EKFB Working in partnership with HS2

High Speed 2 - 1MC06 - Stage One C2 - MWCC – North Portal of Chiltern Tunnels to Brackley

Chetwode Cutting Geotechnical Design Report

1MC06-CEK-GT-REP-CS06_CL10-000031

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Stakeholder review required (SRR)	Purpose of SRR
☐ County / District / London Borough Council	☐ Acceptance
☐ LOV	☐ Approval
☐ LUL	☐ No Objection
☐ NRL	☐ Consent
☐ TFL	
☐ Utilities Company	
☐ Other (please specify)	

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1 Glossary of Terms

Acronym	Description	Acronym	Description
ACEC	Aggressive Chemical Environment for Concrete	**ENV**	Environmental
ACSW	Advanced Continuous Surface Wave	**ERD**	Data Modelling Software
AGS	Association of Geotechnical and Geoenvironmental Specialists	**E_u**	Elastic Modulus (undrained)
AIP	Approval In Principle	**EV2**	Modulus of Deformation
ALARP	As Low As Reasonably Practicable	**EW**	Earthworks
AONB	Area of Outstanding Natural Beauty	**EWC**	Early Works Contractor
ATS	Autotransformer Station	**FMB**	Forest Marble Group
BGS	British Geological Survey	**FOC**	Fraction Organic Carbon
BRE	Building Research Establishment	**FPD**	Final Preliminary Design
BTEX	Benzene; Toluene; Ethylbenzene; and *o*-, *m*-, and P-xylenes	**GBR**	Geotechnical Baseline Report
c'_{cv}	Critical State Effective Cohesion	**GC**	Geotechnical Category
CB	Cornbrash Formation	**GDMS**	Geotechnical Database Management System
CBR	California Bearing Ratio	**GDR**	Geotechnical Design Report
CC	Concrete Core	**GFDMP**	Glaciofluvial Deposits, Mid Pleistocene
CIRIA	Construction Industry Research and Information Association	**GI**	Ground Investigation
CO	Cable Percussion borehole with Rotary Open Hole follow on	**GIR**	Ground Investigation Report
CP	Cable Percussion borehole	**GIS**	Geographical Information System
c'_{peak}	Peak Effective Cohesion	**GOG**	Great Oolite Group
CPT	Cone Penetration Test	**GRR**	Geotechnical Risk Register
CR	Cable Percussion borehole with Rotary Cored follow on	**HP**	Hand Dug Pit
CSO	Combined Service Overflow	**HS2**	High Speed 2 Limited
CSW	Continuous Surface Wave	**HSV**	Hand Shear Vane Test
CT	Cone Penetration Testing	**INNS**	Invasive Non-Native Species
c_u	Undrained Shear Strength	**IP**	Inspection Pit
c_v	Coefficient of Consolidation	**ISRM**	International Society for Rock Mechanics
DA1 C1	Eurocode 7 Design Approach 1, Combination 1	**KLB**	Kellaways Formation
DA1 C2	Eurocode 7 Design Approach 1, Combination 2	**LCA**	Local Character Area
DCP	Dynamic Cone Penetration	**LCRM**	Land Contamination Risk Management
DGN	CAD drawing	**LEL**	Lower Explosive Limit
DJV	Design Joint Venture	**LIDAR**	Light Imaging Detection and Ranging
DLS	Design Limit State	**LL**	Liquid Limit
DoU	Degree of Utilization	**LLAU**	Limits of Land to be Acquired or Used
DP	Dynamic Probing	**LOCA**	Location ID

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Acronym	Description	Acronym	Description
E'	Elastic Modulus (drained)	**m AOD**	metres Above Ordnance Datum
EIA	Environmental Impact Assessment	**MASW**	Multiple Channel Analysis of Surface Wave
EKFB	Eiffage Kier Ferrovial Bam Nuttall	**SMUG**	Strategy for Management of Uncertainty in Ground Conditions
MGR	Made Ground	**m bFL**	Metres Below Formation Level
MOD	Ministry Of Defence	**m bgl**	Metres Below Ground Level
MPATS	Mid Point Auto Transformer Site	**MCV**	Moisture Condition Value
m_v	Coefficient of Volume Compressibility	**MDD**	Maximum Dry Density
MWCC	Main Works Civils Contract	**RLD**	Rutland Formation
N	SPT 'N' blow count	**SHHB**	Sharp's Hill Formation
NCA	National Character Areas	**SP**	Self-boring Pressuremeter Testing
NCR	No Core Recovery	**SPT**	Standard Penetration Test
NMC	Natural Moisture Content	**SPZ**	Source Protection Zone
OLE	Overhead Line Electrification	**SRR**	Stakeholder Review Required
OMC	Optimum Moisture Content	**SSSI**	Site of Special Scientific Interest
OP	Observation pit (shored)	**TFL**	Transport for London
OSMM	Ordnance Survey Master Map	**TILMP**	Till, Mild Pleistocene
OT	Observation trench (shored)	**TP**	Trial Pit (mechanically dug)
OXC	Oxford Clay Formation	**TPH**	Total Petroleum Hydrocarbons
PBT	Plate Bearing Test	**TPS**	Total Potential Sulphate
PC	Pavement Core	**TSA**	Thaumasite Sulphate Attack
PCB	Polychlorinated biphenyl	**TT**	Trial Trench
PGA	Peak Ground Acceleration	**TY**	Taynton Limestone Formation
PI	Plasticity Index	**UCS**	Unconfined Compressive Strength
PSD	Particle Size Distribution	**ULS**	Ultimate Limit State
RAG	Red-Amber-Green	**UXB**	Unexploded Bomb
RC	Rotary Coring	**UXO**	Unexploded Ordnance
RO	Open Hole Rotary Drilling	**v'**	Drained Poisson's Ratio
RQD	Rock Quality Designation	**v_u**	Undrained Poisson's Ratio
Ru	Pore Pressure Ratio	**WLS**	Windowless Sampling
SB	Sonic Resonance Borehole	**WS**	Windowless Sampling (also Windowless sampling + Dynamic probing)
SCEW	HS2 Specification for Civil Engineering Works (Series 600 Earthworks)	**WWI**	World War 1
SCPT	Seismic Cone Penetration Test	**WWII**	World War 2
SHC	Subsidence Hazard Category	**γ_b or γ_{bulk}**	Bulk Density
SHCN	Hazard Rating for Ground Dissolution	**φ'_{cv}**	Critical Value Effective Angle of Friction
SHRN	Subsidence Hazard Rating Value	**φ'_{peak}**	Peak Effective Angle of Friction
SMC	Saturation Moisture Content	**WHL**	White Limestone Formation

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2 Executive Summary

GDR revision	Purpose
P01	Pre IDR submission IDR 221.1 (Chetwode Cutting)
P02	Internal Review
C01	Post IDR submission IDR 221.1 (Chetwode Cutting) Post IDR submission IDR 221.2 (School End Overbridge and associated highway realignments; CHW/18 Overbridge and associated highway realignments)
C02	Post IDR submission IDR 221.2_1 (School End Overbridge and associated highway realignments; Footpath CHW/18 Accommodation Overbridge) and 221.2 (Footpath CHW/18 associated highways realignments), also following HS2 comments on revision C01.

This revision C02 of the document 1MC06-CEK-GT-REP-CS06_CL10-000031 Chetwode Cutting Geotechnical Design report is issued for post IDR submission of IDR 221.2_1 and 221.2 which are for the following level 2 assets:

- School End Overbridge and associated highway realignments (IDR 221.2_1)

- Footpath CHW/18 Overbridge (IDR 221.2_1) and associated highway realignments (IDR 221.2)

Refer to section 5 (non-mainline earthworks) and section 6 (structures), as well as Appendix D for the elements relevant to the design of non-mainline earthworks assets and Appendix H, I, J, K and L for the elements relevant to the design of the overbridges: available GI considered for Detailed Design, ground models and associated geotechnical parameters, and the geotechnical design of the overbridges foundations and associated non-mainline embankments.

The purpose of this Geotechnical Design Report (GDR) is to present the geotechnical design of the earthworks and structures associated with the HS2 Chetwode Cutting Group, which forms part of the EKFB works in the Twyford to Greatworth area (T2G), at Stage 2 Detailed Design, for the IDR221.1, IDR 221.2_1 and IDR 221.2.

It includes the technical output of the following assets (IDR 221.1):

- Chetwode Cutting –HS2-000001054- Mainline asset
- Chetwode Cutting Landscape Earthworks –HS2-00002BVHU – Mitigation Earthworks
- Chetwode ATS – HS2-000020864 – Construction Compound High Voltage

Following assets belong to the Chetwode Cutting Group and are part of the IDR 221.2_1 and IDR 221.2:

- Footpath CHW/18 Accommodation Overbridge – HS2-000001321 – Overbridge (IDR 221.2_1)
- School End Overbridge – HS2-000001322 – Overbridge (IDR 221.2_1)
- School End Road Realignment – HS2-00002BJUR – Carriageway (IDR 221.2_1)
- Maintenance Access Road to Pond (Off School End Road-North) – HS2-000020NM3- Carriageway (IDR 221.2_1)

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- Maintenance Access Road to Pond (Off School End Road-South) – HS2-000020NM2 – Carriageway (IDR 221.2_1)
- Maintenance Access Road to GSMR (off School End Road Realignment) and Compound – HS2-00002VXUC – Carriageway (IDR 221.2_1)
- Chetwode ATS Access Road and Maintenance Access Road to Pond – HS2-000020NLY – Carriageway (IDR 221.2)
- Footpath CHW/18 Accommodation Access Realignment – HS2-000020NLZ – Carriageway (IDR 221.2)
- Footpath CHW/18 Eastern Link - HS2-00002NAH7- Public Right of Way (IDR 221.2)
- The Green Highway Realignment – HS2-000020357 – Carriageway (IDR 221.2)

Chetwode Cutting is a medium cutting (maximum depth of 9m at Ch. 86+300) located within Delivery Package T2G (Twyford to Greatworth), between Ch. 84+925 and Ch. 86+852 (1927 m long). The asset sits between Barton Hartshorn Embankment to the north and Chetwode Embankment to the south. It is located around 350m to the West of Chetwode Village, and 2.0 km to the north of Godington Village.

The Level 2 assets associated with the design of Chetwode Cutting are detailed below:

- Chetwode Cutting Landscape Earthworks (+3 to 6 m/cutting crest; Internal Slope 1V:4H and external slope variable) are proposed on both sides of the HS2 mainline.
- Footpath CHW/18 Accommodation Overbridge/Realignment is crossing the mainline at Ch. 85+577.
- School End Overbridge/Realignment is crossing the mainline at Ch. 86+438.
- These Overbridges/Realignments are associated with several access roads located on the Chetwode Cutting crests: Footpath CHW/18 Accommodation Access Realignment, Footpath CHW/18 Eastern Link, Maintenance Access Road to Pond (Off School End Road-North), Maintenance Access Road to Pond (Off School End Road-South), School End Road Realignment, Maintenance Access Road to GSMR (off School End Road Realignment) and Compound, Green Highway Realignment.
- Chetwode ATS Platform is a Construction Compound High Voltage, it sits on a berm in Chetwode Cutting down slope between Ch.85+400 and Ch. 85+550. The Chetwode ATS Access Road allows the access to the Chetwode ATS Platform from the CHW/18 Realignment.

Schedule 17 study is however ongoing in parallel with the Detailed Design and the landscape design may therefore change after this consultation. Any changes are likely to impact the earthworks design recommended in this current GDR.

The design of the **mainline earthwork asset** has been completed using the available ground investigations of the Datadrop 2 (March 2020). The design of Rayleigh Waves mitigation measures has been assessed using geophysical survey until the Datadrop 14.

A GI impact review has been performed as part of this GDR. The analysis of GI obtained between the Datadrop 2 and the Datadrop 17 shows that assumptions made for the design (geological long section, design values, mitigation measures) of the mainline earthwork asset are confirmed and validated.

The analysis of GI obtained between the Datadrop 1 and the Datadrop 17 (CHW/18) and 21 (School End) shows that assumptions made for the design (geological long section, design values, mitigation measures) of the overbridges are confirmed and validated.

Based on available GI at the beginning of Detailed Design, the uncertainty in ground conditions classification for the mainline earthwork asset has been assessed as Class 3 due to the identified risk of heave in Oxford

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Clay in the deepest part of the cutting and at the ovrebridges location. The Detailed Design has proceeded with a realistic geological scenario and cautious design values, using routewide values to increase confidence in the design assumptions and decrease the uncertainty in ground conditions. Following the development of Detailed Design supported by the GI Impact assessment done on the outstanding GI data received after the freeze date, the SMUG class for Chetwode Cutting and associated overbridges has been revised to Class 2.

The proposed route crosses the “Clay Vale”, characterised by flat open valley floors and gentle hills in Jurassic Clays (Oxford Clays and Kellaways Formations). The terrain at this location rises towards the North-West through the two main hill systems on the route (104 m AOD at Ch. 85+380; 110 m AOD at Ch. 86+400) separated by a dry valley (at Ch.85+700).

Between Ch. 84+925 and Ch. 85+300, the natural slope of the ground is comprised between 5° and 10° and is parallel to the HS2 route. Between Ch. 85+300 and Ch. 86+300, and between Ch. 86+450 and Ch. 86+852, the natural slope of the ground is comprised between 5° and 10° and is oriented towards HS2.

The ground conditions for the cutting mainly comprise glacial deposits (TILMP and GFDMP) overlying Oxford Clay (OXC), which is weathered on top. A set of faults has been identified between Ch. 86+350 and Ch. 86+700, but at this location, the cutting excavation will intercept only the glacial deposits, not impacted by the faults.

The groundwater level and associated water ingress are expected to be encountered in GFDMP layers which present more sandy and permeable facies than the TILMP and underlying OXC. Perched groundwaters are assumed to be also present in TILMP.

From a review of the available background and site context information and the ground investigation data available, the key risks associated with design of the asset are:

- **Soft ground**: Unacceptable subgrade performances in weathered bedrock and Clayey glacial deposits with potential of progressive failure in time.
- **Rayleigh Waves**: Risk of Rayleigh waves is high in weathered OXC and TILMP.
- **Potential of Relic Slip Surfaces:** Potential risk of relic shear surface in OXC and TILMP (Level 1) where the natural ground falls toward HS2 with a natural slope > 5° (Between Ch. 85+300 and Ch. 86+300, and between Ch. 86+450 and Ch. 86+852).
- **Groundwater:** Water ingress on slopes through the sandy GFDMP and perched groundwater in TILMP.
- **Heave**: low heave risk where the cutting depth is more than 5 m due to the presence of OXC formation at and below formation level.
- **Chemically aggressive ground**: OXC formations have been identified with high sulphate content and a design sulphate class DS4. No stabilisation planned in this material.
- **Loose /unstable ground :** especially where temporary excavations are planned in sandy GFDMP.
- **Contamination** associated with the Rugby to Quainton Great Central Railway parallel to route (LQ 13.07)
- **3rd party assets :** Chetwode Cutting will be excavated in the vicinity of several existing buildings.

The design has been completed with the main following assumptions:

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- The Northern part of Chetwode Cutting (from Stratton Audley Road to the end of the asset) is a part of priority works and will be excavated prior to the rest of the cutting. The excavation depth for these priority works is around the project level.
- It is assumed that Chetwode cutting will be excavated evenly over the entire footprint of the excavation in 2 to 5m lifts to lead to an even rate of unloading and heave.
- CHW18 and School End Overbridges construction methodology are bottom-up.

Based on analysis of the available data as set out in the following technical sections of this report, the design and associated mitigation requirements for the **mainline earthwork** are summarised below.

- Slopes of the cutting:
    - 1V:3H from Ch. 84+925 to Ch. 85+130 and from Ch. 85+620 to Ch. 86+852;
    - 1V:4H from Ch. 85+130 to Ch.85+620
- Excavate and replace 2 m bFL along the entire asset to achieve the required subgrade stiffness as set out in HS2 technical standard for earthworks.

Mitigation measures for Rayleigh waves issue include:

- From Ch. 84+925 to Ch. 84+950: excavate and replace (E&R) 2 m bFL;
- From Ch. 84+950 to Ch. 84+130 : 1 m bFL E&R;
- From Ch. 86+350 to Ch. 86+800 : 0.50 m bFL E&R;
- From Ch. 86+800 to Ch. 86+852 : 1.50 m bFL E&R.

Those mitigations for dynamic performance along the asset are covered by HS2 requirements on required static subgrade stiffness (EV2) for which 2m E&R bFL is planned.

No mitigations for heave are required but a minimum monitoring period of 6 months must be applied to confirm stabilisation of the ground before handover.

Onward management of ground uncertainty includes :

- Additional E&R in case of unexpected over thickness of soft spot/Made Ground;
- Unstable ground in temporary excavation to be managed with adequate temporary slope design/slope mitigations, including potential sump pumping for localised groundwater ingress in temporary excavations (out of the scope of this GDR);and temporary slope reinforcements
- Site inspection to manage potential of relic shear surfaces and water ingress on slopes;
- Provision for slope drainage if water ingress on slopes;
- Provision for slope reinforcement if confirmed relic shear surfaces;
- Verification testing are required during works to verify the static and the dynamic performance at formation level (MASW/CSW and Plate Load tests);
- Instrumentation and monitoring to manage potential risk of slope instability and heave.

The Detailed Design of the **non-mainline earthworks assets** have been based on GI data received until Datadrop 17. In the post IDR submission, Datadrop 23 (dated 23rd May 2022) has been incorporated in the design through GI Impact Assessment.

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School End Road Realignment and associated realignment:

Based on the analysis of the available data, the design and associated mitigation requirements for the non-mainline earthwork are summarized below.

- There are at grade sections at Ch.0 to Ch.170 and Ch.380 to Ch.462.3. Embankment sections between Ch. 170 to Ch. 260 (downside) and Ch.340 to Ch.380 (upside), the asset is raised on approach embankments on either side of the overbridge. The maximum embankment height would be 5.6 m (Ch. 200) maximum and at a gradient of 1V:4H. The at grade section are generally 1V:3H;
- Steep slope 1V:2H (left side) along the Maintenance Access Road to Pond (Off School End Road - South) between Ch. 610 and Ch. 660.
- Subgrade improvements are required at Ch.0 to 170, Ch.380 to Ch.462.3 by way of excavate and replace with Class 1A4/A5/A6 to depth of 0.6 m;
- Secondary axes MC02 (Ch.35 to Ch.610 and Ch.670 to Ch.700), MC03 (Ch. 0 to Ch.519.5) and MC04 (Ch.0 to Ch.40 and Ch.87 to Ch.131.4), all require subgrade improvement by way of excavate and replace with Class 1A4/A5/A6 to depth of 0.6 m.

Below is the list of all the axes for the above highway.

MC01 - School End Road Realignment

MC02 - Maintenance Access Road to Pond (Off School End Road - South)

MC03 - Maintenance Access Road to Pond (Off School End Road - North)

MC04 - Maintenance Access Road to GSMR (off School End Road Realignment) and Compound

Footpath CHW/18 Accommodation Access Realignment and associated realignment:

Based on the analysis of the available data, the design and associated mitigation requirements for the non-mainline earthwork are summarized below.

- There are at grade sections at Ch.0 to Ch.35.2 and Ch.193 to Ch.257.8. The sections between Ch. 35.2 to Ch.79.2 (downside) and Ch.153.3 to Ch.193 (upside), the asset is raised on approach embankments on either side of the overbridge. The maximum embankment height would be 3.2 m (Ch. 163) maximum and at a gradient of 1V:4H. The at grade section are generally 1V:3H;
- Steep slope 1V:1.25H (left side) along the Footpath CHW/18 Accommodation Access Realignment Ch. 180 and Ch. 210.
- Subgrade improvements are required at Ch.0 to Ch.35.2 and Ch.193 to Ch.257.8 by way of excavate and replace with Class 1A4/A5/A6 to depth of 0.6 m;
- The Secondary axes MC02 (Ch.0 to Ch.10 and Ch.60 to Ch.204.4, where HW Fill is on natural ground), MC03 (Ch. 0 to Ch.50 and Ch. 210 to Ch. 714) and MC05 (Ch.0 to Ch.65 and Ch.120 to Ch.324), all require subgrade improvement by way of excavate and replace with Class 1A4/A5/A6 to depth of 0.6 m.

Below is the list of all the axes for the above highway.

MC01 - Footpath CHW/18 Accommodation Access Realignment

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MC02 - Footpath CHW/18 Diversion

MC03 - Chetwode ATS Access Road and Maintenance Access Road to Pond

MC05 - The Green Highway Realignment

Starter layer is required in all areas where height of embankment is greater than 3m. In these areas, 300 mm thickness of Class 6C1 fill is recommended

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3 Introduction

3.1 Background

In January 2012, the UK Government announced its intention to proceed with a new high-speed railway line (HS2) and announced the preferred line of the route from London to the West Midlands as the first phase (Phase 1) of a national high-speed rail network which is illustrated in Image 3-1 will involve construction of a new railway line of approximately 230 kilometres (km) between London and the West Midlands with stations at Euston, Old Oak Common, Birmingham Interchange and Birmingham Curzon Street.

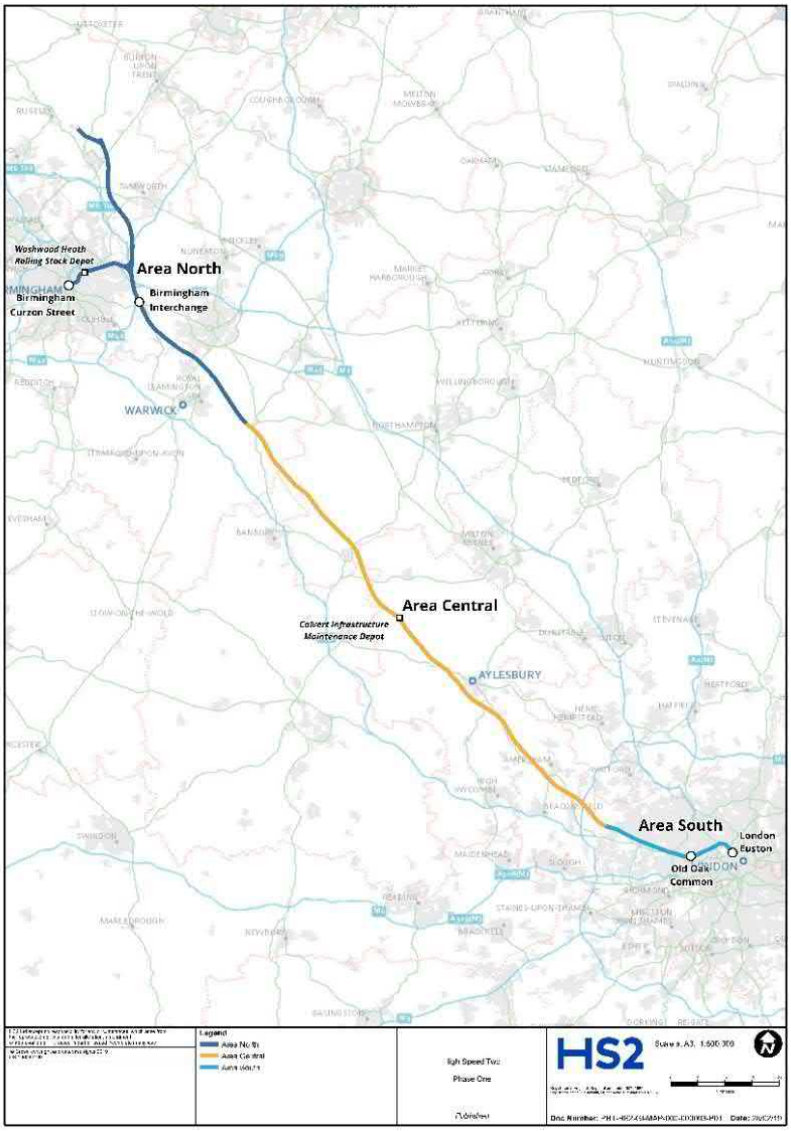


Image 3-1 : HS2 Phase 1 Route

For design and construction purposes, the overall route has been divided into three Delivery Areas as illustrated in Image 3-1 and Table 3**.1** below.

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Table 3.1 – HS2 Delivery Areas

Area	Comment
Southern	The former London Metropolitan and London Euston Station
Central	The former Country South, with part of Country North
Northern	The remainder of Country North and Birmingham Metropolitan

The delivery areas have been further sub-divided into Contracts, each of which represent a Main Works Civils Contract (MWCC). The Arcadis, Setec, COWI Design Joint Venture (ASC) has been appointed by Eiffage, Kier, Ferrovial, and BAM Nuttall Joint Venture (EKFB) to provide detailed design services for the civil engineering assets within HS2 Contract C23 (Formally Central Area 2 and Central Area 3), which have been further subdivided into the five delivery packages with the approximate extents provided in Table 3**.2** below.

Table 3.2 – Approximate Extents of HS2 Contract C23 Delivery Packages

Delivery Package Title	Extents (Snake Grid)
North Chilterns Area (NCA)	47+750 to 57+850
Aylesbury Area (AA)	57+850 to 71+850
Calvert Area (CA)	71+850 to 81+450
Twyford to Greatworth (T2G)	81+450 to 101+620
Greatworth to Southam (G2S)	101+620 to 126+540

3.2 Scope and Objective of the Report

In accordance with the HS2 MWCC Works Information WI 300 Contractors Ref[50], and the HS2 Technical Standard – Earthworks Ref[49], EKFB is required to prepare a Geotechnical Design Report (GDR) as part of the geotechnical design process.

This report meets the requirements of a GDR as set out in BS-EN1997-2 Ref[38] and includes reference to the requirements for supervision and monitoring as required by BS-EN 1997-1 Ref [37] for Chetwode Cutting. In addition, the content of this GDR has been prepared to follow the general guidance as set out in CD622 for Managing Geotechnical Risk (formerly HD22/08).

The design within this report satisfies the requirements of the HS2 Technical Standard–Earthworks Ref [49] and where relevant, cross-references the Geo-environmental and Remediation Strategy Reports as required by HS2 Technical Standard –Land Quality Ref[54].

This document details the geotechnical design of the permanent works for Chetwode Cutting and level 2 transverse assets/structures, for the Stage 2 Detailed Design, following the Phase 1 Scheme Design as presented in the Stage 1 GDR Ref [1]. The Table 3.3 provides a summary of the level 2 Assets which are analysed in this Detailed Design GDR.

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Table 3.3 – Level 2 non-mainline earthworks assets covered by this document

Level 2 Non-mainline Asset ID	Level 2 Non-mainline Asset Name	Asset Type	Approximate Chainage
HS2-000001321	Footpath CHW/18 Accommodation Overbridge	Overbridge	85+577
HS2-000001322	School End Overbridge	Overbridge	86+438
HS2-000020357	The Green Highway Realignment	Carriageway	85+300
HS2-000020NLY	Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Carriageway	85+550 – 85+600
HS2-000020NLZ	Footpath CHW/18 Accommodation Access Realignment	Carriageway	85+700
HS2-00002NAH7	Footpath CHW/18 Eastern Link Diversion	Public Right of Way (ProW)	85+580 – 85+750
HS2-000020864	Chetwode ATS	Construction Compound High Voltage	85+400 – 85+550
HS2-000020NM2	Maintenance Access Road to Pond (Off School End Road – South)	Carriageway	86+500 – 87+000
HS2-000020NM3	Maintenance Access Road to Pond (Off School End Road – North)	Carriageway	86+500 – 87+000
HS2-00002BJUR	School End Road Realignment	Carriageway	86+480
HS2-00002VXUC	Maintenance Access Road to GSMR (off School End Road Realignment) and Compound	Carriageway and GSMR platform	86+400

This GDR presents the design and outputs, taking into account the available information which includes supporting geotechnical data and ground investigation (GI) data. The report focuses on the key performance considerations for the particular assets and defines the geometry and the construction measures together with the risks and opportunities associated with the earthworks and geotechnical design.

This GDR includes updates to the data made available after the Scheme Design. The updates to the information include the following, with further details provided in the accompanying GIR Ref [6]:

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- Additional laboratory testing and monitoring data from the HS2 Main GI up to 28 March 2020;
- Additional GI and monitoring data from the Supplementary GI up to 28 March 2020;
- Data available from Stage 2 GI up to March 2020 (Datadrop 2) – Beginning of Detailed Design for this asset.

The additional GI undertaken (and made available) post March 2020, will be required to be processed and interpreted to validate and/or revise the submitted Detailed Design and Geo-environmental conditions. This will include updating the Geotechnical Risk Register (GRR) to reflect the full or partial mitigation of the geotechnical risks.

Section 10 of this GDR therefore includes an impact assessment of GI obtained after the Datadrop 2 and until Datadrop 17 released early December 2021. This section also identifies the Stage 2 GI which still have not been officially received at the time of issuing the revision P01 of this report (4 CPTs and 1 CR).

A summary of existing information, findings of field studies, interpretation of factual data from Desk Study, available Ground Investigation Factual Reports and associated AGS files, from which a geological model and evaluation of ground conditions are provided in the Supplementary GIR Ref [6].

3.3 Report structure

A summary of existing information, findings of field studies, interpretation of factual data from Desk Study, available Ground Investigation Factual Reports and associated AGS files, from which a geological model and evaluation of ground conditions are provided in the Supplementary GIR Ref[6].

The format of the GDR includes the following sections:

- Section 3.8 provides a summary of the general context of the asset and the main site conditions;
- Sections 4 and 5 present ground models, design assumptions, calculation results and mitigation measures for earthworks (mainline and non-mainline, respectively)
- Section 6 presents a summary of the geotechnical design for the structures (2 overbridges, School End Overbridge and Footpath CHW18 Accommodation Overbridge)
- Section 7 details drainage design conditions and assumptions;
- Section 8 gives information about contamination and ground treatment;
- Section 9 gives general information about material re-use
- Section 10 presents the GI Impact assessment done in GI data received post freeze date and until Datadrop 17
- Section 11, 12 and 13 are presenting the GRR, CDM and onward management of risks.
- Sections 15 provide guidance on the proposed testing and verification plan;
- Section 16 details specifications appendices.

3.4 Uncertainty in Ground Conditions Classification

The Configuration Baseline Report Ref [11] outlines the framework for the assurance of the Detailed Design including the strategy for management of new GI data.

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As part of this strategy, ASC has developed a project specific framework for assessing the level of uncertainty in ground conditions that is linked with the ability to develop the Scheme Design into a Detailed Design ready for construction. The framework is set out in detail within the Ground Engineering Design Basis Statement – Management of Uncertainty in Ground Conditions (MUGC) Ref [19].

It introduces 5 classes that are used to communicate the level of uncertainty in ground conditions with Class 2 representing a position where the Scheme Design can successfully be developed into a Detailed Design with the ground related risks managed to an acceptable level. It is considered to be a dynamic assessment that will evolve through design and construction as additional information becomes available. The uncertainty in ground conditions class specific to the level 2 assets that form the works covered by this GDR are set out in Table 3**.4** below.

Table 3.4 – Uncertainty Class of Earthworks and Structures

Level 2 Asset ID	Level 2 Asset Name	Asset Type	Location	Uncertainty Class[1]
HS2-000001054	Chetwode Cutting	Mainline Cutting	HS2 Mainline	3
HS2-000001321	Footpath CHW/18 Accommodation OB	Overbridge	Offline	3
HS2-000001321	School End OB	Overbridge	Offline	3

Notes:

1. The Uncertainty class has been assessed using the framework set out in the Ground Engineering Design Basis Statement – Management of Uncertainty in Ground Conditions (MUGC) Ref [19].
2. The Uncertainty in Ground Conditions Classification has not been established for the highway earthworks, nor for the landscape earthworks.

The assessment given in the Table 3**.4** above has been done at the beginning of Detailed Design in the last quarter of 2020. For Chetwode Cutting and associated overbirdges, the score in uncertainty class was due to the risk of heave in Oxford Clay in the deepest part of the cutting.

During Detailed Design, the following elements have been taken into account:

- Use of routewide information to define the geotechnical parameters in OXC and KLB,
- High level review of the available Groundwater Monitoring data post DataDrop 02,
- Use of the available CSW results received post Datadrop 02 for the design of the mitigations measures for Rayleigh Waves.
- GI impact assessment on data received up to datadrop 17 is part of the current GDR.

Few Stage 2 supplementary GI data have been received in the Datadrop 2, at the start of Detailed Design for Chetwode Cutting and associated overbirdges. Consequently, the design presented in this report has been completed following MUGC Approach 2 that requires using a cautious estimate of the characteristic

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values/conditions governing a limit state based on the limited GI and Field Trial information and the assumption that the outstanding scope of GI and Field Trials will validate the design assumptions.

Following the GI Impact assessment done on the data received post freeze date, the design assumptions considered for Detailed Design have been validated and therefore the Uncertainty class for Chetwode cutting and associated ovebridges is now revised to Class 2.

3.5 Strategy for Management of Uncertainty in Ground Conditions

The availability of Supplementary GI information for Detailed Design has been limited due to a number of constraints (access, permits, etc) and this problem has been exacerbated by the Covid-19 pandemic. Much of the additional ground investigation information requested for Detailed Design has been delayed.

To minimise the impact on project programme, a Ground Engineering Design Basis Statement – Management of Uncertainty in Ground Conditions (MUGC) – Ref [19] was prepared by ASC and EKFB for implementation across the C2 and C3 contract areas, which details the risk management process currently in production and will be shared with HS2.

The fundamental steps in the design process that support the management of the uncertainty in ground conditions are set out below:

- Initial assessment of uncertainty in ground condition classification (SMUG Class) for each L1 and L2 assets;
- Meeting between ASC and EKFB to clearly communicate ground risks and to agree asset specific mitigation strategy which can be one of the following:
  - obtain additional GI and/or field trials
  - design to reduce risk to acceptable level
  - validate/manage the risk through construction
- Implementation of the mitigation strategy;
- Updates to ground model and Geotechnical Risk Register on receipt of new data;
- Update to SMUG Class, if required;
- Detailed Design and mitigation of identified hazards including technical reporting.

GI Impact assessment following the receipt of supplementary GI data that post-dates the beginning of Detailed Design for this asset (Datadrop 2) and up to Datadrop 17 is presented in section 10 in accordance with the SMUG Ref [19] including their impacts on the Detailed Design as set out in this report.

Additionnal elements up to Datapdrop17 and datadrop 21 are presented in annex H and J respectively for Chetwode 18 overbridge and School End overbridge.

3.6 Limitations

No walkover for the purpose of geomorphological mapping has been undertaken prior to Stage 2 Detailed Design for the assets covered by this revision of the GDR due to restrictions on access to site and also the COVID-19 Epidemic. Data used to undertake virtual walkovers and details of the physical walkovers is presented within the Scheme Design GIR Ref[12].

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Detailed walkovers and geomorphological mapping exercises are planned to be undertaken to provide additional data to inform updates of the ground model when sufficient and safe site access are available to inform the Stage 2 Detailed Design. This is required to confirm that the observations made associated with previous physical and virtual walkovers are valid. The lack of on-site observations significantly increases the risks associated with the identification and mitigation of geomorphological hazards and could impact the assurance process.

For IDR 221.1 and associated Level 2 asset (Chetwode Cutting), I GDR is based on the GI information given with the Datadrop 2 (March 2020).

At the time of writing this report, the Stage 2 Detailed Design GI was ongoing, which incorporates elements of the supplementary GI that were not completed as per the original scope.

Updates to the Detailed Design due to receipt of supplementary GI data that post-dates this report will be assessed in accordance with the Strategy for Managing the Uncertainty in Ground Conditions –Permanent Works Ref [19] for their impact on the design as set out in this report.

It is proposed in this report that unforeseen ground conditions be managed by the inspection of exposed excavation surfaces, and control and verification testing of foundations, to identify any ‘soft spots’ and appropriate remedial measures.

Ground investigations by nature only reveal a small percentage of the ground conditions present beneath the site. The possibility of significant variation in ground conditions existing between sampling locations cannot be discounted. Groundwater conditions are based on observations made at the time of the investigation and during monitoring visits and may be subject to significant variation due to atmospheric, seasonal, or other effects.

The Geotechnical Risk Register (GRR) Ref [3], [4], [5] appropriate to the assets covered by this GDR will be progressively updated during Stage 2 Detailed Design. An extract of the GRR is provided in Appendix D.

Schedule 17 was being undertaken in parallel with the Detailed Design of the asset. Any future changes to the position or height of landscape areas, swales or ponds may require changes to the design and mitigation measures recommended in this GDR.

ASC has endeavoured to assess all information provided to them during the development of this report but makes no guarantees or warranties as to the accuracy or completeness of this information.

The information contained in this report is intended for the use of EKFB, HS2 and their Consultant partners. ASC can take no responsibility for the use of this information by any third party for uses other than described in this report. A review of historical land uses, published geological, hydrological and hydrogeological information has been undertaken by third parties including the records of regulatory and statutory bodies. ASC does not warrant, nor does it accept any responsibility or liability for, the accuracy or completeness of the content or for any loss which may arise from reliance on information provided in any third-party information on which this report is based.

3.7 Summary of changes

Compared to revision P01, the present document has been updated with :

- Section 5 and Section 6 with the design of CHW18 overbridge and School End overbridge as well as the various associated highways realignments (see Table 3.3) for IDR 221.2
- Comments done on revision P01 by HS2 / EKFB have been taken into account

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3.8 Description of the works

3.8.1 Assets Description

This GDR covers the level 2 assets contained within Chetwode Cutting Group.

The above asset group is located within Delivery Package T2G (Twyford to Greatworth) and sits between Barton Hartshorn Embankment to the north and Chetwode Embankment to the south.

The approximate locations and dimensions of the level 2 mainline assets that are used to define the extent of the Level 1 Asset Group are summarised in Table 3**.5** below.

Table 3.5 - Level 2 Mainline Asset Approximate ***Locations and Dimensions***

Level 2 Mainline Asset ID	Level 2 Mainline Asset Name	Mainline Chainage Start	Mainline Chainage End	OS Grid Reference Start	OS Grid Reference End	Length (m)	Maximum depth (m)
HS2-000001054	Chetwode Cutting	84+925	86+852	SP644286	SP633302	1 927	9 m

The level 2 assets that generally cross or are located adjacent to the mainline assets are referred to as non-mainline assets. The major non-mainline assets that are covered by this GDR are identified in Table 3**.6** below.

Table 3.6 - Level 2 non-mainline earthworks assets

Level 2 Non-mainline Asset ID	Level 2 Non-mainline Asset Name	Asset Type	Approximate Chainage
HS2-00002BVHU	Chetwode Cutting Landscape Earthworks	Mitigation Earthworks	84+900 – 86+850 both sides
HS2-000001321	Footpath CHW/18 Accommodation Overbridge	Overbridge	85+577
HS2-000001322	School End Overbridge	Overbridge	86+438
HS2-000020357	The Green Highway Realignment	Carriageway	85+300
HS2-000020NLY	Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Carriageway	85+550 – 85+600
HS2-000020NLZ	Footpath CHW/18 Accommodation Access Realignment	Carriageway	85+700
HS2-00002NAH7	Footpath CHW/18 Diversion	Public Right of Way (PRoW)	85+580 – 85+750

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Level 2 Non-mainline Asset ID	Level 2 Non-mainline Asset Name	Asset Type	Approximate Chainage
HS2-000020864	Chetwode ATS	Construction Compound High Voltage	85+400 – 85+550
HS2-000020NM2	Maintenance Access Road to Pond (Off School End R–ad - South)	Carriageway	86+500 – 87+000
HS2-000020NM3	Maintenance Access Road to Pond (Off School End R–ad - North)	Carriageway	86+500 – 87+000
HS2-00002BJUR	School End Road Realignment	Carriageway	86+480
HS2-00002VXUC	Maintenance Access Road to GSMR (off School End Road Realignment) and Compound	Carriageway	86+400
HS2-00002EK7C	Chetwode ATS UTX	Undertrack Crossing	85+479
HS2-00002N7WA	Chetwode Cutt–ng - Ancillary Culvert 085-AC1	Culvert	85+500
HS2-00002N7WB	Chetwode Cutt–ng - Ancillary Culvert 086-AC1	Culvert	86+500
HS2-00002N7WC	Chetwode Cutt–ng - Ancillary Culvert 086-AC2	Culvert	86+450
HS2-00002N7WD	Chetwode Cutt–ng - Ancillary Culvert 086-AC3	Culvert	86+830

3.8.2 Geotechnical Category of the Works

For design purposes, the earthworks and structures have been assessed and placed in a Geotechnical Category (GC) in accordance with BS EN 1997-1 Ref[37] but no lower than the minimum category defined by Table 2.2/2 from the HS2 Technical Stand–rd - Earthworks Ref[49] for Earthworks.

Table 3.7 - Geotechnical Category of Earthworks

Level 2 Asset ID	Level 2 Asset Name	Asset Type	Location	HS2 Earthworks Case[1]	Geotechnical Category
HS2-000001054	Chetwode Cutting	Mainline Cutting	HS2 Mainline	EW2	GC3

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HS2-00002BVHU	Chetwode Cutting Landscape Earthworks	Landscape Earthworks presenting that will present a significant risk to HS2 Railway	HS2 Mainline	EW7	GC3

Notes:

1. The HS2 Earthworks Case has been assessed using the definitions provided in the HS2 Technical Stand–rd - Earthworks Ref[49]

3.8.3 General Site Description

A site description is provided in the Detailed Design Chetwode Cutting GIR Ref[6]. The section below gives a summary of the site description.

Chetwode cutting passes through the “Clay Vale”, characterised by flat open valley floors and gentle hills in Jurassic Clays (Oxford Clays and Kellaways Formations).

The clay vale landscape area comprises a combination of shallow valleys landscape type and undulating clay plateau landscape type. The shallow valleys landscape comprises Twyford Vale LCA and the undulating clay plateau comprises Preston Bissett Plateau Edge LCA and Godington Hall Rolling Farmland LCA.

The land use is rural, dominated by small to medium sized hedged fields.

The asset is located approximately 300 m to the South-West of Chetwode village. The proposed route runs approximately 50 to 120 m East side of the existing Dismantled Rugby to Quainton Great Central Railway.

The terrain at this location rises towards the North-West through the two main hill systems on the route (104 m AOD at Ch. 85+380; 110 m AOD at Ch. 86+400) separated by a dry valley (at Ch.85+700).

Between Ch. 84+925 and Ch. 85+300, the natural ground slope is comprised between 5° and 10° and is parallel to the HS2 route. Between Ch. 85+300 and Ch. 86+300, and between Ch. 86+450 and Ch. 86+852, the natural ground slope is comprised between 5° and 10° and is oriented towards HS2.

The landscape consists of open farmland.

A site location plan is presented in Image 3-2.

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Image 3-2 : Location Plan

3.8.4 General Ground Conditions

The paragraph below refers to the geological conditions of the site, as described in the GIR Ref[6].

- Drift deposits

BGS map shows that Glacial Deposits of Mid Pleistocene age cover the entire length of the asset. They are composed of Glacial Till deposits (TILMP) which are overlying Glaciofluvial Deposits (GFDMP), on the Northern part.

Boreholes have shown the TILMP between Ch. 84+925 and Ch. 86+582. TILMP are over the GFDMP between Ch. 85+100 and Ch. 86+582.

- Bedrock

The BGS Map of solid geology reveals that the drift deposits are underlain by a sequence of over consolidated clay from Peterborough Member group of Jurassic age which belongs to Oxford Clay formation (OXC) from Ch. 84+925 to Ch. 86+700. Kellaways Formation (KLB) is located directly under the drift deposits at the Northern extremity of the cutting, between Ch. 86+700 and Ch. 86+852.

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These formations are shown to be underlain by an important sequence of limestones, siltstones and mudstones Formations belonging to the Great Oolite Group: Cornbrash Formation (CB), Forest Marble Formation (FMB), White Limestone Formation (WHL), Bladon Member, Rutland Formation (RLD), Taynton Limestone Formation (TY), Sharp's Hill Formation (SHHB) and Horsehay Sand Formation (HYSA).

There are no faults identified on BGS map, at Chetwode Cutting location.

However, the geological long section provided in Appendix A shows a fault zone located between Ch. 86+350 and Ch. 86+700, comprising 4 faults identified as follow:

- At Ch. 86+380: 2 m throw
- At Ch. 86+420: 1 m throw
- At Ch. 86+460: 4 m throw
- At Ch. 86+700: 9 m throw

A summary of ground conditions is provided in Table 3.8 below:

Table 3.8 – Summary of Ground conditions

Stratigraphy	Depth range / Thickness (m bgl)	Summary description	Start chainage	End Chainage
Glacial Till deposits (TILMP)	Thickness ranges from 1.8 to 4.5 m	Glacial deposit is recovered predominantly as CLAY, locally as SAND. The Clay is described as slightly sandy slightly gravelly Clay.	84+925	86+852
Glaciofluvial deposits (GFDMP)	Depth to top of stratum ranges from 1.8 to 4.5 m bgl. Thickness ranges from 1.8 to 5.5 m (in boreholes)	Glaciofluvial deposits mostly comprises SAND with interbeds of CLAY. The Clay is described as gravely soft to stiff clay with portions of sand, flint and limestone. The Sand is described as gravelly fine to coarse sand with granular portion.	85+100	86+852
Oxford Clay (OXC)	Depth to top of stratum ranges from 3.5 to 10 m bgl. Average thickness ranges from 4 to 13.7 m	The Oxford Clay is recovered predominantly as CLAY and occasionally as MUDSTONE. The Clay is described as firm to stiff thinly laminated sandy gravelly clay. The Mudstone is described as extremely weak thinly laminated mudstone.	84+925	86+700

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Stratigraphy	Depth range / Thickness (m bgl)	Summary description	Start chainage	End Chainage
Kellaways Formation (KLB)	Depth to top of stratum ranges from 6.5 to 20.5 m bgl. Thickness ranges from 5.0 to 6.1m	The Kellaways Formation is recovered as CLAY and MUDSTONE, occasionally as SAND and rarely as LIMESTONE, SILTSTONE and SANDSTONE. The Clay is described as stiff to very stiff thinly laminated Clay. The Mudstone is described as extremely weak thinly laminated mudstone. The Sand is described as medium to dense fine sand with gravel. The Sandstone is described as extremely weak.	84+925	86+852
Cornbrash Formation (CB)	Depth to top of stratum ranges from 9 to 26 m bgl. Maximum proven thickness of 2 to 3.5 m	The Cornbrash Formation is predominantly recovered as LIMESTONE, occasionally as CLAY, MUDSTONE and SILTSTONE. The Limestone is described as medium strong fossiliferous limestone. The Cla36ngliascribed as stiff thinly laminated sandy or gravelly clay. The Mudstone is described as extremely weak. Siltstone is described as extremely weak.	84+925	86+852

An extract of the geological long section is presented in Appendix A.

The interpreted ground models and geotechnical parameters used in the geotechnical analysis are presented in Section 4.4.

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3.8.5 Hydrogeological Context

The following sections provide a summary of the groundwater conditions and features in the vicinity of Chetwode Cutting as described in the GIR Ref[6].

The impact of the permanent state of the Chetwode Cutting Group has been assessed in the Hydrogeological Appraisal Report (HAR) Ref[23] and any mitigation measures are provided in the following sections of this GDR. Reference should be made to the HAR for further technical detail where required.

The transient risk during temporary construction works of this asset is outside of the ASC design scope for the HARs and has not therefore been assessed. General comments are however included below.

The following solid geology and superficial deposits are present within the asset, and these have been classified by the Environment Agency (EA) as detailed in the Table 3**.9** below.

Table 3.9 - Geological summary and aquifer classification

Formation	Geological Definition	Designation
Glacial Till	Superficial deposit	Secondary A Aquifer
Glaciofluvial deposits	Superficial deposit	Secondary A Aquifer
Oxford Clay Formation	Bedrock	Unproductive Strata
Kellaways Formation	Bedrock	Secondary A Aquifer
Cornbrash Formation	Bedrock	Secondary A Aquifer
Forest Marble Formation	Bedrock	Secondary A Aquifer
White Limestone Formation	Bedrock	Principal Aquifer

For a description of the hydrogeological regime and a summary of the groundwater inflow risk assessment on design and construction, reference should be made to the Supplementary GIR Ref[6].

Groundwater levels recorded at this asset between June 2017 and April 2021 are detailed in Image 3-3.

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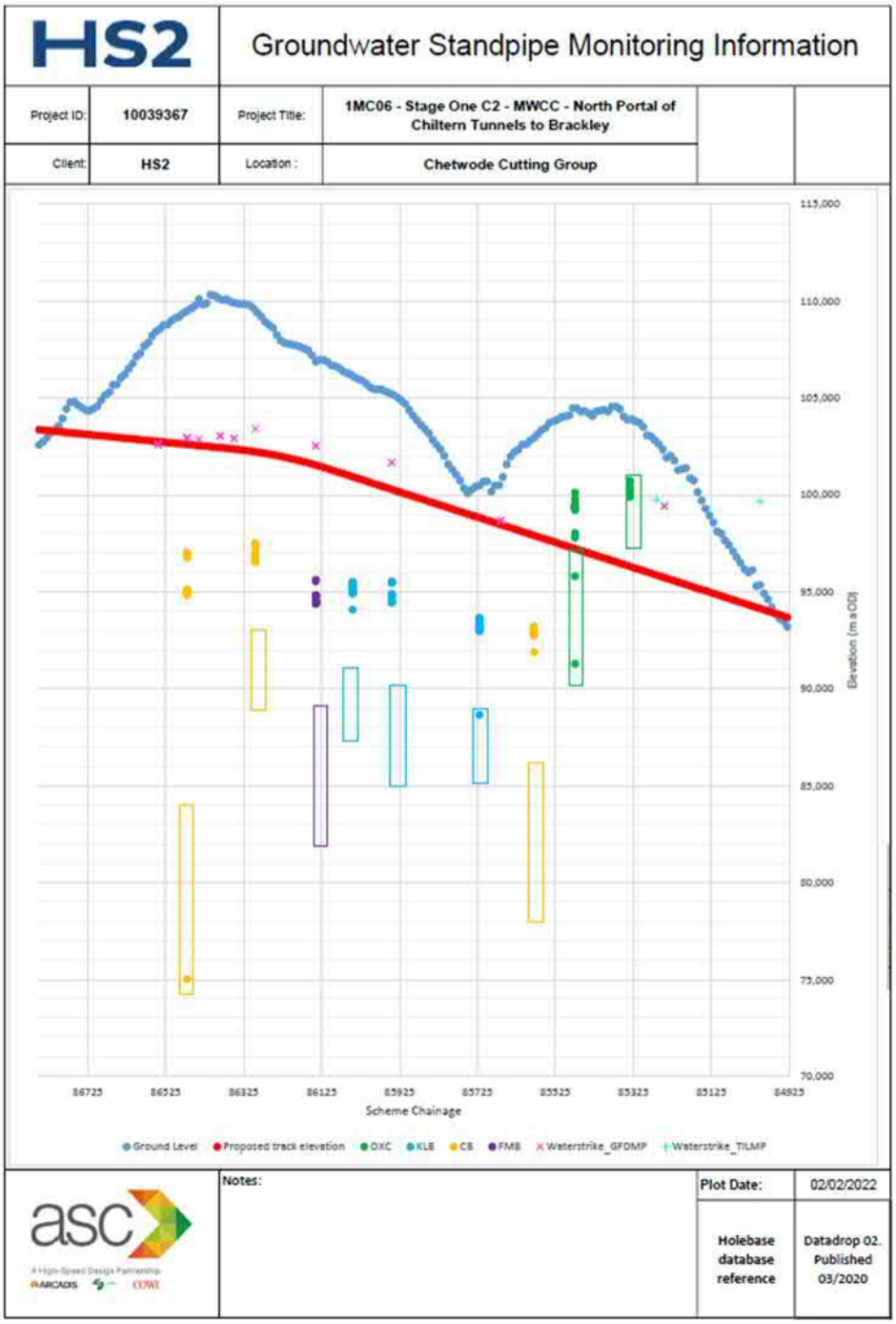


Image 3-3 : Groundwater plot

The cutting works will excavate most of the superficial deposits (TILMP and GFDMP), leaving the lower part of the Glaciofluvial deposits in the north area of the cutting. The top of the Oxford Clay Formation will locally be excavated in several places in the central area of the cutting.

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It should be noted that the Oxford Clay Formations is a clay dominated Unproductive Strata with limited groundwater flow and connectivity; any productivity is likely to be restricted to relatively thin interbedded higher permeability strata. Any water levels encountered within clay dominated strata are unlikely to be in effective hydraulic continuity over any distance greater than a few metres, and the groundwater that is observed within the monitoring boreholes is likely to represent seepages from the surrounding muds and clays and not a continuous flowing water table.

However, in the superficial deposits above the OXC bedrock formations, recorded water strikes show a groundwater level in GFDMP formation. Water ingress is expected in this formation.

“Dry” conditions are expected for this asset due to the manageable inflows anticipated from the Unproductive Strata and perched groundwater during excavation. The inflows are likely to be negligible in the permanent state of this asset.

In all ground models used in the geotechnical calculations and presented in the following sections of this GDR, due to the presence of water ingress through GFDMP, the groundwater level is assumed at the top of GFDMP. Site inspection during the excavation works will be undertaken for identification of water ingress on the slopes and implementation of counterfort drains and/or drainage blanket where deemed necessary.

For temporary excavations within GFDMP the constructions works will need to manage the water ingress in these excavations, including provision for potential sump pumping.

3.8.6 Hydrology Context and Flood risk

The paragraph below refers to the hydrological conditions of the site, as described in the GIR Ref[6].

Chetwode Cutting is located between the catchments known as the Padbury Brook (south-east of the cutting) and Tributary of Padbury Brook (north-west of the cutting). These catchments have both been subject to detailed flood modelling described in their respective Addendum to Flood Level Analysis Reports [Ref [22]] [Ref [78]]. The cutting itself is not located in either floodplain associated with these two watercourse networks.

In the vicinity of chainage 86+100, 200 m up side the route, moats and pounds related with the Wells’ farm/Hermitage development have been identified.

3.8.7 Summary of Geotechnical Risks

The key geotechnical hazards and their locations associated with Chetwode Cutting Group are detailed in the accompanying GIR Ref [6] and in the project IDR 221.1 and 221.2 Geotechnical Risk Register Ref[3], [4].

The proposed mitigation measures, which are required to eliminate or reduce these risks to an acceptable level, are discussed in this section and in Section 11 with respect to Mainline Earthworks design.

The following Table3.10 provides a summary of the key geohazards identified at Detailed Design and their impact on the geotechnical design of the mainline earthwork and of the 2 overbridges, based on an extract of the IDR 221.1 GRR Ref [3] and IDR 221.2 GRR Ref. [4].

The Geotechnical Risk Registers (GRR) Ref[3] and [4] relevant to the assets covered by this GDR are being progressively updated during Stage 2 Detailed Design. A snapshot of the GRRs is provided in Appendix D.

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Table3.10 - Geohazards and implication on the geotechnical design

Geotechnical Risk ID	Level 2 Asset	Hazard Title	Risk Description	Risk Rating	Mitigation Description / Notes
GEO_2312	HS2-000001–54 - Chetwode Cutting	Soft / Compressible Ground	Soft ground or interbedded soils with varying stiffness at transitions and/or within the cutting, which could cause instability of slopes and/or unacceptable total or differential settlements /subgrade performance associated with OXC	6	- Appropriate gentle slopes defined by calculation - Ground improvement of founding soils where required subgrade performance is not achieved - Verification testing during works - Site inspection of excavations by competent geotechnical engineer to confirm complete removal of soft pocket
GEO_2314	HS2-000001–54 - Chetwode Cutting	Shrink / Swell	Soil volume may change significantly (shrink-swell) with water content	10	According to HS Railways design and construction international standards, the shrink/swell behaviour of high plasticity clays is mastered through subgrade treatment to comply with the minimum performance criteria for high-speed rail. The risk is relevant. A foundation treatment (as E&R) will lead to reduction in the risk rating. During works, the drainage must be controlled in order to limit change in water content within the soil and specific haul road must be planned.
GEO_2316	HS2-000001–54 - Chetwode Cutting	Chemically Aggressive Ground	Elevated sulphate levels leading to lower reuse	8	The lime stabilisation of the Oxford Clay Formation for use as embankment fills is prohibited. Adequate material to be used as replacement fill for the foundation treatment and use starter layer as upwelling barrier. For structures, an adequate concrete class must be used, based on asset specific test results.
GEO_2325	HS2-000001–54 - Chetwode Cutting	Relict Periglacial Features	Periglacial shear in Clay-rich materials leading to weakened in-situ geology and increased risk of slope instability such as mudslides, solifluction or gelifluction	6	A reduced (cautious) value of cohesion to be considered in the geotechnical analysis to account for the potential weakening of the geotechnical parameters. Foundation treatment will lead to reduce this risk (E&R)
GEO_3739	HS2-000001–54 - Chetwode Cutting	Heave due to stress relief	During operation : Long term heave movement developing over time at the base of the cutting exceeding the allowable heave limits (total heave and distortion)	9	Heave calculation to be performed where cutting depth is > 5 m Monitoring of ground movement and verification of ground movement estimates during the construction works Monitoring of track movement during operation
GEO_4108	HS2-000001–54 - Chetwode Cutting	Contaminated Ground	Potential risk of soil and groundwater contamination associated with Dismantled Rugby to Quainton Great Central Railway adjacent to route (LQ 13.07) (adjacent to landscape earthworks of asset).	9	Material segregation in line with the Remediation Outline Strategy Report (1MC06-CEK-EV-REP-C002-000029), summarised in section 8
GEO_4162	HS2-000001–54 - Chetwode Cutting	High / Shallow Groundwater	Presence of high / shallow groundwater identified by the ground investigations .	9	This potential risk will be managed in design by: - Conservative groundwater level based of Groundwater monitoring (top of GFDMP) in calculations - Observational approach to be planned during construction to identify water ingress in slopes - Mitigation measures will include provision for slope drainage. - Temporary slope design to take into account this risk (adequate temporary slopes and dewatering measures if needed) - Short and long term instrumentation monitoring in GFDMP

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Geotechnical Risk ID	Level 2 Asset	Hazard Title	Risk Description	Risk Rating	Mitigation Description / Notes
GEO_4677	HS2-000001–54 - Chetwode Cutting	Soft / compressible ground	1. The dynamic performance of the completed earthworks does not achieve the Very Short Term (Instantaneous) performance criteria set out in Table 4.2/1 in the HS2 Standard Doc No. HS2-HS2-GT-STD-000-000001	12	This risk is associated with Rayleigh Waves effect The mitigation will comprise excavate and replace or ground treatment. The ground improvement depth on HS2 will be adjusted using more recent geophysical surveys obtained after the official datadrop 2. A construction validation testing is recommended to confirm the Detailed Design.
GEO_4688	HS2-000001–54 - Chetwode Cutting	Impacts on Groundwater Resources	Impacts on groundwater resources identified by the GIR, which provides details of hydrogeology including aquifer characteristics. This risk was identified by undertakings and assurances (U&A's).	12	Develop and update hydrogeological model as more data becomes available.
GEO_T2G_0019	HS2-000001–54 - Chetwode Cutting	Ground Gas	Risk of ground gases (methane, carbon dioxide, depleted oxygen, carbon monoxide and hydrogen sulph–de - Radon assessed separately).	4	Adopt appropriate PPE, and standard health and safety practices in accordance with Health and Safety Executive (HSE) guidance.
GEO_T2G_0048	HS2-000001–54 - Chetwode Cutting	Heave due to stress relief	During operation : Long term heave movement developing over time at the base of the cutting exceeding the allowable heave limits (total heave and distortion)	4	Monitoring of track movement during operation
GEO_T2G_0050	HS2-000001–54 - Chetwode Cutting	UXO	Threat of explosion during works or maintenance	4	Low risk of UXO. If risk encountered : geophysical survey + refer to SMUG
GEO_T2G_0051	HS2-000001–54 - Chetwode Cutting	Seismic	Co-seismic soil slope instability	4	The design is be carried out taking into account HS2 guidance for seismic design and Eurocode 8 guidance for sites of low seismic activity.
GEO_T2G_0052	HS2-000001–54 - Chetwode Cutting	Variable Weathering Profile	Weathering profile in OXC	6	This detailed design has proceeded using a more cautious estimate of the characteristic soil parameter values/conditions + considering a weathering profile in OXC. This risk will be managed with appropriate ground improvement of founding soils and provision to remove soft soil pocket + adequate stability calculation. Using of adequate design for temporary excavations (slopes, dewatering) Instrumentation and monitoring to be planned to manage residual risks at sensitive location.
GEO_T2G_0053	HS2-000001–54 - Chetwode Cutting	Existing Landslides	Slope movement identified in the HS2 Geomorphological Inspection Report (GZA2–9) - potentially related to relic slip surfaces. Ch. 85800 to Ch.85880	4	Risk is low : the feature has not been identified as geohazard 1. Design gentle slope gradients 2. Instrumentation planned to monitor potential slope movement 3. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction (Site inspection during the excavation works to identify relic slip features)
GEO_T2G_0054	HS2-000001–54 - Chetwode Cutting	Existing Landslides	Slope movement identified in the HS2 Geomorphological Inspection report (GZA2–0) - potentially related to relic slip surfaces. Ch. 86140 to 86160	4	Risk is low : the feature has not been identified as geohazard 1. Design gentle slope gradients 2. Instrumentation planned to monitor potential slope 3. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction (Site inspection during the excavation works to identify relic slip features)

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Geotechnical Risk ID	Level 2 Asset	Hazard Title	Risk Description	Risk Rating	Mitigation Description / Notes
GEO_T2G_0055	HS2-000001–54 - Chetwode Cutting	Existing Landslides	Sl42nglian42ment identified in the HS2 Geomorphological Inspection Report (GZA2–1) - potentially related to relic slip surfaces. Ch. 86260 to 86280	4	Risk is low : the feature has not been identified as geohazard 1. Design gentle slope gradients 2. Instrumentation planned to monitor potential slope 3. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction (Site inspection during the excavation works to identify relic slip features)
GEO_T2G_0056	HS2-000001–54 - Chetwode Cutting	Relict Periglacial Features	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls towards HS2. Ch. 85.100 to Ch. 86300	12	Risk is potential level 1 but low residual risk after mitigation: 1. Design gentle slope gradients 2. Instrumentation planned to monitor potential slope instability 3. Limit/avoid heavy loads (vehicles, stockpile) on top of excavation 4. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction
GEO_T2G_0057	HS2-000001–54 - Chetwode Cutting	Relict Periglacial Features	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls towards HS2. Ch. 86450 to Ch. 86852	8	Risk is low 1. Design gentle slope gradients 2. Instrumentation planned to monitor potential slope instability 3. Limit/avoid heavy loads (vehicles, strockpile) on top of excavation 4. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction
GEO_T2G_0058	HS2-000001–54 - Chetwode Cutting	Faulting	1. Displaced geological units 2. Unexpected variable ground conditions 3. Locally weakened ground conditions 4. Locally higher permeability	3	Low risk due to the bedrock strata depth located beneath the track level. No mitigation measures expected
GEO_T2G_0059	HS2-000001–54 - Chetwode Cutting	Faulting	1. Displaced geological units 2. Unexpected variable ground conditions 3. Locally weakened ground conditions 4. Locally higher permeability	3	Low risk due to the bedrock strata depth located beneath the track level. No mitigation measures expected
GEO_T2G_0061	HS2-000001–54 - Chetwode Cutting	Faulting	Exact fault position assumed between Ch. 86550 and Ch. 86850	2	Low risk due to the bedrock strata depth located beneath the track level. No mitigation measures expected
GEO_T2G_0062	HS2-000001–54 - Chetwode Cutting	Perched groundwater	Water ingress from potential perched water table (seasonal) in OXC Formation	6	This potential risk will be managed in design by: - Observational approach to be planned during construction to identify water ingress in slopes - Mitigation measures will include provision for slope drainage. - Temporary slope design to take into account this risk (adequate temporary slopes and dewatering measures if needed)

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Geotechnical Risk ID	Level 2 Asset	Hazard Title	Risk Description	Risk Rating	Mitigation Description / Notes
GEO_T2G_0063	HS2-000001–54 - Chetwode Cutting	Water bearing soils / rock	Threat of water ingress in permeable strata in OXC and GFDMP formation	12	This potential risk will be managed in design by: - Conservative groundwater level based of Groundwater monitoring (top of GFDMP) in calculations - Observational approach to be planned during construction to identify water ingress in slopes - Mitigation measures will include provision for slope drainage. - Temporary slope design to take into account this risk (adequate temporary slopes and dewatering measures if needed)
GEO_T2G_0064	HS2-000001–54 - Chetwode Cutting	Soft / Compressible Ground	Compressible ground, characterised as having a low strength and high compressibility, is encountered beneath the EW associated with the presence of TILMP	6	- This Detailed Design has proceeded using a more cautious estimate of the characteristic soil parameter values/conditions + considering a weathering profile in OXC. - Appropriate gentle slopes defined by calculation - Ground improvement of founding soils where required subgrade performance is not achieved - Verification testing during works - Site inspection of excavations by competent geotechnical engineer to confirm complete removal of soft pocket
GEO_T2G_0065	HS2-000001–54 - Chetwode Cutting	Made Ground / Fill Material	Poor quality materials (possibly contaminated) present on site associated with local made ground	9	This risk will be managed with appropriate ground improvement of founding soils: total removal of local made ground during construction. Excavated material in line with the Remediation Outline Strategy Report (1MC06-CEK-EV-REP-C002-000029), summarised in Section 8
GEO_T2G_0066	HS2-000001–54 - Chetwode Cutting	Obstructions	Encountering Potential hard ground band in local Made Ground	4	1. Using adequate engine during works
GEO_T2G_0071	HS2-000001–54 - Chetwode Cutting	Existing Buildings / Property	Instabilities on existing building : - Rosehill Farm : Ch; 85–00 - 85250 - Manthorn Farm : Ch. 85–50 - 85810 - Hermitage : Ch. 85800 – 86350 - Interfaces with existing bridges/realignment before diversion	6	GMIA to be performed to check the impact of the project on existing structures. Instrumentation and monitoring to be planned Walkover survey to be planned to check existing structure NOTA: Some buidings which are not mentioned is the risk description are far enough to avoid mitigations
GEO_T2G_0073	HS2-000001–54 - Chetwode Cutting	Loose / Unstable Ground	Loose and instable ground of GFDMP sandy strata if water ingress and steep temporary slopes	12	Adequate permanent slope design to ensure stability Adequate mitigation measures/temporary slope design to be planned by EKFB to ensure temporary slope stability
GEO_T2G_0588	HS2-00002B–HU - Chetwode Cutting Landscape Earthworks	Existing Landslides	Slope movement identified in the HS2 Geomorphological Inspection Report (GZA2–9) - potentially related to relic slip surfaces. Ch. 85800 to 85880	4	Risk is low : the feature has not been identified as geohazard 1. Design gentle slope gradients 2. Instrumentation planned to monitor potential slope instabilities 3. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction : inspection of slopes by competent geologist for indication of landslides
GEO_T2G_0589	HS2-00002B–HU - Chetwode Cutting Landscape Earthworks	Existing Landslides	Slope movement identified in the HS2 Geomorphological Inspection report (GZA2–0) - potentially related to relic slip surfaces. Ch. 86140 to 86160	4	Risk is low : the feature has not been identified as geohazard 1. Design gentle slope gradients 2. Instrumentation planned to monitor potential slope instabilities 3. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction : inspection of slopes by competent geologist for indication of landslides

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Geotechnical Risk ID	Level 2 Asset	Hazard Title	Risk Description	Risk Rating	Mitigation Description / Notes
GEO_T2G_0590	HS2-00002B–HU - Chetwode Cutting Landscape Earthworks	Existing Landslides	Slope movement identified in the HS2 Geomorphological Inspection Report (GZA2–1) - potentially related to relic slip surfaces. Ch. 86260 to 86280	4	Risk is low : the feature has not been identified as geohazard 1. Design gentle slope gradients 2. Instrumentation planned to monitor potential slope instabilities 3. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction : inspection of slopes by competent geologist for indication of landslides
GEO_T2G_0591	HS2-00002B–HU - Chetwode Cutting Landscape Earthworks	Relict Periglacial Features	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls towards HS2. Ch. 85.100 to Ch. 86.300	9	Risk is potential level 1 but low residual risk due to gentle slope gradient adopted in the design. 1. Design gentle slope gradients (1V/4H to 1V/3H) 2. Observational approach to follow potential ground movement during works and inspection of temporary/permanent excavation during works 3. The options for mitigation = provision for risk could include: shear keys, r44nglian44ress or counterforts drains 4. Instrumentation planned at high risk location
GEO_T2G_0592	HS2-00002B–HU - Chetwode Cutting Landscape Earthworks	Relict Periglacial Features	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls towards HS2. Ch. 86.450 to Ch. 86.852	6	Risk is potential level 1 but low residual risk due to gentle slope gradient adopted in the design. 1. Design gentle slope gradients (1V/4H to 1V/3H) 2. Observational approach to follow potential ground movement during works and inspection of temporary/permanent excavation during works 3. The options for mitigation = provision for risk could include: shear keys, r44nglian44ress or counterforts drains 4. Instrumentation planned at high risk location
GEO_T2G_0148	HS2-000020–64 - Chetwode ATS	Chemically Aggressive Ground	Elevated sulphate levels in OXC leading to lower reuse and specific requirement for backfill	8	The lime stabilisation of the Oxford Clay Formation for use as embankment fills is prohibited. Adequate material to be used as replacement fill for the foundation treatment and use starter layer as upwelling barrier. For structures, an adequate concrete class must be used, based on asset specific test results.
GEO_T2G_0149	HS2-000020–64 - Chetwode ATS	Shrink / Swell	Soil volume may change significantly (shrink-swell) with water content	10	According to HS Railways design and construction international standards, the shrink/swell behaviour of high plasticity clays is mastered through subgrade treatment to comply with the minimum performance criteria for high-speed rail. The risk is relevant. A foundation treatment (as E&R) will lead to reduction in the risk rating. During works, the drainage must be controlled in order to limit change in water content within the soil and specific haul road must be planned.
GEO_T2G_0150	HS2-000020–64 - Chetwode ATS	Variable Weathering Profile	Weathering profile in OXC which could cause instabilities and settlements	6	- Ground improvement of founding soils by E&R of OXC beneath tracks - Construction during rainy period : use adequate haul roads - Provision to remove remaining soft pocket of OXC
GEO_T2G_0151	HS2-000020–64 - Chetwode ATS	Relict Periglacial Features	Periglacial shear in Clay-rich materials leading to weakened in-situ geology and increased risk of slope instability	6	- Perform stability calculations with reduced cohesion to ensure safe slope angle and required bearing capacity - Observational approach to follow potential ground movement during works and inspection of temporary excavation during works
GEO_T2G_0152	HS2-000020–64 - Chetwode ATS	Relict Periglacial Features	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls towards HS2. Ch. 85.100 to Ch. 86300	8	Risk is potential level 1 but low residual risk due to gentle slope gradient adopted in the design and limited cutting height. - Design gentle slope gradients - Observational approach during construction - The options for mitigation = provision for risk could include: shear keys, rock buttress or counterforts
GEO_T2G_0154	HS2-000020–64 - Chetwode ATS	High / Shallow Groundwater	Presence of high / shallow groundwater identified by the ground investigations.	9	- Design gentle slope and use conservative assumptions for groundwater level - Observational approach to be planned during the construction - Include a provision for slope drainage - Short and long term instrumentation monitoring in GFDMP

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Geotechnical Risk ID	Level 2 Asset	Hazard Title	Risk Description	Risk Rating	Mitigation Description / Notes
GEO_T2G_0155	HS2-000020–64 - Chetwode ATS	Perched Groundwater	Water ingress from potential perched water table (seasonal) in OXC Formation	6	- Design gentle slope and use conservative assumptions for groundwater level - Observational approach to be planned during the construction - Include a provision for slope drainage
GEO_T2G_0156	HS2-000020–64 - Chetwode ATS	Water Bearing Soils / Rock	Threat of water ingress in permeable strata in OXC and GFDMP formation	9	- Design gentle slope and use conservative assumptions for groundwater level - Observational approach to be planned during the construction - Include a provision for slope drainage
GEO_T2G_0157	HS2-000020–64 - Chetwode ATS	Soft / Compressible Ground	Soft ground or interbedded soils with varying stiffness at transitions and/or within the cutting, which could cause instability of slopes and/or unacceptable total or differential settlements /subgrade performance. Due to weathered compressible strata on top of OXC	6	1. Appropriate gentle slopes (refer to stability calculation) 2. Adequate subgrade stiffness achieved in the design through adequate subbase thickness 3. Use acceptable backfill materials to ensure adequate compaction and stiffness support. 4. Construction during rainy period : use adequate works road and methodology 5. Site inspection of excavations by competent geotechnical engineer to confirm complete removal of soft pocket
GEO_T2G_0158	HS2-000020–64 - Chetwode ATS	Soft / Compressible Ground	Compressible ground (TIMLP), characterised as having a low strength and high compressibility, is encountered beneath the EW	6	1. Appropriate gentle slopes (refer to stability calculation) 2. Adequate subgrade stiffness achieved in the design through adequate subbase thickness 3. Use acceptable backfill materials to ensure adequate compaction and stiffness support. 4. Construction during rainy period : use adequate works road and methodology 5. Site inspection of excavations by competent geotechnical engineer to confirm complete removal of soft pocket
GEO_T2G_0159	HS2-000020–64 - Chetwode ATS	Made Ground / Fill Material	Soft ground potentially contaminated	6	1. Mitigation measure include provision for total removal of made ground 2. Suitable testing during works to determine suitability for re-use and/or disposal off site 3. HSE implications required for handling of contaminated materials and environmental protection during disposal.
GEO_T2G_0161	HS2-000020–64 - Chetwode ATS	Loose / Unstable Ground	Loose and instable ground of GFDMP sandy strata if water ingress and steep temporary slopes	12	1. Appropriate Design slopes (1V/3H in GFDMP) to ensure long term stability [Complete] 2. Provision for mitigation measures if the observational approach during construction show a water inflow : blanket layer / counterfort drains with appropriate drainalered to EK] 3. Temporary slopes in GFDMP not stable without mitigation measures during works. Adequate mitigation measure to be planned by EKFB to ensure temporary slolty [Transfered to EK]

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The following table provides a summary of some key risks identified for Footpath CHW18 accommodation overbridge and School end overbridge, and their impact on the geotechnical design.

Geotechnical Risk ID	Level 2 Asset	Hazard Title	Risk Description	Risk Level Post-Scheme Design	Mitigation Description / Notes	Risk Level Post-Detailed Design
GEO_0427–GEO_0428	HS2-000001321 - Footpath CHW/18 Accommodation Ov–rbridge HS2-000001322 - School End Overbridge	Chemically Aggressive Ground	Due to the chemically aggressive nature of Oxford Clay, there is a risk of chemical attack on concrete, resulting in concrete degrading at a faster rate than anticipated and not meeting its design life	6	Concrete class is chosen in accordance with ground aggressivity and BRE SD1	1
GEO_1967 GEO_2056 GEO_2063 GEO–T2G_0623	HS2-000001321 - Footpath CHW/18 Accommodation Ov–rbridge HS2-000001322 - School End Overbridge	Heave due to stress relief	The ground within this earthwork is likely to heave due to stress relief from removal of cut soil. Bridge piles may be subject to additional loading, including tensile forces, and deflections (lateral and vertical) which will affect the overall performance of the bridge.	12	Heave effects are assessed through a complete modelling. Additional heave induced forces and displacements are calculated and taken into account in the structural design of the piles and the overbridge. Instrumentation implemented to measure displacements during the excavation (starting from the beginning of the excavation). These measurements help validate the calculation models and input data	4
GEO_2482	HS2-000001322 - School End Overbridge	High / Shallow Groundwater	There is a risk of higher groundwater levels than monitored during GI, or absence of groundwater level data. Because of the absence of groundwater data, seasonal variations in groundwater levels which have not been recorded in existing monitoring, or presence of perched water levels not captured in existing monitoring. This results in an increase in pile loads and a reduction in pile capacity.	6	A conservative value is taken for the groundwater level (1 mbgl) based on supplementary and recent monitoring results). The slope stability is verified.	1
GEO_T2G_0749 GEO_T2G_0750	HS2-000001321 - Footpath CHW/18 Accommodation Ov–rbridge HS2-000001322 - School End Overbridge	Uncertain GI Data	There is a risk of mechanical non conformity of the piles base, supposed to be founded in medium strong limestone of the Cornbrash formation. This may be due to local variation of the Cornbrash top level and thickness, and may lead to 1. Insufficiency of the pile bearing resistance 2. Additionnal settlements of the piles	6	1. During piles boring, it is requested to identify the level of the Cornbrash formation top. 2. If the CB formation top is such as the embedded length of the pile in this formation is less than its diameter, it is required to increase the pile length. 3. The pile length is increased until an embedded length of the pile in CB formation is equal to its diameter at least	2

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3.8.8 Construction Method and Sequence

The design has been completed with the main following assumptions:

- The Northern part of the Chetwode Cutting (from Stratton Audley Road to the end of the asset) is a part of priority works and will be excavated prior to the rest of the cutting. The excavation depth for these priority works is around the project level.
- It is assumed that the Chetwode cutting will be excavated evenly over the entire footprint of the excavation in 2 to 5m lifts to lead to an even rate of unloading and heave.
- CHW18 and School End Road overbridges will be constructed bottom-up

The construction sequence taken in the design for the priority works (Northern part of the asset from Ch. 86+400 to Ch. 86+852) is as follows:

- Preliminary phases : Creation of the access road and the Haul Road / Utilities relocation/ Implementation of temporary drainage and ponds / Topsoil and Subsoil Stripping ;
- Phase 1: First stage of excavation (between Stratton Audley Road at Ch. 86+400 and the end of the asset at Ch. 86+852) approximately up to the final formation level
- Phase 2 : Second stage of excavation for the ground improvement (E&R)
- Phase 3 : Backfill of the temporary excavation
- Phase 4: School End Road overbridge construction

The ATS platform is assumed to be constructed during the mainline excavation.

No specific sequence is requested for the landscape bunds construction.

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4 Mainline Earthworks

4.1 Introduction

This section sets out the assumptions for the mainline earthworks design and presents a summary of the calculations undertaken. Design has been undertaken to satisfy the performance requirements of the–HS2 Technical Standard - Earthworks Ref[49].

4.2 General Design Approach

Geotechnical analysis and design for earthworks shall be undertaken in accordance with the HS2 Technical Standard Earthworks Ref[49]. All other HS2 Technical Standards and documents referenced in the HS2 Technical Standard Earthworks Ref[49], and the nationally applicable guidance and standards, Eurocodes and relevant associated UK National Annexes and documents shall apply.

The approach to calculation design for earthworks adopted for Stage 2 Scheme Design is outlined in the Design Basis Statement Ref[7], including loading cases.

4.3 Earthwork Asset Description

The HS2 project layout and associated ground elevations in Chetwode Cutting can be found on the following project drawings:

- General arrangement Drawings Ref [28];
- Report of cross sections Ref [29].

The following sections of the report provide an overview of the mainline earthworks.

Further details on the transverse assets are detailed in the sections 5 and 6.

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4.3.1 Mainline Asset Description

The principal dimensions of the proposed HS2 mainline earthworks are summarised in Table 4**.11** :

Table 4.11 - Geometry of the earthwork asset incl. landscape bunds

Dimension	HS2 Mainline
Con–ract/section/l–t	1MC06 - Stage One C2 - MWCC – North Portal of Chiltern Tunnels to Brackley (C2/CS06)
Name of design element	**084-L2 Chetwode Cutting**
HS2 Asset ID	**HS2-0000010–4**
Type	**Cutting**
Start - end chainage (Approx.)	Chetw–de Cutting: Ch. 84+925 - Ch. 86+852
Length	1927 m
Maximum depth / Minimum depth	9 m (≈ Ch.86+300)
Average depth	- 5.50 m
Preliminary slope angle (FPD stage)	1V:4H in cutting
Design slope angle	From Ch. 84+925 to Ch. 85+130 : 1V/3H From Ch. 85+130 to Ch. 85+620 : 1V/4H From Ch. 85+620 to Ch. 86+852 : 1V/3H
Landscape bunds	A landscape bund Hmax = +3 to 6 m/ground level; Internal slope 1V:4H and external slope varies From Ch.84+900 to Ch. 86+850 – both sides

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4.3.2 Interfaces

The other HS2 assets that interface with Chetwode Cutting mainline earthworks and require geotechnical assessment are listed in Table 4**.12** .

Table 4.12 - Assets in interface with the mainline asset

HS2 ID/ DJV ID	Asset Name/Location and/or type	Approximate Chainage
HS2-00002BVHU	Chetwode Cutting Landscape Earthwork – Mitigation Earthworks	From Ch. 84+900 to Ch. 86+850 both sides
HS2-000001321	Footpath CHW/18 Accomodation Overbridge	Ch. 85+577
HS2-000001322	School End Overbridge	Ch. 86+438
HS2-000020357	T–e Greenway Realignment - Carriageway	Ch. 85+300
HS2-000020NLY	Chetwode ATS Access Road and Maintenance Access Ro–d to Pond (P-RAI-0846) - Carriageway	From Ch.85+550 to Ch.85+600
HS2-000020NLZ	Footpath CHW/18 Accommoda–ion Access Realignment – Carriageway	Ch. 85+700
HS2-00002NAH7	Footpath CHW/18 Eastern Link – Public Right of Way (PRoW)	From Ch. 85+580 to Ch. 85+750
HS2-000020864	Chetwode ATS – Construction Compound High Voltage	From Ch. 85+400 to Ch. 85+550 Sits on the down slope berm
HS2-00002BJUR	Scho–l End Road Realignment - Carriageway	Ch. 86+480
HS2-000020NM2	Maintenance Access Road to Po–d (Off School End Road - South) – Carriageway	From Ch. 86+500 to Ch. 87+000
HS2-000020NM3	Maintenance Access Road to Po–d (Off School End Road - North) – Carriageway	From Ch. 86+500 to Ch. 87+000
HS2-00002EK7C	Chetwode ATS UTX – Undertrack Crossing	Ch. 85+479
HS2-00002VXUC	Maintenance Access Road to GSMR (off School End Road Realignment) and Compound – Carriageway and GSMR platform	Ch. 86+400 – down side – crest of cutting

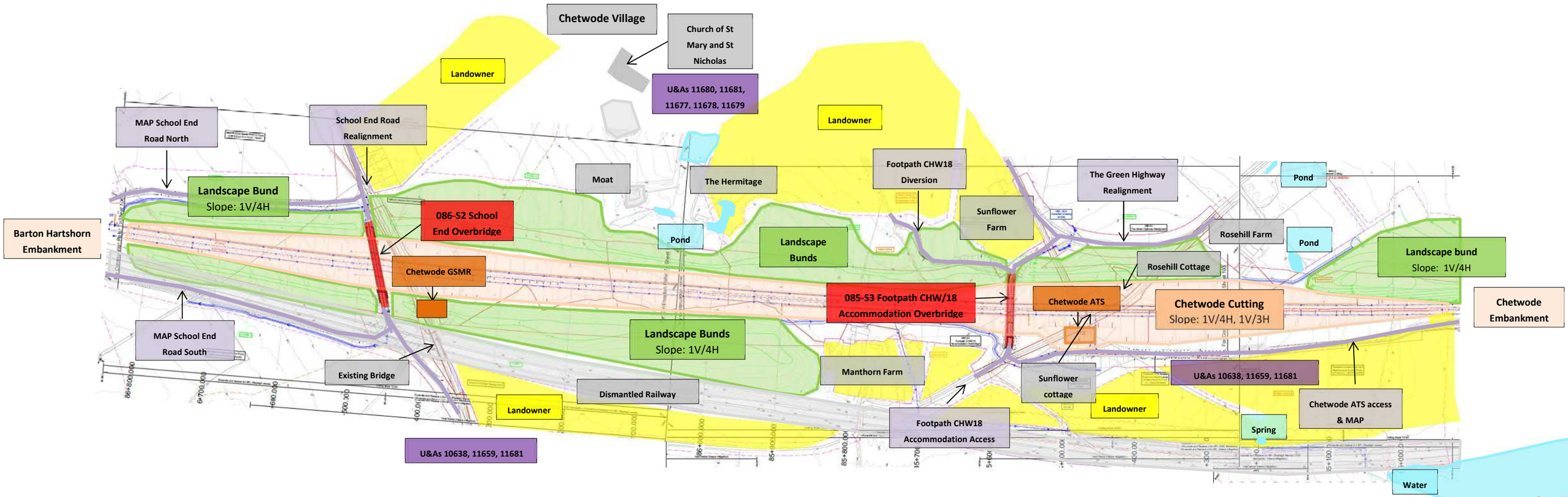
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HS2 ID/ DJV ID	Asset Name/Location and/or type	Approximate Chainage
N/A	Existing farms and cottages in the vicinity of the asset	Rosehill Cottage : to be removed Ch. 85+400 Sunflower cottage : to be removed Ch. 85+500 Rosehill Farm : Ch. 85+250 up side Sunflower Farm : Ch. 85+600 up side Manthorm Farm : partially removed – Ch. 85+700 – 85+800 down side The Hermitage : Ch. 86+000 up side

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Image 4-4 provides a schematic illustration of the main project features and interfaces in the vicinity of the asset at the stage of detailed design.

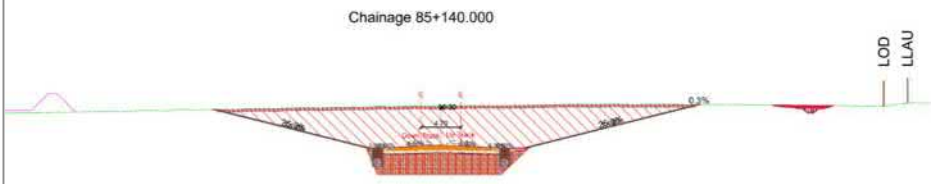
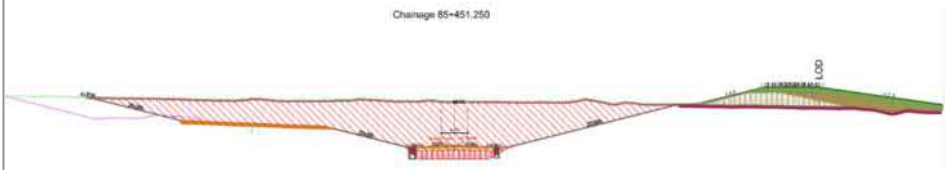
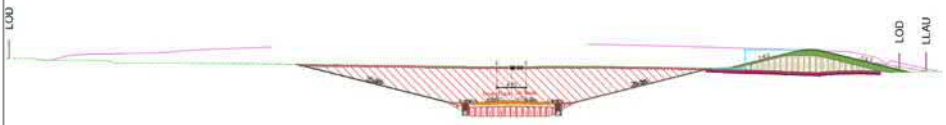
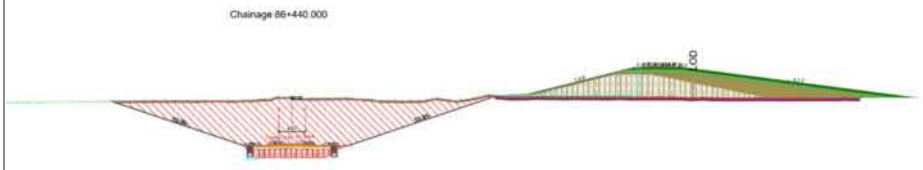
Image 4-4 : Constraint plan of Chetwode Cutting at Detailed Design



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Commentary on earthwork geometry/interfaces from the detailed design is shown in the

Table 4.13: Commentary on earthworks geometry from detailed design

Chainages	Extract of cross section / Long sectionTable 4.**13** (extracts from Chetwode Cutting Report of Cross-Sections Ref [29]) :	Comments
Ch. 85+140		Hmax=5.6 m No landscape bund
Ch. 85+450		Hmax=9m ATS platform down side on a berm (- 4 m /existing gl) Landscape bund up side, H=+3m
Ch. 85+580		Hmax= 6.5 m CHW/18 Accommodation Overbridge crossing. OB approach embankments with a 1V/4H slope; H =3.50m.
Ch. 86+440		Hmax= 9 m School End Road Overbridge crossing. OB approach embankments with a 1V/4H slope; H = 1.50m.

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4.4 Geotechnical Ground Model

This section of the report details the soil and rock parameters used in the geotechnical analysis per geological unit identified in the ground model. The selection of parameters is based on the parametric analysis presented in Appendix A on the basis of the available GI data and bibliography.

The parameters should be reviewed via an impact assessment when the last EKFB supplementary GI data becomes available.

A GI impact assessment, using Datadrop 17, is detailed in Section 10.

4.4.1 Summary of Available GI Information

Reference should be made to the accompanying GIR Ref [6] for a summary on the as-encountered ground conditions. A GI location plan and a geotechnical long section are provided in Appendix A.

The design for the mainline earthworks has been developed on the data drop n°2, received by ASC up to March 2020.

Table4.14 below summarises the fieldwork used for the development of this GDR for the design of the mainline earthworks.

Table4.14 - Fieldwork Summary

Fieldwork	HS2 Main GI Total No.	Supplementary GI Total No.	Exploratory Hole ID's	Depth Range (mbgl)
Hand Dug Pit (HP)	1		ML086-HP003	1.5
Cable Percussion (CP)	1		ML085-CP007	15
Cable Percussion and Rotary Core (CP+RC)	14	1	ML084-CR012 ML085-CR004 ML085-CR006 ML085-CR007 ML085-CR008 ML085-CR009 ML086-CR002 ML086-CR004 ML086-CR005 ML086-CR006 ML086-CR009 ML086-CR010 ML086-CR012 ML086-CR014 ML086-CR400	20-40

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Fieldwork	HS2 Main GI Total No.	Supplementary GI Total No.	Exploratory Hole ID's	Depth Range (mbgl)
Cone Penetration Test (CPT)	10	1	ML084-CT400 ML085-CT001 ML085-CT002 ML086-CT001 ML086-CT002 ML086-CT003 ML086-CT004 ML086-CT004a ML086-CT005 ML087-CT004 ML087-CT005	1.2-10.6
Pavement Core (PC)	12		ML085-PC001 ML085-PC002 ML085-PC003 ML085-PC004 ML085-PC005 ML085-PC006 ML085-PC007 ML086-PC001 ML086-PC002 ML086-PC003 ML086-PC004 ML086-PC005	0.06-0.11

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Fieldwork	HS2 Main GI Total No.	Supplementary GI Total No.	Exploratory Hole ID's	Depth Range (mbgl)
Trial Pit (TP)	-	20	ML084-TP401 ML084-TP402 ML085-TP400 ML085-TP401 ML085-TP402 ML085-TP403 ML085-TP404 ML085-TP405 ML085-TP406 ML085-TP407 ML086-TP400 ML086-TP401 ML086-TP402 ML086-TP403 ML086-TP404 ML086-TP405 ML086-TP406 ML086-TP407 ML086-TP408 ML086-TP409	2.2 – 4.0
Open Pit (OP)	4	-	ML084-OP001 ML085-OP001 ML085-OP002 ML085-OP003	2.1-4.0

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Fieldwork	HS2 Main GI Total No.	Supplementary GI Total No.	Exploratory Hole ID's	Depth Range (mbgl)
Window Sample (WLS)	23	-	ML084-WS009 ML085-WS002 ML085-WS003 ML085-WS004 ML085-WS005 ML085-WS006 ML085-WS007 ML085-WS008 ML085-WS009 ML085-WS010 ML085-WS011 ML085-WS012 ML086-WS001 ML086-WS002 ML086-WS003 ML086-WS003a ML086-WS004 ML086-WS005 ML086-WS006 ML086-WS007 ML086-WS008 ML086-WS011 ML086-WS014	1-5

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The exploratory hole locations plan identifying the available GI data informing this report is included in Appendix A of this report. An extract of the GI locations plan is given in the Image 4-5, Image 4-6 and Image 4-7 below:



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Image 4-5 : - Extract of GI Locations plan 1/3



Image 4-6 : Extract of GI Locations plan 2/3

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Image 4-7 : Extract of GI Locations plan 3/3

Going forward, it is anticipated that regular data-drops will become available from the on-going Stage 2 GI. These will be evaluated as part of the MUGC strategy and will form part of an impact assessment report as described in Section 3.5 above to verify and validate the Detailed Design detailed in this GDR.

A GI impact assessment, based on Datadrop 17, is given in Section 10 of this GDR.

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4.4.2 Ground Models and Characteristic Design Parameters

This section sets out the ground models used in the geotechnical design of earthworks.

Reference should be made to the Supplementary GIR Ref [6] and Section 3.8 of this report for a high-level summary on the background geology and as-encountered ground conditions.

A GI locations plan is presented in the Supplementary GIR Ref [6] and an extract is presented on Appendix A.

4.4.2.1 Ground Models

A summary of the ground models identified for design is given in Table 4**.15** below:

Table 4.15: Ground Models

Geological strata	Acronym's definition	Geotechnical descriptions	Base (m bgl)	Thickness expected (m)
Ground Model 1 (Ch. 84+925 – Ch. 85+130)				
TIMLP-CZ	Till, Mid Pleistocene – Clay or Silt	Glacial deposit is recovered predominantly as CLAY, locally as SAND. The Clay is described as slightly sandy slightly gravelly Clay.	4	4
OXC-CZ w	Weathered Oxford Clay Formation – Clay or Silt	The Oxford (weathered) Clay Formation was recovered predominantly as CLAY and described as firm to stiff grey thinly laminated slightly sandy gravelly Clay.	6	2
OXC-CZ u1	Unweathere– Oxford Clay Formation - Clay or Silt	The Oxford (unweathered) Clay Formation was recovered predominantly as CLAY and described as firm to stiff grey thinly laminated slightly sandy gravelly Clay	9	3
KLB-S V–SV	Kellaways Formation - Sand and/or Gravel	The Kellaways Formation is characterised as a SAND stratum overlying a CLAY/MUDSTONE stratum. The Sand comprised medium to very dense grey fine Sand. The Clay comprised stiff to very stiff dark grey thinly laminated sandy Clay. The Mudstone was recorded as an extremely weak thinly laminated dark grey Mudstone.	-	-
KLB-CZ	Kellaways Formation – Clay or Silt	The Kellaways Formation is characterised as a SAND stratum overlying a CLAY/MUDSTONE stratum. The Sand comprised medium to very dense grey fine Sand. The Clay comprised stiff to very stiff dark grey thinly laminated sandy Clay. The Mudstone was recorded as an extremely weak thinly laminated dark grey Mudstone.	-	-
CB-L–ST	Cornbrash Formation - Limestone	The Cornbrash Formation was recorded in 2 boreholes and comprised a LIMESTONE, generally described as medium strong, grey, and fossiliferous.	-	-
Ground Model 2 (Ch. 85+130– Ch. 85+620)				
TIMLP-CZ	Till, Mid Pleistocene – Clay or Silt	Glacial deposit is recovered predominantly as CLAY, locally as SAND. The Clay is described as slightly sandy slightly gravelly Clay.	2	2
GFDMP- S V SV	Glaciofluvial Deposits, Mid Pleistocene – Sand and/or Gravel	Glaciofluvial deposits mostly comprises SAND with interbeds of CLAY. The Clay is described as gravely soft to stiff clay with portions of sand, flint and limestone. The Sand is described as gravelly fine to coarse sand with granular portion.	4	2
OXC-CZ w	Weathered Oxford Clay Formation – Clay or Silt	The Oxford (weathered) Clay Formation was recovered predominantly as CLAY and described as firm to stiff grey thinly laminated slightly sandy gravelly Clay.	6	2
OXC-CZ u1	Unweathere– Oxford Clay Formation - Clay or Silt	The Oxford (unweathered) Clay Formation was recovered predominantly as CLAY and described as stiff grey thinly laminated slightly sandy gravelly Clay.	11	5
OXC-CZ u2 (MDST)	Unweathere– Oxford Clay Formation - Clay or Silt or Mustone	The Oxford (unweathered) Clay Formation was recovered predominantly as VERY STIFF CLAY OR MUDSTONE. The Mudstone is described as extremely weak thinly laminated mudstone. This stratum contains shell fragments and some gypsum crystals.	17	6

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Geological strata	Acronym's definition	Geotechnical descriptions	Base (m bgl)	Thickness expected (m)
KLB-CZ MDST	Kellaways Formation – Clay or Silt or Mudstone	The Kellaways Formation is characterised as a SAND stratum overlying a CLAY/MUDSTONE stratum. The Sand comprised medium to very dense grey fine Sand. The Clay comprised stiff to very stiff dark grey thinly laminated sandy Clay. The Mudstone was recorded as an extremely weak thinly laminated dark grey Mudstone.	23	6
CB-L–ST	Cornbrash Formation - Limestone	The Cornbrash Formation was recorded in 14 boreholes and comprised a LIMESTONE, generally described as medium strong, grey, and fossiliferous.	-	-
		Ground Model 3 (Ch. 85+620 – Ch. 86+852)		
TILMP-CZ	Till, Mid Pleistocene – Clay or Silt	Glacial deposit is recovered predominantly as CLAY, locally as SAND. The Clay is described as slightly sandy slightly gravelly Clay.	3.5	3.5
GFDMP- S V SV	Glaciofluvial Deposits, Mid Pleistocene – Sand and/or Gravel	Glaciofluvial deposits mostly comprises SAND with interbeds of CLAY. The Clay is described as gravely soft to stiff clay with portions of sand, flint and limestone. The Sand is described as gravelly fine to coarse sand with granular portion.	7	3.5
OXC-CZ u1	Unweathered Oxford Clay Formation, Clayey Facies	The Oxford (unweathered) Clay Formation was recovered predominantly as CLAY and described as firm to stiff grey thinly laminated slightly sandy gravelly Clay.	12	5
OXC-CZ u2 (MDST)	Unweathere– Oxford Clay Formation - Clay or Silt or Mustone	The Oxford (unweathered) Clay Formation was recovered predominantly as VERY STIFF CLAY OR MUDSTONE. The Mudstone is described as extremely weak thinly laminated mudstone. This stratum contains shell fragments and some gypsum crystals.	15	3
KLB-CZ MDST	Kellaways Formation – Clay or Silt or Mudstone	The Kellaways Formation is characterised as a SAND stratum overlying a CLAY/MUDSTONE stratum. The Sand comprised medium to very dense grey fine Sand. The Clay comprised stiff to very stiff dark grey thinly laminated sandy Clay. The Mudstone was recorded as an extremely weak thinly laminated dark grey Mudstone.	21	6
CB-L–ST	Cornbrash Formation - Limestone	The Cornbrash Formation was recorded in 14 boreholes and comprised a LIMESTONE, generally described as medium strong, grey, and fossiliferous.	-	-

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4.4.2.2 Characteristic Design Parameters – In Situ Material

Reference should be made to Appendix A of this report for the justification and selection of characteristic parameters associated with the design of this asset.

The geotechnical characteristic design values adopted in design are summarised in Table 4**.16** below.

Table 4.16 - Geotechnical design values – In situ material

Geological strata	PI (%)	TPS (%)	N SPT	qc (MPa)	γ' (kN/m^3)	c' (kPa)	φ'cv (°)	c_u (kPa)	Eoed MPa	Eyoung MPa	Cv (m²/s)	μg (Skempton & Bjerrum geological factor)
TIMLP-CZ	29	0,06	14	1	21	2	27	72	9	8	3,00E-07	0.5
GFDMP-SV	-	-	9	>6.5	19	0	30	-	-	18	N/A	0
OXC-CZ w	30	6	12	1.2	20	2	26	60	7	6.7	3,00E-07	0.5
OXC-CZ u1	31	6	35	3	21	5	28	120	16	14	3,00E-07	0.4
OXC-CZ u2 (MDST)	29	6	46	>3	21	5	28	180	23	21	3,00E-07	0.3
KLB-S V SV	-	-	45	9	21	0	33	NA	100	90,0	NA	0
KLB-CZ	35	6	28	3	20	5	27	145	19	17,5	6E-08	0.4

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4.4.2.3 Characteristic Design Parameters – Fill Material

The minimum soil parameters values for fill materials to be used as engineered backfill and landscape fills are given in the Table 4.**17** below. The characteristic parameters for fill material are in accordance with material planned to be used, as detailed in the latest EKFB mass haul (1MC12-EKF-GT-PLN-C000-500001 – 20/09/2021) Ref.[44].

Table 4.17 Fill material properties

Fill material	Origin of material (1)	Thickness (m)	γ_b (Mg/m^3)	Treatment type	c_u (kPa)	c' (kPa)	ϕ' (°)	v'	E' (MPa)	Comments
Foundation layer Fill for E&R	Finmere Borrow Pit Class 1 – selected material	Variable	2.0	-	-	0	35	0.2	60 (3)	Due to the presence of formation with high sulphate content, lime stabilised materials are prohibited as replacement fills. Class 1 is recommended. Cross drainage will be required at topographic low points, if present.
Landscape Bunds	Chetwode Cutting (OXC + TILMP + GFDMP)	Variable	1.9	-	40 to 50 (5)	1	23	0.2	9	High plasticity clays Class 2 and Class 4

NOTES:

- (1) *According to EKFB mass haul information Ref[44]*
- *(2) Measured at sub-formation level in accordance with HS2 Technical Standard for Earthworks Ref[49]*
- *(3) Where the top of the foundation is <2.0m below Formation Level in accordance with HS2 Technical Standard for Earthworks Ref[49]*
- *(5) Landscape bund material will comprise material with undrained shear strength not less than 40kPa; where lower strength material is used it will be placed in an appropriate non-critical location within the bund beyond any slopes facing the HS2 mainline property.*

4.4.2.4 Design Groundwater level

The groundwater levels adopted in design are listed in Table4.18 below.

Table4.18. Hydrological parameters adopted in design

Model	Assumption of groundwater level (m depth bgl)	Comment
Ground Model 1	4m	A groundwater level is assumed at the interface between the impermeable bedrock and the glacial deposits
Ground Model 2	2 m	A groundwater level is assumed to be on the top of the GFDMP layer
Ground Model 3	3.5 m	A groundwater level is assumed to be on the top of the GFDMP layer

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4.4.3 Calculation profiles

Geotechnical calculation profiles have been selected for the purpose of design based on a critical combination of acceptable distortion and proximity to structural elements.

The profiles selected for geotechnical stability represent the worst-case scenario in terms of height of the asset and ground conditions.

The calculation profiles and the associated ground model considered for Chetwode Cutting are summarised in Table4.19 below.

Table4.19: Calculation profiles

N° profile	Chainage	Type	Maximum depth (m)	Side slope	Particular constraints	Ground model	Groundwater level
1	85+140	Cutting	5.6 m	1V/3H	Existing cutting associated with de dismantled railway line	Back analysis, GM1	4 m bgl
2	85+140	Cutting	5.6 m	1V/3H	Landscape bund + 4 m	GM1	4 m bgl
3	85+450	Cutting	9 m	1V/4H	ATS platform at -4m bgl 75 kPa surcharge at ATS level	GM2	2 m bgl
4	85+580	Cutting	6.5 m	1V/4H	Accommodation OB of CHW18 Embankment – = 3.3 m – slope 1V/4H - 5 m from the cutting crest	GM2	2 m bgl
5	86+440	Cutting	9 m	1V/3H	Landscape bund + 6 m/gl Internal Slope = 1V/4H	GM3	3,5 m bgl
5-GSMR	86+400	Cutting	9 m	1V/3H	GSMR platform at 1 mbgl 75 kPa surcharge at GSMR platform level	GM3	3,5 m bgl
6	85+450	Cutting	9 m	1V/4H	Landscape bund + 4.1 m/gl Internal Slope = 1V/4H	GM2	2 m bgl

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4.5 Geotechnical Design

The design for each asset satisfies the performance requirements of–the Technical Standard - Earthworks Ref[49]. The design approach is detailed in section 4.2.

This section outlines the geotechnical calculation results. Detail of each calculation is provided in Appendix C.

4.5.1 Slope Stability

4.5.1.1 Calculation methodology

The static global stability of earthworks has been calculated adopting the principles of limit state equilibrium in accordance with Eurocode 7 Ref[37][38].

Specifically, Ultimate Limit State (ULS) Design Approach 1 Combination 1 (DA1 C1) and Combination 2 (DA1 C2) have been assessed adopting partial factors in accordance with Eurocode 7 Ref [37] with the requirement to achieve a Factor of Safety (FoS) ≥ 1. Where stability analysis shows that FoS is less than 1, then mitigation measures are to be applied.

Assessments have been undertaken to satisfy the requirements of the–HS2 Technical Standard - Earthworks Ref[49].

Slope stability was modelled using Talren 5 software. Bishop circular method of analysis was used due to soil conditions. The geological formations encountered in Chetwode cutting generally comprise firm to stiff clayey soils. The typical stratigraphy is firm to stiff overconsolidated glacial clays (TILMP), with a more sandy facies (GFDMP), overlying firm to stiff overconsolidated clays of the OXC Formation. In geotechnical terms these clayey formations show no strong contrast (or no abrupt change) in either nature or stiffness with depth. As a result there are no obvious identifiable planes of failure for non-circular analysis. The circular slope failure is the expected critical mechanism of failure.

Both the short-term (undrained) and the long-term (drained) conditions were analysed for the static condition.

The long-term condition (drained conditions) applies a variable construction surcharge of 10 kPa at the crest of cutting slopes/ on embankment berms and on landscapes. A 57 kPa surcharge is applied on embankment at rail position.

The short-term condition (undrained conditions) applies a variable construction surcharge of 20 kPa at the crest of embankment slopes, and on landscapes. It leads to a temporary excavation for ground improvement. This is not a full temporary works analysis and will need to be completed by the temporary works designer.

In compliance with the HS2 Technical Standard Ref[49] and given the hydrogeological context, a groundwater profile has been modelled in the slope stability calculations.

The groundwater level is in accordance with the section 4.4.2.4. In cutting, the groundwater level has been assumed at the rear of the vadose zone.

A vadose zone (2.0 m thick) has been modelled below final ground level comprising cohesive materials at critical state, subject to surface water infiltration, to represent high disturbance/softening and progressive long-term degradation at the slope surface. To represent this area, the friction angle is reduced by 1 or 2 degrees from the initial value and the soil cohesion is reduced to 1kPa.

A depth of 0.3 m was used as minimum slip surface depth in order to rule out insignificant shallow slip surfaces.

The seismic global stability was also assessed in accordance with Eurocode 8 Ref[39] and the requirements of HS2 Technical Standard – Civil Engineering Seismic Design Ref[48]. A two-level approach to assess the ULS (1 in 2500-year return period) and Damage Limitation State (DLS) (1 in 475-year return period) has been

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considered. Pseudo-static methods were adopted in the seismic ULS case and therefore the Damage Limitation State (DLS) was deemed satisfied.

Seismic analysis was undertaken adopting short-term parameters where applicable. Strength degradation was not applicable (α.S<0.15) and cyclic undrained shear strength has not been considered.

For seismic analysis, variable surcharges are not considered but a 30 kPa rail load is applied on embankments.

The internal stability of the landscape bund has been verified by routewide calculation, but is not presented in this report.

4.5.1.2 Back analysis

An existing cutting associated with the dismantled railway line has been identified in the vicinity of the proposed Chetwode Cutting. Based on the topographical surveys, this cutting has been excavated in TILMP (Ground model 1) with a 1V/3H slope and Hmax = 5.6m. A walkover survey shows no evidence of instabilities on the existing cutting slopes.

In order to confirm the chosen drained parameters in TILMP, a calculation has been carried out using the proposed ground model.

No partial factor has been applied on parameters.

The output of the calculation is given in Appendix C.

The calculation shows a global safety factor of 1.3. This result is consistent with the site observation (no slope instability), and in general, with the expected safety factor when designing such an earthwork structure.

Shear parameters of c' = 2 kPa and φ' = 27° have been chosen as design values for TILMP.

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4.5.1.3 Calculation Results

A summary of slopes stability calculations is provided in Table 4**.20** for static and seismic assessments respectively.

A selection of the calculation outputs is presented in Table 4.20.

Table 4.20. Slope Stability results

		Slope stability (Safety factor Γmin)					
	Calculation profile	2	3	4	5	5-GSMR	6
	Geotechnical Model	GM1	GM2	GM2	GM3	GM3	GM2
	Chainage (HS2)	85+140	85+450	85+580	86+440	86+400	85+450
	Geometry	Cutting	Cutting	Cutting	Cutting	Cutting	Cutting
	SLOPE GEOMETRY	1V/3H H = 5.6m Landscape H=3m	1V/4H H = 9m ATS Platform - 4m bgl	1V/4H H = 6.5m Embankment (for HW) H=3.3m	1V/3H H = 9m Landscape H=6m	1V/3H H = 9m GSMR platform (1 mbgl & 75 kPa)	1V/4H H = 9m Landscape = 4.1m
		WITHOUT MITIGATION MEASURES					
Static	Short term (1) – General stability	2.17	1.73 (Upper slope) 3.12 (General)	1.90 (Upper slope) 2.46 (General)	1.84	Not studied similar to profile 5	2.17 (Upper slope) 2.21 (General)
	Short term (1) – Temporary slope stability	0.40 if excavation in GFDMP > 1 if excavation in OXC or TILMP	0.40 if excavation in GFDMP > 1 if excavation in OXC or TILMP	0.40 if excavation in GFDMP > 1 if excavation in OXC or TILMP	0.40 if excavation in GFDMP > 1 if excavation in OXC or TILMP	Not studied similar to profile 5	0.40 if excavation in GFDMP > 1 if excavation in OXC or TILMP
	Long-term – stability in the vadose zone	1.04	1.45	1.49	1.13	Not studied similar to profile 5	1.44 (Slope) 1;40 (Landscape)

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		Slope stability (Safety factor Γmin)					
	Long-term – General stability	1.30	1.56	1.68	1.27	1.26	1.51
Seismic	+2500 – General stability	2.07	2.23	2.38	1.81	1.58	1.81 (Upper slope) 2.04 (General)
	-2500 – General stability	2.09	2.27	2.42	1.81	1.60	1.82 (Upper slope) 2.04 (General)
	MITIGATION for permanent SLOPE STABILITY	No	No	No	No	No	No
	Temporary slopes				Mitigation measures to be implemented when temporary excavation are made in GFDMP formations. To be developed by Temporary works designers.		

NOTE:

- *(1) The short term condition (undrained conditions) applies a variable construction surcharge of 20 kPa at the crest of cutting/embankment slopes, and on landscapes. It leads with a temporary excavation for ground improvement. This is not a full temporary works analysis and will need to be completed by the temporary works designer.*
- *(2) The long term condition (drained conditions) applies a variable construction surcharge of 10 kPa at the crest of cutting slopes/ on embankment berms and on landscapes. A 57 kPa surcharge is applied on embankment at rail position.*
- *Superficial instability corresponds to very shallow mechanisms of failure (<0.3m depth) and is usually considered not an issue for the stability of the slopes and the design of the cutting, and are therefore not given in the above table..*
- *The dig out stage is a short-term condition. The undrained shear strength is used for this calculation stage.*
- *Any future changes to the position or height of the landscape bunds/overbridges would require additional verification.*
- *Any future changes to the position or depth of drainage features would require additional verification.*

4.5.2 Heave due to Stress Relief

4.5.2.1 Scheme Design Heave Assessment

Chetwode Cutting is identified as a low risk asset with respect to the potential for long term heave effects. According to HS2 technical standards, the cutting is considered as long (longer than 800m), and the maximum allowable heave to occur during operation is of 60mm Ref [49].

As outlined within the Scheme Design GDR for Chetwode Cutting Ref [1], an Excavate-Replace-Hold Period was required as a heave mitigation measure at the deepest section of the cutting, between 85+171 and 85+581.

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The scheme design risk mitigation includes :

- Excavate-Replace and Hold Period of 12 months between 85+171 and 85+581 (total length of 410 m).

The Scheme Design heave assessment considered a heave requirement of only 15mm and was based on a simplified construction sequence comprising three consecutive stages of excavation of 200 days each. Where heave compliance criterion was exceeded, an assumed 12 month hold period was designed to ensure compliance. The duration of the hold period was not optimised during Scheme Design.

The key changes between the Scheme Design and Detailed Design heave assessment includes:

- Updating HS2 performance requirements (60mm instead of 15mm limit value to be satisfied by design for slab track for long term from the time of installation of track slab; Transversal distortion 1:1000)
- Implementing the updated EKFB stages construction sequence
- Refining design parameters, following the update in derivation of heave parameters done at the end of Scheme Design Ref [75] and accounting specifically for the updated set of ground parameters derived for the Oxford Clay Ref [76]
- Updates of geological long section and platform level

4.5.2.2 Calculation methodology

Stress relief in the underlying over-consolidated Oxford clay due to removal of overburden will result in heave effects to the cutting base. This effect will be time dependent and may extend long into the operation phase of HS2. Heave analyses have been performed to satisfy compliance with deformation criteria set out in the–HS2 Technical Standard - Earthworks Ref [49]. The performance criteria to be assessed includes maximum allowable heave during operation, maximum allowable longitudinal and transverse distortion.

The heave assessment was carried out through 2D Finite Element modelling, using PLAXIS 2D software, in accordance with the Modelling Methodology Report for Heave Prone Cuttings Ref [30]. The Hardening Soil Model with small-strain stiffness (HSS) was used for the over-consolidated clay layers prone to heave in PLAXIS, which is compliant with the HS2 requirements given in Section 4.7.3 of HS2 Technical Standard - Earthworks Ref [49].

For the asset, the main requirements associated with the cutting design and heave limits are summarised below:

- Long earthwork: 60 mm / 1:1000 longitudinal distortion.
- Transverse distortion: 1:1000
- The stratigraphy used for the 2D FE modelling is based on the interpretative geological long section of the cutting.

Ground parameters (E_{50}, Permeability, etc…) used in calculation are based on the following technical notes:

- Document No. 1MC06-CEK-GT-NOT-C002-000027- OXC Heave parameters Ref [76]

The duration of the excavation works and of the Hold-Period available before the asset handover considered by EKFB for the area has been considered in the calculations (information from TQ 950):

- Duration of excavation works to reach final excavation level (formation level): 8 months for the area with heave 85+150 to 85+615 and 85+900 to 86+450 and 12 months for the rest.
- Duration from reaching final excavation level until handover date: 16 months

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4.5.2.3 Modelling Assumptions

The design cross-sections located at different chainages were selected as part of the Detailed Design heave assessment to confirm and refine the findings of the Scheme Design analyses. Their characteristics are presented in the Table4.21 below.
First model is taken at Ch. 85+451, where top of OXC is encountered at approximately 5m below ground level (3.3m above formation level). This section is assumed to be the worst-case scenario in the Chetwode Cutting area since OXC strata is the thickest of all cutting and platform level is directly excavated in these clays. The cutting depth is about 8.3m.

Another section is considered between the faults at Ch. 86+400, to characterise the soil behaviour in this area. The cutting is 8.9 m depth, and the OXC is encountered at 7.8m depth.

KLB formation is also assumed prone to heave and is included in the OXC strata in the PLAXIS models.

According to the calculations presented in Appendix C, the totality of the ground displacements occurs during the excavation works before handover date. The remaining heave during operation at both analysed cross sections in this area is very limited (0 mm from the analyses). Hence, no additional cross-sections have been studied and the longitudinal remaining heave profile during operation is assumed to be very limited (0 mm from the calculation), as well as the associated longitudinal distortion.

Table4.21. Cross sections analysed for the heave assessment

Chainage	Natural ground level (mAoD)	Platform level (mAoD) (Cutting depth (m))	Groundwater level (mAoD)	Ground model (layer thickness (m))	Comments
85+451	104.3	96 (8.3m)	102.3 (Top of GFDMP)	TILMP (2 m) GFDMP (3 m) OXC – CZ w (1 m) (1) OXC – CZ u1 (6.5 m) (1) OXC – CZ/MDST u2 (5.7 m) (1) KLB (5.5 m) (2) CB (3 m) FMB (5 m) WHL MDST (3)	Thickest OXC strata.

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Chainage	Natural ground level (mAoD)	Platform level (mAoD) (Cutting depth (m))	Groundwater level (mAoD)	Ground model (layer thickness (m))	Comments
86+400	110.3	101.4 (8.9m)	106 (Top of GFDMP)	TILMP (4.3 m) GFDMP (3.5 m) OXC – CZ u1 (4.5 m) (1) OXC – CZ/MDST u2 (3.5 m) (1) KLB (5.5 m) (2) CB (1.5 m) FMB (5 m) WHL MDST (3)	Deepest area of the cutting Describing the fault area

(1) In the PLAXIS model, Oxford Clay is discretized according to the technical note No 1MC06-CEK-GT-NOT-C002-000027.

(2) In the PLAXIS models, the Oxford Clay parameters have been considered for Kellaways Formation (KLB), to be conservative. Thus, KLB strata is considered as an extra thickness of OXC.

(3) For the heave analysis, the WHL formation has been extended to the bottom of the FE model.

The ground parameters considered for the heave analysis and implemented in the Plaxis FE model are summarised in the Table 4.22 and Table 4.23 below.

The geotechnical parameters for the superficial deposits (GFDMP and TILMP) were derived from route wide analyses within the Clay Vale area. For the very stiff geological formations for which there are no updated values of moduli (formation of the Great Oolithe group: CB, FMB, WHL), the value of E' = 300MPa adopted in Scheme Design was considered.

Table 4.22. Ground parameters for FE analysis – Superficial Deposits and Great Oolite Group Formations (linear elastic perfectly plastic "Mohr Coulomb"'mo'el' d'ained)

Layer	γ' [kN/m³]	c' [kPa]	φ' °	E' [MPa]	ν	$k_h = k_v$ m/s
TILMP	21	2	27	9.6	0.2	4E-07
GFDMP (1)	19	1(2)	30	18	0.2	1E-06
CB	21.5	10	26	300	0.25	1E-06
FMB	21	1	38	300	0.25	1E-06
WHL-LMST	20.5	5	30	300	0.25	1E-06

(1) Route wide parameters of GFDMP between 0 and 3m depth are considered to be conservative.
(2) Cohesion to avoid superficial soil body collapses in PLAXIS.

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Geotechnical Parameters for OXC and HSS model are retrieved from the Ground Engineering Technical Note – Deriving Parameters for the Assessment of Heave – Oxford Clay Ref [75]. The upper stiffness values are considered for OXC.

Because the stiffness increases with depth, a depth discretisation has been done by creating fictive soil layers (0-10m, 10-15m, 15-25m, >25m, from existing ground level), each of them being attributed proper mechanical parameters.

Table 4.23. Ground parameters for FE analysis – OXC Formation –upper bounds of stiffness

Depth range [m]	OXC [0-10m]	OXC [10-15m]	OXC [15-25m]	OXC [>25m]
Material Model	**HSS Undrained A**			
γ_{sat} [kN/m^3]	20	20	20	20
γ_{unsat} [kN/m^3]	20	20	20	20
E_{50}^{ref} [MPa]	15	25	50	120
E_{oed}^{ref} [MPa]	15	25	50	120
E_{ur}^{ref} [MPa]	30	70	250	350
m [-]	0	0	0	0
p_{ref} [kPa]	100	100	100	100
G_0^{ref} [MPa]	100	200	350	450
$\gamma_{0.7}$ [-]	0.015	0.010	0.010	0.010
v' [-]	0.2	0.2	0.2	0.2
c' [kPa]	25	25	25	25
φ' [°]	22	22	22	22
K_h [m/s]	$1x10^{-8}$	$1x10^{-8}$	$1x10^{-8}$	$1x10^{-8}$
K_v [m/s]	$2x10^{-9}$	$2x10^{-9}$	$2x10^{-9}$	$2x10^{-9}$
K_0 [-]	1.5	1.5	1.5	1.5

Notes:

1. The ground parameters of the HSS model used for the heave prone strata have been derived based on the available GI (boreholes, in situ tests, laboratory tests) in the Oxford Clay along HS2 route located within the central part of the C2 section. For more details, refer to doc Ref [75]
2. Superficial deposits parameters are retrieved from the route wide analysis and supplemented with the Scheme Design GDR data.

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3. Non-heave prone strata are modelled considering Mohr-Coulomb drained behaviour:
    a. shear strength parameters gamma, c' and φ' have been retrieved from the Updated Scheme Design GDR when this information is available

The construction stages adopted during cutting excavation phase and operation phase in FE modelling are shown in Table 4.*24* below.

Table *4.24. Modelling stages*

Phase no.	Programme Stage	Analysis Stage	Duration
1	Initialisation of state of stress	K_0 procedure	-
2	Excavation works	Excavation 1 (0 – 4.3 m)	80 days (2.7 months)
3		Excavation 2 (4.3 -8 m)	80 days (2.7 months)
4		Excavation 3 (8 – 9 m)	80 days (2.7 months)
7		Over-Excavation	5 days
8		Backfill	5 days
9	Overload activation (landscape bunds)	Overload	5
10	Hold-Period	Hold-Period	480 days (16 months)
11	Operation	1-year operation. Application of a load of 12.5 kPa over the width of the tracks to account for the self-weight of the track slab.	365 days (12 months)
12		3 years operation	730 days (24 months)
13		10 years operation	2555 days (84 months)
14		20 years operation	3650 days (120 months)
15		50 years operation	10950 days (360 months)
16		120 years operation	25550 days (840 months)

Notes:

1. For additional details on the modelling methodology, refer to 1MC06-CEK-GT-REP-C002-000047 Ref [29]
2. K_0 procedure used in the calculation leads to considering horizontal topography in the 2D FE model

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3. In the FE model, each excavation stage has a thickness of around 2 to 4.5 m. The quantity of excavation stages varies with the depth of the studied cutting. The above table presents the stages for both studied cross sections analysed since they have a comparable depth.
4. The duration of each excavation stage is adjusted to fit the total duration of the excavation works assumed from the mass-haul programme. For Chetwode Cutting, the total duration of the excavation works has been assumed to be 8 months, based on the information shared by EKFB.
5. Over-Excavation and Backfill stages: the depth of over-excavation and thickness of associated backfill depends on the considered mitigation measure. When considering Hold-Period only, the over-excavation and backfill is 0.4 m thick.
6. Overload: This phase is created to model the construction of the landscape bunds before the Hold period.
7. The Hold-Period duration is assumed to be 16 months, from reaching the base of cutting, until handover date. This is based on the information shared by EKFB.
8. Apart from the initialisation of state of stress, the calculation stages are set to “consolidation” in PLAXIS, allowing the analysis of the development and dissipation of excess pore pressures in saturated clay-type soil as a function of time, and therefore the heave occurring during the excavation works, hold-period and design life of the cutting.

To check the requirements of HS2 regarding the 60 mm of allowable heave during 120 years of operation for a long cutting, vertical displacement u_Y is extracted from the PLAXIS models at one calculation node:

- For Hold-Period only (HP): at the axis of the project in the centre of the platform, 0.5m below the prepared subgrade.
- For Excavate-Replace-Hold (ERH): at the axis of the project in the centre of the platform, 0.5m below the over-excavation.

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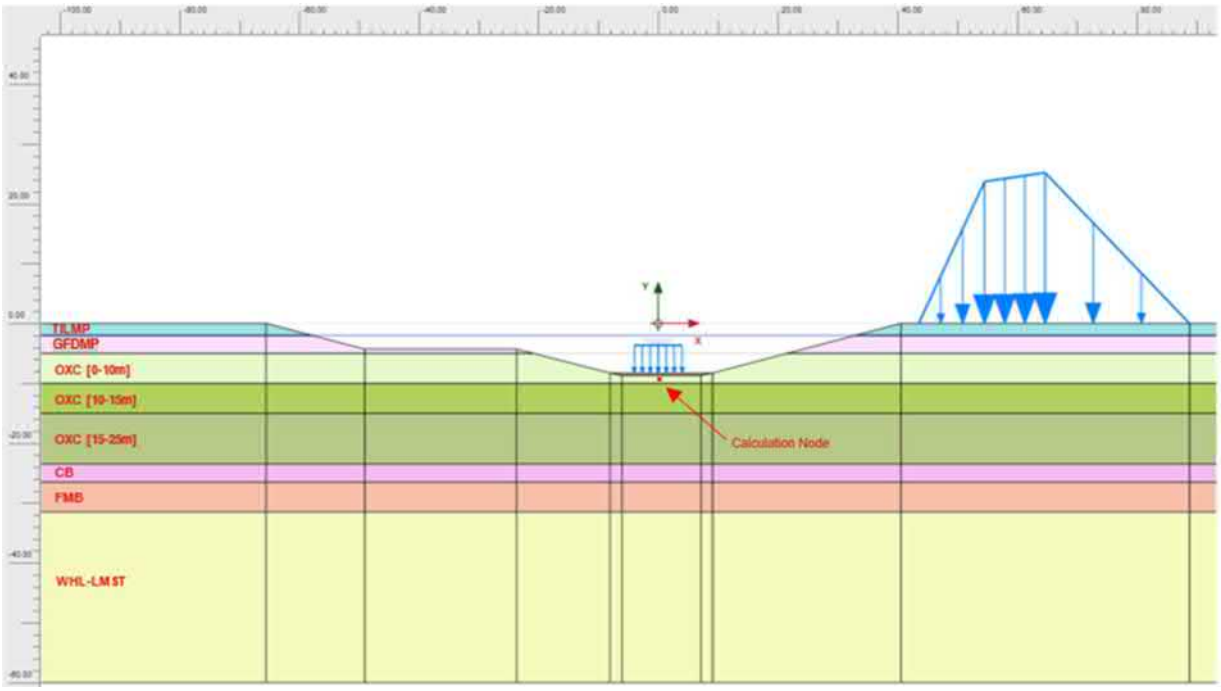


Image 4-8 : PLAXIS model – Node used to follow-up the vertical displacements

Notes :

1- A full modelling of the cross sections was done due to unsymmetric conditions.

2- The overload at the ground level corresponds to the landscape bunds.

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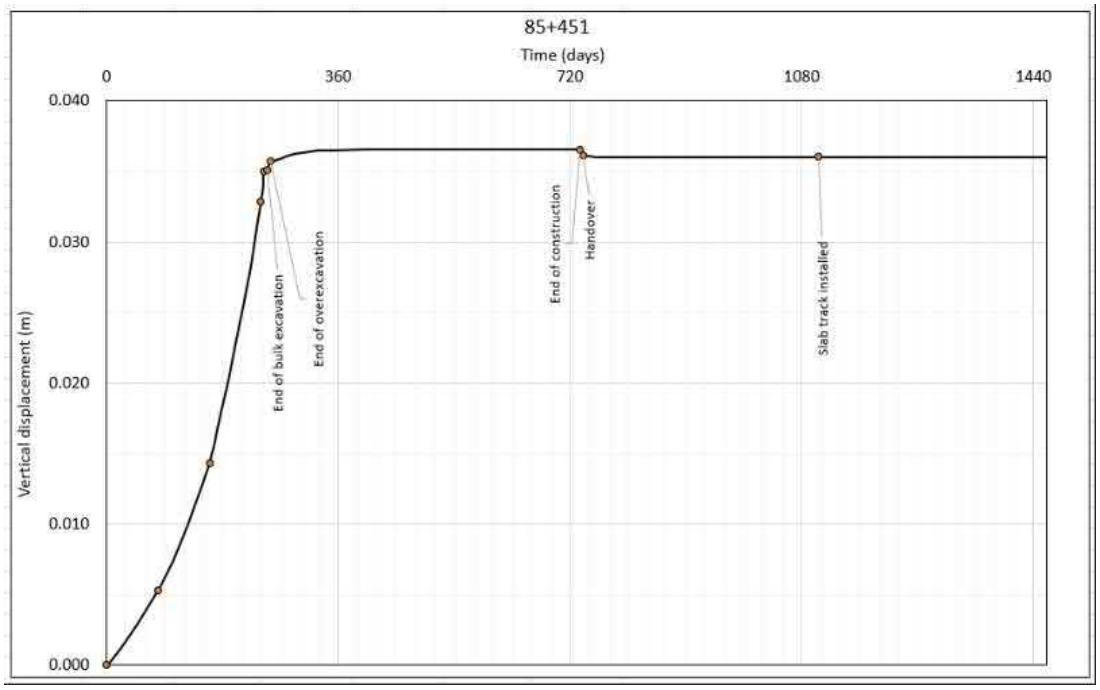


Image 4-9 : Vertical displacement Vs Time Ch. 85+451

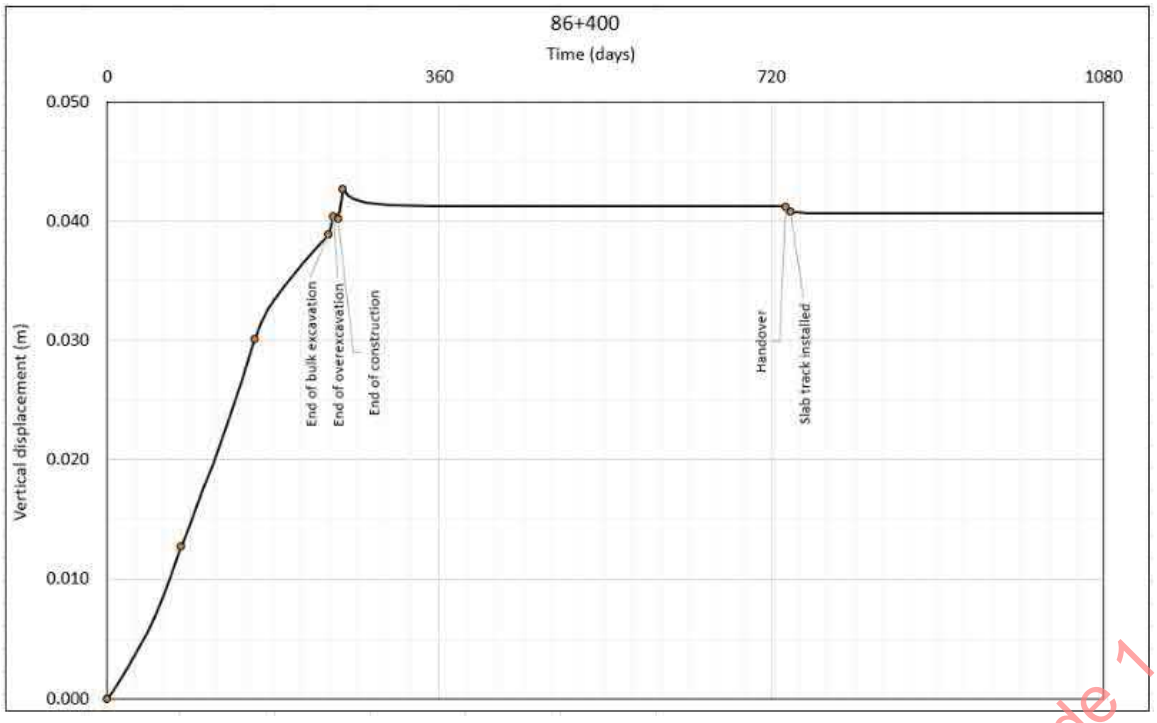


Image 4-10 : Vertical displacement Vs Time Ch. 86+400

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4.5.2.4 Calculation Results

a) Total heave at the base of the cutting

A summary of the Heave Assessment results is presented in Table ***4.25*** below.

A selection of the calculation outputs is presented in Appendix C.

Table 4.25. *Plaxis 2D Heave Assessment Results*

Analysed cross-section	85+451 – Upper bound of OXC parameters	86+400 – Upper bound of OXC parameters
Cutting Depth	8.3 m	8.9 m
No excavation stages	3	3
Duration of each excavation phase (months)	2.7 months	2.7 months
Duration of hold period (months)	16 months	16 months
ASSESSMENT HP		
Total Heave (mm)	36	41
Heave during excavation (mm)	35	40
Heave during hold period (mm)	1	1
Heave during operation (120 ys) (mm)	**0**	**0**

Notes:

1. Analysis with only Hold-Period shows that heave is totally consumed during excavation works and there are very limited displacements that occur during Hold-Period (1mm). Thus, there is no compliance period to respect and the Excavate and Replace is not considered in the heave analysis since it is assumed that these mitigations are unnecessary regarding heave issues.
2. Following the uncertainties regarding the permeability of OXC at the location of Chetwode cutting, I&M should be considered to confirm these results and the stabilisation of ground movement at platform level before handover date.
3. Since all displacements occur before slab track installation, neither longitudinal nor transversal distortions are verified during operation.

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b) Heave mitigation measures

The required mitigation measures to meet HS2 heave requirements are summarised in the Table4.26 below. The analysis is considered to be valid for the whole cutting, between Ch 84+925 and 86+852.

Table4.26. Heave mitigation measures

Cutting ID	Start Chainage	End Chainage	Length (m)	Mitigation measure	Comments
Chetwode Cutting	84+925	86+852	1927	No additional requirement for heave mitigation	Excavate and Replace is required in this area to meet other HS2 requirements (Rayleigh wave, subgrade static performance). This has not been considered in the heave analysis since no heave occur during HP. The construction programme shared by EKFB allows for 16 months of Hold-Period between end of excavation works to reach base of cutting and handover date. This has been considered in the heave analysis. A minimum monitoring period of 6 months on Topo targets installed at formation level in the cutting is recommended to confirm the stabilisation of the ground movement before handover. Refer to Chetwode Cutting Designers Monitoring Plan Ref.[10] for the quantity and location of these topo targets.

With the above proposed mitigation measures, the HS2 requirements for allowable heave during operation in Chetwode cutting are met (maximum allowable heave 60 mm).

The beneficial effects of the Excavate and Replace required to meet other HS2 requirements to help mitigate heave have been considered in the analyses. In this specific case, these effects are only marginal. For this reason, in case the E&R for Rayleigh Waves or static performance come to be optimised, there is no need to revisit the heave analysis.

According to the 2D FE Plaxis analysis, most of the heave would occur mostly during the 8 months of the excavation works, with some limited amount of remaining heave (1 mm) occurring also during the 16 months of Hold-Period covering the period from the moment reaching the base of the cutting until the handover date for the asset.

Due to the existing ground uncertainties regarding soil parameters and especially permeability of the OXC which controls the duration of dissipation of heave over time, Instrumentation & Monitoring is planned in this area to monitor:

- Vertical ground displacements at platform level over time.

The planned I&M includes only topo targets at formation level. For more details on the locations, quantities, and type of I&M, refer to Chetwode Cutting Designers Monitoring Plan Ref.[10]. Regardless of the outcome of the 2D FE analyses, a minimum monitoring period of 6 months after reaching the base of the cutting is required to check and confirm stabilisation of ground movement at platform level.

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4.5.3 Transitions

4.5.3.1 Transition Cutting / Embankment

At the transitions from Chetwode Cutting to adjacent embankments, Rayleigh wave and static performance requirements are met by implementing Excavate and Replace over 2 m depth below Formation Level: this allows homogenisation of the ground properties below track level in these transition areas.

4.5.3.2 Excavate and Replace Transition

Excavate and Replace mitigations are planned to mitigate Rayleigh Wave or Subgrade Design Requirements (EV2). When there are different depths for Excavation, the depth of treatment and methodology has been developed with reference to the specific analysis as set out in Sections 4.5.4 and 4.5.5 of this report.

In the areas requiring a change of depth of E&R, the transition from one depth to another shall be done progressively with longitudinal slopes not steeper than 1V:20H.

4.5.4 Subgrade Static Performance

In accordance with HS2 Technical Standard – Earthworks Ref[49], specific mitigation measures are to be applied where the subgrade does not achieve the required static stiffness determined by deformation modulus (EV_2).

Key requirements from HS2 standards and associated proposed mitigation measures to be applied where required are listed in Table 4-27 below :

Table 4-27 – Subgrade assessment from technical standards.

Design Criteria			Design Requirements	Details
Subgrade Design Requirements	Foundation treatment. Note to table 4.2/2	DS ≥230kph	At cut/fill transition EV2 ≥ 60 MPa at least 2 m below Formation Level	Suitable backfill is Class 1, or 9 material – depending on ground conditions
			On embankment: EV2 ≥ 60 MPa at Sub-Formation Level	Suitable backfill is Class 1, or 9 material – depending on ground conditions
		DS ≤ 230kph	EV2 ≥ 60 MPa at least 1.5m below Formation Level	Suitable backfill is Class 1, or 9 material – depending on ground conditions
	Thickness of prepared subgrade		0.40m (minimum)	Class 6F8 high quality granular fill
	Dynamic Railway Loading		Rayleigh Wave velocity measured at the Formation of >1.6* Design Speed (DS)	-

The foundation layers must meet the above minimum stiffness requirements of EV2 ≥ 60 MPa.

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In the absence of specific plate load test data from which the deformation modulus (EV_2) may be measured directly, the E' values reported in Appendix A has been used for the subgrade assessment.

The geotechnical parameters defined for the TIMLP (E'_{TIMLP} = 9.6 MPa) suggest that subgrade material will not achieve the required value of 60 MPa at depths of less than 2 m below formation level.

The geotechnical parameters defined for the GFDMP (E'_{GFDMP} = 18 MPa) suggest that subgrade material will not achieve the required value of 60 MPa at depths of less than 2 m below formation level.

The geotechnical parameters defined for the OXC weathered (E'_{OXC-W} = 6.7 MPa) suggest that subgrade material will not achieve the required value of 60 MPa at depths of less than 2 m below formation level.

The geotechnical parameters defined for the unweathered OXC (E'_{OXC-U} = 14.1 MPa) suggest that subgrade material will not achieve the required value of 60 MPa at depths of less than 2 m below formation level.

Using the UIC classification Ref.[61] for subgrade design, these soils are classed QS0 / QS1 with an inadequate quality to achieve the EV2 requirement. It is therefore recommended that a minimum thickness of 2m of granular material is placed below formation level to meet HS2 requirements.

Due to the high sulphate content identified in OXC (see Section 8.1), the use of stabilised material as replacement fill is not suitable. Considering E' for each formation crossed by the track, the planned mitigation measures are presented in the Table 4.28 below:

Table 4.28. Subgrade mitigation measures

Initial chainage	Final Chainage	Length	Excavated material	Subgrade mitigation
84+925	86+852	1927 m	TIMLP, GFDMP, OXC-w & OXCu	Excavate and replace to minimum 2 m bFL with Class1 material

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4.5.5 Subgrade Dynamic Performance (Rayleigh Waves)

4.5.5.1 Calculation Methodology

The risk assessment and mitigation design process is set out in the Guidance on the Assessment of the Dynamic Performance of Earthwork Structures Ref [65] 1MC06-CEK-GT-NOT-C002-000022.

Until such time that further GI and field trial test information is provided, the findings outlined in this section are unlikely to change.

The Earthworks Technical Standard Ref [49], Table 4.2/1 sets a minimum Rayleigh Wave velocity to be achieved at the formation level.

The dynamic performance of an earthwork is dependent on the small strain stiffness of each layer, with layers closest to the surface having the largest influence on the performance, reducing to negligible at depths greater than about 15m. An assessment of the stiffness has been undertaken of each of the material types that make up the Embankment and the foundation to allow an assessment of the expected dynamic performance of the completed earthwork.

Image 4-11 below has been used for the basis for establishing the requirement for foundation treatment to be specified for Chetwode Cutting to manage the potential for low dynamic performance.

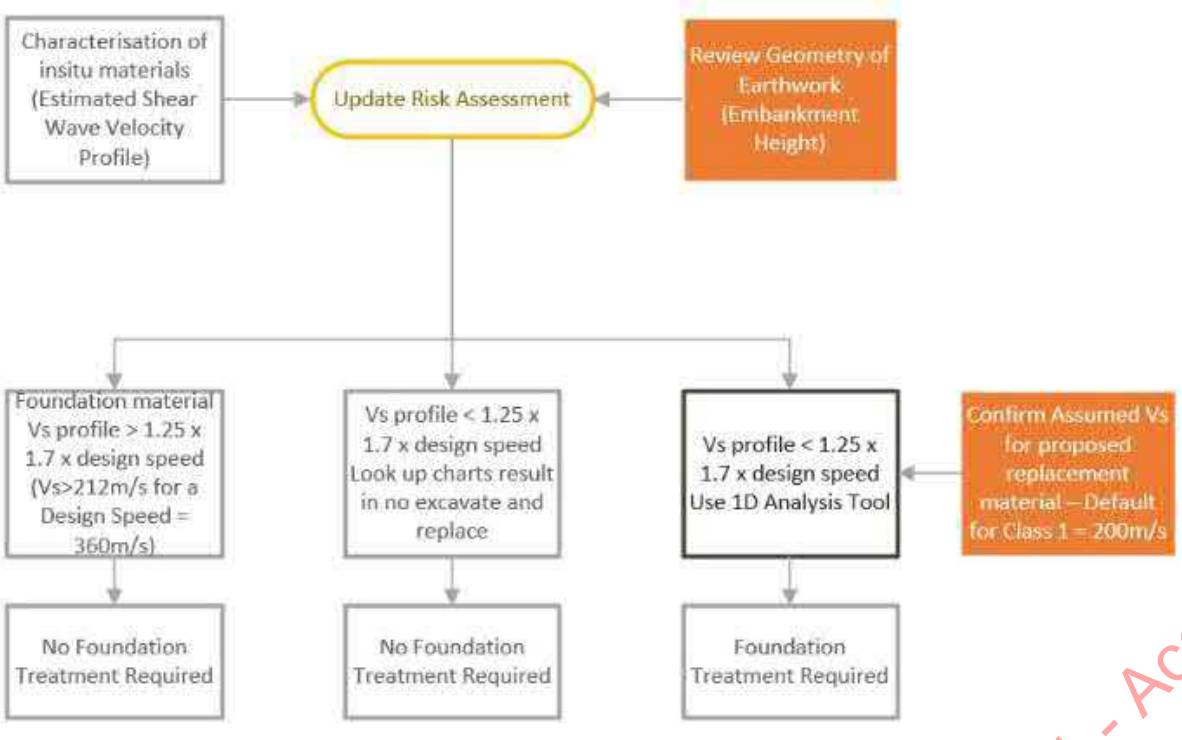


Image 4-11: Dynamic Performance Foundation Design Process

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Note:

(1) Rayleigh wave speed (VR) of 1.6 x the design train speed as given in the Earthworks Technical Standard Ref [5] is assumed equivalent to shear wave speed (Vs) of 1.7 x the design train speed.

(2) The analysis considers two criteria for shear wave velocity: 160m/s (concordant with HS2 standards) and 200 m/s (due to a partial factor of 1.25). The analysis is then carried out considering a lower and upper Vs profile for the 160m/s and the 200m/s criteria respectively to evaluate the effect of the security factor on E&R depth.

