**REPORT**

# Mechanically Stabilised Earth Retaining Wall Erskine Park Landfill

*Preliminary Design Report*

Submitted to:

**Enviroguard Pty Ltd**
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Erskine Park, NSW, 2759

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# Study Limitations

Your attention is drawn to the document titled - “Important Information Relating to this Report”, which is included in APPENDIX E of this report. The statements presented in that document are intended to inform a reader of the report about its proper use. There are important limitations as to who can use the report and how it can be used. It is important that a reader of the report understands and has realistic expectations about those matters. The Important Information document does not alter the obligations Golder has under the contract between it and its client.

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# 1.0 INTRODUCTION

This report has been prepared on behalf of Enviroguard and presents a preliminary design for the proposed Mechanically Stabilised Earth (MSE) wall project at the Erskine Park Landfill. This preliminary design report forms part of the development application documentation for the proposed project. The objective of this report is to provide appropriate explanation and documentation of the design and to facilitate regulator reviewl.

## 1.1 Site Location and Description

The site is located within the Erskine Park Area. The landfill is located wholly within and above the former quarry void formed through the mining of breccia from the Erskine Park diatreme. The main site details are summarised in Table 1 below. The aerial photograph provided in Figure 1 shows the existing site.

**Figure 1: Existing site aerial photograph (NearMap 27 October, 2019)**

**Table 1: Site Location and Description**

| | |
|---|---|
| Site Name | Erskine Park Landfill |
| Street Address | 4 Quarry Road<br>Erskine Park, NSW, 2759 |
| Area | 22 Hectares |
| Ownership | Enviroguard Pty Ltd |
| Topography | The local topography in the vicinity of the site is a gently undulating landform with a surface elevation between 45 m AHD and 60 m AHD. There are 2 north-south aligned meandering creek/gully lines that lie about 2km either side of the site, to the east and west.<br><br>The landform surface at the site comprises a landfill mound about 500 m across in the east-west direction and 380 m in the north-south direction (About 17 Ha). The highest point of the mound is about RL92m AHD with side slopes constructed at batters of 4H:1V. An imported clay stockpile is situated at the southern boundary of the site. |
| Final Land Use | The 17 Ha area of the landfill is proposed to be capped and vegetated with a mixture of native shrubs, lawn and grasses to be used for passive recreation. |
| Climate | The Penrith region is located within a broad rain shadow which is created by the high lying coastal plateau to the east capturing rain from the south-east wind.<br><br>The average annual rainfall is approximately 800 mm. Average temperatures are $28^0$ C in summer and $5^0$ C in the winter. |
| Site History | The site history is summarise as follows (after *Report on Geological and Groundwater Assessment* (Douglas Partners, 2005)):<br><br>"Prior to the 1920s the site was occupied by a prominent hill which was about 50 m higher than the adjacent creek level. The countryside surrounding the hill was mostly gently undulating and sloped towards the west towards South Creek. Two tributary creeks were located to the north and south of the hill, draining towards the west.<br><br>The hill was formed by a volcanic neck of breccia and dolerite which was quarried to supply rock for construction of roads and aggregate for concrete. The quarry started operating in the 1920s and the original hill on the site was gradually excavated as an open pit comprising a series of near vertical faces and horizontal benches, down to a minimum level of about RL -45 m AHD. The average level of the rim surrounding the quarry was about RL 55 m AHD to RL 65 m AHD.<br><br>By 1992 quarrying had finished, with operations on the site being limited to supply from stockpiles. Following approval of the development application in November 1992 filling of the quarry commenced. The type of filling accepted at the site was restricted to non-putrescible waste."<br><br>In 2005, a new development application was submitted and granted for the placement of non-putrescible waste to an RL of 92 m AHD, with ongoing settlement of material expected to reach a final RL of 87 m AHD. |

## 1.2 Report Overview

This report provides preliminary design information, design approach and relevant guidelines for the mechanically stabilised earth retaining wall and associated landfill lining and drainage infrastructure. This report should be read in conjunction with the Preliminary Design Drawings (included as APPENDIX A).

## 1.3 Key Reference Documents

The following references have been considered in the preparation of the preliminary design.

1. NSW EPA Environmental Guidelines Solid Waste Landfills 2016
2. Proposal for Mechanically Stabilized Earth (MSE) Retaining Wall by Golder, Document No. P19135625-001-P-Rev1
3. Council's Engineering Requirements for Subdivisions and Developments.
4. Penrith City Council pre-lodgement advice.
5. Erskine Park Business Park Development Control Plan (DCP).
6. 191211.1a Design and Approval Scope of Works for Proposed MSE wall, prepared by Mr Paul Antony, received from Mr Paul Antony via email on 12 December, 2019.

# 2.0 DESIGN DESCRIPTION

## 2.1 Design Objective

The objective of the project is to extend the life of the existing landfill at Erskine Park to make use of the existing waste management infrastructure by a vertical raising of the landfill boundary at the eastern, southern and western extents of the landfill. The proposed mechanism for achieving such an increase is an MSE Retaining Wall up to 20 m in retained height.

## 2.2 Design Constraints

As part of the preliminary design, the following constraints were considered:

**1) Existing approved landform geometry**

The existing approved final top of waste profile for the landfill has side slopes with maximum slope of 1 vertical to 4 horizontal, minimum slopes of 1 vertical to 20 horizontal, with a maximum surface level of RL 92 m AHD at the peak of the landfill. There are access roads around the perimeter of the site as well as towards the centre of the landfill cell. The side slopes are intended to achieve a desired end landuse and to provide for maintainability post landfill closure.

**2) Wall type and geometry:**

MSE walls and alternatives to MSE walls were considered. This included an assessment of case studies for retaining walls within landfills at locations within Australia and internationally. Key design considerations include serviceability, settlement, design life and durability from exposure to adverse environments, foundation requirements, backfill quality requirements and construction costs.

**3) Landfill leachate and gas management:**

Appropriate leachate and gas management is required for landfill waste occupying additional airspace. This includes consideration of new liner systems constructed as part of the retaining wall works and tie-in and compatibility with existing leachate and gas collection systems. Leachate and gas management assessment will consider the current (2016) NSW landfill design guidelines as well as the currently approved systems at the site. This design item also includes consideration of compatibility with future capping systems for the final landform.

**4) Geotechnical slope stability:**

Slope stability is a key consideration for the project due to the significant retaining wall heights under consideration, loading from the future waste material slope (i.e., landfilling of the additional airspace), and in some areas the presence of significant slopes comprising uncontrolled fill (inferred to be quarry overburden material) below the wall base level.

**5) Impacts on adjacent properties / structures**

A key concern of the project is to ensure there are no adverse effects on the structures of the adjacent properties. Detailed analysis is required to assess the predicted effects of the wall construction in terms of ground and structure movements. Monitoring of instrumentation is an important component of any significant engineering project of similar scale to verify that the observed behaviour is consistent with the design.

In general, the MSE wall has been designed such that the majority of the higher wall sections are on the southern landfill edge along the property boundary with CSR where no site development is present. In particular, MSE wall height is relatively limited along the western and eastern landfill edges in consideration of the downward sloping topography and presence of cut retaining walls and existing development on the adjacent property.

**6) Surface water Management**

The management of surface water will be a key consideration both in the construction phase and post construction phase of the project. Management of surface water during construction is required to reduce the generation of leachate from water percolating through the exposed waste placement areas and to prevent off site flow of impacted water. Management of surface water in the operation phase is required to ensure there is appropriate drainage of stormwater and that the site detention facilities are sufficient for any changes to the flow regime.

A separate stormwater management report has been prepared for the MSE wall project. Please refer to: *Erskine Park Landfill, Stormwater Management Report*, Golder Associates, April 2020.

## 2.3 NSW EPA Landfill Guidelines

NSW EPA has developed Environmental Guidelines for Solid Waste Landfills to provide guidance on the environmental management of landfills in NSW by specifying ‘minimum standards’ for design, construction, operation, monitoring, reporting and post-closure management. Compliance of the proposed lining design with the required outcomes for landfill lining as per the NSW EPA Environmental Guidelines Solid Waste Landfills 2016 (herein referred to as NSW EPA Landfill Guidelines) is summarised in Section 7.1.

## 2.4 Development Control Plan (DCP) requirements

Review of the “Penrith Development Control Plan 2014 , E6 Erskine Business Park” (DCP) indicates that the site lies in the designated Southern Area of the Erskine Business Park site (per DCP Figure E6.1) and that the guidelines of the DCP as identified in this section may be relevant to the MSE Wall project. The proposed MSE wall project is considered consistent with DCP guidelines for the reasons presented below.

### 2.4.1 DCP Section 6.3.1 - Height

DCP Objectives for this item comprise: a) To encourage building forms that respond to the topography of the site and the relative position of the allotment to other allotments and the street; b) To ensure a scale of buildings which minimises the impact of development on adjoining residential areas; and c) To minimise the impact of development on views from adjoining residential areas.

DCP Controls for this item include: 2) The maximum height for buildings and structures in the Southern Area shown in Figure E6.1 shall not exceed 15 m, unless otherwise specified below.

The MSE Wall design drawings indicate that the average height above ground of the proposed wall is approximately 13 m. However, the wall height varies from 1 m to 19 m and approximately 40% of the wall length is greater than 15 m in height. The portion with wall height above 15 m is a 330 m length in the southeastern area.

It is noted that although a portion of the proposed MSE wall exceeds the DCP height guideline, the project is considered consistent with the DCP objectives because: (i) the wall responds to the topography of the site as it is integral with and forms a part of the significant landfill landform that forms a visual backdrop to the wall and rises 10 to 20 m above the top of the wall; and (ii) the visual impact of the wall is limited by the nature of the site surrounds and lack of significant street frontage for view access. The minimal visual impact of the wall is reflected in the Visual Impact Assessment for the project which states the following:

*Views toward the proposed MSE Wall from local roads and service roads within the Erskine Park Industrial Estate will be largely screened by factory/warehouse buildings as well as other large scale structures fronting Quarry Road, Erskine Park Road and Templar Road within the industrial estate.*

*Views from north to south toward the proposed MSE Wall, including views from the St. Clair and Erskine Park residential areas and Erskine Park Road, would be effectively blocked by the existing landfill site landform rising above the level of the proposed MSE wall.*

### 2.4.2 DCP Section 6.3.2 - Setbacks

DCP Controls for this item include the setback standards as outlined in DCP Table E6.2., which indicate a required setback of 5 m from rear and side boundaries.

The MSE Wall design drawings indicate that a minimum wall setback from the site boundary of 5 m is maintained along the entire length of the wall, thus complying with the DCP guideline.

### 2.4.3 DCP Section 6.3.4 - Urban Design

DCP Objectives for this item include: c) To minimise perceived scale and mass and to prevent monotonous building forms resulting from poor design of walls or rooflines.

DCP Controls for this item include: 3) Large unrelieved expanses of wall or building mass will not be supported by Council, and as such should be broken up by the use of suitable building articulation, fenestration or alternative architectural enhancements; and 4) The use of large, uninterrupted areas of metal cladding or untreated concrete surfaces for wall construction is not supported. Applicants shall vary materials or finishes for external walls to provide attractive streetscapes and quality building designs. Council may limit the use of a single construction material to 50% of a wall surface area.

The MSE Wall design drawings present the proposed geometry and materials for the wall facing system and additional information is provided in Section 5.0 of this report. The wall alignment includes a few gentle curves along its approximate 900 m length and the facing, although planar, is not vertical, but is distinctly inclined back at approximately 20 degrees from vertical. The visible wall facing materials will comprise a welded galvanised steel mesh (with 50-100 mm square apertures) underlain by a dark green thick matting material with high uV resistance that will be clearly visible through the apertures. The unconventional inclination of the wall, the unusual textured geometric nature of the facing, and its non-industrial green colouring will serve to reduce visual impacts. Given these geometry and material factors, along with the Visual Impact Assessment statements indicating minimal visual impact due to wall position and surrounds (refer Section 2.4.1 above), we consider that the DCP objectives are adequately achieved by the design.

### 2.4.4 DCP Section 6.5 – Drainage

A separate stormwater management report has been prepared for the MSE wall project (*Erskine Park Landfill, Stormwater Management Report*, Golder Associates, April 2020). We consider that the report provides adequate demonstration that the design achieves the DCP drainage objectives.

### 2.4.5 DCP Section 6.7 - Biodiversity

The landfill site is within Biodiversity Conservation Area as per DCP Figure E6.12.

DCP Objectives for this item include: e) To provide a biodiversity corridor linking system linking remnant native vegetation across the site with the riparian biodiversity system within South Creek, the remnant native vegetation in Erskine Business Park and the Ropes Creek Riparian Biodiversity system.

The overall site landscaping plan for landfill post-closure is not altered by the proposed MSE Wall project. The MSE Wall design drawings indicate that required boundary setback (5 m minimum) are maintained in all areas and that the finished wall footprint is small compared to the total landfill landform area. For these reasons we consider that the MSE Wall project will maintain a suitable biodiversity corridor and meet DCP objectives.

# 3.0 RETAINING WALL DESIGN

A Mechanically Stabilised Earth (MSE) wall is proposed for the retaining wall along the proposed alignment. The MSE wall is constructed using primarily granular soil with multiple layers of reinforcement. Details of the preliminary design are provided below.

## 3.1 Design Development

The design of the proposed retaining wall considers a design life of 100 years. Each component of the wall has been proposed to meet the durability requirement. The following factors have been considered in the design of the MSE wall:

*Site and Subsurface Conditions:*

- Ground conditions including thickness of different units.
- Extent of the existing landfill and quarry geometry.
- Groundwater and flood conditions.
- Short-term and long-term behaviour of the soils.
- Soil behaviour based on its history.

*Geometry and Loading:*

- Geometry of the MSE wall including project boundary, extent of the existing and future landfill, and the amount of air space for future landfill.
- Permanent load including the lateral earth pressure induced by the future landfill.
- Extreme loading events such as earthquake and collision loading.
- Future traffic conditions and drainage requirements.
- Potential variations in load during operation.
- Ground support for capping and its installation.

*Construction Materials and Methods:*

- Foundation requirements and foundation treatment (if required).
- Wall reinforcement by geogrid, including degradation over time for durability considerations.
- Material requirement for reinforced soil and liner support fill.
- Wall facing and its durability.
- Construction sequences including wall construction, capping installation and landfill placement.

*Wall Stability and Deformation in Service:*

- Stability of the wall including internal and external stability, and overall stability.
- Serviceability of the wall including settlement and lateral movement.

The following sections detail the process adopted for the geotechnical design, including demonstration of the compliance with industry accepted codes of practice for the design of such a structure.

## 3.2 Ground Conditions

The Geotechnical Investigation Report (ref: 19135652-006-R-Rev0) includes a detail description of the anticipated subsurface conditions along the project alignment and the subsurface geotechnical units identified.

Geotechnical long and cross sections developed are provided in Appendix C1. Further details of the ground conditions are provided in the Geotechnical Investigation Report. The MSE wall is currently proposed to be founded on the uncontrolled fill from Ch25 to Ch100, Controlled fill (Unit 1b) from Ch100 to of Ch550 (approx.) and on Residual soil/Very low to low strength sedimentary rock from Ch550 to Ch800.

Based on the existing geotechnical investigation details, consistencies of the different units encountered along the wall alignment are provided in Table 2.

**Table 2: Stratigraphic Units along Wall Alignment**

| Unit | Description |
|---|---|
| Unit 1a | Uncontrolled fill<br>Gravelly, Sandy, Clayey fill |
| Unit 1b | Controlled fill<br>Gravelly, Sandy, Clayey fill |
| Unit 1c | Landfill Waste - mix of cohesive and granular with consistencies of firm to stiff or loose to medium dense. |
| Unit 1d | Southern stockpile fill |
| Unit 2 | Residual soil<br>High plasticity silty clay/sandy clay, Very stiff |
| Unit 3a | Very Low and low Strength Volcanic Breccia and Dolerite |
| Unit 3b | Medium Strength Volcanic Breccia and Dolerite |
| Unit 4a | Very Low and Low strength Siltstone bedrock |
| Unit 4B | Medium strength or better Siltstone bedrock |

## 3.3 Groundwater

The groundwater levels along the MSE wall are generally a subdued reflection of the surface topography, which slopes gently towards South Creek in the west. To the east of the landfill, the standing water levels are typically RL 37 m AHD to RL 48 m AHD, while to the west and south of the landfill the standing water level are typically RL 37 m AHD to RL 39 m AHD.

For the design of the proposed retaining wall, the groundwater was assumed at an elevated level that is within the Unit 2 (Residual Clay). Generally, the Unit 2 is underlying the controlled fill at an RL varying from 48 m AHD to 55 m AHD (approx.) along the wall alignment.

## 3.4 Preliminary Geotechnical Parameters

The preliminary geotechnical parameters adopted for the design of the retaining wall are derived from test results and previous engineering experience in similar ground conditions. Table 3 presents a summary of geotechnical properties adopted in the design.

**Table 3: Preliminary Geotechnical Design parameters**

| Unit | | Bulk Unit Weight, ($kN/m^3$) | Undrained Shear Strength, $S_u$ (kPa) | Drained Cohesion, c' (kPa) | Drained Friction Angle, φ' (deg) | Young's modulus, E' (MPa) | Poisson's Ratio |
|---|---|---|---|---|---|---|---|
| 1a & 1b | | 18 | 100 | 2 | 30 | 15 | 0.30 |
| 1c | Old | 17 | 75 | 1 | 27 | - | - |
| | New | 16 | 75 | | | - | - |
| 2 | | 19 | 150 | 5 | 29 | 25 | 0.3 |
| 3a | | 21 | - | 40 | 35 | 125 | 0.25 |
| 3b | | 23 | - | 30 | 40 | 500 | 0.2 |
| 5 | | 22 | - | 20 | 33 | 75 | 0.3 |
| Reinforced Fill | | 20 | - | 0 | 32 | - | 0.3 |
| Liner support Fill | | 20 | - | 0 | 32 | - | 0.3 |

Table 4 presents a summary of consolidation properties for compressible soils along the wall alignment. Empirical correlations and previous engineering experience have been used to assist with characterisation of compressibility behaviour. The over-consolidation ratios (OCR) for the units provided in Table 4 have been chosen based on correlations from Cone Penetrometer Tests (CPTs) and previous engineering experience on similar materials in Sydney.

We understand that the old landfill was placed in an uncontrolled manner with the source material being mainly soil waste and some construction demolition waste. The landfill material is considered to undergo ongoing settlement over time. However, its behaviour is different from the traditional 'creep' settlement observed in cohesive soils. The landfill waste is expected to progressively degrade over time due to rotting/corrosion of materials and potential re-orientation of waste within the soil mass.

For analyses of the landfill, we have assessed that the material can be modelled with long term 'creep' defined as logarithmic volume change expressed as a percentage of fill height per log time cycle of 1% (Old landfill) and 2% (new landfill).

Consolidation parameters for volcanic layers (i.e. Unit 3a and 3b) have not been considered on the basis that these materials are likely to have high overconsolidation ratio (OCR) values and low void ratios. These units are not considered to contribute to creep settlement.

**Table 4: Preliminary Consolidation Design Parameters**

| Unit | Design OCR | Design Compression Ratio, $C_c/(1+e_0)$ | Design Recompression Ratio, $C_r/(1+e_0)$ | Design Creep Coefficient/Ratio $C\alpha/(1+e_0)$ |
|---|---|---|---|---|
| Unit 1a and 1b | 1.5 | 0.15 | 0.022 | 0.008 |
| Unit 1c - New | 1.1 | 0.4 | 0.10 | 0.02 |
| Unit 1c - Old | 1.2 | 0.2 | 0.05 | 0.01 |
| Unit 2 | 3.0 | 0.1 | 0.015 | 0.005 |

## 3.5 Wall Geometry

The typical geometry of the MSE wall is shown in Figure 2. A summary of wall geometry along the control line is provided in Table 5. The wall width at the top of the wall (w) is about 13.5 m to accommodate a roadway and drainage system.

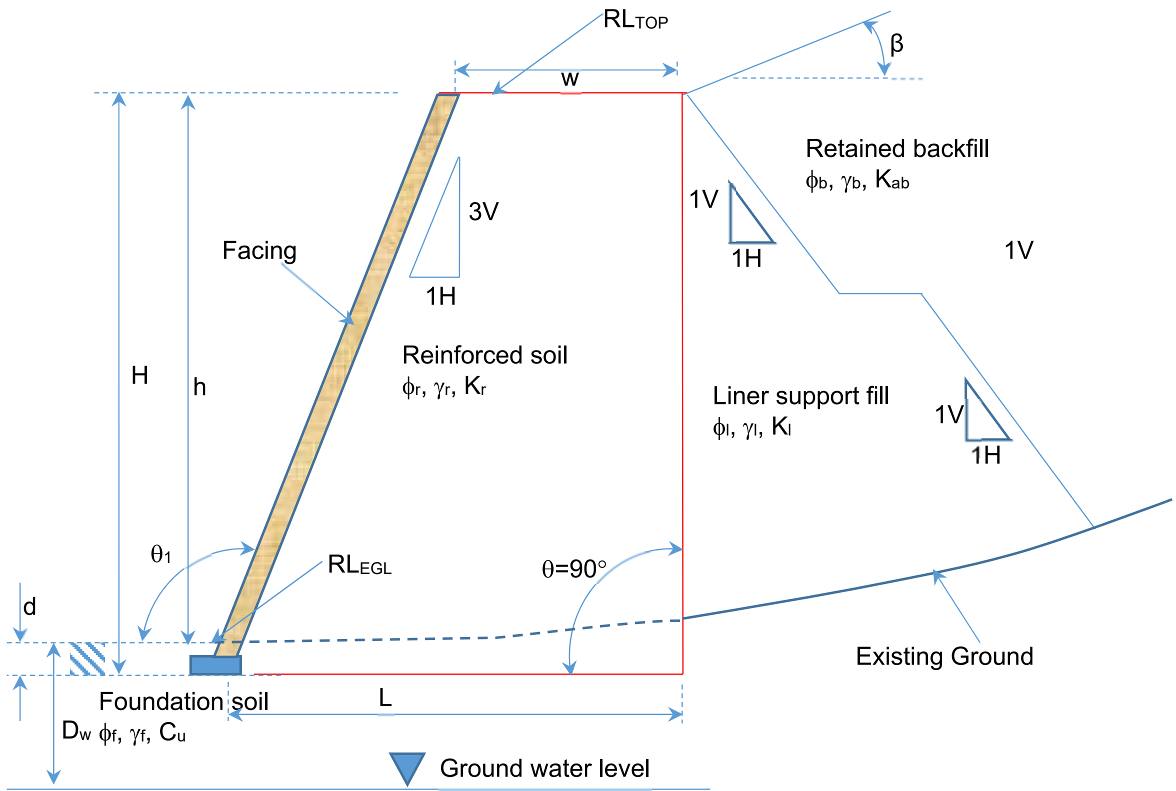



**Figure 2: Typical Geometry of the MSE Wall**

**Table 5: Minimum Dimensions Adopted for the Preliminary Wall Design**

| Ch | $RL_{TOP}$ (m AHD) | $RL_{EGL}$ (m AHD) | h (m) [Height of MSE wall to existing ground level] | d (m) | H (m) [Total height of MSE wall including foundation embedment] | Anticipated foundation material |
|---|---|---|---|---|---|---|
| 0 | 60.6 | 60.5 | 0.1 | 0.6 | 0.7 | Unit 1a - Fill |
| 100 | 69.0 | 64.2 | 4.8 | 1.2 | 6.0 | |
| 200 | 78.6 | 66.8 | 11.8 | 1.5 | 13.3 | Unit 1b - Controlled Fill |
| 300 | 80.0 | 67.6 | 12.4 | 1.5 | 13.9 | |
| 400 | 78.4 | 63.1 | 15.3 | 1.8 | 17.1 | |
| 500 | 76.8 | 61.3 | 15.5 | 1.8 | 17.2 | |
| 600 | 75.1 | 57.5 | 17.6 | 2.1 | 19.7 | Unit 2 /Unit 4a |
| 700 | 73.5 | 56.5 | 17.0 | 2.1 | 19.1 | |
| 800 | 71.9 | 62.3 | 9.6 | 1.2 | 10.8 | |
| 900 | 64.9 | 64.7 | 0.2 | 0.6 | 0.9 | |
| 920 | 64.7 | 64.7 | 0.0 | 0.0 | 0.0 | |

The overall stability of the MSE wall is a key consideration for the design. Factors that significantly influence the stability include the retaining wall height (up to 20 m), the lateral earth pressure from the future landfill (i.e., landfilling of the additional airspace), in some areas the presence of an existing pond in front of the wall (i.e. the slope in front of the wall), and in some areas the presence of significant controlled fill below the foundation of the wall.

The embedment of the wall is a measure used to improve the stability of the wall. Where a slope exists in front of the wall, an increase embedment is required. For example, the MSE wall between Ch500 and Ch700 (approx.), a minimum embedment depth ratio of H/10 has been adopted considering the slope in front of the wall. It is noted that greater embedment may be required based upon settlement, and/or global stability calculations to be carried out at the detailed design stage.

## 3.6 Reinforcement

Tensile reinforcements are included to enhance the stability of the MSE wall. Uniaxial geogrid has been considered with the ultimate tensile strength ($T_{ult}$). ACEGrid® Pet Geogrid (polyester) or approved equivalent has been considered for the design of the MSE wall. Product details for ACEGrid® Pet Geogrid used in the analysis are provided in Appendix C2. Further advice will be provided regarding product specifications, use of equivalent product, guidance on installation and testing in a detailed project technical specification.

The available long-term strength of the geogrid reinforcement ($T_{al}$) is assessed as below.

$$T_{al} = T_{ult} / (RF_{ID} * RF_{CR} * RF_{D})$$

Where the following factors are applied for ACEGrid products. Reduction factors commensurate with other approved products should be adopted when alternative design measures are adopted:

$RF_{ID}$ - Reduction factor for installation damage = 1.10

$RF_{CR}$ - Reduction factor for creep = 1.43

$RF_{D}$ - Reduction factor for chemical/biological degradation = 1.05

## 3.7 Design Methodology

The Load and Resistance Factor Design (LFRD) approach was adopted in the design of the MSE wall as per FHWA GEC 011 – Volume I. This approach adopts load factors greater than 1.0 for the estimation of design loads. The design resistance is determined using a resistance factor, which is typically less than 1.0. This guideline was used as it is relevant to the scale and type of the proposed retaining wall for this project.

### 3.7.1 References

The standards, codes and documents considered in the design of the MSE wall (external and internal stability) are listed below.

- Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume I, Publication No. FHWA-NHI-10-024, Federal Highway Administration FHWA GEC 011 – Volume I.
- AASHTO LRFD Bridge Design Specifications, Seventh Edition, 2014.
- AS 4678-2002 - Earth-retaining structures.
- AS1170.4 -1993 - Minimum Design Loads on Structures, Part 4: Earthquake Loads.

### 3.7.2 Loads

#### *3.7.2.1 Self-weight (EV)*

The weight of the MSE wall is estimated based on its geometry and unit weight of the reinforced fill.

#### *3.7.2.2 Lateral earth pressure (EH)*

Lateral earth pressure is developed on the back face of the MSE wall due to the future landfill. The earth pressure is estimated based on the Coulomb earth pressure theories. The active earth pressure coefficient is estimated as a function of slope of back fill ($\beta$), angle of friction between retained soil and reinforced soil ($\delta$), effective friction angle of retained soil ($\phi_b$) and the angle of back face of the MSE wall ($\theta$).

#### *3.7.2.3 Live load (LL)*

AS4678 outlines that "*In the calculation of traffic surcharge, the unfactored value has to be 20 kPa for roads of functional road classes 1, 2, 3, 6 or 7 (see HB77)*. For all other functional class roads or temporary roads (e.g. ramps) the unfactored traffic loading has to be 10 kPa."

For the design of MSE wall, 20 kPa of traffic surcharge has been adopted for long term condition and 10 kPa has been adopted for short term (construction stage).

#### *3.7.2.4 Earthquake Load (EQ)*

An acceleration coefficient (a) of 0.08 is considered for Sydney in accordance with AS1170.4 for an earthquake event with 1 in 500 years return period and site factor of 1.0 as per AS4678 – 2002 Table I2.

Where traffic load or other live load is directly applied on the retaining structure, the load factor for live load should be taken as 0.5 resulting in a design live load of 10 kPa.

#### 3.7.2.5 Vehicle impact load (CT)

The traffic barriers are to be installed at top of the MSE wall. The vehicular impact on the barrier will induce additional load on the MSE wall which is expected to affect only the internal stability of the wall. The impact load (dynamic load) is considered as a static impact load for the design.

As detailed in FWHA NHI-10-024, the static impact load is considered to be acting on the upper two layers of reinforcements. The top layer of the layer is designed with static impact load of 33.5 kN/m and second layer with 8.8 kN/m.

### 3.7.3 Load Combinations

Design of the MSE wall has been carried out considering combinations of above loads that the MSE wall will experience during construction and its operation. For the design of the MSE wall, the following combinations with appropriate load factors have been considered. The load factors are provided in Section 3.7.4.

- Load Case 1: “EV” + “EH” + “LL” (Strength)
- Load Case 2: “EV” + “EH” + “LL” + “EQ” (Earthquake)
- Load Case 3: “EV” + “EH” + “LL” (Construction)
- Load Case 4: “EV” + “EH” + “LL” + “CT” (Collision)
- Load Case 5: EV” + “EH” + “LL” (Serviceability)

### 3.7.4 Load Factors

In the LFRD, the load factors have been adopted as provided in Table 6.

**Table 6: Load factors adopted for the load case**

| Load case | Load | | | | |
|---|---|---|---|---|---|
| | EV (max/min)[1] | EH (max/min)[1] | LL | EQ | CT |
| 1 | 1.35/1.00 | 1.50/0.90 | 1.75 | - | - |
| 2 | 1.00 | 1.00 | 0.50 | 1.00 | - |
| 3 | 1.35/1.00 | 1.50/0.90 | 1.75 | - | - |
| 4 | 1.0 | 1.00 | 0.50 | - | 1.00 |
| 5 | 1.0 | 1.0 | 1.0 | - | - |

***Note***

1. *Minimum value was applied to the load combination where the corresponding load reduces the force effect.*

### 3.7.5 Resistance Factors

The resistance factor for external stability analyses adopted is provided in Table 7.

**Table 7: Resistance factor adopted for the external stability**

| Mode of failure | Value |
|---|---|
| Bearing resistance | 0.65 |
| Sliding | 1.00 |

| Mode of failure | Value |
|---|---|
| Overall stability | 0.65[1,2,3] |

***Note***

1. *Geotechnical parameters have been defined using the available information.*
2. *The resistance factor is approximately equivalent to a safety factor of 1.5.*
3. *The overall stability of MSE wall was carried out using the working stress design approach.*

The resistance factor for the internal stability of the MSE walls is provided in Table 7.

**Table 8: Resistance factor adopted for the internal stability**

| Load Type (Load Cases) | Failure Mechanisms | |
|---|---|---|
| | Tensile | Pull-out |
| Static loading (Load Cases 1, 3, 5) | 0.65 | 0.90 |
| Combined Static/EQ (Load Case 2) | 1.20 | 1.20 |
| Combined Static/Collision (Load Case 4) | 1.20 | 1.00 |

## 3.8 External Stability

For the MSE walls, four potential external failure mechanisms are considered as follows.

- Sliding at the foundation.
- Overturning the wall.
- Bearing resistance.
- Overall/global stability (addressed in Section 3.10).

External stability analysis has been carried out using a worksheet prepared in Mathcad. The preliminary design calculations for external stability at Ch 500 are provided in Appendix C3.

The external stability check shows that the proposed geometry of the wall is adequate at Ch. 500. Additional analyses will be undertaken along the alignment for detailed design

## 3.9 Internal Stability

Internal failure of the MSE wall can occur in two different mechanisms as below:

- Tensile failure of reinforcement.
- Pullout failure of reinforcement.

Internal stability analysis has been carried out using a worksheet in Mathcad and Excel spreadsheets calculations. Appendix C4 provides the detailed calculations on tensile and pullout failure of reinforcements at Ch500.

The internal stability check shows that the proposed reinforcement (length, spacing and ultimate strength) is adequate at Ch 500. Additional analyses will be undertaken along the alignment for detailed design.

## 3.10 Overall Stability

### 3.10.1 Analysis Cases

Overall stability is assessed at Ch300 (CS5) and Ch500 (CS6) for the following load cases based on the preliminary geometry of the MSE walls.

- Case 1: End of MSE wall construction – SHANSEP parameters for the soil (residual soil) below the groundwater level (GWL) and drained parameters (Mohr-Coulomb) for soil above the GWL.
- Case 2: End of landfill construction – SHANSEP parameters for the soil (residual soil) below the GWL and drained parameters for soil above the GWL.
- Case 3: Long term with undrained condition – SHANSEP parameters for the soil below the GWL (with strength gain/loss) and drained parameters for soil above GWL.
- Case 4: Long term with drained condition – Drained parameters for the soils below and above the GWL.
- Case 5: Long term extreme GWL - Drained parameters for the soil below and above GWL. The GWL is assumed to be at the base (foundation) of MSE wall.
- Case 6: Earthquake - SHANSEP parameters for the soil below WT (with strength gain/loss) and drained parameters for soil above WT.

Cases 1 and 2 are assumed as rapid installation of MSE wall and rapid placement of landfill, the short-term undrained strength is estimated based on the OCR in Table 4. For the estimation of effective vertical stress ($\sigma'_v$), the average depth of the residual soil from existing ground level has been used. In these cases, the SlopeW model has been set such that MSE wall and Landfill above existing ground will increase the pore-pressure equal to the MSE wall and Landfill weight. The effective stress will remain the same (undrained shear strength is not changed).

Cases 3 and 6, with time, the excess pore resulting from the MSE wall and landfill placement will dissipate. The effective vertical stress will increase, and OCR will reduce. The undrained strength is estimated based on the increase of effective vertical stress ($\sigma'_v$) with the consideration of the reduction in OCR as detailed in **Error! Reference source not found.**.

### 3.10.2 Analysis Outcome

A summary of stability assessment results at CS5 and CS6 is presented in Table 9 and Appendix C5 for long-term, short-term and earthquake conditions. Based on the analysed preliminary geometry of the sections, the results indicate that MSE wall has adequate factor of safety.

**Table 9: Summary of Overall Factor of Safety**

| Cross section | Factor of Safety | | | | | |
|---|---|---|---|---|---|---|
| | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 |
| CS5 | 1.80 | 1.55 | 1.65 | 1.80 | 1.60 | 1.50 |
| CS6 | 2.00 | 1.70 | 1.70 | 1.85 | 1.70 | 1.55 |

For this preliminary design, we have only carried the analyses at CS5 and CS6. Additional global stability assessment will be carried out in the detailed design stage and any foundation treatment requirements will be developed at that stage, if required.

## 3.11 Wall Movements

Settlement analyses of the MSE walls have been carried out using the finite element program PLAXIS2D. PLAXIS2D is a commercial two-dimensional finite element software used in calculations of stresses and displacements for a wide range of geotechnical, civil engineering and mining problems.

The purpose of the analyses has been to estimate the settlement and lateral movement of the MSE wall during its construction and operation.

The MSE wall is installed along the existing quarry slope and the wall may experience differential settlement at the foundation level which may induce additional load in the reinforcement. The analyses can be used to estimate such additional loading. This will be addressed further in the detailed design stage.

Elastic, primary and secondary consolidation settlements have been assessed.

The displacement output results present the impact of the proposed new landfill on the vertical and lateral movement of the MSE wall after 100 years.

### 3.11.1 Results

Figures C6.1 to C6.12 in Appendix C6 present graphical representations of the geotechnical model, induced horizontal and vertical movements during construction and at 100 years estimated using finite element analyses.

Summary of the finite element analysis results are presented in Table 10 and Table 11. The table provides the predicted vertical and horizontal displacements at the level of wall foundation. The level of wall foundation is expected to move laterally during construction from 25 mm to 55 mm and settle from 130 mm to 195 mm. The wall foundation is expected to deform laterally during its design life from 75 mm to 135 mm and settle from 165 mm to 370 mm.

It is noted that at this stage of the design, the MSE wall and liner support fill are modelled as linear elastic to understand the lateral and vertical movement at the foundation level of the MSE wall. A detailed analysis will be carried out with inclusion of geogrids within the wall in the detailed design submission.

**Table 10: Vertical and horizontal displacement during Construction at the foundation level**

| Section | Location | L/H | Assessed Max. horizontal movement (mm) | Assessed Max. vertical settlement (mm) |
|---|---|---|---|---|
| CS4 (Ch300) | Wall foundation | 1.1 | 25 | 130 |
| CS6 (Ch500) | | 0.9 | 25 | 195 |
| CS7 (Ch650) | | 0.9 | 55 | 135 |

**Table 11: Total vertical and horizontal displacement at the foundation level after 100 years**

| Section | Location | Assessed Max. horizontal movement (mm) | Assessed Max. vertical settlement (mm) |
|---|---|---|---|
| CS4 (Ch300) | Wall foundation | 75 | 165 |
| CS6 (Ch500) | | 135 | 370 |
| CS7 (Ch650) | | 130 | 225 |

## 3.12 Preliminary Reinforcement Details

For the overall geometry of the retaining wall detailed in 3.5, the preliminary internal geometry of the wall reinforcement arrangement is detailed below.

**Table 12: Preliminary Details of the Reinforcement within the MSE Wall**

| Wall Height, H (m) | Wall Location | | | | | |
|---|---|---|---|---|---|---|
| | Bottom H/3 | | Middle H/3 | | Top H/3 | |
| | Ultimate Strength of the Geogrid (kN/m) | Vertical spacing (mm) | Ultimate Strength of the Geogrid (kN/m) | Vertical spacing (mm) | Ultimate Strength of the Geogrid (kN/m) | Vertical spacing (mm) |
| 20 - 16 | 200 | 300 | 200 | 600 | 120 | 600 |
| 16 - 13 | 200 | 300 | 200 | 600 | 120 | 600 |
| 13 - 10 | 200 | 600 | 200 | 600 | 120 | 600 |
| 10 - 7 | 200 | 600 | 120 | 600 | 80 | 600 |
| 7 - 4 | 120 | 600 | 120 | 600 | 80 | 600 |
| < 4 | 80 | 600 | 80 | 600 | 80 | 600 |

The preliminary design has assumed that the reinforcement will be extended within the entire reinforced soil (from facing to drainage chimney). The length of the reinforcement within the MSE wall will be optimised in the detailed design.

## 3.13 Foundation Treatment

The edge of existing liner/waste has been recently assessed by Enviroguard,  Subsurface investigation and geophysical surveys carried out in some areas by Golder are consistent with the Enviroguard assessment. The assessment indicates that the edge of the waste from Ch650 to Ch850 (approx.) extends partially within the foundation of the MSE wall as shown below. The depth of landfill waste below existing ground level varies and is expected to be up to 4 m to 5 m within the footprint of the MSE wall. Within these chainages, the wall height varies from approximately 20 m (Ch650) to 10 m (Ch850). Foundation treatment such as excavation of waste within the footprint of MSE wall may be required. This foundation treatment option will be further developed during the detailed design and extent of the treatment will be refined.

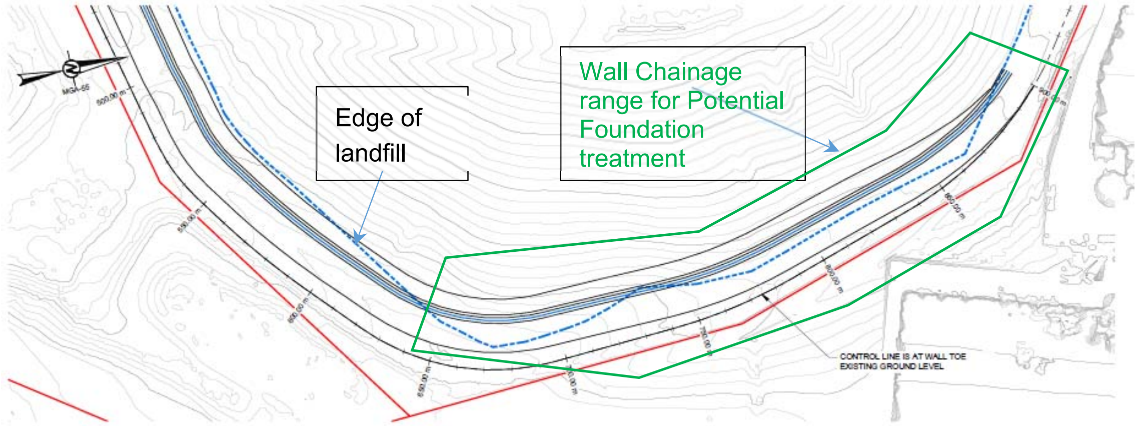



**Figure 3: Extent of the MSE Wall Requiring Potential Foundation Treatment**

## 3.14 Instrumentation and Monitoring

Instrumentation will be installed prior to commencement of construction and during construction of the MSE wall to verify that the observed ground and wall behaviour is consistent with the predicted effects modelled in the design. Instrumentation may include but will not be limited to the use of inclinometers, survey targets, settlement plates, settlement pins and piezometers.

A trigger response system will be developed to identify appropriate actions to be implemented, should certain amount of movement be observed during and immediately after construction. Following the detailed assessment of anticipated movements using tools such as finite element analysis, a table will be prepared that identifies the appropriate actions to be undertaken that are commensurate with the level of movement observed. For example, alarms are generally set at specific percentages of the anticipated or tolerable movement and typically represent an Alert Level, An Response Level and a Stop Work Level.

At the Alert Level, actions that could be implemented include:

- Check that the movement is commensurate with the amount of construction that has occurred.
- Increase frequency of monitoring (for example increase survey target monitoring from weekly to 3 times per week).

At the Response Level, actions that could be implemented include:

- Increase frequency of monitoring to daily for survey.
- Review rate of movement occurring with time.
- Stop work and review the ground model and the analysis.
- Supplement the monitoring regime.
- Prepare measures to enact should excessive movements continue.

At the Stop Work Level, actions that could be implemented include:

- Continue daily monitoring.
- Stop work and review the ground model and the analysis.

- Implement additional short-term measures to immediately reduce adverse behaviour (such as placement of a toe berm in front of a wall)
- Assess and implement remedial measures to reduce ongoing adverse movement in the long term.

By adopting such a system, it provides a verification loop during construction that the observed movements of the MSE wall are consistent with the design. It also provides additional confidence that the MSE Wall will behave as designed and will not pose a risk to the neighbouring properties. It is anticipated that the monitoring program would be required during construction and for a period of up to 6 months after construction. The monitoring period could be adjusted following review of the available data.

## 4.0 LINER SUPPORT FILL

The liner support fill (LSF) is to be installed behind the MSE wall to support the landfill liner system. The liner support fill is to be constructed at a 1H:1V external slope with a maximum individual batter height of 8 m. Preliminary assessment of overall stability detailed in Section 3.9 indicates that reinforcement within the liner support fill is required to provide adequate Factor of Safety for overall stability of the MSE wall between approximately Ch550 and Ch700 where the wall height, H is approximately 20 m

The minimum reinforcement within the liner support fill between Ch550 and Ch700 is proposed below and shown in Figure 4.

- Bottom bench - geogrid reinforcement with ultimate tensile strength 200 kN/m at1200 mm vertical spacing
- Top bench – geogrid reinforcement with ultimate tensile strength 80 kN/m at 1200 mm vertical spacing
- The reinforcement within the liner support fill will be separate from reinforcement within reinforced fill (not continuous) as the liner support fill is expected to settle more than the MSE wall.

This is referred to as primary reinforcement for the liner support fill. The extent of primary reinforcement within liner support fill between Ch550 and Ch700 has been assessed for the preliminary design assuming the geotechnical properties of the liner support fill (similar properties as reinforced fill) as detailed in Table 3.

Additional load induced by settlement of the liner support fill will be addressed in the detailed design stage. If required, spacing and strength of the reinforcement will be revisited.

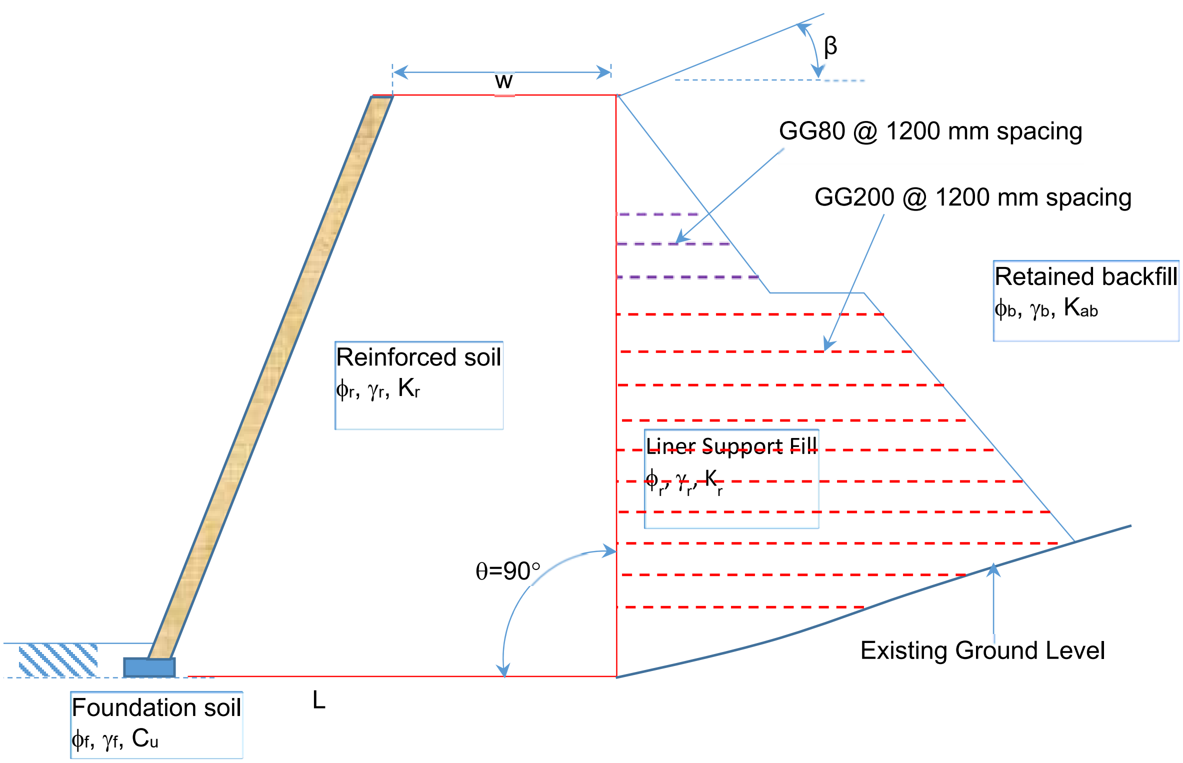



**Figure 4: Typical Arrangement of Geogrid within Liner Support Fill**

*Intermediate Reinforcement*: The liner support fill at all wall chainages will include intermediate reinforcement layers at 300 mm vertical spacing, and generally 1.5 m long, in order to provide local support to allow 1H:1V batter construction and batter surface preparation for liner material placement. This is a temporary stability requirement. In some areas, longer lengths of intermediate reinforcement will be needed, subject to detailed design. The intermediate reinforcement will comprise relatively low strength biaxial geogrid.

# 5.0 RETAINING WALL FACING SYSTEM

## 5.1 Facing Type

The facing system for the MSE wall will provide physical support for the retained soil adjacent to the wall face to prevent the retained soil from ravelling out between the rows of reinforcement. It is important to note that overall wall stability and soil retention is provided not by the facing system, but by the main reinforcement layers within the fill. The facing system also serves to protect the main reinforcement layers from ultraviolet (uV) exposure to avoid long-term reinforcement degradation. In addition, the facing system promotes safe construction at the wall face because compaction is not required immediately adjacent to steep slopes face. As the MSE wall is permanent, the geogrid within the MSE wall is designed to be the primary face soil retention element and it is wrapped back within the reinforced fill as shown Figure 5.

The schematic arrangement of the facing system is provided in Figure 5. The component of the system and their functions are detailed below.

- Main geogrid reinforcement wrap-around: The geogrid supports the gravel zone and fill soil laterally. This is the primary long-term facing soil retention measure.
- Steel bar mesh “L-shape”: The steel mesh is proposed as the outer element of the facing and is used as a forming device for the geogrid wrap-around during construction. The steel mesh is left in place after construction. The steel mesh is designed to carry no long-term load in the stability of the MSE wall.
- uV resistant Turf Reinforcement Mat: This material is heavily stabilised against uV attack and will line the inner face of the steel bar mesh. It provides a long-term UV shield for the main geogrid reinforcement and also assists in retaining the gravel. This material will be visible through the steel mesh and will give the wall its primary colour.
- Gravel (or suitably sized rock): Prevents water pressure build up at face. Provides for facing constructability because the gravel zone can be placed without the need to operate soil compactors immediately adjacent to the wall face.
- Separation geotextile: This material will line the inner face of the geogrid wrap-around. It prevents fill soil migrating into the gravel and assists in retaining the gravel.

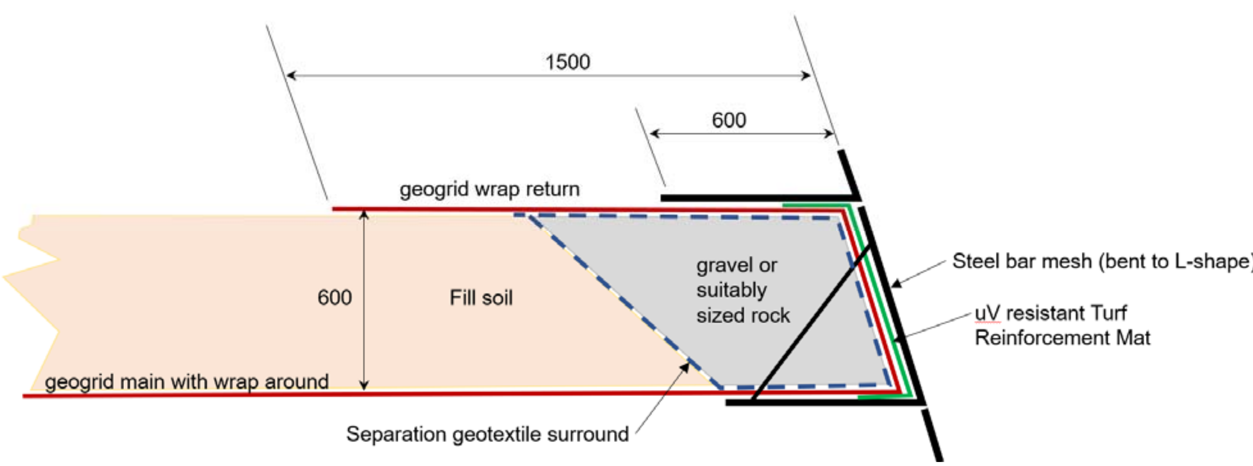



**Figure 5: Schematic Arrangement of Facing**

## 5.2 Visual Appearance

The visual appearance of the wall facing will be governed by the galvanised steel mesh and the uV resistant Turf Reinforcement Mat lining the inside of the steel mesh. A dark green colour is proposed for the uV resistant Turf Reinforcement Mat to enhance the aesthetic appearance of the wall. This colour is expected to be clearly visible through the apertures of the steel mesh.

## 5.3 Design life and durability

A very long facing design life (approximately 100 years) can be achieved with appropriate selection of the uV resistant Turf Reinforcement Mat. In addition, the steel wire mesh will be heavily galvanised for durability, as in gabion and similar construction, and is likely to achieve a long design life.

# 6.0 TRAFFIC BARRIER

## 6.1 F-Type Barrier System

The proposed traffic barrier design considers two load cases:

1) During construction: dump trucks with a maximum weight of 72 tonnes.

2) In operation: garbage trucks with a maximum weight of 36 tonne.

In both load cases, the design intent is to use readily available proprietary barrier systems and specify the required site controls in order for a given barrier system to be structurally adequate.

The F-Type (MASH TL-5) concrete barrier is proposed as a suitable traffic barrier system. The F-Type barrier system comprises of precast concrete segments that are joined through a pin and loop system. As the system can be assembled on site, it can be also be demobilised and adjusted during the different phases of construction and operation.

## 6.2 Site limits

In accordance with AS3845.1: 2015 “Road safety barriers systems and devices”, a TL-5 rated barrier is designed for a 36 tonne vehicle travelling at 80km/hr at an angle of 15 degrees to the barrier. Given the geometry of the proposed MSE wall, a direct collision into the barrier must also be considered given the risk and consequences of failure. As such it has been determined that for the given load cases, the following site limits must be implemented for the F-Type concrete barrier system to be applicable.

3) During construction:

- 72 tonne maximum vehicle weight
- 10km/hr maximum speed limit
- 2 metre minimum working width (this is the horizontal distance from the crest of the MSE wall)

4) In operation:

- 36 tonne maximum vehicle weight
- 15km/hr maximum speed limit
- 2 metre minimum working width

These were determined based on the kinetic energy capacity of 595.4 kJ for a TL-5 barrier as shown in AS 3845.1: 2015 Table D1. Furthermore, the minimum height barrier for a TL-5 system is 1100mm high minimum from the ground as per Roads and Maritime Services – NSW Government (RMS).

# 7.0 LINER SYSTEM

To manage potential leachate generation and lateral gas migration associated with the new landfill waste, the optioneering design includes a composite landfill liner system below the new landfill waste and overlying the liner support fill (inner side of the MSE wall). This is illustrated in preliminary design drawing 040, included in APPENDIX A.

Appropriate leachate and gas management is required for landfill waste occupying additional airspace. This includes consideration of new liner systems constructed as part of the retaining wall works and tie-in and compatibility with existing leachate and gas collection systems. Leachate and gas management assessment will consider the current (2016) NSW landfill design guidelines as well as the currently approved systems at the site. This design item also includes consideration of compatibility with future capping systems for the final landform.

## 7.1 NSW EPA Landfill Guidelines

The designed liner system functions as a leachate barrier system as per the 2016 NSW Landfills Guidelines. The following minimum standards for a leachate barrier system components apply to the design, construction and operation of the proposed landfill. The minimum standards listed are relevant to the proposed design and taken from the 2016 NSW Landfill Guidelines. The required outcomes of the design include:

- The landfill must have a leachate barrier system to contain leachate and prevent the contamination of surface water and groundwater over the life of the landfill.
- Pollutants with the potential to degrade the quality of groundwater must not migrate through the strata to any point beyond the boundary of the premises or beyond 150 metres from the landfill footprint, whichever is smaller. If this occurs, additional engineered controls may be required to prevent further pollutant migration. It may also be necessary to remediate the existing pollution.

The following sections summarise acceptable designs, specifications and operating practises for the leachate barrier system that have been considered as part of the liner system design.

