessment requires the development of a Conceptual Site Model. Assessing the stability of landfill sites requires consideration of the main landfill elements. The main elements are:

- the subgrade (comprising the basal subgrade and the sideslope subgrade),
- the basal liner,
- the sideslope liner,
- the waste, and
- the capping.

These are shown in **Figure 2.2-1**

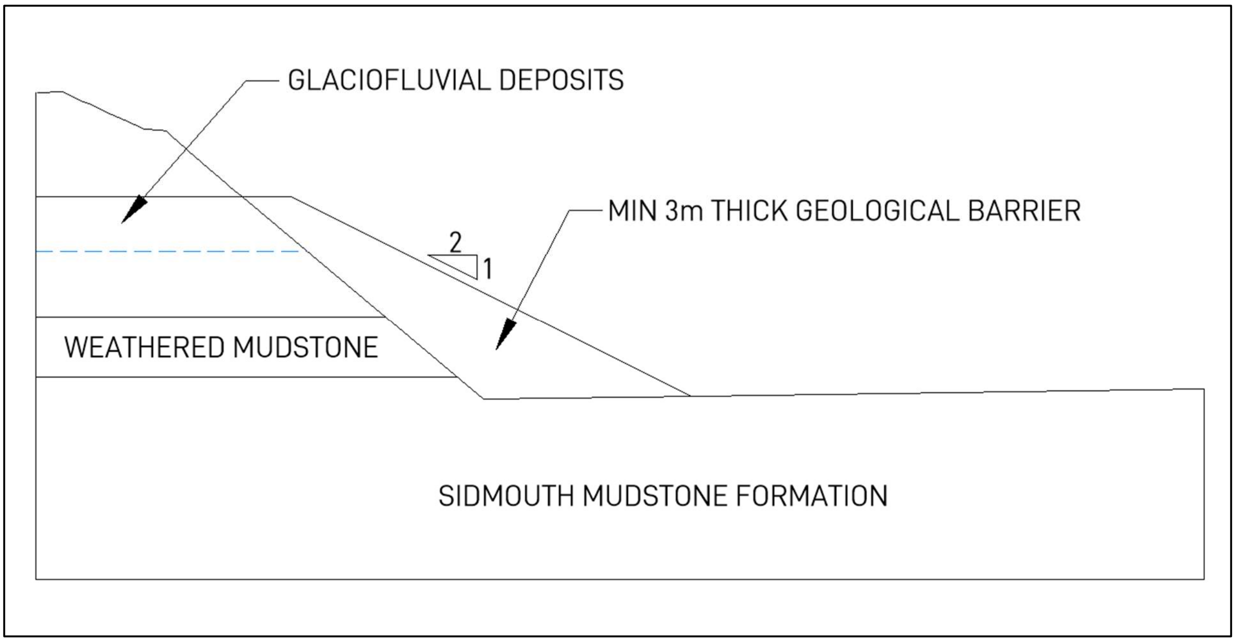


Figure 2.2-1: Details of Lining System

2.2.1 Basal Subgrade Model

The basal subgrade will be formed in in-situ strata of the Sidmouth Mudstone Formation. The formation level is assumed to be at 71mAOD.

2.2.2 Side Slope Subgrade Model

The side slopes have been assumed to comprise Glaciofluvial deposits along the quarry margins, locally overlying weathered Sidmouth Mudstone and Sidmouth Mudstone bedrock, based on information provided in the Hydrogeological Risk Assessment. However, as the geological barrier has already been constructed, the pre-construction side slope subgrade has not been modelled.

2.2.3 Basal Lining Model

No basal lining is proposed at the site. The quarry is underlain by low permeability Sidmouth Formation clay marl, which acts as a natural basal barrier.

2.2.4 Side Slope Lining Model

The side slope lining comprises site-won Sidmouth Mudstone excavated from the quarry floor and placed to form the sidewall geological barrier. The CQA Validation Report states that the liner was designed to be a minimum of 3m thick. Permeability testing recorded values between 1.6×10^{-9} m/s and 5.1×10^{-9} m/s, which are below the specified maximum permeability criterion of 1×10^{-7} m/s. For the purpose of the model, a representative permeability of 1×10^{-7} m/s has been taken.