(3) The upper bound Shear Wave Velocity value (200 m/s) referenced above includes a partial factor of 1.25 and is intended to account for variability of sub-grade material.

On that basis, the following Shear Wave velocity target values have been assumed:

- Sub-grade material following sufficient pre-construction testing = 250m/s – based on the results from the Rayleigh Wave Mini Trial.
- Fill material (Cutting or replacement) = 250m/s – based on the results from the Rayleigh Wave Mini Trial.

A summary of test data used in Chetwode Cutting for the material assessment is provided in Table4.29.

Table4.29. Shear Wave Velocity analysis

Test Type	Location reference	Strata	Use	Comment
Geophysical tests	ML082-CW425; ML082-CW426; ML082-CW427 ML082-CW428;ML083-CW406; ML083-CW407; ML083-CW408; ML083-CW412; ML083-CW413; ML083-CW414; ML084-CW414; ML084-CW417; ML084-CW424; ML084-CW446; ML084-CW447;ML084-CW451; ML084-CW453; ML084-CW457; ML085-CW416; ML085-CW423; ML086-CW439; ML086-CW429; ML086-CW430; ML086-CW432	CB, FMB, KLB, OXC, TILMP, GFDMP	Direct measurement of Vs	Values obtained in geophysics give globally average to high assumptions regarding other correlations.

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Test Type	Location reference	Strata	Use	Comment
Seismic Cone Penetration Tests (SCPT)	ML082-CT014; ML082-CT005; ML082-CT015; ML082-CT013; ML082-CT011; ML082-CT012; ML084-CT001; ML084-CT002; ML085-CT001; ML085-CT002; ML086-CT002; ML086-CT001; ML086-CT003; ML087-CT005; ML087-CT004	KLB, OXC, TILMP, GFDMP	Direct measurement of Vs	Values obtained in SCPT give globally average to hight assumptions regarding other correlations.
Cone Penetration Tests (CPT)	ML082-CT011; ML082-CT012; ML083-CT005; ML083-CT006; ML083-CT004; ML084-CT001; ML084-CT002; ML084-CT002a; ML084-CT004; ML084-CT006; ML084-CT400; ML085-CT001; ML085-CT002; ML086-CT002; ML086-CT001; ML086-CT003; ML087-CT005; ML087-CT004; ML086-CT400	FMB, KLB, TILMP, OXC, GFDMP	Vs = 1.75 $(qc)^{0.627}$ (Mayne and Rix –1995) Ref [58]	Test data used to estimate Vs, either using site specific correlations or empirical relationships Usable for Clay fissured material only

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Test Type	Location reference	Strata	Use	Comment
Standard Penetration Tests (SPT)	ML082-CR008; ML082-WS009; ML082-WS008; ML082-CP006; ML082-CP008; ML082-CP009; ML082-CP026; ML082-CR002; ML082-CR003; ML082-CR400; ML082-CR401; ML082-CP016; ML082-CR006; ML083-CR004; ML083-CR002; ML083-CP007; ML083-CR003; ML084-CR002; ML084-CR400; ML084-CR401; ML084-CR402; ML084-CR003; ML084-CP007; ML084-CR005; ML084-CR403; ML084-CR404; ML084-CR008; ML084-CP023; ML084-CP021; ML084-CR012; ML085-CR006; ML085-RC009; ML085-CP007; ML085-CR004; ML085-CR007; ML085-CR008; ML085-CR009; ML086-CR009; ML086-CR010; ML086-CR014; ML086-CR012; ML086-CR004; ML086-CR400; ML086-CR005; ML086-CR002; ML086-CR006; ML086-CR007; ML087-CP009	CB, KLB, OXC, TILMP, GFDMP	Vs = 30 $N60^{0.215}$ $\sigma'v^{0.27}$ Wair et al 2012 Ref[62]	An age correlation factor of 1.13 has been applied to the above formulae, which is applied to soils that originated from the Pleistocene era, or before Test data used to estimate Vs, either using site specific correlations or empirical relationships

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UU/Vane tests	ML082-CR008; ML082-CR008; ML082-CP008; ML082-CR002; ML082-CR003; ML082-CR400; ML082-CR401; ML082-CR006; ML082-RC012; ML083-CR004; ML083-RC010; ML083-CR002; ML083-CP007; ML083-CR003; ML084-CR002; ML084-CR400; ML084-CR401; ML084-CR402; ML084-CR003; ML084-CP007; ML084-CR005; ML084-CR403; ML084-CR404; ML084-CR008; ML084-CR012; ML085-RC010; ML085-CR006; ML085-RC009; ML085-CP007; ML085-CR004; ML085-CR008; ML085-CR009; ML086-CR009; ML086-CR010; ML086-CR014; ML086-CR004; ML086-CR005; ML086-CR002; ML086-CR006; ML082-OP001; ML083-OP001; ML083-OP004; ML083-OP002; ML083-OP005; ML083-OP003; ML083-OP006; ML084-TP400; ML084-OP002; ML084-TP401; ML084-TP402; ML084-OP001; ML085-TP400; ML085-OP002;	FMB, KLB, TILMP, WHL, OXC, GFDMP	Vs = 23 $Cu^{0.475}$ Wair et al (2012) Ref[62]	the following empirical relationship proposed by Wair et al (2012) Ref[62] indicates that an Undrained Shear strength >60 kPa will correlate to a Vs > 160 m/s and an Undrained Shear strength>95 kPa will correlate to a Vs> 200 m/s.

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Test Type	Location reference	Strata	Use	Comment
	ML085-OP001; ML085-TP403; ML085-TP404; ML085-TP406; ML085-TP407; ML086-TP400; ML086-TP402; ML086-TP405; ML086-TP406; ML086-TP407; ML086-TP409; ML087-TP400			

Note:

A limited amount of data was available in Chetwode Cutting area. Analysis of shear wave velocity in formations were then carried out including GI measures of all the Clay Vale area, since geotechnical conditions are comparable.

4.5.5.2 Shear Waves Velocity Assessment

Based on the assumed ground profiles outlined in Section 4, an assessment into the Shear Wave Velocities of the formations identified at the base of the earthworks has been carried out.

The asset is subdivided into six areas according to sub platform ground condition after excavation. The 6 ground conditions at platform level identified along Chetwode Cutting are illustrated in the image below. In fact, Area 1 is similar to Area 3 where GFDMP lenses are assumed to have the same dynamic performance as TILMPs. Area 2 is also similar to area 4, where platform level is at the Oxford Clays. In areas 5 and 6, respectively GFDMP and TILMP are expected at platform level.

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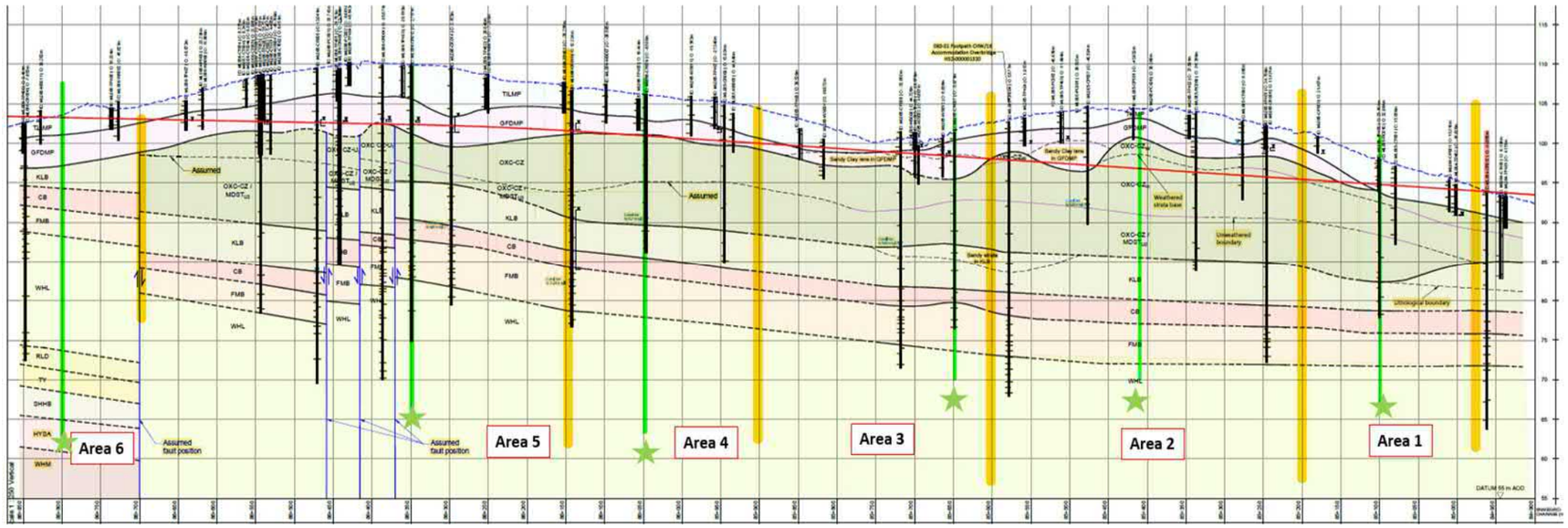


Image 4-12: Definition of ground conditions for the dynamic performances

The long section is discretised to six areas according to the strata below platform. Calculations have been carried out for pessimistic geological strata beneath platform.

The Table 4.*30* shows the calculation sections in the Chetwode Cutting area.

Table 4.30. Calculation profiles

Ground condition	Chainage	Geological strata beneath platform level	Thickness of the strata beneath platform level (m)	Top of the strata (m bgl)
Area 1	84950	TILMP	3.5	0
		OXC-CZ w	0.5	-3.5
		OXC-CZ u1	5	-4
		OXC-CZ u2	0.5	-9
		KLB	6.5	-9.5
		CB	3	-16
		FMB	4	-19
		WHL	10	-23

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Ground condition	Chainage	Geological strata beneath platform level	Thickness of the strata beneath platform level (m)	Top of the strata (m bgl)
Area 1	85100	TILMP	1	-3
		OXC-CZ w	5	-4
		OXC-CZ u1	6.5	-9
		KLB	4	-15.5
		CB	3	-19.5
		FMB	4	-22.5
Area 2 & 4	85420	OXC-CZ u1	2	-7
		OXC-CZ u2	9.5	-9
		KLB	5.5	-18.5
		CB	3	-24
		FMB	5	-27
Area 3	85650	GFDMP(Clay lens)	3	-4
		OXC-CZ u1	2	-7
		OXC-CZ u2	6.5	-9
		KLB	5.5	-15.5
		CB	2	-21
		FMB	6	-23
Area 5	86+350	GFDMP	1.5	-6.5
		OXC-CZ u1	1	-8
		OXC-CZ u2	7	-9
		KLB	5	-16
		CB	2	-21
		FMB	5	-23
Area 6	86+800	TILMP	2.5	0
		GFDMP	4	-2.5
		KLB	2.5	-6.5
		CB	3	-9
		FMB	3.5	-12
		WHL	14	-15.5

Note :
This table is not exhaustive; other sections were considered to complete the E&R calculations.

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The direct results of Shear Wave Velocities formation and values derived from laboratory and in situ tests have been plotted in Figures A12, B12, C12 and D12 in Appendix A for each formation

For each plot of Shear Wave Velocity, two design lines have been set, one for a 160m/s criterion (Green design line) and another for 200m/s (Red design line). The design line for the lower criterion (160m/s) is a low average of the available test results, whereas the upper criterion (200m/s) represent a design line carefully approaching higher values.

The velocity profiles with depth show the following:

TILMP: Shear wave velocity profiles in TILMPs are mainly set based on SPTs, geophysics and vane tests, remaining lower than SCPT measures for both design lines. The lower design line (green) is set to align with minimum geophysical measures, whereas upper design line (red) is a low average of higher values.

GFDMP: Available measures in GFDMP of the Clay Vale show good correlation except for SPT results which underestimate velocity and CPTs that show scattered and higher results. Lower design line is set according to minimum values of Vane tests for small depths then minimum geophysical measures. As for upper design line, higher values are considered (Geophysics, SCPTs, Vane tests). Where the GFDMP is identified as a sandy clayey strata, shear waves velocity is assumed to be similar to TILMP.

OXC: Several test types are available for the Oxford Clay formation in the Clay Vale. CPT's are well correlated with the other tests (forming a frame to velocity profiles). To a depth of 4m, Lower design line is set according to Vane test and minimum geophysical measures, whereas higher design line is set as an average of high geophysical measures and CU tests. Between 4m and 9m of depth, Vs profiles are set to frame the available values (mostly SPTs, CU tests and geophysics). Rare values are available in the OXC for depths higher than 9m, however, SPTs and CU tests are used to set the Vs profiles.

KLB: Measures in KLB formation in Clay Vale area are essentially SPTs, CU and geophysics. CPT results are scattered and were only considered when correlated with other measures (Clays design line). Two global design lines are set to differentiate KLB Clays and KLB Sands. The Clayey strata is defined by an average Vs profile of 250m/s, whereas the sandy KLB is characterised by a velocity of 300m/s and encountered at less than 10m of depth.

Based on the above, velocity profiles for each material are provided in Table 4.*31* :

Table 4.*31. Rayleigh Wave Risk Assessment*

Material	Depth (m bgl)	Assumed Vs (m/s)	
		160 m/s criterion	200m/s criterion
TILMP	0 – 6 m	Vs = 40z+80	Vs = 40z+120
GFDMP	2.5 – 8 m	Vs = 33.3z+66.7	Vs = 51.4z+68.7
GFDMP lenses	2 – 7m	Vs = 40z+80	Vs = 40z+120 180 at 2 m depth
KLB clayey (*)	6.5 – 24 m	250	250
OXC	0 – 4 m	Vs=18.75z+75	Vs=18.75z+125
OXC	4 – 9 m	Vs=25z+50	Vs=25z+100
OXC	>9 m	Vs=12.5z+162.5	Vs=12.5z+212.5

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Material	Depth (m bgl)	Assumed Vs (m/s)	
		160 m/s criterion	200m/s criterion
Rock (KLB sandy, CB, FMB, WHL)	-	> 300	>300

(*) In a conservative approach, KLBs are assumed to be Clayey all over the cutting and KLB sandy lenses are ignored.

Note: For rocks, a shear wave velocity of 300m/s is assumed to be high enough to eliminate Rayleigh Wave issues. Calculations have confirmed that considering higher values (>300m/s) does not change results.

4.5.5.3 Calculation Methodology

Calculations were carried out using 1D Tool, which, from a Vs profile, Vs criterion and Vs of replacement material, calculates the minimum width of excavate and replace to ensure HS2 Rayleigh Wave criterion.

Discussions with HS2 and EKFB have concluded that the safety factor of 1.25 should be applied on the targeted Vs value. Thus, calculations were carried out considering two scenarios:

- Shear wave velocity target = 160 m/s
- Shear wave velocity target = 160*1.25 = 200 m/s

As described previously, two different design lines were considered, each one for a Vs targeted where security is insured by either considering low average Vs profile (For 160m/s criterion) or high average with a Fos applied (for 200m/s criterion).

Depth of excavate and replace mitigations for each criterion along Chetwode Cutting are provided in Table4.32.

Table4.32. Depth of excavate and replace

Chainage Start	Chainage End	Cutting height at start [m]	Cutting height at end [m]	E&R approx. depth [mBFL]	
				160 m/s criterion	200m/s criterion
84925	84950	0.5	1	1	2
84950	85100	1	4	0	1
85100	85420	4	8.5	0	0
85420	85650	8.5	4	0	0
85650	85850 (1)	4 (but min depth = 2 m)	4	1	1
85850	86350	4	8.5	0	0
86350	86800	8.5	1.5	0.5	0.5
86800	86852	1.5	0	0.5	1.5

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Notes:

(1) In this specific area, where the cutting is low and the ground at platform level is characterised by GFDMP-CZ, a specific analysis has been carried out using CSW performed in this area (ML085-CW 416)
(2) Considering a design line adjusted for each criterion helps to avoid scattered results between the two criteria. The E&R results are comparable.
(3) The 200m/s criterion gives more important depths of excavate and replace. These depths have been retained as mitigation measures as they are the most pessimistic results.
(4) At the beginning of the cutting, mitigations have been adapted to meet results at the end of Chetwode Embankment.
(5) Cutting depths are calculated by reference to the top of subgrade level.
(6) Depths of E&R along the asset will be driven by the static performance criterion with EV2 > 60 MPa which requires a 2 mbFL of E&R along the cutting, rather than by the dynamic performance as presented in the table above, which requires depth shallower than 2 mbFL.

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4.6 Design solution

The proposed mitigation measures for Chetwode Cutting mainline earthworks covering geometry and formation treatment are summarised in Table 4-33.

These mitigations are also indicated on the general arrangement drawings Ref[28], and the report of cross sections Ref[29].

Table 4-33: Mitigation measures HS2 Mainline

Asset	**Chetwode C–tting**					
Chainage	**84+925 - 84+950**	**84+950– 85+130**	**85+130 – 85+62–**	**85+620- 86+350–86+350 - 86+800**	**86+800 - 86+852**	
Type	Cutting	Cutting	Cutting	Cutting	Cutting	Cutting
Depth (m)	H ≈ 1 m	0 m ≤ D ≤ 3.5 m	3.5 m ≤ D ≤ 8 m	1.5 m ≤ D ≤ 7 m	1 m ≤ D ≤ 8 m	0 m ≤ H ≤ 1.5 m
Slopes	1V/3H	1V/3H	1V/4H	1V/3H	1V/3H	1V/3H
Slope reinforcement	N/A	N/A	N/A	N/A	N/A	N/A
Drainage mitigations	N/A	N/A	N/A	N/A	N/A	N/A
Rayleigh waves mitigations requirement (See Note 1)	2 m BFL	1 m bFL	-	- 1 m bfL between Ch. 85+650 and 85+850 (In GFDMP-CZ)	0.5 m bFL	1.5 m bFL
Excavate and replace due to HS2 standards requirement (EV2 > 60Mpa) (See Note 1)	2 m bFL	2 m bFL	2 m bFL	2 m bFL	2 m bFL	2 m bFL
Shrink/Swell Mitigations	Not applicable due to previous mitigation measures					
Aggressive ground mitigations	Design concrete resistance – DS5					
Specific Requirement	Provision for slope drainage (counterfort drains, drainage blanket layer) if water ingress, and slope reinforcement if relic shear surfaces identified during excavation works Removal of soft spots (Cu<45 kPa) below landscape bunds					

NOTES

1. *Reference to ground level is given for indication only – Real measurements are provided in the report of cross sections Ref [29]*

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4.7 Specification for Temporary works

The specifications for temporary works should consider the following:

- Temporary stockpile at the crest of the proposed cutting slope: Slope stability calculations carried out in this GDR do not take into account any stockpile although 20kpa and 10kpa have respectively been applied at crest of the slope for short and long term. The short-term stability (temporary works – out of the ASC scope) will take into account the additional load due to temporary stockpile in the top of the cutting slope. As a rule, a minimum 5 m width will be applied between the proposed stockpile and the top of the cutting.
- Temporary drainage and dewatering measures will be required at the base of excavations to remove rainfall and to prevent loss of subgrade strength to include correct cross falls.
- The temporary works designer will also need to consider short term stability of steeper cut slopes within temporary excavations done for E/R. As a rule, the ground improvement should be backfilled immediately to protect the subgrade and prevent instability issues.
- Temporary slope instabilities are expected when temporary excavations are performed in sandy GFDMP. Temporary work designers to propose mitigations in order to ensure temporary slope stability.
- Site inspections of the water coming into the slopes during excavation works, especially at the level of the GFDMP and TIMLP formations where potential for perched water table / water ingress has been identified: provision for implementation of counterfort drains and/or drainage blanket layer on the permanent slopes and pumping in the temporary excavations at the base of the cutting
- The excavate and replace works will have to be carried out by sections of limited lengths to reduce the size of the excavation to ensure the stability of the temporary excavation slopes.
- Using adequate haul roads to avoid decrease in subgrade performance.
- Take the necessary constructive measures during rainy days such as inspection of the excavation to control the foundation and to confirm or not the presence of relic slip surface
- Provision for mitigation measures if the site inspection during construction shows a water inflow (blanket layer/counterfort drain with appropriate drainage)
- During the works, the level of the earthwork must have a minimum transverse slope of 4% to allow water to drain away from the excavation

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5 Non-mainline Earthworks

5.1 Introduction

This section sets out the assumptions for the non-mainline earthworks design and presents a summary of the calculations undertaken. Design has been undertaken to satisfy the performance requirements of the applicable standards.

The non-mainline earthworks that are covered by this GDR are School End Road Realignment and its associated maintenance access roads, Footpath CHW/18 and its associated access roads and the Green Highway Realignment:

- School End Road Realignment (MC01);
- Maintenance Access Road to Pond (Off School End Road South, MC02);
- Maintenance Access Road to Pond (Off School End Road North, MC03);
- Maintenance Access Road to GSMR (Off School End Road Realignment) and Compound (MC04);
- Footpath CHW/18 Accommodation Access Realignment (MC01);
- Footpath CHW/18 Eastern Link Diversion (MC02);
- Chetwode ATS Access Road and Maintenance Access Road to Pond (MC03);
- The Green Highway Realignment (MC05);
- The Chetwode ATS Platform.

5.2 Standards and General Design Approach

The design has been based on HS2 Technical Standard – Earthworks Ref [49] and supporting standards and guidance with reference to Clause 2.8.1 and 3.9, and as set out in Table 2.2/1 of the Technical Standard – Earthworks. The design approach, where relevant follows specifically BS 8006-1 Ref [41] and the nationally applicable guidance and standards, Eurocodes and relevant associated UK National Annexes and documents shall apply. Clause 3.10 of the HS2 Technical Standard relating to earthwork transitions to structures has also been complied with.

The approach to calculation design for earthworks adopted for Stage 2 Detailed Design is outlined in the Design Basis Statement Ref [7], including loading cases.

The slope stability analysis carried on the non-mainline assets have been undertaken using the slope stability software ‘Talren v6’, developed by Terrasol. Talren v6, which is a two-dimensional (2D) software. It uses classical moment equilibrium (Bishop or Fellenius) or global (force and moment) equilibrium methods to evaluate the stability along circular or non-circular failure surfaces. The slope stability can be determined by a traditional analysis (global safety factor) or by an Ultimate Limit State Analysis considering partial safety factors defined by the user. The Bishop Method has been employed for this assessment. A representative profile of the slope is given for the School End Road Realignment and its Maintenance Access Roads approach embankment, for the Footpath CHW/18 and its associated Access Roads and The Green Highway Realignment in Appendix D.

The traffic loading was taken as 20kPa (equivalent to HA loading: BD 37/01) as the surcharge on the immediate verge and over the width of the School End Road Realignment and its Maintenance Access Roads, the Footpath CHW/18 Accommodation Access Realignment and its Maintenance Access Roads and The Green

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Highway Realignment which is considered to reflect anticipated loading. Traffic loading fulfilled the two loading requirements of a 10kPa for live traffic adjacent to the carriageway, and a loading of 10kPa to represent temporary vehicle loading on the verge during heavy traffic or emergency breakdown.

The assessment followed the requirements of Design Approach 1 (DA1) of Eurocode 7 (EC7). This requires the analysis of two models: Combination 1 and Combination 2. The former applies partial factors to actions, or the effects of actions and the latter applies partial factors to material properties and actions. In order to satisfy stability requirements, an Over Design Factor (ODF) of 1.0 or greater would be required for each model.

The partial factors applied to the actions or effects of the actions and to soil properties are given in Table 5-34 and Table 5-35 respectively.

Table 5-34: Partial Factors on Actions or the Effects of Actions - BS EN 1997-1

Action		Combination 1	Combination 2
Permanent	Unfavourable	1.35	1.0
	Favourable	1.0	1.0
Variable	Unfavourable	1.5	1.3
	Favourable	0	0

Table 5-35: Partial Factors for Soil Parameters - BS EN 1997-1

Soil Parameter	Combination 1	Combination 2
Coefficient of Shearing Resistance (tan Φ')	1.0	1.25
Effective cohesion c' (kPa)	1.0	1.25
Undrained Shear Strength c_u (kPa)	1.0	1.4
Unit Weight γ (kN/m^3)	1.0	1.0

The slope stability outputs are presented as Models and are included in Appendix D of this report.

Where possible, side slopes have been graded to the minimum gradient possible, drainage, land made available and other restrictions permitting.

A basal drainage blanket (Class 6C1 starter layer, nominal 300mm thick) will be required for all embankments with height greater than 3m to avoid capillary water rise in the embankment.

No basal drainage blanket is required for embankments less than 3m in height which are more than 50m from the approach to a structure except in areas where high groundwater is anticipated.

The internal settlement of the embankment fill material will be managed using suitable compaction method during construction. The provision of internal horizontal drainage layers at 1.5m c/c (vertically) in embankments of height 3m or higher at critical locations i.e. on the approach to major structures is an additional means of

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mitigation against internal settlement of the fill material. The spacing is aimed at achieving 90% consolidation over a 2/3-month period.

Where localised soft ground (Cu<50 kPa or low CBR) is encountered below embankments or at grade, excavate and replace could be adopted using either Class 2 or Class 1 (Class 1A4, 1A5 or 1A6) fill material to achieve a minimum CBR of 3% at formation. The exception is where excavate and replace is required to reduce settlements on the approach to structures, where Class 1 fill material will be required to be used.

For side-slopes of greater than 1V:3H, and for embankments greater than 1m in height, where over-the-edge drainage is proposed up to a maximum of 3m height, a topsoil retention system is proposed.

Asset Specific Drawings supporting the non-mainline earthworks design and the design approach as set out in Table 5-36 below.

Table 5-36: Summary of Asset Specific Drawings

Ref	Drawing Number	Description
-	1MC06-CEK-HW-DGA-CS06_CL10-000014	School End Realignment General Arrangement Sheet 1
-	1MC06-CEK-HW-DGA-CS06_CL10-000049	School End Realignment (086) (C) General Arrangement Sheet 1
-	1MC06-CEK-HW-DGA-CS06_CL10-000099	Footpath CHW-18 Diversion General Arrangement Sheet 1
-	1MC06-CEK-HW-DGA-CS06_CL10-000117	Footpath CHW-18 Diversion General Arrangement Sheet 2
-	1MC06-CEK-BR-DGA-CS06_CL10-00068–	School End Overbridge – Earthworks Transition - Sheet 1
	1MC06-CEK-BR-DGA-CS06_CL10-00069–	School End Overbridge – Earthworks Transition - Sheet 2
-	1MC06-CEK-HW-DGA-CS06_CL10-000010	Footpath CHW18 Accommodation Overbridge and the Green Realignment General Arrangement Sheet 1
-	1MC06-CEK-BR-DGA-CS06_CL10-000759	Footpath CHW-18 Accommodation Overbridge – Earthworks Transition - Sheet 2
-	1MC06-CEK-HW-DSE-CS06_CL10-000002	School End Realignment (086) (C) Cross Sections
-	1MC06-CEK-HW-DSE-CS06_CL10-000001	Footpath CHW18 Diversion Cross Sections
-	1MC06-CEK-HW-DGA-CS06_CL10-000050	School End Realignment (086) (C) Highway Drainage Sheet 1

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Ref	Drawing Number	Description
-	1MC06-CEK-GT-DSE-CS06_CL10-000037	School End Realignment Asset specific cross section
-	1MC06-CEK-GT-DSE-CS06_CL10-000036	Footpath CHW-18 Diversion Asset specific cross section
	1MC06-CEK-HW-DGA-CS06_CL10-000050	School End Realignment (086) (C) Highway Drainage Sheet 1
-	1MC06-CEK-HW-DGA-CS06_CL10-000151	School End Realignment (086) (C) Highway Drainage Sheet 2
-	1MC06-CEK-HW-DGA-CS06_CL10-000152	School End Realignment (086) (C) Highway Drainage Sheet 3
-	1MC06-CEK-HW-DGA-CS06_CL10-000148	Footpath CHW-18 Diversion Drainage Layout sheet 1
-	1MC06-CEK-HW-DGA-CS06_CL10-000149	Footpath CHW-18 Diversion Drainage Layout sheet 2
-	1MC06-CEK-HW-DGA-CS06_CL10-000150	Footpath CHW-18 Diversion Drainage Layout sheet 3
-	1MC06-CEK-HW-DMA-CS06_CL10-000006	School End Realignment (086) (C) - 2D Model
-	1MC06-CEK-HW-DMA-CS06_CL10-000014	Footpath CHW-18 Accommodation Overbridge and The Green Highway Realignment 2D Model

5.2.1 Identified Utilities

According to the design joint venture GIS database, there are no non-contestable utilities present between Ch. 84+900 and Ch. 86+875 where Footpath CHW/18, School End Road Realignment and their associated secondary axes are located. However, a number of contestable utility assets within the zone of influence of this Level 1 Asset Group have been identified.

Around the immediate vicinity of School End Road Overbridge, there is the BT Openreach Telecom Utility (CSO-03-3106) which was diverted on the Overbridge. Around the immediate vicinity of Footpath CHW/18 Overbridge, there is the BT Openreach Telecom Utility (CSO-03-3102) which is diverted on the Overbridge. It also run along the toe of the upside landscape.

The GIS database shows that there are a number of contestable utility assets located within the extents of the proposed location of the School End Road Realignment and Footpath CHW/18 Accommodation Access Realignment which are to be constructed at Ch. 85+575 and Ch. 86+475 across the HS2 mainline. There is

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an Undertakings and Assurances Areas covering Ch. 31+500 to Ch. 95+600 which is an assurance to Buckinghamshire County Council regarding public transport (construction traffic mitigation).

The identified contestable utility assets and their chainages are presented in the Table 5-37 below:

Table 5-37– Contestable Utility Assets Identified for Assessment

Asset ID	Asset Chainage	Asset Owner and Type	Existing or New Asset	Diameter (mm) Pipe/ Cable Material	Depth (mm)	Initial identification Phase	Planned intervention
UTI-WAM-022	085+540	Anglian Water Potable Water	Existing	>125 HPPE	TBC[1]	Phase 1	Potable Water Pipe to be diverted as CSO-03-6102. The utility is diverted at Ch. 85+580, it also runs along the upside landscape toe. Category C
UTI-ELC-013	085+495	WPD Electricity	Existing	-	TBC[1]	Phase 2	Electricity distribution cable diverted as CSO-03-1305. The utility is diverted at Ch. 85+580, it also runs along the upside landscape toe. Category C
UTI-WAM-023	086+440	Anglian Water Potable Water	Existing	-	TBC[1]	Phase 2	Potable water pipe diverted as C23-086-0001 Category C
CSO-03-3102	085+580	BT Openreach Telecom Cable	Existing	-	TBC[1]	Phase 2	The utility is diverted at Ch. 85+580. It also runs along the upside landscape toe. Category C

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Asset ID	Asset Chainage	Asset Owner and Type	Existing or New Asset	Diameter (mm) Pipe/ Cable Material	Depth (mm)	Initial identification Phase	Planned intervention
CSO-03-1306	085+460	WPD Electricity	New	-	TBC[1]	Phase 2	The utility is temporarily diverted at Ch. 85+460 but there is a branch along the landscape toe from Ch. 086+000 to Ch. 086+300 which is used to supply Chetwode Site Compound Category C
CSO-03-3106	086+450	BT Openreach Telecom Cable	Existing	-	TBC[1]	Phase 2	Telecom cable diverted on School End Overbridge. Category C
TBC	086+000 to 086+300	WP Electricity	New	-	TBC[1]	Phase 2	HV UG WP running downside the toe of the landscape bund, to supply the Site Compound Category C

1- The depths of existing buried utilities are currently unknown. However, it is anticipated that buried utilities would be installed within the top 1.2m bgl.

All proposed utilities are likely to be buried within the proposed embankment verges and run under the overbridge.

5.2.2 Description

The restricted School End Road Realignment and its associated secondary axes comprise the assets summarised in the Table 5-38 below:

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Table 5-38– School End Road Realignment and its Associated Access Roads - Highways Description

Level 2 Non-mainline Asset ID	Level 2 Non-mainline Asset Name	Axis	Chainage	Length (m)	Earthworks
HS2-00002BJUR	School End Road Realignment	Principal, MC01	Ch. 0 to 260, Ch. 340 to 462.3	382.3 m	At grade from Ch. 0 to Ch. 170 and from Ch. 365 to Ch. 462.3 Embankment from Ch. 170 to Ch. 260 and from Ch. 340 to Ch. 365
HS2-000020NM2	Maintenance Access Road to Pond (off School End Road South)	Secondary, MC02	From Ch. 0 to Ch. 700	700 m	Embankment from Ch. 0 to Ch. 35 At grade from Ch. 35 to Ch. 610 Embankment from Ch. 610 to Ch. 670 At grade from Ch. 670 to Ch. 700
HS2-000020NM3	Maintenance Access Road to Pond (off School End Road North)	Secondary, MC03	From Ch. 0 to Ch. 519.5	519.5 m	At grade from Ch. 0 to Ch. 519.5
HS2-00002VXUC	Maintenance Access Road to GSMR and Compound (off School End Road Realignment)	Secondary, MC04	From Ch. 0 to Ch. 131.4	131.4 m	At grade from Ch. 0 to Ch. 40 and from Ch. 87 to Ch. 13 Embankment from Ch. 40 to Ch. 87

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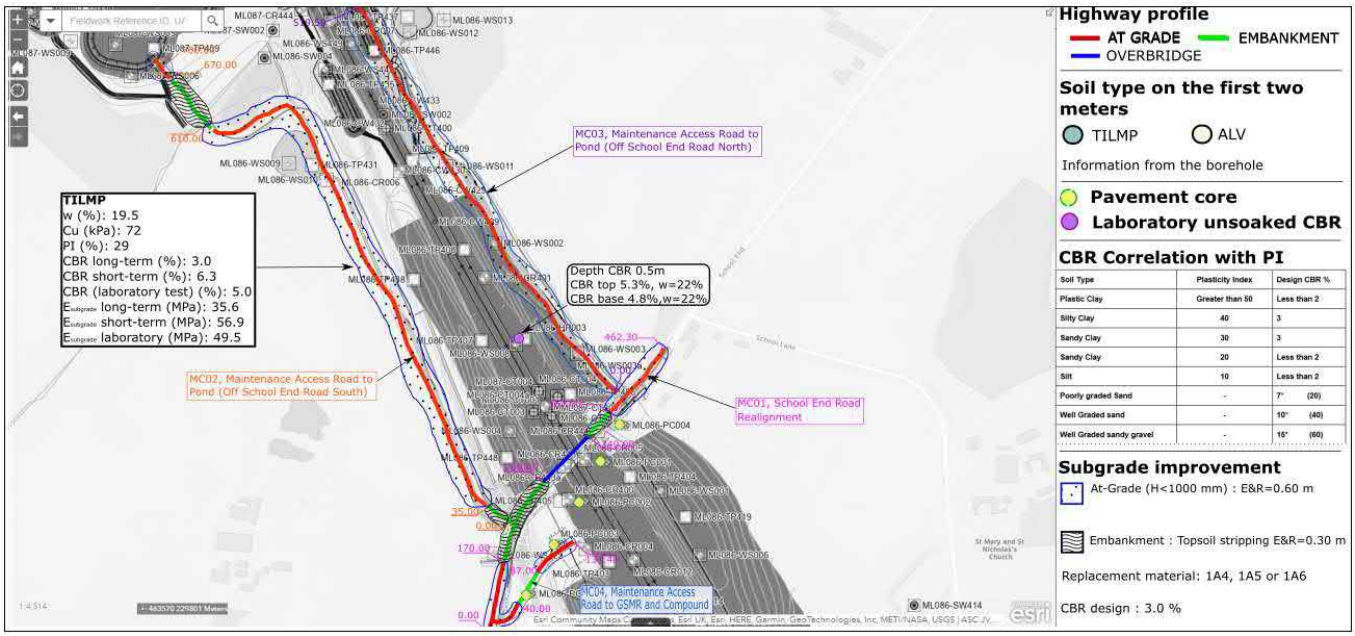


Image 5-13 : Highways Profile, Mitigation Measures and Design CBR for School End Road Realignment and its Associated Access Roads

The restricted Footpath CHW/18 Accommodation Access Realignment and its associated secondary axes comprises the assets summarised in the Table 5-39.

Table 5-39– Footpath CHW/18 Accommodation Access Realignment and its Associated Access Roads - Highways Description

Level 2 Non-mainline Asset ID	Level 2 Non-mainline Asset Name	Axis	Chainage	Length (m)	Earthworks
HS2-000020NLZ	Footpath CHW/18 Accommodation Access Realignment	Principal, MC01	Ch. 0 to 79.2, Ch. 153.3 to 257.8	183.7m	At grade from Ch. 0 to Ch. 35.2 and from Ch. 193 to Ch. 257.8 Embankment from Ch. 35.2 to Ch. 79.2 and from Ch. 153.3 to Ch. 193
HS2-00002QH92	Footpath CHW/18 Diversion	Secondary, MC02	From Ch. 0 to Ch. 204.4	204.4 m	At grade from Ch. 0 to Ch. 10 and Ch. 60 to Ch. 204.4 Embankment from Ch. 10 to Ch. 60
HS2-000020NLY	Chetwode ATS Access Road and Maintenance	Secondary, MC03	From Ch. 0 to Ch. 714	714 m	At grade from Ch. 0 to Ch. 50 and from Ch. 210 to Ch. 714

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Level 2 Non-mainline Asset ID	Level 2 Non-mainline Asset Name	Axis	Chainage	Length (m)	Earthworks
	Access Road to Pond				Cutting from Ch. 50 to Ch. 210
HS2-000020357	The Green Highway Realignment	Secondary, MC05	From Ch. 0 to Ch. 324	324 m	At grade from Ch. 0 to Ch. 65 and from Ch. 120 to Ch. 324 Embankment from Ch. 65 to Ch. 120

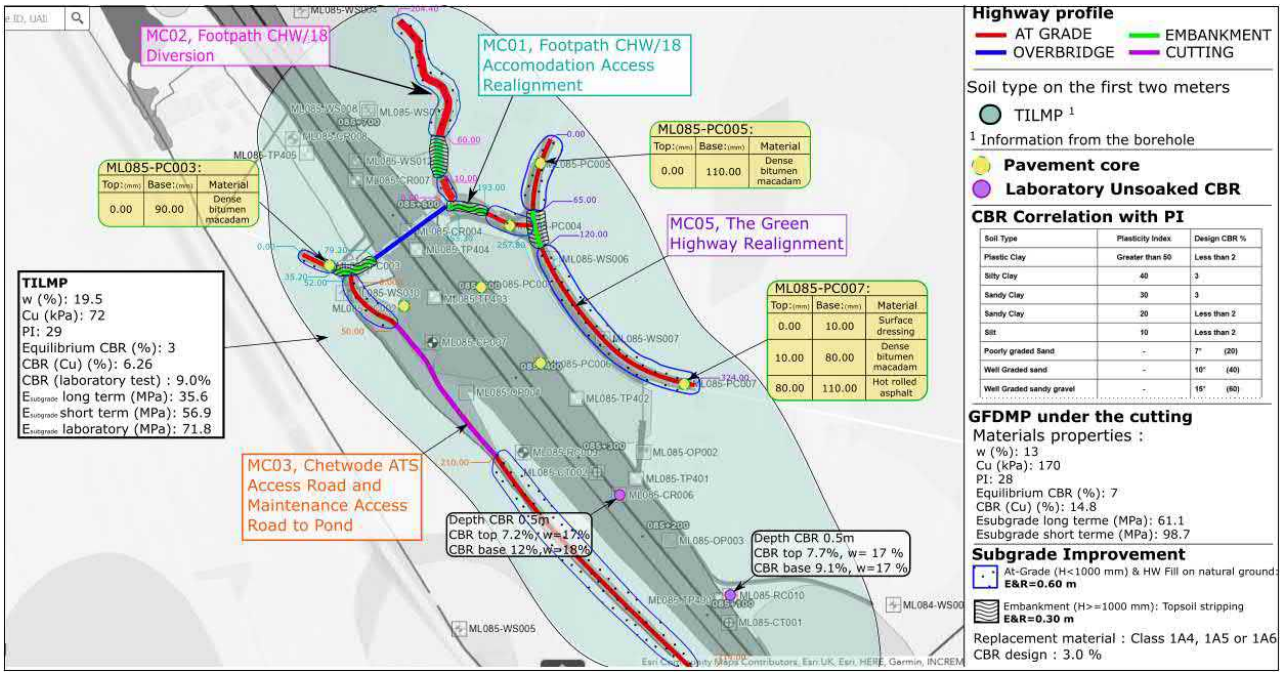


Image 5-14 : Highway Profile, Mitigation Measures and Design CBR for Footpath CHW/18 Accommodation Access Realignment and its Associated Access Roads

5.2.3 ATS Platform

An ATS Platform is planned to be constructed on the Chetwode Cutting downside slope.

The ATS Platform sits on a berm located at 4 m below the existing ground level.

Regarding the local geology, the ATS platform will be constructed on GFDMP-CZ formation.

No settlements issues are expected due to the Chetwode ATS is in cutting.

According to the HS2 Rail System Compound Technical Note Doc No. HS2-HS2-SY-NOT-000-000001, for a subgrade CBR value of 2% (silty clay) a pavement thickness of 700mm is indicated, decreasing to a pavement

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thickness of 475 mm for a subgrade CBR of 4% (sandy clay) and 150 mm for a subgrade CBR of 20% (graded sandy gravel).

No CBR tests have been performed on the GFDMP-CZ.

The design has assumed the similar ground behaviour between TILMP and GFDMP-CZ.

CBR tests performed on TILMP shows a range of CBR values between 2% and 8% with an average value of 3%.

In order to obtain the required bearing capacity/subgrade requirements beneath the platform, a 0.60 m excavate and replace is needed.

A granular fill material will be used.

5.2.4 GSMR Platform

A GSMR compound is proposed on the downside of the Chetwode Cutting (approximate mainline chainage is between circa Ch. 86+375 and Ch. 86+425), at the end of Maintenance Access Road to GSMR (off School End Road Realignment) between approximate chainages Ch. 0+103.3 and Ch. 0+131.4. A preliminary foundation assessment including bearing capacity and anticipated settlements has been carried out and presented in Section 5.5.

The mitigation measures required to achieve an allowable bearing capacity of 75kN/m^2 for the GSMR platform is also presented in Section 5.5.

Based on the available information, the proposed finish level at the GSMR compound is around 110.20m AOD. Given the relatively lower existing ground level in this area at around 110.5m AOD, the GSMR Compound would require filling to achieve the final proposed level.

It is recommended to use Class 1A4/1A5/1A6 for the filling following the removal of topsoil (0.30m nominal thickness) within the GSMR Compound. It is recommended a minimum 0.60m thick Class 1A4/1A5/1A6 to be placed within the GSMR Compound. This Class 1 fill serves as a protective layer on the surface trafficable by road vehicles and small plant, however, it is not appropriate to operate any heavy machinery (i.e. piling rigs, cranes, Hiab, Muck Away Trucks etc). A separate working platform design must be carried out to determine suitable platform dimensions (i.e. piling mat thickness / outrigger pad dimensions for cranes etc) and it is outside the scope of this GDR.

In the absence of detailed layout of the GSMR Compound and foundation details, it is envisaged that:

- the Rail Systems Cabinets will be supported on individual raft foundations with an anticipated design load of 20kPa below the raft foundation.
- the GSMR Mast will be supported on either a buried concrete block or series of small diameter piles to resist wind loading.

Preliminary design of the GSMR therefore assumed a raft foundation with a design load of 20kPa, located approximately 1.50 m below the proposed finish level. As per the local geology (BH ID: ML086-CR004) this level corresponds to superficial deposits composed of TILMP with an undrained shear strength (Cu) in excess of 50kPa (SPT ‘N’ 12 to15).

Preliminary settlement assessment results indicate that a maximum settlement of up to 10mm can be expected beneath such raft foundation assuming a minimum undrained shear strength of 50kPa is achieved at the formation level. The formation level shall be verified by means of in-situ testing prior to placing any foundation.

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In the absence of detailed foundation schedule (type, loads, dimensions, depth etc), preliminary bearing capacity calculations indicated that a minimum allowable bearing capacity of 75kPa is achievable for a shallow foundation with a Cu value of 50kPa at formation level.

Based on guidelines from BRE SD1 (2005) Design Sulphate Class DS3 and an Aggressive Chemical Environment for Concrete (ACEC) Class AC-2s are recommended for shallow foundations found within TILMP, whereas DS5 – AC4s is recommended for any pile foundations found within the Oxford Clay Formation.

The preliminary results reported above will be revised upon receiving detailed information of the GSMR Compound.

5.3 Interfaces and Constraints

Site constraints are identified in the GIR Ref[6] and have been detailed in the GRR Ref[3] and [4].

The main constraints (or associated risks) and interface for the Asset Level 2 Group are listed below:

- Groundwater: Presence of high / shallow groundwater identified by the ground investigations as well as the short and long-term instrumentation monitoring in the GFDMP. The presence of this high groundwater is due to a combination of water bearing soil, topography and seasonal fluctuations in the groundwater table through the GFDMP. Groundwater inflow into temporary excavations, if not controlled, could cause side slope instability or flooding of temporary excavations that could affect the bearing capacity of the proposed realignment foundation and rate of consolidation of the embankment loading;
- Relic-slip surfaces: Potential relic shear surfaces in clay-rich materials associated with previous glacial and periglacial activity within this layer leading to weakened in-situ geology and increased risk of slope instability (gradient is > 5° and falls towards HS2). These relic-slip surfaces could cause slope failure and/or lack of bearing capacity which may require re-design, delay/loss/cessations of works.
- Soft or compressible ground: Soft ground or interbedded soils with varying stiffness at transitions, which could cause instability of embankment slopes and/or unacceptable total or differential settlements /subgrade performance. Compressible ground, characterised as having a low strength and high compressibility, is encountered beneath the earthworks of the highways.
- Shrink/Swell: Soil volume may change significantly with variations in water content and there is also the risk of shrinking and swelling of soil underlying the pavement. This risk is due to the presence of high plasticity clays within the TILMP that could cause unacceptable, total and/or differential settlements or ground movements which could impact the earthworks or road pavement.
- Contaminated Ground: Potential risk of soil and groundwater contamination associated with Dismantled Rugby to Quainton Great Central Railway within LOD (LQ 13.07). This contamination could have an impact on human health and controlled waters during works and cause delays to the programme.

5.4 Geotechnical Ground Model

This section of the report details the soil and rock parameters used in the geotechnical analysis per geological unit identified in the ground model. The selection of parameters is based on the parametric analysis presented in Appendix B on the basis of the available GI data and bibliography.

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The parameters have been reviewed via the GI impact assessment presented in Appendix G when the new EKFB supplementary GI data became available.

5.4.1 Summary of Available GI Information

Reference should be made to the accompanying GIR Ref [6] for a summary on the as-encountered ground conditions. A GI location plan and a general geotechnical long section are provided in Appendix A.

A geological map and a geological long section are provided in Appendix D for each highway based on all available GI information up to Datadrop 23.

An analysis of a new GI ML086-CR422 (data drop 23, May 2022) located at the alignment of School End Road alignment (approx. Ch. MC01 260.00) has been included in the post IDR of this asset. A higher groundwater level has been determined according to the readings of the piezometer installed in this borehole. However, the ground model and parameters remain identical.

5.4.2 Ground Models and Characteristic Design Parameters

This section sets out the ground models used in the geotechnical design of earthworks.

Reference should be made to the Supplementary GIR Ref [6] and Section 3.8.4 of this report for a high-level summary on the background geology and as-encountered ground conditions.

A geological map and a geological long section are provided in Appendix D for each highway.

5.4.2.1 Ground Models

A summary of the ground models identified for design is given in Table 5-40 to Table 5-47 below:

Table 5-40: Ground Models for Highways – School End Road Realignment - MC01

Asset name	School End Road Realignment - MC01			
Chainage	0-170	170-260	340-365	365-462.3
Type	At grade on natural ground	Embankment	Embankment	At grade on natural ground
Strata	TILMP-CZ: 0.0 – 3.5 m bgl GFDMP-SV: 3.5 – 7.5 m bgl OXC-CZ u1: 7.5 – 12.0 m bgl OXC-CZ u2 (MDST): 12.0 – 15.0 m bgl KLB-CZ (MDST): 15.0 – 21.0 m bgl CB FMB	TILMP-CZ: 0.0 – 3.5 m bgl GFDMP-SV: 3.5 – 7.8 m bgl OXC-CZ u1: 7.8 – 15.5 m bgl OXC-CZ u2 (MDST): 15.5 – 20.5 m bgl KLB-CZ (MDST): 20.5 – 26.0 m bgl CB: 26.0 – 28.8 m bgl FMB: 28.8 – 32.1 m bgl		
H (m)	<1.00 m	H max=5,60 m (Disused Railway Cutting)	H<1.80 m	<1.00 m

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Asset name	School End Road Realignment - MC01			
Slopes	1V/3H	1V/4H	1V/4H	1V/3H

Table 5-41: Ground Models for Highways – Maintenance Access Road to Pond (Off School End Road - South) - MC02

Asset name	Maintenance Access Road to Pond (Off School End Road South) - MC02			
Chainage	0-35	35-610	610-670	670-700
Type	Embankment	At grade on natural ground	Embankment	At grade on natural ground
Strata	TILMP-CZ: 0.0 – 4.5 m bgl GFDMP-SV: 4.5 – 7.5 m bgl OXC-CZ u1: 7.5 – 12.0 m bgl OXC-CZ u2 (MDST): 12.0 – 15.5.m bgl KLB-CZ (MDST): 15.5 – 21.5 m bgl CB: 21.5 – 22.8 m bgl FMB: 22.8 – 27.9 m bgl	TILMP-CZ: 0.0 – 4.5 m bgl GFDMP-SV: 4.5 – 7.5 m bgl OXC-CZ u1: 7.5 – 12.0 m bgl OXC-CZ u2 (MDST): 12.0 – 15.5.m bgl KLB-CZ (MDST): 15.5 – 21.5 m bgl CB: 21.5 – 22.8 m bgl FMB: 22.8 – 27.9 m bgl	ALV-C Z: 0.0 – 2.3 m bgl CB-LMST: 2.3 – 4.3 m bgl KLB-CZ (MDST): 4.3 – 21.5 m bgl FMB: 21.5 – 27.9 m bgl	TILMP-CZ: 0.0 – 4.5 m bgl GFDMP-SV: 4.5 – 7.5 m bgl OXC-CZ u1: 7.5 – 12.0 m bgl OXC-CZ u2 (MDST): 12.0 – 15.5.m bgl KLB-CZ (MDST): 15.5 – 21.5 m bgl CB: 21.5 – 22.8 m bgl FMB: 22.8 – 27.9 m bgl
H (m)	Hmax= 6.00 m (Disused Railway Cutting)	<1.00 m	Hmax= 2.70m	< 1.00 m
Slopes	1V/4H	1V/3H	1V/4H Steeper left slope 1V/2H between Ch. 610 to Ch. 660	1V/3H

Table 5-42: Ground Models for Highways – Maintenance Access Road to Pond (Off School End Road - North) - MC03

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Asset name	Maintenance Access Road to Pond Off School End Road North (MC03)		
Chainage	0-519.5		
Type	At grade on natural ground		
Strata	GM1 Ch.$_{MC3}$ 0+000 - Ch.$_{MC2}$ 0+220 TILMP-CZ: 0.0 – 3.5 m bgl GFDMP-SV: 3.5 – 12.0 m bgl OXC-CZ u1: 12.0 – 18.0 m bgl OXC-CZ u2 (MDST): 18.0 – 20.5 m bgl KLB-CZ (MDST): 20.5 – 24.5 m bgl–CB FMB	GM2 Ch.$_{MC3}$ 0+220 - Ch.$_{MC2}$ 0+470 TILMP-CZ: 0.0 – 3.5 m bgl GFDMP-SV: 3.5 – 7.5 m bgl OXC-CZ u1: 7.5 – 13.5 m bgl OXC-CZ u2 (MDST): 13.5 – 16.0 m bgl KLB-CZ (MDST): 16.0 – 20.0 m bgl–CB FMB	GM3 Ch.$_{MC3}$ 0+470 - Ch.$_{MC2}$ 0+519.5 TILMP-CZ: 0.0 – 2.5 m bgl GFDMP-SV: 2.5 – 3.5 m bgl OXC-CZ u1: 3.5 – 9.5 m bgl OXC-CZ u2 (MDST): 9.5 – 12.0 m bgl KLB-CZ (MDST): 12.0 – 16.0 m bgl CB FMB
H (m)	< 1.00 m		
Slopes	1V/3H		

Table 5-43: Ground Models for Highways – Maintenance Access Road to GSMR (off School End Road Realignment) and Compound – MC04

Asset name	Maintenance Access Road to GSMR (off School End Road Realignment)		
Chainage	0-40	40-87	87-131.4
Type	At grade on natural ground	Embankment	At grade on natural ground
Strata	TILMP-CZ: 0.0 – 4.5 m bgl GFDMP-SV: 4.5 – 7.5 m bgl OXC-CZ u1: 7.5 – 14.0 m bgl OXC-CZ u2 (MDST): 14.0 – 17.0 m bgl KLB-CZ (MDST): 17.0 – 22.0 m bgl CB FMB		
H (m)	<1.00 m	Hmax=6.20m (Disused Railway Cutting)	<1.00 m

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Asset name	Maintenance Access Road to GSMR (off School End Road Realignment)		
Slopes	1V/3H	1V/4H	1V/3H

Table 5-44: Ground Models for Highways – Footpath CHW/18 Accommodation Access Realignment - MC01

Asset name	Footpath CHW/18 Accommodation Access Realignment (MC01)			
Chainage	0-35.2	35.2-79.2	153.3-193	193-257.8
Type	At grade on natural ground	Embankment	Embankment	At grade on natural ground
Strata	- Landscape bund TILMP (variable thickness) -TILMP: 0.2 – 2.2 m bgl - GFDMP: 1.8 – 3.8 m bgl - OXC: 2.3 – 7.5 m bgl -KLB: 17-23m bgl - CB			
H (m)	< 1.00 m	< 2.50 m	<3.20 m	< 1.00 m
Slopes	1V/3H	1V/4H	1V/4H Steeper left slope 1V/1.25H between Ch. 180.00 to Ch. 193.00	1V/3H

Table 5-45: Ground Models for Highways – Footpath CHW/18 Diversion - MC02

Asset name	Footpath CHW/18 Diversion (MC02)		
Chainage	0-10	10-60	60-204.4
Type	At grade	Embankment on landscape bund over natural ground	At grade on landcape bund then on natural ground from Ch. 170
Strata	- Landscape bund TILMP (variable thickness) -TILMP: 0.2 – 3.0 m bgl - GFDMP: 1.2 – 6.2 m bgl - OXC: 3.2 – 22.5 m bgl -KLB: 22.5-27.5 m bgl		

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Asset name	Footpath CHW/18 Diversion (MC02)		
	- CB		
H (m)	< 1.00 m	H<1.60 m	< 1.00 m
Slopes	1V/3H	1V/4H	1V/4H

Table 5-46: Ground Models for Highways –Chetwode ATS Access Road and Maintenance Access Road to Pond - MC03

Asset name	Chetwode ATS Access Road and Maintenance Access Road to Pond - MC03		
Chainage	0-50	50-210	210-714
Type	At grade	Cutting	At grade
Strata	- TILMP: 0.3 – 4.2 m bgl - GFDMP: 1.2 – 5.8 m bgl - OXC: 3.2 – 20.2 m bgl - KLB: 20.2 – 26.2 m bgl - CB: 26.2 – 28.2 m bgl - FMB		
H (m)	< 1.00 m	H > -3.50 m	< 1.00 m
Slopes	1V/4H	1V/4H	1V/3H

Table 5-47: Ground Models for Highways – The Green Highway Realignment (MC05)

Asset name	The Green Highway Realignment (MC05)		
Chainage	0-65	65-120	120-324
Type	At grade	Embankment	At grade
Strata	- TILMP: 0.2 – 1.8 m bgl - GFDMP: 0.5 – 3.8 m bgl - OXC: From 1.8 m bgl - KLB -CB		
H (m)	< 1.00 m	H average = 1.10 m	<1.00 m
Slopes	1V/3H	1V/3H	1V/3H

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5.4.2.2 Characteristic Design Parameters

This section sets out the ground models used in the geotechnical design of earthworks.

Reference should be made to Appendix B of this report for the justification and selection of characteristic parameters associated with the design of the asset. The characteristic geotechnical design values adopted in the design are the same as described in Section 4.4.2.

Table 5-48: Geotechnical Parameters – In situ material

Geological strata	PI (%)	γ' (kN/m³)	c' (kPa)	φ' (°)	N-SPT	c_u (kPa)	Eoed (MPa)	v	vu	Cv (m²/s)	μg (Skempton & Bjerrum geological factor)
TILMP-CZ	29	21	2	27	14	72	9	0.2	0.5	3E-7	0.5
GFDMP-SV	-	19	0	30	12	60	-	0.2	0.5	N/A	0
OXC-CZ w	30	20	2	26	12	60	7	0.2	0.5	3E-7	0.5
OXC-CZ u1	31	21	5	28	35	120	16	0.2	0.5	3E-7	0.4
OXC-CZ u2 (MDST)	29	21	5	28	46	180	23	0.2	0.4	3E-7	0.3
KLB-CZ (MDST)	35	20	5	27	28	145	19	0.2	0.4	6E-8	0.4

It is proposed for the embankments for the School End Road Realignment and its associated maintenance access roads, Footpath CHW/18 and its associated access roads and The Green Highway Realignment to be constructed with Class 2B1 or 7E2 non-stabilised material using excavated TILMP and/or GFDMP (from Chetwode Cutting), where the highway embankment height is greater than 0.75 m. If the plasticity index of the cohesive material to be used is classed as a material of intermediate to high plasticity, then it is recommended for it to be stabilised before reuse to mitigate against progressive long-term weakening of the compacted fill, provided the sulphate content is low. Geotechnical parameters of fill materials are detailed in Section 4.4.2.3

A minimum undrained shear strength of compacted Class 2B1 or Class 7E2 (selected cohesive fill) embankment material has been specified as 50 kPa for analysis of embankment stability.

The slope stability analysis has been carried out for the highways and the geotechnical parameters have been used are summarised in Table 5-49 and Table 5-50 below:

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Table 5-49: Ground Parameters for stabilised Embankment Fill – Embankment Height > 0.75 m

Parameter	Characteristic Design Value	Justification
Bulk Unit Weight ɣ (kN/m^3)	21	Characteristic value based on results
Effective cohesion *c'* (kPa)	5	Lime stabilised Class 7E2 to form Class 9J2 (Cohesive soil)
Effective Angle of Shearing Resistance Φ'_{cv}	28°	Lime stabilised Class 7E2 to form Class 9J2

It is proposed for the embankments of School End Road Realignment and its associated Maintenance Access Roads, Footpath CHW/18 and its associated Access Roads and the Green Highway Realignment to be constructed with Class 1 granular material, where the highway embankment height is less than or equal to 0.75 m.

Table 5-50: Ground Parameters for Embankments – Embankment Height ≤ 0.75 m

Parameter	Characteristic Design Value	Justification
Bulk Unit Weight ɣ (kN/m3)	20	Characteristic value based on results
Effective cohesion *c'* (kPa)	0	Class 1 (Granular material)
Effective Angle of Shearing Resistance Φ'_{cv}	33°	Based on BS 8002 and granular fill (conservative)

Table 5-51: Geotechnical Parameters for Highway Design – School End Road Realignment

Asset	Replacement Fill Type	CBR Long term (%)	CBR Short term (%)	Design CBR (%)
School End Road Realignment MC01 – At grade on natural ground (TILMP – CZ) From Ch. 0 to 170 From Ch. 365 to 462.3	0.60 m ground improvement in TILMP-CZ Class 1A4/1A5/1A6	2.5	5.0	≥ 3.0

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Asset	Replacement Fill Type	CBR Long term (%)	CBR Short term (%)	Design CBR (%)
School End Road Realignment MC01 – Embankment From Ch. 170 to Ch. 260 From Ch. 354 to Ch. 365	0.30 m nominal thickness of topsoil stripping in TILMP-CZ Class 1A4/1A5/1A6	2.5	5.0	≥ 3.0

Table 5-52: Geotechnical Parameters for Highway Design – Maintenance Access Road to Pond (Off School End Road South)

Asset	Replacement Fill Type	CBR Long term (%)	CBR Short term (%)	Design CBR (%)
Maintenance Access Road to Pond (Off School End Road South) MC02 – At grade on natural ground (TILMP – CZ) From Ch. 35 to Ch. 610 From Ch. 670 to Ch. 700	0.60 m ground improvement in TILMP-CZ Class 1A4/1A5/1A6	2.5	5.0	≥ 3.0
Maintenance Access Road to Pond (Off School End Road South) MC02 – Embankment From Ch. 0 to 35 From Ch. 610 to 670	0.30 m nominal thickness of topsoil stripping in TILMP-CZ Class 1A4/1A5/1A6	2.5	5.0	≥ 3.0

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Table 5-53: Geotechnical Parameters for Highway Design – Maintenance Access Road to Pond (Off School End Road North)

Asset	Replacement Fill Type	CBR long term (%)	CBR Short term (%)	Design CBR (%)
Maintenance Access Road to Pond (Off School End Road North) MC03 – At grade on natural ground (TILMP – CZ) From Ch. 35 to Ch. 519.5	0.60 m ground improvement in TILMP-CZ Class 1A4/1A5/1A6	2.50	5.00	≥ 3.00

Table 5-54: Geotechnical Parameters for Highway Design – Maintenance Access Road to GSMR (Off School End Road Realignment)

Asset	Replacement fill type	CBR long term (%)	CBR Short term (%)	Design CBR (%)
Maintenance Access Road to GSMR (Off School End Road Realignment) – At grade on natural ground (TILMP – CZ) From Ch. 0 to 40 From Ch. 87 to 131.4	0.60 m ground improvement in TILMP-CZ Class 1A4/1A5/1A6	2.5	5.0	≥ 3.0
School End Road Realignment – Embankment From Ch. 40 to Ch. 87	0.30 m nominal thickness of topsoil stripping in TILMP-CZ Class 1A4/1A5/1A6	2.5	5.0	≥ 3.0

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Table 5-55: Geotechnical Parameters for Highway Design – Footpath CHW/18 Accommodation Access Realignment

Asset	Replacement fill type	CBR long term (%)	CBR Short term (%)	Design CBR (%)
Footpath CHW/18 Accommodation Access Realignment – At grade on natural ground (TILMP – CZ) From Ch. 0 to 35.2 From Ch. 193 to 257.8	0.60 m ground improvement in TILMP-CZ if at grade section Class 1A4/1A5/1A6	2.5	6.2	≥ 3.0
Footpath CHW/18 Accommodation Access Realignment – Embankment From Ch. 35.2 to Ch. 79.2 From Ch. 153.3 to Ch. 193	0.30 m nominal thickness of topsoil stripping in TILMP-CZ Class 1A4/1A5/1A6	2.5	6.2	≥ 3.0

Table 5-56: Geotechnical Parameters for Highway Design – Footpath CHW/18 Diversion

Asset	Replacement fill type	CBR Long term (%)	CBR Short term (%)	Design CBR (%)
Footpath CHW/18 Diversion – At grade on landscape bund (Class 4) From Ch. 0 to 10	0.60 m ground improvement if at grade and on natural ground Class 1A4/1A5/1A6	2.5	6.2	≥ 3.0
Footpath CHW/18 Diversion – Embankment on landscape bund and/or natural ground *From Ch. 10 to 60*	0.30 m nominal thickness of topsoil stripping if embankment where embankment on natural ground Class 1A4/1A5/1A6	2.5	6.2	≥ 3.0
Footpath CHW/18 Diversion – At grade on landscape bund and/or (TILMP-CZ) *From Ch. 60 to 204.4*	0.60 m ground improvement if at grade and on natural ground Class 1A4/1A5/1A6	2.5	6.2	≥ 3.0

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Table 5-57: Geotechnical Parameters for Highway Design – Chetwode ATS Access Road and Maintenance Access Road to Pond

Asset	Replacement fill type	CBR Long term (%)	CBR Short term (%)	Design CBR (%)
Chetwode ATS Access Road and Maintenance Access Road to Pond – At grade on natural ground (TILMP – CZ) *From Ch. 0 to 50* *From Ch. 210 to 714*	0.60 m ground improvement in TILMP-CZ Class 1A4/1A5/1A6	2.5	6.2	≥ 3.0
Chetwode ATS Access Road and Maintenance Access Road to Pond – Cutting *From Ch. 50 to Ch. 210*	*N/A*	*2.5*	*6.2*	*≥ 3.0*

Table 5-58: Geotechnical Parameters for Highway Design – The Green Highway Realignment

Asset	Replacement fill type	CBR Long term (%)	CBR Short term (%)	Design CBR (%)
The Green Highway Realignment – At grade on natural ground (TILMP – CZ) From Ch. 0 to 65 From Ch. 120 to 324	0.60 m ground improvement in TILMP-CZ Class 1A4/1A5/1A6	2.5	6.2	≥ 3.0
The Green Highway Realignment – Embankment From Ch. 65 to Ch.120	0.30 m nominal thickness of topsoil stripping Class 1A4/1A5/1A6	2.5	6.2	≥ 3.0

5.4.2.3 Design Groundwater Level

The main hydrogeological conditions identified are as follow:

- Perched groundwater within Glaciofluvial Deposits (GFDMP);

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- Kellaways Formation (KLB) is designated as Secondary A Aquifer;
- Cornbrash Formation (CB) is designated as Secondary A Aquifer;
- Forest Marble Formation (FMB) is designated as Secondary A Aquifer;
- White Limestone Formation (WHL) is designated as Principal Aquifer.

HS2 ground investigation data show the presence of perched groundwater within the superficial deposits (GFDMP). The perched groundwater is most likely to be localised and discontinuous.

The WHL is assumed to be a fully saturated aquifer.

Based on the groundwater monitoring data shown in the Table 5-59 below, the highest groundwater level is encountered at 104.02 m AOD (between the TILMP and GFDMP formations). This groundwater level has been considered as the conservative design groundwater level for the School End Road Realignment and its associated maintenance access roads.

Based on the groundwater monitoring data shown in the Table 5-59 below, the highest groundwater level is encountered at 101.33 m AOD at the top of the GFDMP. This groundwater level has been considered as the design groundwater level for the Footpath CHW/18 Accommodation Access Realignment and its associated access roads and The Green Highway Realignment.

The table below summarises the maximum groundwater levels recorded above the base of the proposed excavation at Chetwode Cutting.

Table 5-59: Groundwater Monitoring Data

Location ID	ASC Chainage HS2	Ground Level [m. AOD]	Piezometric Monitoring	Water Level (min – max m bgl)	Reference Ordnance Datum (min – max m AOD)
ML085-RC009	85+350	103.83	From 22/11/2017 to 21/11/2018	2.50 – 5.50	98.33 – 101.33
ML085-CP007	85+480	104.72	From 22/08/2017 to 21/11/2018	8.00 – 14.00	90.72 – 96.72
ML085-CR004	85+600	102.70	From 29/08/2017 to 21/11/2018	18.00 – 24.00	78.79 – 84.79
ML085-CR008	85+720	101.45	From 05/09/2017 to 21/11/2018	13.00 – 16.00	85.45 – 88.45
ML085-CR009	85+950	104.87	From 25/09/2017 to 22/11/2018	15.00 – 20.00	84.87 – 89.87
ML086-CR009	86+080	106.19	From 25/09/2017 to 22/11/2018	16.00 – 19.00	87.19 – 90.19

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Location ID	ASC Chainage HS2	Ground Level [m. AOD]	Piezometric Monitoring	Water Level (min – max m bgl)	Reference Ordnance Datum (min – max m AOD)
ML086-CR010	86+150	106.63	From 03/10/2017 to 17/10/2018	18.00 – 24.00	82.63 – 88.63
ML086-CR014	86+300	109.41	From 02/10/2017 to 17/10/2018	17.00 – 20.00	89.41 – 92.41
ML086-CR422	86+467	109.38	From 16/02/2021 to 28/10/2021	5.36 – 11.71	97.66 – 104.02
ML086-CR005	86+470	109.54	From 11/08/2017 to 21/11/2018	26.00 – 35.00	74.54 – 83.54

From experience there is likelihood for some porewater interactions to take place within the embankment fill or on the outer face of the embankment, based on site observations. In order to replicate likely porewater pressure conditions arising from seepage of surface water ingress through minor backscarps which may be formed as a result of slipped soil (caused by progressive long-term rainfall), r_u (porewater pressure ratio) value of 0.20 was adopted for the upside and downside embankments. There is no existing pond in the vicinity of the School End Road Realignment and its associated maintenance access roads, Footpath CHW/18 and its associated access roads and The Green Highway Realignment, considered likely to alter the value of the ru.

Separate slope stability analyses have been carried out for all embankments proposed within the extents of School End Road Realignment and its associated maintenance access roads, Footpath CHW/18 and its associated Access Roads and The Green Highway Realignment.

On the School End Road Realignment and its associated maintenance access roads embankment (both the downside and upside), groundwater was modelled by assuming piezometric surface within the GFDMP immediately below the ‘toe’ of embankment.

On the Footpath CHW/18 Accommodation Access Realignment and its associated access roads, and The Green Highway Realignment (both the downside and upside), groundwater was modelled by assuming piezometric surface within the GFDMP immediately below the ‘toe’ of embankment.

5.5 Geotechnical Design

5.5.1 Settlements

The self-weight settlement is assumed to be 0.5% to 1% of the embankment height. The provision of internal horizontal drainage layers at 1.5m c/c (vertically) in embankments of height 3m or higher at critical locations i.e. on the approach to major structures is an additional means of mitigation against internal settlement of the fill material. The spacing is aimed at achieving 90% consolidation over a 2/3-month period.

According to the TQ-384, settlement criteria for Highway, Bridleway and Footpath Earthworks have been defined as follow:

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- Where National Speed Limit applies:
  - Between any two points within 10 metres of the interface between any structure and an approach embankment, the differential settlement (i.e. consolidation settlement) shall not exceed 25 millimetres at any time from completion of the road pavement up to the defects date.
  - Over a distance of 10 to 50 metres back from any such structure, the maximum permitted change in gradient from the design gradient shall be 0.25 percent (1/400) at any time from completion of the road pavement up to the defects date.
  - Notwithstanding the requirements above, the maximum permitted change in gradient from the design gradient shall not exceed 0.5 per cent (1/200) at any time from completion of the road pavement up to the defects date.
- Where speed restriction is equal to or less than 30 mph and for bridleway/footpaths:
  - Highways – Between any two points within 10 metres of the interface between any Structure and any approach embankments, the differential settlement shall not exceed 50 millimetres at any time from completion of the road pavement up to the defects date.
  - Highways – Over a distance of 10-50 metres back from any such Structure, the maximum permitted change in gradient from the design gradient shall be 0.4 percent (1/250) at any time from completion of the road pavement up to the defects date.
- Bridleways, Footpaths – Between any two points within 10 metres of the interface between any Structure and any approach embankments, the differential settlement shall not exceed 100 millimetres at any time from completion of the pavement up to the defects date.

Beneath ancillary culverts, allowed maximum settlements shall be less than 30 mm.

School End Road Realignment (MC01)

Settlement assessments beneath School End Road Realignment embankments on upside and downside of the overbridge have been carried out with the geotechnical parameters presented in Table 5-48.

Table 5-60: Settlement Assessments School End Road Realignment

Section Assessed at Chainage	Case	Post-construction Settlement Criteria	Post construction total settlement (mm)	Post-construction Differential settlement (mm)	Compliance with criteria
Ch. 260.00	OB Abutment downside	< 25mm	17	-	Yes
Ch. 250.00	0-10m from OB	< 25mm	19	0.0002	Yes
Ch. 240.00	10-20m from OB	1V:250H	16	0.0003	Yes
Ch. 340.00	OB Abutment upside	< 25mm	17	-	Yes
Ch. 350.00	0-10m from OB	< 25mm	15	0.0002	Yes

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Section Assessed at Chainage	Case	Post-construction Settlement Criteria	Post construction total settlement (mm)	Post-construction Differential settlement (mm)	Compliance with criteria
Ch. 360.00	10-20m from OB	1V:250H	11	0.0004	Yes

The results obtained from the settlement assessment are considered acceptable without a need for ground improvement

However, it is recommended to excavate and replace 0.6 m of the existing ground (TILMP-C Z) beneath the proposed route of School End Road Realignment where the fill height is less than 1.00 m for subgrade improvement. The proposed improvement works within the existing ground should result in the design CBR (≥3%).

A 0.30 m nominal thickness of topsoil or subsoil stripping is recommended beneath all embankment areas as a good practice before constructing to its maximum proposed height.

Maintenance Access Road to Pond (Off School End Road - South) (MC02)

Settlement assessments beneath the Maintenance Access Road to Pond (off School End Road – South) have been carried out with the geotechnical parameters presented in Table 5-48.

Table 5-61: Settlement Assessments Maintenance Access Road to Pond (Off School End Road - South)

Section Assessed at Chainage	Case	Post-construction Settlement Criteria	Post construction total settlement (mm)	Post-construction Differential settlement (mm)	Compliance with criteria
Ch. 12.78	Hmax = 6.00 m	< 100 mm	56	-	Yes
Ch. 635.00	H = 2.70 m	< 100 mm	4	0.0000	Yes

The results obtained from the settlement assessment are considered acceptable without a need for ground improvement

However, it is recommended to excavate and replace 0.6 m of the existing ground (TILMP-C Z) beneath the proposed route of the Maintenance Access Road to Pond (Off School End Road - South) where the fill height is less than 1.00 m for the subgrade improvement. The proposed improvement works within the existing ground should result in the design CBR (≥3%).

A 0.30 m nominal thickness of topsoil or subsoil stripping is recommended beneath all embankment areas as a good practice before constructing to its maximum proposed height.

Maintenance Access Road to Pond (Off School End Road - North) (MC03)

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There were no settlement assessments carried out beneath Maintenance Access Road to Pond (Off School End Road - North) because it is only at grade.

It is recommended to excavate and replace 0.6 m of the existing ground (TILMP-C Z) beneath the proposed route of the Maintenance Access Road to Pond (Off School End Road - North) where the Fill height is less than 1.00 m for the subgrade improvement. The proposed improvement works within the existing ground should result in the design CBR (≥3%).

Maintenance Access Road to GSMR (off School End Road Realignment) (MC04)

Settlement assessments beneath Maintenance Access Road to GSMR (off School End Road Realignment) and Compound Embankments have been carried out with the geotechnical parameters presented in Table 5-48.

Table 5-62: Maintenance Access Road to GSMR (off School End Road Realignment) and Compound

Section Assessed at Chainage	Case	Post-construction Settlement Criteria	Post construction total settlement (mm)	Post-construction Differential settlement (mm)	Compliance with criteria
Ch. 64.00	Hmax = 6.50 m	< 100mm	75	-	Yes
Ch. 80.00	H = 2.85 m	< 100mm	35	0.0025	Yes

The results obtained from the settlement assessment are considered acceptable without a need for ground improvement

However, it is recommended to excavate and replace 0.6 m of the existing ground (TILMP-C Z) beneath the proposed route of Maintenance Access Road to GSMR (off School End Road Realignment) where the fill height is less than 1.00 m for the subgrade improvement. The proposed improvement works within the existing ground should result in the design CBR (≥3%).

A 0.30 m nominal thickness of topsoil or subsoil stripping is recommended beneath all embankment areas as a good practice before constructing to its maximum proposed height.

Based on the available information, the proposed finished level within the GSMR Compound (MC04-between approximate chainages Ch. 0+103.3 and Ch. 0+131.4) varies between approximate levels of 109.2 m AOD and 110.20 m AOD. The existing ground level within the GSMR Compound is very similar to the proposed levels.

Due to the potential presence of poor subgrade in the GSMR Compound area, it is recommended to excavate and replace (E&R) 0.60m of the existing ground (topsoil/GFDMP) for subgrade improvement using Class 1A4/1A5/1A6 material. These proposed subgrade mitigation works within the existing ground should result in a minimum design CBR of 3%.

An allowable bearing capacity of 75kN/m^2 is achievable on top of this Class 1 fill. However, as a good site practice, it is recommended to carry out in-situ Plate Bearing Tests on the completed surface of Class 1 fill to verify the bearing capacity assumption. The proposed Class 1 fill within the GSMR Compound provides a protective layer on the surface trafficable by road vehicles and small plant, however, it is not appropriate to

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operate any heavy machinery (i.e. piling rigs, mobile cranes, Hiab, Muck Away Trucks etc). A separate working platform design must be carried out to determine suitable platform dimensions (i.e. piling mat thickness / outrigger pad dimensions for cranes etc) and it is outside the scope of this GDR.

GSMR Foundations:

Preliminary foundation assessment of the GSMR therefore assumed a raft foundation (up to 6.50m x 3.50m) with a design load of 20kPa, located approximately 1.50 m below the proposed finish level. As per the local geology (BH ID: ML086-CR004) this level corresponds to superficial deposits composed of TILMP with an undrained shear strength (c_u) varies between 54kPa at 1.70 m bgl (based on SPT 'N' 12) and 120kPa at 1.45mBGL (based on lab UU test). Therefore, for the foundation assessment a cu value of 50kPa has been conservatively assumed at formation level of the raft.

Preliminary settlement assessment results indicate that a maximum settlement of up to 9mm can be expected beneath such raft foundation assuming a minimum undrained shear strength of 50kPa is achieved at the formation level in TILMP. The formation level shall be verified by means of in-situ testing prior to placing any foundation.

In the absence of detailed foundation schedule (type, loads, dimensions, depth etc), preliminary bearing capacity calculations indicated that a minimum allowable bearing capacity of 75kPa is achievable for a shallow foundation when a c_u value of 50kPa is assumed at formation level.

In the absence of location specific chemical test data, based on site-wide information and in accordance with the guidelines from BRE SD1 (2005) Design Sulphate Class DS2 and an Aggressive Chemical Environment for Concrete (ACEC) Class AC-2 are recommended for shallow foundations found within GFDMP.

The preliminary results reported above are subject to revision upon receiving detailed information of the GSMR foundation schedule.

Footpath CHW/18 Accommodation Access Realignment (MC01)

Settlement assessments beneath Footpath CHW/18 Accommodation Access Realignment Approach Embankments on up and downside of the overbridge have been carried out with the geotechnical parameters presented in Table 5-48.

Table 5-63: Settlement Assessments Footpath CHW/18 Accommodation Access Realignment

Section Assessed at Chainage	Case	Post-construction Settlement Criteria	Post construction total settlement (mm)	Post-construction Differential settlement (mm)	Compliance with criteria
Ch. 79.20	OB Abutment downside	< 25mm	22	-	Yes
Ch. 69.20	0-10m from OB	< 25mm	18	0.0004	Yes
Ch. 66.00	10-20m from OB	1V:250H	15	0.0000	Yes

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Section Assessed at Chainage	Case	Post-construction Settlement Criteria	Post construction total settlement (mm)	Post-construction Differential settlement (mm)	Compliance with criteria
Ch. 153.30	OB Abutment upside	< 25mm	20	-	Yes
Ch. 163.30	0-10m from OB	< 25mm	25	0.0005	Yes
Ch. 170.00	10-20m from OB	1V:250H	23	0.0004	Yes

The results obtained from the settlement assessment are considered acceptable without a need for ground improvement

However, it is recommended to excavate and replace 0.6 m of the existing ground (TILMP-C Z) beneath Footpath CHW/18 Accommodation Access Realignment where the fill height is less than 1.00 m for the subgrade improvement. The proposed improvement works within the existing ground should result in the design CBR (≥3%).

A 0.30 m nominal thickness of topsoil or subsoil stripping is recommended beneath all embankment areas as a good practice before constructing to its maximum proposed height.

Footpath CHW18 Diversion (MC02)

Settlement assessments beneath Footpath CHW/18 Diversion have been carried out with the geotechnical parameters presented in Table 5-48.

Table 5-64: Settlement Assessments Footpath CHW18 Diversion

Section Assessed at Chainage	Case	Post-construction Settlement Criteria	Post construction total settlement (mm)	Post-construction Differential settlement (mm)	Compliance with criteria
Ch. 30.00	Hmax Embankment = 1.607 m & H landscape = 1.60 m	< 100 mm	12	-	Yes
Ch. 60.00	Hmax landscape = 3.71 m & H Embankment =1.00m	< 100 mm	15	0.0001	Yes

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The results obtained from the settlement assessment are considered acceptable without a need for ground improvement.

However, it is recommended to excavate and replace 0.6 m of the existing ground (TILMP-C Z) beneath the proposed route of Footpath CHW18 Diversion where the embankment height is less than 1.00 m for the subgrade improvement. The proposed improvement works within the existing ground should result in the design CBR (≥3%).

A 0.30 m nominal thickness of topsoil or subsoil stripping is recommended beneath all embankment areas as a good practice before constructing to its maximum proposed height.

Chetwode ATS Access Road to Pond (MC03)

There were no settlement assessments carried out beneath Maintenance Access Road to Pond (Off School End Road - North) because it is only at grade and cutting.

However, it is recommended to excavate and replace 0.6 m of the existing ground (TILMP-C Z) beneath the proposed route of Chetwode ATS Access Road to Pond where the fill height is less than 1.00 m for the subgrade improvement. The proposed improvement works within the existing ground should result in the design CBR (≥3%).

The Green Highway Realignment (MC05)

Settlement assessments beneath The Green Highway Realignment Embankments have been carried out with the geotechnical parameters presented in Table 5-48.

Table 5-65: Settlement Assessments for The Green Highway Realignment

Section Assessed at Chainage	Case	Post-construction Settlement Criteria	Post construction total settlement (mm)	Post-construction Differential settlement (mm)	Compliance with criteria
Ch. 127.00	Hmax = 1.67 m	< 100mm	15	-	Yes

The results obtained from the settlement assessment are considered acceptable without a need for ground improvement

However, it is recommended to excavate and replace 0.6 m of the existing ground (TILMP-C Z) beneath the proposed route of The Green Highway Realignment where the fill height is less than 1.00 m for the subgrade improvement. The proposed improvement works within the existing ground should result in the design CBR (≥3%).

A 0.30 m nominal thickness of topsoil or subsoil stripping is recommended beneath all embankment areas as a good practice before constructing to its maximum proposed height.

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5.5.2 Bearing resistance failure

A calculation has been performed to verify the bearing resistance failure.

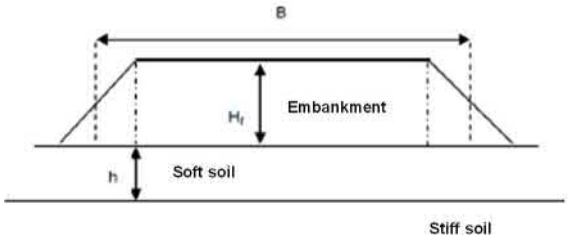
The following equation is used to assess bearing resistance of soils to shear punch failure.

$$F = \frac{q_{max}}{q} = \frac{Cu\ x\ Nc}{\gamma_r H_r + Q}$$

c_u: undrained shear stress, γ_r: bulk density of embankment fill,

H_r: height of embankment, Q: surcharge

N_c bearing capacity factor for a structure with width (B) build on soft soil with thickness (h)



for $0 < \frac{B}{h} \le 1{,}49 \Rightarrow Nc = \Pi + 2$

for $1{,}49 < \frac{B}{h} \le 10 \Rightarrow Nc \approx 0{,}49\frac{B}{h} + 4{,}225$

for $\frac{B}{h} > 10 \Rightarrow Nc \approx 9{,}125$

Image 5-15 : Equation used for the evaluation of bearing resistance failure

For School End Road Realignment and its associated access roads, the calculations have been performed on the worst-case scenario for the ground model of the Maintenance Access Road to Pond (Off School End Road - South) – MC02.

The calculation is carried out in the unfavourable case where the thickness of the TILMP is about 4.5 m (see Table 5-40 to Table 5-43.

Table 5-66. Calculation Results for Bearing Resistance Failure_ School End Road Realignment and its Associated Access Roads

Calculation profile	under embankment axis
Ground model (1)	GM – MC02
Hr (m) (1)	6.0
γ_r (kN/m^3)	21
Q (kPa)	20
B (m)	11
h (m)	4.5
Nc	5.42
C_u (kPa)	72

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Calculation profile	under embankment axis
Safety factor F	**2.67**

NOTE

(1) This ground model for the bearing resistance failure has been calculated using the worst case (before E&R) or any other mitigation measures.

For School End Road Realignment and its associated access roads. The safety factor F equal to 2.67 is higher than the factor required by the standards (which is 1.5), the bearing resistance stability is satisfied.

For Footpath CHW/18 and its associated access roads, the calculations have been performed on the worst-case scenario for the ground model of the Footpath CHW/18 Realignment – MC01.

The calculation is carried out in the unfavourable case where the thickness of the TILMP is about 3.0 m (see Table 5-44 to Table 5-47.

Table 5-67. Calculation Results for Bearing Resistance Failure_ Footpath CHW/18 Realignment and its Associated Access Roads

Calculation profile	under embankment axis
Ground model (1)	GM - MC01
Hr (m) (1)	3.37
γ_r (kN/m^3)	21
Q (kPa)	20
B (m)	9.0
h (m)	2.2
Nc	6.22
C_u (kPa)	72
Safety factor F	**4.94**

NOTE

(1) This ground model for the bearing resistance failure has been calculated using the worst case (before E&R) or any other mitigation measures.

For Footpath CHW/18 Realignment and its associated access roads. The safety factor F equal to 4.94 is higher than the factor required by the standards (which is 1.5), the bearing resistance stability is satisfied.

5.5.3 Slope Stability

For stability analysis, the following surcharges have been adopted

- A short-term temporary construction surcharge of 20 kPa across the embankment platform;

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- A 10 kPa long-term maintenance' surcharge of 10 kPa in the highway verges;
- A 10 kPa long-term surcharge modelled for bridleways and footpaths;
- A 20 kPa long-term traffic surcharge representing HB loading; and
- Where routes are planned for heavy construction traffic, a traffic surcharge of 37 kPa will be modelled for analysis of stability.

Under Clause 3.2 of the HS2 Technical Standard Ref[49], there is a requirement to model progressive failure in all earthworks designs including non-mainline assets. The specific requirements as set out in the HS2 mainline earthworks Section 4.5.1 are therefore assumed to apply also to non-mainline earthworks, i.e., the modelling of a Vadose Zone on earthwork side-slopes within medium to high plasticity non-stabilised clay material.

It has been assumed for slope stability calculations that over-the-edge drainage will be adopted for embankment of less than 3 m height. Kerb and gulley systems will be used for earthwork of greater height.

Where over-the-edge drainage is proposed, an increased pore pressure coefficient (r_u) of 0.20 was adopted in the Vadose Zone.

External stability of the earthwork using the generic model was then checked in accordance with BS EN 1997 Ref[37]. Where an adequate Over Design Factor (ODF) could not be demonstrated (i.e. ODF > 1.0) in the global stability checks (failure beneath the earthwork), basal reinforcement (eg. geogrid or excavate and replace) has been adopted to enhance the stability and ensure that it meets the required standards (BS8006 Ref[41]).

In general for the highways (i.e. fill height ≥ 0.75 m) will be constructed using Class 2B1 or 7E2 non-stabilised material using excavated TILMP and/or GFDMP (from Chetwode Cutting) except for the section from Ch. 610 to Ch. 660 of Maintenance Access Road to Pond (off School End Road South) and from Ch. 180 to Ch. 210 of Footpath CHW/18 Accommodation Access Realignment where a steeper slope will require the use of lime stabilised Selected Cohesive Material (Class 9J2).

Parameters for the Class 2 non-stabilised and stabilised materials for School End Road Realignment and Footpath CHW/18 Accommodation Access Realignment and their access roads are presented with the output Models being presented in Appendix D of this report.

A generic analysis has been undertaken for this material to verify the internal stability and to establish the slope heights and gradients that will stand unsupported.

The following ground models have been considered in the analysis for the **School End Road Realignment and its associated Access Roads**:

- The section used for the slope stability analysis representing the **School End Road Realignment** Embankment MC01 (Ch.200).
- The section used for the slope stability analysis representing the **Maintenance Access Road to Pond (Off School End Road – South)** Approach Embankment MC02 (Ch.12.779) and MC02 (Ch. 635).
- The section used for the slope stability analysis representing the **Maintenance Access Road to GSMR (off School End Road Realignment)** Approach Embankment (Ch.60).

The section location which has been considered in the slope stability depends on maximum embankment height, the steeper slope and the most unfavourable ground model and hydrogeological parameters.

Ground and groundwater conditions (Section 5.4.2.3) of the embankment fill, superficial deposits (TILMP and GFDMP) and bedrock geology were as outlined in Table 5-48 and the Supplementary GIR.

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The results of the stability analysis of School End Road Realignement and its associated access roads are summarized in the Table 5-68 below.

Table 5-68: Over Design Factor of Stability Analysis School End Road Realignment and its Associated Access Roads

Axis	Long-term	Short-term	Seismicity
School End Road Realignment - MC01	1.37	1.37	1.87
Maintenance Access Road to Pond (Off School End Road - South) –MC02	1.57	1.32	-
Maintenance Access Road to GSMR (off School End Road Realignment) and Compound - MC04	1.76	1.58	1.73

The following ground model has been considered in the analysis for the **Footpath CHW/18 and its associated Access Roads and the Green Highway Realignment.**

- The section used for the slope stability analysis representing the **Footpath CHW/18 Accommodation Access Realignment** embankment.
- The section used for the slope stability analysis representing the **Footpath CHW/18 Diversion** embankment.
- The section used for the slope stability analysis representing **The Green Highway Realignment** embankment.

The section location has been considered in the slope stability depends on maximum embankment height, the steeper slope and the most unfavourable ground model and hydrogeological parameters.

Ground and groundwater conditions (Section 5.4.2.3) of the Embankment Fill, superficial deposits (TILMP and GFDMP) and bedrock geology were as outlined in Table 5-48 and the Supplementary GIR.

The results of the stability analysis of Footpath CHW/18 Accommodation Access Realignment and its associated access roads are summarized in the Table 5-71 below.

Table 5-69: Over Design Factor of Stability Analysis School End Road Realignment and its associated access roads

Axis	Long-term	Short-term	Seismicity
Footpath CHW/18 Accommodation Access Realignment - MC01	1.13	1.00 between Ch.171 and 193 where the design slope is 1(V):1.25(H)	1.47
Footpath CHW/18 Diversion - MC02	1.12	1.28	1.47

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Axis	Long-term	Short-term	Seismicity
Chetwode ATS Access Road and Maintenance Access Road to Pond - MC03	1.19	2.35	2.11
The Green Highway Realignment - MC05	1.08	1.26	1.82

5.5.4 Subgrade Design

Regarding the lack of soaked CBR, CD225 Ref [91] has been adopted as the basis of the pavement foundation design based on equilibrium CBR values, subject to validation by laboratory and in-situ testing.

Where the design subgrade surface modulus (short or long-term) is lower than 30 MPa, improvement of the subgrade shall be undertaken. Where the short-term (construction) subgrade surface modulus is 50 MPa or lower, the foundation design shall consist of subbase and capping or ground improvement.

Options for improvement of the subgrade include excavation and replacing between 500 to 1000 mm of the soft subgrade with granular fill, mechanical stabilisation (geogrids and/or geotextiles) and/or soil stabilisation.

The preferred solution for subgrade improvement is to excavate and replace (0.60 m) using Class 1 fill material (if height H < 1.0 m) to achieve a minimum CBR of 3% at formation level (i.e., a surface modulus for areas of improvement of the subgrade = 35.6 MPa).

A demonstration area, specified in accordance with the Manual of Contract Document for Highway Works (MCHW), shall be detailed to establish the construction subgrade surface modulus.

Where the construction subgrade surface modulus is found to be lower than the design subgrade surface modulus, then action shall be taken by either effecting improvement of the subgrade or by reviewing the design subgrade surface modulus with a view to redesign using the lower value.

On the proposed School End Road Realignment, the assessment showed poor performance of the natural subgrade (CBR).

The mitigation measures for School End Road Realignment and its associated access roads are presented in Table 5-51 to Table 5-54.

On the proposed Footpath CHW/18 Accommodation Access Realignment, the assessment showed poor performance of the natural subgrade (CBR).

The mitigation measures for Footpath CHW/18 Access Realignment and its associated access roads are presented in Table 5-54 to Table 5-58.

A summary of the proposed subgrade improvement and the resultant design CBR is provided in the Table 5-70 and Table 5-71 below.

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Table 5-70. Subgrade Improvement for the School End Road Realignment and its associated Maintenance Access Roads

Asset (axis)	Chainage	Geological strata at subgrade	CBR long term (%)	CBR Short term (%)	Proposed ground improvement	Design CBR after mitigation (%)
School End Road Realignment (MC01)	From Ch. 0 to 170	TILMP	2.5	5.0	E&R=0.60m Subgrade improvement	≥ 3.0
	From Ch. 170 to 260	TILMP	2.5	5.0	E&R=0.30 m Topsoil stripping	≥ 3.0
	From Ch. 340 to 365	TILMP	2.5	5.0	E&R=0.30 m Topsoil stripping	≥ 3.0
	From Ch. 365 to 462.3	TILMP	2.5	5.0	E&R=0.60m Subgrade improvement	≥ 3.0
Maintenance Access Road to Pond (Off School End Road South, MC02)	From Ch. 0 to 35	TILMP	2.5	5.0	E&R=0.30 m Topsoil stripping	≥ 3.0
	From Ch. 35 to Ch. 610	TILMP	2.5	5.0	E&R=0.60m Subgrade improvement	≥ 3.0
	From Ch. 610 to 670	TILMP	2.5	5.0	E&R=0.30 m Topsoil stripping	≥ 3.0
	From Ch. 670 to Ch. 700	TILMP	2.5	5.0	E&R=0.60 m Subgrade improvement	≥ 3.0
Maintenance Access Road to Pond (Off School End Road North, MC03)	From Ch. 0 to Ch. 519.5	TILMP	2.5	5.0	E&R=0.60 m Subgrade improvement	≥ 3.0
Maintenance Access Road to GSMR (Off School End Road Realignment)	From Ch. 0 to 40	TILMP	2.5	5.0	E&R=0.60 m Subgrade improvement	≥ 3.0
	From Ch. 40 to 87	TILMP	2.5	5.0	E&R=0.30 m Topsoil stripping	≥ 3.0
	From Ch. 87 to 131.4	TILMP	2.5	5.0	E&R=0.60 m Subgrade improvement	≥ 3.0

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Table 5-71: Footpath CHW/18 Accommodation Access Realignment and its Associated Maintenance Access Roads

Asset (axis)	Chainage	Geological strata at subgrade	CBR long term (%)	CBR Short term (%)	Proposed ground improvement	Design CBR after mitigation
Footpath CHW/18 Accommodation Access Realignment (MC01)	From Ch. 0 to 35.2	TILMP	2.5	6.2	E&R=0.60m Subgrade improvement	≥ 3.0
	From Ch. 35.2to 79.2	TILMP	2.5	6.2	E&R=0.30 m Topsoil stripping	≥ 3.0
	From Ch. 153.3 to 193	TILMP	2.5	6.2	E&R=0.30 m Topsoil stripping	≥ 3.0
	From Ch. 193 to 257.8	TILMP	2.5	6.2	E&R=0.60m Subgrade improvement	≥ 3.0
Footpath CHW/18 Diversion (MC02)	From Ch. 0 to Ch. 10, Ch. 60 to Ch. 204.4	TILMP	2.5	6.2	E&R=0.60m Subgrade improvement where HW Fill (H<1.00) is on natural ground	≥ 3.0
	Ch. 10 to Ch. 60	TILMP & GFDMP	2.5	6.2	E&R=0.30 m Topsoil stripping	≥ 3.0
Chetwode ATS Access Road and Maintenance Access Road to Pond (MC03)	From Ch. 0 to Ch. 50	TILMP	2.5	6.3	E&R=0.60m Subgrade improvement	≥ 3.0
	From Ch. 50 to Ch. 210	TILMP	2.5	14	No	≥ 3.0
	From Ch. 210 to Ch. 714	TILMP	2.5	6.2	E&R=0.60m Subgrade improvement	≥ 3.0
The Green Highway Realignment (MC05)	From Ch. 0 to 65	TILMP	2.5	6.2	E&R=0.60m Subgrade improvement	≥ 3.0
	From Ch. 65 to 120	TILMP	2.5	6.2	E&R=0.30 m Topsoil stripping	≥ 3.0
	From Ch. 120 to 324	TILMP	2.5	6.2	E&R=0.60m Subgrade improvement	≥ 3.0

5.5.5 Calculation Results

Output and calculation results are provided in the asset summary sheet in Appendix D. The following constructive measures is recommended for School End Road Realignment and Footpath CHW/18 Accommodation Access Realignment and their associated Maintenance Access Roads design:

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- For the at grade sections, a ground improvement by way of excavating and replacement of 0.60 m shall be carried out beneath the proposed routes for the subgrade improvement using Class 1A4, 1A5 or 1A6 material. The proposed improvement works within the existing ground should result in a minimum CBR values ≥ 3%.
- A 0.30 m nominal thickness of topsoil or subsoil stripping is recommended as a good practice before constructing to its maximum proposed height beneath all embankment areas along the following roads:
  - School End Road Realignment (MC01);
  - Maintenance Access Road to Pond (Off School End Road South, MC02);
  - Maintenance Access Road to GSMR (Off School End Road Realignment) and Compound (MC04);
  - Footpath CHW/18 Accommodation Access Realignment (MC01);
  - Footpath CHW/18 Eastern Link Diversion (MC02);
  - The Green Highway Realignment (MC05);

5.6 Geotechnical Design Solution

The proposed mitigation measures for School End Road Realignment (non-mainline earthworks) covering geometry and formation treatment are summarised in Table 5-72 below.

Table 5-72: Mitigation Measures for Highways – School End Road Realignment

Asset name	School End Road Realignment – MC01					
Approx. Chainage	0-170	170-250	250-260	340-350	350-365	380-462.3
Type	At grade on natural ground	Embankment	Embankment (OB transition)	Embankment (OB transition)	Embankment	At grade on natural ground
H (m)	H < 1.00 m	Hmax = 5.60 m Between Ch. 170 and Ch. 185: 1.00 < H ≤ 3.00 m Between Ch. 0+185 and Ch. 0+215: H > 3.00 m Between Ch. 0+215 and Ch. 0+260: 1 <H ≤ 3.00 m	Hmax = 1.74 m	Hmax = 1.70 m	Hmax = 1.70 m	H < 1.00 m
Embankment Fill Class	If H ≤ 750 mm, Class 1 (1A4 or Class 1A5 or Class 1A6) If H > 750 mm, Class 2B1 or 7E2					

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Asset name	School End Road Realignment – MC01					
Approx. Chainage	0-170	170-250	250-260	340-350	350-365	380-462.3
Stabilised embankment Fill	No	No	No	No	No	No
Slopes	1V/3H	1V/4H	1V/4H	1V/4H	1V/4H	1V/3H
Slope reinforcement	No	No	No	No	No	No
Geotextile separator at base of topsoil strip (2)	Yes	Yes	Yes	Yes	Yes	Yes
Foundation treatment for settlements	No	No	No	No	No	No
Topsoil / subsoil strip	N/A	Yes, E&R 0.30 m	Yes, E&R 0.30 m	Yes, E&R 0.30 m	Yes, E&R 0.30 m	N/A
Subgrade improvement (1)	Yes, E&R 0.60 m if H < 1.00 m	No	No	No	No	Yes, E&R 0.60 m if H < 1.00 m
Starter layer	No	Yes, if H≥ 3m: Class 6C1 (300 mm thick)	No	No	No	No
Flood mitigation measures	No	No	No	No	No	No

NOTES

(1) Highway constructed at grade on natural ground

(2) According with SED's Ref. [1MC06-CEK-GT-DSE-C002-000104]

The proposed mitigation measures for Maintenance Access Road to Pond (Off School End Road South) non-mainline earthworks covering geometry and formation treatment are summarised in Table 5-73.

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Table 5-73: Mitigation Measures for Highways – Maintenance Access Road to Pond (Off School End Road South)

Asset name	Maintenance Access Road to Pond (off School End Road South) – MC02			
Approx. Chainage	0-35	35-610	610-670	670-700
Type	Embankment	At grade on natural ground	Embankment	At grade on natural ground
H (m)	Hmax = 6.00 m	H < 1.00	Hmax = 2.70 m	H < 1.00
Embankment Fill Class	If H ≤ 750 mm, Class 1 (1A4 or Class 1A5 or Class 1A6) If H > 750 mm, Class 2B1 or 7E2			
Stabilised Embankment Fill	No	No	Yes, between Ch. 610 and Ch. 660 for the steep slope	No
Slope right side	1V/4H	1V/4H	1V/4H	1V/3H
Slope left side	1V/4H	1V/4H	(1V/2H between Ch. 610 and Ch. 660) 1V/4H	1V/3H
Slope reinforcement	No	No	Yes, using a stabilised fill material Class 9J2	No
Geotextile separator at base of topsoil strip (2)	Yes	Yes	Yes	Yes
Topsoil / subsoil strip	Yes, E&R 0.30 m	N/A	Yes, E&R 0.30 m	N/A
Foundation treatment for settlements	No	No	No	No
Subgrade improvement (1)	No	Yes, E&R = 0.60 m if H < 1.00 m	No	Yes, E&R = 0.60 m if H < 1.00 m
Starter layer	Yes, if H≥ 3.00 m: Class 6C1 (0.30 m thick)	No	No	No
Flood mitigation measures	No	No	No	No

NOTES

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(1) Highway constructed at grade on natural ground

(2) According with SED's Ref. [1MC06-CEK-GT-DSE-C002-000104]

The proposed mitigation measures for Maintenance Access Road to Pond (off School End Road North: non-mainline earthworks) covering geometry and formation treatment are summarised in Table 5-74.

Table 5-74: Mitigation Measures for Highways – Maintenance Access Road to Pond (off School End Road North)

Asset name	**Maintenance Access Road to Pond (off School End Road North) – MC03**
Approx. Chainage	**0-519.5**
Type	At grade on natural ground
H (m)	H < 1.00 m
Embankment Fill Class	If H ≤ 750 mm, Class 1 (1A4 or Class 1A5 or Class 1A6) If H > 750 mm, Class 2B1 or 7E2
Stabilised embankment Fill	No
Slopes	1V/3H
Slope reinforcement	No
Geotextile separator at base of topsoil strip (2)	Yes
Foundation treatment for settlements	No
Subgrade improvement (1)	Yes, E&R 0.60 m
Starter layer	No
Flood mitigation measures	No

NOTES

(1) Highway constructed at grade on natural ground

(2) According with SED's Ref. [1MC06-CEK-GT-DSE-C002-000104]

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The proposed mitigation measures for Maintenance Access Road to GSMR (non-mainline earthworks) covering geometry and formation treatment are summarised in Table 5-75 below.

Table 5-75: Mitigation Measures for Highways – Maintenance Access Road to GSMR

Asset name	**Maintenance Access Road to GSMR (off School End Road Realignment)**		
Approx. Chainage	**0-40**	**40-87**	**87-131.4**
Type	At grade on natural ground	Embankment	At grade on natural ground
H (m)	H < 1.00 m	Hmax = 6.50 m Between Ch. 0+40 and Ch. 0+50 :1 <H ≤ 3.00 m Between Ch. 0+50and Ch. 0+80: H > 3.00 m Between Ch. 0+80 and Ch. 0+87: 1 <H ≤ 3.00 m	H < 1.00 m
Embankment Fill Class	If H ≤ 750 mm, Class 1 (1A4 or Class 1A5 or Class 1A6) If H > 750 mm, Class 2B1 or 7E2		
Stabilised embankment Fill	No	No	No
Slopes	1V/3H	1V/4H	1V/3H
Slope reinforcement	No	No	No
Topsoil / subsoil strip	No	Yes, E&R 0.30 m	No
Geotextile separator at base of topsoil strip (2)	Yes	Yes	Yes
Foundation treatment for settlements	No	No	No
Subgrade improvement (1)	Yes, E&R = 0.60 m if H< 1.00 m	No	Yes, E&R = 0.60 m if H< 1.00 m
Starter layer	No	Yes, if H>3.00 m, 0.30 m thick, Class 6C1	No
Flood mitigation measures	No	No	No

NOTES

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(1) Highway constructed at grade on natural ground

(2) According with SED's Ref. [1MC06-CEK-GT-DSE-C002-000104]

The proposed mitigation measures for Footpath CHW18 Accommodation Access Realignement (non-mainline earthworks), covering geometry and formation treatment, are summarised in Table 5-76 below.

Table 5-76: Mitigation Measures for Highways - Footpath CHW/18 Accommodation Access Realignment

Asset name	**Footpath CHW/18 Accommodation Access- Approach Embankments – MC01**						
Approx. Chainage	**0-35.2**	**35.2-70**	**70-79.2**	**153.3-163.3**	**163.3-180**	**180-193**	**193-257.8**
Type	At-grade on natural ground	Embankment	Embankment (OB transition)	Embankment (OB transition)	Embankment	Embankment	At grade on natural ground
H (m)	At grade H < 1.0 m	Hmax=2.00 m	Hmax=2.50 m	Hmax=3.20 m	Hmax=2.90 m	Hmax=2.20 m	At grade H < 1.00 m
Embankment Fill Class	If H ≤ 0.75 m, Class 1 (1A4 or Class 1A5 or Class 1A6) If H > 0.75 m, Class 2B1, 7E2 or 9J2 between Ch. 180 and 210 for the steep slope 1V/1.25H						
Stabilised embankment Fill	No	No	No	No	No	Yes	No
Slope right side	1V/3H	1V/4H	1V/4H	1V/4H	1V/4H	1V/4H	1V/3H
Slope left side	1V/3H	1V/4H	1V/4H	1V/4H	1V/4H	1V/1.25H	1V/3H
Slope reinforcement	No	No	No	No	No	Yes, using a stabilised fill material class 9J2	No
Topsoil / subsoil strip	N/A	Yes, 0.30 m	Yes, 0.30 m	Yes, 0.30 m	Yes, 0.30 m	Yes, 0.30 m	N/A
Geotextile separator at base of	Yes	Yes	Yes	Yes	Yes	Yes	Yes

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Asset name	Footpath CHW/18 Accommodation Access- Approach Embankments – MC01						
Approx. Chainage	0-35.2	35.2-70	70-79.2	153.3-163.3	163.3-180	180-193	193-257.8
topsoil strip (3)							
Foundation treatment for settlements	NA	No	No	No	No	No	NA
Subgrade improvement (1)	Yes, E&R = 0.60 m if H < 1.00 m	No	No	No	No	No	Yes, E&R = 0.60 m H < 1.00 m
Starter layer (2)	No	No	No	Yes, if H≥ 3.00 m: Class 6C1 (300 mm thick)	No	No	No
Flood mitigation measures	No	No	No	No	No	No	No

NOTES

(2) Highway constructed at grade on natural ground

(3) Highway constructed at grade on landscape bund

(4) According with SED's Ref. [1MC06-CEK-GT-DSE-C002-000104]

(5) Stabilised cohesive material (Class 9J2) used as embankment fill due to steepened slopes.

The proposed mitigation measures for Footpath CHW/18 Diversion (non-mainline earthworks) covering geometry and formation treatment are summarised in Table 5-77 below.

Table 5-77: Mitigation Measures for Highways – Footpath CHW/18 Diversion

Asset name	Footpath CHW18 Diversion- Embankments – MC02			
Approx. Chainage	0.00-10	10-60	60-170	170-204.4
Type	At-grade	Embankment on landscape bund	At-grade on landscape bund	At-grade on natural ground

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Asset name	Footpath CHW18 Diversion- Embankments – MC02			
Approx. Chainage	0.00-10	10-60	60-170	170-204.4
H (m)	H < 1.00 m	Hmax = 1.60 m	H < 1.00 m	H < 1.00 m
Embankment Fill Class	If H ≤ 0.75 m, Class 1 (1A4 or Class 1A5 or Class 1A6) If H > 0.75 m, Class 2B1 or 7E2			
Stabilised Embankment Fill	No	No	No	No
Slopes	NA	>1V/4H	> 1V/4H	1V/4H
Slope reinforcement	No	No	No	No
Topsoil / subsoil strip	Yes	Yes, 0.30 m	No, Highway Fill to be built over the landscape bund	No
Geotextile separator at base of topsoil strip (3)	Yes	Yes	Yes	Yes
Foundation treatment for settlements	No	NA	NA	NA
Topsoil / subsoil strip	No	Yes	No	No
Subgrade improvement (1)	Yes, E&R=0.60 m if HW Fill is on natural ground	N/A	No, Highway Fill to be built over the landscape bund	Yes, E&R=0.60 m if H < 1.00 m
Starter layer (2)	No	No	No	No
Flood mitigation measures	No	No	No	No

NOTES

(1) Highway constructed at grade on natural ground

(2) Highway constructed at grade on landscape bund

(3) According with SED's Ref. [1MC06-CEK-GT-DSE-C002-000104]

The proposed mitigation measures for Chetwode ATS Access Road and MAP (non-mainline earthworks) covering geometry and formation treatment are summarised in Table 5-78 below.

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Table 5-78: Mitigation Measures for Highways – ATS Chetwode Access Road and Maintenance Access Road to Pond

Asset name	Chetwode ATS Access Road and Maintenance access Road to Pond – MC03		
Approx. Chainage	0.00-50	50-210	210-714
Type	At grade	Cutting	At grade
H (m)	H < 1.0 m	H ≤ - 3.5 m	H < 1.0 m
Embankment Fill Class	If H ≤ 750 mm, Class 1 (1A4 or Class 1A5 or Class 1A6) If H > 750 mm, Class 2B1 or 7E2	NA	If H ≤ 750 mm, Class 1 (1A4 or Class 1A5 or Class 1A6) If H > 750 mm, Class 2B1 or 7E2
Stabilised embankment Fill	No	NA	No
Slopes	1V/4H	1V/4H	1V/3H
Slope reinforcement	No	No	No
Topsoil / subsoil strip	N/A	NA	N/A
Geotextile separator at base of topsoil strip (2)	Yes	Yes, E&R 0.60 m if CBR < 3%, validated by in-situ testing	Yes
Foundation treatment for settlements	NA	NA	NA
Subgrade improvement (1)	Yes, E&R=0.60 m if H < 1.00 m	Yes, E&R 0.60 m if CBR < 3%, validated by in-situ testing	Yes, E&R=0.60 m if H < 1.00 m
Starter layer	No	No	No

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Asset name	Chetwode ATS Access Road and Maintenance access Road to Pond – MC03		
Approx. Chainage	0.00-50	50-210	210-714
Flood mitigation measures	No	No	No

NOTES

(1) Highway constructed at grade on natural ground

(2) According with SED's Ref. [1MC06-CEK-GT-DSE-C002-000104]

The proposed mitigation measures for the Green Highway Realignment (non-mainline earthworks) covering geometry and formation treatment are summarised in Table 5-79 below.

Table 5-79: Mitigation Measures for Highways – The Green Highway Realignment

Asset name	The Green Highway Realignment – MC05		
Approx. Chainage	0.00-65	65-120	120-324
Type	At grade	Embankment	At grade
H (m)	H < 1.00 m	Hmax = 1.67 m	H < 1.00 m
Embankment Fill Class	If H ≤ 750 mm, Class 1 (1A4 or Class 1A5 or Class 1A6) If H > 750 mm, Class 2B1 or 7E2		
Stabilised embankment Fill	NA	No	NA
Slopes	1V/3H	1V/3H	1V/3H
Slope reinforcement	No	No	No
Geotextile separator at base of topsoil strip (2)	Yes	Yes	Yes
Foundation treatment for settlements	NA	No	NA
Topsoil / subsoil strip	N/A	Yes, E&R=0.30 m	N/A

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Asset name	The Green Highway Realignment – MC05		
Approx. Chainage	0.00-65	65-120	120-324
Subgrade improvement (1)	Yes, E&R =0.60 m	No	Yes, E&R=0.60 m
Starter layer	No	No	No
Flood mitigation measures	No	No	No

NOTES

(1) Highway constructed at grade on natural ground

(2) According with SED's Ref. [1MC06-CEK-GT-DSE-C002-000104]

5.7 Pavement Design

The Pavement Design is set out for each axes of School End Road Realignment and Footpath CHW/18 Accommodation Access Realignment in the Highway Asset Design Statements, Ref [80][81][82][83][84][85][86] and [87].

5.8 Risk Management Non-Mainline Earthworks

The Footpath CHW/18 Accommodation Access Realignment and the School End Road Realignment cross the HS2 mainline respectively at Ch.85+575 and Ch.86+475.

Asset specific risks identified for all the other non-mainline earthworks within the extents of Chetwode Cutting have been outlined in the GRR with associated mitigation measures.

5.8.1 Introduction

A number of hazards identified in Section 5.8.2 are difficult to account for in the Detailed Design due to limited available information of the presence, location, and extent of the hazard or design consideration.

The subsequent sections summarise the risks and provide an indication of the type of mitigation that may need to be deployed should a particular hazard be encountered.

5.8.2 Tolerable Risks

A number of hazards identified in Section 3.8.7 have been assumed to be acceptable, and thus, no particular mitigation measures have been planned to reduce associated risks.

Tolerable risk identified within the non-mainline assets are listed below:

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Table 5-80: Acceptable Risks for Non-mainline Assets

Asset (Axis)	Geohazards assumed to be tolerable	Description of the potential impact	Justification
School End Road Realignment	Shrink / Swell	Near-surface soil volume change potential	Presence of High plasticity clays. The Maintenance Access Road is at grade between Ch. 0 to Ch. 160 and between Ch. 380 to Ch. 462.3 with a limited height. Use of conservative equilibrium CBR values in at grade section is considered a prudent approach.
Maintenance Access Road to Pond (Off School End Road - South)	Shrink / Swell	Near-surface soil volume change potential	Presence of High plasticity clays. The Maintenance Access Road is at grade between Ch. 47 to Ch. 700 with a limited height. Use of conservative equilibrium CBR values in at grade section is considered a prudent approach.
Maintenance Access Road to Pond (Off School End Road - North)	Shrink / Swell	Near-surface soil volume change potential	Presence of High plasticity clays. The Maintenance Access Road is at grade with a limited height. Use of conservative equilibrium CBR values in at grade section is considered a prudent approach.
Maintenance Access Road to GSMR (off School End Road Realignment)	Shrink / Swell	Near-surface soil volume change potential	Presence of High plasticity clays. The Maintenance Access Road is at grade between Ch. 0 to Ch. 40 and Ch. 87 to Ch. 131.4 with a limited hight. Use of conservative equilibrium CBR values in at grade section is considered a prudent approach.
Footpath CHW/18 Accommodation Access Realignment	Shrink / Swell	Near-surface soil volume change potential	Presence of High plasticity clays. The Maintenance Access Road is at grade between Ch. 0 to Ch. 35.2 and Ch. 193 to Ch. 257.8 with a limited hight. Use of conservative equilibrium CBR values in at grade section is considered a prudent approach.
Footpath CHW/18 Diversion	Shrink / Swell	Near-surface soil volume change potential	Presence of High plasticity clays.

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Asset (Axis)	Geohazards assumed to be tolerable	Description of the potential impact	Justification
Chetwode ATS Access Road and Maintenance Access Road to Pond	Shrink / Swell	Near-surface soil volume change potential	Presence of High plasticity clays. The Maintenance Access Road is at grade between Ch. 0 to Ch. 50 and Ch. 200 to Ch. 713 with a limited hight. Use of conservative equilibrium CBR values in at grade section is considered a prudent approach.
The Green Highway Realignment	Shrink / Swell	Near-surface soil volume change potential	Presence of High plasticity clays. The Maintenance Access Road is at grade between Ch. 0 to Ch. 70 and Ch. 110 to Ch. 324 with a limited hight. Use of conservative equilibrium CBR values in at grade section is considered a prudent approach.

5.8.3 Additional Ground Investigation

All planned GI have now been received and GI impact assessment has been carried out on the new data. Refer to Section 5.4.1 for a summary of the assessment.

5.8.4 Excavate and Replace of Soft Soils

Refer to Section 5.6 regarding specific chainages identified at detailed design stage for the non-mainline assets which would require ground improvement by way of excavating and replacement of the existing soil.

The underlying TILMP or GFDMP have been found to be highly variable locally. There is a risk of hotspot of soft soils (Cu < 50kPa) containing organic matter within the upper horizon of these strata and pockets of perched water which influence the shear strength of the materials. If encountered, it is recommended that this material is excavated and replaced with Class 1A material to ensure adequate long-term stability of the embankment (minimise secondary settlements) and/or provide sufficient bearing capacity during construction.

There is a risk that softer ground than anticipated in the current analysis (in TILMP/GFDMP) will be encountered locally at formation level, leading to the need for additional ground improvement by excavating and replacement, by anticipation of highway loading (surcharge) and/or by taking a longer hold period to accommodate settlements.

This risk may be managed by additional GI and verification testing during construction.

There is a potential risk of ground movements including slope instability, unacceptable total or differential settlements between the infilled Disused Railway Cutting and the adjacent section which is at grade.

There is also specific requirement to dig out and replace 0.60 m of soil materials within the School End Road Realignment and its associated maintenance access roads, Footpath CHW/18 and its associated access roads and The Green Highway Realignment.

The ground improvement along the main axis of School End Road Realignment and adjoining access road is mainly topsoil stripping of 0.30 m (embankment height greater than 1.0 m) and 0.60 m (earthworks height less than 1.0 m) of soil materials depending on the nature of superficial deposits observed on site during works.

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The natural ground used as subgrade is very sensitive to changes in moisture content. The bearing capacity may substantially reduce in case of wet conditions during works. Natural moisture content, CBR and bearing capacity must be verified before works within a demonstration area (required EV2 = 35.6 MPa).

In all cases, it is recommended to carry out the works in dry period and avoid circulation on the subgrade.

If circulation is planned on the subgrade, a temporary subbase shall be provided.

5.8.5 Earthworks Transitions

There is significantly low risk concern for settlement or longitudinal distortion at transitions with School End Overbridge and CHW/18 Overbridge.

5.8.6 Groundwater Management

Based on available groundwater monitoring data, there is a risk of encountering perched groundwater in the superficial deposits. This water ingress could cause slope instability.

The results from the permeability testing conducted using field test and oedometer test on the TILMP (C Z) and GFDMP (C Z) and indicates that these materials are low permeability soils. Furthermore, the cohesive OXC, KLB, CB are low permeability materials and would restrict groundwater migration. The low depth expected for the temporary excavations (slope gradient of 1H:1V), the rate of groundwater migration is expected to be low.

The risk of seepage during the construction stage can be controlled by using appropriate dewatering measures and the backfilling of excavations for ground improvement as soon as possible.

The application of these measures will depend on site observations and the identification of water.

Temporary works would be required during the excavate and replace ground improvement works in order to control high or perched groundwater ingress.

Careful planning will also be required to check the presence and functionality of any existing drainage during the excavation works to avoid any damage. The same planning is recommended for the School End Road Realignment and its associated Maintenance Access Roads, Footpath CHW/18 and its associated access roads and The Green Highway Realignment. If encountered, it is recommended to protect it from any potential damage from the adjacent works and recommended to carry out CCTV surveys to confirm the functionality of the pipework on completion of the works.

Temporary works for the construction of these assets will require careful planning to control any potential groundwater seepages.

During wet period, it is expected that the groundwater table could rise very near to the ground level in the location of the Footpath CHW/18 and its associated access roads and The Green Highway Realignment. In order to ensure this does not impact the stability of the excavation or affect personnel working on the asset, the contractor should consider a suitable construction technique to prevent the excavations becoming flooded.

There is a risk of encountering groundwater ingress on the side walls of temporary excavations through granular pockets of the GFDMP. This water ingress could cause slope instability.

There is no requirement for placement of a starter layer (at grade) and no flood mitigation measures are required prior to the construction of the School End Road Realignment and its associated maintenance access

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roads, Footpath CHW/18 and its associated access roads and The Green Highway Realignment. However, the current assessment indicates that a starter layer will be required at sections of the School End Road Realignment and its associated maintenance access roads, Footpath CHW/18 and its associated access roads and The Green Highway Realignment. (see Section 5.7) where the embankment height if greater than 3 m high. A starter layer (Class 6C1) will be required.

5.8.7 Temporary Drainage

In order to avoid decrease of the subgrade bearing capacity during works, adequate drainage measures need to be planned.

The temporary platform needs to be inclined from 3 to 4% towards longitudinal ditches.

5.8.8 Mitigation for Relic Slip Surfaces

There is no relic shear surfaces has been identified along HS2 non-mainline assets (School End Road Realignment and Footpath CHW/18 Accommodation Access Realignment) and thus no mitigation measures are required.

5.8.9 Chemically Aggressive Ground

There is a risk of high degradation of construction materials and/or the creating an adverse environmental impact due to the elevated levels of sulphates, sulphides or high/low pH in TILMP.

These elevated levels can lead to the chemical attack on concrete slab of the adjacent structures and, to a limited reuse of materials due to adverse reactions during modification with lime resulting in an increase of imported materials or larger haul distances, to an increase of volume of landscape fill and to a limited use of as dug or stabilised materials.

This risk is managed in design by:

- Recommending BRE Special Digest SD1 Ref[34], adopting correct concrete class accordingly (DS3 AC-2s is recommended for the TILMP),
- Undertaking material specific durability and volumetric stability tests during construction where soil re-use or soil stabilisation is proposed,
- Using adequate material for dig-out and replace which will be not impacted by aggressive ground (Class 1 material is planned),

The lime stabilisation of the Oxford Clay Formation for use as embankment fill is prohibited.

5.8.10 CDM Register

In accordance with the requirements of Lead Designer under the CDM Regulations 2015, a Designer's Risk Assessment has been undertaken in connection with the geotechnical design of the earthworks.

Reference should be made to the CDM Risk Register Document Ref [16] for details of the general and asset specific risks associated with this earthwork design.

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The following risks have an impact on health and safety and will be updated to the CDM register:

- Flooding and soil erosion of side slopes due to water ingress from perched water in glacial till. Flooding of sub-excavations by excessive rainfall/rising groundwater during construction and/or related to flood plain. This could potentially lead to instability of temporary excavations and slope instability of embankments. It impacts the safety of site workers;
- Working in compressible ground or areas of soft ground: soft ground could cause issues with access for machinery for additional ground investigation and construction of geotechnical assets. Consequently, it could impact safety of site workers and lead to delays to pre-construction ground investigation and/or construction programme;
- Working near buried utilities (electric, telecommunication, etc) associated to electrocution risk. This could potentially impact safety of site workers and lasting adverse legacy of the HS2 project;
- Ground gas: Potential risk for ground gas, i.e. carbon dioxide (CO_2) and methane (CH_4) possibly associated with Land Quality (LQ) and Made Ground (MGR) could be encountered. Radon gas risk associated with possible confined spaces during the construction of the non-mainline assets. This could potentially impact health of site workers and lasting adverse legacy of the HS2 project;
- Working adjacent to UXO (Unexploded Ordnance), located about 250 m north-east of the starting chainage of The Green Highway Realignment. This may potentially lead to mortality of site workers and lasting adverse legacy of the HS2 project.

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6 Structures

This section of the report is about the two overbridges crossing HS2 mainline above Chetwode Cutting, as part of the IDR 221.2 package.

6.1 Footpath CHW18 accommodation overbridge

The Footpath CHW18 accommodation overbridge is located at chainage 85+575.
The structure is composed of three spans: two side spans of 19.8 m each and a central span of 33.5 m. The deck is supported on two integral piers and two non-integral abutments.
The bridge will be constructed following a bottom-up construction sequence.
The design working life of the structure will be 120 years in accordance with the UK National Annex (NA) to EN 1990.
The soil model for the overbridge design is defined using soil data available up to Data drop 17. The stratigraphy is composed of:

- firm sandy clay of 1.7 m in thickness (Till),
- loose gravely fine sand of 2.1 m in thickness (Glaciofluvial Deposits),
- 13.1 m of the Oxford Clay Formation composed of 7.8 m of firm to very stiff sandy clay and 5.3 m of weak mudstone,
- 5.1 m of the Kellaways Formation composed of extremely weak sandstone and mudstone,
- and a substratum of the Great Oolite Group, composed of:
  - medium strong to strong limestone of the Cornbrash Formation, of 5.5 m in thickness,
  - 1.7 m of the Forest Marble formation composed of weak mudstone with siltstone interbeds. Very locally, this formation is composed of medium strong limestone.
  - and medium strong limestone of the White Limestone Formation, with sublayers of firm laminated clay.

Due to the weak nature of the soil layers over an important depth below the surface, piles foundations system is proposed for both abutments and piers. These piles are designed in accordance with BS EN 1997. Bored piles without stabilizing fluid will be used, as the borehole walls are expected to be stable.

The piles are founded in the Cornbrash Formation, composed of medium strong to strong limestone near the overbridge.
The length of each pile is calculated based on the load values provided by the structures team. The guideline of the design is to verify that the piles are founded in a sufficiently resistant soil formation, preferably rocky (in the present case the medium strong to strong limestone of the Cornbrash Formation), with an embedded length of the pile in sand formation equal to its diameter at least.
During piles boring, the level of the Cornbrash formation top has to be identified and the piles length has to be increased if needed in order to guarantee the embedded length in CB formation.
On the other side, it is worth noting that the main excavation is done in heave prone soils (Oxford Clay formation), a heave assessment is thus performed. The design of the piles and the overbridge is verified under heave induced forces and displacements.
The features of the proposed piled foundations are given in Table 6**.81**.

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Table 6.81. Footpath CHW18 accommodation overbridge piled foundation features

Support	Piles layout	Diameter (mm)	Pile head elevation (m AOD)	Pile base elevation (m AOD)	Pile length (m)
West abutment	2 piles d = 4.1 m	1050	101.2	78.5	22.7
West pier	2 piles d = 4.1 m	1200	96.2	78.5	17.7
East pier	2 piles d = 4.1 m	1200	96.1	78.5	17.6
East abutment	2 piles d = 4.1 m	1050	101.1	78.5	22.6

On the other side, the structural backfill height in the transition zone behind each abutment is around 4.5 m, of which 3.5 m are above the initial ground level and thus generate settlements. This settlement is estimated at around 30-33 mm. It is estimated that half of the settlements will be generated immediately at the end of the construction of the wingwalls. The differential settlement is approximately equal to 1/500. These values are quite acceptable according to the project standards.
6N8 material will be used behind the abutments, with a peak value of the angle of shear friction guaranteed between 35° and 45°.

6.2 School End Overbridge

The School End overbridge is located at chainage 86+475.
The structure is composed of three spans: two side spans of 21.0 m each and a central span of 33.0 m. The deck is supported on two integral piers and two non-integral abutments.
The bridge will be constructed following a bottom-up construction sequence.
The design working life of the structure will be 120 years in accordance with the UK National Annex (NA) to EN 1990.
The soil model for the overbridge design is defined using soil data available up to Data drop 2. The stratigraphy is composed of:

- Firm to stiff sandy gravelly clay of 3.5 m in thickness (Till formation)
- Loose to medium dense fine to medium sand of 5.5 m in thickness (Glaciofluvial Deposits),
- 11.5 m of stiff to very stiff clay of the Oxford Clay Formation
- 5.5 m of extremely weak mudstone of the Kellaways Formation.
- and a substratum of the Great Oolite Group, composed of:
  - 2.7 m of medium strong to strong limestone of the Cornbrash Formation,
  - 3.3 m of alterations of medium strong limestone and weak siltstone of the Forest Marble Formation,
  - And around 17.5 m of weak to medium strong limestone of the White Limestone Formation.

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Due to the weak nature of the soil layers over an important depth below the surface, piles foundations system is proposed for both abutments and piers. These piles are designed in accordance with BS EN 1997. Bored piles without stabilizing fluid will be used, as the borehole walls are expected to be stable.
The piles are founded in the Cornbrash Formation, composed of medium strong to strong limestone near the overbridge.
The length of each pile is calculated based on the load values provided by the structures team. The guideline of the design is to verify that the piles are founded in a sufficiently resistant soil formation, preferably rocky (in the present case the medium strong to strong limestone of the Cornbrash Formation), with an embedded length of the pile in sand formation equal to its diameter at least.
During piles boring, the level of the Cornbrash Formation top has to be identified and the piles length has to be increased if needed in order to guarantee the embedded length in CB formation.
On the other side, it is worth noting that the main excavation is done in heave prone soils (Oxford Clay Formation), a heave assessment is thus performed. The design of the piles and the overbridge is verified under heave induced forces and displacements.
The features of the proposed piled foundations are given in Table 6.82.

Table 6.82. School End Overbridge Piled Foundation Features

Support	Piles layout	Diameter (mm)	Pile head elevation (m AOD)	Pile base elevation (m AOD)	Pile length (m)
West abutment	3 piles d = 3.3 m	1500	105.7	82.1	23.6
West pier	3 piles d = 3.3 m	1200	101.1	82.2	18.9
East pier	3 piles d = 3.3 m	1200	101.3	82.2	19.1
East abutment	3 piles d = 3.3 m	1500	106.1	82.1	24

On the other side, the structural backfill height in the transition zone behind each abutment is around 3.5 m, of which 2.0 m are above the initial ground level and thus generate settlements. This settlement is estimated at around 8 mm. It is estimated that half of the settlements will be generated immediately at the end of the construction of the wingwalls. The differential settlement is around 1/1000. These values are quite acceptable according to the project standards.
6N8 material will be used behind the abutments, with a peak value of the angle of shear friction guaranteed between 35° and 45°.

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7 Drainage

Reference to be made to the following drainage catchment reports for details on HS2 drainage detail design:

- C2.T.80 [69] for track drainage, mainly composed of filter drains.
- C2.L.83 [70] for land drainage Down side composed of concrete ditches.
- C2.L.84 [71] for land drainage Up side composed of concrete ditches.
- C2.L.86 [72] for land drainage Down side composed of earth ditches.
- C2.L.87 [73] for land drainage Up side composed of concrete ditches.

7.1 Management of Groundwater Risks

7.1.1 Groundwater Protection

Land drainage network is made of concrete ditches at the top of cutting, or concrete and earth ditches at the toe of landscape bunds. Track drainage is made of filter drains, to collect the upper slope runoff water, and lower the groundwater level, in a wet cutting condition.

Perimeter drainage as well as track drainage systems have been designed considering the highest ground water level in the area. Indeed, Track drainage has been set so that the middle of pipe is 1.422m below the edge of HS2 platform, following requirements of HS2 standards and the Basis of Design Statement - Land and Track Drainage Ref [74] in case of wet cutting Ref[69].

The capacity of filter drains compared to groundwater estimated flows has been assessed in all relevant drainage reports

7.1.2 Construction Risk

Water ingress during the construction phase is an identified risk for the earthworks.

Water has an influence on

- the stability of the slopes,
- the trafficability of machinery.

The following measures will be adopted:

The earthworks will be subject to geological and hydrogeological monitoring during their execution. The purpose of this monitoring is to ensure that the encountered conditions remain broadly consistent with the geological model taken into account in the stability studies.

Prior to the execution of the cutting, the drainage and lowering of the water table in aquifer terrain, as well as the temporary works that will be necessary for the proper execution of the work, such as the connection of drainage devices to existing ditches and the flaring of ditches to retain the fines from the earthworks (hay filter, etc.) will be carried out without delay.

With regards to the risk of gullying of the excavated slopes in erosion-sensitive formations, the slopes must be preserved by the early creation of temporary crest ditches and by the implementation of a material barrier at the crest.

During the works, the level of the earthwork must have a minimum transverse slope of 4% to allow water to drain away from the excavation.

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Vigilance will be implemented by carrying out regular inspections of the water coming into the slopes, especially at the level of the GFDMP and TIMLP formations where potential for perched water table / water ingress has been identified. Temporary drainage and dewatering measures will be required at the base of excavations to remove rainfall and to prevent loss of subgrade strength to include correct cross falls.

In general, the drainage ditches and the E/R must not constitute water traps. Lateral drainage (or pumping) should be provided to direct water to the outlets.

When the work is stopped, the earthwork level should have a slope of 4% towards the outside to avoid water accumulation and the temporary earthwork platform should be closed with an appropriate compactor to avoid any degradation of the bearing capacity due to water inflow.

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8 Assessment of Potential Contamination

8.1 Potential Contamination and Remediation Requirements

The contaminant risk assessment has been restricted to the HS2 identified Land Quality (LQ) areas only that were identified in the Environmental Statement, Ref [55] and Ref [56]. The primary potential source of contamination identified within the Chetwode Cutting Group area is the Dismantled Rugby to Quainton Great Central Railway (LQ 13.07) which is situated parallel and southwest to the Chetwode Cutting Group and is predominantly located within the LLAU, with one small section within the LOD of School End Road overbridge/ realignment (see Image below). The Chetwode Cutting Group is predominantly located within rural Greenfields with agricultural land uses.

The geo-environmental assessment of the above LQ 13.07 constraint area (Image 8-16) addressing the potential risk to human health, controlled water and, infrastructure is reported in the Aylesbury Link and Dismantled Great Central Railway Geo-Environmental Assessment Report, Ref [64].

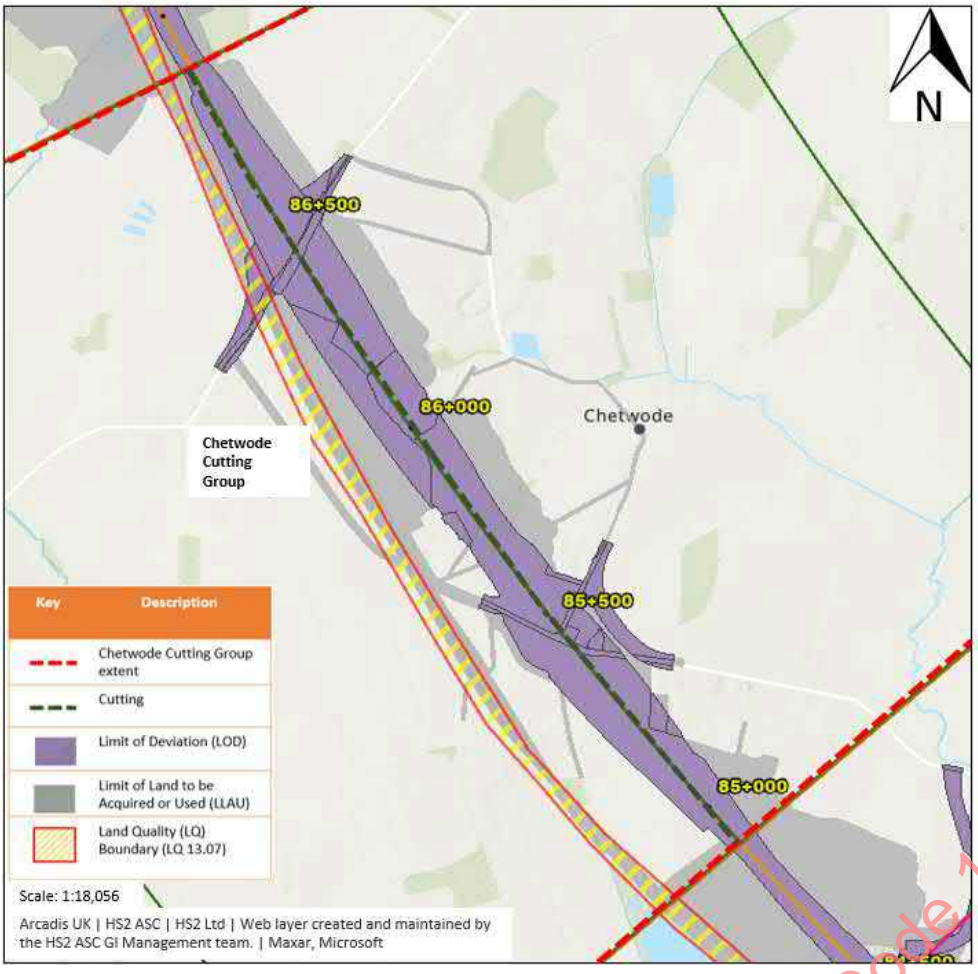


Image 8-16. Land Quality (LQ) constraints identified within Chetwode Cutting

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At the time of writing the Geo-Environmental Assessment report Ref [64] states a total of 7 soil samples, 7 leachate samples and 5 groundwater samples have been taken across Chetwode Cutting Group region. Testing results showed no soil exceedances against human health screening criteria or asbestos detected.

Made Ground has been found in one location within the LLAU within LQ 13.07 (ML086-TP438), to a depth of 1.70 m bgl and described as clayey silt with gravel of slag, chalk, chert and limestone with traces of black carbonaceous mudstone.

Out of 7 leachate and 5 groundwater samples tested within Chetwode Cutting there were 7 leachate metal exceedances and 3 groundwater metal exceedances against Water Quality Standards (WQS). The Geo-Environmental Assessment report Ref [64] states that leachable metals could have an impact on groundwater and surface water quality if disturbed/ mobilised by the works.

Based on proposed excavation depths and groundwater monitoring levels, groundwater is considered likely to be encountered during construction. Where groundwater is drawn into the cutting excavation during dewatering there is a potential for potentially contaminated groundwater to be encountered and for iron to oxidise at the surface, which could potentially lead to brown ochreous discharges visible at the surface.

Gas monitoring was undertaken in four exploratory holes (ML085-CR400, ML085-RO411, ML086-CR401, ML086-CR444) within the Chetwode Cutting. The Geo-Environmental Assessment report Ref [64] states that gas screening values within the site wide Dismantled Rugby Quainton Great Central Railway (LQ 13.07) is categorized as Characteristic Situation (CS): 1 (very low risk).

In summary, the primary source of potential contamination is likely to be from soil, groundwater and ground gas contamination from the Dismantled Rugby to Quainton Great Central Railway (LQ 13.07), which could be encountered during the proposed works within the LLAU. Potentially contaminated groundwater could migrate into the LOD where they could be encountered during the works.

8.2 Summary of commitments

The proposed remediation strategy and material reuse criteria for the Aylesbury Link area including the proposed Chetwode Cutting Group are captured in the Aylesbury Link and Dismantled Great Central Railway Remediation Outline Strategy Report Ref [17].

The remediation strategy and material reuse criteria have been agreed based on discussions with the Environment Agency (EA) (outlined within the Derivation of Made Ground Chemical Acceptance Criteria Report [67]).

8.3 Summary of risk and remedial approach

The contamination risk assessment within the Aylesbury Link and Dismantled Great Central Railway Geo-Environmental Assessment Report, Ref [64] has identified potential risks associated with soil, human health, controlled waters and property pollutant linkages. Chetwode Cutting Group interacts with the Dismantled Rugby to Quainton Great Central Railway (LQ 13.07) in one LOD location within the LOD of School End Road155nglianridge/ Realignment approx. Ch 86 + 400. However the Chetwode Cutting Group is, in general, within close proximity to the LQ 13.07, therefore risks remain from potential contaminated groundwater and ground gas migration. Mitigation measures, where appropriate, are captured in the Aylesbury Link and Dismantled Great Central Railway Remediation Outline Strategy Report Ref [17].

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Should it be encountered during the works, anthropogenic impacted Made Ground will be segregated and stockpiled separately from the 'natural' Made Ground (i.e., contains little to no anthropogenic material), and natural soil. Made Ground materials will be moved to an appropriate area for re-use at an appropriate depth within the works based on the chemical characteristics and the material re-use zone as noted in the Aylesbury Link and Dismantled Great Central Railway Remediation Outline Strategy Report Ref [17].

All Made Ground material will be tested to identify whether they are chemically suitable i.e., acceptable which will include geotechnically acceptable material including Class U1A or U1B and U2. Unacceptable contaminated earthworks materials shall fall into the Classes U1B and U2 as defined below:

- Unacceptable material Class U1B are contaminated materials excavated within the site, whose level of contamination is above the set re-use criteria noted in the earthworks specification Appendix 6/14 and Appendix 6/15, and can be managed by appropriate placement of the materials or treated and processed to meet suitability requirements.
- Unacceptable material Class U2 are contaminated materials excavated from within the site which shall not be used in the permanent works (in terms of chemical use), as they are impacted materials which are unsuitable for remediation or fail acceptance or re-use criteria following treatment; hence may require offsite disposal. Class U2 materials are likely to be radioactive waste (as defined in the Radioactive Substances Act 1993), asbestos unsuitable for incorporation within earthworks materials, heavy end hydrocarbons (compounds >40 carbon atoms) materials unsuitable for remediation or failing to meet the remediation targets.

Appropriate construction management practices should be adopted during construction works including a watching brief, measures to intercept run off to prevent contamination of controlled waters, minimise potential favourable conditions that can cause leaching of contamination, dust suppression measures to damp down excavated arisings. Unforeseen contamination will be managed in accordance with the EKFB Construction Environmental Management Plan (CEMP) Ref [66]. Further mitigation measures are provided in the Aylesbury Link and Dismantled Great Central Railway Remediation Outline Strategy Report Ref [17].

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9 Reuse of Materials

This section of the report presents an assessment and potential suitability of the underlying materials encountered during the intrusive works to be reused during the construction stage. Where materials are assessed to be unsuitable for it to be reused at the construction stage, recommendation will be provided for its safe removal and transport to a suitably licenced landfill facility. The assessment is based on summary of available test results carried within individual stratum that is considered to be directly relevant to the geotechnical design of the proposed works covered by this GDR. In this discussion of potential for reuse of excavated material, references have been made to Ref [49].

9.1 Durability

Analysis of chemical testing has been undertaken, and a classification linked to individual stratum types and groundwater within individual stratum has been developed and is presented within the GIR Ref[6].

Table 9.**83** shows the Total Potential Sulfate testing results on Chetwode cutting formations and the corresponding Design Sulfate Class combined with the ACEC Class.

Table 9.83: Summary of durability tests results

Geological strata	Total Potential Sulphate (%) (=total Sulphur * 3)	Design Sulphate Class	–CEC Class
Glacial Till - TILMP	0.69	DS3 – Medium risk	AC-2s
Glaciofluvial deposit – GFDMP CZ (1)	1.73	DS4 – High risk	AC-3s
Glaciofluvial deposit – GFDMP SV	0.08	DS1 – Low–risk	AC-1s
Oxford Clay - OXC	2.85 – High risk	AC-4s	

(G) (1) Clayey GFDMP have been identified locally along the asset just below the ATS platform level and locally below the platform of the mainline cutting around Ch.85+600 to Ch.85+850. GFDMP are mainly constituted by sand and gravels.