### 7.1.1 Design of Leachate Barrier System

This primary barrier system should include the following components:

- a compacted clay liner at least 1000 mm thick, with an in situ hydraulic conductivity of less than 1 x 10–9 m/s; for landfills receiving more than 20,000 tonnes of waste per year, the liner should include a geomembrane over the compacted clay;
- The elements of leachate barrier systems installed on slopes must have adequate slope stability. A slope stability analysis should demonstrate that there are adequate factors of safety for all potential failure mechanisms (e.g. veneer and global stability) at the proposed final landform and at interim stages during construction.

### 7.1.2 Protection Geotextile

The protection or cushion geotextile should:

- be a non-woven, needle-punched geotextile, typically made of polyester or polypropylene formulated to meet landfill conditions and not containing recycled materials
- be of sufficient mass, strength and thickness to protect the underlying geomembrane from puncture and from excess stresses and strains due to indentations from overlying gravel particles or from the ribbing, edges and joints of drainage geocomposites

- meet or exceed the requirements for manufacture and performance contained in the relevant specifications published by the Geosynthetic Research Institute (Folsom, PA, USA) from time to time, or in equivalent recognized industry standard specifications. See GRI Test Method GT12(a) and GRI Test Method GT12(b) (Geosynthetic Research Institute, 2012a and 2012b).
- The expected field performance of a geomembrane liner under gravel aggregate should be tested using the two published methods recommended by the NSW EPA Landfill Guidelines Section 1.6.

### 7.1.3 Geosynthetic Clay Liner

When used as alternatives to compact clay, the geosynthetic clay liner should:

- Consist of a thin layer of bentonite ‘sandwiched’ between layers of geotextiles with a hydraulic conductivity less than 5 x 10–11 m/s
- Be reinforced (i.e. the geotextile layers are bonded by needle punching or stitching to enhance the internal shear strength of the geosynthetic clay liner compared with that of unreinforced products)
- Have adequate strength, flexibility and durability to maintain performance over the entire life of the landfill (including the operating and post-closure periods)
- Meet or exceed the requirements for manufacture and performance contained in the relevant specifications published by Geosynthetic Research Institute (Folsom, PA, USA) or in equivalent recognised industry standard specifications, see GRI-GCL3 (Geosynthetic Research Institute 2010)
- Be made from bentonite that has been formulated for landfill applications and meet indicated specifications

### 7.1.4 Drainage Geocomposites

An appropriately designed geonet drainage geocomposite may be used as an alternative to the gravel drainage layer in secondary applications, such as sidewall leachate drainage systems.

The geonet drainage geocomposite should be protected by an overlying padding or protection layer. This layer should have adequate thickness, particle size distribution, permeability, internal shear strength and interface friction with adjacent layers.

The geonet drainage geocomposite should:

- have an internal geonet drainage core manufactured from high-density polyethylene (plus anti-oxidants) and consisting of layers of parallel ribs creating drainage channels through which liquid can flow
- have a geotextile fabric bonded to the upper surface of the geonet to prevent fines from entering the drainage channels, and a geotextile fabric bonded to the lower surface to prevent damage to adjacent geosynthetic layers from the ribbing, edges and ties of the geonet
- be able to resist degradation caused by factors such as chemical attack, temperature, oxidation and stress cracking over the entire life of the landfill (this includes chemical resistance of the geotextile fabric polymers to the site’s leachate)
- have adequate internal shear strength and interface friction with adjacent layers
- have adequate long-term flow capacity for the calculated leachate flow rate at the site.

The allowable flow rate should be determined from a standard 100-hour test simulating field conditions (adjacent layers, waste loads and hydraulic gradient).

## 7.2 Geosynthetic lining system design

Two options for the lining system overlying the liner support fill have been proposed as part of the preliminary design. Refer to typical details included in preliminary design drawing 050, included in APPENDIX A.

**Option 1** is proposed to comprise the following components, from top to bottom:

i) Cushion geotextile, to provide UV protection prior to waste placement and cushion function during/after

ii) Geosynthetic drainage net, to provide leachate drainage and cushion function. Together with cushion geotextile, also provides a preferential slip layer present above GCL for protection against waste settlement downdrag.

iii) Coated GCL

iv) 1 m thick clay-rich soil liner (i.e. the outer 1m of the liner support fill), to act in conjunction with coated GCL to provide composite liner function.

Note: Clay rich material is required to mitigate the high risk of geosynthetic penetration due to the potential presence of larger particles in waste placed directly over liner (max. 100-200mm). A 1 m thickness was selected based on constructability on the 1V:1H batter in a presumed overfill/cutback approach.

**Option 2** is proposed to comprise:

v) Select waste (maximum particle size approximately 50 mm), placed against liner to mitigate the risk of geosynthetic penetration, noting Option 2 does not include the clay rich material below the liner

vi) Cushion geotextile, per Option 1

vii) Geosynthetic drainage net, per Option 1

viii) HDPE geomembrane, to provide composite liner in conjunction with the GCL

ix) GCL, to provide composite liner in conjunction with the geomembrane

x) Prepared surface of liner support fill – Fill to be placed with overfill and cutback approach. Surface preparation (smooth rolling) of liner support fill required to prepare suitable surface for GCL placement.

Both proposed systems comprise a low permeability element, being the composite of coated GCL geomembrane overlying low-permeability clay (Option 1), and geomembrane over GCL (Option 2) and an overlying leachate drainage element, being the geosynthetic drainage net. The systems have high differential settlement tolerance due the use of geosynthetic materials, which have inherent flexibility and strain tolerance, and compacted clay, which generally has significant strain tolerance if under confining stresses representing liner system burial depths.

A comparison of the key components of lining system Options 1 and 2 against the relevant NSW EPA Landfill Guidelines is presented in Table 13 below.

**Table 13: Compliance Assessment for Liner System Design Option 1 and Option 2**

| NSW EPA Landfill Guideline Section | Design Report Section | Design Option 1 | Design Option 2 |
|---|---|---|---|
| 1.1 Design of leachate barrier system | 7.1.1 | 1 m thick low permeability clay liner (i.e. the outer 1m of the liner support fill), to act in conjunction with coated GCL to provide a credible composite liner.<br>Note: Summary of global stability assessment is presented in Section 3.0. Veneer stability will be assessed as part of the detailed design. | Compliant – HDPE geomembrane and GCL to provide composite liner composite liner.<br>Note: Summary of global stability assessment is presented in Section 3.0. Veneer stability will be assessed as part of the detailed design. |
| 1.3 Geosynthetic Clay Liner | 7.1.3 | Compliant | Compliant |
| 1.6 Protection Geotextile | 7.1.2 | Compliant | Compliant |
| 1.8 Drainage Geocomposites | 7.1.4 | Geosynthetic drainage net and overlying cushion geotextile and underlying HDPE material to function together in place of drainage geocomposite | As per Option 1 |

## 7.3 Connection to existing clay liner

The new liner system has been designed to tie into the existing landfill liner system to maintain continuity for leachate and gas collection.

*Leachate*: The collection approach for leachate generated within new waste above the liner support fill is: (a) leachate generally seeps downward and enters the geosynthetic drainage net; (b) leachate then flows within the geosynthetic drainage net to the base of the liner support fill; (c1) leachate then drains directly into the underlying existing leachate collection layer, where possible; or (c2) leachate drains into a soak trench and then eventually infiltrates downward into the underlying existing leachate collection layer. For leachate generated within the new waste, but not above the liner support fill, the leachate would generally seep downward into the existing waste mass and eventually be collected/managed as per current methods. As current methods are understood to be acceptable, a piggyback liner is not proposed for the interface between new waste and existing waste. Refer to typical section in preliminary design drawing 040, included in APPENDIX A.

*Landfill Gas*: The design approach for landfill gas management is to: (i) install low-permeability barriers along the inside edge of the MSE wall system to prevent landfill gas migrating into the wall backfill; and (ii) rely on extension and/or relocation of the existing active gas collection infrastructure into the new waste to collect gas from both old and new waste. The low-permeability barriers referred to above comprise the composite liner on the liner support fill surface and compacted clay liners below the liner support fill, as described above.

As the location of the existing landfill liner system below the MSE wall and liner support backfill varies, the design includes provision for the following cases:

- **Case 1: Edge of existing waste not below MSE wall and liner support fill**

  In areas where the existing waste is located inside the footprint of both the MSE wall reinforced zone and the liner support fill, to manage leachate and gas generation, the liner will be extended to tie-in to the existing landfill liner. The clay liner component is proposed to be a minimum 0.6 m thick and shaped as needed to allow leachate to drain under gravity into the existing system. The composite liner system will also provide a gas barrier to limit lateral migration and allow gas generated to be managed by the existing landfill gas system.

- **Case 2: Edge of existing waste below liner support fill or MSE wall**

  In areas where the existing waste extends to within the liner support fill or MSE wall footprint, a 0.6 m thick clay liner is proposed to manage potential gas migration from the existing waste mass into the liner support fill. A gravel filled soak away trench is proposed to be installed to allow leachate from the new waste to infiltrate into the existing leachate collection system.

In addition to the environmental protection functions of the proposed leachate and gas management systems described above, an additional benefit of these system is to reduce the risk of destabilising water/leachate pressures developing within the MSE wall backfill.

## 7.4 Anchorage details at top of retaining wall

As presented in preliminary design drawing 040, anchor trenches are included at the top and base of batter slopes. At the top of the retaining wall, the anchor trench for the liner is located adjacent to the surface water drain and includes allowance for tie-in with future capping systems for the final landform, which is documented within the Post Closure Rehabilitation Plan (ref: 19135652-018-R-Rev0).

# 8.0 RELOCATION OF EXISTING MONITORING WELLS

Existing gas, groundwater and dust deposition monitoring locations that are affected by wall construction and waste filing will be required to be relocated to maintain equitant environmental monitoring of the site. Figure 2 of the Post Closure Rehabilitation Plan (ref: 19135652-018-R-Rev0) shows the current monitoring network and footprint of proposed wall and waste filling. The wells that would be affected due to wall construction are;

- Groundwater wells: BH21, BH22, BH23, BH16A, BH16B and BH 2
- Gas wells: GS2, GS3 and GS4 likely
- Dust gauge: D2

These monitoring locations will be relocated as close as practicable to their current location and in consultation with the site owner.

# 9.0 SAFETY IN DESIGN

The planning level design has been prepared by Golder with consideration of a range of project risk issues as discussed internally throughout the preliminary design process, with key safety considerations discussed throughout the optioneering phase with Enviroguard. A workshop session on Safety in Design (SiD) is proposed to be held in late April 2020 to engage with key stakeholders, including attendees to represent the construction, operation and maintenance phases of the project. The design components and layout from the preliminary design will be considered to provide an appropriate basis for the workshop.

An initial SiD register has been prepared to identify a range of issues to be addressed throughout the design and construction process (refer to APPENDIX D). Golder has raised Safety in Design issues focusing on the following elements:

- hazard identification;
- construction materials;
- possible methods of construction, operation, and maintenance and their potential safety risks; and
- potential safety risks to persons in the project vicinity.

The SiD register includes a qualitative assessment to assess the risk of a certain event occurring through the assessment of the consequence of an event occurring as well as the likelihood of it occurring (See Table 14). The risk associated with a given event is assessed both before control measures are in place as well as after control measures are identified and implemented.

**Table 14: Qualitative Risk Assessment Framework**

| Likelihood | | Consequence | | | | |
|---|---|---|---|---|---|---|
| | | Negligible | Minor | Moderate | Major | Substantial |
| | | C1 | C2 | C3 | C4 | C5 |
| Almost Certain | L5 | LOW | MOD | V HIGH | EXTM | EXTM |
| Likely | L4 | LOW | MOD | V HIGH | V HIGH | EXTM |
| Possible | L3 | LOW | MOD | HIGH | V HIGH | V HIGH |
| Unlikely | L2 | LOW | LOW | HIGH | HIGH | V HIGH |
| Rare | L1 | LOW | LOW | MOD | HIGH | HIGH |

Where possible, control measures are to be implemented to reduce the risk to a moderate or low level. The hierarchy of control measures are used as a guiding principle for implementation of mitigation measures. That is, the order of precedence for risk mitigation controls is:

1. Elimination.
2. Substitution.
3. Engineering Controls.
4. Isolation.
5. Administration.
6. Personal Protective Equipment.

Future workshops or discussions with site operations personnel and construction contractor personnel will be conducted to communicate identified risks, mitigation measures, and residual risks presented in the Risk Register.

# 10.0 CONSTRUCTION QUALITY MANAGEMENT

The construction quality management system will comprise construction Contractor requirements and CQA Engineer actions. Contractor requirements include preparing management plans, preparing work method statements, material testing, compaction testing, surveying, notifying for Inspection Points, and preparing Hold Point documentation and works-as-executed (WAE) documentation. CQA Engineer actions include review and approval of Contractor submittals and documentation, inspecting construction works, conducting audit testing, attending Inspection Points, and releasing Hold Points.

Quality management requirements for the construction will include the items given below.

- *Hold Point*: An identified point in the construction sequence where the Contractor must halt work and provide required information to the CQA Engineer. The Contractor must not resume work until the Hold Point is released, in writing, by the CQA Engineer.
- *Full Time Inspection*: The CQA Engineer or in some cases the GITA (Geotechnical Inspection and Testing Authority), will be present on a full-time (continuous) basis for certain construction activities to confirm that construction is proceeding in accordance with Technical Specification requirements and design intent. Activities where full-time inspection should be undertaken include liner geosynthetics installation.
- *Field Testing*: Certain construction activities will require real-time field testing during construction. Examples include testing for confirmation of as-delivered material properties and compaction testing (refer following bullet point).
- *Compaction Testing*: Testing for as-constructed density and moisture content will be routinely performed on all soil construction materials. The Contractor will be required to engage an independent GITA to inspect earthworks construction and perform compaction testing.
- *Survey*: Numerous requirements for surveying of constructed alignments, inverts, and constructed soil and geosynthetic material surfaces will be included in the Technical Specification. The survey provides data for Works-as-Executed (WAE) documentation and for confirming that design layer thicknesses have been achieved in the liner system.
- *Audit Testing*: The CQA Engineer will arrange, at their discretion, for sampling and testing of delivered and emplaced construction materials, including soils and geosynthetics, to provide material property measurements that are independent of measurements by the Contractor. Activities where audit testing should potentially be undertaken include geosynthetics and clay installation/compaction.
- *CQA Engineer:* A suitably qualified and experienced Construction Quality Assurance Engineer to verify and report on all Construction Quality Assurance matters. The Quality Assurance engineer is to be independent of the construction contractor.

The Technical Specification will provide comprehensive details of construction quality management requirements including CQA Plan.

# Signature Page

**Golder Associates Pty Ltd**

Gary Schmertmann
*Principal Geotechnical Engineer*

JR:AY:PR:TM/LP:GRS

A.B.N. 64 006 107 857



https://golderassociates.sharepoint.com/sites/120150/project files/6 deliverables/19135652-006-r-prelim design report/rev0/19135652-006-r-rev0 preliminary design report.docx

**APPENDIX A**

# Preliminary Design Drawings

# ENVIROGUARD PTY LTD
# ERSKINE PARK LANDFILL - MSE WALL DESIGN


LOCALITY PLAN
SCALE: 1:5 mm

DRAWING LIST

| SHEET No. | DATE | REV No | SHEET TITLE | ISSUE |
|---|---|---|---|---|
| 001 | 2020-04-08 | A | COVER SHEET | PRELIMINARY |
| 003 | 2020-04-08 | A | EXISTING SITE CONDITIONS AND SERVICES | PRELIMINARY |
| 004 | 2020-04-08 | A | GENERAL ARRANGEMENT PLAN | PRELIMINARY |
| 011 | 2020-04-08 | A | STAGE 1 - RETAINING WALL PLAN | PRELIMINARY |
| 012 | 2020-04-08 | A | STAGE 1 - FILLING PLAN (TOP OF WASTE) | PRELIMINARY |
| 021 | 2020-04-08 | A | STAGE 2 - RETAINING WALL PLAN | PRELIMINARY |
| 022 | 2020-04-08 | A | STAGE 2 - FILLING PLAN (TOP OF WASTE) | PRELIMINARY |
| 030 | 2020-04-08 | A | PLAN AND LONGSECTION - SHEET 1 OF 2 | PRELIMINARY |
| 031 | 2020-04-08 | A | PLAN AND LONGSECTION - SHEET 2 OF 2 | PRELIMINARY |
| 032 | 2020-04-08 | A | SITE CROSS SECTIONS | PRELIMINARY |
| 040 | 2020-04-08 | A | RETAINING WALL TYPICAL SECTIONS SHEET 1 OF 2 | PRELIMINARY |
| 041 | 2020-04-08 | A | RETAINING WALL TYPICAL SECTIONS SHEET 2 OF 2 | PRELIMINARY |
| 042 | 2020-04-08 | A | REINFORCING SECTIONS | PRELIMINARY |
| 050 | 2020-04-08 | A | TYPICAL LINER DETAILS | PRELIMINARY |

**NOTES**

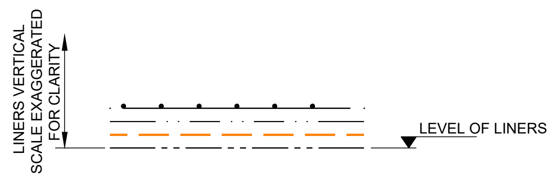
1. THESE NOTES APPLY TO ALL PROJECT DRAWINGS IN THE SET UNLESS NOTED OTHERWISE AND SHALL BE READ IN CONJUNCTION WITH THE SPECIFICATION.
2. ALL LEVELS ARE IN METRES TO AHD DATUM.
3. ALL CO-ORDINATES ARE IN METRES TO MAP GRID AUSTRALIA (MGA 94, ZONE 56).
4. ALL DIMENSIONS ARE IN METRES UNLESS NOTED OTHERWISE
5. LOCATION AND DEPTH OF ALL SERVICES TO BE VERIFIED BY THE CONTRACTOR PRIOR TO COMMENCEMENT OF WORKS.
6. DIMENSIONS SHALL NOT BE SCALED OFF DRAWINGS.
7. DRAWINGS MUST BE PRINTED IN COLOUR TO CORRECTLY IDENTIFY ALL DESIGN ELEMENTS

**REFERENCES**

1. SITE BOUNDARIES TAKEN FROM FILE "2220BASE.dwg"
2. AERIAL IMAGERY PROVIDED BY CLIENT "Erskine_Park_2019_12_04_map.ecw"
3. EXISTING GROUND IS COMBINATION OF THE FOLLOWING DATA SOURCES, ORDERED BY PRIOIRTY (1 is LOWEST)
   - 3.1. SITE SURVEY FROM CLIENT "2019_12_04_Erskine_Park_3m_Grid_Faces.dxf"
   - 3.2. EAST EMBANKMENT SURVEY "2220DET08.dwg" CAPTURE DATE 2020-02-18
   - 3.3. GHD "TOP OF WASTE" LANDFORM "21-19620-ERSKINE PARK DESN 20190314.dwg"
4. INTERNAL LANDFILL GAS INFRASTRUCTURE TAKEN FROM "RE-ERSKINE-001_ERSKINE PARK.dwg" AND POSITIONED MANUALLY USING AERIAL PHOTOGRAPHY. ACCURACY +/- 5m
5. EXTERNAL LANDFILL GAS INFRASTRUCTURE DIGITIZED FROM DBYD PDF "DBYD easement maps.pdf" SURVEYOR REF # 111783514_00 CAPTURE DATE 2014-07-01. ACCURACY +/- 5m
6. INFERRED WASTE BOUNDARY/EDGE OF SIDELINER TAKEN FROM "SS17375_INFERRED EDGE OF SIDELINER (2020.02.04) _ 3D LINES.dwg"

**LINER VERTICAL EXAGERATION DETAILS**

1. LINER MATERIALS HAVE BEEN EXAGGERATED ON ALL PLANS AS IN DETAIL BELOW




2. LINER MAY COVER PIPES AND MATERIALS ON DETAILS

NOT FOR CONSTRUCTION

**PRELIMINARY**

0 100 200
1:5,000 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-04-08 | FOR APPROVAL | PR/JR | BK/JF | GRS | GRS |

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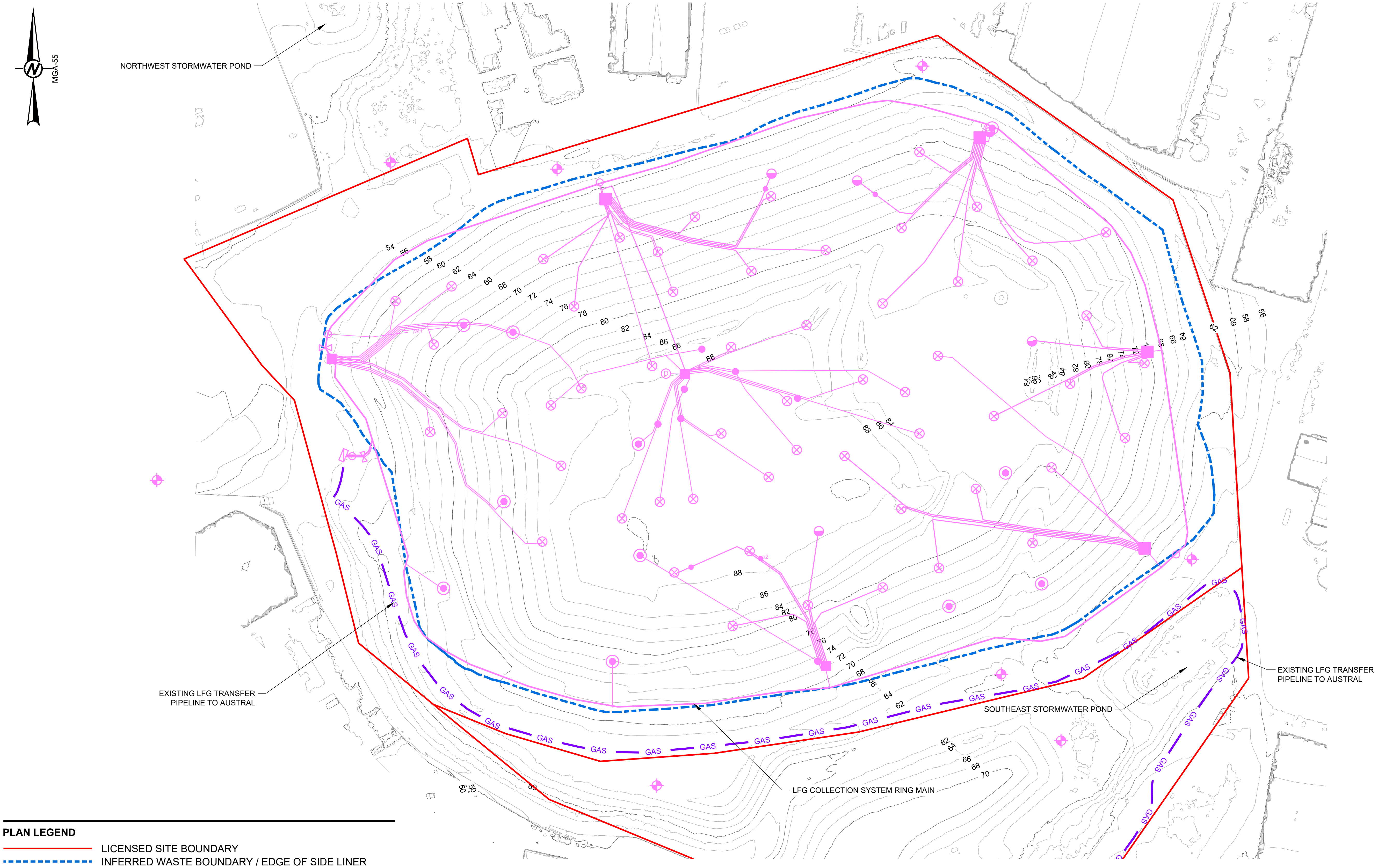
PROJECT
ERSKINE PARK LANDFILL
MSE WALL DESIGN

TITLE
**COVER SHEET**

| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | 28 of 26 | 001 |

25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3




**PLAN LEGEND**

- LICENSED SITE BOUNDARY
- INFERRED WASTE BOUNDARY / EDGE OF SIDE LINER
- INTERNAL GAS INFRASTRUCTURE
- EXISTING GROUND CONTOURS

0 50 100
1:2,500 METRES

NOT FOR CONSTRUCTION

**PRELIMINARY**

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-04-08 | FOR APPROVAL | PR/JR | BK/JF | GRS | GRS |

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PROJECT
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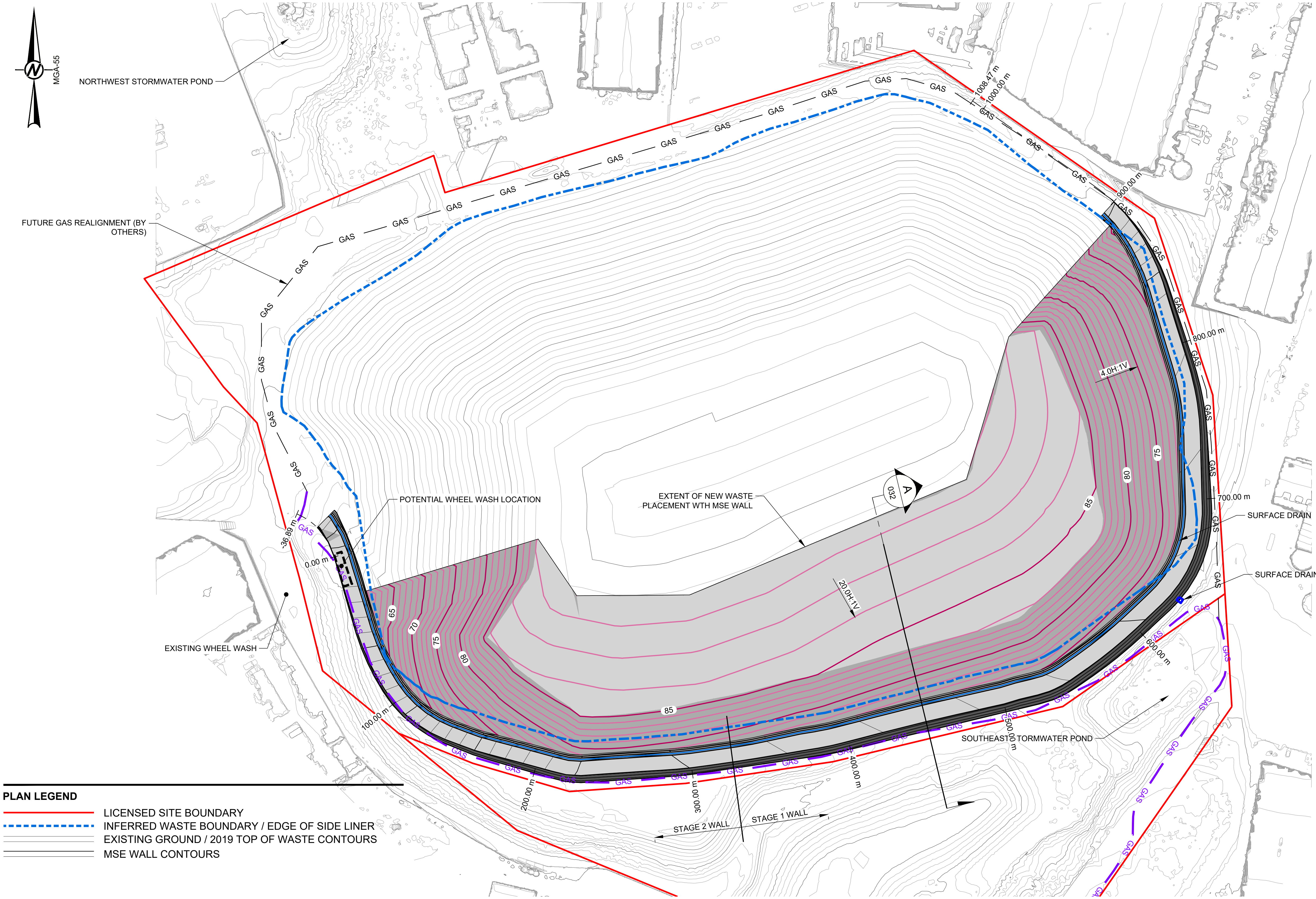
TITLE
**EXISTING SITE CONDITIONS AND SERVICES**

| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | 30 of 26 | 003 |

25 mm

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3




**PLAN LEGEND**

- LICENSED SITE BOUNDARY
- INFERRED WASTE BOUNDARY / EDGE OF SIDE LINER
- EXISTING GROUND / 2019 TOP OF WASTE CONTOURS
- MSE WALL CONTOURS

NOTE(S)

1. THE EXISTING GAS PIPELINE WILL BE RELOCATED OUTSIDE OF THE MSE WALL PROJECT AREA PRIOR TO CONSTRUCTION AND IS NOT SHOWN ON THIS DRAWING FOR CLARITY

0 50 100
1:2,500 METRES

NOT FOR CONSTRUCTION

**PRELIMINARY**

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-04-08 | FOR APPROVAL | PR/JR | BK/JF | GRS | GRS |

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PROJECT
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MSE WALL DESIGN

TITLE
**GENERAL ARRANGEMENT PLAN**

| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | 31 of 26 | 004 |

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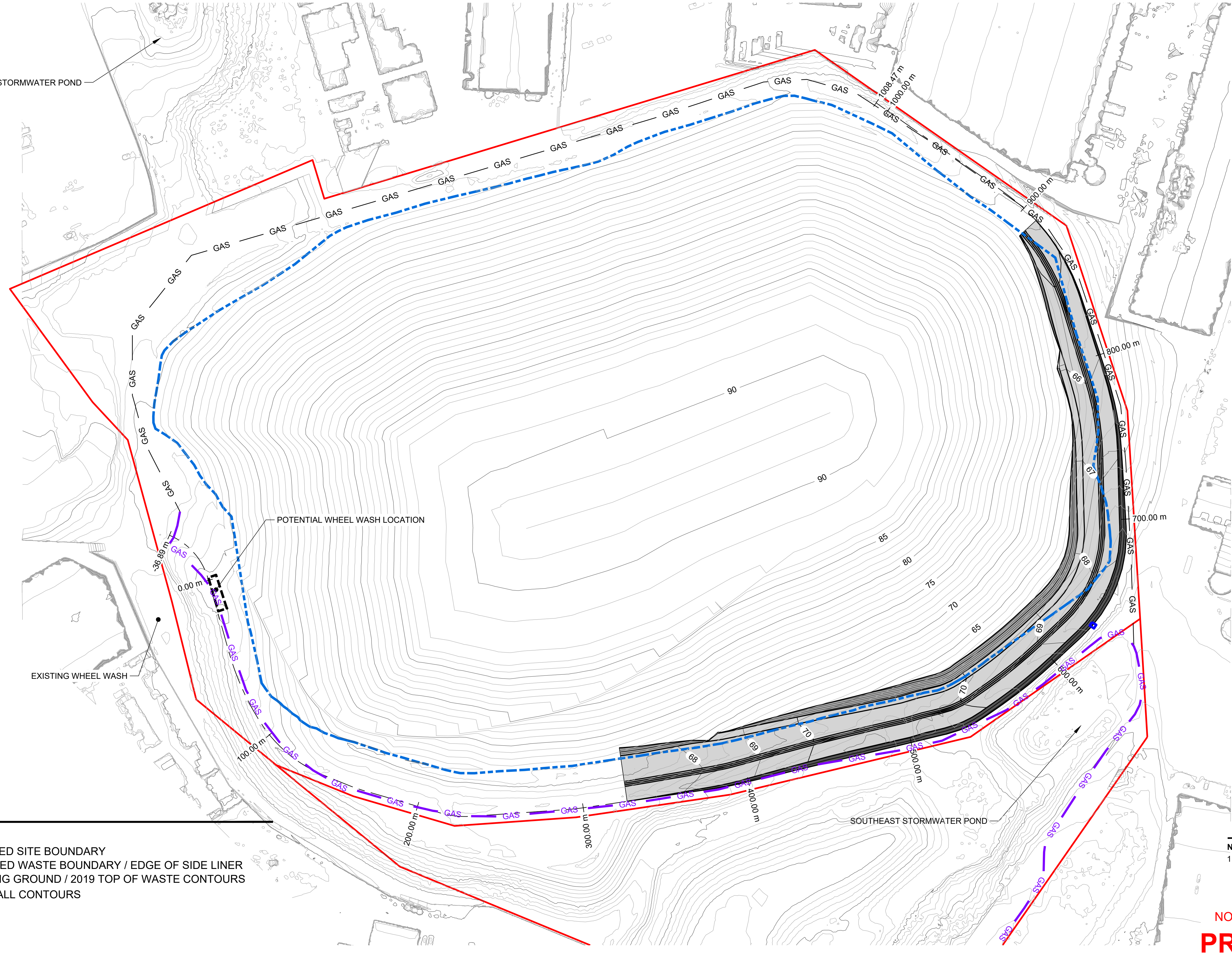


**PLAN LEGEND**

- LICENSED SITE BOUNDARY
- INFERRED WASTE BOUNDARY / EDGE OF SIDE LINER
- EXISTING GROUND / 2019 TOP OF WASTE CONTOURS
- MSE WALL CONTOURS

**NOTE(S)**

1. THE EXISTING GAS PIPELINE WILL BE RELOCATED OUTSIDE OF THE MSE WALL PROJECT AREA PRIOR TO CONSTRUCTION AND IS NOT SHOWN ON THIS DRAWING FOR CLARITY

NOT FOR CONSTRUCTION

**PRELIMINARY**

0 50 100

1:2,500 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
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PROJECT
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MSE WALL DESIGN

TITLE
**STAGE 1 - RETAINING WALL PLAN**

| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | 33 of 26 | 011 |

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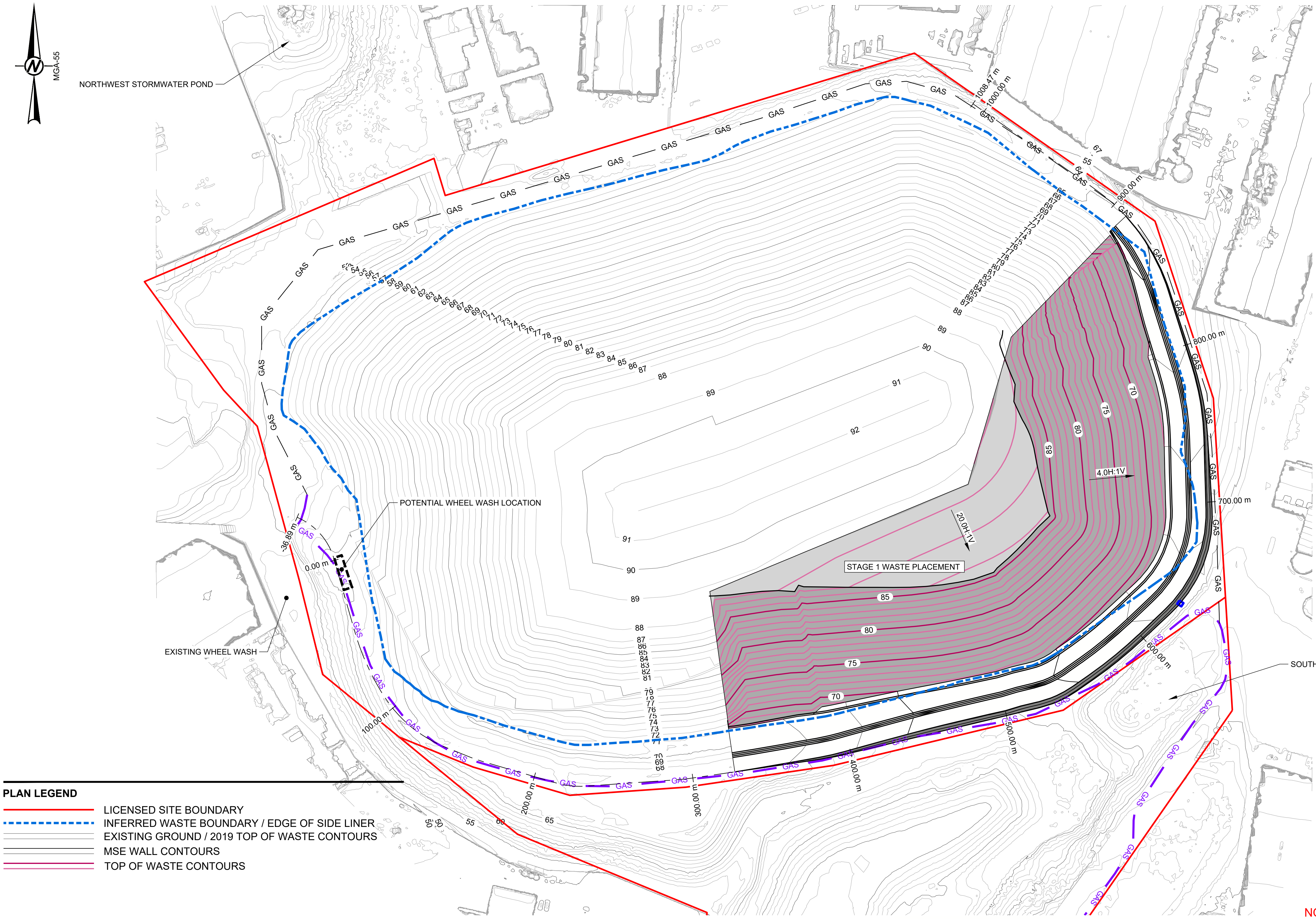


**PLAN LEGEND**

- LICENSED SITE BOUNDARY
- INFERRED WASTE BOUNDARY / EDGE OF SIDE LINER
- EXISTING GROUND / 2019 TOP OF WASTE CONTOURS
- MSE WALL CONTOURS
- TOP OF WASTE CONTOURS

**NOTE(S)**

1. THE EXISTING GAS PIPELINE WILL BE RELOCATED OUTSIDE OF THE MSE WALL PROJECT AREA PRIOR TO CONSTRUCTION AND IS NOT SHOWN ON THIS DRAWING FOR CLARITY

0 50 100
1:2,500 METRES

NOT FOR CONSTRUCTION

**PRELIMINARY**

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
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PROJECT
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MSE WALL DESIGN

TITLE
STAGE 1 - FILLING PLAN (TOP OF WASTE)

| PROJECT NO. | CONTROL | REV. | DRAWING |
|---|---|---|---|
| 19135652 | 005 | A | 012 |

34 of 26

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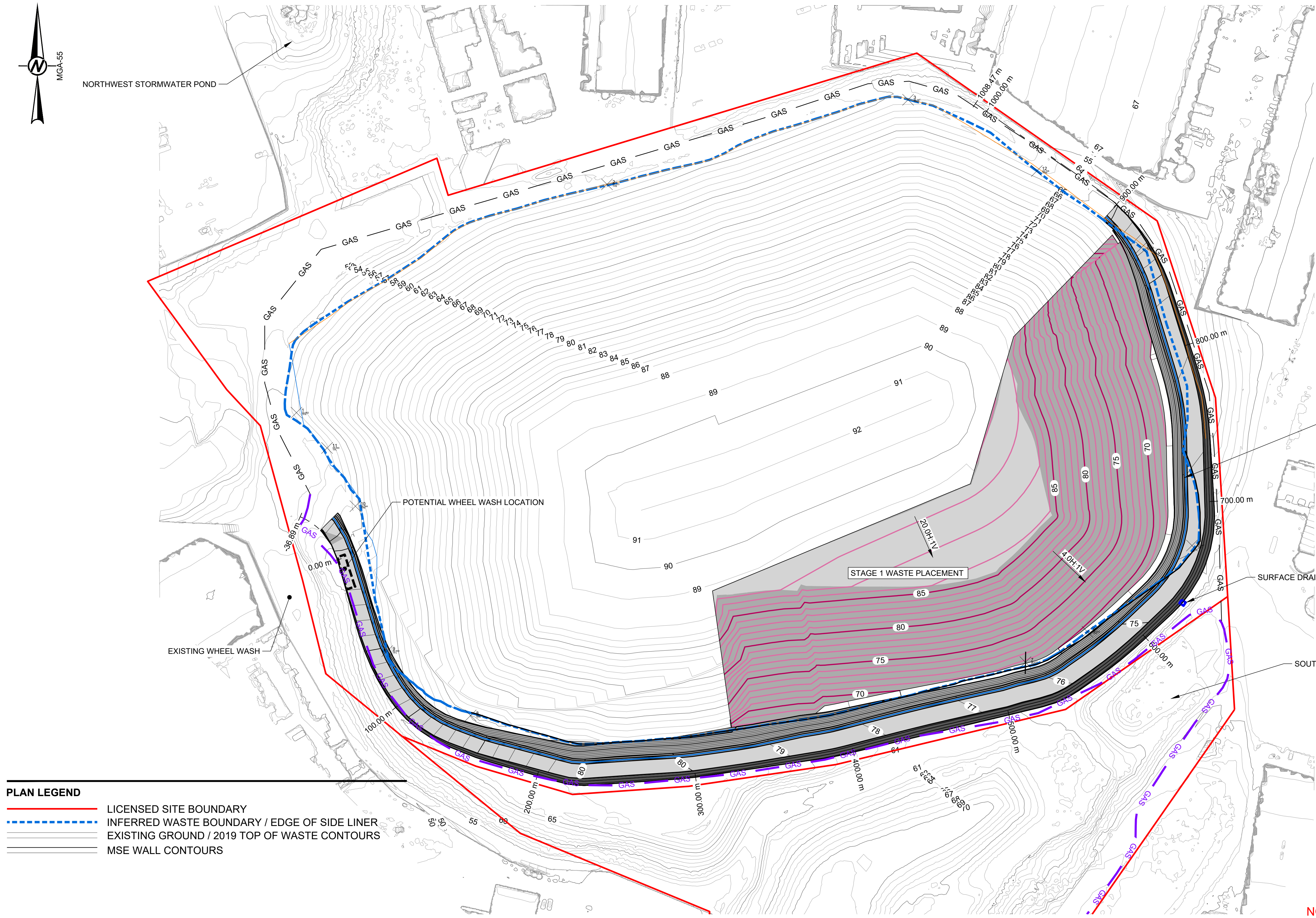


**PLAN LEGEND**

- LICENSED SITE BOUNDARY
- INFERRED WASTE BOUNDARY / EDGE OF SIDE LINER
- EXISTING GROUND / 2019 TOP OF WASTE CONTOURS
- MSE WALL CONTOURS

**NOTE(S)**

1. THE EXISTING GAS PIPELINE WILL BE RELOCATED OUTSIDE OF THE MSE WALL PROJECT AREA PRIOR TO CONSTRUCTION AND IS NOT SHOWN ON THIS DRAWING FOR CLARITY

NOT FOR CONSTRUCTION

**PRELIMINARY**

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
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PROJECT
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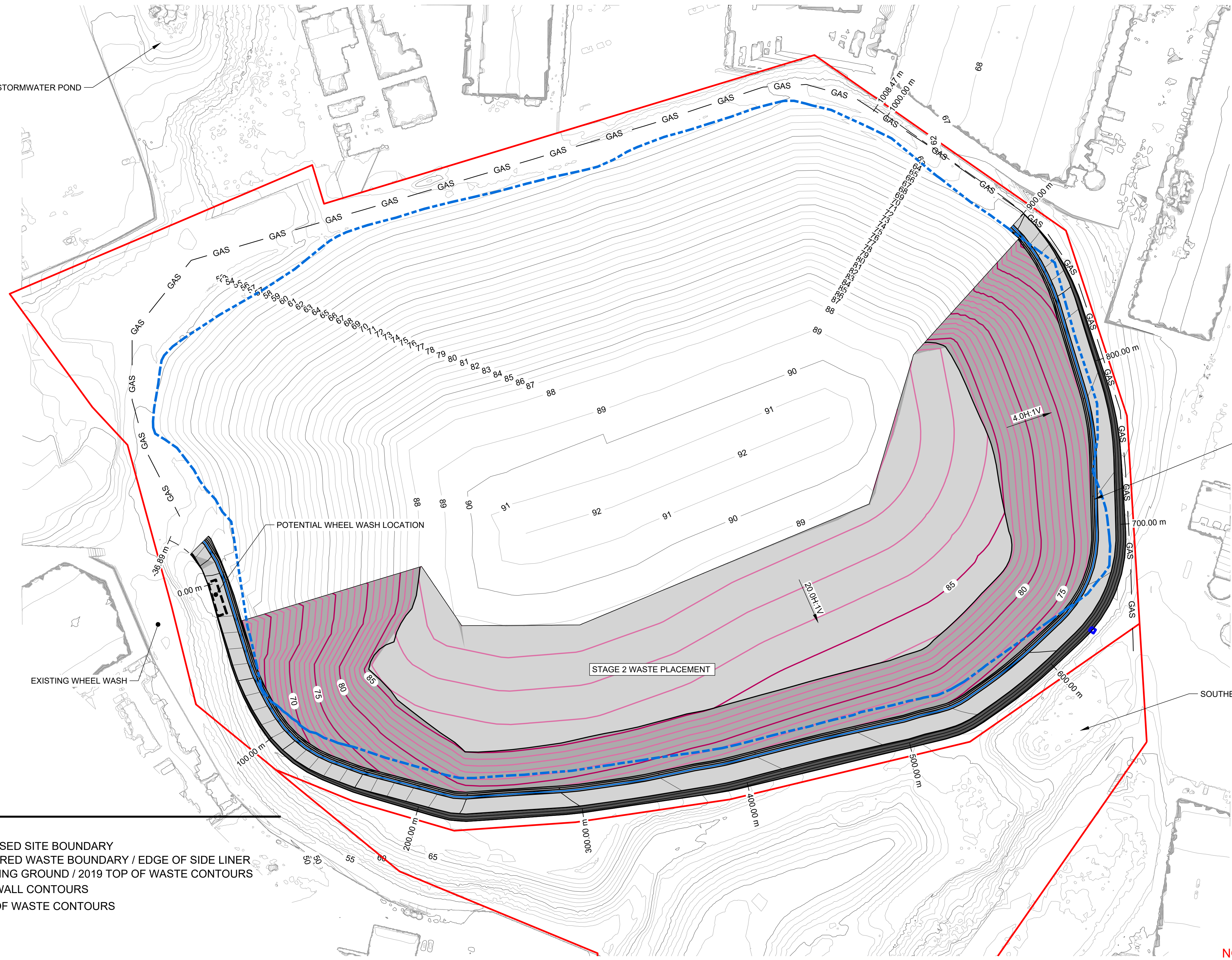
MSE WALL DESIGN

TITLE
**STAGE 2 - RETAINING WALL PLAN**

| PROJECT NO. | CONTROL | REV. | 36 of 26 | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | | 021 |




**PLAN LEGEND**

- LICENSED SITE BOUNDARY
- INFERRED WASTE BOUNDARY / EDGE OF SIDE LINER
- EXISTING GROUND / 2019 TOP OF WASTE CONTOURS
- MSE WALL CONTOURS
- TOP OF WASTE CONTOURS

**NOTE(S)**

1. THE EXISTING GAS PIPELINE WILL BE RELOCATED OUTSIDE OF THE MSE WALL PROJECT AREA PRIOR TO CONSTRUCTION AND IS NOT SHOWN ON THIS DRAWING FOR CLARITY

0 50 100
1:2,500 METRES

NOT FOR CONSTRUCTION

**PRELIMINARY**

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-04-08 | FOR APPROVAL | PR/JR | BK/JF | GRS | GRS |

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PROJECT
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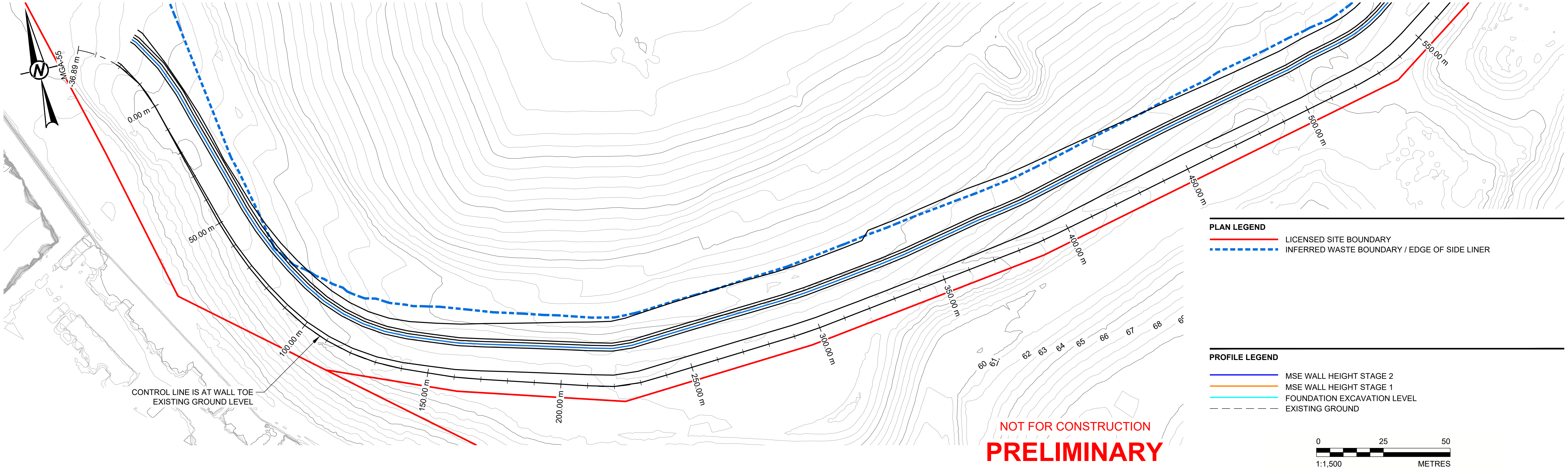
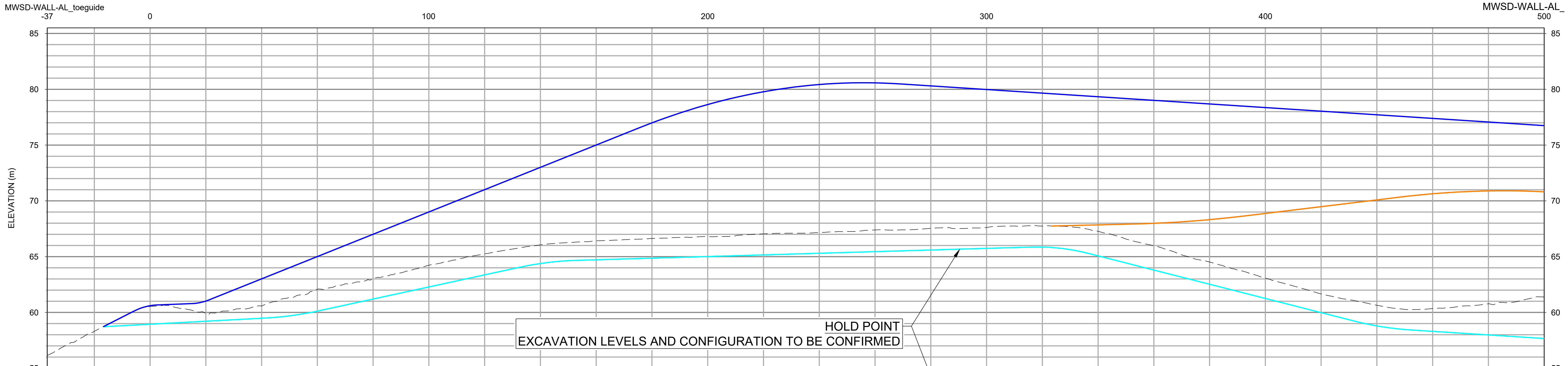
TITLE
**STAGE 2 - FILLING PLAN (TOP OF WASTE)**

| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | 37 of 26 | 022 |

25 mm

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3




| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOP OF WALL RL (mAHD) | | | 60.601 | 61.014 | 63.001 | 65.001 | 67.001 | 69.001 | 71.001 | 73.001 | 75.001 | 76.990 | 78.633 | 79.778 |
| EXISTING GROUND | 56.138 | 58.295 | 60.532 | 59.867 | 60.575 | 62.068 | 63.006 | 64.227 | 65.240 | 66.052 | 66.412 | 66.624 | 66.800 | 67.041 |
| EXCAVATION RL (mAHD) | | | 58.941 | 59.207 | 59.473 | 60.113 | 61.196 | 62.280 | 63.363 | 64.384 | 64.717 | 64.863 | 65.009 | 65.155 |
| CHAINAGE | -36.89 | -20.00 | 0.00 | 20.00 | 40.00 | 60.00 | 80.00 | 100.00 | 120.00 | 140.00 | 160.00 | 180.00 | 200.00 | 220.00 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOP OF WALL RL (mAHD) | 80.426 | 80.576 | 80.303 | 79.980 | 79.656 | 79.333 | 79.009 | 78.685 | 78.362 | 78.038 | 77.715 | 77.391 | 77.067 | 76.744 |
| EXISTING GROUND | 67.145 | 67.387 | 67.534 | 67.611 | 67.735 | 67.271 | 65.971 | 64.513 | 63.073 | 61.654 | 60.637 | 60.354 | 60.772 | 61.342 |
| EXCAVATION RL (mAHD) | 65.301 | 65.446 | 65.592 | 65.738 | 65.861 | 65.068 | 63.798 | 62.527 | 61.256 | 59.985 | 58.793 | 58.305 | 57.984 | 57.663 |
| CHAINAGE | 240.00 | 260.00 | 280.00 | 300.00 | 320.00 | 340.00 | 360.00 | 380.00 | 400.00 | 420.00 | 440.00 | 460.00 | 480.00 | 500.00 |

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-04-08 | FOR APPROVAL | PR/JR | BK/JF | GRS | GRS |