2.3 Waste Model

The waste mass will consist of materials described as inert non-reactive wastes, typically construction and demolition waste. Due to the inert nature of the waste material, leachate and gas extraction measures are not proposed. It is planned that restoration will be undertaken progressively as each phase is completed although this will depend on the availability of suitable materials.

The waste materials will be places in compacted layers of thickness appropriate for the material being deposited; the maximum anticipated layer thickness is 1m with maximum lift heights of 2m and with temporary slopes in the waste no steeper than a 1v:2h gradient.

For the purposes of design, it will be assumed that the waste is an intermediate plasticity clay or a medium density sand. The more critical case is an intermediate plasticity clay, as this has a lower drained friction angle.

2.3.1 Capping System Model

The capping system is assumed to comprise the proposed restoration soil profile rather than an engineered low permeability cap. Based on the information provided, this consist of 30mm of topsoil, 300mm of subsoil and 600mm of overburden, giving a total cover thickness of 1.2m.

2.4 Pore Fluid Pressures

Groundwater levels have been assumed based on the groundwater level monitoring data presented in the Hydrogeological Risk Assessment, which indicates that groundwater is present within the Glaciofluvial deposits. A seepage analysis will be undertaken to model groundwater flow and derive pore-water pressure for the stability analysis using Rocscience SLIDE software. As the geological barrier has already been constructed and the pre-construction side slopes subgrade has not been explicitly modelled, the seepage and stability analysis will be based on the as-built survey of the barrier.

3 Stability Risk Assessment

Of the six principal components usually considered in a Conceptual Stability Site Model, only three are present at Banana Field, Meriden Quarry.

The principal components considered are:

- the basal subgrade;
- the side slope lining system, and
- the waste.

The components not considered, as they are not present, are:

- the basal lining system;
- the side slope subgrade, and
- the capping system

3.1 Risk Screening

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

3.1.1 Basal Subgrade Screening

The stability and deformability of the basal subgrade will be ensured during the construction and in the long-term by appropriate design of the components in the table below. The stability of the slope has been assessed in accordance with the requirements of BS EN 1997-1 using the software SLIDE by Rocscience.

Table 3.1-1: Stability Components for Basal Subgrade

Deformation Hazard	Comment
Compressible Subgrade	The basal subgrade will comprise in-situ Sidmouth Mudstone Formation. The mudstone will be of low compressibility.
Basal Heave	No groundwater was encountered in the Sidmouth Mudstone Formation. No artesian water pressure is present and therefore, basal heave of the subgrade is not considered possible.
Cavities in Subgrade	Natural or man-made cavities are not known to exist in the strata; therefore, this aspect is not considered further.

Given the above, the basal subgrade system does not require further assessment but will be included in the global stability analysis.

3.1.2 Side Slope Screening

Stability Hazards	Comments
Stability	The pre-construction side slope has not been explicitly assessed, as the geological barrier has already been constructed and the assessment is based on the as-built survey of the sidewall barrier.
Groundwater	Groundwater is understood to be present within the Glaciofluvial deposits. For the purposes of the analysis, groundwater levels have been assumed based on the monitoring data in the Hydrogeological Risk assessment, which indicates an approximate groundwater level of 89 to 89.5mAOD in the west of the site and 92 to 92.5mAOD in the east.

3.1.3 Basal Lining Screening

This has not been considered as part of the assessment, as the basal stratum is understood to comprise the in-situ Sidmouth Mudstone Formation, which is described as firm to very stiff and forms a natural basal barrier beneath the site.

3.1.4 Side Slope Lining Screening

The side slope lining system has already been constructed to a maximum height of c.14m. Inert waste will be backfilled against it to a similar elevation. The controlling factors that will affect the stability are:

Stability Hazards	Comments
Stability of Lining	The maximum height of the barrier will be a maximum c.14m high with a side slope gradient of c. 26°, formed as a wedge of low permeability site-won clay.
Failure involving subgrade and waste	The waste slopes will result in the generation of partially backfilled slopes. Instability within the waste and basal subgrade could potentially occur and this will be considered further.

3.1.5 Waste Mass Screening

The controlling factors that will affect the stability and deformability of the waste mass are detailed in the table below.

Table 3.1-2: Stability Components for Waste Slopes

Stability Hazards	Comments
Failure wholly in waste	The waste materials will be placed in compacted layers of thickness appropriate for the material being deposited and the type of compaction plant being used. The slope gradients will be no steeper than 1v in 2h
Failure involving subgrade and waste	The waste slopes will result in the generation of partially backfilled slopes. Instability within the waste and the basal subgrade could potentially occur and this will be considered further.
Slope failure	The stability of the slope will be verified by limit equilibrium assessment.