Concrete Class

In accordance with Part C5 of BRE Special Digest 1 Ref[34] “a limitation can be applied [to the Design sulphate Class] if the sulphate class for the Total Potential Sulphate (TPS) is initially found to be Sulphate Class 5, but the sulphate classes for groundwater and the water extracts tests are Sulphate Class 3 or less. In this case, the Design Sulphate Class for the site location can be limited to DS-4.

Soil Stabilisation or Modification

For suitability of treatment with lime/cement, the following guidance has been adopted for soils:

- TPS < 0.25% Low Risk

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- TPS ≥ 1.0% Significant Risk

The geological long section covering this asset area indicates that the proposed rail level is likely to cut through the TILMP and GFDMP over the entire asset length, and locally also excavating the top part of the OXC formation.

By reviewing the result for TPS concentrations for the formations within this asset, it is assessed that:

- The result for TILMP and GFDMP SV formations suggests that the TSP of these material is lower than 1% and can be considered suitable for stabilisation for use as upper embankment. Further asset-specific testing is required to prove the suitability of materials for stabilisation during works.
- The OXC and GFDMP CZ formations are above the Upper Limit of 1% TPS for use of stabilisation techniques and should not be considered for re-use as stabilised material.

9.2 Relationship testing and Material plots

The results of the available material testing are presented on the E-GDR dashboards appended to this report in Appendix F. The following dashboards have been included in the reuse analysis for the mainline asset:

- Chetwode Cutting Group – TILMP (C Z)
- Chetwode Cutting Cutting Group – GFDMP (C Z)
- Chetwode Cutting Cutting Group – GFDMP (S V SV)
- Chetwode Cutting Cutting Group – OXC

Any future updates to the material plots will be included in the E-GDR Ref[9], whenever new results become available.

The observation below is extracted from the Materials Re-Use Plots Dashboard based on Data Drop 17.

9.2.1 Glacial Till, TILMP

The following observation can be made with respect to materials reuse plots obtained for the Glacial Till (TILMP – C Z) encountered within the extents of the asset:

Table 9.84. Observations on material reuse for (TILMP – C Z)

Plot ref	Parameter	N° tests	Observations on material reuse
Chetwode Cutting (TILMP-C Z)	w%	182	ranges from 9.50% to 43% with an average of 19.5%.
	PL/LL	75	The plastic limit ranges from 14.0% to 31.0% with an average of 17.0%. The liquid limit ranges from 34.0% to 69.0% with an average of 47%.
	Sieve analysis	18	Ranges from 82-98% passing sieve 2 mm with an average 90% Ranges from 50% to 75% passing sieve 63µm with an average 70%
	TPS	100	The TPS ranges from 0.03 to 7.5% with average 0.69

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Plot ref	Parameter	N° tests	Observations on material reuse
	Compaction Test result	50	The maximum dry density ranges between 1.83 Mg/m^3 to 1.98 Mg/m^3. The optimum water content varies respectively between 15% and 12%.
	MCV	33	Generally, between 4 to 17 with average around 10.
	CBR	6	CBR > 2.5% when w% is less than 25%.
	Cu	15	Generally, between 90 kN/m^2 and 200 kN/m^2 when w% is less than 25%

In conclusion, the TILMP (C Z) is described as a slightly gravelly sandy very silty clay. The ratio is 94% fine soil and 6% gravelly sand.

The result shows plasticity indices of 19% to 46% with average value of 29%, indicative of clays of intermediate to high plasticity. The TILMP (C Z) is predominantly Class 7E (cohesive material suitable for HS2 earthworks if stabilised).

The average moisture content is around 19.5%. The proctor test indicates an optimum moisture content of between 12% and 15%. Given the average natural moisture content of this material is higher than the optimum moisture content required for compaction, a drying of the material may be required to ensure a good compaction.

During favourable climatic conditions (summer period), open air drying may be considered for a non HSR utilisation. Alternatively, drying by lime improvement/stabilisation could be the safest solution. It is considered more appropriate to stabilise this material for a HSR usage.

Based on available data, the most likely reuse for these materials would be the Main Line if the materials are stabilised to satisfy both stiffness and compaction requirement.

Careful extraction and deposition during the summer months may allow for reuse as General Highway Fills in its natural state, but this will need on-site quality checks.

Further testing may be required to prove acceptability limits in line with specifications, to include proctor tests (2.5kg rammer and 4.5kg rammer methods) with Cu and CBR relationship testing on remoulded samples.

If Made Ground is encountered, a Material Management and Cover Systems remediation approach is considered to be the most suitable and cost-effective solution for the site at this stage although further testing may be required, as explained later in this report.

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9.2.2 Glaciofluvial Deposits, GFDMP

The following observation can be made with respect to materials reuse of the Glaciofluvial Deposits, GFDMP encountered within the extents of the asset:

Table 9.85. Observations on material reuse for GFDMP

Plot ref	Parameter	N° tests	Observations on material reuse
Chetwode Cutting (GFDMP)	w%	10(C Z) 33 (S V SV)	ranges from 13% to 26% with an average of 18.5%. ranges from 6% to 22% with an average of 16.5%.
	PL/LL	3(C Z) 3 (S V SV)	The plastic limit ranges from 16.0% to 20.0% with an average of 18.0%. The liquid limit ranges from 46.0% to 49.0% with an average of 47.7%. The plastic limit ranges from 12.0% to 18.0% with an average of 15.5%. The liquid limit ranges from 30.0% to 42.0% with an average of 35.7%.
	Sieve analysis	4(C Z) 14(S V SV)	Ranges from 97-100% passing sieve 2 mm with an average 98% Ranges from 75% to 80% passing sieve 63µm with an average 78%
	TPS	7(C Z) 16(S V SV)	The TPS ranges from 0.04 to 3% with average 1.73% The TPS ranges from 0.04 to 0.13% with average 0.07%
	Compaction Test result	0(C Z) 2 (S V SV)	No asset specific value The maximum dry density ranges between 2.00 Mg/m^3 to 2.1 Mg/m^3. The optimum water content around 10%
	MCV	1 (C Z) 1 (S V SV)	No asset specific value Not representative
	CBR	0(C Z) 0 (S V SV)	No asset specific value No asset specific value

In conclusion, the GFDMP is described as a clayey silty very gravelly sand. The ratio is 74% gravelly sand and 26% silty clay. As the clayey fraction is not negligible, the analysis has been done for both sub-formations (GFDMP-CZ and GFDMP-SV SV).

The result shows plasticity indices of:

- GFDMP-CZ plasticity index ranges between 28% to 31% with average value of 29.7%, indicative of clays of intermediate to high plasticity. The high sulphate content leads to class the GFDMP-CZ as Class 2A material (cohesive).
- GFDMP-SV SV is a uniformly graded sandy material and is predominantly Class 1A.

It will be difficult to separate the 2 sub-formations on site. The GFDMP will be mainly governed by GFDMP-SV SV sub-formation as it represents more than 90% of the total formation.

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The average moisture content is around 17% for both sub-formations. The proctor test within the GFDMP gives an optimum moisture content around 10% which is considered appropriate for the reuse of materials.

Given the average natural moisture content of this material is higher than the optimum moisture content required for compaction, a drying of the material may be necessary to ensure a perfect implementation.

During favourable climatic conditions (summer period), open air drying may be considered. Alternatively, drying by lime stabilisation could be the safest solution.

During excavation, and regarding the high sulphate content expected in this formation, GFDMP-CZ should be used in landscapes or as General fill for Highways.

Based on available data, the most likely reuse for these materials would be the Main Line if the materials (Class 1) are stabilised to satisfy both stiffness and compaction requirement. However, it will be mandatory to perform further TPS test before stabilisation as the available data show the GFDMP-CZ sub-formation cannot be stabilised.

Further testing may be required to prove acceptability limits in line with specifications, to include proctor tests (2.5kg rammer) with Cu and CBR relationship testing on remoulded samples.

Careful extraction and deposition during the summer months may allow for reuse as General Highway Fills in its natural state, but this will need on-site quality checks.

A Material Management and Cover Systems remediation approach is considered to be the most suitable and cost-effective solution for the site at this stage although further testing may be required.

9.2.3 Oxford Clay, OXC.

The following observation can be made with respect to materials reuse of the Oxford Clay Formation, OXC encountered within the extents of the asset:

Table 9.86 : Observations on material reuse for OXC

Plot ref	Parameter	N° tests	Observations on material reuse
Chetwode Cutting (OXC-CZ)	w%	82	ranges from 12% to 57% with an average of 21%.
	PL/LL	34	The plastic limit ranges from 14.0% to 32.0% with an average of 20.6%. The liquid limit ranges from 38.0% to 65.0% with an average of 50.5%.
	TPS	44	The TPS ranges from 0.06 to 9.6% with average 2.88%
	Sieve analysis	11	Ranges from 90-100%
	MCV	10	Generally, between 6 to 13 with average around 10.
	Compaction	01	Not representative

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Plot ref	Parameter	N° tests	Observations on material reuse
	Test result		
	CBR	1	Not representative
	Cu	29	Generally, between 50 kN/m^2 and 200 kN/m^2 with average 100 kN/m^2 when w% is less than 25%

The test result on OXC formation shows that the plasticity indices range between 24% to 38% with average value of 30%, indicative of clays of intermediate to high plasticity. Due to the high sulphate content, the OXC formation is considered Class 2A or Class 4 material.

The average moisture content is around 21%. Further proctor test is required on this formation to identify the optimum moisture content. But it is anticipated that it will be lower than the previous average moisture content. Therefore, drying of the material may be necessary to ensure good compaction.

It considered not appropriate to stabilise this material with lime given the high sulphate content (2.88% average) recorded within the formation.

Based on available data, the most likely reuse for these materials would be the landscape bund. Moreover, the amount of the excavated OXC is limited to the Excavate and Replace in some areas of the cutting.

9.3 General Reuse

The table below summarise in accordance with HS2 Technical Standard for Earthworks Ref.[49], the condition of soil reuse for all the relevant formations of the cutting.

Proportion of each material has been defined regarding the long section and the volume of total excavation in the cutting (including volume for E&R).

The destination of each material previously defined has been proposed regarding ground uncertainty and moisture content uncertainty during works.

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Table 9.87 : Condition in soil reuse

Formation	Total Proportion in cutting (%)	SCEW Class	Reuse in landscape of the total formation (%)	Reuse in HS2 mainline of the total formation (%) (3)	Reuse in Non-mainline asset of the total formation (%)(3)
Glacial Till – TILMP (1)	50	Class 7E	-	80% (2)	20% (2)
	5	Class 2A	-	-	100%
Glaciofluvial Deposit – GFDMP – SV SV (3)	30	Class 1A	-	90% (4)	10%
Glaciofluvial Deposit – GFDMP – CZ (3)	5	Class 2A	-	-	100%
Oxford Clay – OXC	10	Class 2A or Class 4	100% (5)	-	-

Note: All references made to Mass Haul document SEQS (Summarised Earthworks Quantity Schedule) Doc N° 1MC06-CEK-GT-SCH-C002-600001.

(1) 55% of TILMP will be extracted from the total volume of Chetwode Cutting. 90% of the TILMP are class7E and assumed suitable for reuse as HSR fill after stabilisation. 10% of the TILMP are class 2Aand could be used as general fill for Highways.

(2) Regarding the uncertainty on moisture content expected during works, it has been assumed as a conservative approach that 20 % of the TILMP Class 7E material could not be stabilised during works and will be used as general fill for Highways.

(3) Ground investigations have shown the presence of GFDMP sandy clay lenses characterised by a high sulphate content and so, not suitable for stabilisation. Proportion of GFDMP-CZ is estimated at 5% of the total volume of Chetwode Cutting.

(4) Regarding the uncertainty on moisture content expected during works, it has been assumed as a conservative approach that 10 % of the GFDMP Class 1A material could not be stabilised during works and will be used as general fill for Highways.

(5) 10% of Class 2A OXC are expected to be extracted from the total volume of Chetwode Cutting excavation. Regarding the high moisture content of this material (22%), the high plasticity and the OPM (15%) reuse as general fill for Highway is not recommended. OXC will be used as landscape fill material.

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9.4 Imported Fill Material – Mainline asset

Due to the presence of formation with hig164nglian164164d content, lime stabilised materials are prohibited as replacement fills. Class 1A1 is recommended.

Class 1A1 material will be imported from Finmere Borrow Pit.

9.5 Imported Fill Materal – Non-Mainline asset

The earthwork quantities and detailed breakdown for Footpath CHW/18 realignment, School End Road Realignment and landscape bund are presented in the E-GDR Ref[9] and the SEQS Ref[25].

In accordance with the current EK mass haul, the non-mainline asset will be constructed with the following site won materials:

- Landscape bund: constructed with the site won materials from Turweston Cutting, Barton Hartshorn Embankment and Chetwode Cutting.
- The highway realignments will be constructed with site won materials from Chetwode Cutting.

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9.6 Remediation Strategy for Material Reuse

The proposed remediation strategy and material reuse criteria for the Chetwode Cutting Group has been captured in the Aylesbury Link and Dismantled Great Central Railway Remediation Outline Strategy Report Ref [17].
The remediation strategy and material reuse criteria are based on discussions with the Environment Agency (EA) Ref [67] [24].

Based on the above analysis, it can be broadly concluded that the data available across the site shows the following issues have been identified:

- Leachate exceedances of metals were reported in 7 locations.
- Groundwater exceedances of metals were reported in 3 locations.
- Made Ground located in one position on site.
- Based on proposed excavation depths and groundwater monitoring levels, groundwater is considered likely to be encountered during construction phase.

The risk to the proposed railway system and associated infrastructure across the site is considered moderate in view of direct contact with potentially contaminated soil and potentially poor-quality groundwater.

9.6.1 Preferred Remediation Strategy

The evaluation of the various remedial options has indicated that a Materials Management (segregation) and Cover Systems (appropriate placement of materials within the proposed earthworks embankments) is considered the most suitable and cost-effective remediation approach across the Site. This will provide a viable and effective solution for managing impacted materials and severing the identified source-pathway-receptor linkages through the placement of a cover layer of a minimum thickness of 600mm to protect human health end users.

9.6.2 Outline of Remediation Strategy

The outline of the remediation strategy is a summary of Section 4.1 of the Remediation Outline Strategy Report Ref[17].

- Segregation and cover system

Excavated materials will be segregated and moved to an appropriate area, based on the chemical characteristics of the Made Ground and the material re-use zone according to the zoning system discussed in Section 4. During excavation, a watching brief will be employed, and visual and or olfactory evidence of contamination will be immediately reported to the contaminated land supervisor.

- Watching Brief

A watching brief procedure should be put in place during construction, to ensure that if any unforeseen contamination, including asbestos, is encountered it is dealt with appropriately. This may involve additional chemical analysis and assessment of soils suspected of being contaminated to ensure that the appropriate action is undertaken.

- Site Clearance

Based on the ground investigation to date materials arising from site clearance will include hardstanding, building materials and vegetation. All materials following clearance shall be reused appropriately during the works.

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Cleared vegetation will be removed from site for composting, where suitable.

Demolished materials are to be processed crushed and incorporated within the works including underground obstructions, where encountered.

- Soils

Topsoil will be stripped before construction commences in line with the HS2 technical Standard MMP Framework. Excavated Topsoil will be retained on site and re-used during restoration of the area once construction activities have ceased. Topsoil derived from existing agricultural area will be replaced during restoration in accordance with appropriate handling and management practice/guidance, any Topsoil that does not meet these standards will not be re-used. Where further improvements are required to enhance the quality of Topsoil, an appropriate permit or exemption may be required as noted in the Waste Environmental Permitting Framework.

Treatment for Made Ground includes suitability testing for reuse, segregation, cover system depending on the type of material and level of contamination (in accordance with the threshold values given) or eventually disposal off site (as a last resort). Reference should be made to Section 5.0 of the Remediation Outline Strategy Report Ref [17] for more detail of the reuse of Made Ground.

Natural excavated arisings will be classified as inert, where segregated from Made Ground materials and free from cross-contamination. Hence, once characterised they will be considered chemically suitable without further chemical testing. All materials will need to be tested to ensure they are geotechnically suitable. Arisings will be stored in an appropriate manner to prevent leaching of metals from the material.

- Groundwater

Potentially contaminated ground water and perched water encountered during excavation / dewatering will be collected, tested, and removed/treated prior to discharge or offsite disposal.

- Ground Gas

The gas assessment to date suggests a CS1 such that it is unlikely that special precautionary measures are required in relation of ground gases.

- Unforeseen Contamination

Unforeseen contamination will be managed in accordance with the EKFB Construction Environmental Management Plan (CEMP) Ref [66].

9.6.3 Verification Procedure

A verification programme will be carried out for the duration of the works which will include sampling of Made Ground stockpiles. Details of the verification procedure are provided in the Aylesbury Link and Dismantled Great Central Railway Remediation Verification Plan Ref [77].

All records, testing and treatment/ disposal of previously undiscovered Made Ground or suspected contaminated materials shall be maintained in accordance with the details set out in Section 4 for inclusion in the final Verification Report.

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10 GI Impact Assessment

Geotechnical risks identified in section 3.8.7 are difficult to evaluate at the current stage of Detailed Design due to a lack of information on the presence, location, and extent of the hazard or design consideration. Table 10.**88** presents the outstanding Stage 2 GI received between Data Drop 3 and Data Drop 17 (December 2021). Hence, the idea in this section is to assess the impact of those additional GI on the earthwork design and mitigation presented in this GDR.

Table 10.88 – Outstanding GI (Data Drop 3 to 17 and Uncontrolled data up to December 21)

Acronym	Location ID	Data Drop N°	Status	Approximate Chainage	Comments
	UNCONTROLLED DATA				
CR	ML086-CR442	-	-		Chetwode Cutting
CT	ML085-CT422 ML085-CT424 ML086-CT427 ML086-CT428	-	-		Chetwode Cutting
	COMPLETED				
IP + CP + RC	ML085-CR400 ML085-CR401 ML085-CR408 ML085-CR409 ML085-CR413 ML085-CR414 ML085-CR425 ML086-CR401 ML086-CR411 ML086-CR443a ML086-CR444	Data Drop 6 Data Drop 6 Data Drop 16 Data Drop 16 Data Drop 16 Data Drop 13 Data Drop 17 Data Drop 6 Data Drop 14 Data Drop 16 Data Drop 16	FINAL FINAL Interim Interim Interim Interim Interim FINAL Interim Interim Interim	85+435 85+845 85+300 85+400 85+575 85+575 85+575 86+700 86+075 86+475 86+490	Chetwode Cutting Chetwode Cutting Chetwode Cutting Chetwode Cutting Footpath CHW/18 Footpath CHW/18 Chetwode Cutting Chetwode Cutting Chetwode Cutting School End Overbridge School End Overbridge
IP+CP	ML086-CP413 ML086-CR443	Data Drop 15 Data Drop 14	Interim Interim	86+130 86+475	Chetwode Cutting School End Overbridge

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Acronym	Location ID	Data Drop N°	Status	Approximate Chainage	Comments
TP	ML084-TP454	Data Drop 11	FINAL	84+940	Chetwode Cutting
	ML085-TP410	Data Drop 15	Interim	85+455	
	ML085-TP412	Data Drop 11	FINAL	85+530	
	ML085-TP417	Data Drop 11	FINAL	85+705	
	ML085-TP420	Data Drop 11	FINAL	85+900	
	ML085-TP421	Data Drop 13	FINAL	85+925	
	ML086-TP410	Data Drop 11	FINAL	86+060	
	ML086-TP415	Data Drop 11	FINAL	86+140	
	ML086-TP418	Data Drop 08	FINAL	86+245	
	ML086-TP419	Data Drop 14	Interim	86+360	
	ML086-TP438	Data Drop 16	Interim	86+735	
	ML086-TP445	Data Drop 14	FINAL	86+170	
	ML086-TP448	Data Drop 15	Interim	86+515	
CW	ML084-CW455	Data Drop 11	FINAL	84+945	Chetwode Cutting
	ML084-CW457	Data Drop 11	FINAL	85+000	
	ML085-CW416	Data Drop 11	FINAL	85+670	
	ML085-CW423	Data Drop 11	FINAL	85+800	
	ML086-CW429	Data Drop 11	FINAL	86+815	
	ML086-CW430	Data Drop 11	FINAL	86+845	
	ML086-CW439	Data Drop 11	FINAL	86+780	
IP+CPT	ML084-CT456	Data Drop 11	Final	85+000	Chetwode Cutting
IP+WLS	ML086-WS422	Data Drop 14	Interim	86+430	Chetwode Cutting
SL	ML086-SW412	Data Drop 12	Final	86+170	Chetwode Cutting
	ML086-SW414	Data Drop 12	Final	86+140	Chetwode Cutting
IP+RC	ML085-RO411	Data Drop 11	Interim	85+500	Chetwode Cutting
	ML086-RO417	Data Drop 14	Interim	86+200	Chetwode Cutting
OUTSTANDING GI					
WS	ML085-WS486 ML085-WS487 ML085-WS488	-	-	Variable	For the dismantled railway line – potential contamination

Note: The current GI impact assessment has been done only on the completed GI but not on the uncontrolled data.

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The uncertainty in design requires the impact assessment of outstanding GI (Table 10.**88**) to verify and validate the design at least 6 weeks prior to L3 (refer to Section 3.5). However, for this specific asset (due to the limited amount of available GI), an impact assessment has been done prior to IDR. The current GI impact assessment has been performed on partial GI and has to be completed with the last uncontrolled data/outstanding GI when validated.

Table10.89 presents those uncertainties in the design with the associated recommendations, based on the assessment of both laboratory and in-situ investigations. The assessment details are presented in appendix F.

Table10.89 - Uncertainty in Design. Actions and recommendations

Borehole ID	Risks	Target information	Action and recommendation for onward management
ML084-CW455 ML084-CW457 ML085-CW416 ML085-CW423 ML086-CW429 ML086-CW430 ML086-CW439	Rayleigh Waves	Vs of the ground from geophysical results	All the borehole data have already been included in the current GDR: No further GI assessment is required.
All CT; TP; IP+CP+RC; IP+WLS tests.	Presence of Soft Ground /variable weathering profile	Geological long section	The supplementary borehole logs confirm the ground model used in the current GDR. This has to be checked regarding the last uncontrolled data before L3.
All CT; TP; IP+CP+RC; IP+WLS tests.	Relic shear surfaces	fissures	Fissures and polished surface have been identified in ML085-CR413 and ML085-CR414 between 21m and 30m. However, regarding the depth of this polished surface, it is unlikely associated with relic shear surfaces.

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Borehole ID	Risks	Target information	Action and recommendation for onward management
ML085-CR400 ML085-CR401 ML085-CR408 ML085-CR409 ML085-CR413 ML085-CR414 ML085-CR425 ML086-CR401 ML086-CR411 ML086-CR443a ML086-CR444	Slope stability	In-situ and laboratory test results (controlled data)	The additional tests have been used to assess the impact on the parameters (including shear strength parameters) chosen in the current GDR: the plots are shown in appendix F. They confirm the design parameters for slope stability. Therefore, no 170nglian170l assessment is requuired. This has to be updated regarding the last uncontrolled data before L3.
ML085-CR400 ML085-CR401 ML085-CR409 ML085-CR413 ML085-CR414 ML085-RO411 ML086-CP413 ML086-CR401 ML086-CR444	Shallow groundwater	Groundwater Table	The additional ground water monitoring data confirm the design assumption in the current GDR (water level at within the GFDMP Formation). Refer to the plot in Appendix F for more details.

The impact level of outstanding GI in Table 10.**88** on geotechnical design is presented in Table 10.**90** .

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Table 10.90 - Impact on Geotechnical Design

Impact in Design	Analysis	Design impact	Action required
Geological ground model	Borehole description of controlled data	Low impact	No action recommended
Design parameters	Vs: CSW included in the RW analysis Compressibility and mec'anical parameters (c', ϕ', Cu, cv, E', E_{oed}, N_{SPT})	Low impact	No action recommended
Design mitigations	-	Low impact	No action recommended

It is needed to review the last final outstanding GI (currently in uncontrolled data) prior to L3, to confirm the design assumptions and the current GI Impact assessment.

In the latest available Datadrops, the 4 CPTs listed as uncontrolled in the table above are now in Datadrop 22. However, no available result showing qc vs depth are provided in these Datadrops for these CPTs. These 4 boreholes do not provide any additional information to compare to the assumptions considered for Detailed Design.

ML086-CR442 now available as Interim status in Datadrop 23 has been reviewed for the School End OB and associated highways (refer to the relevant sections 5 and 6).

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11 Geotechnical Risk Register

The Geotechnical risk register (GRR) has been updated to reflect the detailed design. An extract of relevant risks from the T2G delivery GRR Ref[3] and [4] is contained within Appendix D and records the geotechnical risk management strategy discussed within the design summary for each asset.

The following Table provides a summary of the 'level of risk' indicated in the GRR after ground treatment and implementation of various mitigations measures ; it proposes the method for the onward management of ground risks still carrying uncertainty, through: appropriate design, review of additional GI and field trials, specific requirements, construction stage management, testing and monitoring and the transfer of risks.

The communication of ground risks is developed further in the following sections of this DD-GDR:

- Section 10– GI Impact assessment – This section will outline uncertainty in ground conditions that require additional review of outstanding GI at the design stage, which may lead to a subsequent update of this GDR
- Section 12– Risk Management during Construction: this section will inform EKFB on any uncertainty in the ground model requiring construction stage management such as site inspection by a qualified geotechnical engineer or trial trenches
- Section 13– CDM Register: this register will inform on the HSE risks that will be transferred to EKFB or HS2
- Section 15– Inspection, testing and Monitoring Plan: this section will inform EKFB of the site testing and verification and/or monitoring plans required to control and manage the uncertainty related to design assumptions and requirements in order to comply to the Technical Standard requirements Ref[49] and the SCEW Earthworks 600 series requirements
- Section 16– Specification Appendices: this section will inform the earthwork engineers responsible for the development of the earthwork specification appendices on the asset specific specification requirements.

Table 11.91: Risk management strategy for the mainline – Extract GRR 08/02/2022

Geotechnical Risk ID	Level 2 Asset	Hazard Title	Residual Risk Rating	Detailed Design Mitigation	Uncertainty in Design	Impact Assessment on outstanding GI, field trialsl or DD study	Request additional GI	Asset specific specification requirements	Construction stage management	Verification Testing and I&M	Transfer to CDM
GEO_2314 GE–_T2G_0149	HS2-000001054 - Chetwod– Cutting HS2-000020864 - Chetwode ATS	Shrink / Swell	2	- Excavate and replace susceptible soils exposed to changes in moisture content : a minimum 2 m bFL is planned along the entire asset [Complete]	No	X	X	X	- Control drainage during works to limit change in water content of soil. - Use adequate temporary roads during works	X	Yes
GEO_2316 GE–_T2G_0148	HS2-000001054 - Chetwod– Cutting HS2-000020864 - Chetwode ATS	Chemically Aggressive Ground	2	- Adopt DS4 concrete class [Complete] - Use adequate material for dig-out and replace / Base of embankment which will be not impacted by aggressive ground : at Chetwode Cutting proposed replacement fill material is class1 [Complete]	No	X	X	X	X	X	X

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Geotechnical Risk ID	Level 2 Asset	Hazard Title	Residual Risk Rating	Detailed Design Mitigation	Uncertainty in Design	Impact Assessment on outstanding GI, field trialsl or DD study	Request additional GI	Asset specific specification requirements	Construction stage management	Verification Testing and I&M	Transfer to CDM
GEO_2312 GEO_T2G_0064 GEO_T2G_0052 GE–_T2G_0150	HS2-000001054 - Chetwod– Cutting HS2-000020864 - Chetwode ATS	Soft / compressible ground in TILMP and OXC Weathering profile in OXC	2	- Design has been performed using T2G routewide values in OXC and KLB in order to ensure a better reliability in the design parameters [Complete] - Conservative values have been used in design [Complete] - Foundation treatment is planned to manage differential ground movement or unacceptable subgrade performance : excavate and replace [Complete]	Decrease in subgrade performance in rainy period	- GI impact assessment (cf. 1MC06-CEK- GT-REP-CS06_CL10-000031, Section 10) confirm the ground model and geotechnical parameters used in the design [Complete]	X	- Remove and replace soft pockets of material at base of excavation - Use acceptable backfill materials to ensure adequate compaction and stiffness support : a class 1 material is planned as replacement fill with minimum EV2> 45 to 60 MPa [Complete]	- Control the total removal of soft spot by site inspeIng excavation [transfered to EK] - Adequate temporary slope design to be performed and adequate mImeasures to be planned) [transfered to EK] - Construction dul period : use adequate works road [transfered to EK] - The ground improvement should be backfilled immediately tolhe subgrade and prevent instability issues. [transfered to EK]	- Verification testing (refer to lions for minimum EV2 requirements at for–ation level) [transfered to EK]	Yes
GEO_3739 GEO_T2G_0048	HS2-000001054 - Chetwode Cutting	Heave due to stress relief		- Design has been performed using T2G routewide values in OXC in order to ensure a better reliability in the design parameters [Complete] - Heave calculations lead to no mitigation measures are required for this issue [Complete]	Permeability of the ground, duration of dissipation of heav movement after the excavation works	Trial cutting is being undertaken to increase the confidence in the geotechnical parameters considered for design [cl	X	X	Minor adjustments in the slab track systems where required [Transfered to HS2]	Monitoring of ground movement and verification of ground movement estimates during the cIn works . Minimum monitoring period of 6 monthsl excavation works[Transfered to EK] Monitoring of track movement during operation [Transfered–to HS2	Yes
GEO_4162 GEO_T2G_00–2 GEO_T2G_0063 GEO_T2G_0154 GEO_T2G_0155 GEO_T2G_0156	HS2-000001054 - Chetwode Cutting HS2-000020864 - Chetwode ATS	High / Shallow Groundwater Perched Groundwater Water bearing soils rocks	2	- Conservative groundwater level (top of GFDMP)) used in design and in calculations. [Complete] - Provision for slope drainage (counterfort drains) if water ingress il[transferred to EK]	Yes	X	X	- Temporary excavation to be done during low groundwater period Id to EK] - Observational approach to be planned during construclentify water ingress in slopes [transfered to EK] - Mitigation lill include provision for slope drainage [translK]	- Design of temporary slopes (E&R) to ensure stability if water [transfered to EK] - Temporary works to plan dewatering measures. [transfered to –K]	X	Yes
GEO_T2G_0053 GEO_T2G_00–4 GEO_T2G_0055 GEO_T2G_0056 GEO_T2G_0057 GEO_T2G_0589 –EO_T2G_0590 GEO_T2G_0591 GEO_T2G_0592 GEO_T2G_0152	HS2-000001054 - Chetwode Cutting HS2-00002BVHU - Chetwode Cutting Landscape Earthworks HS2-000020864 - Chetwode ATS	Existing Landslides Relict Periglacial Features	2	- Perform stability calculations with reduced cohesion to ensure safe slope angle and required bearing capacity [Complete] - Adopt gentle slope gradients [Complete]	Yes	X	X	X	Observational approach to follow potential ground movement during works and inspection of temporary excavation during works and permanent slopes as well [transferred to EK] Provision for slopes reinforcement to be deployed during construc–ion, if necessary[transferred to –K]	Instrumentation in order to monitor potential slope instability [Complete]	Yes

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Geotechnical Risk ID	Level 2 Asset	Hazard Title	Residual Risk Rating	Detailed Design Mitigation	Uncertainty in Design	Impact Assessment on outstanding GI, field trialsl or DD study	Request additional GI	Asset specific specification requirements	Construction stage management	Verification Testing and I&M	Transfer to CDM
GEO_2325 GEO_T2G_0151	HS2-000001054 - Chetwode Cutting HS2-000020864 - Chetwode ATS	Relict Periglacial Features	2	- As a conservative approach, stability calculations have been performed with reduced cohesion to ensure safe slope angle and required bearing capacity. [Complete] - A vadose zone has been integrated in the slope stab–lity calculation in order to take into account the progressive weathering of exposed strata. [Complete]	No	X	X	X	X	X	Yes
GEO_4108 GEO_4651	HS2-000001054 - Chetwode Cutting	Contaminated Ground	6	Mitigation could include excavation and disposal to landfill, isolation of potentially contaminated materials, temporary and permanent measures to control leachate and ground gas and mitigation for human health and protection of the environment	Targeted GI, laboratory testing and monitoring in identified LQ areas and locations of Made Ground outside these areas.	Update assessments as more data becomes available to feed into the earthworks and temporary works design, method statements for construction and design mitigation measures where identified.	Further GI including soil, leachate and groundwater sampling and testing has been proposed.– Appropriate risk assessment and PPE.	X	Discharge consents, de-watering, collect and treat/tanker contamination if necessary	X	Yes
GEO_4677	HS2-000001054 - Chetwode Cutting	Soft / compressible ground – Rayleigh Waves	4	Mitigation will comprise excavate and replace (0.5 to 2 m bFL)[Complete]	Geophysical survey performed before Datadrop 14 has been used in the design of the Raileigh Waves mitigations. [Complete]	X	X	- Use acceptable backfill materials to ensure adequate compaction and stiffness support : a class 1 material is planned as replacement fill with minimum Vs > 250 m/s	X	Construction validation testing to confirm performance criteria has been achieved and to conf–rm mitigations at the transition –ith adjacent embankments (Asset Specific) [transferred to EK]	No
GEO_T2G_0065 GEO_T2G_0158 GEO_T2G_0159	HS2-000001054 - Chetwode Cutting HS2-000020864 - Chetwode ATS	Soft / Compressible Ground Presence of local made ground	2	Ground improvement of founding soils include **provision** for total removal of made ground. [transferred to EK] ATS platform : 0.60 m subgrade improvement Class 6 [Complete]	No GI where made ground is expected. However. The presence of made ground is expected in a very limited area.	X	X	Use acceptable backfill materials to ensure adequate compaction and stiffness support: a class 1 material is planned as replacement fill with minimum EV2> 45 to 60 MPa [Complete]	- Adequate temporary slope design to be performed and adequate mitigation measures to be planned (dewatering measures if needed) [transferred to EK] - Construction during rainy period : use adequate works road [transferred to EK– -Inspection to insure any Made –round is removed during construction stage management transferred to EK]	X	Yes
GEO_T2G_0066 GEO_T2G_0160	HS2-000001054 - Chetwode Cutting HS2-000020864 - Chetwode ATS	Obstructions	2	Provision–or total – emoval of made ground	Made ground could contain obstructions	X	X	X	Using adequate engine during works [transferred to EK]	X	X
GEO_T2G_0051	HS2—00001054 - Chetwode Cutting	Seismic–3	Slope stability analysis with s–ismic conditions and proposed suitable se angles. [Complete]	X	X	X	X	X	X	X	

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Geotechnical Risk ID	Level 2 Asset	Hazard Title	Residual Risk Rating	Detailed Design Mitigation	Uncertainty in Design	Impact Assessment on outstanding GI, field trialsl or DD study	Request additional GI	Asset specific specification requirements	Construction stage management	Verification Testing and I&M	Transfer to CDM
GEO_T2G_0073 GEO_T2G_0161	HS2-000001054 - Chetwode Cutting G. HS2-000020864 - Chetwode ATS	Loose / unstable ground	4	1. Design completed with additional load impact on slope stability (landscapes, overbridges, ATS platform) [Complete] - Appropriate Design slopes (1V/3H in GFDMP) to ensure long term stability [Complete]	X	X	X	- Sequential excavation over limited length (for temporary excavation for E&R [transferred to EK] - The ground improvement should be backfilled immediately to protect the subgrade and prevent instability issues. [transferred to EK] - Respect of the the construction sequence planned for Overbridge embankments in the GDR [transferred to EK]	Adequate mitigation measures/temporary slope design and dewatering measures to be planned by EKFB to ensure temporary slope stability [transferred to EK] Temporary slopes in GFDMP not stable without mitigation measures during works. Adequate mitigation measure to be planned by EKFB to ensure temporary slope stability [transferred to EK] - Provision for mitigation measures if the observational approach during construction show a water inflow : blanket layer / counterfort drain –ith appropriate drainage [transferred to EK]	Instrntation planned to monitor potential slope instabilities [Complete]	Yes
GEO_T2G_0071	G. HS2-000001054 - Chetwode Cutting	Existing Buildings / Property	2	1. Ground movement impact assessment has been performed [doc n° 1MC06-CEK-GT-REP-CS06_CL10-000028. [Complete] NOTA: Some building are far enough to avoid mitigations No I&M is planned for 3rd party assets	Existing buildings conditions	X	- Walkover survey	X	Observational approach of existing buildings during c–nstruction [transferred to EK]	1.Walkover su–vey to be planned to check the existing buildings condition [TBC]	Yes
GEO_T2G_0723	HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Flood Risk	4	No action required	X	X	X	X	X	X	Yes

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Table 11.92 provides a summary of geotechnical risks indicated in the GRR after mitigation and proposes the method for the onward management of ground risks still carrying uncertainty through: appropriate design, review of additional GI and field trials, specification of specific requirements, construction stage management, testing and monitoring, and the transfer of risks, specific for Footpath CHW18 accommodation overbridge and School End overbridge.

Table 11.92: Risk management strategy for the overbridges

Geotechnical Risk ID	Level 2 Asset	Hazard Title	Residual Risk Rating	Detailed Design Mitigation	Uncertainty in Design	Impact Assessment on outstanding GI, field trialsl or DD study	Request additional GI	Asset specific sp–cification requirements	Construction stage management	Ver–fication Testing and I&M	Transfer to CDM
GEO_1967 GEO_2056 GEO_2063 GEO_T2G_0623	HS2-000001321 - Footpath CHW/18 Accommodation Overbridge HS2-000001322 - School End Overbridge	Heave due to stress relief	4	Heave effects are assessed through a complete modelling. Additional heave induced forces and displacements are calculated and taken into account in the structural design of the piles and the overbridge.	No	X	X	X	X	Instrumentation implemented to measure displacements during the excavation (start–ng from the beginning of the excavation). These measureme–ts help validate the calculation models and input data	Yes
GEO_1969 GEO_T2G_0624	HS2-000001321 - Footpath CHW/18 Accommodation Overbridge HS2-000001322 - School End Overbridge	Shear surfaces (relic)	3	Gentle excavation slope (4H/1V). Slope stability has been verified along the level 1 asset (Chetwode cutting)	No	X	X	X	Regular visual inspection of temporary slopes	X	Yes
GEO_T2G_0749 GEO_T2G_0750	HS2-000001321 - Footpath CHW/18 Accommodation Overbridge HS2-000001322 - School End Overbridge	Uncertain GI Data	6	Adjust pile length if Cornbrash formation top level is different than expected	No	X	X	X	During piles boring, it is requested to identify the level of the Cornbrash formation top. If the CB formation top is such as the embedded length of the pile in this formation is less than its diameter, it is required to increase the pile length. The pile length is increased until an embedded length of the pile in CB formation is equal to its diameter at least	X	Yes

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12 Risk Management during construction

12.1 Risk Management for Earthworks

A number of hazards identified in Section 3.8.7 are difficult to account for in the scheme design due to a lack of information on the presence, location, and extent of the hazard or design consideration. These will need to be addressed as and when additional information is obtained from further GI and through observation during construction.

The subsequent sections summarise the risks and provide an indication of the type of mitigation that may need to be deployed should the particular hazard be encountered.

12.1.1 Inspections and verification testing

inspections and verification testing is recommended to confirm and to validate the treatment of the following risks:

- Loose/unstable ground in temporary excavation: Perform adequate temporary slope design to ensure stability.
- Water ingress/Flooding in temporary excavations:
  - Water monitoring (brook) and weather moni–oring to prevent flood issues
- Potential for relic shear surfaces:
  - Walk over survey during works to identify the presence of potential relic shear surface - including in the excavation planned for the E&R
- Subgrade Dynamic Performance (Rayleigh Waves) :
  - Direct geophysical testing (CSW) at transition with the adjacent embankments
- Subgrade Static Performance (EV2) :
  - Direct testing to follow HS2 requirements at formation level (especially at the transition with the adjacent embankments)
- Highways:
  - Laboratory testing with CBR (soaked and unsoaked)

12.1.2 Excavate and replace of soft soils

There is a risk of:

- thicker / softer ground than anticipated in the current analysis (in TILMP or OXC) will be encountered locally at foundation level, leading to the need for additional ground improvement by excavate and replace.
- unachievable bearing capacity requirements and Rayleigh Wave requirements in the founding soils at formation level, where the above geological formations are present.

This risk will be managed with a specific foundation treatment (E&R).

This risk will be managed by site inspection of the excavation base during works. A sequential excavation over limited length should be planned, and the ground improvement should be backfilled immediately to protect the subgrade and prevent any issues

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The constructor will plan adequate temporary roads.

The acceptable performance criteria will be confirmed with construction validation testing (EV2 and Vs for Rayleigh Waves issue)

A risk allowance for additional excavate and replace is recommended in order to achieve a total removal of soft spots (Cu<50kPa) and/or obtain the adequate subgrade performance.

Soft spots (Cu<45 kPa) should be also removed below landscape bunds.

12.1.3 Loose/Unstable Ground

For the permanent slopes, the risk of loose/unstable ground resulting in the failure of the excavation is managed through:

- Conservative parameters / ground water level using in design
- Observational approach of cutting slopes/base E&R / base of landscape bunds during construction
- Monitoring instrumentation as topographical targets on slopes + inclinometers at the top of the cutting

For the temporary slopes, the temporary work designer should use conservative parameters/groundwater assumptions.

In GFDMP, it is assumed that the temporary slopes must be slackened to ensure stability. Temporary retaining structure should be employed to ensure the temporary stability in the respect of permanent slope design.

12.1.4 Shrink-swell

There is a risk of variations in water content within the highly plastic fine-grained soils (TILMP and OXC-C), which could lead to shrink-swell ground movements (changes in volume).

The potential risk impacts are the shrinkage and swelling of formation soils and causing changes in ground stress and the development of earth pressures, ground movement and cracking in soil deposits, the longitudinal and the lateral shrinkage / swelling in subgrade formation leading to uneven track profile and unacceptable total and differential ground movements.

This risk is managed in design by:

- According to HS Railways design and construction international standards, the shrink/swell behaviour of high plasticity clays at subgrade level is mastered through compliance with the suitability rules of soils for substructure works.
- Control drainage to limit change in water content of soil during works.
- Excavate and replace of susceptible soils exposed to changes in moisture content.
- Use adequate temporary roads

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12.1.5 Groundwater Management

Based on available groundwater monitoring data, there is a risk of encountering perched groundwater in the TILMP and GFDMP during construction. This water ingress can cause slope instability and loss of strength in clayey soils.

The stability calculations performed are considering conservative ground water level.

Open standpipe piezometers need to be installed prior to construction to fix baseline water levels and monitor water levels during construction as the Design and Monitoring Plan of Chetwode Cutting Ref [10] mentions it.

It is recommended to construct the mainline during dry season.

During construction, an observational approach is recommended to identify the area of seepages and water ingress, sandy layers and pockets which could be prone to water ingress, and slope instability (erosion).

Provision for dewatering, sumps and slope drainage (as counterfort drains) must be planned.

12.1.6 Mitigation for relic slip surfaces / Potential existing landslides

The risk of instability due to existing relic slip surfaces along HS2 Line is considered to be moderate due to the transversal natural slope gradient (between 5 and 10° at some locations).

Periglacial shears develop in clay-rich materials that have experienced long-term freeze-thaw processes (Spink, 1991, Ref [79]). The processes act to weaken the in-situ geology, which will develop atypical geotechnical properties that require specific geotechnical consideration during interpretation of ground investigation data and subsequent design.

Periglacial shears are likely to be encountered in clay-rich materials down to maximum 5m depth. According to the available data, periglacial shears are likely to be encountered in superficial TILMP deposits and OXC.

The main risk is to reactivate potential relict slips and to cause slope instability and ground movement which can include delay or cessation of work.

Mitigations for this risk include:

- Conservative parameters used in the design
- Observational approach of cutting slopes/base E&R / base of landscape bunds during construction
- Monitoring instrumentation as topographical targets on slopes + inclinometers at the top of the cutting
- Provision for slope reinforcement must be planned as part of the design.

12.1.7 Chemically Aggressive Ground

There is a risk of high degradation of construction materials and/or the creating an adverse environmental impact due to the elevated levels of sulphates, sulphides or high/low pH in OXC.

These elevated levels can lead to the chemical attack on concrete slab of the adjacent structures and, to a limited reuse of materials due to adverse reactions during modification with lime resulting in an increase of imported materials or larger haul distances, to an increase of volume of landscape fill and to a limited use of as dug or stabilised materials.

This risk is managed in design by:

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- Recommending BRE Special Digest SD1 Ref[34], adopting correct concrete class accordingly (DS5 AC4 is recommended),
- Undertaking material specific durability and volumetric stability tests during construction where soil re-use or soil stabilisation is proposed,
- Using adequate material for dig-out and replace which will be not impacted by aggressive ground (Class 1 material is planned),

12.1.8 Base heave due to stress relief

Stress relief due to unloading of the ground in the base of deep cuttings in highly plastic over-consolidated clays and mudstones will result in heave effects at the cutting base. It is a time dependent process that occurs at a rate linked to the permeability of the in-situ materials. There will be a tendency for volume change as the in-situ materials are unloaded during excavation.

The Oxford Clay Formation is likely to be subject to base heave because of stress relief.

Calculation performed shows no need for mitigation measures.

However residual risk is managed using:

- Excavate and replace planned below formation level will reduce this risk
- Topographical target at formation level to be monitored (minimum monitoring period of 6 months to confirm stabilisation of ground movements);
- During operation and maintenance, the track movement should be monitored and the slab track systems should be adjusted where required.

12.1.9 Contaminated Ground

The contaminant risk assessment has been restricted to the HS2 identified Land Quality (LQ) areas only that were identified in the Environmental Statement, Ref [55] and Ref [56]. The primary potential source of contamination identified within the Chetwode Cutting Group area is the Dismantled Rugby to Quainton Great Central Railway (LQ 13.07) which is situated parallel and southwest to the Chetwode Cutting Group and is predominantly located within the LLAU, with one small section within the LOD of School End Road overbridge/ realignment (see Image below).

The contamination risk assessment within the Aylesbury Link and Dismantled Great Central Railway Geo-Environmental Assessment Report, Ref [64] has identified potential risks associated with soil, human health, controlled waters and property pollutant linkages. Chetwode Cutting Group inte180nglianwith the Dismantled Rugby to Quainton Great Central Railway (LQ 13.07) in one LOD location within the LOD of School End Road Overbridge/ Realignment approx. Ch 86 + 400. However the Chetwode Cutting Group is, in general, within close proximity to the LQ 13.07, therefore risks remain from potential contaminated groundwater and ground gas migration. Mitigation measures, where appropriate, are captured in the Aylesbury Link and Dismantled Great Central Railway Remediation Outline Strategy Report Ref [17].

12.2 Risk Management for Structures

Refer to Table 11.92.

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13 CDM Register

In accordance with the requirements of Lead Designer under the CDM Regulations 2015, a Designers Risk Assessment has been undertaken in connection with the geotechnical design of the earthworks.

Reference should be made to the CDM Risk Register Document Ref[15] for details of the general and asset specific risks associated with this earthwork design.

Risks which need to be captured in the CDM are listed in section 11.

The following risks have an impact on health and safety and will be updated to the CDM register:

- Working in areas of soft ground and shrink Swell (slips and falls of machinery and site workers);
- Ground instability: due to relict slip, existing landslide, E&R in sandy facies of GFDMP formation and groundwater ingress
- Contaminated land associated with existing Dismantled Rugby to Quainton Great Central Railway (LQ 13.07);
- Ground gas
- Health disorders due to lime stabilisation activities;
- Flooding of sub-excavations by excessive rainfall/rising groundwater during construction.
- Stability of temporary slope (Excavate and Replace) in Chetwode cutting, especially when excavating in GFDMP sandy formations.
- Temporary excavation collapse/failure due to loose/unstable ground or water ingress
- Uplift movement due to heave prone strata;

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14 Ground Movement Impact Assessment

The HS2 works will generate ground movements in and around the footprint of the HS2 route due to stress changes in the ground resulting from earthworks construction and associated impacts on the groundwater table. The main sources of ground movement are settlement beneath embankment and loaded area, ground movement due to stress relief in cuttings and settlement due to dewatering.

The existing 3rd Party owned assets in the surrounding area of Chetwode Cutting have the potential to be adversely affected as a result of the potential scale and pattern of ground movements generated by Chetwode Cutting.

The specific 3rd party assets which are at Chetwode Cutting and their location are listed in the GMIA report Ref [14].

The ZoI has been reassessed during Det182nglianesign.

The impact of HS2 works on the third-party assets identified can be summarised as follows:

- Anglian water utility UTI-WAM-022 at ch. 085+440, anglian water utility UTI-WAM-023 at ch. 086+440, WPD electricity utility UTI-ELC-013 at ch. 085+495, WPD electricity utility CSO-03-1306 at ch. 085+460 are all subjected to 30 mm settlement. **They pass phase 2 by screening therefore no further assessment is required.**
- The BT Openreach telecom utilities (CSO-03-3106 and CSO-03-3102 respectively at ch. 086+450 and 085+580) are subjected to settlement < 50mm. **They have passed phase 2 by screening: no further assessment is required.**
- **All the buildings have passed phase 2 assessment by screening because they are subjected to settlement less than 10 mm. No monitoring is required.**

BRI-HWY-001 is located at the boundary of the updated ZoI. The ground movement due to the landscape bund on the bridge is therefore negligible: **no monitoring is required.**

No monitoring is required for 3rd party assets in the Chetwode Cutting area.

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15 Inspection, Testing and Verification Plan

15.1 Earthwork's control and verification requirements

The details of Earthworks Control and Verification Plan are given in:

- HS2 Specification for Civil Engineering Works. Series 0600: Earthworks (Document No. HS2-HS2-CV-SPE-000-010600)
- IDR 221 .1 Specifications, Document No: 1MC06-CEK-AU-SPE-CS06-000007. Ref.[15] – Appendix 6/1 to 6/15 and Appendix 1/5.
- IDR 221 .2 Specification, Document No: 1MC06-CEK-AU-SPE-CS06-000008. Ref.[92] – Appendix 6/1 to 6/15 and Appendix 1/5.

15.2 Preconstruction GI and Verification Testing

Based on the available GI data for this asset, no additional Pre-Construction GI is requested for Chetwode cutting mainline earthworks.

Verification testing during construction is required to verify the ground conditions and associated parameters adopted for design based on a review of the current scope of the EKFB Supplementary GI for Stage 2.

The minimum list of required verification testing is detailed in Table *15*.93. below for information. For more details, refer to the IDR 221.1 Specifications Ref.[15].

Table 15.93. Verification testing

GI Type	Approximative No of exploratory holes / length	Indicative depth (m)	In situ/Laboratory testing	Comments/Notes
MASW or CSW	100 ml between Ch. 84+925 and Ch. 85+025 (TILMP at transition with Chetwode Embankment) 100 ml between Ch. 85+250 and Ch. 85+350 (in OXCu) 100 ml between Ch. 85+650 and Ch. 85+750 (clayey GFDMP) 100 ml between Ch. 86+200 and 86+300 (Sandy GFDMP) 100 ml between Ch. 86+750 and Ch. 86+850	Formation level	-	- Verification testing for dynamic performance at transition with the cutting

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GI Type	Approximative No of exploratory holes / length	Indicative depth (m)	In situ/Laboratory testing	Comments/Notes
Plate bearing test	2 tests (base and top of E&R) between Ch. 84+925 and Ch. 85+025 (TILMP at transition with Chetwode Embankment) 2 tests (base and top of E&R) between Ch. 85+250 and Ch. 85+350 (in OXCu) 2 tests (base and top of E&R) between Ch. 85+650 and Ch. 85+750 (clayey GFDMP) 2 tests (base and top of E&R) between Ch. 86+200 and 86+300 (Sandy GFDMP) 2 tests (base and top of E&R) between Ch. 86+750 and Ch. 86+850	Base of E&R Top of E&R	-	- Verification testing for static performance at transition with the cutting after E&R trial

In addition to the above, a visual inspection of the exposed formations is required during works for design verification.

15.3 Instrumentation and Monitoring

Instrumentation and monitoring within the HS2 contract area for this stage is included within a separate asset specific document, namely Chetwode Cutting Designer's Monitoring Plan Ref.[10].

In summary, Instrumentation arrays will be applied in several different locations along the Chetwode Cutting's mainline, as follows.

- Ch. 85+300 – 3D Geodetic prism proposed to be installed during construction to control potential slope instability and heave after excavation
- Ch. 85+450 – 3D Geodetic prism proposed to be installed during construction to control potential slope instability and heave after excavation
- Ch. 85+550 – Manual inclinometer and standpipe before construction, 3D Geodetic prism during construction to control potential slope instability (risk Level 2) and heave after excavation
- Ch. 86+260 – Manual inclinometer before construction and 3D Geodetic prism during construction to control potential slope instability (risk Level 2) and heave after excavation
- Ch. 86+500– 3D Geodetic prism proposed to be installed during construction to control potential slope instability and heave after excavation

Instrumentation arrays will be applied in two different locations (at the approach embankments of the overbridges) along Chetwode Cutting, as follows.

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- Ch. 85+600 – Footpath CHW/18 Accommodation Overbridge, installation of 3D Geodetic Prism to control Ground Movement associated with settlements at transition with the overbridge and Magnetic extensometer + Manual Inclinometer to control heave on piled foundations.
- Ch. 86+480 – Near School End Overbridge, Magnetic extensometer, and Manual Inclinometer to control heave on piled foundations

The monitoring at key locations will be carried out using Inclinometers and surface monitoring points (topographical targets).

In this regard, reference has been made to the HS2 Specification for Civil Engineering Works' Series 4500 – Instrumentation and Monitoring.

The Instrumentation arrays, monitoring periods, locations for the instruments and instrumented boreholes details are presented in the Designer's Monitoring Plan Ref.[10].

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16 Specification Appendices

The specification appendices Ref[15], Ref[92] determine the contract specific requirements to the main HS2 SCEW Series 600 Earthworks Ref[51]. They include the following:

- Appendix 6/1 Requirements for Acceptability and Testing etc. of Earthworks Materials
- Appendix 6/2 Requirements for Dealing with Class U1B and Class U2 Unacceptable Materials
- Appendix 6/3 Requirements for Excavation, Deposition, Compaction (other than Dynamic Compaction)
- Appendix 6/4 Requirements for Class 3 Material
- Appendix 6/5 Geotextiles Used to Separate Earthworks Materials
- Appendix 6/7 Sub Formation and Capping and Preparation and Surface Treatment of Formation
- Appendix 6/8 Topsoiling
- Appendix 6/9 Earthworks Environmental Bunds, Landscape Areas, Strengthened Embankments
- Appendix 6/10 Ground Anchorages, crib walling and gabions
- Appendix 6/11 Swallow Holes and other Naturally Occurring Cavities and Disused Mine Workings
- Appendix 6/12 Instrumentation and Monitoring
- Appendix 6/13 Ground Improvement

The following list captures the geotechnical output and considerations that will need to be developed in the specification appendices:

- Works methodology ensure short term stability and adequate dewatering measures of sub-excavations
- Reuse of excavated materials as landscape fill (mitigation bund and landscape), railway fill (upper and lower embankment), highway fill, ground and slopes improvement, structural backfill (Green Tunnel and Overbridges) and also for temporary usage (surcharge, Temp. Protection Layer,)
- Requirements for backfill materials to ground improvement due to high sulphate contents in natural soils and groundwater. Stabilisation is not recommended.
- Requirements for backfill materials and specific drainage for E&R excavations in impermeable clays
- Demonstration area for natural subgrade at cut and fill transitions
- Backfill to ground improvement (granular soils)
- Dewatering with the use of blanket layer or counterfort drain with appropriate drainage
- Construction sequence for the installation of the landscape bund and the ATS platform
- Instrumentation and monitoring
- Total removal of soft spots (Cu<45kPa) below landscape bunds.

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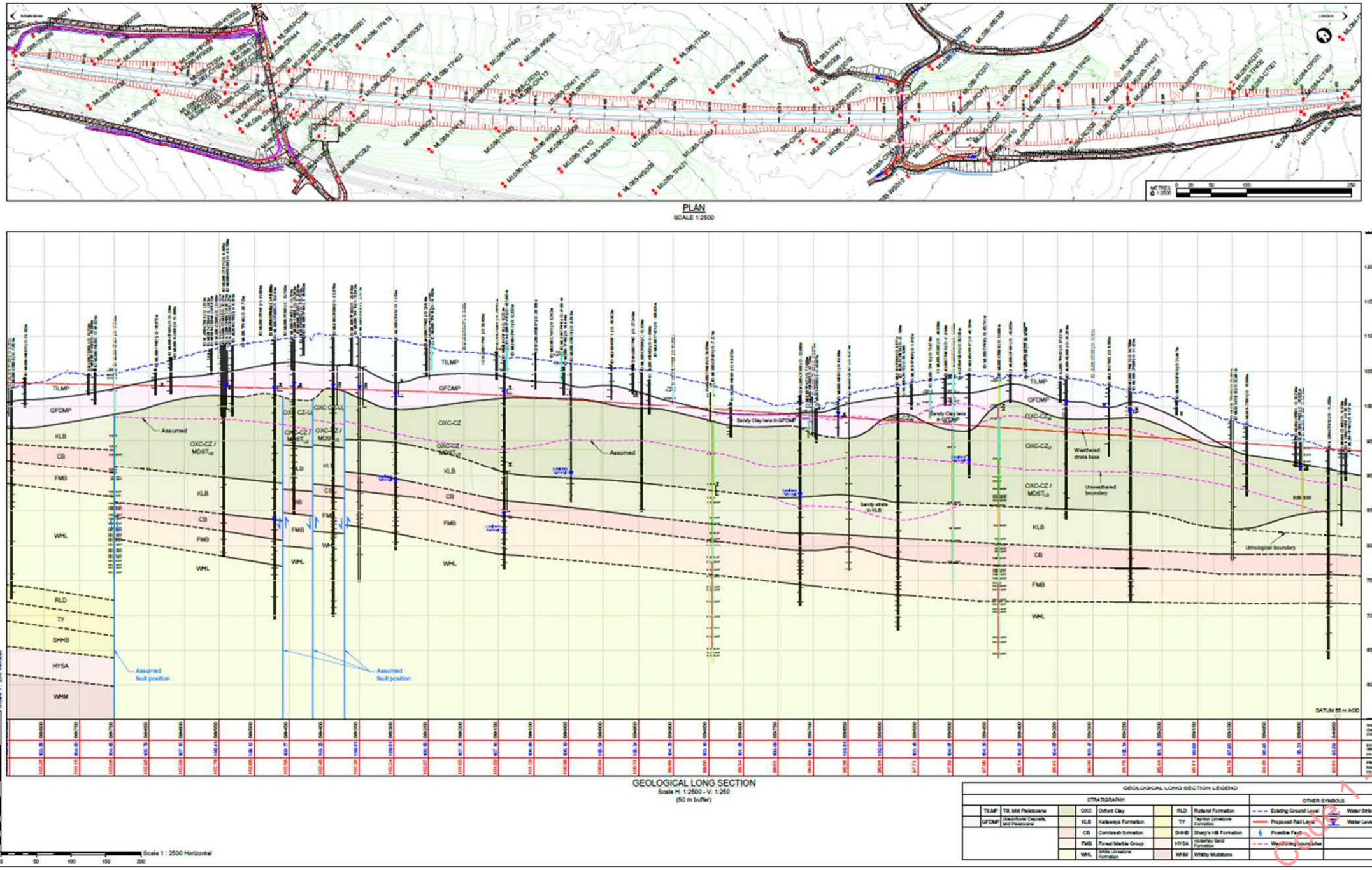
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APPENDIX A

Ground Investigation Plan and Geological Long Sections – Datadrop 2

Number of Pages: 1

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APPENDIX B

Justification of Characteristic Design Parameters – Mainline Earthworks

Number of Pages: 69

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General design methodology

Geological descriptions and geotechnical parameters used in earthworks design have been derived from several sources including published data, previous HS2 reports such as the Geotechnical Desk Study Report Ref[45] and asset specific GI data as described in the GIR Ref[6].

Where the asset specific GI data are not sufficient to perform the design, the GI analysis has been extended to adjacent structures and assets, with similar ground conditions.

Cautious design values have been estimated, in line with EC7 guidance.

Geotechnical parameters have been defined, for each material, by the analysis of:

- In situ test results
- Laboratory test results
- Usual correlations
- Typical design values for the geological formation based on UK experience

GI Data

The GI data used for the geotechnical design of the asset are asset specific, when the amount of ground investigation is sufficient.

For some parameters, where the GI data at the location of the asset are not sufficient, a routewide value has been adopted.

For Chetwode Cutting, the asset specific analysis is based on ground investigation performed on the asset.

When the available asset specific GI through Chetwode Cutting are not sufficient, the analysis of ground parameters has been performed through the “Clay Vale” (geological condition characterised by outcropping Jurassic Clays), regarding GI from Cowley Embankment to Barton Hartshorn Embankment (from Ch. 82+349 to Ch. 87+204).

GI from the Data drop n°2 have been used for the current analysis.

No additional GI have been received for this asset from the datadrop n°3 to the datadrop n°6.

Effective stress parameters

The selection of effective stress parameters in over consolidated clays has considered the following guidance by Nowak and Gilbert for the selection of drained parameters:

- Intact clays will use max. *c*’=5kPa
- Fissured clays will use max *c*’=3kPa

In Quaternary superficial deposits a cautious value of c’ = 0 kPa has been used.

Homogeneity of the strata/ Geological description of the strata

Glacial Till deposits are characterised as a slightly sandy slightly gravelly clay. Presence of Gravel/silts will accelerate the consolidation process.

Glacio-fluvial deposits are identified as sand and gravels with bands of sandy clay.

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Oxford Clay Formation (OXC) is described as a laminated clay with fine bands of shell fragments and sand. It is considered that these thin bands will accelerate the consolidation process. Deeper, in unweathered strata, the OXC is described as a stiff to very stiff clay and mudstone.

Kellaways Formations (KLB) is separated in 2 distinct lithologies: a sandy stratum on the top of the formation which is assumed to be continuous all along the asset, and a clayey stratum at the base. The sandy stratum is assumed to be prone to immediate settlement only.

Regarding the geological conditions and the presence of a sand layer on the top of KLB, the drainage path length could be estimated as the half of clayey strata thickness.

Correlations used in design

- Friction angle in granular soils could be estimated with the relation defined by Peck & al. (1974)
- $c_u = k * Nspt$; where c_u=undrained shear strength and K ranges between 4.5 and 5 for cohesive soils (CIRIA R143) Ref.[42]
- $E' = K \cdot Nspt$ where K=0.6-0.9 for normally consolidated or weathered clayey soils; and K=0.6 for over-consolidated clayey soils; and K = 1-2 for gravelly sandy soils (CIRIA R143) Ref.[42]
- PI is used to find $E_{oed} = 1/m_v = f_2 \cdot N$ (Tomlinson and Woodward, 2001 Ref[60])
- The following relationship with Total Sulphur TS (%) is considered: TPS (%)= TS(%) · 3

Guidance and correlations/derivations used to justify the geotechnical parameters are based on the Technical Note – Guidance on the Assessment of Settlement Ref[31].

Deformation Modulus relationships:

- ν'=Poisson's ratio=0.2 is assumed
- $E' = E_u \frac{1+\nu'}{1+\nu_u}$ Where: E'=Young Modulus; E_u=Undrained Young Modulus; ν'=Poisson's ratio=0.2 and ν_u=Undrained Poisson's ratio=0.5.
- $E' = E_{oed} \frac{(1-2\cdot\nu')\cdot(1+\nu')}{1-\nu'}$ Where: E'=Young Modulus (see below); E_{oed}=Oedometer Modulus; and ν'=Poisson's ratio=0.2

- In stiff to very stiff over consolidated clays or in weak mudrocks, Eu/Cu for clays could be estimated thanks to plasticity index and OCR. A ratio of 150 is applied for stiff clays and a ratio of 300 is applied for mudrocks/very stiff clays of the Jurassic age.
- Compression and swelling indexes (c_c and c_s) from oedometer tests are not used for settlements calculations.
- Coefficient of consolidation is defined as $c_v = \frac{k}{m_v \cdot \gamma_w}$ where: c_v=coefficient of consolidation (m^2/s); k=hydraulic conductivity (m/s), m_v=coefficient of volume change (m^2/kN) γ_w=unit weight of pore fluid/water (kN/m^3)
  - As the k is proportionally related c_v and it is assumed that $c_{v_insitu} = 4 \cdot c_{v_lab}$, it is also assumed that $k_{_insitu} = 4 \cdot k_{_lab}$
  - Due to limited data, it is assumed that $c_r = 2.5\ c_{v_insitu}$.

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Plots References:

The following table presen–s the different geotechnical plots created for each geological formation.

Table 17.94 - Geotechnical Plots Summary Table

Formation	1. Particle Size Distribution	2. Atterberg Limit Plot	3. Atterberg values vs depth	4. total sulphur vs depth	5. SPT-N_{60} vs depth	6. CPT vs depth	7. Undrained Shear Strength Vs Depth	8. Normal Stress Vs Shear Stress (triaxial or Shear box where relevant)	9. E Vs Depth	10. Eoed Vs Depth	11. Cv vs Depth	12. Shear Waves Velocity profile Vs Depth
Glacial Till Deposits (TILMP-CZ)	A.1	A.2	A.3	A.4	A.5	A.6	A.7	A.8 (2)	A9	A10	N/A	A12
Glavo Fluvial Deposits (GFDMP-S SV)	B.1	N/A	N/A	N/A	B.5	B.6	N/A	N/A	N/A	N/A	N/A	B12
Oxford ClayFormation – Weathered (OXCw-CZ)	C.1	C.2	C.3	C.4	C.5	C.6	C.7	Ca.8 (1)	Ca.9	Ca.10	C.11	C12
Oxford Clay Formation – Unweathered (OXCu1-CZ)	C.1	C.2	C.3	C.4	C.5	C.6	C.7	Cb.8 (1)	Cb.9	Cb.10	C.11	C12
Kellaways Formation – Sandy (KLB-S SV)	N/A	D.2	N/A	D.4	N/A	D.6	N/A	Da.8 (1)	N/A	N/A	N/A	D12
Kellaways Formation – Clayey (K–B- CZ)	N/A	N/A	D.3	D.4	D5	N/A	D.7	Db.8 (1)	D9	N/A	D11	D12

(1) Results from Cu+U triaxial tests

(2) Results from Shear box tests

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A- GlacialTill deposits – TILMP - CZ

The table provides brief commentary on :

- the type and quantity of tests to prove the geotechnical design values,
- general trends of geotechnical values with depth,
- the plots used to determine the design values of each geotechnical parameter.

Reference to the plots of the GDR for confirmation of characteristic design values adopted in the geotechnical calculations.

Table D- 1. Commentaries and justifications related to the design geotechnical parameters for TILMP

Parameter	Symbol	Commentary / Justification	Plots	Design Value
Fines content	#0.063	• Fines content is comprised between 30% and 84% of particles passing by the #0.063 mm sieve • TILMP is described as a slightly sandy slightly gravelly clay.	A1	66%
Atterberg Limits	LL,PL, PI	• Asset specific results are consistent with routewide results • Average values are assumed as design value • Plots reveal a slight decrease of LL and PL value with depth, between 0 and 2 m depth. And shows a constant value of LL and PL below 2 m depth.	A2, A3	LL=47% PL =17% PI=29%
Total Sulphur contents	TS	• The only TSP test result performed in TILMP reveals a very low total sulphur content • The relevance of this only test could be discussed.	A4	0.02%
Blow N number from SPT, corrected to 60% test energy	N_{60}	• Chetwode Cutting SPT results are represented. • the plot reveals a general increase with depth, with NSPT values comprised between 7 and 27. • Design values is the mean NSPT values obtained in Chetwode Cutting. It indicates firm to stiff clays.	A5	14
Cone resistance from CPT	q_c	• Qc results are specific from Chetwode Cutting • Qc is slightly increasing with depth and values are comprised between 1 and 3 MPa. • Regarding the lack of CPT tests, the min value has been considered as design value for Chetwode Cuttng.	A6	1 MPa

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Parameter	Symbol	Commentary / Justification	Plots	Design Value
Undrained shear strength	c_u	• Values obtained in Chetwode Cutting are represented in the plot. In the background, routewide data through the Clay Vale are represented • UU triaxial test results obtained in Chetwode Cutting are comprised between 74 and 260 kPa. The mean UU value is 147 kPa. • Routewide Vane test results obtained in Chetwode Cutting are comprised between 25 and 127 kPa. The mean value is 78 kPa. • The plot shows a slight increase in Cu Value from 50 to 110 kPa with depth. The design 'alue is defined as 72 kPa. This value is concordant with Cu obtained with SPT correlation (5 x NSPT = 5 x 14 = 70 kPa)	A7	72 kPa
Drained shear strength	c'; φ'	• Drained parameters have been defined using Chetwode Cutting specific tests and routewide (T2G) results. • Shear box tests have been performed. • For Chetwode Cutting, drained parameters have been defined (c'=15 kPa; φ' = 31°). Routewide results shows (c'=10 kPa; φ' = 28°). Drained cohesion results have been considered too high regarding UK experience and possible decrease of cohesion with time. • Chetwode Cutting is in the vicinity of an existing cutting associated with the dismantled railway line. This earthwork has been excavated in 6 m height of TILMP with 1H/3V slope. • A back analysis has been performed in TILMP in order to research the best drained parameters with a limited cohesion of 2 to 5 kPa. Results of this analysis is given in Section 4.5.1.2.	A8	C'=2 kPa φ'=27°
Young/Effective Deformation Modulus	E'	• Tests used in the E' plot are from Chetwode Cutting. • The plot represents E' obtained by Eoed correlation, SPT correlation, Cu correlations detailed in introduction of this appendix. • Results obtained from UU triaxial tests are globally higher than others and have been ignored in the current analysis. • Eoed correlation shows very low results. • SPT and In-situ Vane tests results are used to find the representative values.	A9	8 MPa

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Parameter	Symbol	Commentary / Justification	Plots	Design Value
Oedometer Deformation Modulus	E_{oed}	• Tests used in the Eoed plot are from Chetwode Cutting. • The plot represents Eeod obtained by oedometer tests, E' correlations, and SPT correlations detailed in introduction of this appendix • The design value has been chosen to be consistent with the E' design value	A10	9 MPa
Coefficient of Consolidation	Cv	• Cv has been defined using oedometer test results performed in the Clay Vale. • No plot has been created regarding the limited number of available data. • Cv in situ is assumed = 4 . Cv labo • Cr = 2.5 x Cvinsitu	N/A	3E-07 m²/s
Shear Wave Velocity	Vs	• Vs values are extracted from direct geophysical test results from Datadrop 14 and from usual correlations. Results are from Routewide data. • Plots shows Vs increase with depth.	A12	40z+120

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Particle size distribution

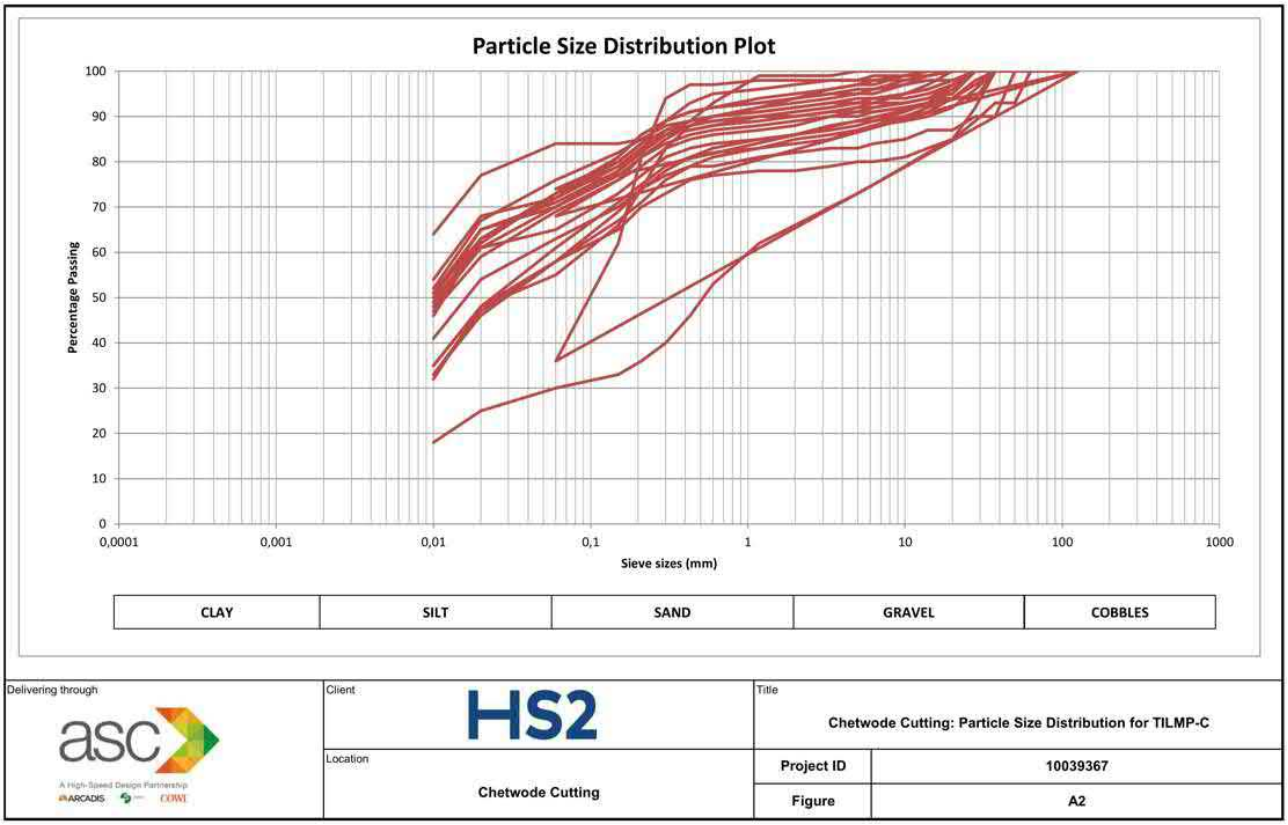


Figure A-1: Particles size distribution for TILMP

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Atterberg limits

Table A- 2. Summary of Classification testing in TILMP

Type of soil / rock testing	TILMP-C Z			
Classification	**N°**	**Min**	**Max**	**Average**
Fines (%)	21	30	84	**66**
Liquid limit (%)	27	34	67	**47**
Plastic limit (%)	27	14	21	**17**
Plasticity index (%)	27	19	46	**29**
Bulk density (Mg/m3)	18	1.93	2.38	**2.1**

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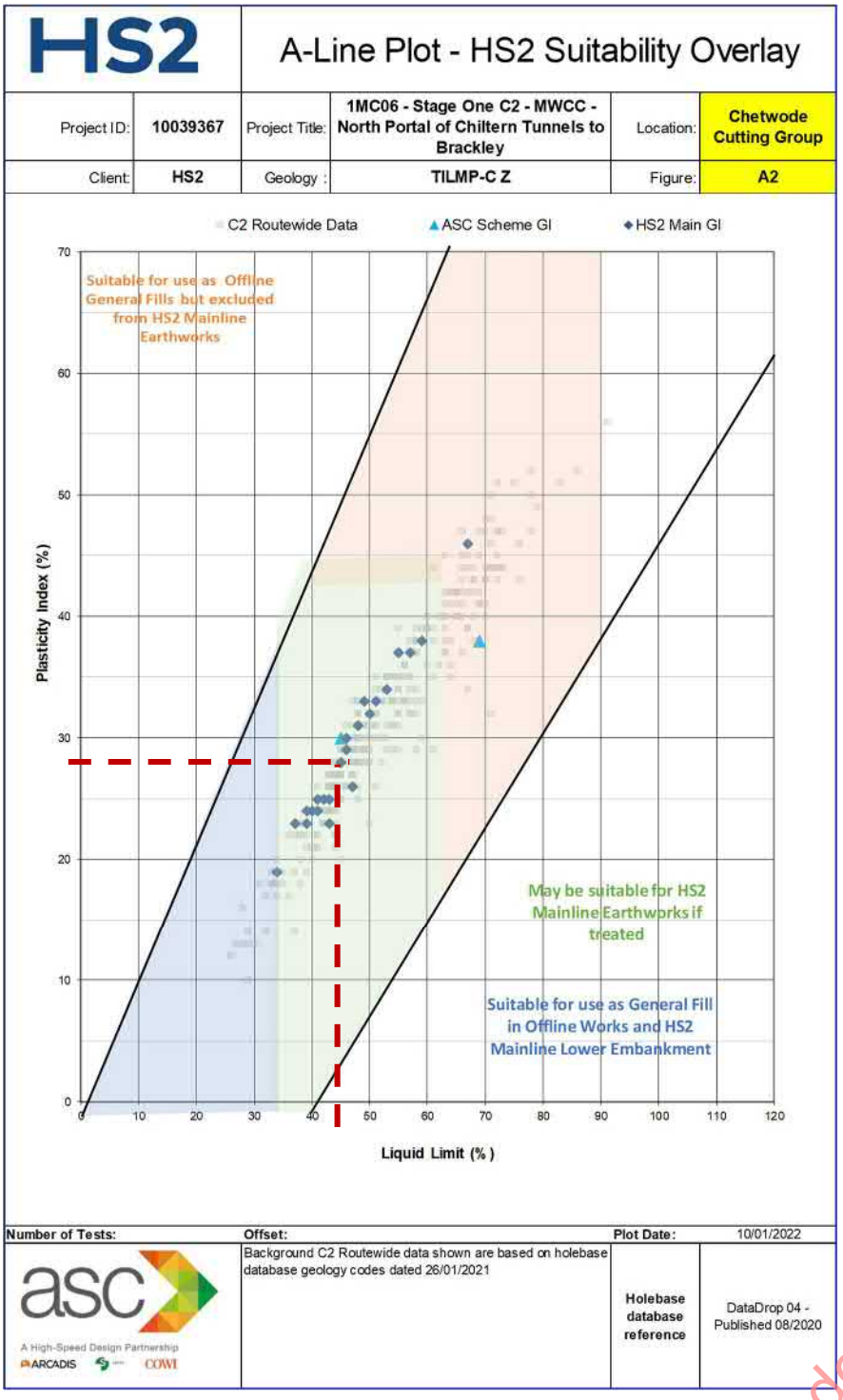


Figure A-2. Plasticity Index vs. Liquid Limit within the TILMP

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Figure A-3. Plasticity Index vs. depth within the TILMP

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Sulphur content

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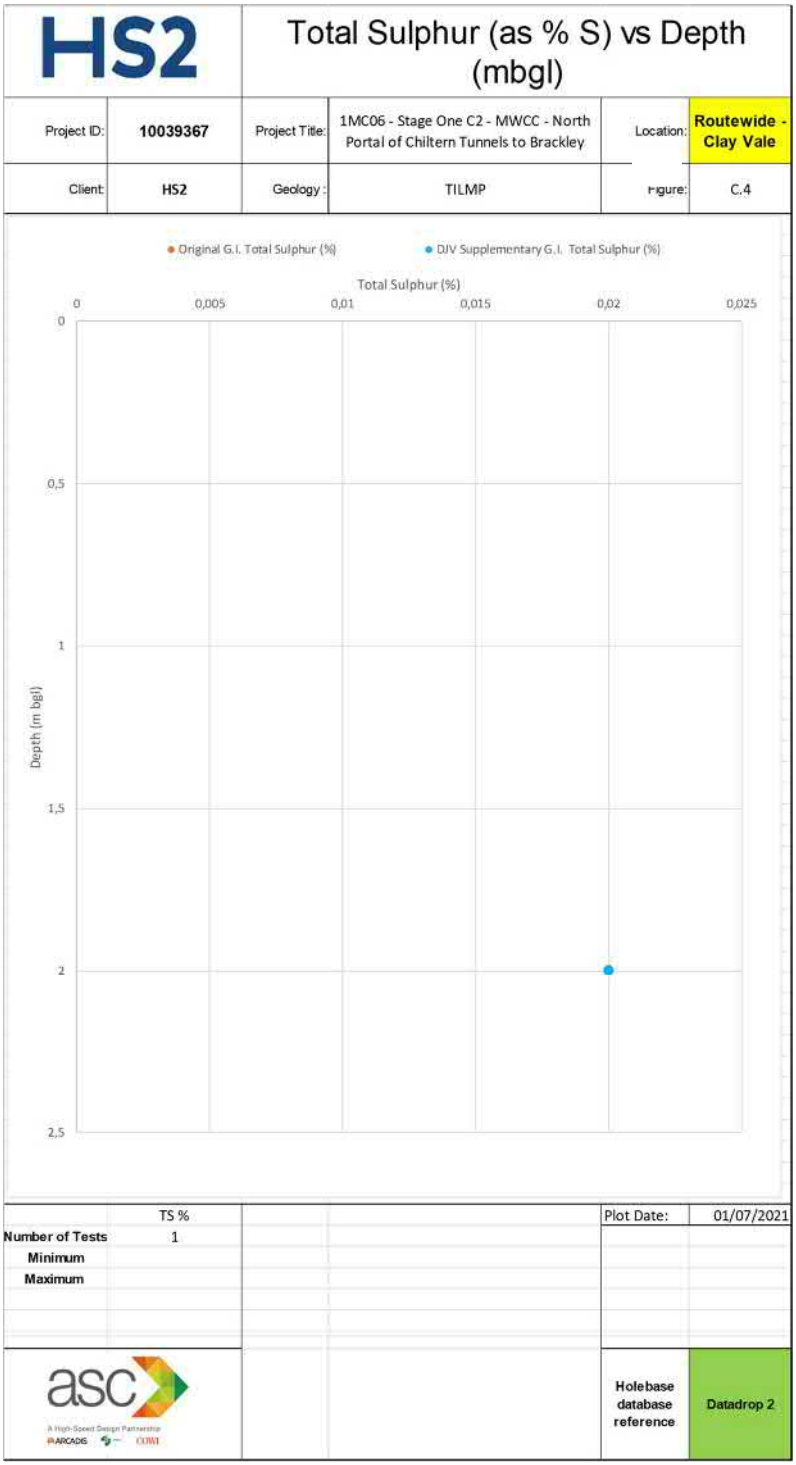


Figure A-4. Total sulphur TS(%) within the TILMP

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Standard Penetration Test desistance N_{SPT}

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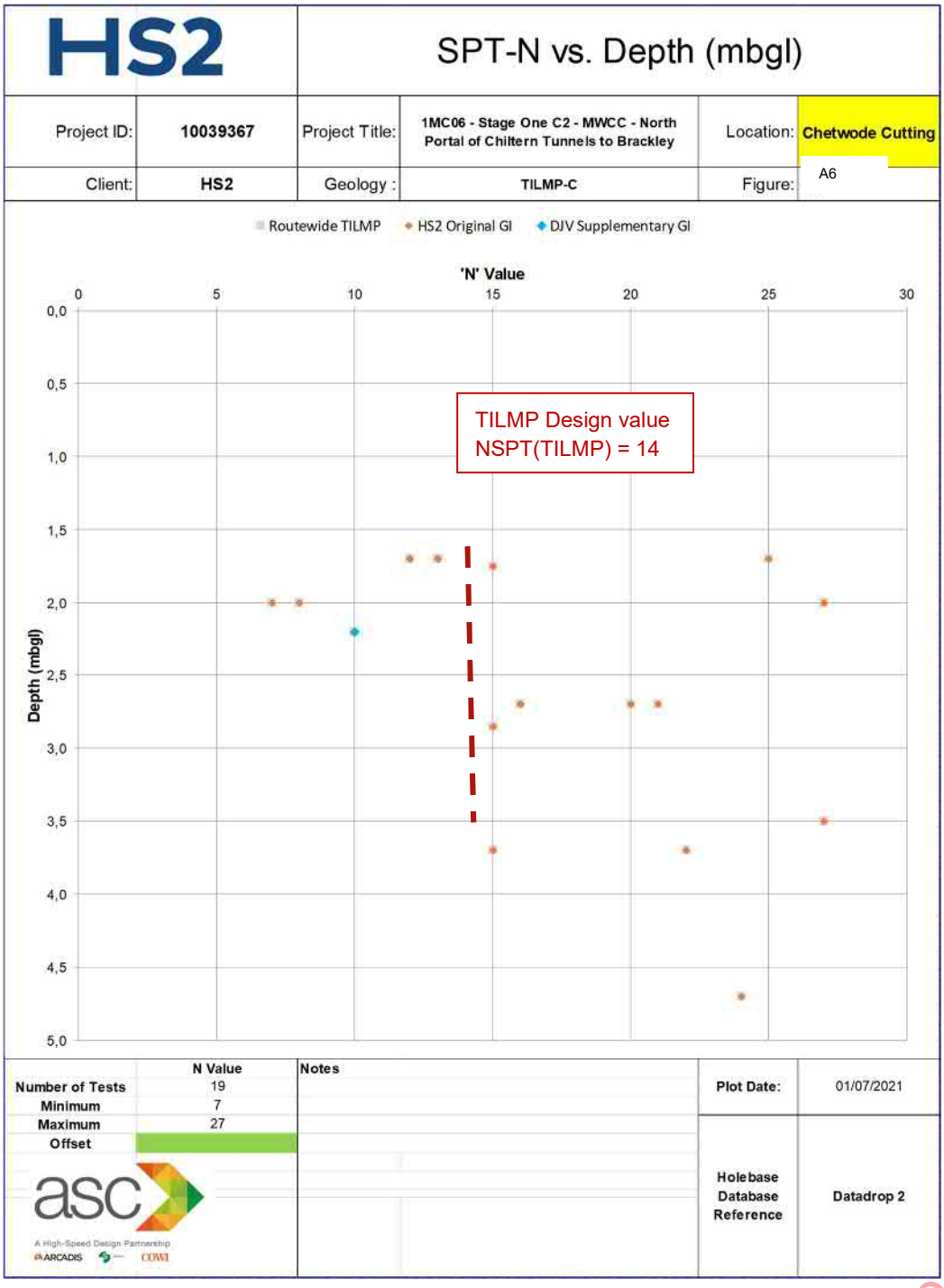
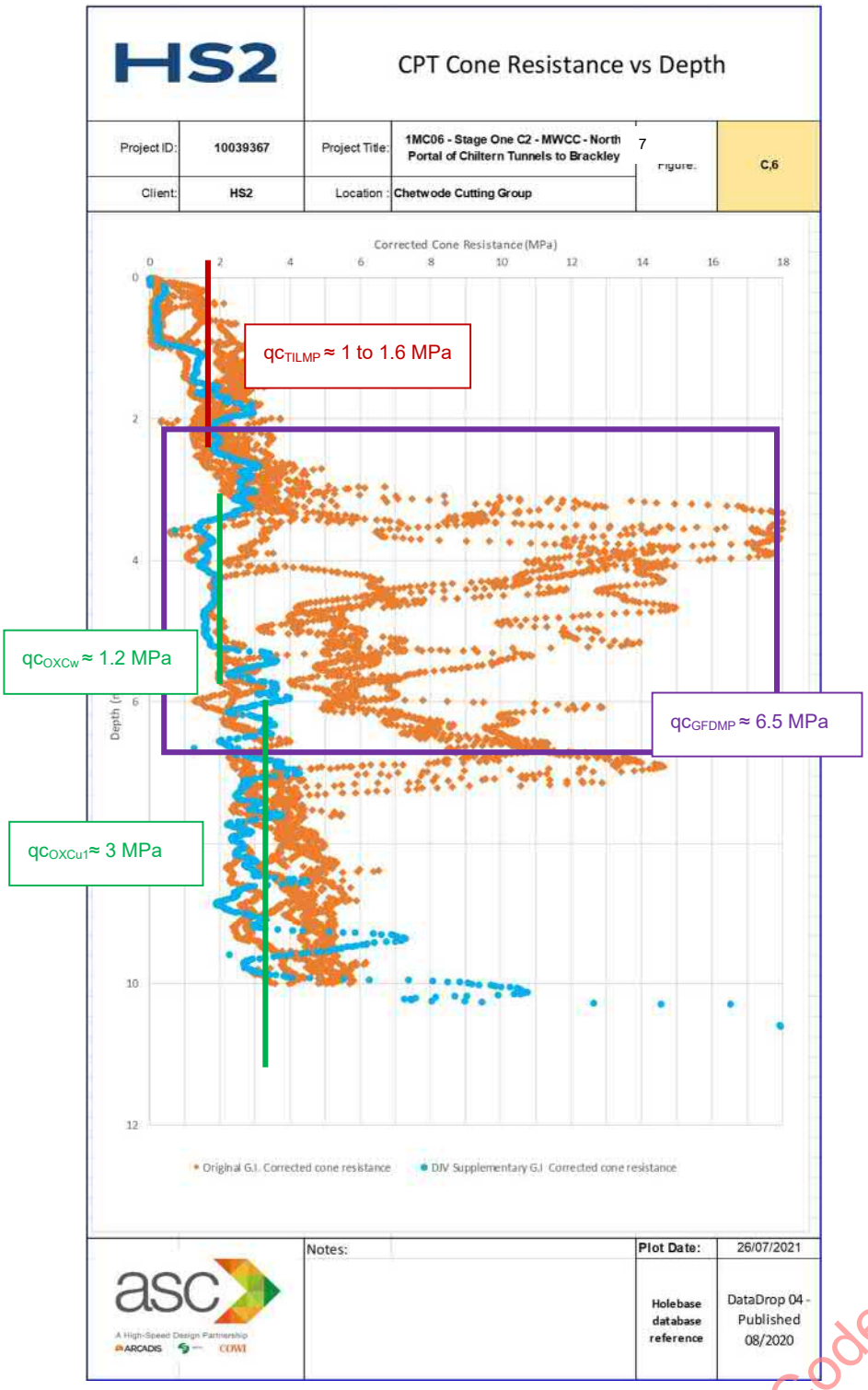


Figure A-5. SPT results within the TILMP - Chetwode Cutting

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Cone Penetration test resistance q_c

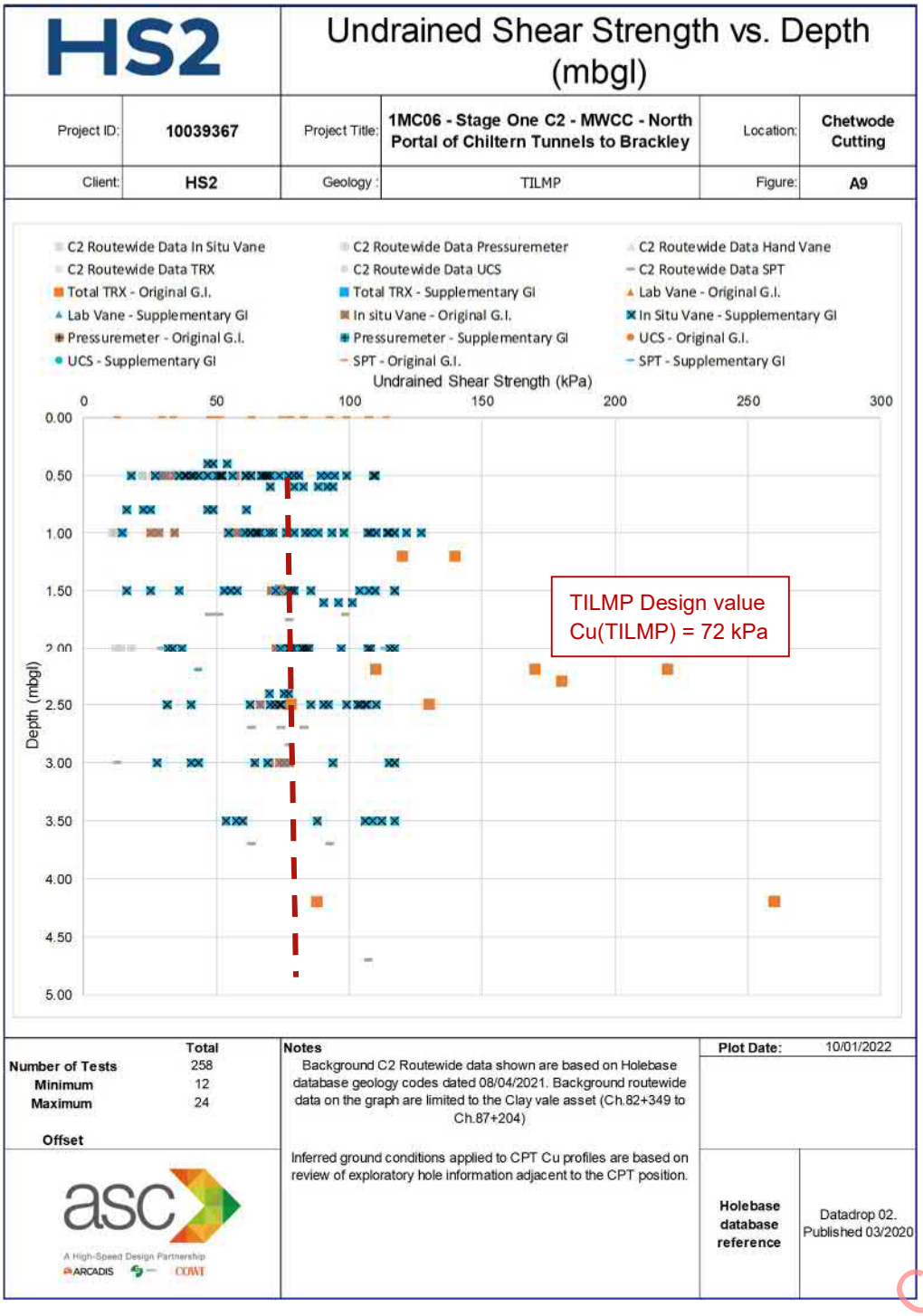
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HS2 Ltd - Code 1 - Accepted

Figure 6. CPT resu–ts

Undrained Shear strength c_u



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Figure A-7. Undrained shear strength obtained from different lab and in situ tests - TILMP

Effective cohesion c' and effective friction angle ϕ'

As TILMP are over consolidated materials, the derivation of friction angle by Ladd & al. is not relevant. No triaxial tests have been performed in this formation.

The design parameters have been chosen regarding :

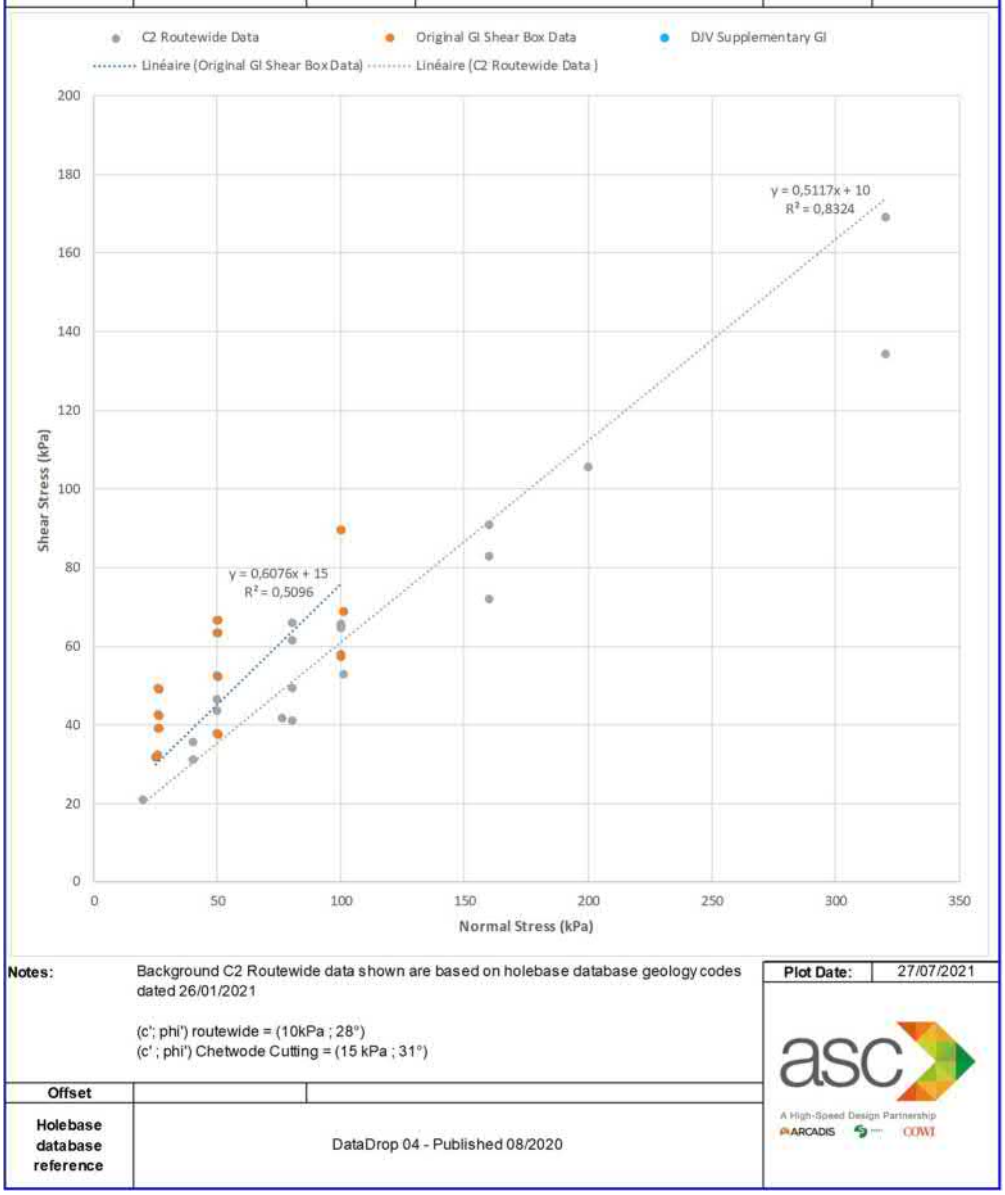
- Shear box test results obtained along the Clay Vale
- Back analysis based on existing slope stability identified along the proposed alignment. Results of the back analysis study are given in Section 4.5.1.2.

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HS2

Shear Box Shear Stress vs. Normal Stress

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Location:	Chetwode Cutting Group
Client:	HS2	Geology:	TILMP-C Z	Figure:	C.8



Notes:	Background C2 Routewide data shown are based on holebase database geology codes dated 26/01/2021 (c'; phi') routewide = (10kPa ; 28°) (c' ; phi') Chetwode Cutting = (15 kPa ; 31°)	Plot Date:	27/07/2021
Offset			
Holebase database reference	DataDrop 04 - Published 08/2020		

Figure A-8. Shear stress vs. Normal Stress in TILMP

HS2 Ltd - Code 1 - Accepted

Young Modulus E'

Correlation with N obtained from SPT

E'=K·N

Where K=0.6 for over-consolidated clayey soils (CIRIA R143) Ref.[42]

Correlation with E_{oed}

$$\boldsymbol{E}' = E_{oed}\frac{(1-2\cdot\nu')\cdot(1+\nu')}{1-\nu'}$$

Where: E'=Young Modulus;
E_{oed}=Oedometer Modulus;
and ν'=Poisson's ratio=0.2

Correlation with c_u obtained from various lab and site tests (after Jamiolkowski et al. 1979)

$$\boldsymbol{E}' = E_u\frac{1+\nu'}{1+\nu_u}$$

Where: E'=Young Modulus;
*E_u=Undrained Young Modulus obtained with Jamiolkowski et al. 1979 plot with **Eu/Cu = 150***
ν'=Poisson's ratio=0.2
and ν_u=Undrained Poisson's ratio=0.5.

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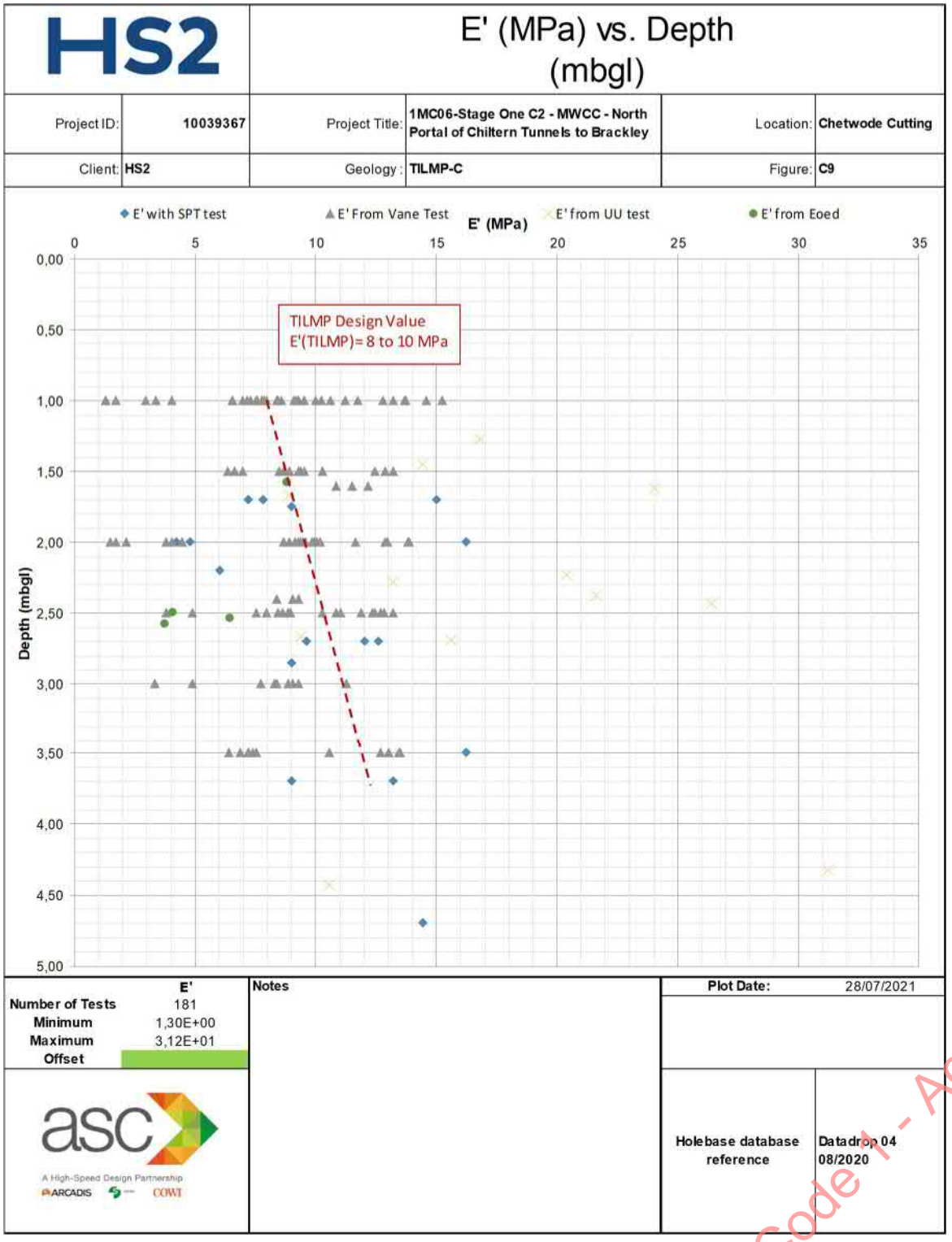


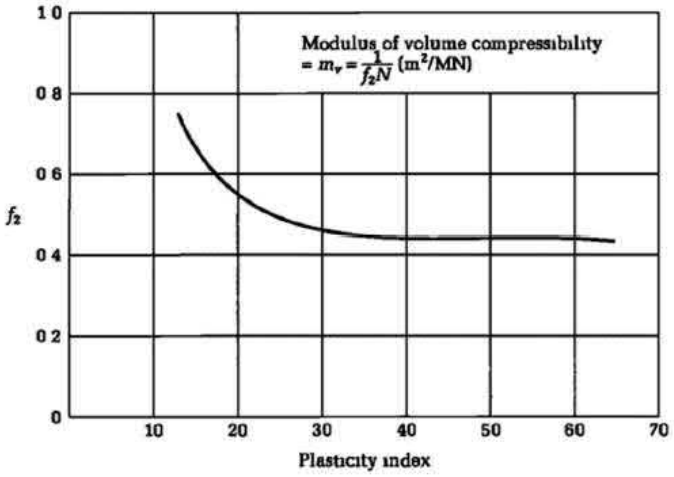
Figure A-9. E' obtained from different lab and in-situ tests within the TILMP

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Oedometer Modulus E_{oed} (or Coefficient of volume change $m_v=1/E_{oed}$)

Correlation with N from SPT

Eoed=1/mv=f2·N (Tomlinson and Woodward, 2001 Ref.[60]) where f2 = 0.45



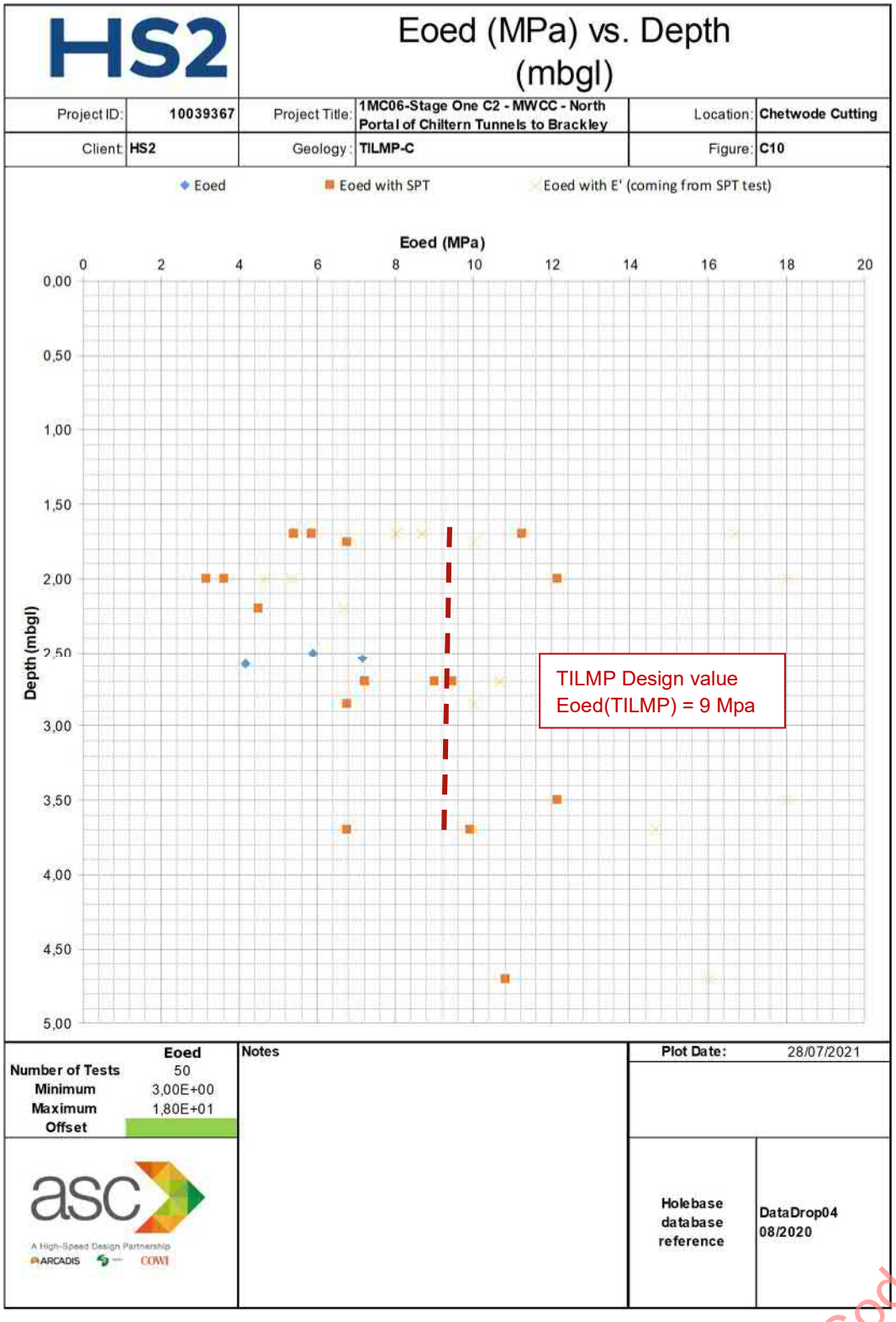
Relationship between mv, SPT and plasticity index (Tomlinson and Woodward 2008)

Correlation with E' coming from N of SPT

$$E' = E_{oed}\frac{(1-2\cdot\nu')\cdot(1+\nu')}{1-\nu'}$$

Where: E'=Young Modulus (see previous paragraph); E_{oed}=Oedometer Modulus; and ν'=Poisson's ratio=0.2

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HS2 Ltd - Code 1 - Accepted

Figure A-10. E_{-ed} obtained from different lab tests within the TILMP

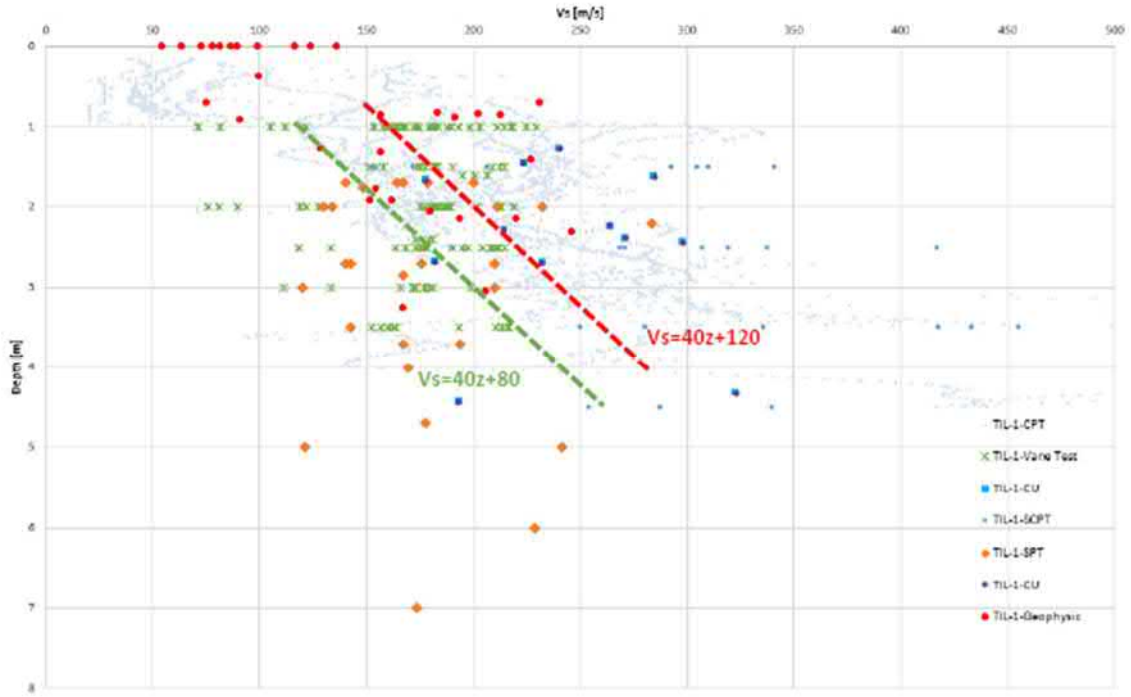
HS2 Ltd - Code 1 - Accepted

Shear Waves Velocity Profile Vs

HS2

Shear Wave Velocity vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC07 - Stage One C3 -MWCC – Brackley to South Portal of Long Itchington Tunnel	Location:	Chetwode cutting
Client:	HS2	Geology :	TILMP	Figure:	A12



	Notes	Plot Date:	17/01/2022
		Holebase Database Reference	DataDrop 14

Figure A-11 Shear waves velocity - TILMP

HS2 Ltd - Code 1 - Accepted

B- Glacio-Fluvial Deposits – GFDMP-S SV

The table provides brief commentary on :

- the type and quantity of tests to prove the geotechnical design values,
- general trends of geotechnical values with depth,
- the plots used to determine the design values of each geotechnical parameter.
- Reference to the plots of the GDR for confirmation of characteristic design values adopted in the geotechnical calculations.

Table D- 3. Commentaries and justifications related to the design geotechnical parameters for GFDMP

Parameter	Symbol	Commentary / Justification	Plots	Design Value
Fines content	#0.063	• Results are from Chetwode Cutting • GFDMP are sandy gravelly material. • Average fines content is 16% of particles passing by the #0.063 mm sieve	B1	N/A
Blow N number from SPT, corrected to 60% test energy	N_{60}	• Asset specific in-situ test results are represented. Routewide values are represented in grey. • NSPT In situ test results are scattered between 5 and 29. • The N-SPT value increase with depth.	B6	0-3 m =9 3-6 m= 15 6-9 m= 19
Cone resi'tance from CPT	q_c	• Results are from Chetwode Cutting • On CPT results, GFDMP are characterised by higher values of qc.	B6	> 6.5 MPa
Drained shear strength	c'	• Regarding the particle size distri'ution and the geological description, GFDMP are described as non-cohesive and granular materials. No cohesion is expected in this material.	N/A	0 kPa
	ϕ'	• Few laboratory tests have been performed in this formation. • Friction angle could be estimated using the relation of N-Values and friction angles by Peck et al. (1974) (Kulhawy & Mayne, 1990).		30°
Young/Effective Deformation Modulus	E'	• Results are asset specific • SPT tests results are used to find the representative values. Vane tests give too high and non-representative values • E' is correlated by N coming from SPT (CIRIA R143) Ref [42]	N/A	0-3 m =18 MPa 3-6 m= 30 MPa 6-9 m= 38 MPa
Oedometer Deformation Modulus	E_{oed}	• Eoed has been defined using the correlation with the E' previously defined	N/A	N/A

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Parameter	Symbol	Commentary / Justification	Plots	Design Value
Shear Wave Velocity	Vs	• The Vs profile has been established using the routewide data from the Datadrop 14 (including geophysical survey) • Vs profile is increasing versus depth	B12	51.4z+68.7 m/s

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Particle size distribution

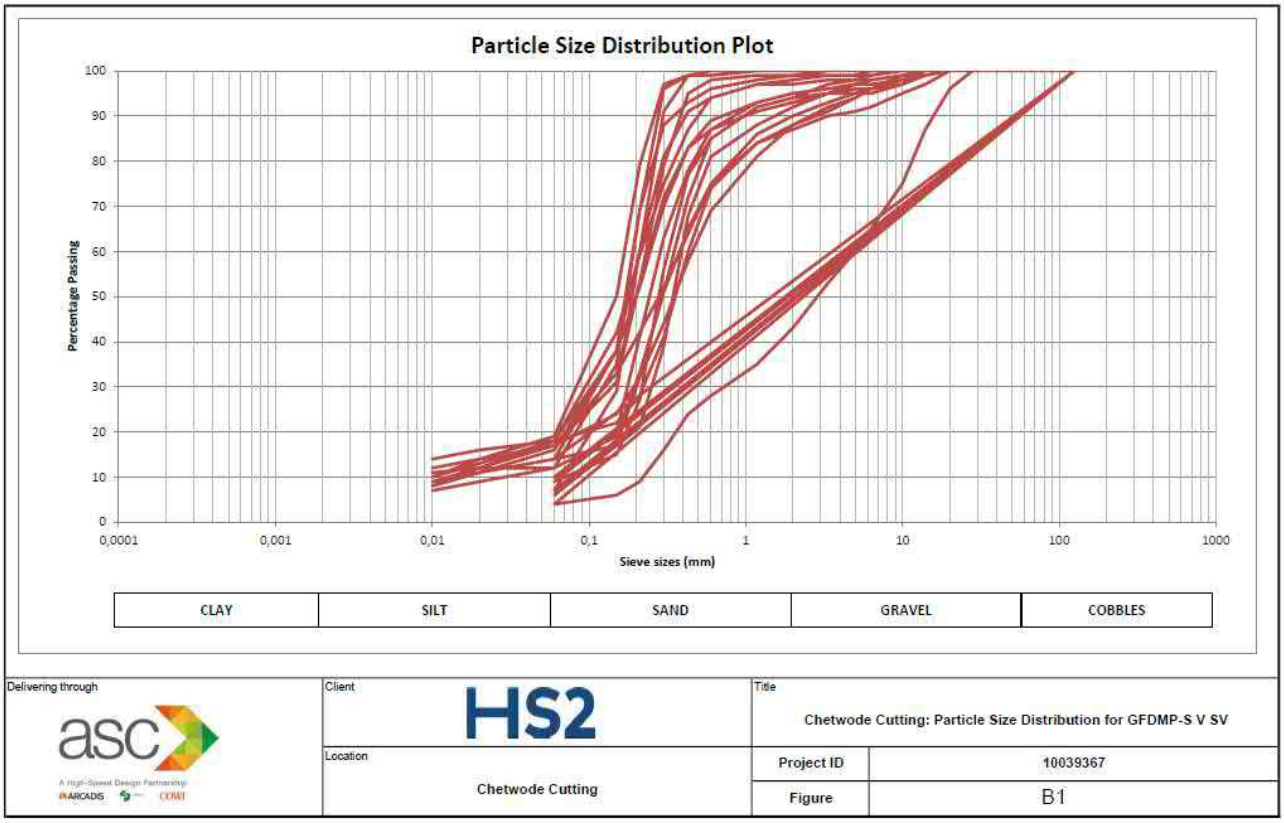


Figure B-12: Particles size distribution for GFDMP

Classification

Table D- 4. Summary of Classification testing and fine contents for GFDMP

Type of soil / rock testing	RTD-S V SV			
Classification	N°	Min	Max	Average
Fines (%)	29	12	19	**16**

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Standard Penetration Test desistance N_{SPT}

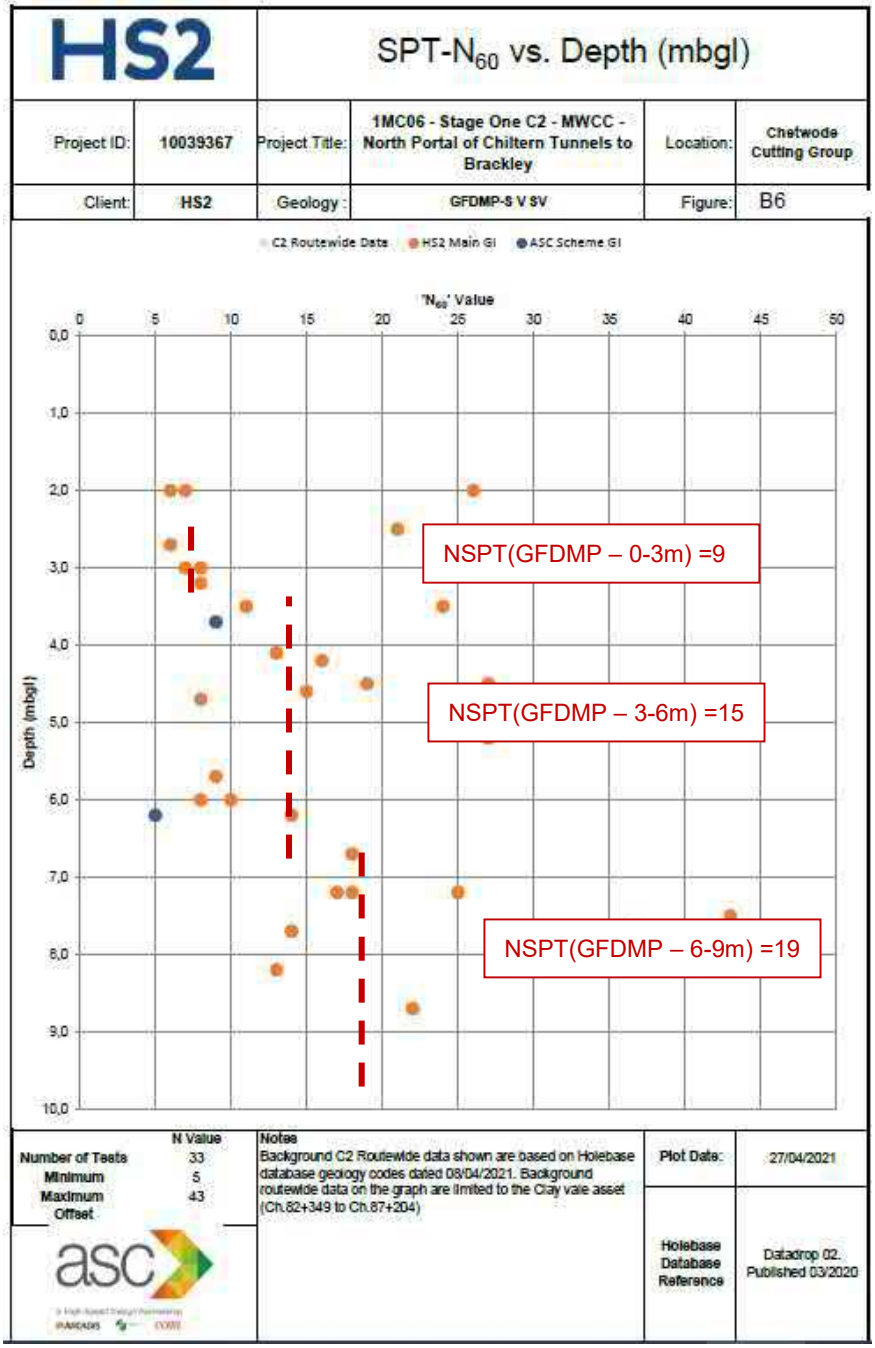


Figure B-13. SPT results within the GFDMP

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Cone Penetration test resistance q_c

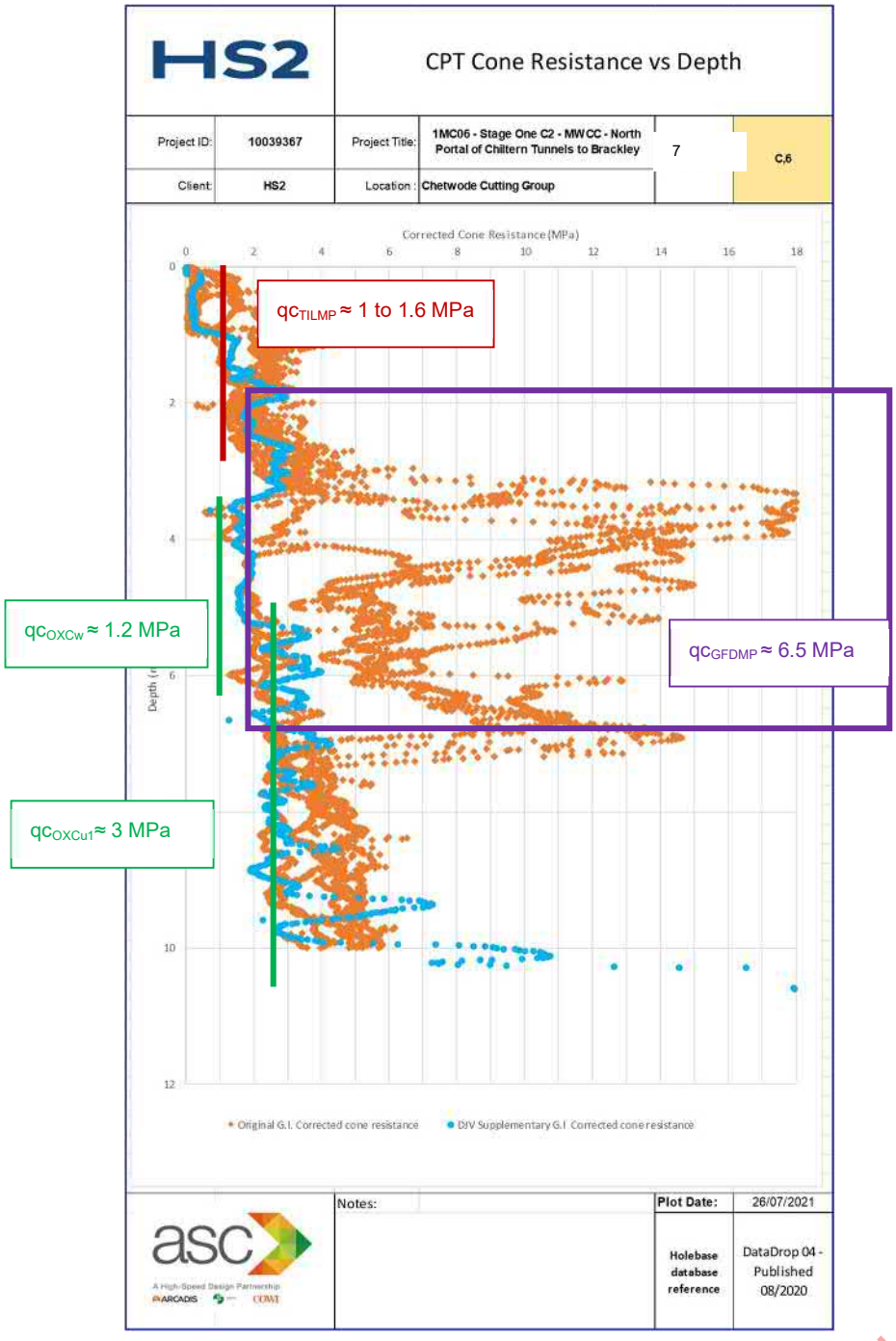


Figure 14. CPT results

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Effective cohesion c' and effective friction angle ϕ'

In granular and non-cohesive material, friction angle could be estimated using the relation of N-Values and friction angles by Peck et al. (1974) (Kulhawy & Mayne, 1990).

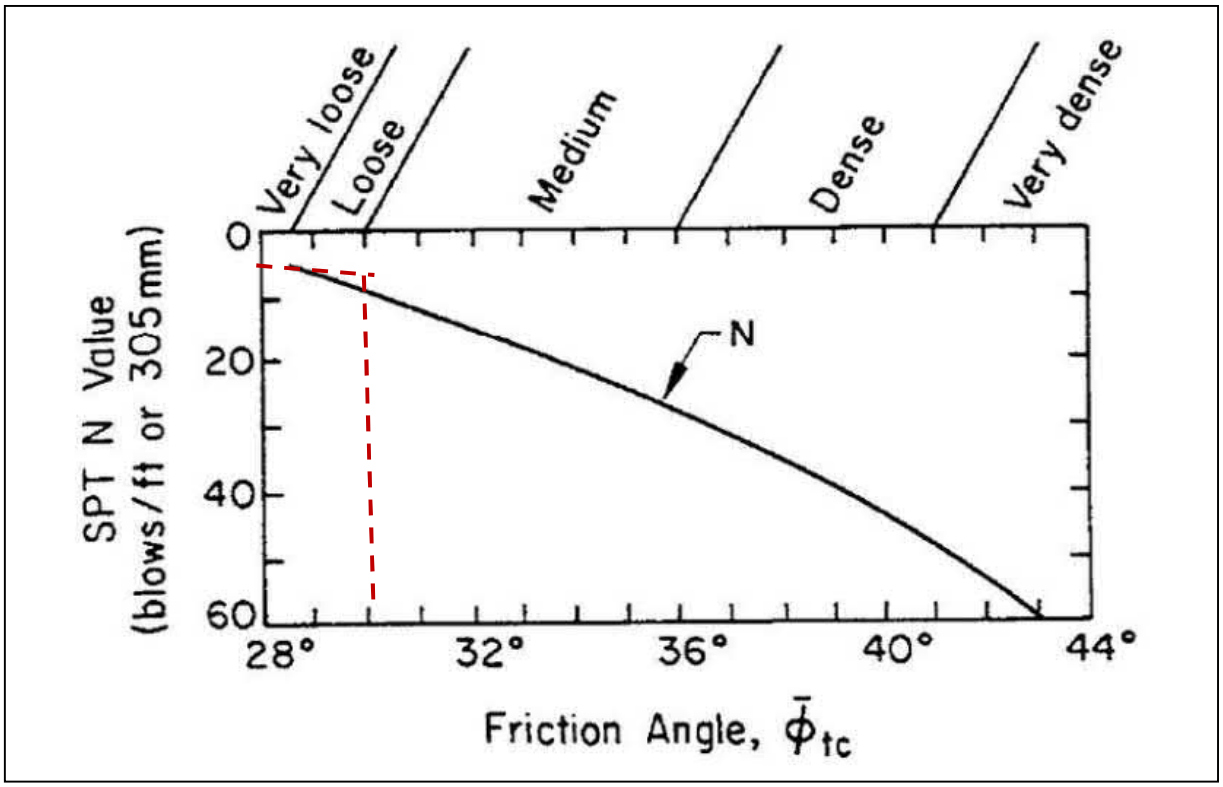


Figure B-15. Relation of N-Values and Friction Angles by Peck et al. (1974) (Kulhawy & Mayne, 1990)

Young Modulus E'

Regarding the lack of laboratory tests in ALV, the correlation with N obtained from SPT has been used

E'=K·N = 2 * 9 = 18 MPa

Where K=2 for granular and non-cohesive soils (CIRIA R143) Ref.[42]

Oedometer Modulus Eoed (or Coefficient of volume change mv=1/Eoed)

Eoed has been defined using the following correlation, with the E' previously defined

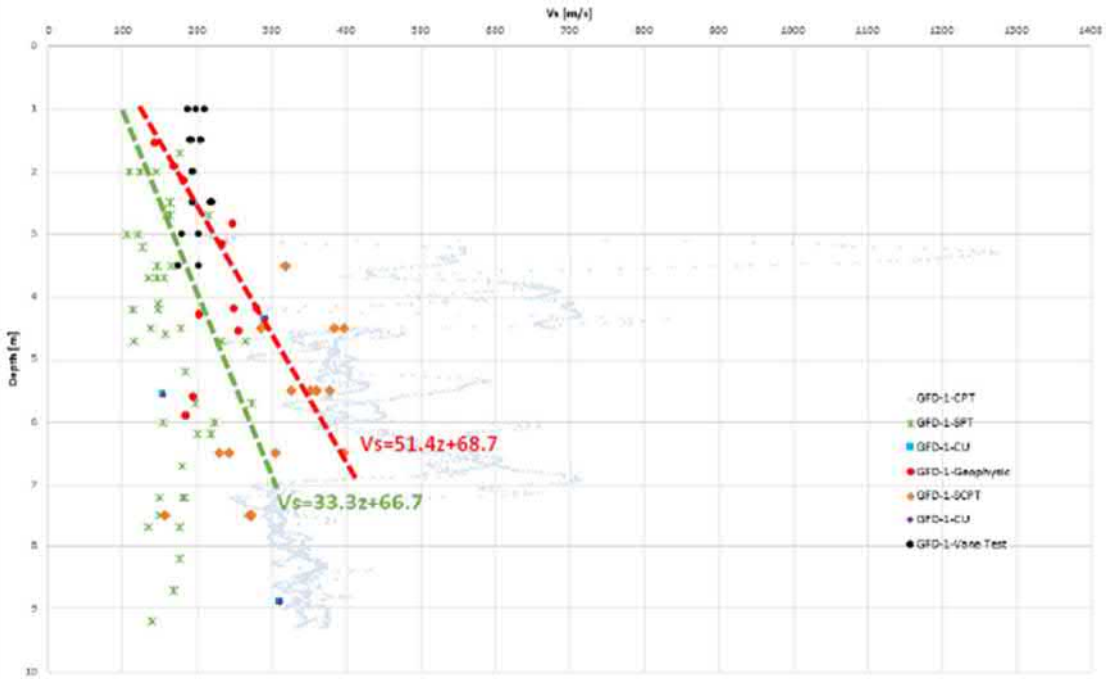
$$\boldsymbol{E'} = E_{oed}\frac{(1-2\cdot\nu')\cdot(1+\nu')}{1-\nu'}$$

Where: E'=Young Modulus (see previous paragraph); E_{oed}=Oedometer Modulus; and ν'=Poisson's ratio=0.2

HS2 Ltd - Code 1 - Accepted

Shear Waves Velocity Profile Vs

HS2	Shear Wave Velocity vs. Depth (mbgl)				
Project ID:	10039367	Project Title:	1MC07 - Stage One C3 -MWCC – Brackley to South Portal of Long Itchington Tunnel	Location:	Chetwode cutting
Client:	HS2	Geology :	GFDMP	Figure:	B12



	Notes	Plot Date:	17/01/2022
		Holebase Database Reference	DataDrop 14

HS2 Ltd - Code 1 - Accepted

Figure B-16 Shear waves velocity - GFDMP

C- Oxford Clay Formation (OXC): OXCw, OXCu1, OXCu2

Within this Geological Formation, 2 facies with different state of weathering have been identified: the weathered strata (OXCw) at the top up to 5 m depth, and the unweathered strata (OXCu1) up to 8-10 m depth, showing increasing stiffness with depth.

OXCw and OXCu1 are constituted by clays. The consistency increases with the depth from OXCw to OXCu2.

The table provides brief commentary on :

- the type and quantity of tests to prove the geotechnical design values,
- general trends of geotechnical values with depth,
- the plots used to determine the design values of each geotechnical parameter.

Reference to the plots of the GDR for confirmation of characteristic design values adopted in the geotechnical calculations.