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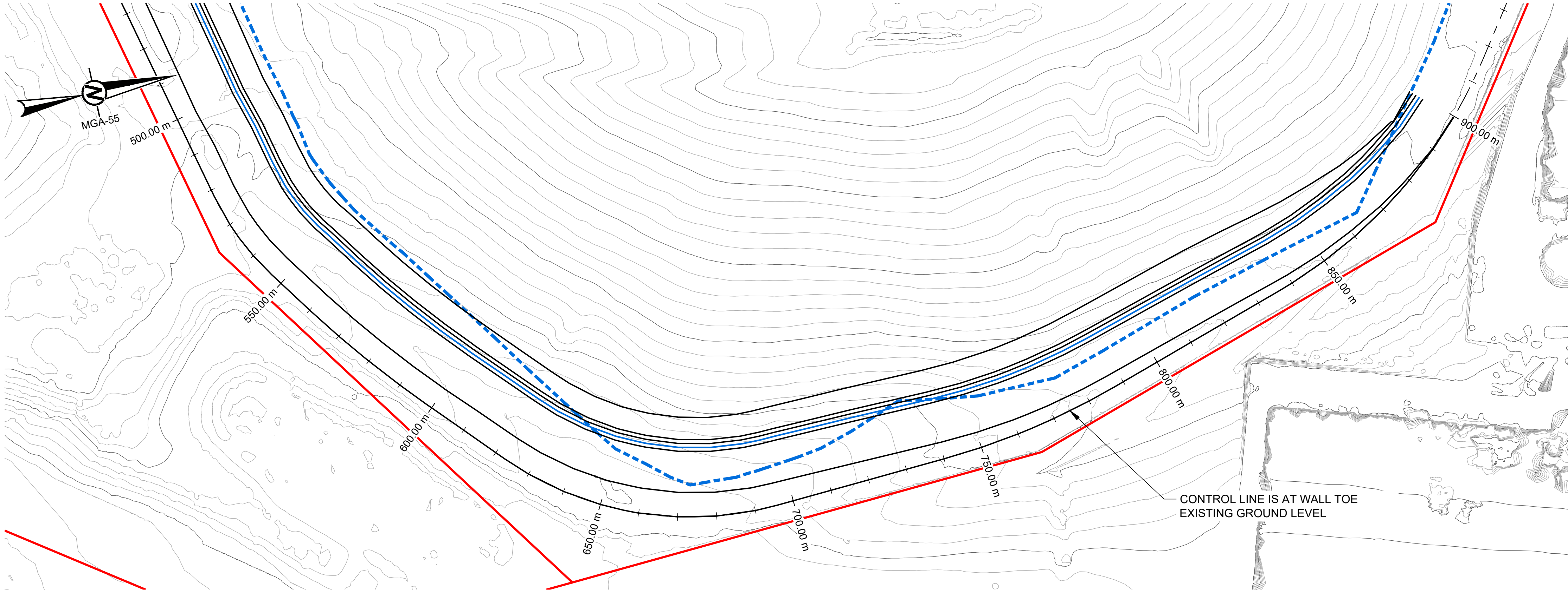
PROJECT
ERSKINE PARK LANDFILL
MSE WALL DESIGN

TITLE
**PLAN AND LONGSECTION - SHEET 1 OF 2**

| PROJECT NO. | CONTROL | REV. | 39 of 26 | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | | 030 |




**PLAN LEGEND**

- LICENSED SITE BOUNDARY
- INFERRED WASTE BOUNDARY / EDGE OF SIDE LINER

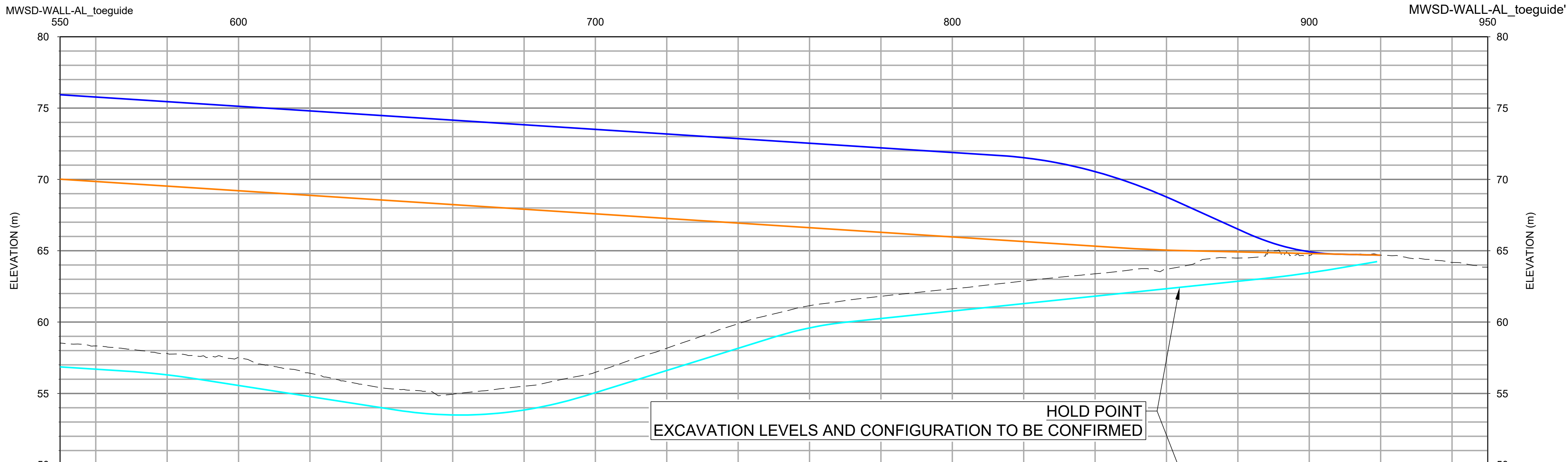
**PROFILE LEGEND**

- MSE WALL HEIGHT STAGE 2
- MSE WALL HEIGHT STAGE 1
- FOUNDATION EXCAVATION LEVEL
- EXISTING GROUND

NOT FOR CONSTRUCTION

# PRELIMINARY

0 25 50
1:1,500 METRES




| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TOP OF WALL RL (mAHD) | 75.935 | 75.773 | 75.449 | 75.126 | 74.802 | 74.479 | 74.155 | 73.831 | 73.508 | 73.184 | 72.861 | 72.537 | 72.213 | 71.890 | 71.526 | 70.549 | 68.772 | 66.517 | 64.931 | | | |
| EXISTING GROUND | 58.533 | 58.328 | 57.793 | 57.532 | 56.415 | 55.400 | 54.947 | 55.508 | 56.484 | 58.167 | 59.885 | 61.152 | 61.811 | 62.333 | 62.877 | 63.384 | 63.717 | 64.493 | 64.668 | 64.694 | 64.187 | 63.838 |
| EXCAVATION RL (mAHD) | 56.861 | 56.701 | 56.300 | 55.560 | 54.781 | 54.002 | 53.492 | 53.839 | 55.059 | 56.611 | 58.164 | 59.592 | 60.248 | 60.772 | 61.295 | 61.818 | 62.341 | 62.864 | 63.451 | | | |
| CHAINAGE | 550.00 | 560.00 | 580.00 | 600.00 | 620.00 | 640.00 | 660.00 | 680.00 | 700.00 | 720.00 | 740.00 | 760.00 | 780.00 | 800.00 | 820.00 | 840.00 | 860.00 | 880.00 | 900.00 | 920.00 | 940.00 | 950.00 |

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-04-08 | FOR APPROVAL | PR/JR | BK/JF | GRS | GRS |

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PROJECT
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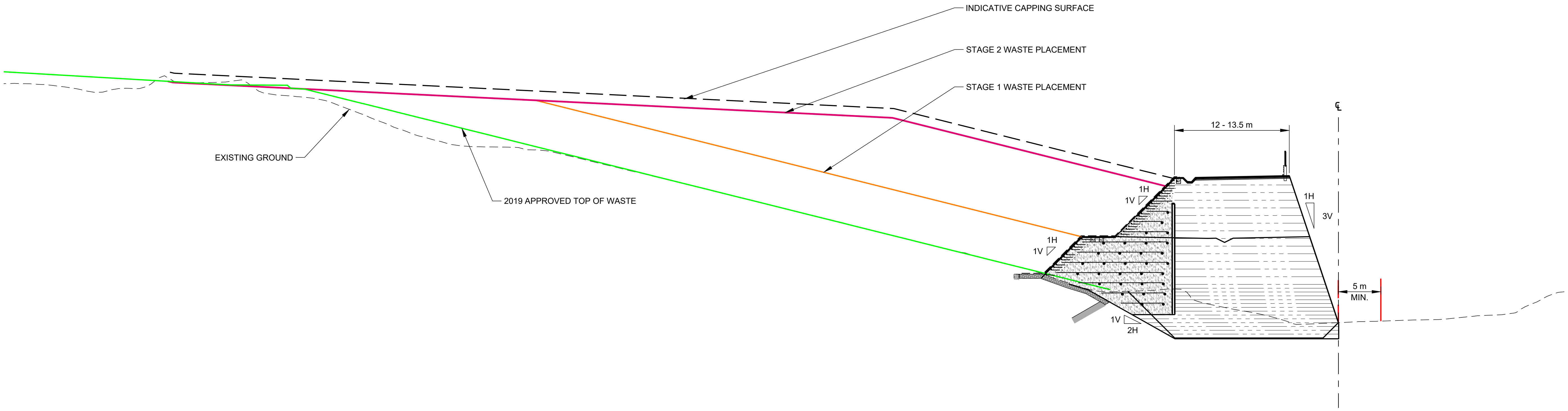
MSE WALL DESIGN

TITLE
**PLAN AND LONGSECTION - SHEET 2 OF 2**

| PROJECT NO. | CONTROL | REV. | 40 of 26 | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | | 031 |




SCALE 1:1,500 m A 004 SITE CROSS SECTION

NOT FOR CONSTRUCTION

**PRELIMINARY**

0 25 50
1:1,500 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-04-08 | FOR APPROVAL | PR/JR | BK/JF | GRS | GRS |

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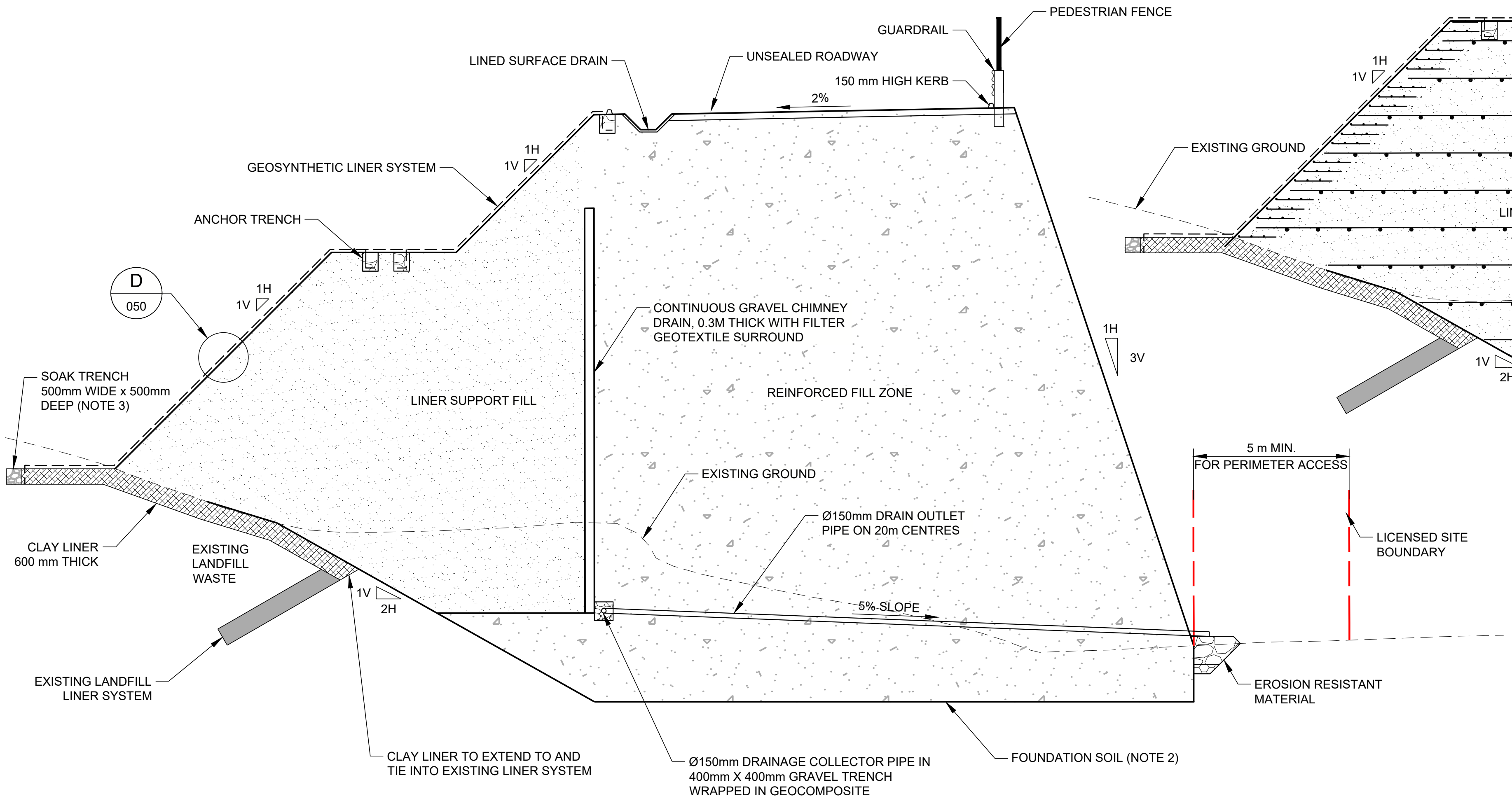
PROJECT
ERSKINE PARK LANDFILL
MSE WALL DESIGN

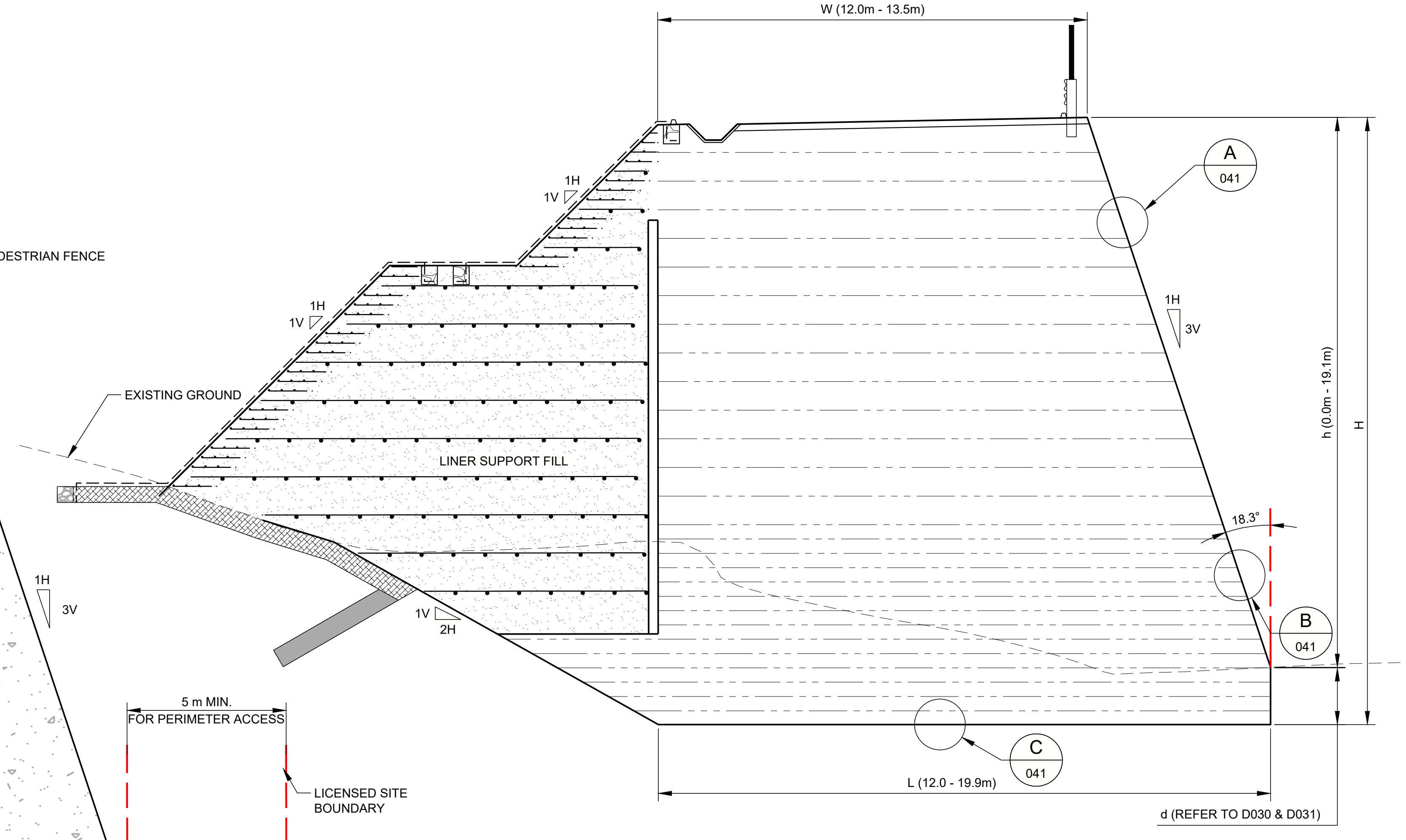
TITLE
**SITE CROSS SECTIONS**

| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | 41 of 26 | 032 |

25 mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3




TYPICAL SECTION AND WALL COMPONENTS
SCALE 1:200 m




TYPICAL SECTION AND INTERNAL REINFORCEMENT
SCALE 1:200 m

**NOTE(S)**

1. FOR GENERAL NOTES, REFER TO DRAWING 001.
2. ANTICIPATED FOUNDATION MATERIAL AND ITS CONSISTENCY WILL BE CONFIRMED PRIOR TO THE INSTALLATION OF MSE WALL.
3. SOAK TRENCH REQUIRED IN PORTIONS OF THE WALL WHERE LINER SUPPORTING FILL IS LOCATED WITHIN FOOTPRINT OF EXISTING LANDFILL WASTE.

NOT FOR CONSTRUCTION

**PRELIMINARY**

0 5 10
1:200 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-04-08 | FOR APPROVAL | PR/JR | BK/JF | GRS | GRS |

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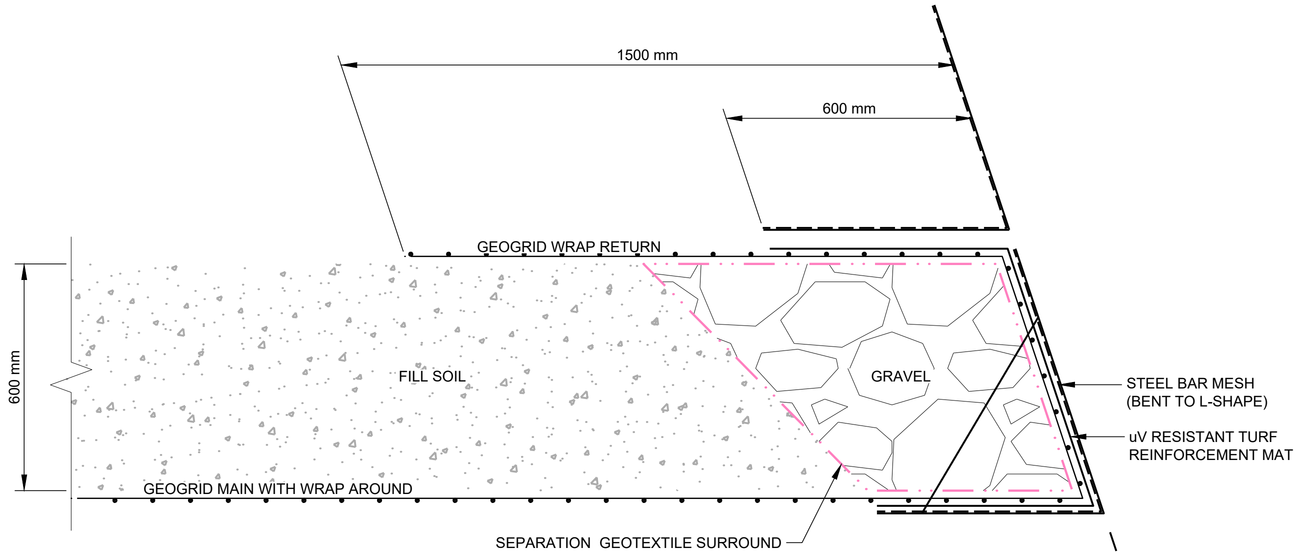
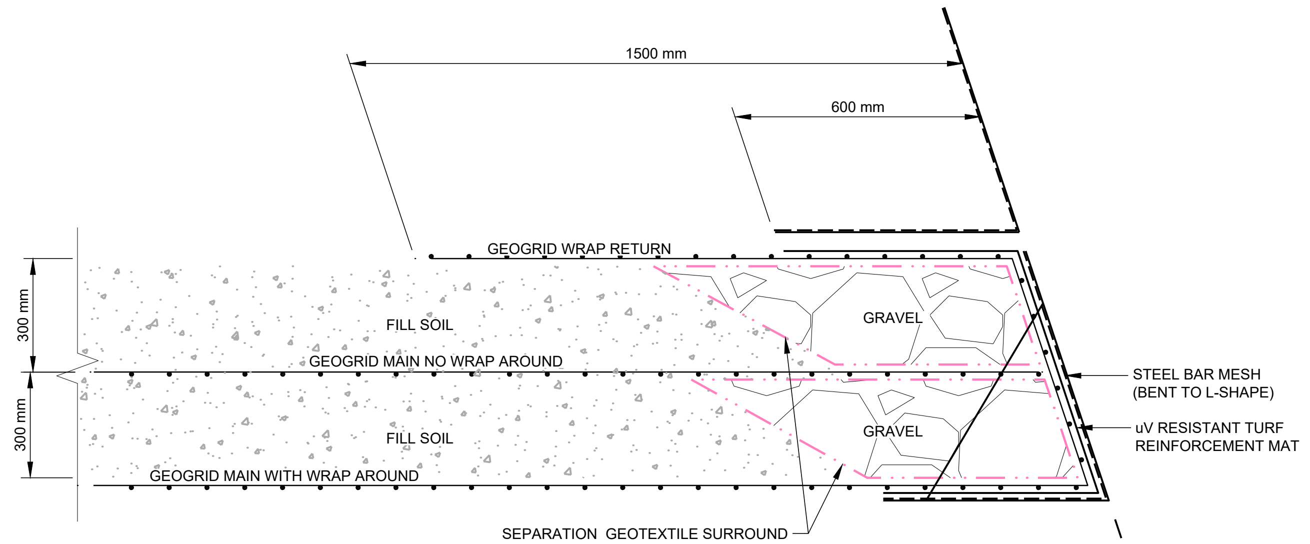
PROJECT
ERSKINE PARK LANDFILL
MSE WALL DESIGN

TITLE
**RETAINING WALL TYPICAL SECTIONS SHEET 1 OF 2**

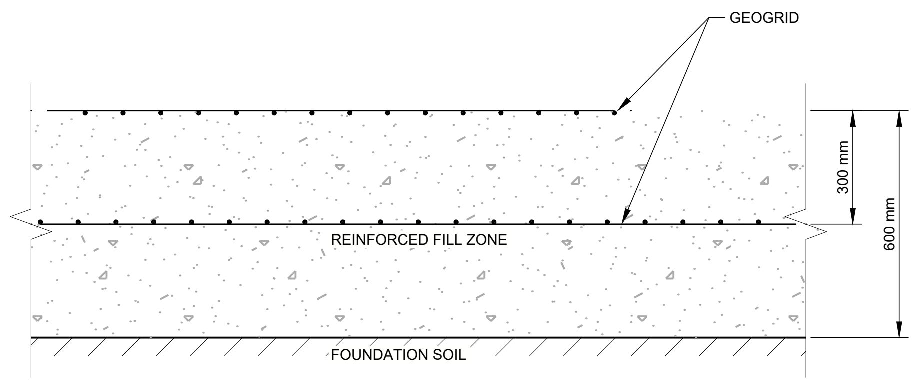
| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | 42 of 26 | 040 |




SCALE 1:20 m A 040 DETAIL A




SCALE 1:20 m B 040 DETAIL B




SCALE 1:20 m C 040 DETAIL C

**NOTE(S)**

1. FOR GENERAL NOTES, REFER TO DRAWING 001

NOT FOR CONSTRUCTION

**PRELIMINARY**

0 5 10

1:200 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-04-08 | FOR APPROVAL | PR/JR | BK/JF | GRS | GRS |

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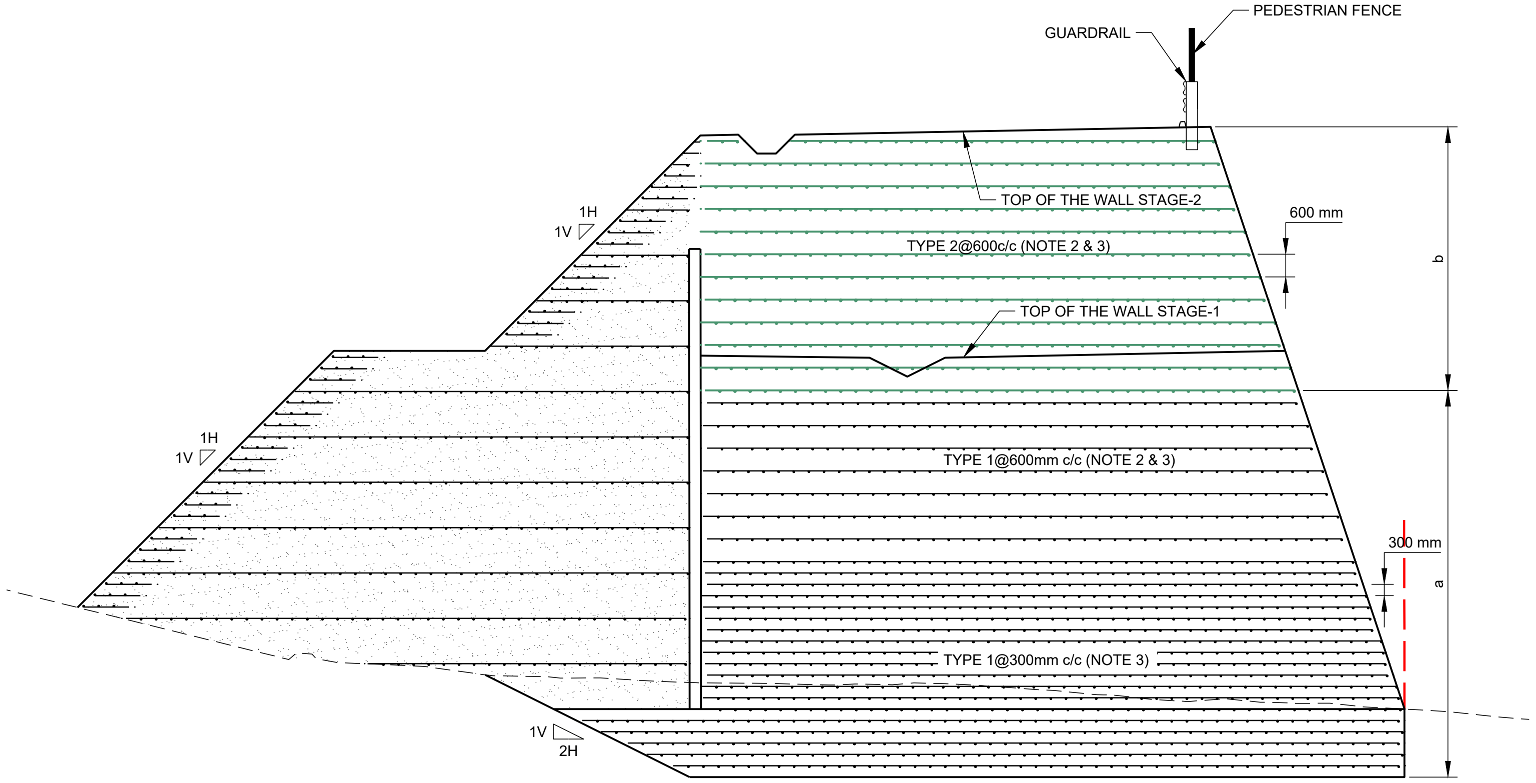
PROJECT
ERSKINE PARK LANDFILL
MSE WALL DESIGN

TITLE
**RETAINING WALL TYPICAL SECTIONS SHEET 2 OF 2**

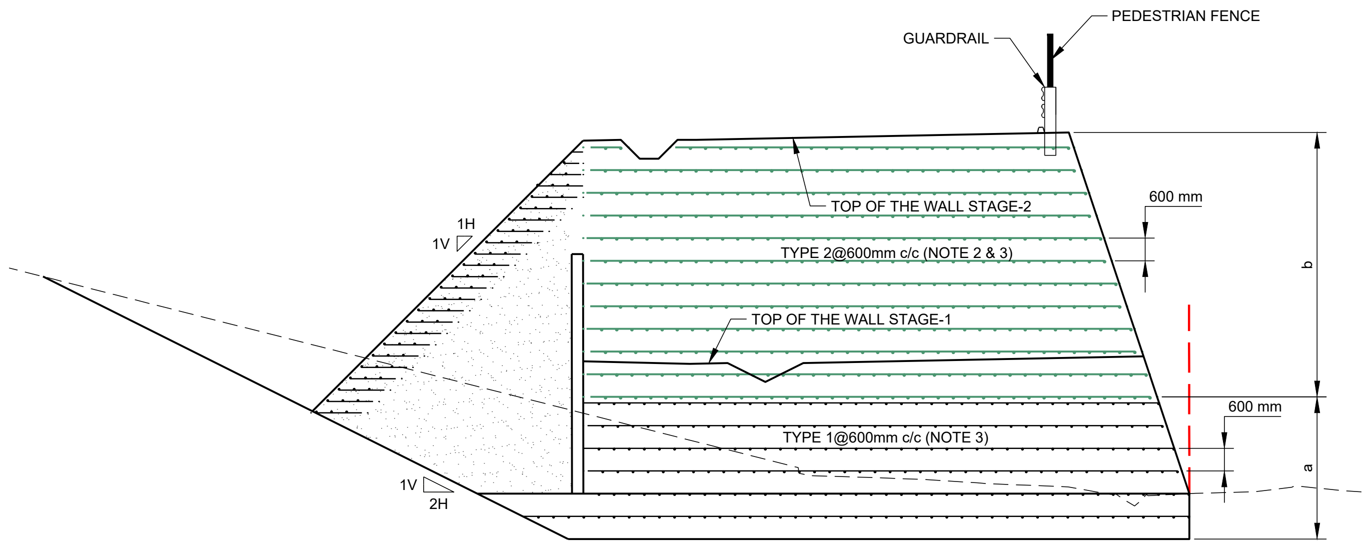
| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | 43 of 26 | 041 |



Document Set ID: 9100745
Version: 1, Version Date: 16/04/2020




CH 600.000




CH 800.000

**NOTE(S)**

1. FOR GENERAL NOTES, REFER TO DRAWING 001.
2. THE LENGTH OF THE REINFORCEMENT WILL BE OPTIMIZED DURING THE DETAILED DESIGN.
3. TYPE 1 AND TYPE 2 ARE GEOGRIDS WITH ULTIMATE STRENGTH OF 200kN/m AND 120kN/m RESPECTIVELY.

NOT FOR CONSTRUCTION

**PRELIMINARY**

0 5 10

1:200 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-04-08 | FOR APPROVAL | PR/JR | BK/JF | GRS | GRS |

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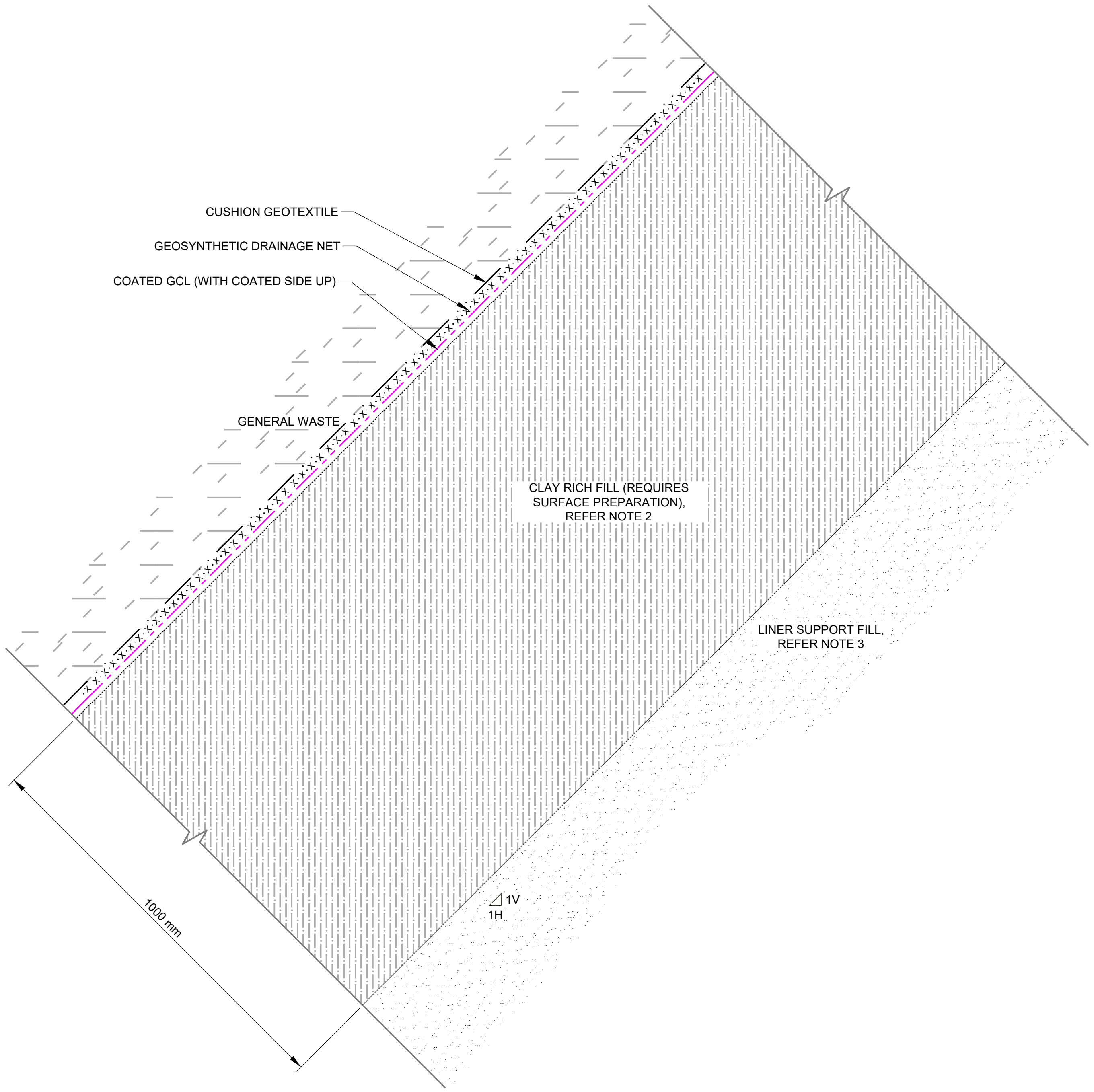
PROJECT
ERSKINE PARK LANDFILL
MSE WALL DESIGN

TITLE
**REINFORCING SECTIONS**

| PROJECT NO. | CONTROL | REV. | 44 of 26 | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | | 042 |

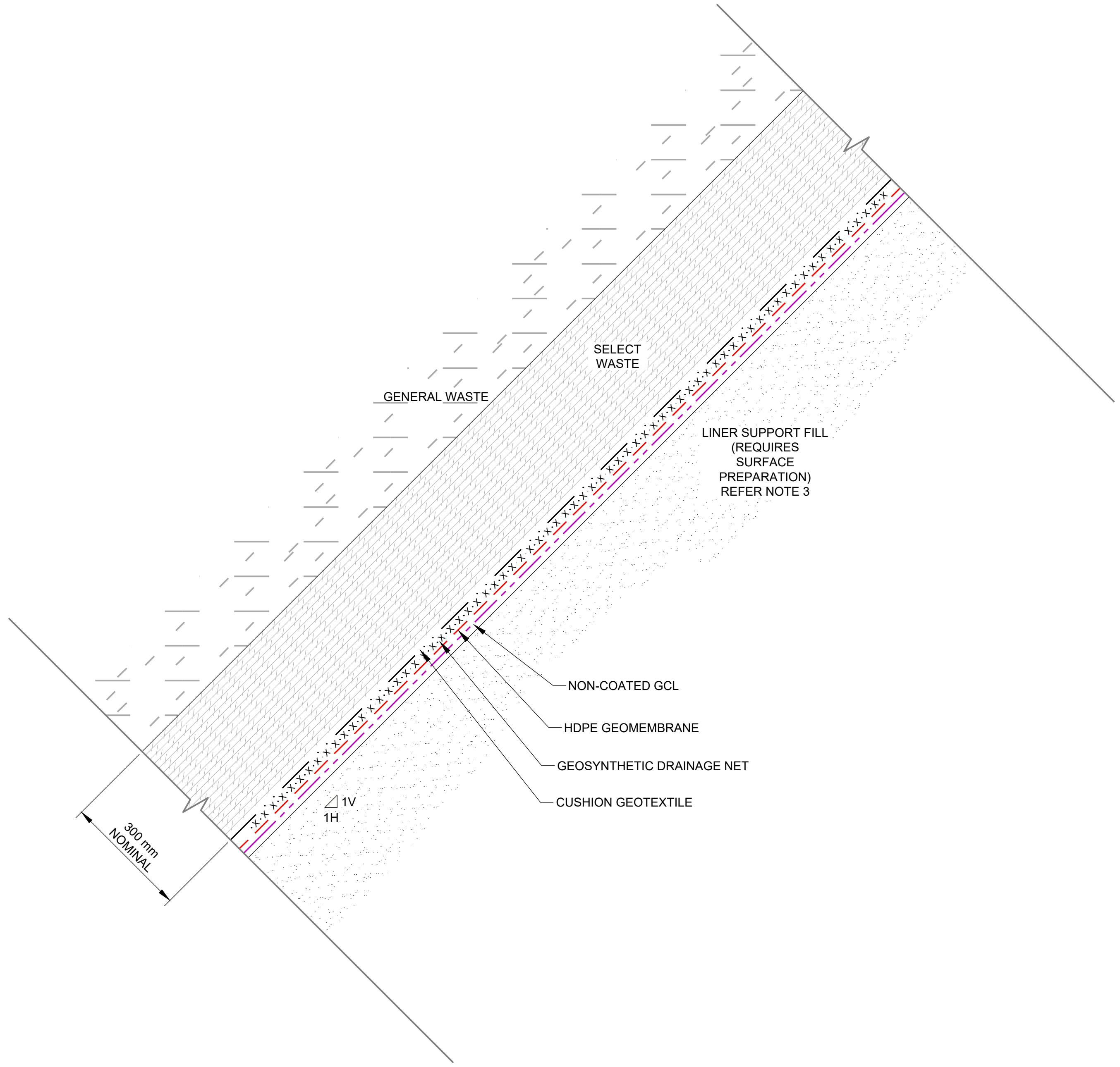
25 mm  IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

Path: \\golder.gds\gap\Brisbane\Geomatics\cleanaway\erskine_park\99_projects\19135652_erskinepark_mwsa_wall\005_detaileddesign\02_PRODUCTION\DWG | File Name: 19135652-005-042_045.dwg | Last Edited By: bkanther Date: 2020-04-08 Time:7:23:57 PM | Printed By: BKanther Date: 2020-04-08 Time:8:30:57 PM




## TYPICAL LINER DETAIL - OPTION 1

SCALE 1:15 m




## TYPICAL LINER DETAIL - OPTION 2

SCALE 1:15 m

**NOTE(S)**

1. FOR GENERAL NOTES, REFER TO DRAWING 001.
2. CLAY RICH MATERIAL INSTALLED AS OUTER EDGE OF LINER SUPPORT FILL.
3. REINFORCEMENT WITHIN LINER SUPPORT FILL NOT SHOWN FOR CLARITY. REFER TO DRAWINGS 040 TO 042.

NOT FOR CONSTRUCTION

**PRELIMINARY**

0 0.25 0.5
1:15 METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-04-08 | FOR APPROVAL | PR | BK/SD | GRS | GRS |

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PROJECT
ERSKINE PARK LANDFILL
MSE WALL DESIGN

TITLE
**TYPICAL LINER DETAILS**

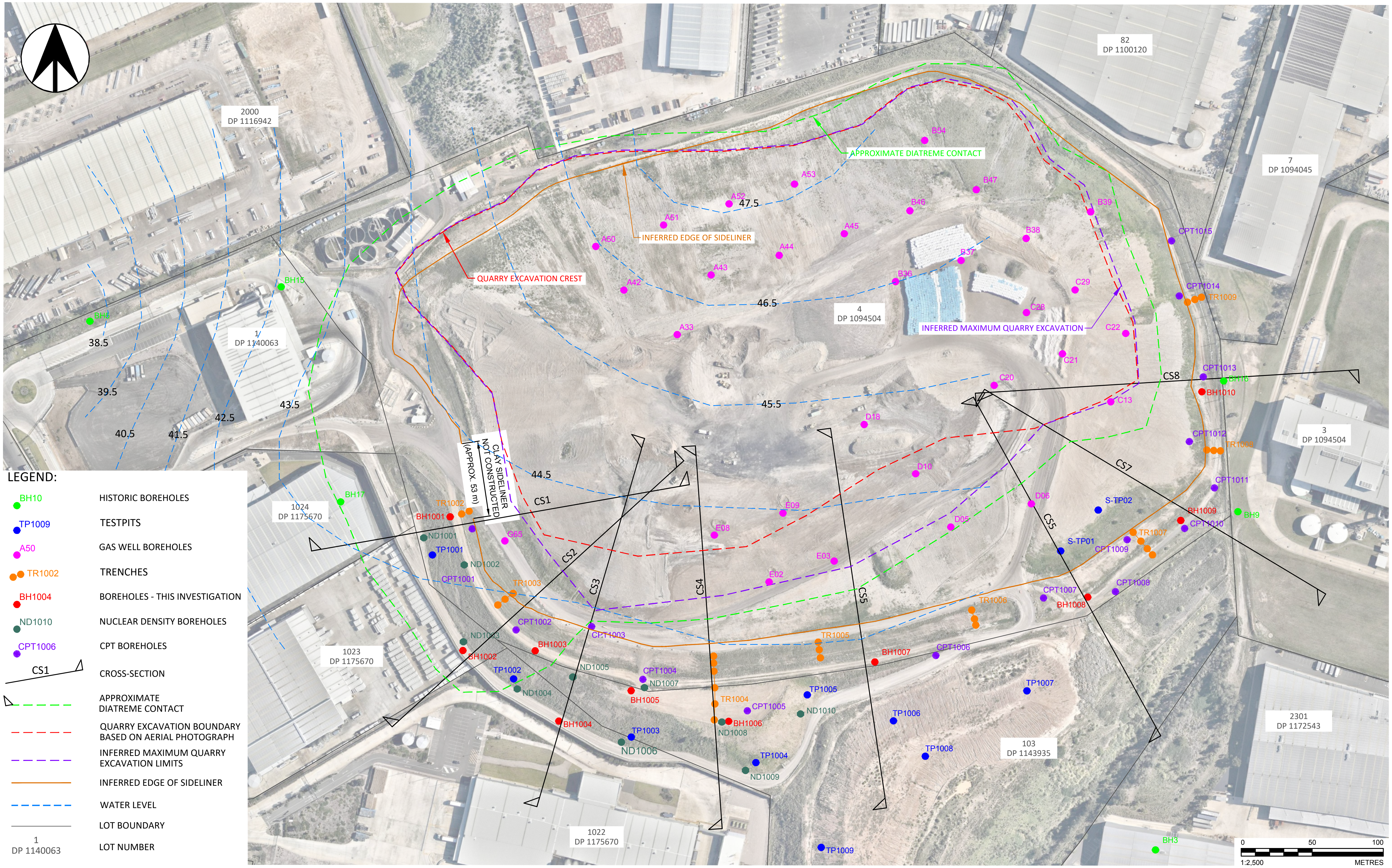
| PROJECT NO. | CONTROL | REV. | | DRAWING |
|---|---|---|---|---|
| 19135652 | 005 | A | 48 of 26 | 050 |

# APPENDIX B

## Not used

**APPENDIX C**

# Supporting Calculations




| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
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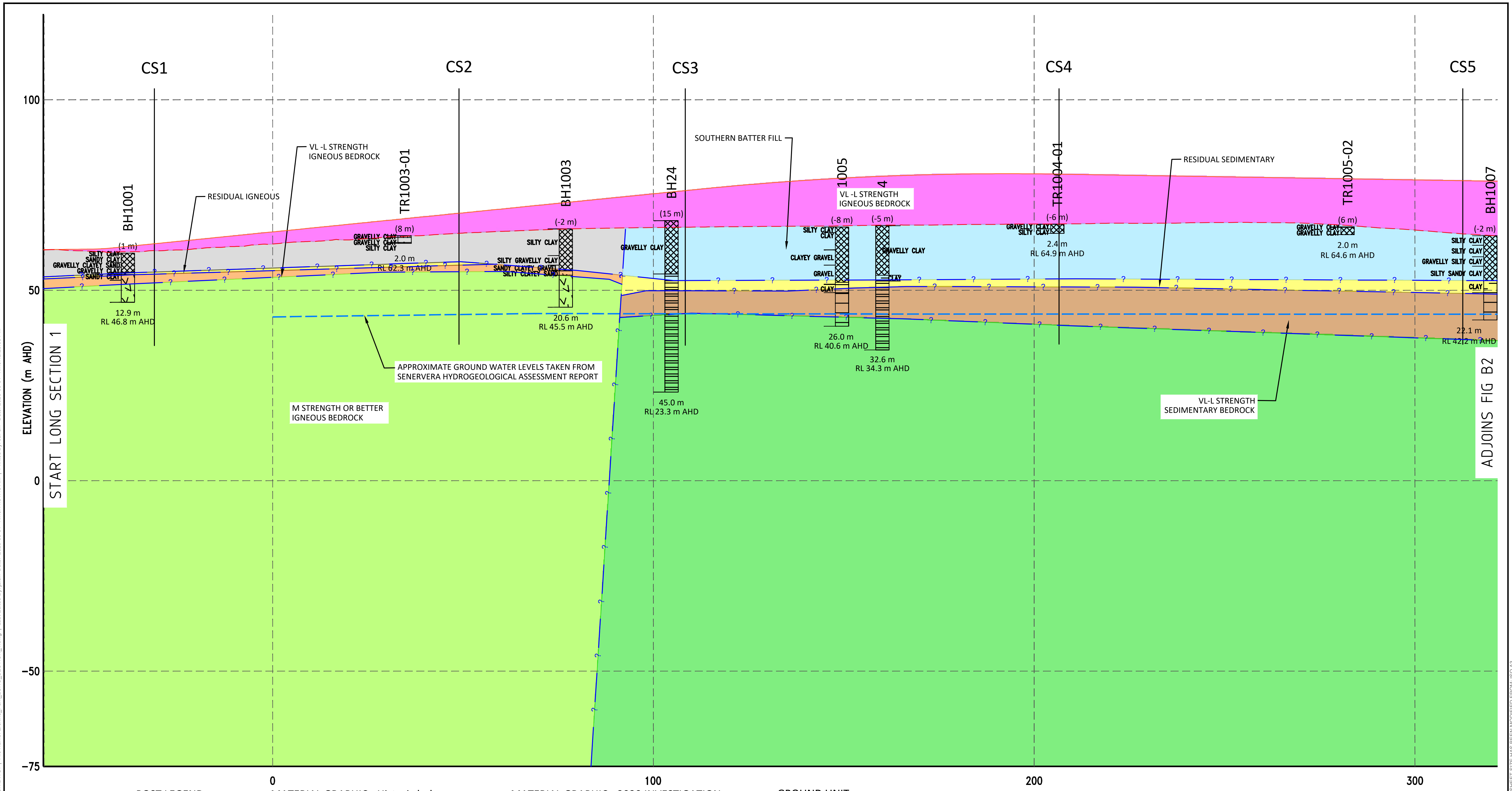
PROJECT
PROPOSED MSE RETAINING WALL
85-87 QUARRY ROAD, ERSKINE PARK NSW 2759

TITLE
**INFERRED SUBSURFACE**

| PROJECT NO. | CONTROL | REV. | of | FIGURE |
|---|---|---|---|---|
| 19130799 | 002 | A | | P-1 |

25 mm
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3




POST LEGEND

Baseline Offset
Material Name
MUDSTONE
BH #
(0 m)
Geology Unit 1
A
Depth and Elevation at EOH

MATERIAL GRAPHIC - Historic holes

- FILL
- SILTSTONE
- TOPSOIL
- Sandy CLAY
- CLAY
- Clayey GRAVEL
- DOLERITE
- SHALE
- WATER LEVEL
- EG-SURVEY_2019-12-04_FULL_SIMPLIFIED_1M

MATERIAL GRAPHIC - 2020 INVESTIGATION

- FILL Material
- Very Stiff Clay
- Very low and low strength Dolerite
- Medium strength or better Dolerite
- Very Low and Low strength Siltstone bedrock
- Medium strength Siltstone bedrock
- Very Low Strength Volcanic Breccia
- Medium Strength Volcanic Breccia

GROUND UNIT

- 1a - Fill
- 1b - Controlled Fill
- 1c - Landfill Waste
- 2 - Residual
- 3a - Very Low to Low Strength Igneous Bedrock
- 3b - Medium Strength Igneous Bedrock or better
- 4a - Very Low to Low Strength Sedimentary Bedrock
- 4b - Medium Strength Sedimentary Bedrock or Better
- 5 - Proposed MSE Retaining Wall by Golder

CS4
CROSS SECTION LOCATION

0 25 50
1:1,000 VERTICAL METRES

0 25 50
1:1,000 HORIZONTAL METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
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| A | 2020-02-28 | DRAFT | FY | FY | XX | XX | XXX |

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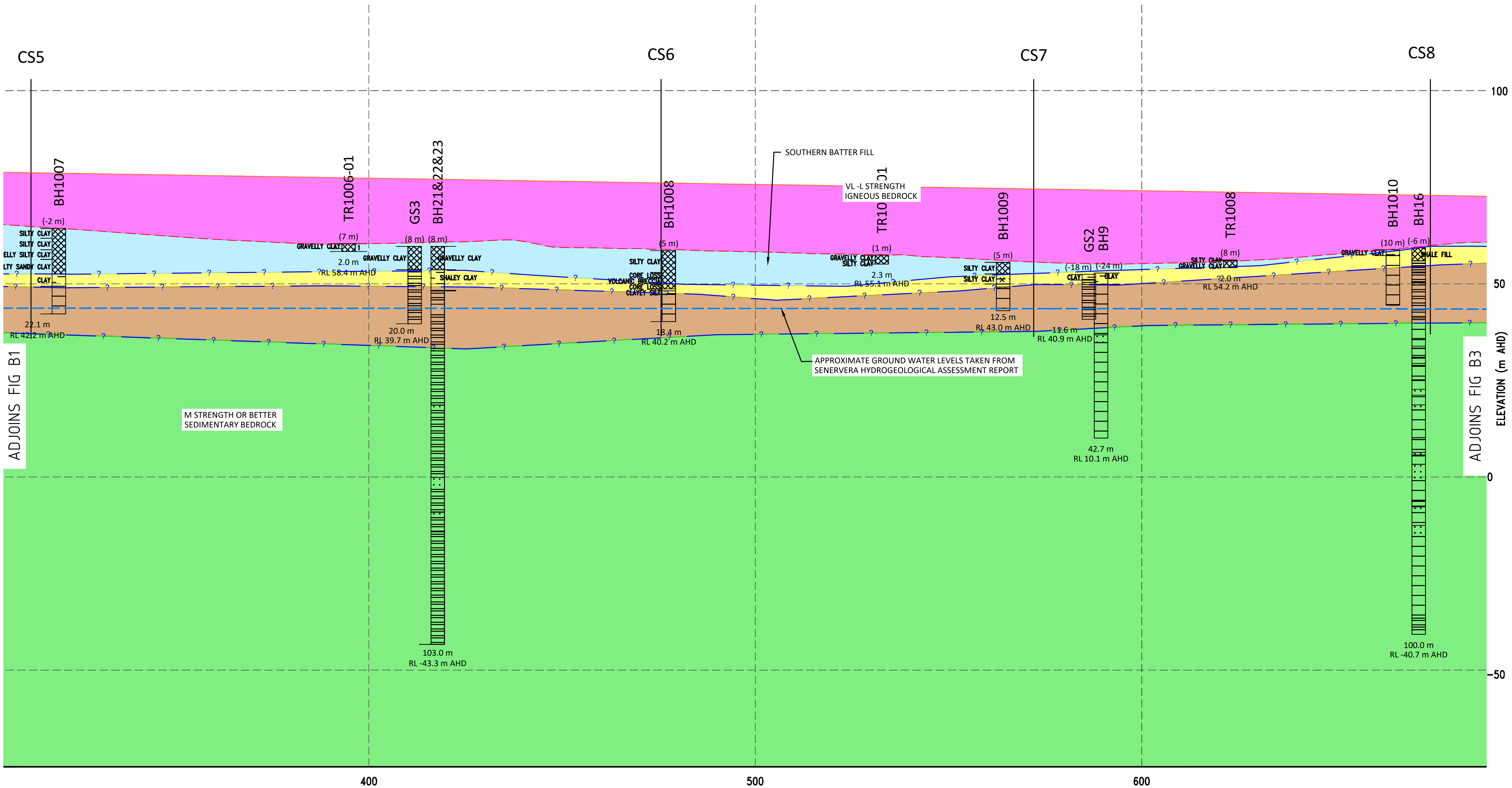
PROJECT
PROPOSED MSE RETAINING WALL
85-87 QUARRY ROAD, ERSKINE PARK NSW 2759

TITLE
**INFERRED SUBSURFACE LONG SECTION - LS1**
**0m - 315m**

| PROJECT NO. | CONTROL | REV. | of | FIGURE |
|---|---|---|---|---|
| 19135652 | 002 | A | | C1 |




POST LEGEND

BH #

Baseline Offset

Material Name

(0 m)

Geology Unit 1

MUDSTONE

A

Depth and Elevation at EOH

MATERIAL GRAPHIC - Historic holes

FILL
SILTSTONE
TOPSOIL
Sandy CLAY
CLAY
Clayey GRAVEL
DOLERITE
SHALE

WATER LEVEL

EG-SURVEY_2019-12-04_FULL_SIMPLIFIED_1M

MATERIAL GRAPHIC - 2020 INVESTIGATION

FILL Material
Very Stiff Clay
Very low and low strength Dolerite
Medium strength or better Dolerite
Very Low and Low strength Siltstone bedrock
Medium strength Siltstone bedrock
Very Low Strength Volcanic Breccia
Medium Strength Volcanic Breccia

GROUND UNIT

1a - Fill
1b - Controlled Fill
1c - Landfill Waste
2 - Residual
3a - Very Low to Low Strength Igneous Bedrock
3b - Medium Strength Igneous Bedrock or better
4a - Very Low to Low Strength Sedimentary Bedrock
4b - Medium Strength Sedimentary Bedrock or Better
5 - Proposed MSE Retaining Wall by Golder

CS4

CROSS SECTION LOCATION

0 25 50
1:1,000 VERTICAL METRES

0 25 50
1:1,000 HORIZONTAL METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-02-28 | DRAFT | FY | FY | XX | XX | XXX |