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

3.1.6 Capping System Screening

This has not been considered as part of the assessment.

4 Lifecycle Phases

The inert waste will be built up in layers and not end tipped. Following preparation of the formation, the waste material will be placed and compacted in layers in accordance with the project specification.

5 Data Summary

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

- material unit weight;
- drained and undrained shear strength of soil / rock and waste;
- hydrogeological conditions.

The geotechnical parameter values adopted are discussed in more detail in Section 7.

6 Justification for Modelling Approach and Software

In order to perform the Stability Risk Assessment, the components of the proposed development, as previously described in Section 3 of this document, have to be considered not only individually but in conjunction with one another where relevant.

It is considered that rotational failure through the mass of the material is the most likely form of instability.

With the proposed system being a simple construction, it is only necessary to employ limit equilibrium stability analyses to demonstrate that the overall stability of the slope is acceptable. The stability of the slope, including the sub-grade below will be verified in accordance with the procedures described in BS EN 1997-1. Partial factors are applied to the actions and materials to determine the design actions and design resistances. The Ultimate Limit State stability is verified using Design Approach 1. This considers two combinations of actions, material properties and resistances. The appropriate partial factors are applied to the characteristic actions, material properties and resistances to determine the design values.

The limit equilibrium analyses have been undertaken using the commercially available software package SLIDE by Rocscience.

7 Justification of Geotechnical Parameters Selected for Analysis

7.1 Characteristic Geotechnical Parameters

The stability analyses that have been undertaken as part of this assessment have assumed various geotechnical parameters for the in-situ strata, capping liner and waste materials. The parameters that have been used are provided below in Table 7.1-1.

Table 7.1-1: Characteristic Geotechnical Parameters

Material Type	Undrained Shear Strength, c_u (kN/m^2)	Effective Cohesion, c' (kN/m^2)	Angle of shearing Resistance, Ø' (°)	Bulk Density (kN/m^3)	Permeability (ms^{-1})	Typical Description
Geological Barrier	50	1	25	20	1×10^{-7}	Remoulded clay
Inert Waste Fill	50	1	26	20	1×10^{-5}	Imported inert waste material
Glaciofluvial Deposits	N/A	0	35	20	4×10^{-5}	Sand and gravel
Weathered Sidmouth Mudstone Formation	50	10	25	20	1×10^{-7}	Weak mudstone, firm sandy clay
Sidmouth Mudstone Formation	100	50	45	22	1×10^{-7}	Mudstone, firm to very stiff clay

The steady state groundwater profile is calculated by the Rocscience software. The software calculates the flow net for the cross-section based on the groundwater level in the Glaciofluvial deposits the permeability of the strata. The calculated profile is shown below.

7.1.1 Parameters Selected for Basal Subgrade and Side Slope Subgrade Analysis

The side slope subgrade is assumed based on information provided in the Hydrogeological Risk Assessment, to comprise remnant Glaciofluvial deposits locally overlying weathered Sidmouth Mudstone Formation and underlying Sidmouth Mudstone Formation bedrock. The Glaciofluvial deposits are described as sand and gravel and are therefore treated as a granular stratum for the purpose of the assessment. Drained strength parameters have been adopted for this material, and a representative permeability of 3.5m/day, equivalent to approximately 4×10^{-5} m/s, has been adopted based on the Hydrogeological Assessment.

The weathered Sidmouth Mudstone Formation is assumed to comprise a stiff sandy clay and to represent the weaker mudstone horizon present at the site. An undrained shear strength of 50kPa is assumed for the weathered Sidmouth Mudstone Formation. The underlying Sidmouth Mudstone Formation is assumed to be stronger and an undrained shear strength of 100kPa has been adopted for the purpose of the assessment.

The characteristic geotechnical parameters provided in Table 7.1-1 for the Glaciofluvial deposits, weathered Sidmouth Mudstone Formation and unweathered Sidmouth Mudstone Formation are based on the geological descriptions presented in the Hydrogeological Risk Assessment and conservative engineering assumptions adopted for this preliminary stability risk assessment. The weathered horizon is described as red stiff sandy clay interpreted as weathered bedrock, while the underlying Sidmouth Mudstone Formation is described as red/orange mudstone, with core described as form to very stiff red/brown clay.