Table D- 5. Commentaries and justifications related to the design geotechnical parameters for OXC Formation

Parameter	Symbol	Commentary / Justification	Plots	Design values
Fines content	#0.063	• large number of results from asset specific lab tests • fines content is between 59% and 97% • based on them and on the borehole logs, OXC is described as firm to stiff slightly sandy/slightly gravelly silts and clays, fissured in the facies OXC W and non-fissured in OXC U1.	C1	81%
Atterberg Limits	LL;PL;PI	• asset specific results are slightly lower than routewide results • average values for each weathering profile (see plots and Table 4.16) are assumed as design value • Plot reveals a constant value of Atterberg limits with depth	C2, C3	LL =50% PL=20% PI=30%
Bulk density	γ'	• Bulk density chosen as design value is the mean value from laboratory tests	N/A	OXCw = 20 kN/m3 OXCu1 = 21 kN/m3

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Parameter	Symbol	Commentary / Justification	Plots	Design values
Total Sulphur contents	TS	• Asset specific laboratory test results are represented • asset specific mean value is used to obtain the design value of Total Potential Sulfate contents TPS (%) to assess its re-use	C4	2%
Blow N number from SPT, corrected to 60% test energy	N_{60}	• Results are asset specific • both asset specific and routewide in-situ test results are represented • Plots shows a regular increase of stiffness with depth. Asset specific results shows a gap in NSPT result at 5 m and 10 m depth. • for OXCw and OXCu1, less competent soils, the average value N=12 and N=35 of total population is fixed as design value • Below 10 m depth, OXC-CZ u2 the design value chosen is up to 46.	C5	OXCw=12 OXCu1=35 OXCu2=46
Cone resistance from CPT	q_c	• Only asset specific tests are considered to find the design value • Design value of this parameter is used to differentiate OXc weathering profiles • Plots shows a regular increase of stiffness with depth. Asset specific results shows a gap in NSPT result at 5 m depth.	C6	OXCw=1.2 MPa OXCu1=3 MPa
Undrained shear strength	c_u	• Results are asset specific • Triaxial UU, In-situ Vane test, and SPT derived c_u are used to find the design values of undrained shear strength • As illustrated with in situ test results (detailed above), Cu increase with depth and the OXC formation can be splited in 3 strata up to 5 m and 10 m depth. • For OXCw, where Cu from vane tests gives mean value of 50 kPa and UU tests give mean value of 61 kPa, the design value has been defined using SPT derived Cu (60 kPa) • For OXCu1, mean value is obtained with UU triaxial tests and are concordant with SPT 'erivations • For OXCu2, the design value is defined regarding routewide values in OXCu2	C7	OXCw=60 kPa OXCu1=120 kPa OXCu2=180 kPa

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Parameter	Symbol	Commentary / Justification	Plots	Design values
Drained shear strength	c', φ'	• Triaxial tests are considered more reliable in drained test conditions and consistently give values more representative of ϕ' than Shear box tests in drained conditions • Routewide (Clay Vale) triaxial test results have been used for the analysis • The plot shows a lower bound cohesion intercept of about 5 kPa in OXCw and 9kPa in OXCu1. • However, in line with guidance by Nowak and Gilbert (see general guidance at the start of Appendix D), long term drained values of c'=5 kPa for intact clays and of c'=3 kPa for fissured clays have been used in design. • The plot shows φ' values comprised between 27 and 28°. The lower bund has been used in OXCw and the upper bund in OXCu1.	Ca8 Cb8	C'(OXCw) = 2 kPa C'(OXCu1)=5kPa φ'(OXCw)=26° φ'(OXCu1)=28°
Young/Effective Deformation Modulus	E'	• All data used in the plot are asset specific. • SPT and In-situ Vane tests results are used to find the representative values using usual correlation described in introduction. • Direct results from Eoed are given by oedometer tests and triaxial tests, then using usual correlation between E', Eoed and v. • The relation Eu/Cu is assumed to be 150 in OXCw and 300 in OXCu1 • For OXCw, All the results obtained shows a range of E' comprised between 4 and 12 MPa, with an average value of 6.7 MPa. • For OXCu1, a cautious design value is assumed with E' = 14 MPa regarding results obtained in SPT correlation. Values obtained with UU tests are assumed to be too high and non relevant. • For OXCu2, the E' value is obtain using correlation from Eoed	C9	OXCw=6.7 MPa OXCu1=14 MPa OXCu2 = 21 MPa

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Parameter	Symbol	Commentary / Justification	Plots	Design values
Oedometer Deformation Modulus	E_{oed}	• Results are asset specific • PI is used to obtain relationship between Eoed=1/mv and N coming from SPT • Relationship between the Oedometer Modulus Eoed and E' is coming from N of SPT (cIRIA R143) • Direct results from Eoed are given by oedometer tests and triaxial tests. • For OXCw, results are scattered between 4 MPa (2.5 m depth) and 12 MPa (4 m depth). The design value (7 MPa) has been chosen to insure consistency with E' value. • Very few values are available for OXCu1. The design value (16 MPa) has been chosen to insure consistency with E' value. • For OXCu2, design value is obtained using NSPT correlation detailed below	C10	OXCw=7 MPa OXCu1=16 MPa OXCu2=23 MPa
Coefficient of consolidation	Cv	• Cv are from oedometer tests performed in the Clay Vale. • Cvinsitu = 4. Cv laboratory • The minimum value (5E-08 m²/s) is not relevant and has not been used in the chosen of the design value. • The design value is the mean value comprised between 5E-08 and 6E-07 m²/s	C11	3E-07 m²/s
Shear Wave Velocity	Vs	• Vs values are extracted from di ect geophysical te st results from Datadrop 14 and from usual correlations. Results are from Routewide data. • Plots shows Vs increase with depth.	C12	OXCw : 18.75z+125 OXCu1: 25z+100

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Particle size distribution

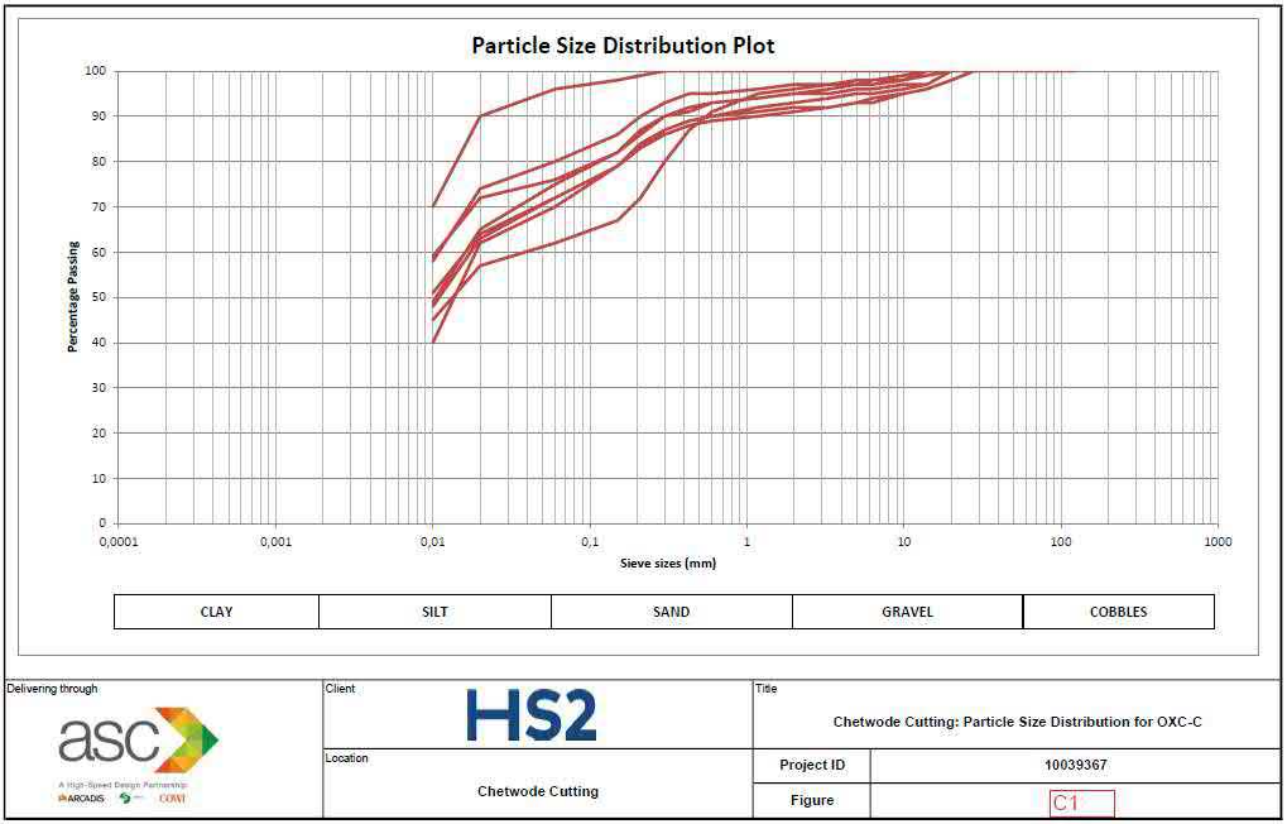


Figure C-17: Particles size distribution for Oxford Clay Formation OXC

HS2 Ltd - Code 1 - Accepted

Atterberg limits

Table D- 6. Summary of Classification testing in OXC Formation, differenced by weathering profiles

Type of soil / rock testing	OXC-C Zw				OXC-C Z u1				OXC-C Z u1			
Classification	**N°**	**Min**	**Max**	**Average**	**N°**	**Min**	**Max**	**Average**	**N°**	**Min**	**Max**	**Average**
Fines (%)	2	71	96	**83**	3	72	95	**81**	**7**	**59**	**97**	**81**
Liquid limit (%)	7	38	69	**52**	6	43	61	**52**	9	45	54	**48**
Plastic limit (%)	7	14	31	**22**	6	17	27	**21**	9	16	25	**19**
Plasticity index (%)	7	24	38	**30**	6	26	38	**31**	9	27	31	**29**
Bulk density (Mg/m3)	5	1.87	2.05	**1.95**	8	2	2.23	**2.16**	9	2.01	2.24	**2.11**

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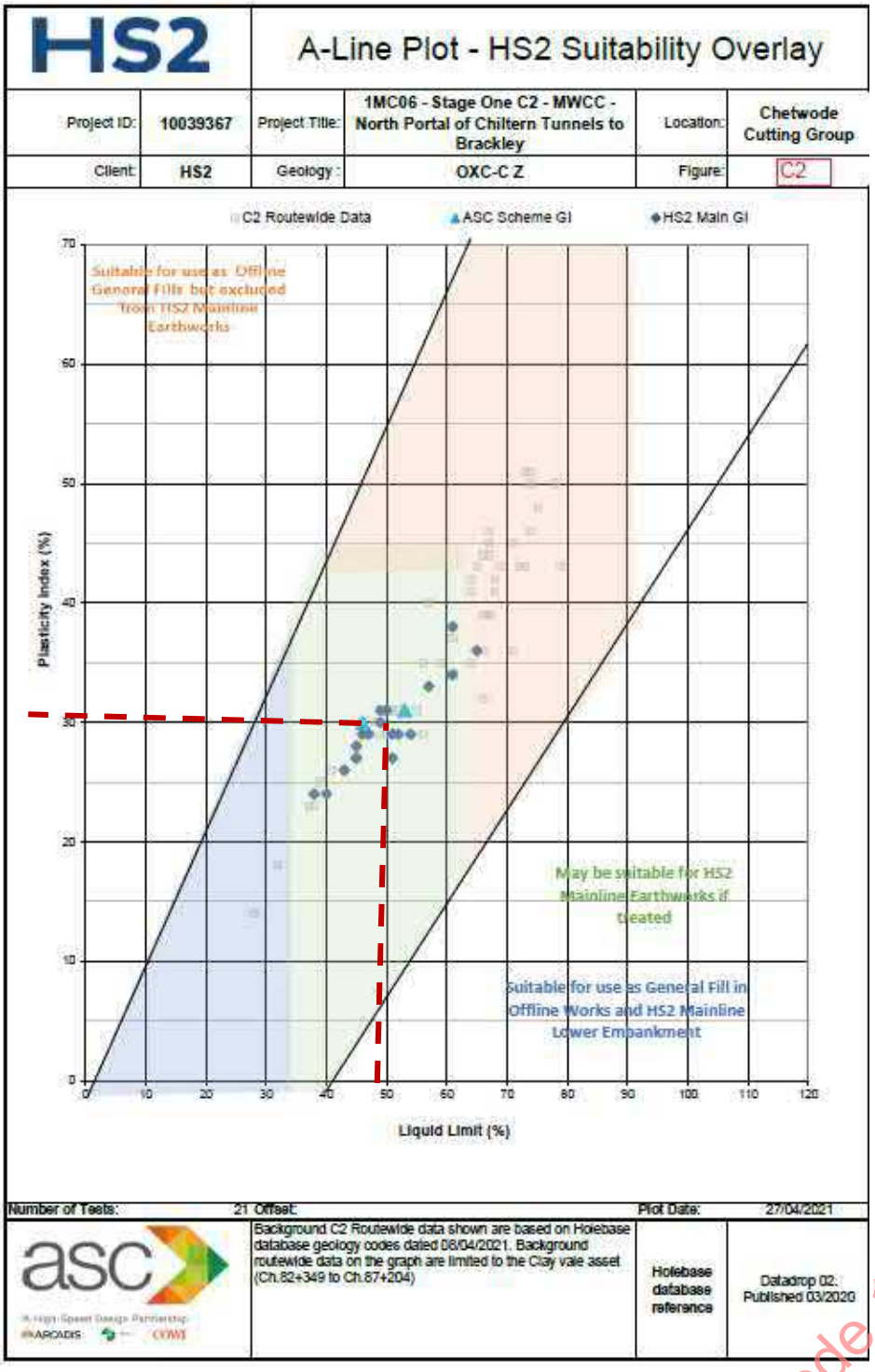


Figure C-18. Plasticity Index vs. Liquid Limit within the Oxford Clay Formation OXC

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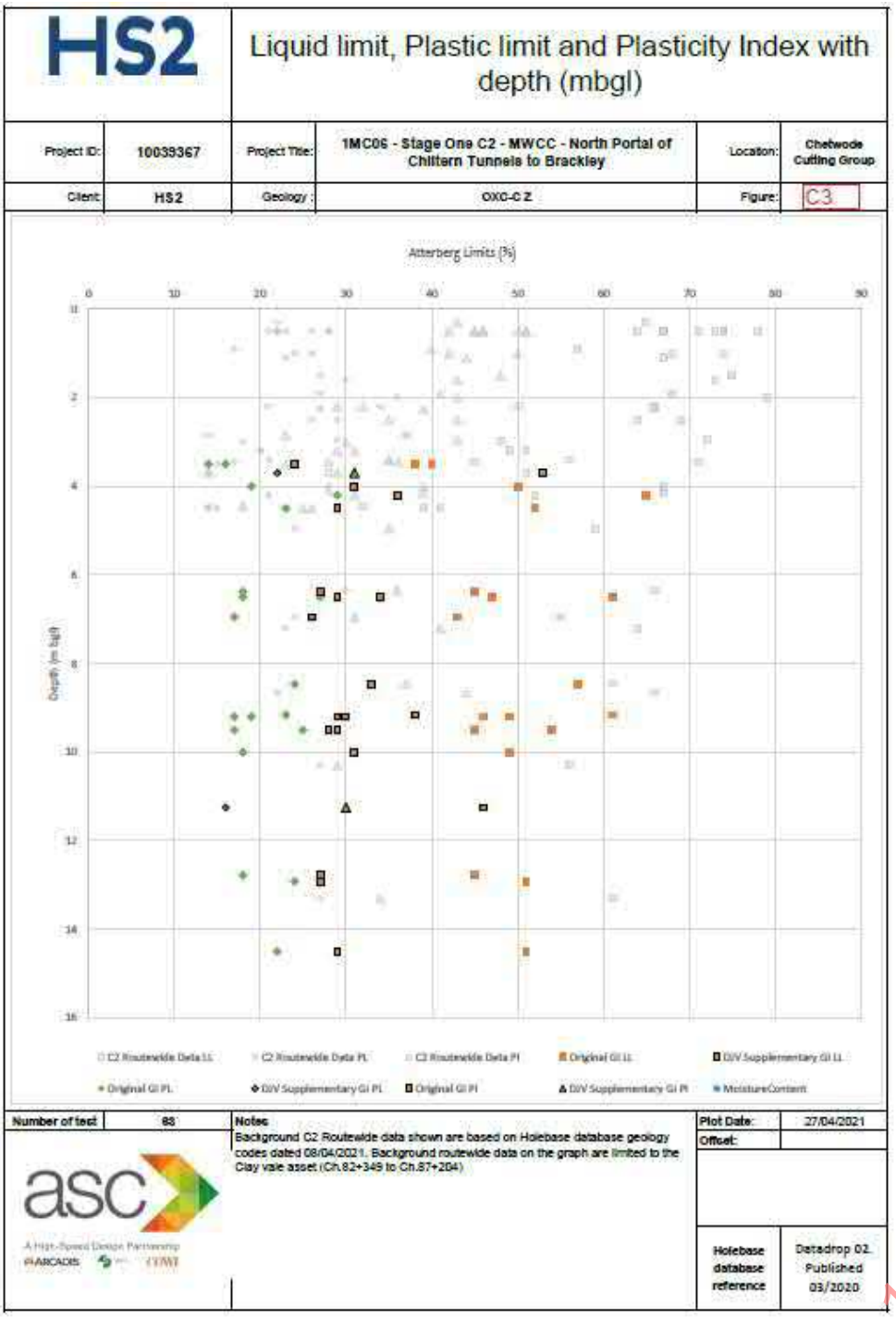


Figure C-19. Plasticity Index vs. depth within the Oxford Clay Formation OXC

HS2 Ltd - Code 1 - Accepted

Sulphur content

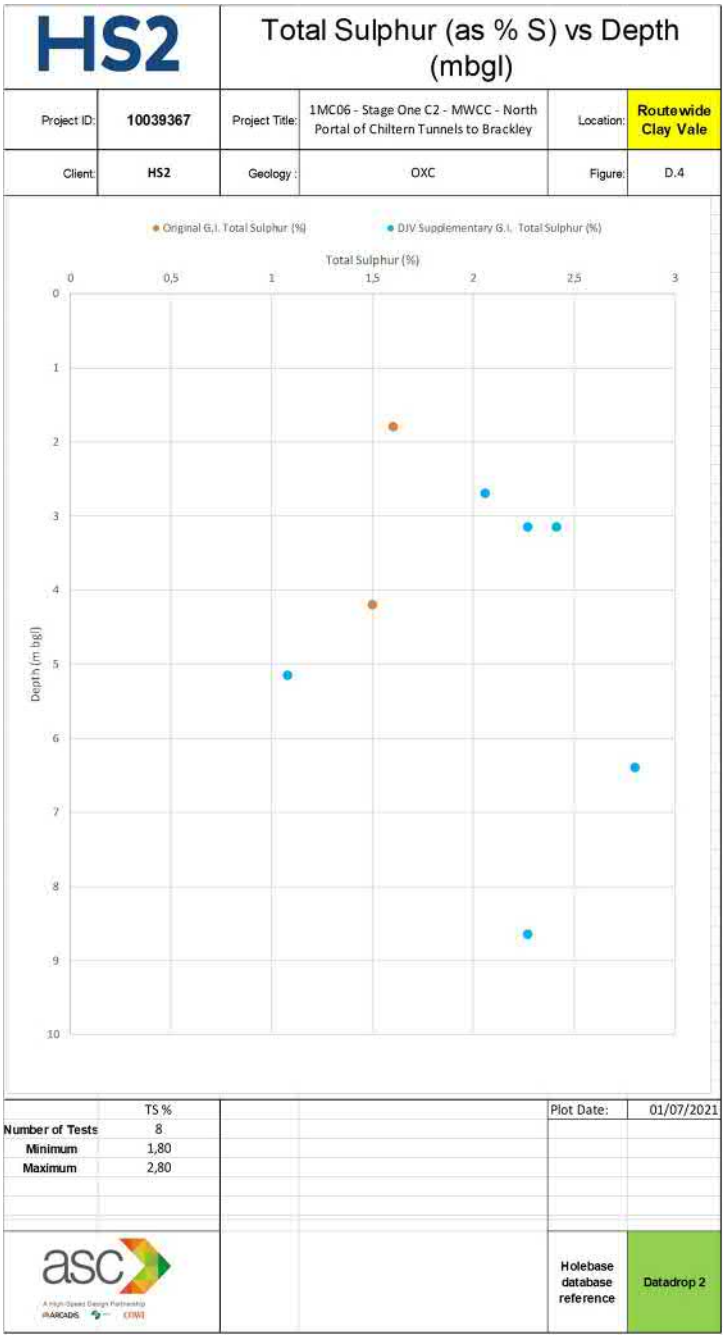


Figure C-20. Total sulphur TS(%) within the OXC Formation

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Standard Penetration Test desistance N_{SPT}

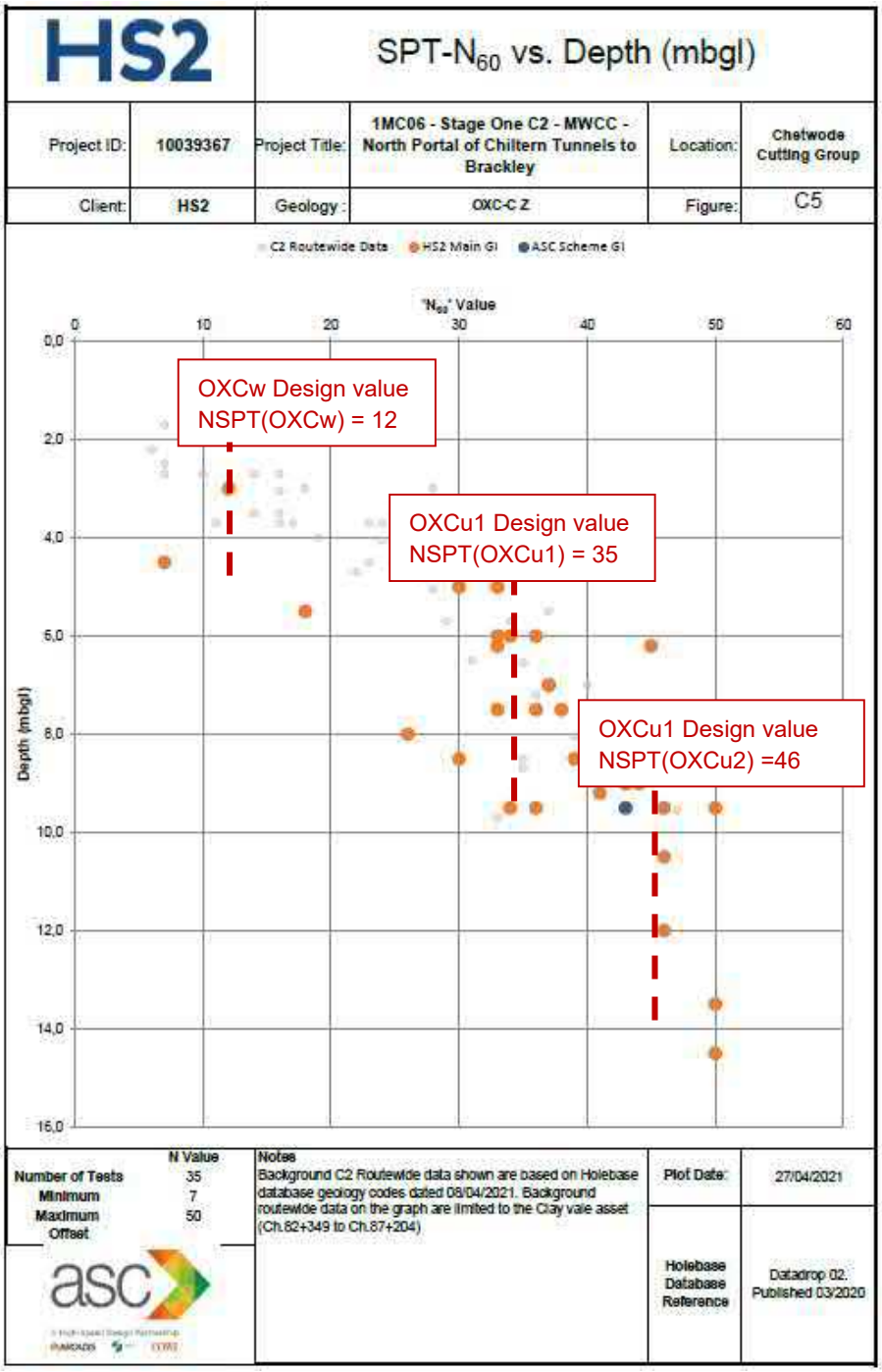


Figure C-21. SPT results within the OXC Formation

HS2 Ltd - Code 1 - Accepted

Cone Penetration test resistance q_c

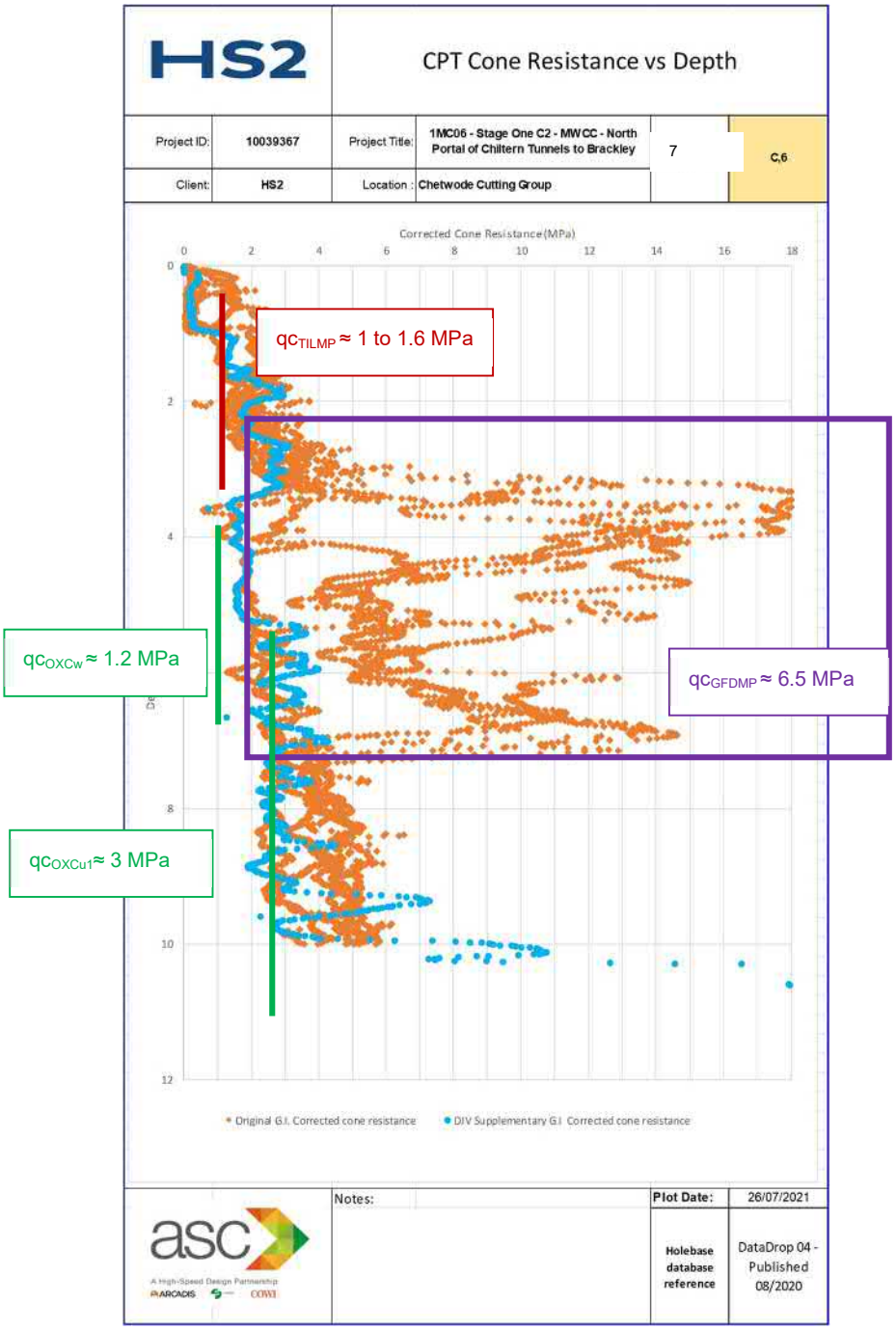


Figure 22. CPT results

HS2 Ltd - Code 1 - Accepted

Undrained Shear strength c_u

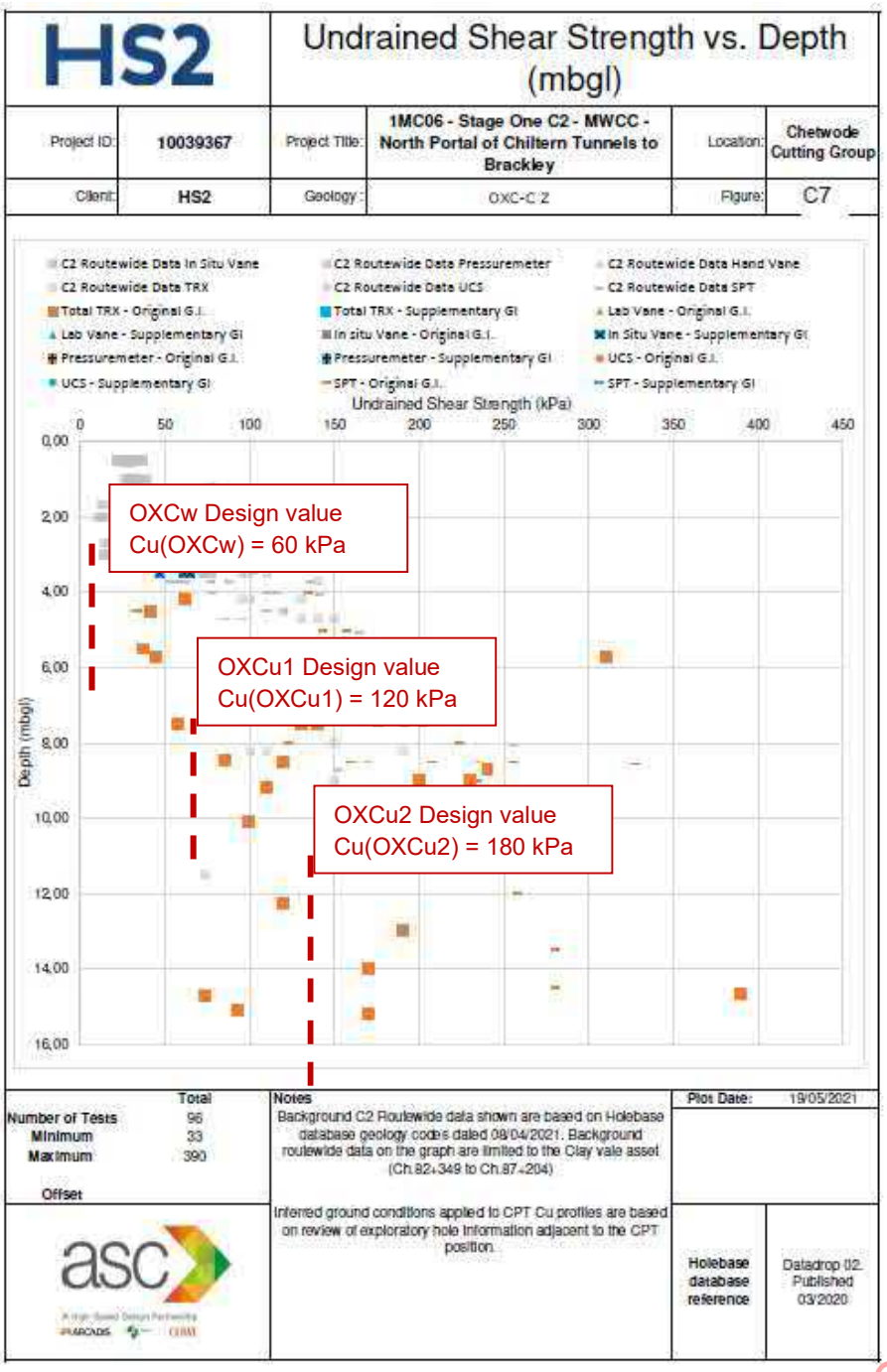


Figure C-23. Undrained shear strength obtained from different lab and in situ tests OXC

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Effective cohesion c' and effective friction angle ϕ'

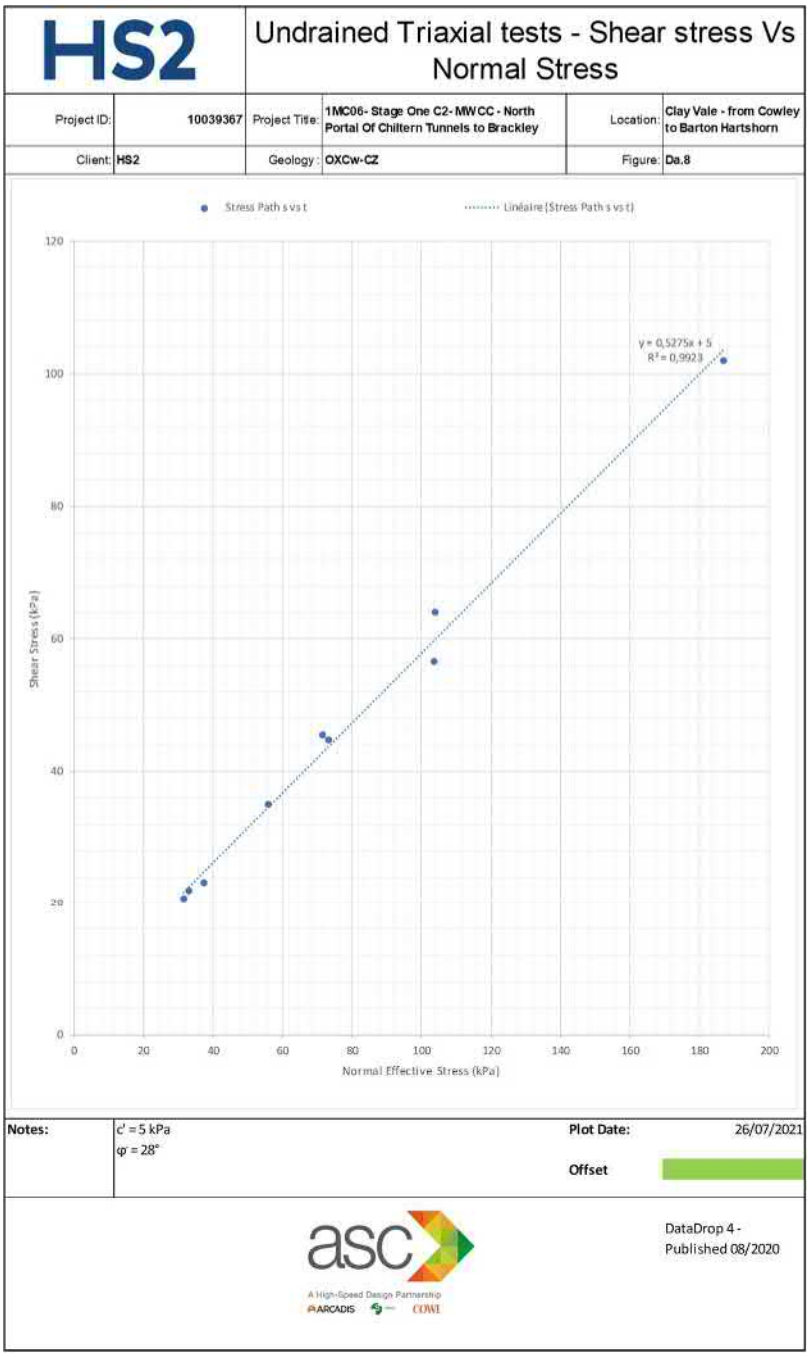


Figure C-24. Shear stress vs. Normal Stress in OXCw Formation

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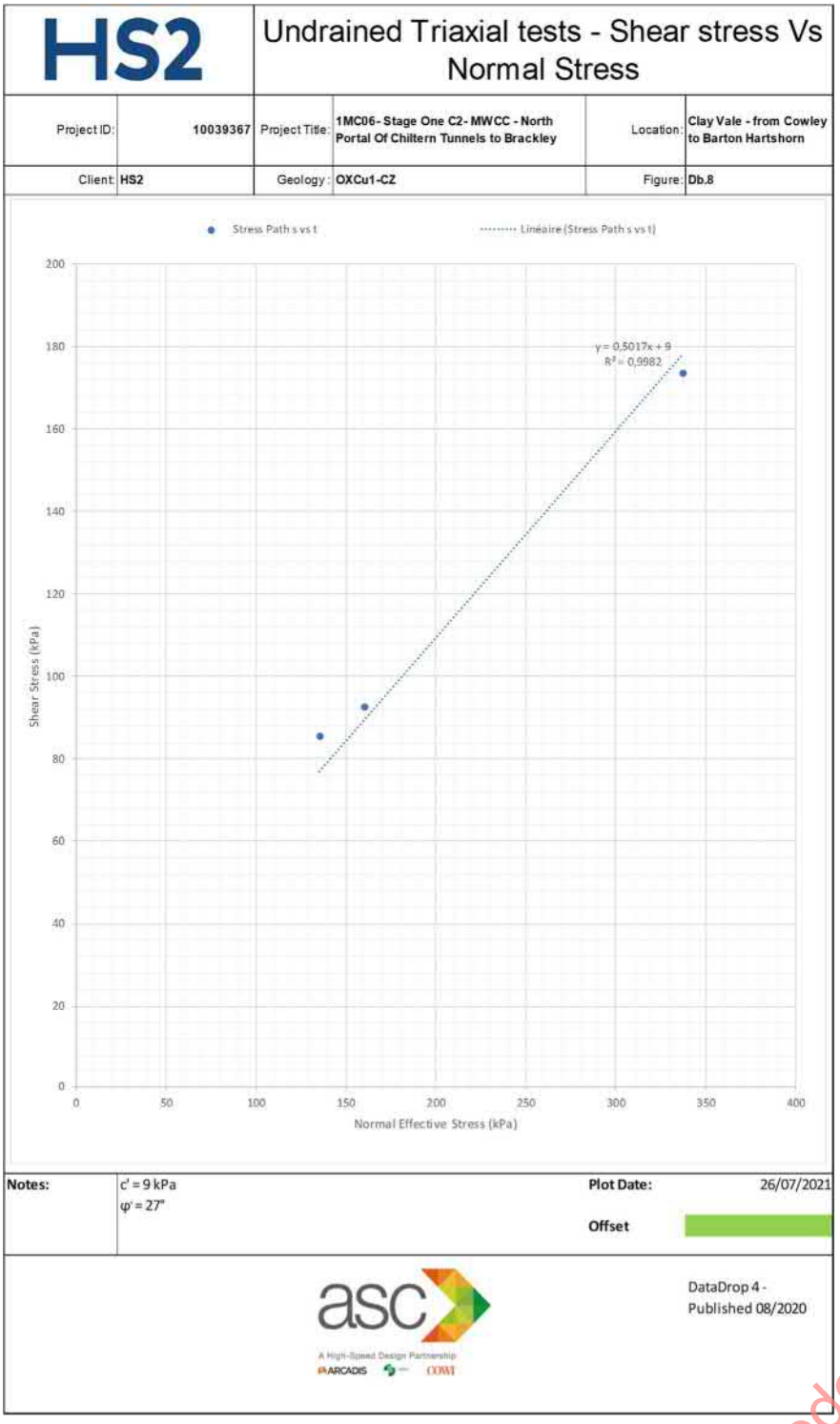


Figure C-25. Shear stress vs. Normal Stress in OXCu1 Formation

HS2 Ltd - Code 1 - Accepted

Young Modulus E'

Correlation with N obtained from SPT

E'=K·N

Where K=0.6 for over-consolidated clayey soils (CIRIA R143) Ref.[42]

Correlation with E_{oed}

$$\boldsymbol{E}' = E_{oed}\frac{(1-2\cdot\nu')\cdot(1+\nu')}{1-\nu'}$$

Where: E'=Young Modulus;
E_{oed}=Oedometer Modulus;
and ν'=Poisson's ratio=0.2

Correlation with c_u obtained from various lab and site tests

$$\boldsymbol{E}' = E_u\frac{1+\nu'}{1+\nu_u}$$

Where: E'=Young Modulus;
E_u=Undrained Young Modulus using Jamiolkowski et al. 1979 Eu/Cu = 150 for OXCw and Eu/Cu = 300 for OXCu1;
ν'=Poisson's ratio=0.2
and ν_u=Undrained Poisson's ratio=0.5.

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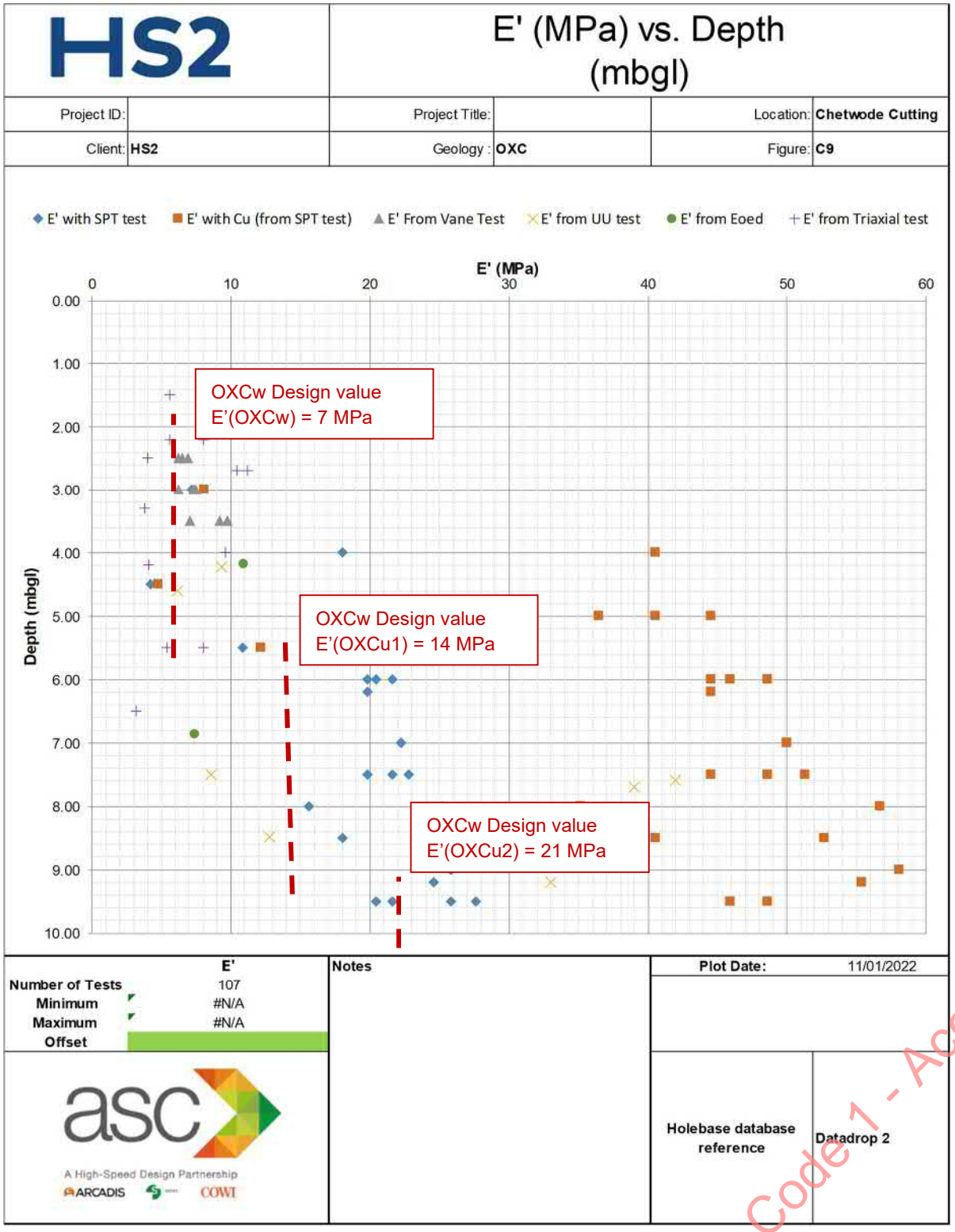


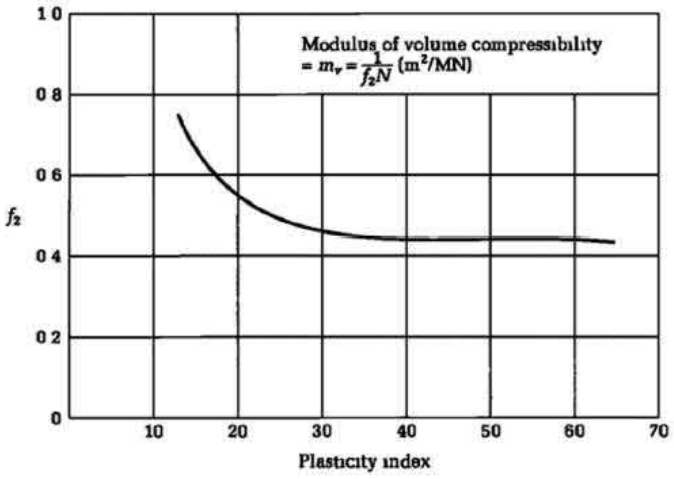
Figure C-26. E' obtained from different lab and in-situ tests within the OXC Formation

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Oedometer Modulus E_{oed} (or Coefficient of volume change $m_v=1/E_{oed}$)

Correlation with N from SPT

Eoed=1/mv=f2·N (Tomlinson and Woodward, 2001 Ref.[60]) where f2 = 0.45



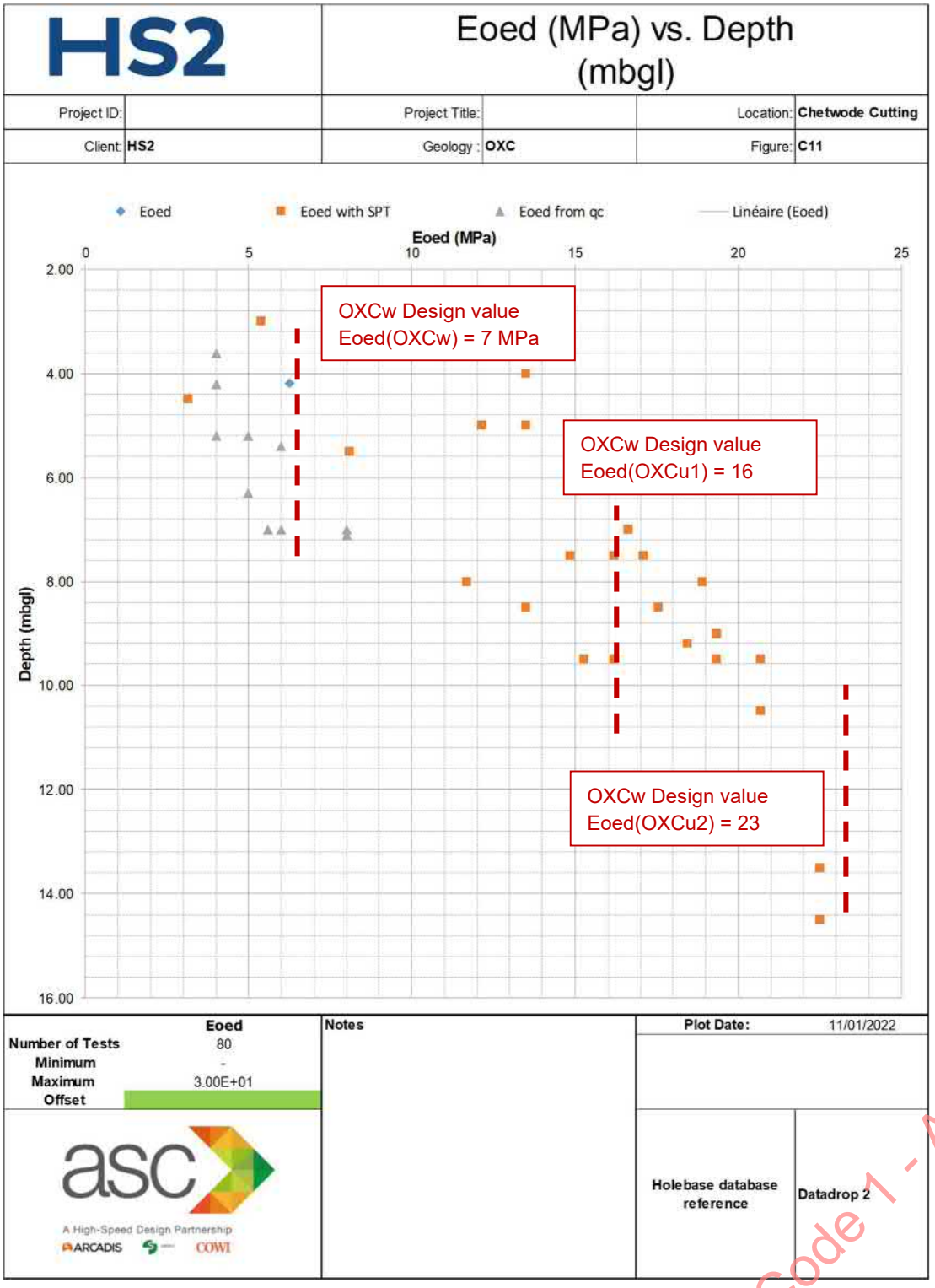
Relationship between mv, SPT and plasticity index (Tomlinson and Woodward 2008)

Correlation with E' coming from N of SPT

$$E' = E_{oed}\frac{(1-2\cdot\nu')\cdot(1+\nu')}{1-\nu'}$$

Where: E'=Young Modulus (see previous paragraph); E_{oed}=Oedometer Modulus; and ν'=Poisson's ratio=0.2

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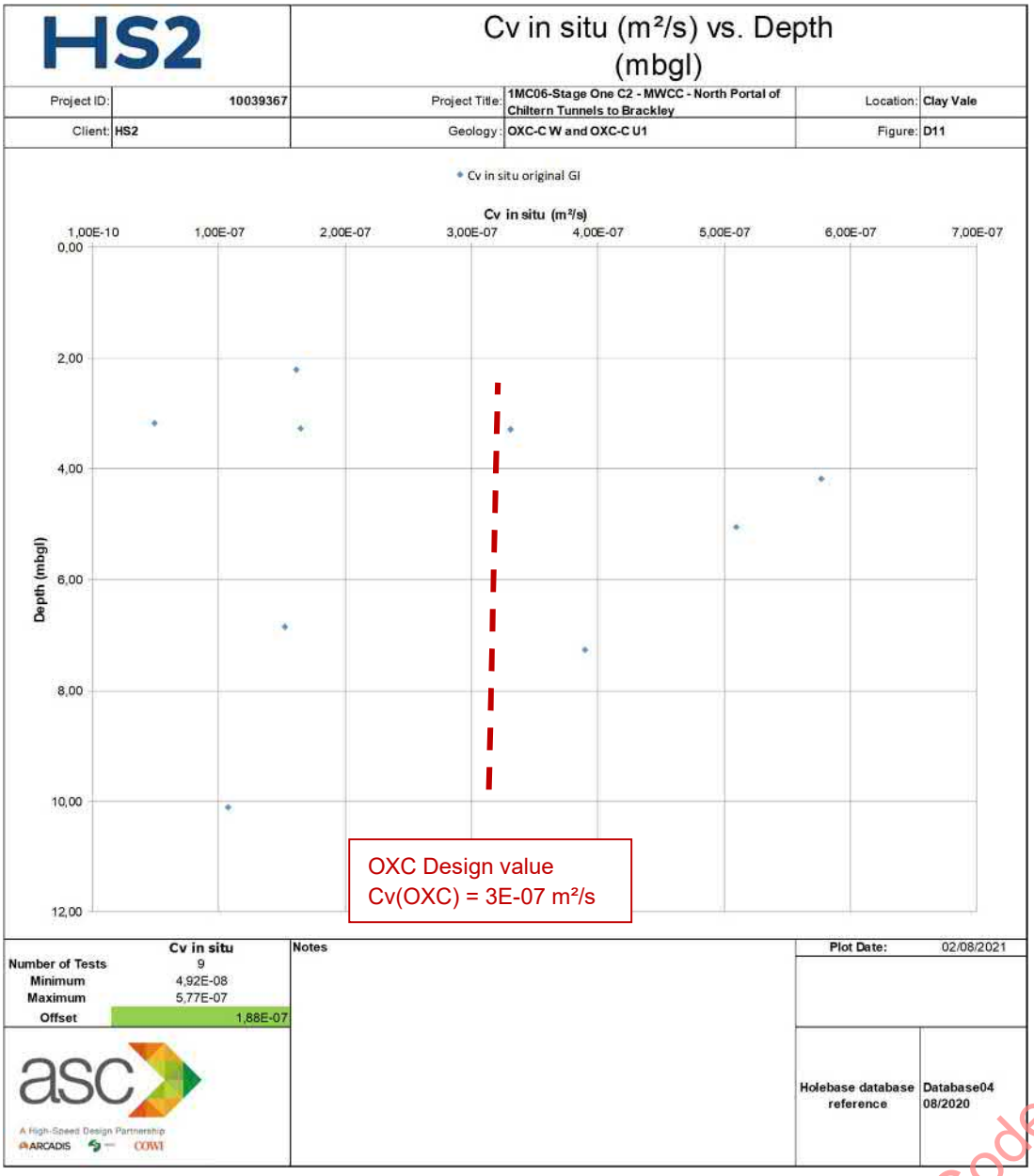


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Figure C-27. E_{oed} obtained from different lab tests within the OXC Formation

Coefficient of consolidation Cv; Cr

$c_{v_insitu} = 4 \cdot c_{v_lab}$
$c_r = 2.5\ c_{v_insitu}$



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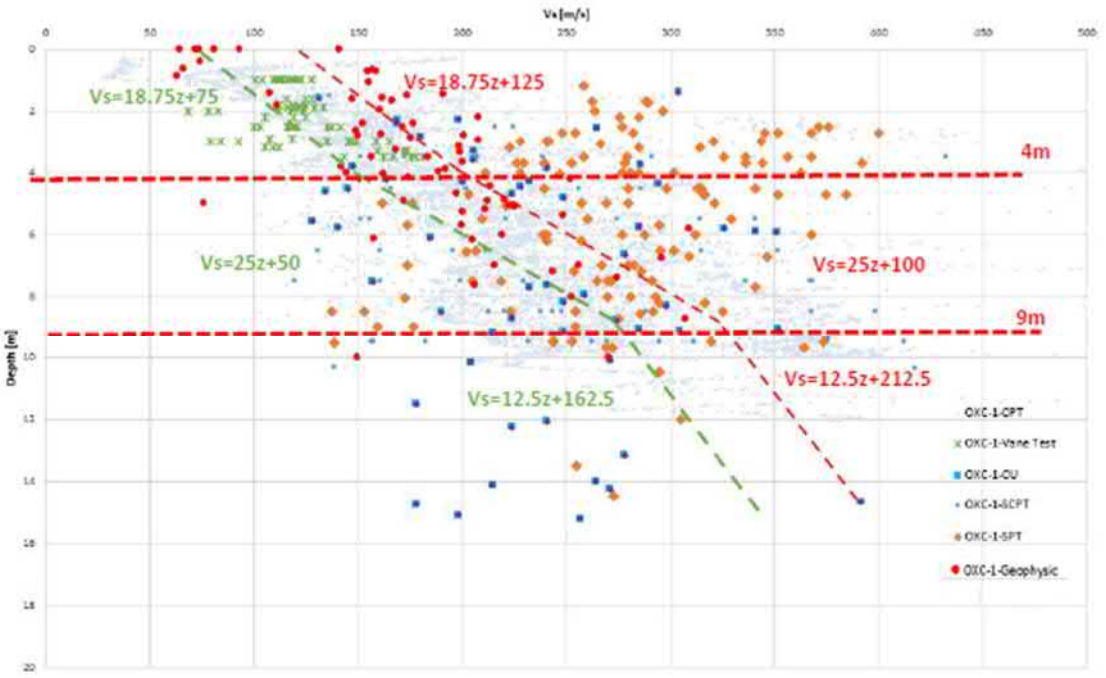
Figure D-28 k and c_v obtained from different in-situ and lab tests within the OXC formation

Shear Waves Velocity Profile Vs

HS2

Shear Wave Velocity vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC07 - Stage One C3 -MWCC – Brackley to South Portal of Long Itchington Tunnel	Location:	Chetwode cutting
Client:	HS2	Geology :	OXC	Figure:	C12



	Notes	Plot Date:	17/01/2022
		Holebase Database Reference	DataDrop 14

HS2 Ltd - Code 1 - Accepted

Figure D-29 Shear waves velocity – OXC

HS2 Ltd - Code 1 - Accepted

D- Kellaways Formation – KLB-S & KLB- CZ

The table provides brief commentary on :

- the type and quantity of tests to prove the geotechnical design values,
- general trends of geotechnical values with depth,
- the plots used to determine the design values of each geotechnical parameter.

Reference to the plots of the GDR for confirmation of characteristic design values adopted in the geotechnical calculations.

Table D- 7. Commentaries and justifications related to the design geotechnical parameters for KLB Formation

Parameter	Symbol	Commentary / Justification	Plots	Design Value
Fines content	#0.063	• Limited number of results from asset specific laboratory tests (only 2 grading tests performed on KLB-C) • For KLB-CZ, fines content is between 82% and 91% of particles passing by the #0.063 mm sieve	N/A	KLB-C Z = 86%
Atterberg Limits	LL;PL;PI	• Atterberg limits are relevant in clayey soils (KLB-CZ) • asset specific results are lower than routewide results. Average values are assumed as design value • Plot reveals a constant value of Atterberg limits with depth	D2, D3	LL=45% PL = 22% PI = 35%
Bulk density	γ'	• Bulk density chosen as design value is the mean value from laboratory tests	N/A	KLB-S = 21 kg/m3 KLB-CZ =20 kg/m3
Total Sulphur contents	TS	• both asset specific and routewide lab test results are represented for the KLB strata • Values are scattered between 0.6 and 2.7%. • Low values (less than 1%) are representative of the sandy strata (KLB-S). Higher values are from the clayey strata. • mean value is used to obtain the design value of Total Potential Sulfate contents TPS (%) to assess its re-use	D4	KLB-S = 0.8% KLB-C Z = 2%
Blow N number from SPT, corrected to 60% test energy	N_{60}	• both asset specific and routewide in-situ test results are represented • For KLB-S, N-SPT have reached a refusal. Routewide values obtained in KLB-S have been chosen as design value. • For KLB-C, plot shows a slight increase of stiffness with depth.	D5	KLB-S = 45 KLB-C Z = 28

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Parameter	Symbol	Commentary / Justification	Plots	Design Value
Cone resistance from CPT	q_c	• The CPT refusal is reached at the top of the KLB-S	N/A	-
Undrained shear strength	c_u	• Triaxial UU, In-situ Vane test, and SPT derived c_u are used to find the design values of undrained shear strength • For KLB-C, Cu from UU tests give mean value of 98 kPa. Mean Cu value from derived SPT is 159 kPa.	D7	KLB-C= 145 kPa
Drained shear strength	c', φ'	• Triaxial tests are considered more reliable in drained test conditions and consistently give values more representative of ϕ' than Shear box tests in drained conditions • Routewide triaxial test (Clay Vale) results have been used for the analysis • For KLB-S, cohesion is assumed to be negligible regarding the grading and the geological description (sand). The plot shows a φ' value of 33 °. • In KLB-C, the plot shows a cohesion intercept of about 5 kPa. • However, in line with guidance by Nowak and Gilbert (see general guidance at the start of Appendix D), long term drained values of c'=5 kPa for intact clays and of c'=2 kPa for fissured clays have been used in design. A cohesion value of 5 kPa has been chosen in KLB-C. • For KLB-C, the plot shows a φ' value of 27°.	Da8, Db8	C'(KLB-SV) = 0 kPa C'(KLB-CZ)=5kPa φ'(KLB-SV)=33° φ'(KLB-CZ)=27°
Young/Effective Deformation Modulus	E'	• Values used on the plot are asset specific. Routewide values are included in the background. • For KLB-S, SPT tests results are used to find the representative values. E' is correlated by N coming from SPT (CIRIA R143) • For KLB-C, design value has been defined using SPT tests, UU tests and oedometer tests. • The relation Eu/Cu is assumed to be 300 in KLB-C • The design value matches with the lower bund	D9	E'(KLB-S) = 90 Mpa E'(KLB-C)=17.5Mpa
Oedometer Deformation Modulus	E_{oed}	• Eoed has been defined using the correlation with the E' previously defined	N/A	Eoed(KLB-S) = 100 Mpa Eoed(KLB-C)=19Mpa

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Parameter	Symbol	Commentary / Justification	Plots	Design Value
Coefficient of consolidation	Cv	• Cv are from oedometer tests performed in the Clay Vale. • Cvinsitu = 4. Cv laboratory • The design value is the mean value comprised between 5E-07 and 3E-08 m²/s	D11	6E-08 m²/s
Shear Wave Velocity	Vs	• The Vs profile has been established using the routewide data from the Datadrop 14 (including geophysical survey) • Regarding the formation depth, signle design value has been chosen on the KLB sandy layer and on the KLB mudstone layer	D12	Vs (KLB-S) = 300 m/s Vs (KLBB-CZ) = 250 m/s

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Atterberg limits

Table D- 8. Summary of Classification testing in KLB

Type of soil / rock testing	KLB-C Z			
Classification	**N°**	**Min**	**Max**	**Average**
Fines (%)	2	82	91	**86**
Liquid limit (%)	5	27	68	**45**
Plastic limit (%)	3	15	27	**22**
Plasticity index (%)	3	23	41	**35**
Bulk density (Mg/m3)	4	2	2.07	**2.04**

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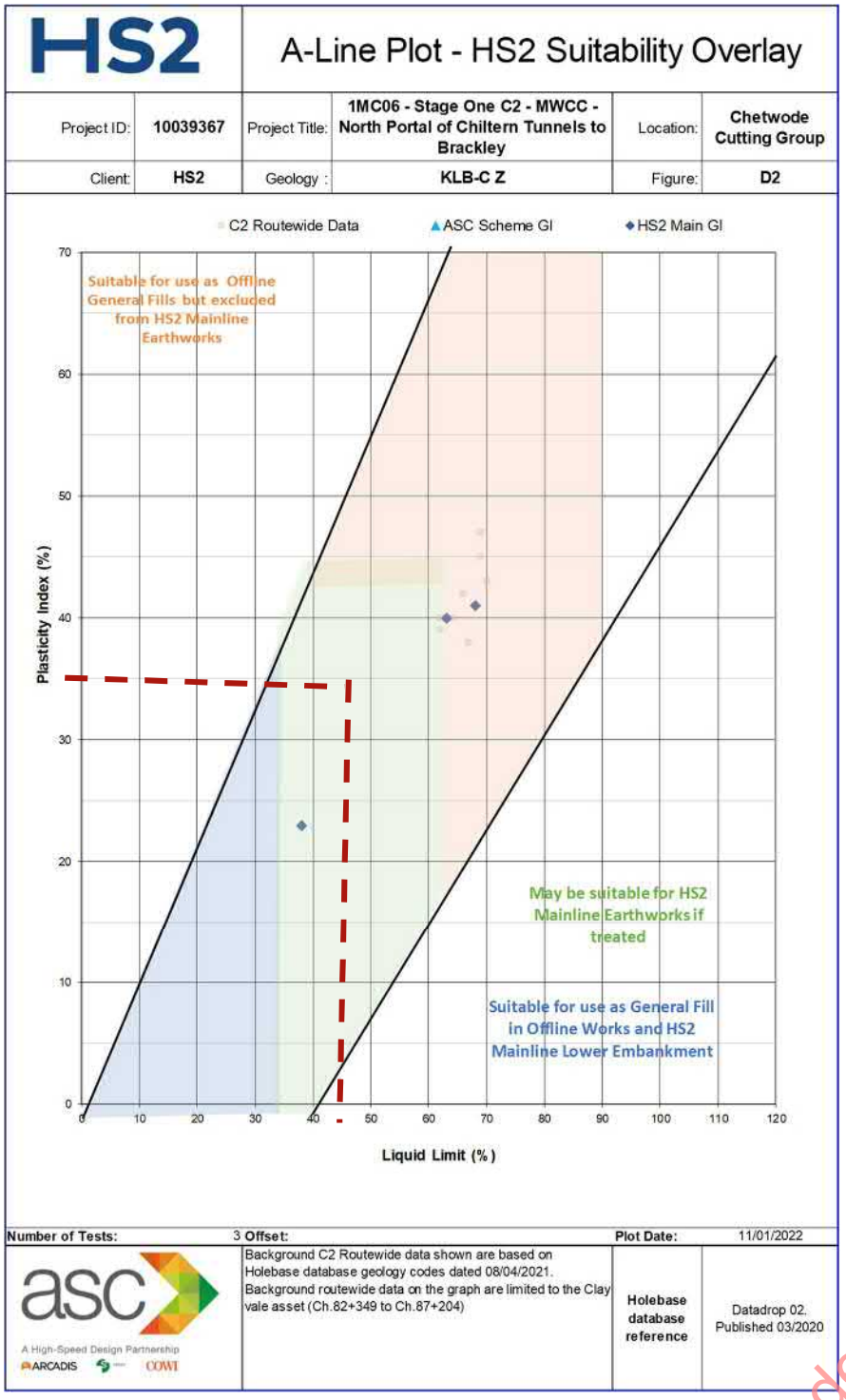


Figure D-30. Plasticity Index vs. Liquid Limit within the KLB-C

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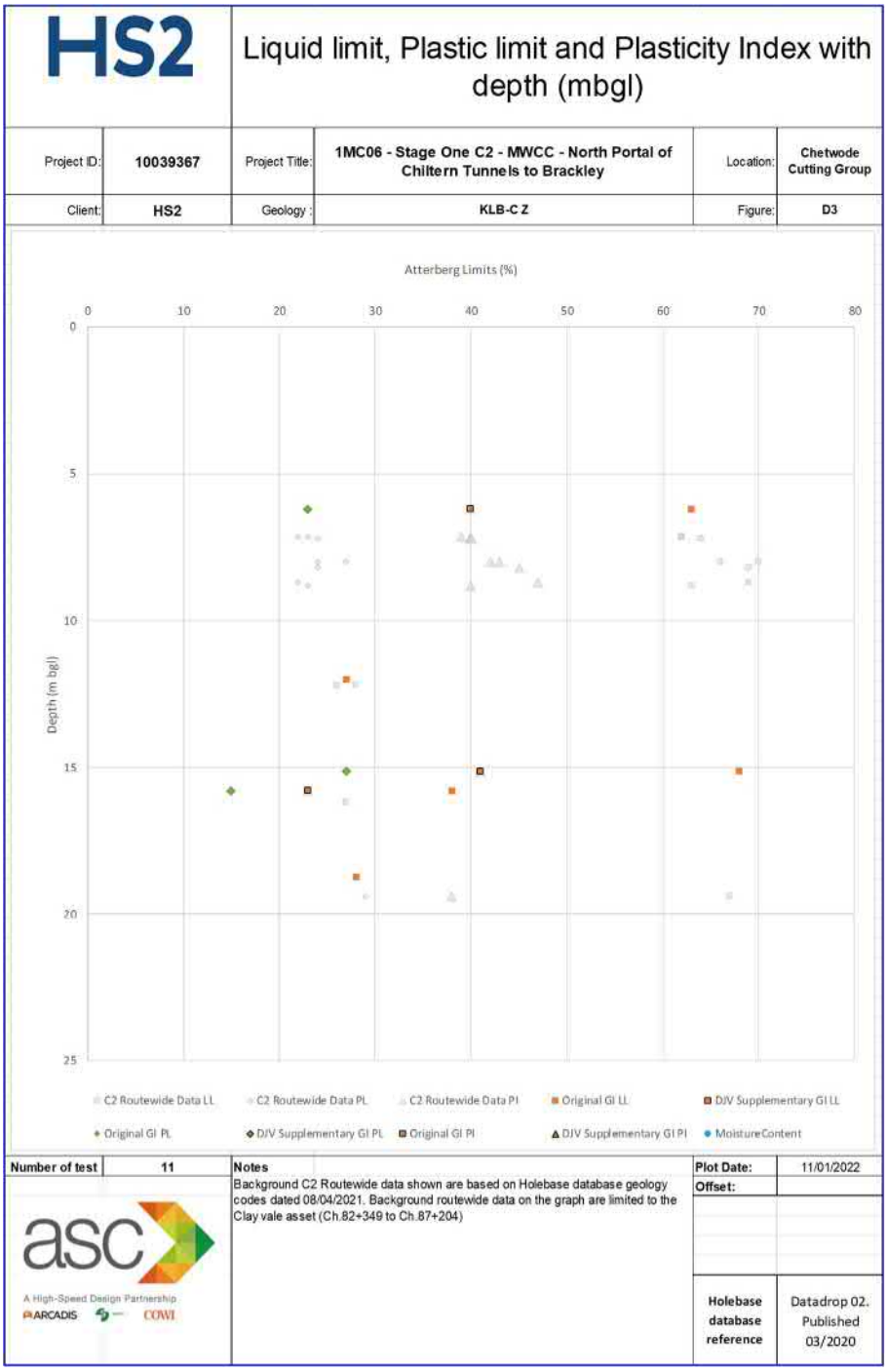


Figure D-31. Plasticity Index vs. depth within the KLB-C

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Sulphur content

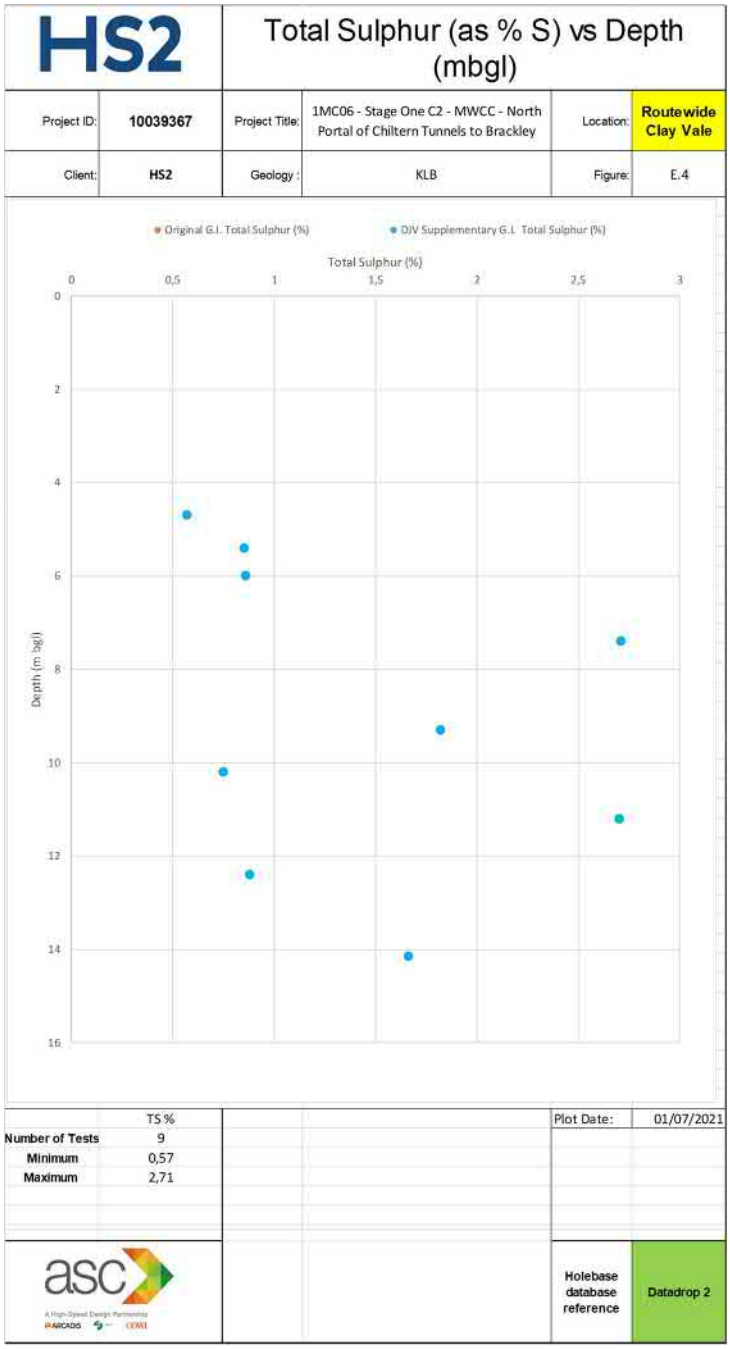


Figure D-32. Total sulphur TS(%) within the KLB

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Standard Penetration Test desistance N_{SPT}

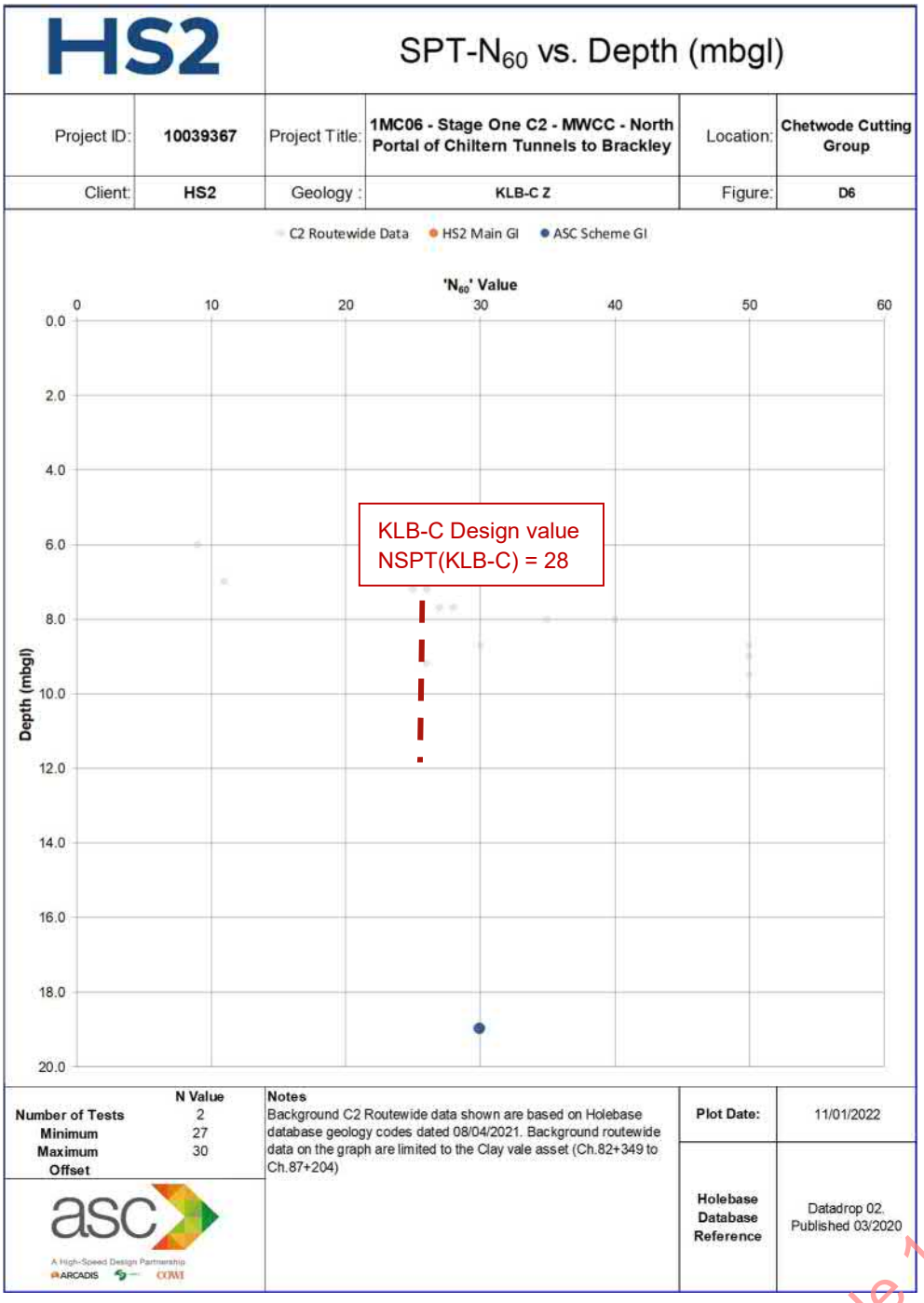


Figure D-33. SPT results within the KLB-C

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Undrained Shear strength c_u

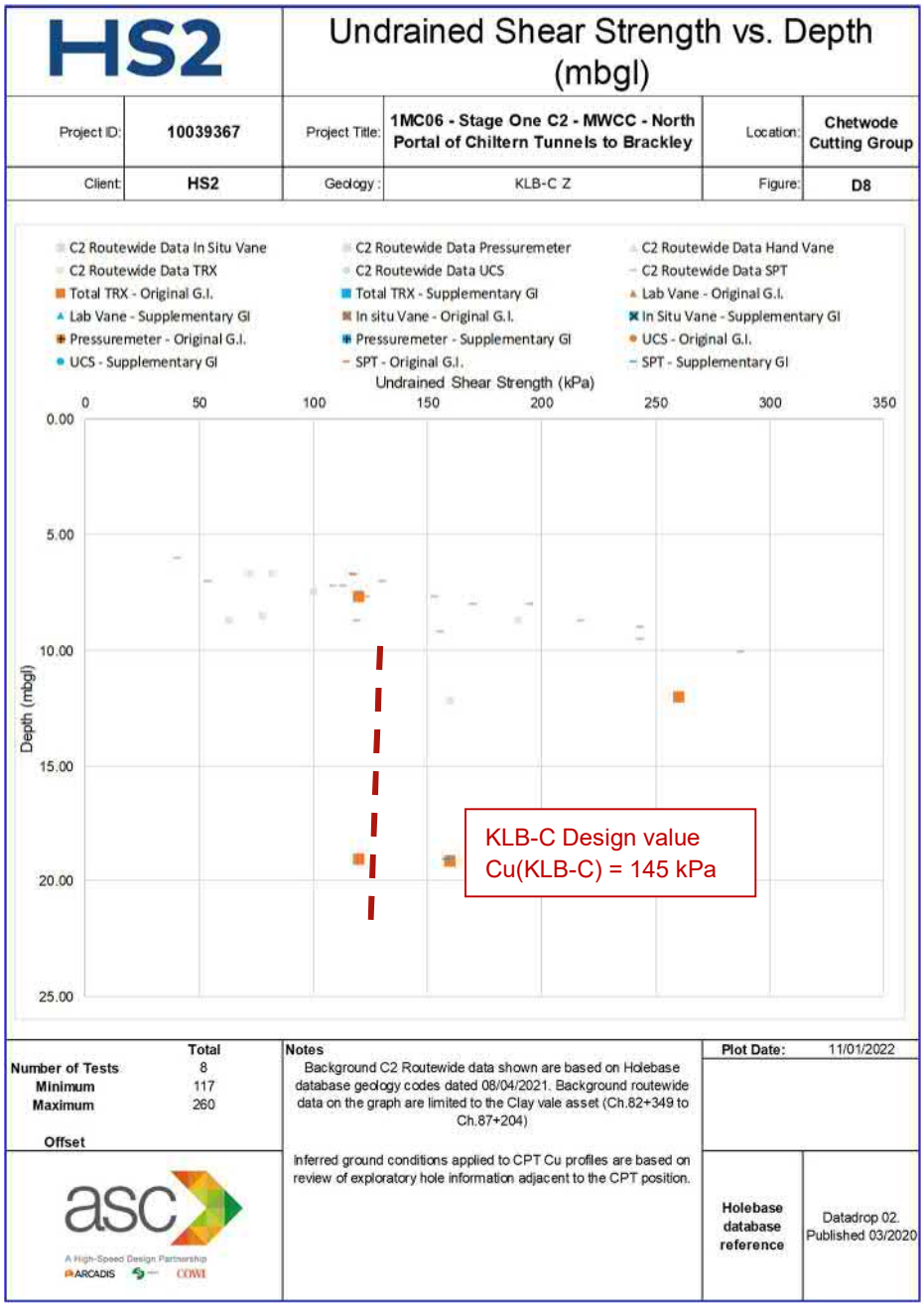


Figure D-34. Undrained shear strength obtained from different lab and in situ tests within the KLB-C

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Effective cohesion c' and effective friction angle ϕ'

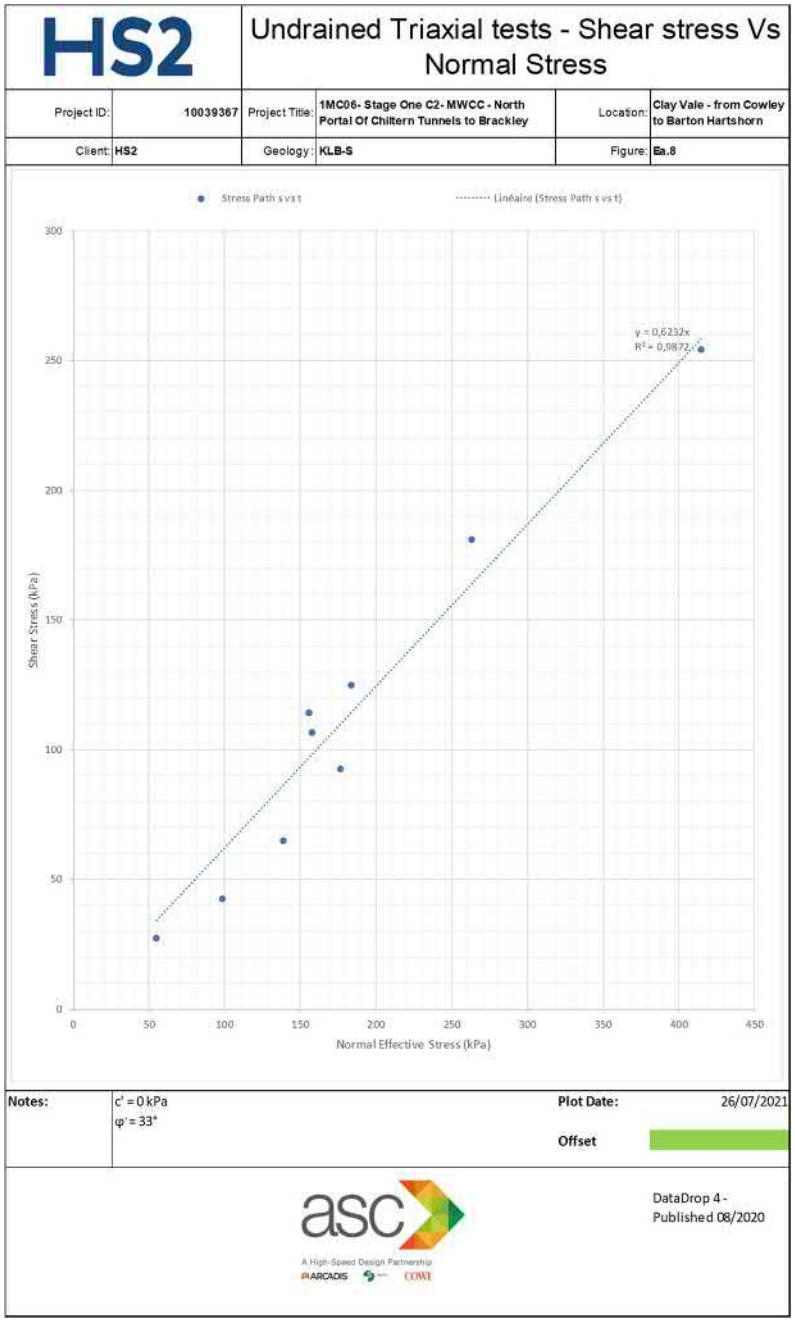


Figure D-35. Shear stress vs. Normal Stress in KLB-S Formation

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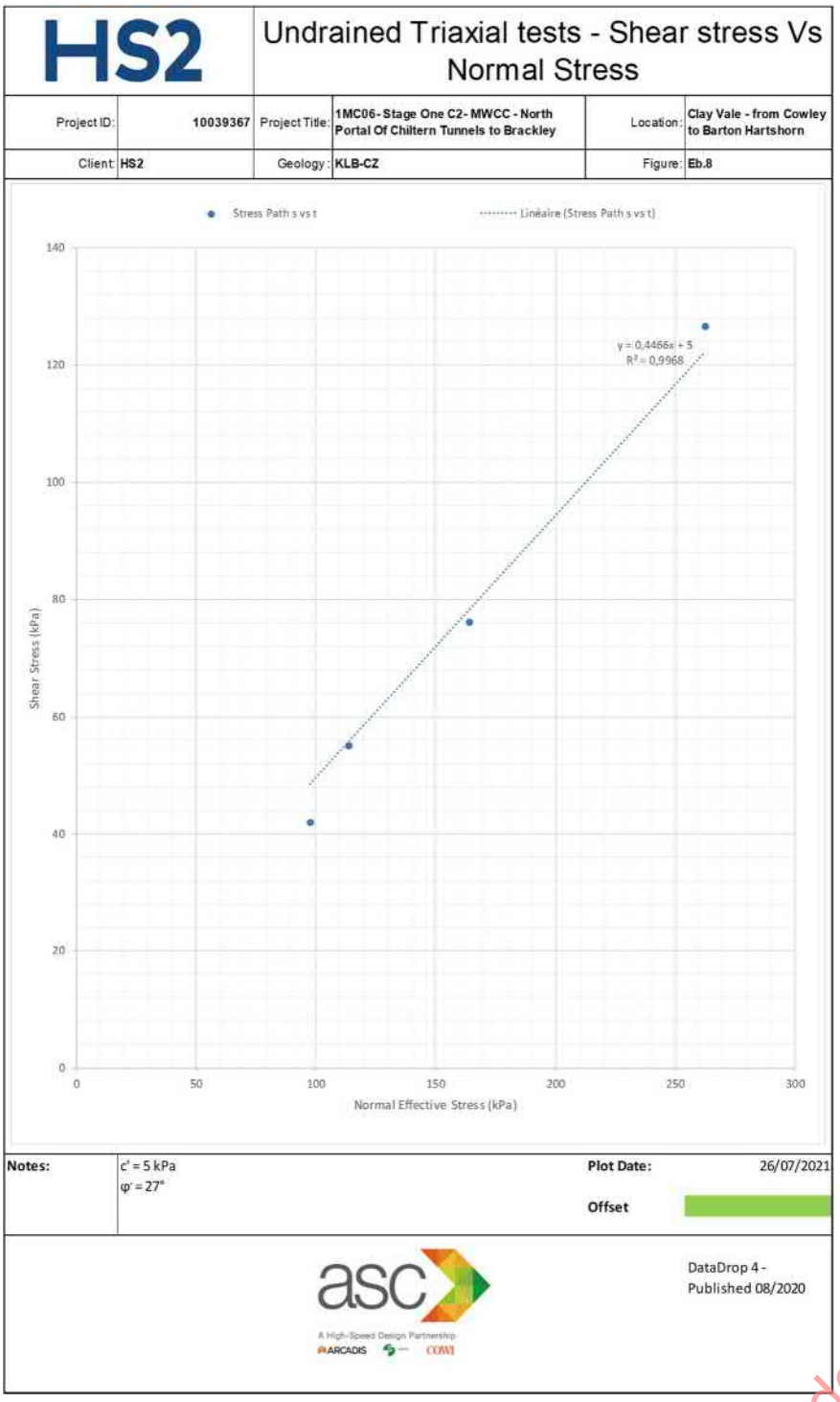


Figure D-36. Shear stress vs. Normal Stress in KLB-CZ Formation

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Young Modulus E'

Correlation with N obtained from SPT

E'=K·N

Where K=0.6 for over-consolidated clayey soils and K=2 for non-cohesive material (CIRIA R143) Ref.[42]

Correlation with E_{oed}

$$E' = E_{oed}\frac{(1-2\cdot\nu')\cdot(1+\nu')}{1-\nu'}$$

Where: E'=Young Modulus;
E_{oed}=Oedometer Modulus;
and ν'=Poisson's ratio=0.2

Correlation with c_u obtained from various lab and site tests

$$E' = E_u\frac{1+\nu'}{1+\nu_u}$$

Where: E'=Young Modulus;
E_u=Undrained Young Modulus using Jamiolkowski et al. 1979 Eu/Cu 300 for KLB-C;
ν'=Poisson's ratio=0.2
and ν_u=Undrained Poisson's ratio=0.5.

Regarding the lack of laboratory tests in KLB-S, the correlation with N obtained from SPT has been used

E'=K·N = 2 * 45 = 90 MPa

Where K=2 for granular and non-cohesive soils (CIRIA R143) Ref.[42]

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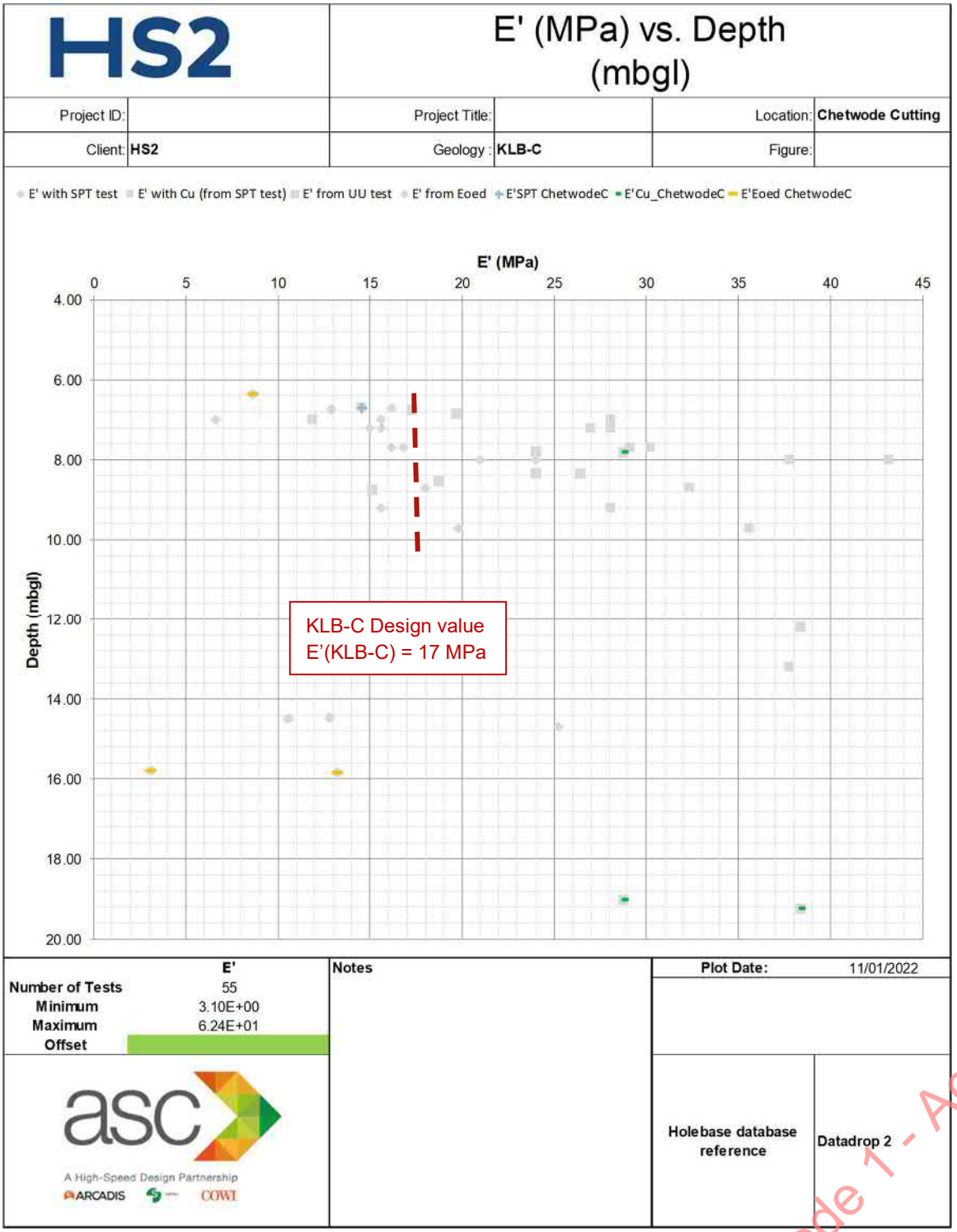


Figure D-37. E' obtained from different lab and in-situ tests within the KLB-CZ

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Oedometer Modulus E_{oed} (or Coefficient of volume change $m_v=1/E_{oed}$)

Correlation with E' coming from N of SPT

$$E' = E_{oed}\frac{(1-2\cdot\nu')\cdot(1+\nu')}{1-\nu'}$$

Where: E'=Young Modulus (see previous paragraph); E_{oed}=Oedometer Modulus; and ν'=Poisson's ratio=0.2

Coefficient of consolidation Cv; Cr

$c_{v_insitu} = 4 \cdot c_{v_lab}$ >> $k_{_insitu} = 4 \cdot k_{_lab}$
$c_r = 2.5\ c_{v_insitu}$

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Figure D-38 k and c_v obtained from diff–rent in-situ and lab tests within the KLB-C formation

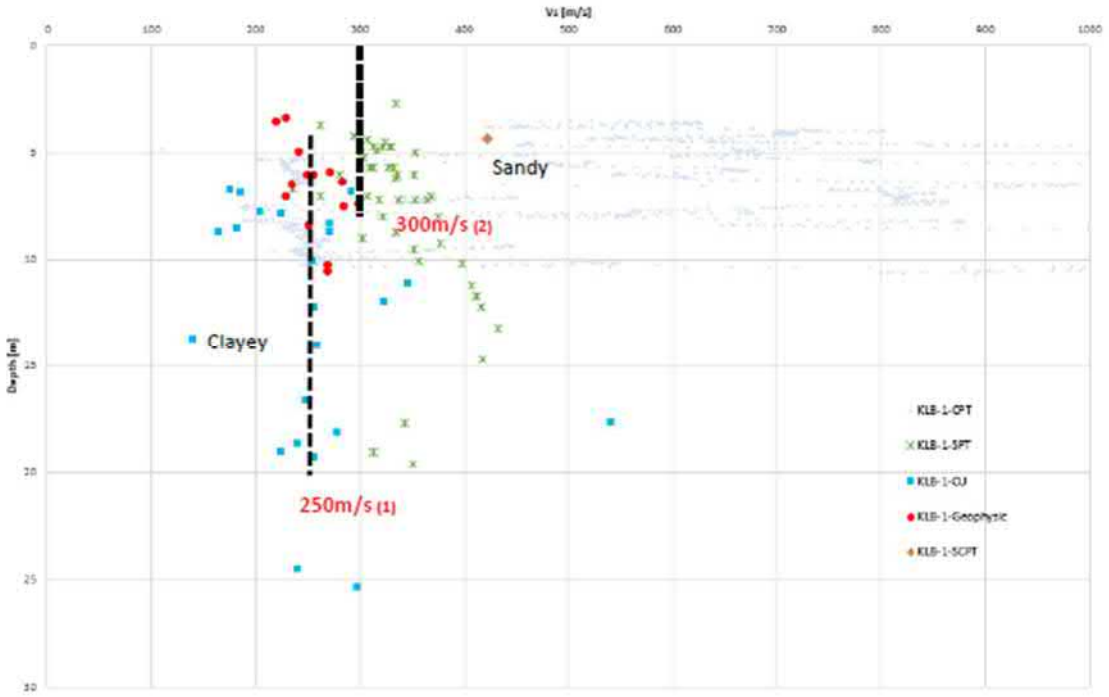
HS2 Ltd - Code 1 - Accepted

Shear Waves Velocity Profile Vs

HS2

Shear Wave Velocity vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC07 - Stage One C3 -MWCC – Brackley to South Portal of Long Itchington Tunnel	Location:	Chetwode cutting
Client:	HS2	Geology :	KLB	Figure:	D12



Notes
(1) value set for clayey KLB.
(2) value set for sandy KLB.

Plot Date:	17/01/2022
Holebase Database Reference	DataDrop 14

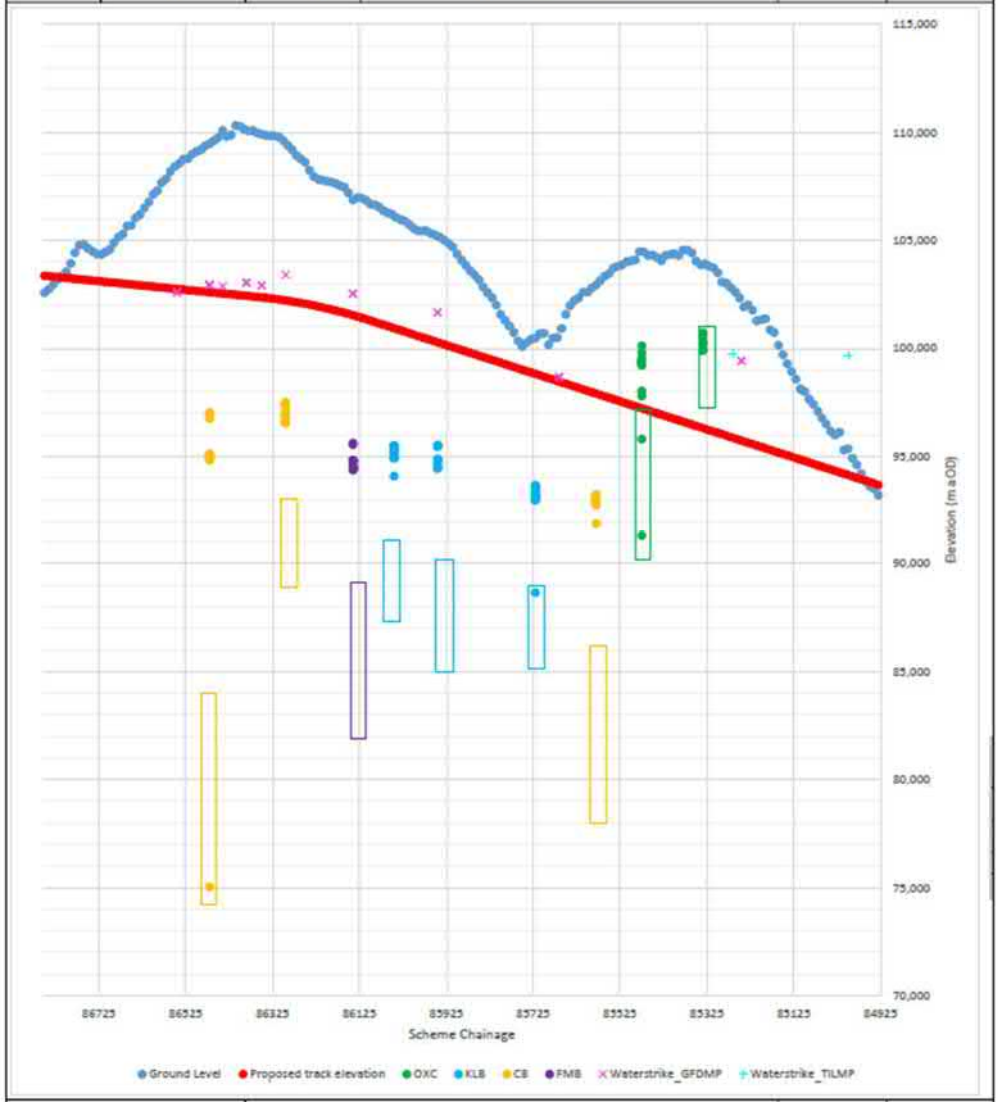
Figure D-39 Shear waves velocity - KLB

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Groundwater level

HS2 Groundwater Standpipe Monitoring Information

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley
Client:	HS2	Location :	Chetwode Cutting Group



Notes:	Plot Date:	02/02/2022
	Holebase database reference	Datadrop 02. Published 03/2020

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APPENDIX C

Calculation Output – Mainline Earthworks

Number of Pages: 97

HS2 Ltd - Code 1 - Accepted

Stability calculations

Calculation profile Ch 85+140, Back Analysis

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Project data

Project reference : HS2 Detail Design
Calculation title : Chetwode Cutting GM1_Ch. 85140 _ H = 5.6 m
Location : Ch. 85140
Comments : Slope 1V/3H Landscape bund H = +3m
Units : kN, kPa, kN/m³
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	landscape		19,0	23,00	1,0	0,0	-	-	-	No	No	No
2	E&R class1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
3	OXCw		19,0	26,00	3,0	0,0	-	-	-	No	No	No
4	OXCu		21,0	28,00	5,0	0,0	-	-	-	No	No	No
5	TILMP		21,0	27,00	2,0	0,0	-	-	-	No	No	No
6	TILMP vadose		21,0	26,00	1,0	0,0	-	-	-	No	No	No
7	OXCw vadose		19,0	25,00	1,0	0,0	-	-	-	No	No	No
8	KLB S		21,0	34,00	0,0	0,0	-	-	-	No	No	No
9	OXCu_Cu		21,0	0,00	120,0	0,0	-	-	-	No	No	No
10	TILMP_Cu		21,0	0,01	72,0	0,0	-	-	-	No	No	No
11	OXCw_Cu		19,0	0,00	60,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	landscape		-	-	-	Effective	Linear	No	-	-
2	E&R class1		-	-	-	Effective	Linear	No	-	-
3	OXCw		-	-	-	Effective	Linear	No	-	-
4	OXCu		-	-	-	Effective	Linear	No	-	-
5	TILMP		-	-	-	Effective	Linear	No	-	-
6	TILMP vadose		-	-	-	Effective	Linear	No	-	-
7	OXCw vadose		-	-	-	Effective	Linear	No	-	-
8	KLB S		-	-	-	Effective	Linear	No	-	-
9	OXCu_Cu		-	-	-	Undrained	Linear	No	-	-
10	TILMP_Cu		-	-	-	Undrained	Linear	No	-	-
11	OXCw_Cu		-	-	-	Undrained	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	0,000	0,000	2	26,000	0,000	3	42,800	-5,600	4	100,000	-5,600	5	38,000	-4,000	6	0,000	-4,000
7	0,000	-6,000	8	100,000	-6,000	9	100,000	-9,000	10	0,000	-9,000	11	23,000	0,000	14	20,000	0,000
15	36,800	-5,600	16	32,007	-4,000	17	45,800	-8,600	18	43,198	-6,000	19	100,000	-8,600	20	32,000	-2,000
21	0,000	-2,000	22	26,003	-2,000												

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
3	3	4	5	3	5	8	9	10	10	2	11	14	1	14	15	11	14	17	16	5
18	16	6	19	16	15	20	15	3	21	3	18	22	18	7	23	18	8	24	18	17
25	17	19	26	2	20	27	5	20	28	20	22	29	22	14	30	22	16	31	22	21

Distributed loads

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	20 kPa works	23,000	0,000	20,0	25,500	0,000	20,0	90,00
2	10 kPa	23,000	0,000	10,0	25,500	0,000	10,0	90,00

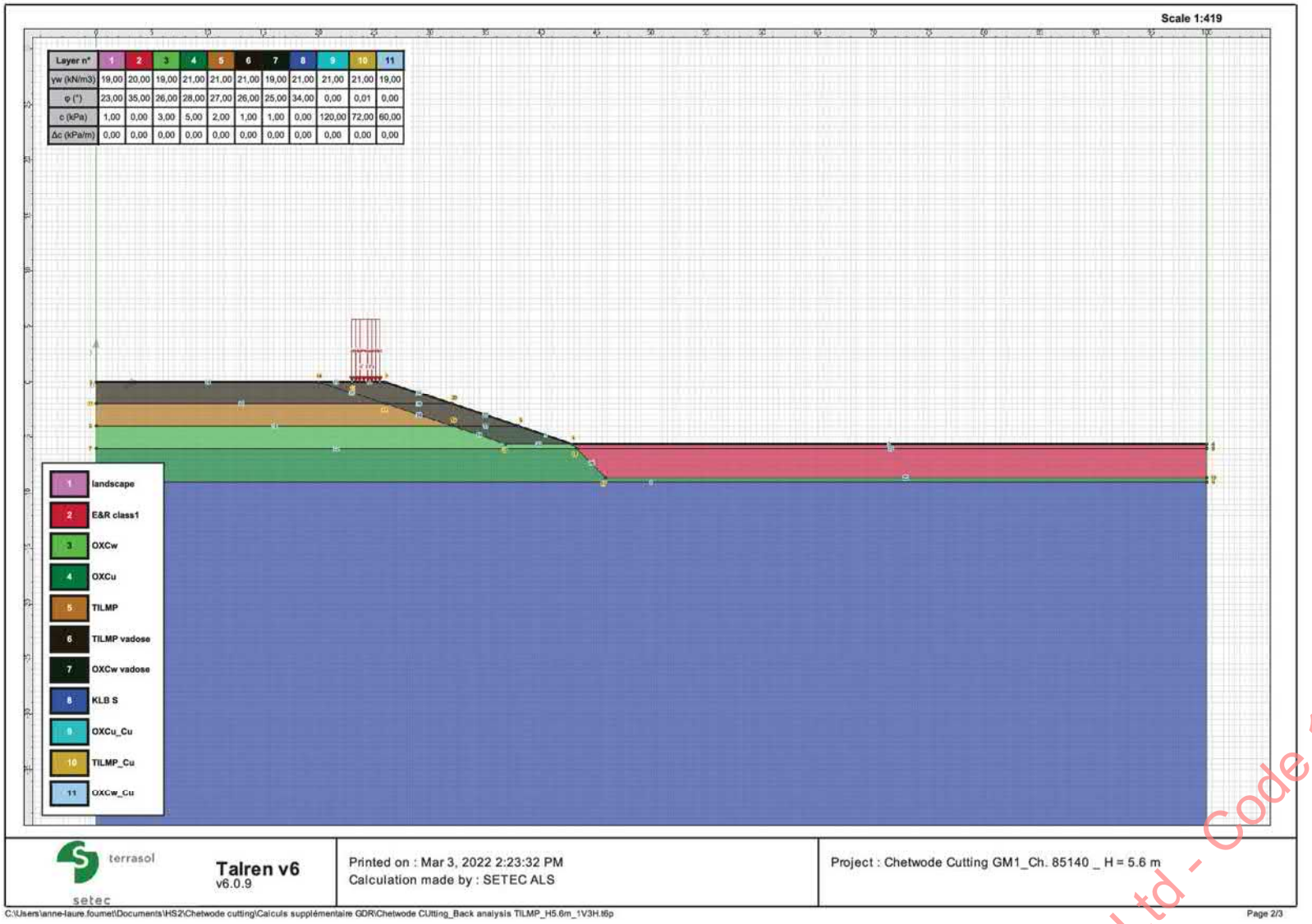
terrasol
setec

Talren v6
v6.0.9

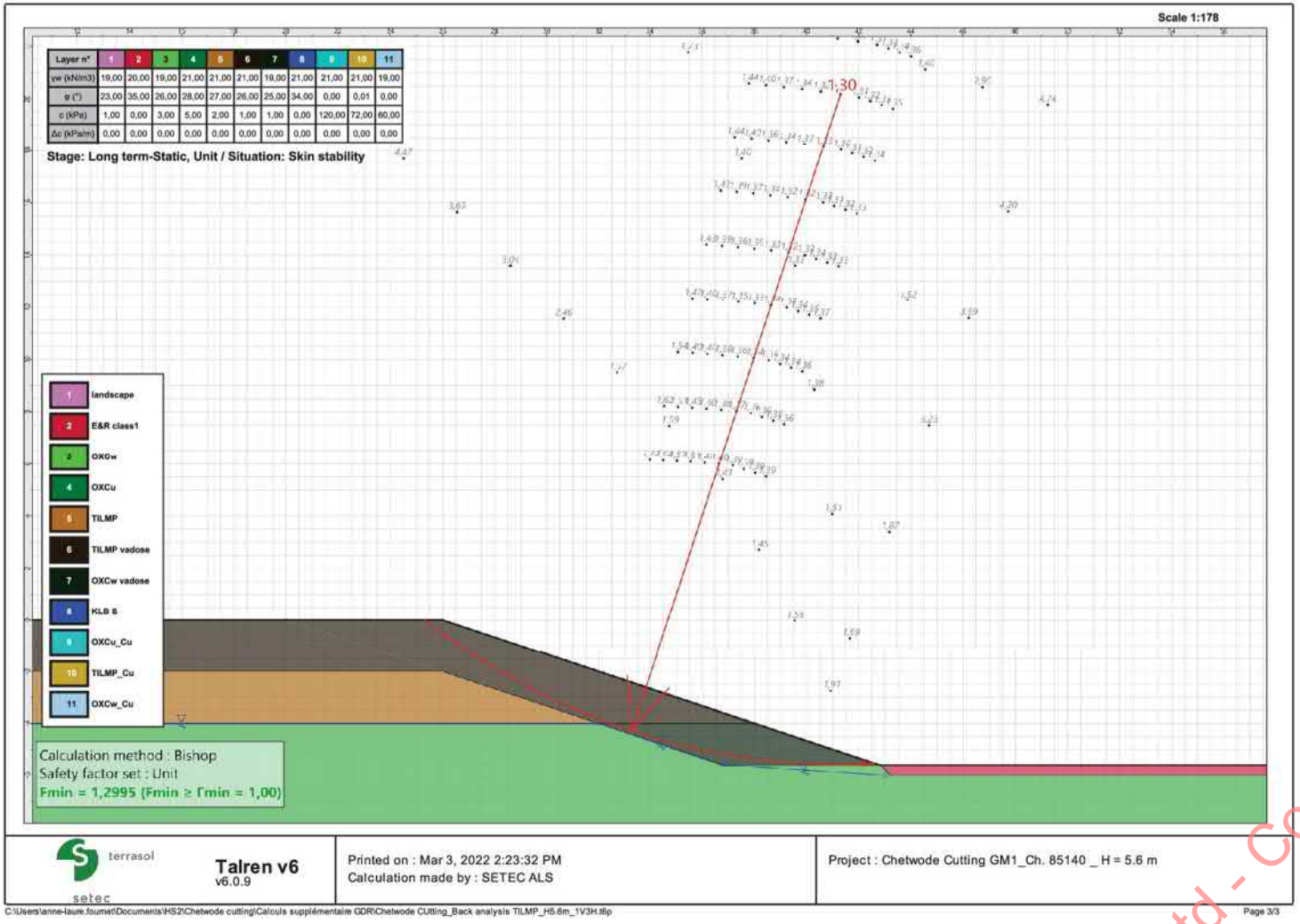
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Calculation made by : SETEC ALS
Project : Chetwode Cutting GM1_Ch. 85140 _ H = 5.6 m

C:\Users\anne-laure.fournet\Documents\HS2\Chetwode cutting\Calculs supplémentaire GDR\Chetwode Cutting_Back analysis TILMP_H5.6m_1V3H.tlp Page 1/3

HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

Calculation profile Ch 85+140, Ground Model

HS2 Ltd - Code 1 - Accepted

Project data

Project reference : HS2 Detail Design

Calculation title : Chetwode Cutting GM1_Ch. 85140 _ H = 5.6 m

Location : Ch. 85140

Comments : Slope 1V/3H Landscape bund H = +3m

Units : kN, kPa, kN/m3

γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs nails	pl	KsB	Anisotropy	Favorable	Specific safety factors
1	landscape		19,0	23,00	1,0	0,0	-	-	-	No	No	No
2	E&R class1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
3	OXCw		19,0	26,00	3,0	0,0	-	-	-	No	No	No
4	OXCu		21,0	28,00	5,0	0,0	-	-	-	No	No	No
5	TILMP		21,0	27,00	2,0	0,0	-	-	-	No	No	No
6	TILMP vadose		21,0	26,00	1,0	0,0	-	-	-	No	No	No
7	OXCw vadose		19,0	25,00	1,0	0,0	-	-	-	No	No	No
8	KLB S		21,0	34,00	0,0	0,0	-	-	-	No	No	No
9	OXCu_Cu		21,0	0,00	120,0	0,0	-	-	-	No	No	No
10	TILMP_Cu		21,0	0,00	72,0	0,0	-	-	-	No	No	No
11	OXCw_Cu		19,0	0,00	60,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve
1	landscape		-	-	-	Effective	Linear
2	E&R class1		-	-	-	Effective	Linear
3	OXCw		-	-	-	Effective	Linear
4	OXCu		-	-	-	Effective	Linear
5	TILMP		-	-	-	Effective	Linear
6	TILMP vadose		-	-	-	Effective	Linear
7	OXCw vadose		-	-	-	Effective	Linear
8	KLB S		-	-	-	Effective	Linear
9	OXCu_Cu		-	-	-	Undrained	Linear
10	TILMP_Cu		-	-	-	Undrained	Linear
11	OXCw_Cu		-	-	-	Undrained	Linear

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	0,000	0,000	2	26,000	0,000	3	42,800	-5,600	4	100,000	-5,600	5	38,000	-4,000	6	0,000	-4,000
7	0,000	-6,000	8	100,000	-6,000	9	100,000	-9,000	10	0,000	-9,000	11	23,000	0,000	12	11,000	3,000
13	8,000	3,000	14	20,000	0,000	15	36,800	-5,600	16	32,007	-4,000	17	43,400	-8,000	18	43,000	-6,000
19	100,000	-8,000	20	32,000	-2,000	21	0,000	-2,000	22	26,003	-2,000						

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
3	3	4	5	3	5	8	9	10	10	2	11	11	11	12	12	12	13	13	13	1
14	1	14	15	11	14	17	16	5	18	16	6	19	16	15	20	15	3	21	3	18
22	18	7	23	18	8	24	18	17	25	17	19	26	2	20	27	5	20	28	20	22
29	22	14	30	22	16	31	22	21												

Distributed loads

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	20 kPa works	23,000	0,000	20,0	25,500	0,000	20,0	90,00
2	10 kPa	23,000	0,000	10,0	25,500	0,000	10,0	90,00
3	10 kPa LS	8,500	3,000	10,0	10,500	3,000	10,0	90,00

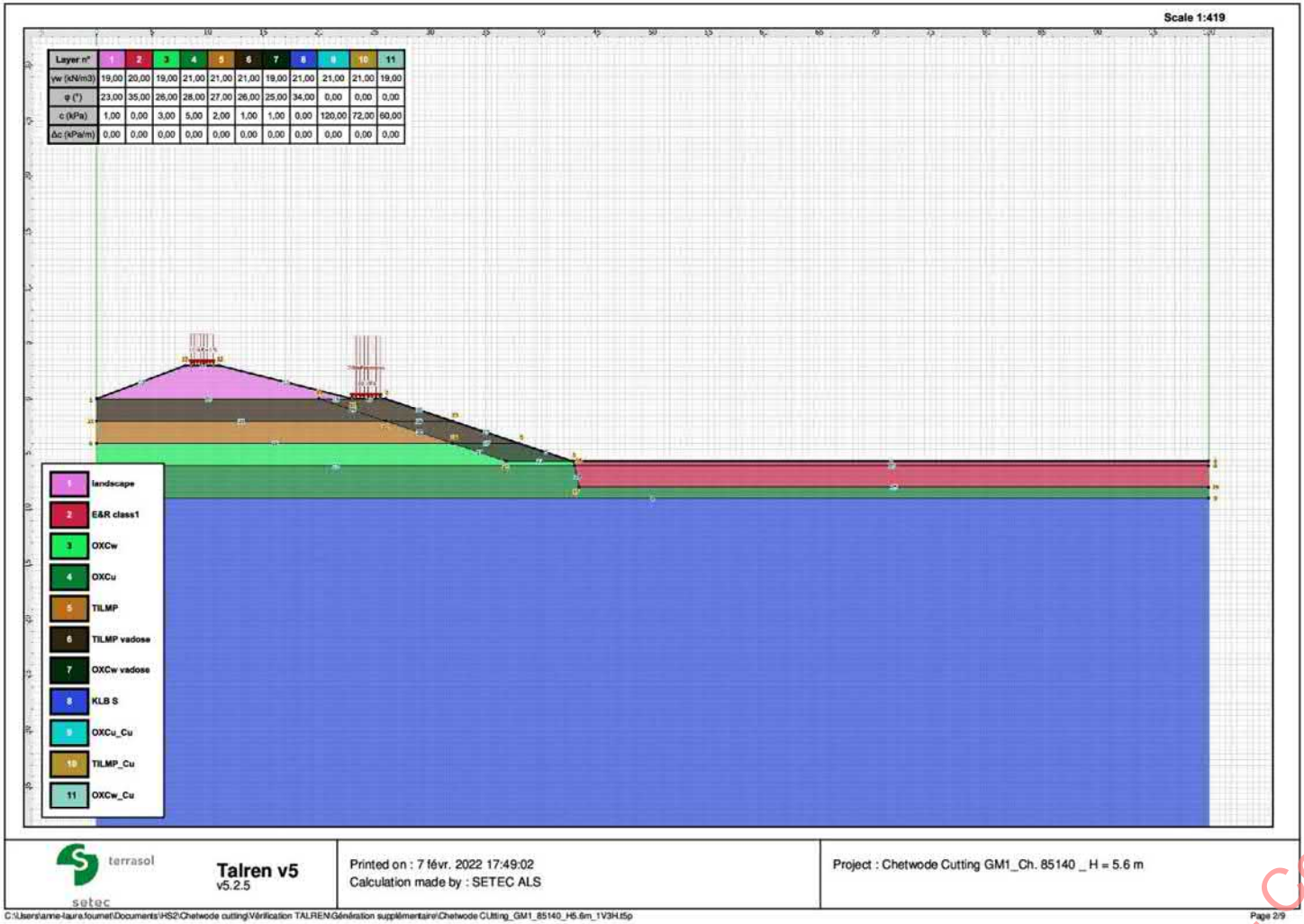
terrasol setec

Talren v5
v5.2.5

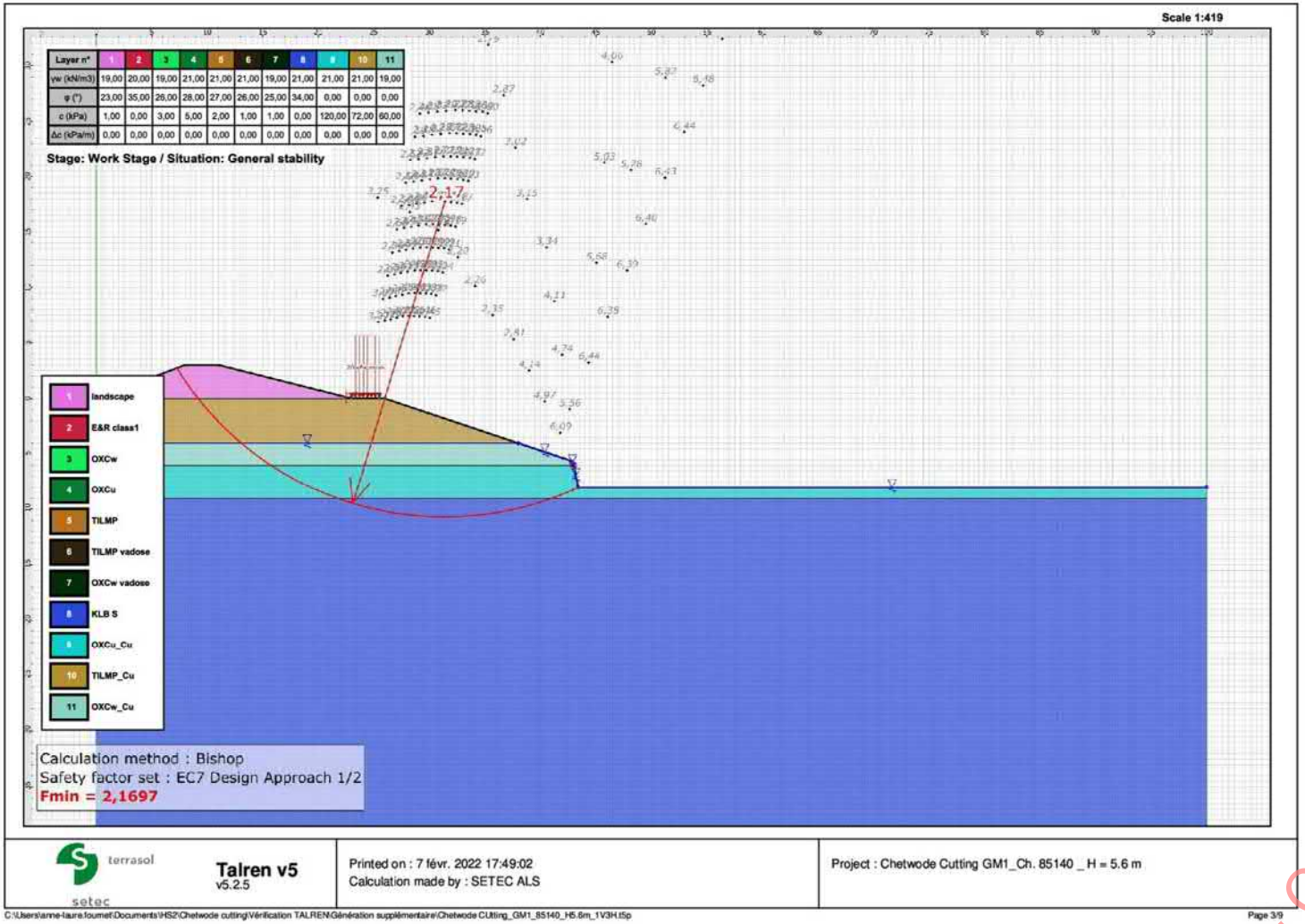
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Calculation made by : SETEC ALS
Project : Chetwode Cutting GM1_Ch. 85140 _ H = 5.6 m

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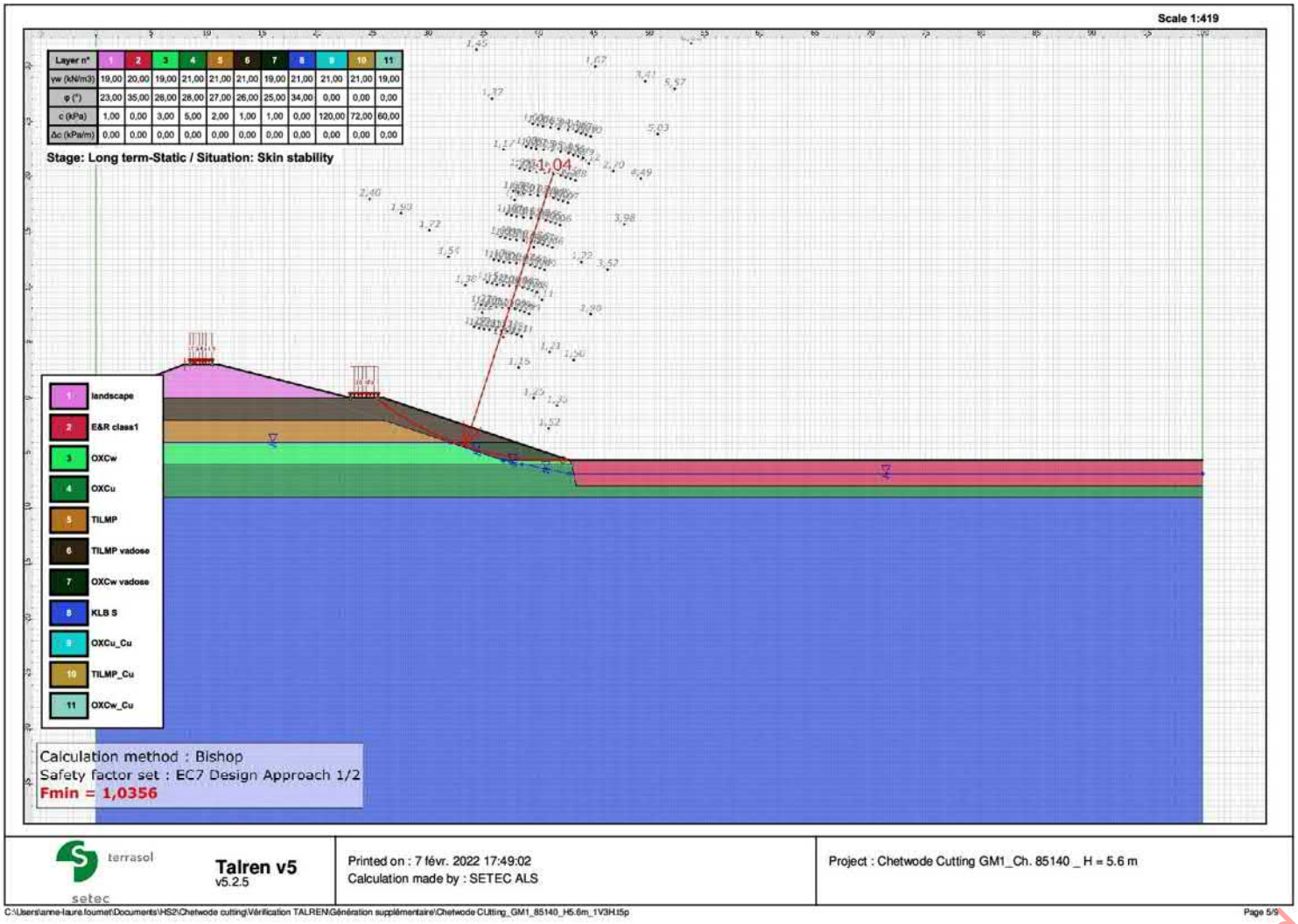
HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

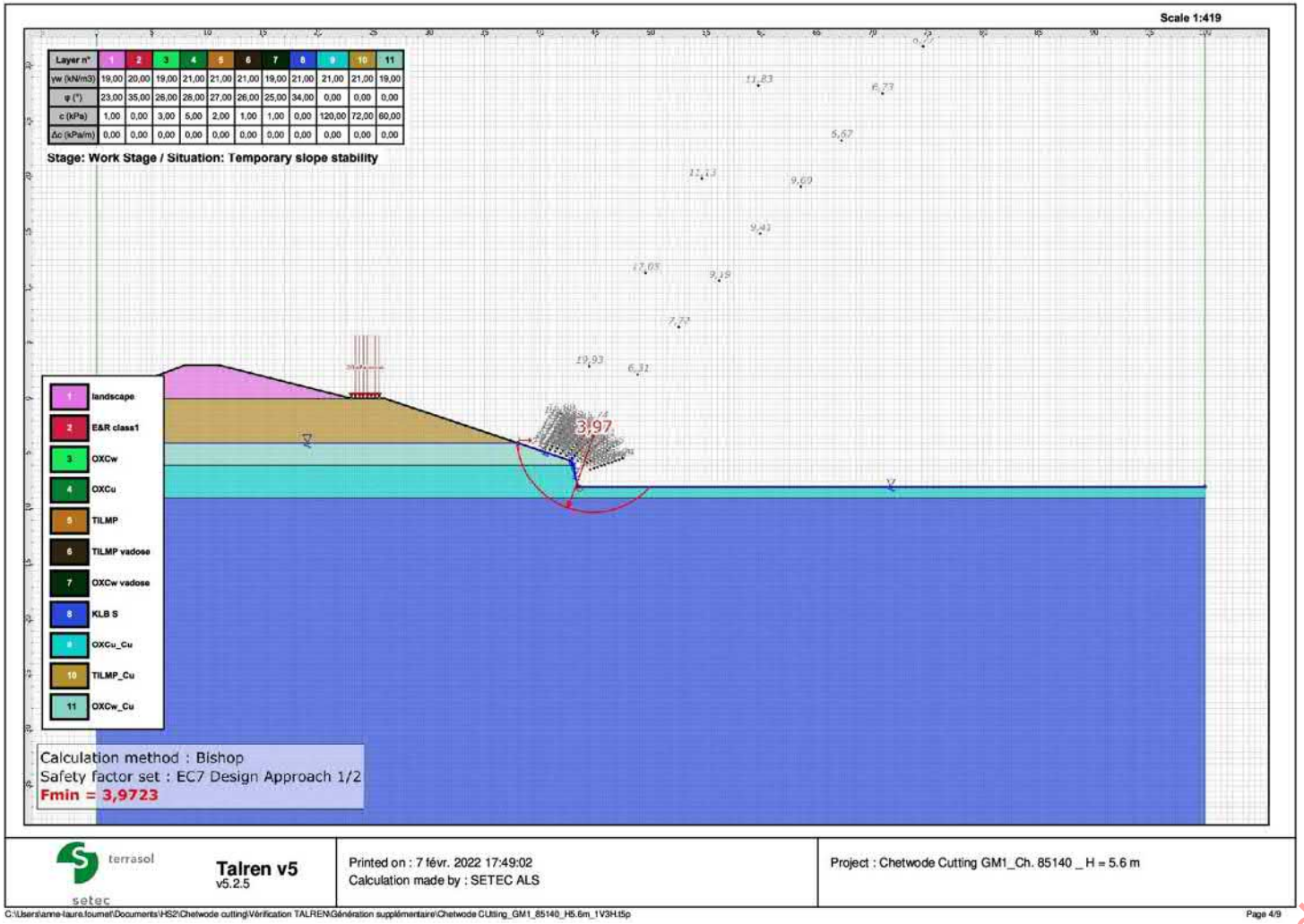


HS2 Ltd - Code 1 - Accepted

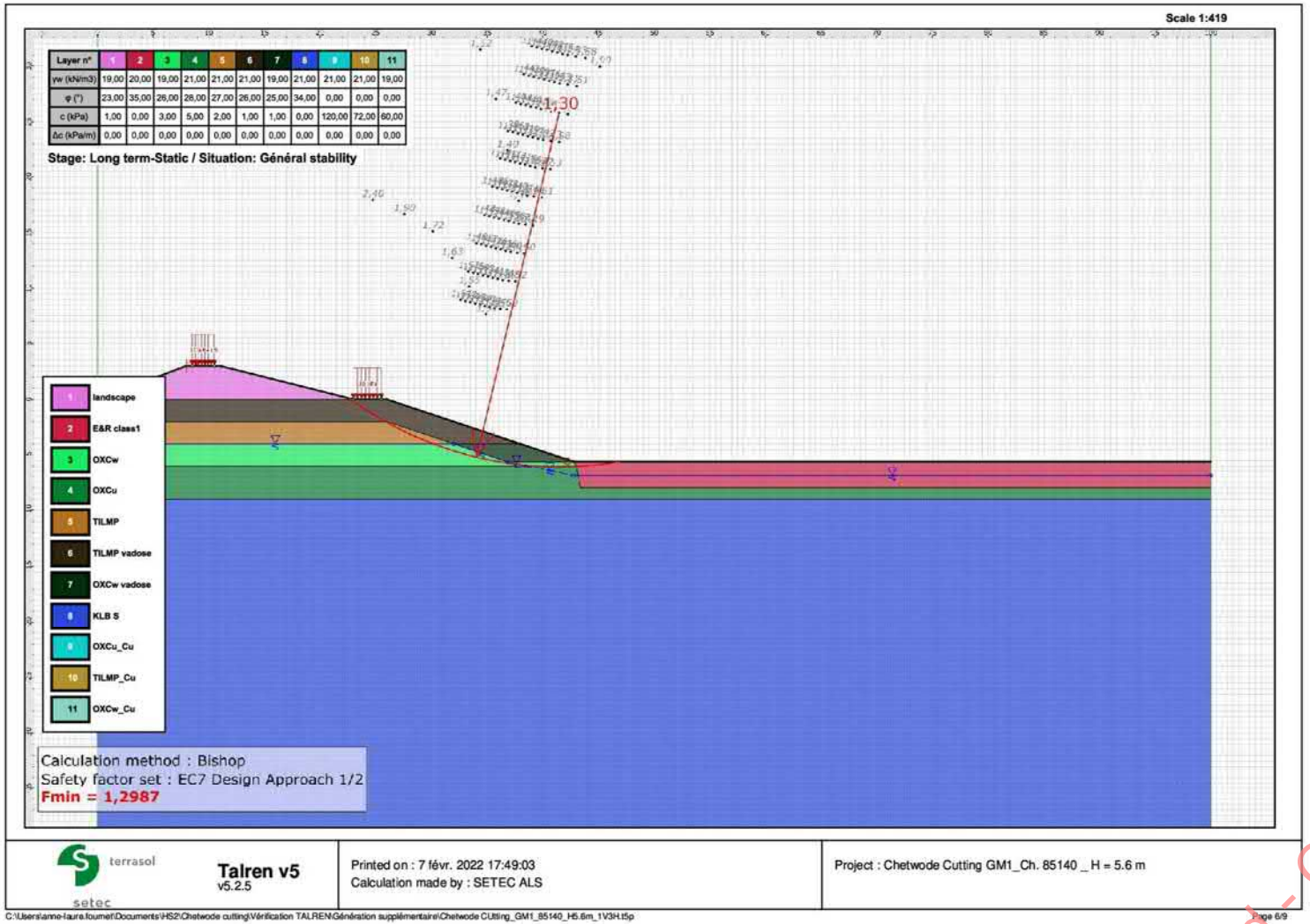


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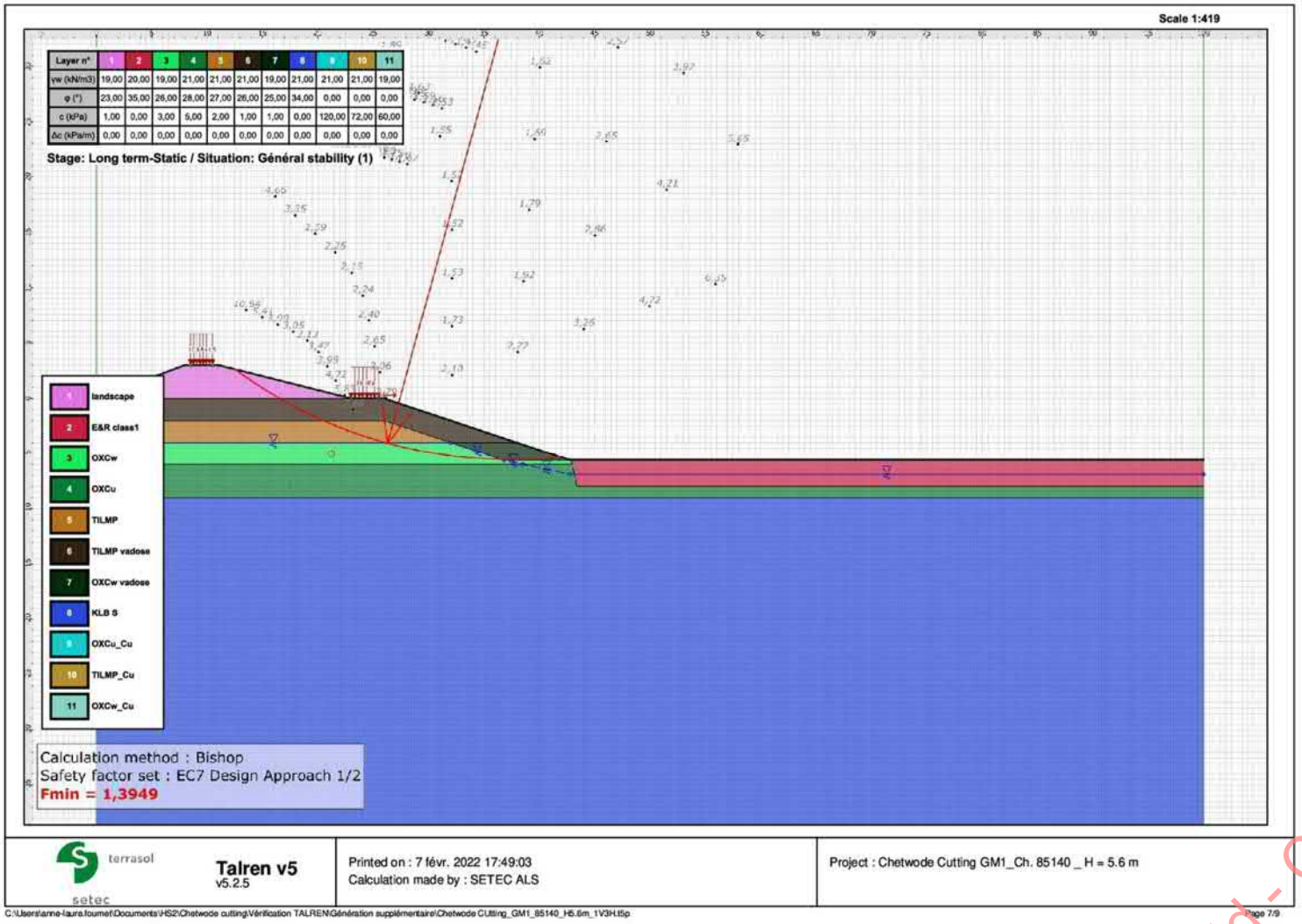
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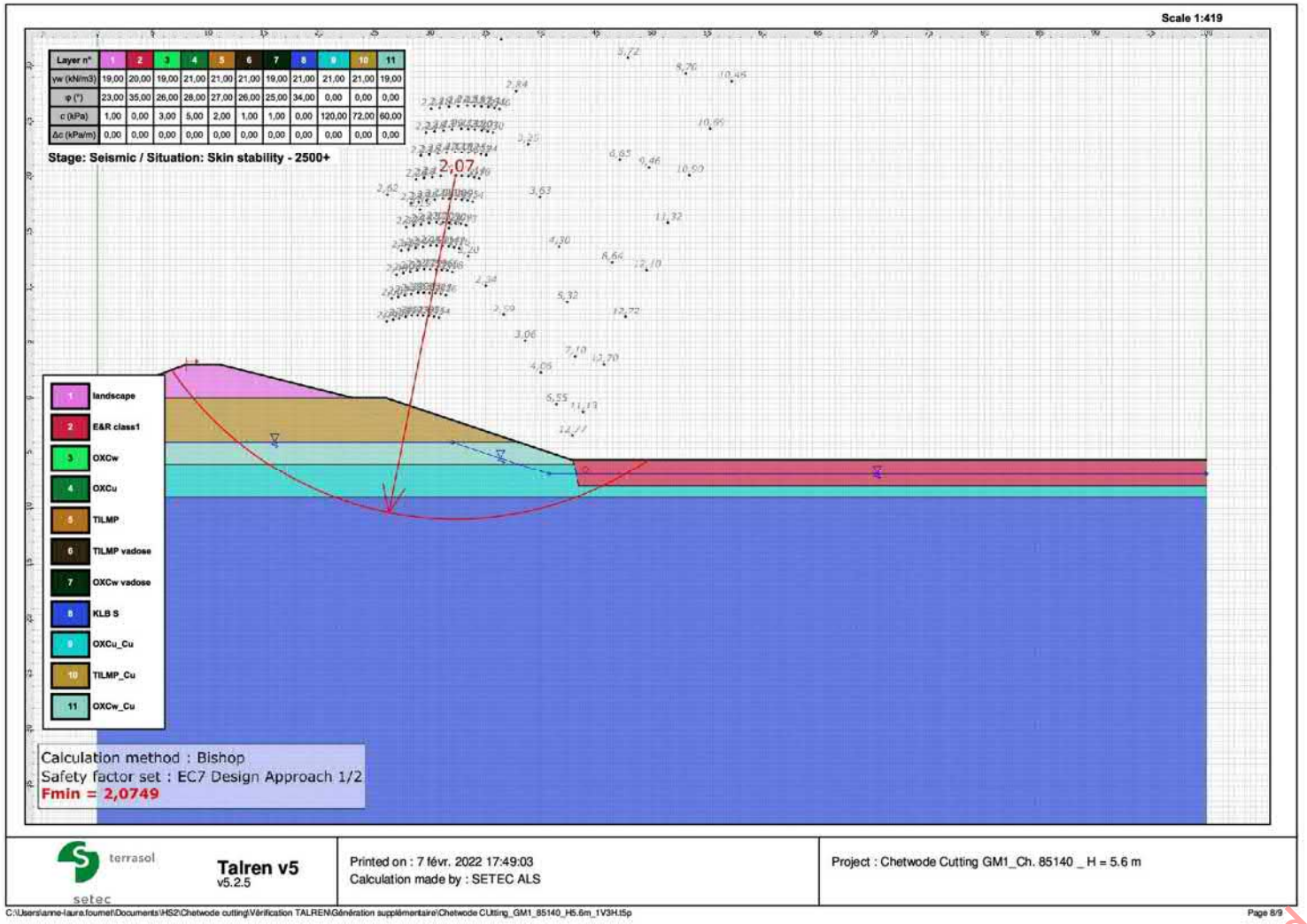
HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

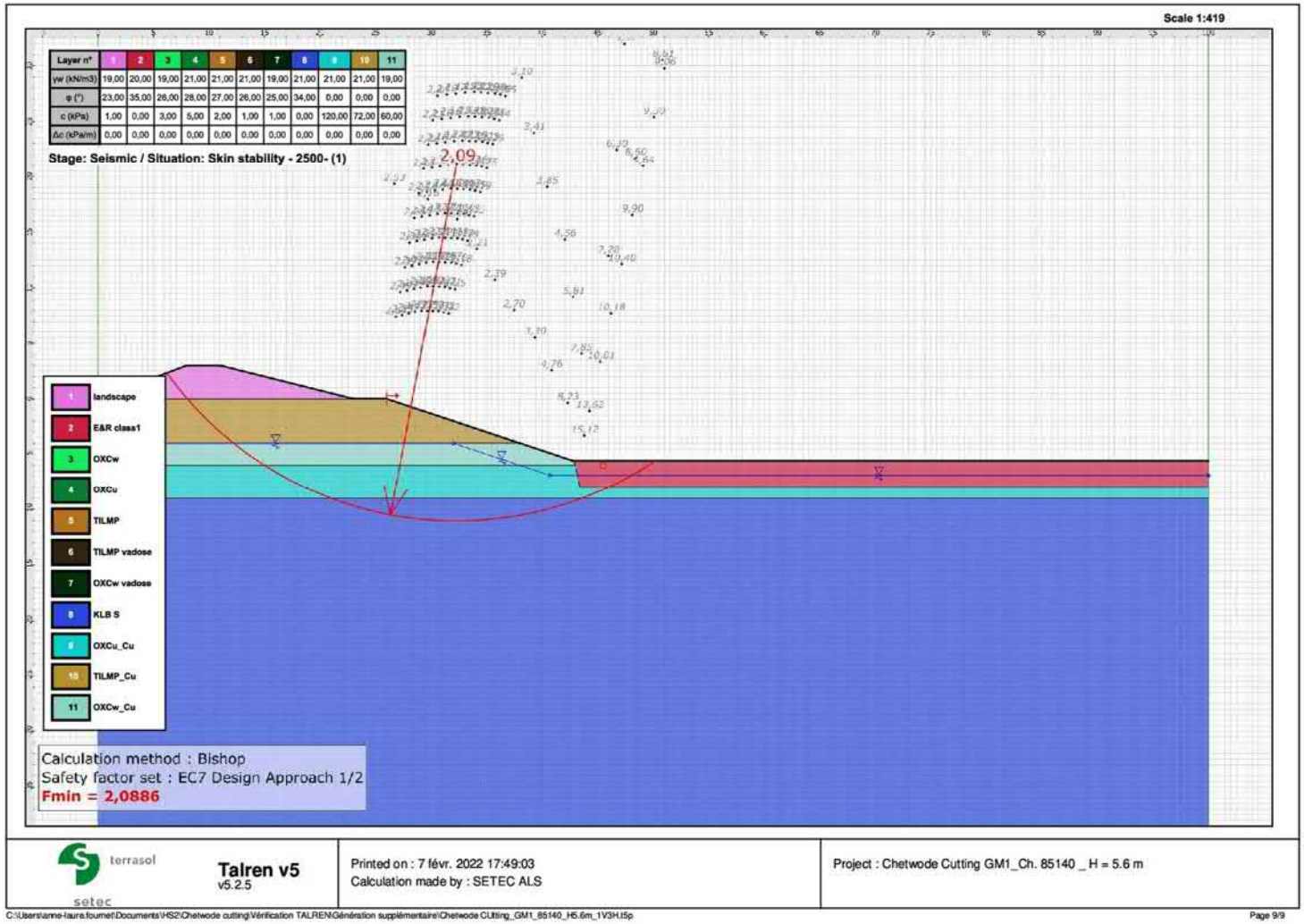


HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

Calculation profile Ch 85+450, Ground Model 2, ATS Platform

HS2 Ltd - Code 1 - Accepted

Project data

Project reference : HS2 Detail Design
Calculation title : Chetwode Cutting GM2_Ch. 85450 _ H = 9 m
Location : Ch. 85450
Comments : Slope 1V/4H ATS Platform -4 m bgl
Units : kN, kPa, kN/m3
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs nails	pl	KsB	Anisotropy	Favorable	Specific safety factors
1	landscape		19,0	23,00	1,0	0,0	-	-	-	No	No	No
2	E&R class1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
3	OXCw		19,0	26,00	2,0	0,0	-	-	-	No	No	No
4	OXCu		21,0	28,00	5,0	0,0	-	-	-	No	No	No
5	TILMP		21,0	27,00	2,0	0,0	-	-	-	No	No	No
6	TILMP vadose		21,0	26,00	1,0	0,0	-	-	-	No	No	No
7	OXCw vadose		19,0	25,00	1,0	0,0	-	-	-	No	No	No
8	KLB CZ		20,0	27,00	5,0	0,0	-	-	-	No	No	No
9	OXCu_Cu		21,0	0,00	120,0	0,0	-	-	-	No	No	No
10	GFDMP		19,0	30,00	0,0	0,0	-	-	-	No	No	No
11	OXCu vadose		21,0	26,00	1,0	0,0	-	-	-	No	No	No
12	TILMP_Cu		21,0	0,00	72,0	0,0	-	-	-	No	No	No
13	OXCw_Cu		19,0	0,00	60,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve
1	landscape		-	-	-	Effective	Linear
2	E&R class1		-	-	-	Effective	Linear
3	OXCw		-	-	-	Effective	Linear
4	OXCu		-	-	-	Effective	Linear
5	TILMP		-	-	-	Effective	Linear
6	TILMP vadose		-	-	-	Effective	Linear
7	OXCw vadose		-	-	-	Effective	Linear
8	KLB CZ		-	-	-	Effective	Linear
9	OXCu_Cu		-	-	-	Undrained	Linear
10	GFDMP		-	-	-	Effective	Linear
11	OXCu vadose		-	-	-	Effective	Linear
12	TILMP_Cu		-	-	-	Undrained	Linear
13	OXCw_Cu		-	-	-	Undrained	Linear

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	0,000	0,000	6	-10,000	-4,000	7	-10,000	-6,000	9	100,000	-11,000	10	-10,000	-11,000	16	32,007	-4,000
18	43,198	-6,000	21	-10,000	-2,000	24	50,397	-5,600	25	42,400	-5,600	28	43,998	-4,000	29	36,000	-4,000
30	50,797	-6,000	31	-10,000	-17,000	32	100,000	-17,000	33	64,000	-9,000	34	51,997	-6,000	35	100,000	-9,000
36	56,000	-9,000	37	44,000	-6,000	38	66,000	-11,000	39	24,000	-4,000	40	8,000	0,000	41	16,000	-2,000
42	16,000	-4,000	43	8,000	-2,000	44	-10,000	0,000	45	24,500	-4,500	46	43,500	-4,500	47	38,000	-4,500

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
22	18	7	45	24	28	47	28	29	50	29	16	55	31	32	56	24	34	57	34	30
59	34	33	60	33	35	61	25	37	62	37	30	63	37	18	64	37	36	65	36	33
66	9	38	67	10	38	68	38	33	69	16	39	71	1	40	73	39	41	76	41	40
77	6	42	78	39	42	79	42	43	80	43	41	81	43	21	82	43	1	83	1	44
84	39	45	85	45	47	86	47	29	87	47	25	88	47	46	89	46	28			

Distributed loads (1/2)

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	20 kPa works	0,000	0,000	20,0	7,500	0,000	20,0	90,00
2	10 kPa	5,000	0,000	10,0	7,500	0,000	10,0	90,00
3	ATS 75 kPa	24,000	-4,000	75,0	39,000	-4,000	75,0	90,00

terrasol
setec

Talren v5
v5.2.10

Printed on : 26 janv. 2022 17:19:31
Calculation made by : SETEC INTERNATIONAL
Project : Chetwode Cutting GM2_Ch. 85450 _ H = 9 m

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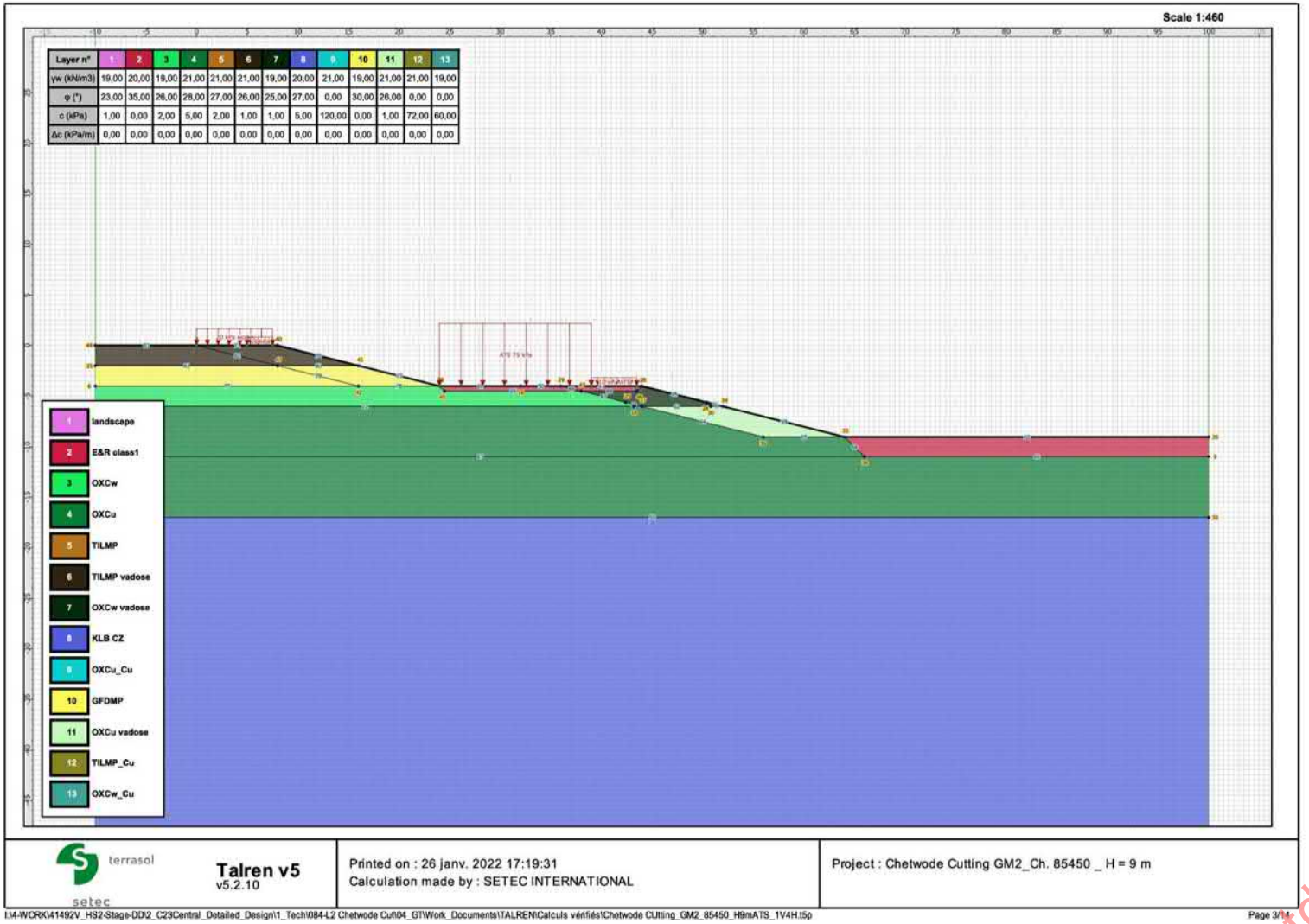
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Project data