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PROJECT
PROPOSED MSE RETAINING WALL
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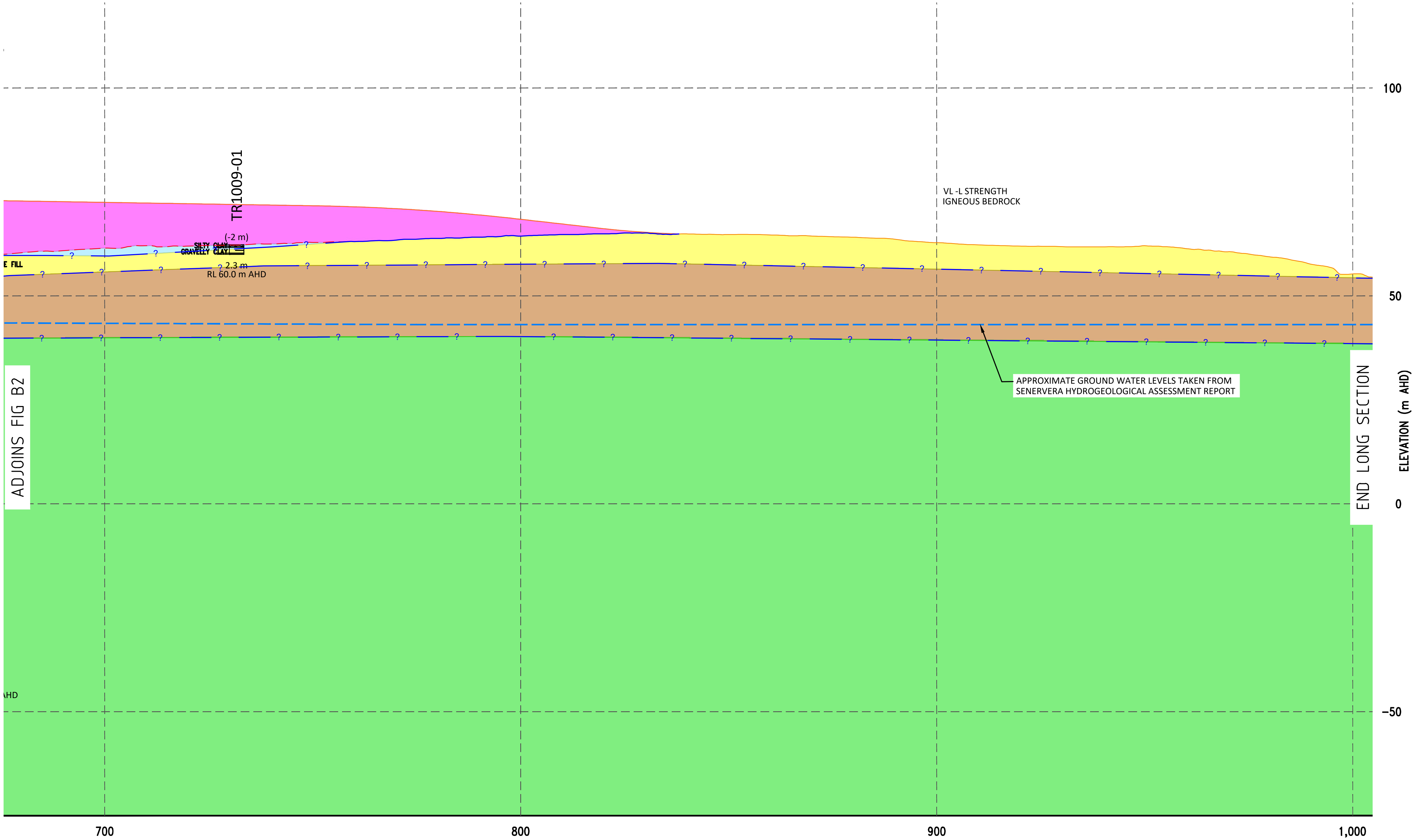
TITLE
**INFERRED SUBSURFACE LONG SECTION - LS1**
**315m - 675m**

| PROJECT NO. | CONTROL | REV. | of | FIGURE |
|---|---|---|---|---|
| 19135652 | 002 | A | | C2 |




POST LEGEND

BH #
Baseline Offset
Material Name
(0 m)
MUDSTONE
A
Geology Unit 1
Depth and Elevation at EOH

MATERIAL GRAPHIC - Historic holes

FILL, SILTSTONE, TOPSOIL, Sandy CLAY, CLAY, Clayey GRAVEL, DOLERITE, SHALE

WATER LEVEL

EG-SURVEY_2019-12-04_FULL_SIMPLIFIED_1M

MATERIAL GRAPHIC - 2020 INVESTIGATION

- FILL Material
- Very Stiff Clay
- Very low and low strength Dolerite
- Medium strength or better Dolerite
- Very Low and Low strength Siltstone bedrock
- Medium strength Siltstone bedrock
- Very Low Strength Volcanic Breccia
- Medium Strength Volcanic Breccia

GROUND UNIT

- 1a - Fill
- 1b - Controlled Fill
- 1c - Landfill Waste
- 2 - Residual
- 3a - Very Low to Low Strength Igneous Bedrock
- 3b - Medium Strength Igneous Bedrock or better
- 4a - Very Low to Low Strength Sedimentary Bedrock
- 4b - Medium Strength Sedimentary Bedrock or Better
- 5 - Proposed MSE Retaining Wall by Golder

CS4

CROSS SECTION LOCATION

0 25 50
1:1,000 VERTICAL METRES

0 25 50
1:1,000 HORIZONTAL METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-02-28 | DRAFT | FY | FY | XX | XX | XXX |

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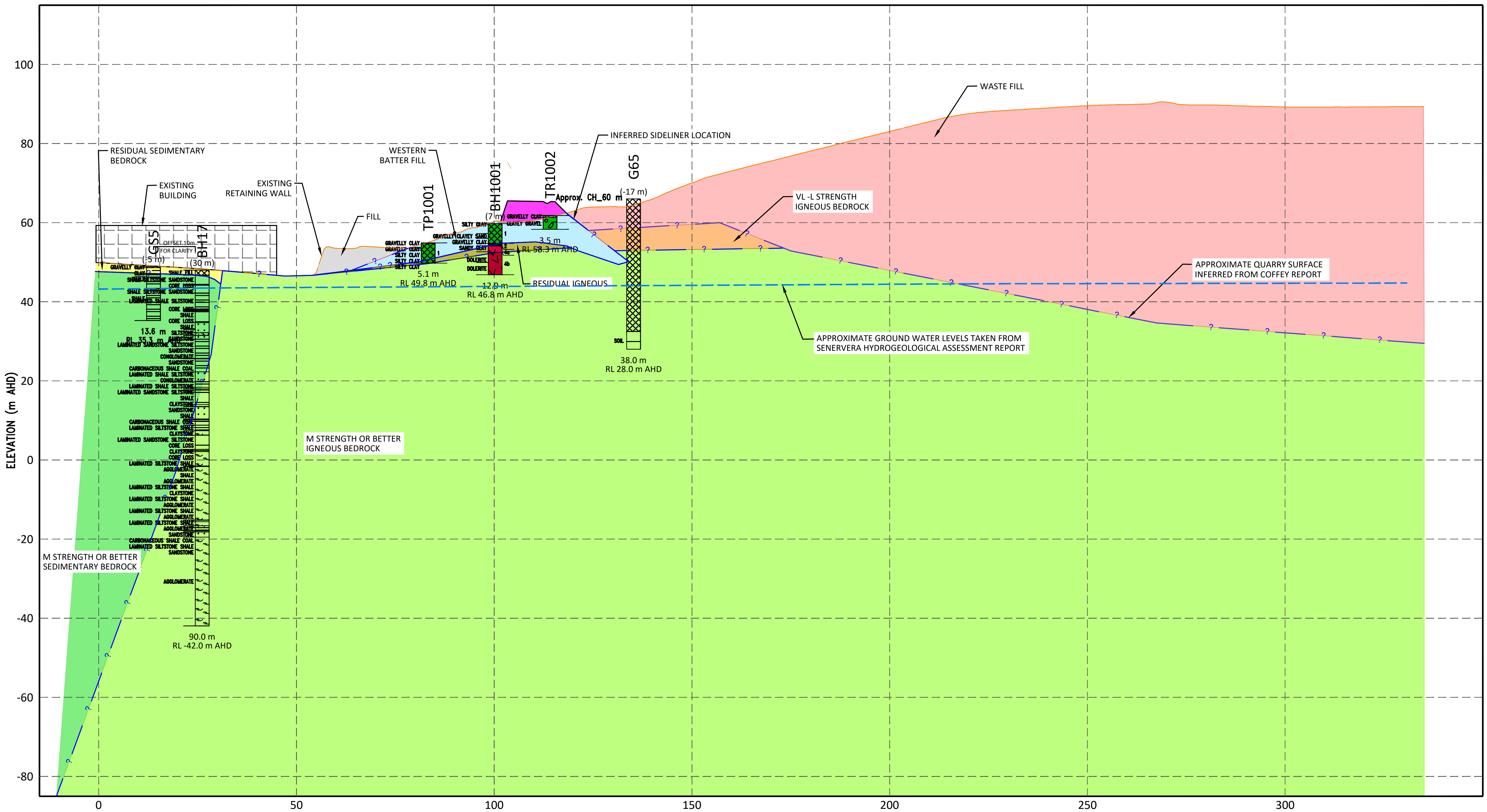
85-87 QUARRY ROAD, ERSKINE PARK NSW 2759

TITLE
**INFERRED SUBSURFACE LONG SECTION - LS1**
**675m - 1,000m**

| PROJECT NO. | CONTROL | REV. | of | FIGURE |
|---|---|---|---|---|
| 19135652 | 002 | A | | C3 |




POST LEGEND

BH #
Baseline Offset (0 m)
Material Name
MUDSTONE
Geology Unit 1
A
Depth and Elevation at EOH

MATERIAL GRAPHIC - Historic holes

- FILL
- SILTSTONE
- TOPSOIL
- Sandy CLAY
- CLAY
- Clayey GRAVEL
- DOLERITE
- SHALE
- WATER LEVEL
- EG-SURVEY_2019-12-04_FULL_SIMPLIFIED_1M

MATERIAL GRAPHIC - 2020 INVESTIGATION

- FILL Material
- Very Stiff Clay
- Very low and low strength Dolerite
- Medium strength or better Dolerite
- Very Low and Low strength Siltstone bedrock
- Medium strength Siltstone bedrock
- Very Low Strength Volcanic Breccia
- Medium Strength Volcanic Breccia

GROUND UNIT

- 1a - Fill
- 1b - Controlled Fill
- 1c - Landfill Waste
- 2 - Residual
- 3a - Very Low to Low Strength Igneous Bedrock
- 3b - Medium Strength Igneous Bedrock or better
- 4a - Very Low to Low Strength Sedimentary Bedrock
- 4b - Medium Strength Sedimentary Bedrock or Better
- 5 - Proposed MSE Retaining Wall by Golder

0 25 50
1:1,000 VERTICAL METRES

0 25 50
1:1,000 HORIZONTAL METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-02-28 | DRAFT | FY | FY | XX | XX |

XXX

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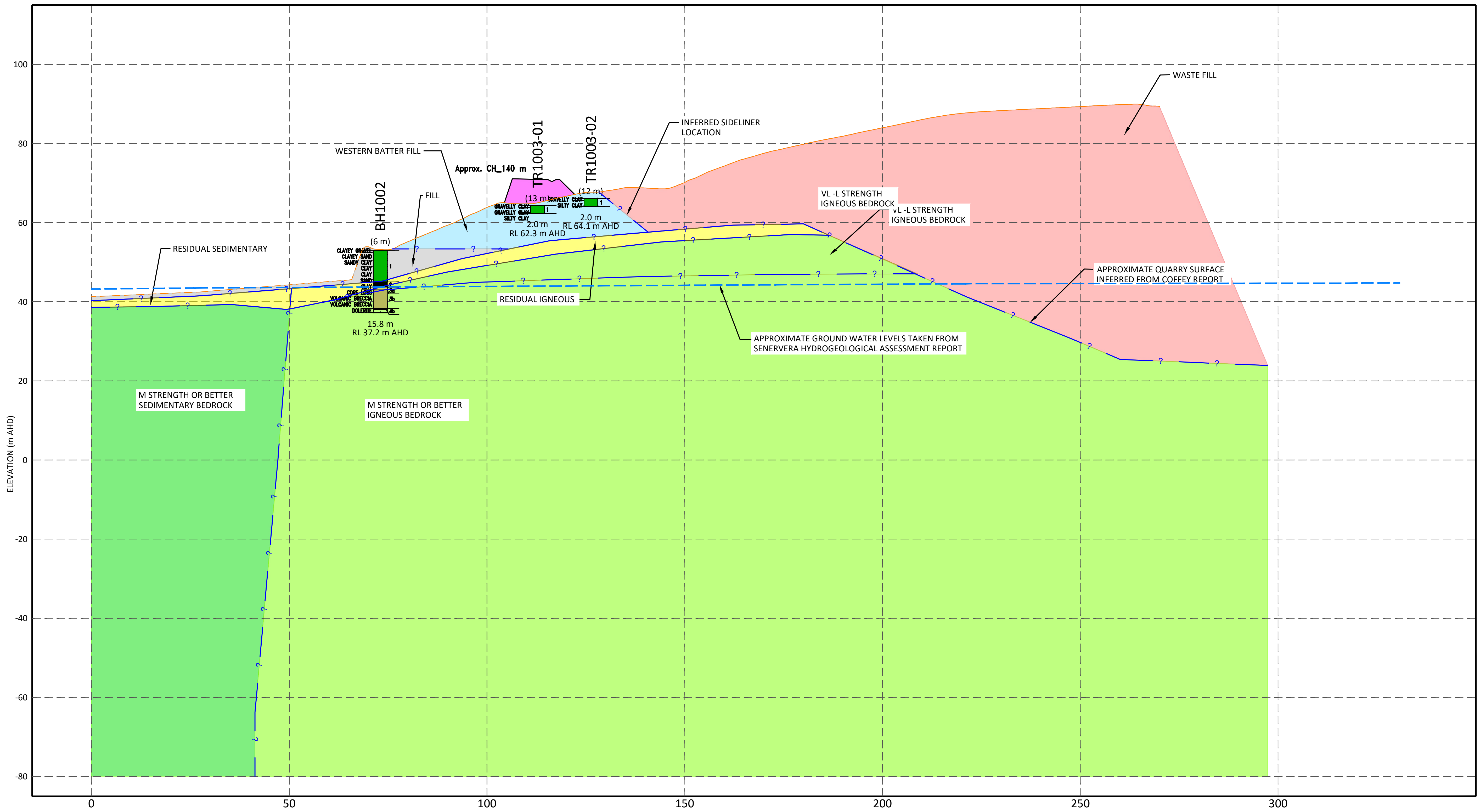
PROJECT
PROPOSED MSE RETAINING WALL
85-87 QUARRY ROAD, ERSKINE PARK NSW 2759

TITLE
**INFERRED SUBSURFACE SECTION - CS1**

| PROJECT NO. | CONTROL | REV. | of | FIGURE |
|---|---|---|---|---|
| 19135652 | 002 | A | | B-1 |




## POST LEGEND

Baseline Offset
Material Name
MUDSTONE
BH #
(0 m)
A
Geology Unit 1
Depth and Elevation at EOH

## MATERIAL GRAPHIC - Historic holes

- FILL
- SILTSTONE
- TOPSOIL
- Sandy CLAY
- CLAY
- Clayey GRAVEL
- DOLERITE
- SHALE
- WATER LEVEL
- EG-SURVEY_2019-12-04_FULL_SIMPLIFIED_1M

## MATERIAL GRAPHIC - 2020 INVESTIGATION

- FILL Material
- Very Stiff Clay
- Very low and low strength Dolerite
- Medium strength or better Dolerite
- Very Low and Low strength Siltstone bedrock
- Medium strength Siltstone bedrock
- Very Low Strength Volcanic Breccia
- Medium Strength Volcanic Breccia

## GROUND UNIT

- 1a - Fill
- 1b - Controlled Fill
- 1c - Landfill Waste
- 2 - Residual
- 3a - Very Low and Low Sedimentary Bedrock
- 3b - Medium Strength Sedimentary Bedrock or better
- 4a - Very Low and Low Sedimentary Bedrock
- 4b - Medium Strength Sedimentary Bedrock or better
- 5 - Proposed MSE Retaining Wall by Golder

0 25 50
1:1,000 VERTICAL METRES

0 25 50
1:1,000 HORIZONTAL METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-02-28 | DRAFT | FY | FY | XX | XX XXX |

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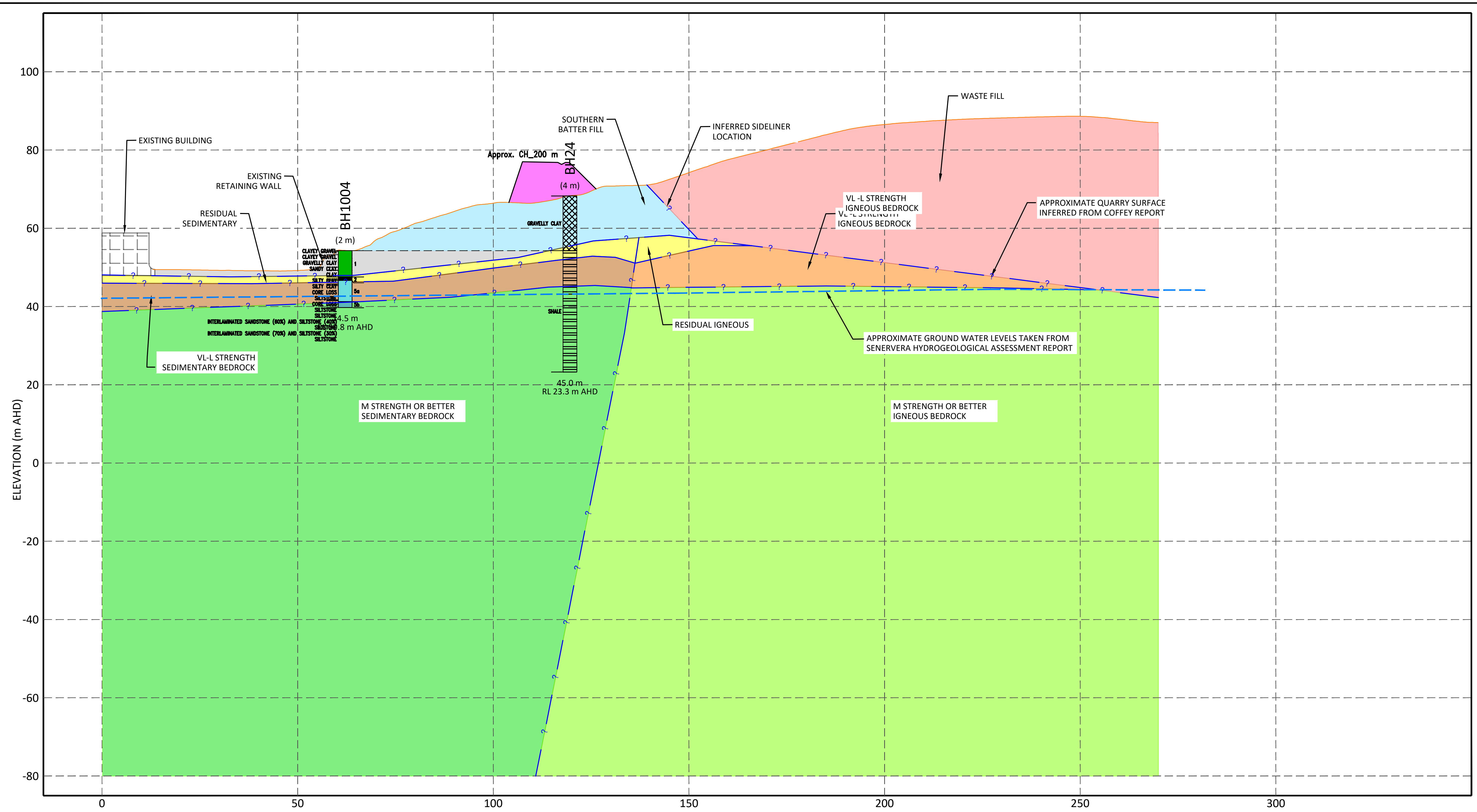
PROJECT
PROPOSED MSE RETAINING WALL
85-87 QUARRY ROAD, ERSKINE PARK NSW 2759

TITLE
**INFERRED SUBSURFACE SECTION - CS2**

| PROJECT NO. | CONTROL | REV. | of | FIGURE |
|---|---|---|---|---|
| 19135652 | 002 | A | | B-2 |




**POST LEGEND**

BH #
Baseline Offset
Material Name
(0 m)
MUDSTONE
Geology Unit 1
Depth and Elevation at EOH

**MATERIAL GRAPHIC - Historic holes**

- FILL
- SILTSTONE
- TOPSOIL
- Sandy CLAY
- CLAY
- Clayey GRAVEL
- DOLERITE
- SHALE
- WATER LEVEL
- EG-SURVEY_2019-12-04_FULL_SIMPLIFIED_1M

**MATERIAL GRAPHIC - 2020 INVESTIGATION**

- FILL Material
- Very Stiff Clay
- Very low and low strength Dolerite
- Medium strength or better Dolerite
- Very Low and Low strength Siltstone bedrock
- Medium strength Siltstone bedrock
- Very Low Strength Volcanic Breccia
- Medium Strength Volcanic Breccia

**GROUND UNIT**

- 1a - Fill
- 1b - Controlled Fill
- 1c - Landfill Waste
- 2 - Residual
- 3a - Very Low and Low Sedimentary Bedrock
- 3b - Medium Strength Sedimentary Bedrock or better
- 4a - Very Low and Low Sedimentary Bedrock
- 4b - Medium Strength Sedimentary Bedrock or better
- 5 - Proposed MSE Retaining Wall by Golder

0 25 50
1:1,000 VERTICAL METRES

0 25 50
1:1,000 HORIZONTAL METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-02-28 | DRAFT | FY | FY | XX | XX XXX |

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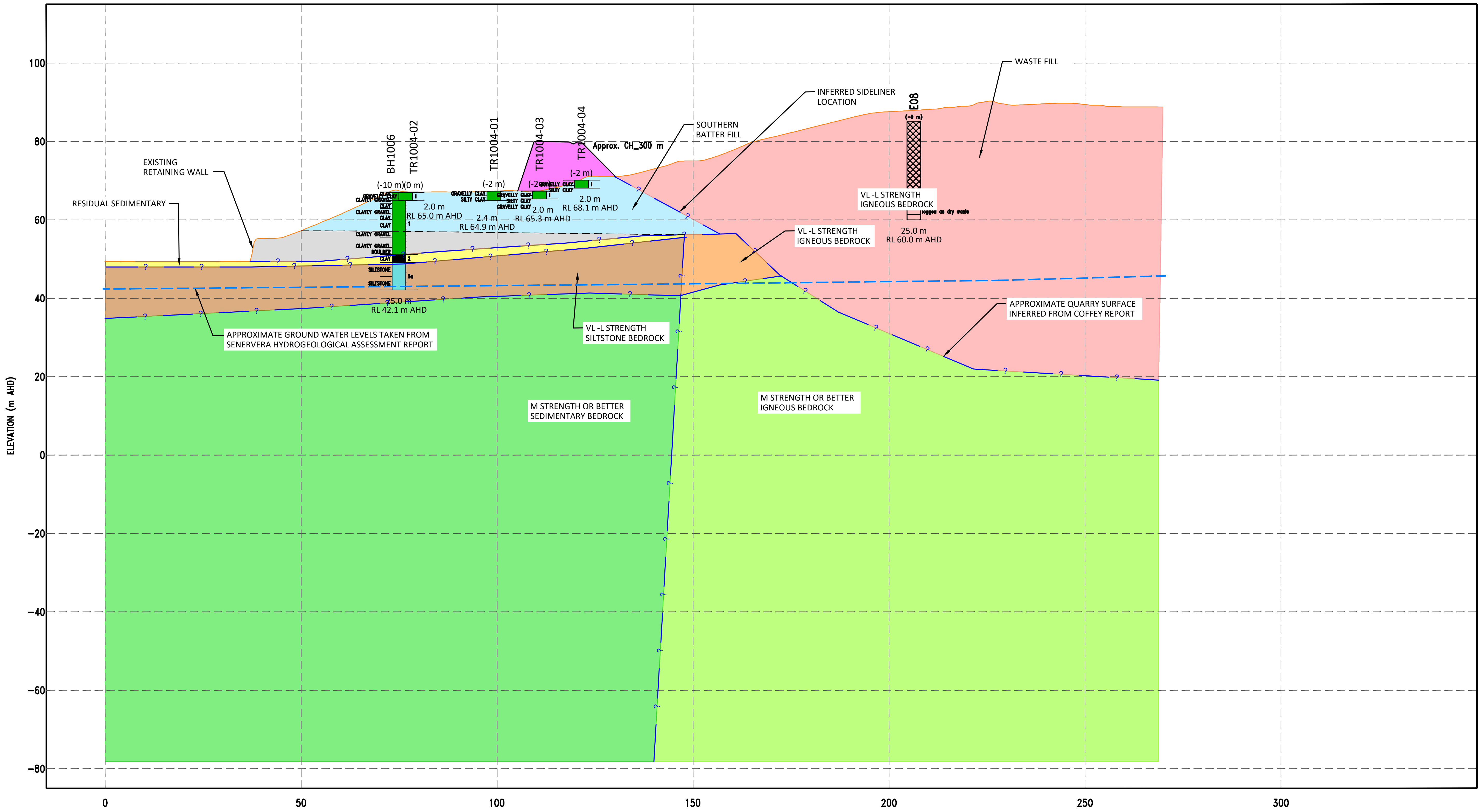
PROJECT
PROPOSED MSE RETAINING WALL
85-87 QUARRY ROAD, ERSKINE PARK NSW 2759

TITLE
**INFERRED SUBSURFACE SECTION - CS3**

| PROJECT NO. | CONTROL | REV. | of | FIGURE |
|---|---|---|---|---|
| 19135652 | 002 | A | | B-3 |




POST LEGEND

Baseline Offset
Material Name
MUDSTONE
BH #
(0 m)
Geology Unit 1
A
Depth and Elevation at EOH

MATERIAL GRAPHIC - Historic holes

- FILL
- SILTSTONE
- TOPSOIL
- Sandy CLAY
- CLAY
- Clayey GRAVEL
- DOLERITE
- SHALE
- WATER LEVEL
- EG-SURVEY_2019-12-04_FULL_SIMPLIFIED_1M

MATERIAL GRAPHIC - 2020 INVESTIGATION

- FILL Material
- Very Stiff Clay
- Very low and low strength Dolerite
- Medium strength or better Dolerite
- Very Low and Low strength Siltstone bedrock
- Medium strength Siltstone bedrock
- Very Low Strength Volcanic Breccia
- Medium Strength Volcanic Breccia

GROUND UNIT

- 1a - Fill
- 1b - Controlled Fill
- 1c - Landfill Waste
- 2 - Residual
- 3a - Very Low and Low Sedimentary Bedrock
- 3b - Medium Strength Sedimentary Bedrock or better
- 4a - Very Low and Low Sedimentary Bedrock
- 4b - Medium Strength Sedimentary Bedrock or better
- 5 - Proposed MSE Retaining Wall by Golder

0 25 50
1:1,000 VERTICAL METRES

0 25 50
1:1,000 HORIZONTAL METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-02-28 | DRAFT | FY | FY | XX | XX |

XXX

CLIENT
ENVIROGUARD PTY LTD

CONSULTANT
GOLDER

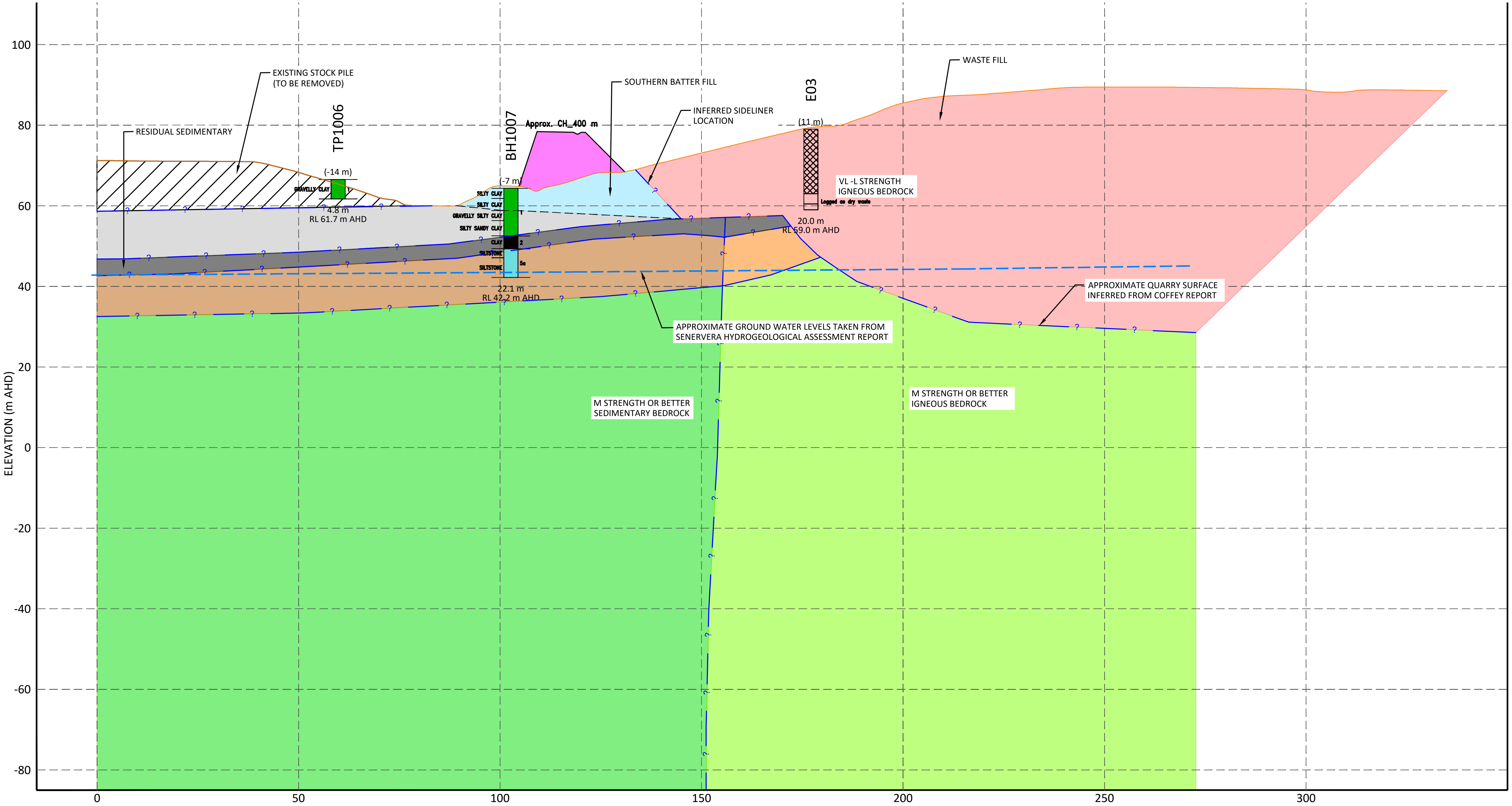
SYDNEY OFFICE
LEVEL 8, 40 MOUNT STREET
NORTH SYDNEY, NSW 2060
AUSTRALIA
[+61] (02) 9478 3900
www.golder.com

PROJECT
PROPOSED MSE RETAINING WALL
85-87 QUARRY ROAD, ERSKINE PARK NSW 2759

TITLE
**INFERRED SUBSURFACE SECTION - CS4**

| PROJECT NO. | CONTROL | REV. | of | FIGURE |
|---|---|---|---|---|
| 1913562 | 002 | A | | B-4 |

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3
25 mm




## POST LEGEND

Baseline Offset
Material Name
MUDSTONE
BH #
(0 m)
Geology Unit 1
A
Depth and Elevation at EOH

## MATERIAL GRAPHIC - Historic holes

- FILL
- SILTSTONE
- TOPSOIL
- Sandy CLAY
- CLAY
- Clayey GRAVEL
- DOLERITE
- SHALE
- WATER LEVEL
- EG-SURVEY_2019-12-04_FULL_SIMPLIFIED_1M

## MATERIAL GRAPHIC - 2020 INVESTIGATION

- FILL Material
- Very Stiff Clay
- Very low and low strength Dolerite
- Medium strength or better Dolerite
- Very Low and Low strength Siltstone bedrock
- Medium strength Siltstone bedrock
- Very Low Strength Volcanic Breccia
- Medium Strength Volcanic Breccia

## GROUND UNIT

- 1a - Fill
- 1b - Controlled Fill
- 1c - Landfill Waste
- 2 - Residual
- 3a - Very Low and Low Sedimentary Bedrock
- 3b - Medium Strength Sedimentary Bedrock or better
- 4a - Very Low and Low Sedimentary Bedrock
- 4b - Medium Strength Sedimentary Bedrock or better
- 5 - Proposed MSE Retaining Wall by Golder

0 25 50
1:1,000 VERTICAL METRES

0 25 50
1:1,000 HORIZONTAL METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-02-28 | DRAFT | FY | FY | XX | XX XXX |

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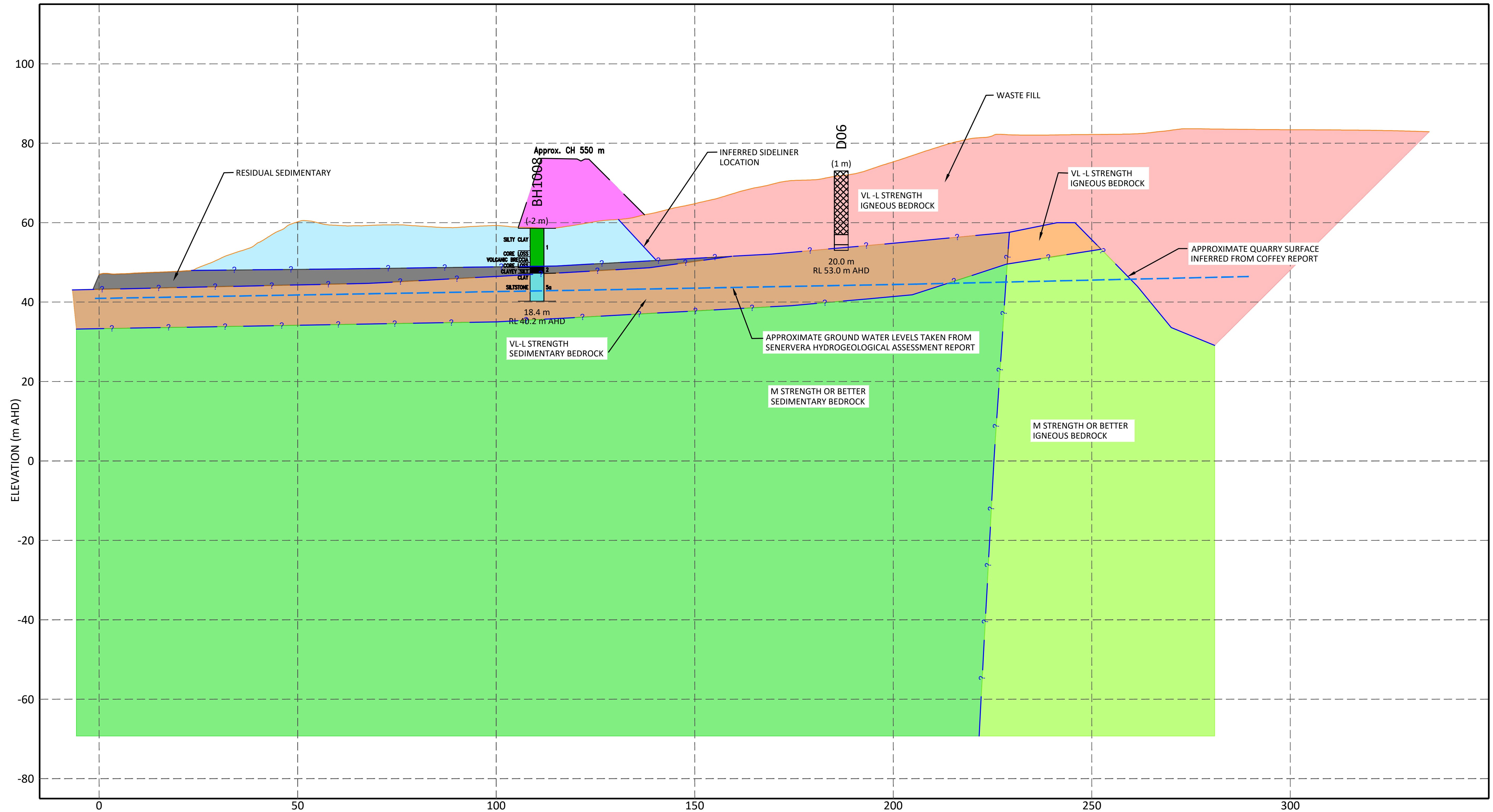
PROJECT
PROPOSED MSE RETAINING WALL
85-87 QUARRY ROAD, ERSKINE PARK NSW 2759

TITLE
**INFERRED SUBSURFACE SECTION - CS5**

| PROJECT NO. | CONTROL | REV. | of | FIGURE |
|---|---|---|---|---|
| 19135652 | 002 | A | | B-5 |

25 mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3




**POST LEGEND**

Baseline Offset
Material Name
MUDSTONE
BH #
(0 m)
A
Geology Unit 1
Depth and Elevation at EOH

**MATERIAL GRAPHIC - Historic holes**

- FILL
- SILTSTONE
- TOPSOIL
- Sandy CLAY
- CLAY
- Clayey GRAVEL
- DOLERITE
- SHALE
- WATER LEVEL
- EG-SURVEY_2019-12-04_FULL_SIMPLIFIED_1M

**MATERIAL GRAPHIC - 2020 INVESTIGATION**

- FILL Material
- Very Stiff Clay
- Very low and low strength Dolerite
- Medium strength or better Dolerite
- Very Low and Low strength Siltstone bedrock
- Medium strength Siltstone bedrock
- Very Low Strength Volcanic Breccia
- Medium Strength Volcanic Breccia

**GROUND UNIT**

- 1a - Fill
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- 1c - Landfill Waste
- 2 - Residual
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- 4a - Very Low and Low Sedimentary Bedrock
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- 5 - Proposed MSE Retaining Wall by Golder

0 25 50
1:1,000 VERTICAL METRES

0 25 50
1:1,000 HORIZONTAL METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-02-28 | DRAFT | FY | FY | XX | XX | XXX |

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PROJECT
PROPOSED MSE RETAINING WALL
85-87 QUARRY ROAD, ERSKINE PARK NSW 2759

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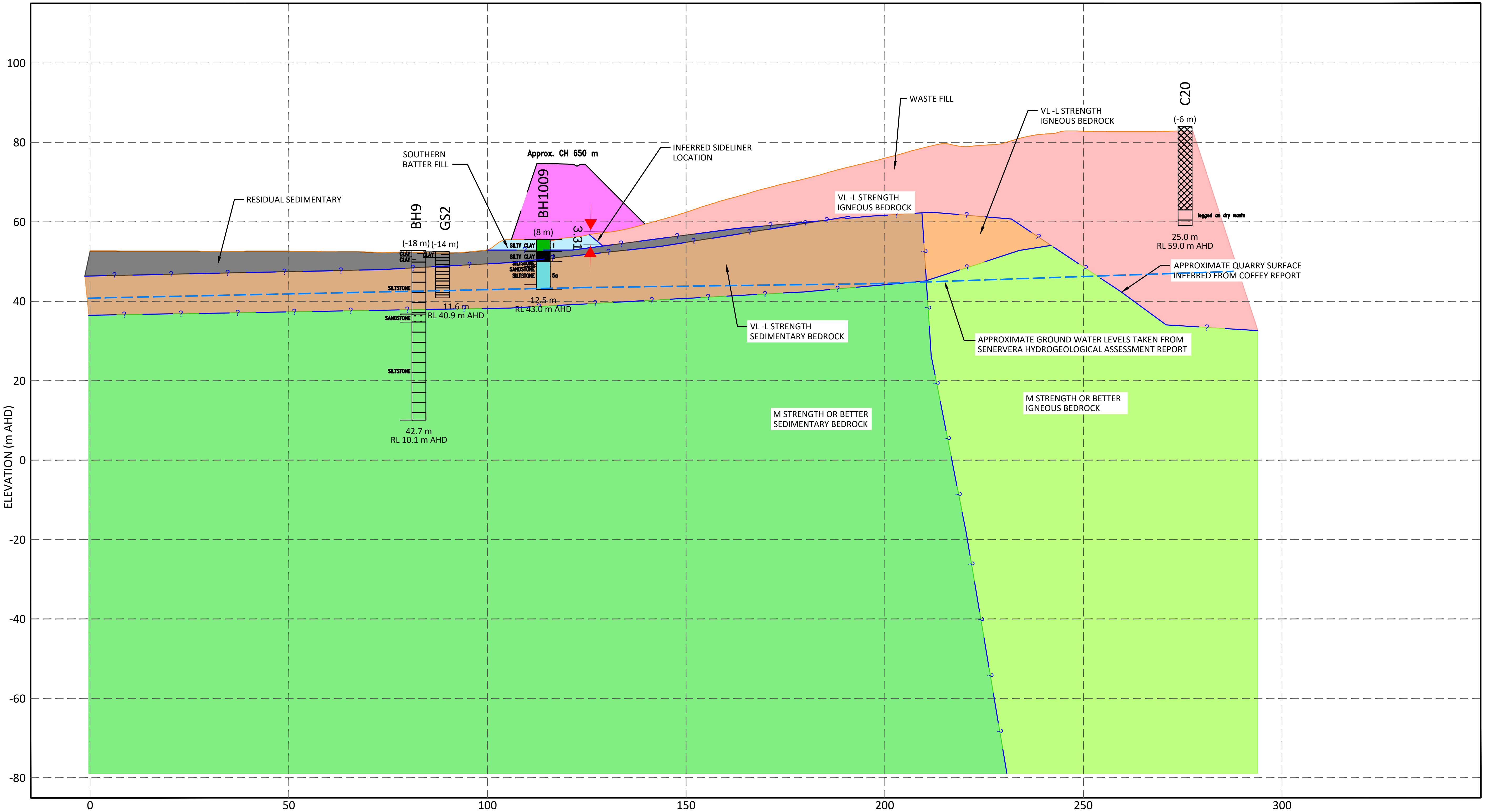
TITLE
**INFERRED SUBSURFACE SECTION - CS6**

| PROJECT NO. | CONTROL | REV. | of | FIGURE |
|---|---|---|---|---|
| 19135652 | 002 | A | | B-6 |

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ISO A3

25 mm




POST LEGEND

Baseline Offset
Material Name
BH #
(0 m)
Geology Unit 1
MUDSTONE
A
Depth and Elevation at EOH

MATERIAL GRAPHIC - Historic holes

- FILL
- SILTSTONE
- TOPSOIL
- Sandy CLAY
- CLAY
- Clayey GRAVEL
- DOLERITE
- SHALE

WATER LEVEL

EG-SURVEY_2019-12-04_FULL_SIMPLIFIED_1M

MATERIAL GRAPHIC - 2020 INVESTIGATION

- FILL Material
- Very Stiff Clay
- Very low and low strength Dolerite
- Medium strength or better Dolerite
- Very Low and Low strength Siltstone bedrock
- Medium strength Siltstone bedrock
- Very Low Strength Volcanic Breccia
- Medium Strength Volcanic Breccia

GROUND UNIT

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1:1,000 HORIZONTAL METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
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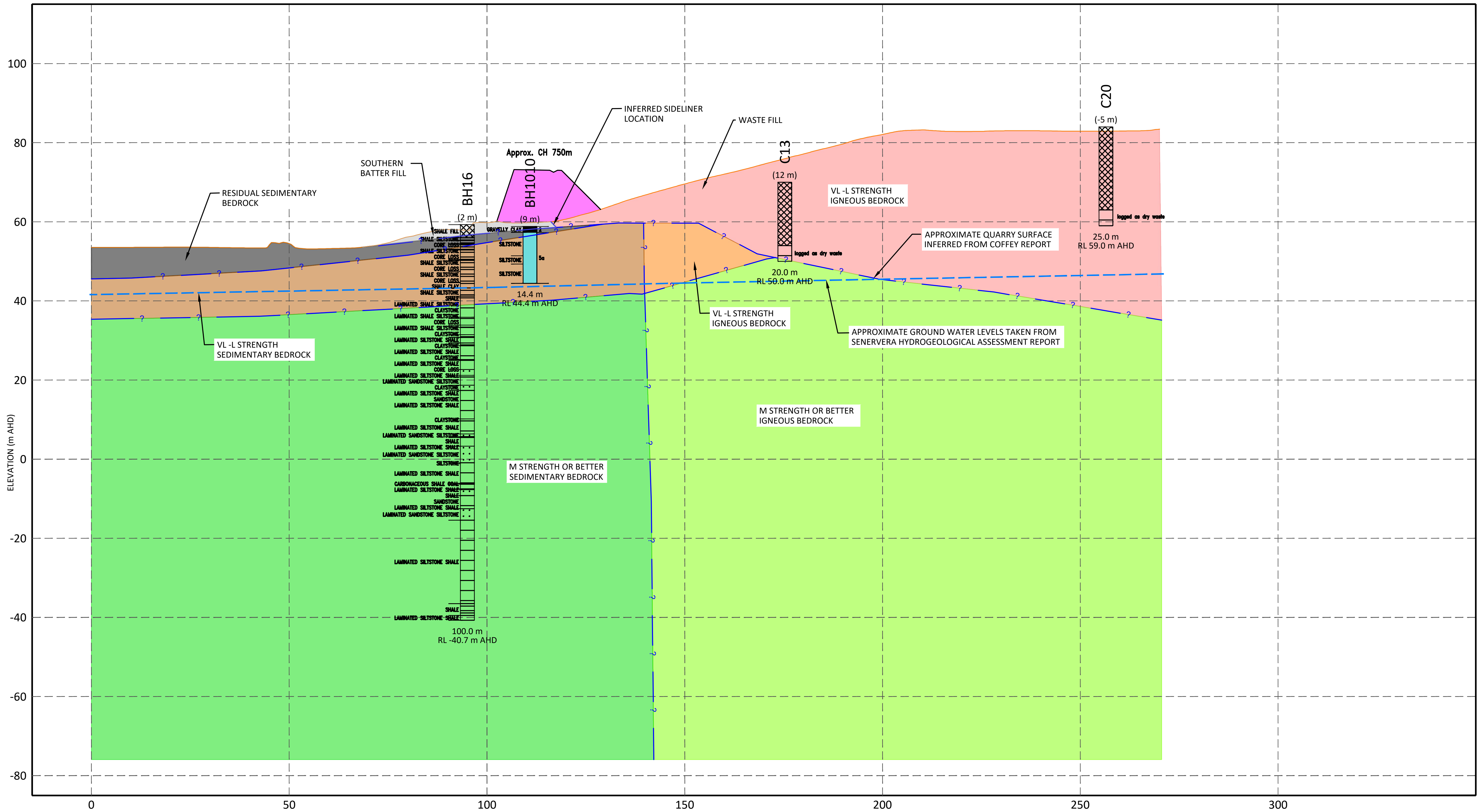
85-87 QUARRY ROAD, ERSKINE PARK NSW 2759

TITLE
**INFERRED SUBSURFACE SECTION - CS7**

| PROJECT NO. | CONTROL | REV. | of | FIGURE |
|---|---|---|---|---|
| 19135652 | 002 | A | | B-7 |




**POST LEGEND**

BH #
Baseline Offset
Material Name
(0 m)
Geology Unit 1
MUDSTONE A
Depth and Elevation at EOH

**MATERIAL GRAPHIC - Historic holes**

- FILL
- SILTSTONE
- TOPSOIL
- Sandy CLAY
- CLAY
- Clayey GRAVEL
- DOLERITE
- SHALE
- WATER LEVEL
- EG-SURVEY_2019-12-04_FULL_SIMPLIFIED_1M

**MATERIAL GRAPHIC - 2020 INVESTIGATION**

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- Medium strength or better Dolerite
- Very Low and Low strength Siltstone bedrock
- Medium strength Siltstone bedrock
- Very Low Strength Volcanic Breccia
- Medium Strength Volcanic Breccia

**GROUND UNIT**

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- 1c - Landfill Waste
- 2 - Residual
- 3a - Very Low and Low Sedimentary Bedrock
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- 5 - Proposed MSE Retaining Wall by Golder

0 25 50
1:1,000 VERTICAL METRES
0 25 50
1:1,000 HORIZONTAL METRES

| REV. | YYYY-MM-DD | DESCRIPTION | DESIGNED | PREPARED | REVIEWED | APPROVED |
|---|---|---|---|---|---|---|
| A | 2020-02-28 | DRAFT | FY | FY | XX | XX | XXX |

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PROJECT
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85-87 QUARRY ROAD, ERSKINE PARK NSW 2759

TITLE
**INFERRED SUBSURFACE SECTION - CS8**

| PROJECT NO. | CONTROL | REV. | of | FIGURE |
|---|---|---|---|---|
| 19135652 | 002 | A | | B-8 |

Global Synthetics
Australian Company – Global Expertise

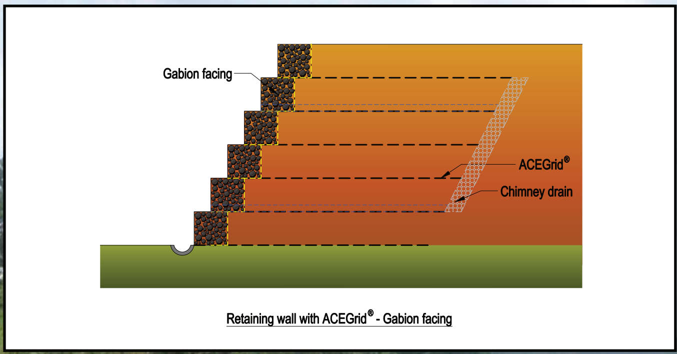
# WOVEN POLYESTER HIGH PERFORMANCE GEOGRID ACEGrid® the proven choice for:

## LONG TERM SOIL REINFORCEMENT IN APPLICATIONS OF

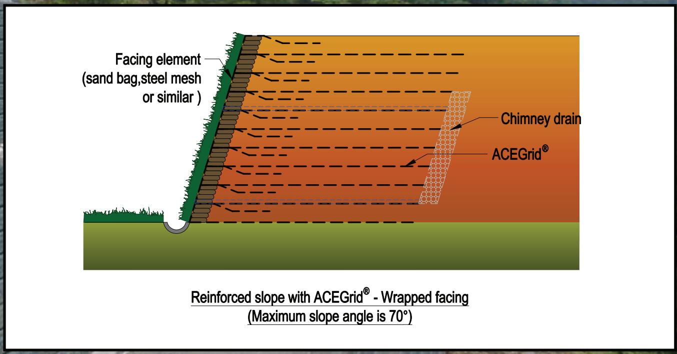
- STEEPENED REINFORCED SLOPES
- RETAINING WALLS
- VENEER REINFORCEMENT FOR LANDFILLS
- SOIL REINFORCEMENT OVER PILED FOUNDATIONS
- SUPPORT OVER VOIDS
- CAPPING OF TAILINGS PONDS
- BASAL REINFORCEMENT OF SOFT SOILS

*and other applications where soil will benefit from the inclusion of a tensile element for additional load carrying capacity.*

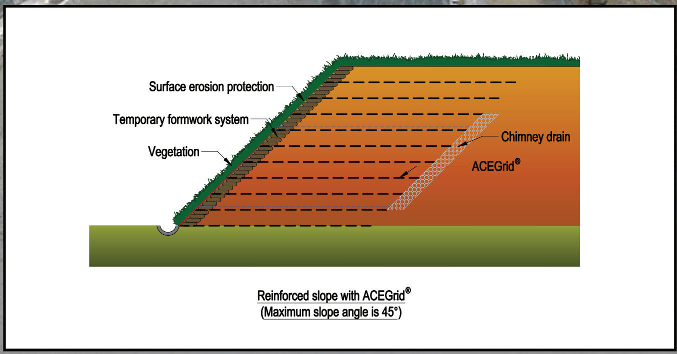
Significant ACEGrid® soil reinforced structure for highway reconstruction works.




Retaining wall with ACEGrid® - Gabion facing

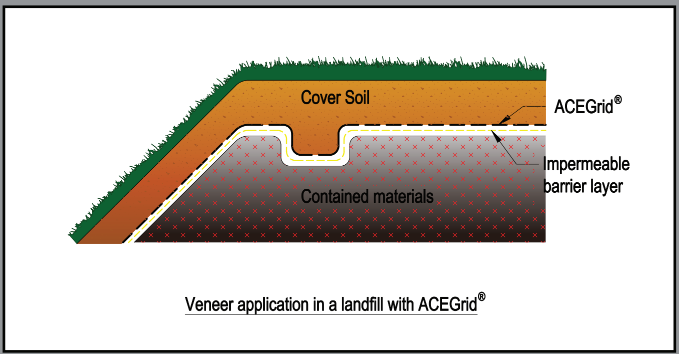



Reinforced slope with ACEGrid® - Wrapped facing
(Maximum slope angle is 70°)

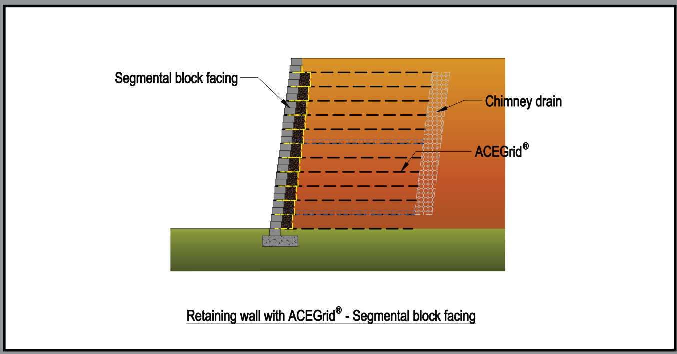



Reinforced slope with ACEGrid®
(Maximum slope angle is 45°)

# Global Synthetics proudly brings you ACEGrid®




Veneer application in a landfill with ACEGrid®




Retaining wall with ACEGrid® - Segmental block facing

ACEGrid® is an engineered woven geogrid that has exceptionally high strength characteristics at low levels of strain. The product is additionally coated with a polymer that provides high resistance to degradation in soil environments as well as providing additional UV and mechanical damage protection to the fibres. The ACEGrid® geogrids may be constructed with tensile strengths up to 900 kN/m. Strains generated at ultimate tensile strength are typically less than 10%. Being composed of high tenacity polyester fibres they deliver low creep strains when subject to high tensile loads. Creep strains of less than 1% at design loads of 40% of the initial characteristic tensile strength at 120 year design life, are obtained.

ACEGrid® is made from high tenacity polyester fibres that have a demonstrated history of performance both here in Australia and around the world. ACEGrid® has the ability to carry significant loads imposed upon the product from a range of soil reinforcement applications including slopes and walls and provide innovative solutions in applications that will benefit from the inclusion of a tensile element within the soil structure.