7.1.2 Parameters Selected for Basal Liner and Side Slope Liner Analysis

No basal liner is proposed at the site. Based on information provided in the Hydrogeological Risk Assessment, the quarry is underlain by low permeability Mercia Mudstone clay marl of the Sidmouth Mudstone Formation, which is understood to act as a natural basal barrier beneath the quarry floor.

The side slope liner comprises the as-constructed geological barrier formed from site-won Mercia Mudstone clay excavated from the quarry floor. The CQA validation report states that the liner was designed to be a minimum of 3m thick and that an overall slope gradient of approximately 1v:2h has been achieved. For the purposes of the assessment, a permeability of $1x10^{-7}$ m/s had been assumed.

7.1.3 Parameters Selected for Waste Analysis

The proposed waste mass is understood to comprise inert, non-reactive waste material. Based on the waste placement information provided, the waste has temporary slopes no steeper than 1v:2h. The Hydrogeological Risk Assessment recommends that generic Waste Acceptance Criteria for inert landfills are adopted for the site.

In the absence of site-specific test data, the waste has been treated as a compacted engineered fill and the characteristic parameters in Table 7.1-1 have been adopted as conservative preliminary values for the assessment. For the waste fill, an undrained shear strength of 50kPa, effective cohesion of 1kPa and an effective friction angle of 26, a bulk density of 20kN/m^3, and an assumed permeability of 1 x 10^{-6} m/s have been adopted.

7.1.4 Parameter Selected for Capping Analysis

Not applicable

8 Selection of Appropriate Factors of Safety

The verification of the stability is undertaken in accordance with the procedure described in BS EN 1997-1. Partial factors are applied to the loads, materials and resistances. An acceptable over-design factor is greater than 1.

For Design Approach 1, which is the approach followed in the UK, two load combinations are considered. In Combination 1 partial factors are applied to the permanent and variable loads and the partial factors applied to the materials and resistances are all unity.

In Combination 2, a partial load factor is applied to the variable loads and to the materials i.e. the soil strength.

8.1 Assessment

Details of the Stability Risk Assessment analyses undertaken for the site are presented in the following sections. A schematic cross section has been produced to represent the average slope profile through the development area.

8.1.1 Basal Subgrade Analysis

Not applicable.

8.1.2 Side Slope Subgrade Analysis

Not applicable.

8.1.3 Basal Lining Analysis

Not applicable

8.1.4 Side Slope Lining Analysis

The stability analyses program SLIDE has been used to analyse the section using Bishop's circular analysis. As the side slope liner is constructed under temporary conditions, undrained parameters have been applied.

Details of the analysis are summarised below in

Table 8.1-1 and analysis outputs are presented in Appendix 1.

Table 8.1-1: Summary of Stability Analysis for Side Slope Lining

Combination	Failure Mechanism Analysed	Overdesign Factor	Comments
1	Circular	1.273	Failure through Geological Barrier

2	Circular	1.081	Failure through Geological Barrier

An overdesign factor greater than 1 indicated that design resistance of the side slope liner under temporary conditions is acceptable.

8.1.5 Waste Mass Analysis

The stability analyses program SLIDE has been used to analyse the section using Bishop's circular analysis. Undrained parameters have been applied to the inert waste and side slope liner. Details of the analysis are summarised below in Table 8.1-2 and analysis outputs are presented in Appendix 1.

Table 8.1-2: Summary of Stability Analysis for Waste Mass

Combination	Failure Mechanism Analysed	Overdesign Factor	Comments
1	Circular	1.261	Failure through waste mass
2	Circular	1.216	Failure through waste mass

An acceptable overdesign factor against a failure through the waste mass has been determined; these results demonstrate that a 1v:2h overall slope within the backfilled inert waste will remain stable during infilling. The worst-case condition, with inert waste placed at the same level as the geological barrier, has been assessed and is considered acceptable. Ultimately the whole void of the excavated void will be filled with waste and no slopes will remain.

8.2 Capping Analysis

Not applicable

8.3 Assessment

8.3.1 Basal Subgrade Assessment

Not applicable.

8.3.2 Side Slope Subgrade Assessment

Not applicable.

8.3.3 Basal Lining Assessment

Not applicable.