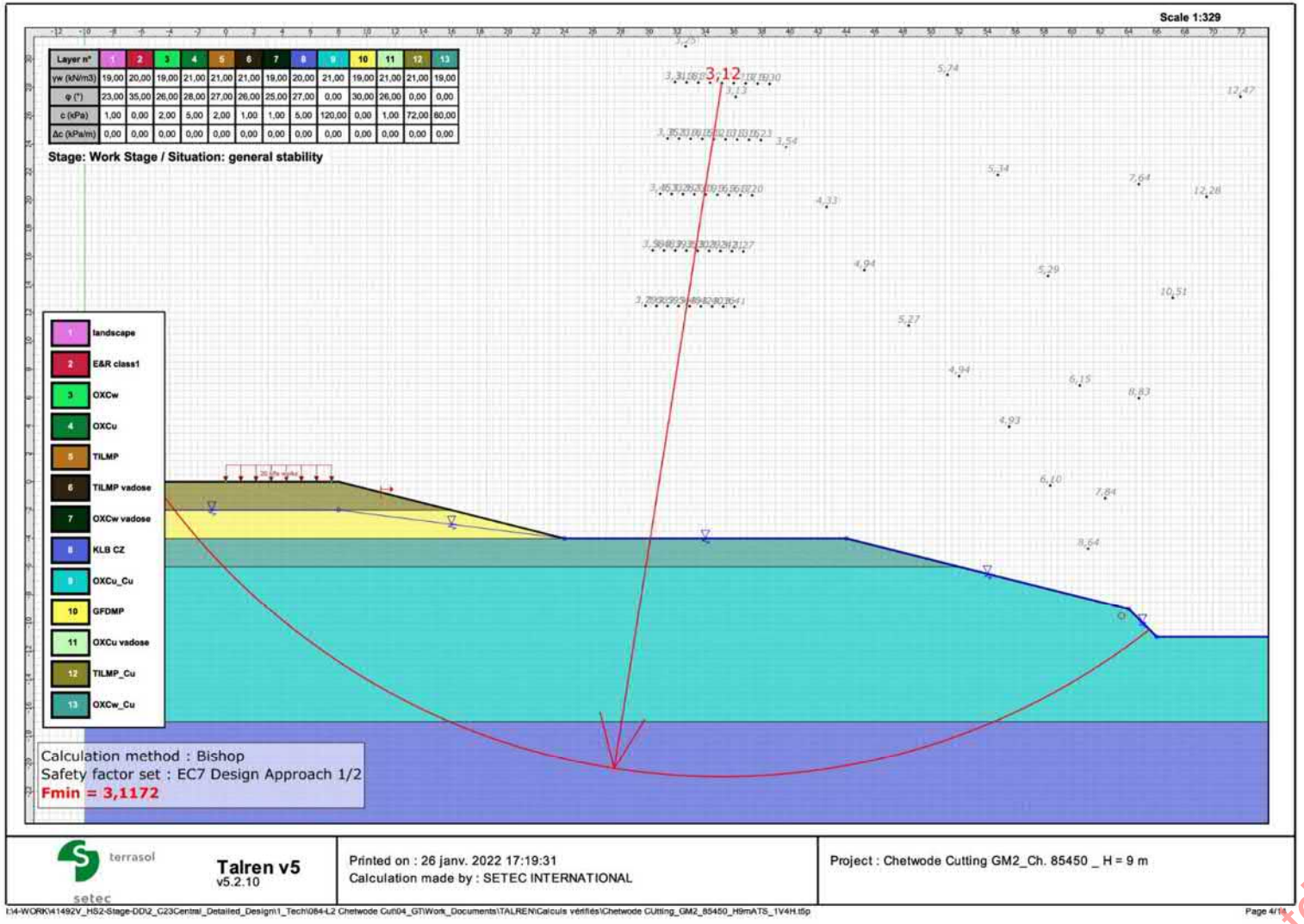
Distributed loads (2/2)

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
4	10 kPa ATS	39,000	-4,000	10,0	43,500	-4,000	10,0	90,00

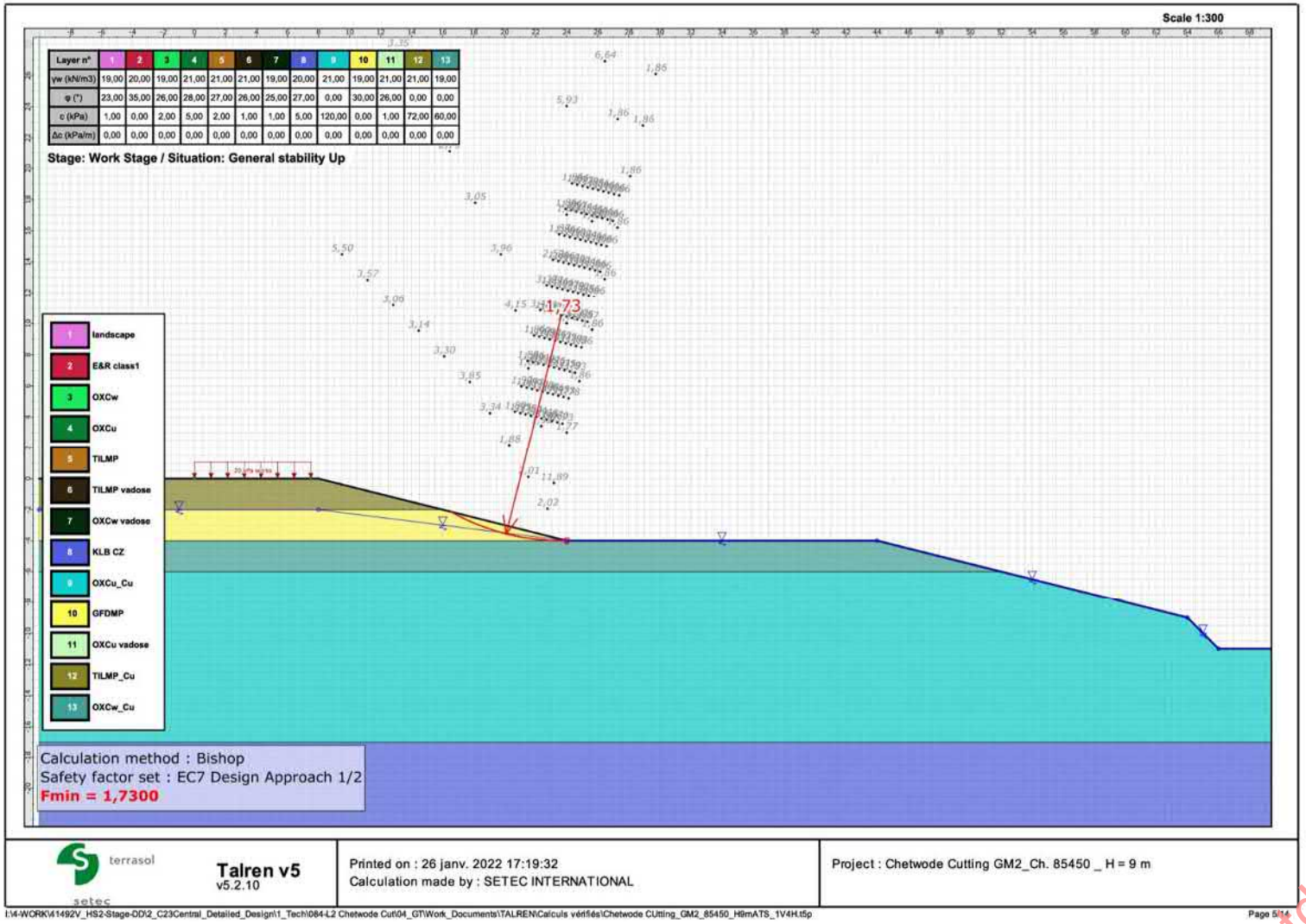
HS2 Ltd - Code 1 - Accepted



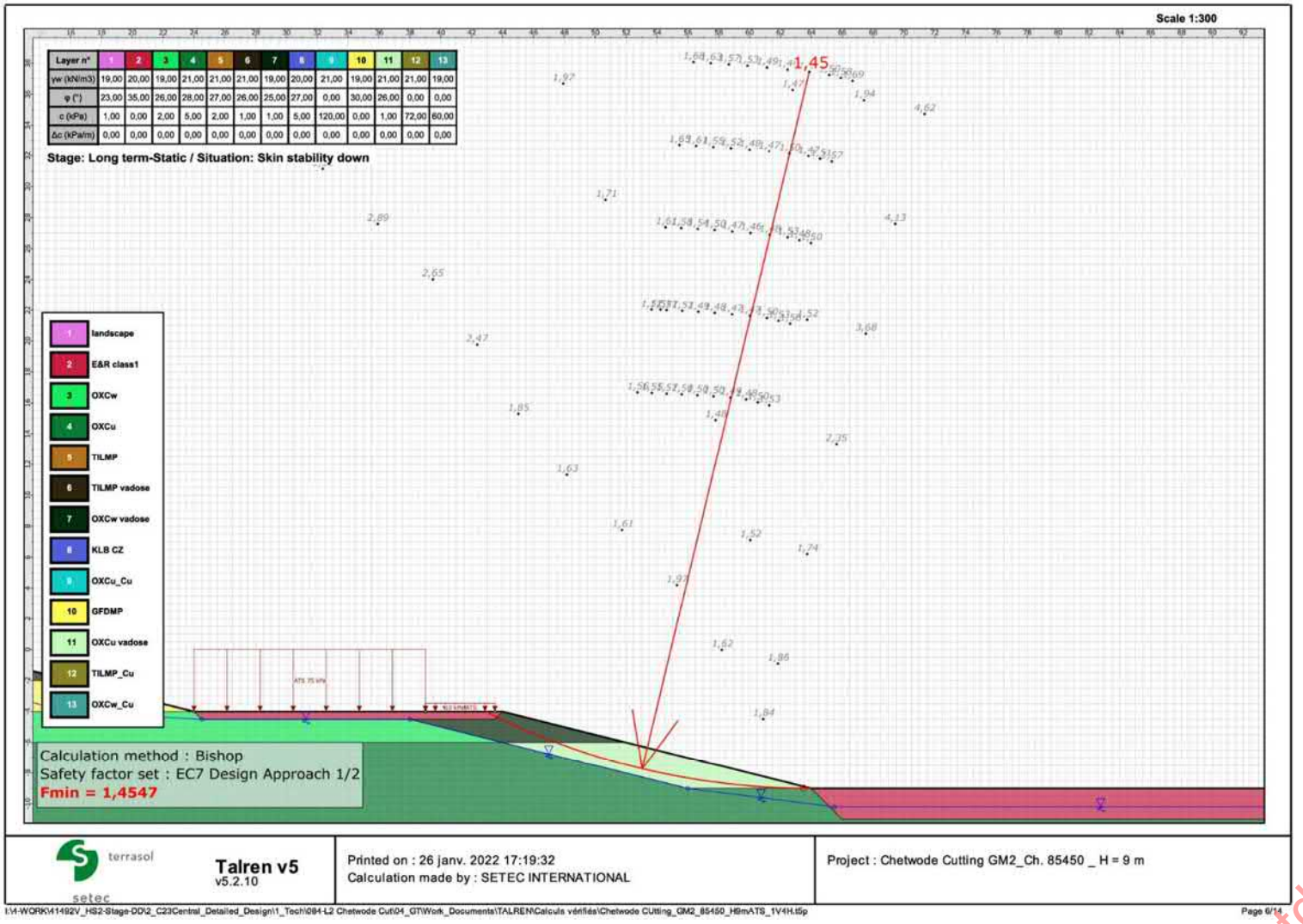
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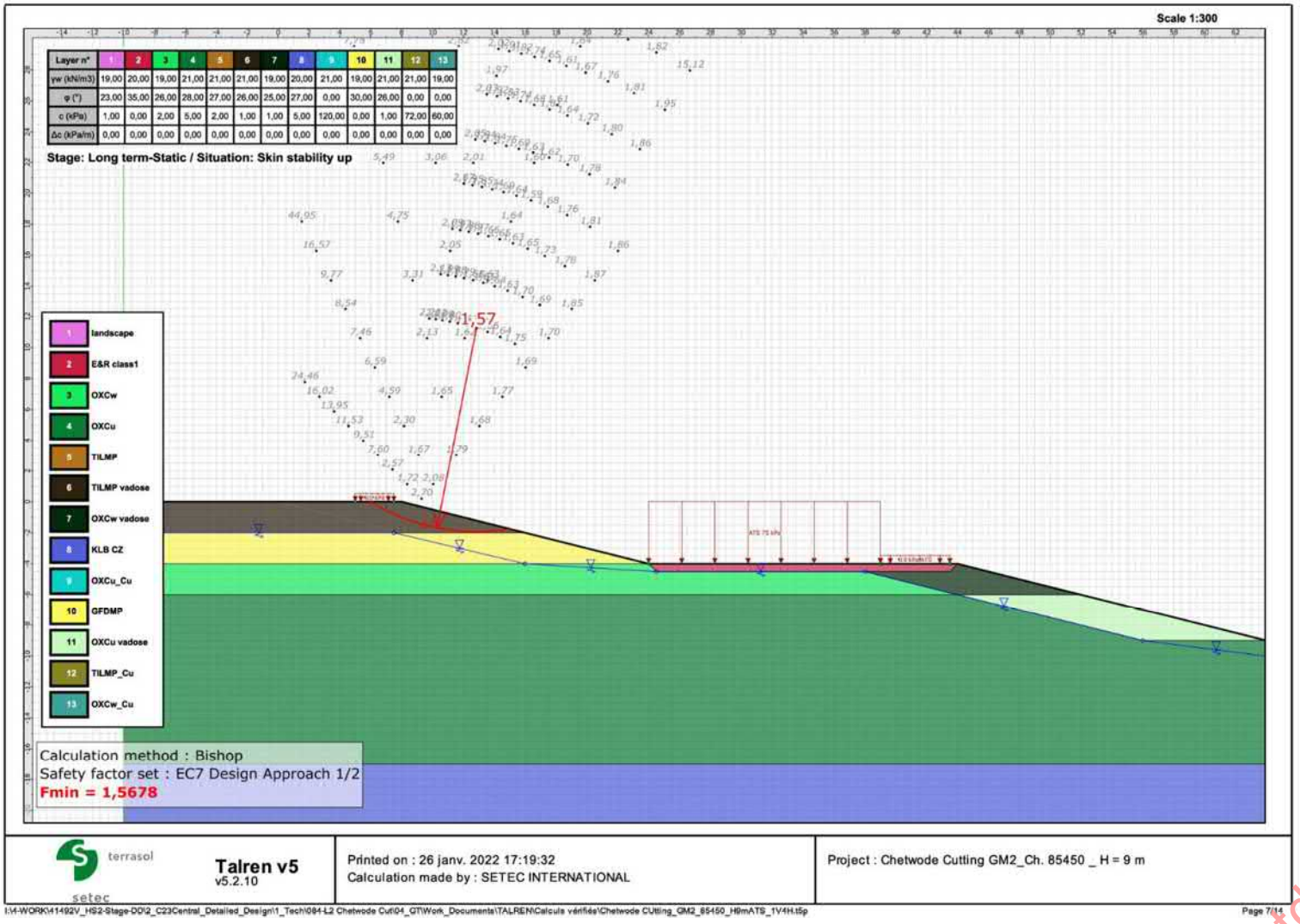
HS2 Ltd - Code 1 - Accepted



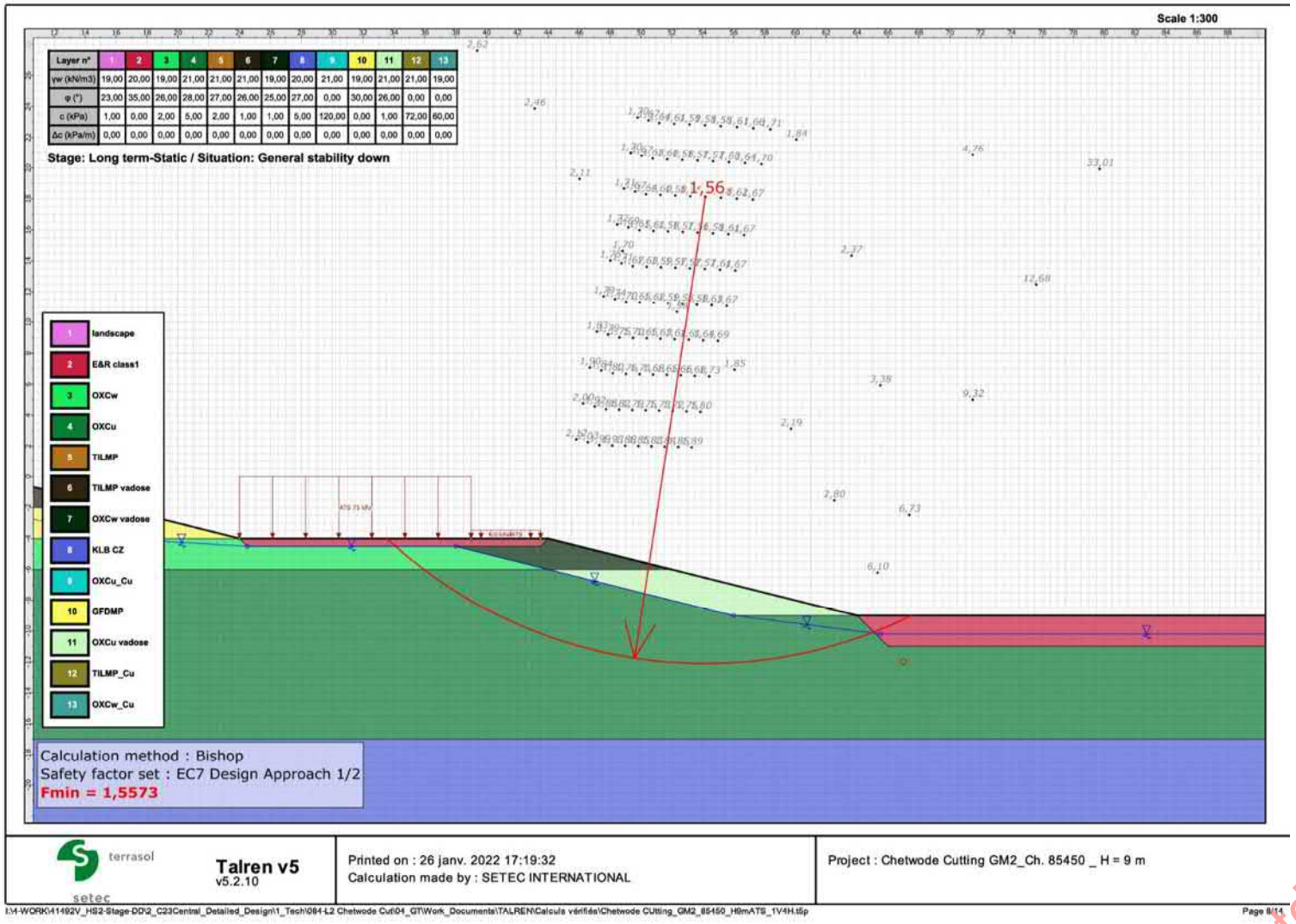
HS2 Ltd - Code 1 - Accepted



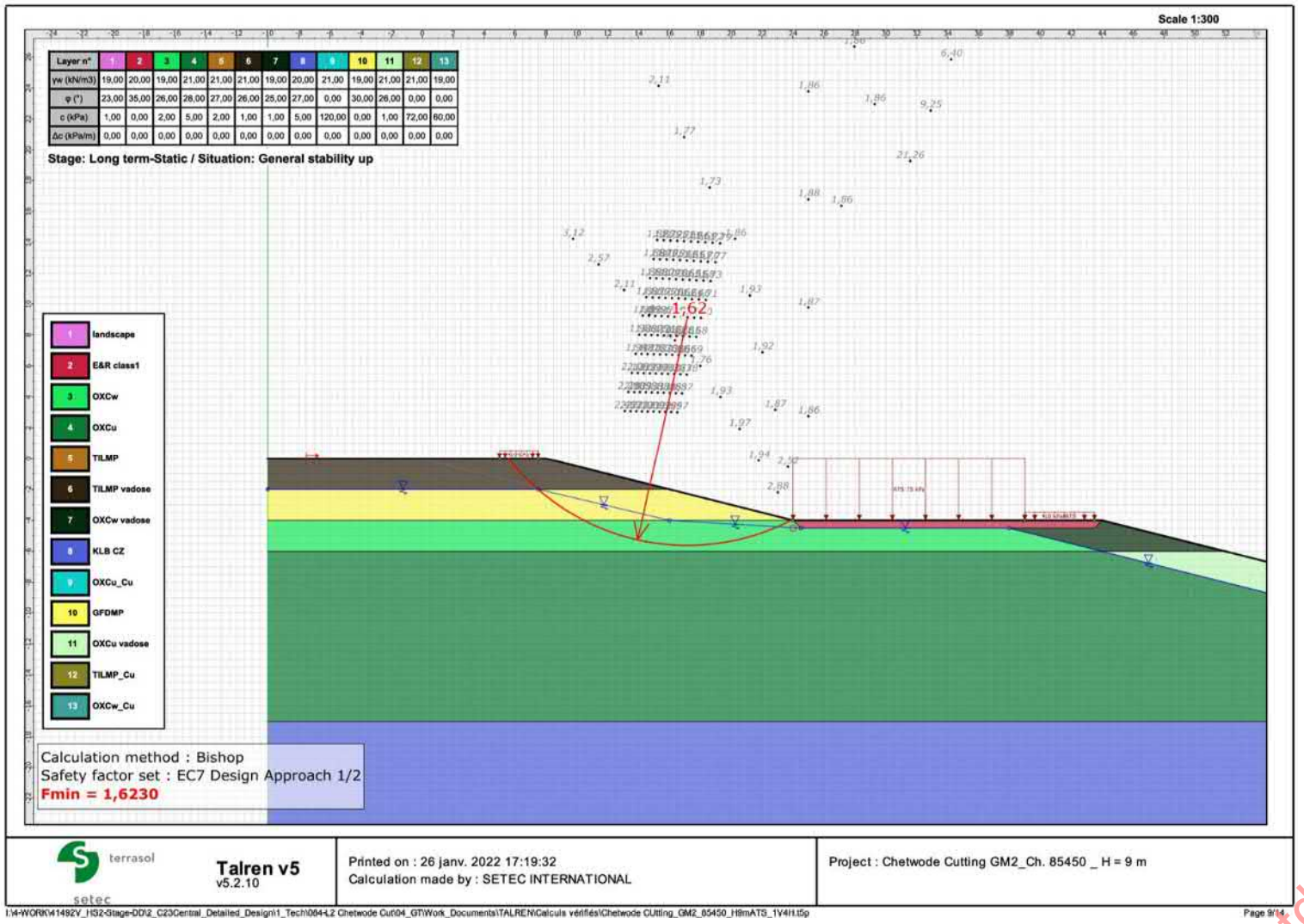
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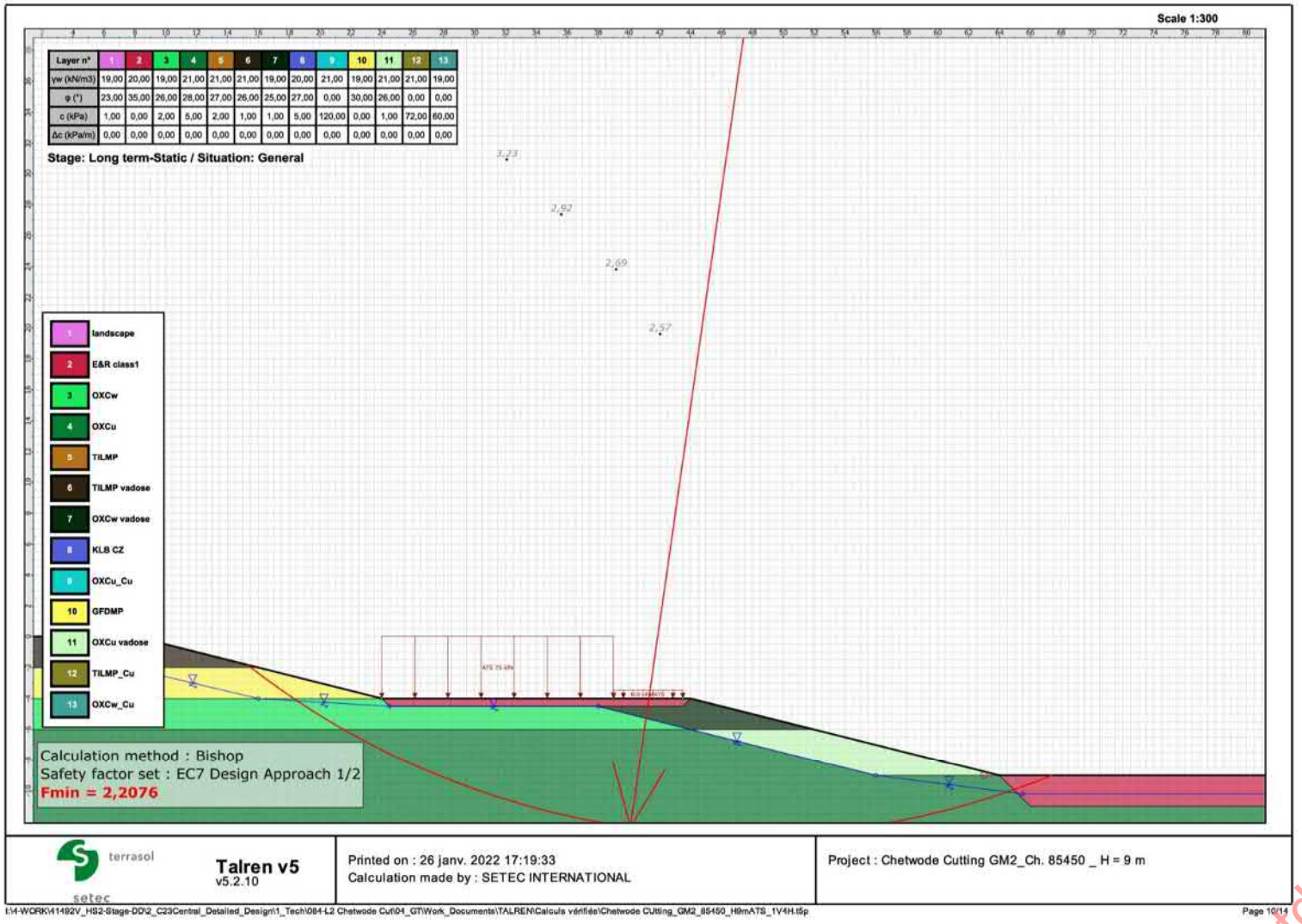
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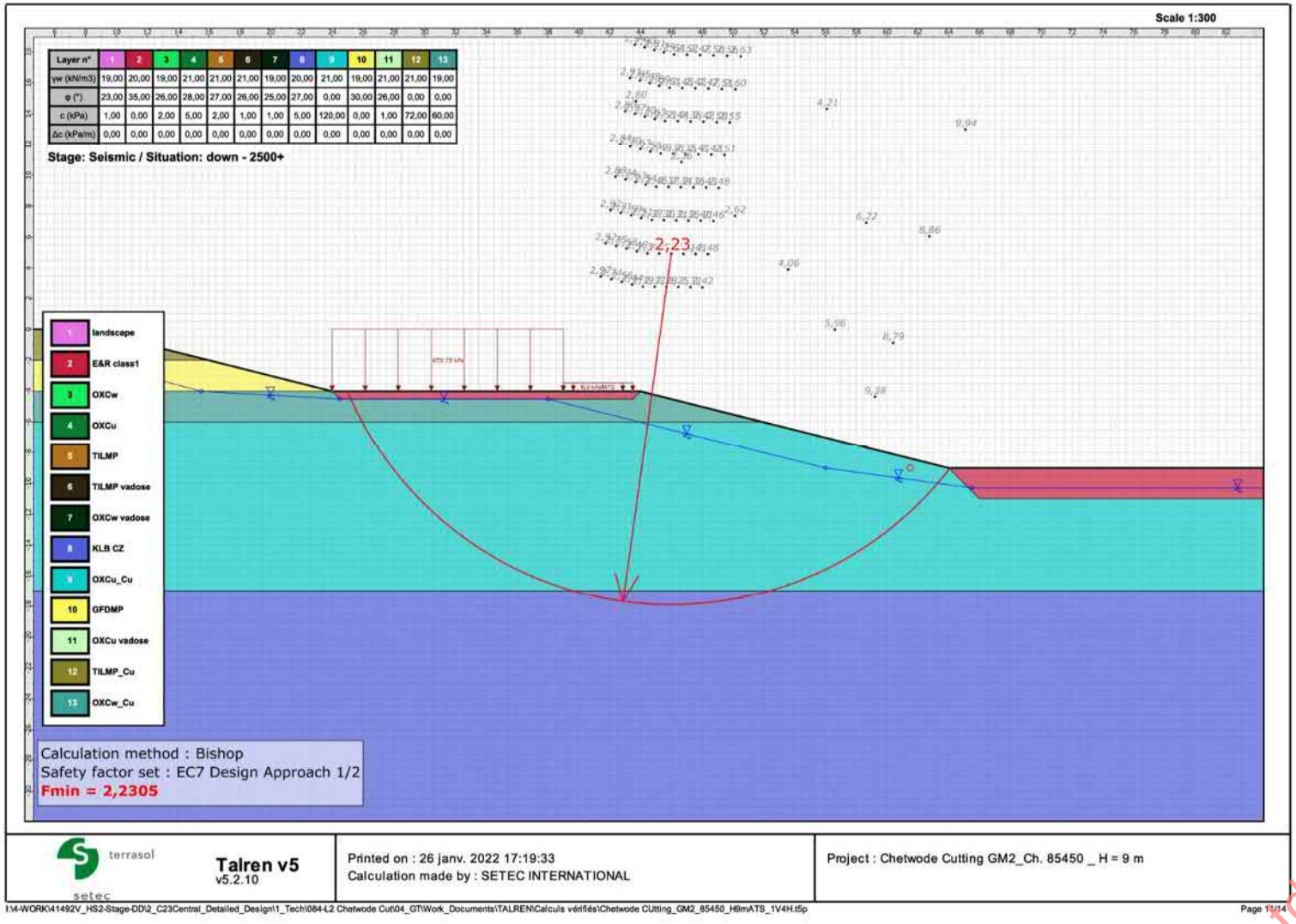
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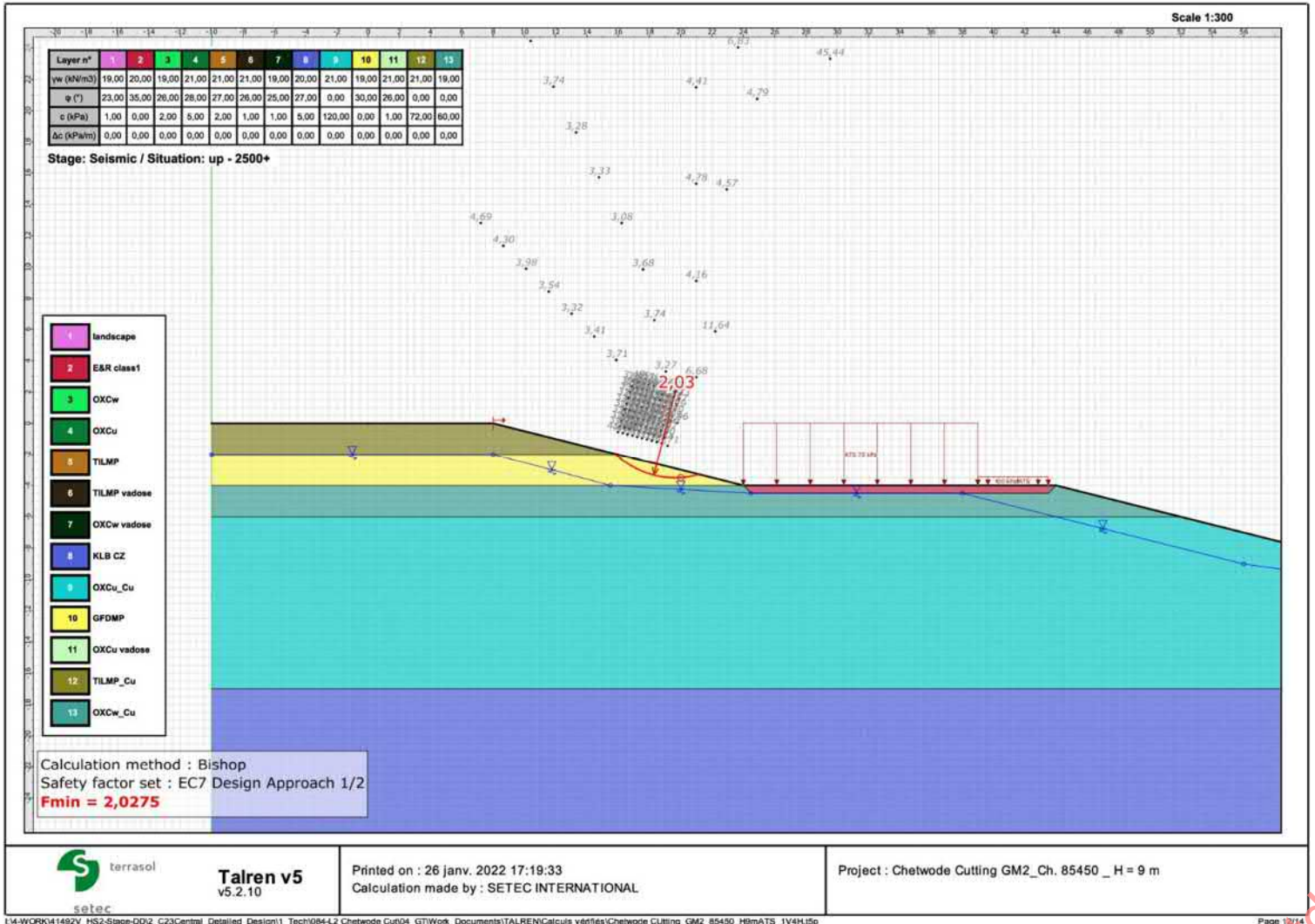
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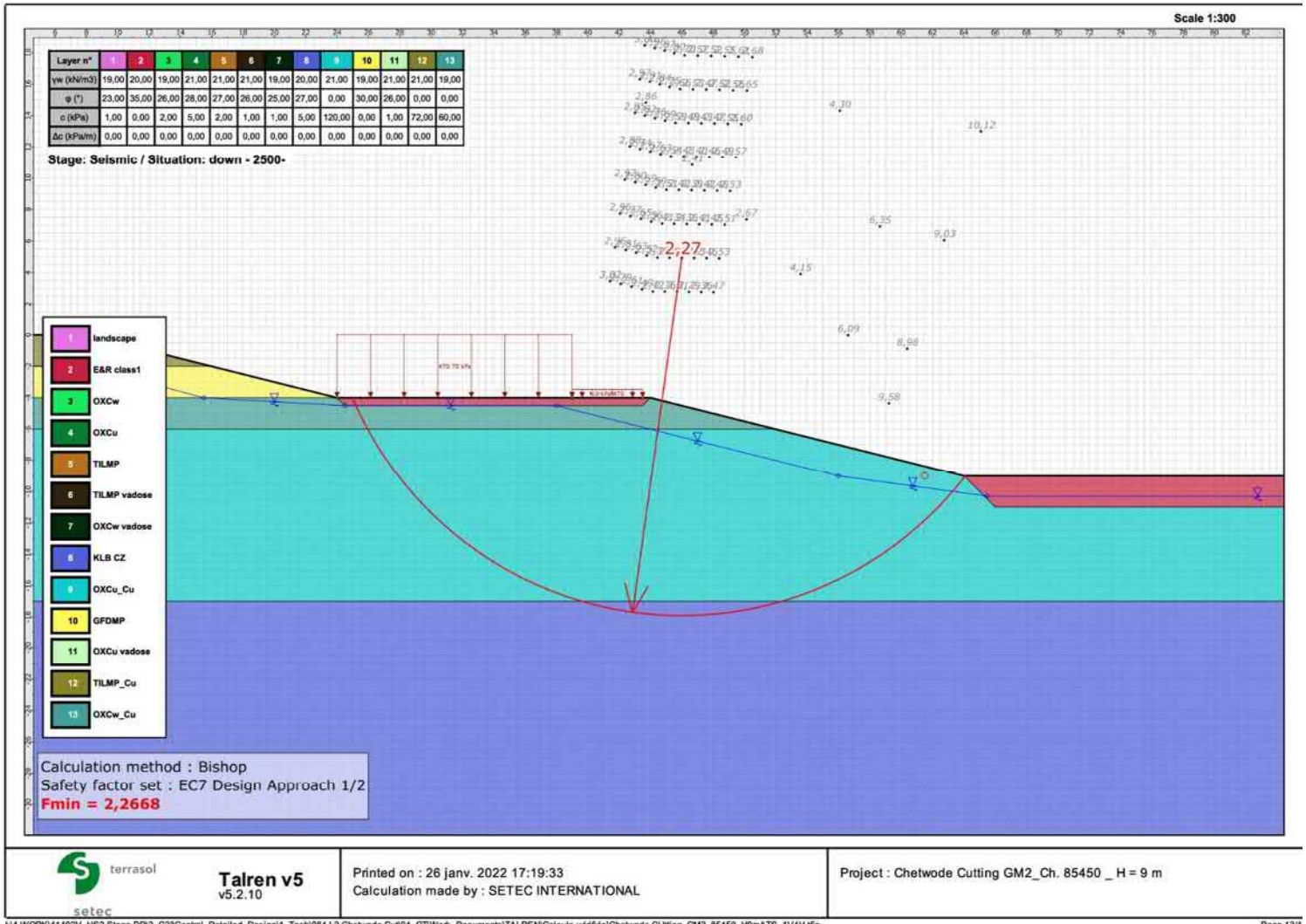
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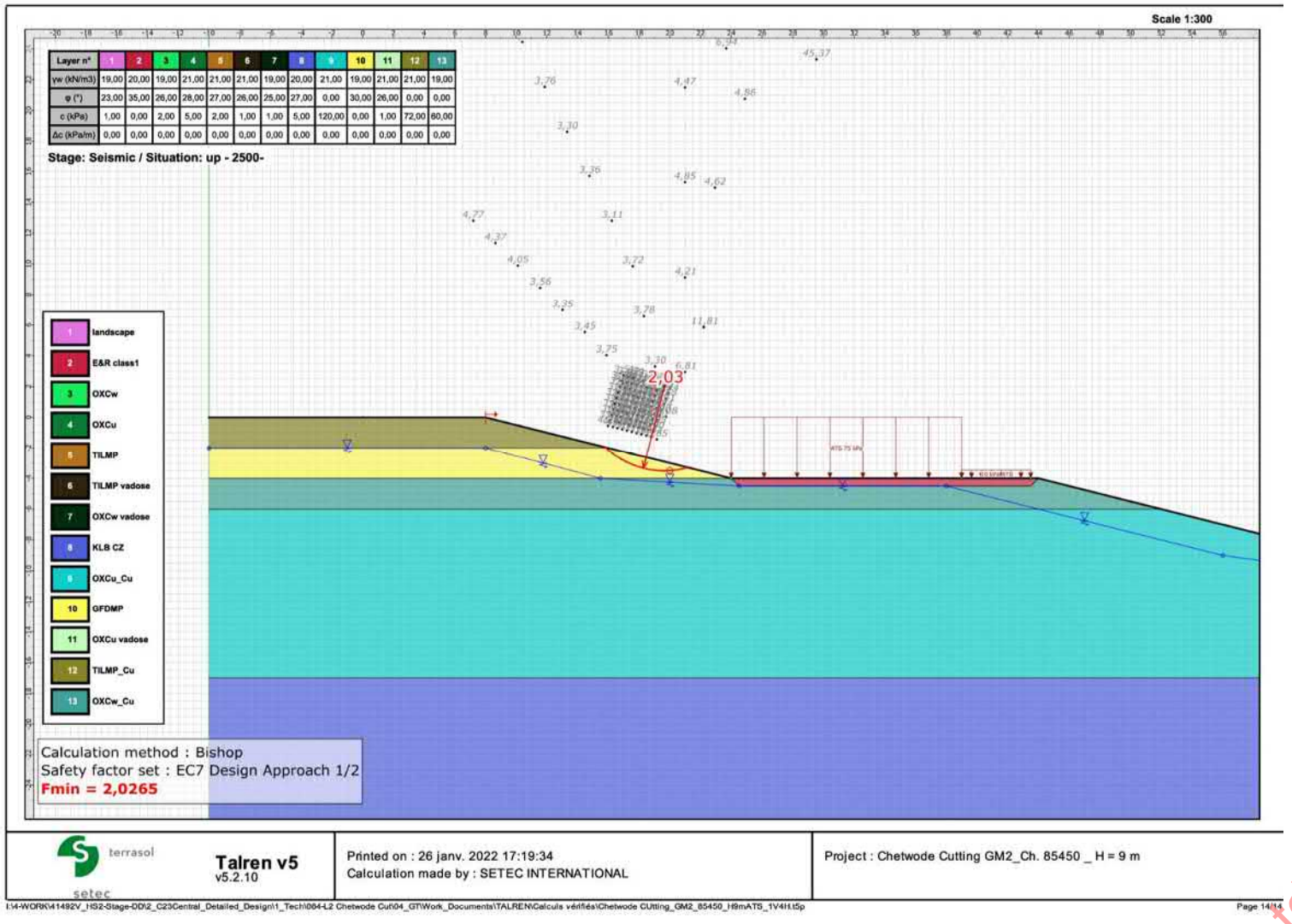
HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

Calculation profile Ch. 85+450, Ground Model 2, Landscape bund with H=4.1m

HS2 Ltd - Code 1 - Accepted

Project data

Project reference : HS2 Detail Design
Calculation title : Chetwode Cutting GM2_Ch. 85450 _ H = 9 m _Landscape Bund
Location : Ch. 85450
Comments : Slope 1V/4H Landscape bund H=4.1m
Units : kN, kPa, kN/m³
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	landscape		19,0	23,00	1,0	0,0	-	-	-	No	No	No
2	E&R class1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
3	OXCw		19,0	26,00	2,0	0,0	-	-	-	No	No	No
4	OXCu		21,0	28,00	5,0	0,0	-	-	-	No	No	No
5	TILMP		21,0	27,00	2,0	0,0	-	-	-	No	No	No
6	TILMP vadose		21,0	26,00	1,0	0,0	-	-	-	No	No	No
7	OXCw vadose		19,0	25,00	1,0	0,0	-	-	-	No	No	No
8	KLB CZ		20,0	27,00	5,0	0,0	-	-	-	No	No	No
9	OXCu1_Cu		21,0	0,00	120,0	0,0	-	-	-	No	No	No
10	GFDMP		19,0	30,00	0,0	0,0	-	-	-	No	No	No
11	OXCu vadose		21,0	26,00	1,0	0,0	-	-	-	No	No	No
12	TILMP_Cu		21,0	0,00	72,0	0,0	-	-	-	No	No	No
13	OXCw_Cu		19,0	0,00	60,0	0,0	-	-	-	No	No	No
14	OXCu2_Cu		21,0	0,01	180,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	landscape		-	-	-	Effective	Linear	No	-	-
2	E&R class1		-	-	-	Effective	Linear	No	-	-
3	OXCw		-	-	-	Effective	Linear	No	-	-
4	OXCu		-	-	-	Effective	Linear	No	-	-
5	TILMP		-	-	-	Effective	Linear	No	-	-
6	TILMP vadose		-	-	-	Effective	Linear	No	-	-
7	OXCw vadose		-	-	-	Effective	Linear	No	-	-
8	KLB CZ		-	-	-	Effective	Linear	No	-	-
9	OXCu1_Cu		-	-	-	Undrained	Linear	No	-	-
10	GFDMP		-	-	-	Effective	Linear	No	-	-
11	OXCu vadose		-	-	-	Effective	Linear	No	-	-
12	TILMP_Cu		-	-	-	Undrained	Linear	No	-	-
13	OXCw_Cu		-	-	-	Undrained	Linear	No	-	-
14	OXCu2_Cu		-	-	-	Undrained	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	0,000	0,000	6	-42,000	-4,000	7	-42,000	-6,000	9	100,000	-11,000	10	-42,000	-11,000	21	-42,000	-2,000
31	-42,000	-17,000	32	100,000	-17,000	33	44,000	-9,000	35	100,000	-9,000	36	36,000	-9,000	38	46,000	-11,000
39	24,000	-4,000	40	8,000	0,000	41	16,000	-2,000	42	16,000	-4,000	43	8,000	-2,000	44	-42,000	0,000
48	32,000	-6,000	49	5,000	0,000	50	-8,400	4,100	51	-18,400	4,100	52	24,000	-6,000			

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
55	31	32	60	33	35	65	36	33	66	9	38	67	10	38	68	38	33	73	39	41
76	41	40	77	6	42	78	39	42	79	42	43	80	43	41	81	43	21	82	43	1
92	39	48	95	44	51	96	51	50	97	50	49	98	7	52	99	48	52	100	52	42
101	36	52	102	48	33	104	40	49	105	44	1	106	1	49						

Distributed loads

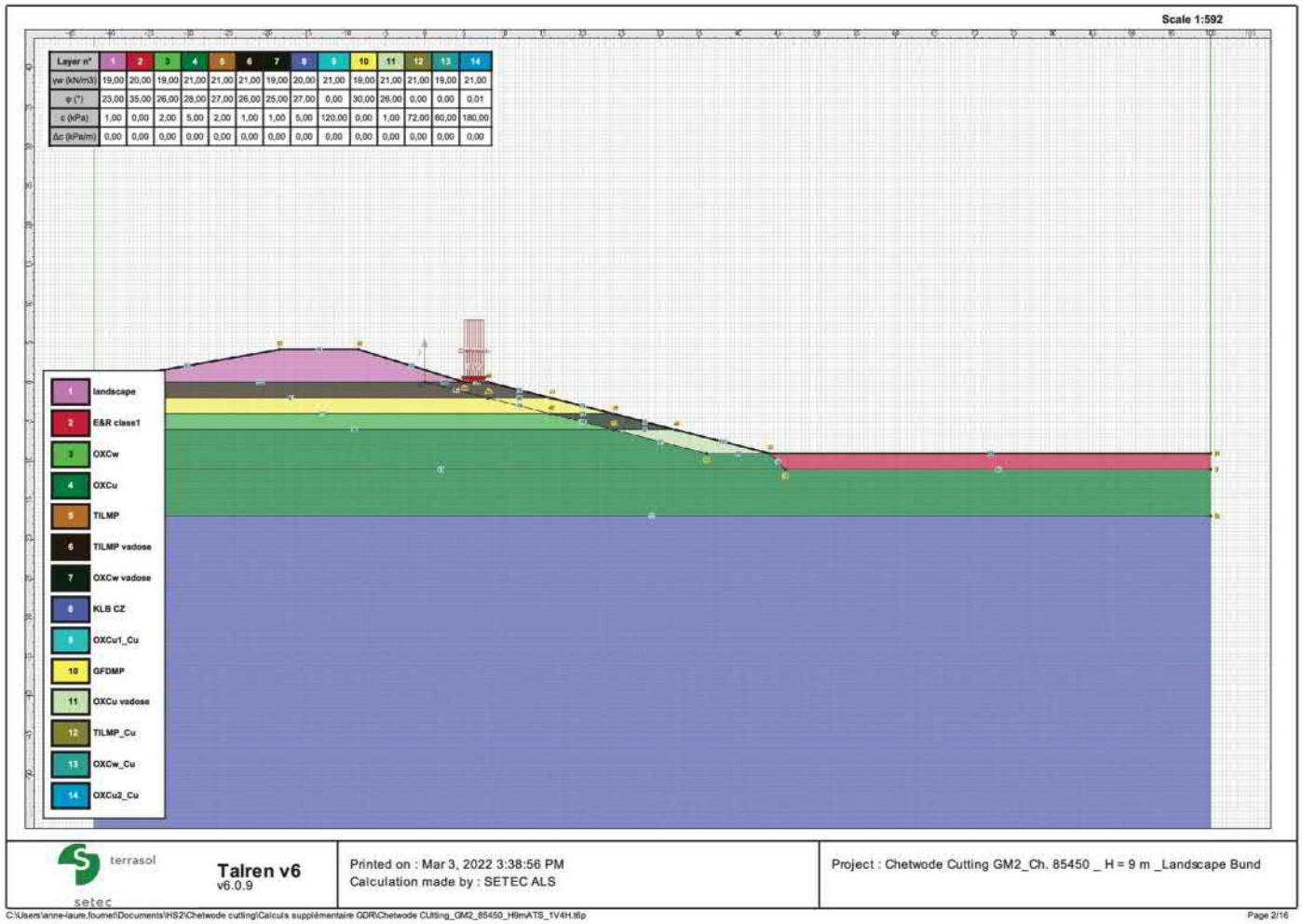
	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	20 kPa works	5,000	0,000	20,0	7,500	0,000	20,0	90,00
2	10 kPa	5,000	0,000	10,0	7,500	0,000	10,0	90,00

terrasol
setec
Talren v6
v6.0.9

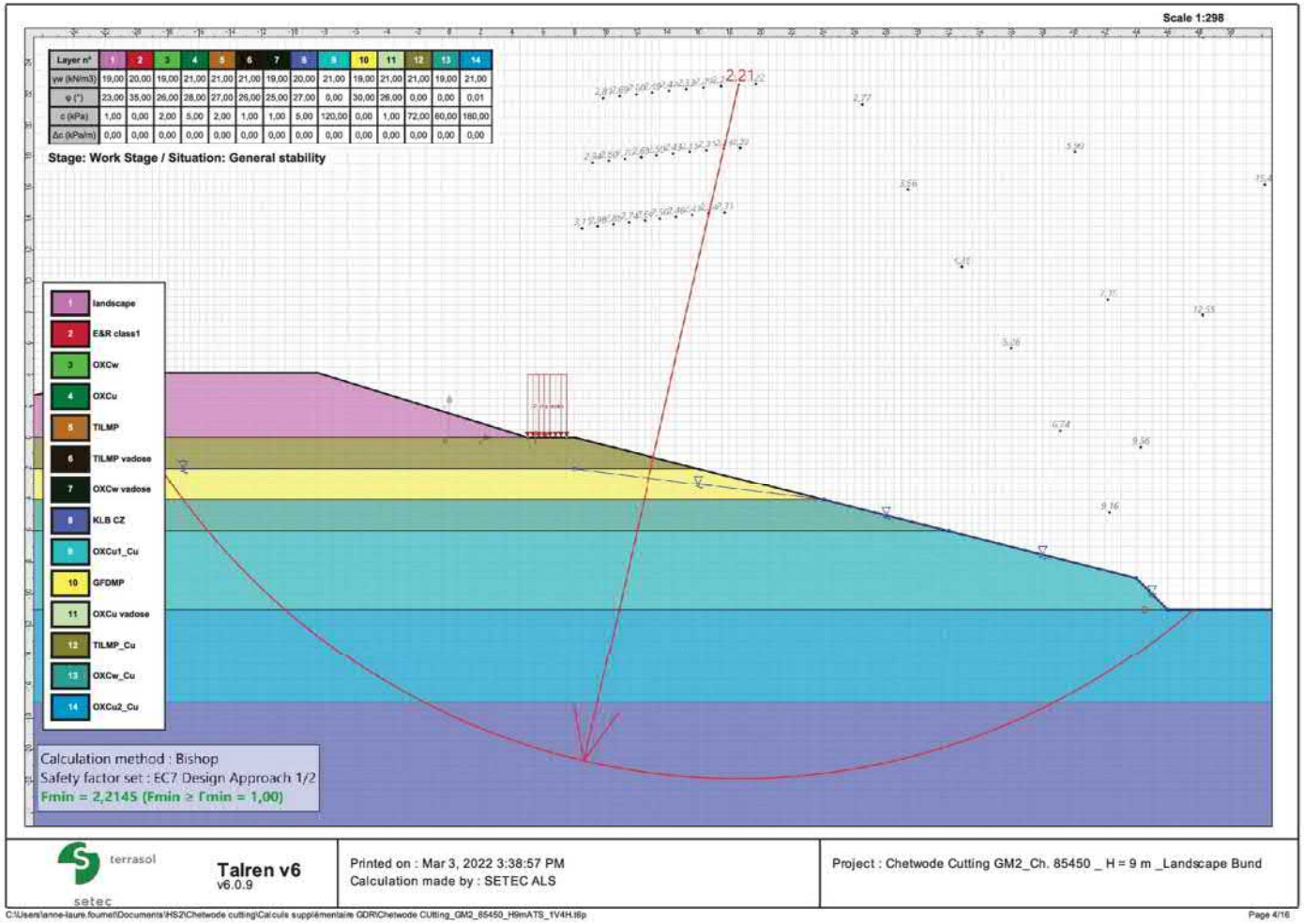
Printed on : Mar 3, 2022 3:38:56 PM
Calculation made by : SETEC ALS
Project : Chetwode Cutting GM2_Ch. 85450 _ H = 9 m _Landscape Bund

C:\Users\anne-laure.frumet\Documents\HS2\Chetwode cutting\Calculs supplémentaire GDR\Chetwode Cutting_GM2_85450_H9mAT8_1V4H.tlp Page 1/16

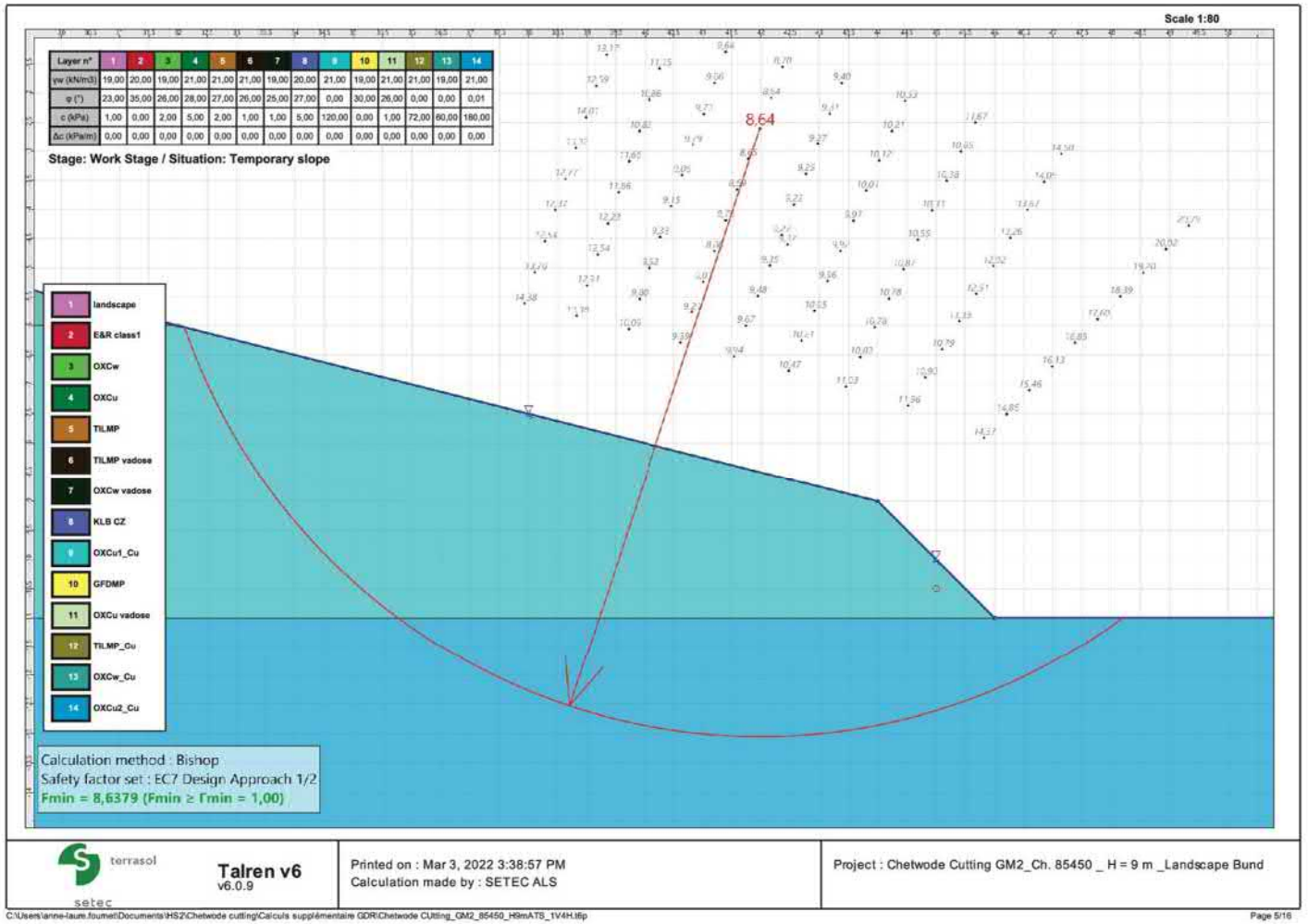
HS2 Ltd - Code 1 - Accepted



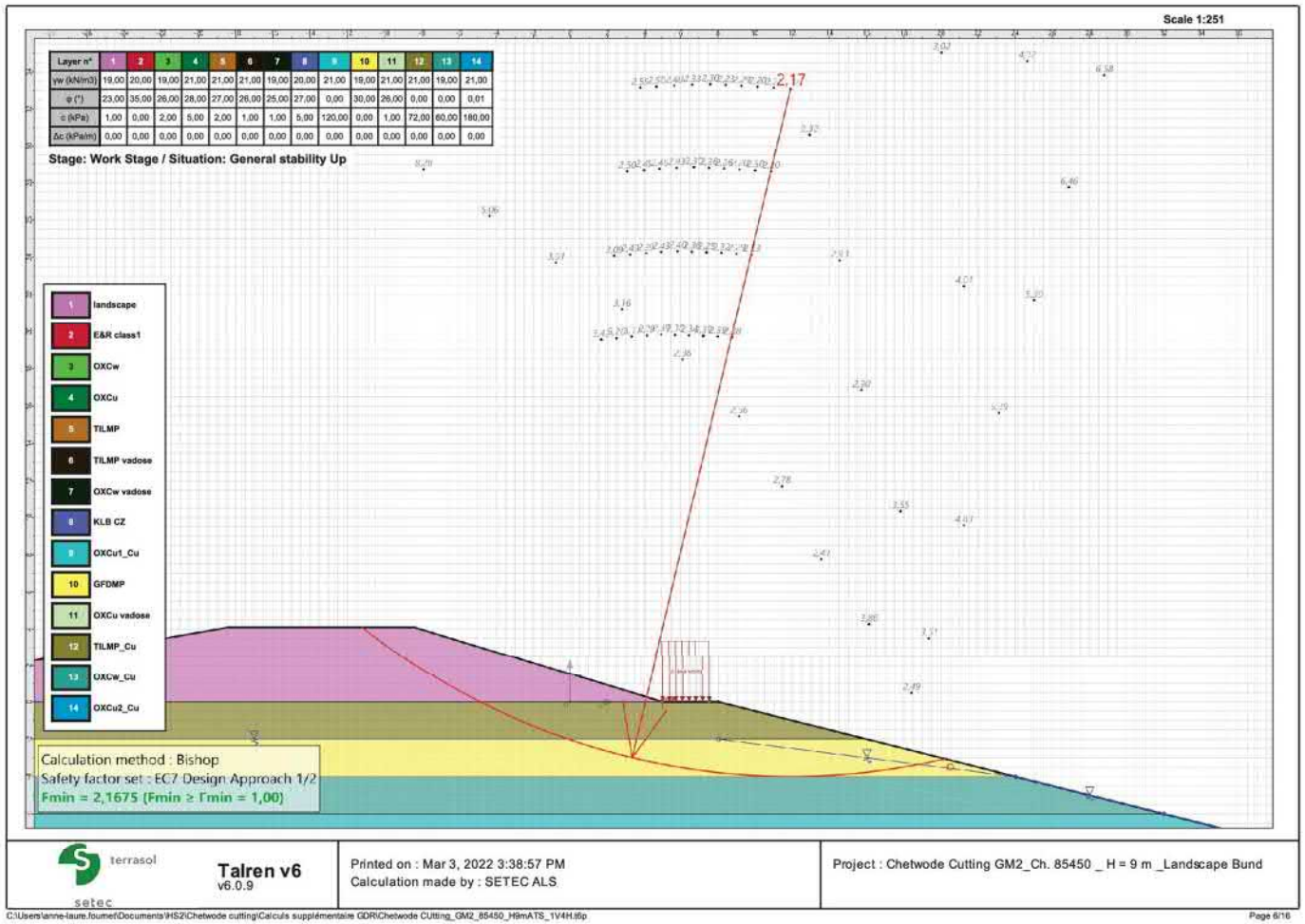
HS2 Ltd - Code 1 - Accepted



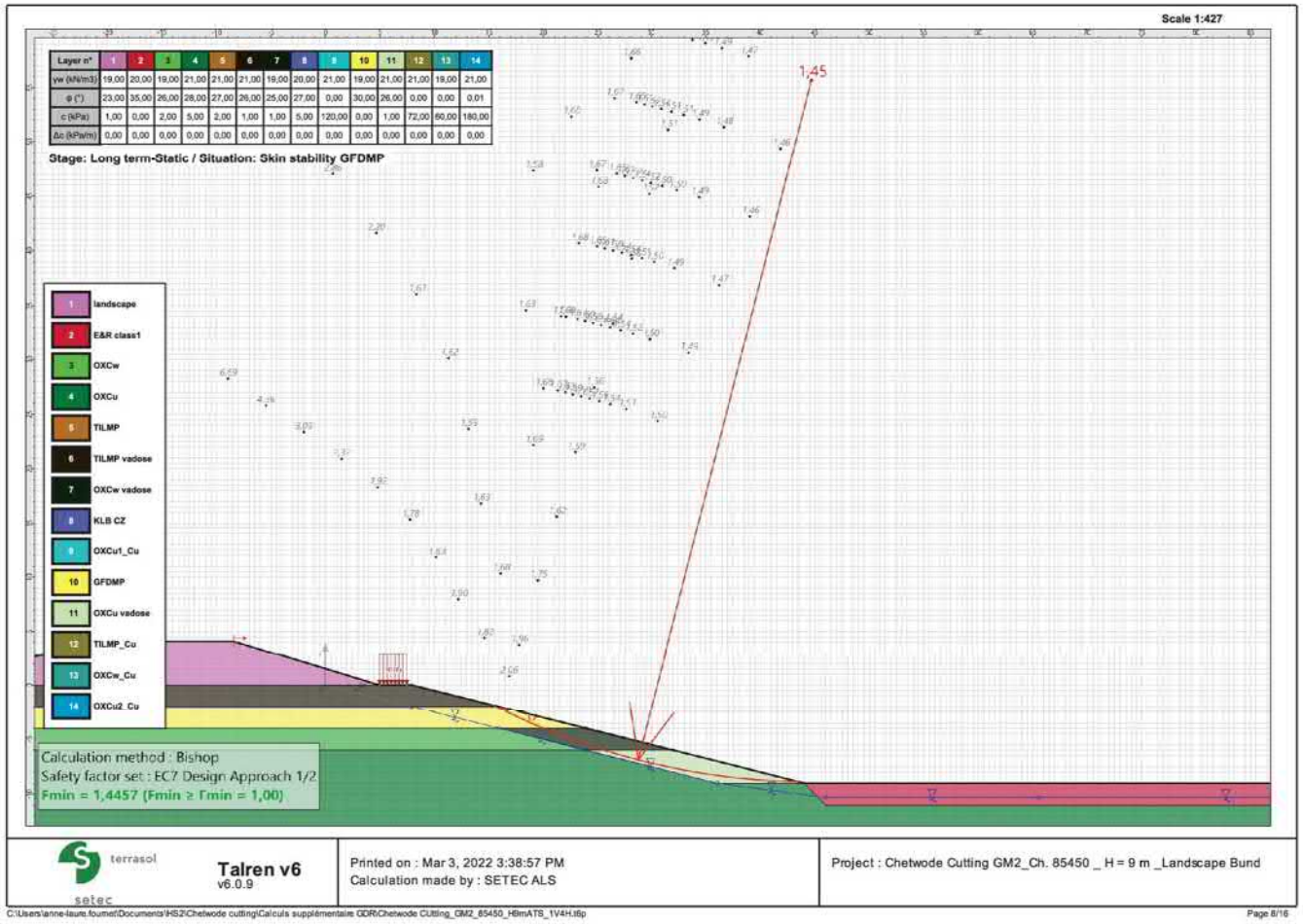
HS2 Ltd - Code 1 - Accepted



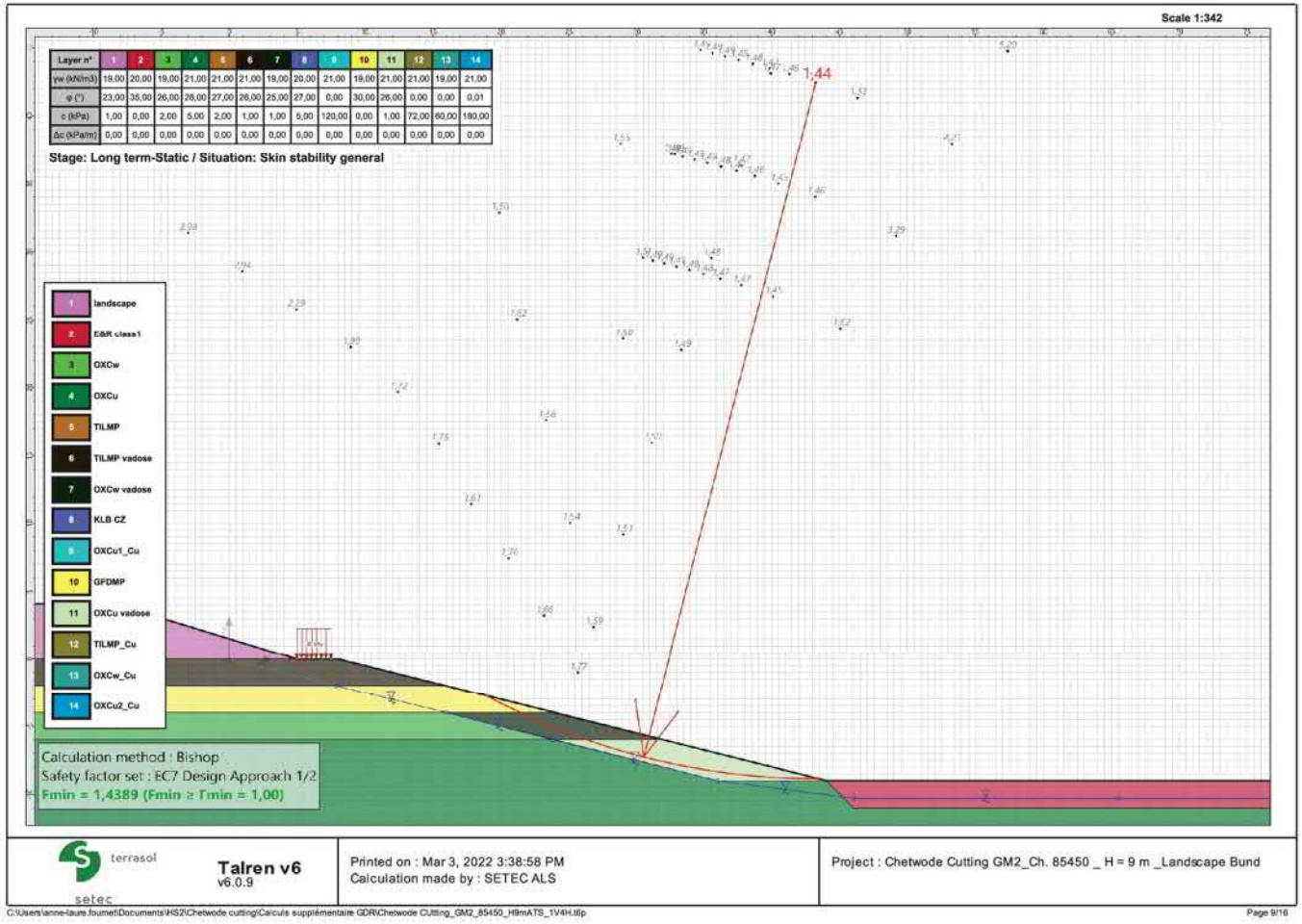
HS2 Ltd - Code 1 - Accepted



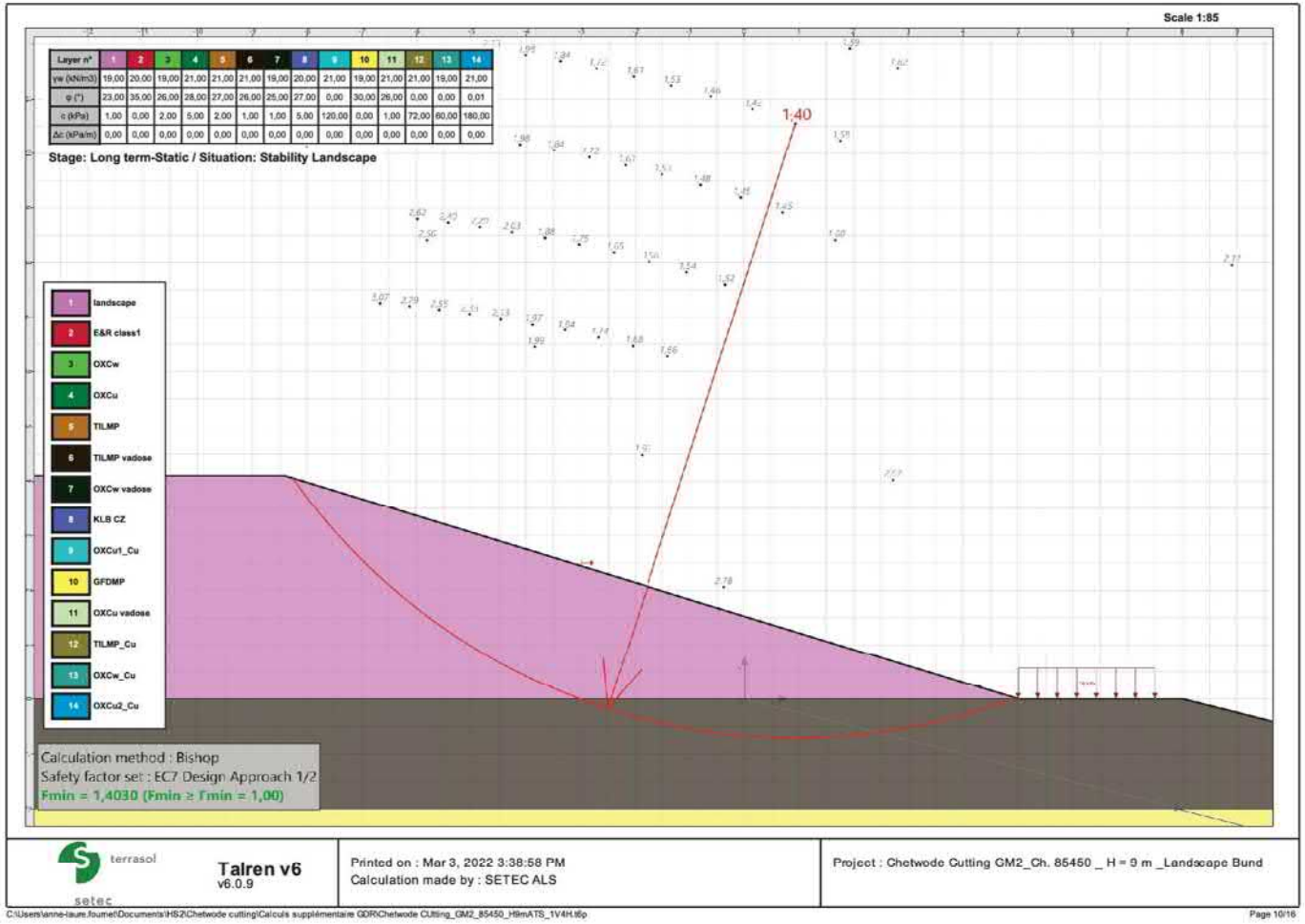
HS2 Ltd - Code 1 - Accepted



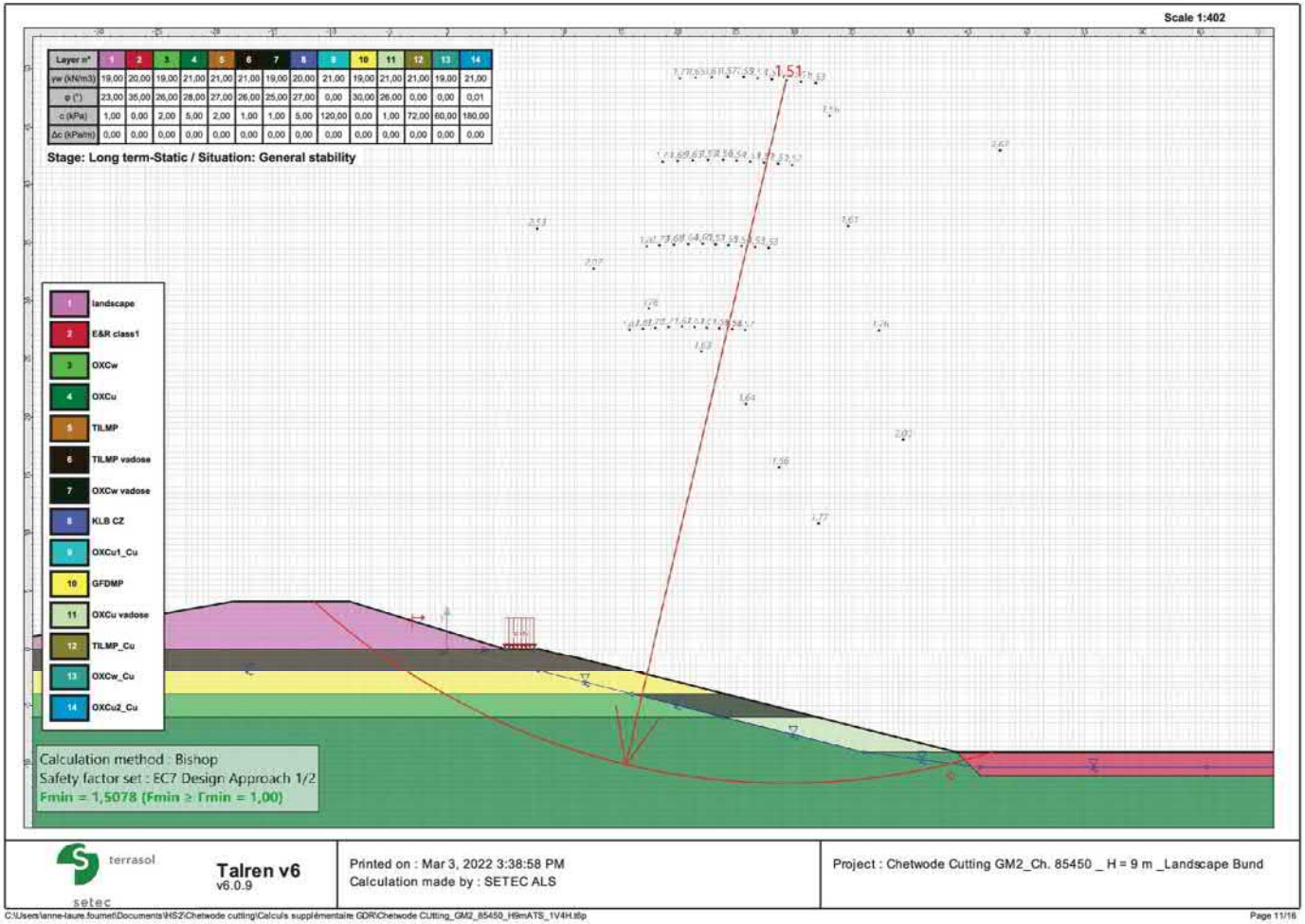
HS2 Ltd - Code 1 - Accepted



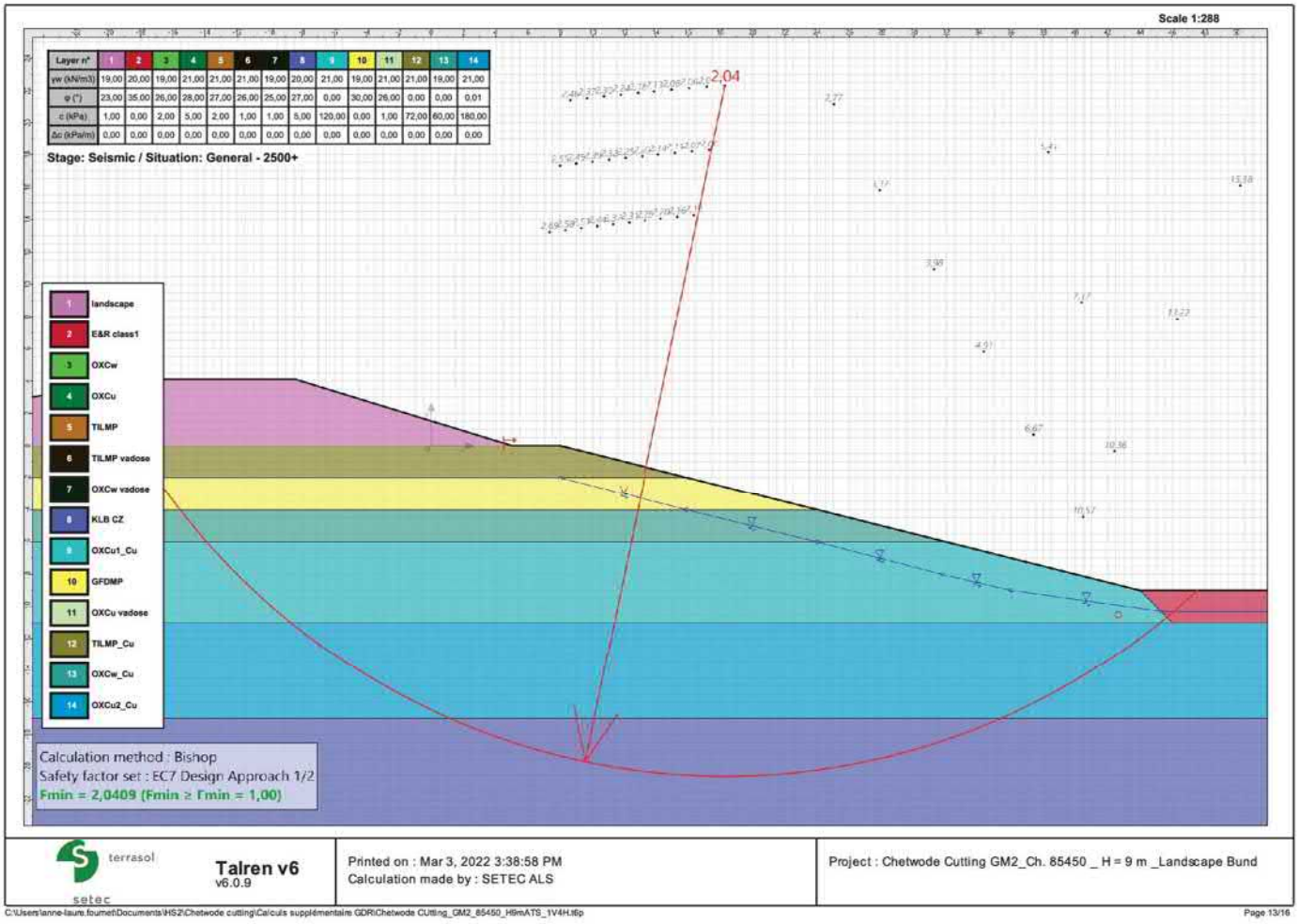
HS2 Ltd - Code 1 - Accepted



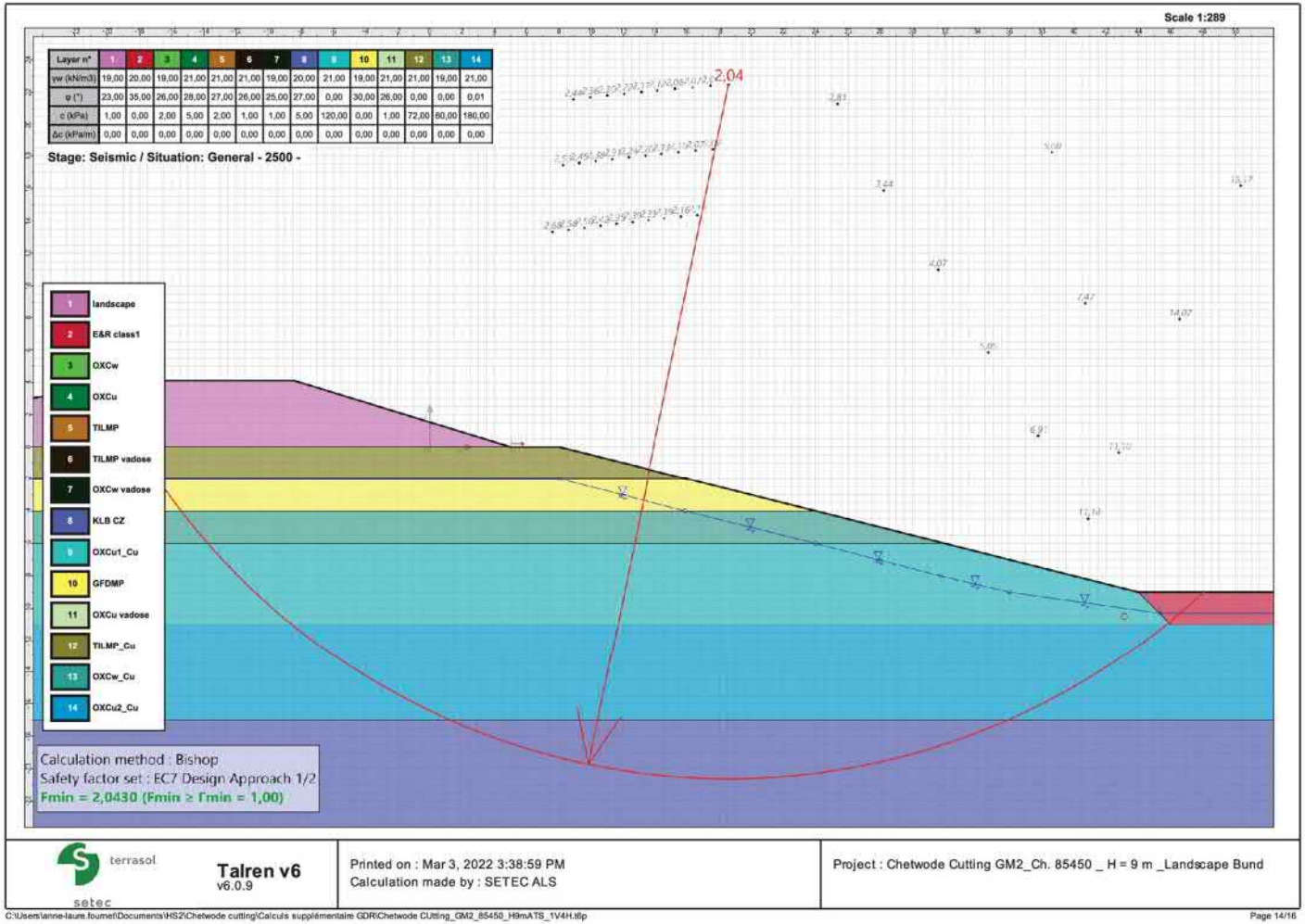
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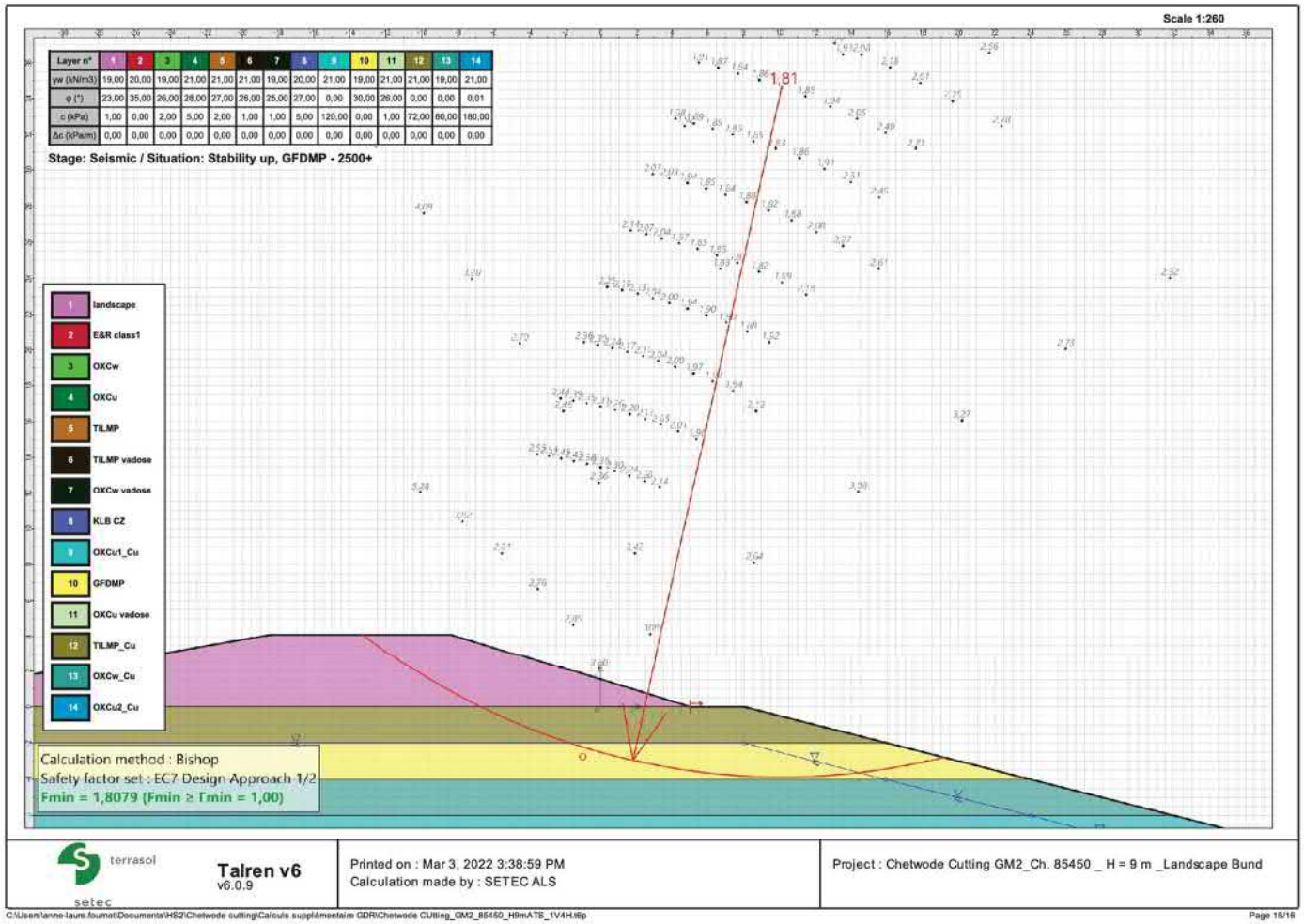
HS2 Ltd - Code 1 - Accepted



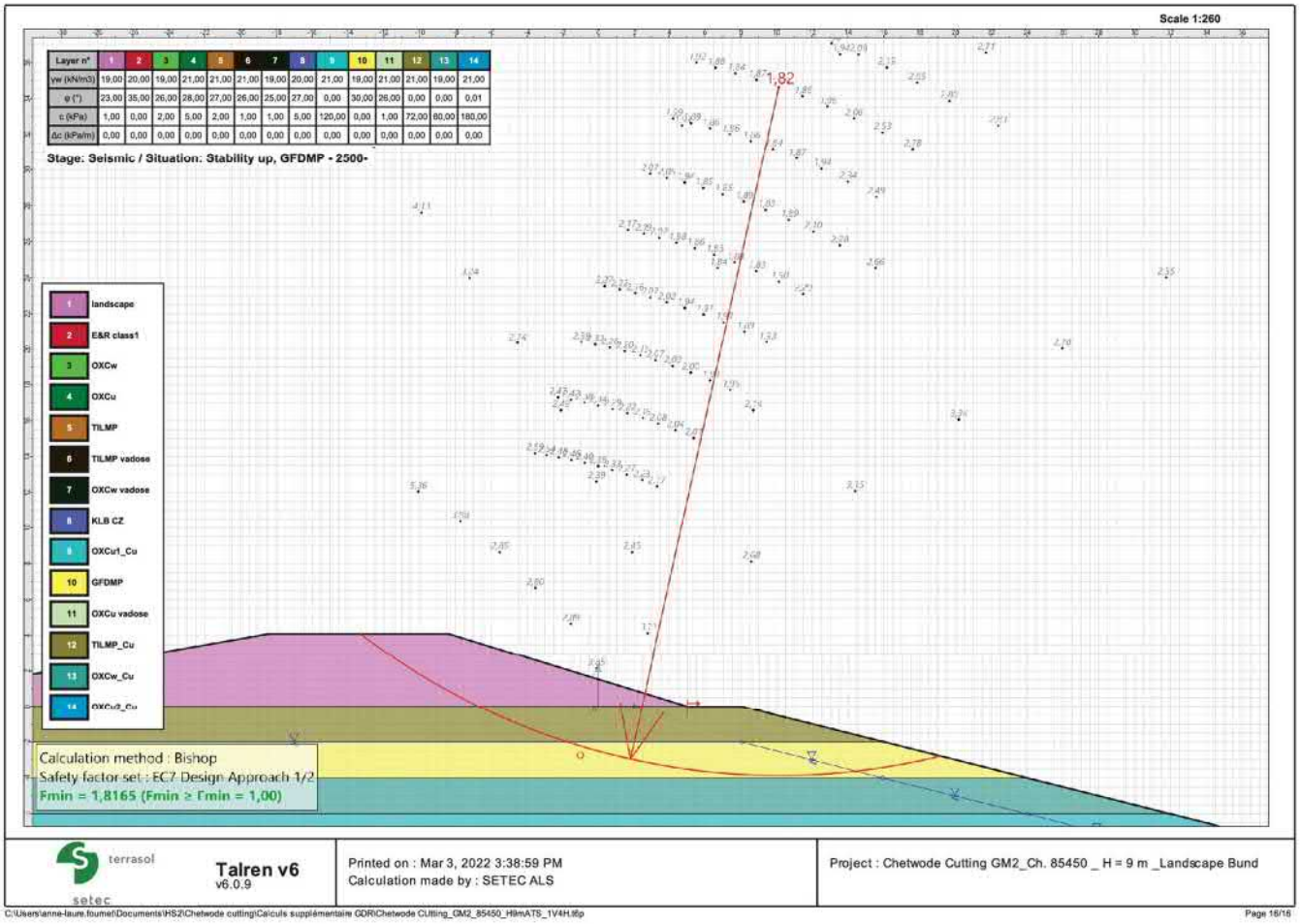
HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

Calculation profile Ch 85+580, Ground Model 2, CHW18 Accommodation Overbridge

HS2 Ltd - Code 1 - Accepted

Project data

Project reference : HS2 Detail Design
Calculation title : Chetwode Cutting GM2_Ch. 85580_OBCHW18 _ H = 6.5 m
Location : Ch. 85580
Comments : Slope 1V/4H OB approach embankments : H = 3.3m; d=5m/HS2
Units : kN, kPa, kN/m3
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs nails	pl	KsB	Anisotropy	Favorable	Specific safety factors
1	Highways		19,0	24,00	1,0	0,0	-	-	-	No	No	No
2	E&R class1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
3	OXCw		19,0	26,00	2,0	0,0	-	-	-	No	No	No
4	OXCu		21,0	28,00	5,0	0,0	-	-	-	No	No	No
5	TILMP		21,0	27,00	2,0	0,0	-	-	-	No	No	No
6	TILMP vadose		21,0	26,00	1,0	0,0	-	-	-	No	No	No
7	OXCw vadose		19,0	25,00	1,0	0,0	-	-	-	No	No	No
8	KLB S		20,0	27,00	5,0	0,0	-	-	-	No	No	No
9	OXCu_Cu		21,0	0,00	120,0	0,0	-	-	-	No	No	No
10	GFDMP		19,0	30,00	0,0	0,0	-	-	-	No	No	No
11	OXCu vadose		21,0	26,00	1,0	0,0	-	-	-	No	No	No
12	TILMP_Cu		21,0	0,00	72,0	0,0	-	-	-	No	No	No
13	OXCw_Cu		19,0	0,00	60,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve
1	Highways		-	-	-	Effective	Linear
2	E&R class1		-	-	-	Effective	Linear
3	OXCw		-	-	-	Effective	Linear
4	OXCu		-	-	-	Effective	Linear
5	TILMP		-	-	-	Effective	Linear
6	TILMP vadose		-	-	-	Effective	Linear
7	OXCw vadose		-	-	-	Effective	Linear
8	KLB S		-	-	-	Effective	Linear
9	OXCu_Cu		-	-	-	Undrained	Linear
10	GFDMP		-	-	-	Effective	Linear
11	OXCu vadose		-	-	-	Effective	Linear
12	TILMP_Cu		-	-	-	Undrained	Linear
13	OXCw_Cu		-	-	-	Undrained	Linear

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	0,000	0,000	2	26,000	0,000	6	0,000	-4,000	7	0,000	-6,000	9	100,000	-11,000	10	0,000	-11,000
11	23,000	0,000	12	9,000	3,500	13	6,000	3,500	14	20,000	0,000	16	32,007	-4,000	18	43,198	-6,000
21	0,000	-2,000	22	26,003	-2,000	23	28,000	0,000	24	50,397	-5,600	25	42,400	-5,600	26	35,999	-2,000
27	28,000	-2,000	28	43,998	-4,000	29	36,000	-4,000	30	50,797	-6,000	31	0,000	-17,000	32	100,000	-17,000
34	51,997	-6,000	37	44,000	-6,000	38	66,000	-11,000	39	0,000	3,500	40	46,000	-6,500	41	100,000	-6,500
42	53,998	-6,500	43	56,000	-8,500	44	100,000	-8,500									

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
10	2	11	11	11	12	12	12	13	14	1	14	15	11	14	18	16	6	22	18	7
31	22	21	32	2	23	40	23	26	41	26	27	42	27	14	44	27	22	45	24	28
46	26	28	47	28	29	48	29	27	49	29	25	50	29	16	55	31	32	56	24	34
57	34	30	61	25	37	62	37	30	63	37	18	66	9	38	67	10	38	69	13	39
70	37	40	72	40	42	73	42	34	75	42	41	76	42	43	77	43	44			

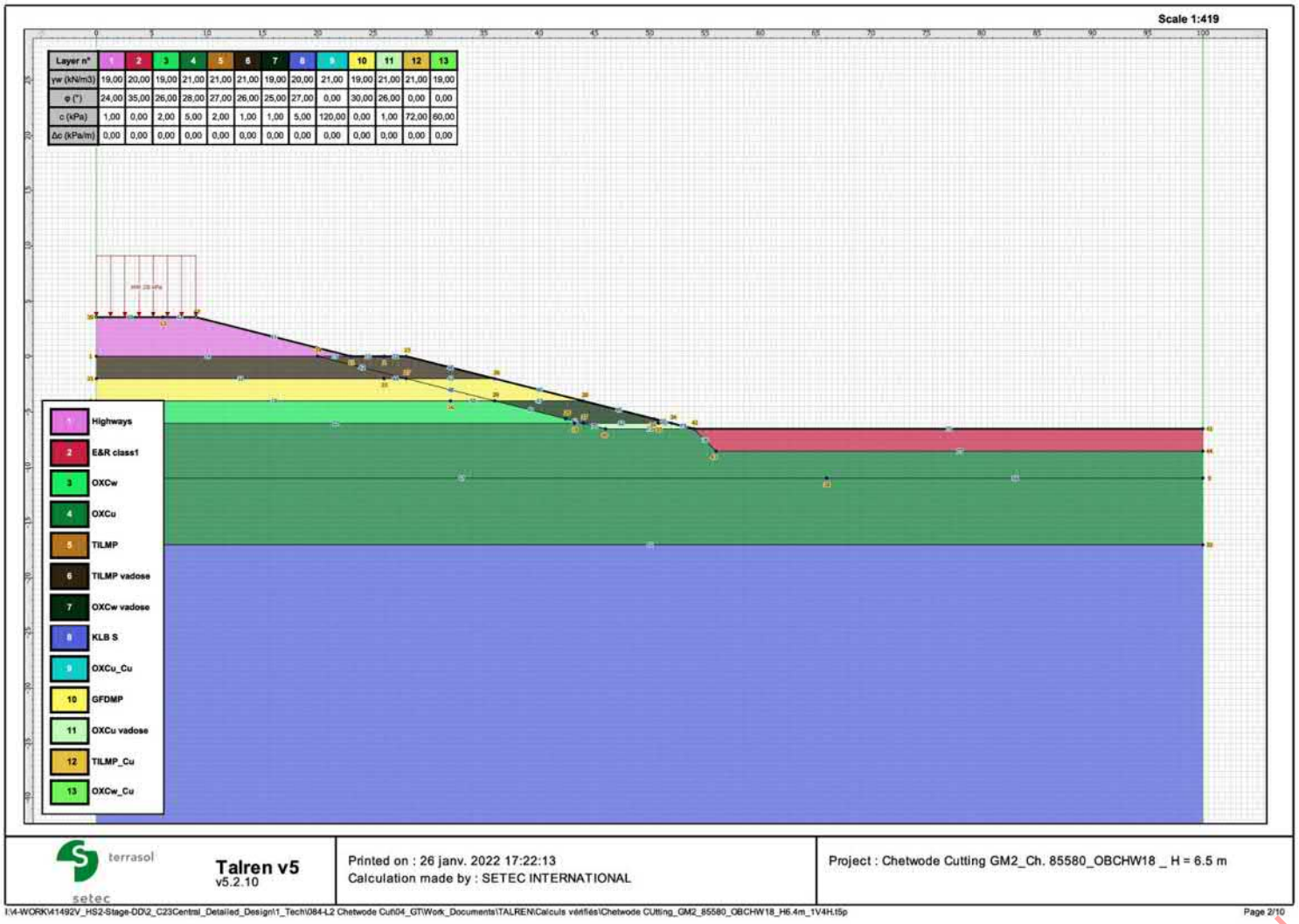
Distributed loads

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	HW 20 kPa	0,000	3,500	20,0	9,000	3,500	20,0	90,00

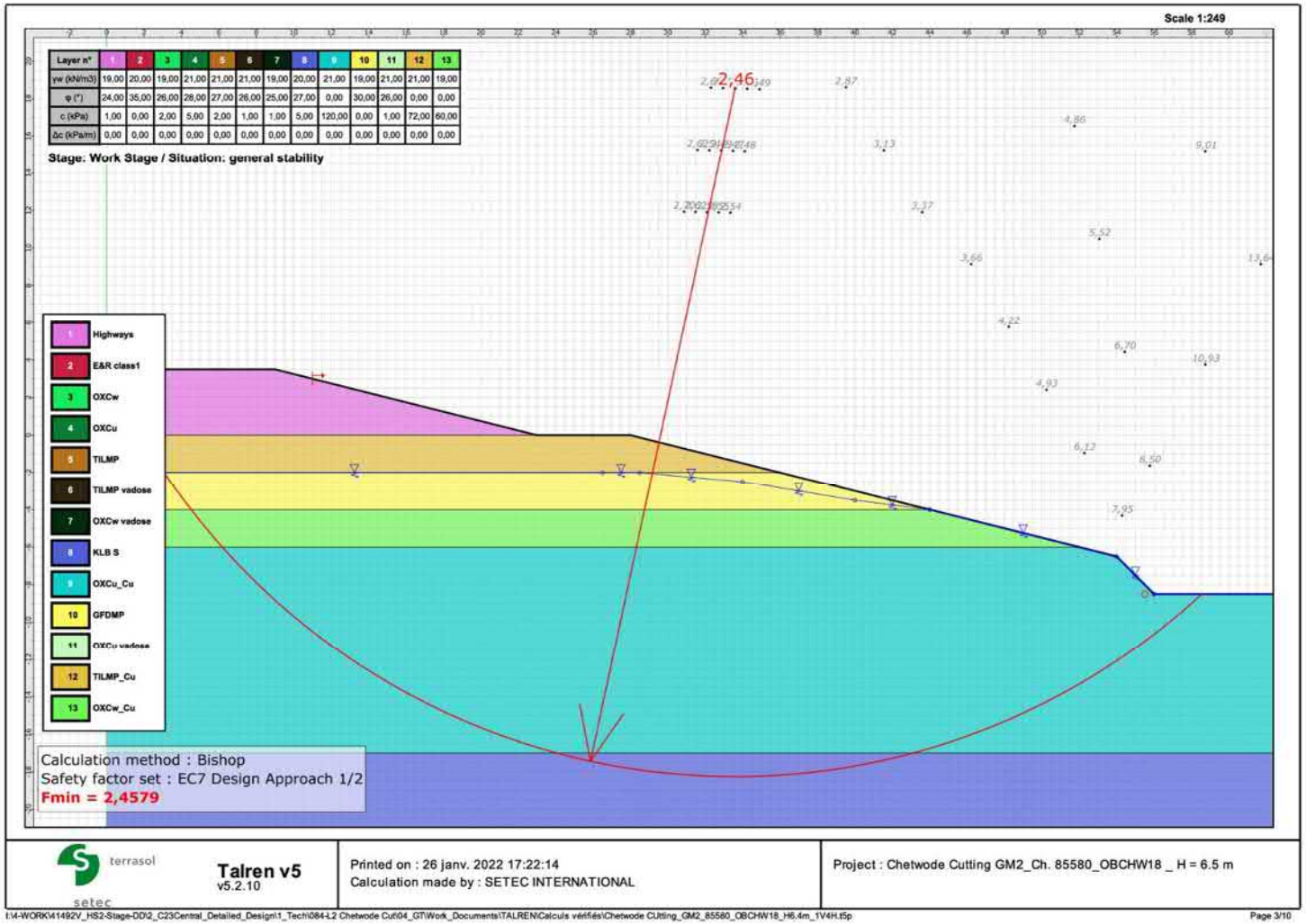
terrasol setec **Talren v5** v5.2.10

Printed on : 26 janv. 2022 17:22:13
Calculation made by : SETEC INTERNATIONAL
Project : Chetwode Cutting GM2_Ch. 85580_OBCHW18 _ H = 6.5 m

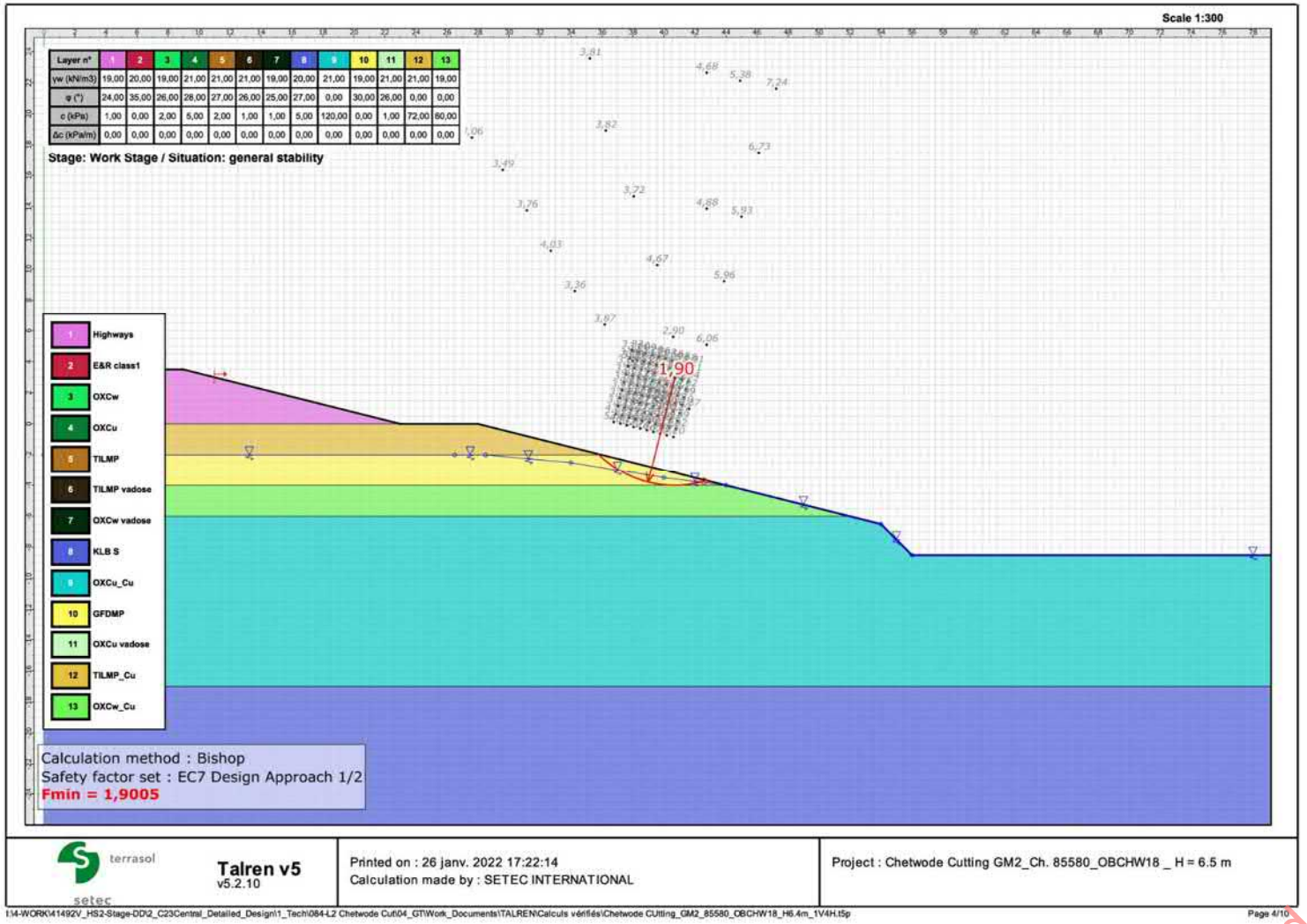
HS2 Ltd - Code 1 - Accepted



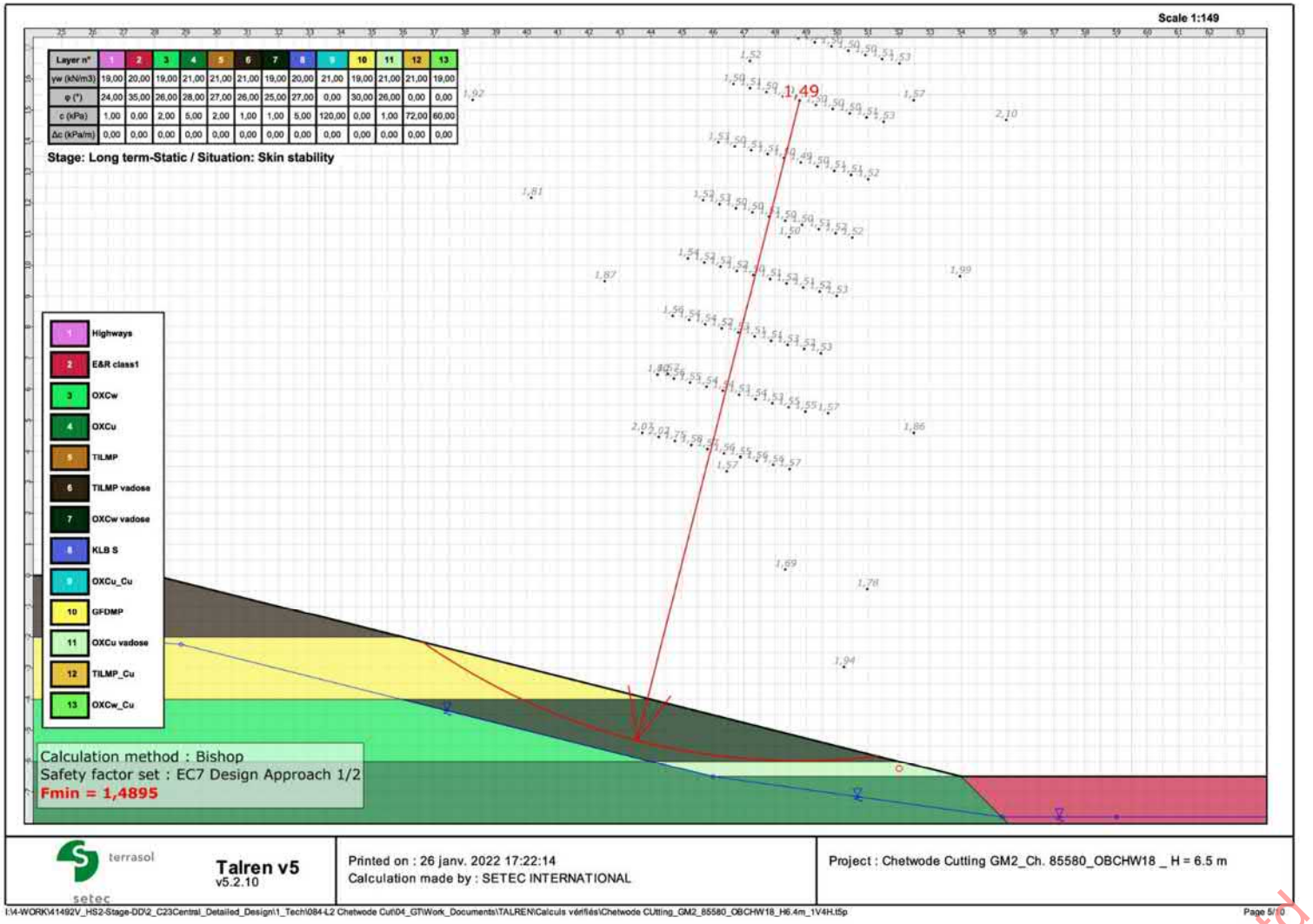
HS2 Ltd - Code 1 - Accepted



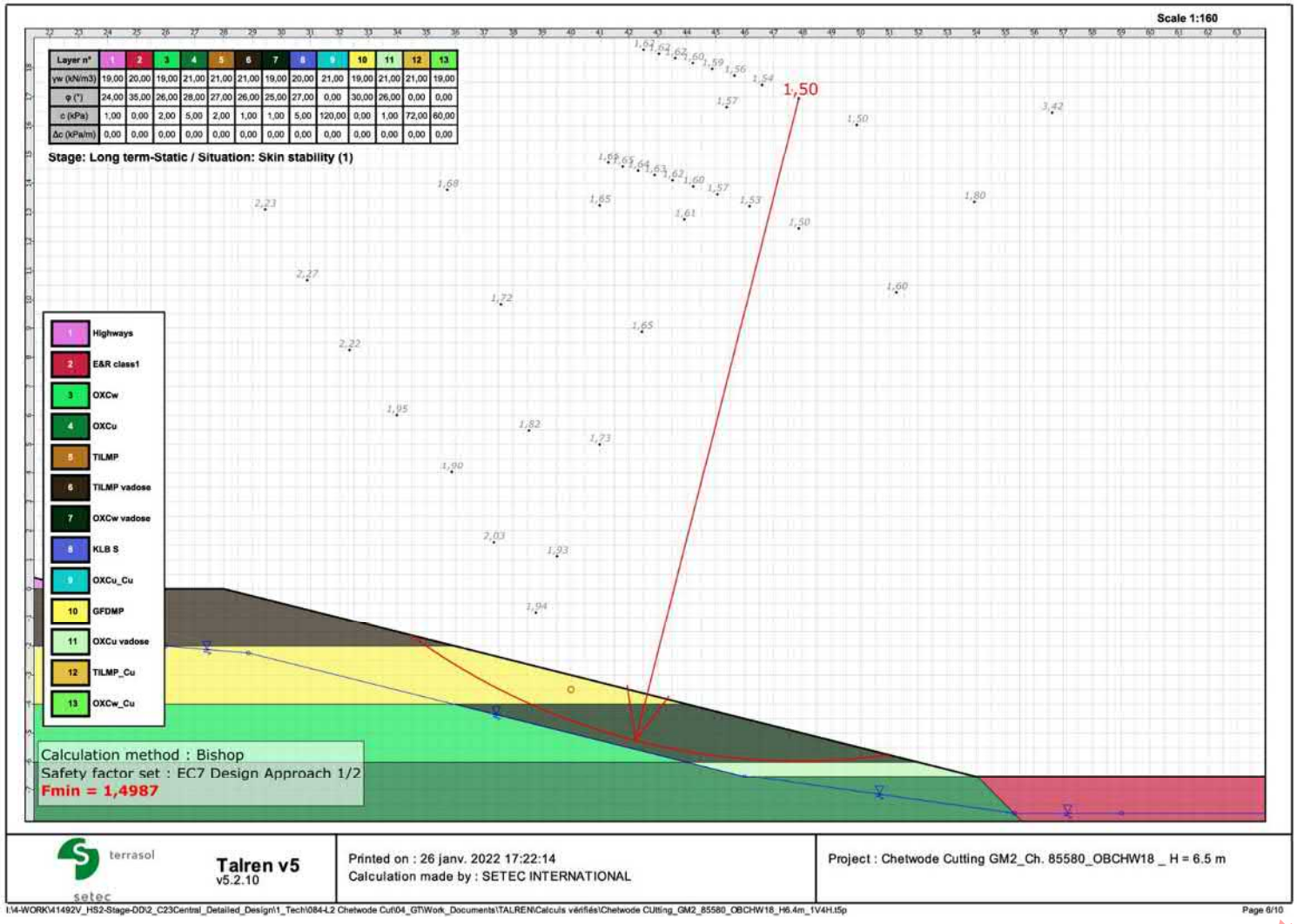
HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

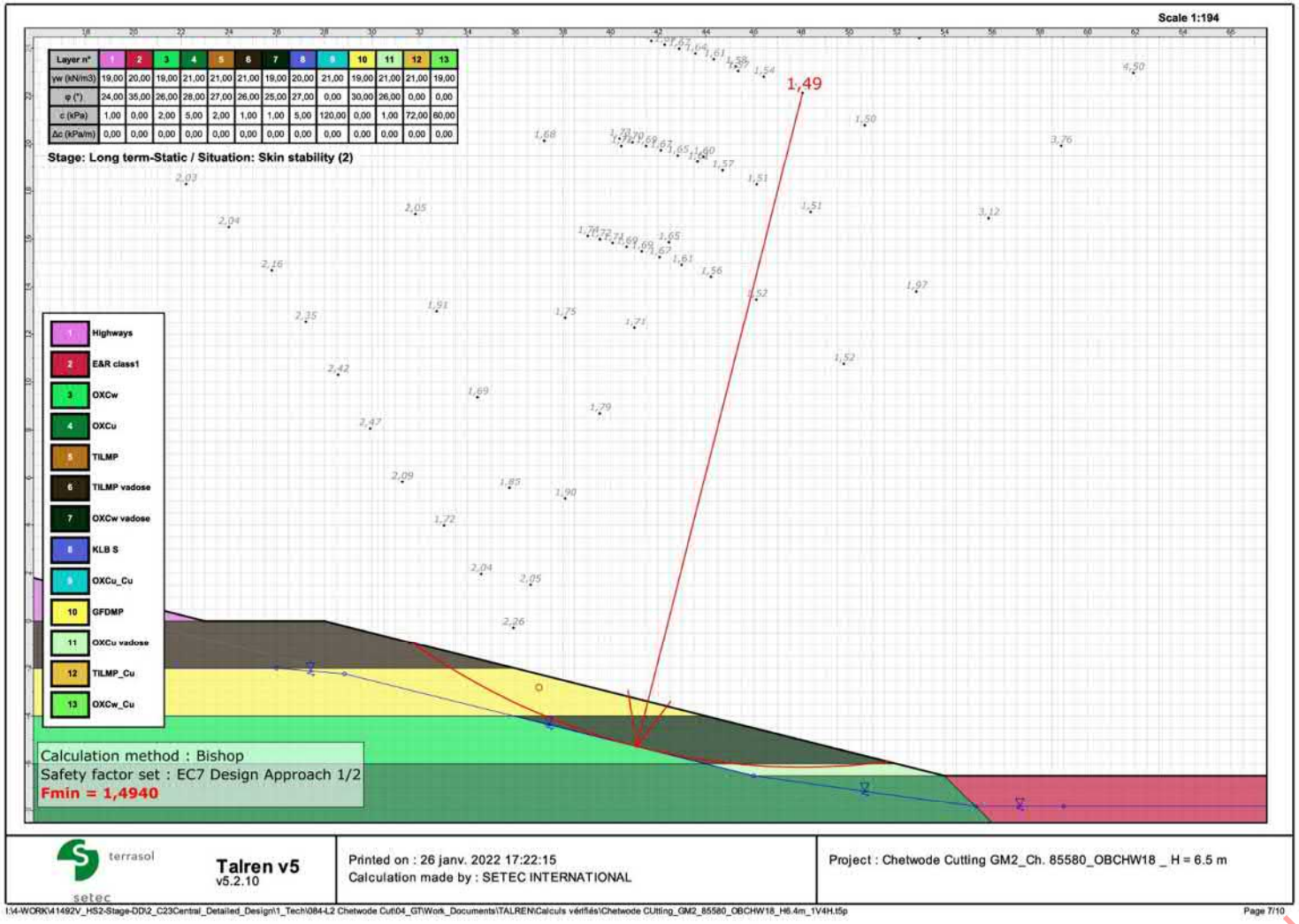


HS2 Ltd - Code 1 - Accepted

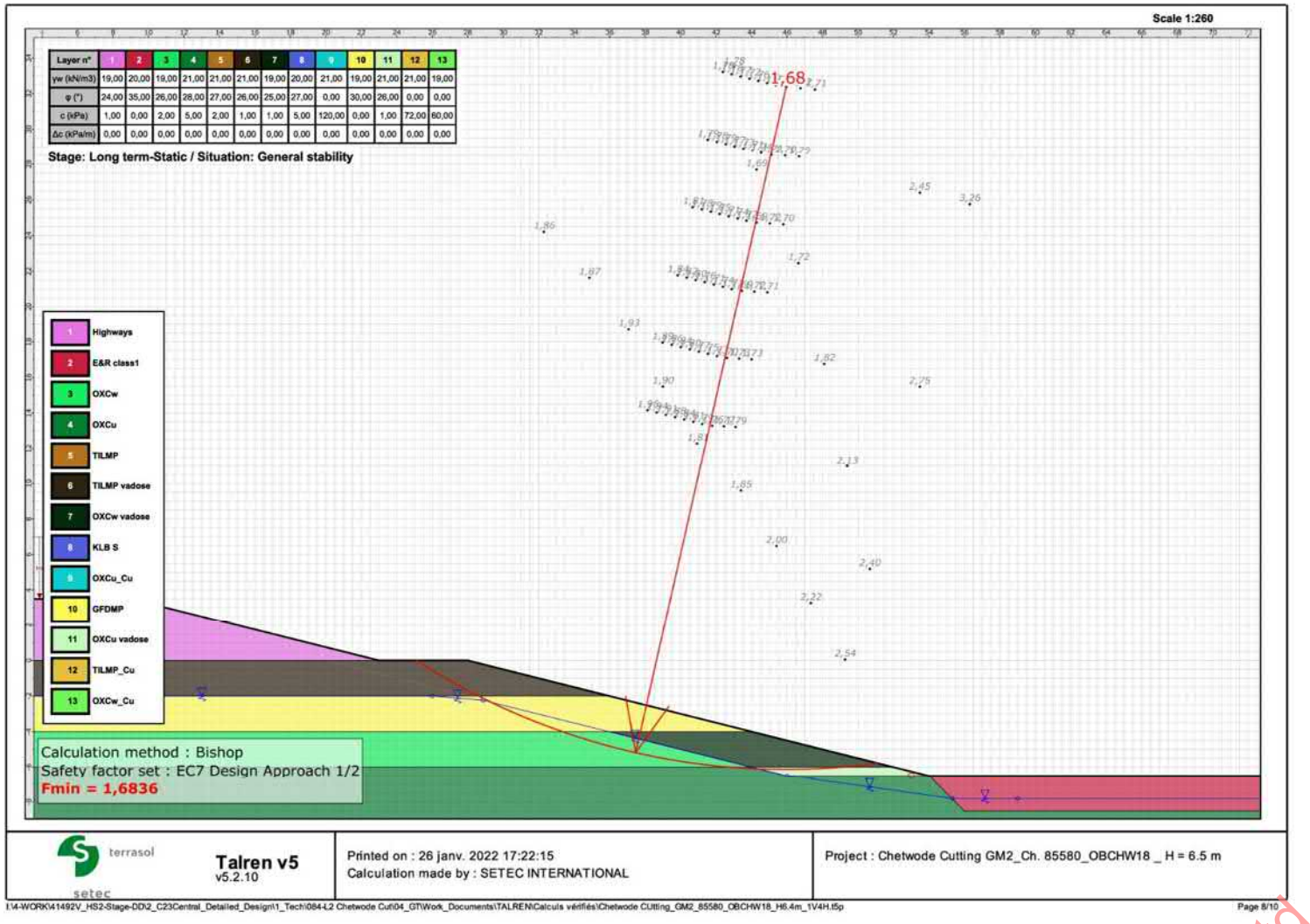


Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13
γw (kN/m3)	19,00	20,00	19,00	21,00	21,00	21,00	19,00	20,00	21,00	19,00	21,00	21,00	19,00
φ (°)	24,00	35,00	26,00	28,00	27,00	26,00	25,00	27,00	0,00	30,00	26,00	0,00	0,00
c (kPa)	1,00	0,00	2,00	5,00	2,00	1,00	1,00	5,00	120,00	0,00	1,00	72,00	60,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

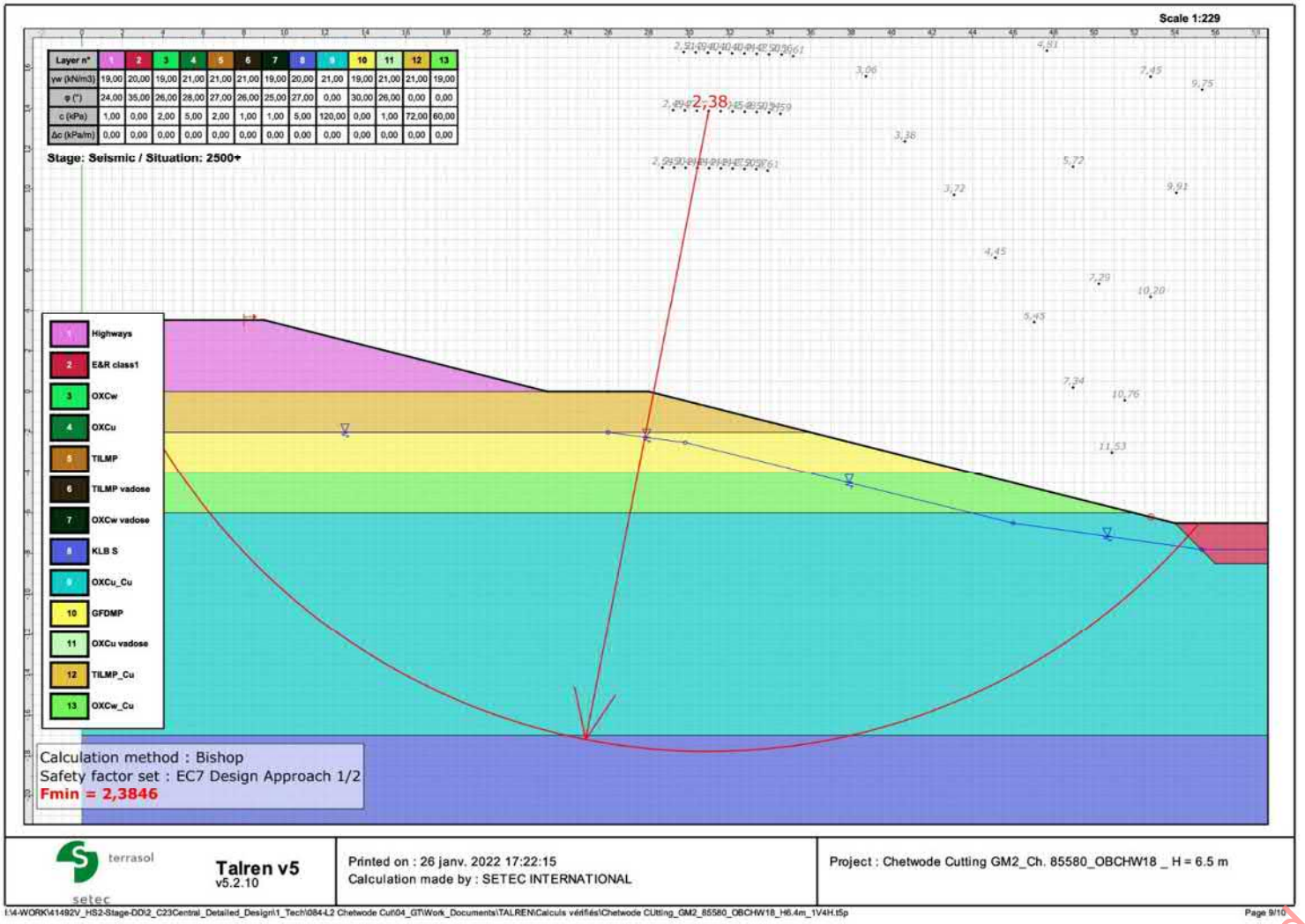
HS2 Ltd - Code 1 - Accepted



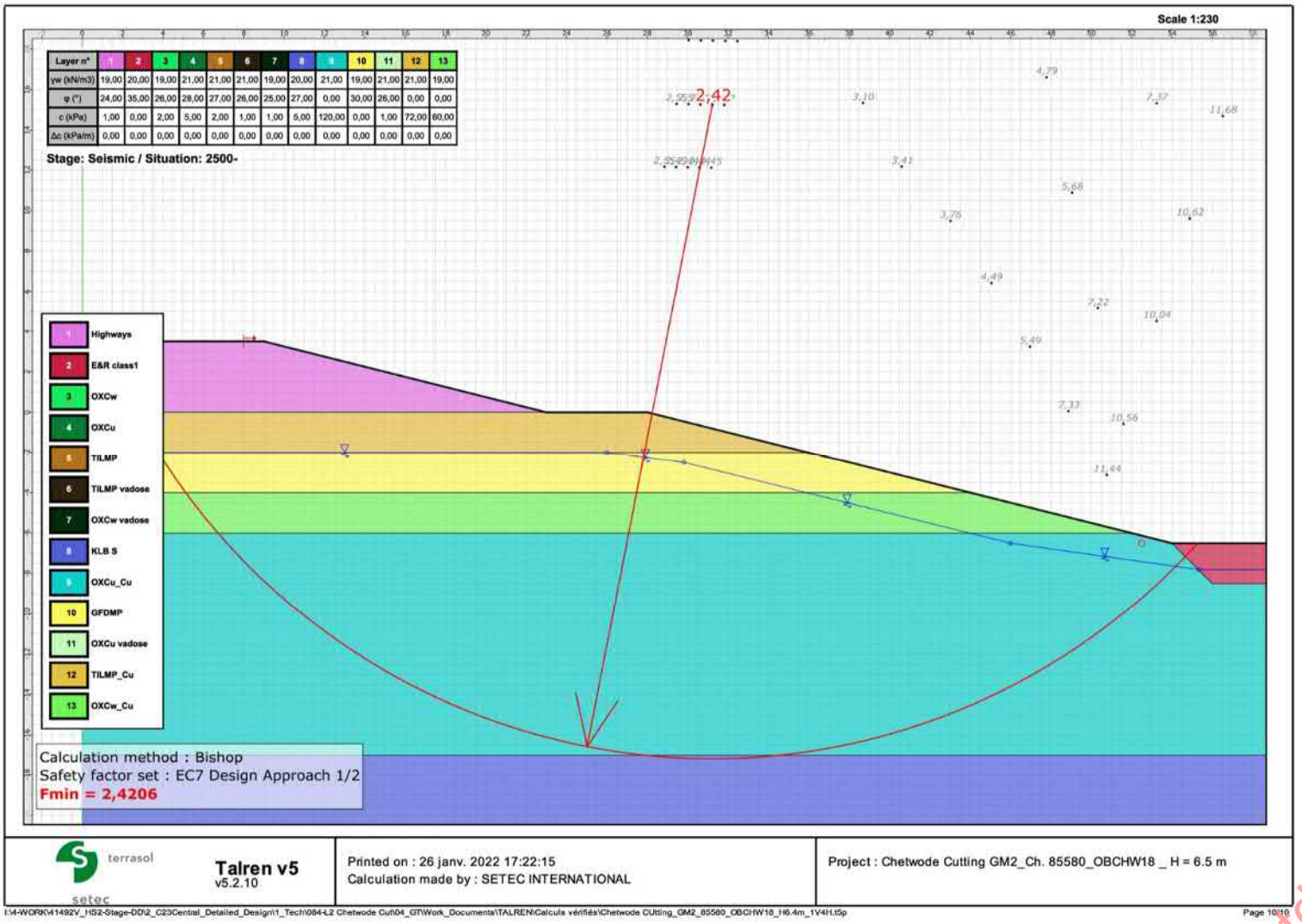
HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

Calculation profile Ch 86+440, Ground Model 3

HS2 Ltd - Code 1 - Accepted

Project data

Project reference : HS2 Detail Design
Calculation title : Chetwode Cutting GM3_Ch. 86440 _ H = 9 m
Location : Ch. 86440
Comments : Slope 1V/4H Landscape bund H = +6m
Units : kN, kPa, kN/m3
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs nails	pl	KsB	Anisotropy	Favorable	Specific safety factors
1	landscape		19,0	23,00	1,0	0,0	-	-	-	No	No	No
2	E&R class1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
3	OXCw		19,0	26,00	2,0	0,0	-	-	-	No	No	No
4	OXCu1,2		21,0	28,00	5,0	0,0	-	-	-	No	No	No
5	TILMP		21,0	27,00	2,0	0,0	-	-	-	No	No	No
6	TILMP vadose		21,0	26,00	1,0	0,0	-	-	-	No	No	No
7	OXCw vadose		19,0	25,00	1,0	0,0	-	-	-	No	No	No
8	KLB CZ		20,0	27,00	5,0	0,0	-	-	-	No	No	No
9	GFDMP		19,0	30,00	0,0	0,0	-	-	-	No	No	No
10	OXCu vadose		21,0	26,00	1,0	0,0	-	-	-	No	No	No
11	TILMP_Cu		21,0	0,01	72,0	0,0	-	-	-	No	No	No
12	OXCu1_Cu		21,0	0,01	120,0	0,0	-	-	-	No	No	No
13	OXCu2_Cu		21,0	0,01	180,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve
1	landscape		-	-	-	Effective	Linear
2	E&R class1		-	-	-	Effective	Linear
3	OXCw		-	-	-	Effective	Linear
4	OXCu1,2		-	-	-	Effective	Linear
5	TILMP		-	-	-	Effective	Linear
6	TILMP vadose		-	-	-	Effective	Linear
7	OXCw vadose		-	-	-	Effective	Linear
8	KLB CZ		-	-	-	Effective	Linear
9	GFDMP		-	-	-	Effective	Linear
10	OXCu vadose		-	-	-	Effective	Linear
11	TILMP_Cu		-	-	-	Undrained	Linear
12	OXCu1_Cu		-	-	-	Undrained	Linear
13	OXCu2_Cu		-	-	-	Undrained	Linear

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	0,000	0,000	2	26,000	0,000	6	0,000	-6,500	7	0,000	-7,000	9	100,000	-11,000	11	25,000	0,000
12	1,000	6,000	13	0,500	6,000	14	20,000	0,000	18	44,142	-7,000	21	0,000	-3,500	22	26,000	-3,500
23	28,000	0,000	27	32,500	-3,500	31	0,000	-15,000	32	100,000	-15,000	33	64,000	-9,000	35	100,000	-9,000
36	56,000	-9,000	37	46,000	-7,000	38	57,000	-11,000	39	0,000	6,000	40	54,880	-9,000	41	38,500	-3,516
42	46,284	-6,122	43	48,906	-7,000	44	51,579	-7,895	45	49,000	-9,000	46	22,000	0,000	47	39,339	-5,780
48	43,000	-7,000	49	100,000	-12,000	50	0,000	-12,000	51	0,000	-2,000	52	28,000	-2,000	53	34,000	-2,000

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
10	2	11	11	11	12	12	12	13	14	1	14	31	22	21	32	2	23	44	27	22
55	31	32	60	33	35	63	37	18	65	36	33	66	9	38	69	13	39	72	41	27
73	41	42	76	42	43	77	43	37	79	43	44	82	44	40	83	40	36	84	40	45
85	11	46	86	14	46	88	27	47	91	47	48	92	48	18	93	48	7	94	48	45
95	38	40	96	49	50	97	51	52	98	52	27	100	52	53	101	53	23	102	53	41
103	52	46																		

Distributed loads (1/2)

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	20 kPa works	25,000	0,000	20,0	27,500	0,000	20,0	90,00

terrasol setec
Talren v5
v5.2.10
Printed on : 26 janv. 2022 17:24:56
Calculation made by : SETEC INTERNATIONAL
Project : Chetwode Cutting GM3_Ch. 86440 _ H = 9 m

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HS2 Ltd - Code 1 - Accepted

Project data

Distributed loads (2/2)

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
2	10 kPa	25,000	0,000	10,0	27,500	0,000	10,0	90,00
3	10 kPa LS	0,000	6,000	10,0	1,000	6,000	10,0	90,00

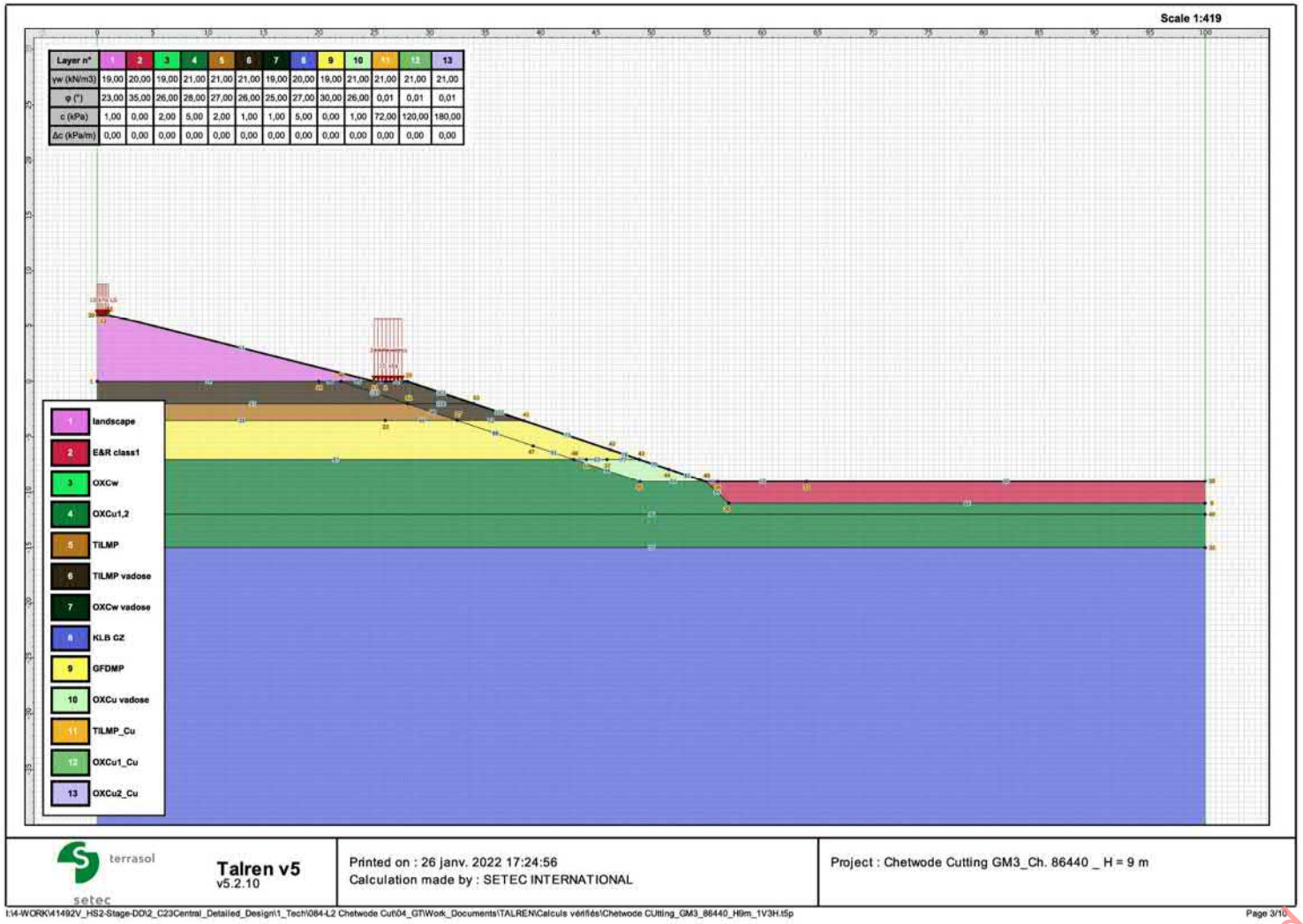
terrasol
setec

Talren v5
v5.2.10

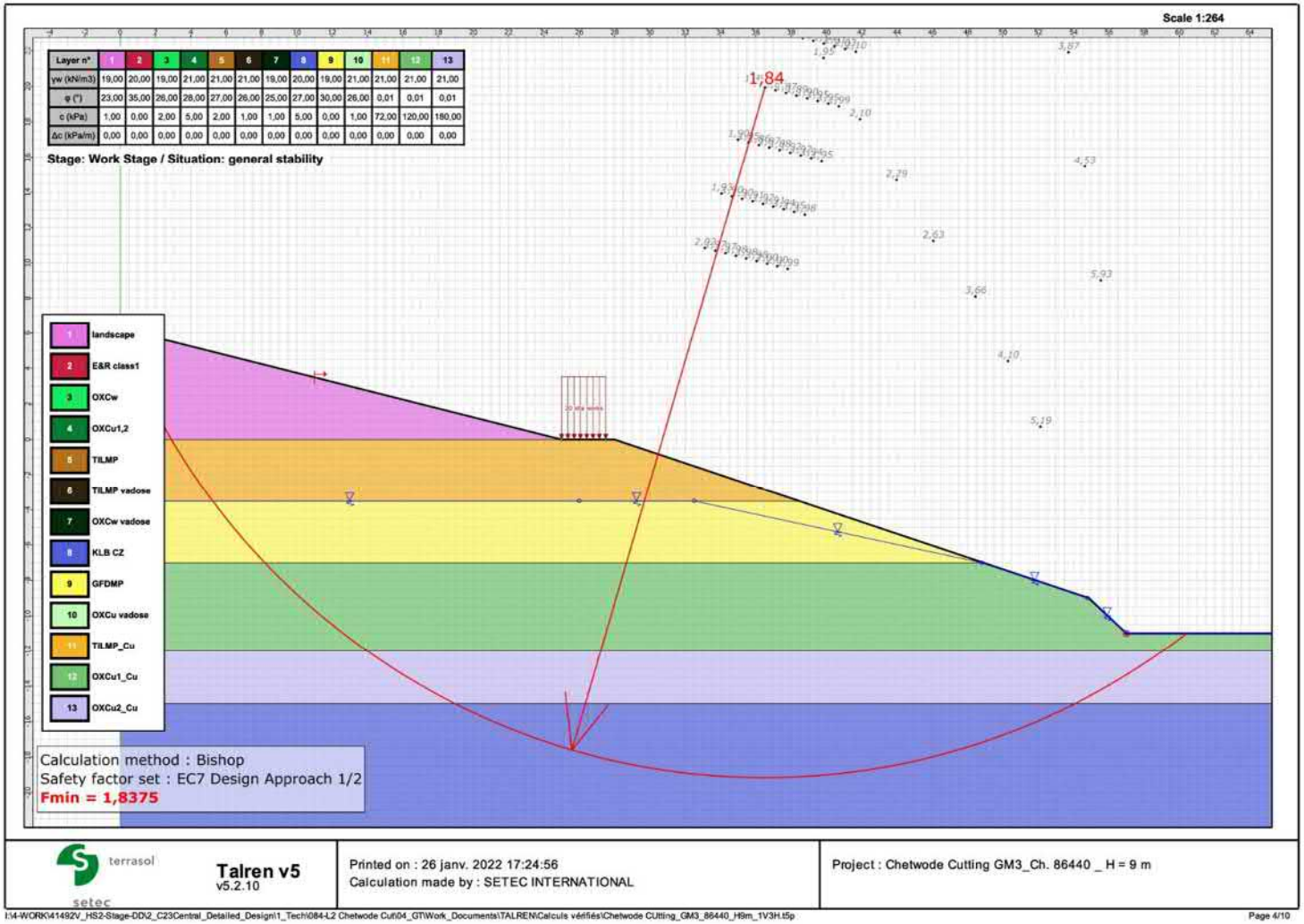
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Calculation made by : SETEC INTERNATIONAL
Project : Chetwode Cutting GM3_Ch. 86440 _ H = 9 m