ACEGrid® is suitable for use in short term as well as very long term ground support applications with design lives in excess of 120 years. The product may be manufactured for site specific requirements. The rolls are available in wide widths up to 5.0m to minimise wastage from overlap requirements.

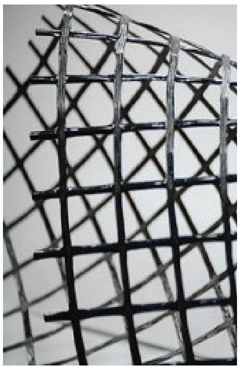
# The Challenge

**Road and geotechnical design engineers are facing an increasing challenge throughout Australia of building roads, retaining structures and related structures with a wide range of soil types and over problematic soil conditions. Relatively low shear capacity soils benefit significantly with the inclusion of an appropriate geosynthetic. ACEGrid® provides engineers with a cost effective, proven alternative to the importation of expensive fills and allows structures to be built relatively economically than would normally be possible.**

# Meeting the Challenge

### Quality

Ace Geosynthetics have a commitment to using the latest technology in weaving processes that delivers highest strengths possible at low soil compatible strains. Quality control within the manufacturing process ensures consistency of manufacture at all times. Ace Geosynthetics hold a number of internationally recognised accreditation approvals for their manufacturing processes.

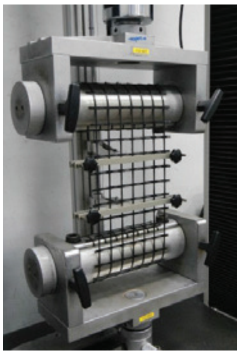


### Materials

Ace Geosynthetics use the best available polymers and the highest tenacity yarn to make the ACEGrid® product. Of importance is the choice of polymer used to make the ACEGrid® structural geogrid. Polyester polymer, in such applications of structural reinforcement, is the most resistant to loss of strength through creep effects over very long periods of time. The use of low carboxyl end group, high molecular weight, base polymer, has been proven to withstand the effects of hydrolysis and subsequent loss of strength in alkaline environments. Polyester polymer is the least susceptible to long term temperature effects.

### Testing

Ace Geosynthetics have a commitment to fully understand the short term and long term behavior of their product. Significant internal and external testing has been carried out at some of the world's most well recognised research and test facilities to independently verify product performance when subjected to physical damage, chemical resistance, load and temperature effects. Both real time and accelerated test methods have been performed to ensure that the ACEGrid® product performance is understood over design lives in excess of 120 years.



### History

Ace Geosynthetics high performance geogrid has been used for years on many Australian soil reinforcement projects with outstanding success. ACEGrid® geogrid is stocked locally with larger requirements made to order with speedy lead times to suit construction requirements. ACEGrid® can be custom manufactured to suit specific project demands such as roll width or length. ACEGrid® product is supported in Australia, New Zealand and the South Pacific by Global Synthetics engineers. ACEGrid® geogrid has been approved for use under the NSW RMS R57 Specification process. Similarly this approval is accepted by the Queensland Department of Transport and Main Roads. International approvals are held with the product accredited with BBA (British Board of Agreement) for applications of basal and slope reinforcement. Product evaluations have been carried out in the USA through the AASHTO- NTPEP programme.

The use of ACEGrid® as a front wrapped reinforcement treatment and after completion showing the vegetated structure.

# 1. General

The ACEGrid® high performance geogrid range, are engineered products for applications of short term and long soil reinforcement. The product is woven with strength in both the roll length direction (commonly called the machine direction-MD) and with strength manufactured in the cross roll direction (commonly called the cross direction-CD). Generally the strength of the product will be dominant in one direction of the roll (normally the MD) with sufficient strength in the other direction of the fabric (normally CD) such that the fibres are dimensionally stable and the roll may be easily deployed.

In applications of soil reinforcement the use of ACEGrid® engineered geogrids allows significant tensile strength to be imparted to soils. Soils are very weak in tension. The use of soil reinforcement techniques has proven to be a very cost effective method of construction. ACEGrid® engineered geogrids are manufactured from high tenacity polyester (PET) fibres with high molecular weights and low carboxyl end groups such that the product is suitable for use in normally occurring soil types, for design lives in excess of 120 years. ACEGrid® high performance geogrids are available in a range of strengths from 40kN/m to 900 kN/m tensile strength.

# 2. Load assessment of ACEGrid®

The use of ACEGrid® high performance geogrid, in long term soil reinforcement applications, requires an assessment of the long term load carrying capabilities of the product.

The procedure adopted for ACEGrid® high performance geogrid follows a partial factor approach that accounts for influences of time, temperature, environment and load.

The assessment procedures for ACEGrid® geogrids are compatible with US Federal Highway of Administration (FHWA), British Code of Practice BS8006:2010, EN ISO 20432:2007 and Australian Standard AS 4678. Australian Standards Handbook HB154- Geosynthetics-Guidelines on Durability may be read in conjunction with this data sheet. There may be additional considerations in some design situations such as the need to satisfy appropriate connection criteria. Additional guidance is given in Section 9 of this document, for further reference.

*The following procedure is an accepted method for determining the long term design strength of the reinforcement at differing design lives.*

$$T_d = \frac{T_c}{f_c \cdot f_d \cdot f_e \cdot f_{m11} \cdot f_{m12}}$$

*where,*

$T_d$ *is the long term design strength of the reinforcement at the required design life.*

$T_c$ *is the characteristic short term tensile strength of the reinforcement.*

$f_c$ *is the partial factor relating to creep effects over the required design life of the reinforcement.*

$f_d$ *is the partial factor relating to damage effects on the reinforcement.*

$f_e$ *is the partial factor relating to environmental effects on the reinforcement.*

$f_{m11}$ *is the partial factor relating to consistency of manufacture of the reinforcement.*

$f_{m12}$ *is the partial factor relating to extrapolation of test data.*

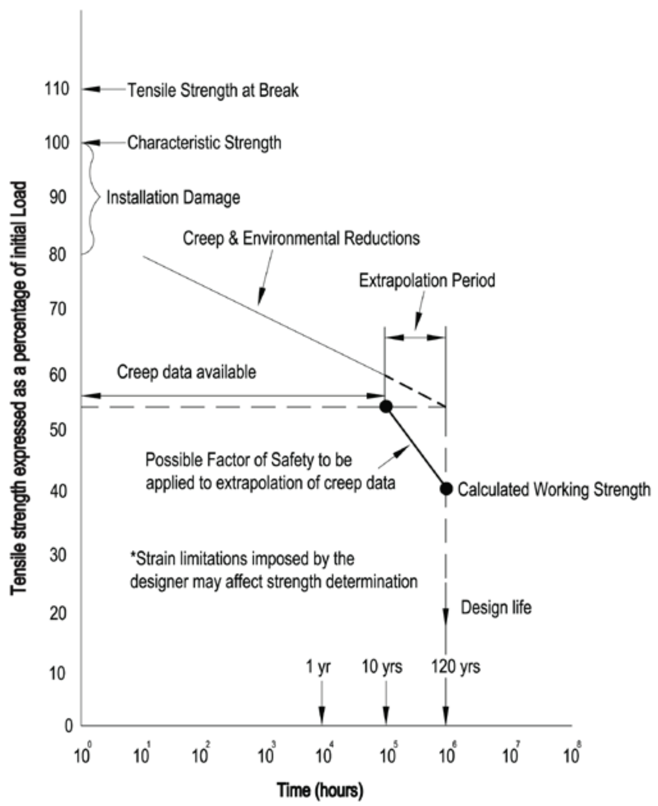



Fig. 1 Partial Factor Reductions to be considered in long term strength derivation

## 3. Partial factor relating to creep, $f_c$

In any assessment of the partial factor for creep, $f_c$, the creep rupture characteristics of the reinforcement must be known.

Significant independent testing has been carried out using both conventional creep rupture testing under long term loading conditions as well as accelerated test methods. From Fig.2 the values of fc can be obtained for different design lives. For example, at 60 years design life the ACEGrid® geogrid shows a 71 % strength retention which equates to a partial factor of $f_c$= 1.41. The published value of $f_c$ for a 120 year design life is 1.45.

ACEGrid®, being composed of high tenacity polyester fibres exhibit very low creep strains even at high tensile load levels. Creep strains of less than 1% over a 120 year design life at a design load of 40% of initial tensile strength are obtained.

The treatment of long term total and creep strains is referenced in Section 8 of this document. The reader is encouraged to carefully consider strain requirements and the effects on the allowable design strength of the geogrid.

Manufacturers of these products must be able to demonstrate creep testing of the manufactured product rather than simple creep testing of the yarn only.

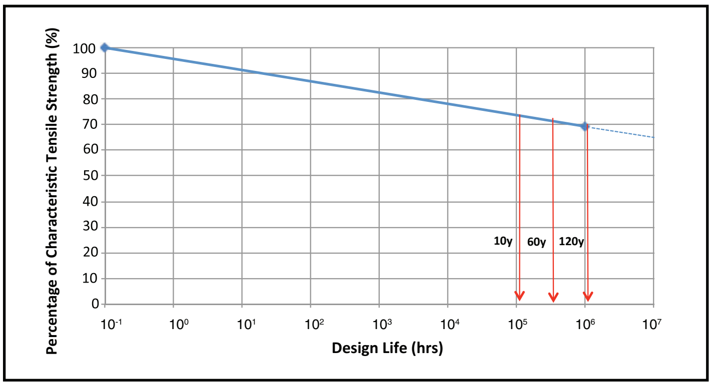



Fig. 2 Creep Rupture Curve
ACEGrid® Geogrid

## 4. Partial factor relating to installation damage, $f_d$

The magnitude of damage, $f_d$, imposed upon the ACEGrid® geogrid is a function of the structure of the reinforcement, the aggressiveness of the fill placed either side of the reinforcement, the method of placement of the fill and the level of compaction performed.

The damage factors used for ACEGrid® geogrid are derived from independent field and large scale laboratory tests. Values of $f_d$ for ACEGrid® geogrid placed in varying soil environments may be obtained from Global Synthetics.

## 5. Partial factor relating to environmental effects, $f_e$

The magnitude of the partial factor, $f_e$, is a function of the polymers used as well as the structure of the reinforcement used. ACEGrid® geogrids are manufactured from virgin, high tenacity polyester fibres. Polyester fibres have over many years demonstrated high resistance to strength loss when buried in soil environments for long periods of time. The ACEGrid® geogrid range is made of high molecular weight, low carboxyl end group fibres that are very stable in a range of pH environments. A range of partial factors, $f_d$, are given in the data sheet for a range of design lives.

## 6. Partial factor relating to consistency of manufacture, $f_{m11}$

ACEGrid® geogrids are manufactured according to independently audited Quality Control and Assurance standards to meet a confidence level of 95% of the published tensile strengths.

The partial factor adopted for ACEGrid® geogrid for consistency of manufacture, **$f_{m11}$, has a value of 1.0 for design lives up to 120 years** in accordance with BS 8006: 2010.

## 7. Partial factor relating to extrapolation of creep data, $f_{m12}$

ACEGrid® geogrids have been extensively tested both in real time creep testing and using time temperature shifting curves to account for long period of time. Both methods are carried out using ASTM and ISO test protocols. The examination of creep data and the suitability of use to extrapolate such data is referenced to BS8006:2010 and EN ISO 20432:2007. The partial factor based on the validity of the statistical envelope between real time testing and time, temperature shifting methods (SIM) **allows $f_{m12}$ to be assigned a value of 1.0 for design lives up to 120 years.**

# 8. Tensile strength strain properties

## 8.1 Short term tensile strength and strain with time = 0 hours

**The short term tensile strength** relationship to strain of ACEGrid® geogrid is shown as a master curve in Fig.3. The graph shows, as the "y" ordinate, the strength of the ACEGrid® geogrid as a percentage of the characteristic short term tensile strength. Thus one master curve may be used to represent all ACEGrid® grades available by converting the percentage values into actual strength values for individual grades. It is important to note that a relationship exists between strength, strain and time for all geosynthetic reinforcement products.

Isochronous stress curves (refer to Fig. 4) must be used to calculate the long term design strength that will limit design strain for a given design life. Some manufacturers do not provide such information on their data sheets which may lead to an over estimation of achievable geogrid strength for a long term design strain requirement.

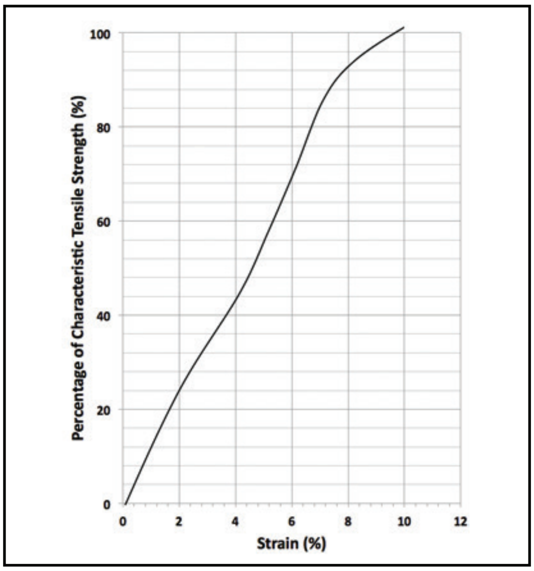



Fig. 3 Short term tensile strength-strain relationship for ACEGrid® Geogrid.

## 8.2 Long term tensile strength and strain with time dependency to 120 years

**The long term tensile strength** relationship to **strain** with the influence of **time dependency** for ACEGrid® geogrid is shown as a master curve in Fig.4. The graph shows, as the "y" ordinate, the strength of the ACEGrid® geogrid as a percentage of the characteristic tensile strength. The "x" axis is the strain component that is appropriate to long term loading conditions. This is theoretically any time greater than t=0 mins. Superimposed upon the curves is the time relationship. A number of long term design lives have been plotted that allow the designer to limit the load within the ACEGrid® geogrid such that a design strain limit is not exceeded for the structure to be constructed. Thus one master curve may be used to represent all ACEGrid® grades by converting the percentage values into actual strength values for individual grades.

Shown at Fig.5 are the components of strain that are necessary to understand when specifying any structural soil reinforcement geosynthetic.

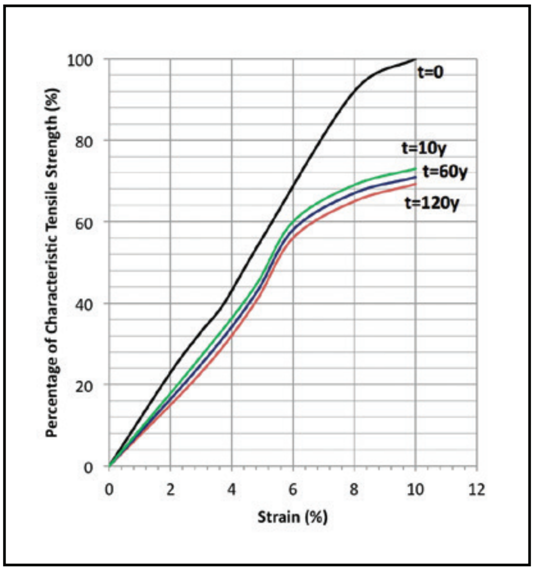



Fig. 4 Long term tensile strength-strain- time relationship for ACEGrid® Geogrid Isochronous curves.

## 9.0 Other Design Considerations and Benefits

**9.1 Designing with Gabion Facing and ACEGrid®**
A comprehensive design manual – "Link Gabions and Mattresses" details the use of gabions as the facing element in combination with ACEGrid® soil reinforcement techniques. Contact Global Synthetics.

**9.2 Segmental Block Facing and ACEGrid®**
Software is available for a range of proprietary facing options such as Keystone® and Anchor® Wall Systems. Contact Global Synthetics.

**9.3 RMS (NSW) and TMR (QLD) Approval and ACEGrid®**
Full approval details may be downloaded from the RMS (ex RTA NSW) website. Specifications RMS R57 and TMR 11.06 apply.

**9.4 BBA Certification for Applications of Slopes and Basal Reinforcement**
Full documentation available for design to BBA certification-contact Global Synthetics.

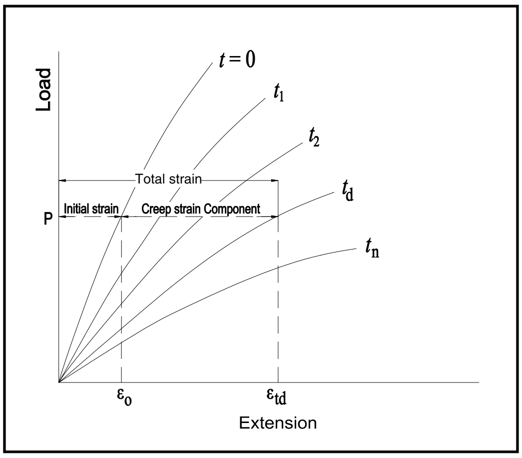



Fig. 5 Method of determining the various components of strain.

## PROPERTIES OF ACEGrid® HIGH PERFORMANCE UNIAXIAL GEOGRID

| PROPERTY | | UNITS | GG40 | GG60 | GG80 | GG100 | GG120 | GG150 | GG200 |
|---|---|---|---|---|---|---|---|---|---|
| **MECHANICAL PROPERTIES** | | | | | | | | | |
| **Mean ultimate tensile strength** ISO 10319 | MD | kN/m | 45 | 70 | 90 | 110 | 130 | 165 | 219 |
| **Characteristic ultimate tensile strength** ISO 10319 | MD | kN/m | 42 | 65 | 84 | 106 | 121 | 157 | 206 |
| **Strain at short term strength** ISO 10319 | MD | % | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| **Partial factor - creep rupture - $f_c$** | | | | | | | | | |
| at 10 years design life | | | 1.37 | 1.37 | 1.37 | 1.37 | 1.37 | 1.37 | 1.37 |
| at 60 years design life | | | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 | 1.41 |
| at 120 years design life | | | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 | 1.45 |
| **Creep limited strength** | | | | | | | | | |
| at 10 years design life | MD | kN/m | 30.7 | 47.4 | 61.3 | 77.4 | 88.3 | 114.6 | 150.4 |
| at 60 years design life | MD | kN/m | 29.8 | 46.1 | 59.6 | 75.2 | 85.8 | 111.3 | 146.1 |
| at 120 years design life | MD | kN/m | 29.0 | 44.8 | 57.9 | 73.1 | 83.4 | 108.3 | 142.1 |
| **Partial factor - construction damage - $f_d$** in coarse gravel less than 50mm | | | 1.12 | 1.1 | 1.1 | 1.1 | 1.1 | 1.1 | 1.05 |
| **Partial factor - environmental effects in soil environment 2 < soil pH < 10 - $f_e$** | | | | | | | | | |
| not exceeding 10 years design life | | | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| at 60 years design life | | | 1.03 | 1.03 | 1.03 | 1.03 | 1.03 | 1.03 | 1.03 |
| at 120 years design life | | | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 | 1.05 |
| **Long term design strengths - $t_d$** in coarse gravel less than 50mm | | | | | | | | | |
| at 10 years design life | MD | kN/m | 27 | 43 | 56 | 70 | 80 | 104 | 143 |
| at 60 years design life | MD | kN/m | 26 | 41 | 53 | 66 | 76 | 98 | 135 |
| at 120 years design life | MD | kN/m | 25 | 39 | 50 | 63 | 72 | 94 | 129 |
| Nominal roll width | | m | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| Nominal roll length | | m | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| Nominal roll mass | | kg | 55 | 60 | 65 | 80 | 95 | 108 | 140 |

NOTE:

1. The characteristic short term strength is the statistical 95% confidence limit.
2. All creep testing has been carried out at 20$^0$ C.
3. Roll widths to 5m are available.
4. The cross direction ( C.D.) strength is 30kN/m
5. Long term design strength are characteristic values.

afaq PAS 2050 Greenhouse Gas Emissions

afaq ISO 9001 Qualité AFNOR CERTIFICATION

Long term design strength is determined by compounding the reduction factors for creep, installation, and environmental effects. ACEGrid® is made from polyester yarn with high molecular weight, Mn > 30,000 and a Carboxyl End Group, CEG of <14 mmol/kg. ACEGrid® is resistant to all naturally occurring soil acids and alkalines, pH 2 - 10. Values quoted are statistically 95% confident and are described as the characteristic value. Testing on the product is carried out in a credited testing laboratories within factory and at third party accredited testing laboratories and institutions.

# Design assistance provided

Contact Global Synthetics for assistance using the ACEGrid® high performance geogrids reinforcement solution.

## More about ACE Geosynthetics

ACE Geosynthetics are a specialist manufacturer of a wide range of geosynthetic products including ACETex® PET structural geotextiles and ACEGrid® soil reinforcement geogrids. ACE Geosynthetics are fully accredited to international quality standards and a commitment to their customers worldwide. ACE Geosynthetics are a market innovator and are continually striving in their product development.

## More about Global Synthetics

Global Synthetics is a 100% Australian-owned company, proud to offer a complete range of high-quality geosynthetic products backed by over 100 years of combined staff experience in the industry. We have supplied products to some of the largest recent infrastructure works in Australia. Global Synthetics provides major benefits to any geotechnical engineering project with the right products and our technical expertise.

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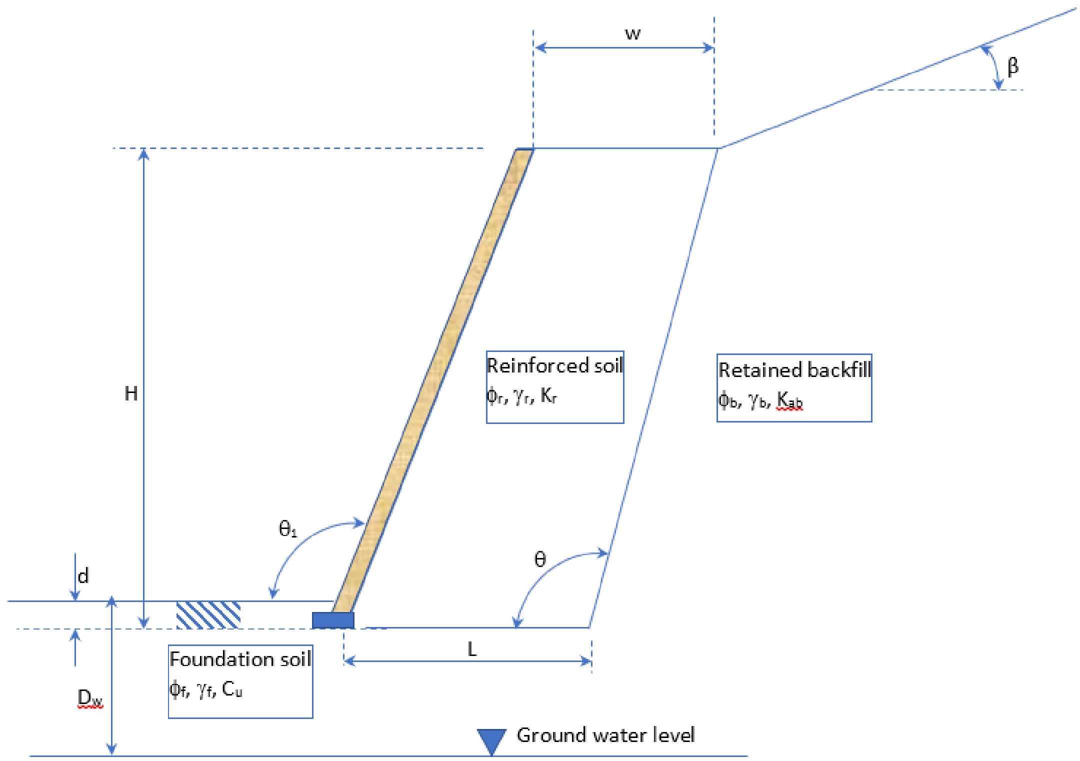
Global Synthetics

Australian Company – Global Expertise

August 2018

# DESIGN OF MECHNICALLY STABILISED EARTH (MSE) WALLS




**References:**

**1. Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume I, Publication No. FHWA-NHI-10-024, Federal Highway Administration FHWA GEC 011 – Volume I.**

**2. AASHTO LRFD Bridge Design Specifications, Seventh. Edition, 2014.**

**3. AS 4678-2002 - Earth-retaining structures.**

**4. AS1170.4-1993 - Minimum Design Loads on Structures, Part 4: Earthquake Loads.**

## 1. External Stability Design Paramaters

Wall location Ch500

### 1.1. Wall Geometry

Wall Height $H := 17.23\ m$

Top width of wall $w := 13.5\ m$

Bottom width of wall $L := 18.64\ m$

| Slope in Front of Structure | Minimum Embedment Depth |
|---|---|
| Horizontal | H/20.0 |
| 3.0H : 1.0V | H/10.0 |
| 2.0H : 1.0V | H/7.0 |
| 1.5H : 1.0V | H/5.0 |

| | | |
|---|---|---|
| Embedment depth | $d := \frac{H}{10}$ | Use above table |
| Slope of backfill behind wall | $\beta := 14\ deg$ | |
| Face inclination from horizontal | $\theta_1 := 108.4\ deg$ | Wall slope: 3V:1H |
| Depth of groundwater below the existing ground level | $D_w := 10\ m$ | |

**1.2. Reinforced Soil Block Parameters**

| | | |
|---|---|---|
| Eff. Frcition of reinforced block | $\phi_r := 32\ deg$ | |
| Unit weight of reinforced block | $\gamma_r := 20\ \frac{kN}{m^3}$ | |

**1.3. Retained backfill Parameters**

| | | |
|---|---|---|
| Eff. Frcition of retained backfill | $\phi_b := 27\ deg$ | |
| Unit weight of backfill | $\gamma_b := 16\ \frac{kN}{m^3}$ | |

**1.4. Foundation Soil Parameters**

| | | |
|---|---|---|
| Drained friction angle of foundation soil | $\phi_f := 28\ deg$ | |
| Undrained shear strength of foundation soil | $C_u := 100\ kPa$ | Enter "NA", if Cu is not applicable to foundation soil |
| Unit weight of foundation soil | $\gamma_f := 18\ \frac{kN}{m^3}$ | |

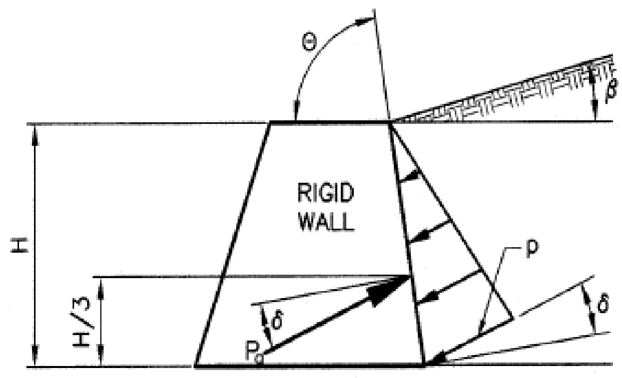
## 2. Loads

| | | |
|---|---|---|
| Angle of fric between retained backfill and rein. Soil | $\delta := \beta$ | Assumed Equal to $\beta$ |

Wall batter

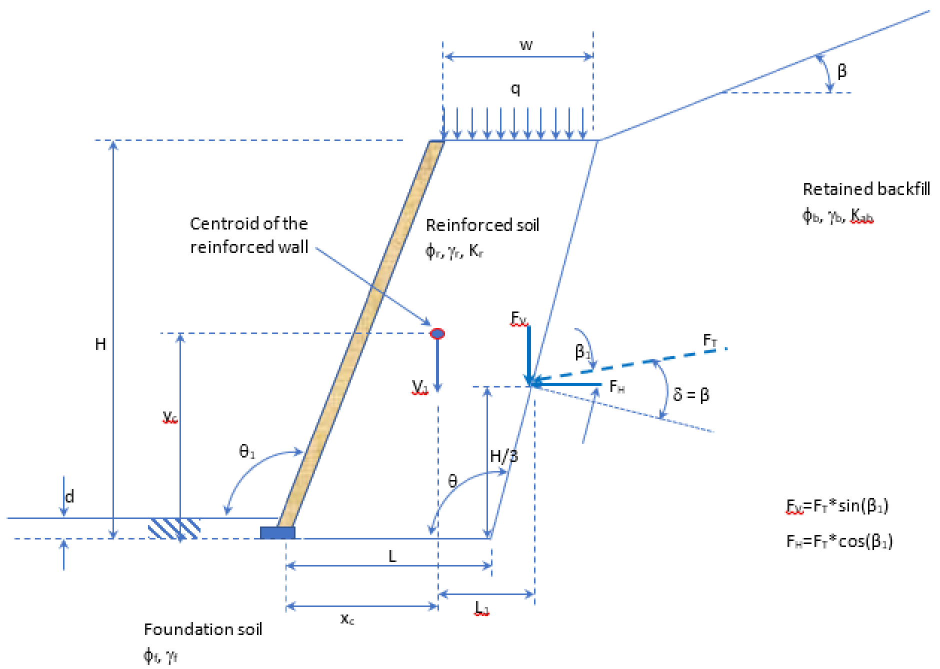
$$\theta := 180.\ deg - \operatorname{atan}\left(\frac{H}{\frac{H}{\tan(180.\ deg - \theta_1)} + w - L}\right)$$

$$\theta := \text{if}(\theta \geq 180.\ deg, \theta - 180\ deg, \theta)$$



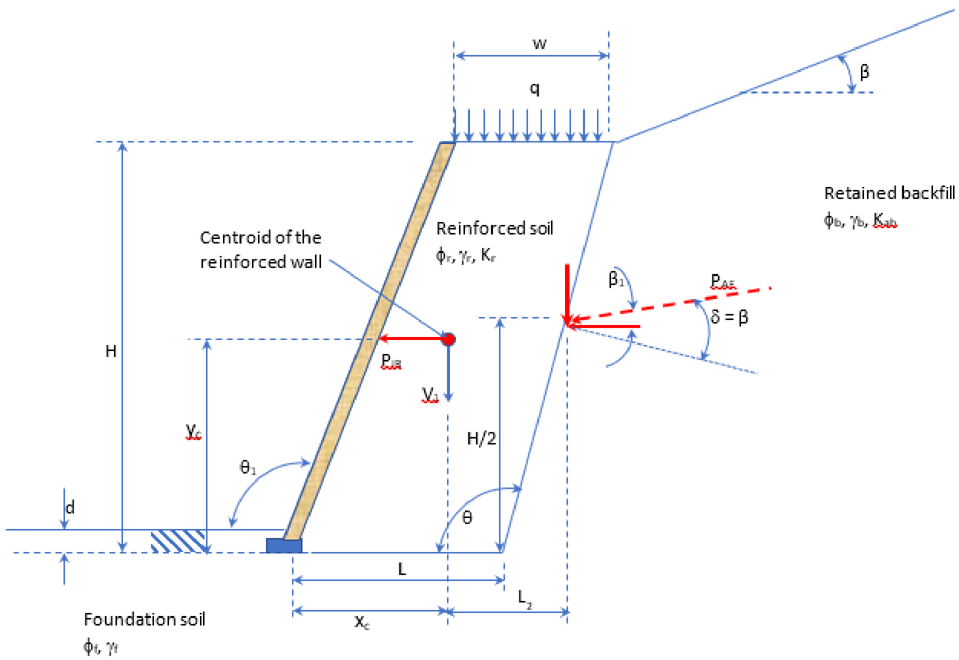

## 2.1. Load Combinations

**Load Case 1 (Strength):** $"\gamma_p \cdot EV" + "\gamma_p \cdot EH" + "\gamma_{LS} \cdot LS"$



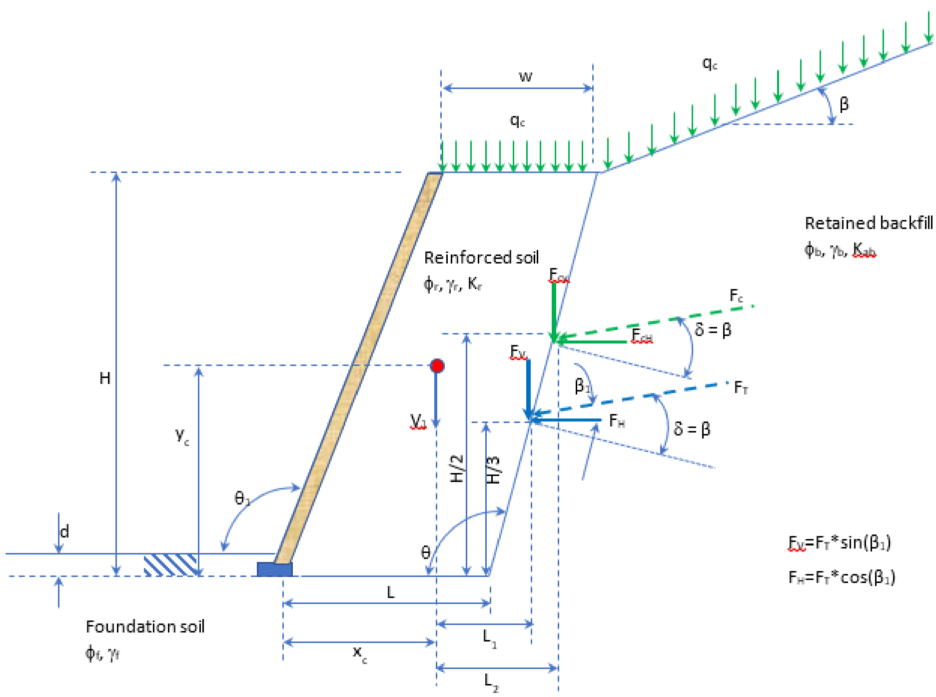
## Load Case 2 (Earth quake):

$$"\gamma_p \cdot EV" + "\gamma_p \cdot EH" + "\gamma_{EQ} \cdot LS" + "1.0 \cdot EQ"$$




## Load Case 3 (Construction):

$$"\gamma_p \cdot EV" + "\gamma_p \cdot EH" + "\gamma_{LS} \cdot LS"$$



**Load Case 4 (Vehicular Impact):**

Vehicular impact on traffic barrier tends to affect only the internal stability of MSE walls (reinforcement). So, the external stability assessment has not been carried for this load case.

## 2.2. Applicable loads

Horizontal earth pressure (EH) Vertcial earth pressure (EV) Earthquake Load (EQ)

Live load (traffic) surcharge (LS) $q_L := 20\ kPa$

Live load (construction) surcharge (LS) $q_c := 10\ kPa$

$$\Gamma := \left(1 + \sqrt{\frac{\sin\left(\phi_b + \delta\right) \cdot \sin\left(\phi_b - \beta\right)}{\sin\left(\theta - \delta\right) \cdot \sin\left(\theta + \beta\right)}}\right)^2$$

Cofficient of active earth pressure $$K_{ab} := \frac{\left(\sin\left(\theta + \phi_b\right)\right)^2}{\Gamma \cdot \left(\sin\left(\theta\right)\right)^2 \cdot \sin\left(\theta - \delta\right)}$$

Assumption: live loads due to traffic and construction have been considered as a surcharge in the external stability estimation.

### 2.3. Load and Resistance factors

Maximum horizontal earth pressure factor $\gamma_{EHmax} := 1.50$

Minimum horizontal earth pressure factor $\gamma_{EHmin} := 0.90$

Minimum vertical earth pressure factor $\gamma_{EVmin} := 1.00$

Maximum vertcial earth pressure factor $\gamma_{EVmax} := 1.35$

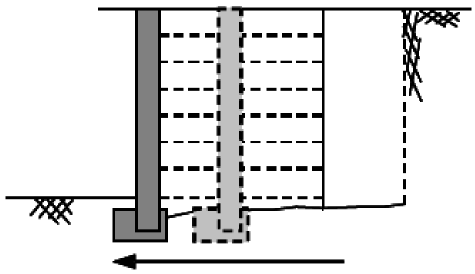
Live load factor $\gamma_{LS} := 1.75$

Load factor for live load for load case 2 $\gamma_{EQ} := 1.00$

Resistance factor for shear resistance between soil and foundation $\phi_\tau := 1.00$

Resistance factor for bearing $\phi := 0.65$

## 3. Sliding Stability



### 3.1. Load Case 1

**Note**

1. Inclination of retained backfill force resultant to normal of the back wall face ($\delta$) is assumed to be $\beta$ ($\delta = \beta$).
2. Inclination of retained backfill force resultant to horizontal ($\beta_1$) will be function of back wall inclination $\theta$ and $\delta$.
3. $\beta_1$ is estimated for three different cases
   a) $\theta \geq 90\ deg \wedge (\theta - 90.\ deg) \geq \delta$
   b) $\theta \geq 90\ deg \wedge (\theta - 90.\ deg) < \delta$
   C) $\theta < 90\ deg$

$\beta_a := (\theta - 90\ deg) - \delta$ $\qquad$ $\beta_b := \delta - (\theta - 90\ deg)$ $\qquad$ $\beta_c := 90\ deg - \theta + \delta$

$\beta_1 := \text{if}\left(\theta \geq 90\ deg \wedge (\theta - 90.\ deg) \geq \delta, \beta_a, \text{if}\left(\theta \geq 90\ deg \wedge (\theta - 90.\ deg) < \delta, \beta_b, \beta_c\right)\right)$

Retained backfill force resultant per unit width $\qquad$ $F_T := \frac{1}{2} K_{ab} \cdot \gamma_b \cdot H^2$

Horizontal driving force per unit width $\qquad$ $F_H := F_T \cdot \cos(\beta_1)$

Vertical force per unit width $\qquad$ $F_V := F_T \cdot \sin(\beta_1)$

Factored horizontal driving force per unit width $\qquad$ $P_{d1} := \gamma_{EHmax} \cdot F_H$

Weight of reinforced block $\qquad$ $V_1 := \gamma_r \cdot H \cdot \frac{(L + w)}{2}$

Minimum soil friction angle $\qquad$ $\mu := min(\tan(\phi_r), \tan(\phi_f))$

Undrained shear strength reduction factor to account SHANSEP $\qquad$ $\zeta := 1.0$

**Notes:**
1. Live load is excluded as it increases the sliding stability.

Sliding resistance between rein. soil and foundation - Drained

$$R_{\tau\_drained} := \left(\gamma_{EVmin} \cdot V_1 + \gamma_{EHmin} \cdot F_V\right) \cdot \mu$$

Sliding resistance between rein. soil and foundation -Undrained

$$R_{\tau\_undrained} := \mathbf{if}\left(C_u = \text{"NA"}, \text{"NA"}, \zeta \cdot C_u \cdot L\right)$$

**Note:**
If ground water is below the foundation level (Dw-d > 2.0 m below foundation level), sliding resistance (undrained) was not considered in the external stability.

$$R_{\tau\_undrained} := \mathbf{if}\left(D_w - d \geq 2.0\ m, \text{"NA"}, R_{\tau\_undrained}\right)$$

Factored Sliding resistance

$$R_r := \mathbf{if}\left(R_{\tau\_undrained} = \text{"NA"}, \phi_\tau \cdot R_{\tau\_drained}, min\left(\phi_\tau \cdot R_{\tau\_drained}, \phi_\tau \cdot R_{\tau\_undrained}\right)\right)$$

Sliding Check

$$\mathbf{SlidingCheckCase1} := \mathbf{if}\left(R_r \geq P_{d1}, \text{"OK"}, \text{"Not OK"}\right)$$

$$\mathbf{SlidingCheckCase1} = \text{"OK"}$$

## 3.2. Load Case 2

AS4678 is adopted for the estimation of acceleration coefficient.

Live load (traffic) has been assumed to an equivalent live load surcharge of 20 kPa as it increases the horizontal force.

Peak ground acceleration coefficient $a := 0.08$

Horizontal coefficient of acceleration $a_h := 0.5 \cdot a$

Horizontal coefficient of acceleration with amplification of motion

$$k_h := \left(1.45 - a_h\right) \cdot a_h \qquad k_v := 0.00$$

$$\xi := \operatorname{atan}\left(\frac{k_h}{1 - k_v}\right)$$

$$\delta_1 := min\left(\phi_r, \phi_b\right)$$

$$I := \beta$$

$$\chi := 90.\ deg$$

**Mononobe-Okabe (M-O) formulation**

$$K_{AE} := \frac{\cos\left(\phi_b - \xi - \chi + \theta\right)^2}{\cos(\xi)\cdot\cos(\chi-\theta)^2\cdot\cos\left(\delta_1+\chi-\theta+\xi\right)\cdot\left(1+\sqrt{\frac{\sin\left(\phi_b+\delta_1\right)\cdot\sin\left(\phi_b-\xi-I\right)}{\cos\left(\delta_1+\chi-\theta+\xi\right)\cdot\cos\left(I-\chi+\theta\right)}}\right)^2}$$

Total (static + dynamic) thrust $P_{AE} := 0.5\cdot K_{AE}\cdot\gamma_b\cdot H^2$

Horizontal inertial force $P_{IR} := 0.5\cdot\left(k_h\cdot V_1+\gamma_{EQ}\cdot q_L\cdot w\cdot k_h\right)$

Total horizontal force $T_{HF} := P_{AE}\cdot\cos\left(\delta_1\right)+P_{IR}$

**Notes:**
1. Live load was considered as part of the reinforced soil mass

Sliding Check $\mathbf{SlidingCheckCase2} := \mathbf{if}\left(R_r \ge T_{HF}, \text{“OK”}, \text{“Not OK”}\right)$

$\mathbf{SlidingCheckCase2} = \text{“OK”}$

**3.3. Load Case 3**

Uniform construction surcharge resultant per unit width $F_C := K_{ab}\cdot q_c\cdot H$

Horizontal component of Fc $F_{CH} := F_C\cdot\cos\left(\beta_1\right)$

Vertical component of Fc $F_{CV} := F_C\cdot\sin\left(\beta_1\right)$

Factored horizontal driving force per unit width $P_{d3} := \gamma_{EHmax}\cdot F_H+\gamma_{LS}\cdot F_{CH}$

Weight of reinforced block $V_1 := \gamma_r\cdot H\cdot\frac{(L+w)}{2}$

Minimum soil friction angle $\mu := min\left(\tan\left(\phi_r\right), \tan\left(\phi_f\right)\right)$

**Notes:**
1. Live load surcharge immidiately above the reinforced fill is excluded as it increases the sliding stability.

Sliding resistance between rein. soil and foundation - Drained $R_{\tau\_drained} := \left(\gamma_{EVmin}\cdot V_1+\gamma_{EHmin}\cdot F_V+\gamma_{EHmin}\cdot F_{CV}\right)\cdot\mu$

Sliding resistance between rein. soil and foundation
-Undrained

$$R_{\tau\_undrained\_con} := \text{if}\left(C_u = \text{“NA”}, \text{“NA”}, \zeta \cdot C_u \cdot L\right)$$

**Note:**
If ground water is below the foundation level (if Dw-d > 2.0 m below foundation level), sliding resistance (undrained) was not considered in the external stability.

$$R_{\tau\_undrained\_con} := \text{if}\left(D_w - d \geq 2.0\ m, \text{“NA”}, R_{\tau\_undrained}\right)$$

Factored Sliding resistance

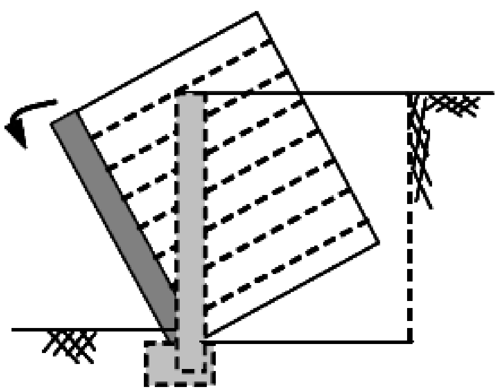
$$R_r := \text{if}\left(R_{\tau\_undrained\_con} = \text{“NA”}, \phi_\tau \cdot R_{\tau\_drained}, min\left(\phi_\tau \cdot R_{\tau\_drained}, \phi_\tau \cdot R_{\tau\_undrained\_con}\right)\right)$$

Sliding Check

$$\textbf{SlidingCheckCase3} := \text{if}\left(R_r \geq P_{d3}, \text{“OK”}, \text{“Not OK”}\right)$$

$$\textbf{SlidingCheckCase3} = \text{“OK”}$$

## 4. Rotational/Overturning Stability



**4.1. Load Case 1**

**Notes:**
1. Weight and width of the facing is neglected in this calculation
2. Traffic surcharge was ignored as it contribute to reduce the eccentricity
3. Moment is estimated about the middle of the bottom width of wall.

Estimation of Centeroid of the wall from the toe

$$l_1 := \frac{H}{\tan\left(180.\ deg - \theta_1\right)}$$

$$l_2 := L - l_1 - w = -0.592\ m$$

X distance to centeroid of the reforced wall from toe of the wall

$$x_c := \frac{\frac{l_1^{\,2}}{3} + w \cdot \left(l_1 + \frac{w}{2}\right) + \frac{1}{2} \cdot l_2 \cdot \left(l_1 + w + \frac{1}{3} \cdot l_2\right)}{\frac{(L + w)}{2}}$$

Y distance to centeroid of the reforced wall from toe of the wall

$$y_c := \frac{H}{3} \cdot \frac{(L + 2 \cdot w)}{L + w}$$

$$L_1 := \textbf{if}\left(l_2 \le 0, l_1 + w - x_c + \frac{2}{3} \cdot l_2, L - x_c - \frac{2}{3} \cdot l_2\right)$$

Eccentricity $$e_1 := \frac{\gamma_{EHmax} \cdot F_H \cdot \frac{H}{3} - \gamma_{EHmax} \cdot F_V \cdot L_1}{\gamma_{EVmin} \cdot V_1 + \gamma_{EHmax} \cdot F_V}$$

Rotation Check $$\textbf{RotationCheckCase1} := \textbf{if}\left(\frac{L}{4} \ge e_1, \text{“OK”}, \text{“Not OK”}\right)$$

$$\textbf{RotationCheckCase1} = \text{“OK”}$$

#### 4.2. Load Case 2

$$L_2 := \textbf{if}\left(l_2 \le 0, l_1 + w - x_c + \frac{1}{2} \cdot l_2, L - x_c - \frac{1}{2} \cdot l_2\right)$$

**Notes:**
1. Weight and width of the facing is neglected in this calculation
2. Traffic surcharge was ignored as it contribute to reduce the eccentricity
3. Moment is estimated about the middle of the bottom width of wall.

Eccentricity $$e_2 := \frac{P_{IR} \cdot y_c + P_{AE} \cdot \cos\left(\beta_1\right) \cdot 0.5 \cdot H - P_{AE} \cdot \sin\left(\beta_1\right) \cdot L_2}{\gamma_{EVmin} \cdot V_1 + P_{AE} \cdot \sin\left(\beta_1\right)}$$

Rotation Check $$\textbf{RotationCheckCase2} := \textbf{if}\left(\frac{2 \cdot L}{5} \ge e_2, \text{“OK”}, \text{“Not OK”}\right)$$

$$\textbf{RotationCheckCase2} = \text{“OK”}$$

#### 4.3. Load Case 3

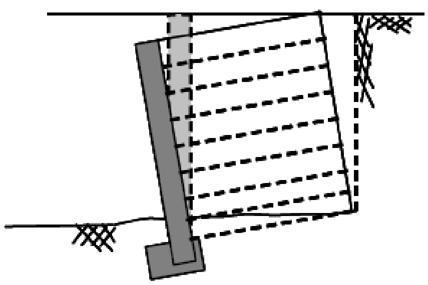
**Notes:**
1. Weight and width of the facing is neglected in this calculation
2. Traffic surcharge was ignored as it contribute to reduce the eccentricity
3. Moment is estimated about the middle of the bottom width of wall.

Eccentricity $$e_3 := \frac{\gamma_{EHmax} \cdot F_H \cdot \frac{H}{3} - \gamma_{EHmax} \cdot F_V \cdot L_1 + \gamma_{LS} \cdot F_{CH} \cdot \frac{H}{2} - \gamma_{LS} \cdot F_{CV} \cdot L_2}{\gamma_{EVmin} \cdot V_1 + \gamma_{EHmax} \cdot F_V + \gamma_{LS} \cdot F_{CV}}$$

Rotation Check $$\mathbf{RotationCheckCase3} := \mathbf{if}\left(\frac{L}{4} \ge e_3, \text{“OK”}, \text{“Not OK”}\right)$$

$$\mathbf{RotationCheckCase3} = \text{“OK”}$$

## 5. Bearing Capacity of Foundation Soil



Live load (traffic) has been assumed as an equivalent live load surcharge of 20 kPa

### 5.1. Load Case 1

Eccentricity $$e_{B1} := \frac{\gamma_{EHmax} \cdot F_H \cdot \frac{H}{3} - \gamma_{EHmax} \cdot F_V \cdot L_1}{\gamma_{EVmax} \cdot V_1 + \gamma_{EHmax} \cdot F_V + \gamma_{LS} \cdot q_L \cdot w}$$

Effective foundation width $$L' := \mathbf{if}\left(\left(L - 2 \cdot e_{B1}\right) \le 0, L, L - 2 \cdot e_{B1}\right)$$

Factored vertical stress $$q_{vf1} := \frac{\gamma_{EVmax} \cdot V_1 + \gamma_{LS} \cdot q_L \cdot w + \gamma_{EHmax} \cdot F_V}{L'}$$

<u>Estimation of bearing capacity of the foundation</u>

$$N_q := e^{\pi \cdot \tan(\phi_f)} \cdot \tan\left(45.\ deg + \frac{\phi_f}{2}\right)^2$$

Bearing resistance - Undrained $$q_{n\_undrained} := \mathbf{if}\left(C_u = \text{“NA”}, \text{“NA”}, 5.14\ C_u + N_q \cdot \gamma_f \cdot d\right)$$

$$N_\gamma := 2 \cdot \left(N_q + 1\right) \cdot \tan\left(\phi_f\right)$$

Unit weight of water $\gamma_w := 9.81 \frac{kN}{m^3}$

Effective unit weight of soil adjusted to ground water

$$\gamma_{fdw} := \textbf{if}\left(\left(D_w - d\right) \ge L + d, \gamma_f, \textbf{if}\left(D_w \le d, \left(\gamma_f - \gamma_w\right), \frac{\left(L + d - D_w\right) \cdot \left(\gamma_f - \gamma_w\right) + \left(D_w - d\right) \cdot \gamma_f}{L}\right)\right)$$

Bearing resistance - Drained $q_{n\_drained} := 0.5 \cdot L' \cdot N_\gamma \cdot \gamma_{fdw}$

$$q_n := \textbf{if}\left(C_u = \text{“NA”}, q_{n\_drained}, min\left(q_{n\_undrained}, q_{n\_drained}\right)\right)$$

Factored bearing resistance $q_R := \phi \cdot q_n$

Bearing capacity check $\textbf{BearingCheckCase1} := \textbf{if}\left(q_R \ge q_{vf1}, \text{“OK”}, \text{“Not OK”}\right)$

$\textbf{BearingCheckCase1} = \text{“OK”}$

**5.2. Load Case 2**

Eccentricity $e_{B2} := \frac{P_{IR} \cdot y_c + P_{AE} \cdot \cos\left(\beta_1\right) \cdot 0.5 \cdot H - P_{AE} \cdot \sin\left(\beta_1\right) \cdot L_2}{\gamma_{EVmin} \cdot V_1 + P_{AE} \cdot \sin\left(\beta_1\right)}$

Effective foundation width $L'' := \textbf{if}\left(\left(L - 2 \cdot e_{B2}\right) \le 0, L, L - 2 \cdot e_{B2}\right)$

Factored vertical stress $q_{vf2} := \frac{\gamma_{EVmin} \cdot V_1 + \gamma_{EQ} \cdot q_L \cdot w + P_{AE} \cdot \sin\left(\beta_1\right)}{L''}$

**Note:**
Resistance factor = 1.0 is recommended for the Load Case: 2

Bearing capacity check $\textbf{BearingCheckCase2} := \textbf{if}\left(\frac{q_R}{\phi} \ge q_{vf2}, \text{“OK”}, \text{“Not OK”}\right)$

$\textbf{BearingCheckCase2} = \text{“OK”}$

**5.1. Load Case 3**

Eccentricity

$$e_{B3} := \frac{\gamma_{EHmax} \cdot F_H \cdot \frac{H}{3} - \gamma_{EHmax} \cdot F_V \cdot L_1 + \gamma_{LS} \cdot F_{CH} \cdot \frac{H}{2} - \gamma_{LS} \cdot F_{CV} \cdot L_2}{\gamma_{EVmax} \cdot V_1 + \gamma_{EHmax} \cdot F_V + \gamma_{LS} \cdot q_c \cdot w + \gamma_{LS} \cdot F_{CV}}$$

Effective foundation width $L''' := \textbf{if}\left(\left(L - 2 \cdot e_{B3}\right) \le 0, L, L - 2 \cdot e_{B3}\right)$

Factored vertical stress $q_{vf3} := \dfrac{\gamma_{EVmax} \cdot V_1 + \gamma_{LS} \cdot q_c \cdot w + \gamma_{EHmax} \cdot F_V + \gamma_{LS} \cdot F_{CV}}{L'''}$

Bearing resistance - Undrained $q_{n\_undrained\_con} := \textbf{if}\left(C_u = \text{“NA”}, \text{“NA”}, 5.14\ C_u \cdot \zeta + N_q \cdot \gamma_f \cdot d\right)$

$$q_{n\_con} := \textbf{if}\left(C_u = \text{“NA”}, q_{n\_drained}, min\left(q_{n\_undrained\_con}, q_{n\_drained}\right)\right)$$

Factored bearing resistance $q_R := \phi \cdot q_{n\_con}$

Bearing capacity check $\text{BearingCheckCase3} := \textbf{if}\left(q_R \ge q_{vf3}, \text{“OK”}, \text{“Not OK”}\right)$

$\text{BearingCheckCase3} = \text{“OK”}$

## 6. Design Check - External Stability

### 6.1. Load Case 1

$\text{SlidingCheckCase1} = \text{“OK”}$

$\text{RotationCheckCase1} = \text{“OK”}$

$\text{BearingCheckCase1} = \text{“OK”}$

### 6.2. Load Case 2

$\text{SlidingCheckCase2} = \text{“OK”}$

$\text{RotationCheckCase2} = \text{“OK”}$

$\text{BearingCheckCase2} = \text{“OK”}$

### 6.3. Load Case 3

$\text{SlidingCheckCase3} = \text{“OK”}$

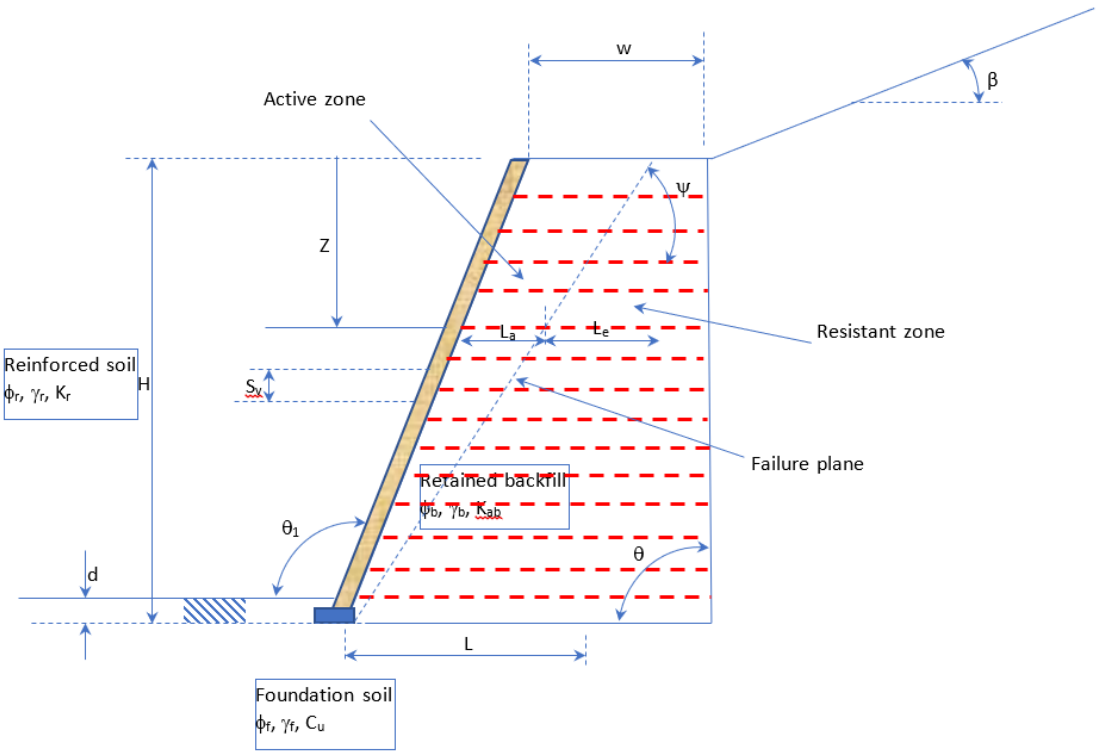
$\text{RotationCheckCase3} = \text{“OK”}$

$\text{BearingCheckCase3} = \text{“OK”}$

### 6.4. Load Case 4

Vehicular impact on traffic barrier tends to affect only the internal stability of MSE walls (reinforcement). So, the external stability assessment has not been carried for this load case.