8.3.4 Side Slope Lining Assessment

The stability of the side slope liner has been assessed and is considered to be acceptable.

The groundwater profile within the glaciofluvial deposits has been calculated by the software based on the assumed steady-state seepage conditions. The analysis confirms that the constructed 1v:2h side slopes provide an adequate level of stability for the side slope liner.

On this basis, the stability of the side slope liner is considered acceptable

8.3.5 Waste Mass Assessment

The waste mass analysis incorporates analyses of the side slope liner since this component will play a role in waste mass stability.

The groundwater profile assumed to be present within the glaciofluvial deposits calculated by the software assuming steady state seepage.

Hence it is considered that the calculated overdesign factor for the temporary slopes in the waste mass are adequate and that any minor surface instability can be dealt with through appropriate management of the site.

8.3.6 Capping Assessment

Not applicable.

9 Monitoring

9.1.1 The Risk Based Monitoring Scheme

Based upon the foregoing Stability Risk Assessment, a simple risk-based monitoring scheme is considered appropriate for the site.

9.1.2 Basal Subgrade Monitoring

Not applicable.

9.1.3 Side Slope Subgrade Monitoring

Not applicable.

9.1.4 Basal Lining Monitoring

Not applicable.

9.1.5 Side Slope Lining 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.

9.1.6 Waste Mass Monitoring

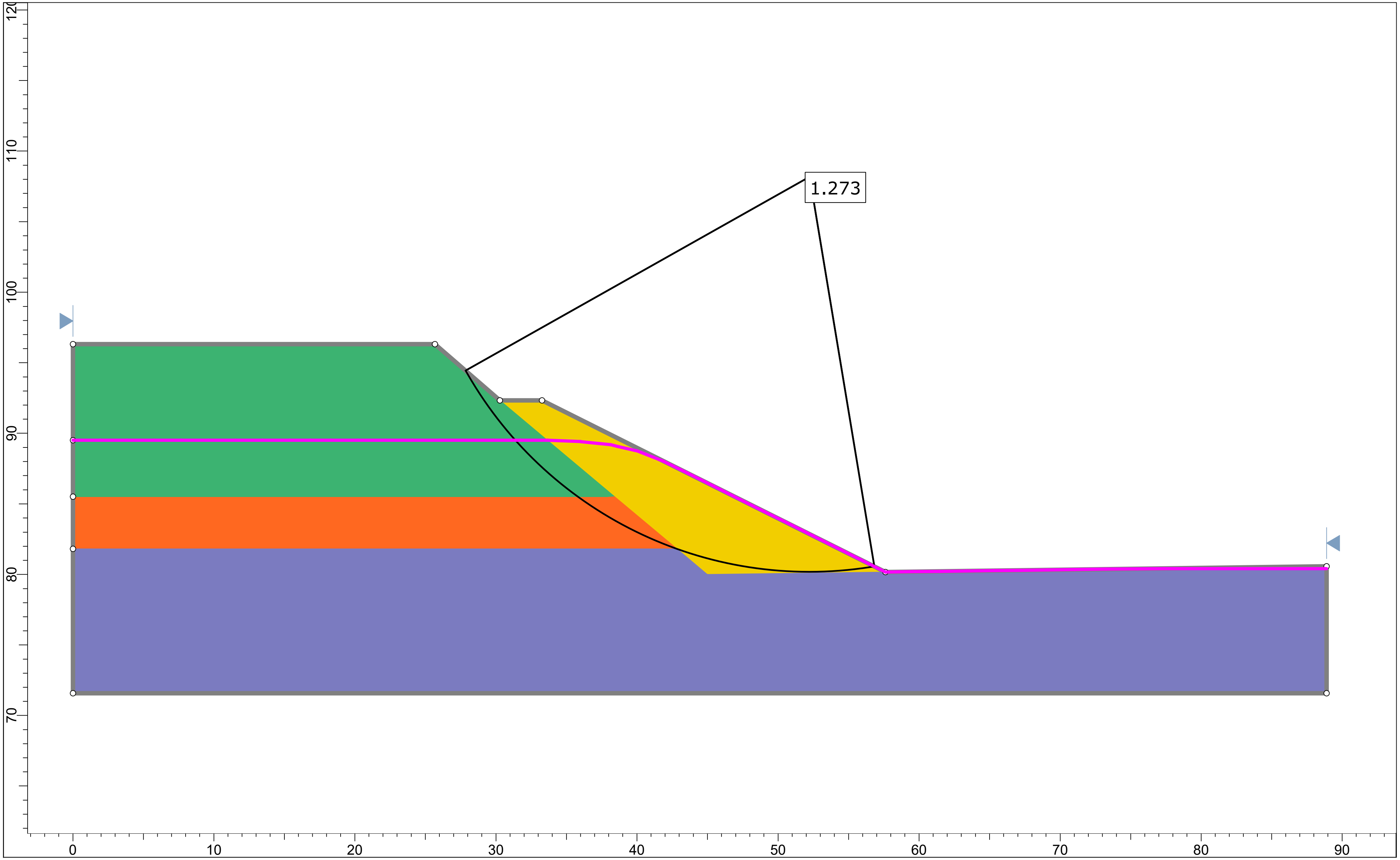
Monitoring during construction will comprise construction quality assurance to ensure compliance with the construction specification.