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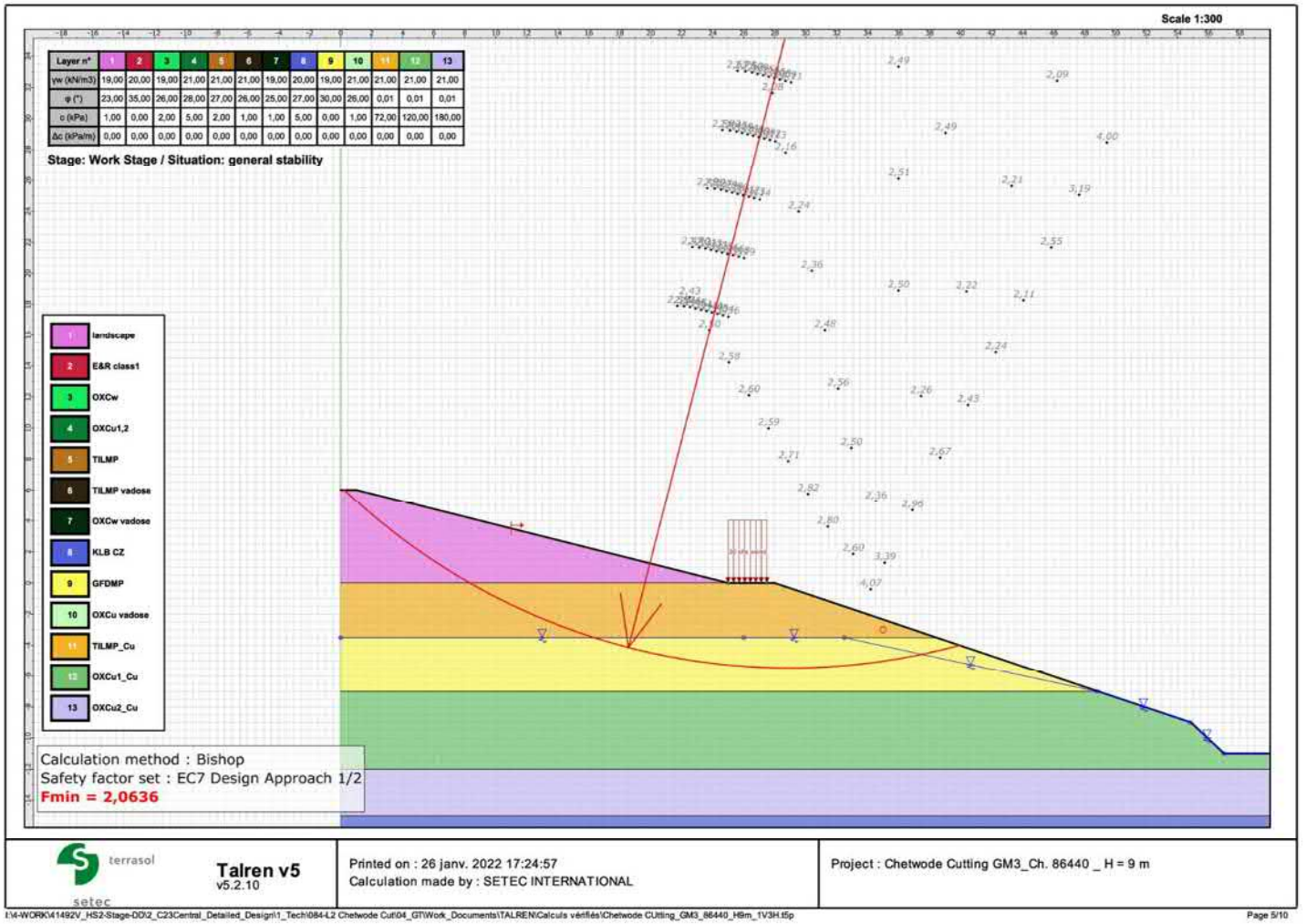
HS2 Ltd - Code 1 - Accepted



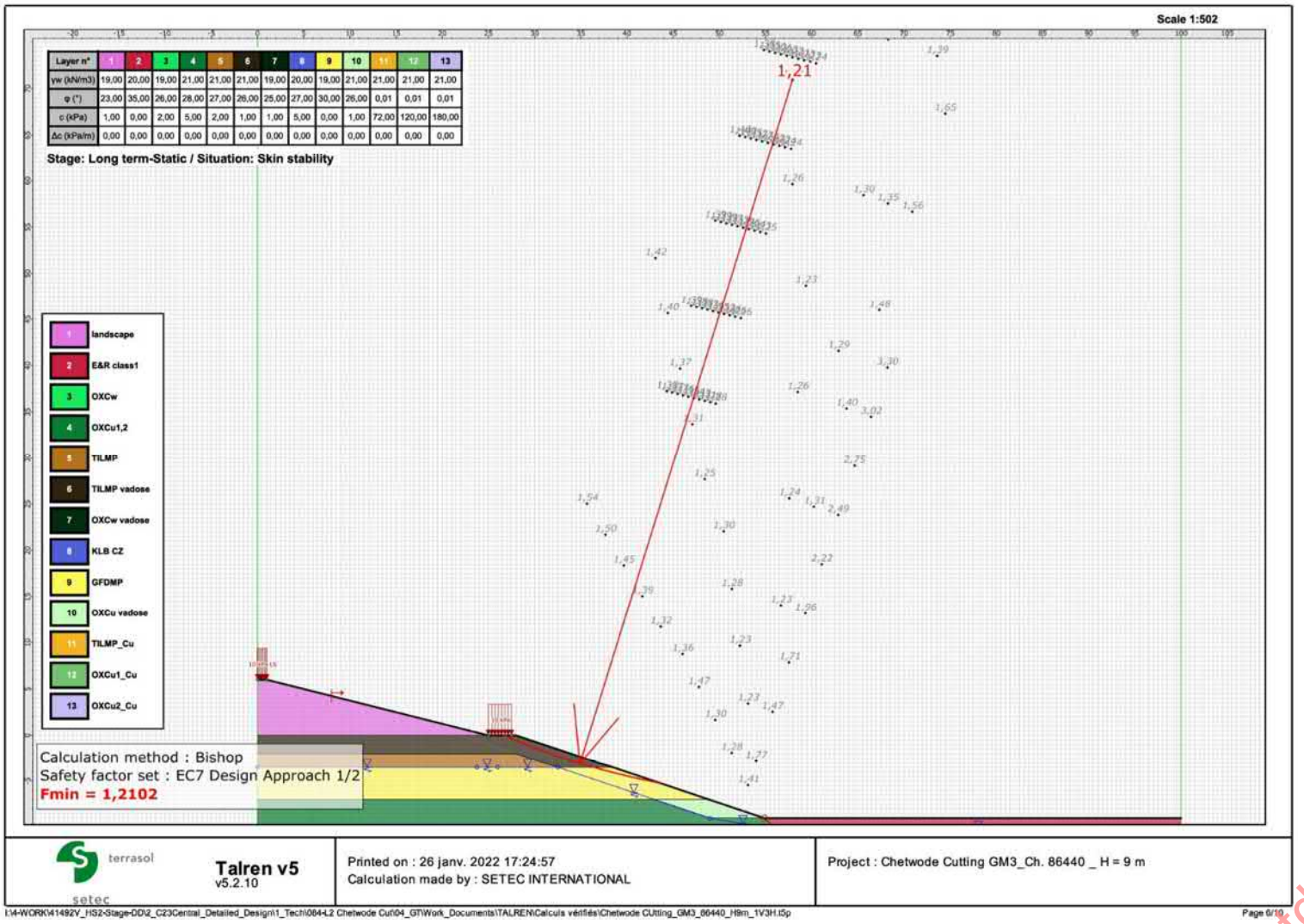
HS2 Ltd - Code 1 - Accepted



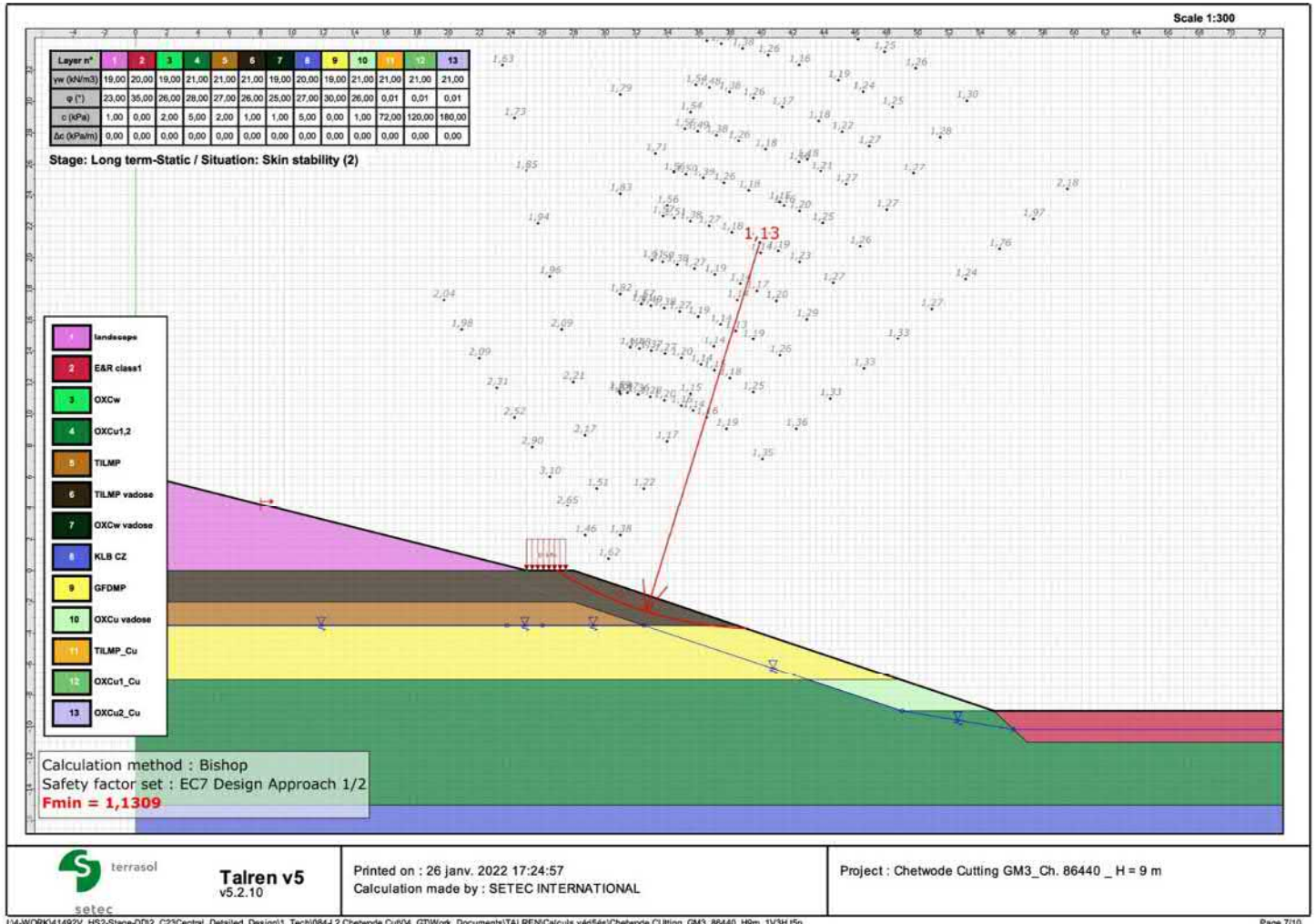
HS2 Ltd - Code 1 - Accepted



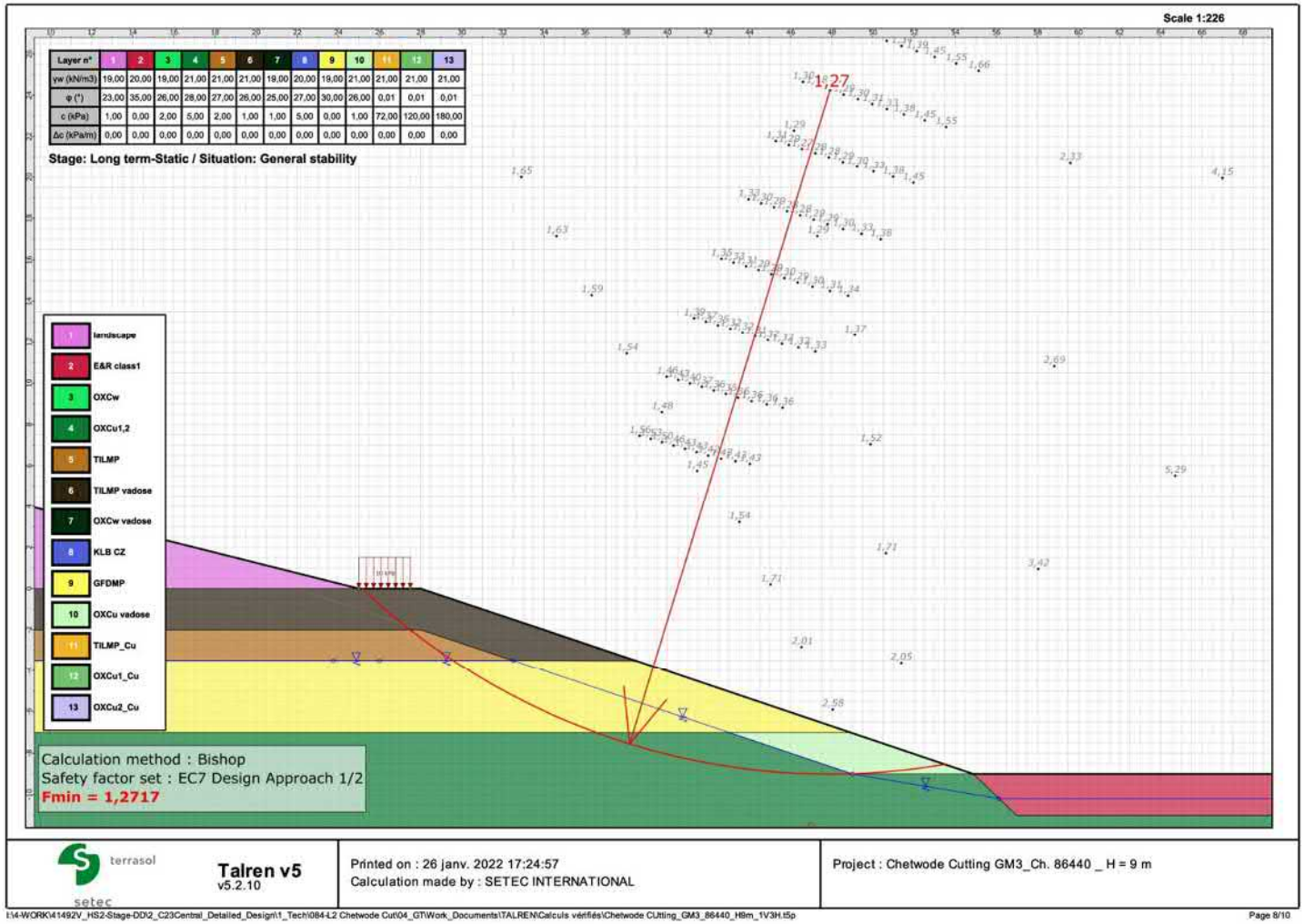
HS2 Ltd - Code 1 - Accepted



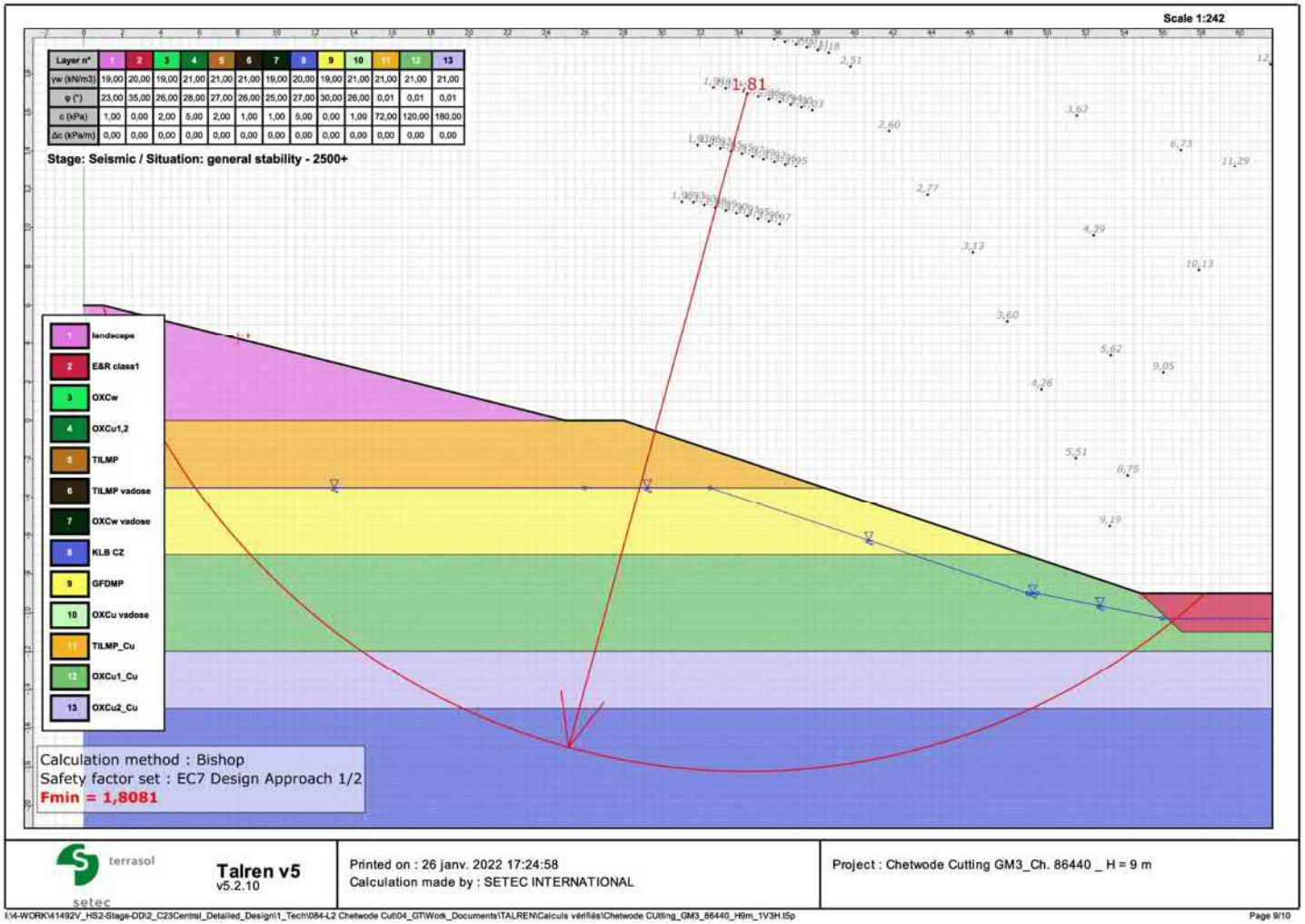
HS2 Ltd - Code 1 - Accepted



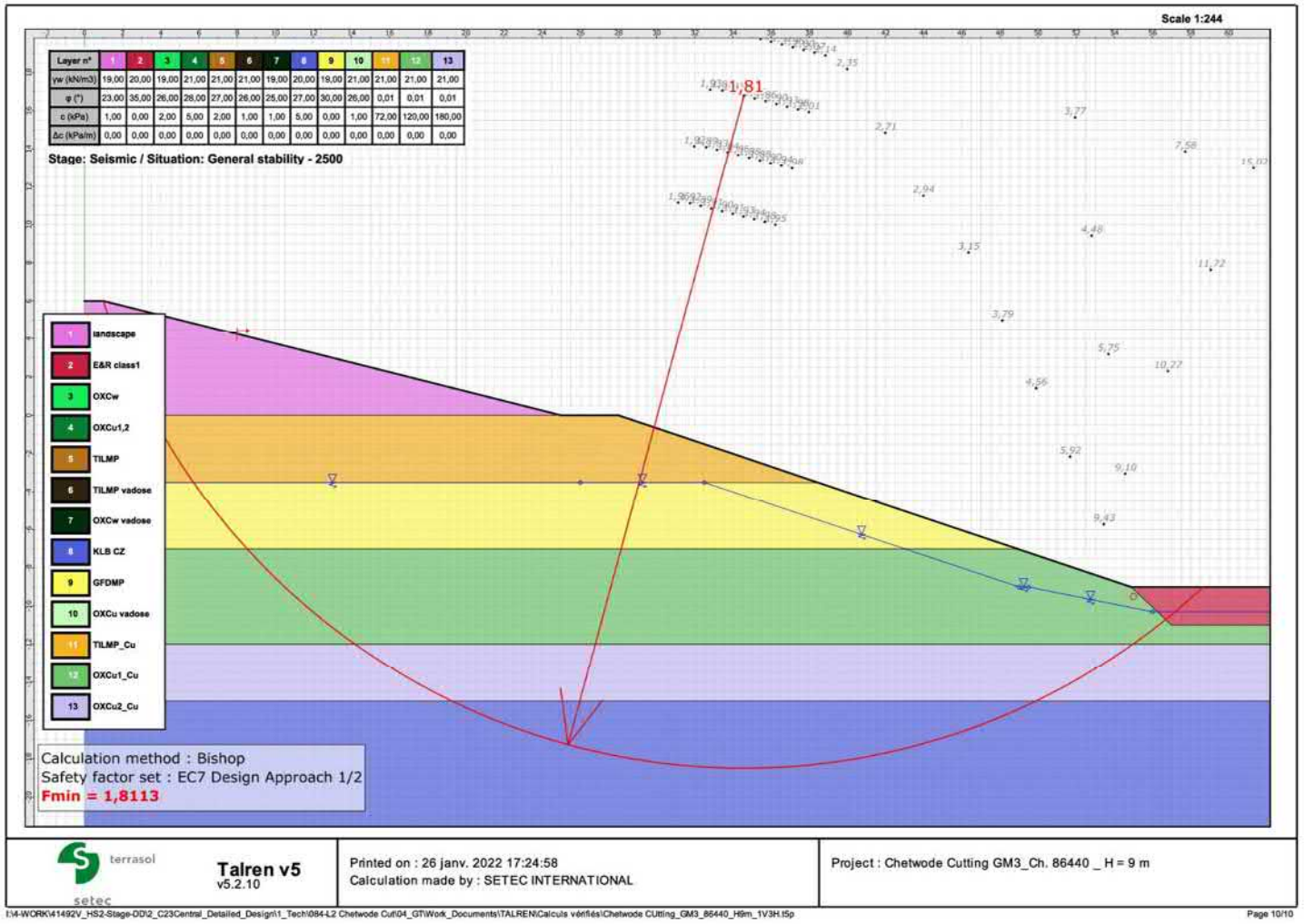
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Calculation profile 5-GSMR Ch 86+400, Ground Model 3 – GSMR platform

Données du projet

Numéro d'affaire : HS2 Detail Design
Titre du calcul : Chetwode Cutting GM3_Ch. 86400 _ H = 9 m
Lieu : Ch. 86400
Commentaires : Slope 1V/3H GSMR platform
Système d'unités : kN, kPa, kN/m³
γw : 10.0

Couches de sol

	Nom	Couleur	γ	φ	c	Δc	qs,clou	pmax	ks×B	Anisotropie	Favorable	Coefficients de sécurité spécifiques
1	landscape		19,0	23,00	1,0	0,0	-	-	-	Non	Non	Non
2	E&R class1		20,0	35,00	0,0	0,0	-	-	-	Non	Non	Non
3	OXCw		19,0	26,00	2,0	0,0	-	-	-	Non	Non	Non
4	OXCu1,2		21,0	28,00	5,0	0,0	-	-	-	Non	Non	Non
5	TILMP		21,0	27,00	2,0	0,0	-	-	-	Non	Non	Non
6	TILMP vadose		21,0	26,00	1,0	0,0	-	-	-	Non	Non	Non
7	OXCw vadose		19,0	25,00	1,0	0,0	-	-	-	Non	Non	Non
8	KLB CZ		20,0	27,00	5,0	0,0	-	-	-	Non	Non	Non
9	GFDMP		19,0	30,00	0,0	0,0	-	-	-	Non	Non	Non
10	OXCu vadose		21,0	26,00	1,0	0,0	-	-	-	Non	Non	Non
11	TILMP_Cu		21,0	0,01	72,0	0,0	-	-	-	Non	Non	Non
12	OXCu1_Cu		21,0	0,01	120,0	0,0	-	-	-	Non	Non	Non
13	OXCu2_Cu		21,0	0,01	180,0	0,0	-	-	-	Non	Non	Non
14	GSMR platform		20,0	30,00	0,0	0,0	-	-	-	Non	Non	Non

Couches de sol (cont.)

	Nom	Couleur	Γγ	Γc	Γtan(φ)	Type de cohésion	Courbe	Écoulement dans le sol	kh	kv
1	landscape		-	-	-	Effective	Linéaire	Non	-	-
2	E&R class1		-	-	-	Effective	Linéaire	Non	-	-
3	OXCw		-	-	-	Effective	Linéaire	Non	-	-
4	OXCu1,2		-	-	-	Effective	Linéaire	Non	-	-
5	TILMP		-	-	-	Effective	Linéaire	Non	-	-
6	TILMP vadose		-	-	-	Effective	Linéaire	Non	-	-
7	OXCw vadose		-	-	-	Effective	Linéaire	Non	-	-
8	KLB CZ		-	-	-	Effective	Linéaire	Non	-	-
9	GFDMP		-	-	-	Effective	Linéaire	Non	-	-
10	OXCu vadose		-	-	-	Effective	Linéaire	Non	-	-
11	TILMP_Cu		-	-	-	Non drainée	Linéaire	Non	-	-
12	OXCu1_Cu		-	-	-	Non drainée	Linéaire	Non	-	-
13	OXCu2_Cu		-	-	-	Non drainée	Linéaire	Non	-	-
14	GSMR platform		-	-	-	Effective	Linéaire	Non	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	0,000	0,000	2	26,000	0,000	6	0,000	-6,500	7	0,000	-7,000	9	100,000	-11,000	11	23,000	0,000			
12	20,000	1,000	13	0,000	1,000	14	20,000	0,000	18	44,142	-7,000	21	0,000	-3,500	22	26,000	-3,500			
23	28,000	0,000	27	32,500	-3,500	31	0,000	-15,000	32	100,000	-15,000	33	64,000	-9,000	35	100,000	-9,000			
36	56,000	-9,000	37	46,000	-7,000	38	57,000	-11,000	39	0,000	6,000	40	54,880	-9,000	41	38,500	-3,516			
42	46,264	-6,122	43	48,906	-7,000	44	51,579	-7,895	45	49,000	-9,000	46	22,000	0,000	47	39,339	-5,780			
48	43,000	-7,000	49	100,000	-12,000	50	0,000	-12,000	51	0,000	-2,000	52	28,000	-2,000	53	34,000	-2,000			

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
10	2	11	11	11	12	12	12	13	14	1	14	31	22	21	32	2	23	44	27	22
55	31	32	60	33	35	63	37	18	65	36	33	66	9	38	69	13	39	72	41	27
73	41	42	76	42	43	77	43	37	79	43	44	82	44	40	83	40	36	84	40	45
85	11	46	86	14	46	88	27	47	91	47	48	92	48	18	93	48	7	94	48	45
95	38	40	96	49	50	97	51	52	98	52	27	100	52	53	101	53	23	102	53	41
103	52	46																		

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sotec

Talren v6
v6.0.15

Imprimé le : 5 sept. 2022 16:47:52
Calcul réalisé par : Terrasol
Projet : Chetwode Cutting GM3_Ch. 86400 _ H = 9 m

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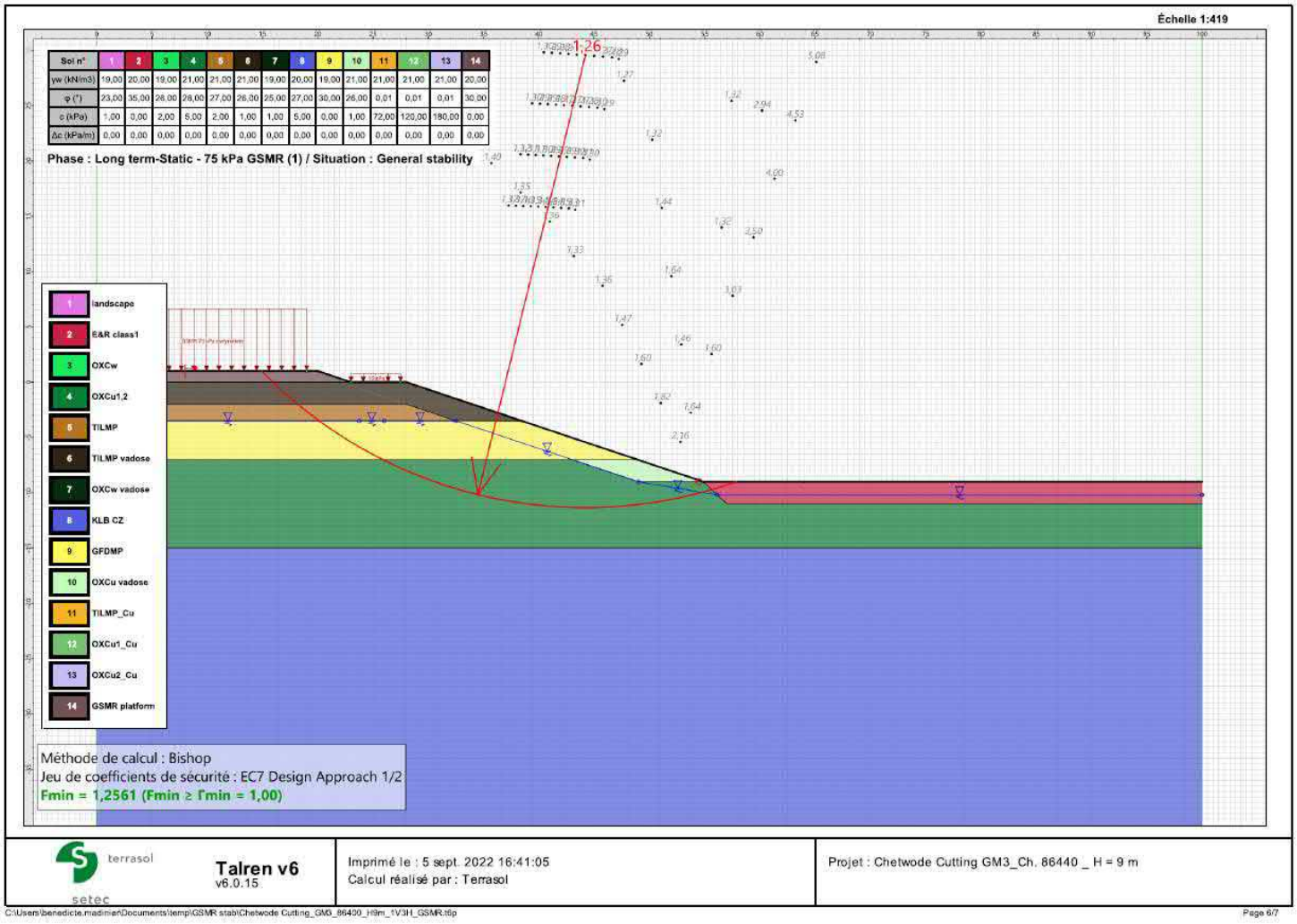
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Données du projet

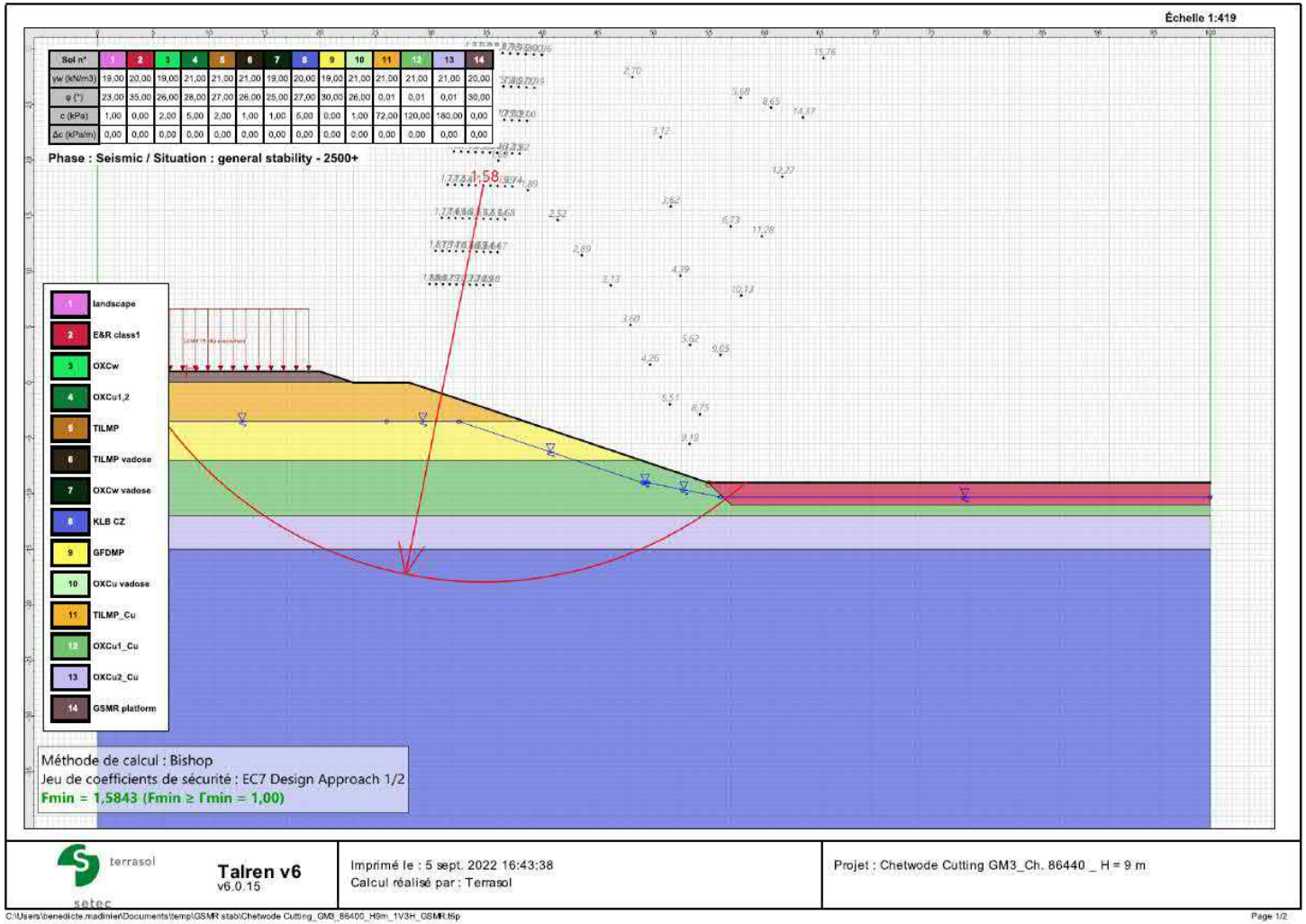
Surcharges réparties

	Nom	X gauche	Y gauche	q gauche	X droite	Y droite	q droite	Ang/horizontale
1	20 kPa works	23,000	0,000	20,0	27,500	0,000	20,0	90,00
2	10 kPa	23,000	0,000	10,0	27,500	0,000	10,0	90,00
3	GSMR 20 kPa everywhere	0,000	1,000	20,0	19,000	1,000	20,0	90,00
4	GSMR 50 kPa everywhere	1,000	1,000	50,0	19,000	1,000	50,0	90,00
5	GSMR 75 kPa everywhere	2,000	1,000	75,0	19,000	1,000	75,0	90,00

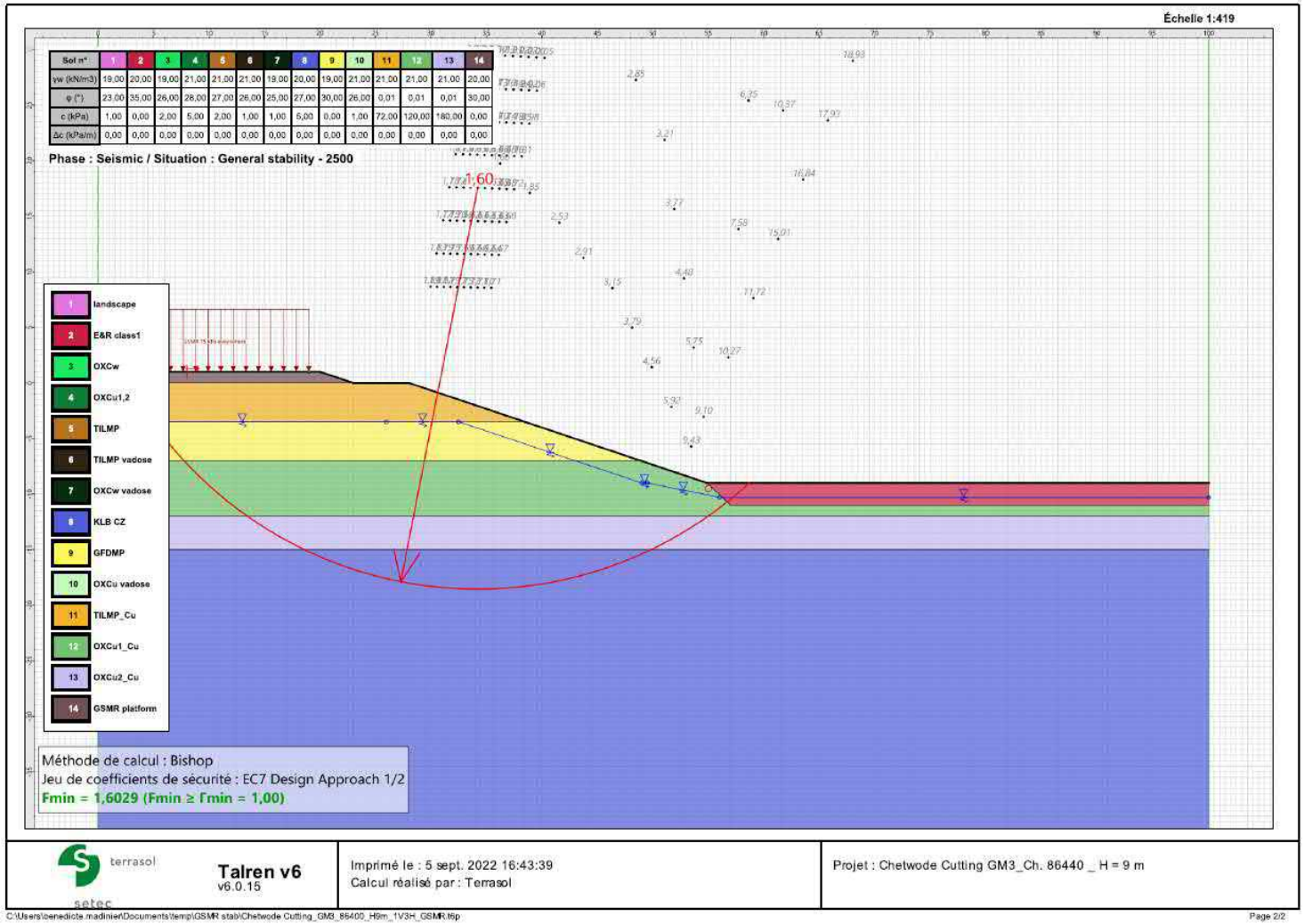
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Calculation profile Ch 86+440, Ground Model 3, Temporary slope

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Project data

Project reference : HS2 Detail Design
Calculation title : Chetwode Cutting GM3_Ch. 86440 _ H = 9 m
Location : Ch. 86440
Comments : Slope 1V/4H Landscape bund H = +6m
Units : kN, kPa, kN/m3
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs nails	pi	KsB	Anisotropy	Favorable	Specific safety factors
1	landscape		19,0	23,00	1,0	0,0	-	-	-	No	No	No
2	E&R class1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
3	OXCw		19,0	26,00	3,0	0,0	-	-	-	No	No	No
4	OXCu		21,0	28,00	5,0	0,0	-	-	-	No	No	No
5	TILMP		21,0	27,00	2,0	0,0	-	-	-	No	No	No
6	TILMP vadose		21,0	26,00	1,0	0,0	-	-	-	No	No	No
7	OXCw vadose		19,0	25,00	1,0	0,0	-	-	-	No	No	No
8	KLB		20,0	27,00	5,0	0,0	-	-	-	No	No	No
9	GFDMP		19,0	30,00	0,0	0,0	-	-	-	No	No	No
10	OXCu vadose		21,0	26,00	1,0	0,0	-	-	-	No	No	No
11	TILMP_Cu		21,0	0,01	72,0	0,0	-	-	-	No	No	No
12	OXCu1_Cu		21,0	0,01	120,0	0,0	-	-	-	No	No	No
13	OXCu2_Cu		21,0	0,01	180,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve
1	landscape		-	-	-	Effective	Linear
2	E&R class1		-	-	-	Effective	Linear
3	OXCw		-	-	-	Effective	Linear
4	OXCu		-	-	-	Effective	Linear
5	TILMP		-	-	-	Effective	Linear
6	TILMP vadose		-	-	-	Effective	Linear
7	OXCw vadose		-	-	-	Effective	Linear
8	KLB		-	-	-	Effective	Linear
9	GFDMP		-	-	-	Effective	Linear
10	OXCu vadose		-	-	-	Effective	Linear
11	TILMP_Cu		-	-	-	Undrained	Linear
12	OXCu1_Cu		-	-	-	Undrained	Linear
13	OXCu2_Cu		-	-	-	Undrained	Linear

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	0,000	0,000	2	26,000	0,000	7	0,000	-7,000	11	25,000	0,000	12	1,000	6,000	13	0,500	6,000
14	20,000	0,000	18	44,142	-7,000	21	0,000	-3,500	22	26,000	-3,500	23	28,000	0,000	27	32,500	-3,500
31	0,000	-15,000	32	100,000	-15,000	37	45,000	-7,000	39	0,000	6,000	41	38,500	-3,516	43	48,906	-7,000
46	22,000	0,000	47	39,339	-5,780	48	43,000	-7,000	49	100,000	-12,000	50	0,000	-12,000	51	0,000	-5,000
52	100,000	-4,500	53	36,875	-4,959	54	42,934	-5,000	55	100,000	-7,000	56	0,000	-2,000	57	28,000	-2,000
58	34,000	-2,000															

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
10	2	11	11	11	12	12	12	13	14	1	14	31	22	21	32	2	23	44	27	22
55	31	32	63	37	18	69	13	39	72	41	27	77	43	37	85	11	46	86	14	46
91	47	48	92	48	18	93	48	7	96	49	50	97	51	53	98	53	27	99	53	47
100	53	54	101	54	41	103	54	52	104	43	55	105	37	54	106	56	57	107	57	46
108	23	58	109	58	41	110	57	27												

Distributed loads (1/2)

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	20 kPa works	25,000	0,000	20,0	27,500	0,000	20,0	90,00
2	10 kPa	25,000	0,000	10,0	27,500	0,000	10,0	90,00

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Printed on : 26 janv. 2022 17:34:42
Calculation made by : SETEC INTERNATIONAL
Project : Chetwode Cutting GM3_Ch. 86440 _ H = 9 m

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Project data

Distributed loads (2/2)

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
3	10 kPa LS	0,000	6,000	10,0	1,000	6,000	10,0	90,00

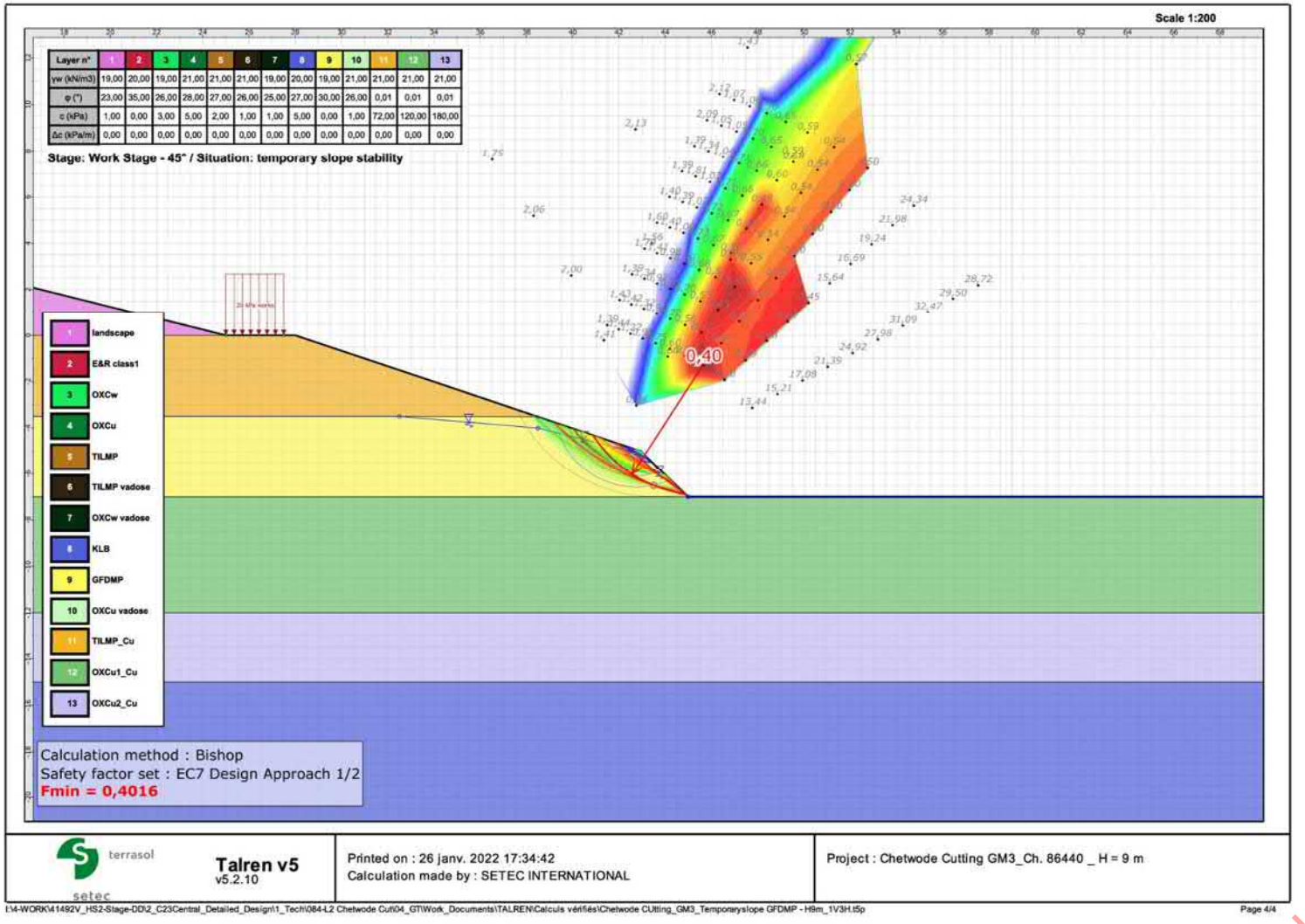
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Talren v5
v5.2.10

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Project : Chetwode Cutting GM3_Ch. 86440 _ H = 9 m

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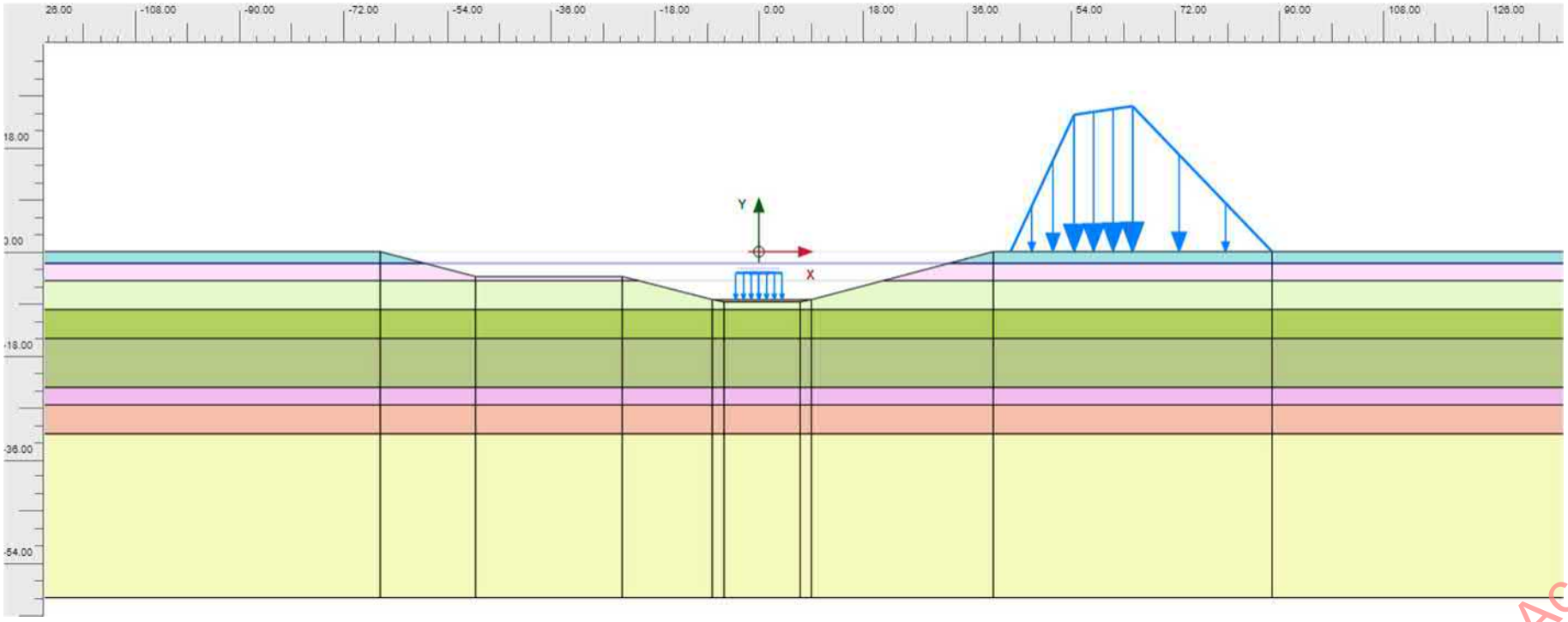
HS2 Ltd - Code 1 - Accepted



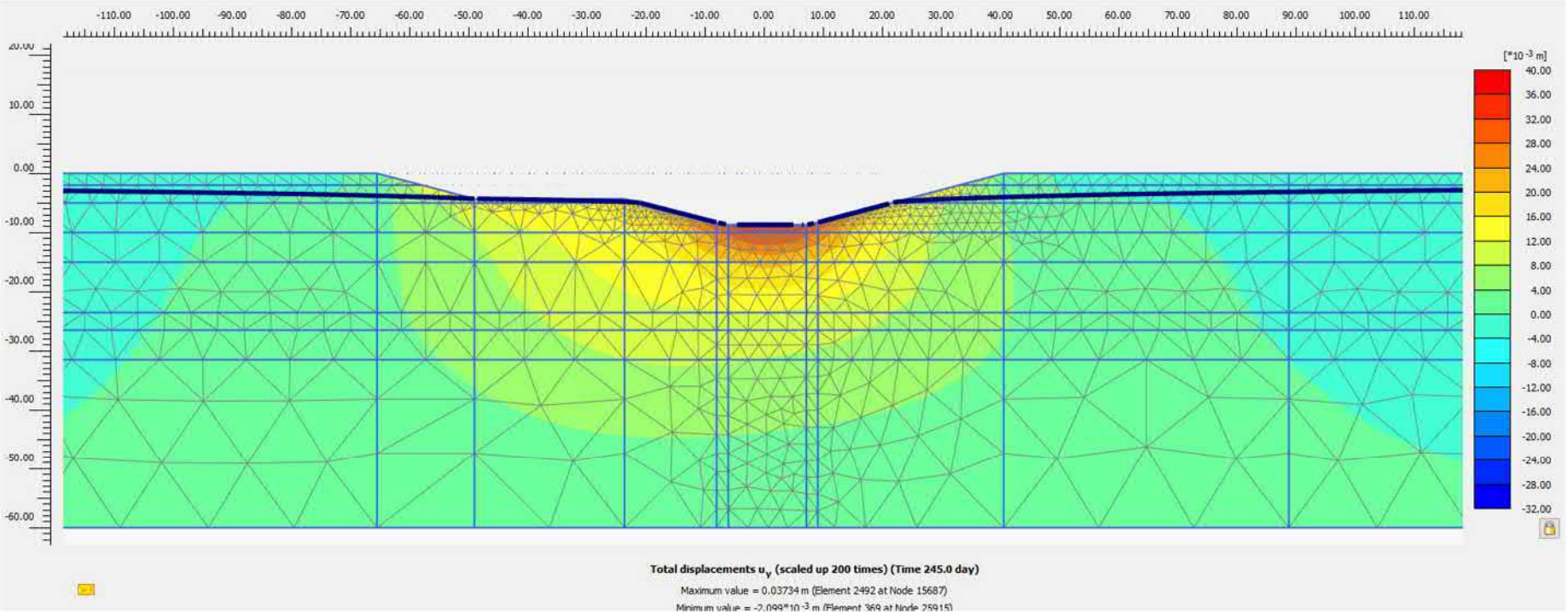
HS2 Ltd - Code 1 - Accepted

Heave calculations

Ch. 85+451

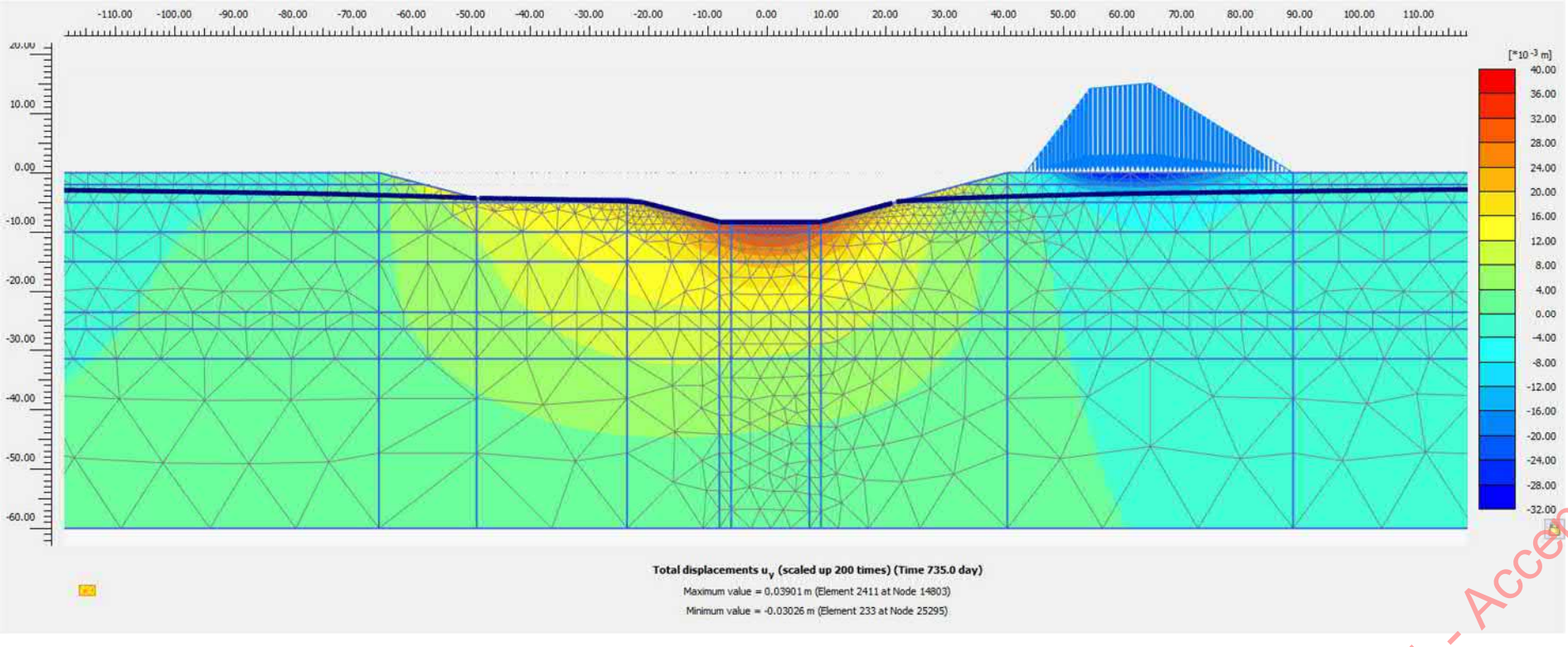


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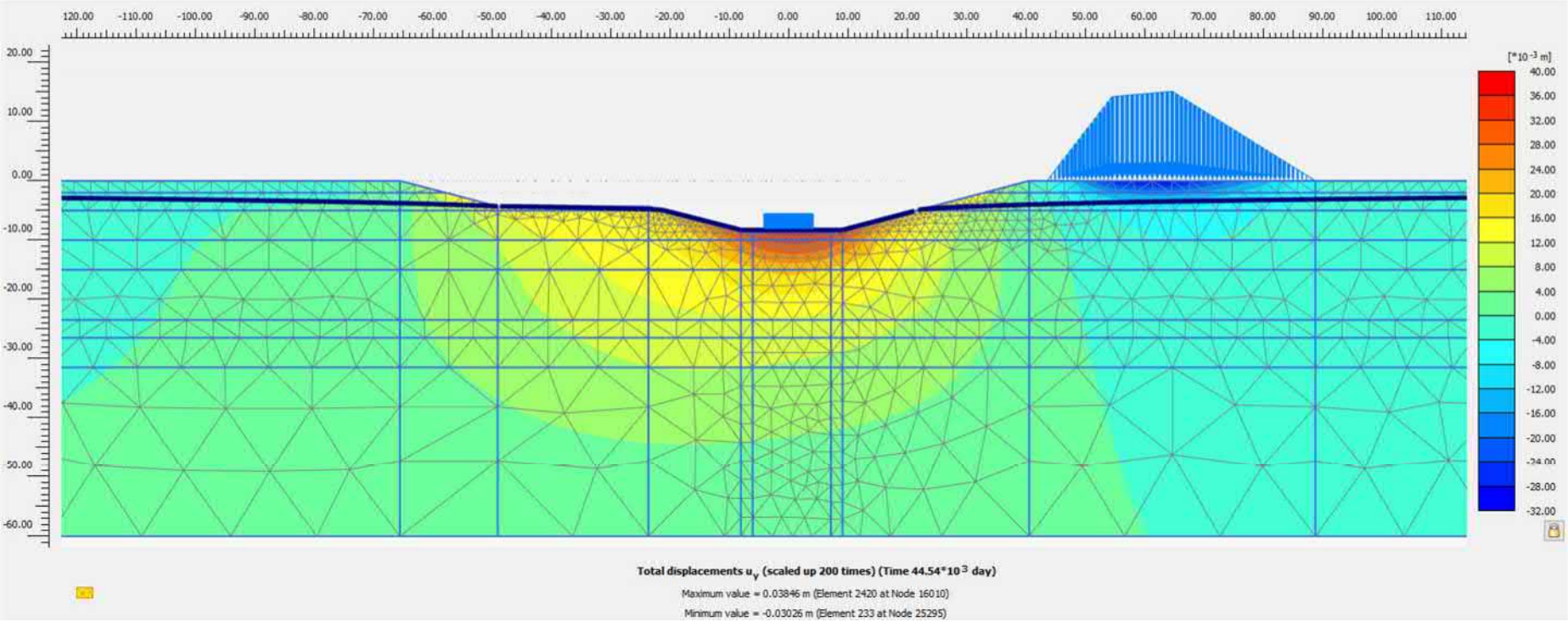
Total Vertical Displacements – End of excavation works

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Total vertical displacements – End of 16 months of Hold-Period

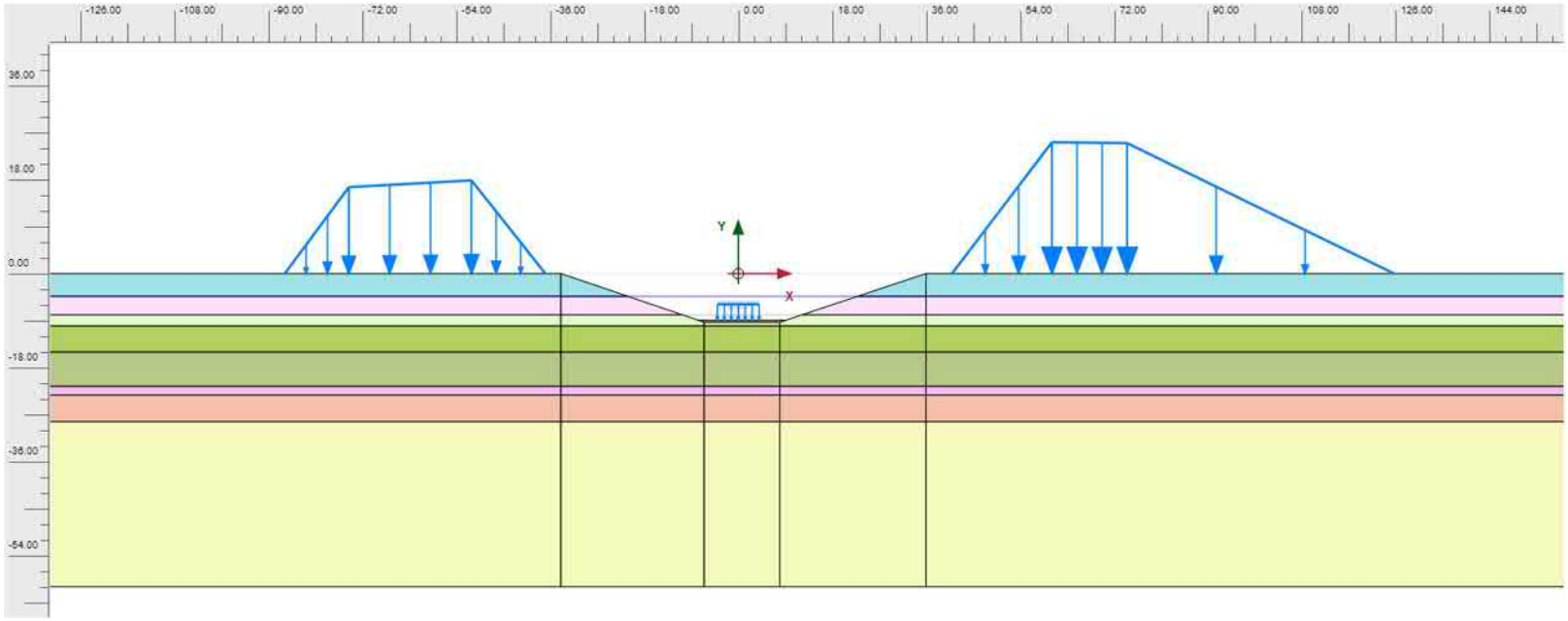
HS2 Ltd - Code 1 - Accepted



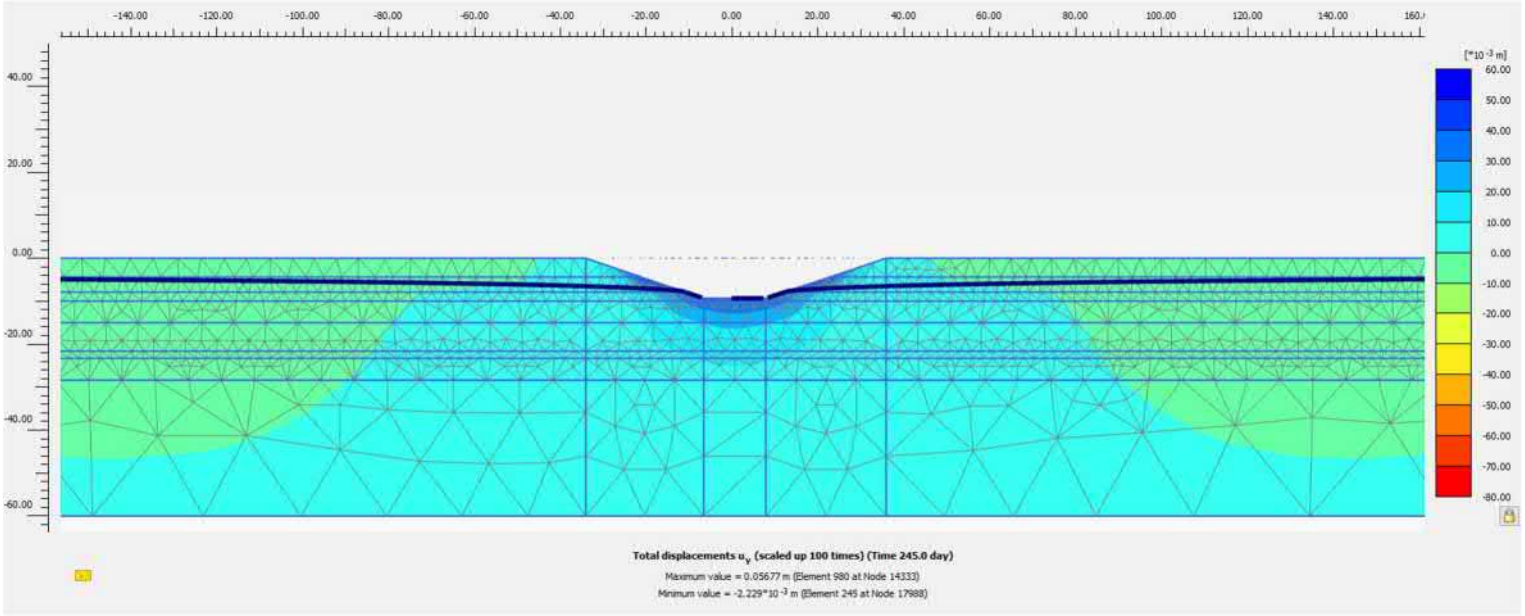
Total vertical displacements – End of 120 years of operation

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Ch. 86+400

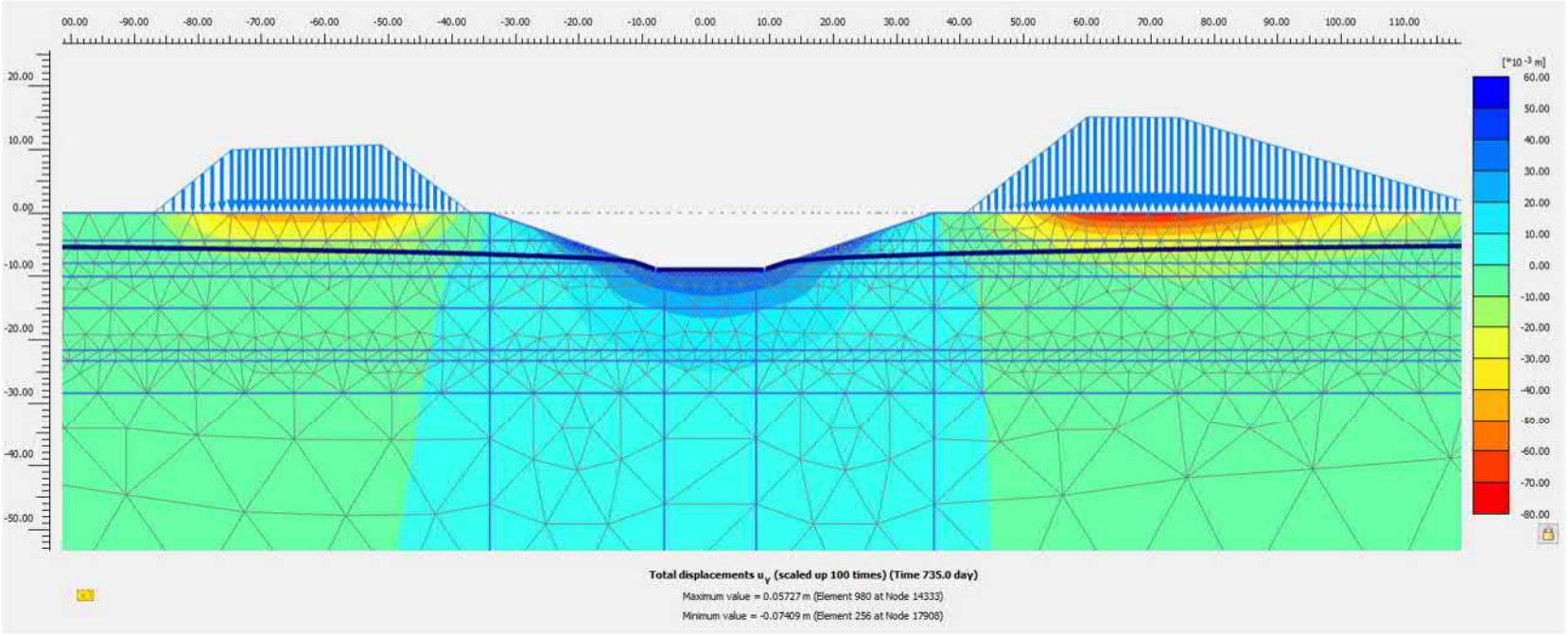


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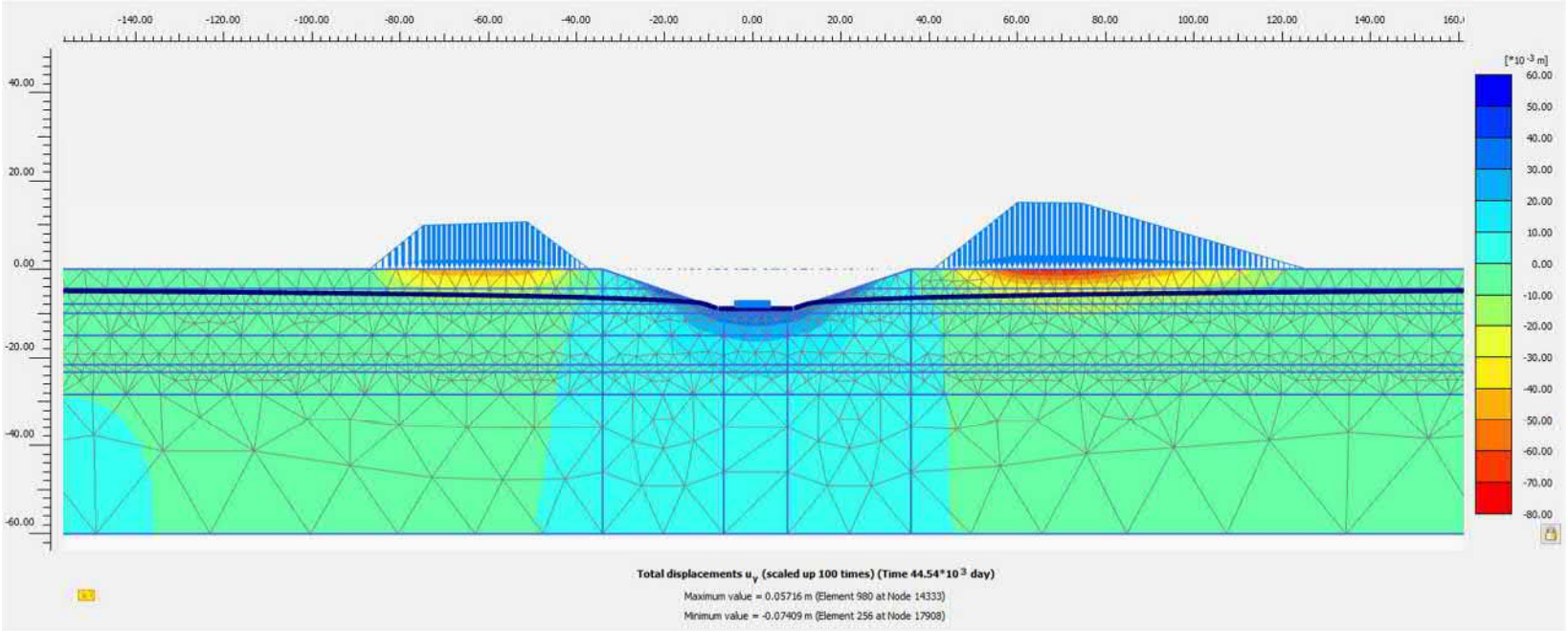
Total Vertical Displacements – End of Excavation works

HS2 Ltd - Code 1 - Accepted



Total vertical displacements – End of 16 months of Hold-Period

HS2 Ltd - Code 1 - Accepted



Total vertical displacements – End of 120 years operation

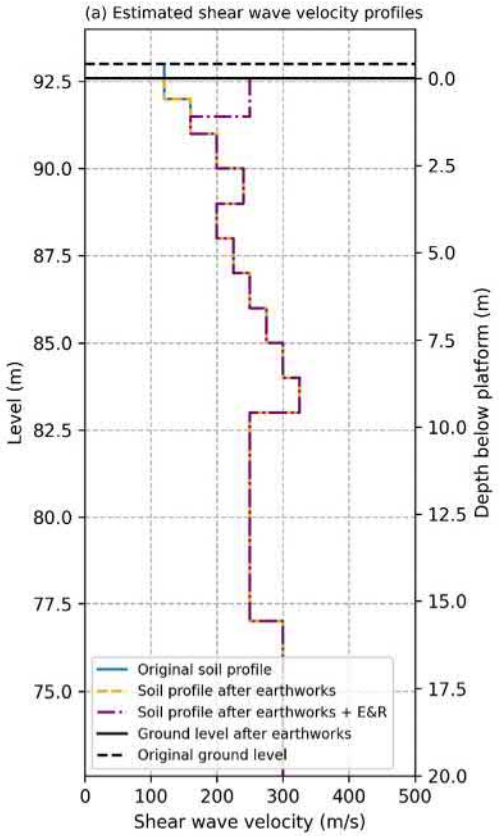
HS2 Ltd - Code 1 - Accepted

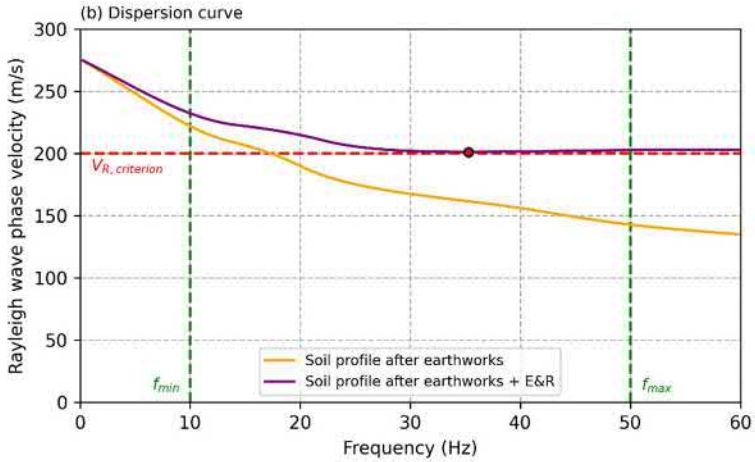
Rayleigh waves calculations

200m/s criterion

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Section ID 84+925





(c) Input data

Original ground level = 93.0 m
Ground level after earthworks = 92.6 m
Replacement V_s = 250 m/s
ν = 0.25
$V_{R,criterion}$ = 200 m/s
f_{min} = 10 Hz
f_{max} = 50 Hz
section type = cutting
h_{exc} = 0.4 m
Δh_{subst} = 0.1 m

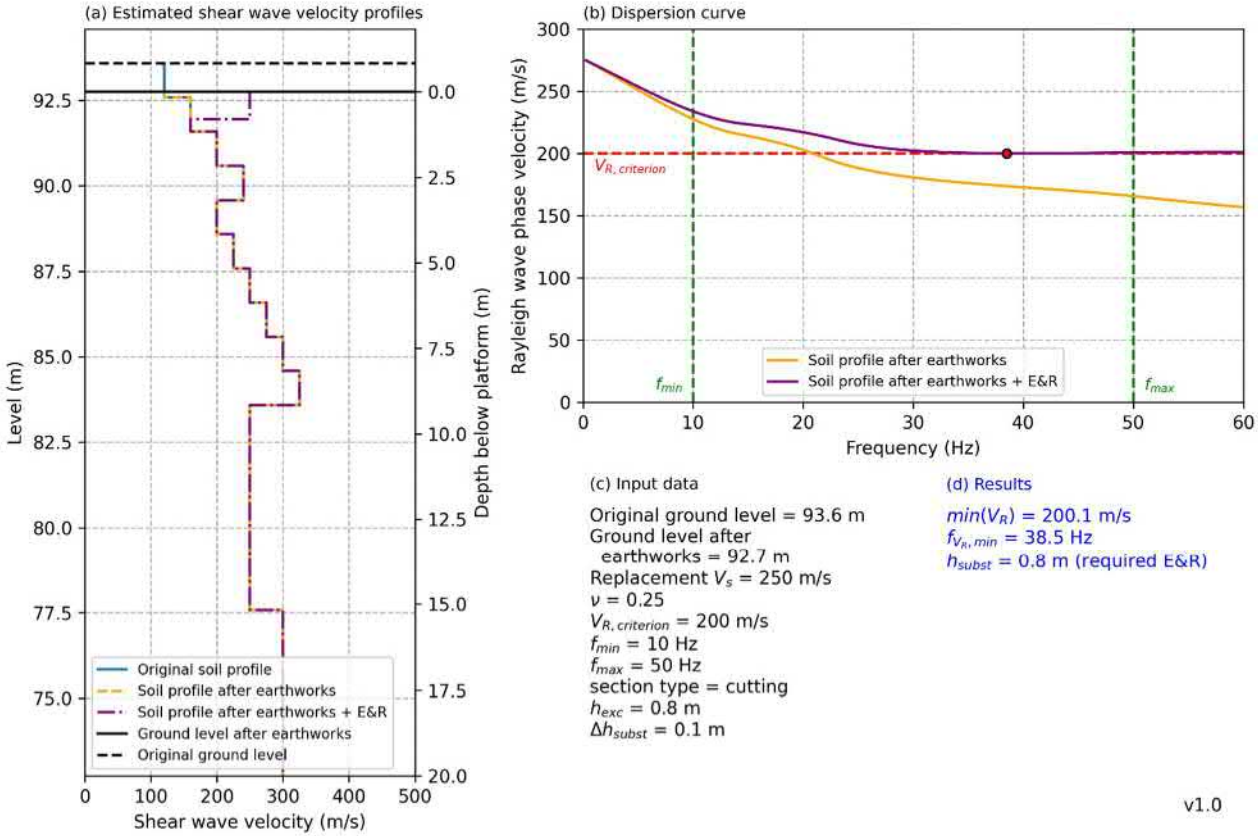
(d) Results

$min(V_R)$ = 201.2 m/s
$f_{V_R,min}$ = 35.3 Hz
h_{subst} = 1.1 m (required E&R)

v1.0

HS2 Ltd - Code 1 - Accepted

Section ID 84+950



(c) Input data

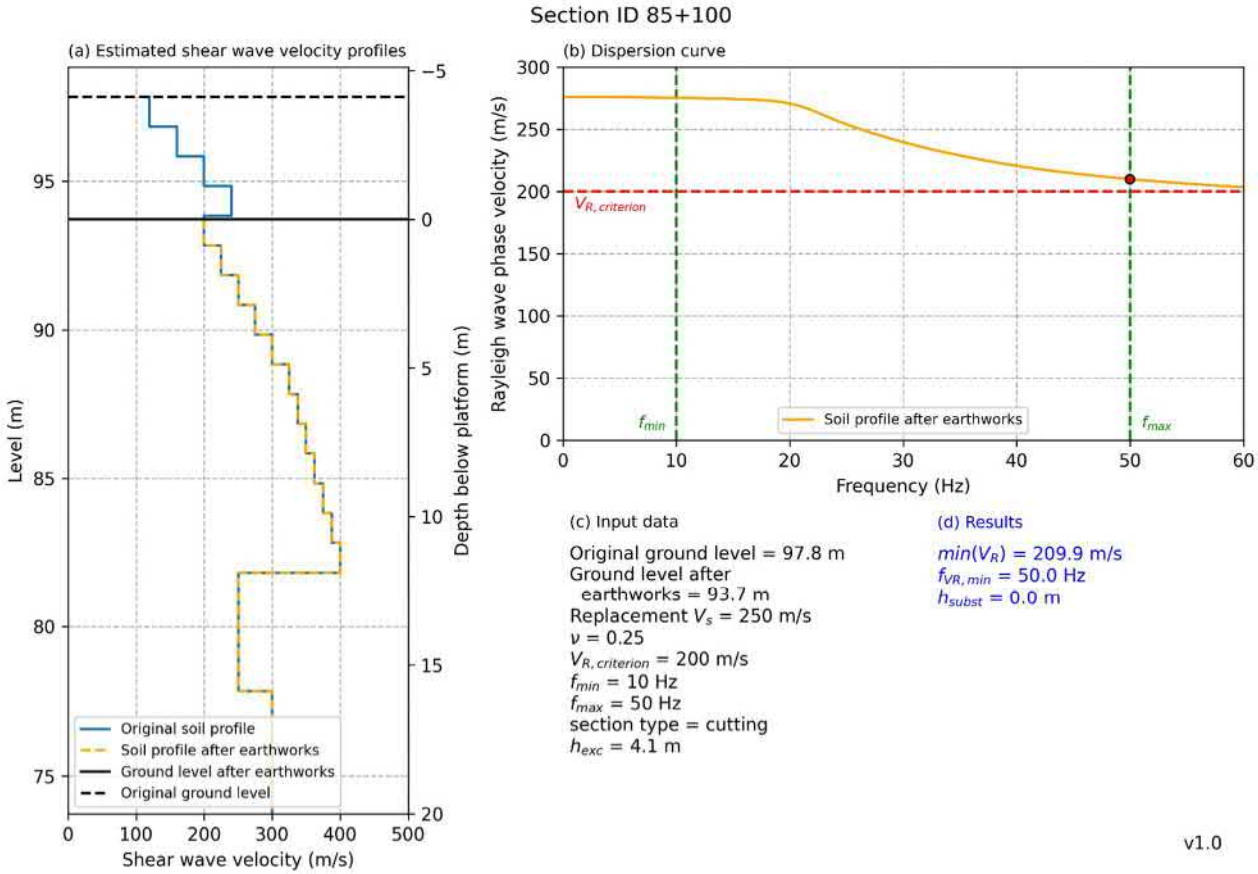
Original ground level = 93.6 m
Ground level after earthworks = 92.7 m
Replacement V_s = 250 m/s
ν = 0.25
$V_{R,criterion}$ = 200 m/s
f_{min} = 10 Hz
f_{max} = 50 Hz
section type = cutting
h_{exc} = 0.8 m
Δh_{subst} = 0.1 m

(d) Results

$min(V_R)$ = 200.1 m/s
$f_{V_R,min}$ = 38.5 Hz
h_{subst} = 0.8 m (required E&R)

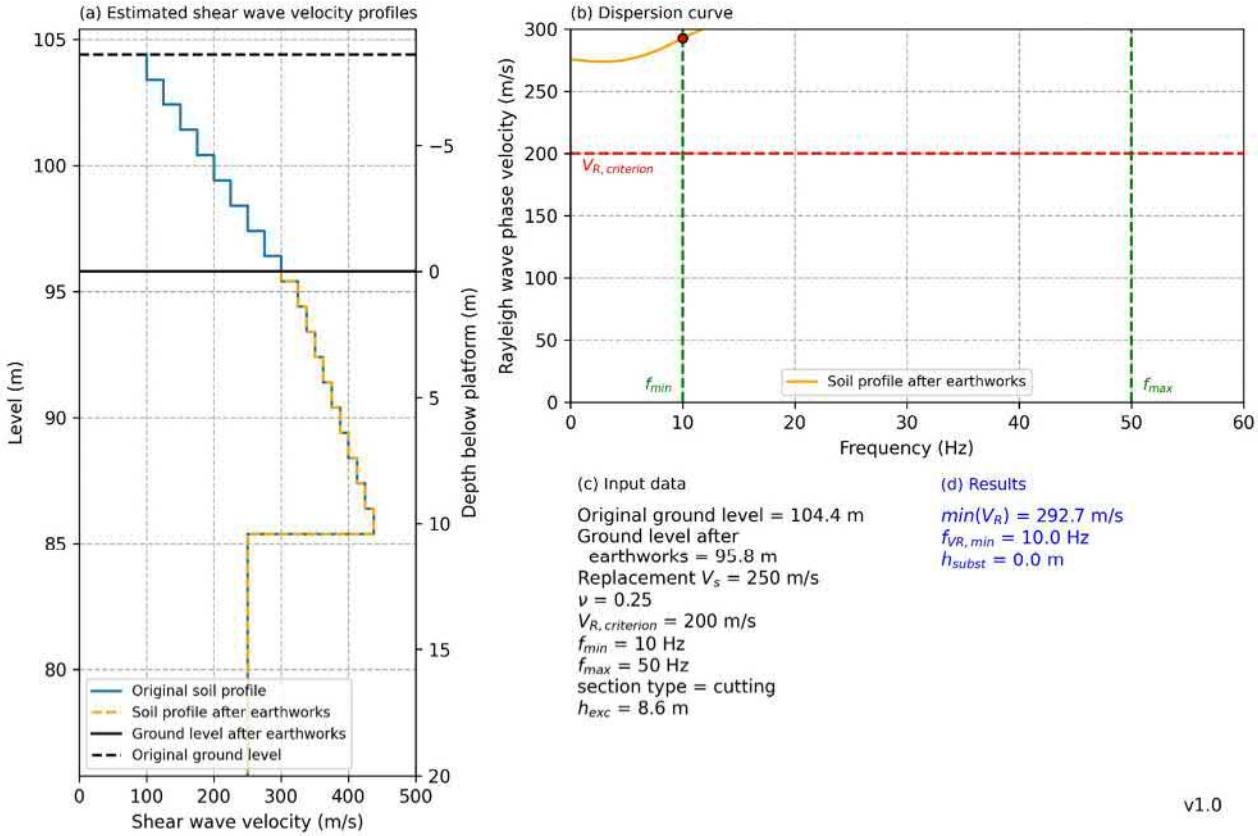
v1.0

HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

Section ID 85+420



(c) Input data

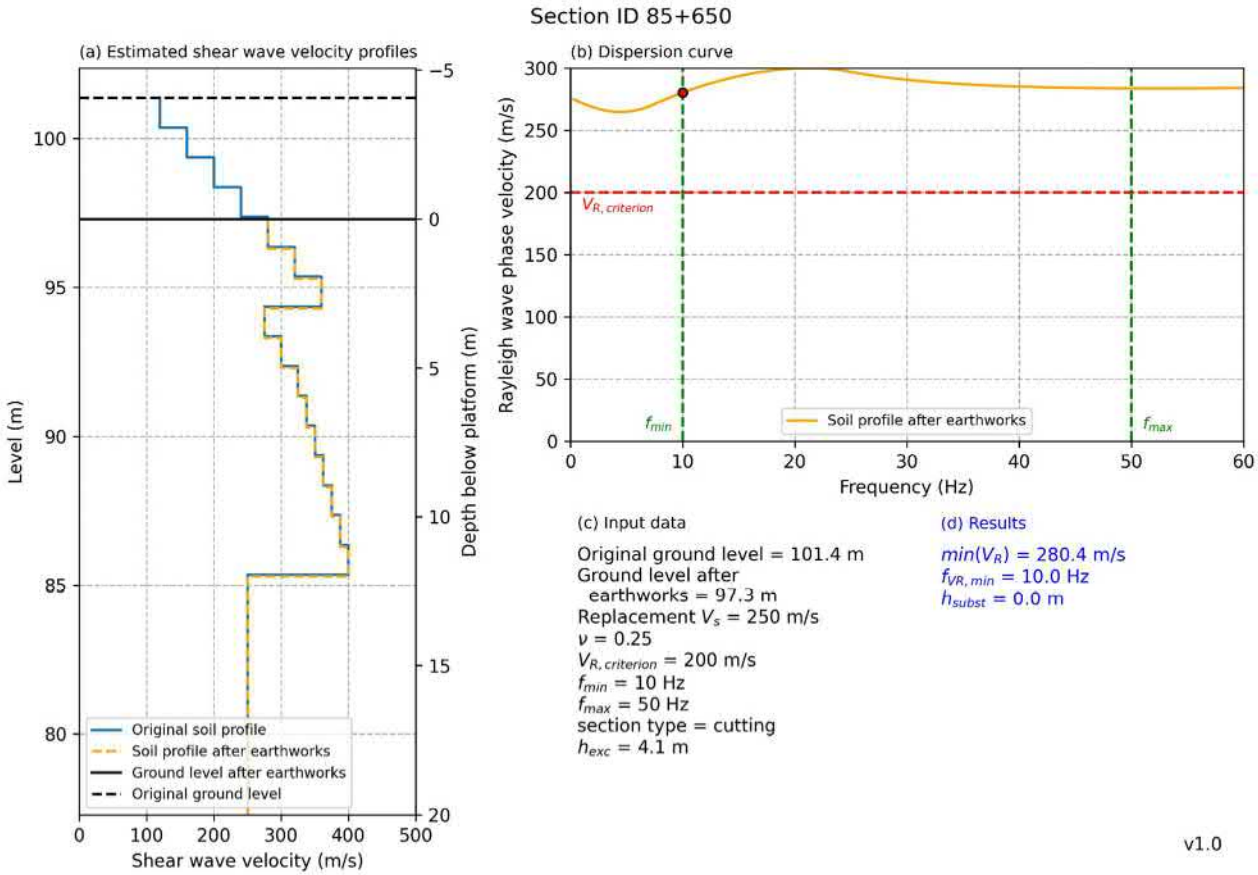
Original ground level = 104.4 m
Ground level after earthworks = 95.8 m
Replacement V_s = 250 m/s
ν = 0.25
$V_{R,\,criterion}$ = 200 m/s
f_{min} = 10 Hz
f_{max} = 50 Hz
section type = cutting
h_{exc} = 8.6 m

(d) Results

$min(V_R)$ = 292.7 m/s
$f_{VR,\,min}$ = 10.0 Hz
h_{subst} = 0.0 m

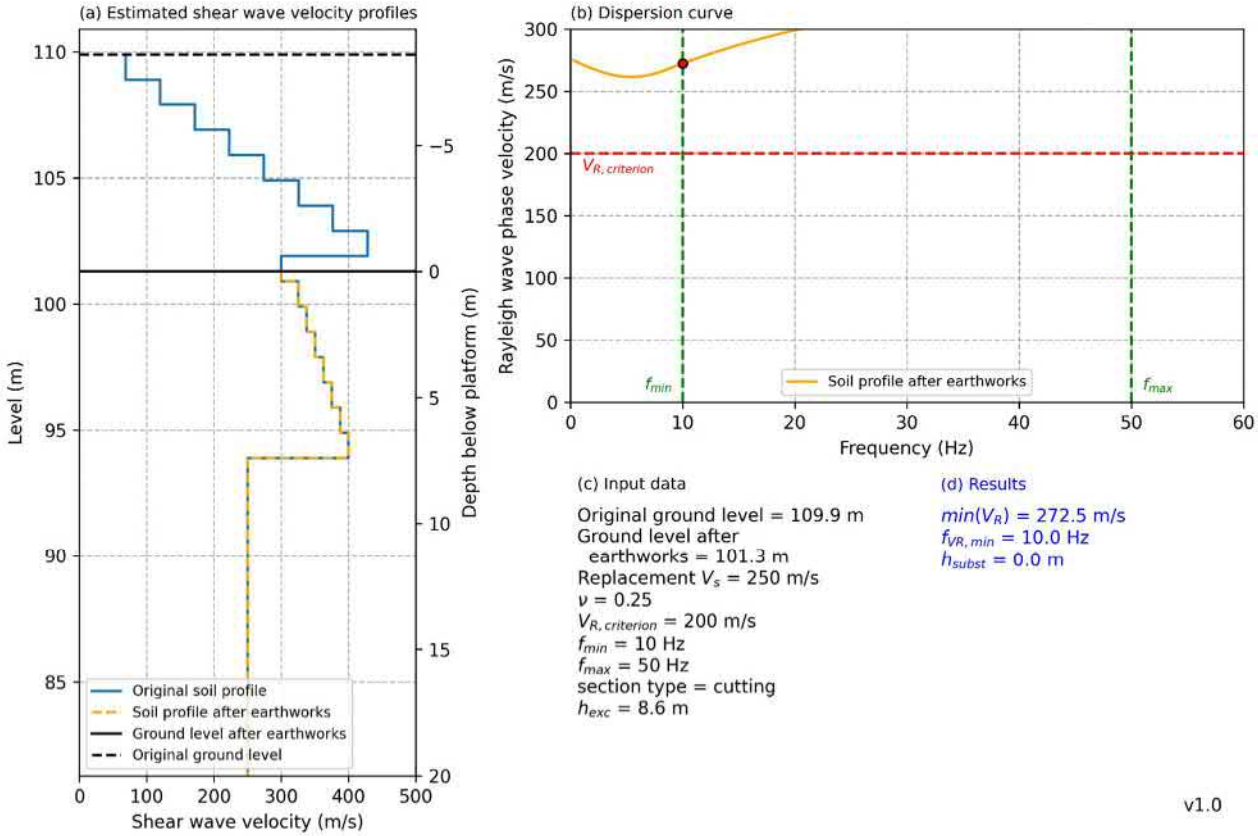
v1.0

HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

Section ID 86+350



(c) Input data

Original ground level = 109.9 m
Ground level after earthworks = 101.3 m
Replacement V_s = 250 m/s
ν = 0.25
$V_{R,criterion}$ = 200 m/s
f_{min} = 10 Hz
f_{max} = 50 Hz
section type = cutting
h_{exc} = 8.6 m

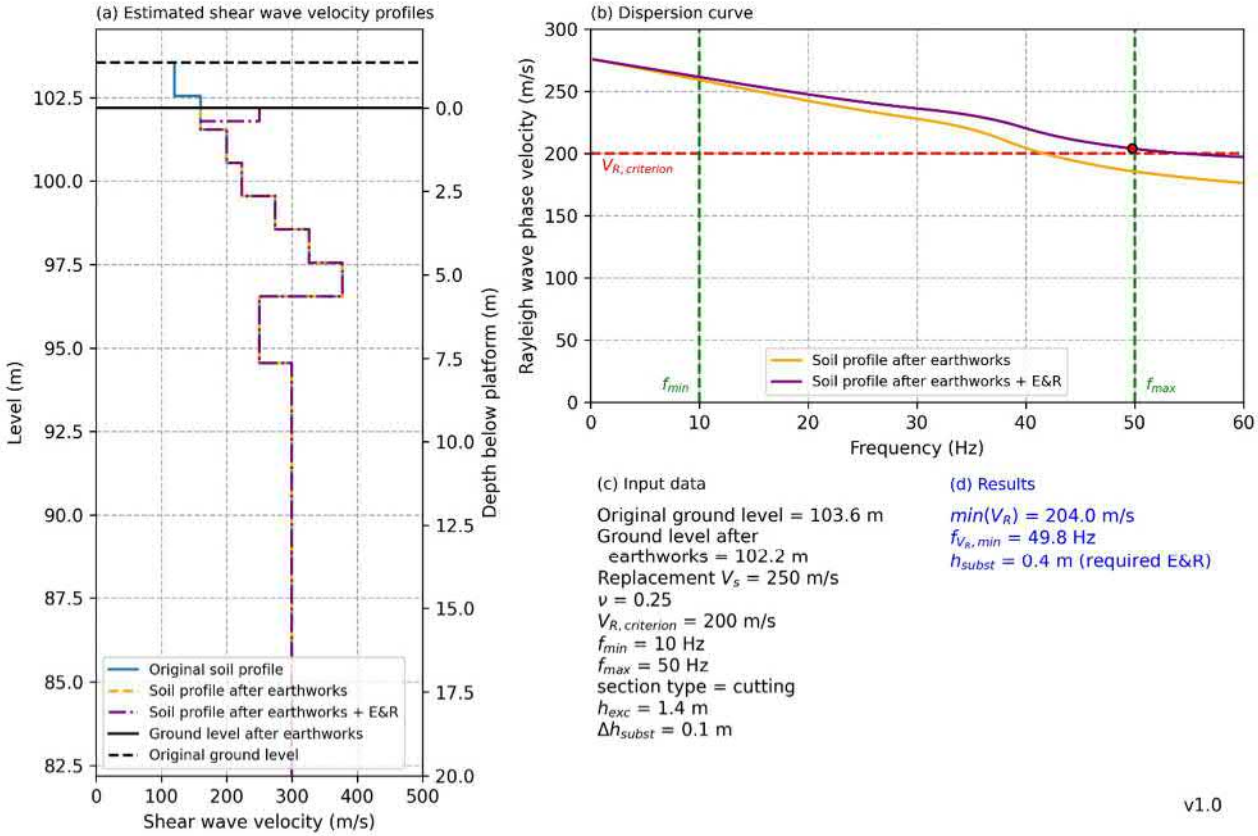
(d) Results

$min(V_R)$ = 272.5 m/s
$f_{VR,min}$ = 10.0 Hz
h_{subst} = 0.0 m

v1.0

HS2 Ltd - Code 1 - Accepted

Section ID 86+800



(c) Input data

Original ground level = 103.6 m
Ground level after earthworks = 102.2 m
Replacement V_s = 250 m/s
ν = 0.25
$V_{R,criterion}$ = 200 m/s
f_{min} = 10 Hz
f_{max} = 50 Hz
section type = cutting
h_{exc} = 1.4 m
Δh_{subst} = 0.1 m

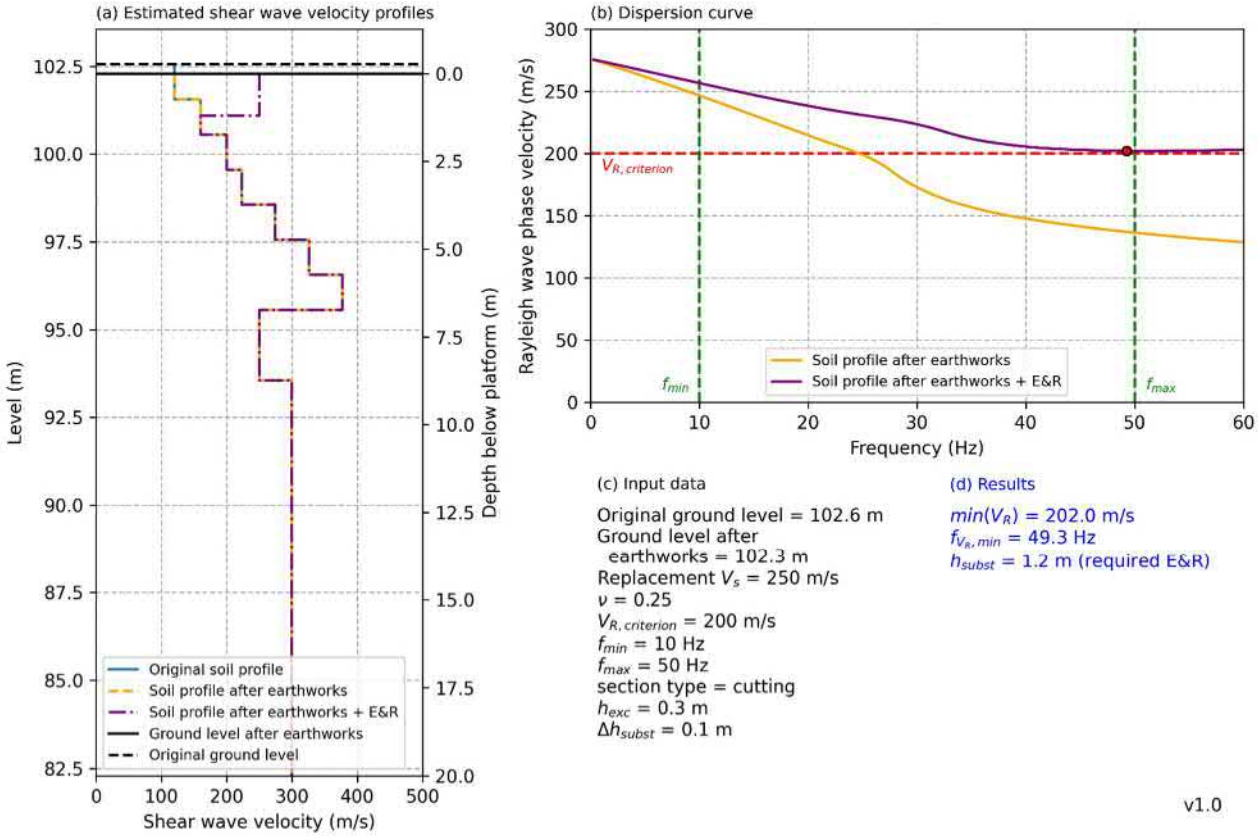
(d) Results

$min(V_R)$ = 204.0 m/s
$f_{V_R,min}$ = 49.8 Hz
h_{subst} = 0.4 m (required E&R)

v1.0

HS2 Ltd - Code 1 - Accepted

Section ID 86+852



(c) Input data

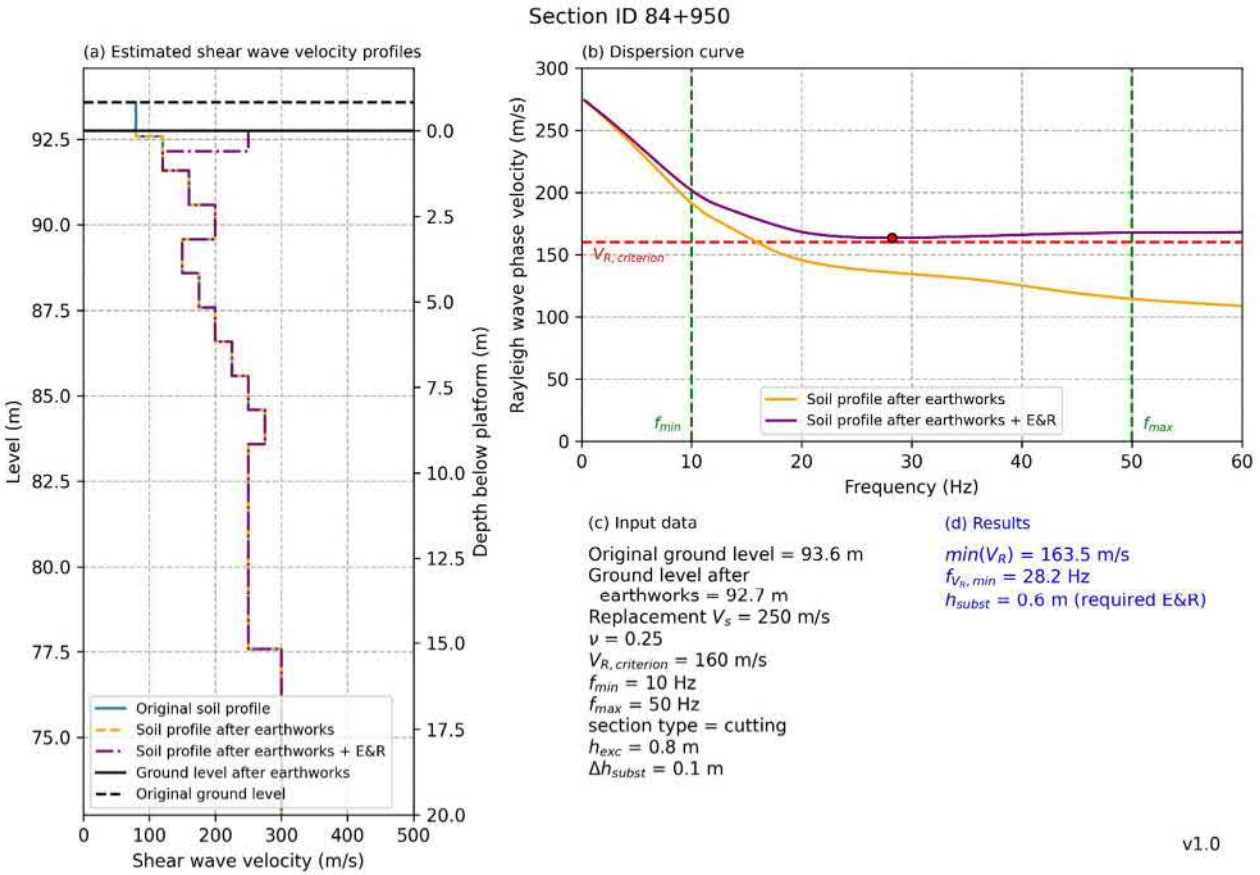
Original ground level = 102.6 m
Ground level after earthworks = 102.3 m
Replacement V_s = 250 m/s
ν = 0.25
$V_{R,criterion}$ = 200 m/s
f_{min} = 10 Hz
f_{max} = 50 Hz
section type = cutting
h_{exc} = 0.3 m
Δh_{subst} = 0.1 m

(d) Results

$min(V_R)$ = 202.0 m/s
$f_{V_R,min}$ = 49.3 Hz
h_{subst} = 1.2 m (required E&R)

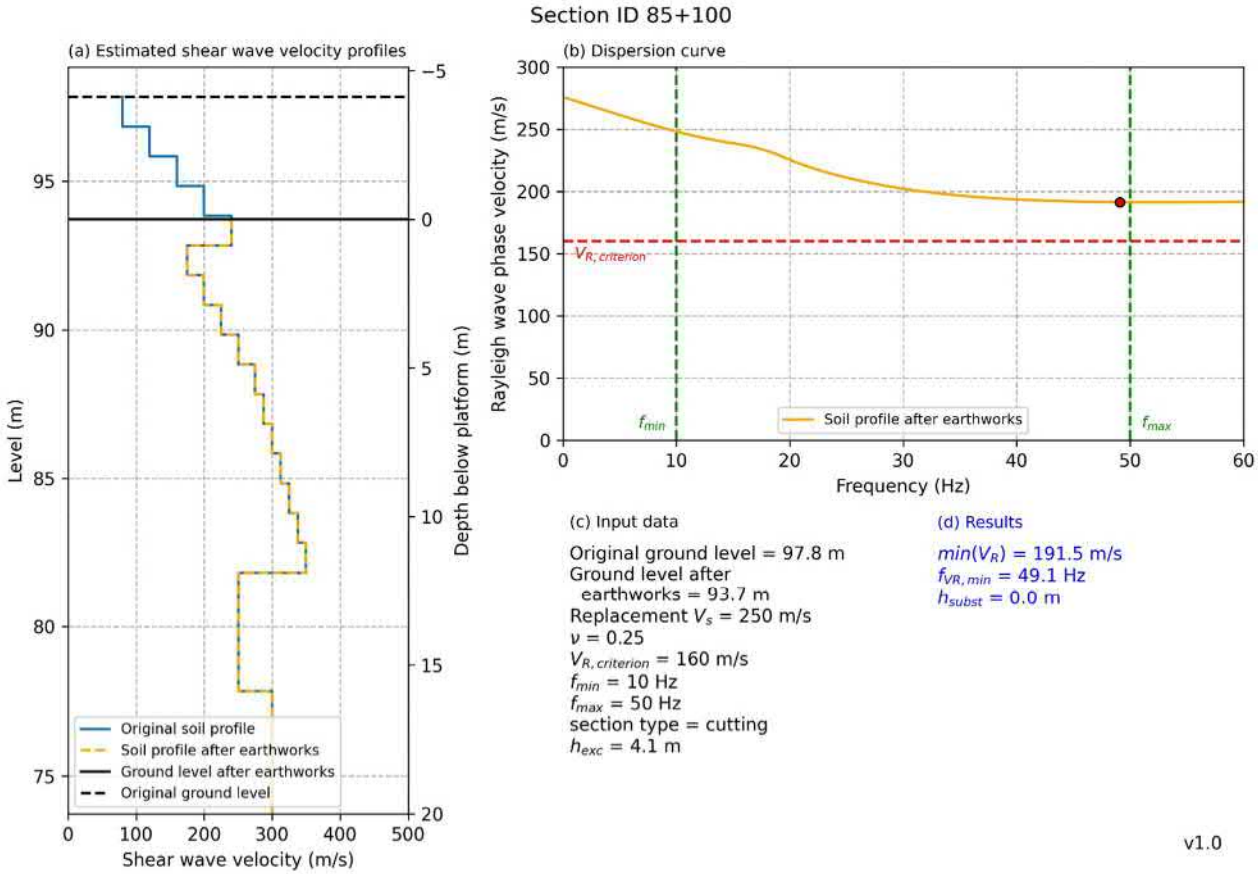
v1.0

HS2 Ltd - Code 1 - Accepted

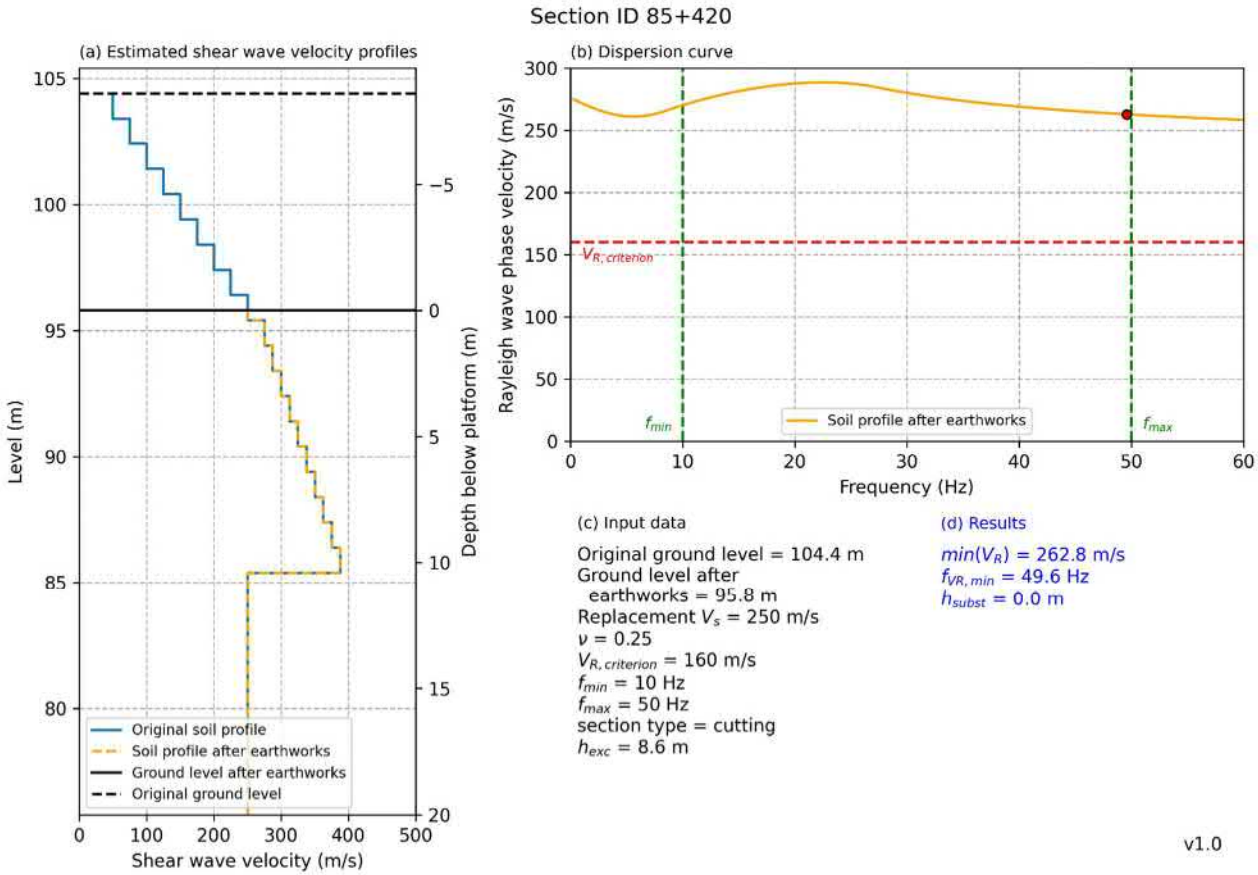


160m/s **Criterion**:

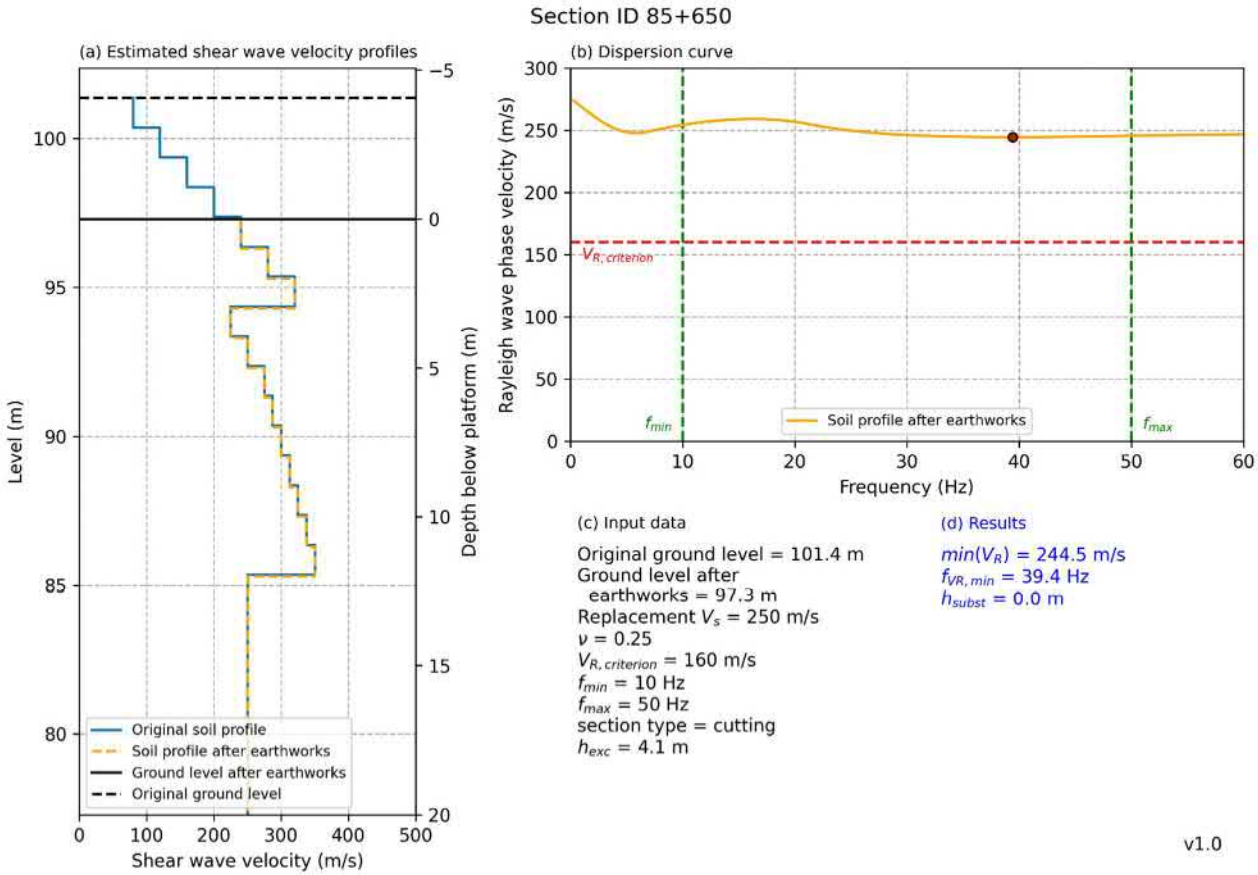
HS2 Ltd - Code 1 - Accepted



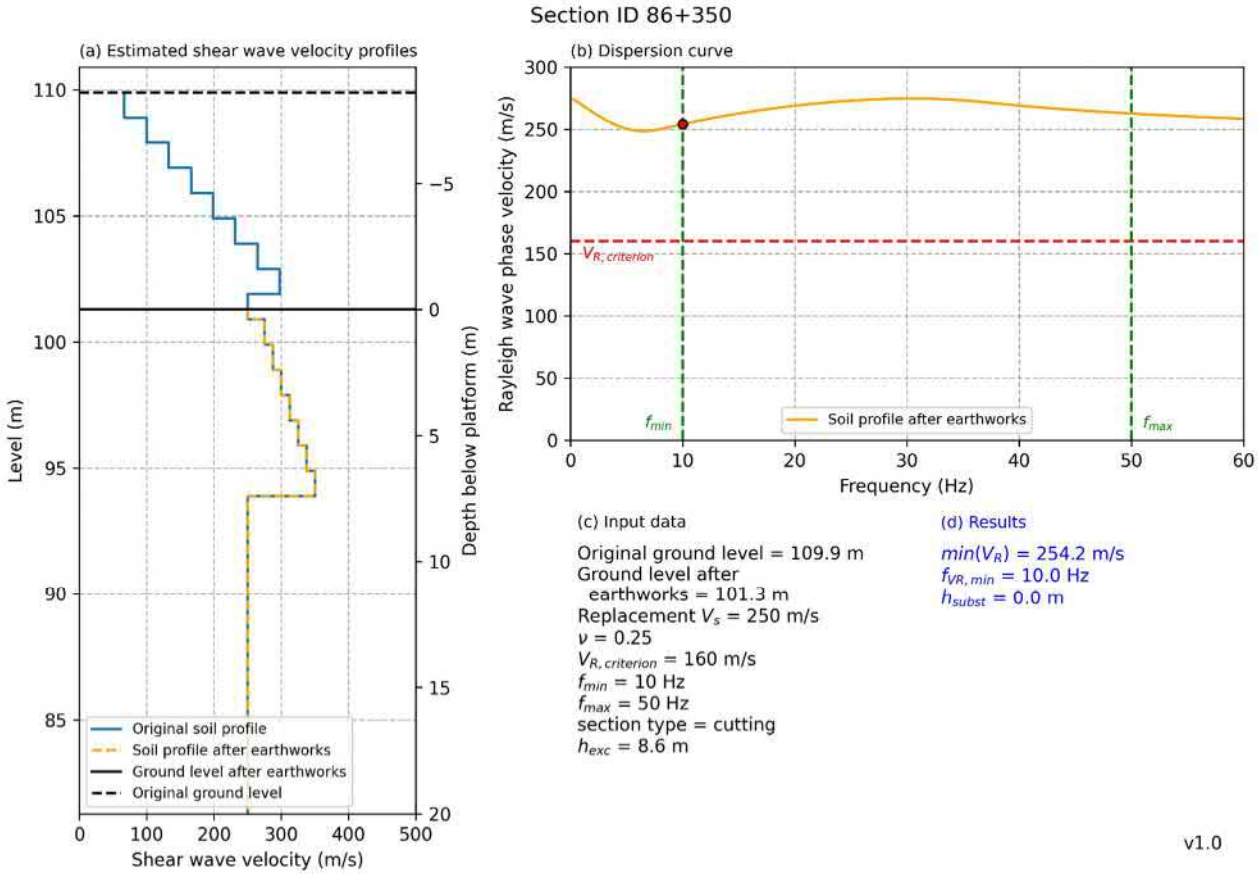
HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

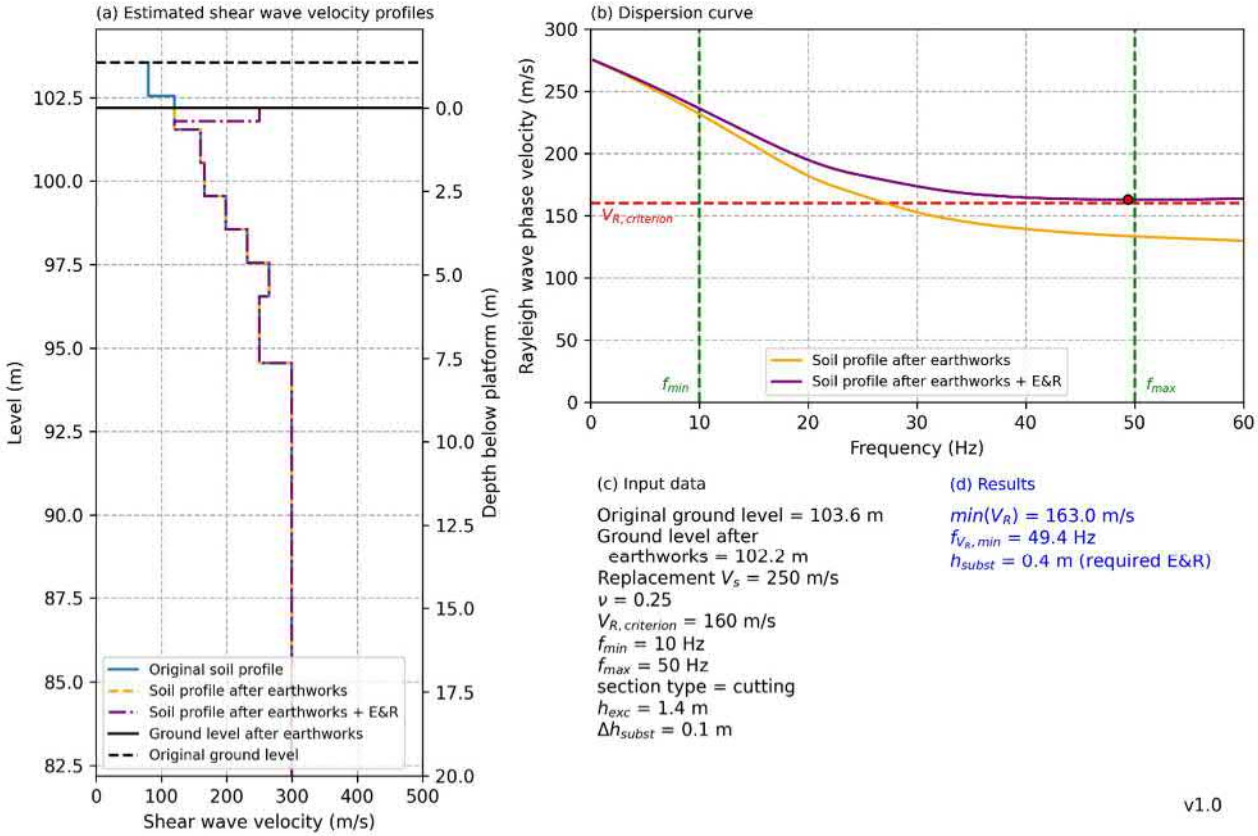


HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

Section ID 86+800



(c) Input data

Original ground level = 103.6 m
Ground level after earthworks = 102.2 m
Replacement V_s = 250 m/s
ν = 0.25
$V_{R,criterion}$ = 160 m/s
f_{min} = 10 Hz
f_{max} = 50 Hz
section type = cutting
h_{exc} = 1.4 m
Δh_{subst} = 0.1 m

(d) Results

$min(V_R)$ = 163.0 m/s
$f_{V_R,min}$ = 49.4 Hz
h_{subst} = 0.4 m (required E&R)

v1.0

HS2 Ltd - Code 1 - Accepted

APPENDIX D

Non-mainline Earthworks School End Road Realignment and Footpath CHW/18 Accommodation Access Realignment and their associated access roads

Geological Long Sections

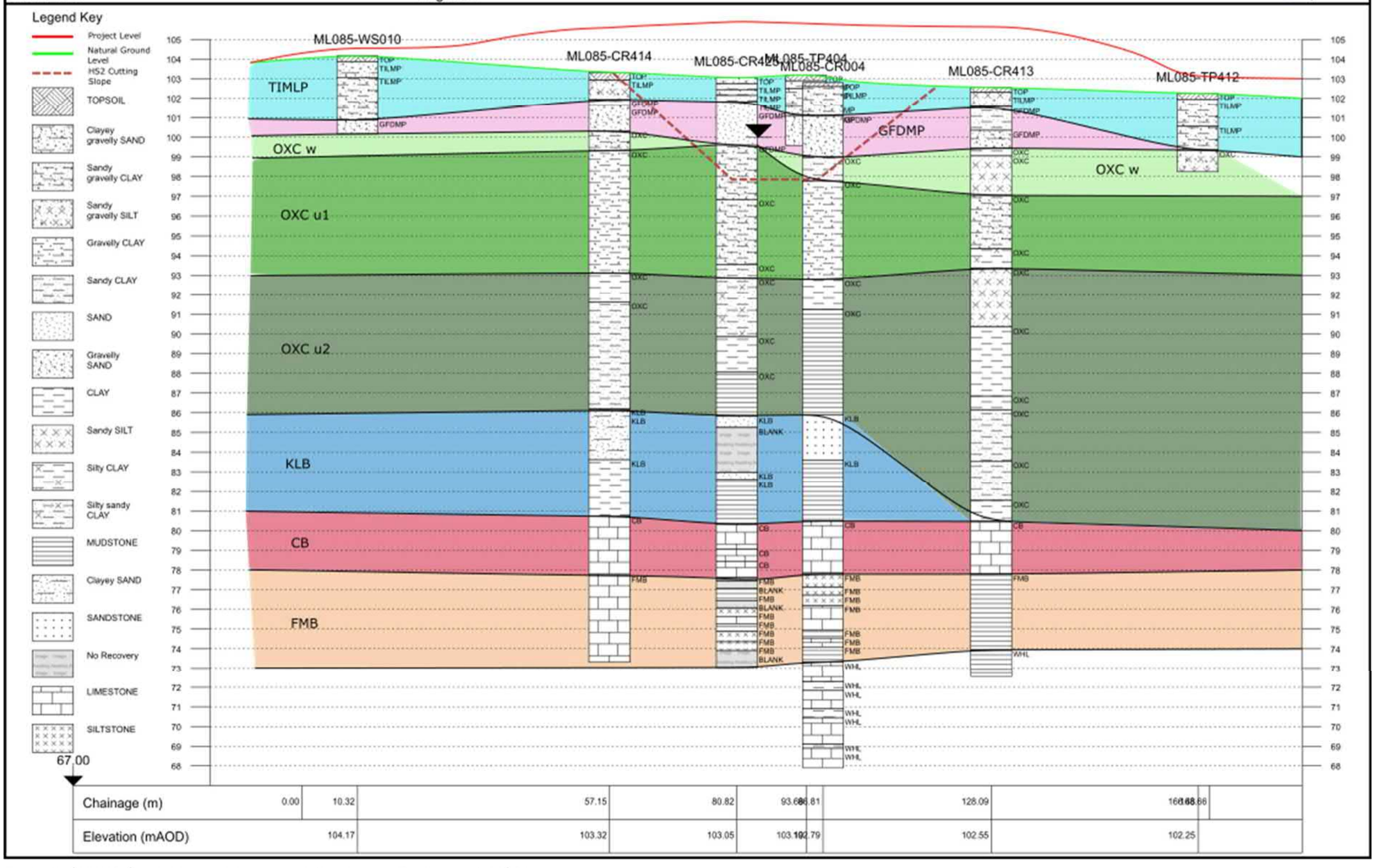
Number of Pages: 105

HS2 Ltd - Code 1 - Accepted

Project Id: C2-C3-CONT-ASC
Project Title: ASC C2 & C3 Controlled Data
Location: 1MC06 North Portal of Chiltern Tunnels to Brackley & 1MC07 Brackley to Long Itchington Wood Green Tunnel South Portal
Client: HS2

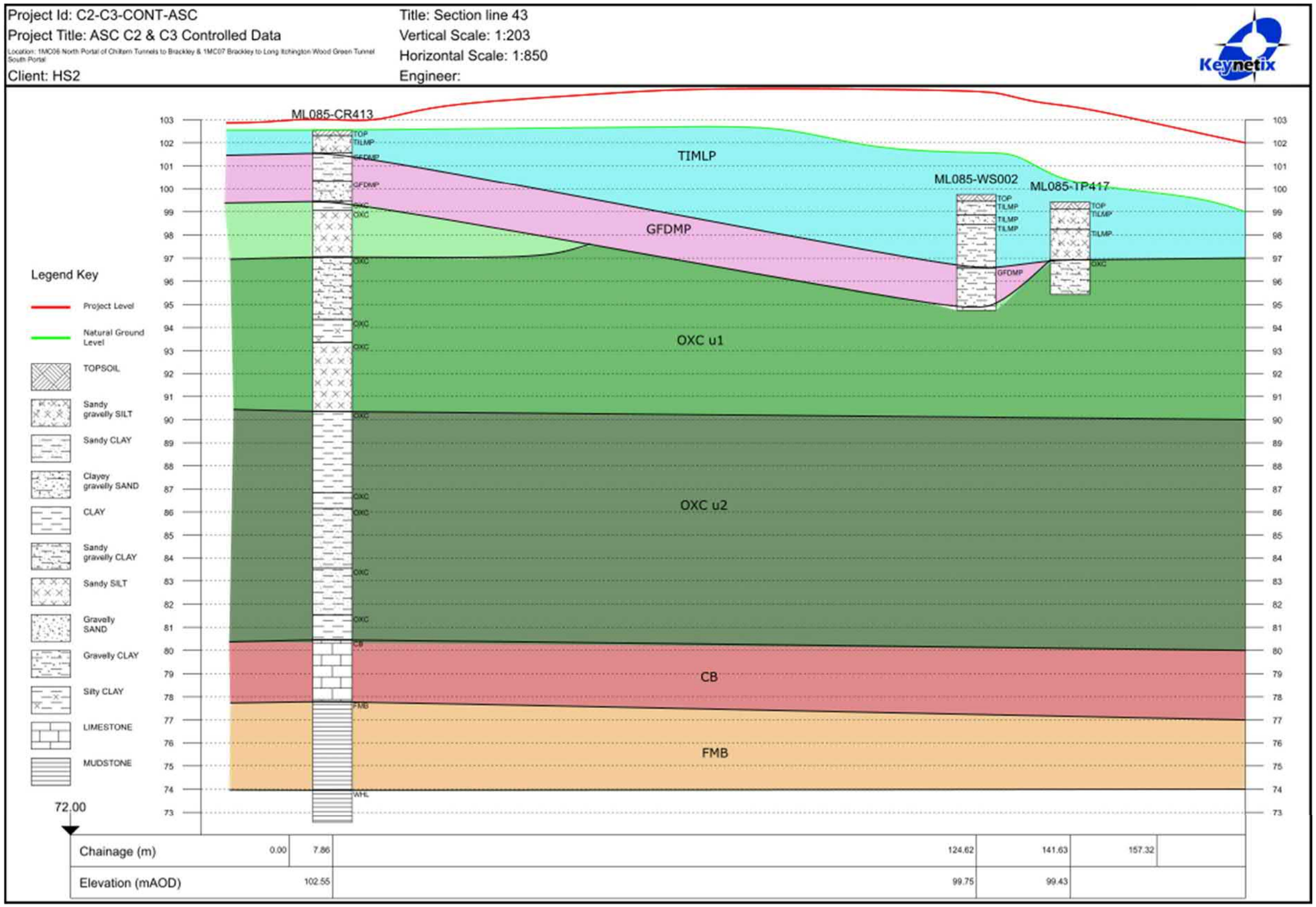
Title: Section line 43
Vertical Scale: 1:249
Horizontal Scale: 1:911
Engineer:

Keynetix



Footpath CHW18 Overbridge and Accommodation Access Realignment, MC01

HS2 Ltd - Code 1 - Accepted



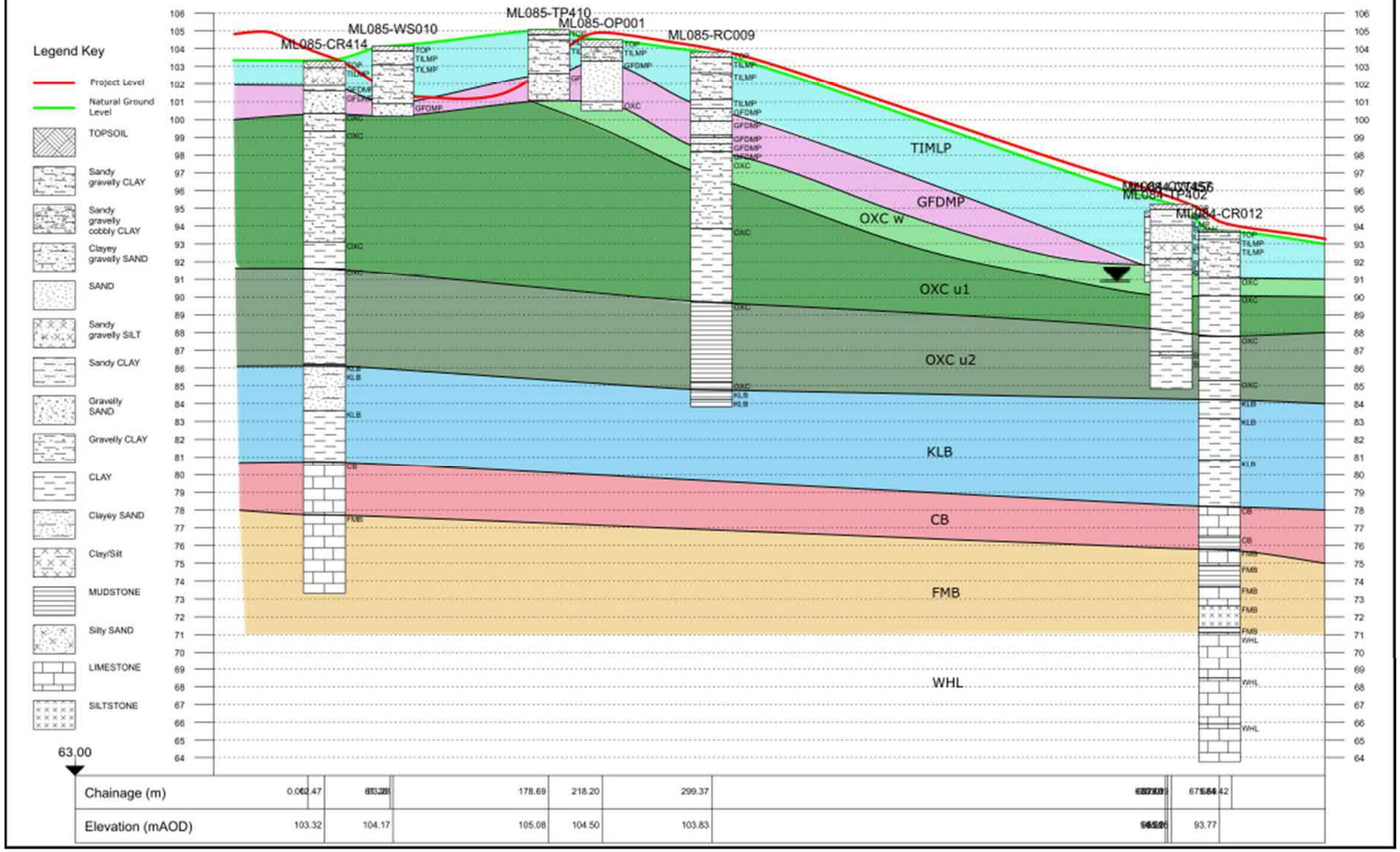
Footpath CHW18 Diversion, MC02

HS2 Ltd - Code 1 - Accepted

Project Id: C2-C3-CONT-ASC
Project Title: ASC C2 & C3 Controlled Data
Location: 1MC06 North Portal of Chiltern Tunnels to Brackley & 1MC07 Brackley to Long Itchington Wood Green Tunnel South Portal
Client: HS2

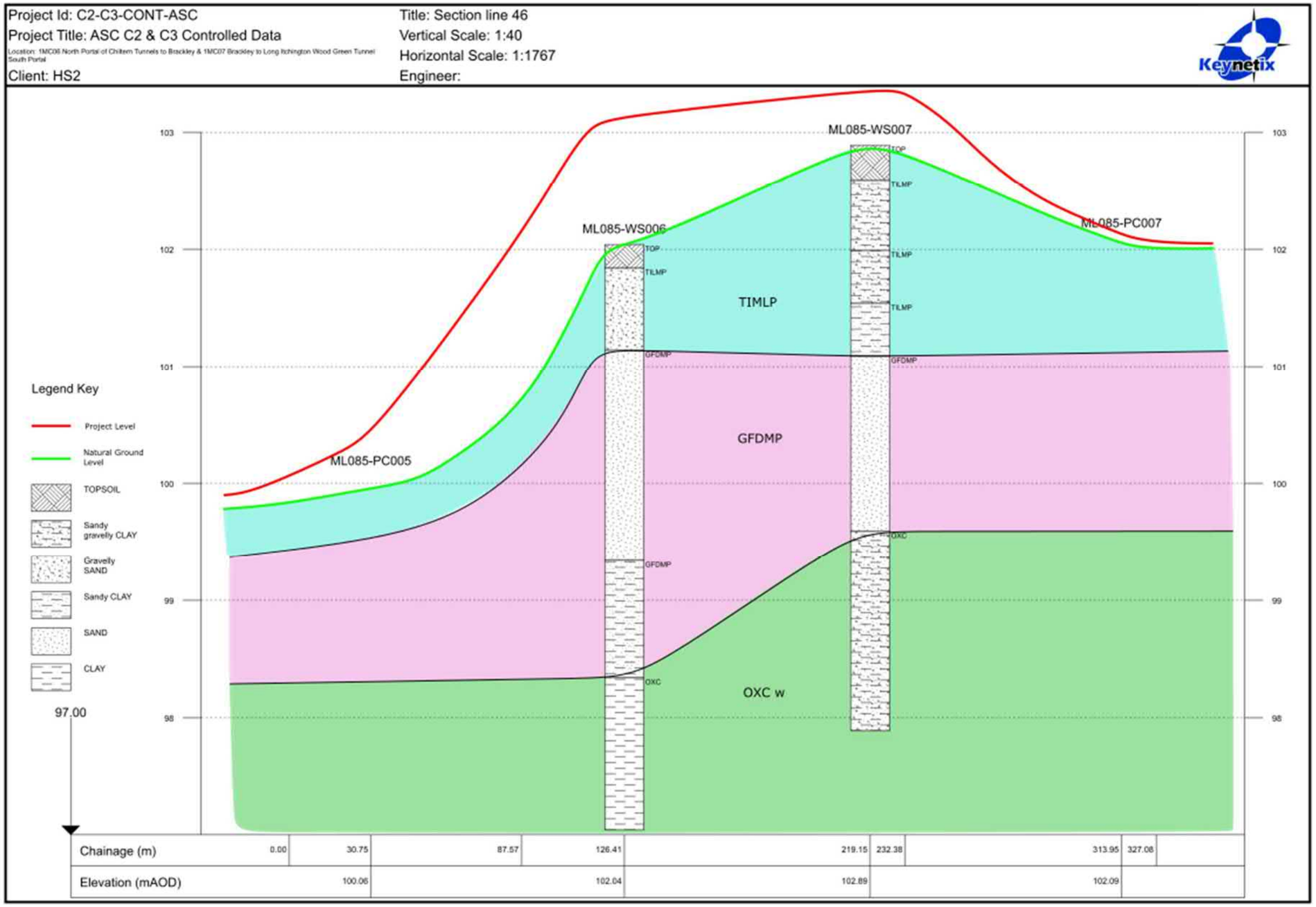
Title: Section line 43
Vertical Scale: 1:281
Horizontal Scale: 1:3696
Engineer:

Keynetix



Chetwode ATS Access Road and Maintenance Access Road to Pond, MC03

HS2 Ltd - Code 1 - Accepted



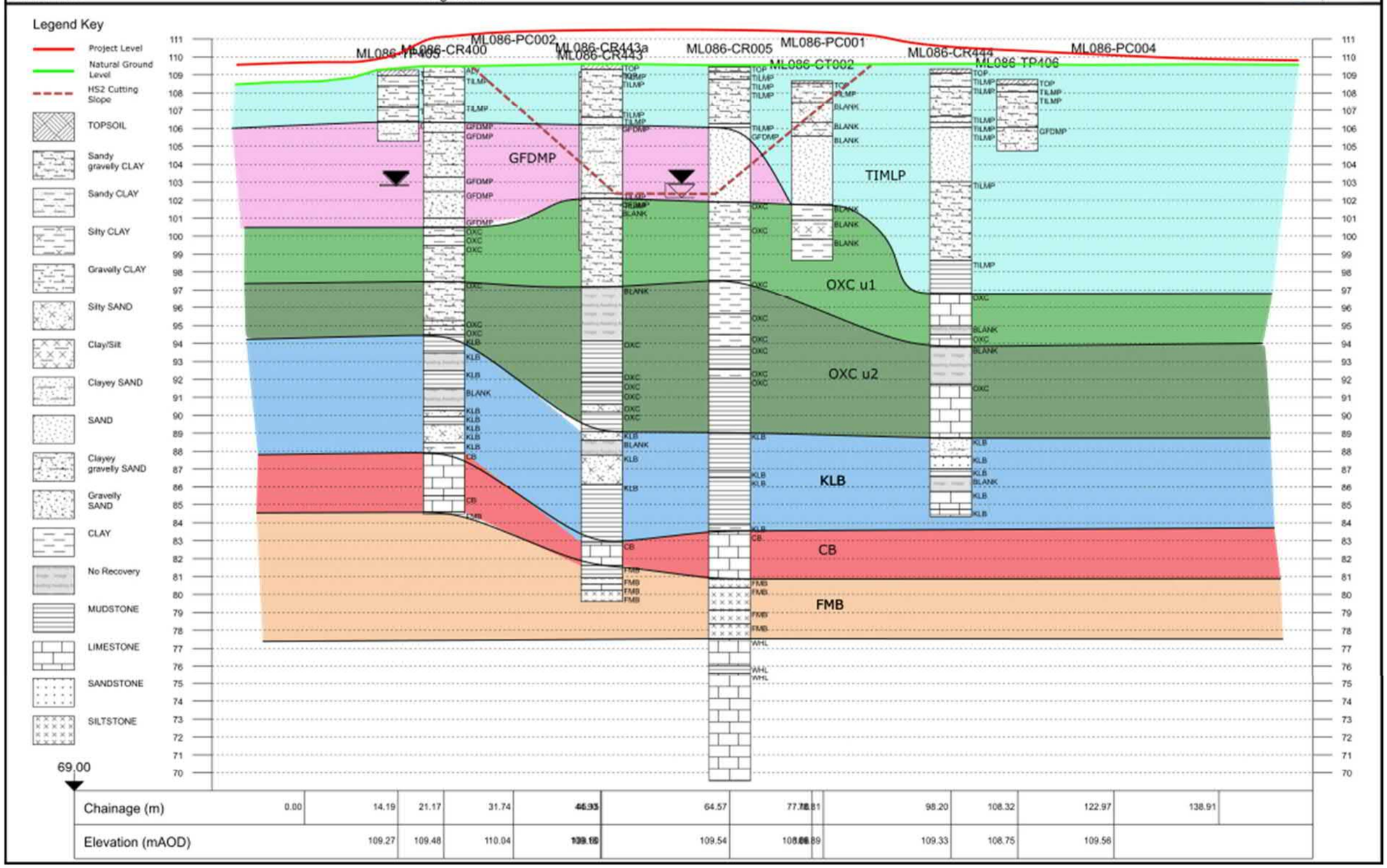
The Green Highway Realignment, MC05

HS2 Ltd - Code 1 - Accepted

Project Id: C2-C3-CONT-ASC
Project Title: ASC C2 & C3 Controlled Data
Location: 1MC06 North Portal of Chiltern Tunnels to Brackley & 1MC07 Brackley to Long Itchington Wood Green Tunnel South Portal
Client: HS2