## Internal Stability - Sample Calculations




Calculation below shows the sample calcuation of tensile and pull-out failure of reinforcement at a specific depth/layer.

Layer # $n := 20$ Refer to excel sheet below

Depth of reinforcement $Z := 9.1\ m$

Vertical reinforcement spacing/Contributory height $S_v := 0.6\ m$

Ultimate Tensile Strength $T_{ult} := 200\ \dfrac{kN}{m}$ For GG150

Length of reinforcement $L_r := 15.3\ m$

Total no of reinforcement layers within the wall $N := 35$ To be estimated based on geometry and spacing

Partial factor - creep rupture $RF_{CR} := 1.45$

Partial factor - construction damage $RF_{ID} := 1.1$

Partial factor - environmental effects $RF_D := 1.05$

Combined strength reduction factor $RF := RF_{CR} \cdot RF_{ID} \cdot RF_D$

Pullout resistance factor $F := 0.42$

Scale correction factor $\alpha := 0.8$

Coverage ratio $R_c := 1$ $C := 2$

Rankine active earth pressure coefficient $$K_a := \frac{\sin\left(\theta + \phi_r\right)^2}{\sin(\theta)^3 \cdot \left(1 + \frac{\sin\left(\phi_r\right)}{\sin(\theta)}\right)}$$

lateral earth pressure coefficient $K_r := K_a$ Extensible reinforcement (geogrid)

$a_1 := \tan\left(\phi_r - \beta\right)$ $a_2 := \cot\left(\phi_r + \theta - 90.\ \mathit{deg}\right)$ $a_3 := \tan\left(\delta + 90.\ \mathit{deg} - \theta\right)$

Inclination of failure plane $$\psi := \operatorname{atan}\left(\frac{-a_1 + \sqrt{a_1 \cdot \left(a_1 + a_2\right)\ \left(1 + a_3 \cdot a_2\right)}}{1 + a_3 \cdot \left(a_1 + a_2\right)}\right) + \phi_r$$

## 1. Tensile Failure of Reinforcement

### 1.1. Load Case 1

Surcharge equivalent height $$h_{eq1} := \frac{q_L \cdot \gamma_{LS}}{\gamma_r \cdot \gamma_{EVmax}}$$

Horizontal stress at depth Z $\sigma_{H1} := K_r \cdot \gamma_r \cdot \left(Z + h_{eq1}\right) \cdot \gamma_{EVmax}$

Maximum factored tension $T_{max1} := \sigma_{H1} \cdot S_v$

Nominal long-term reinforcement strength $$T_{al1} := \frac{T_{ult}}{RF_{CR} \cdot RF_{ID} \cdot RF_D}$$

Resistance Factors for tensile and pullout resistance $\phi_{GG1} := 0.9$

Factored tensile resistance $T_{r1} := \phi_{GG1} \cdot T_{al1}$

Tensile Check $\mathbf{TensileCheck1} := \mathbf{if}\left(T_{r1} \ge T_{max1}, \text{“OK”}, \text{“Not OK”}\right)$

$\mathbf{TensileCheck1} = \text{“OK”}$

**1.2. Load Case 2**

Surcharge equivalent height $h_{eq2} := \dfrac{q_L \cdot \gamma_{EQ}}{\gamma_r \cdot \gamma_{EVmax}}$

Horizontal stress at depth Z $\sigma_{H2} := K_r \cdot \gamma_r \cdot \left(Z + h_{eq2}\right) \cdot \gamma_{EVmax}$

Maximum factored tension $T_{max2} := \sigma_{H2} \cdot S_v$

Soil weight of the active zone $W_a := \dfrac{1}{2} \cdot \gamma_r \cdot H^2 \cdot \left(\tan\left(90.\ deg - \psi\right) - \tan\left(\theta_1 - 90.\ deg\right)\right)$

Factored incremental dynamic inertia force $T_{md} := \dfrac{k_h \cdot W_a}{N-1}$

Resistance Factors for tensile and pullout resistance $\phi_{GG2} := 1.2$

Static component of resistance $S_{rs2} := \dfrac{T_{max2} \cdot RF}{\phi_{GG2} \cdot R_c}$

Dynamic component of resistance $S_{rt2} := \dfrac{T_{md} \cdot RF_{ID} \cdot RF_D}{\phi_{GG2} \cdot R_c}$

Tensile Check $\mathbf{TensileCheck2} := \mathbf{if}\left(T_{ult} \ge \left(S_{rs2} + S_{rt2}\right), \text{“OK”}, \text{“Not OK”}\right)$

$\mathbf{TensileCheck2} = \text{“OK”}$

**1.3. Load Case 3**

Surcharge equivalent height $h_{eq3} := \dfrac{q_c \cdot \gamma_{LS}}{\gamma_r \cdot \gamma_{EVmax}}$

Horizontal stress at depth Z $\sigma_{H3} := K_r \cdot \gamma_r \cdot \left(Z + h_{eq3}\right) \cdot \gamma_{EVmax}$

Maximum factored tension $T_{max3} := \sigma_{H3} \cdot S_v$

Nominal long-term reinforcement strength $T_{al3} := \dfrac{T_{ult}}{RF_{ID} \cdot RF_D}$ No creep considered during construction

Resistance Factors for tensile and pullout resistance $\phi_{GG3} := 0.9$

Factored tensile resistance $T_{r3} := \phi_{GG3} \cdot T_{al3}$

Tensile Check $\mathbf{TensileCheck3} := \mathbf{if}\left(T_{r3} \geq T_{max3}, \text{“OK”}, \text{“Not OK”}\right)$

$\mathbf{TensileCheck3} = \text{“OK”}$

**1.4. Load Case 4**

Surcharge equivalent height $h_{eq4} := \dfrac{q_L \cdot 1.0}{\gamma_r}$ Assumed 1 m

Horizontal stress at depth Z $\sigma_{H4} := K_r \cdot \gamma_r \cdot \left(Z + h_{eq4}\right) \cdot \gamma_{EVmax}$

Maximum factored tension $T_{max4} := \sigma_{H4} \cdot S_v$

**Note**

1. Traffic railing impact events tend to affect only the internal stability of MSE walls

2. The recommended static impact force is assumed 45 kN applied on a barrier with a minimum height of 810 mm above the road surface.

3. As per FHWA NHI-10-024, the static impact force, adds an additional horizontal force to the upper 2 layers of soil reinforcement.

4. The upper layer of soil reinforcement be designed for a rupture impact load equivalent to a static load of 33.5 kN/m of wall.

5. The second layer be designed with a rupture impact load equivalent to a static load of 8.8 kN/m.

Factored impact load $T_I := \mathbf{if}\left(n = N - 1, 33.5\ \dfrac{kN}{m}, \mathbf{if}\left(n = N - 2, 8.8\ \dfrac{kN}{m}, 0\ \dfrac{kN}{m}\right)\right)$

Resistance Factors for tensile and pullout resistance $\phi_{GG4} := 1.0$

Static component of resistance $S_{rs4} := \frac{T_{max4} \cdot RF}{\phi_{GG4} \cdot R_c}$

Dynamic component of resistance $S_{rt4} := \frac{T_I \cdot RF_{ID} \cdot RF_D}{\phi_{GG2} \cdot R_c}$

Tensile Check $\textbf{TensileCheck4} := \textbf{if}\left(T_{ult} \geq \left(S_{rs4} + S_{rt4}\right), \text{“OK”}, \text{“Not OK”}\right)$

$\textbf{TensileCheck4} = \text{“OK”}$

## 2. Pullout Failure of Reinforcement

### 2.1. Load Case 1

Nominal vertical stress at depth Z $\sigma_v := \gamma_r \cdot Z$

min. length of embedment in resistant zone $L_{e1} := \textbf{if}\left(\frac{T_{max1}}{\phi_{GG1} \cdot F \cdot \alpha \cdot \sigma_v \cdot C \cdot R_c} \leq 1\ m, 1\ m, \frac{T_{max1}}{\phi_{GG1} \cdot F \cdot \alpha \cdot \sigma_v \cdot C \cdot R_c}\right)$

min. length of embedment in active zone $L_a := (H - Z) \cdot \left(\tan(90.\ deg - \psi) - \tan\left(\theta_1 - 90.\ deg\right)\right)$

Pullout Check $\textbf{PulloutCheck1} := \textbf{if}\left(L_r \geq L_{e1} + L_a, \text{“OK”}, \text{“Not OK”}\right)$

$\textbf{PulloutCheck1} = \text{“OK”}$

### 2.2. Load Case 2

Total factored load (static = dynamic) $T_{total2} := T_{max2} + T_{md}$

min. length of embedment in resistant zone

$$L_{e2} := \textbf{if}\left(\frac{T_{total2}}{\phi_{GG2} \cdot 0.8 \cdot F \cdot \alpha \cdot \sigma_v \cdot C \cdot R_c} \leq 1\ m, 1\ m, \frac{T_{total2}}{\phi_{GG2} \cdot 0.8 \cdot F \cdot \alpha \cdot \sigma_v \cdot C \cdot R_c}\right)$$

Available length of embedment in resistant zone $L_{ea} := L_r - L_a$

Pullout Check $\textbf{PulloutCheck2} := \textbf{if}\left(L_{ea} \geq L_{e2}, \text{“OK”}, \text{“Not OK”}\right)$

**2.3. Load Case 3**

min. length of embedment in resistant zone $L_{e3} := \text{if}\left(\dfrac{T_{max3}}{\phi_{GG3} \cdot F \cdot \alpha \cdot \sigma_v \cdot C \cdot R_c} \le 1\ m, 1\ m, \dfrac{T_{max3}}{\phi_{GG3} \cdot F \cdot \alpha \cdot \sigma_v \cdot C \cdot R_c}\right)$

min. length of embedment in active zone $L_a := (H - Z) \cdot (\tan(90.\ deg - \psi) - \tan(\theta_1 - 90.\ deg))$

Pullout Check $\textbf{PulloutCheck3} := \text{if}(L_r \ge L_{e3} + L_a, \text{"OK"}, \text{"Not OK"})$

$\textbf{PulloutCheck3} = \text{"OK"}$

**2.4. Load Case 4**

Note.

1. Soil reinforcement be designed for a pullout impact load equivalent to a static load of 19.0 kN/m.

2. The second layer be designed with a pullout impact load equivalent to a static load of 8.8 kN/m.

Factored impact load for pullout $T_{IP} := \text{if}\left(n = N - 1, 19.0\ \dfrac{kN}{m}, \text{if}\left(n = N - 2, 8.8\ \dfrac{kN}{m}, 0\ \dfrac{kN}{m}\right)\right)$

Total factored load (static = dynamic) $T_{total4} := T_{max4} + T_{IP}$

min. length of embedment in resistant zone

$$L_{e4} := \text{if}\left(\dfrac{T_{total4}}{\phi_{GG4} \cdot 0.8 \cdot F \cdot \alpha \cdot \sigma_v \cdot C \cdot R_c} \le 1\ m, 1\ m, \dfrac{T_{total4}}{\phi_{GG4} \cdot 0.8 \cdot F \cdot \alpha \cdot \sigma_v \cdot C \cdot R_c}\right)$$

Top layer to be extended and wrapped within the liner support fill to length of 1.5 m $l_{add} := \text{if}(n = N, Z, 0)$

Available length of embedment in resistant zone $L_{ea} := L_r - L_a + l_{add}$

Pullout Check $\textbf{PulloutCheck4} := \text{if}(L_{ea} \ge L_{e4}, \text{"OK"}, \text{"Not OK"})$

$\textbf{PulloutCheck4} = \text{"OK"}$

## 3. Design Check - Internal Stability

The check is only carried above for a reinforcement at the depth of Z. Table attached below details the check for the all reinforement within MSE wall for Load Cases 1 to 4.

### 10.1. Load Case 1

$\mathrm{TensileCheck1} = \text{“OK”}$

$\mathrm{PulloutCheck1} = \text{“OK”}$

### 10.2. Load Case 2

$\mathrm{TensileCheck2} = \text{“OK”}$

$\mathrm{PulloutCheck2} = \text{“OK”}$

### 10.3. Load Case 3

$\mathrm{TensileCheck3} = \text{“OK”}$

$\mathrm{PulloutCheck3} = \text{“OK”}$

### 10.4. Load Case 4

$\mathrm{TensileCheck4} = \text{“OK”}$

$\mathrm{PulloutCheck4} = \text{“OK”}$

| DESIGN OF MECHNICALLY STABILISED EARTH (MSE) WALLS - Load Case 1 | | | |
|---|---|---|---|
| **Wall Geometry** | | | |
| Wall Height (m), H | 17.23 | | |
| Bottom width of wall, L | 18.64 | | |
| Top width of wall, w | 13.5 | | |
| Slope of backfill behind wall (Deg), β | 14 | | |
| Face inclination from horizontal (Deg), $\theta_I$ | 108.4 | | |
| | | | |
| | | | |
| **Reinforced Soil Block Parameters** | | | |
| Eff. Frcition of reinforced soil (Deg), $\phi'_r$ | 32 | | |
| Unit weight of reinfoced soil (kN/m$^3$), $\gamma_r$ | 20 | | |
| | | | |
| **Load and Resistance factors** | | | |
| Traffic surcharge, $q_L$ | 20 | | |
| Live load factor , $\gamma_{LS}$ | 1.75 | | |
| Maximum vertcial earth pressure factor $\gamma_{EVmax}$ | 1.35 | | |
| Load Case | 1 | | |
| | | | |
| **Geogrid paramaters** | | | |
| | **Top** | **Middle** | **Bottom** |
| Ultimate strength of reinforcement, $_{Tult}$ | GG120 | GG200 | GG200 |
| Vertical spacing | 0.6 | 0.6 | 0.3 |
| Length | 12.5 | 15.3 | 18.1 |
| No of reinforcment layer | 11 | 12 | 12 |
| | | | |
| | | | |
| Partial factor - creep rupture - $RF_{CR}$ | 1.45 | 1.45 | 1.45 |
| Partial factor - construction damage - $RF_{ID}$ | 1.1 | 1.1 | 1.1 |
| Partial factor - environmental effects - $RF_D$ | 1.05 | 1.05 | 1.05 |
| | | | |
| | | | |
| Resistance Factors for tensile and pullout resistance, $\phi_{GG}$ | 0.9 | | |
| Pullout resistance factor, F* | 0.42 | | |
| Scale correction factor, α | 0.8 | | |
| Coverage ratio, $R_c$ | 1 | | |
| C | 2 | | |
| | 92.0 | | |
| Batter angle, θ (Deg) | 92.0 | | |
| Angle of fric between retained backfill and rein. Soil (Deg), δ | 14 | | |
| Rankine active earth pressure coefficient, $K_a$ | 0.45 | | |
| lateral earth pressure coefficient, $K_r$ | 0.45 | | |
| Surcharge equivalent height, $h_{eq}$ (m) | 1.3 | | |
| Inclination of failure surface with horizontal, ψ (Deg) | 53.8 | | |
| Note: | | | |
| 1. For extensible reinforcement (geogrid), lateral stress ratio is equla to 1.0 | | | |
| | | | |
| a1 | 0.32 | | |
| a2 | 1.48 | | |
| a3 | 0.21 | | |
| | | | |
| | | | |

| Internal Stability with Respect to Tensile Failure of Reinforcement | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Layer # | Z (m) | $\sigma_H$ (kPa) | $S_v$ (m) | $T_{max}$ (kN/m) | Rein. Type | $T_{ult}$ (kN/m) | $T_{al}$ (kN/m) | $T_r$ (kN/m) | Check |
| 1 | 17.2 | 225.14 | 0.15 | 33.77 | GG200 | 200 | 119.42 | 107.48 | OK |
| 2 | 16.9 | 221.49 | 0.3 | 66.45 | GG200 | 200 | 119.42 | 107.48 | OK |
| 3 | 16.6 | 217.85 | 0.3 | 65.35 | GG200 | 200 | 119.42 | 107.48 | OK |
| 4 | 16.3 | 214.20 | 0.3 | 64.26 | GG200 | 200 | 119.42 | 107.48 | OK |
| 5 | 16.0 | 210.56 | 0.3 | 63.17 | GG200 | 200 | 119.42 | 107.48 | OK |
| 6 | 15.7 | 206.91 | 0.3 | 62.07 | GG200 | 200 | 119.42 | 107.48 | OK |
| 7 | 15.4 | 203.27 | 0.3 | 60.98 | GG200 | 200 | 119.42 | 107.48 | OK |
| 8 | 15.1 | 199.62 | 0.3 | 59.89 | GG200 | 200 | 119.42 | 107.48 | OK |
| 9 | 14.8 | 195.98 | 0.3 | 58.79 | GG200 | 200 | 119.42 | 107.48 | OK |
| 10 | 14.5 | 192.33 | 0.3 | 57.70 | GG200 | 200 | 119.42 | 107.48 | OK |
| 11 | 14.2 | 188.69 | 0.3 | 56.61 | GG200 | 200 | 119.42 | 107.48 | OK |
| 12 | 13.9 | 185.04 | 0.45 | 83.27 | GG200 | 200 | 119.42 | 107.48 | OK |
| 13 | 13.3 | 177.75 | 0.6 | 106.65 | GG200 | 200 | 119.42 | 107.48 | OK |
| 14 | 12.7 | 170.46 | 0.6 | 102.28 | GG200 | 200 | 119.42 | 107.48 | OK |
| 15 | 12.1 | 163.17 | 0.6 | 97.90 | GG200 | 200 | 119.42 | 107.48 | OK |
| 16 | 11.5 | 155.88 | 0.6 | 93.53 | GG200 | 200 | 119.42 | 107.48 | OK |
| 17 | 10.9 | 148.59 | 0.6 | 89.16 | GG200 | 200 | 119.42 | 107.48 | OK |
| 18 | 10.3 | 141.30 | 0.6 | 84.78 | GG200 | 200 | 119.42 | 107.48 | OK |
| 19 | 9.7 | 134.01 | 0.6 | 80.41 | GG200 | 200 | 119.42 | 107.48 | OK |
| 20 | 9.1 | 126.72 | 0.6 | 76.03 | GG200 | 200 | 119.42 | 107.48 | OK |
| 21 | 8.5 | 119.43 | 0.6 | 71.66 | GG200 | 200 | 119.42 | 107.48 | OK |
| 22 | 7.9 | 112.14 | 0.6 | 67.29 | GG200 | 200 | 119.42 | 107.48 | OK |
| 23 | 7.3 | 104.85 | 0.6 | 62.91 | GG200 | 200 | 119.42 | 107.48 | OK |
| 24 | 6.7 | 97.56 | 0.6 | 58.54 | GG200 | 200 | 119.42 | 107.48 | OK |
| 25 | 6.1 | 90.27 | 0.6 | 54.16 | GG120 | 120 | 71.65 | 64.49 | OK |
| 26 | 5.5 | 82.98 | 0.6 | 49.79 | GG120 | 120 | 71.65 | 64.49 | OK |
| 27 | 4.9 | 75.69 | 0.6 | 45.42 | GG120 | 120 | 71.65 | 64.49 | OK |
| 28 | 4.3 | 68.40 | 0.6 | 41.04 | GG120 | 120 | 71.65 | 64.49 | OK |
| 29 | 3.7 | 61.11 | 0.6 | 36.67 | GG120 | 120 | 71.65 | 64.49 | OK |
| 30 | 3.1 | 53.82 | 0.6 | 32.29 | GG120 | 120 | 71.65 | 64.49 | OK |
| 31 | 2.5 | 46.53 | 0.6 | 27.92 | GG120 | 120 | 71.65 | 64.49 | OK |
| 32 | 1.9 | 39.24 | 0.6 | 23.55 | GG120 | 120 | 71.65 | 64.49 | OK |
| 33 | 1.3 | 31.95 | 0.6 | 19.17 | GG120 | 120 | 71.65 | 64.49 | OK |
| 34 | 0.7 | 24.66 | 0.6 | 14.80 | GG120 | 120 | 71.65 | 64.49 | OK |
| 35 | 0.1 | 17.37 | 0.43 | 7.47 | GG120 | 120 | 71.65 | 64.49 | OK |

| Internal Stability with Respect to Pullout Failure of Reinforcement | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Layer #** | **Z (m)** | **$\sigma'_v$ (kPa)** | **$T_{max}$ (kN/m)** | **$L_e$ (m)** | **$L_a$ (m)** | **L (m)** | **Check** |
| 1 | 17.2 | 344.6 | 33.77 | 1.00 | 0 | 18.1 | OK |
| 2 | 16.9 | 338.6 | 66.45 | 1.00 | 0.2 | 18.1 | OK |
| 3 | 16.6 | 332.6 | 65.35 | 1.00 | 0.3 | 18.1 | OK |
| 4 | 16.3 | 326.6 | 64.26 | 1.00 | 0.4 | 18.1 | OK |
| 5 | 16.0 | 320.6 | 63.17 | 1.00 | 0.5 | 18.1 | OK |
| 6 | 15.7 | 314.6 | 62.07 | 1.00 | 0.6 | 18.1 | OK |
| 7 | 15.4 | 308.6 | 60.98 | 1.00 | 0.8 | 18.1 | OK |
| 8 | 15.1 | 302.6 | 59.89 | 1.00 | 0.9 | 18.1 | OK |
| 9 | 14.8 | 296.6 | 58.79 | 1.00 | 1 | 18.1 | OK |
| 10 | 14.5 | 290.6 | 57.70 | 1.00 | 1.1 | 18.1 | OK |
| 11 | 14.2 | 284.6 | 56.61 | 1.00 | 1.2 | 18.1 | OK |
| 12 | 13.9 | 278.6 | 83.27 | 1.00 | 1.4 | 18.1 | OK |
| 13 | 13.3 | 266.6 | 106.65 | 1.00 | 1.6 | 15.3 | OK |
| 14 | 12.7 | 254.6 | 102.28 | 1.00 | 1.8 | 15.3 | OK |
| 15 | 12.1 | 242.6 | 97.90 | 1.00 | 2.1 | 15.3 | OK |
| 16 | 11.5 | 230.6 | 93.53 | 1.00 | 2.3 | 15.3 | OK |
| 17 | 10.9 | 218.6 | 89.16 | 1.00 | 2.6 | 15.3 | OK |
| 18 | 10.3 | 206.6 | 84.78 | 1.00 | 2.8 | 15.3 | OK |
| 19 | 9.7 | 194.6 | 80.41 | 1.00 | 3 | 15.3 | OK |
| 20 | 9.1 | 182.6 | 76.03 | 1.00 | 3.3 | 15.3 | OK |
| 21 | 8.5 | 170.6 | 71.66 | 1.00 | 3.5 | 15.3 | OK |
| 22 | 7.9 | 158.6 | 67.29 | 1.00 | 3.8 | 15.3 | OK |
| 23 | 7.3 | 146.6 | 62.91 | 1.00 | 4 | 15.3 | OK |
| 24 | 6.7 | 134.6 | 58.54 | 1.00 | 4.2 | 15.3 | OK |
| 25 | 6.1 | 122.6 | 54.16 | 1.00 | 4.5 | 12.5 | OK |
| 26 | 5.5 | 110.6 | 49.79 | 1.00 | 4.7 | 12.5 | OK |
| 27 | 4.9 | 98.6 | 45.42 | 1.00 | 5 | 12.5 | OK |
| 28 | 4.3 | 86.6 | 41.04 | 1.00 | 5.2 | 12.5 | OK |
| 29 | 3.7 | 74.6 | 36.67 | 1.00 | 5.4 | 12.5 | OK |
| 30 | 3.1 | 62.6 | 32.29 | 1.00 | 5.7 | 12.5 | OK |
| 31 | 2.5 | 50.6 | 27.92 | 1.00 | 5.9 | 12.5 | OK |
| 32 | 1.9 | 38.6 | 23.55 | 1.01 | 6.2 | 12.5 | OK |
| 33 | 1.3 | 26.6 | 19.17 | 1.19 | 6.4 | 12.5 | OK |
| 34 | 0.7 | 14.6 | 14.80 | 1.68 | 6.6 | 12.5 | OK |
| 35 | 0.1 | 2.6 | 7.47 | 4.75 | 6.9 | 12.5 | OK |

## DESIGN OF MECHNICALLY STABILISED EARTH (MSE) WALLS - Load Case 2

| | | | |
|---|---|---|---|
| **Earthquake Parameters** | | | |
| Peak ground acceleration coefficient, a | 0.08 | | |
| Horizontal coefficient of acceleration, $a_h$ | 0.04 | | |
| Hor. Coeffi. of acceleration with amplification of motion, kh | 0.056 | | |
| Weight of active zone, $W_a$ | 1185 | | |
| | | | |
| | | | |
| **Load and Resistance factors** | | | |
| Traffic surcharge, $q_L$ | 20 | | |
| Live load factor , $\gamma_{EQ}$ | 1.00 | | |
| Maximum vertcial earth pressure factor $\gamma_{EVmax}$ | 1.35 | | |
| Load Case | 2 | | |
| Resistance Factors for tensile and pullout resistance, $\phi_{GG}$ | 1.2 | | |
| Surcharge equivalent height, $h_{eq}$ (m) | 0.74 | | |

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| Internal Stability with Respect to Tensile Failure of Reinforcement | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Layer #** | **Z (m)** | **$\sigma_H$ (kPa)** | **$S_v$ (m)** | **$T_{max}$ (kN/m)** | **$T_{md}$ (kN/m)** | **$T_{ult}$ (kN/m)** | **$S_{rs}$ (kN/m)** | **$S_{rt}$ (kN/m)** | **Check** |
| 1 | 17.2 | 218.34 | 0.15 | 32.75 | 1.97 | 200 | 45.71 | 1.89 | OK |
| 2 | 16.9 | 214.69 | 0.3 | 64.41 | 1.97 | 200 | 89.89 | 1.89 | OK |
| 3 | 16.6 | 211.05 | 0.3 | 63.31 | 1.97 | 200 | 88.36 | 1.89 | OK |
| 4 | 16.3 | 207.40 | 0.3 | 62.22 | 1.97 | 200 | 86.84 | 1.89 | OK |
| 5 | 16.0 | 203.76 | 0.3 | 61.13 | 1.97 | 200 | 85.31 | 1.89 | OK |
| 6 | 15.7 | 200.11 | 0.3 | 60.03 | 1.97 | 200 | 83.78 | 1.89 | OK |
| 7 | 15.4 | 196.47 | 0.3 | 58.94 | 1.97 | 200 | 82.26 | 1.89 | OK |
| 8 | 15.1 | 192.82 | 0.3 | 57.85 | 1.97 | 200 | 80.73 | 1.89 | OK |
| 9 | 14.8 | 189.18 | 0.3 | 56.75 | 1.97 | 200 | 79.21 | 1.89 | OK |
| 10 | 14.5 | 185.53 | 0.3 | 55.66 | 1.97 | 200 | 77.68 | 1.89 | OK |
| 11 | 14.2 | 181.89 | 0.3 | 54.57 | 1.97 | 200 | 76.15 | 1.89 | OK |
| 12 | 13.9 | 178.24 | 0.45 | 80.21 | 1.97 | 200 | 111.94 | 1.89 | OK |
| 13 | 13.3 | 170.95 | 0.6 | 102.57 | 1.97 | 200 | 143.15 | 1.89 | OK |
| 14 | 12.7 | 163.66 | 0.6 | 98.20 | 1.97 | 200 | 137.05 | 1.89 | OK |
| 15 | 12.1 | 156.37 | 0.6 | 93.82 | 1.97 | 200 | 130.94 | 1.89 | OK |
| 16 | 11.5 | 149.08 | 0.6 | 89.45 | 1.97 | 200 | 124.84 | 1.89 | OK |
| 17 | 10.9 | 141.79 | 0.6 | 85.07 | 1.97 | 200 | 118.73 | 1.89 | OK |
| 18 | 10.3 | 134.50 | 0.6 | 80.70 | 1.97 | 200 | 112.63 | 1.89 | OK |
| 19 | 9.7 | 127.21 | 0.6 | 76.33 | 1.97 | 200 | 106.52 | 1.89 | OK |
| 20 | 9.1 | 119.92 | 0.6 | 71.95 | 1.97 | 200 | 100.42 | 1.89 | OK |
| 21 | 8.5 | 112.63 | 0.6 | 67.58 | 1.97 | 200 | 94.31 | 1.89 | OK |
| 22 | 7.9 | 105.34 | 0.6 | 63.20 | 1.97 | 200 | 88.21 | 1.89 | OK |
| 23 | 7.3 | 98.05 | 0.6 | 58.83 | 1.97 | 200 | 82.11 | 1.89 | OK |
| 24 | 6.7 | 90.76 | 0.6 | 54.46 | 1.97 | 200 | 76.00 | 1.89 | OK |
| 25 | 6.1 | 83.47 | 0.6 | 50.08 | 1.97 | 120 | 69.90 | 1.89 | OK |
| 26 | 5.5 | 76.18 | 0.6 | 45.71 | 1.97 | 120 | 63.79 | 1.89 | OK |
| 27 | 4.9 | 68.89 | 0.6 | 41.33 | 1.97 | 120 | 57.69 | 1.89 | OK |
| 28 | 4.3 | 61.60 | 0.6 | 36.96 | 1.97 | 120 | 51.58 | 1.89 | OK |
| 29 | 3.7 | 54.31 | 0.6 | 32.59 | 1.97 | 120 | 45.48 | 1.89 | OK |
| 30 | 3.1 | 47.02 | 0.6 | 28.21 | 1.97 | 120 | 39.37 | 1.89 | OK |
| 31 | 2.5 | 39.73 | 0.6 | 23.84 | 1.97 | 120 | 33.27 | 1.89 | OK |
| 32 | 1.9 | 32.44 | 0.6 | 19.46 | 1.97 | 120 | 27.16 | 1.89 | OK |
| 33 | 1.3 | 25.15 | 0.6 | 15.09 | 1.97 | 120 | 21.06 | 1.89 | OK |
| 34 | 0.7 | 17.86 | 0.6 | 10.72 | 1.97 | 120 | 14.96 | 1.89 | OK |
| 35 | 0.1 | 10.57 | 0.43 | 4.55 | 1.97 | 120 | 6.34 | 1.89 | OK |

| Internal Stability with Respect to Pullout Failure of Reinforcement | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Layer #** | **Z (m)** | **$\sigma'_v$ (kPa)** | **$T_{total}$ (kN/m)** | **Required $L_e$ (m)** | **L (m)** | **Available $L_e$ (m)** | **Check** |
| 1 | 17.2 | 344.6 | 34.72 | 1.00 | 18.1 | 18.1 | OK |
| 2 | 16.9 | 338.6 | 66.37 | 1.00 | 18.1 | 18 | OK |
| 3 | 16.6 | 332.6 | 65.28 | 1.00 | 18.1 | 17.9 | OK |
| 4 | 16.3 | 326.6 | 64.19 | 1.00 | 18.1 | 17.7 | OK |
| 5 | 16.0 | 320.6 | 63.09 | 1.00 | 18.1 | 17.6 | OK |
| 6 | 15.7 | 314.6 | 62.00 | 1.00 | 18.1 | 17.5 | OK |
| 7 | 15.4 | 308.6 | 60.91 | 1.00 | 18.1 | 17.4 | OK |
| 8 | 15.1 | 302.6 | 59.81 | 1.00 | 18.1 | 17.3 | OK |
| 9 | 14.8 | 296.6 | 58.72 | 1.00 | 18.1 | 17.1 | OK |
| 10 | 14.5 | 290.6 | 57.63 | 1.00 | 18.1 | 17 | OK |
| 11 | 14.2 | 284.6 | 56.53 | 1.00 | 18.1 | 16.9 | OK |
| 12 | 13.9 | 278.6 | 82.17 | 1.00 | 18.1 | 16.8 | OK |
| 13 | 13.3 | 266.6 | 104.54 | 1.00 | 15.3 | 13.7 | OK |
| 14 | 12.7 | 254.6 | 100.16 | 1.00 | 15.3 | 13.5 | OK |
| 15 | 12.1 | 242.6 | 95.79 | 1.00 | 15.3 | 13.3 | OK |
| 16 | 11.5 | 230.6 | 91.41 | 1.00 | 15.3 | 13 | OK |
| 17 | 10.9 | 218.6 | 87.04 | 1.00 | 15.3 | 12.8 | OK |
| 18 | 10.3 | 206.6 | 82.67 | 1.00 | 15.3 | 12.5 | OK |
| 19 | 9.7 | 194.6 | 78.29 | 1.00 | 15.3 | 12.3 | OK |
| 20 | 9.1 | 182.6 | 73.92 | 1.00 | 15.3 | 12.1 | OK |
| 21 | 8.5 | 170.6 | 69.54 | 1.00 | 15.3 | 11.8 | OK |
| 22 | 7.9 | 158.6 | 65.17 | 1.00 | 15.3 | 11.6 | OK |
| 23 | 7.3 | 146.6 | 60.80 | 1.00 | 15.3 | 11.3 | OK |
| 24 | 6.7 | 134.6 | 56.42 | 1.00 | 15.3 | 11.1 | OK |
| 25 | 6.1 | 122.6 | 52.05 | 1.00 | 12.5 | 8.1 | OK |
| 26 | 5.5 | 110.6 | 47.67 | 1.00 | 12.5 | 7.8 | OK |
| 27 | 4.9 | 98.6 | 43.30 | 1.00 | 12.5 | 7.6 | OK |
| 28 | 4.3 | 86.6 | 38.93 | 1.00 | 12.5 | 7.3 | OK |
| 29 | 3.7 | 74.6 | 34.55 | 1.00 | 12.5 | 7.1 | OK |
| 30 | 3.1 | 62.6 | 30.18 | 1.00 | 12.5 | 6.9 | OK |
| 31 | 2.5 | 50.6 | 25.80 | 1.00 | 12.5 | 6.6 | OK |
| 32 | 1.9 | 38.6 | 21.43 | 1.00 | 12.5 | 6.4 | OK |
| 33 | 1.3 | 26.6 | 17.06 | 1.00 | 12.5 | 6.2 | OK |
| 34 | 0.7 | 14.6 | 12.68 | 1.35 | 12.5 | 5.9 | OK |
| 35 | 0.1 | 2.6 | 6.51 | 3.88 | 12.5 | 5.7 | OK |

## DESIGN OF MECHNICALLY STABILISED EARTH (MSE) WALLS - Load Case 3

| | | | |
|---|---|---|---|
| **Wall Geometry** | | | |
| Wall Height (m), H | 17.23 | | |
| Bottom width of wall, L | 18.64 | | |
| Top width of wall, w | 13.5 | | |
| Slope of backfill behind wall (Deg), β | 14 | | |
| Face inclination from horizontal (Deg), $\theta_I$ | 108.4 | | |
| | | | |
| | | | |
| **Reinforced Soil Block Parameters** | | | |
| Eff. Frcition of reinforced soil (Deg), $\phi'_r$ | 32 | | |
| Unit weight of reinfoced soil (kN/m$^3$), $\gamma_r$ | 20 | | |
| | | | |
| **Load and Resistance factors** | | | |
| Traffic surcharge, $q_L$ | 10 | | |
| Live load factor , $\gamma_{LS}$ | 1.75 | | |
| Maximum vertcial earth pressure factor $\gamma_{EVmax}$ | 1.35 | | |
| Load Case | 3 | | |
| | | | |
| **Geogrid paramaters** | | | |
| | **Top** | **Middle** | **Bottom** |
| Ultimate strength of reinforcement, $_{Tult}$ | GG120 | GG200 | GG200 |
| Vertical spacing | 0.6 | 0.6 | 0.3 |
| Length | 12.5 | 15.3 | 18.1 |
| No of reinforcment layer | 11 | 12 | 12 |
| | | | |
| | | | |
| Partial factor - creep rupture - $RF_{CR}$ | 1.00 | 1.00 | 1.00 |
| Partial factor - construction damage - $RF_{ID}$ | 1.1 | 1.1 | 1.1 |
| Partial factor - environmental effects - $RF_D$ | 1.05 | 1.05 | 1.05 |
| | | | |
| | | | |
| Resistance Factors for tensile and pullout resistance, $\phi_{GG}$ | 0.9 | | |
| Pullout resistance factor, F* | 0.42 | | |
| Scale correction factor, α | 0.8 | | |
| Coverage ratio, $R_c$ | 1 | | |
| C | 2 | | |
| | | | |
| Batter angle, $\theta$ (Deg) | 92.0 | | |
| Angle of fric between retained backfill and rein. Soil (Deg), $\delta$ | 14 | | |
| Rankine active earth pressure coefficient, $K_a$ | 0.45 | | |
| lateral earth pressure coefficient, $K_r$ | 0.45 | | |
| Surcharge equivalent height, $h_{eq}$ (m) | 0.65 | | |
| Inclination of failure surface with horizontal, $\psi$ (Deg) | 53.8 | | |
| Note: | | | |
| 1. For extensible reinforcement (geogrid), lateral stress ratio is equla to 1.0 | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

| Internal Stability with Respect to Tensile Failure of Reinforcement | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Layer #** | **Z (m)** | **$\sigma_H$ (kPa)** | **$S_v$ (m)** | **$T_{max}$ (kN/m)** | **Rein. Type** | **$T_{ult}$ (kN/m)** | **$T_{al}$ (kN/m)** | **$T_r$ (kN/m)** | **Check** |
| 1 | 17.2 | 217.24 | 0.15 | 32.59 | GG200 | 200 | 173.16 | 155.84 | OK |
| 2 | 16.9 | 213.60 | 0.3 | 64.08 | GG200 | 200 | 173.16 | 155.84 | OK |
| 3 | 16.6 | 209.95 | 0.3 | 62.99 | GG200 | 200 | 173.16 | 155.84 | OK |
| 4 | 16.3 | 206.31 | 0.3 | 61.89 | GG200 | 200 | 173.16 | 155.84 | OK |
| 5 | 16.0 | 202.66 | 0.3 | 60.80 | GG200 | 200 | 173.16 | 155.84 | OK |
| 6 | 15.7 | 199.02 | 0.3 | 59.71 | GG200 | 200 | 173.16 | 155.84 | OK |
| 7 | 15.4 | 195.37 | 0.3 | 58.61 | GG200 | 200 | 173.16 | 155.84 | OK |
| 8 | 15.1 | 191.73 | 0.3 | 57.52 | GG200 | 200 | 173.16 | 155.84 | OK |
| 9 | 14.8 | 188.08 | 0.3 | 56.42 | GG200 | 200 | 173.16 | 155.84 | OK |
| 10 | 14.5 | 184.44 | 0.3 | 55.33 | GG200 | 200 | 173.16 | 155.84 | OK |
| 11 | 14.2 | 180.79 | 0.3 | 54.24 | GG200 | 200 | 173.16 | 155.84 | OK |
| 12 | 13.9 | 177.15 | 0.45 | 79.72 | GG200 | 200 | 173.16 | 155.84 | OK |
| 13 | 13.3 | 169.86 | 0.6 | 101.91 | GG200 | 200 | 173.16 | 155.84 | OK |
| 14 | 12.7 | 162.57 | 0.6 | 97.54 | GG200 | 200 | 173.16 | 155.84 | OK |
| 15 | 12.1 | 155.28 | 0.6 | 93.17 | GG200 | 200 | 173.16 | 155.84 | OK |
| 16 | 11.5 | 147.99 | 0.6 | 88.79 | GG200 | 200 | 173.16 | 155.84 | OK |
| 17 | 10.9 | 140.70 | 0.6 | 84.42 | GG200 | 200 | 173.16 | 155.84 | OK |
| 18 | 10.3 | 133.41 | 0.6 | 80.04 | GG200 | 200 | 173.16 | 155.84 | OK |
| 19 | 9.7 | 126.12 | 0.6 | 75.67 | GG200 | 200 | 173.16 | 155.84 | OK |
| 20 | 9.1 | 118.83 | 0.6 | 71.30 | GG200 | 200 | 173.16 | 155.84 | OK |
| 21 | 8.5 | 111.54 | 0.6 | 66.92 | GG200 | 200 | 173.16 | 155.84 | OK |
| 22 | 7.9 | 104.25 | 0.6 | 62.55 | GG200 | 200 | 173.16 | 155.84 | OK |
| 23 | 7.3 | 96.96 | 0.6 | 58.17 | GG200 | 200 | 173.16 | 155.84 | OK |
| 24 | 6.7 | 89.67 | 0.6 | 53.80 | GG200 | 200 | 173.16 | 155.84 | OK |
| 25 | 6.1 | 82.38 | 0.6 | 49.43 | GG120 | 120 | 103.90 | 93.51 | OK |
| 26 | 5.5 | 75.09 | 0.6 | 45.05 | GG120 | 120 | 103.90 | 93.51 | OK |
| 27 | 4.9 | 67.80 | 0.6 | 40.68 | GG120 | 120 | 103.90 | 93.51 | OK |
| 28 | 4.3 | 60.51 | 0.6 | 36.30 | GG120 | 120 | 103.90 | 93.51 | OK |
| 29 | 3.7 | 53.22 | 0.6 | 31.93 | GG120 | 120 | 103.90 | 93.51 | OK |
| 30 | 3.1 | 45.93 | 0.6 | 27.56 | GG120 | 120 | 103.90 | 93.51 | OK |
| 31 | 2.5 | 38.64 | 0.6 | 23.18 | GG120 | 120 | 103.90 | 93.51 | OK |
| 32 | 1.9 | 31.35 | 0.6 | 18.81 | GG120 | 120 | 103.90 | 93.51 | OK |
| 33 | 1.3 | 24.06 | 0.6 | 14.43 | GG120 | 120 | 103.90 | 93.51 | OK |
| 34 | 0.7 | 16.77 | 0.6 | 10.06 | GG120 | 120 | 103.90 | 93.51 | OK |
| 35 | 0.1 | 9.48 | 0.43 | 4.08 | GG120 | 120 | 103.90 | 93.51 | OK |

| Internal Stability with Respect to Pullout Failure of Reinforcement | | | | | | | |
|---|---|---|---|---|---|---|---|
| Layer # | Z (m) | σ′$_v$ (kPa) | $T_{max}$ (kN/m) | $L_e$ (m) | $L_a$ (m) | L (m) | Check |
| 1 | 17.2 | 344.6 | 32.59 | 1.00 | 0 | 18.1 | OK |
| 2 | 16.9 | 338.6 | 64.08 | 1.00 | 0.2 | 18.1 | OK |
| 3 | 16.6 | 332.6 | 62.99 | 1.00 | 0.3 | 18.1 | OK |
| 4 | 16.3 | 326.6 | 61.89 | 1.00 | 0.4 | 18.1 | OK |
| 5 | 16.0 | 320.6 | 60.80 | 1.00 | 0.5 | 18.1 | OK |
| 6 | 15.7 | 314.6 | 59.71 | 1.00 | 0.6 | 18.1 | OK |
| 7 | 15.4 | 308.6 | 58.61 | 1.00 | 0.8 | 18.1 | OK |
| 8 | 15.1 | 302.6 | 57.52 | 1.00 | 0.9 | 18.1 | OK |
| 9 | 14.8 | 296.6 | 56.42 | 1.00 | 1 | 18.1 | OK |
| 10 | 14.5 | 290.6 | 55.33 | 1.00 | 1.1 | 18.1 | OK |
| 11 | 14.2 | 284.6 | 54.24 | 1.00 | 1.2 | 18.1 | OK |
| 12 | 13.9 | 278.6 | 79.72 | 1.00 | 1.4 | 18.1 | OK |
| 13 | 13.3 | 266.6 | 101.91 | 1.00 | 1.6 | 15.3 | OK |
| 14 | 12.7 | 254.6 | 97.54 | 1.00 | 1.8 | 15.3 | OK |
| 15 | 12.1 | 242.6 | 93.17 | 1.00 | 2.1 | 15.3 | OK |
| 16 | 11.5 | 230.6 | 88.79 | 1.00 | 2.3 | 15.3 | OK |
| 17 | 10.9 | 218.6 | 84.42 | 1.00 | 2.6 | 15.3 | OK |
| 18 | 10.3 | 206.6 | 80.04 | 1.00 | 2.8 | 15.3 | OK |
| 19 | 9.7 | 194.6 | 75.67 | 1.00 | 3 | 15.3 | OK |
| 20 | 9.1 | 182.6 | 71.30 | 1.00 | 3.3 | 15.3 | OK |
| 21 | 8.5 | 170.6 | 66.92 | 1.00 | 3.5 | 15.3 | OK |
| 22 | 7.9 | 158.6 | 62.55 | 1.00 | 3.8 | 15.3 | OK |
| 23 | 7.3 | 146.6 | 58.17 | 1.00 | 4 | 15.3 | OK |
| 24 | 6.7 | 134.6 | 53.80 | 1.00 | 4.2 | 15.3 | OK |
| 25 | 6.1 | 122.6 | 49.43 | 1.00 | 4.5 | 12.5 | OK |
| 26 | 5.5 | 110.6 | 45.05 | 1.00 | 4.7 | 12.5 | OK |
| 27 | 4.9 | 98.6 | 40.68 | 1.00 | 5 | 12.5 | OK |
| 28 | 4.3 | 86.6 | 36.30 | 1.00 | 5.2 | 12.5 | OK |
| 29 | 3.7 | 74.6 | 31.93 | 1.00 | 5.4 | 12.5 | OK |
| 30 | 3.1 | 62.6 | 27.56 | 1.00 | 5.7 | 12.5 | OK |
| 31 | 2.5 | 50.6 | 23.18 | 1.00 | 5.9 | 12.5 | OK |
| 32 | 1.9 | 38.6 | 18.81 | 1.00 | 6.2 | 12.5 | OK |
| 33 | 1.3 | 26.6 | 14.43 | 1.00 | 6.4 | 12.5 | OK |
| 34 | 0.7 | 14.6 | 10.06 | 1.14 | 6.6 | 12.5 | OK |
| 35 | 0.1 | 2.6 | 4.08 | 2.59 | 6.9 | 12.5 | OK |

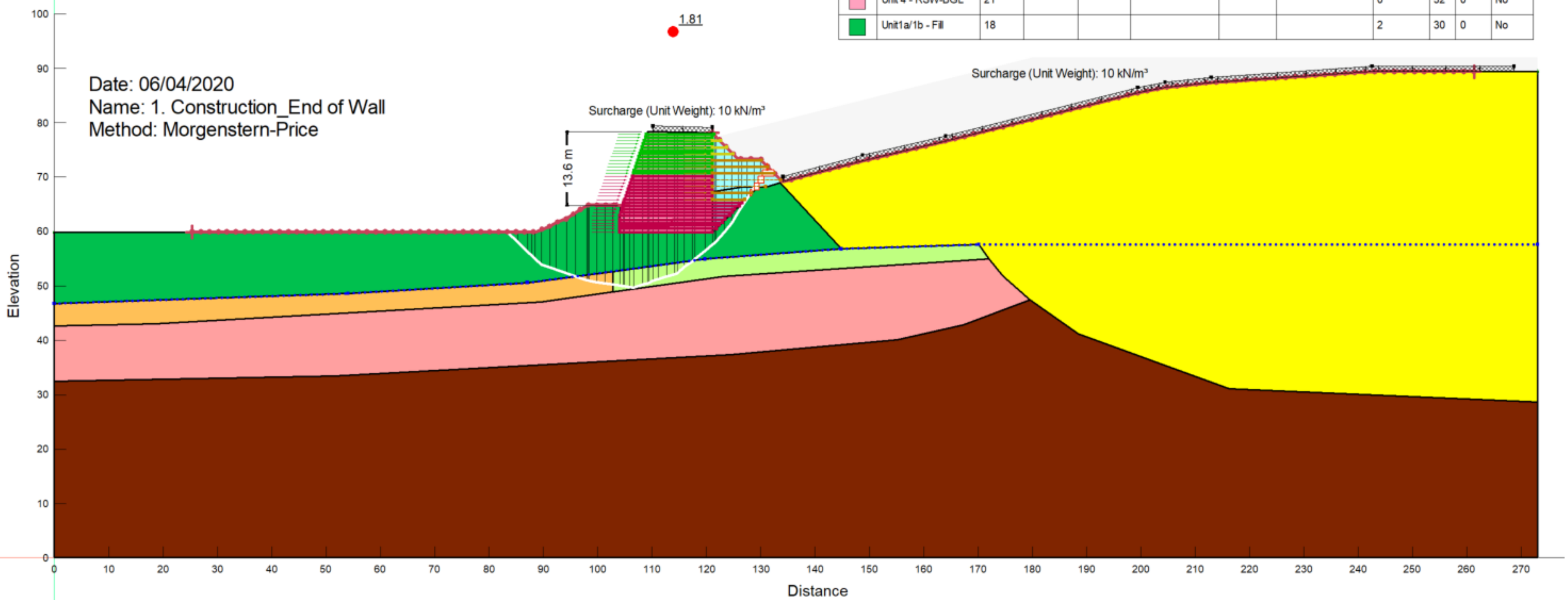
## DESIGN OF MECHNICALLY STABILISED EARTH (MSE) WALLS - Load Case 4

| | | | |
|---|---|---|---|
| **Load and Resistance factors** | | | |
| Traffic surcharge, $q_L$ | 20 | | |
| Live load factor, , $\gamma_{LS}$ | 1.00 | | |
| Maximum vertcial earth pressure factor $\gamma_{EVmax}$ | 1.35 | | |
| Load Case | 4 | | |
| Resistance Factors for tensile and pullout resistance, $\phi_{GG}$ | 1 | | |
| Surcharge equivalent height, $h_{eq}$ (m) | 1 | | |
| | | | |
| | | | |
| **Reinforcement Rupture** | | | |
| Factored impact load on 1st layer (kN/m) | 33.5 | | |
| Factored impact load on 2nd layer (kN/m) | 8.8 | | |
| | | | |
| **Reinforcement Pullout** | | | |
| Factored impact load on 1st layer (kN/m) | 19 | | |
| Factored impact load on 2nd layer (kN/m) | 8.8 | | |

| Internal Stability with Respect to Tensile Failure of Reinforcement | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Layer # | Z (m) | $\sigma_H$ (kPa) | $S_v$ (m) | $T_{max}$ (kN/m) | $T_l$(kN/m) | $T_{ult}$ (kN/m) | $S_{rs}$ (kN/m) | $S_{rt}$ (kN/m) | Check |
| 1 | 17.2 | 221.49 | 0.15 | 33.22 | 0.00 | 200 | 55.64 | 0.00 | OK |
| 2 | 16.9 | 217.85 | 0.3 | 65.35 | 0.00 | 200 | 109.45 | 0.00 | OK |
| 3 | 16.6 | 214.20 | 0.3 | 64.26 | 0.00 | 200 | 107.62 | 0.00 | OK |
| 4 | 16.3 | 210.56 | 0.3 | 63.17 | 0.00 | 200 | 105.79 | 0.00 | OK |
| 5 | 16.0 | 206.91 | 0.3 | 62.07 | 0.00 | 200 | 103.96 | 0.00 | OK |
| 6 | 15.7 | 203.27 | 0.3 | 60.98 | 0.00 | 200 | 102.13 | 0.00 | OK |
| 7 | 15.4 | 199.62 | 0.3 | 59.89 | 0.00 | 200 | 100.30 | 0.00 | OK |
| 8 | 15.1 | 195.98 | 0.3 | 58.79 | 0.00 | 200 | 98.47 | 0.00 | OK |
| 9 | 14.8 | 192.33 | 0.3 | 57.70 | 0.00 | 200 | 96.63 | 0.00 | OK |
| 10 | 14.5 | 188.69 | 0.3 | 56.61 | 0.00 | 200 | 94.80 | 0.00 | OK |
| 11 | 14.2 | 185.04 | 0.3 | 55.51 | 0.00 | 200 | 92.97 | 0.00 | OK |
| 12 | 13.9 | 181.40 | 0.45 | 81.63 | 0.00 | 200 | 136.71 | 0.00 | OK |
| 13 | 13.3 | 174.11 | 0.6 | 104.47 | 0.00 | 200 | 174.95 | 0.00 | OK |
| 14 | 12.7 | 166.82 | 0.6 | 100.09 | 0.00 | 200 | 167.63 | 0.00 | OK |
| 15 | 12.1 | 159.53 | 0.6 | 95.72 | 0.00 | 200 | 160.30 | 0.00 | OK |
| 16 | 11.5 | 152.24 | 0.6 | 91.34 | 0.00 | 200 | 152.98 | 0.00 | OK |
| 17 | 10.9 | 144.95 | 0.6 | 86.97 | 0.00 | 200 | 145.65 | 0.00 | OK |
| 18 | 10.3 | 137.66 | 0.6 | 82.60 | 0.00 | 200 | 138.33 | 0.00 | OK |
| 19 | 9.7 | 130.37 | 0.6 | 78.22 | 0.00 | 200 | 131.00 | 0.00 | OK |
| 20 | 9.1 | 123.08 | 0.6 | 73.85 | 0.00 | 200 | 123.68 | 0.00 | OK |
| 21 | 8.5 | 115.79 | 0.6 | 69.47 | 0.00 | 200 | 116.35 | 0.00 | OK |
| 22 | 7.9 | 108.50 | 0.6 | 65.10 | 0.00 | 200 | 109.03 | 0.00 | OK |
| 23 | 7.3 | 101.21 | 0.6 | 60.73 | 0.00 | 200 | 101.70 | 0.00 | OK |
| 24 | 6.7 | 93.92 | 0.6 | 56.35 | 0.00 | 200 | 94.38 | 0.00 | OK |
| 25 | 6.1 | 86.63 | 0.6 | 51.98 | 0.00 | 120 | 87.05 | 0.00 | OK |
| 26 | 5.5 | 79.34 | 0.6 | 47.60 | 0.00 | 120 | 79.72 | 0.00 | OK |
| 27 | 4.9 | 72.05 | 0.6 | 43.23 | 0.00 | 120 | 72.40 | 0.00 | OK |
| 28 | 4.3 | 64.76 | 0.6 | 38.86 | 0.00 | 120 | 65.07 | 0.00 | OK |
| 29 | 3.7 | 57.47 | 0.6 | 34.48 | 0.00 | 120 | 57.75 | 0.00 | OK |
| 30 | 3.1 | 50.18 | 0.6 | 30.11 | 0.00 | 120 | 50.42 | 0.00 | OK |
| 31 | 2.5 | 42.89 | 0.6 | 25.73 | 0.00 | 120 | 43.10 | 0.00 | OK |
| 32 | 1.9 | 35.60 | 0.6 | 21.36 | 0.00 | 120 | 35.77 | 0.00 | OK |
| 33 | 1.3 | 28.31 | 0.6 | 16.99 | 8.80 | 120 | 28.45 | 10.16 | OK |
| 34 | 0.7 | 21.02 | 0.6 | 12.61 | 33.50 | 120 | 21.12 | 38.69 | OK |
| 35 | 0.1 | 13.73 | 0.43 | 5.90 | 0.00 | 120 | 9.89 | 0.00 | OK |