The site operator shall undertake monthly inspections of the waste mass to confirm its stability and to pay particular attention to any water seepages, a written record of all inspections to be maintained.

9.1.7 Capping System Monitoring

Not applicable.

Appendix 1: Stability Calculations



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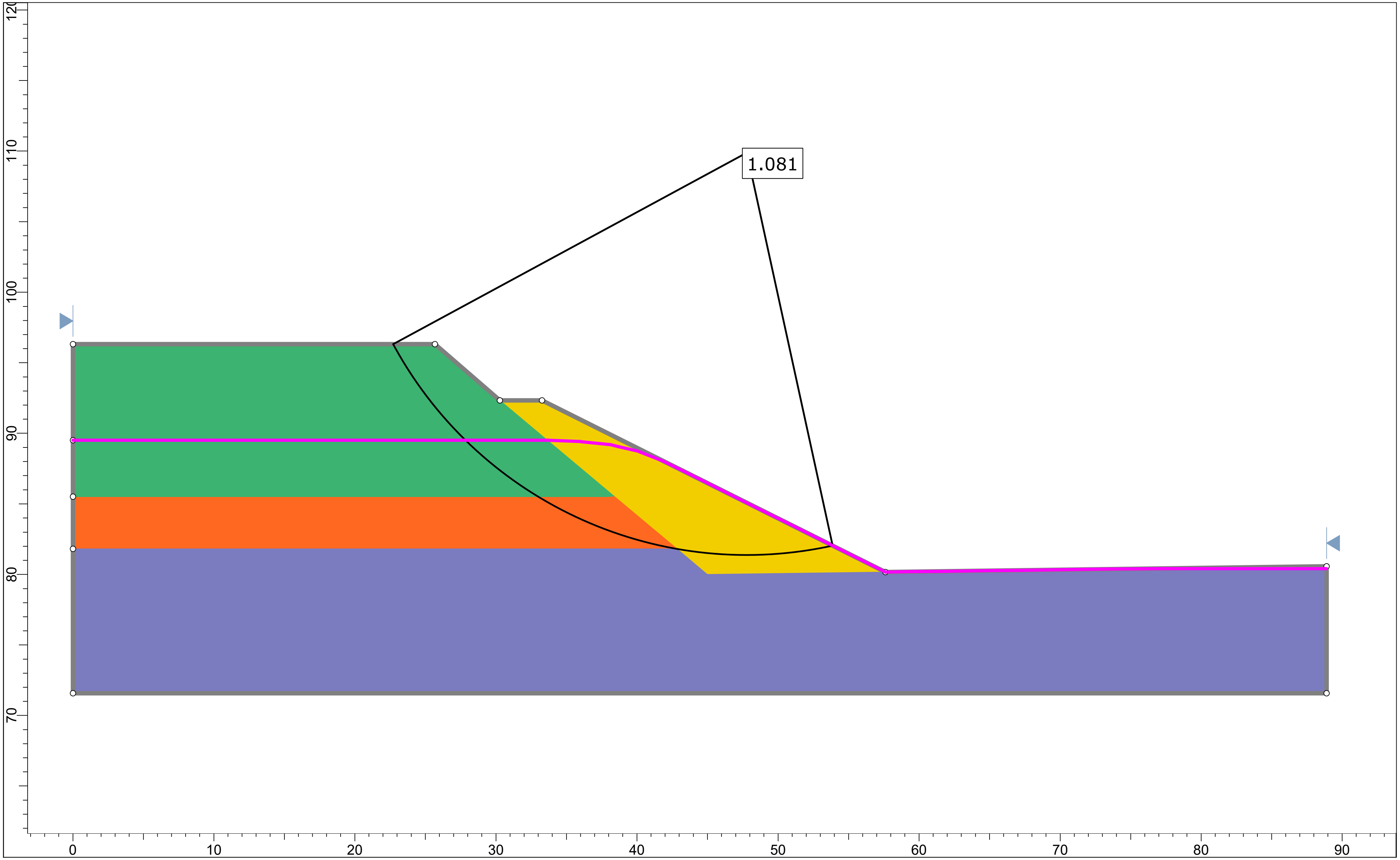
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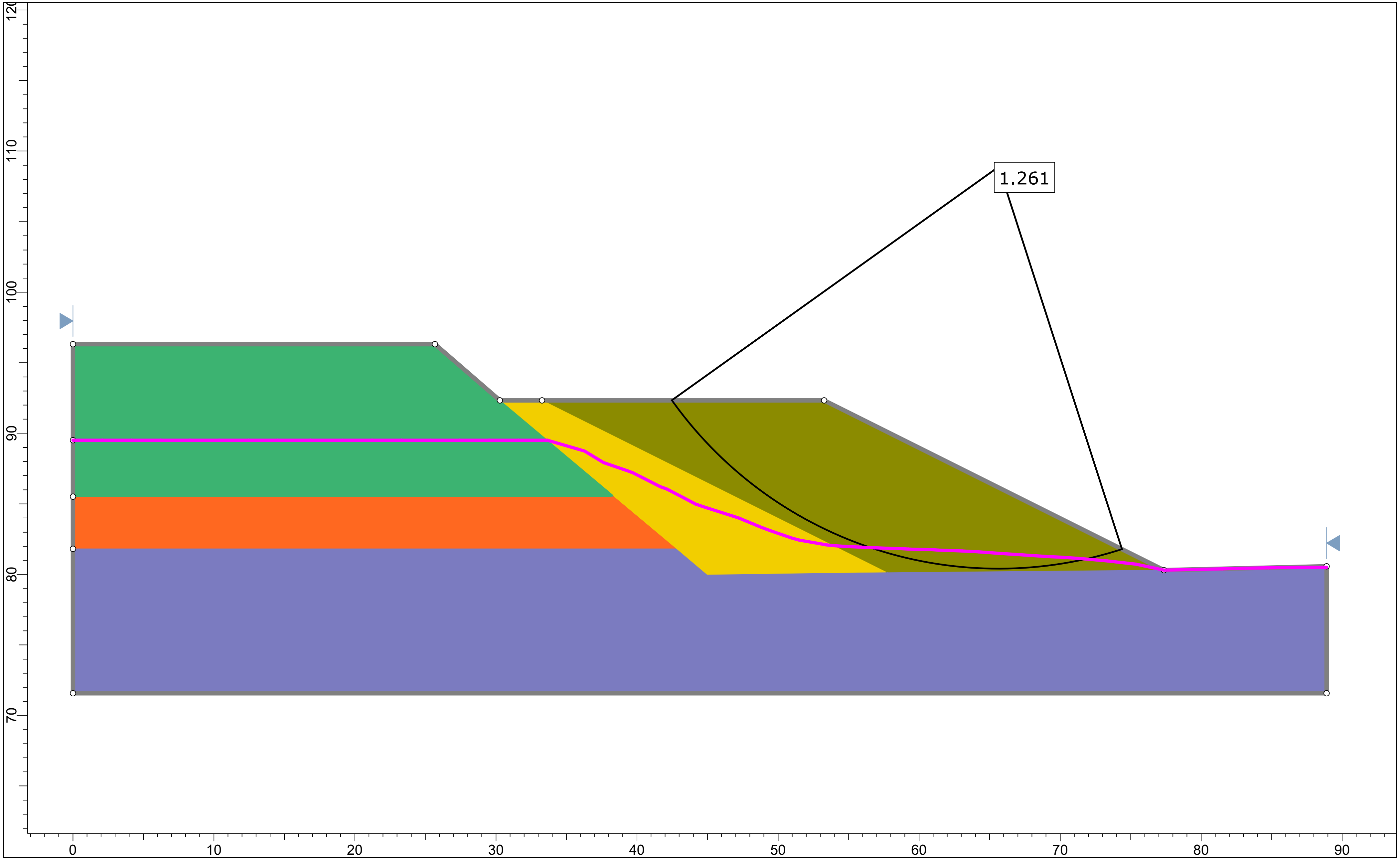