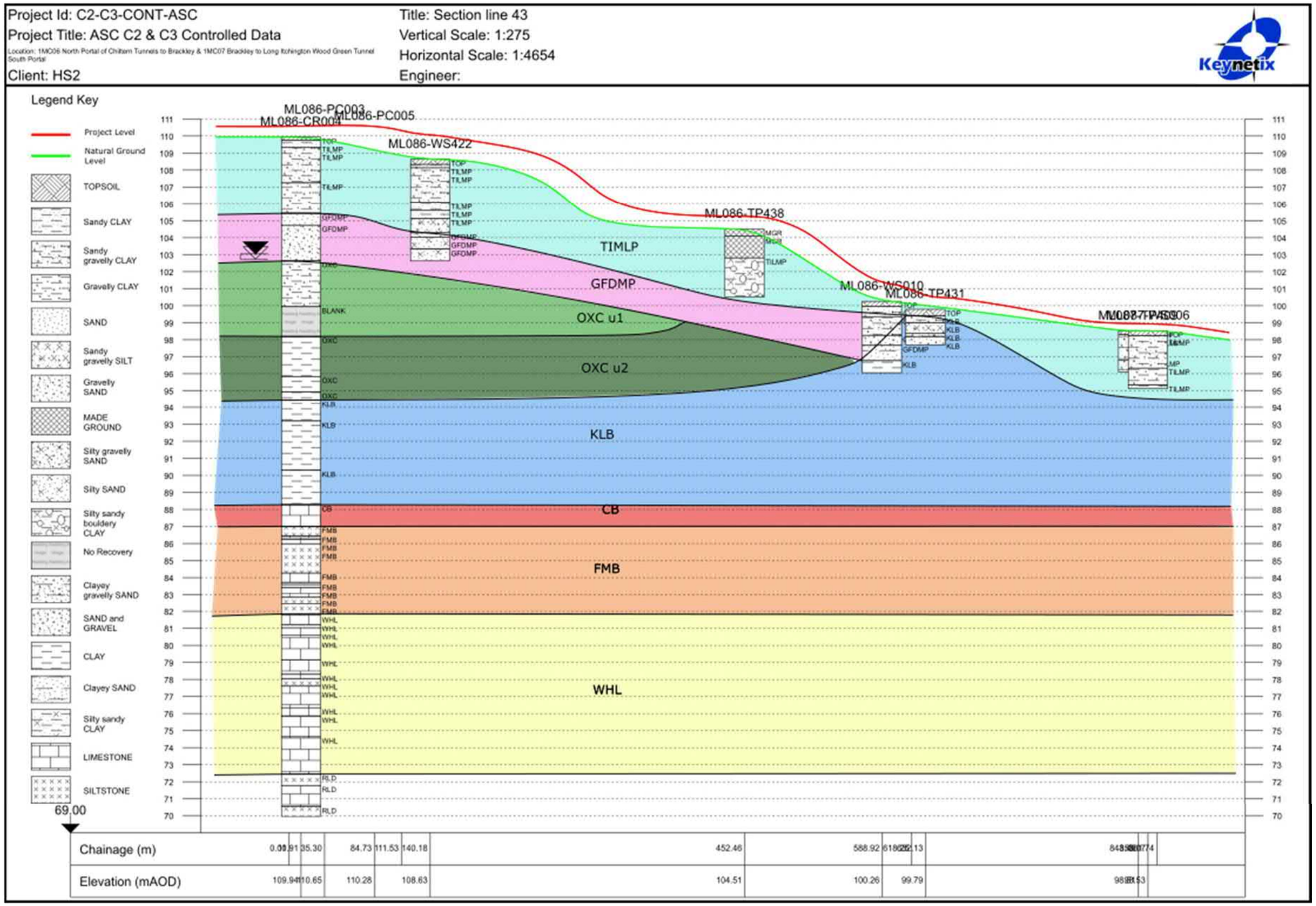
Title: Section line 43
Vertical Scale: 1:275
Horizontal Scale: 1:751
Engineer:

Keynetix



School End Road Overbridge and Realignment, MC01

HS2 Ltd - Code 1 - Accepted



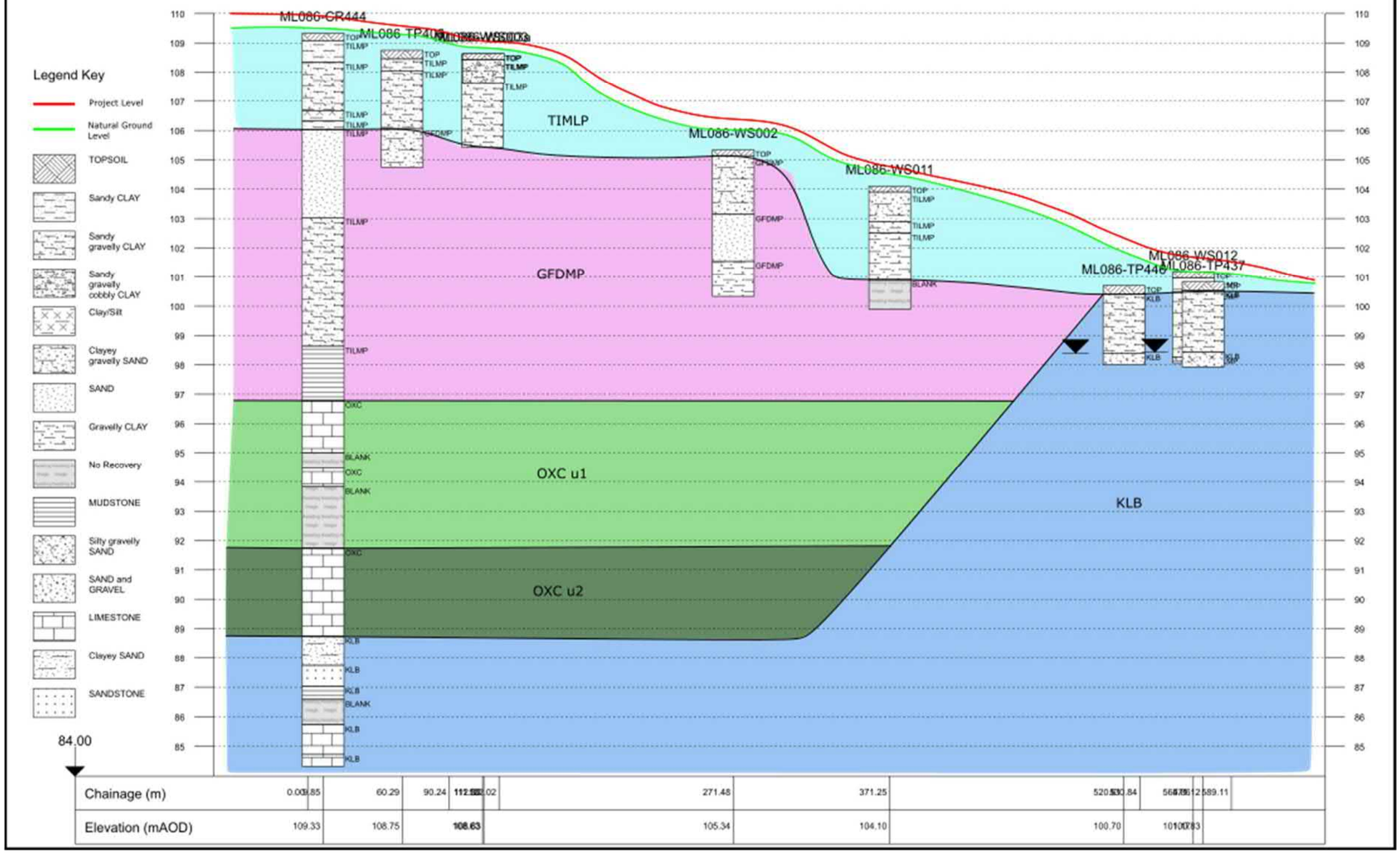
Maintenance Access Road to Pond (Off School End Road South), MC02

HS2 Ltd - Code 1 - Accepted

Project Id: C2-C3-CONT-ASC
Project Title: ASC C2 & C3 Controlled Data
Location: 1MC06 North Portal of Chiltern Tunnels to Brackley & 1MC07 Brackley to Long Itchington Wood Green Tunnel South Portal
Client: HS2

Title: Section line 43
Vertical Scale: 1:170
Horizontal Scale: 1:3182
Engineer:

Keynetix

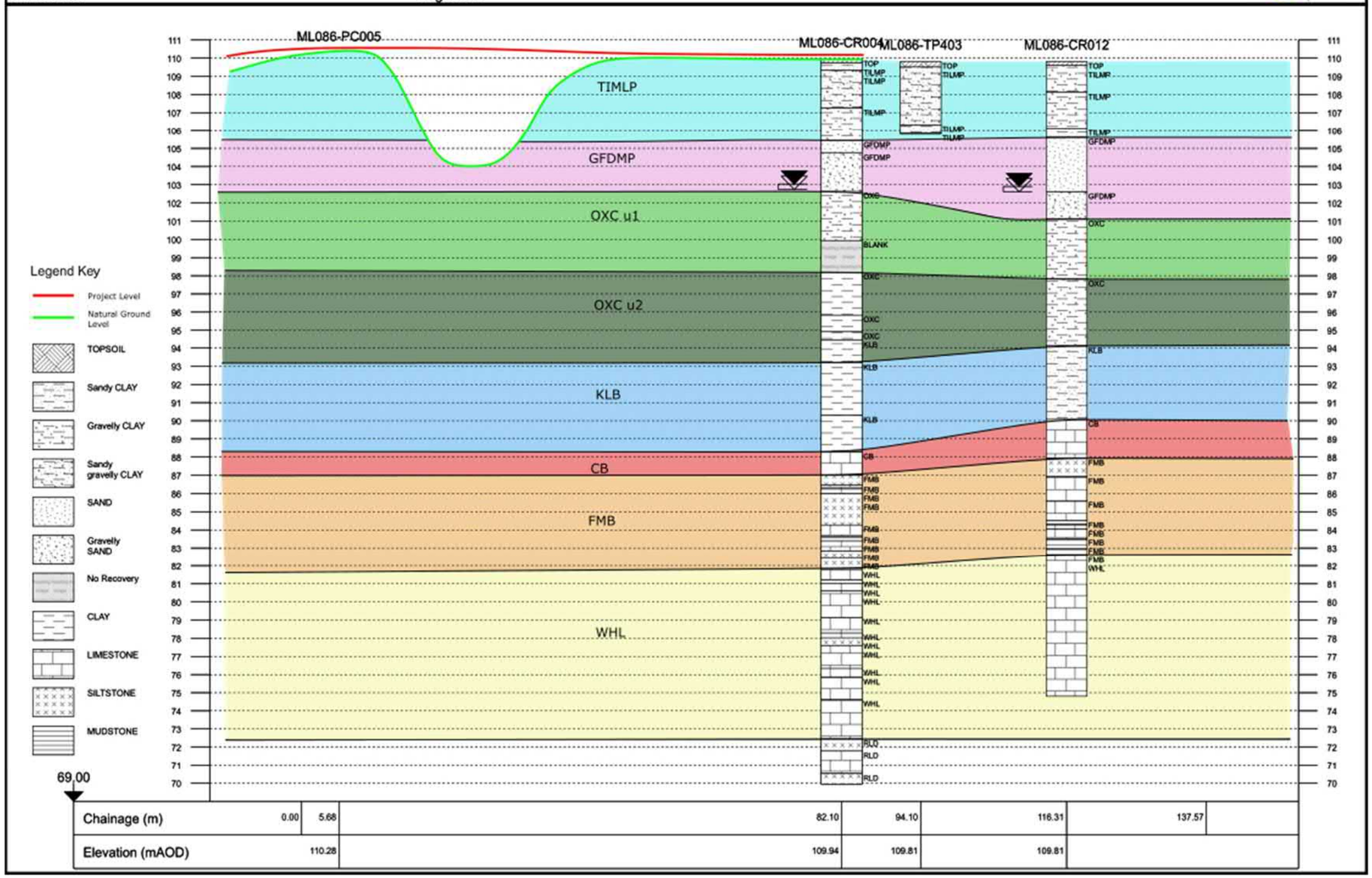


Maintenance Access Road to Pond (Off School End Road North), MC03

HS2 Ltd - Code 1 - Accepted

Project Id: C2-C3-CONT-ASC
Project Title: ASC C2 & C3 Controlled Data
Location: 1MC06 North Portal of Chiltern Tunnels to Brackley & 1MC07 Brackley to Long Itchington Wood Green Tunnel South Portal
Client: HS2

Title: Section line 46
Vertical Scale: 1:275
Horizontal Scale: 1:743
Engineer:



Maintenance Access Road to GSMR (Off School End Road Realignment) and Compound

HS2 Ltd - Code 1 - Accepted

Slope stability Assessment results

HS2 Ltd - Code 1 - Accepted

Footpath CHW18 Accommodation Access Realignment, Ch.153, Slope 1V/4H, Hmax=3,22m

Project data

Project reference : HS2 Detail Design
Calculation title : Footpath CHW/18 _MC01_Hmax=3,22 m
Location : Ch. 153+296
Comments : Hmax Embankment between the Ground Level and the project level Slope 1V/4H
Units : kN, kPa, kN/m³
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	EMBANKMENT FILL (TILMP)-CL2		21,0	27,00	2,0	0,0	-	-	-	No	No	No
2	TILMP - C Z (Cu)		21,0	0,01	72,0	0,0	-	-	-	No	No	No
3	TILMP - vadose (2m bgl)		21,0	26,00	1,0	0,0	-	-	-	No	No	No
4	TILMP - C Z		21,0	27,00	2,0	0,0	-	-	-	No	No	No
5	GFDMP- S V		19,0	30,00	0,0	0,0	-	-	-	No	No	No
6	OXC-C Z u1 (Cu)		21,0	0,01	120,0	0,0	-	-	-	No	No	No
7	OXC- C Z u1		21,0	28,00	5,0	0,0	-	-	-	No	No	No
8	OXC- C Z u2 (Cu)		21,0	0,01	180,0	0,0	-	-	-	No	No	No
9	OXC- C Z u2		21,0	28,00	5,0	0,0	-	-	-	No	No	No
10	KLB-C Z (Cu)		20,0	0,01	145,0	0,0	-	-	-	No	No	No
11	KLB-C Z		20,0	27,00	5,0	0,0	-	-	-	No	No	No
12	E/R 0,45 m - Class 1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
13	OXC-C Z w		19,0	26,00	3,0	0,0	-	-	-	No	No	No
14	OXC- C Z w (Cu)		19,0	0,01	60,0	0,0	-	-	-	No	No	No
15	Landscape Bund		21,0	27,00	2,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	EMBANKMENT FILL (TILMP)-CL2		-	-	-	Effective	Linear	No	-	-
2	TILMP - C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
3	TILMP - vadose (2m bgl)		-	-	-	Effective	Linear	No	-	-
4	TILMP - C Z		-	-	-	Effective	Linear	No	-	-
5	GFDMP- S V		-	-	-	Effective	Linear	No	-	-
6	OXC-C Z u1 (Cu)		-	-	-	Undrained	Linear	No	-	-
7	OXC- C Z u1		-	-	-	Effective	Linear	No	-	-
8	OXC- C Z u2 (Cu)		-	-	-	Undrained	Linear	No	-	-
9	OXC- C Z u2		-	-	-	Effective	Linear	No	-	-
10	KLB-C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
11	KLB-C Z		-	-	-	Effective	Linear	No	-	-
12	E/R 0,45 m - Class 1		-	-	-	Effective	Linear	No	-	-
13	OXC-C Z w		-	-	-	Effective	Linear	No	-	-
14	OXC- C Z w (Cu)		-	-	-	Effective	Linear	No	-	-
15	Landscape Bund		-	-	-	Effective	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	0,000	-7,292	2	3,182	-7,135	3	8,381	-7,000	4	11,630	-6,821	5	17,366	-6,687	6	21,500	-6,500
7	28,500	-6,349	8	30,770	-6,369	9	34,000	-6,299	10	39,500	-6,268	11	45,000	-6,179	12	50,000	-6,167
13	0,000	-2,500	14	10,000	-2,500	15	14,500	-2,285	16	0,000	-9,000	17	50,000	-9,000	18	0,000	-12,000
19	0,000	-13,000	20	0,000	-18,000	21	0,000	-25,000	22	0,000	-30,000	23	50,000	-12,000	24	50,000	-13,000
25	50,000	-18,000	26	50,000	-25,000	27	50,000	-30,000									

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8
8	8	9	9	9	10	10	10	11	11	11	12	12	13	14	13	14	15	14	15	8
15	16	17	16	18	23	17	19	24	18	20	25	19	26	21	20	22	27			

Distributed loads

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	Surcharge 20 kPa	4,223	-2,500	20,0	14,500	-2,285	20,0	90,00

terrasol
setec

Talren v6
v6.0.13

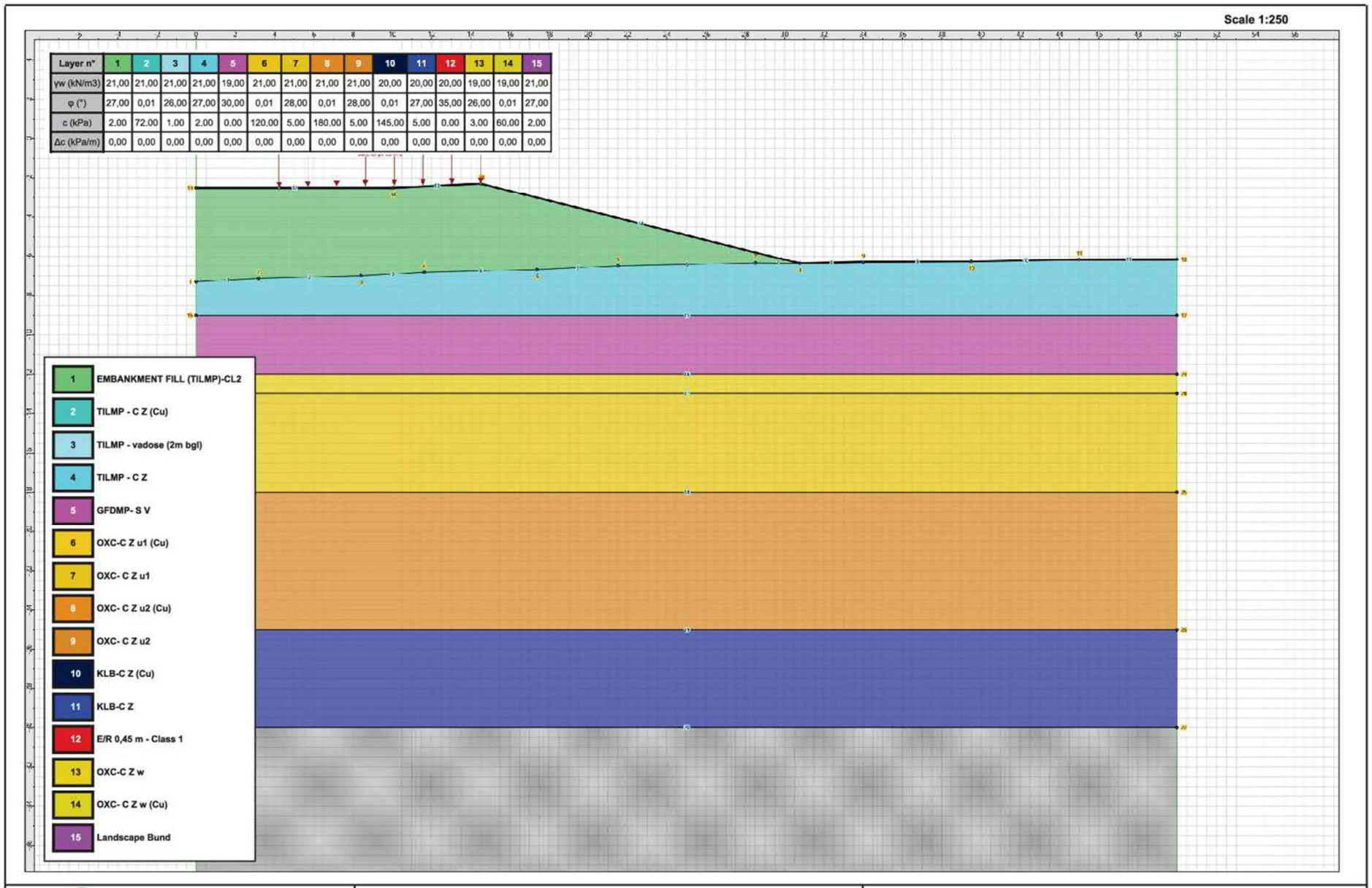
Printed on : May 24, 2022 4:58:50 PM
Calculation made by : SETEC ALS
Project : Footpath CHW/18 _MC01_Hmax=3,22 m

C:\Users\anne-laure.foumel\Documents\HS2\HW\Chetwode Cutting\CHW18\Stability assessment\MC01\CHW18_MC01_Ch.153,296_1V-4H_H=3.22m.t6p Page 1/8

HS2 Ltd - Code 1 - Accepted

Scale 1:250

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2.00	72.00	1.00	2.00	0.00	120.00	5.00	180.00	5.00	145.00	5.00	0.00	3.00	60.00	2.00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00



terrasol
setec

Talren v6
v6.0.13

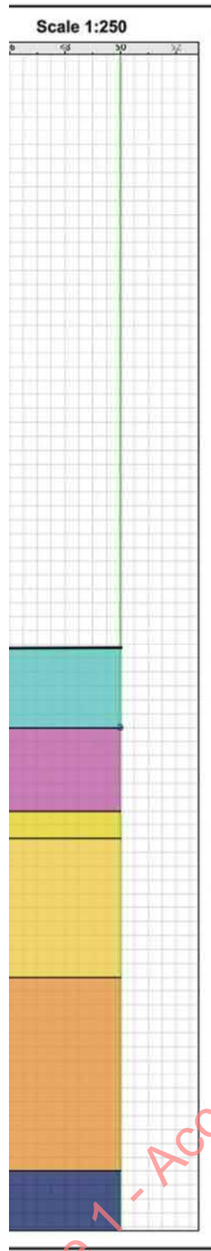
Printed on : May 24, 2022 4:58:50 PM
Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC01_Hmax=3,22 m

C:\Users\anne-laure.foumet\Documents\HS2\HW\Chetwode Cutting\CHW18\Stability assessment\MC01\CHW18_MC01_Ch.153,296_1V-4H_H=3.22m.t6p

Page 2/8

Scale 1:250



setec

C:\Users\anne-laure.foumet\Documents\HS2\HW\Chetwode Cutting\CHW18\Stability assessment\MC01\CHW18_MC01_Ch.153,296_1V-4H_H=3.22m.t6p

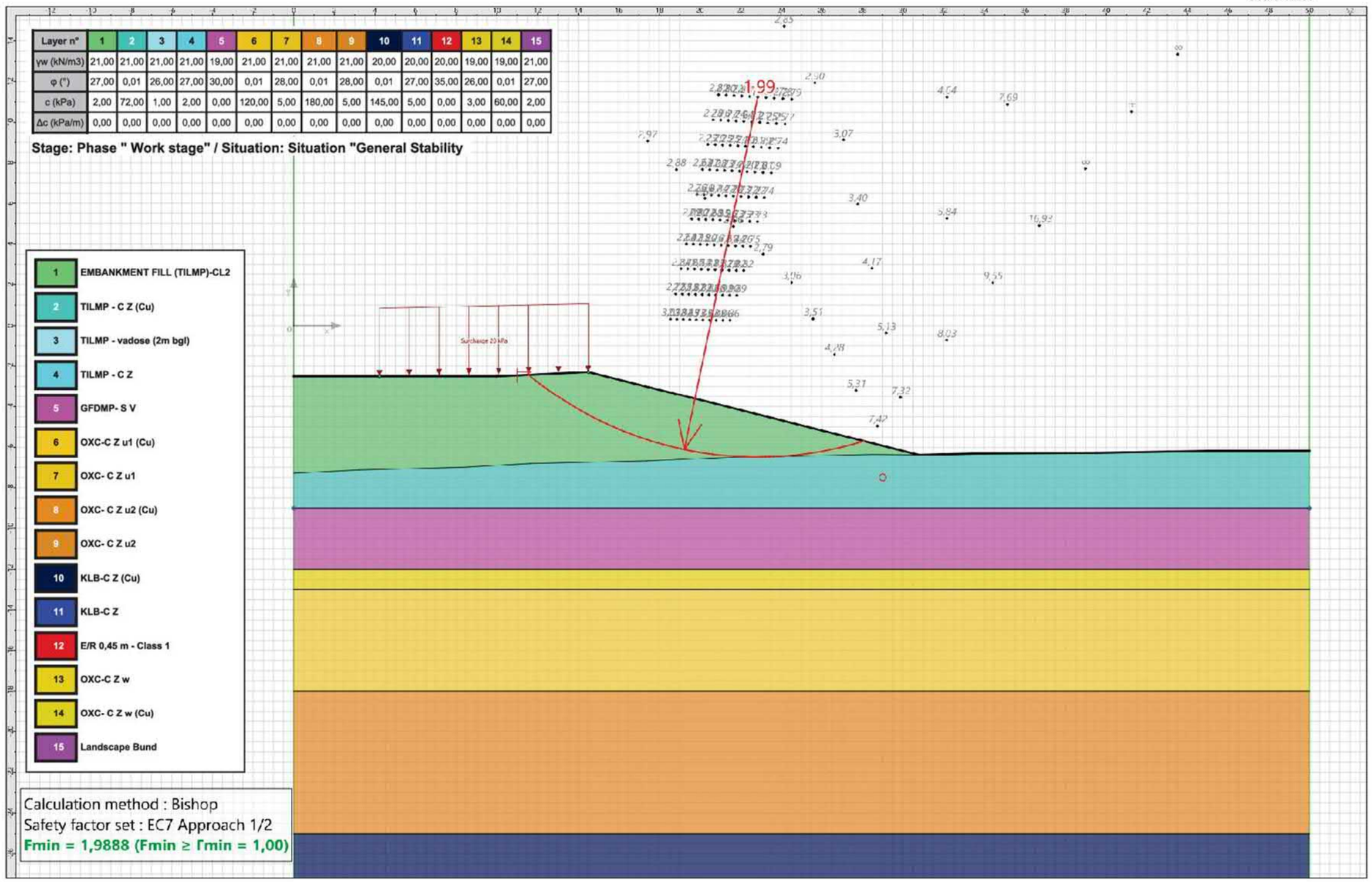
Page 3/8

HS2 Ltd - Code 1 - Accepted

Scale 1:250

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Work stage" / Situation: Situation "General Stability



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Talren v6
v6.0.13

Printed on : May 24, 2022 4:58:50 PM
Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC01_Hmax=3,22 m

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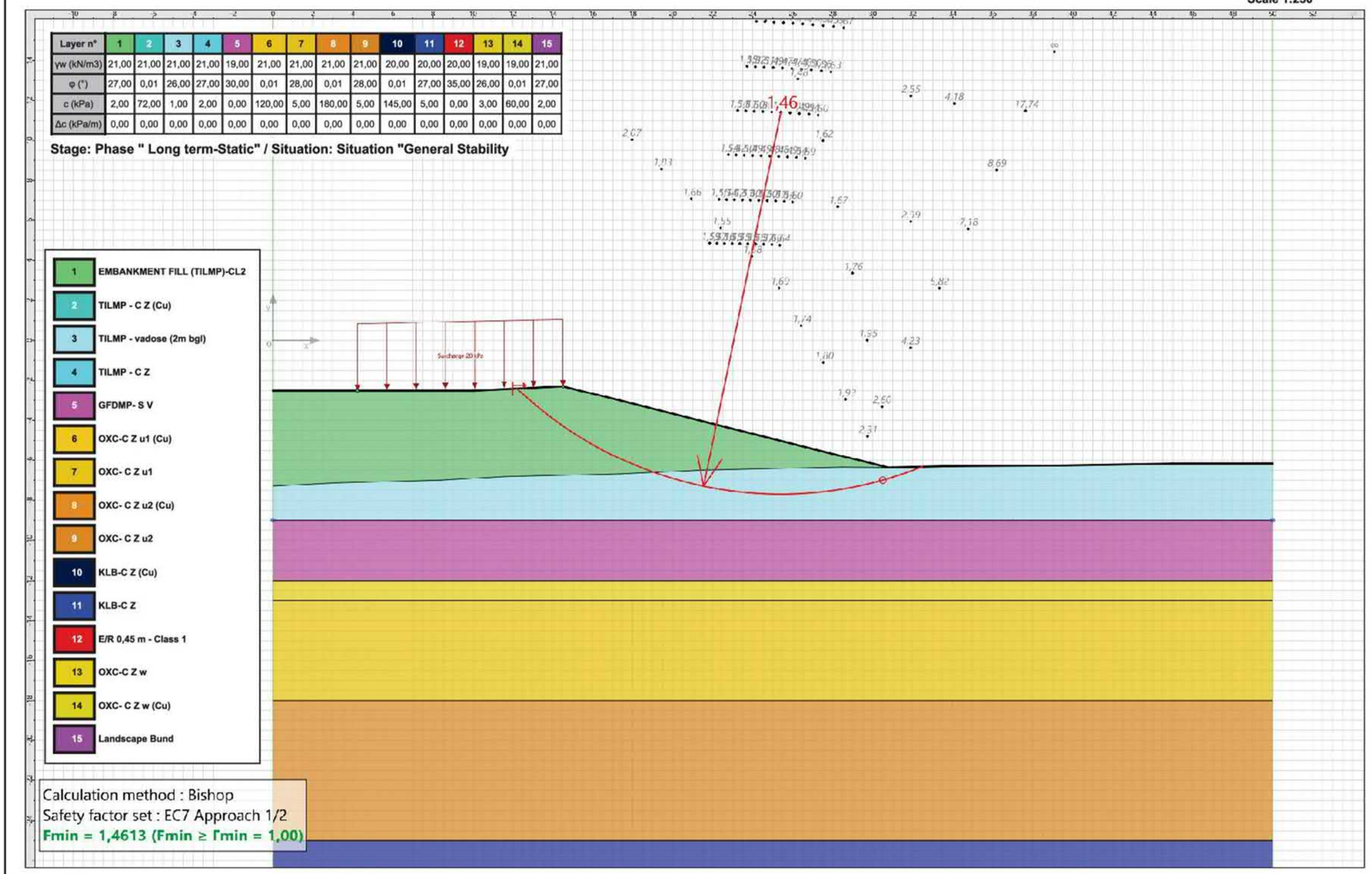
Page 4/8

HS2 Ltd - Code 1 - Accepted

Scale 1:250

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Long term-Static" / Situation: Situation "General Stability



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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC01_Hmax=3,22 m

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HS2 Ltd - Code 1 - Accepted

Scale 1:250

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase "Seismic" / Situation: Situation "General Stability -2500

1 EMBANKMENT FILL (TILMP)-CL2
2 TILMP - C Z (Cu)
3 TILMP - vadose (2m bgl)
4 TILMP - C Z
5 GFDMP- S V
6 OXC-C Z u1 (Cu)
7 OXC- C Z u1
8 OXC- C Z u2 (Cu)
9 OXC- C Z u2
10 KLB-C Z (Cu)
11 KLB-C Z
12 E/R 0,45 m - Class 1
13 OXC-C Z w
14 OXC- C Z w (Cu)
15 Landscape Bund

Calculation method : Bishop
Safety factor set : EC7 Approach 1/2
Fmin = 1,6737 (Fmin ≥ Γmin = 1,00)

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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC01_Hmax=3,22 m

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HS2 Ltd - Code 1 - Accepted

Footpath CHW18 Accommodation Access Realignment, Ch.185, Slope 1V/1.4 H, Hmax=2,52m

Project data

Project reference : HS2 Detail Design
Calculation title : Footpath CHW/18 _MC01_Hmax=2,52 m
Location : Ch. 185+000
Comments : Hmax Embankment between the Ground Level and the project level Slope 1V/1.4H
Units : kN, kPa, kN/m³
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	EMBANKMENT FILL (TILMP)-CL2 Stabilised		20,0	26,00	5,0	0,0	-	-	-	No	No	No
2	TILMP - C Z (Cu)		21,0	0,01	72,0	0,0	-	-	-	No	No	No
3	TILMP - vadose (2m bgl)		21,0	26,00	1,0	0,0	-	-	-	No	No	No
4	TILMP - C Z		21,0	27,00	2,0	0,0	-	-	-	No	No	No
5	GFDMP- S V		19,0	30,00	0,0	0,0	-	-	-	No	No	No
6	OXC-C Z u1 (Cu)		21,0	0,01	120,0	0,0	-	-	-	No	No	No
7	OXC- C Z u1		21,0	28,00	5,0	0,0	-	-	-	No	No	No
8	OXC- C Z u2 (Cu)		21,0	0,01	180,0	0,0	-	-	-	No	No	No
9	OXC- C Z u2		21,0	28,00	5,0	0,0	-	-	-	No	No	No
10	KLB-C Z (Cu)		20,0	0,01	145,0	0,0	-	-	-	No	No	No
11	KLB-C Z		20,0	27,00	5,0	0,0	-	-	-	No	No	No
12	E/R 0,45 m - Class 1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
13	OXC-C Z w		19,0	26,00	3,0	0,0	-	-	-	No	No	No
14	OXC- C Z w (Cu)		19,0	0,01	60,0	0,0	-	-	-	No	No	No
15	Landscape Bund		21,0	27,00	2,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	EMBANKMENT FILL (TILMP)-CL2 Stabilised		-	-	-	Effective	Linear	No	-	-
2	TILMP - C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
3	TILMP - vadose (2m bgl)		-	-	-	Effective	Linear	No	-	-
4	TILMP - C Z		-	-	-	Effective	Linear	No	-	-
5	GFDMP- S V		-	-	-	Effective	Linear	No	-	-
6	OXC-C Z u1 (Cu)		-	-	-	Undrained	Linear	No	-	-
7	OXC- C Z u1		-	-	-	Effective	Linear	No	-	-
8	OXC- C Z u2 (Cu)		-	-	-	Undrained	Linear	No	-	-
9	OXC- C Z u2		-	-	-	Effective	Linear	No	-	-
10	KLB-C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
11	KLB-C Z		-	-	-	Effective	Linear	No	-	-
12	E/R 0,45 m - Class 1		-	-	-	Effective	Linear	No	-	-
13	OXC-C Z w		-	-	-	Effective	Linear	No	-	-
14	OXC- C Z w (Cu)		-	-	-	Effective	Linear	No	-	-
15	Landscape Bund		-	-	-	Effective	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	30,000	-4,500	2	-2,059	-4,500	3	-5,822	-1,812	4	-14,843	-1,812	5	-24,520	-4,500	6	-27,000	-4,500
7	-27,000	-6,500	8	30,000	-6,500	9	30,000	-9,500	10	-27,000	-9,500	11	-27,000	-10,500	12	30,000	-10,500
13	30,000	-15,500	14	-27,000	-15,500	15	-27,000	-22,500	16	30,000	-22,500	17	30,000	-27,500	18	-27,000	-27,500
19	-2,559	-5,100	20	-24,020	-5,100												

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	7	8	7	9	10
8	11	12	9	13	14	10	15	16	11	17	18	12	5	2	13	2	19	14	19	20
15	20	5																		

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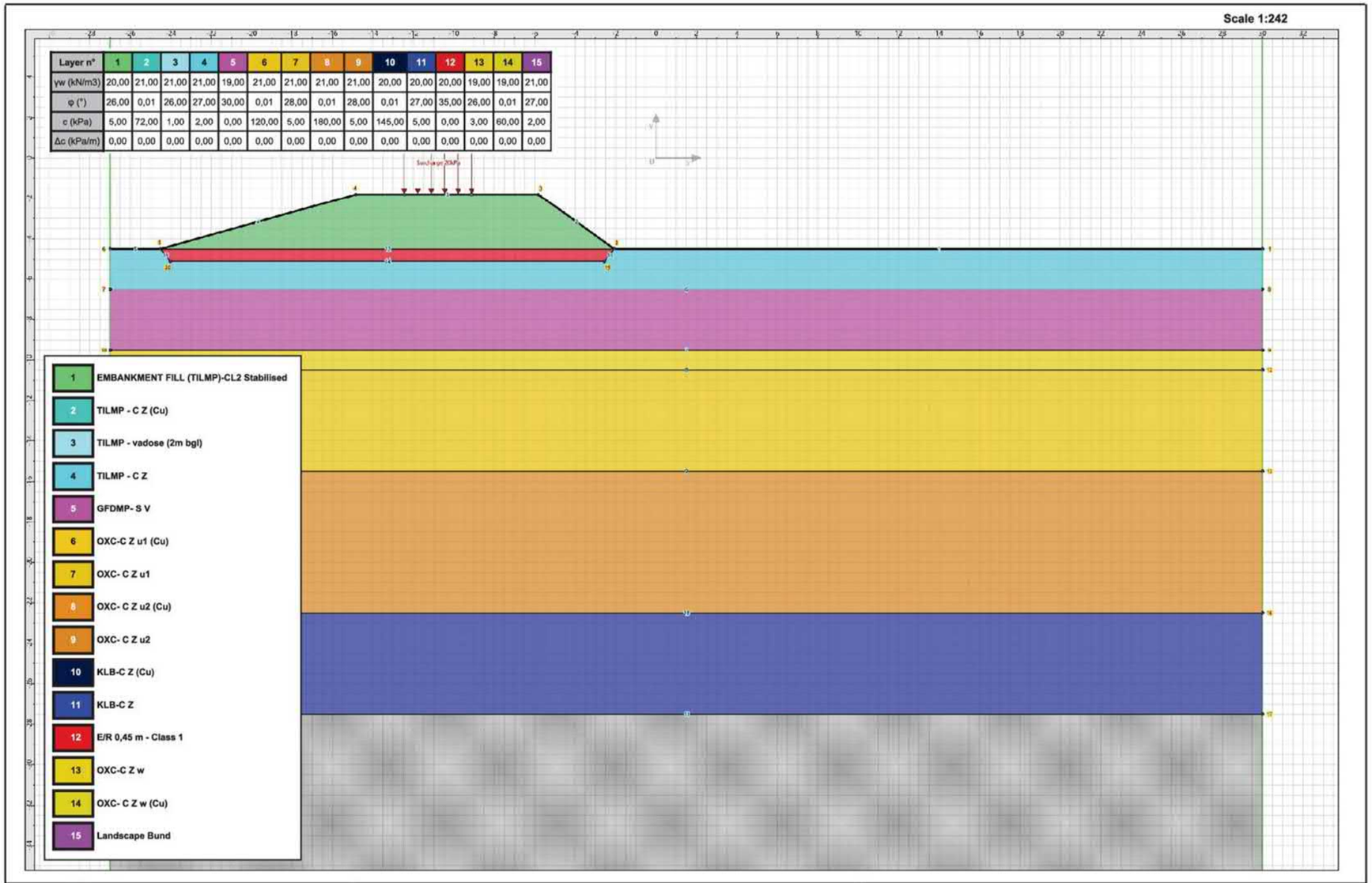
	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	Surcharge 20kPa	-12,443	-1,812	20,0	-9,122	-1,812	20,0	90,00

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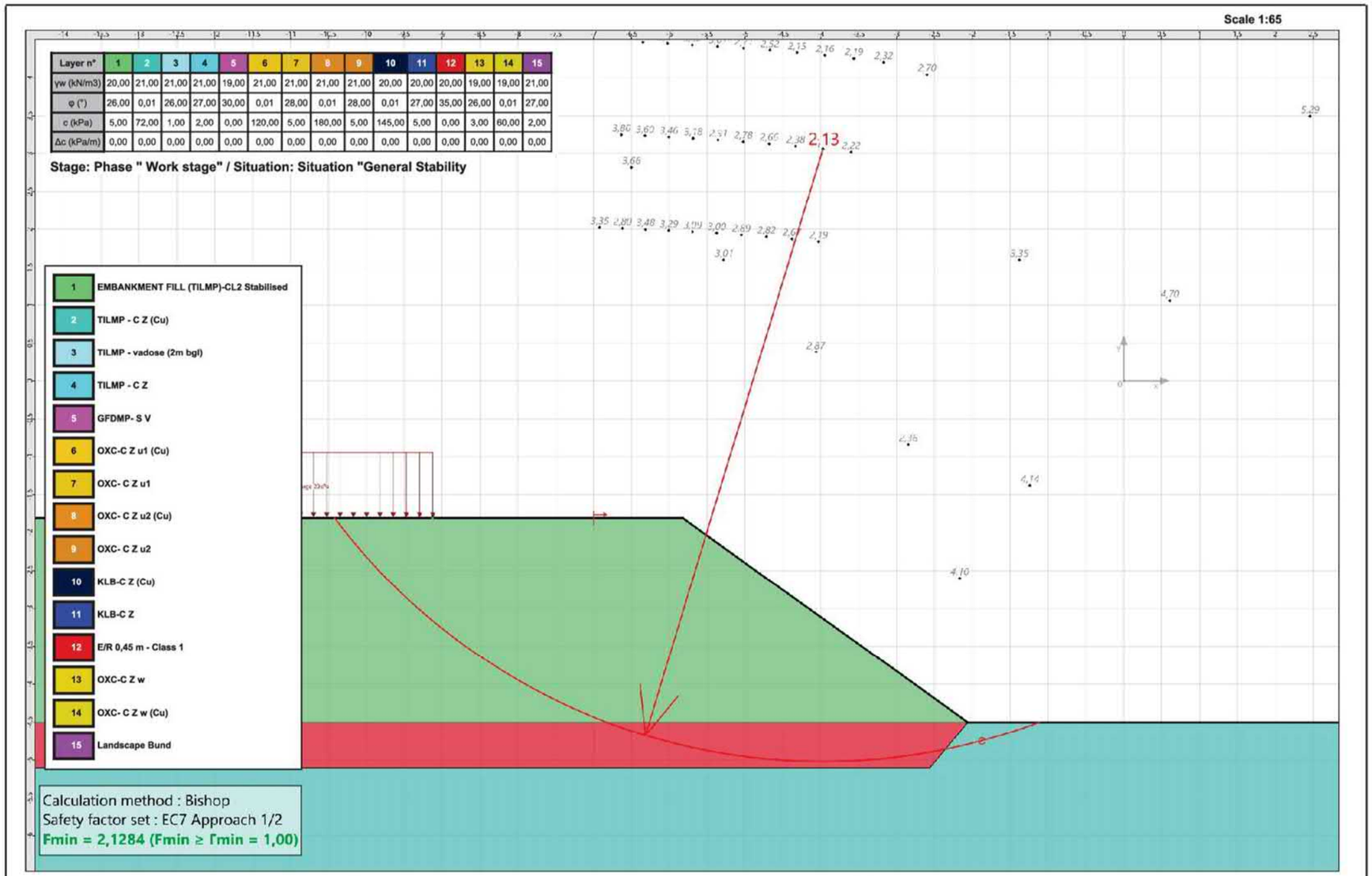
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Calculation made by : SETEC ALS
Project : Footpath CHW/18 _MC01_Hmax=2,52 m

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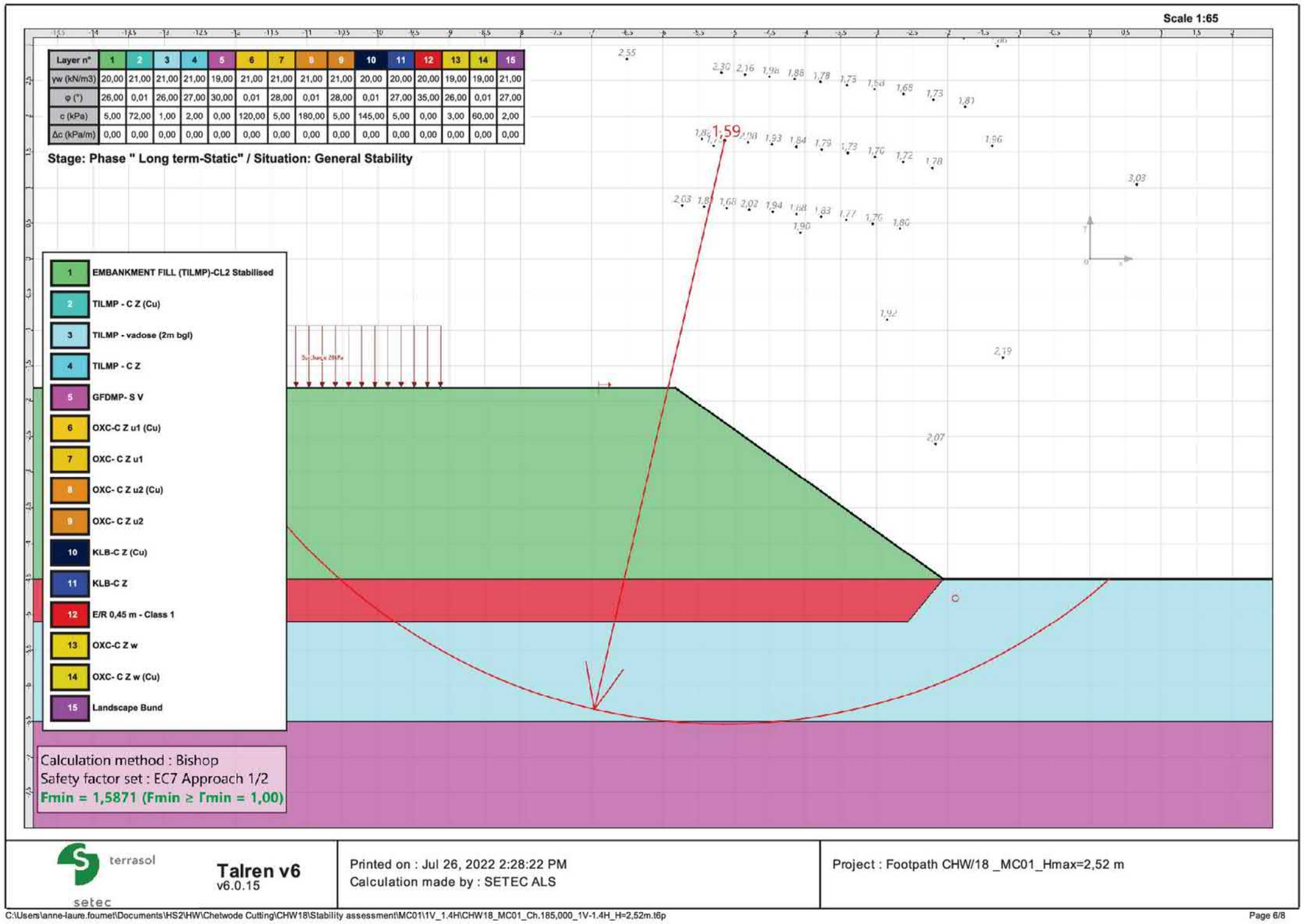
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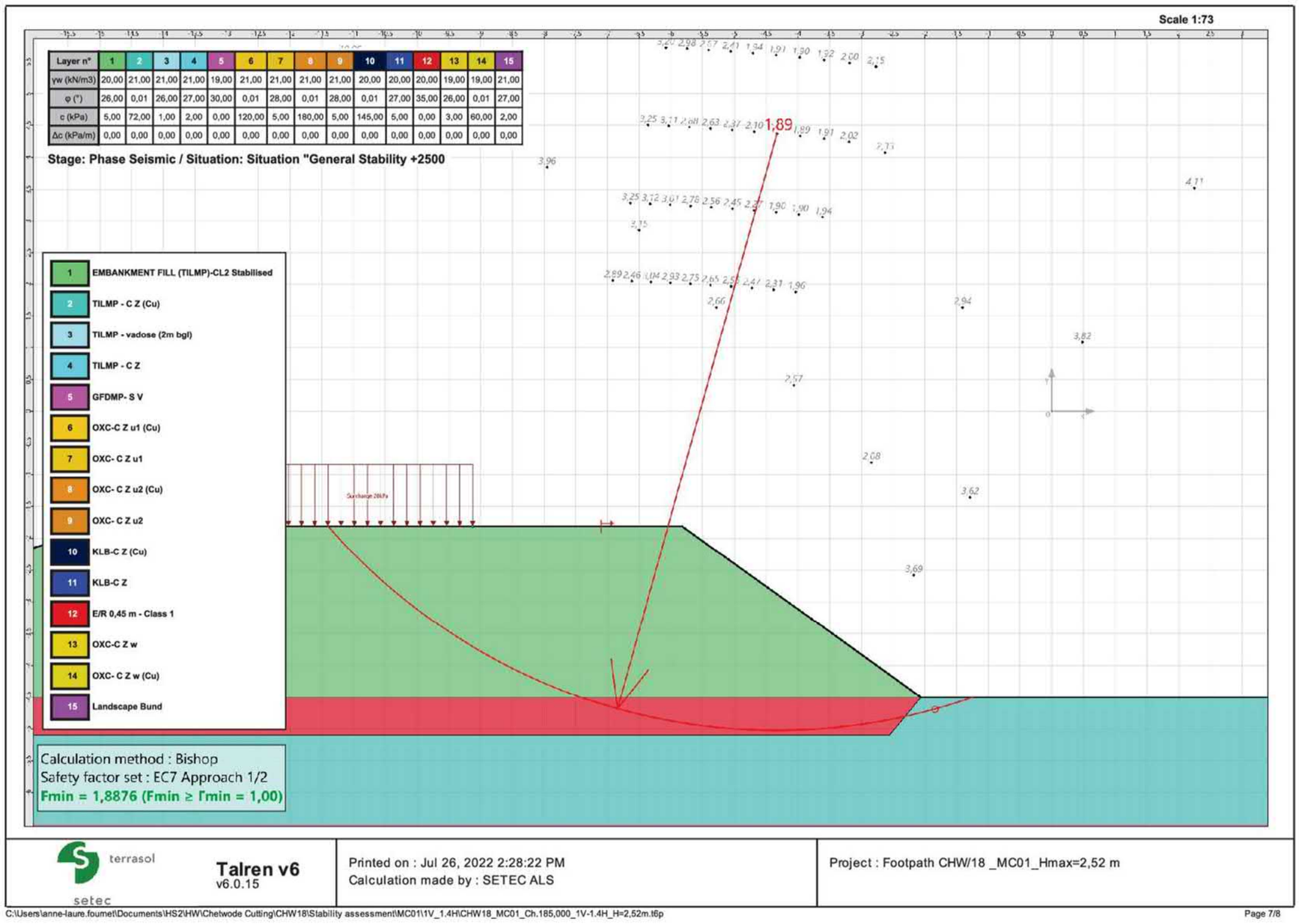
HS2 Ltd - Code 1 - Accepted



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Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	20,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	26,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	5,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC01_Hmax=2,52 m

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Scale 1:73

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	20,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	26,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	5,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase Seismic / Situation: Situation "General Stability -2500

1 EMBANKMENT FILL (TILMP)-CL2 Stabilised
2 TILMP - C Z (Cu)
3 TILMP - vadose (2m bgl)
4 TILMP - C Z
5 GFDMP- S V
6 OXC-C Z u1 (Cu)
7 OXC- C Z u1
8 OXC- C Z u2 (Cu)
9 OXC- C Z u2
10 KLB-C Z (Cu)
11 KLB-C Z
12 E/R 0,45 m - Class 1
13 OXC-C Z w
14 OXC- C Z w (Cu)
15 Landscape Bund

Calculation method : Bishop
Safety factor set : EC7 Approach 1/2
Fmin = 2,0038 (Fmin ≥ Γmin = 1,00)

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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC01_Hmax=2,52 m

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HS2 Ltd - Code 1 - Accepted

Footpath CHW18 Accommodation Access Realignment, Ch.185, Slope 1V/1.25 H, Hmax=2,52m

Project data

Project reference : HS2 Detailed design
Calculation title : Footpath CHW/18_MC01_ Hmax=2.58m
Location : Ch.185+000
Comments : N/A
Units : kN, kPa, kN/m³
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	Embankment Fill (TIMLP) - CL9J2 Stabilised		20,0	28,00	5,0	0,0	-	-	-	No	No	No
2	TIMLP-CZ		21,0	27,00	2,0	0,0	-	-	-	No	No	No
3	TIMLP-CZ (Cu)		21,0	0,01	72,0	0,0	-	-	-	No	No	No
4	GFDMP-SV		19,0	30,00	0,0	0,0	-	-	-	No	No	No
5	OXC-CZ w		19,0	26,00	3,0	0,0	-	-	-	No	No	No
6	OXC-CZ w (Cu)		19,0	0,01	60,0	0,0	-	-	-	No	No	No
7	OXC- CZ u1		21,0	28,00	5,0	0,0	-	-	-	No	No	No
8	OXC-CZ u1 (Cu)		21,0	0,01	120,0	0,0	-	-	-	No	No	No
9	OXC-CZ u2		21,0	28,00	5,0	0,0	-	-	-	No	No	No
10	OXC-CZ u2 (Cu)		21,0	0,01	180,0	0,0	-	-	-	No	No	No
11	KLB-CZ		20,0	27,00	5,0	0,0	-	-	-	No	No	No
12	KLB-CZ (Cu)		20,0	0,01	145,0	0,0	-	-	-	No	No	No
13	E/R Class C1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
14	Embankment fill (TILMP)-Undrained		20,0	0,01	50,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	Embankment Fill (TIMLP) - CL9J2 Stabilised		-	-	-	Effective	Linear	No	-	-
2	TIMLP-CZ		-	-	-	Effective	Linear	No	-	-
3	TIMLP-CZ (Cu)		-	-	-	Undrained	Linear	No	-	-
4	GFDMP-SV		-	-	-	Effective	Linear	No	-	-
5	OXC-CZ w		-	-	-	Effective	Linear	No	-	-
6	OXC-CZ w (Cu)		-	-	-	Undrained	Linear	No	-	-
7	OXC- CZ u1		-	-	-	Effective	Linear	No	-	-
8	OXC-CZ u1 (Cu)		-	-	-	Undrained	Linear	No	-	-
9	OXC-CZ u2		-	-	-	Effective	Linear	No	-	-
10	OXC-CZ u2 (Cu)		-	-	-	Undrained	Linear	No	-	-
11	KLB-CZ		-	-	-	Effective	Linear	No	-	-
12	KLB-CZ (Cu)		-	-	-	Undrained	Linear	No	-	-
13	E/R Class C1		-	-	-	Effective	Linear	No	-	-
14	Embankment fill (TILMP)-Undrained		-	-	-	Undrained	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	20,000	-6,890	2	-4,376	-6,830	3	-7,709	-4,223	4	-16,710	-4,439	5	-23,129	-6,243	6	-30,000	-6,243
7	-22,671	-6,843	8	-5,000	-7,130	9	-30,000	-6,243	10	-30,000	-11,243	11	-30,000	-12,243	12	-30,000	-17,243
13	-30,000	-24,243	14	-30,000	-29,243	15	20,000	-6,243	16	20,000	-11,243	17	20,000	-12,243	18	20,000	-17,243
19	20,000	-24,243	20	20,000	-29,243												

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
1	1	2	2	2	3	3	3	4	4	4	5	5	5	2	6	5	6	7	5	7
8	7	8	9	8	2	10	20	14	11	13	19	12	18	12	13	11	17	14	16	10
15	9	15																		

Distributed loads

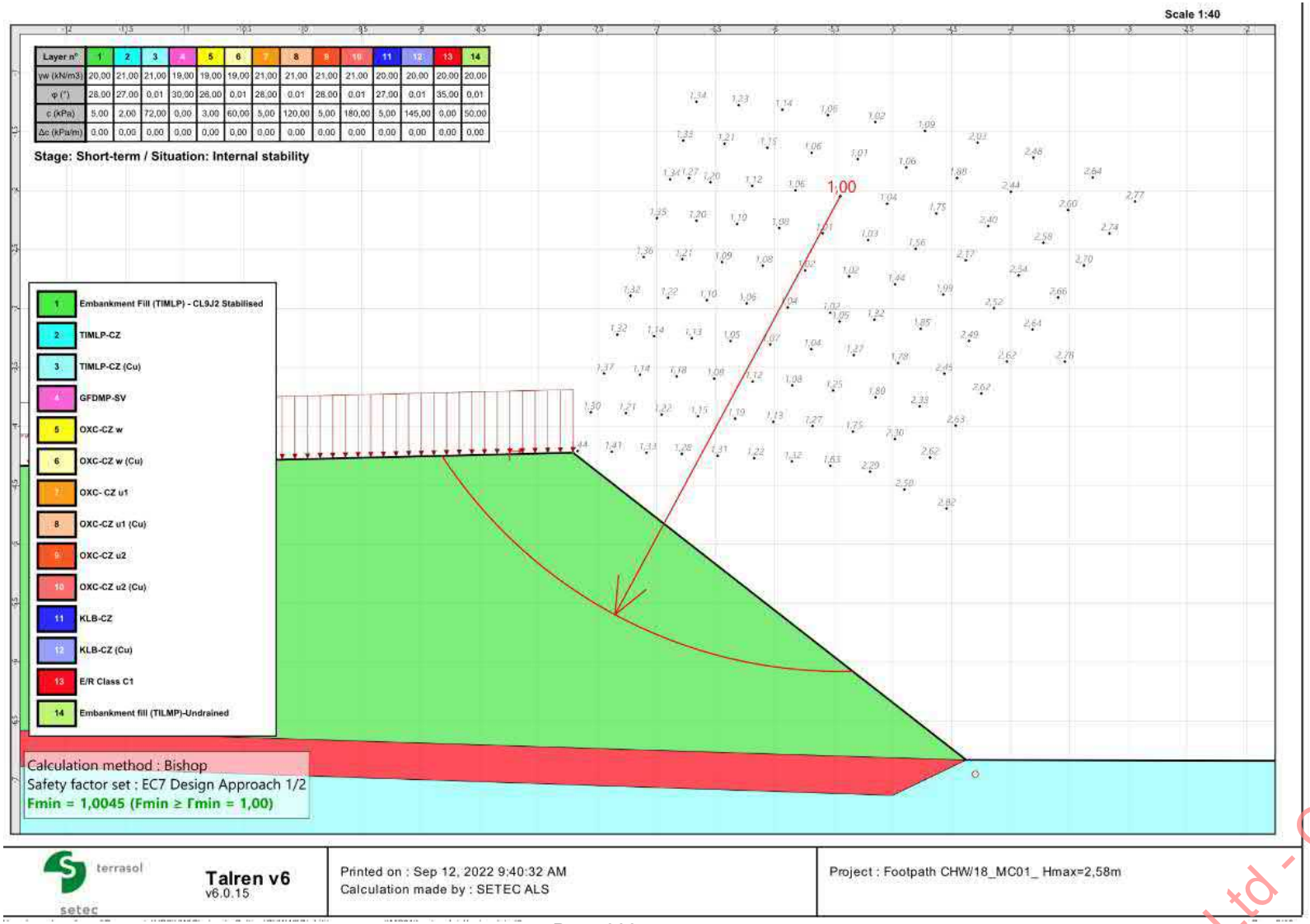
	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	Traffic Surcharge 10kPa-Long term	-15,011	-4,398	10,0	-8,444	-4,241	10,0	90,00
2	Surcharge 20 kPa-Short Term	-16,710	-4,439	20,0	-7,709	-4,223	20,0	90,00

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Project : Footpath CHW/18_MC01_ Hmax=2,58m

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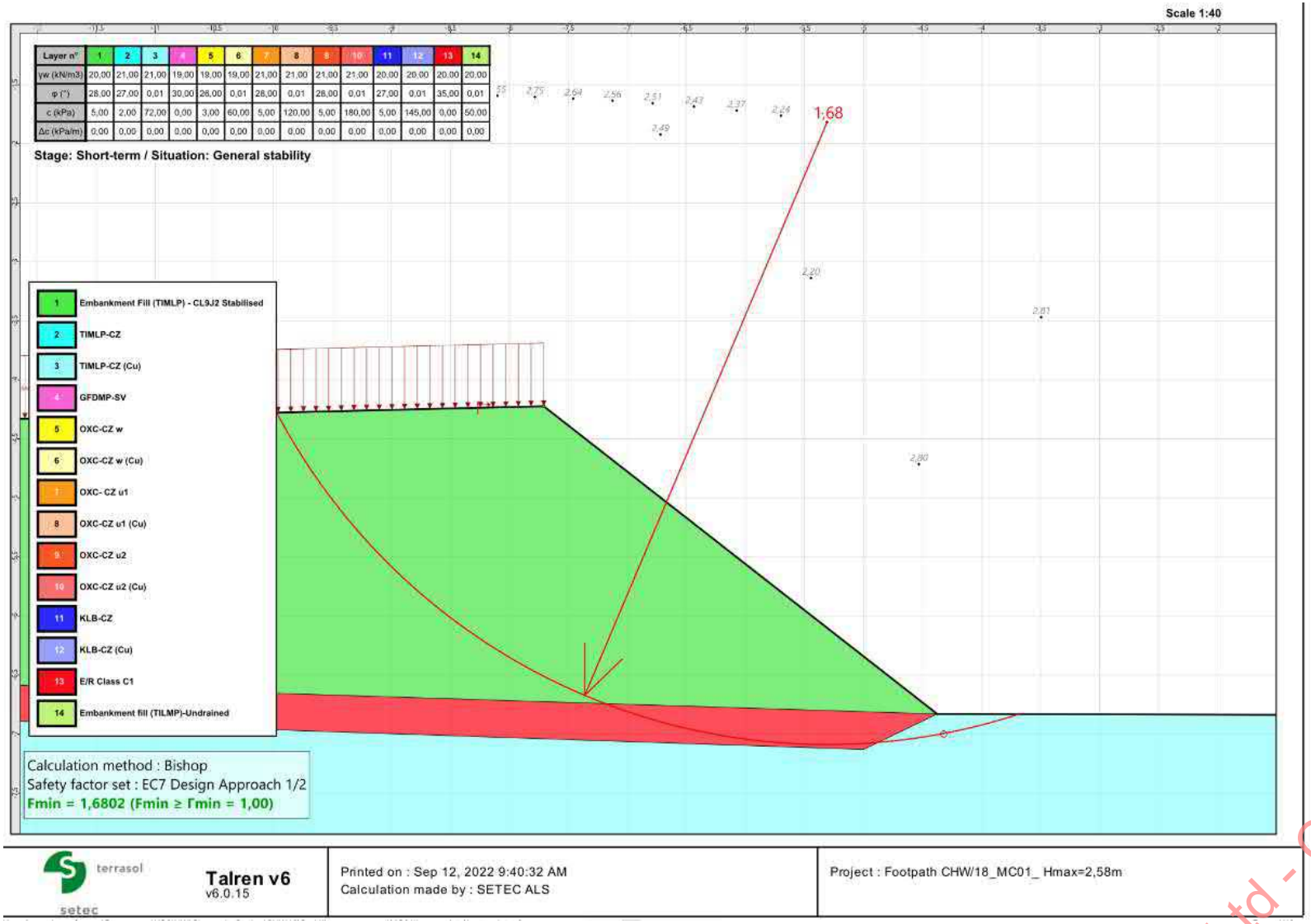


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Calculation made by : SETEC ALS

Project : Footpath CHW/18_MC01_ Hmax=2,58m

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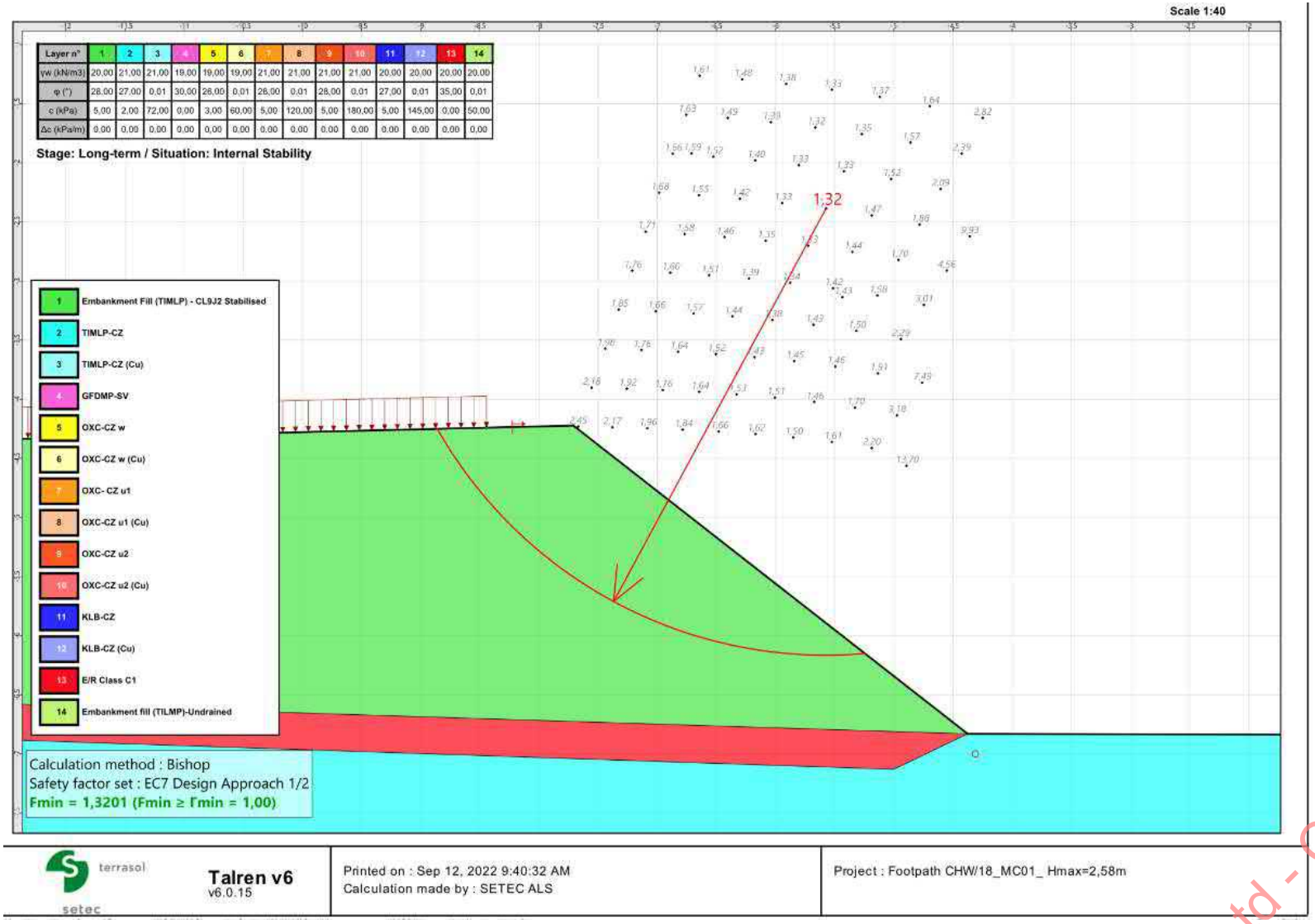


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Calculation made by : SETEC ALS

Project : Footpath CHW/18_MC01_ Hmax=2,58m

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Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14
γw (kN/m3)	20,00	21,00	21,00	19,00	19,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	20,00
φ (°)	28,00	27,00	0,01	30,00	26,00	0,01	26,00	0,01	28,00	0,01	27,00	0,01	35,00	0,01
c (kPa)	5,00	2,00	72,00	0,00	3,00	60,00	5,00	120,00	5,00	180,00	5,00	145,00	0,00	60,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

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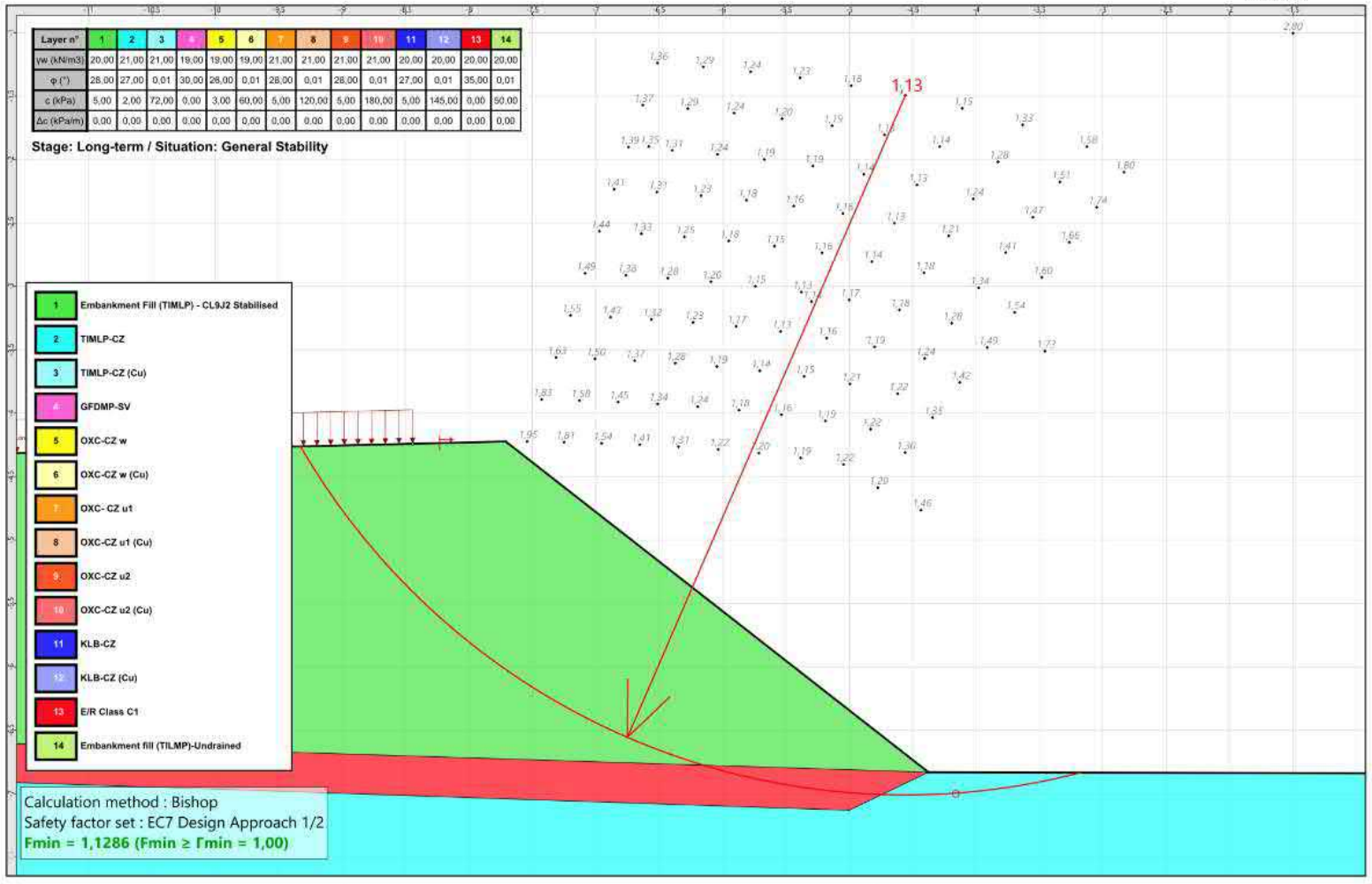
Project : Footpath CHW/18_MC01_ Hmax=2,58m

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Scale 1:40

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14
γw (kN/m3)	20,00	21,00	21,00	19,00	19,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	20,00
φ (°)	28,00	27,00	0,01	30,00	28,00	0,01	28,00	0,01	28,00	0,01	27,00	0,01	35,00	0,01
c (kPa)	5,00	2,00	72,00	0,00	3,00	60,00	5,00	120,00	5,00	180,00	5,00	145,00	0,00	50,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Long-term / Situation: General Stability



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Printed on : Sep 12, 2022 9:40:32 AM
Calculation made by : SETEC ALS

Project : Footpath CHW/18_MC01_ Hmax=2,58m

HS2 Ltd - Code 1 - Accepted

Footpath CHW18 Diversion, Ch. 68.00, Slope 1V/3H, Hmax=4,90m

Project data

Project reference : HS2 Detail Design
Calculation title : Footpath CHW/18 _MC02_Hmax=4,90 m
Location : Ch. 067+740
Comments : Hmax Embankment between the Ground and the Project Levels Slope 1V/3H
Units : kN, kPa, kN/m³
yw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	EMBANKMENT FILL (TILMP)-CL2		21,0	27,00	2,0	0,0	-	-	-	No	No	No
2	TILMP - C Z (Cu)		21,0	0,01	72,0	0,0	-	-	-	No	No	No
3	TILMP - vadose (2m bgl)		21,0	26,00	1,0	0,0	-	-	-	No	No	No
4	TILMP - C Z		21,0	27,00	2,0	0,0	-	-	-	No	No	No
5	GFDMP- S V		19,0	30,00	0,0	0,0	-	-	-	No	No	No
6	OXC-C Z u1 (Cu)		21,0	0,01	120,0	0,0	-	-	-	No	No	No
7	OXC- C Z u1		21,0	28,00	5,0	0,0	-	-	-	No	No	No
8	OXC- C Z u2 (Cu)		21,0	0,01	180,0	0,0	-	-	-	No	No	No
9	OXC- C Z u2		21,0	28,00	5,0	0,0	-	-	-	No	No	No
10	KLB-C Z (Cu)		20,0	0,01	145,0	0,0	-	-	-	No	No	No
11	KLB-C Z		20,0	27,00	5,0	0,0	-	-	-	No	No	No
12	E/R 0,45 m - Class 1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
13	OXC-C Z w		19,0	26,00	3,0	0,0	-	-	-	No	No	No
14	OXC- C Z w (Cu)		19,0	0,01	60,0	0,0	-	-	-	No	No	No
15	Landscape Bund		21,0	27,00	2,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	EMBANKMENT FILL (TILMP)-CL2		-	-	-	Effective	Linear	No	-	-
2	TILMP - C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
3	TILMP - vadose (2m bgl)		-	-	-	Effective	Linear	No	-	-
4	TILMP - C Z		-	-	-	Effective	Linear	No	-	-
5	GFDMP- S V		-	-	-	Effective	Linear	No	-	-
6	OXC-C Z u1 (Cu)		-	-	-	Undrained	Linear	No	-	-
7	OXC- C Z u1		-	-	-	Effective	Linear	No	-	-
8	OXC- C Z u2 (Cu)		-	-	-	Undrained	Linear	No	-	-
9	OXC- C Z u2		-	-	-	Effective	Linear	No	-	-
10	KLB-C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
11	KLB-C Z		-	-	-	Effective	Linear	No	-	-
12	E/R 0,45 m - Class 1		-	-	-	Effective	Linear	No	-	-
13	OXC-C Z w		-	-	-	Effective	Linear	No	-	-
14	OXC- C Z w (Cu)		-	-	-	Effective	Linear	No	-	-
15	Landscape Bund		-	-	-	Effective	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	4,000	-14,000	2	10,000	-14,000	3	17,256	-14,000	4	22,254	-14,169	5	27,669	-14,213	6	34,000	-14,303
7	38,269	-14,375	8	49,166	-14,500	9	54,500	-14,500	11	4,000	-5,500	12	12,500	-5,500	13	18,000	-5,500
14	20,500	-6,000	15	41,380	-9,684	16	68,500	-14,500	17	70,000	-14,500	18	80,000	-14,500	19	4,000	-16,500
20	80,000	-16,500	21	4,000	-19,500	22	80,000	-19,500	23	4,000	-20,500	24	80,000	-20,500	25	4,000	-26,500
26	80,000	-26,500	27	4,000	-33,500	28	80,000	-33,500	29	4,000	-40,500	30	80,000	-40,500	31	30,891	-6,165

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8
8	8	9	10	11	12	11	12	13	12	13	14	13	14	15	14	15	16	15	16	17
16	9	16	17	17	18	18	20	19	19	22	21	20	24	23	21	26	25	22	28	27
23	30	29	24	14	31	25	31	15												

Distributed loads

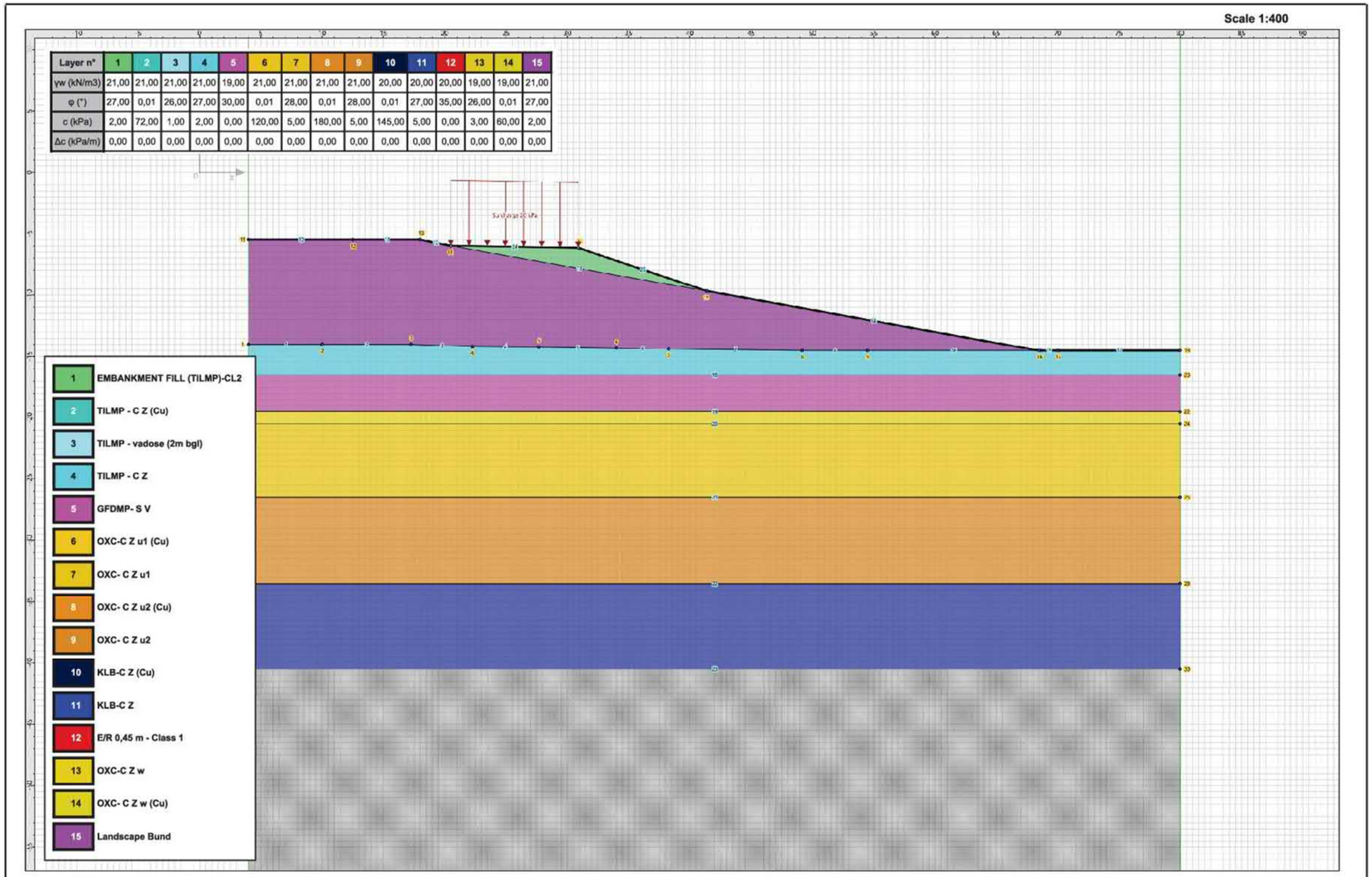
	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	Surcharge 20 kPa	20,500	-6,000	20,0	30,891	-6,165	20,0	90,00

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Printed on : May 24, 2022 5:36:27 PM
Calculation made by : SETEC ALS
Project : Footpath CHW/18 _MC02_Hmax=4,90 m

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HS2 Ltd - Code 1 - Accepted



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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC02_Hmax=4,90 m

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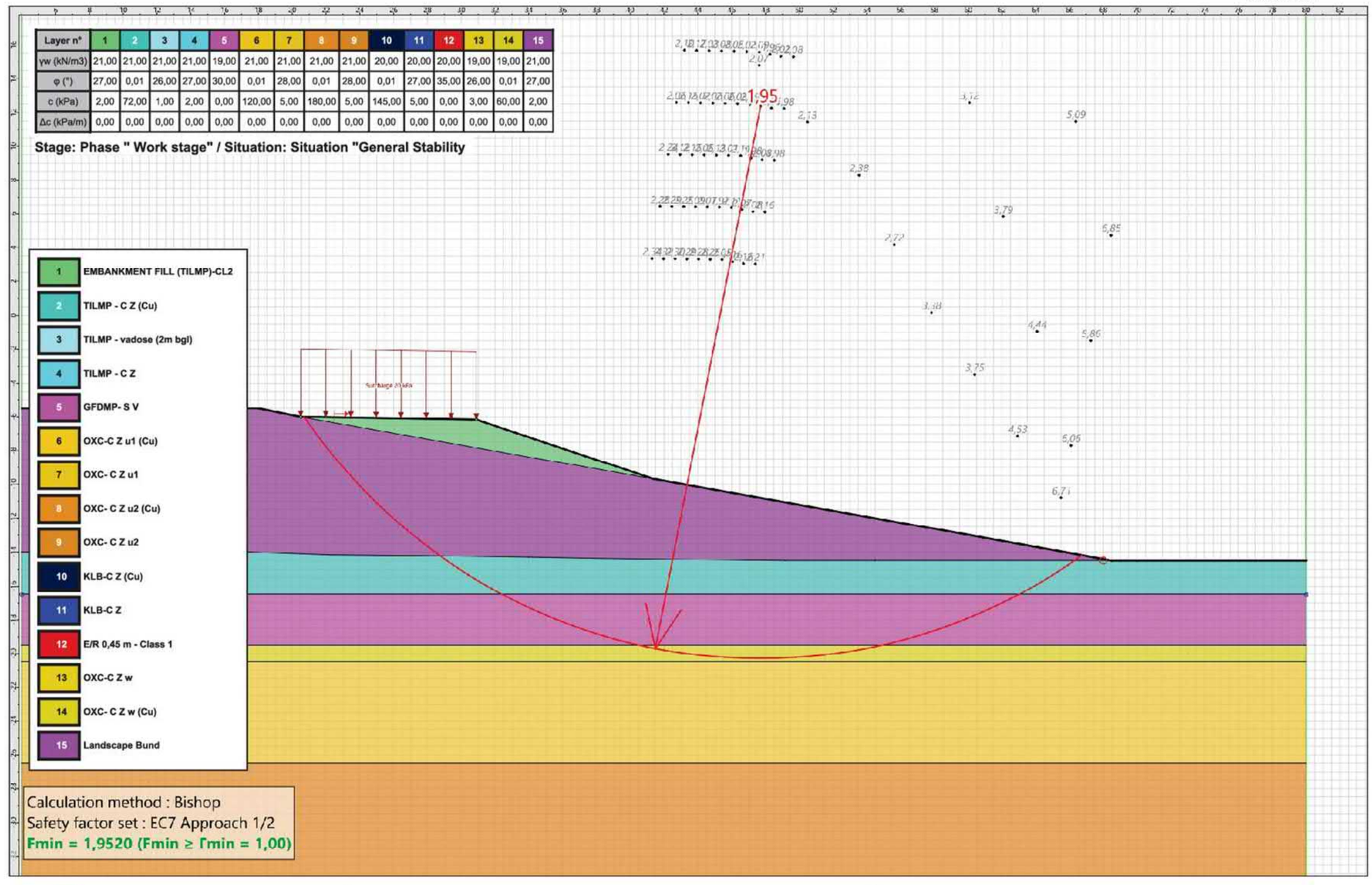


HS2 Ltd - Code 1 - Accepted

Scale 1:300

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Work stage" / Situation: Situation "General Stability



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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC02_Hmax=4,90 m

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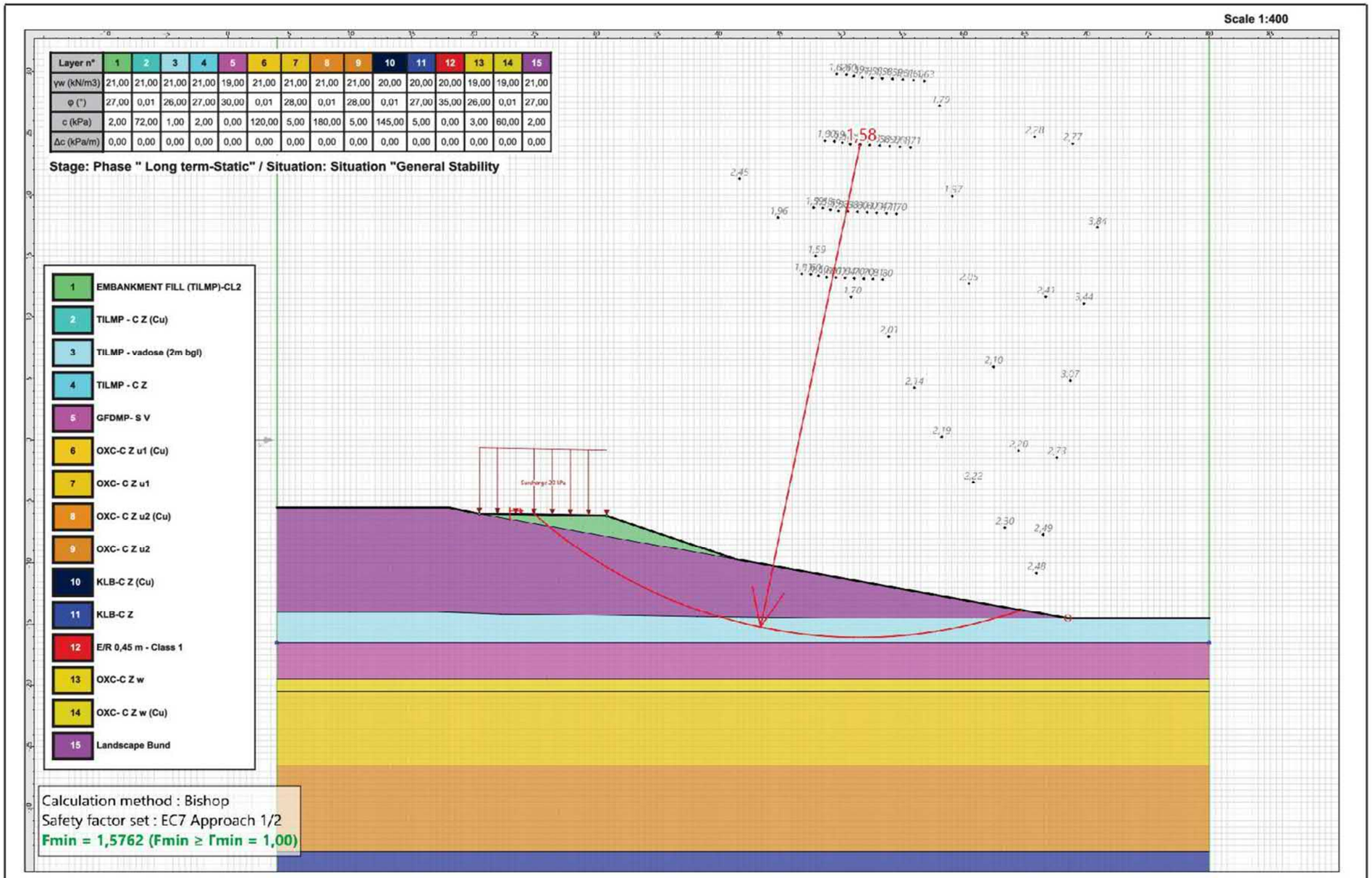
HS2 Ltd - Code 1 - Accepted

Scale 1:400

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Long term-Static" / Situation: Situation "General Stability

1 EMBANKMENT FILL (TILMP)-CL2
2 TILMP - C Z (Cu)
3 TILMP - vadose (2m bgl)
4 TILMP - C Z
5 GFDMP- S V
6 OXC-C Z u1 (Cu)
7 OXC- C Z u1
8 OXC- C Z u2 (Cu)
9 OXC- C Z u2
10 KLB-C Z (Cu)
11 KLB-C Z
12 E/R 0,45 m - Class 1
13 OXC-C Z w
14 OXC- C Z w (Cu)
15 Landscape Bund



Calculation method : Bishop
Safety factor set : EC7 Approach 1/2
Fmin = 1,5762 (Fmin ≥ Γmin = 1,00)

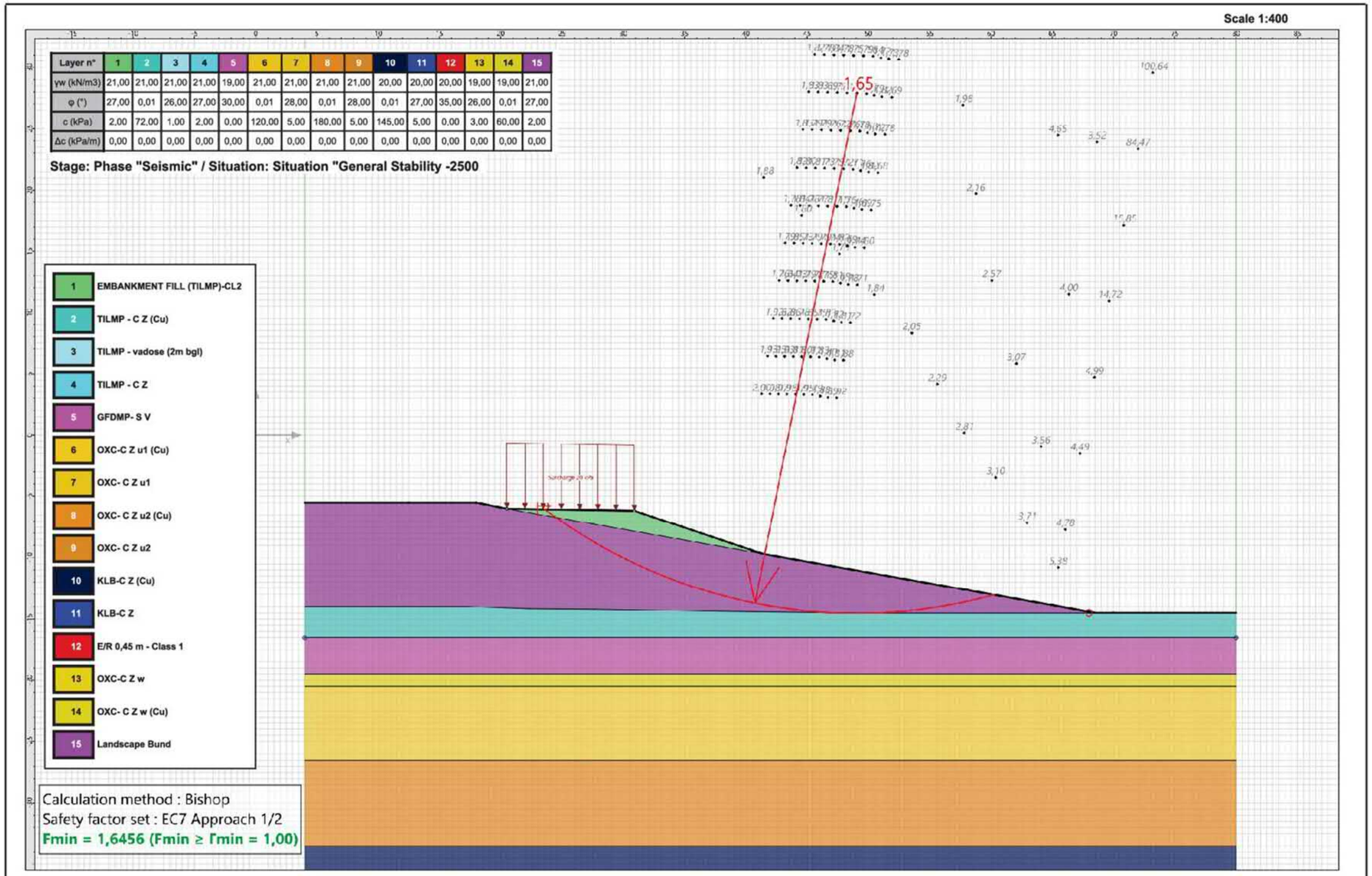
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Printed on : May 24, 2022 5:36:28 PM
Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC02_Hmax=4,90 m

HS2 Ltd - Code 1 - Accepted





HS2 Ltd - Code 1 - Accepted

Footpath CHW18 Diversion, Ch.080, Slope 1V/4H, Hmax=5.04m

Project data

Project reference : HS2 Detail Design
Calculation title : Footpath CHW/18 _MC02_Hmax=5,04 m
Location : Ch. 080+000
Comments : Hmax Embankment between the Ground and the Project Levels Slope 1V/4H
Units : kN, kPa, kN/m³
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	EMBANKMENT FILL (TILMP)-CL2		21,0	27,00	2,0	0,0	-	-	-	No	No	No
2	TILMP - C Z (Cu)		21,0	0,01	72,0	0,0	-	-	-	No	No	No
3	TILMP - vadose (2m bgl)		21,0	26,00	1,0	0,0	-	-	-	No	No	No
4	TILMP - C Z		21,0	27,00	2,0	0,0	-	-	-	No	No	No
5	GFDMP- S V		19,0	30,00	0,0	0,0	-	-	-	No	No	No
6	OXC-C Z u1 (Cu)		21,0	0,01	120,0	0,0	-	-	-	No	No	No
7	OXC- C Z u1		21,0	28,00	5,0	0,0	-	-	-	No	No	No
8	OXC- C Z u2 (Cu)		21,0	0,01	180,0	0,0	-	-	-	No	No	No
9	OXC- C Z u2		21,0	28,00	5,0	0,0	-	-	-	No	No	No
10	KLB-C Z (Cu)		20,0	0,01	145,0	0,0	-	-	-	No	No	No
11	KLB-C Z		20,0	27,00	5,0	0,0	-	-	-	No	No	No
12	E/R 0,45 m - Class 1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
13	OXC-C Z w		19,0	26,00	3,0	0,0	-	-	-	No	No	No
14	OXC- C Z w (Cu)		19,0	0,01	60,0	0,0	-	-	-	No	No	No
15	Landscape Bund		21,0	27,00	2,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	EMBANKMENT FILL (TILMP)-CL2		-	-	-	Effective	Linear	No	-	-
2	TILMP - C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
3	TILMP - vadose (2m bgl)		-	-	-	Effective	Linear	No	-	-
4	TILMP - C Z		-	-	-	Effective	Linear	No	-	-
5	GFDMP- S V		-	-	-	Effective	Linear	No	-	-
6	OXC-C Z u1 (Cu)		-	-	-	Undrained	Linear	No	-	-
7	OXC- C Z u1		-	-	-	Effective	Linear	No	-	-
8	OXC- C Z u2 (Cu)		-	-	-	Undrained	Linear	No	-	-
9	OXC- C Z u2		-	-	-	Effective	Linear	No	-	-
10	KLB-C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
11	KLB-C Z		-	-	-	Effective	Linear	No	-	-
12	E/R 0,45 m - Class 1		-	-	-	Effective	Linear	No	-	-
13	OXC-C Z w		-	-	-	Effective	Linear	No	-	-
14	OXC- C Z w (Cu)		-	-	-	Effective	Linear	No	-	-
15	Landscape Bund		-	-	-	Effective	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	0,000	-12,500	2	5,858	-12,782	3	14,500	-13,000	4	22,000	-13,000	5	34,150	-13,205	6	38,155	-13,233
8	70,000	-13,302	9	0,000	-4,709	10	8,500	-5,000	11	26,500	-7,319	12	100,000	-13,277	13	13,385	-5,632
14	23,816	-7,000	15	18,914	-5,742	16	0,000	-15,250	17	100,000	-15,198	18	0,000	-18,250	19	0,000	-19,250
20	0,000	-25,250	21	0,000	-32,250	22	0,000	-38,250	23	100,000	-18,230	24	100,000	-19,220	25	100,000	-25,284
26	100,000	-32,207	27	100,000	-38,217												

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	8	9	10	10	11	8
11	8	12	12	6	8	13	10	13	14	13	14	15	14	11	16	13	15	17	15	14
18	27	22	19	21	26	20	25	20	21	19	24	22	23	18	23	16	17			

Distributed loads

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	Surcharge 20 kPa	13,385	-5,632	20,0	18,914	-5,742	20,0	90,00

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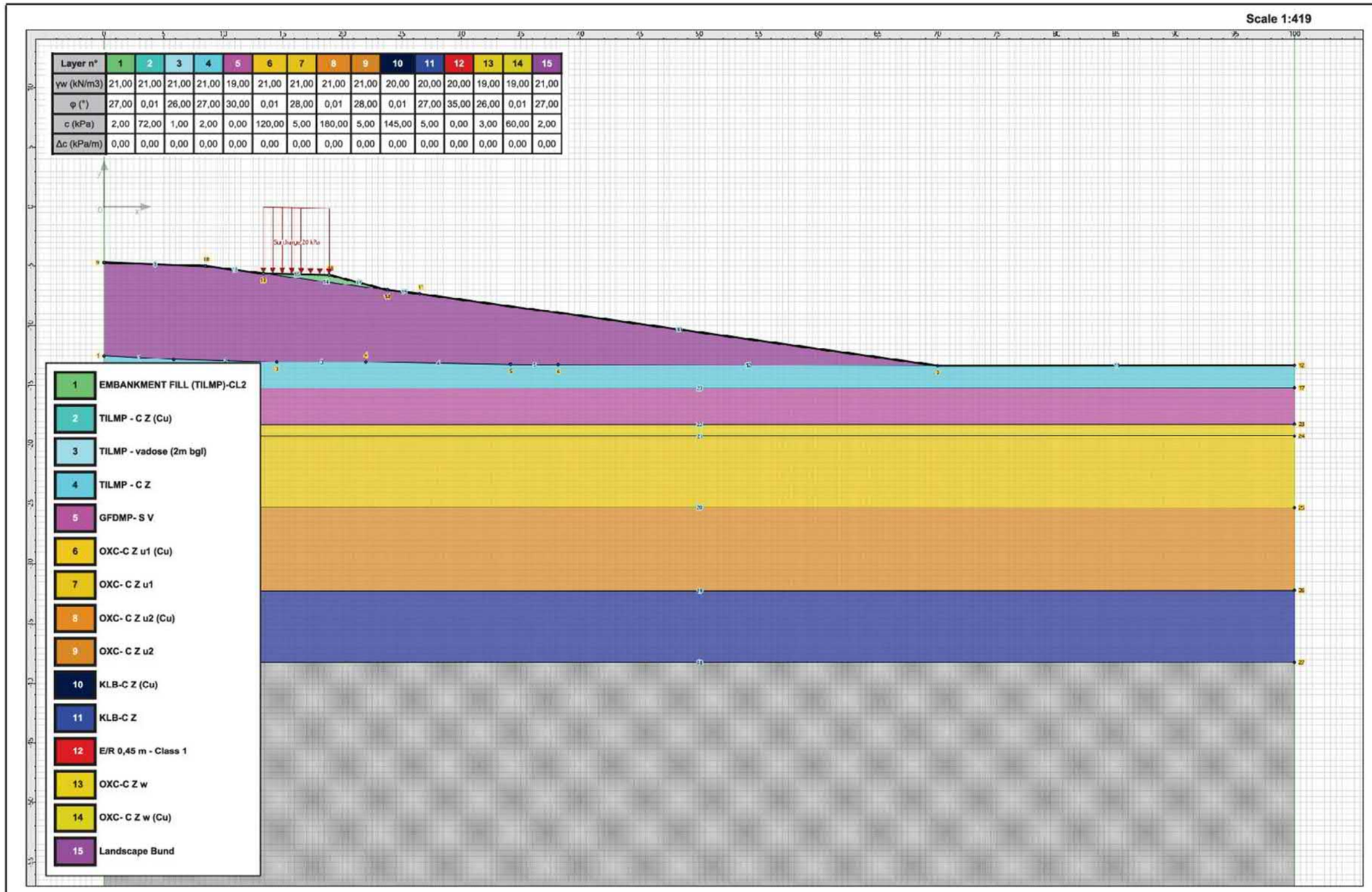
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Calculation made by : SETEC ALS
Project : Footpath CHW/18 _MC02_Hmax=5,04 m

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HS2 Ltd - Code 1 - Accepted

Scale 1:419

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00



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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC02_Hmax=5,04 m

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Scale 1:250

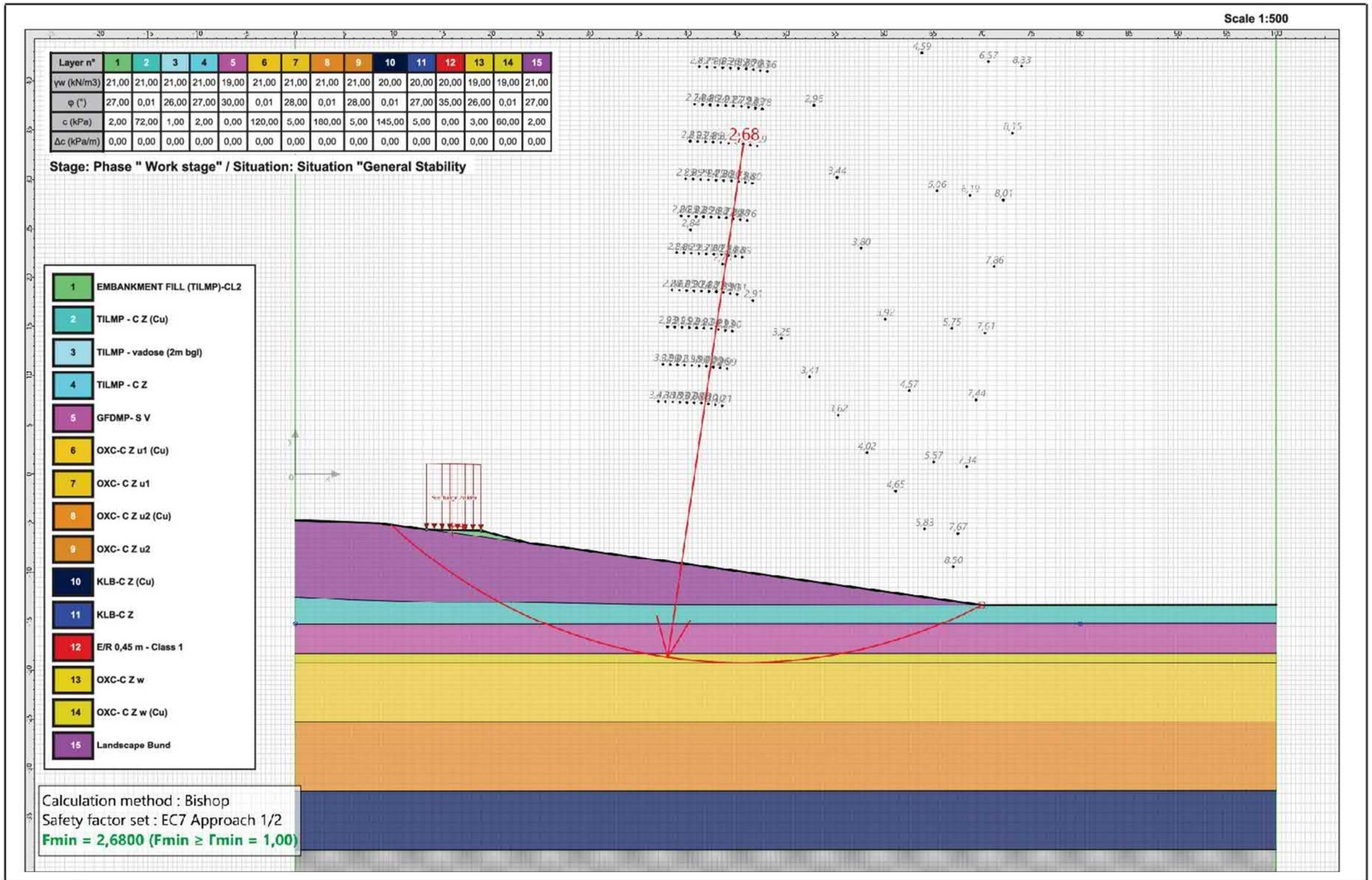
Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00

HS2 Ltd - Code 1 - Accepted

Scale 1:500

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Work stage" / Situation: Situation "General Stability



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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC02_Hmax=5,04 m

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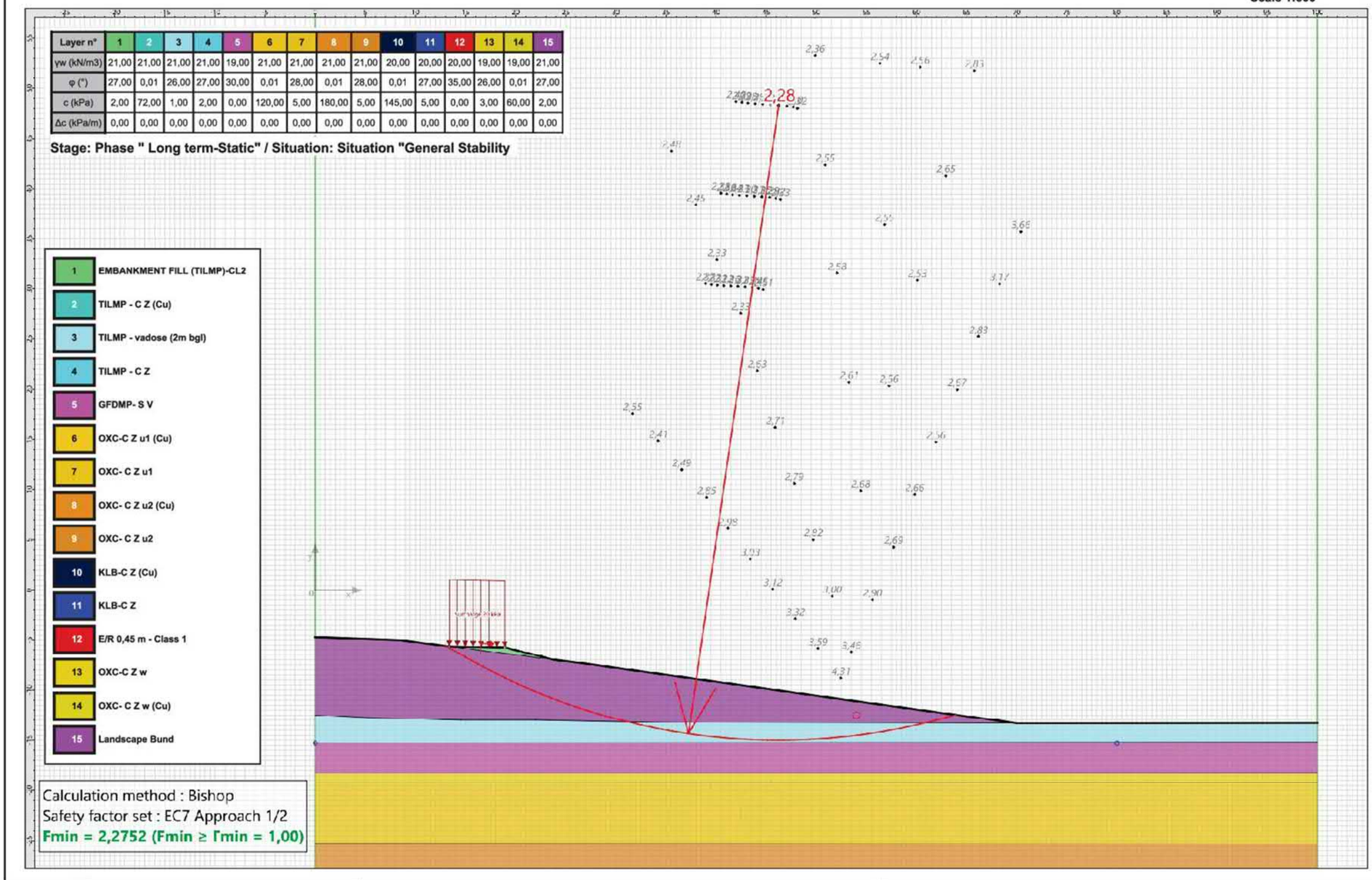
Page 4/8

HS2 Ltd - Code 1 - Accepted

Scale 1:500

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Long term-Static" / Situation: Situation "General Stability



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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC02_Hmax=5,04 m

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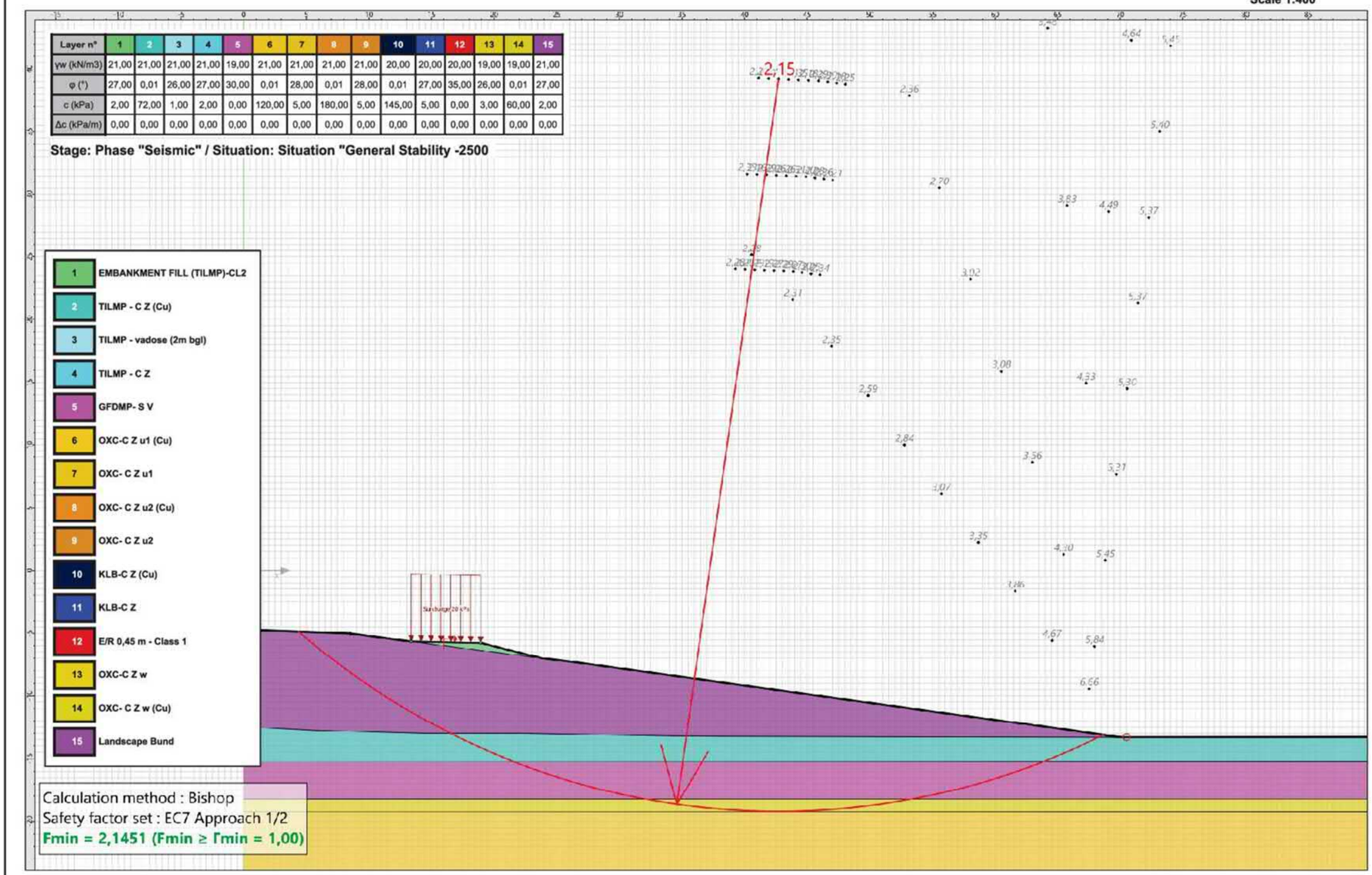
Page 6/8

HS2 Ltd - Code 1 - Accepted

Scale 1:400

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase "Seismic" / Situation: Situation "General Stability -2500



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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC02_Hmax=5,04 m

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HS2 Ltd - Code 1 - Accepted

Chetwode ATS Access Road and Maintenance Access Road to Pond, Ch.140, Slope 1V/4H, Hmax=4.32m

Project data

Project reference : HS2 Detail Design
Calculation title : Footpath CHW/18 _MC03_Hmax=4,326 m
Location : Ch. 139+952
Comments : Hmax Embankment between the Ground and Projects Levels Slope 1V/4H
Units : kN, kPa, kN/m³
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	EMBANKMENT FILL (TILMP)-CL2		21,0	27,00	2,0	0,0	-	-	-	No	No	No
2	TILMP - C Z (Cu)		21,0	0,01	72,0	0,0	-	-	-	No	No	No
3	TILMP - vadose (2m bgl)		21,0	26,00	1,0	0,0	-	-	-	No	No	No
4	TILMP - C Z		21,0	27,00	2,0	0,0	-	-	-	No	No	No
5	GFDMP- S V		19,0	30,00	0,0	0,0	-	-	-	No	No	No
6	OXC-C Z u1 (Cu)		21,0	0,01	120,0	0,0	-	-	-	No	No	No
7	OXC- C Z u1		21,0	28,00	5,0	0,0	-	-	-	No	No	No
8	OXC- C Z u2 (Cu)		21,0	0,01	180,0	0,0	-	-	-	No	No	No
9	OXC- C Z u2		21,0	28,00	5,0	0,0	-	-	-	No	No	No
10	KLB-C Z (Cu)		20,0	0,01	145,0	0,0	-	-	-	No	No	No
11	KLB-C Z		20,0	27,00	5,0	0,0	-	-	-	No	No	No
12	E/R 0,45 m - Class 1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
13	OXC-C Z w		19,0	26,00	3,0	0,0	-	-	-	No	No	No
14	OXC- C Z w (Cu)		19,0	0,01	60,0	0,0	-	-	-	No	No	No
15	Landscape Bund		21,0	27,00	2,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	EMBANKMENT FILL (TILMP)-CL2		-	-	-	Effective	Linear	No	-	-
2	TILMP - C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
3	TILMP - vadose (2m bgl)		-	-	-	Effective	Linear	No	-	-
4	TILMP - C Z		-	-	-	Effective	Linear	No	-	-
5	GFDMP- S V		-	-	-	Effective	Linear	No	-	-
6	OXC-C Z u1 (Cu)		-	-	-	Undrained	Linear	No	-	-
7	OXC- C Z u1		-	-	-	Effective	Linear	No	-	-
8	OXC- C Z u2 (Cu)		-	-	-	Undrained	Linear	No	-	-
9	OXC- C Z u2		-	-	-	Effective	Linear	No	-	-
10	KLB-C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
11	KLB-C Z		-	-	-	Effective	Linear	No	-	-
12	E/R 0,45 m - Class 1		-	-	-	Effective	Linear	No	-	-
13	OXC-C Z w		-	-	-	Effective	Linear	No	-	-
14	OXC- C Z w (Cu)		-	-	-	Effective	Linear	No	-	-
15	Landscape Bund		-	-	-	Effective	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	-50,000	-5,840	2	-48,110	-5,840	3	-44,210	-5,898	4	-39,773	-6,000	5	-25,500	-9,679	6	-22,500	-9,635
7	-16,735	-8,181	8	-11,053	-9,600	9	-0,000	-10,000	10	-26,742	-9,272	11	-20,848	-9,180	12	-50,000	-7,840
13	-48,110	-7,840	14	-44,210	-7,898	15	-39,773	-8,000	16	-34,685	-9,272	17	-33,057	-9,679	18	-50,000	-8,840
19	-50,000	-10,840	20	-50,000	-11,840	21	-50,000	-17,840	22	-50,000	-23,840	23	-50,000	-29,840	24	-36,413	-8,840
25	-0,000	-11,840	26	-0,000	-17,840	27	-0,000	-23,840	28	-0,000	-29,840	29	-28,413	-8,840	30	-0,000	-10,840
31	-19,315	-8,848	32	-14,067	-8,845												

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
1	1	2	2	2	3	3	3	4	5	5	6	8	8	9	10	10	5	12	11	6
13	11	10	14	12	13	15	13	14	16	14	15	18	17	16	19	15	24	20	24	16
21	28	23	22	22	27	23	26	21	24	20	25	25	29	4	26	10	29	27	29	24
28	24	18	29	30	19	30	17	5	31	10	16	32	31	32	33	11	31	34	31	7
35	7	32	36	32	8															

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Calculation made by : SETEC ALS
Project : Footpath CHW/18 _MC03_Hmax=4,326 m

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HS2 Ltd - Code 1 - Accepted

Project data

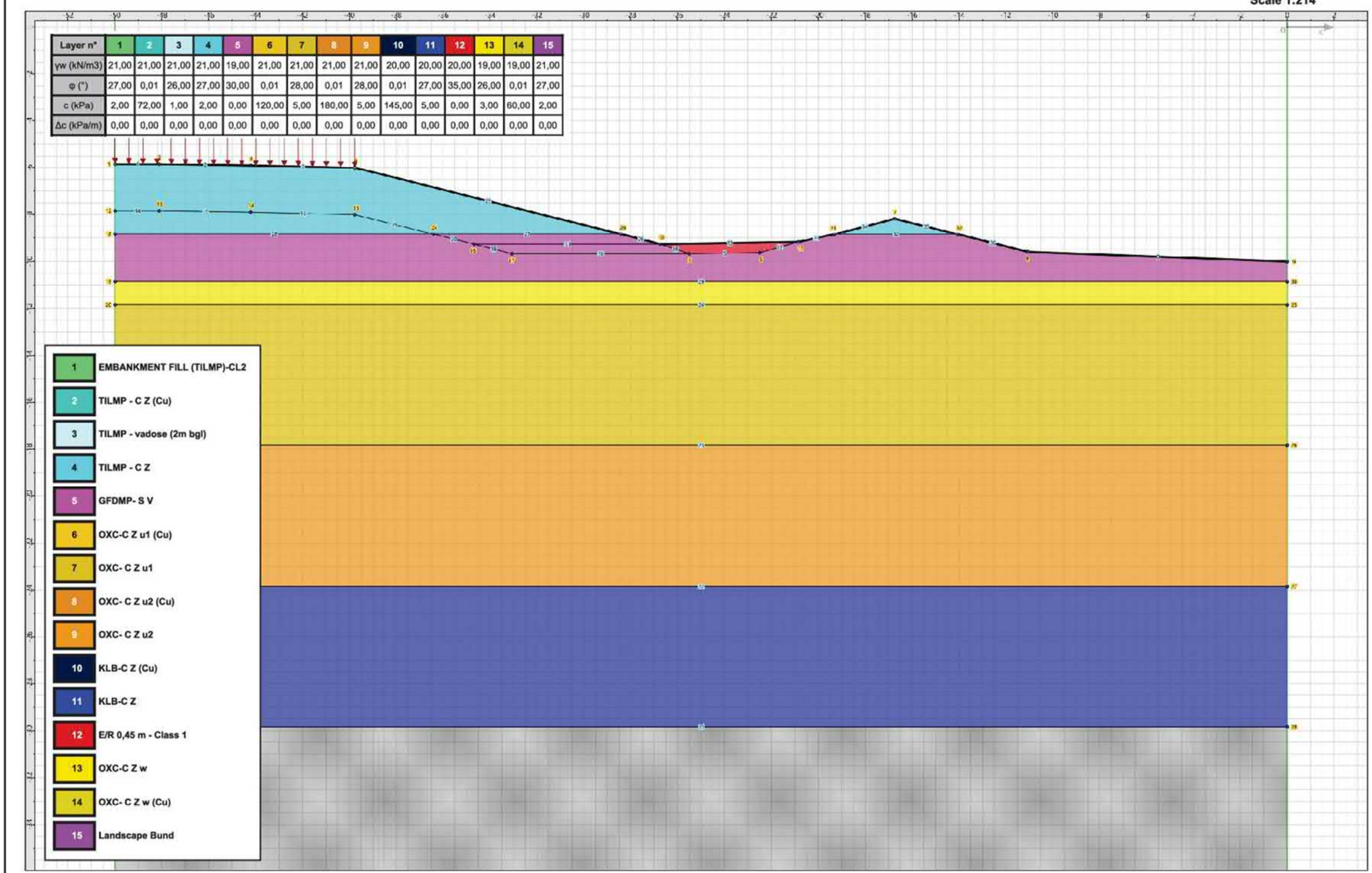
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	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	Surcharge 20 kPa	-50,000	-5,840	20,0	-39,773	-6,000	20,0	90,00

HS2 Ltd - Code 1 - Accepted

Scale 1:214

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00



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Project : Footpath CHW/18 _MC03_Hmax=4,326 m

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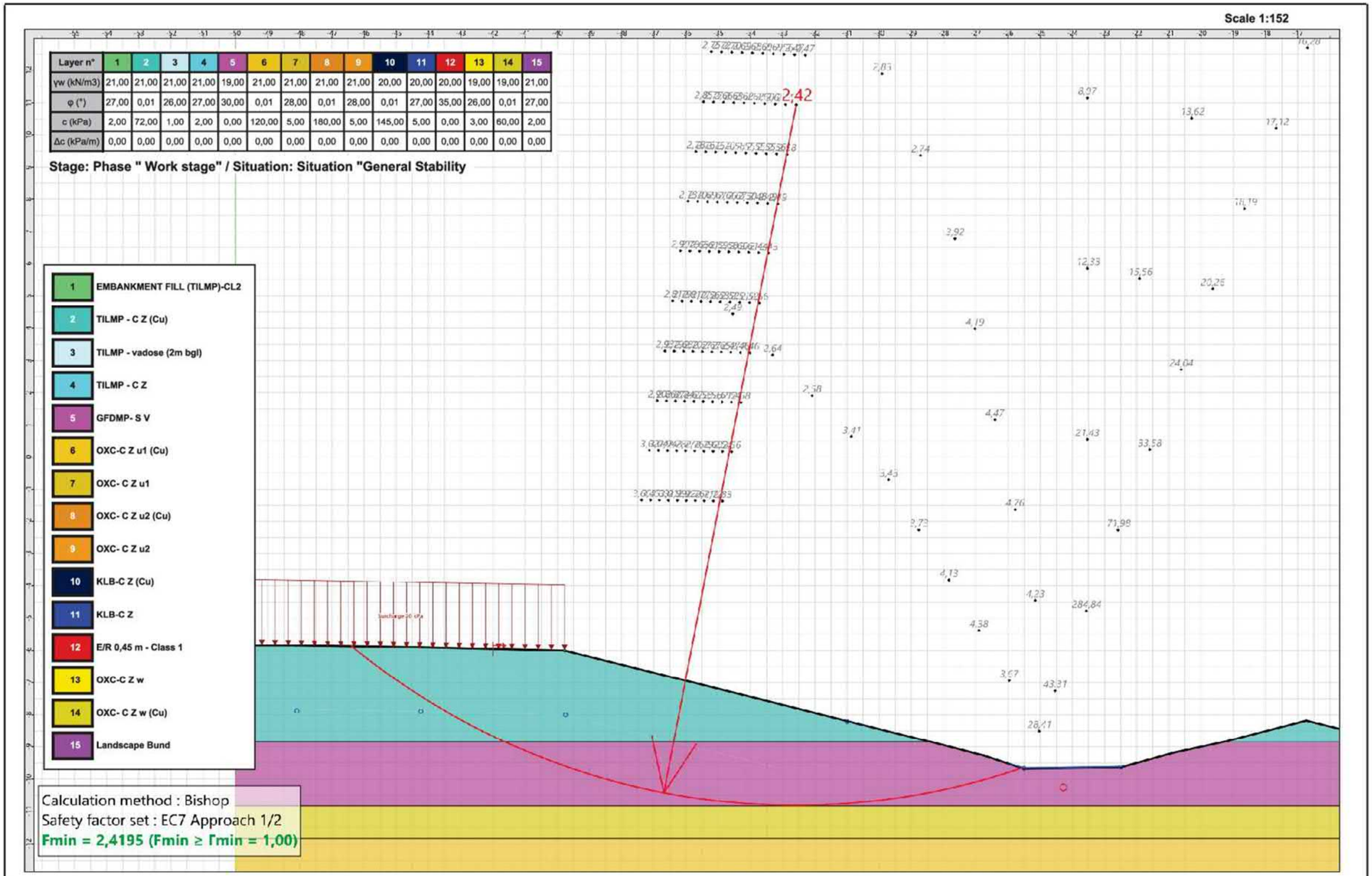
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HS2 Ltd - Code 1 - Accepted

Scale 1:152

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Work stage" / Situation: Situation "General Stability



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Project : Footpath CHW/18 _MC03_Hmax=4,326 m

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HS2 Ltd - Code 1 - Accepted

Scale 1:125

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Long term-Static" / Situation: Situation "General Stability

1 EMBANKMENT FILL (TILMP)-CL2
2 TILMP - C Z (Cu)
3 TILMP - vadose (2m bgl)
4 TILMP - C Z
5 GFDMP- S V
6 OXC-C Z u1 (Cu)
7 OXC- C Z u1
8 OXC- C Z u2 (Cu)
9 OXC- C Z u2
10 KLB-C Z (Cu)
11 KLB-C Z
12 E/R 0,45 m - Class 1
13 OXC-C Z w
14 OXC- C Z w (Cu)
15 Landscape Bund

Calculation method : Bishop
Safety factor set : EC7 Approach 1/2
Fmin = 1,4939 (Fmin ≥ Γmin = 1,00)

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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC03_Hmax=4,326 m

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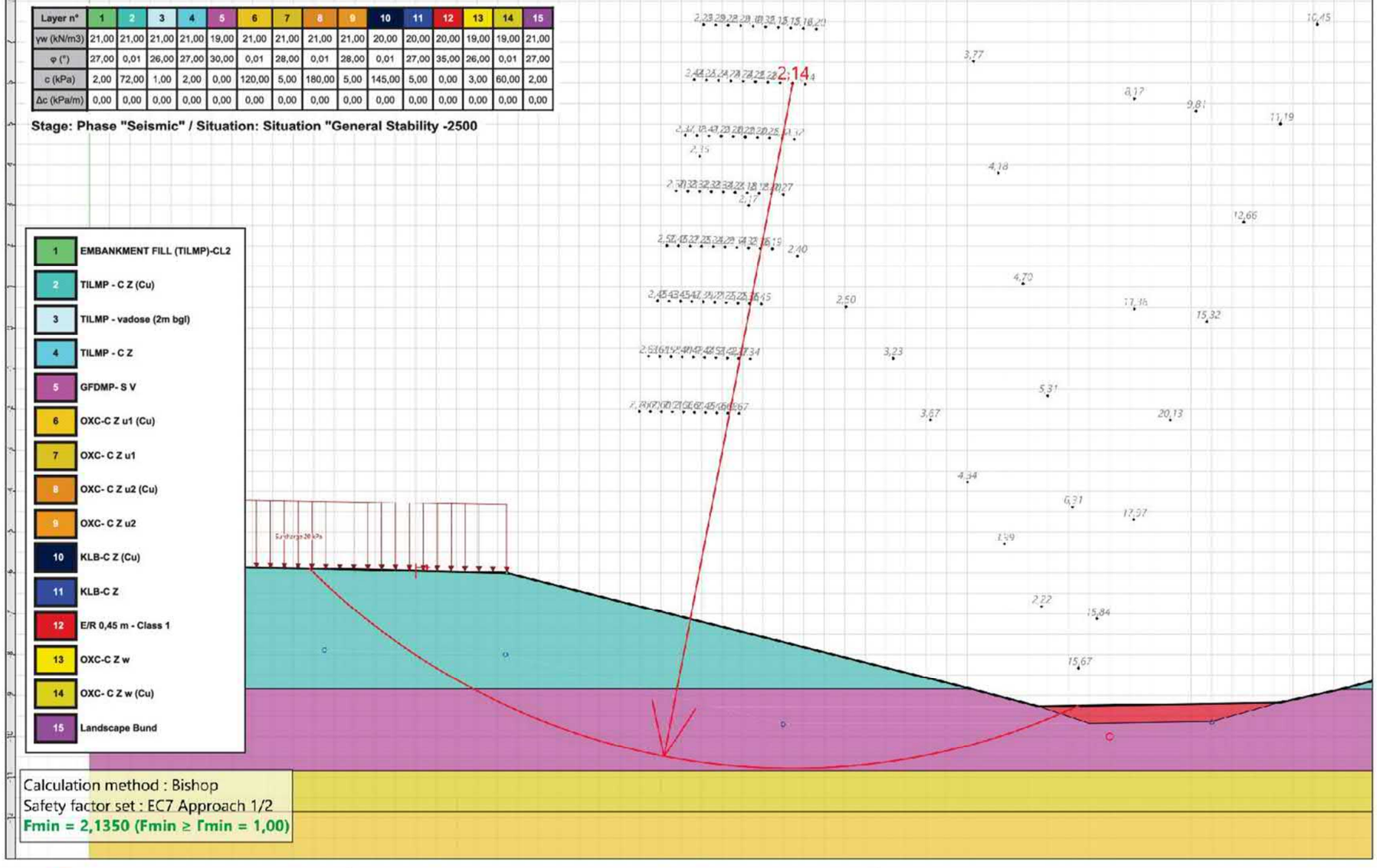
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HS2 Ltd - Code 1 - Accepted

Scale 1:125

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00	21,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01	27,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00	2,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase "Seismic" / Situation: Situation "General Stability -2500



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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _MC03_Hmax=4,326 m

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HS2 Ltd - Code 1 - Accepted

Green Highway Realignment, Ch.100, Slope 1V/4H, Hmax=1.20m

Project data

Project reference : HS2 Detail Design
Calculation title : Footpath CHW/18 _Hmax=1,2 m
Location : Ch. 100+000
Comments : Hmax Embankment between Project and Ground Levels Slope 1V/4H
Units : kN, kPa, kN/m³
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	EMBANKMENT FILL (TILMP)-CL2		21,0	27,00	2,0	0,0	-	-	-	No	No	No
2	TILMP - C Z (Cu)		21,0	0,01	72,0	0,0	-	-	-	No	No	No
3	TILMP - vadose (2m bgl)		21,0	26,00	1,0	0,0	-	-	-	No	No	No
4	TILMP - C Z		21,0	27,00	2,0	0,0	-	-	-	No	No	No
5	GFDMP- S V		19,0	30,00	0,0	0,0	-	-	-	No	No	No
6	OXC-C Z u1 (Cu)		21,0	0,01	120,0	0,0	-	-	-	No	No	No
7	OXC- C Z u1		21,0	28,00	5,0	0,0	-	-	-	No	No	No
8	OXC- C Z u2 (Cu)		21,0	0,01	180,0	0,0	-	-	-	No	No	No
9	OXC- C Z u2		21,0	28,00	5,0	0,0	-	-	-	No	No	No
10	KLB-C Z (Cu)		20,0	0,01	145,0	0,0	-	-	-	No	No	No
11	KLB-C Z		20,0	27,00	5,0	0,0	-	-	-	No	No	No
12	E/R 0,45 m - Class 1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
13	OXC-C Z w		19,0	26,00	3,0	0,0	-	-	-	No	No	No
14	OXC- C Z w (Cu)		19,0	0,01	60,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	EMBANKMENT FILL (TILMP)-CL2		-	-	-	Effective	Linear	No	-	-
2	TILMP - C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
3	TILMP - vadose (2m bgl)		-	-	-	Effective	Linear	No	-	-
4	TILMP - C Z		-	-	-	Effective	Linear	No	-	-
5	GFDMP- S V		-	-	-	Effective	Linear	No	-	-
6	OXC-C Z u1 (Cu)		-	-	-	Undrained	Linear	No	-	-
7	OXC- C Z u1		-	-	-	Effective	Linear	No	-	-
8	OXC- C Z u2 (Cu)		-	-	-	Undrained	Linear	No	-	-
9	OXC- C Z u2		-	-	-	Effective	Linear	No	-	-
10	KLB-C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
11	KLB-C Z		-	-	-	Effective	Linear	No	-	-
12	E/R 0,45 m - Class 1		-	-	-	Effective	Linear	No	-	-
13	OXC-C Z w		-	-	-	Effective	Linear	No	-	-
14	OXC- C Z w (Cu)		-	-	-	Effective	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	30,000	-5,868	2	29,567	-5,681	3	29,295	-5,712	4	28,416	-5,370	5	27,000	-5,370	6	26,198	-5,424
7	25,326	-5,323	8	23,202	-5,000	9	21,886	-4,919	10	20,271	-4,919	11	18,872	-4,919	12	17,000	-5,000
13	14,594	-4,918	14	12,342	-4,841	15	10,332	-4,794	16	9,190	-4,813	17	7,550	-4,874	18	5,371	-4,899
19	4,610	-4,889	20	4,000	-4,889	21	20,875	-3,823	22	20,574	-3,803	23	17,627	-3,739	24	16,713	-3,732
25	14,925	-3,687	26	12,888	-3,744	27	25,000	-5,574	28	23,661	-5,407	29	22,466	-5,289	30	21,429	-5,230
31	19,645	-5,219	32	18,609	-5,230	33	16,500	-5,284	34	15,286	-5,257	35	13,754	-5,198	36	11,612	-5,134
37	9,769	-5,091	38	30,000	-7,868	39	29,567	-7,681	40	29,295	-7,712	41	28,416	-7,370	42	27,000	-7,370
44	25,326	-7,323	45	23,202	-7,000	46	21,886	-6,919	47	20,271	-6,919	48	18,872	-6,919	49	17,000	-7,000
50	14,594	-6,918	51	12,342	-6,841	52	10,332	-6,794	53	9,190	-6,813	54	7,550	-6,874	55	5,371	-6,899
56	4,610	-6,889	57	4,000	-6,889	58	26,130	-7,382	59	40,000	-10,000	60	4,000	-10,000	61	40,000	-14,000
62	4,000	-14,000	63	40,000	-20,000	64	4,000	-20,000	65	40,000	-26,000	66	4,000	-26,000	67	40,000	-32,000
68	4,000	-32,000	69	40,000	-5,863	70	40,000	-7,834									

Segments (1/2)

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8
8	8	9	9	9	10	10	10	11	11	11	12	12	12	13	13	13	14	14	14	15

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Calculation made by : SETEC ALS
Project : Footpath CHW/18 _Hmax=1,2 m

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HS2 Ltd - Code 1 - Accepted

Project data

Segments (2/2)

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
15	15	16	16	16	17	17	17	18	18	18	19	19	19	20	20	7	21	21	21	22
22	22	23	23	23	24	24	24	25	25	25	26	26	26	16	27	7	27	28	27	28
29	28	29	30	29	30	31	30	31	32	31	32	33	32	33	34	33	34	35	34	35
36	35	36	37	36	37	38	37	16	39	57	56	40	56	55	41	55	54	42	54	53
43	53	52	44	52	51	45	51	50	46	50	49	47	49	48	48	48	47	49	47	46
50	46	45	51	45	44	52	44	58	53	58	42	54	42	41	55	41	40	56	40	39
57	39	38	58	59	60	59	61	62	60	63	64	61	65	66	62	67	68	63	69	70
64	1	69	65	38	70															

Distributed loads

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	Surcharge 20kPa	12,888	-3,744	20,0	20,875	-3,823	20,0	90,00

terrasol
setec

Talren v6
v6.0.13

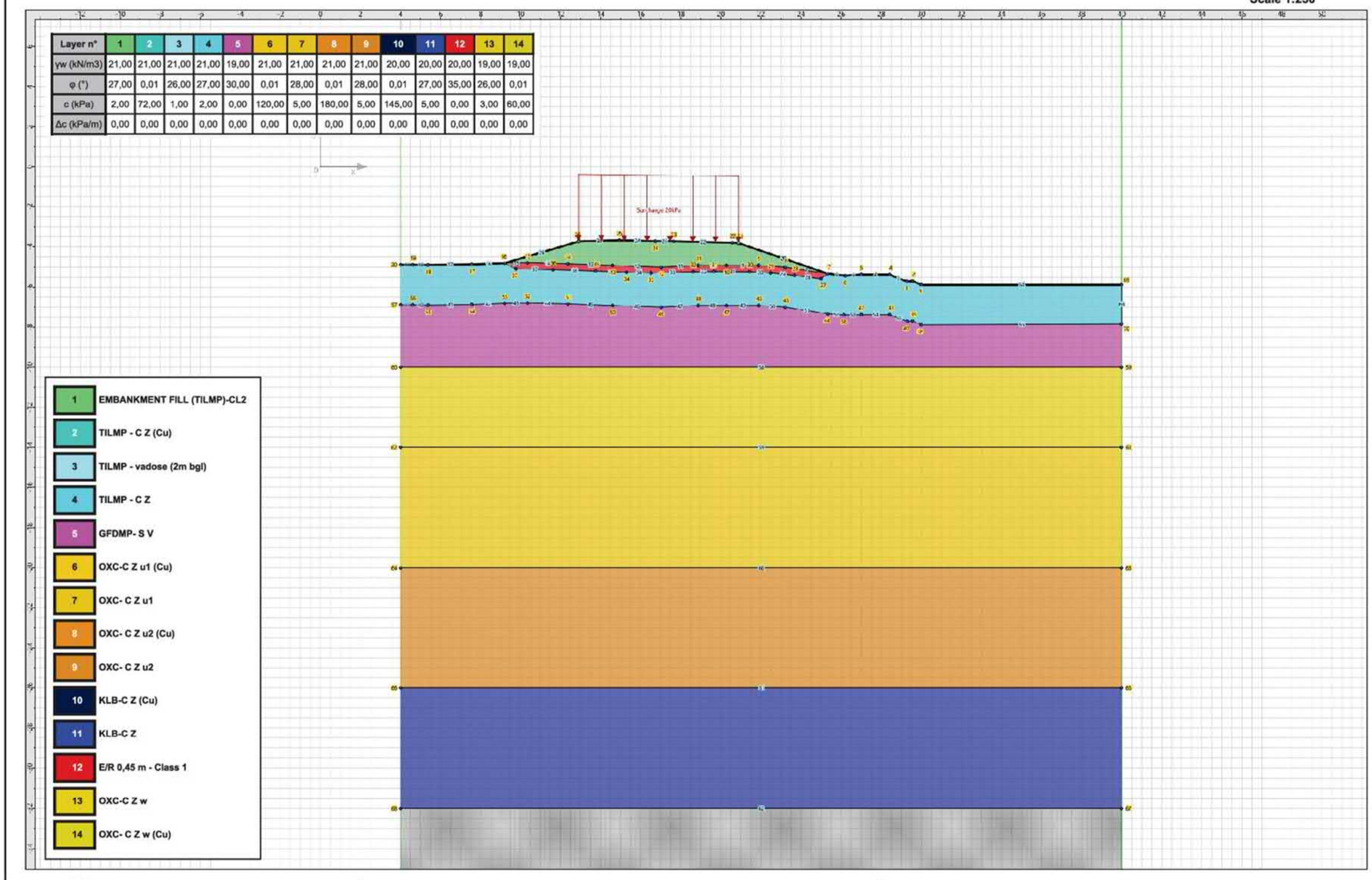
Printed on : May 24, 2022 6:00:57 PM
Calculation made by : SETEC ALS
Project : Footpath CHW/18 _Hmax=1,2 m

C:\Users\anne-laure.foumet\Documents\HS2\HW\Chetwode Cutting\CHW18\Stability assessment\MC05\CHW18_MC05_Ch.100_Max height_H=1.2m.t6p Page 2/9

HS2 Ltd - Code 1 - Accepted

Scale 1:250

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00



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setec

Talren v6
v6.0.13

Printed on : May 24, 2022 6:00:57 PM
Calculation made by : SETEC ALS

Project : Footpath CHW/18 _Hmax=1,2 m

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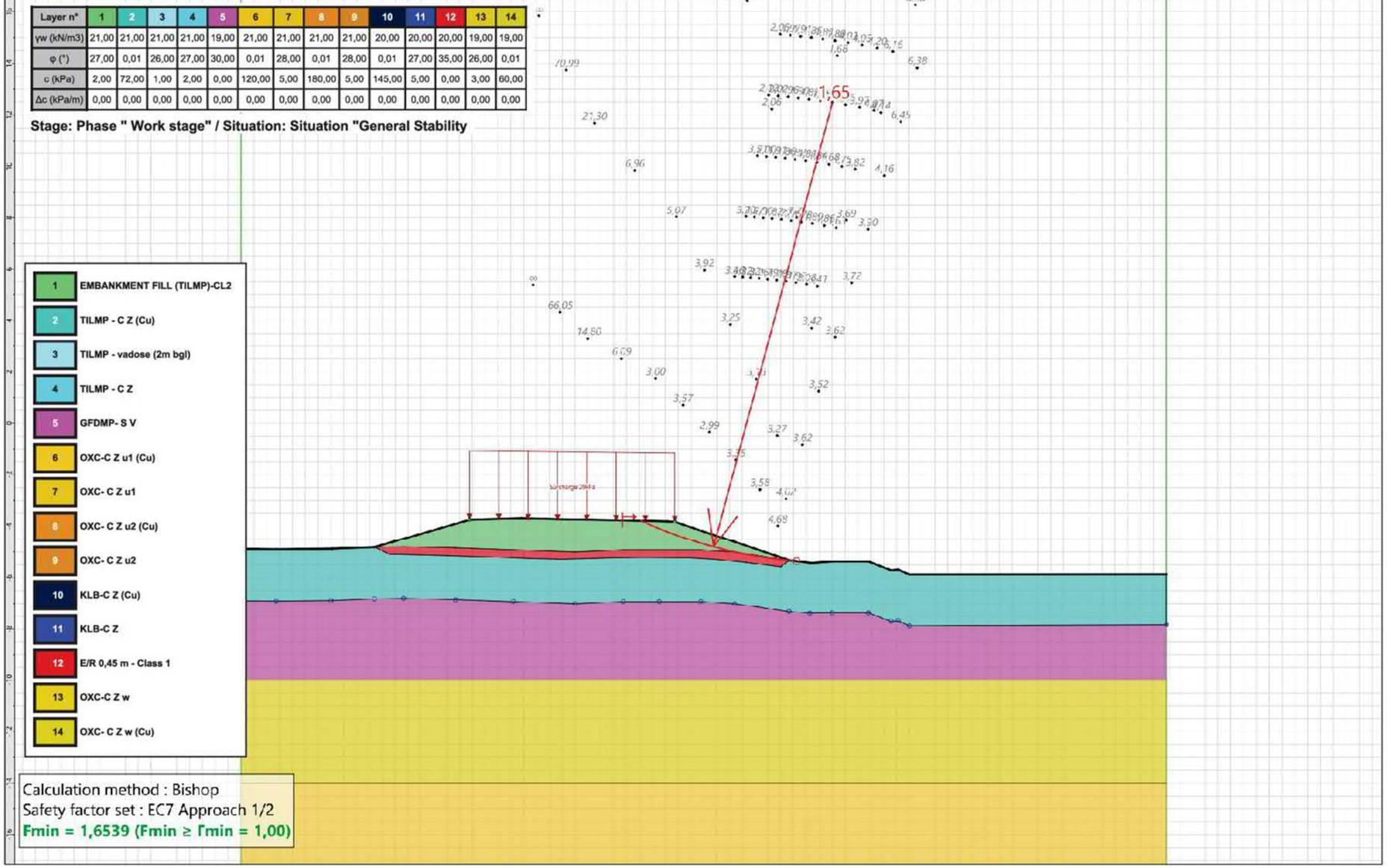
Page 3/9