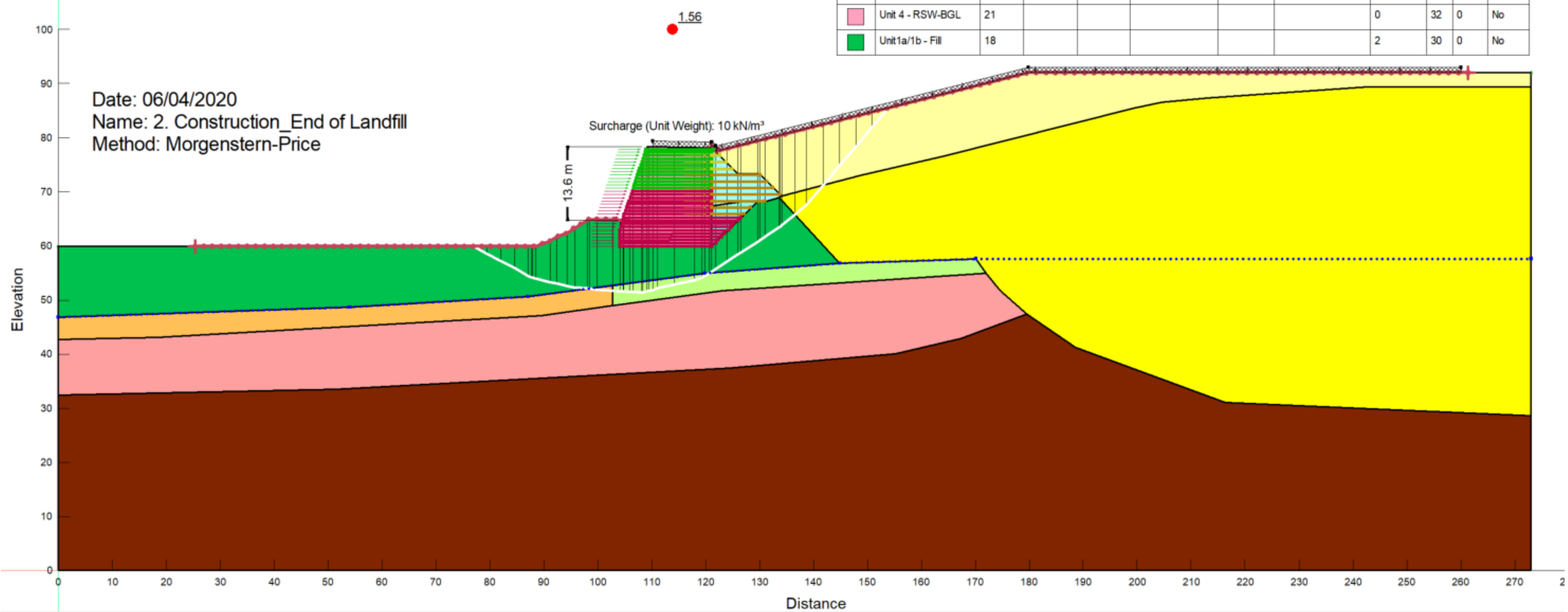
| Internal Stability with Respect to Pullout Failure of Reinforcement | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Layer #** | **Z (m)** | **$\sigma'_v$ (kPa)** | **$T_l$(kN/m)** | **$T_{total}$ (kN/m)** | **Required $L_e$ (m)** | **L (m)** | **Available $L_e$ (m)** | **Check** |
| 1 | 17.2 | 344.6 | 0 | 33.22 | 1.00 | 18.1 | 18.10 | OK |
| 2 | 16.9 | 338.6 | 0 | 65.35 | 1.00 | 18.1 | 17.98 | OK |
| 3 | 16.6 | 332.6 | 0 | 64.26 | 1.00 | 18.1 | 17.86 | OK |
| 4 | 16.3 | 326.6 | 0 | 63.17 | 1.00 | 18.1 | 17.74 | OK |
| 5 | 16.0 | 320.6 | 0 | 62.07 | 1.00 | 18.1 | 17.62 | OK |
| 6 | 15.7 | 314.6 | 0 | 60.98 | 1.00 | 18.1 | 17.50 | OK |
| 7 | 15.4 | 308.6 | 0 | 59.89 | 1.00 | 18.1 | 17.38 | OK |
| 8 | 15.1 | 302.6 | 0 | 58.79 | 1.00 | 18.1 | 17.26 | OK |
| 9 | 14.8 | 296.6 | 0 | 57.70 | 1.00 | 18.1 | 17.14 | OK |
| 10 | 14.5 | 290.6 | 0 | 56.61 | 1.00 | 18.1 | 17.02 | OK |
| 11 | 14.2 | 284.6 | 0 | 55.51 | 1.00 | 18.1 | 16.90 | OK |
| 12 | 13.9 | 278.6 | 0 | 81.63 | 1.00 | 18.1 | 16.78 | OK |
| 13 | 13.3 | 266.6 | 0 | 104.47 | 1.00 | 15.3 | 13.74 | OK |
| 14 | 12.7 | 254.6 | 0 | 100.09 | 1.00 | 15.3 | 13.50 | OK |
| 15 | 12.1 | 242.6 | 0 | 95.72 | 1.00 | 15.3 | 13.26 | OK |
| 16 | 11.5 | 230.6 | 0 | 91.34 | 1.00 | 15.3 | 13.02 | OK |
| 17 | 10.9 | 218.6 | 0 | 86.97 | 1.00 | 15.3 | 12.78 | OK |
| 18 | 10.3 | 206.6 | 0 | 82.60 | 1.00 | 15.3 | 12.55 | OK |
| 19 | 9.7 | 194.6 | 0 | 78.22 | 1.00 | 15.3 | 12.31 | OK |
| 20 | 9.1 | 182.6 | 0 | 73.85 | 1.00 | 15.3 | 12.07 | OK |
| 21 | 8.5 | 170.6 | 0 | 69.47 | 1.00 | 15.3 | 11.83 | OK |
| 22 | 7.9 | 158.6 | 0 | 65.10 | 1.00 | 15.3 | 11.59 | OK |
| 23 | 7.3 | 146.6 | 0 | 60.73 | 1.00 | 15.3 | 11.35 | OK |
| 24 | 6.7 | 134.6 | 0 | 56.35 | 1.00 | 15.3 | 11.11 | OK |
| 25 | 6.1 | 122.6 | 0 | 51.98 | 1.00 | 12.5 | 8.07 | OK |
| 26 | 5.5 | 110.6 | 0 | 47.60 | 1.00 | 12.5 | 7.83 | OK |
| 27 | 4.9 | 98.6 | 0 | 43.23 | 1.00 | 12.5 | 7.59 | OK |
| 28 | 4.3 | 86.6 | 0 | 38.86 | 1.00 | 12.5 | 7.35 | OK |
| 29 | 3.7 | 74.6 | 0 | 34.48 | 1.00 | 12.5 | 7.11 | OK |
| 30 | 3.1 | 62.6 | 0 | 30.11 | 1.00 | 12.5 | 6.87 | OK |
| 31 | 2.5 | 50.6 | 0 | 25.73 | 1.00 | 12.5 | 6.63 | OK |
| 32 | 1.9 | 38.6 | 0 | 21.36 | 1.03 | 12.5 | 6.39 | OK |
| 33 | 1.3 | 26.6 | 8.8 | 25.79 | 1.80 | 12.5 | 6.15 | OK |
| 34 | 0.7 | 14.6 | 19 | 31.61 | 4.03 | 12.5 | 5.91 | OK |
| 35 | 0.1 | 2.6 | 0 | 5.90 | 4.22 | 12.5 | 5.80 | OK |

| Color | Name | Unit Weight (kN/m³) | Cohesion (kPa) | Minimum Strength (kPa) | Non-constrained undrained strength ratio | SHANSEP function exponent | Overconsolidation Ratio Fn. | Cohesion' (kPa) | Phi' (°) | B-bar | Add Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bed Rock | | | | | | | | | 0 | No |
| | Engineered Fil l- BGL | 20 | | | | | | 0 | 32 | 0 | No |
| | Engineered Fill | 20 | | | | | | 0 | 32 | 0 | Yes |
| | Unit 1c- Existing Landfill | 17 | | | | | | 1 | 27 | 0 | No |
| | Unit 2 - Residual Clay_SHANCEP | 19 | | 0 | 0.22 | 0.95 | OCR vs Depth | | | 1 | No |
| | Unit 2 - Residual Clay_Undrained | 19 | 150 | | | | | | | 0 | No |
| | Unit 3a/5- VL & L strength Rock | 22 | | | | | | 10 | 33 | 0 | No |
| | Unit 4 - RSW | 21 | | | | | | 0 | 32 | 0 | Yes |
| | Unit 4 - RSW-BGL | 21 | | | | | | 0 | 32 | 0 | No |
| | Unit1a/1b - Fill | 18 | | | | | | 2 | 30 | 0 | No |





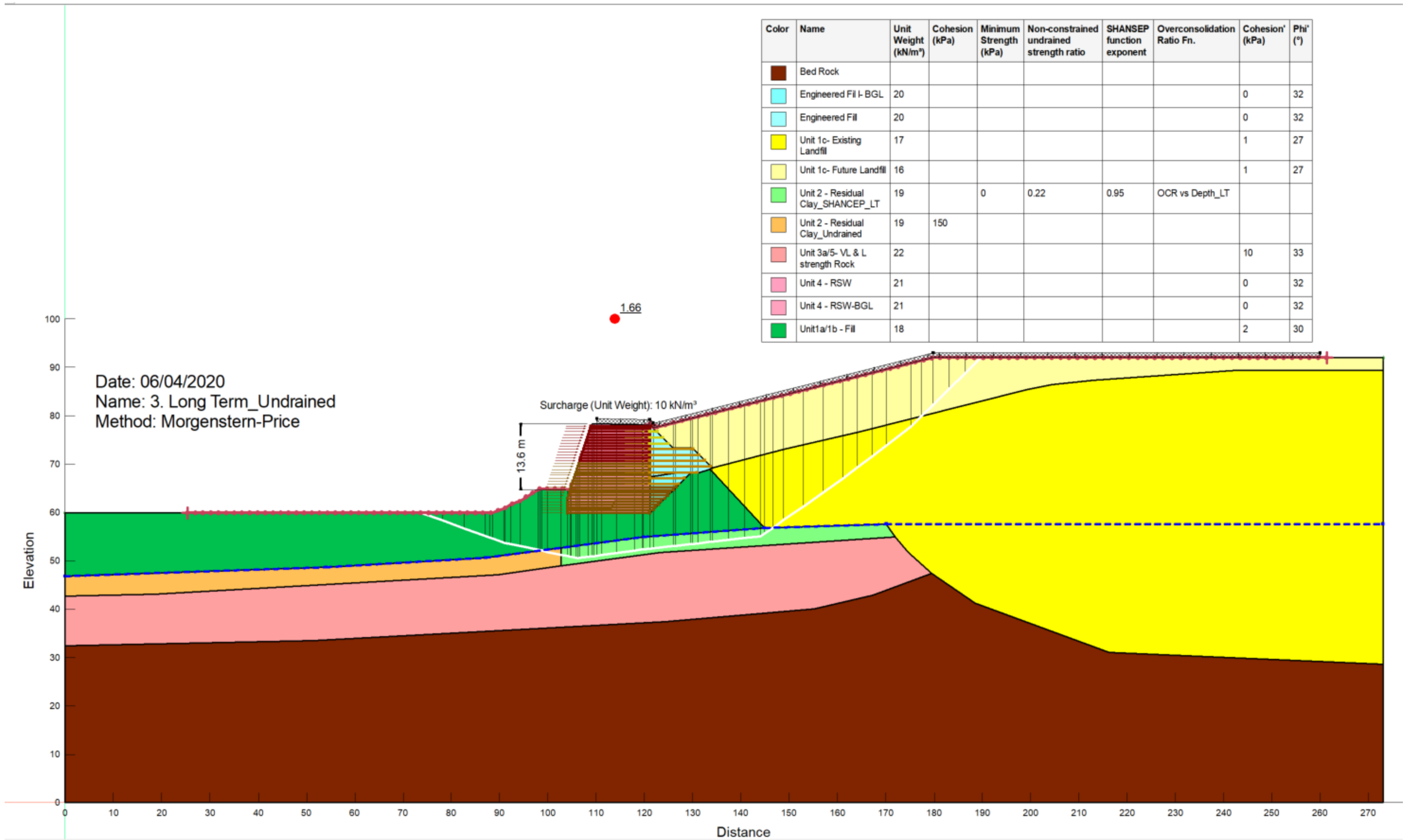

| | | | | |
|---|---|---|---|---|
| GOLDER | CLIENT Cleanaway | | PROJECT Erskine Park Landfill | A4 |
| | DRAWN JR | DATE 6/04/2020 | TITLEs CS5-Construction_End of Wall | |
| | CHECKED TM | DATE 6/04/2020 | | |
| | SCALE N.T.S | | PROJECT No 19135652 | FIGURE C5.1 |




| Color | Name | Unit Weight (kN/m³) | Cohesion (kPa) | Minimum Strength (kPa) | Non-constrained undrained strength ratio | SHANSEP function exponent | Overconsolidation Ratio Fn. | Cohesion' (kPa) | Phi' (°) | B-bar | Add Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bed Rock | | | | | | | | | 0 | No |
| | Engineered Fill- BGL | 20 | | | | | | 0 | 32 | 0 | No |
| | Engineered Fill | 20 | | | | | | 0 | 32 | 0 | Yes |
| | Unit 1c- Existing Landfill | 17 | | | | | | 1 | 27 | 0 | No |
| | Unit 1c- Future Landfill | 16 | | | | | | 1 | 27 | 0 | Yes |
| | Unit 2 - Residual Clay_SHANCEP | 19 | | 0 | 0.22 | 0.95 | OCR vs Depth | | | 1 | No |
| | Unit 2 - Residual Clay_Undrained | 19 | 150 | | | | | | | 0 | No |
| | Unit 3a/5- VL & L strength Rock | 22 | | | | | | 10 | 33 | 0 | No |
| | Unit 4 - RSW | 21 | | | | | | 0 | 32 | 0 | Yes |
| | Unit 4 - RSW-BGL | 21 | | | | | | 0 | 32 | 0 | No |
| | Unit1a/1b - Fill | 18 | | | | | | 2 | 30 | 0 | No |

GOLDER

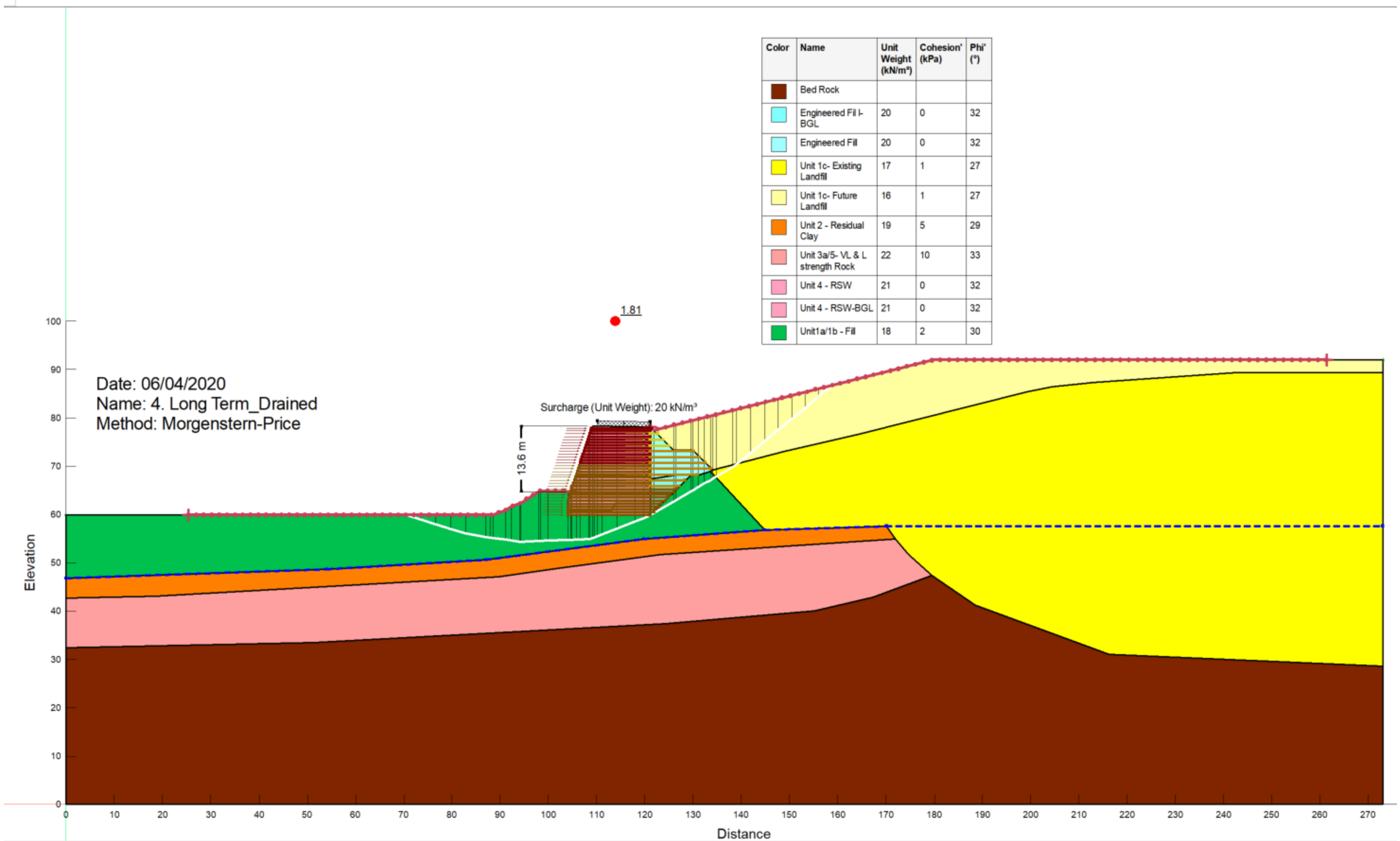
| | | | | |
|---|---|---|---|---|
| CLIENT Cleanaway | | PROJECT Erskine Park Landfill | | A4 |
| DRAWN JR | DATE 6/04/2020 | TITLEs CS5-Construction_End of Landfill | | |
| CHECKED TM | DATE 6/04/2020 | | | |
| SCALE N.T.S | | PROJECT No 19135652 | | FIGURE C5.2 |




| Color | Name | Unit Weight (kN/m³) | Cohesion (kPa) | Minimum Strength (kPa) | Non-constrained undrained strength ratio | SHANSEP function exponent | Overconsolidation Ratio Fn. | Cohesion' (kPa) | Phi' (°) |
|---|---|---|---|---|---|---|---|---|---|
| | Bed Rock | | | | | | | | |
| | Engineered Fil l- BGL | 20 | | | | | | 0 | 32 |
| | Engineered Fill | 20 | | | | | | 0 | 32 |
| | Unit 1c- Existing Landfill | 17 | | | | | | 1 | 27 |
| | Unit 1c- Future Landfill | 16 | | | | | | 1 | 27 |
| | Unit 2 - Residual Clay_SHANCEP_LT | 19 | | 0 | 0.22 | 0.95 | OCR vs Depth_LT | | |
| | Unit 2 - Residual Clay_Undrained | 19 | 150 | | | | | | |
| | Unit 3a/5- VL & L strength Rock | 22 | | | | | | 10 | 33 |
| | Unit 4 - RSW | 21 | | | | | | 0 | 32 |
| | Unit 4 - RSW-BGL | 21 | | | | | | 0 | 32 |
| | Unit1a/1b - Fill | 18 | | | | | | 2 | 30 |

GOLDER

| | | | |
|---|---|---|---|
| CLIENT Cleanaway | | PROJECT Erskine Park Landfill | A4 |
| DRAWN JR | DATE 6/04/2020 | TITLES CS5- Long Term_Undrained | |
| CHECKED TM | DATE 6/04/2020 | | |
| SCALE N.T.S | | PROJECT No 19135652 | FIGURE C5.3 |

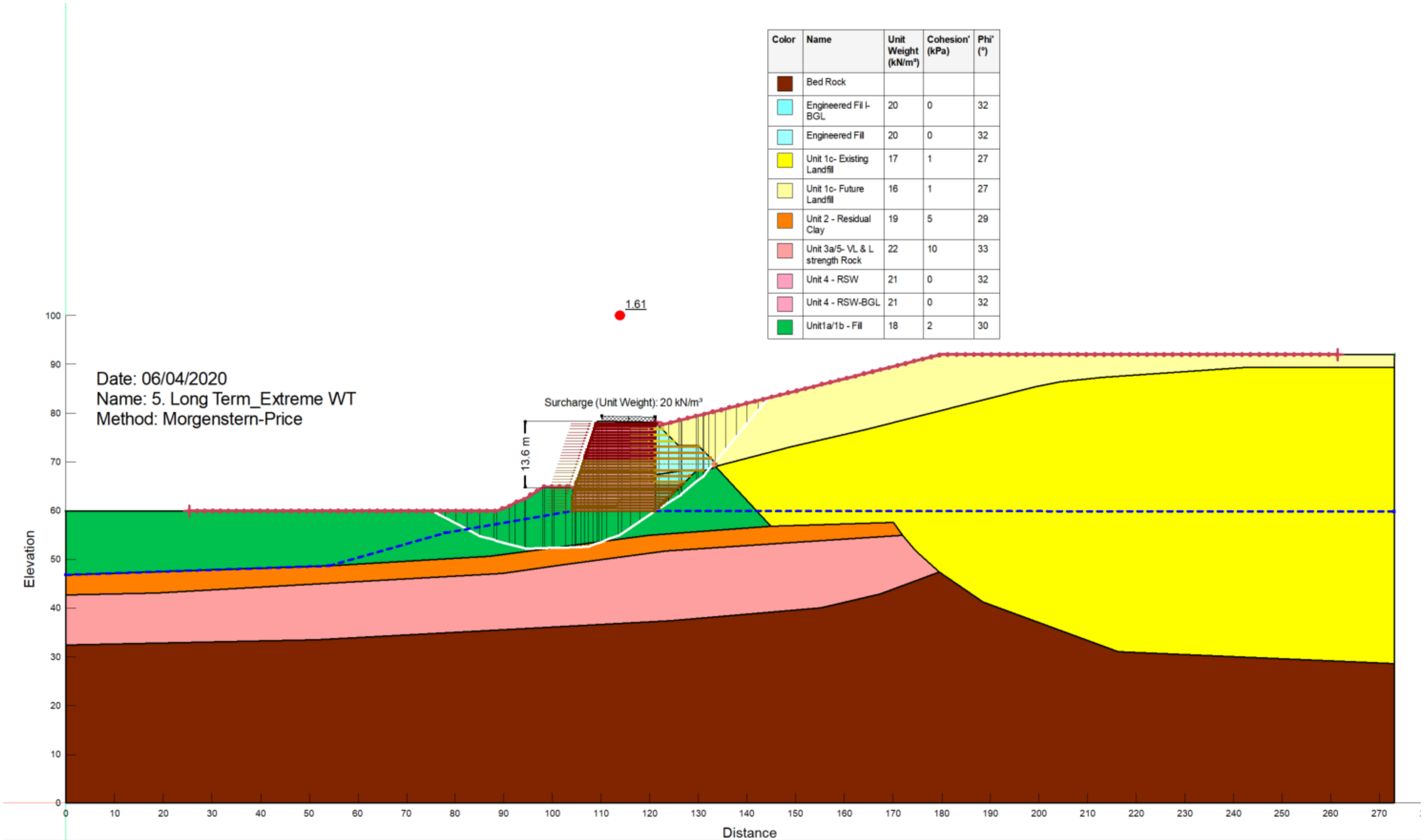



| Color | Name | Unit Weight (kN/m³) | Cohesion' (kPa) | Phi' (°) |
|---|---|---|---|---|
| | Bed Rock | | | |
| | Engineered Fill - BGL | 20 | 0 | 32 |
| | Engineered Fill | 20 | 0 | 32 |
| | Unit 1c- Existing Landfill | 17 | 1 | 27 |
| | Unit 1c- Future Landfill | 16 | 1 | 27 |
| | Unit 2 - Residual Clay | 19 | 5 | 29 |
| | Unit 3a/5- VL & L strength Rock | 22 | 10 | 33 |
| | Unit 4 - RSW | 21 | 0 | 32 |
| | Unit 4 - RSW-BGL | 21 | 0 | 32 |
| | Unit1a/1b - Fill | 18 | 2 | 30 |

GOLDER

| | | | |
|---|---|---|---|
| CLIENT | Cleanaway | PROJECT | Erskine Park Landfill |
| DRAWN JR | DATE 6/04/2020 | TITLEs | CS5- Long Term_Drained |
| CHECKED TM | DATE 6/04/2020 | | |
| SCALE | N.T.S | PROJECT No 19135652 | FIGURE C5.4 |

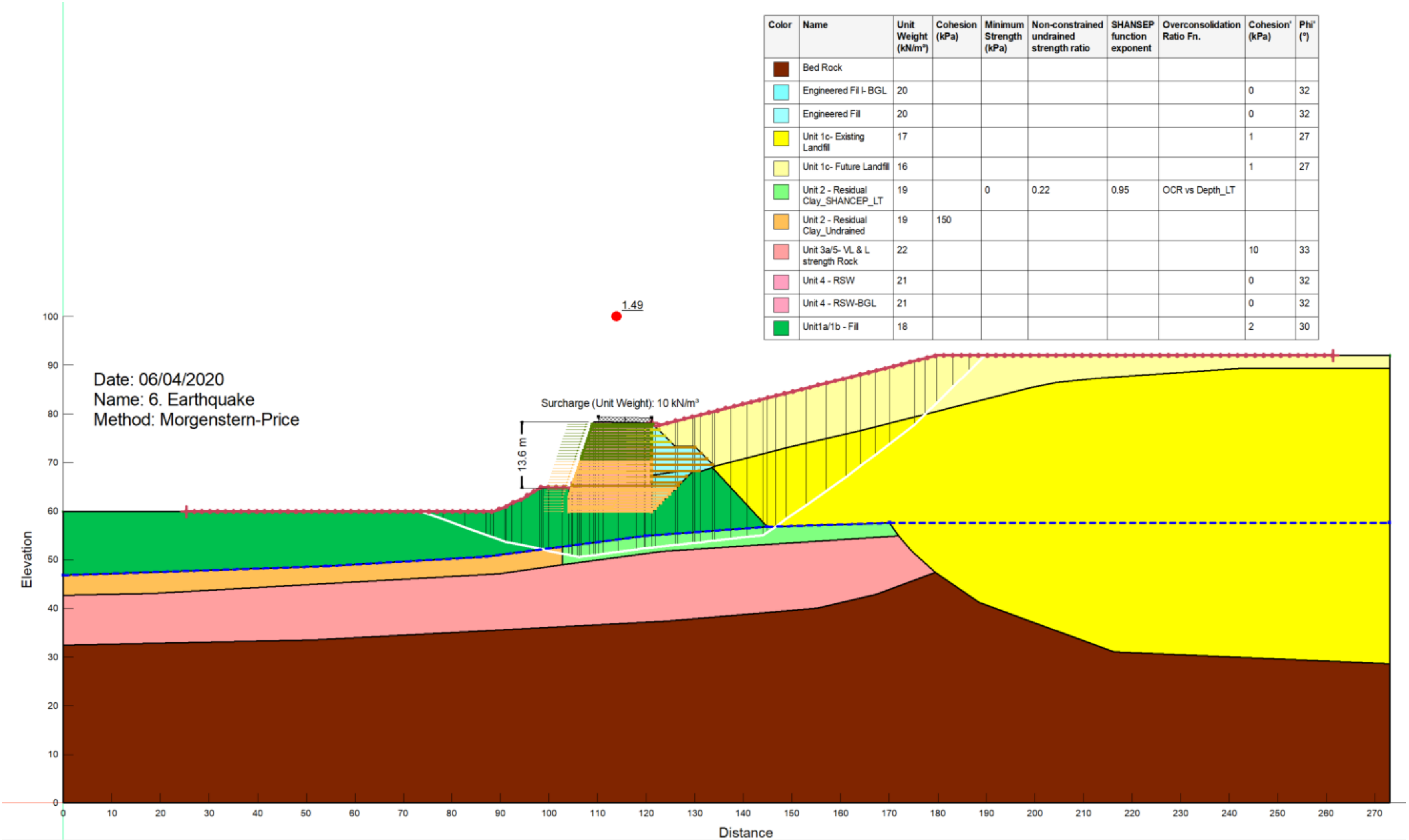
A4




| Color | Name | Unit Weight (kN/m³) | Cohesion' (kPa) | Phi' (°) |
|---|---|---|---|---|
| | Bed Rock | | | |
| | Engineered Fill - BGL | 20 | 0 | 32 |
| | Engineered Fill | 20 | 0 | 32 |
| | Unit 1c- Existing Landfill | 17 | 1 | 27 |
| | Unit 1c- Future Landfill | 16 | 1 | 27 |
| | Unit 2 - Residual Clay | 19 | 5 | 29 |
| | Unit 3a/5- VL & L strength Rock | 22 | 10 | 33 |
| | Unit 4 - RSW | 21 | 0 | 32 |
| | Unit 4 - RSW-BGL | 21 | 0 | 32 |
| | Unit1a/1b - Fill | 18 | 2 | 30 |

GOLDER

| | | | | |
|---|---|---|---|---|
| CLIENT Cleanaway | | PROJECT Erskine Park Landfill | | A4 |
| DRAWN JR | DATE 6/04/2020 | TITLEs CS5-Long Term_Extreme Water Table | | |
| CHECKED TM | DATE 6/04/2020 | | | |
| SCALE N.T.S | | PROJECT No 19135652 | | FIGURE C5.5 |

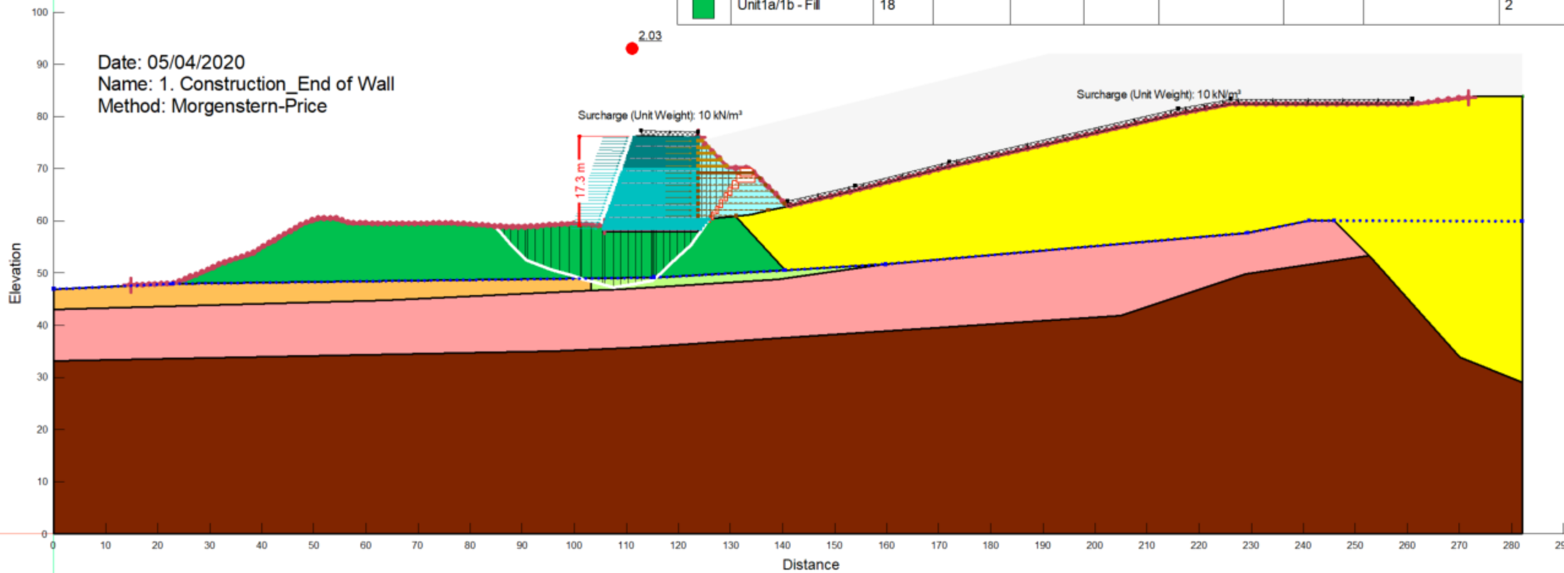



| Color | Name | Unit Weight (kN/m³) | Cohesion (kPa) | Minimum Strength (kPa) | Non-constrained undrained strength ratio | SHANSEP function exponent | Overconsolidation Ratio Fn. | Cohesion' (kPa) | Phi' (°) |
|---|---|---|---|---|---|---|---|---|---|
| | Bed Rock | | | | | | | | |
| | Engineered Fill- BGL | 20 | | | | | | 0 | 32 |
| | Engineered Fill | 20 | | | | | | 0 | 32 |
| | Unit 1c- Existing Landfill | 17 | | | | | | 1 | 27 |
| | Unit 1c- Future Landfill | 16 | | | | | | 1 | 27 |
| | Unit 2 - Residual Clay_SHANCEP_LT | 19 | | 0 | 0.22 | 0.95 | OCR vs Depth_LT | | |
| | Unit 2 - Residual Clay_Undrained | 19 | 150 | | | | | | |
| | Unit 3a/5- VL & L strength Rock | 22 | | | | | | 10 | 33 |
| | Unit 4 - RSW | 21 | | | | | | 0 | 32 |
| | Unit 4 - RSW-BGL | 21 | | | | | | 0 | 32 |
| | Unit1a/1b - Fill | 18 | | | | | | 2 | 30 |

GOLDER

CLIENT Cleanaway
PROJECT Erskine Park Landfill
A4
DRAWN JR DATE 6/04/2020
CHECKED TM DATE 6/04/2020
TITLES CS5- Earthquake
SCALE N.T.S
PROJECT No 19135652
FIGURE C5.6

| Color | Name | Unit Weight (kN/m³) | Cohesion (kPa) | Minimum Strength (kPa) | Maximum Strength (kPa) | Non-constrained undrained strength ratio | SHANSEP function exponent | Overconsolidation Ratio Fn. | Cohesion' (kPa) | Phi' (°) | B-bar | Add Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bed Rock | | | | | | | | | | 0 | No |
| | Engineered Fill | 20 | | | | | | | 0 | 32 | 0 | Yes |
| | Engineered Fill - BGL | 20 | | | | | | | 0 | 32 | 0 | No |
| | RSW-Unit 4 | 21 | | | | | | | 0 | 32 | 0 | Yes |
| | RSW-Unit 4 - BGL | 21 | | | | | | | 0 | 32 | 0 | No |
| | Unit 1c- Existing Landfill | 17 | | | | | | | 1 | 27 | 0 | No |
| | Unit 2 - Residual Clay _SHANCEP | 18 | | 0 | 150 | 0.22 | 0.95 | Depth vs OCR | | | 1 | No |
| | Unit 2 - Residual Clay _Undrained | 19 | 150 | | | | | | | | 0 | No |
| | Unit 3a/5- VL & L Strength Rock | 22 | | | | | | | 10 | 33 | 0 | No |
| | Unit1a/1b - Fill | 18 | | | | | | | 2 | 30 | 0 | No |



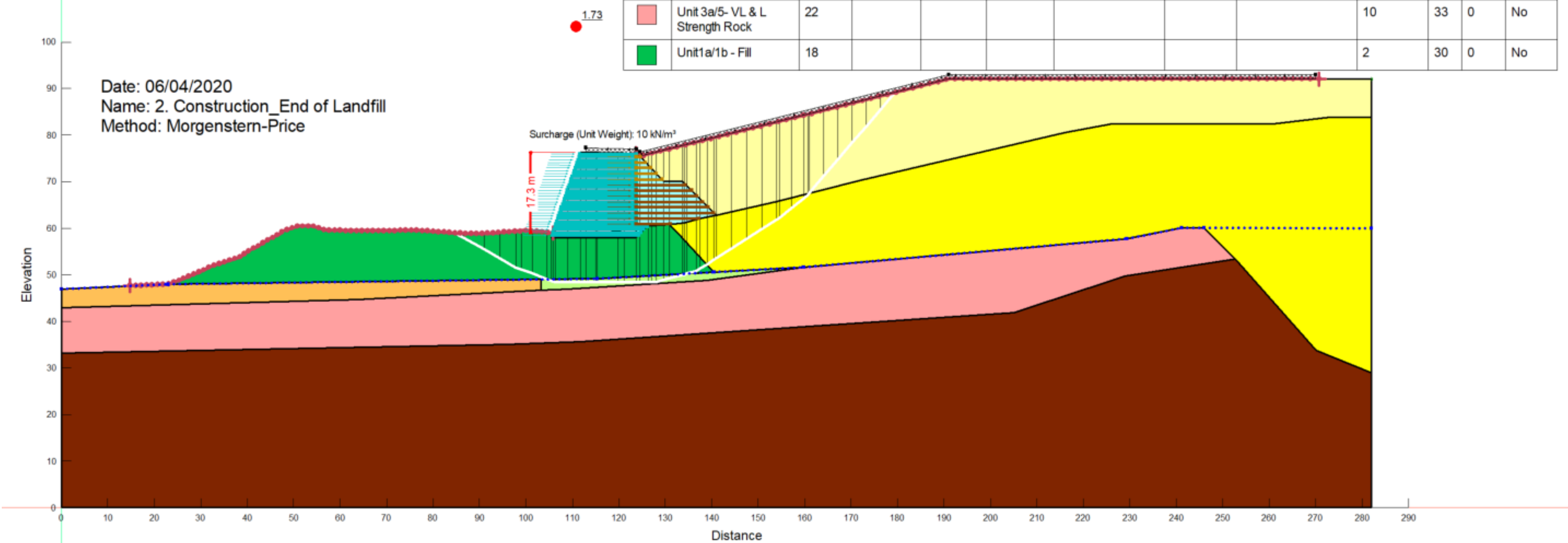

| CLIENT Cleanaway | | PROJECT Erskine Park Landfill | A4 |
|---|---|---|---|
| DRAWN JR | DATE 6/04/2020 | TITLEs CS6-Construction_End of Wall | |
| CHECKED TM | DATE 6/04/2020 | | |
| SCALE N.T.S | | PROJECT No 19135652 | FIGURE C5.7 |

GOLDER



Document Set ID: 9100745
Version: 1, Version Date: 16/04/2020

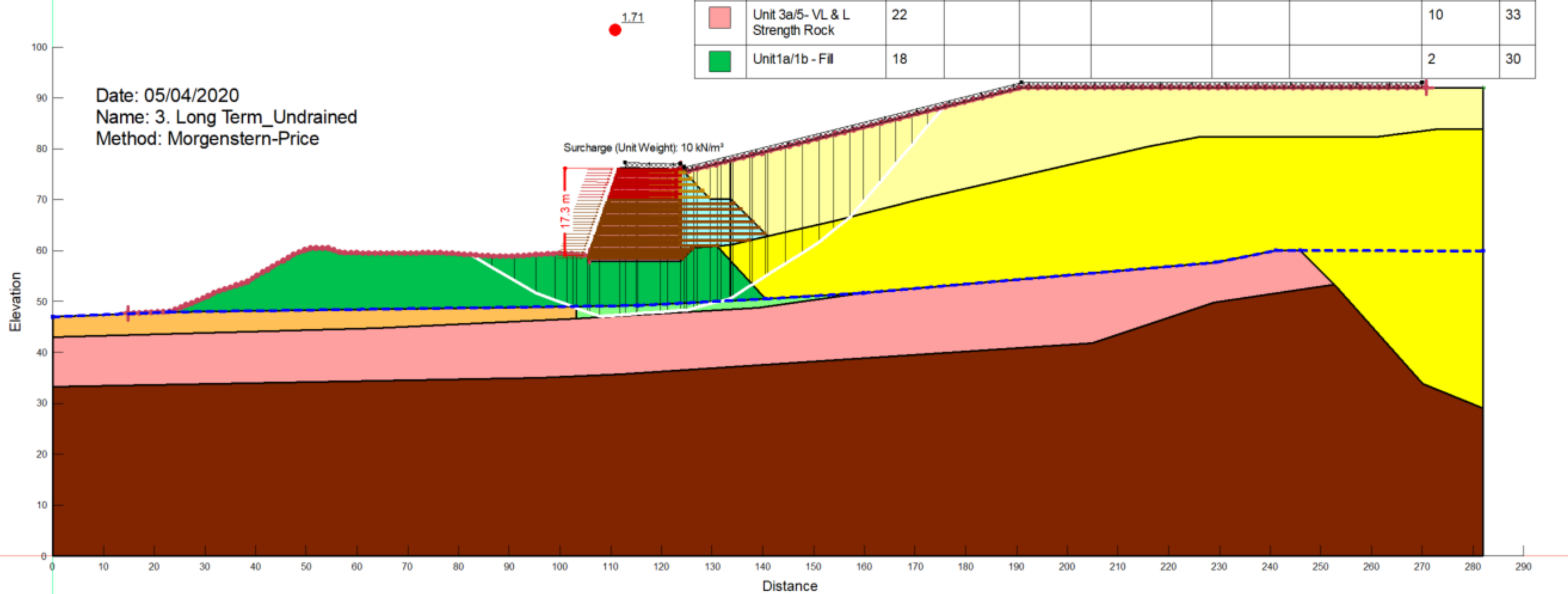
| Color | Name | Unit Weight (kN/m³) | Cohesion (kPa) | Minimum Strength (kPa) | Maximum Strength (kPa) | Non-constrained undrained strength ratio | SHANSEP function exponent | Overconsolidation Ratio Fn. | Cohesion' (kPa) | Phi' (°) | B-bar | Add Weight |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bed Rock | | | | | | | | | | 0 | No |
| | Engineered Fill | 20 | | | | | | | 0 | 32 | 0 | Yes |
| | Engineered Fill - BGL | 20 | | | | | | | 0 | 32 | 0 | No |
| | RSW-Unit 4 | 21 | | | | | | | 0 | 32 | 0 | Yes |
| | RSW-Unit 4 - BGL | 21 | | | | | | | 0 | 32 | 0 | No |
| | Unit 1c- Existing Landfill | 17 | | | | | | | 1 | 27 | 0 | No |
| | Unit 1c- Future Landfill | 16 | | | | | | | 1 | 27 | 0 | Yes |
| | Unit 2 - Residual Clay _SHANCEP | 18 | | 0 | 150 | 0.22 | 0.95 | Depth vs OCR | | | 1 | No |
| | Unit 2 - Residual Clay _Undrained | 19 | 150 | | | | | | | | 0 | No |
| | Unit 3a/5- VL & L Strength Rock | 22 | | | | | | | 10 | 33 | 0 | No |
| | Unit1a/1b - Fill | 18 | | | | | | | 2 | 30 | 0 | No |




| CLIENT | Cleanaway | PROJECT | Erskine Park Landfill | A4 |
|---|---|---|---|---|
| DRAWN JR | DATE 6/04/2020 | TITLEs | CS6-Construction_End of Landfill | |
| CHECKED TM | DATE 6/04/2020 | | | |
| SCALE N.T.S | | PROJECT No 19135652 | | FIGURE C5.8 |

GOLDER

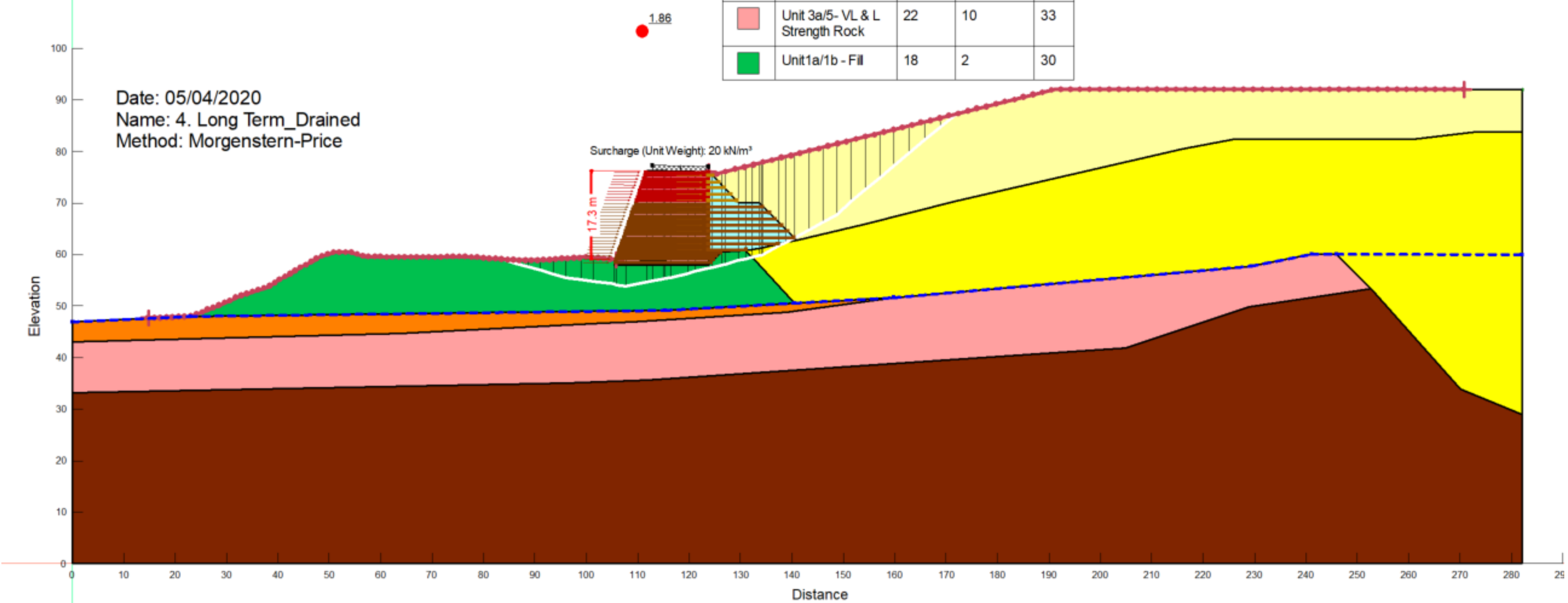
| Color | Name | Unit Weight (kN/m³) | Cohesion (kPa) | Minimum Strength (kPa) | Non-constrained undrained strength ratio | SHANSEP function exponent | Overconsolidation Ratio Fn. | Cohesion' (kPa) | Phi' (°) |
|---|---|---|---|---|---|---|---|---|---|
| | Bed Rock | | | | | | | | |
| | Engineered Fill | 20 | | | | | | 0 | 32 |
| | Engineered Fill - BGL | 20 | | | | | | 0 | 32 |
| | RSW-Unit 4 | 21 | | | | | | 0 | 32 |
| | RSW-Unit 4 - BGL | 21 | | | | | | 0 | 32 |
| | Unit 1c- Existing Landfill | 17 | | | | | | 1 | 27 |
| | Unit 1c- Future Landfill | 16 | | | | | | 1 | 27 |
| | Unit 2 - Residual Clay _SHANCEP_LT | 18 | | 0 | 0.22 | 0.95 | Depth vs OCR- LT | | |
| | Unit 2 - Residual Clay _Undrained | 19 | 150 | | | | | | |
| | Unit 3a/5- VL & L Strength Rock | 22 | | | | | | 10 | 33 |
| | Unit1a/1b - Fill | 18 | | | | | | 2 | 30 |




| | | | | | |
|---|---|---|---|---|---|
| GOLDER | CLIENT Cleanaway | | PROJECT Erskine Park Landfill | | A4 |
| | DRAWN JR | DATE 6/04/2020 | TITLEs CS6-Long Term_Undrained | | |
| | CHECKED TM | DATE 6/04/2020 | | | |
| | SCALE N.T.S | | PROJECT No 19135652 | | FIGURE C5.9 |

| Color | Name | Unit Weight (kN/m³) | Cohesion' (kPa) | Phi' (°) |
|---|---|---|---|---|
| | Bed Rock | | | |
| | Engineered Fill | 20 | 0 | 32 |
| | Engineered Fill - BGL | 20 | 0 | 32 |
| | RSW-Unit 4 | 21 | 0 | 32 |
| | RSW-Unit 4 - BGL | 21 | 0 | 32 |
| | Unit 1c- Existing Landfill | 17 | 1 | 27 |
| | Unit 1c- Future Landfill | 16 | 1 | 27 |
| | Unit 2 - Residual Clay | 19 | 5 | 29 |
| | Unit 3a/5- VL & L Strength Rock | 22 | 10 | 33 |
| | Unit1a/1b - Fill | 18 | 2 | 30 |

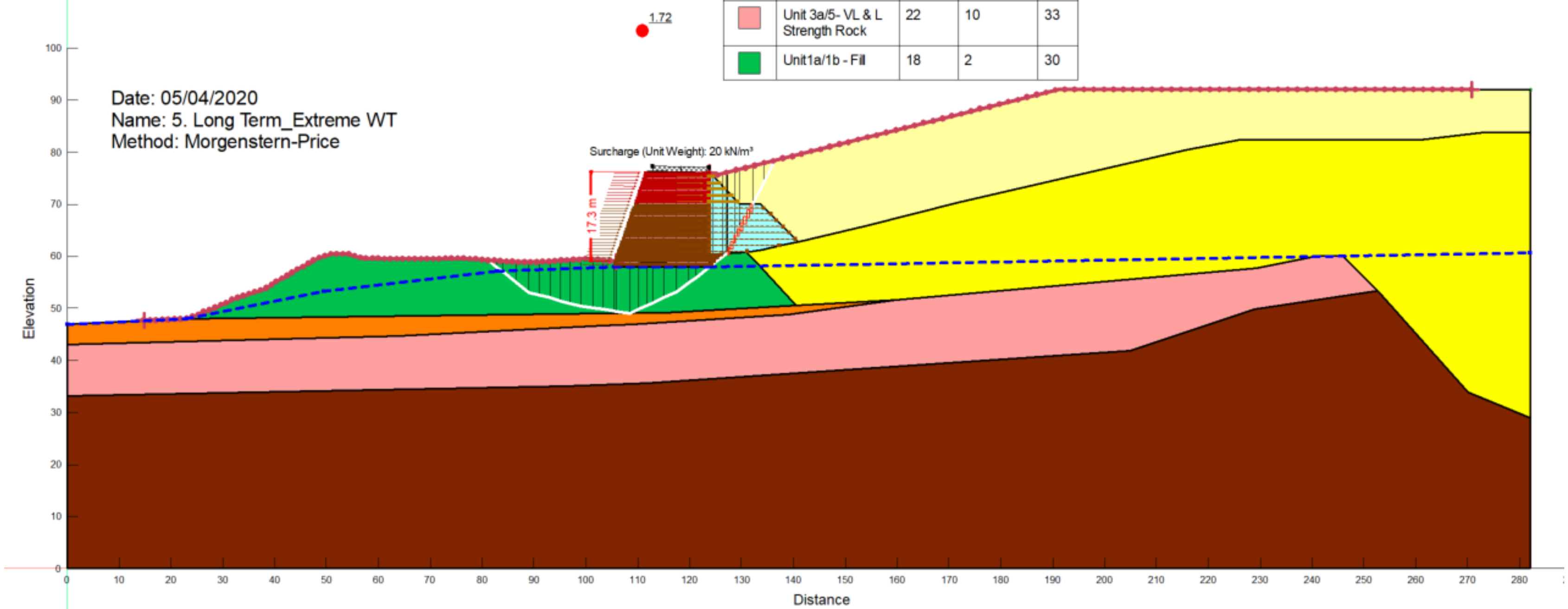
Date: 05/04/2020
Name: 4. Long Term_Drained
Method: Morgenstern-Price




| CLIENT | Cleanaway | PROJECT | Erskine Park Landfill | A4 |
|---|---|---|---|---|
| DRAWN JR | DATE 6/04/2020 | TITLEs | CS6-Long Term_Drained | |
| CHECKED TM | DATE 6/04/2020 | | | |
| SCALE N.T.S | | PROJECT No 19135652 | | FIGURE C5.10 |