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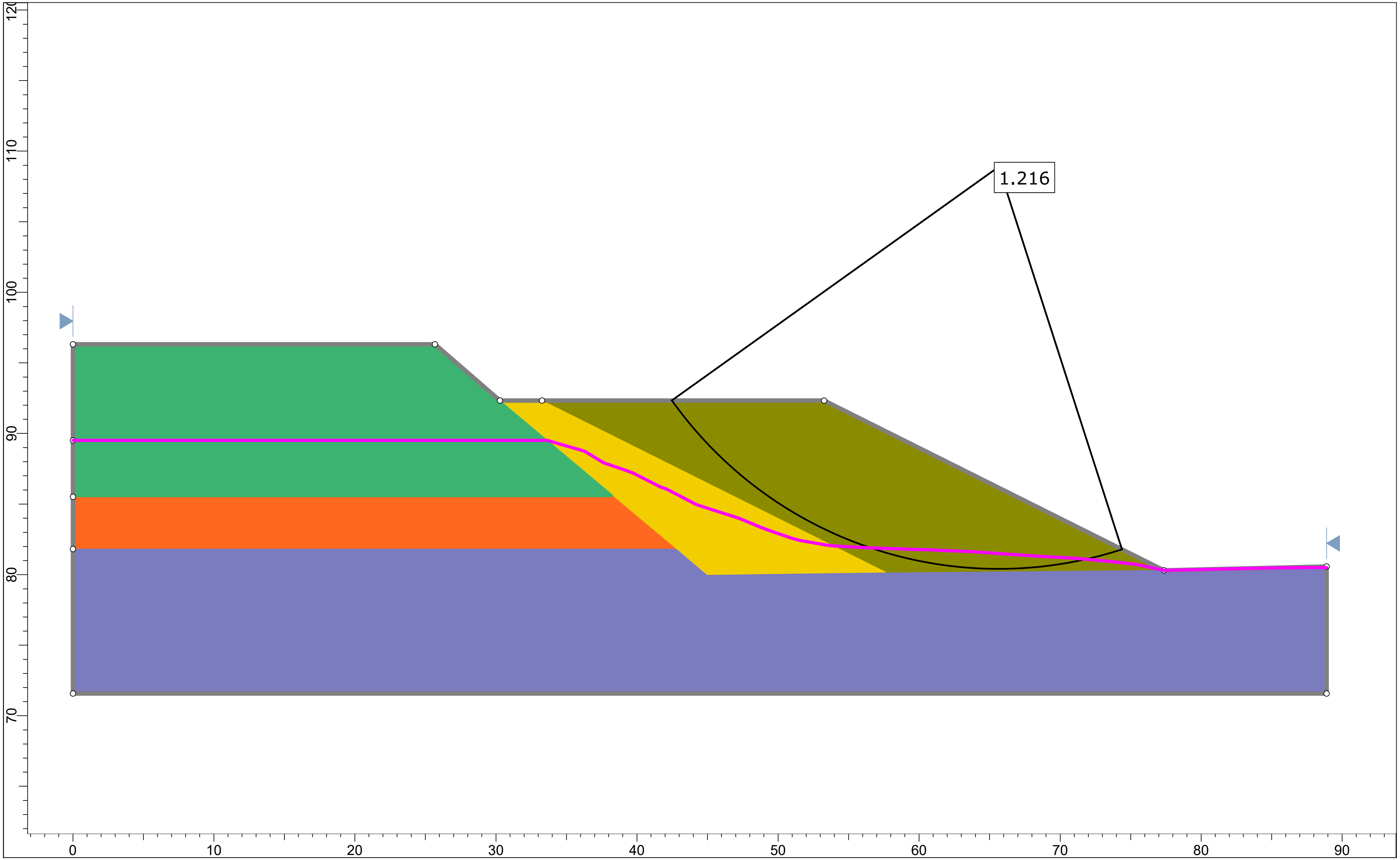
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