GOLDER

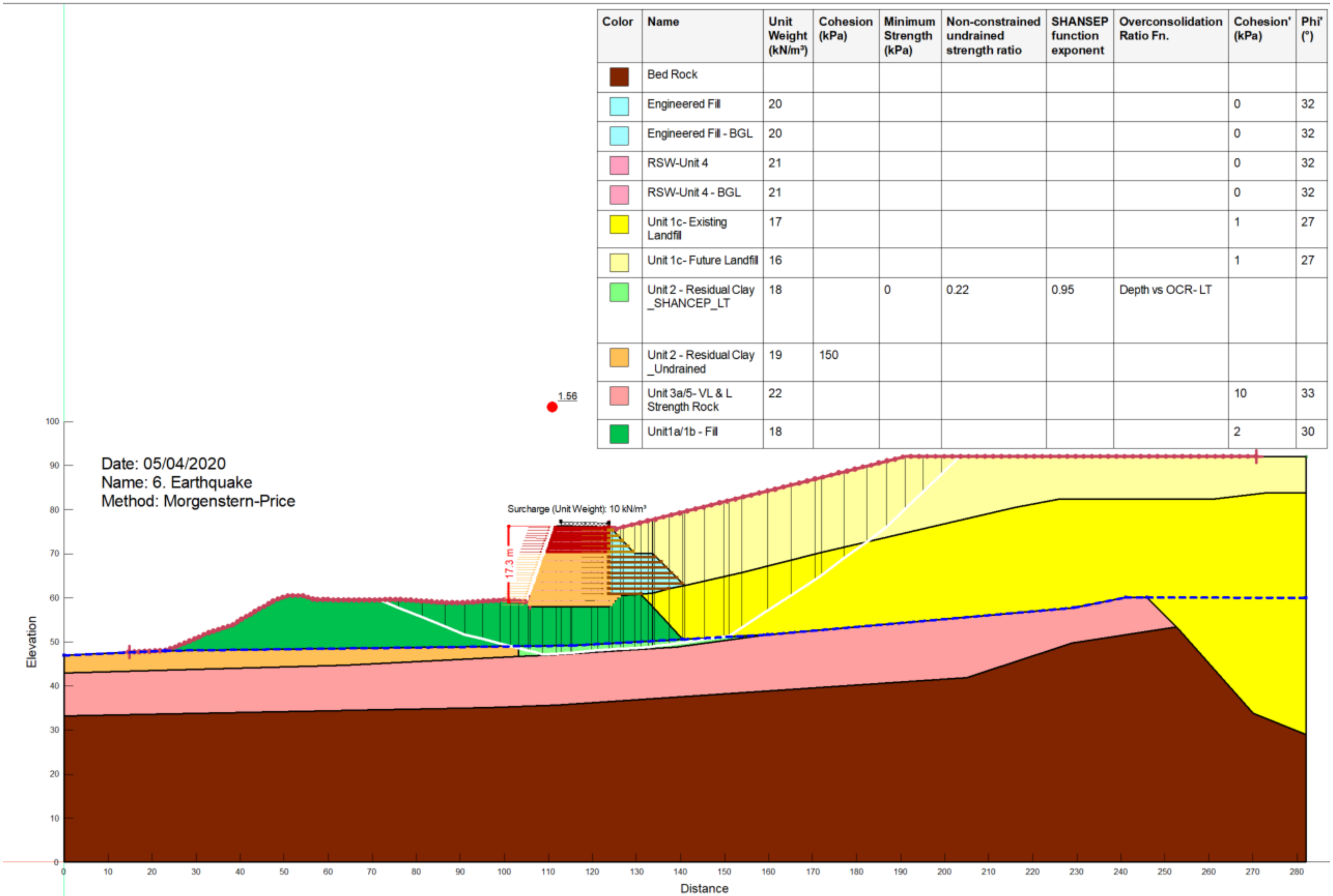
| Color | Name | Unit Weight (kN/m³) | Cohesion' (kPa) | Phi' (°) |
|---|---|---|---|---|
| | Bed Rock | | | |
| | Engineered Fill | 20 | 0 | 32 |
| | Engineered Fill - BGL | 20 | 0 | 32 |
| | RSW-Unit 4 | 21 | 0 | 32 |
| | RSW-Unit 4 - BGL | 21 | 0 | 32 |
| | Unit 1c- Existing Landfill | 17 | 1 | 27 |
| | Unit 1c- Future Landfill | 16 | 1 | 27 |
| | Unit 2 - Residual Clay | 19 | 5 | 29 |
| | Unit 3a/5- VL & L Strength Rock | 22 | 10 | 33 |
| | Unit1a/1b - Fill | 18 | 2 | 30 |




| CLIENT | Cleanaway | PROJECT | Erskine Park Landfill | A4 |
|---|---|---|---|---|
| DRAWN JR | DATE 6/04/2020 | TITLEs | CS6-Long Term_Extreme Water Table | |
| CHECKED TM | DATE 6/04/2020 | | | |
| SCALE N.T.S | | PROJECT No 19135652 | | FIGURE C5.11 |

GOLDER

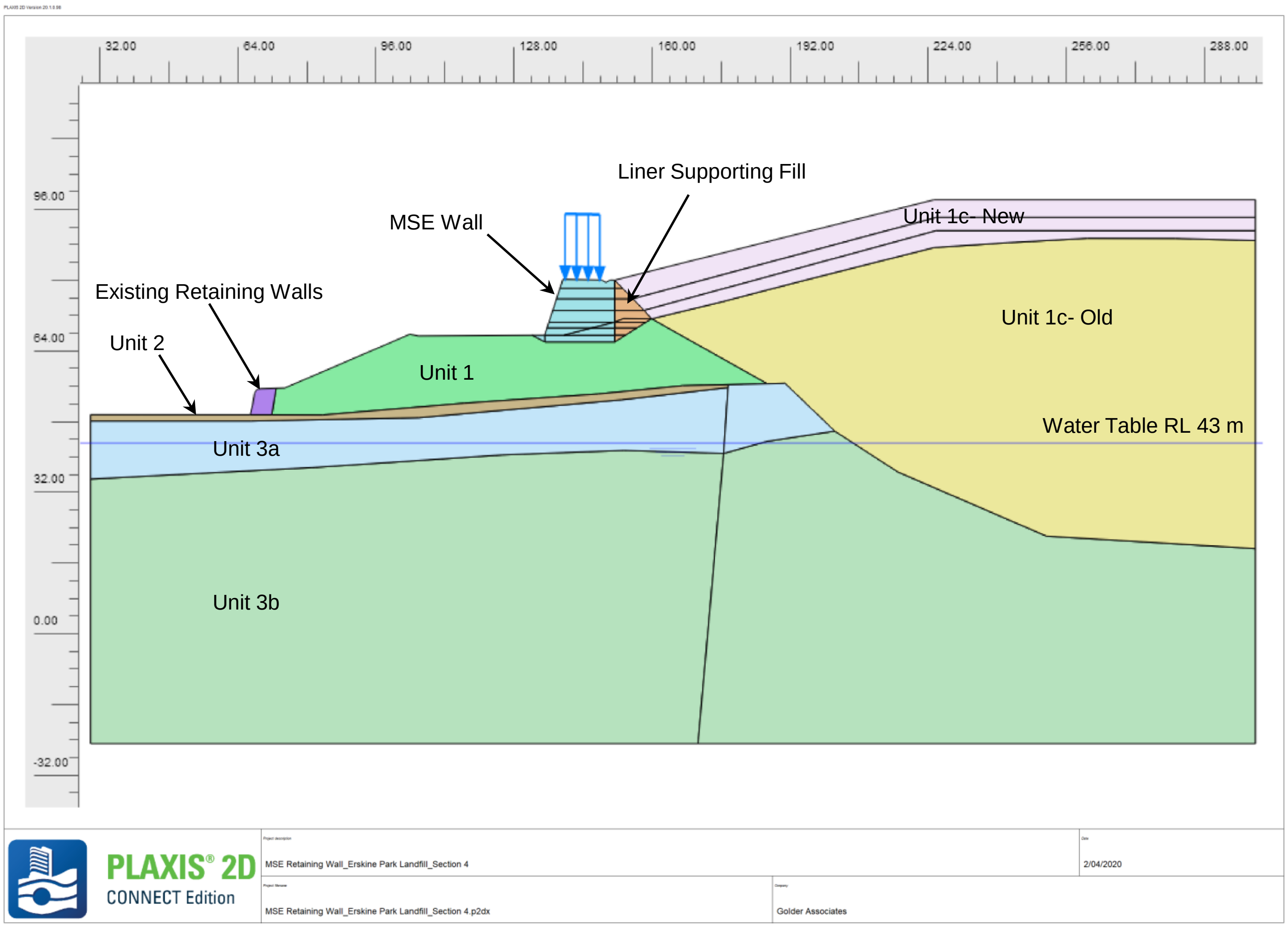
Document Set ID: 9100745
Version: 1, Version Date: 16/04/2020




| Color | Name | Unit Weight (kN/m³) | Cohesion (kPa) | Minimum Strength (kPa) | Non-constrained undrained strength ratio | SHANSEP function exponent | Overconsolidation Ratio Fn. | Cohesion' (kPa) | Phi' (°) |
|---|---|---|---|---|---|---|---|---|---|
| | Bed Rock | | | | | | | | |
| | Engineered Fill | 20 | | | | | | 0 | 32 |
| | Engineered Fill - BGL | 20 | | | | | | 0 | 32 |
| | RSW-Unit 4 | 21 | | | | | | 0 | 32 |
| | RSW-Unit 4 - BGL | 21 | | | | | | 0 | 32 |
| | Unit 1c- Existing Landfill | 17 | | | | | | 1 | 27 |
| | Unit 1c- Future Landfill | 16 | | | | | | 1 | 27 |
| | Unit 2 - Residual Clay _SHANCEP_LT | 18 | | 0 | 0.22 | 0.95 | Depth vs OCR- LT | | |
| | Unit 2 - Residual Clay _Undrained | 19 | 150 | | | | | | |
| | Unit 3a/5- VL & L Strength Rock | 22 | | | | | | 10 | 33 |
| | Unit1a/1b - Fill | 18 | | | | | | 2 | 30 |

| | | | |
|---|---|---|---|
| CLIENT Cleanaway | | PROJECT Erskine Park Landfill | A4 |
| DRAWN JR | DATE 6/04/2020 | TITLEs CS6-Earthquake | |
| CHECKED TM | DATE 6/04/2020 | | |
| SCALE N.T.S | | PROJECT No 19135652 | FIGURE C5.12 |

GOLDER

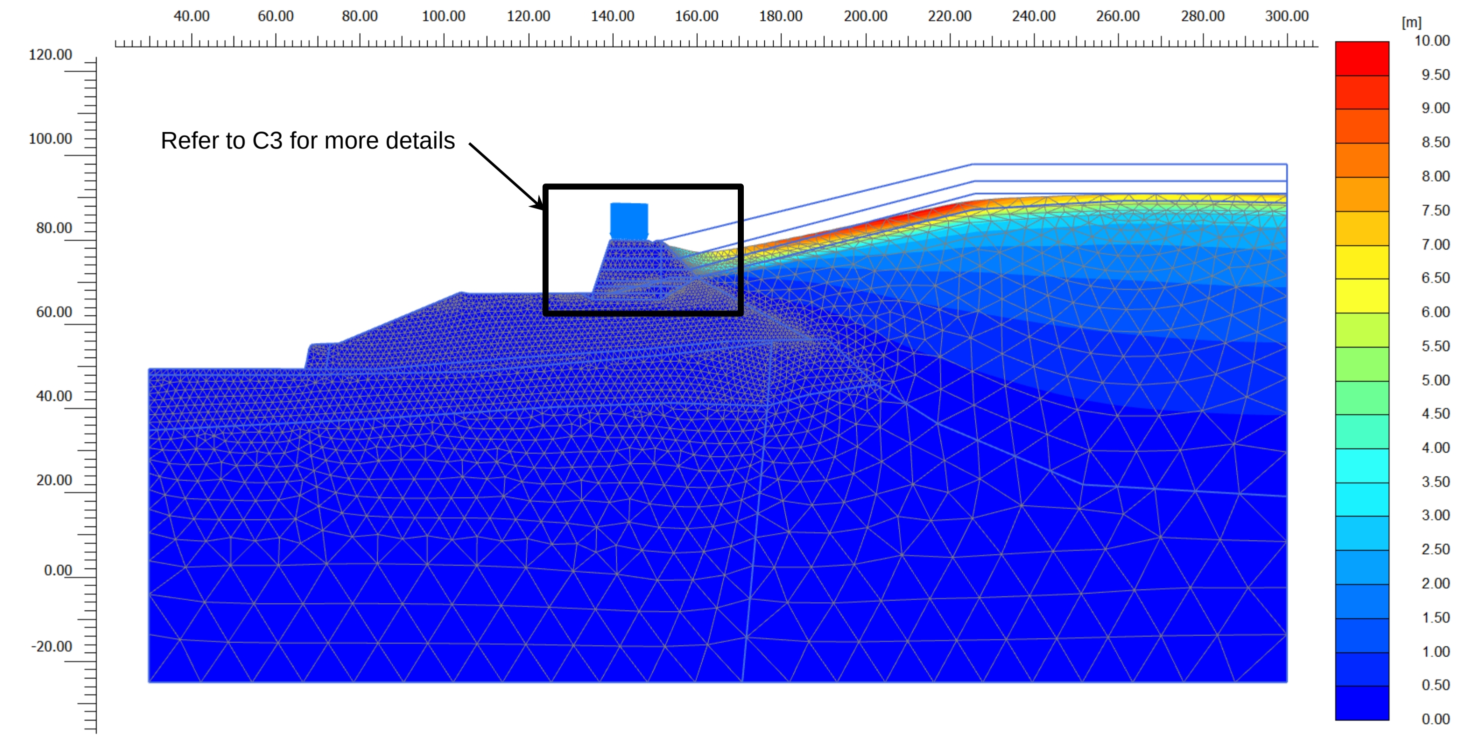



**Section 4 – PLAXIS Model**

**Cross Section View – Output from PLAXIS 2D**

| | | | | |
|---|---|---|---|---|
| GOLDER | CLIENT Enviroguard Pty Ltd | | PROJECT MSE Retaining Wall | A4 |
| | DRAWN KT | DATE 8/04/2020 | TITLE Preliminary Design Report | |
| | CHECKED LP | DATE 8/04/2020 | | |
| | SCALE N.T.S | | PROJECT No 19135652 CONTROL 19135652-006-R-RevA | FIGURE C.1 |

Output Version 20.2.0.83




**Total displacements |u| (scaled up 0.500 times) (Time 38.56*$10^3$ day)**

Maximum value = 9.881 m (Element 14 at Node 9516)

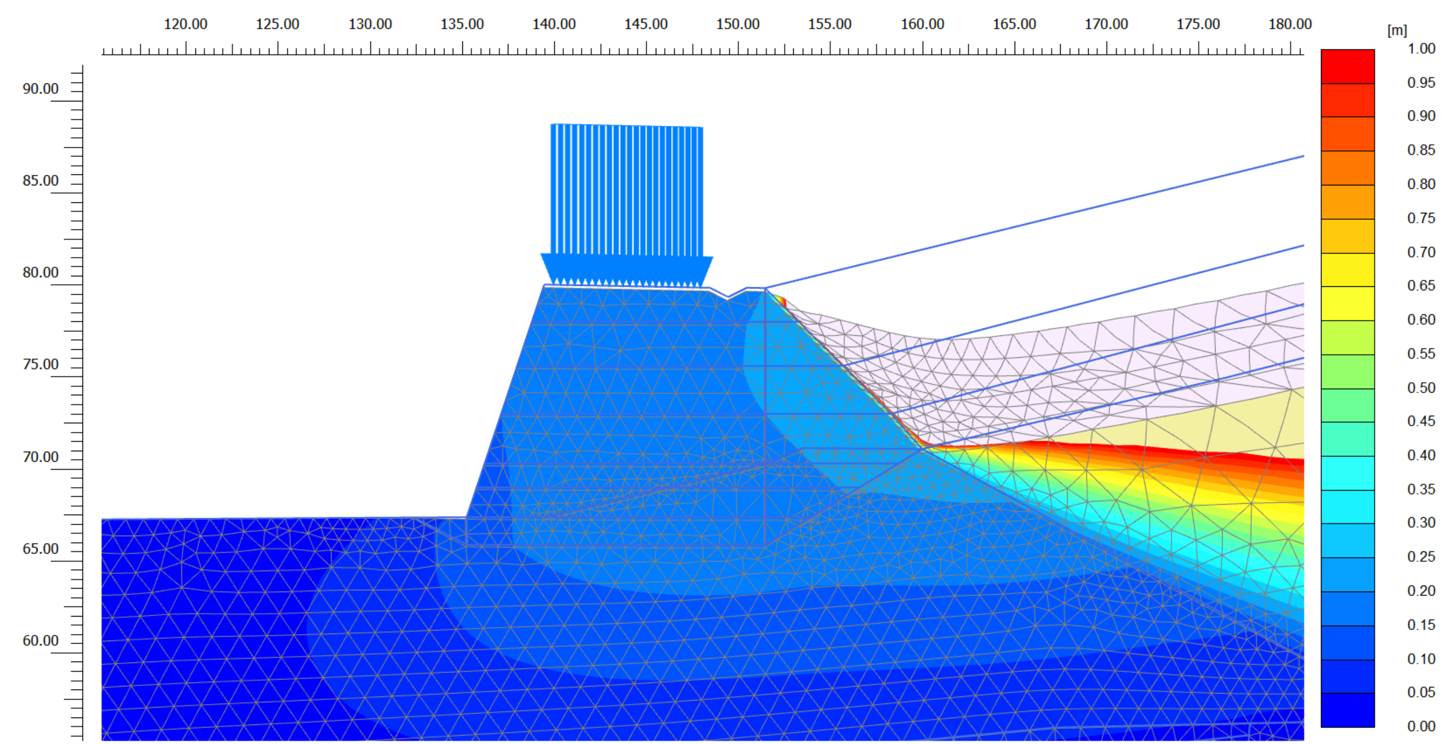
| PLAXIS® 2D CONNECT Edition | Project description: MSE Retaining Wall_Erskine Park Landfill_Section 4 | | Date: 8/04/2020 |
|---|---|---|---|
| | Project filename: MSE Retaining Wall_Erskine ... | Step: 172 | Company: Golder Associates |

**Section 4 – Predicted Total Settlement after 100 yrs**

**Cross Section View – Output from PLAXIS 2D**

| GOLDER | CLIENT: Enviroguard Pty Ltd | | PROJECT: MSE Retaining Wall | A4 |
|---|---|---|---|---|
| | DRAWN: KT | DATE: 8/04/2020 | TITLE: Preliminary Design Report | |
| | CHECKED: LP | DATE: 8/04/2020 | | |
| | SCALE: N.T.S | | PROJECT No: 19135652 / CONTROL: 19135652-006-R-RevA | FIGURE: C.2 |

Output Version 20.2.0.83




**Total displacements |u| (scaled up 0.500 times) (Time 38.56*10$^{3}$ day)**

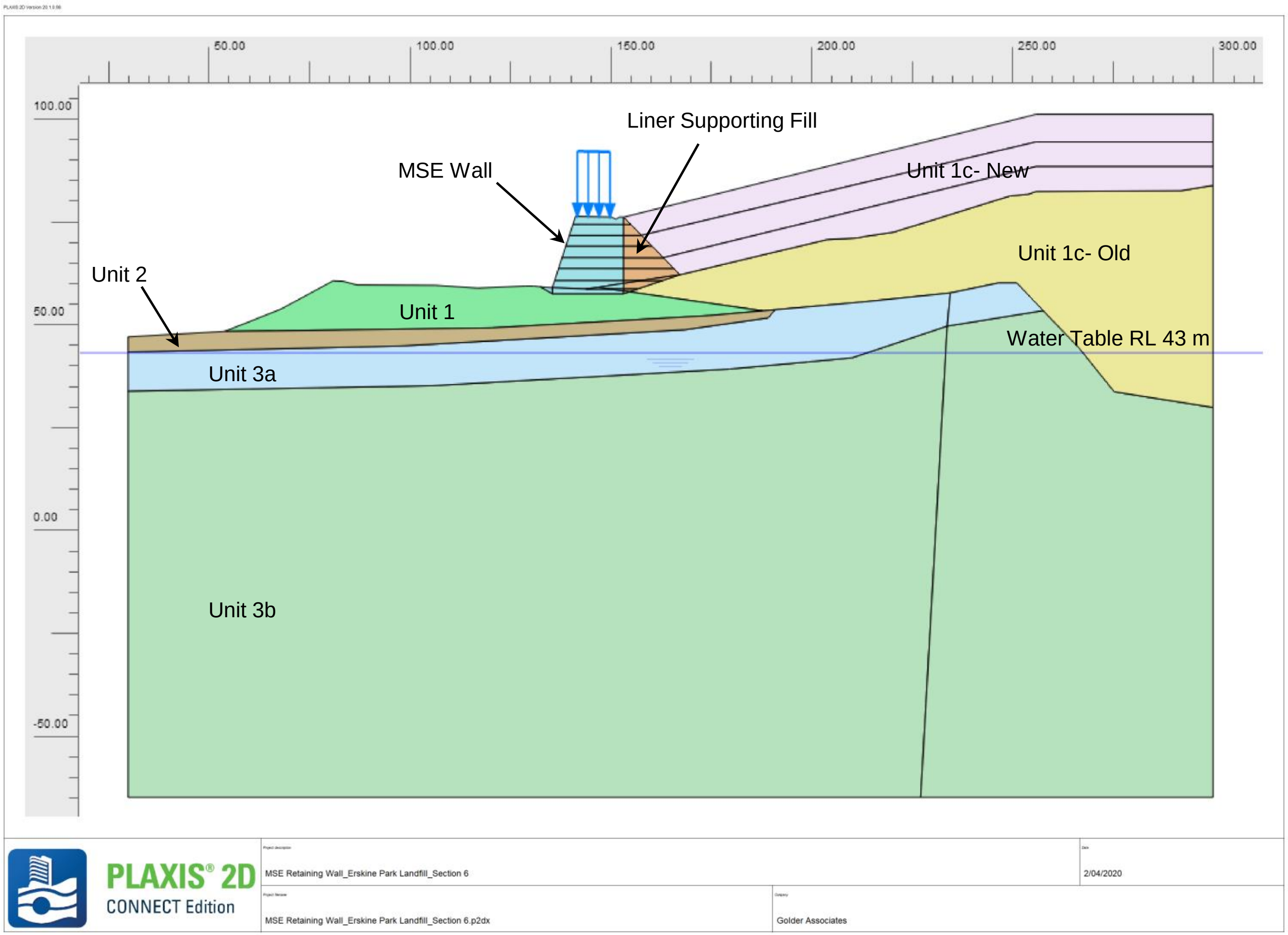
Maximum value = 9.881 m (Element 14 at Node 9516)

| | | | |
|---|---|---|---|
| PLAXIS® 2D CONNECT Edition | *Project description* MSE Retaining Wall_Erskine Park Landfill_Section 4 | | *Date* 8/04/2020 |
| | *Project filename* MSE Retaining Wall_Erskine ... | *Step* 172 | *Company* Golder Associates |

**Section 4 – Predicted Total Settlement after 100 yrs**

**Cross Section View – Output from PLAXIS 2D**

| | | | |
|---|---|---|---|
| GOLDER | CLIENT Enviroguard Pty Ltd | | PROJECT MSE Retaining Wall | A4 |
| | DRAWN KT | DATE 8/04/2020 | TITLE Preliminary Design Report |
| | CHECKED LP | DATE 8/04/2020 | |
| | SCALE N.T.S | | PROJECT No 19135652 / CONTROL 19135652-006-R-RevA / FIGURE C.3 |

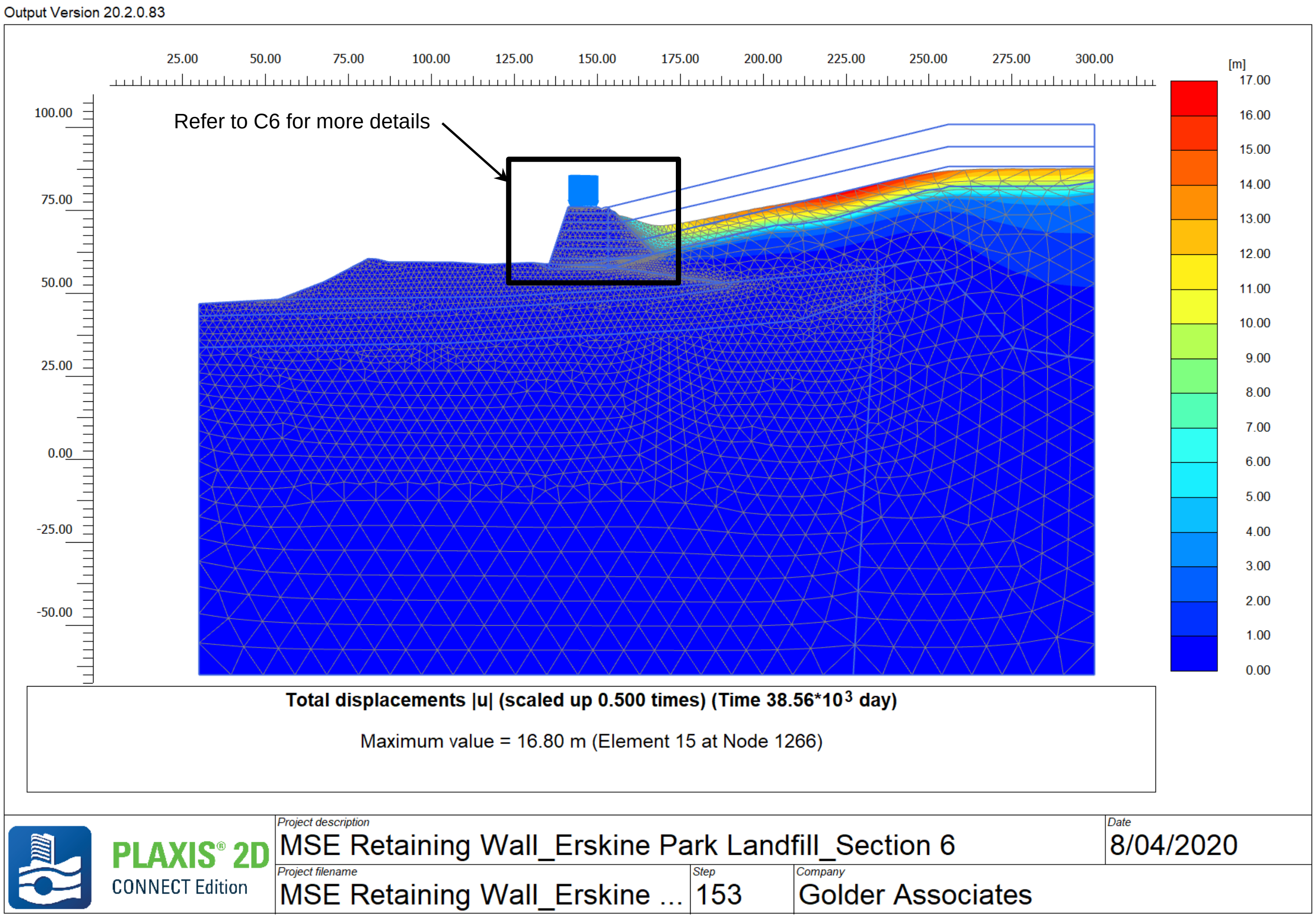



**Section 6 – PLAXIS Model**



**Cross Section View – Output from PLAXIS 2D**

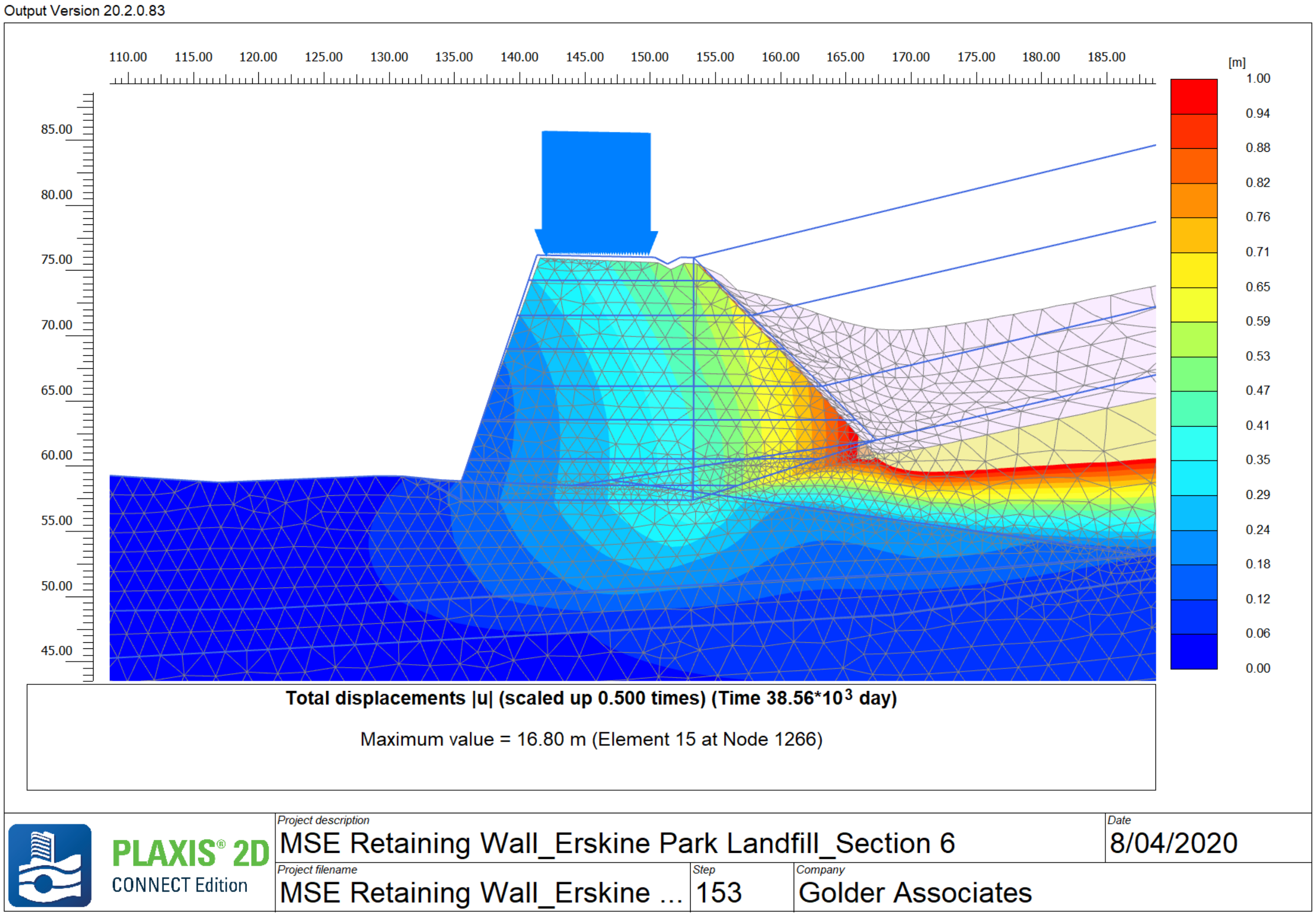
| | | | | |
|---|---|---|---|---|
| GOLDER | CLIENT Enviroguard Pty Ltd | | PROJECT MSE Retaining Wall | A4 |
| | DRAWN KT | DATE 8/04/2020 | TITLE Preliminary Design Report | |
| | CHECKED LP | DATE 8/04/2020 | | |
| | SCALE N.T.S | | PROJECT No 19135652 | CONTROL 19135652-006-R-RevA | FIGURE C.4 |




**Section 6 – Predicted Total Settlement after 100 yrs**

**Cross Section View – Output from PLAXIS 2D**

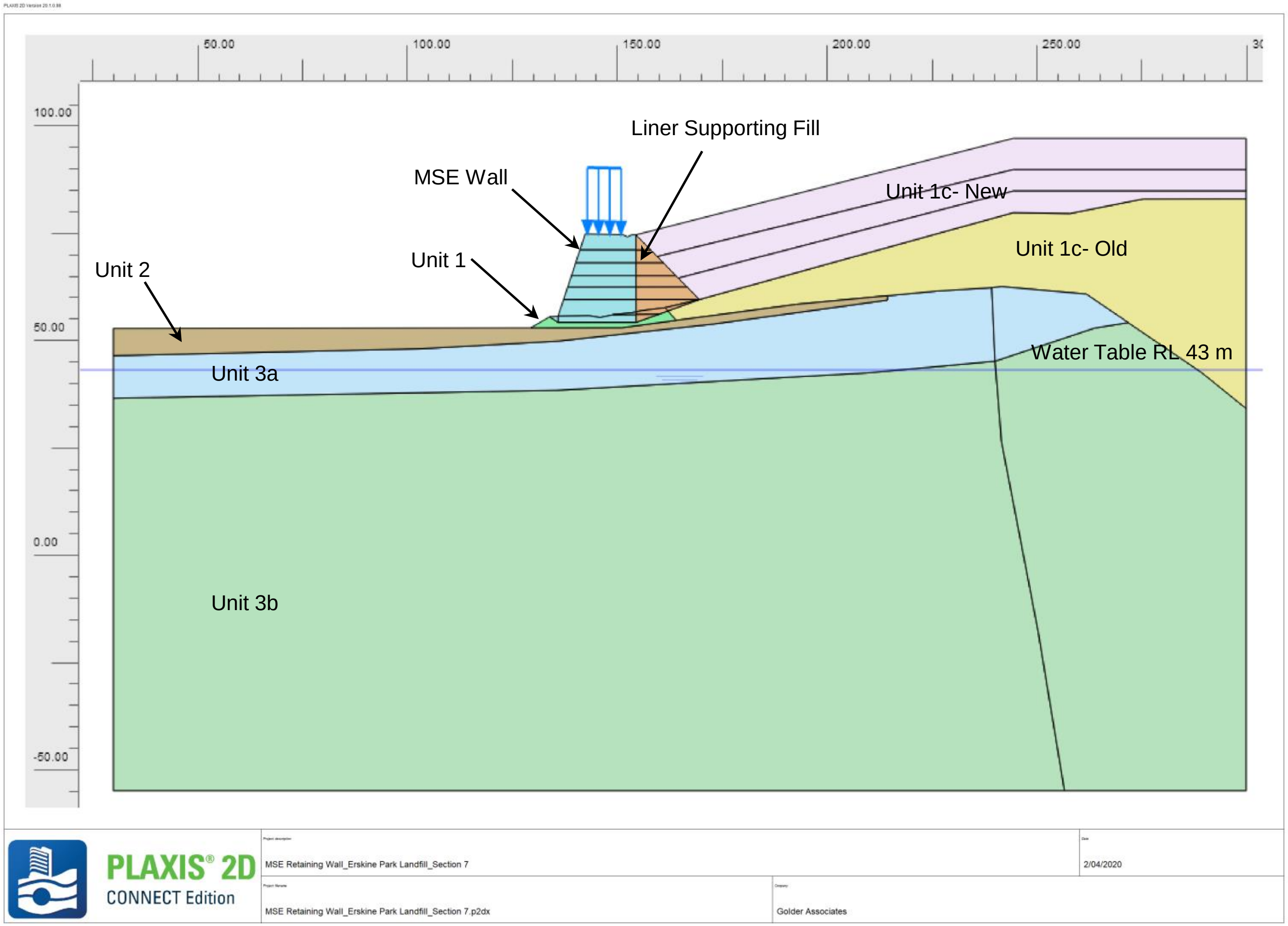
| | | | |
|---|---|---|---|
| GOLDER | CLIENT Enviroguard Pty Ltd | PROJECT MSE Retaining Wall | A4 |
| | DRAWN KT / DATE 8/04/2020 | TITLE Preliminary Design Report | |
| | CHECKED LP / DATE 8/04/2020 | | |
| | SCALE N.T.S | PROJECT No 19135652 / CONTROL 19135652-006-R-RevA | FIGURE C.5 |




**Section 6 – Predicted Total Settlement after 100 yrs**

**Cross Section View – Output from PLAXIS 2D**

| | | | | |
|---|---|---|---|---|
| GOLDER | CLIENT: Enviroguard Pty Ltd | | PROJECT: MSE Retaining Wall | A4 |
| | DRAWN: KT | DATE: 8/04/2020 | TITLE: Preliminary Design Report | |
| | CHECKED: LP | DATE: 8/04/2020 | | |
| | SCALE: N.T.S | | PROJECT No: 19135652 / CONTROL: 19135652-006-R-RevA | FIGURE: C.6 |

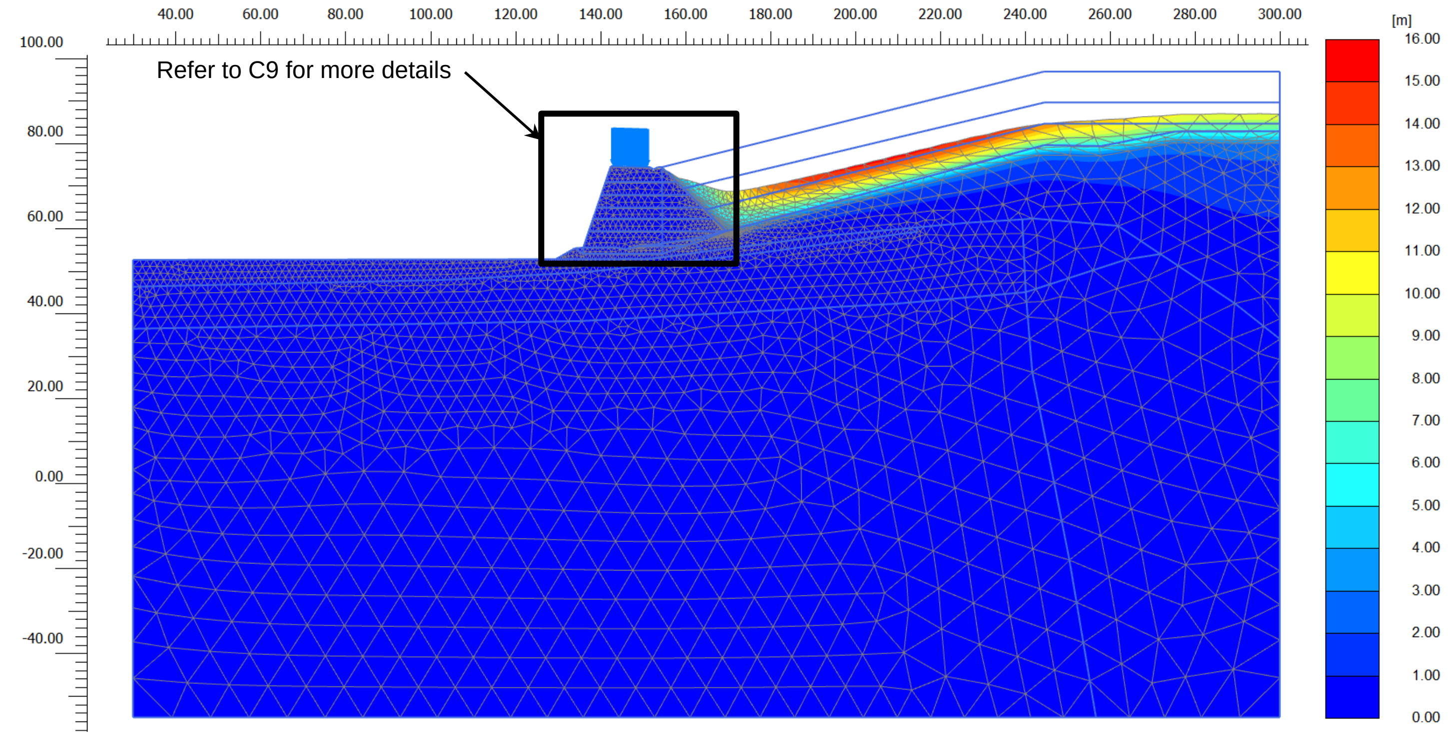



**Section 7 – PLAXIS Model**

**Cross Section View – Output from PLAXIS 2D**

| | | | | |
|---|---|---|---|---|
| GOLDER | CLIENT Enviroguard Pty Ltd | | PROJECT MSE Retaining Wall | A4 |
| | DRAWN KT | DATE 8/04/2020 | TITLE Preliminary Design Report | |
| | CHECKED LP | DATE 8/04/2020 | | |
| | SCALE N.T.S | | PROJECT No 19135652 / CONTROL 19135652-006-R-RevA | FIGURE C.7 |

Output Version 20.2.0.83




**Total displacements |u| (scaled up 0.500 times) (Time $38.56*10^3$ day)**

Maximum value = 15.51 m (Element 24 at Node 7656)

PLAXIS® 2D CONNECT Edition

| Project description | Date |
|---|---|
| MSE Retaining Wall_Erskine Park Landfill_Section 7 | 8/04/2020 |

| Project filename | Step | Company |
|---|---|---|
| MSE Retaining Wall_Erskine ... | 144 | Golder Associates |

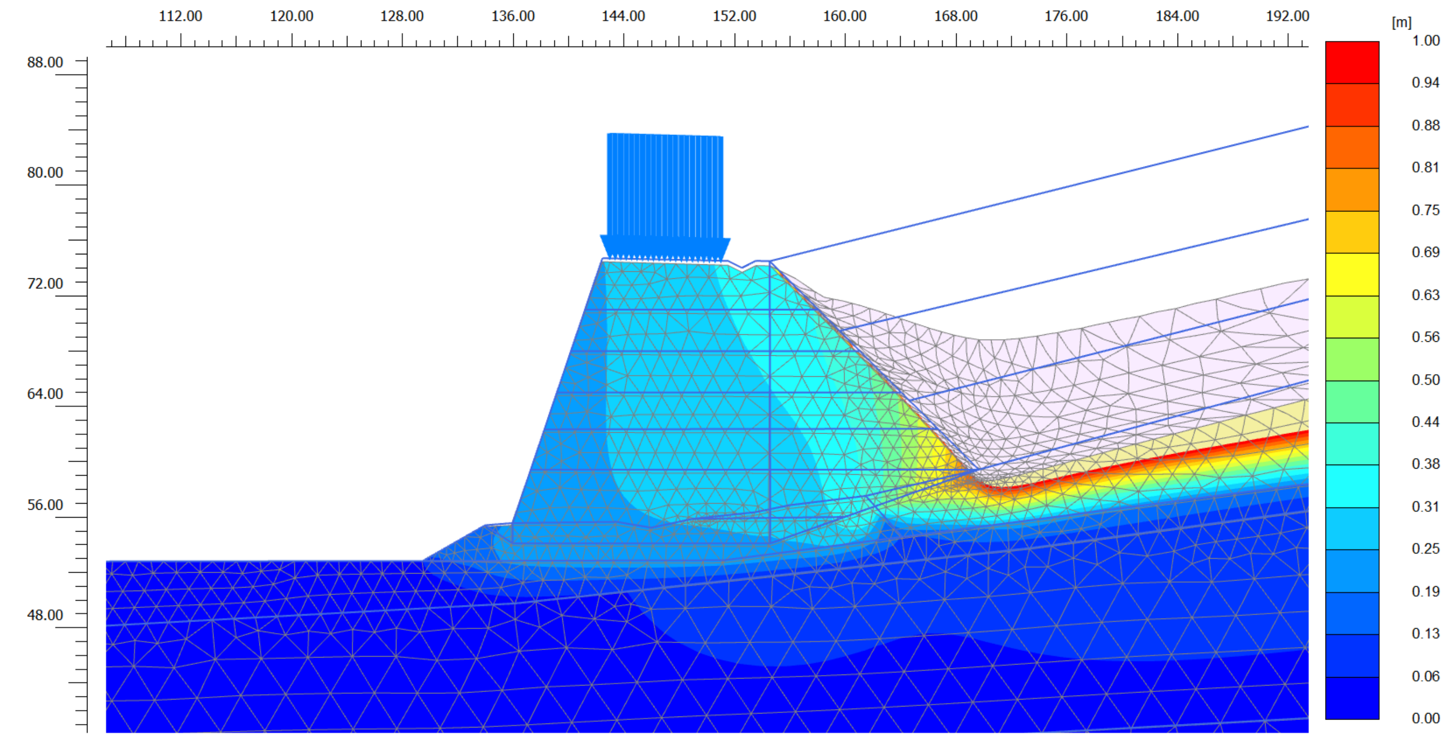
**Section 7 – Predicted Total Settlement after 100 yrs**

**Cross Section View – Output from PLAXIS 2D**

GOLDER

| | | | |
|---|---|---|---|
| CLIENT Enviroguard Pty Ltd | | PROJECT MSE Retaining Wall | A4 |
| DRAWN KT | DATE 8/04/2020 | TITLE Preliminary Design Report | |
| CHECKED LP | DATE 8/04/2020 | | |
| SCALE N.T.S | | PROJECT No 19135652 CONTROL 19135652-006-R-RevA | FIGURE C.8 |

Output Version 20.2.0.83




**Total displacements |u| (scaled up 0.500 times) (Time $38.56*10^3$ day)**

Maximum value = 15.51 m (Element 24 at Node 7656)

| PLAXIS® 2D CONNECT Edition | Project description: MSE Retaining Wall_Erskine Park Landfill_Section 7 | | Date: 8/04/2020 |
|---|---|---|---|
| | Project filename: MSE Retaining Wall_Erskine ... | Step: 144 | Company: Golder Associates |

**Section 7 – Predicted Total Settlement after 100 yrs**



**Cross Section View – Output from PLAXIS 2D**

| | | | | |
|---|---|---|---|---|
| GOLDER | CLIENT: Enviroguard Pty Ltd | | PROJECT: MSE Retaining Wall | A4 |
| | DRAWN: KT | DATE: 8/04/2020 | TITLE: Preliminary Design Report | |
| | CHECKED: LP | DATE: 8/04/2020 | | |
| | SCALE: N.T.S | | PROJECT No: 19135652 · CONTROL: 19135652-006-R-RevA | FIGURE: C.9 |

**APPENDIX D**

# Safety in Design Risk Register

8-Apr-20

| REF NO. | PHASE | DISCIPLINE | RISK / RISK ISSUES (Cause/Hazard/Consequences) | LIKELIHOOD BEFORE | CONSEQ. BEFORE | RISK LVL BEFORE | PROPOSED TREATMENT (Design Risk Controls) | RESIDUAL RISK & PROPOSED SOLUTION | LIKELIHOOD AFTER | CONSEQ. AFTER | RISK LVL AFTER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 01 | Construction | Contamination | **Hazard**: Construction worker exposure to leachate and contamination.<br>**Cause**: Works within waste placement areas.<br>**Consequence**: Illness. | L3 | C3 | HIGH | Protocols to be put in place for earthworks in waste. Intermediate placement of cover soil to reduce potential exposure where practical.<br>Design to limit the volume of excavation required with areas of contamination. | SWMS to be developed for works within waste emplacement. SWMS to be tailored to suit known contaminants. | L1 | C3 | MOD |
| 02 | Maintenance | Retaining Walls | **Hazard**: Unsafe access.<br>**Cause**: Maintenance / visual inspection of retaining wall faces.<br>**Consequence**: Injury / death. | L3 | C2 | MOD | Design to understand maintenance methodology and develop design that fits with these requirements. Incorporate sufficient room at the toe of the wall to facilitate access | SWMS to be developed for maintenance works. | L2 | C2 | LOW |
| 03 | Construction and Operations | Geotechnical | **Hazard**: Ground movements outside property boundary<br>**Cause**: Filling from proposed works impacting adjacent structures<br>**Consequence**: Damage to property | L3 | C2 | MOD | Use of appropriate setbacks and and undertaking detailed finite element modelling to ensure no significant adverse ground movements affect adjacent sensitive structures or services. | Residual risk due to variability of ground.<br>Ongoing instrumentation & monitoring of settlements and lateral ground movements close to sensitive structures. | L1 | C2 | LOW |
| 04 | Construction and Operations | Geotechnical | **Hazard**: Gas leaks over Landfill<br>**Cause**: Differential settlements of the landfill over time<br>**Consequence**: Injury, Death | L2 | C4 | HIGH | Capping design to consider anticipated ground movements including anticipated differential settlements. Implement monitoring system during construction to assess for hazardous gas. | Underperformance / failure of gas collection system.<br>Ongoing monitoring of system. | L1 | C2 | LOW |
| 05 | Construction | Geotechnical | **Hazard**: Damages to existing / new services in and around compressible ground treatment areas<br>**Cause**: Intrusive foundations and excavations<br>**Consequence**: Injury, death | L2 | C4 | HIGH | Use of non-destructive digging and non-intrusive investigations to positively identify existing services. Appropriate foundation systems to be adopted in the vicinity of services. Sequencing of work where possible to install services after ground treatment | Residual risk of unknown / unexpected services.<br>Use of pre-investigation / pre-construction utility identification. | L1 | C3 | MOD |
| 06 | Operation & Maintenance | Geotechnical | **Hazard**: Confined space & gas risk<br>**Cause**: Inspection/cleaning of storm drains, leachate pipes, flush points, gas system<br>**Consequence**: Injury | L3 | C3 | HIGH | Consider in design - Conservatively sized, to minimize need to access/clean, reduce the need for pipes/drains for stormwater system where water can be managed on the surface. | Residual risk of entry for inspection / maintenance.<br>Confined space management procedures to be enforced. | L2 | C2 | LOW |
| 07 | Construction | Geotechnical | **Hazard**: Lateral ground movements causing damage to existing structures<br>**Cause**: Excessive loading of the ground causing deformation<br>**Consequence**: Adverse effects on existing structures, cracking, potentially making them unserviceable | L2 | C4 | HIGH | Detailed analysis to quantify predicted effects on structures.<br>Adopt appropriate construction techniques to reduce effects on structures.<br>Implement instrumentation and monitoring to verify actual effects are consistent with predicted effects. | Residual risk of construction procedures not consistent with what was assumed in design causing excess ground movement.<br>Alternative construction procedures to be planned and implemented if required. | L2 | C2 | LOW |
| 08 | Operation & Maintenance | Geotechnical | **Hazard**: Aquaplaning of vehicles in wet weather<br>**Cause**: Settlement of access rendering the drainage system insufficient<br>**Consequence**: Injury, death | L3 | C4 | V HIGH | Sensitivity analysis to be undertaken of predicted settlement so that drainage system gradients can be checked to be serviceable for the anticipated range of settlement likely to occur. Appropriate sizing of swales/channels to take surface water. Road barriers to be designed and incorporated into the works. Speed limits. | Residual risk of post construction settlement (or lack of settlement) different to predicted.<br>Ongoing instrumentation & monitoring of settlements. | L2 | C2 | LOW |
| 09 | Construction | Geotechnical | **Hazard:** Compaction plant / fill placement plant causing instability of batter slope or falling down batter slope<br>**Cause:** Compaction plant required to work immidiately adjacent to steep batter (liner support fill)<br>**Consequence:** Injury, Plant damage, death | L3 | C5 | V HIGH | Reinforcement to be used within the liner support fill to stabilise the batter. Smaller compaction plant to be used near the batter edge. Bunds may be used at the edge of the slope to jprovide a physical barrier | Residual risk of slope instability or plant running off edge | L1 | C3 | MOD |
| 10 | Construction | Geotechnical | **Hazard:** Construction plant impacting waste placement plant<br>**Cause:** poor traffic management, intersecting haulage routes with poor visibiliy<br>**Consequence:** Injury, damage | L3 | C3 | HIGH | Combined haulage route to eliminate or reduce haulage intersections as much as possible. Locate intersections in areas with high visibility. Common traffic flow direction. Speed limiting vehicles | Residual risk of minor vehicular impact | L2 | C2 | LOW |
| 11 | Construction | Geotechnical & Civil | **Hazard:** Construction plant impacting people<br>**Cause:** people working in close proximity to compaction plant (i.e. sampling, monitoring, compaction testing, liner placement etc)<br>**Consequence:** injury, death | L3 | C4 | V HIGH | Exclusion zones to be set up, visible barriers, positive radio/visual contact for people on foot working near plant, plant to down tools/buckets or isolate when people working in close proximity | Residual risk of vehicular impact | L1 | C3 | MOD |
| 12 | Construction | Civil | **Hazard:** Fall of staff during liner installation on 1:1 batter<br>**Cause:** difficult access<br>**Consequence:** Injury | L3 | C3 | HIGH | Rope access requirements for liner installation. Use of textured geomembrane. Reduce requirements for on-slope work where practical. Appropriate training, implementation of an intermediate bench to reduce working | Residual risk of accident while working on slopes | L2 | C2 | LOW |
| 13 | Construction | Geotechnical & Civil | **Hazard:** Slips, trips, falls<br>**Cause:** uneven ground<br>**Consequence:** injury | L3 | C3 | HIGH | Reduce slopes in waste to 3H:1V. Provide access tracks for long term high volume routes.Limit foot traffic where practical. | Residual risk of slips trips and falls | L2 | C1 | LOW |
| 14 | Operation & Maintenance | Civil | **Hazard:** High velocity flows in channels during flood conditions<br>**Cause:** Concentration of surface water in significant storm events<br>**Consequence:** Injury, Damage | L2 | C3 | HIGH | Operational controls to the site during flooding / significant rainfall events, Design consideration of flows and appropriate amendments to channels where required | Residual risk of significant flows impacting minor operations on site | L2 | C2 | LOW |
| 15 | Operation & Maintenance | Geotechnical & Civil | **Hazard:** Pedestrian fall from height of MSE Wall<br>**Cause:** Pedestrian access to top of wall<br>**Consequence:** Injury, Death | L2 | C5 | V HIGH | Physical barrier designed to prevent fall from significant height at the top of the MSE Wall | Barrier to be maintained so that it is functional | L1 | C2 | LOW |



Document Set ID: 9100745
Version: 1, Version Date: 16/04/2020

| REF NO. | PHASE | DISCIPLINE | RISK / RISK ISSUES (Cause/Hazard/Consequences) | LIKELIHOOD BEFORE | CONSEQ. BEFORE | RISK LVL BEFORE | PROPOSED TREATMENT (Design Risk Controls) | RESIDUAL RISK & PROPOSED SOLUTION | LIKELIHOOD AFTER | CONSEQ. AFTER | RISK LVL AFTER |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | Construction | Civil | **Hazard:** Congested work environment increasing risk of damage to goods and injury to workers<br>**Cause:** Insufficient working space<br>**Consequence:** injury, damage | L3 | C3 | HIGH | Sufficient bench space and storage space to facilitate construction. SWMS and Pre-construction assessment | Ongoing materials management | L2 | C1 | LOW |
| 17 | Operation & Maintenance | Civil | **Hazard:** Maintenance difficulty of onsite infrastructure<br>**Cause:** Poor access to drainage and pipe cleaning points<br>**Consequence:** injury, damage | L2 | C3 | HIGH | Appropriate sizing of pipes, provision of sufficient access to cleaning points where required, Reduce confined spaces where possible during design phase. | Process not followed in maintenance manual | L2 | C2 | LOW |
| 18 | Construction | Geotechnical & Civil | **Hazard:** Trench collapse<br>**Cause:** Insufficient shoring/benching of trenches<br>**Consequence:** injury, damage, death | L2 | C5 | V HIGH | Not entering trenches >1m in height. Appropriate benching and shoring to be implemented. Design out trenching requirements if possible. Not surcharging the sides of trenches | Established processes not followed. | L1 | C3 | MOD |
| | | | | | | | | | | | |

**APPENDIX E**

# Important Information Relating to this Report

The document ("Report") to which this page is attached and which this page forms a part of, has been issued by Golder Associates Pty Ltd ("Golder") subject to the important limitations and other qualifications set out below.

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