HS2 Ltd - Code 1 - Accepted

Scale 1:200

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Work stage" / Situation: Situation "General Stability"



1 EMBANKMENT FILL (TILMP)-CL2
2 TILMP - C Z (Cu)
3 TILMP - vadose (2m bgl)
4 TILMP - C Z
5 GFDMP- S V
6 OXC-C Z u1 (Cu)
7 OXC- C Z u1
8 OXC- C Z u2 (Cu)
9 OXC- C Z u2
10 KLB-C Z (Cu)
11 KLB-C Z
12 E/R 0,45 m - Class 1
13 OXC-C Z w
14 OXC- C Z w (Cu)

Calculation method : Bishop
Safety factor set : EC7 Approach 1/2
Fmin = 1,6539 (Fmin ≥ Γmin = 1,00)

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v6.0.13

Printed on : May 24, 2022 6:00:57 PM
Calculation made by : SETEC ALS

Project : Footpath CHW/18 _Hmax=1,2 m

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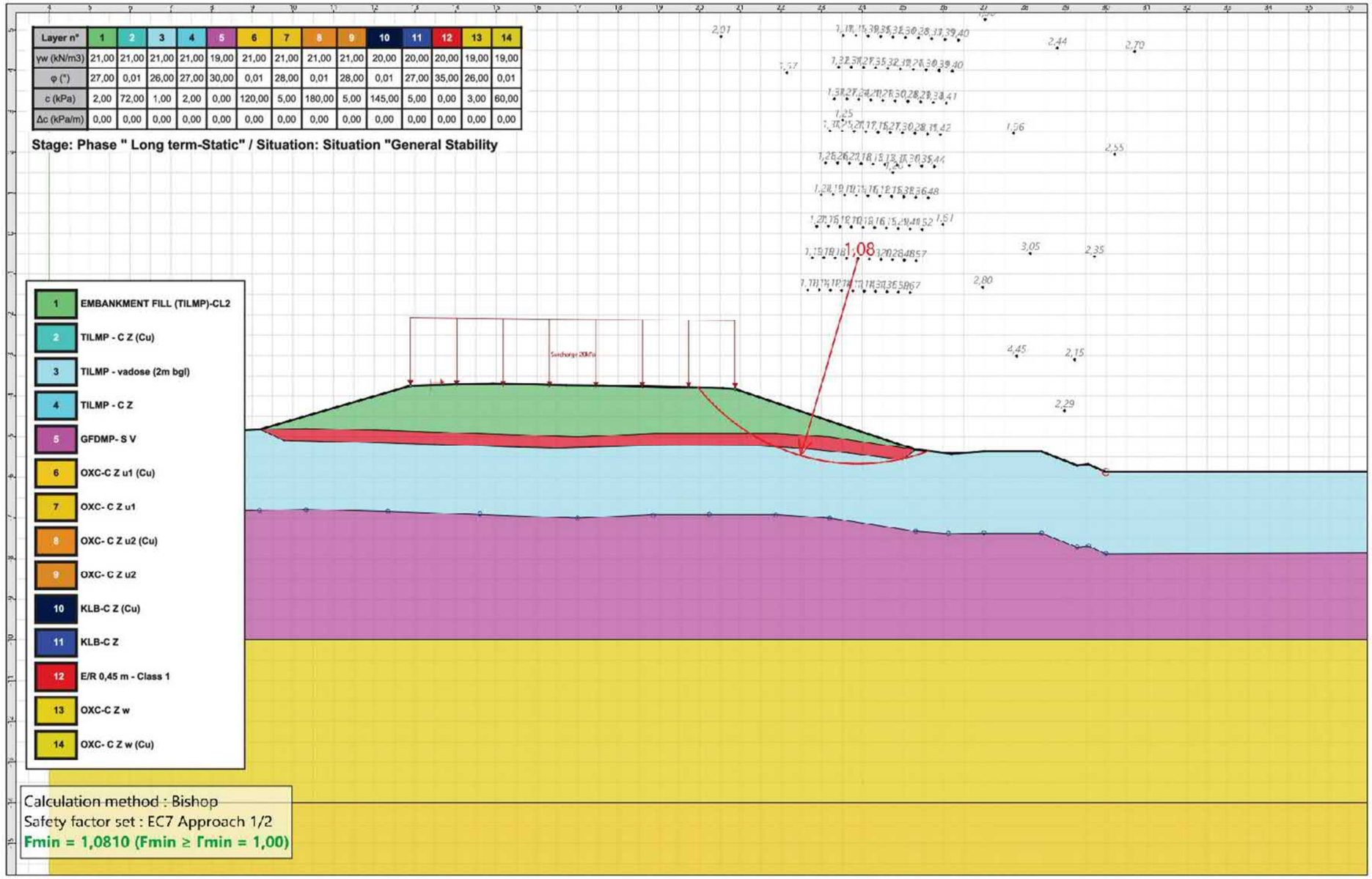
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HS2 Ltd - Code 1 - Accepted

Scale 1:125

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12	13	14
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00	19,00	19,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00	26,00	0,01
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00	3,00	60,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Long term-Static" / Situation: Situation "General Stability"



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Talren v6
v6.0.13

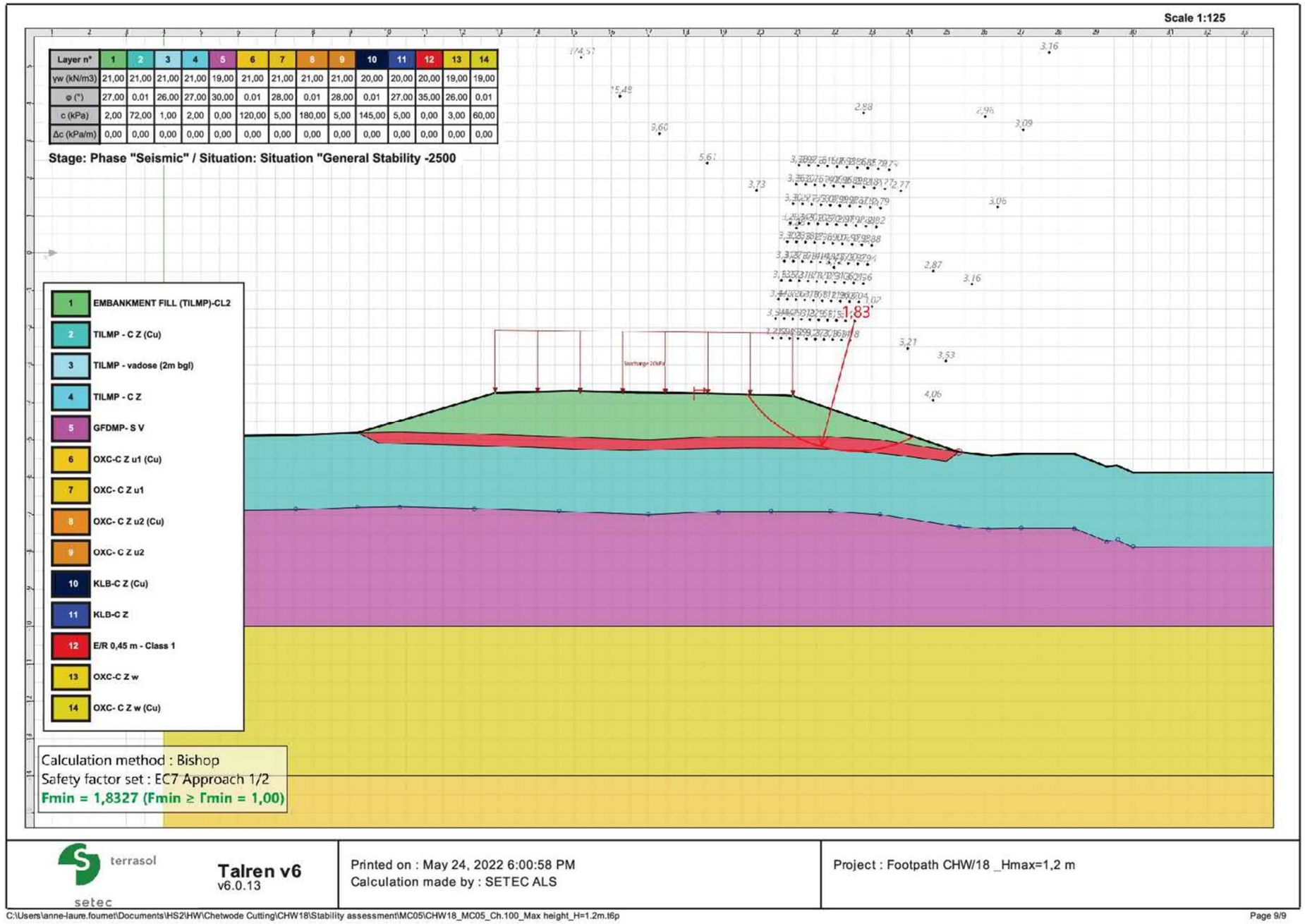
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Calculation made by : SETEC ALS

Project : Footpath CHW/18 _Hmax=1,2 m

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HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

School End Road Realignment, Ch.200, Slope 1V/4H, Hmax=5.62m

Project data

Project reference : HS2 Detail Design
Calculation title : School End Realignment _Hmax=5,62 m
Location : Ch. 200+000
Comments : Hmax Embankment Slope 1V/4H (Both Sides)
Units : kN, kPa, kN/m³
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	EMBANKMENT FILL (TILMP)-CL2		21,0	27,00	2,0	0,0	-	-	-	No	No	No
2	TILMP - C Z (Cu)		21,0	0,01	72,0	0,0	-	-	-	No	No	No
3	TILMP - vadose (2m bgl)		21,0	26,00	1,0	0,0	-	-	-	No	No	No
4	TILMP - C Z		21,0	27,00	2,0	0,0	-	-	-	No	No	No
5	GFDMP- S V		19,0	30,00	0,0	0,0	-	-	-	No	No	No
6	OXC-C Z u1 (Cu)		21,0	0,01	120,0	0,0	-	-	-	No	No	No
7	OXC- C Z u1		21,0	28,00	5,0	0,0	-	-	-	No	No	No
8	OXC- C Z u2 (Cu)		21,0	0,01	180,0	0,0	-	-	-	No	No	No
9	OXC- C Z u2		21,0	28,00	5,0	0,0	-	-	-	No	No	No
10	KLB-C Z (Cu)		20,0	0,01	145,0	0,0	-	-	-	No	No	No
11	KLB-C Z		20,0	27,00	5,0	0,0	-	-	-	No	No	No
12	E/R 0,45 m - Class 1		20,0	35,00	0,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	EMBANKMENT FILL (TILMP)-CL2		-	-	-	Effective	Linear	No	-	-
2	TILMP - C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
3	TILMP - vadose (2m bgl)		-	-	-	Effective	Linear	No	-	-
4	TILMP - C Z		-	-	-	Effective	Linear	No	-	-
5	GFDMP- S V		-	-	-	Effective	Linear	No	-	-
6	OXC-C Z u1 (Cu)		-	-	-	Undrained	Linear	No	-	-
7	OXC- C Z u1		-	-	-	Effective	Linear	No	-	-
8	OXC- C Z u2 (Cu)		-	-	-	Undrained	Linear	No	-	-
9	OXC- C Z u2		-	-	-	Effective	Linear	No	-	-
10	KLB-C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
11	KLB-C Z		-	-	-	Effective	Linear	No	-	-
12	E/R 0,45 m - Class 1		-	-	-	Effective	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	25,000	-10,000	2	18,500	-10,000	3	16,500	-10,155	4	15,500	-10,500	5	13,850	-11,000	6	12,793	-11,156
7	11,819	-11,657	8	11,000	-11,796	9	9,288	-12,000	10	7,313	-12,769	11	6,000	-13,000	12	4,754	-13,000
13	2,696	-14,216	14	1,500	-14,500	15	-0,000	-14,661	16	-1,000	-14,772	17	-1,500	-14,716	18	-5,287	-14,855
19	-6,500	-14,828	20	-8,681	-14,500	21	-10,500	-14,000	22	-12,500	-13,284	23	-14,354	-12,500	24	-16,158	-12,163
25	-17,500	-11,726	26	-18,666	-11,500	27	-19,500	-11,500	28	-20,237	-11,500	29	-21,080	-11,500	30	-22,000	-11,170
31	-23,193	-10,628	32	-24,344	-10,150	33	-25,153	-9,858	34	-26,000	-9,692	35	-27,290	-9,500	36	-28,266	-9,500
37	-29,000	-9,430	38	-29,649	-9,344	39	-30,000	-9,355	40	16,000	-9,349	41	13,143	-9,155	42	9,000	-9,210
43	5,000	-9,238	44	2,500	-9,183	45	-0,000	-8,951	46	-2,712	-9,000	47	-5,285	-9,163	48	-8,500	-9,266
49	-11,404	-9,452	98	-18,660	-11,950	99	-17,567	-12,176	100	-16,161	-12,613	101	-14,366	-12,950	102	-12,500	-13,734
103	-10,500	-14,450	104	-8,683	-14,950	105	-6,500	-15,278	106	-5,298	-15,305	107	-1,500	-15,166	108	0,000	-15,111
109	-1,000	-15,220	110	1,500	-14,950	111	2,708	-14,666	112	4,773	-13,450	113	6,000	-13,450	114	7,317	-13,219
115	9,295	-12,450	116	11,000	-12,219	117	11,837	-12,044	118	12,795	-11,556	119	13,874	-11,450	120	16,500	-10,605
121	18,204	-10,295	122	-19,000	-11,925	123	-1,000	-16,720	124	-1,000	-18,220	125	25,000	-18,220	126	-30,000	-18,220
127	-1,000	-22,520	128	25,000	-22,520	129	-30,000	-22,520	130	-1,000	-30,220	131	-1,000	-35,220	132	-1,000	-40,220
133	25,000	-30,220	134	-30,000	-30,220	135	25,000	-35,220	136	-30,000	-35,220	137	25,000	-40,220	138	-30,000	-40,220
139	0,000	-16,500	140	1,500	-16,241	141	2,730	-15,840	142	4,733	-14,853	143	6,000	-14,810	144	7,323	-14,423
145	9,270	-13,894	146	11,000	-13,579	147	11,803	-13,350	148	12,797	-13,000	149	13,870	-13,000	150	16,500	-12,500
151	18,242	-12,000	152	25,000	-12,000	153	-5,260	-16,699	154	-6,500	-16,657	155	-8,742	-16,500	156	-10,500	-16,131
157	-12,500	-15,599	158	-14,435	-14,897	159	-16,217	-14,500	160	-17,500	-14,028	161	-19,092	-13,570	162	-21,000	-13,500
163	-25,174	-11,858	164	-27,309	-11,500	165	-29,000	-11,430	166	-30,000	-11,372						

terrasol
setec

Talren v6
v6.0.15

Printed on : May 31, 2022 3:47:51 PM
Calculation made by : SETEC ALS
Project : School End Realignment _Hmax=5,62 m

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HS2 Ltd - Code 1 - Accepted

Project data

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8
8	8	9	9	9	10	10	10	11	11	11	12	12	12	13	13	13	14	14	14	15
15	15	16	16	16	17	17	17	18	18	18	19	19	19	20	20	20	21	21	21	22
22	22	23	23	23	24	24	24	25	25	25	26	26	26	27	27	27	28	28	28	29
29	29	30	30	30	31	31	31	32	32	32	33	33	33	34	34	34	35	35	35	36
36	36	37	37	37	38	38	38	39	39	2	40	40	40	41	41	41	42	42	42	43
43	43	44	44	44	45	45	45	46	46	46	47	47	47	48	48	48	49	49	49	27
100	98	99	101	99	100	102	100	101	103	101	102	104	102	103	105	103	104	106	104	105
107	105	106	108	106	107	109	107	109	112	109	108	113	108	110	114	110	111	115	111	112
116	112	113	117	113	114	118	114	115	119	115	116	120	116	117	121	117	118	122	118	119
123	119	120	124	120	121	125	121	2	126	98	122	127	122	27	130	124	125	131	124	126
133	127	128	134	127	129	138	130	133	139	130	134	140	131	135	141	131	136	142	132	137
143	132	138	144	123	139	145	139	140	146	140	141	147	141	142	148	142	143	149	143	144
150	144	145	151	145	146	152	146	147	153	147	148	154	148	149	155	149	150	156	150	151
157	151	152	158	123	153	159	153	154	160	154	155	161	155	156	162	156	157	163	157	158
164	158	159	165	159	160	166	160	161	167	161	162	168	162	163	169	163	164	170	164	165
171	165	166																		

Distributed loads

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	Surcharge = 20kPa	-11,404	-9,452	20,0	16,000	-9,349	20,0	90,00

terrasol setec

Talren v6
v6.0.15

Printed on : May 31, 2022 3:47:51 PM
Calculation made by : SETEC ALS
Project : School End Realignment _Hmax=5,62 m

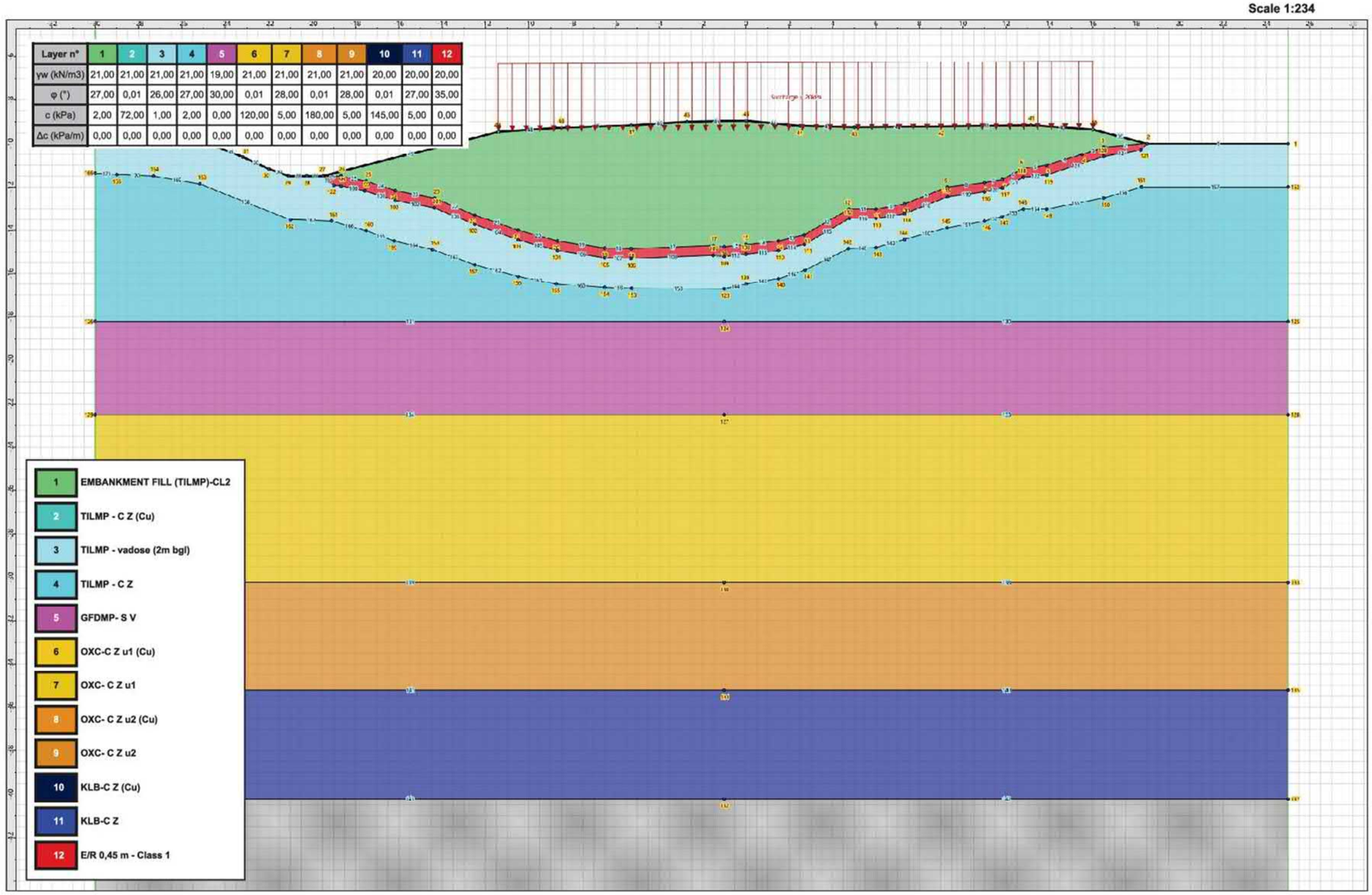
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HS2 Ltd - Code 1 - Accepted

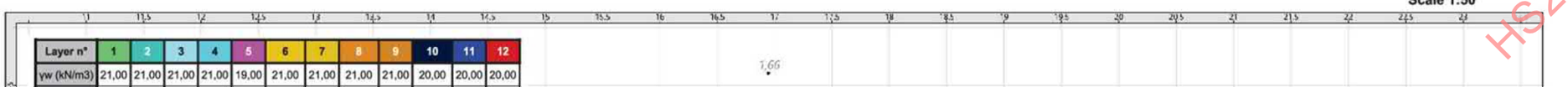
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γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

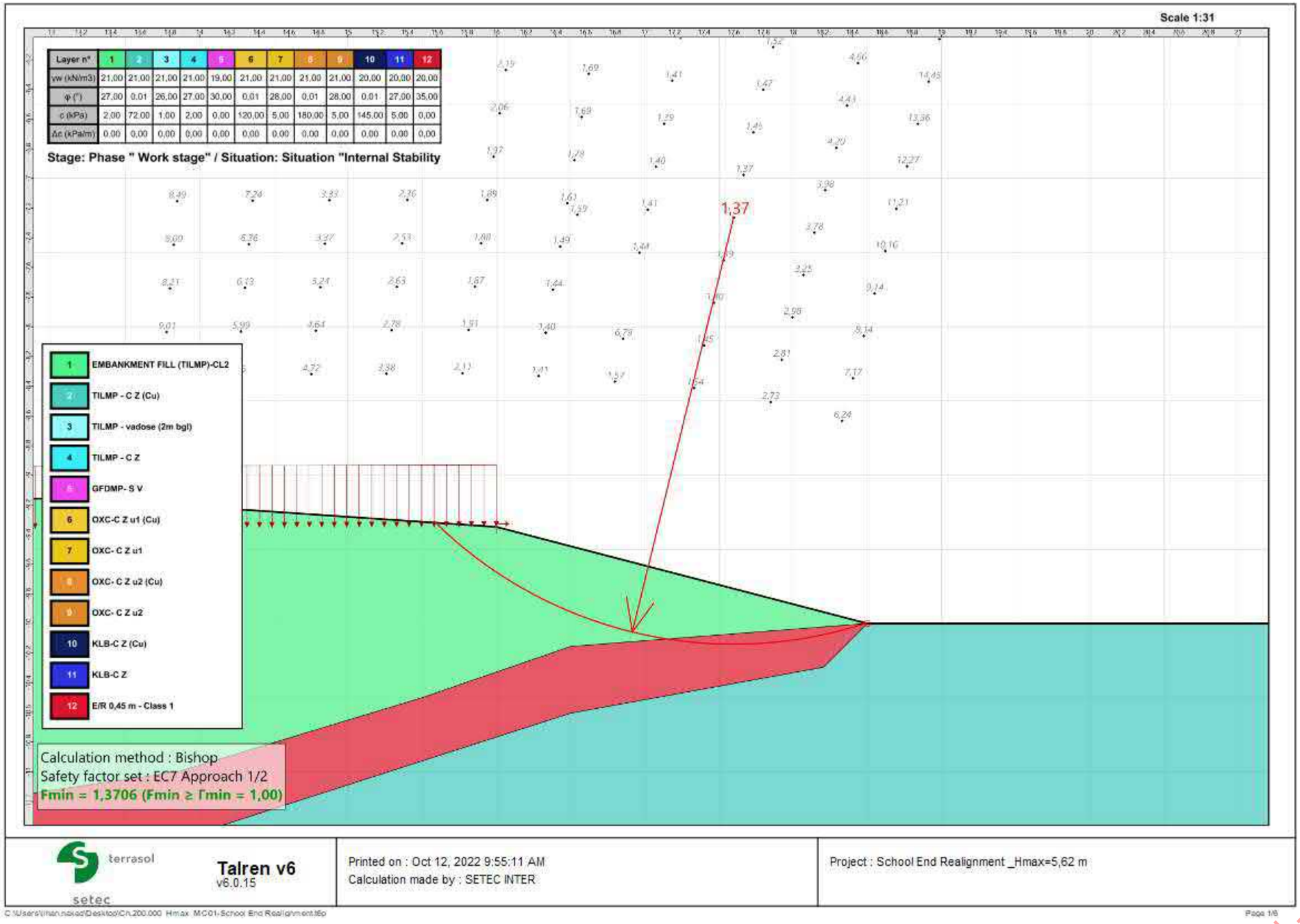


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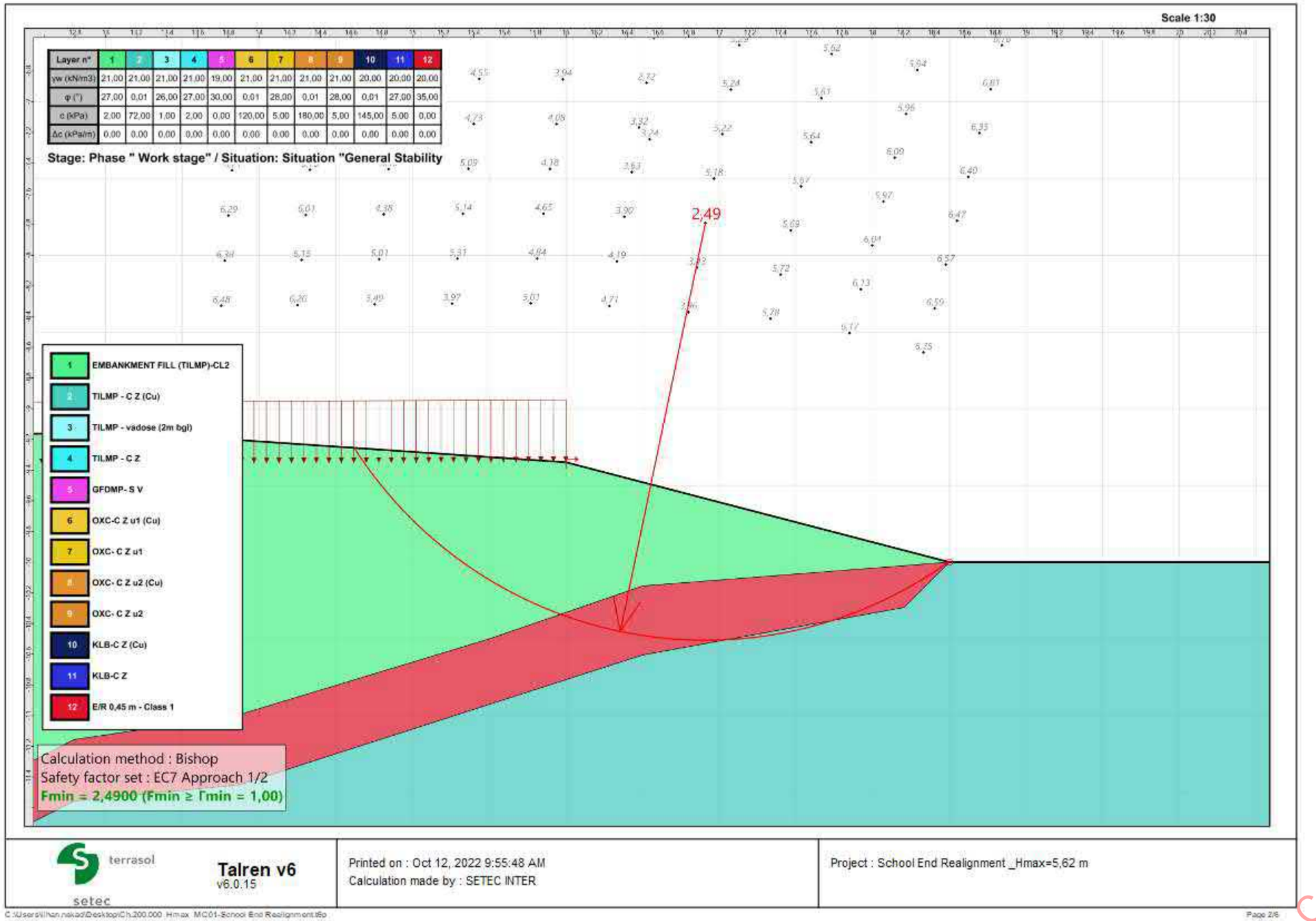
Layer n°	1	2	3	4	5	6	7	8	9	10	11	12
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00



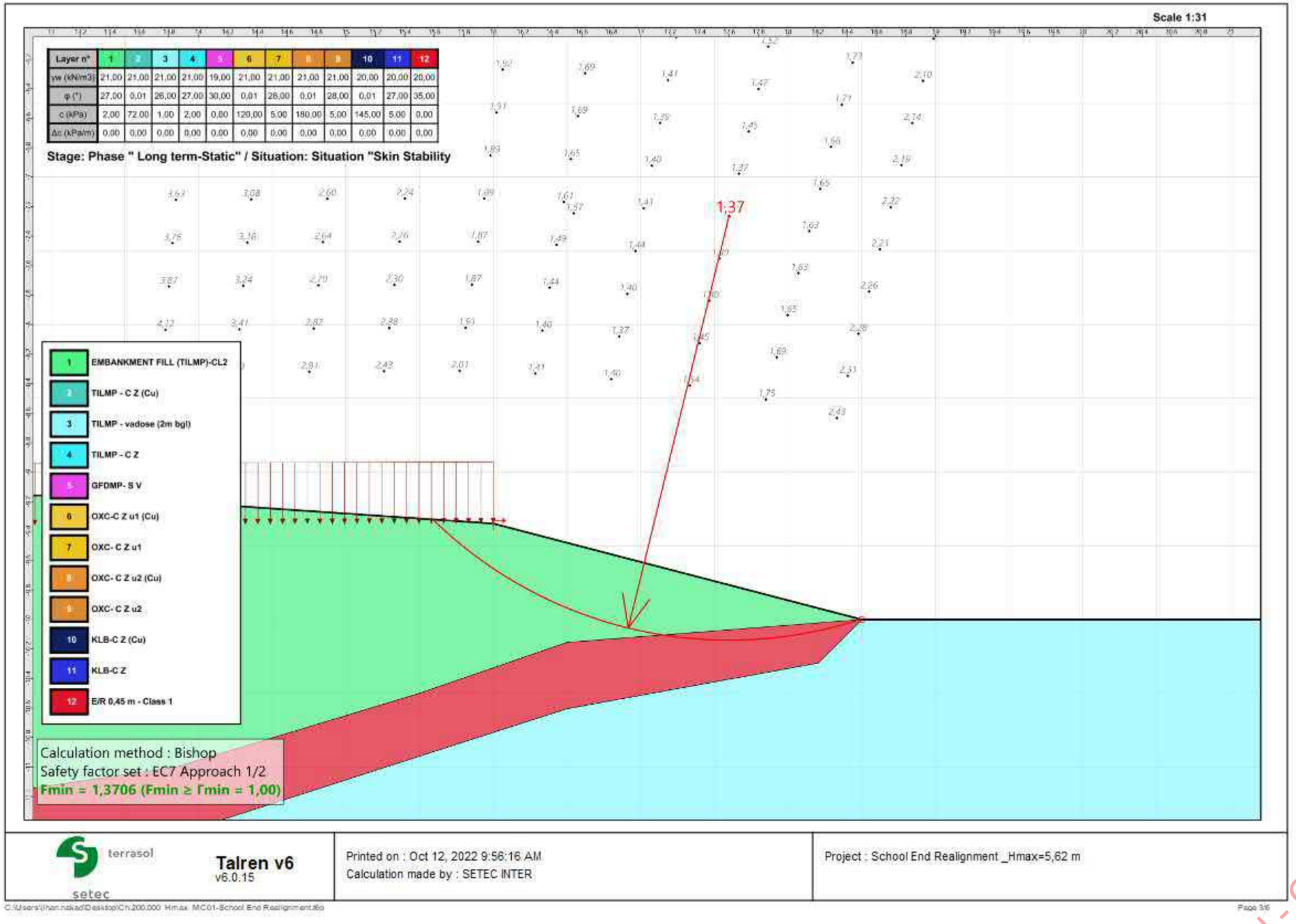
HS2 Ltd - Code 1 - Accepted



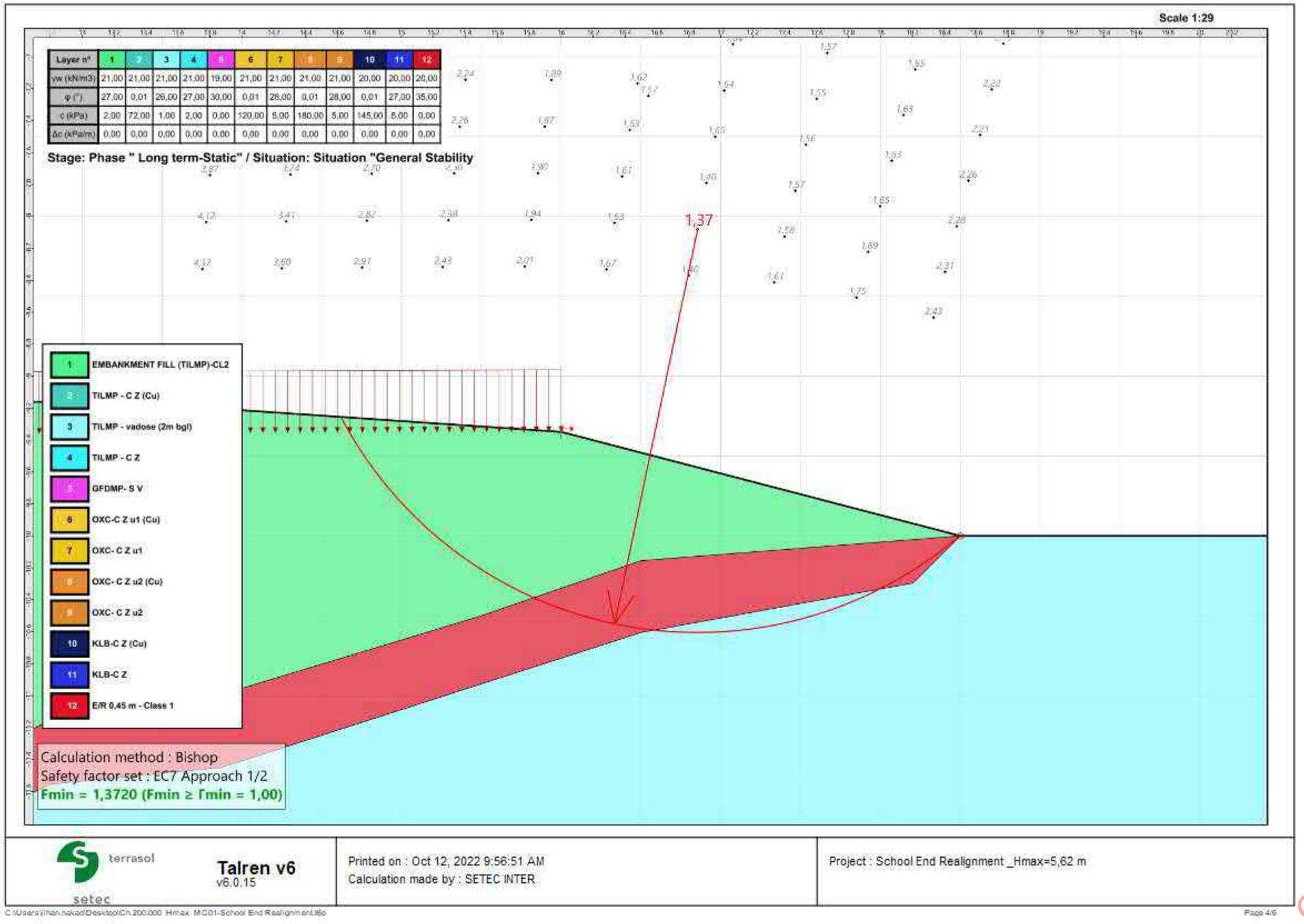
HS2 Ltd - Code 1 - Accepted



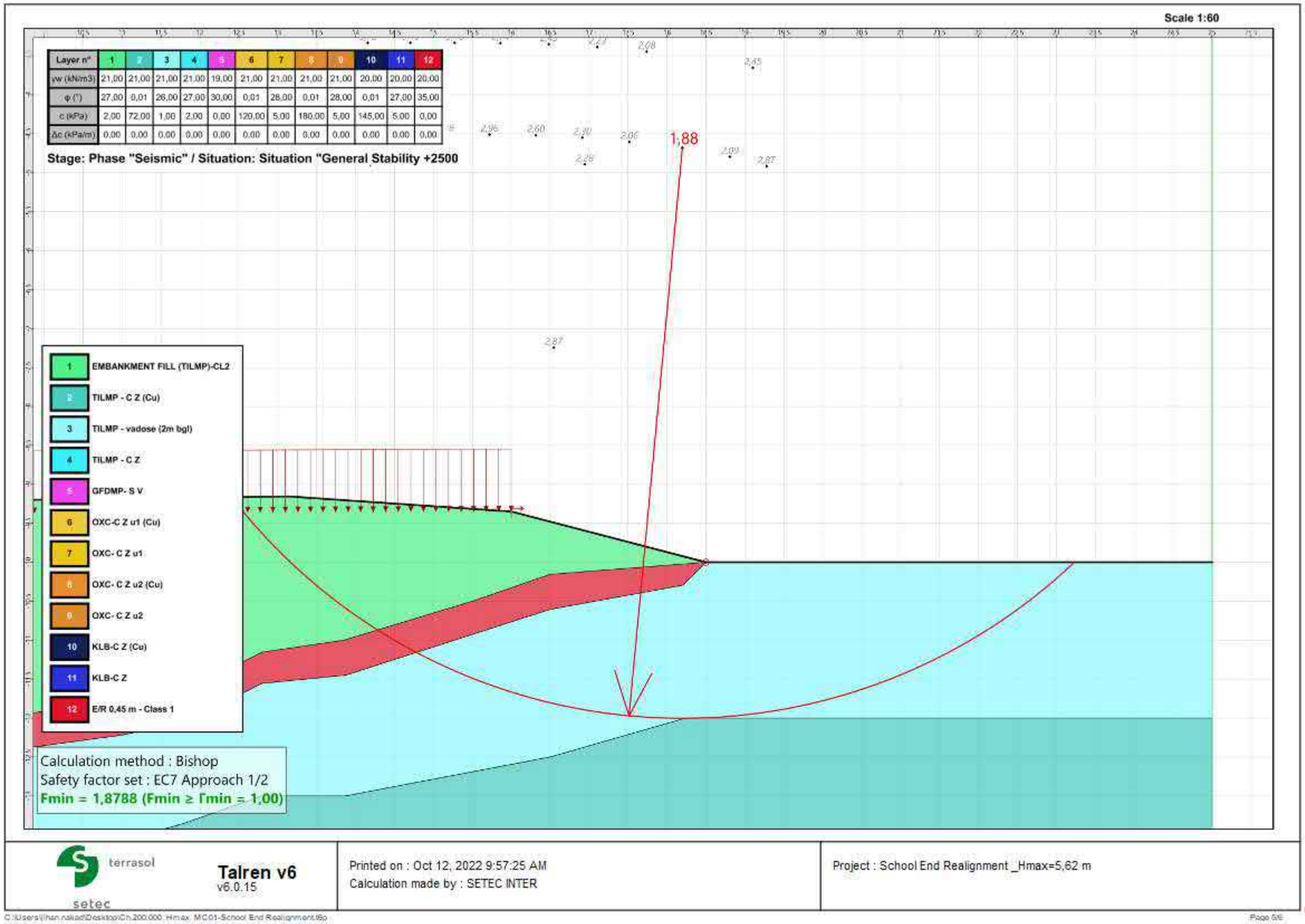
HS2 Ltd - Code 1 - Accepted



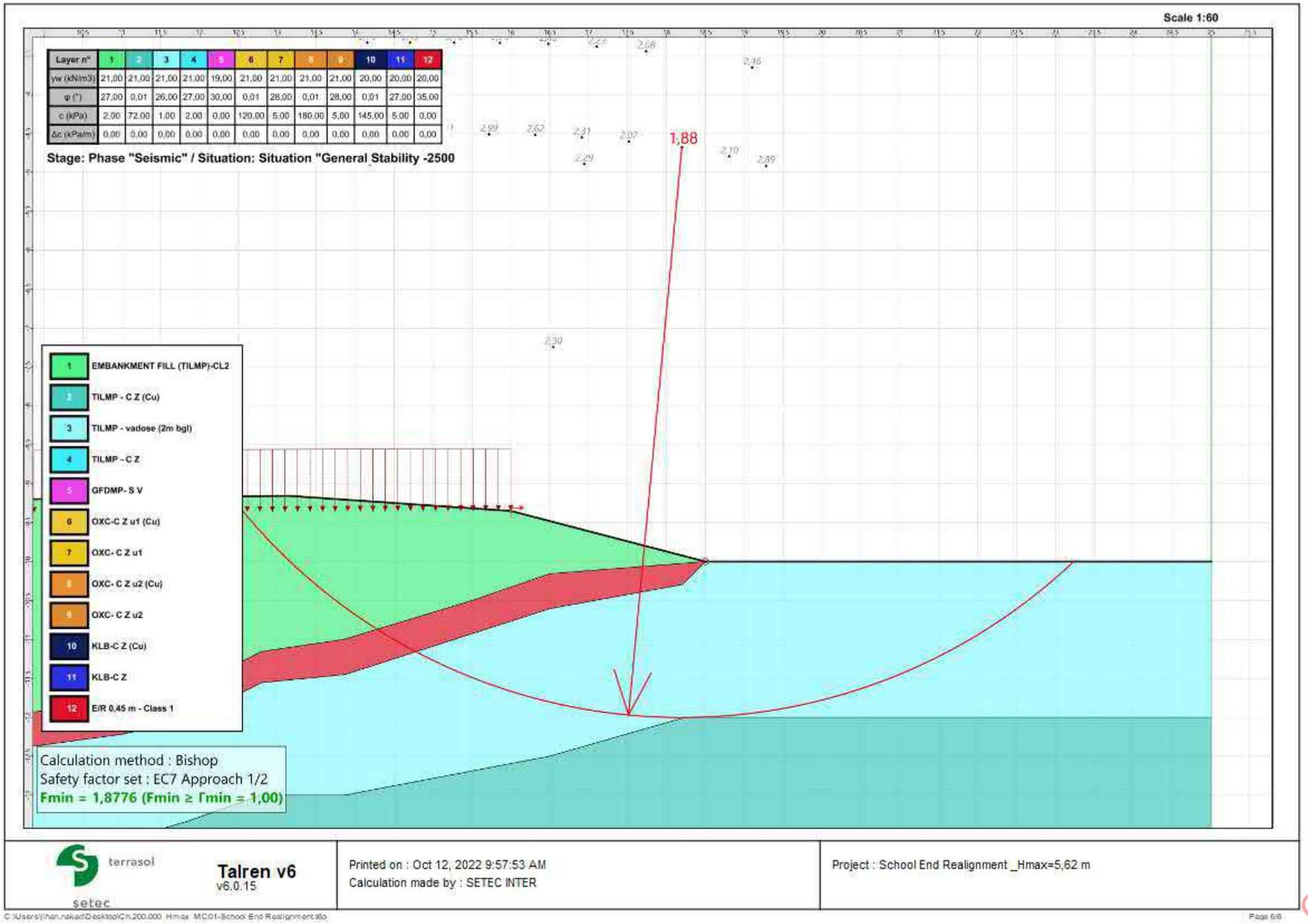
HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

Maintenance Access Road to Pond (off School End Road South), Ch.12.779, Slope 1V/4H, Hmax=6.19m

Project data

Project reference : HS2 Detail Design

Calculation title : Maintenance Access Road to Pond (off School End Road South) _Hmax=6,19 m

Location : Ch. 12+779

Comments : Hmax Embankment

Units : kN, kPa, kN/m³

γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	EMBANKMENT FILL (TILMP) - CL 2		21,0	27,00	2,0	0,0	-	-	-	No	No	No
2	TILMP - C Z (Cu)		21,0	0,01	72,0	0,0	-	-	-	No	No	No
3	TILMP - vadose (2m bgl)		21,0	26,00	1,0	0,0	-	-	-	No	No	No
4	TILMP - C Z		21,0	27,00	2,0	0,0	-	-	-	No	No	No
5	GFDMP- S V		19,0	30,00	0,0	0,0	-	-	-	No	No	No
6	OXC-C Z u1 (Cu)		21,0	0,01	120,0	0,0	-	-	-	No	No	No
7	OXC- C Z u1		21,0	28,00	5,0	0,0	-	-	-	No	No	No
8	OXC- C Z u2 (Cu)		21,0	0,01	180,0	0,0	-	-	-	No	No	No
9	OXC- C Z u2		21,0	28,00	5,0	0,0	-	-	-	No	No	No
10	KLB-C Z (Cu)		20,0	0,01	145,0	0,0	-	-	-	No	No	No
11	KLB-C Z		20,0	27,00	5,0	0,0	-	-	-	No	No	No
12	E/R 0,45 m - Class 1		20,0	35,00	0,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	EMBANKMENT FILL (TILMP) - CL 2		-	-	-	Effective	Linear	No	-	-
2	TILMP - C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
3	TILMP - vadose (2m bgl)		-	-	-	Effective	Linear	No	-	-
4	TILMP - C Z		-	-	-	Effective	Linear	No	-	-
5	GFDMP- S V		-	-	-	Effective	Linear	No	-	-
6	OXC-C Z u1 (Cu)		-	-	-	Undrained	Linear	No	-	-
7	OXC- C Z u1		-	-	-	Effective	Linear	No	-	-
8	OXC- C Z u2 (Cu)		-	-	-	Undrained	Linear	No	-	-
9	OXC- C Z u2		-	-	-	Effective	Linear	No	-	-
10	KLB-C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
11	KLB-C Z		-	-	-	Effective	Linear	No	-	-
12	E/R 0,45 m - Class 1		-	-	-	Effective	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	-0,500	-12,362	2	1,500	-12,399	3	2,500	-12,331	4	4,000	-12,244	5	5,303	-12,000	6	6,500	-11,500
7	8,790	-11,000	8	11,783	-10,000	9	13,166	-9,392	10	13,886	-9,269	11	15,782	-8,500	12	17,171	-7,847
13	18,799	-7,211	14	19,617	-7,222	15	20,000	-7,233	16	-2,500	-12,330	17	-5,000	-12,000	18	-8,500	-10,627
19	-9,374	-10,500	20	-11,000	-10,125	21	-13,000	-9,657	22	-14,241	-9,218	23	-15,371	-8,798	24	-16,000	-8,649
25	-16,940	-8,438	26	-18,500	-8,000	27	-20,000	-7,633	28	-20,000	-7,188	29	-14,694	-7,000	30	-8,383	-6,672
31	-5,500	-6,394	32	-4,392	-6,241	33	-0,500	-6,177	34	2,372	-6,121	35	4,040	-6,144	36	6,295	-6,225
37	12,000	-7,500	38	-20,552	-7,231	39	-21,780	-7,279	40	-22,675	-7,270	41	-23,777	-7,270	42	-24,500	-7,251
43	-25,000	-7,270	44	-0,500	-12,812	45	1,500	-12,849	46	2,500	-12,781	47	4,000	-12,694	48	5,311	-12,450
49	6,500	-11,950	50	8,790	-11,450	51	11,783	-10,450	52	13,166	-9,842	53	13,886	-9,719	54	17,126	-8,157
55	16,384	-8,217	56	-20,425	-7,870	57	-18,500	-8,500	58	-16,915	-8,898	59	-16,000	-9,125	60	-15,500	-9,250
61	-14,241	-9,668	62	-13,000	-10,102	63	-11,000	-10,652	64	-9,374	-10,950	65	-8,500	-11,077	66	-5,000	-12,450
67	-2,500	-12,780	68	-0,500	-14,362	69	1,500	-14,399	70	2,843	-14,331	71	4,094	-14,244	72	5,320	-14,000
73	6,565	-13,401	74	8,909	-13,000	75	11,795	-12,125	76	13,186	-11,500	77	13,887	-11,269	78	16,000	-10,550
79	16,822	-10,000	80	17,500	-9,590	81	18,814	-9,258	82	20,000	-9,233	84	-2,358	-14,330	85	-5,000	-14,000
86	-8,500	-13,000	87	-9,370	-12,656	88	-13,000	-11,793	89	-17,000	-10,433	90	-20,500	-9,358	91	-25,000	-9,270
92	-0,500	-16,862	93	20,000	-16,862	94	-25,000	-16,862	95	-0,500	-19,862	96	20,000	-19,862	97	-25,000	-19,862
98	-0,500	-24,362	99	20,000	-24,362	100	-25,000	-24,362	101	-0,500	-27,862	102	20,000	-27,862	103	-25,000	-27,862
104	-0,500	-33,862	105	20,000	-33,862	106	-25,000	-33,862									

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Talren v6
v6.0.15

Printed on : May 31, 2022 4:02:11 PM
Calculation made by : SETEC ALS
Project : Maintenance Access Road to Pond (off School End Road South) _Hmax=6,19 m

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HS2 Ltd - Code 1 - Accepted

Project data

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8
8	8	9	9	9	10	10	10	11	12	12	13	13	13	14	14	14	15	15	1	16
16	16	17	17	17	18	18	18	19	19	19	20	20	20	21	21	21	22	22	22	23
23	23	24	24	24	25	25	25	26	26	26	27	27	28	29	28	29	30	29	30	31
30	31	32	31	32	33	32	33	34	33	34	35	34	35	36	35	36	37	36	37	12
38	27	38	39	38	28	40	38	39	41	39	40	42	40	41	43	41	42	44	42	43
46	44	45	47	45	46	48	46	47	49	47	48	50	48	49	51	49	50	52	50	51
53	51	52	54	52	53	55	53	54	56	54	12	58	55	11	59	55	12	61	38	56
62	56	57	63	57	58	64	58	59	65	59	60	66	60	61	67	61	62	68	62	63
69	63	64	70	64	65	71	65	66	72	66	67	73	67	44	74	68	69	75	69	70
76	70	71	77	71	72	78	72	73	79	73	74	80	74	75	81	75	76	82	76	77
83	77	78	84	78	79	85	79	80	86	80	81	87	81	82	88	68	84	89	84	85
90	85	86	91	86	87	92	87	88	93	88	89	94	89	90	95	90	91	96	92	93
97	92	94	99	95	96	100	95	97	102	98	99	103	98	100	105	101	102	106	101	103
108	104	105	109	104	106															

Distributed loads

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	Surcharge = 20kPa	-4,392	-6,241	20,0	6,295	-6,225	20,0	90,00

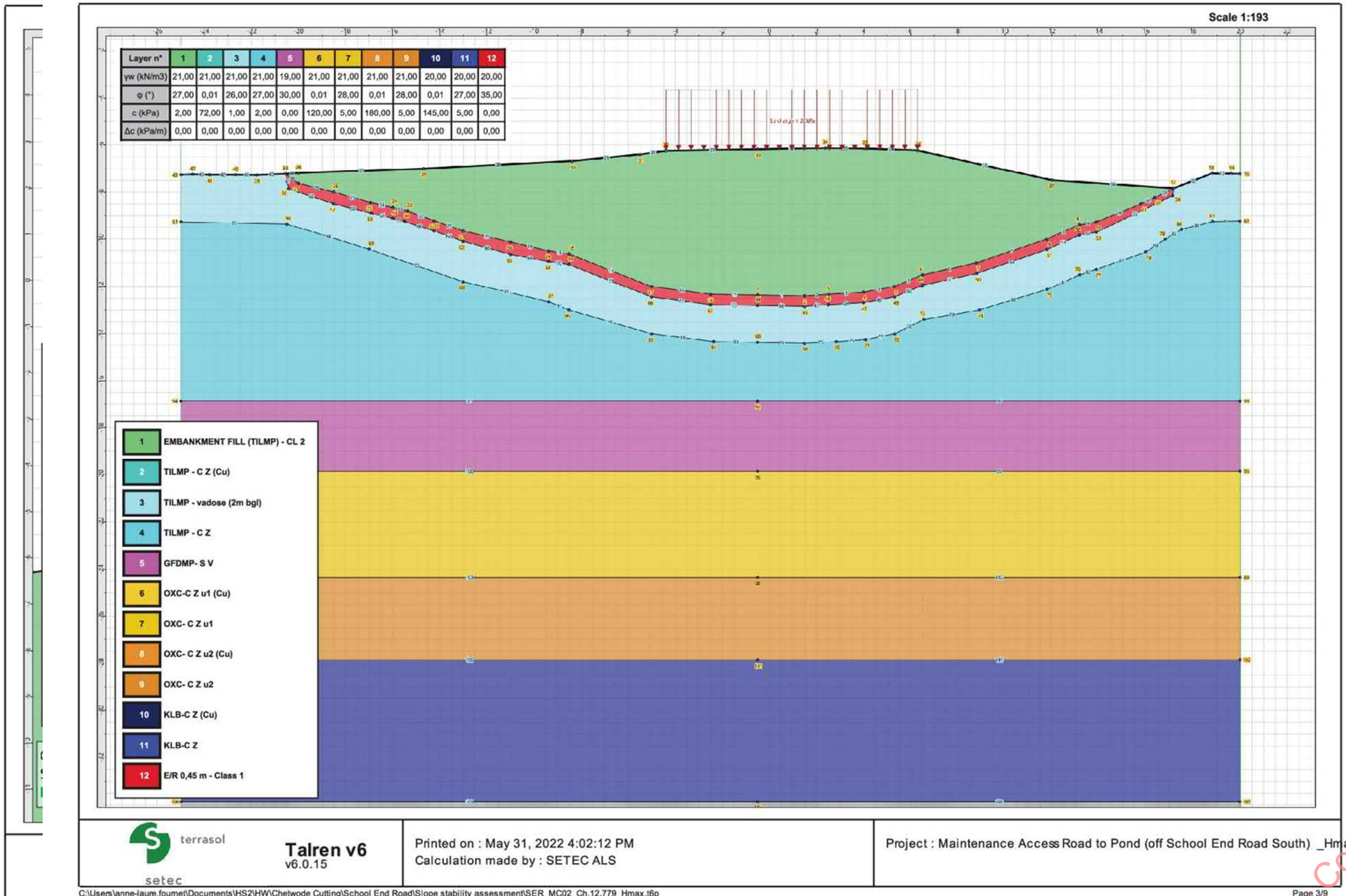
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Talren v6
v6.0.15

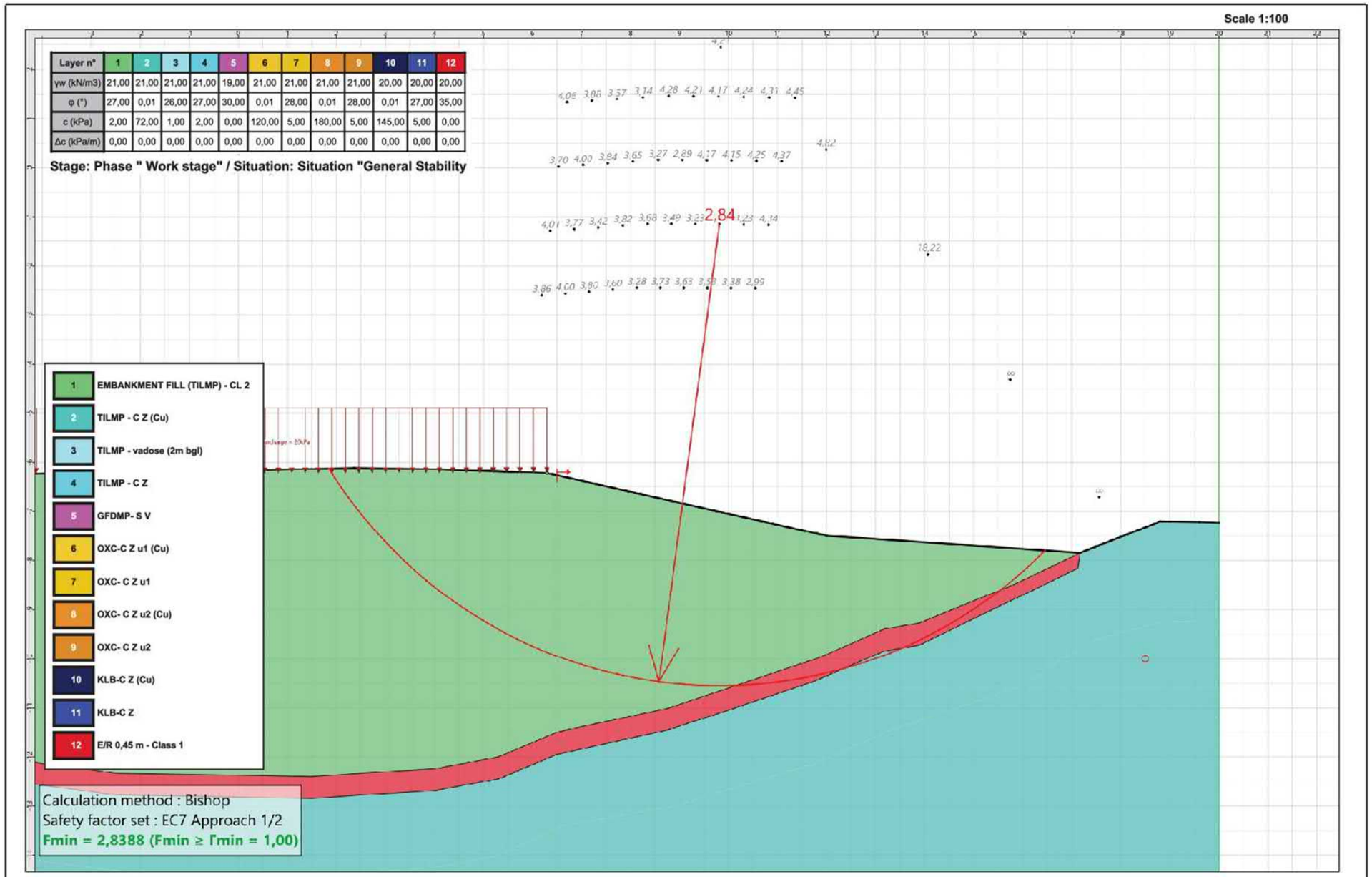
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Project : Maintenance Access Road to Pond (off School End Road South) _Hmax=6,19 m

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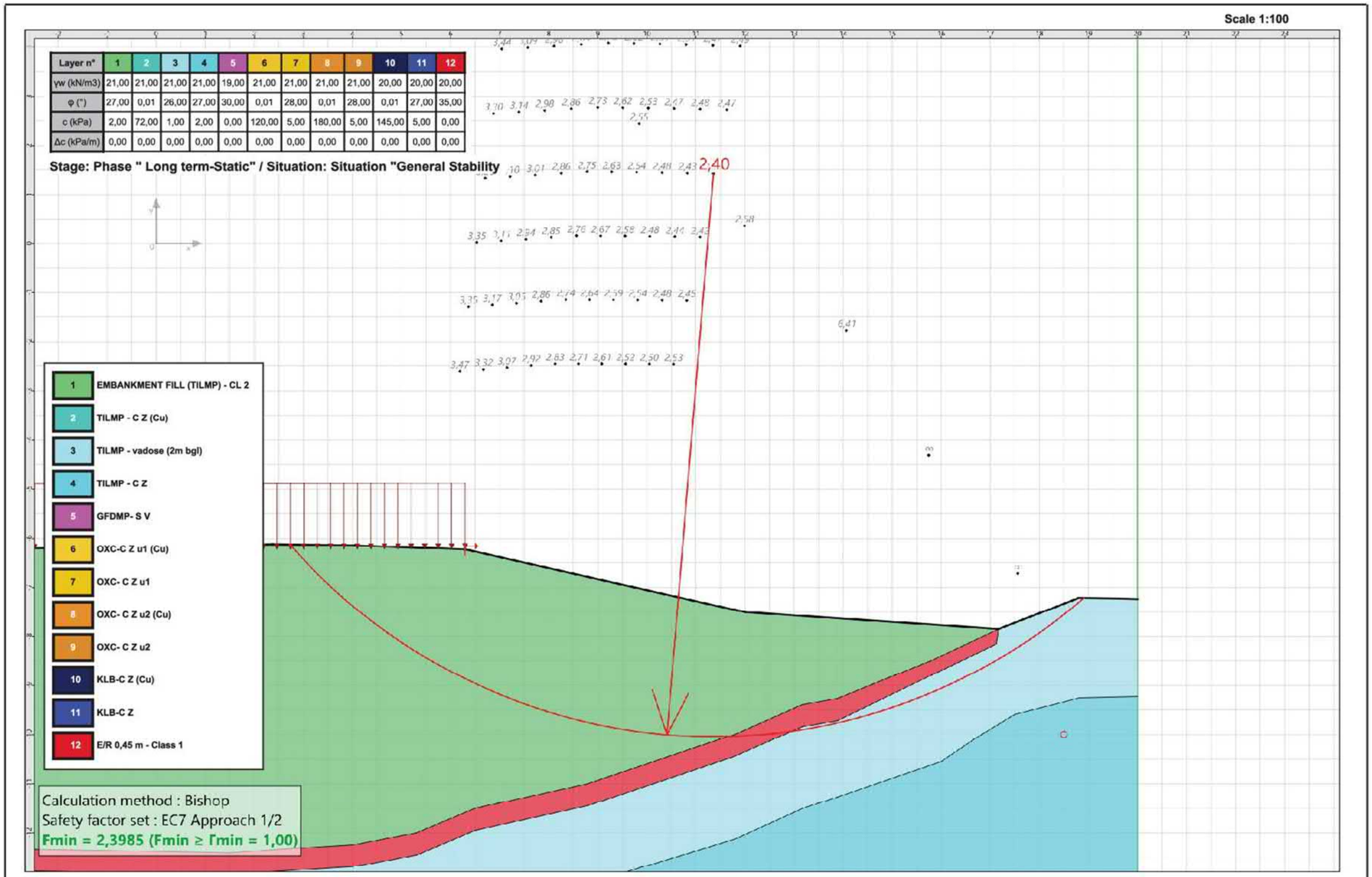
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Calculation made by : SETEC ALS

Project : Maintenance Access Road to Pond (off School End Road South) _Hmax=6,1

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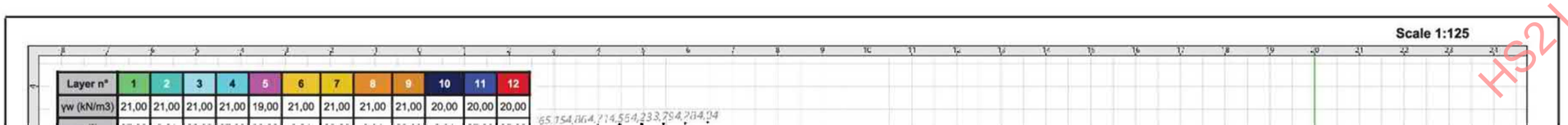


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Calculation made by : SETEC ALS

Project : Maintenance Access Road to Pond (off School End Road South) _Hmax=6.1



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Scale 1:125

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase "Seismic" / Situation: Situation "General Stability -2500

3,45

1 EMBANKMENT FILL (TILMP) - CL 2
2 TILMP - C Z (Cu)
3 TILMP - vadose (2m bgl)
4 TILMP - C Z
5 GFDMP- S V
6 OXC-C Z u1 (Cu)
7 OXC- C Z u1
8 OXC- C Z u2 (Cu)
9 OXC- C Z u2
10 KLB-C Z (Cu)
11 KLB-C Z
12 E/R 0,45 m - Class 1

Calculation method : Bishop
Safety factor set : EC7 Approach 1/2
Fmin = 3,4533 (Fmin ≥ Γmin = 1,00)

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Printed on : May 31, 2022 4:02:13 PM
Calculation made by : SETEC ALS

Project : Maintenance Access Road to Pond (off School End Road South) _Hmax=6,1

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HS2 Ltd - Code 1 - Accepted

Maintenance Access Road to Pond (off School End Road South), Ch. 635.00, Slope 1V/2H, H = 3,20 m

Project data

Project reference : HS2 Detail Design

Calculation title : MC02 _MC02_Hmax=3,2 m

Location : Ch. 185+000

Comments : MC02: Maintenance Access Road to Pond (Off School End Road - South) Ch.635,000_1V-1.2H_Hmax=3,2m Diameter Ancillary culvert : 1600mm

Units : kN, kPa, kN/m³

γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	FILL (TILMP)-CL9J2 Stabilised		20,0	28,00	5,0	0,0	-	-	-	No	No	No
2	KLB-C Z (Cu)		20,0	0,01	145,0	0,0	-	-	-	No	No	No
3	KLB-C Z		20,0	27,00	5,0	0,0	-	-	-	No	No	No
4	STARTER LAYER 0,3 m - Class 6C1		20,0	35,00	0,0	0,0	-	-	-	No	No	No
5	CB-LMST		21,0	27,00	5,0	0,0	-	-	-	No	No	No
6	CB-LMST (Cu)		21,0	0,01	200,0	0,0	-	-	-	No	No	No
7	E/R - Class 2		20,0	25,00	1,0	0,0	-	-	-	No	No	No
8	ALV (Cu)		18,0	0,01	20,0	0,0	-	-	-	No	No	No
9	ALV		18,0	22,00	1,0	0,0	-	-	-	No	No	No
10	E/R (Cu) - CL2		20,0	0,01	50,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	FILL (TILMP)-CL9J2 Stabilised		-	-	-	Effective	Linear	No	-	-
2	KLB-C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
3	KLB-C Z		-	-	-	Effective	Linear	No	-	-
4	STARTER LAYER 0,3 m - Class 6C1		-	-	-	Effective	Linear	No	-	-
5	CB-LMST		-	-	-	Effective	Linear	No	-	-
6	CB-LMST (Cu)		-	-	-	Undrained	Linear	No	-	-
7	E/R - Class 2		-	-	-	Effective	Linear	No	-	-
8	ALV (Cu)		-	-	-	Undrained	Linear	No	-	-
9	ALV		-	-	-	Effective	Linear	No	-	-
10	E/R (Cu) - CL2		-	-	-	Undrained	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	-12,620	-2,100	2	-11,000	-2,100	3	-9,000	-2,100	5	-3,165	-4,113	6	-2,592	-4,148	7	-1,169	-4,131
9	-16,000	-2,300	12	-23,000	-4,316	13	-24,635	-4,392	14	-26,000	-4,392	15	-27,000	-4,500	16	3,000	-4,126
17	-12,762	-5,292	18	-12,216	-5,262	19	-11,230	-5,398	20	-10,365	-5,353	21	-9,500	-5,262	22	-9,000	-5,232
23	-8,500	-5,368	24	-7,772	-5,216	25	-7,000	-5,000	26	-6,252	-4,715	27	-5,776	-4,326	28	-5,137	-4,163
30	-4,929	-4,043	32	-13,416	-5,201	33	-13,934	-5,097	34	-14,628	-5,056	35	-15,135	-5,056	36	-15,622	-5,128
37	-16,161	-5,076	38	-16,782	-4,921	39	-17,500	-4,776	40	-18,233	-4,703	41	-19,000	-4,606	42	-20,167	-4,676
43	-20,500	-4,589	44	-21,576	-4,500	45	-22,206	-4,447	46	-22,598	-4,364	47	-12,800	-5,614	48	-11,518	-5,358
49	-12,262	-5,581	50	-11,580	-5,652	51	-11,000	-5,729	52	-10,634	-5,671	53	-10,094	-5,645	54	-9,554	-5,607
55	-9,296	-5,536	56	-8,743	-5,852	57	-8,299	-5,626	58	-7,445	-5,455	59	-6,851	-5,271	60	-6,305	-5,000
61	-5,899	-4,788	62	-5,560	-4,619	63	-5,217	-4,461	64	-5,059	-4,426	65	-13,327	-5,500	66	-13,601	-5,440
67	-14,118	-5,383	68	-14,665	-5,346	69	-15,183	-5,374	70	-15,663	-5,421	71	-16,135	-5,400	72	-16,707	-5,245
73	-17,228	-5,110	74	-17,582	-5,033	75	-18,065	-5,000	76	-18,637	-4,937	78	-19,584	-4,641	79	-17,222	-4,832
81	-5,583	-4,277	82	-19,317	-4,941	83	-20,159	-4,929	84	-12,203	-7,706	85	-4,660	-7,833	86	-21,192	-7,648
87	-12,143	-9,700	88	3,000	-9,700	89	-27,000	-9,700	90	-12,000	-15,700	91	3,000	-15,700	92	-27,000	-15,700
95	-14,000	-2,174	96	3,000	-7,500	97	-27,000	-7,601	100	-10,500	-2,100						

Segments (1/2)

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
1	1	2	5	5	6	6	6	7	14	12	13	15	13	14	16	14	15	17	7	16
20	19	20	21	20	21	22	21	22	23	22	23	24	23	24	25	24	25	26	25	26
27	26	27	29	28	30	31	30	5	33	32	33	34	33	34	35	34	35	36	35	36
37	36	37	38	37	38	40	39	40	41	40	41	43	42	43	44	43	44	45	44	45
46	45	46	47	46	12	49	48	18	50	48	19	51	47	49	52	49	50	53	50	51
54	51	52	55	52	53	56	53	54	57	54	55	58	55	56	59	56	57	60	57	58
61	58	59	62	59	60	63	60	61	64	61	62	65	62	63	66	63	64	67	64	30

HS2 Ltd - Code 1 - Accepted

Project data

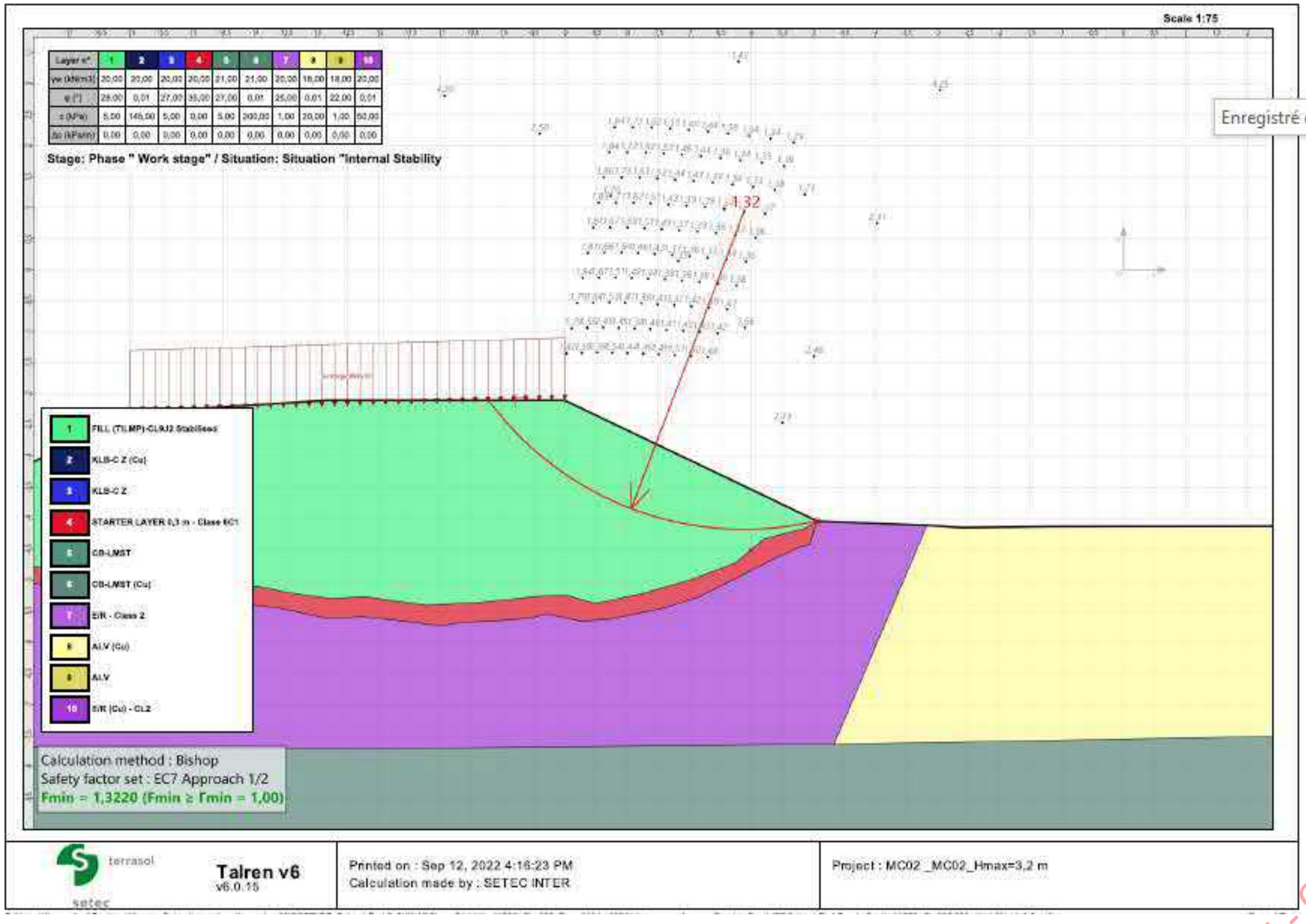
Segments (2/2)

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Poin
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75	71	72	76	72	73	77	73	74	78	74	75	79	75	76	82	76	41	83	78	42
86	79	38	87	79	39	90	81	27	91	81	28	92	76	82	94	3	30	95	9	43
96	82	83	97	83	43	98	18	17	99	17	32	101	94	85	102	85	5	103	84	86
104	86	45	106	87	88	107	87	89	109	90	91	110	90	92	112	95	1	113	95	9
114	85	96	115	86	97	117	100	2	118	100	3									

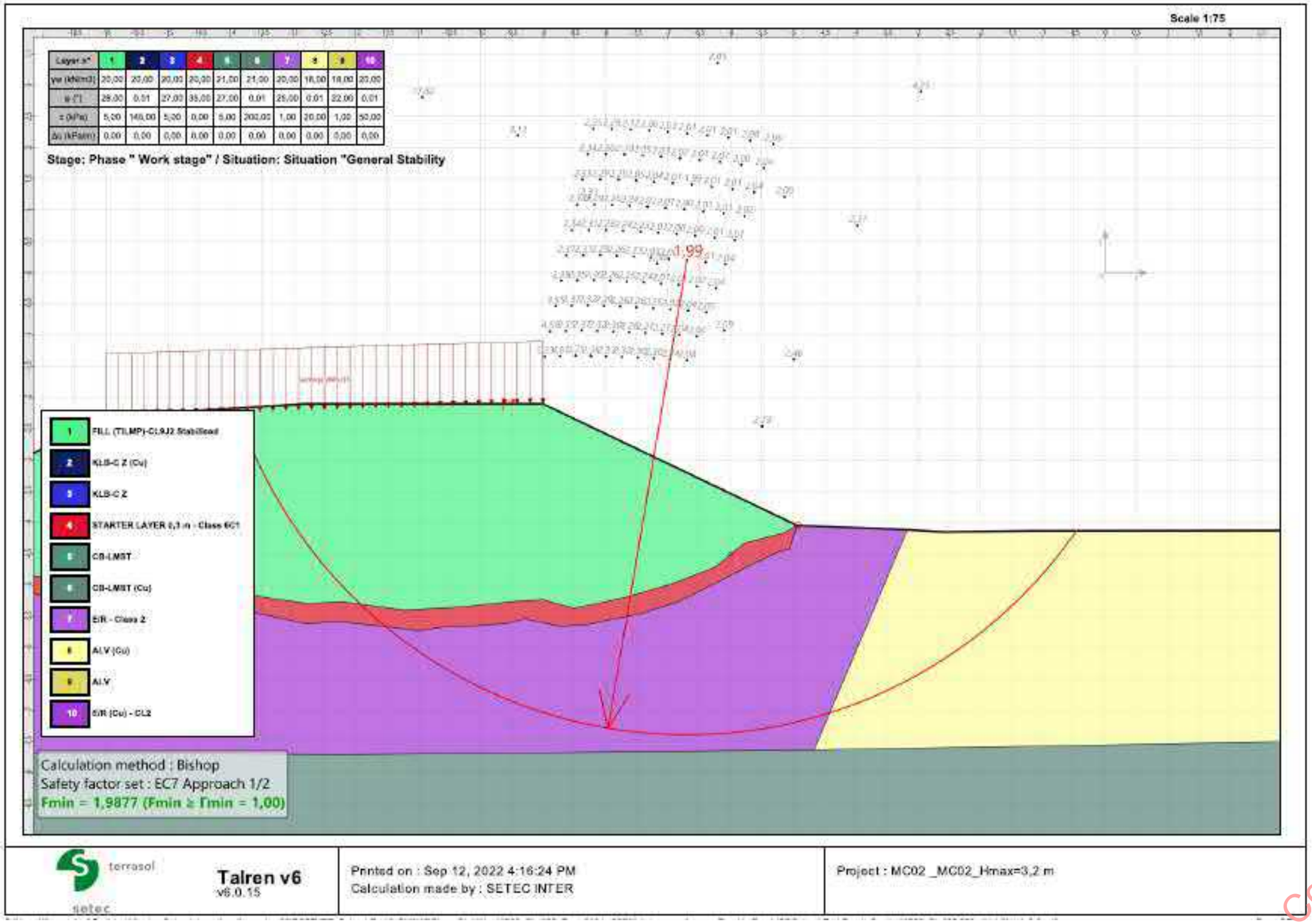
Distributed loads

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	Surcharge 20kPa (ST)	-16,000	-2,300	20,0	-9,000	-2,100	20,0	90,00
2	Surcharge 20kPa (LT)	-14,000	-2,174	20,0	-10,500	-2,100	20,0	90,00

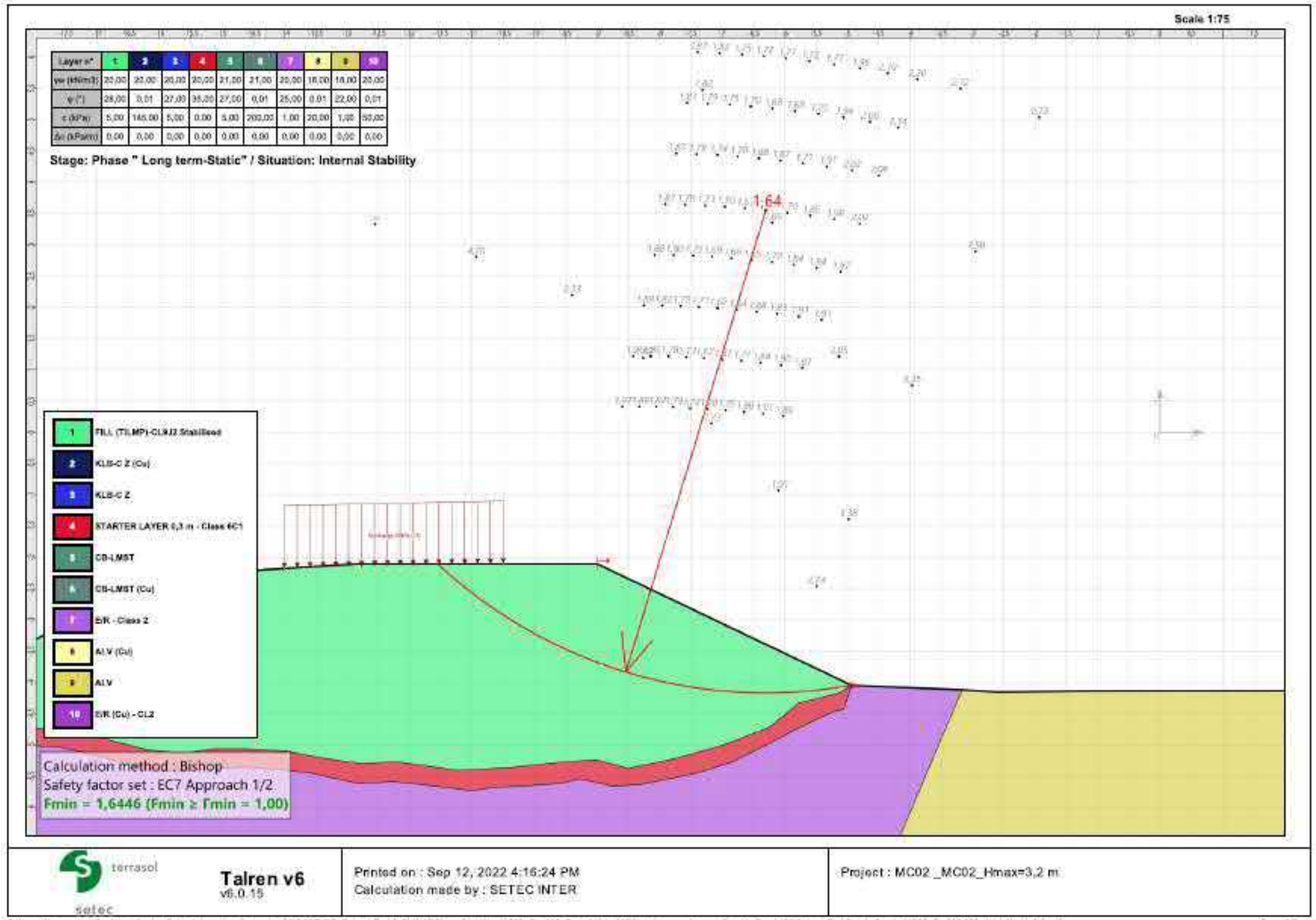
HS2 Ltd - Code 1 - Accepted



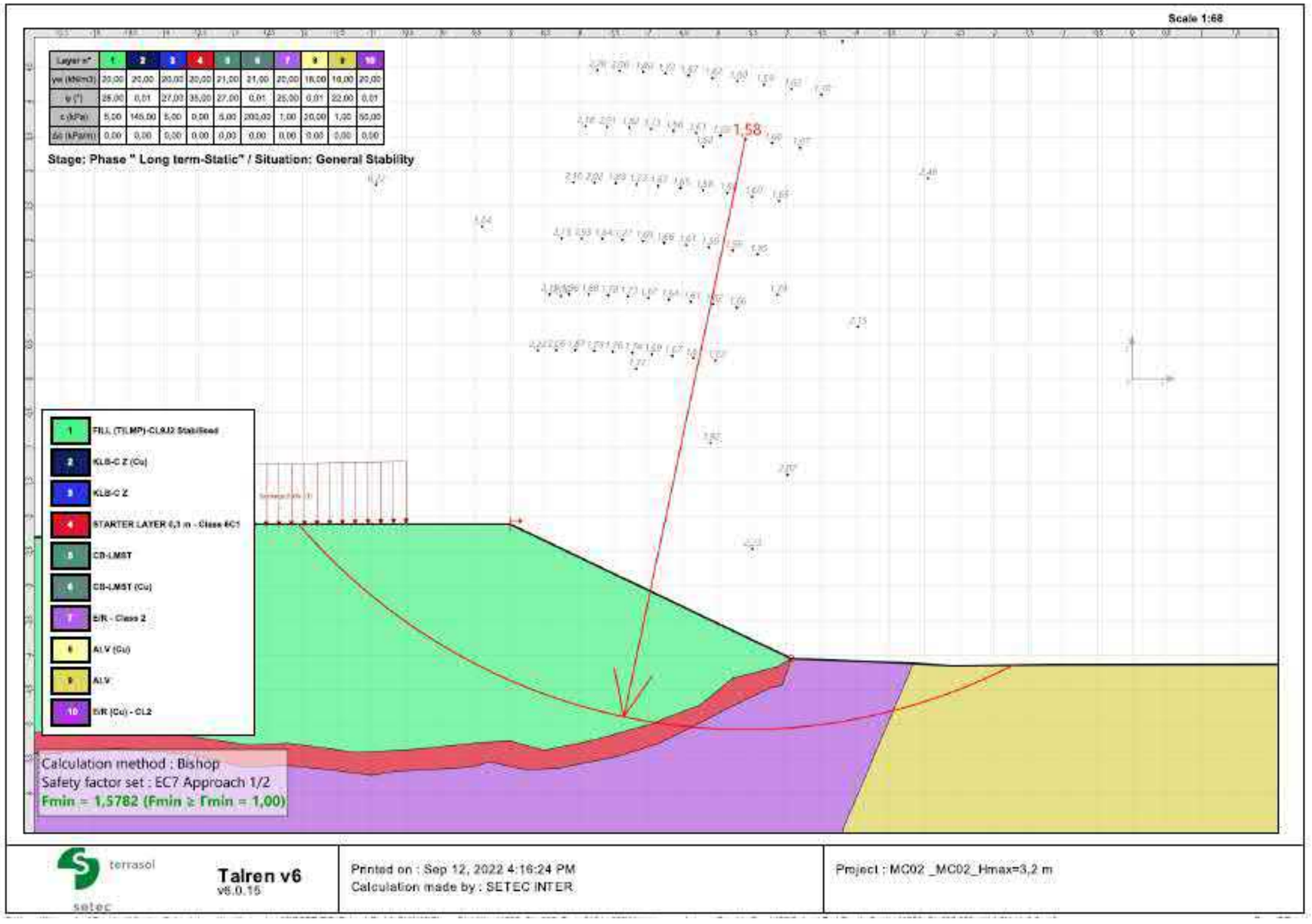
HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

Maintenance Access Road to Pond (off School End Road North), Ch.400, Slope 1V/4H, Hmax=0.44m

Project data

Project reference : HS2 Detail Design
Calculation title : Maintenance Access Road to Pond (off School End Road North)_Hmax=0,44 m
Location : Ch. 400+000
Comments : Hmax Embankment Slope 1V/3H (Both Sides)
Units : kN, kPa, kN/m³
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	EMBANKMENT FILL - CLASS 1		20,0	35,00	2,0	0,0	-	-	-	No	No	No
2	TILMP - C Z (Cu)		21,0	0,01	72,0	0,0	-	-	-	No	No	No
3	TILMP - vadose (2m bgl)		21,0	26,00	1,0	0,0	-	-	-	No	No	No
4	TILMP - C Z		21,0	27,00	2,0	0,0	-	-	-	No	No	No
5	GFDMP- S V		19,0	30,00	0,0	0,0	-	-	-	No	No	No
6	OXC-C Z u1 (Cu)		21,0	0,01	120,0	0,0	-	-	-	No	No	No
7	OXC- C Z u1		21,0	28,00	5,0	0,0	-	-	-	No	No	No
8	OXC- C Z u2 (Cu)		21,0	0,01	180,0	0,0	-	-	-	No	No	No
9	OXC- C Z u2		21,0	28,00	5,0	0,0	-	-	-	No	No	No
10	KLB-C Z (Cu)		20,0	0,01	145,0	0,0	-	-	-	No	No	No
11	KLB-C Z		20,0	27,00	5,0	0,0	-	-	-	No	No	No
12	E/R Class1		20,0	35,00	0,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	EMBANKMENT FILL - CLASS 1		-	-	-	Effective	Linear	No	-	-
2	TILMP - C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
3	TILMP - vadose (2m bgl)		-	-	-	Effective	Linear	No	-	-
4	TILMP - C Z		-	-	-	Effective	Linear	No	-	-
5	GFDMP- S V		-	-	-	Effective	Linear	No	-	-
6	OXC-C Z u1 (Cu)		-	-	-	Undrained	Linear	No	-	-
7	OXC- C Z u1		-	-	-	Effective	Linear	No	-	-
8	OXC- C Z u2 (Cu)		-	-	-	Undrained	Linear	No	-	-
9	OXC- C Z u2		-	-	-	Effective	Linear	No	-	-
10	KLB-C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
11	KLB-C Z		-	-	-	Effective	Linear	No	-	-
12	E/R Class1		-	-	-	Effective	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	10,000	-4,579	2	9,147	-4,591	3	7,248	-4,597	4	6,165	-4,469	5	5,860	-4,462	6	5,000	-4,460
7	3,298	-4,459	8	0,728	-4,427	9	-0,893	-4,449	10	-2,686	-4,368	11	-4,762	-4,360	12	-6,449	-4,385
13	-7,171	-4,350	14	-7,745	-4,262	15	-8,547	-4,244	16	-10,000	-4,242	17	3,441	-3,951	18	1,440	-3,908
19	-0,884	-3,857	20	-5,253	-3,840	21	-6,825	-4,373	22	4,556	-4,500	23	4,000	-5,098	24	2,887	-5,089
26	-5,856	-5,000	27	-3,680	-5,000	28	-0,893	-7,949	29	-0,896	-5,100	30	-10,000	-7,949	31	10,000	-7,949
32	-1,000	-11,949	33	-10,000	-11,949	34	10,000	-11,949	35	-1,000	-17,949	36	-10,000	-17,949	37	10,000	-17,949
38	-1,000	-20,449	39	-10,000	-20,449	40	10,000	-20,449	41	-1,000	-24,449	42	-10,000	-24,449	43	10,000	-24,449
44	-10,000	-6,449	45	10,000	-6,449	46	-0,895	-6,449									

Segments

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	7	7	8	8	8	9
9	9	10	10	10	11	11	11	12	13	13	14	14	14	15	15	15	16	16	6	17
17	17	18	18	18	19	19	19	20	20	20	21	21	12	21	22	21	13	24	23	24
27	6	22	29	26	12	31	27	26	33	22	23	34	22	7	36	29	24	39	29	27
40	28	30	41	28	31	43	32	33	44	32	34	46	35	36	47	35	37	49	38	39
50	38	40	52	41	42	53	41	43	54	45	46	57	46	44						

Distributed loads

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	Surcharge = 20kPa	-5,253	-3,840	20,0	3,441	-3,951	20,0	90,00

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Printed on : Oct 11, 2022 11:24:31 AM
Calculation made by : SETEC INTER
Project : Maintenance Access Road to Pond (off School End Road North)_Hmax=0,44 m

HS2 Ltd - Code 1 - Accepted

Scale 1:125

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12
γw (kN/m3)	20,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00
φ (°)	35,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Surcharge = 20kPa

1 EMBANKMENT FILL - CLASS 1
2 TILMP - C Z (Cu)
3 TILMP - vadose (2m bgl)
4 TILMP - C Z
5 GFDMP- S V
6 OXC-C Z u1 (Cu)
7 OXC- C Z u1
8 OXC- C Z u2 (Cu)
9 OXC- C Z u2
10 KLB-C Z (Cu)
11 KLB-C Z
12 E/R Class1

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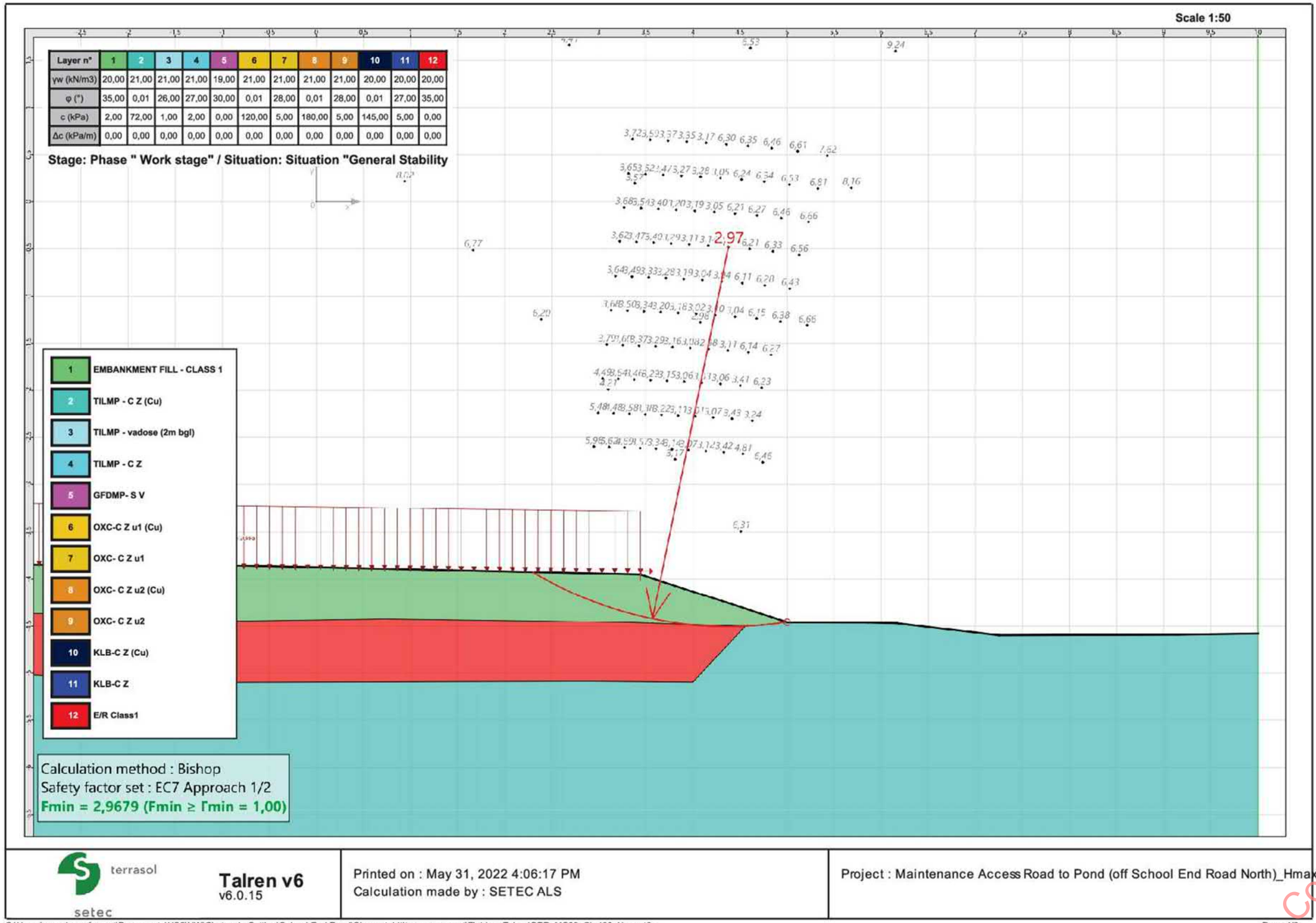
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Calculation made by : SETEC ALS

Project : Maintenance Access Road to Pond (off School End Road North)_Hmax=0,44

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Page 2/8

HS2 Ltd - Code 1 - Accepted

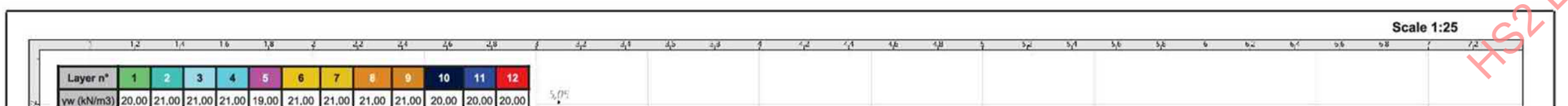


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Calculation made by : SETEC ALS

Project : Maintenance Access Road to Pond (off School End Road North)_Hmax=0,44

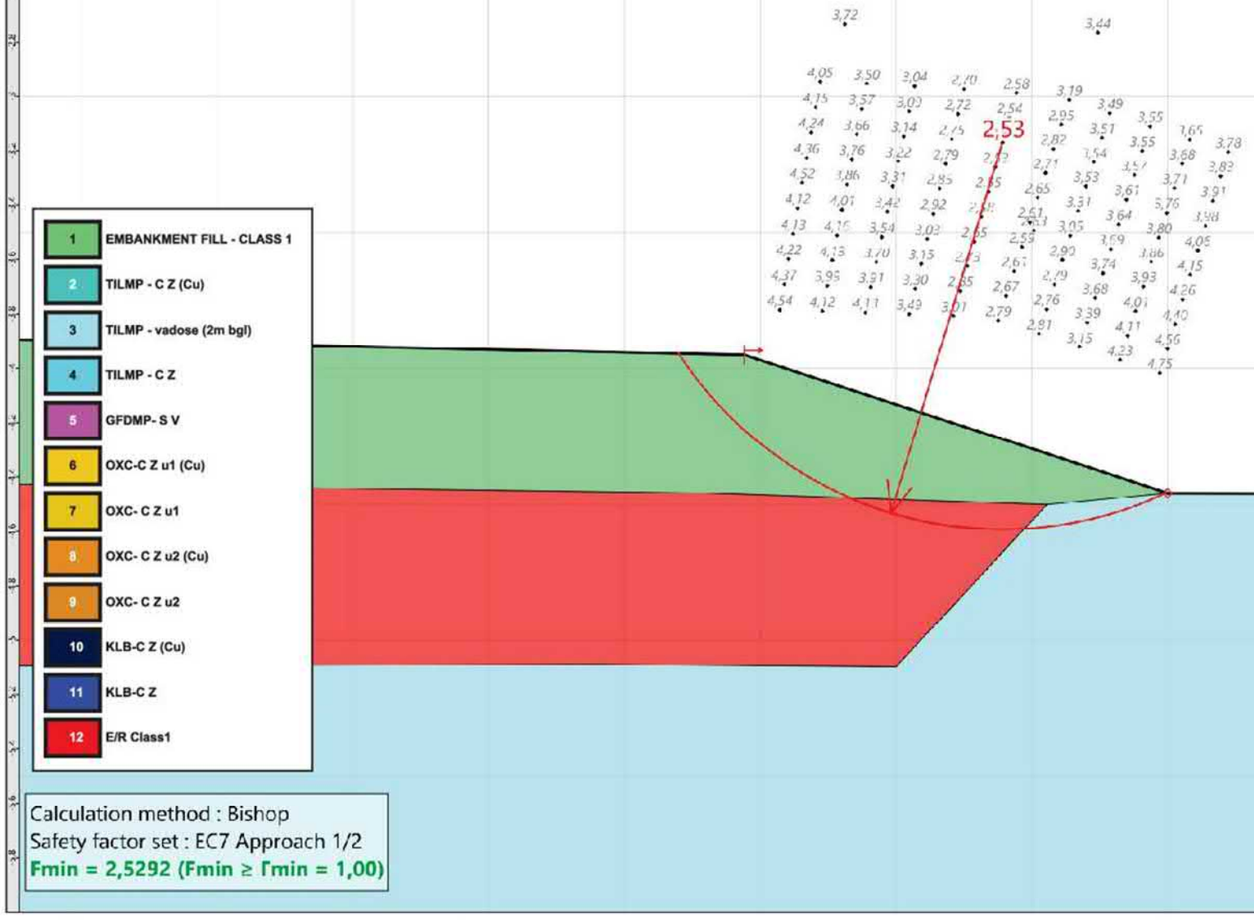


HS2 Ltd - Code 1 - Accepted

Scale 1:25

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12
γw (kN/m3)	20,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00
φ (°)	35,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Long term-Static" / Situation: Situation "General Stability"



Calculation method : Bishop
Safety factor set : EC7 Approach 1/2
Fmin = 2,5292 (Fmin ≥ Γmin = 1,00)

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Talren v6
v6.0.15

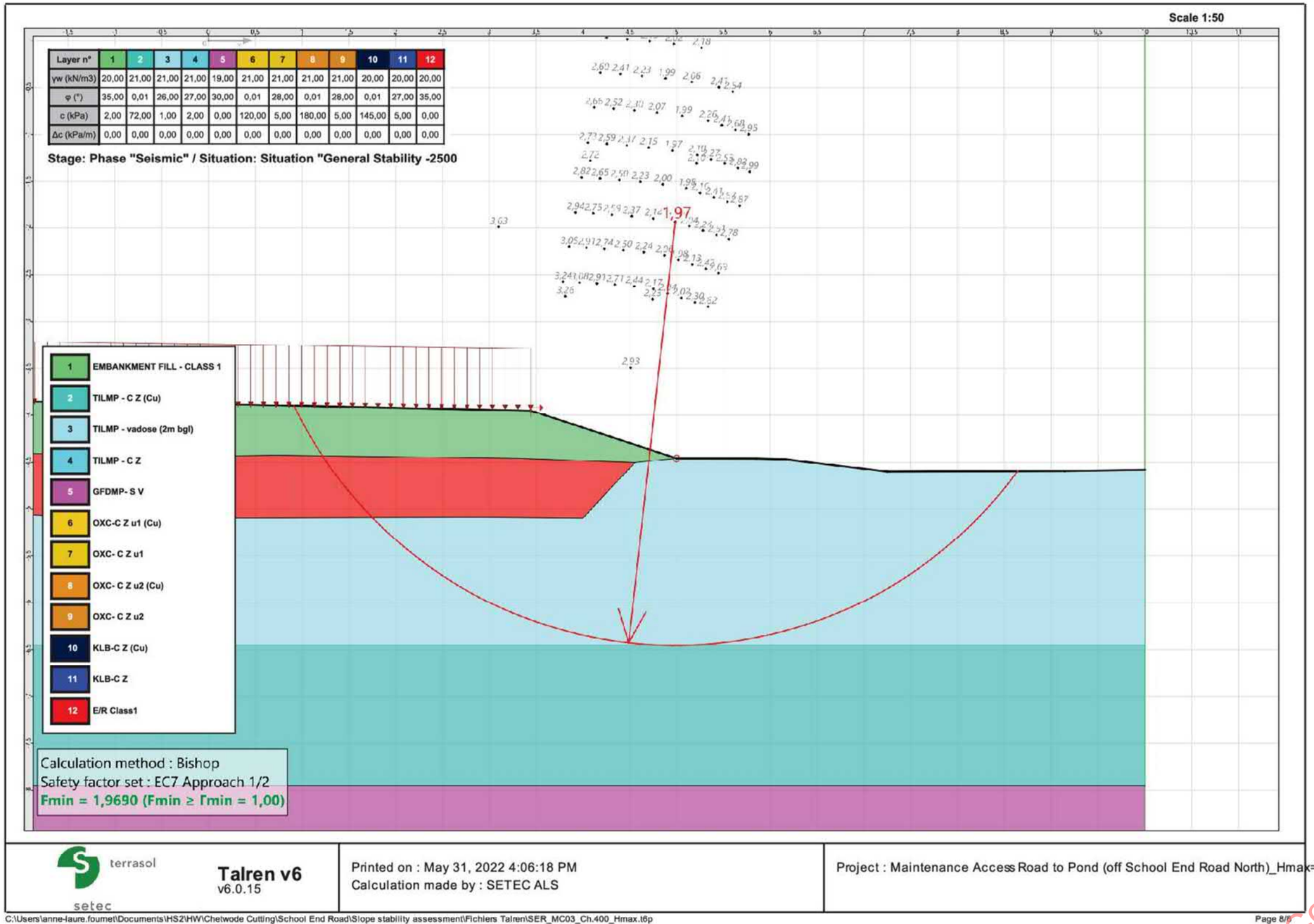
Printed on : May 31, 2022 4:06:18 PM
Calculation made by : SETEC ALS

Project : Maintenance Access Road to Pond (off School End Road North)_Hmax

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HS2 Ltd - Code 1 - Accepted



Layer n°	1	2	3	4	5	6	7	8	9	10	11	12
γw (kN/m3)	20,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00
φ (°)	35,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

HS2 Ltd - Code 1 - Accepted

Maintenance Access Road to GSMR (off School End Road), Ch. 60.00, Slope 1V/4H, Hmax=6.34m

Project data

Project reference : HS2 Detail Design
Calculation title : Maintenance Access Road to GSMR (off School End Road Realignment)_Hmax=6,34 m
Location : Ch. 60+000
Comments : Hmax Embankment Slope 1V/4H (Both Sides)
Units : kN, kPa, kN/m³
γw : 10.0

Soil layers

	Name	Colour	γ	φ	c	Δc	qs,nail	pmax	ks×B	Anisotropy	Favorable	Specific safety factors
1	EMBANKMENT FILL (TILMP) - CL 2		21,0	27,00	2,0	0,0	-	-	-	No	No	No
2	TILMP - C Z (Cu)		21,0	0,01	72,0	0,0	-	-	-	No	No	No
3	TILMP - vadose (2m bgl)		21,0	26,00	1,0	0,0	-	-	-	No	No	No
4	TILMP - C Z		21,0	27,00	2,0	0,0	-	-	-	No	No	No
5	GFDMP- S V		19,0	30,00	0,0	0,0	-	-	-	No	No	No
6	OXC-C Z u1 (Cu)		21,0	0,01	120,0	0,0	-	-	-	No	No	No
7	OXC- C Z u1		21,0	28,00	5,0	0,0	-	-	-	No	No	No
8	OXC- C Z u2 (Cu)		21,0	0,01	180,0	0,0	-	-	-	No	No	No
9	OXC- C Z u2		21,0	28,00	5,0	0,0	-	-	-	No	No	No
10	KLB-C Z (Cu)		20,0	0,01	145,0	0,0	-	-	-	No	No	No
11	KLB-C Z		20,0	27,00	5,0	0,0	-	-	-	No	No	No
12	E/R Class 1		20,0	35,00	0,0	0,0	-	-	-	No	No	No

Soil layers (cont.)

	Name	Colour	Γγ	Γc	Γtan(φ)	Cohesion type	Curve	Groundwater flow	kh	kv
1	EMBANKMENT FILL (TILMP) - CL 2		-	-	-	Effective	Linear	No	-	-
2	TILMP - C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
3	TILMP - vadose (2m bgl)		-	-	-	Effective	Linear	No	-	-
4	TILMP - C Z		-	-	-	Effective	Linear	No	-	-
5	GFDMP- S V		-	-	-	Effective	Linear	No	-	-
6	OXC-C Z u1 (Cu)		-	-	-	Undrained	Linear	No	-	-
7	OXC- C Z u1		-	-	-	Effective	Linear	No	-	-
8	OXC- C Z u2 (Cu)		-	-	-	Undrained	Linear	No	-	-
9	OXC- C Z u2		-	-	-	Effective	Linear	No	-	-
10	KLB-C Z (Cu)		-	-	-	Undrained	Linear	No	-	-
11	KLB-C Z		-	-	-	Effective	Linear	No	-	-
12	E/R Class 1		-	-	-	Effective	Linear	No	-	-

Points

	X	Y		X	Y		X	Y		X	Y		X	Y		X	Y
1	-40,500	2,500	2	-29,000	5,500	3	-22,500	5,500	4	-6,500	1,304	5	-10,241	0,500	6	-11,500	0,000
7	-13,500	-0,760	8	-14,500	-1,000	9	-16,000	-1,299	10	-18,500	-1,229	11	-21,500	-1,000	12	-24,287	-1,000
13	-27,500	-0,730	14	-29,177	-0,500	15	-30,150	-0,500	16	-31,780	0,000	17	-34,000	0,716	18	-35,500	1,000
19	-38,000	2,000	20	-38,690	2,000	21	-43,325	3,500	22	-45,500	3,870	23	-48,000	4,276	24	-49,874	4,500
25	-36,405	3,568	26	-0,000	3,000	27	-7,965	1,688	28	-24,287	-5,500	29	-24,287	-8,500	30	-24,287	-15,000
31	-24,287	-18,000	32	-24,287	-23,000	33	-0,000	-5,500	34	-50,000	-5,500	35	-0,000	-8,500	36	-0,000	-15,000
37	-0,000	-18,000	38	-0,000	-23,000	39	-50,000	-8,500	40	-50,000	-15,000	41	-50,000	-18,000	42	-50,000	-23,000
43	-24,287	-3,000	44	-0,000	-3,000	45	-50,000	-3,000	46	-50,000	4,500	47	-24,287	-1,450	48	-21,500	-1,450
49	-18,500	-1,750	50	-16,000	-1,750	51	-14,500	-1,450	52	-13,500	-1,210	53	-11,500	-0,450	54	-10,184	0,050
57	-38,740	1,550	58	-38,000	1,550	59	-35,500	0,550	60	-34,000	0,250	61	-31,780	-0,450	62	-30,150	-0,950
63	-29,177	-0,950	64	-27,500	-1,180	65	-9,047	0,757	66	-36,742	1,497	67	-37,947	1,529	68	-40,296	2,000
69	-6,804	0,816															

Segments (1/2)

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
2	2	3	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	11
11	11	12	12	12	13	13	13	14	14	14	15	15	15	16	16	16	17	17	17	18
19	19	20	20	20	1	21	1	21	22	21	22	23	22	23	24	23	24	26	25	1
27	25	2	28	4	26	30	27	3	31	27	4	33	28	29	34	29	30	35	30	31
37	28	33	38	28	34	39	31	30	41	32	31	43	29	35	44	30	36	46	32	38
47	31	37	48	29	39	49	30	40	50	31	41	51	32	42	53	37	36	55	28	43

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Calculation made by : SETEC ALS
Project : Maintenance Access Road to GSMR (off School End Road Realignment)_Hmax=6,34 m

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HS2 Ltd - Code 1 - Accepted

Project data

Segments (2/2)

	Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2		Point 1	Point 2
56	43	44	57	43	45	58	45	46	59	24	46	60	12	47	61	43	47	62	47	48			
63	48	49	64	49	50	65	50	51	66	51	52	67	52	53	68	53	54	73	57	58			
75	59	60	76	60	61	77	61	62	78	62	63	79	63	64	80	64	47	82	65	4			
83	65	5	85	66	18	86	66	19	88	67	58	89	67	59	90	67	57	91	57	68			
92	68	1	93	54	69	94	69	4															

Distributed loads

	Name	X left	Y left	q left	X right	Y right	q right	Ang/horizontal
1	Surcharge = 20kPa	-29,000	5,500	20,0	-22,500	5,500	20,0	90,00

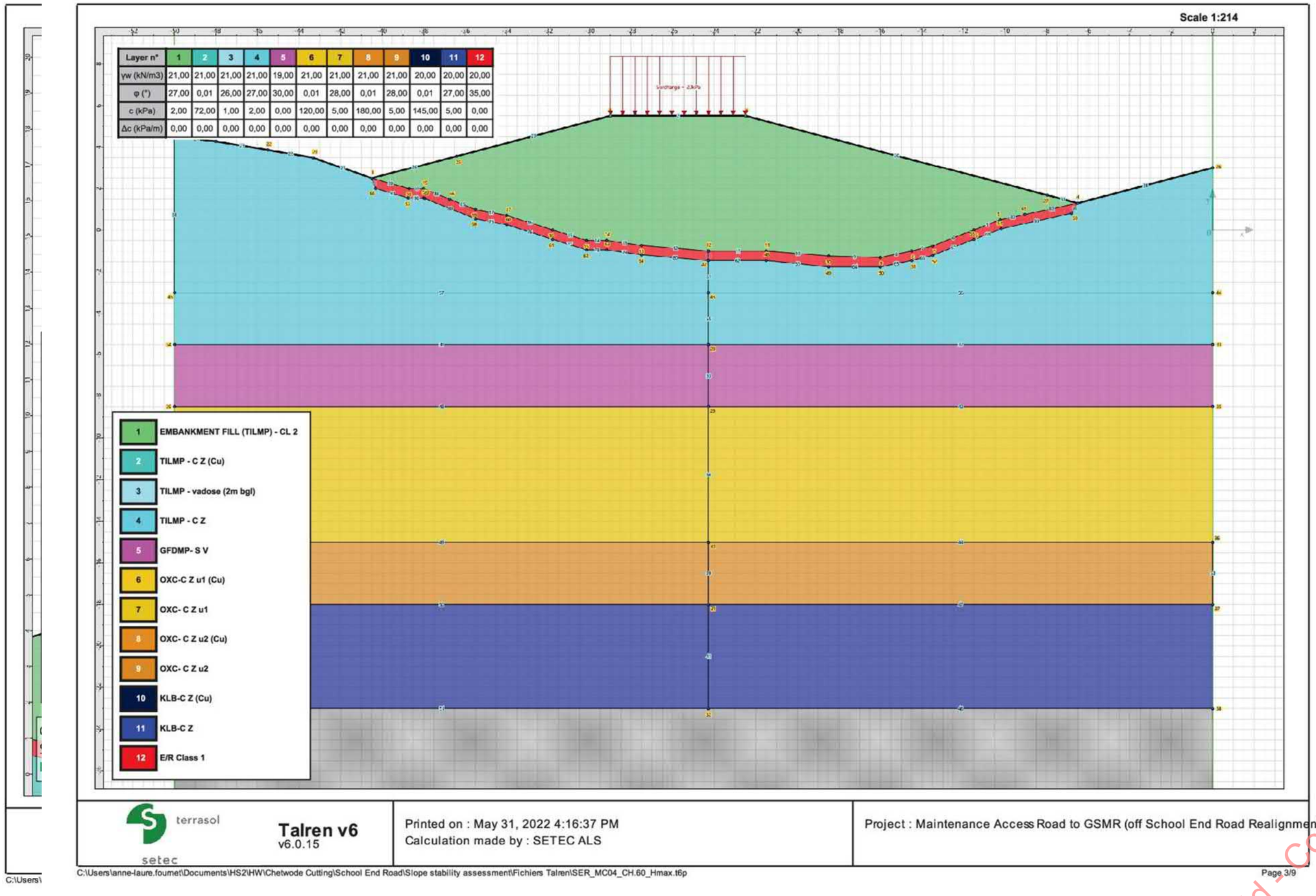
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Talren v6
v6.0.15

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Project : Maintenance Access Road to GSMR (off School End Road Realignment)_Hmax=6,34 m

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HS2 Ltd - Code 1 - Accepted



Layer n°	1	2	3	4	5	6	7	8	9	10	11	12
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

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Talren v6
v6.0.15

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Calculation made by : SETEC ALS

Project : Maintenance Access Road to GSMR (off School End Road Realignment)_Hi

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HS2 Ltd - Code 1 - Accepted

Scale 1:106

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00
Φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	26,00	0,01	28,00	0,01	27,00	35,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Work stage" / Situation: Situation "Internal Stability

1 EMBANKMENT FILL (TILMP) - CL 2
2 TILMP - C Z (Cu)
3 TILMP - vadose (2m bgl)
4 TILMP - C Z
5 GFDMP- S V
6 OXC-C Z u1 (Cu)
7 OXC- C Z u1
8 OXC- C Z u2 (Cu)
9 OXC- C Z u2
10 KLB-C Z (Cu)
11 KLB-C Z
12 E/R Class 1

Calculation method : Bishop
Safety factor set : EC7 Approach 1/2
Fmin = 1,5786 (Fmin ≥ Γmin = 1,00)

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setec
Talren v6
v6.0.15

Printed on : Oct 12, 2022 9:39:40 AM
Calculation made by : SETEC INTER

Project : Maintenance Access Road to GSMR (off School End Road Realignment)_Hmax=6,24

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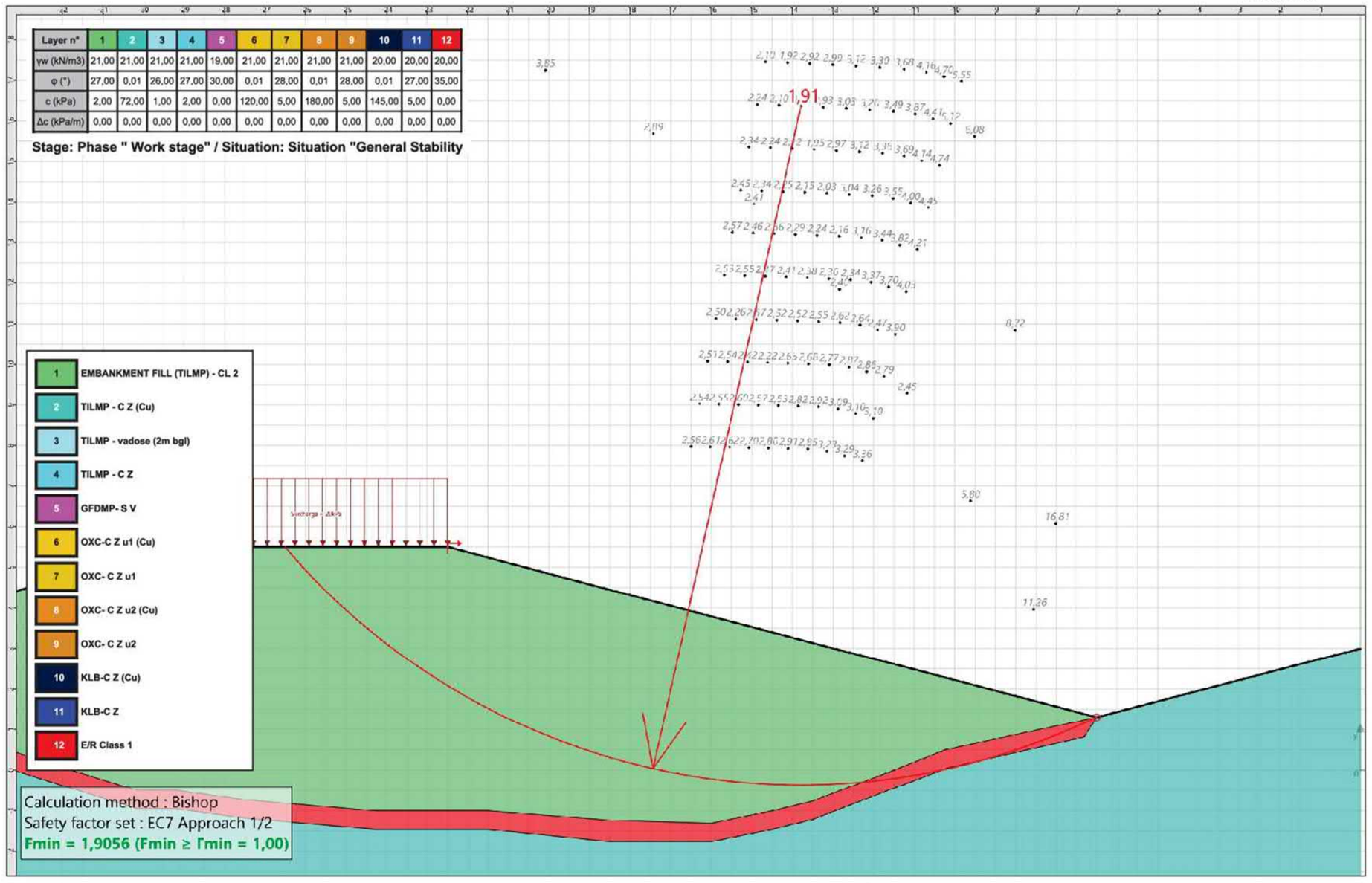
Page 1/6

HS2 Ltd - Code 1 - Accepted

Scale 1:125

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	28,00	0,01	28,00	0,01	27,00	35,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase " Work stage" / Situation: Situation "General Stability



terrasol
setec

Talren v6
v6.0.15

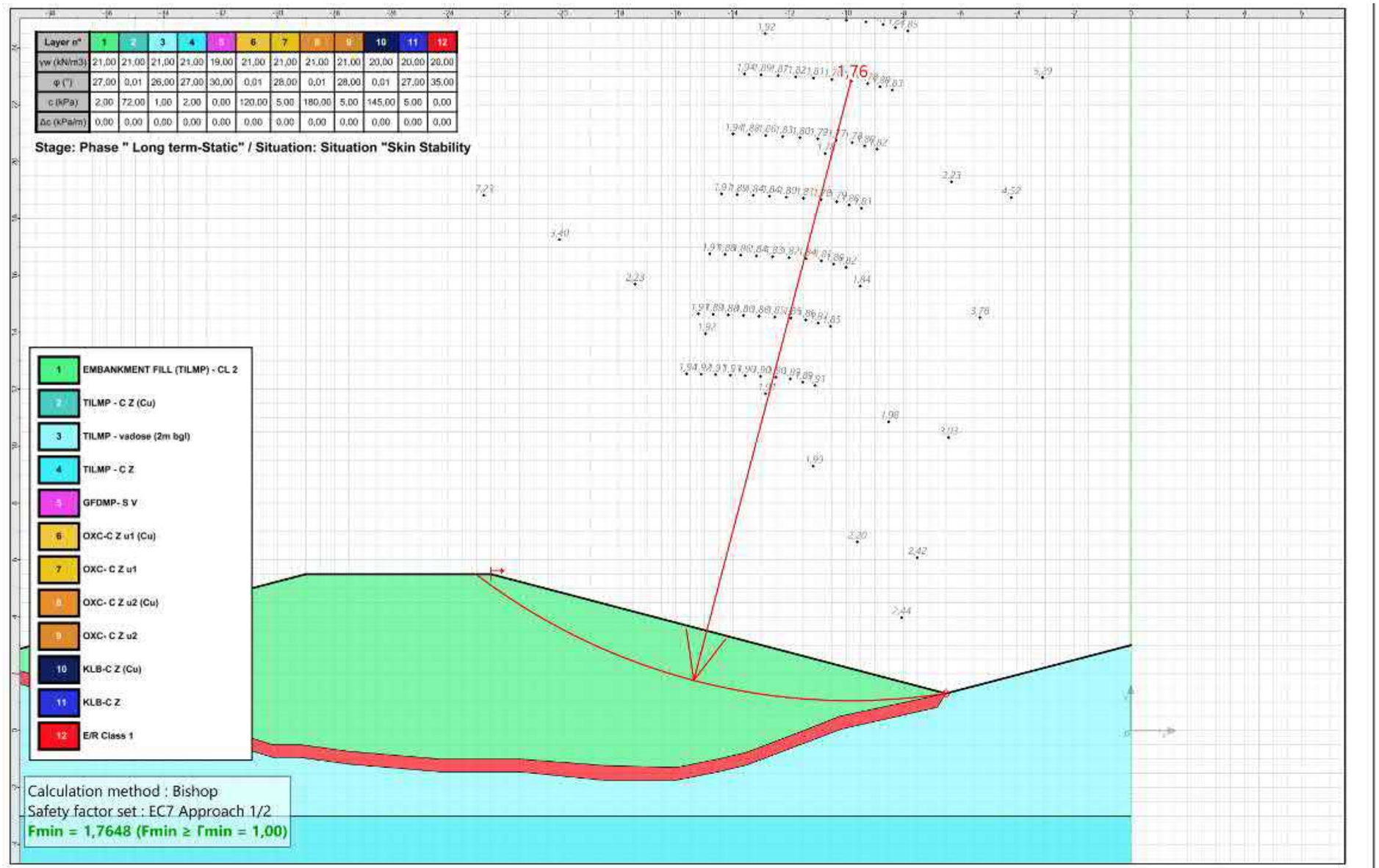
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Calculation made by : SETEC ALS

Project : Maintenance Access Road to GSMR (off School End Road Realignment)_Hn

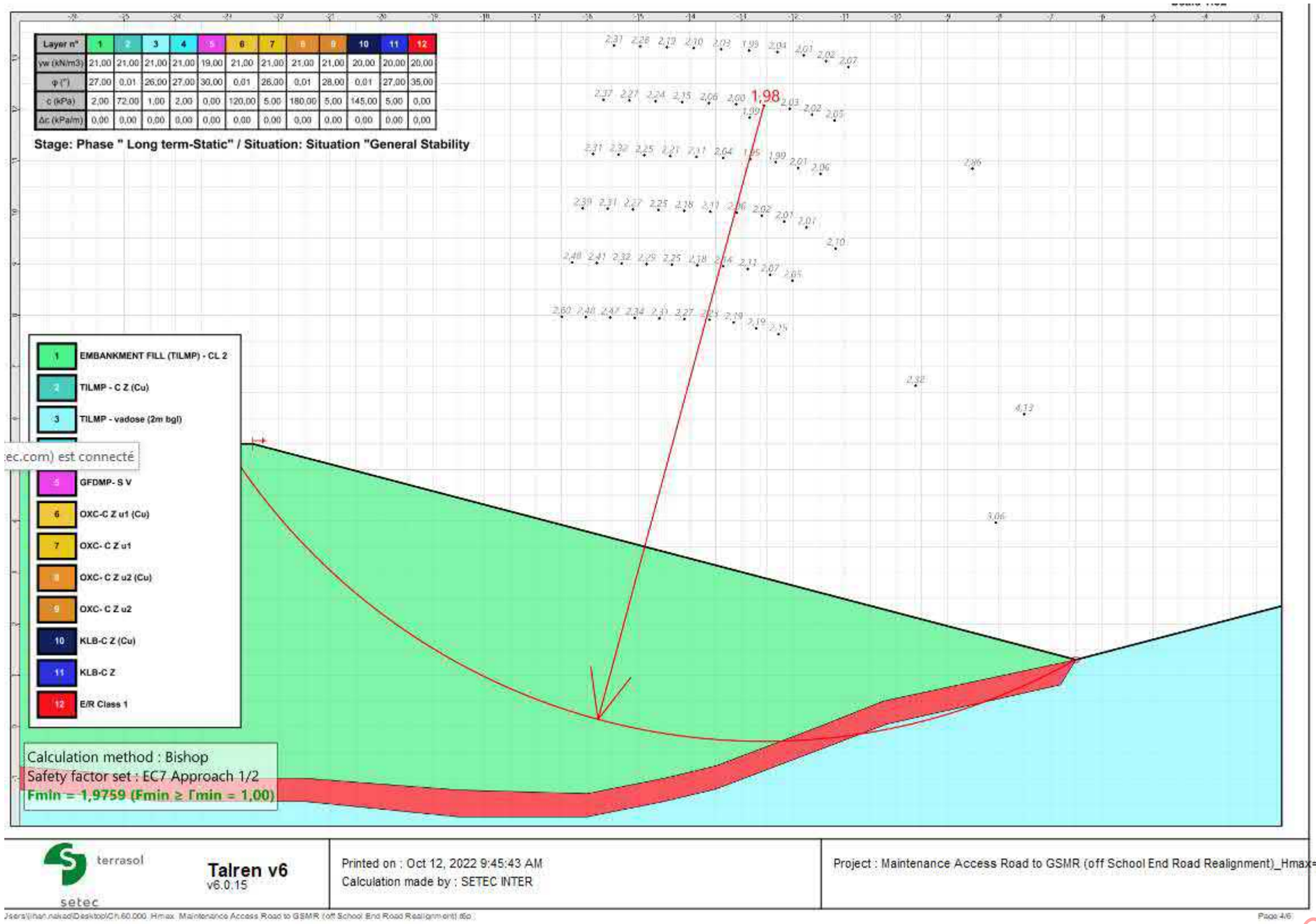
C:\Users\anne-laure.foumet\Documents\HS2\HW\Chetwode Cutting\School End Road\Slope stability assessment\Fichiers Talren\SER_MC04_CH.60_Hmax.t6p

Page 5/9

HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

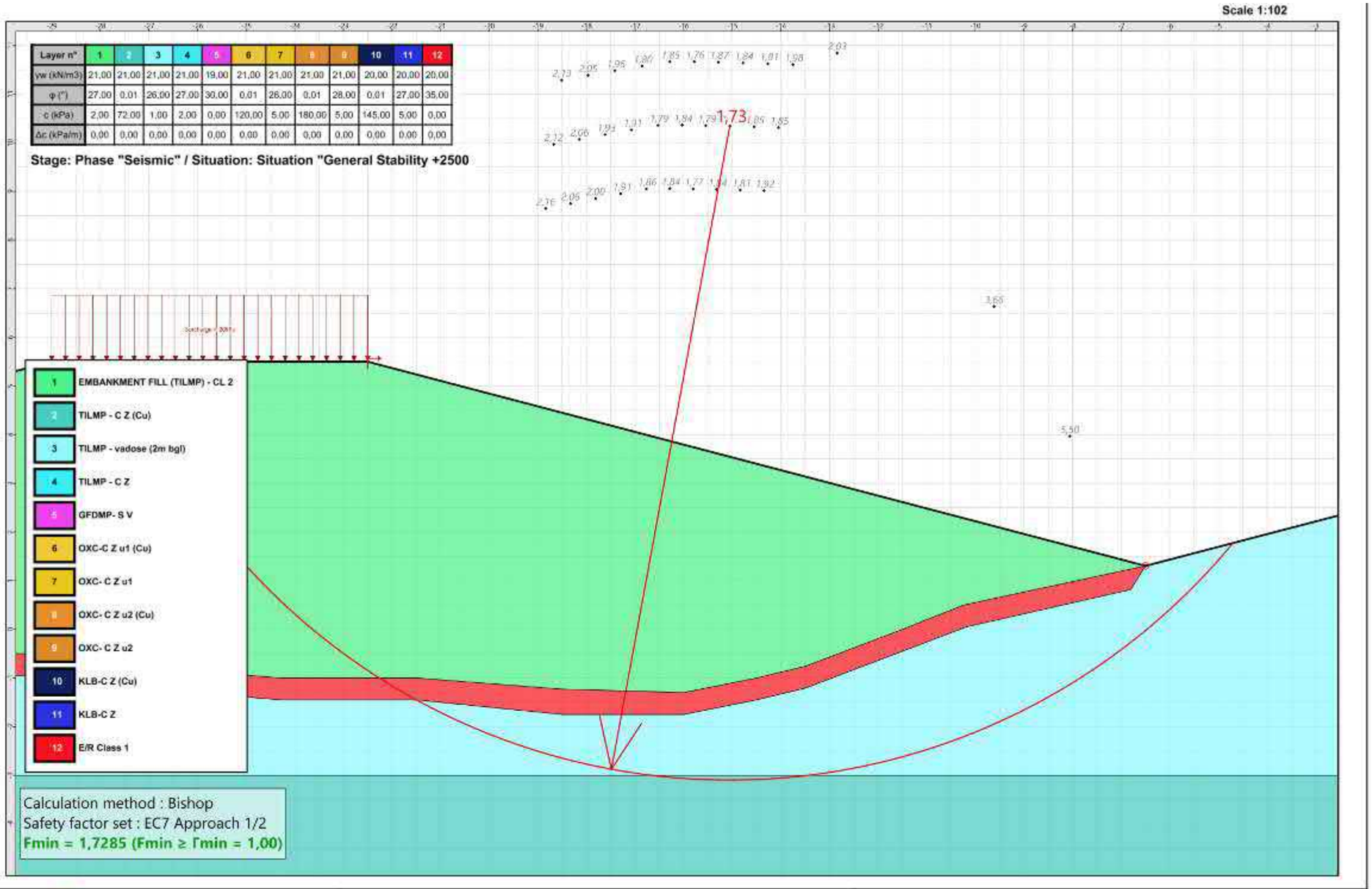


HS2 Ltd - Code 1 - Accepted

Scale 1:102

Layer n°	1	2	3	4	5	6	7	8	9	10	11	12
γw (kN/m3)	21,00	21,00	21,00	21,00	19,00	21,00	21,00	21,00	21,00	20,00	20,00	20,00
φ (°)	27,00	0,01	26,00	27,00	30,00	0,01	26,00	0,01	28,00	0,01	27,00	35,00
c (kPa)	2,00	72,00	1,00	2,00	0,00	120,00	5,00	180,00	5,00	145,00	5,00	0,00
Δc (kPa/m)	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Stage: Phase "Seismic" / Situation: Situation "General Stability +2500



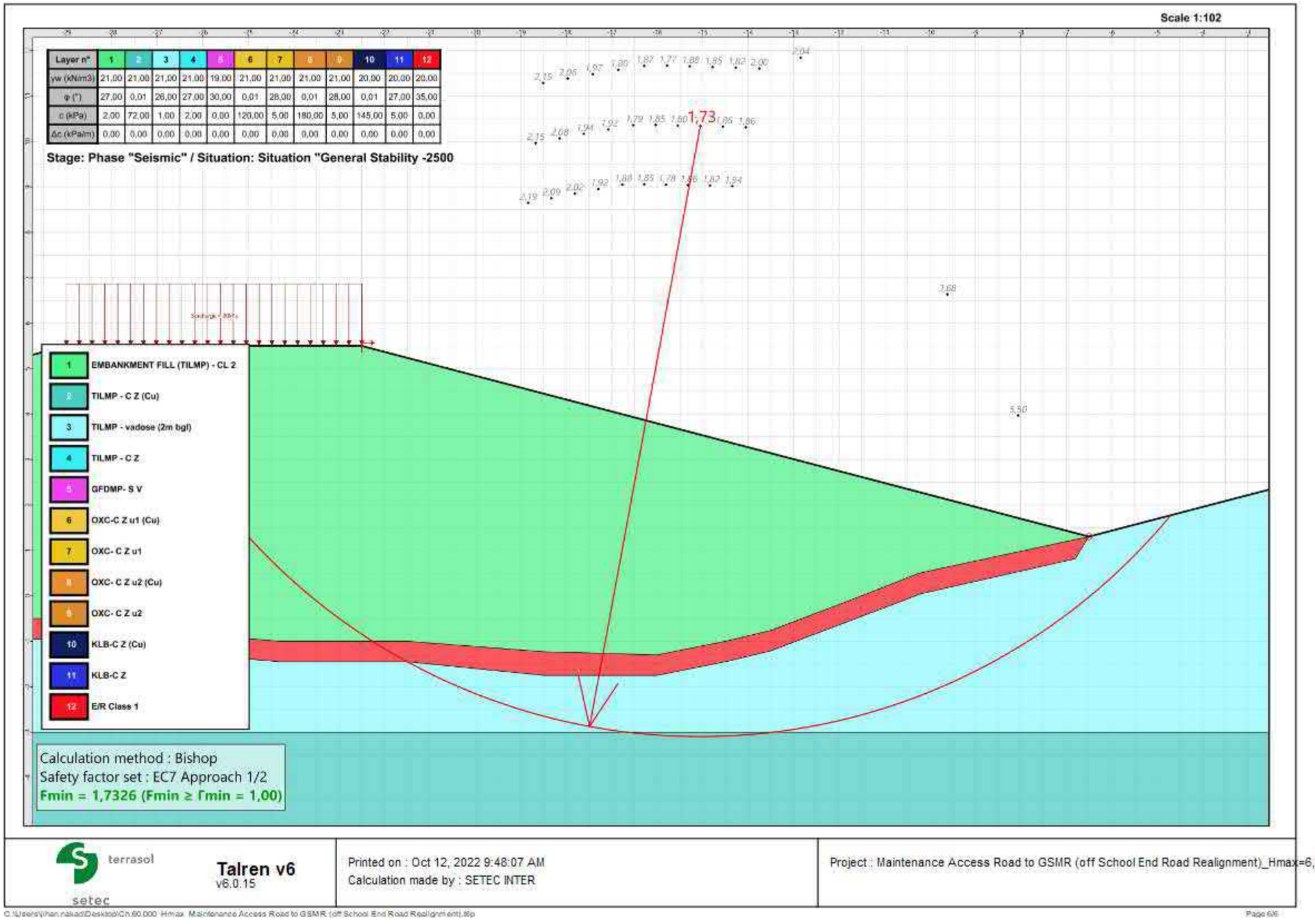
terrasol
setec

Talren v6
v6.0.15

Printed on : Oct 12, 2022 9:46:13 AM
Calculation made by : SETEC INTER

Project : Maintenance Access Road to GSMR (off School End Road Realignment)_Hmax=6,34

HS2 Ltd - Code 1 - Accepted



HS2 Ltd - Code 1 - Accepted

Settlements calculations results

HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design
Chetwode Cutting - MC01 School End Road Realignment
Ch. 240,00
Initial Case E&R 0,3 m

γr (kN/m³)	20,00
Hf (m)	1,28
Hr (m)	1,28
Side slope (H/V)	4,00
W idth Pf (m)	14,37
Surcharge of the embankment (kPa)	25,60
Static surcharge (kPa)	0,00
Sr (kPa)	25,60

Embankment geometry for calculating the influence factor at the axis

distance to the axis (m):	0
c1	5,10
c2	5,10
d1	9,24
d2	9,24

Groundwater level 4,68 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Iz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σV0 (kPa)	Poisson ratio	Characteristic Oedometric Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (= total settlement x geological correction factor)	Immediate Settlement (mm) (= total - consolidation settlement)
E&R	0	0,3	1,000	25,5	19	3	0,2	5,3	0,9	0,0	0,0	0,0
TILMP - CZ	0,3	3,5	0,997	25,4	21	40	0,2	9,0	0,5	9,0	4,5	4,5
GFDMP - S V SV	0,3	7,8	0,972	24,8	19	77	0,2	42,0	0	4,4	0,0	4,4
DKC - CZ lit	7,8	15,5	0,750	19,1	21	242	0,2	15,7	0,5	9,4	4,7	4,7
DKC - CZ lit2	15,5	20,5	0,578	14,7	21	312	0,2	23,0	0,3	3,2	1,0	2,2
KLB - CZ MDST	20,5	26	0,477	12,2	20	343	0,2	145,0	0,4	0,5	0,2	0,3
									Total settlement at 0 m from the axis (mm) :	27	10	16

Stress inc. / σV0 4%

Impact of surcharge	0	0	0
Impact of landscape	13,4	5,0	8,0
Settlement with surcharge			
Informal settlement (mm)	1		

Post-construction Total settlement 16 mm

2 - CONSOLIDATION BY TIME (without vertical drains)

	Time
month	1
number of days / mx	30,5
secondes	2635200

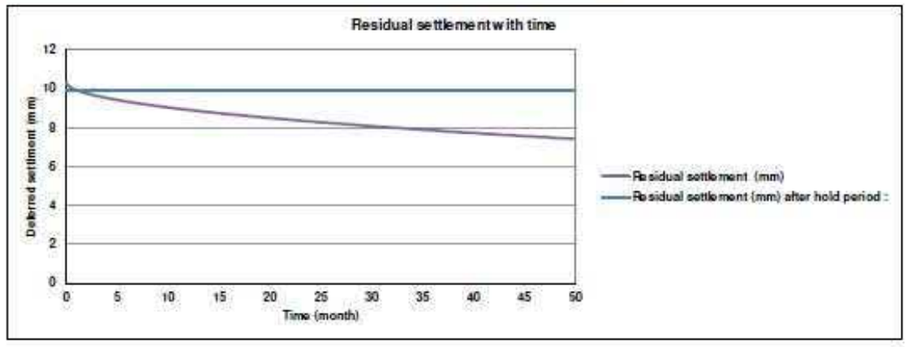
Consolidation settlement

Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ASSI)	5,20E-07	21,40	0,006	4,92	0,4	4%

Total settlement at 0 m from the axis in 1 months (mm): 0,4 4%

Residual settlement

Residual settlement (mm) after hold period :	9,6
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	10,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design
Chetwode Cutting - MC01 School End Road Realignment
Ch. 250,00
Initial Case E&R 0,3 m

γr (kN/m³)	20,00
Hf (m)	1,65
Hr (m)	1,65
Side slopp (H/V)	4,00
Width Pf (m)	13,35
Surcharge of the embankment (kPa)	33,00
Static surcharge (kPa)	0,00
Sr (kPa)	33,00

Embankment geometry for calculating the influence factor at the axis

	distance to the axis (m):
c1	0
c2	6,60
d1	6,60
d2	9,00

Groundwater level 4,88 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Kz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σ'V0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (= total settlement x geological correction factor)	Immediate Settlement (mm) (= total - consolidation settlement)
E&R	0	0,3	1,000	33,0	19	3	0,2	5,3	0,9	0,0	0,0	0,0
TILME - CZ	0,3	3,5	0,986	32,9	21	40	0,2	9,0	0,5	11,7	5,8	5,8
GFDMP - S.V. SV	0,3	7,8	0,972	32,1	19	77	0,2	42,0	0	5,7	0,0	5,7
OXC - CZ u1	7,8	15,5	0,752	24,8	21	244	0,2	15,7	0,5	12,3	6,1	6,1
OXC - CZ u2	15,5	20,5	0,583	19,2	21	314	0,2	23,0	0,3	4,2	1,3	2,9
KLB - CZ MDST	20,5	26	0,482	15,9	20	345	0,2	145,0	0,4	0,6	0,2	0,4
									Total settlement at 0 m from the axis (mm) :	34	13	21

		Impact of surcharge	0	0	0
Stress Inc. / σ'V0	5%	Impact of landscape	-0,72	0,0	0,0
		Settlement with surcharge			
		Internal settlement (mm)	1		

Post-construction Total settlement	19 mm

2 - CONSOLIDATION BY TIME (without vertical drains)

	Time
month	1
number of days / mo	30,5
secondes	2630200

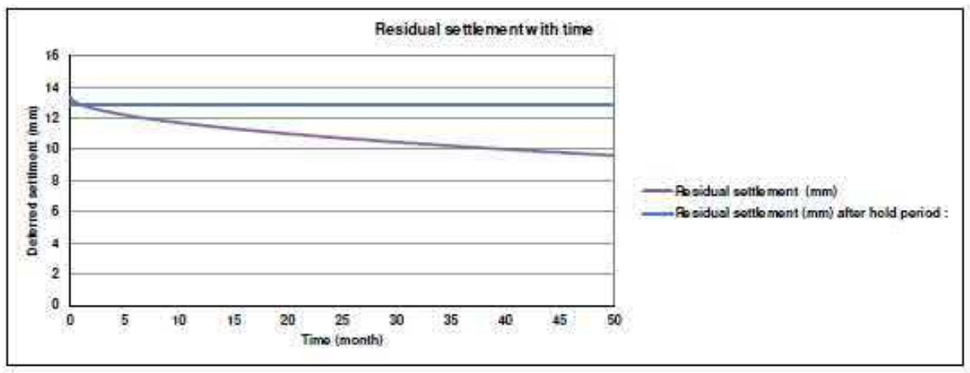
Consolidation settlement

Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ARSI)	2,20E-07	21,40	0,004	4,00	0,5	4%

Total settlement at 0 m from the axis in 1 months (mm):	0,5	4%

Residual settlement

Residual settlement (mm) after hold period :	12,9
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	0,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design
Chetwode Cutting - MC01 School End Road Realignment
Ch. 350.00
Initial Case : E&R 0,3 m

γr (kN/m³)	20,00
Ht (m)	1,70
Hr (m)	1,70
Side slope (H/V)	4,00
Width PF (m)	12,55
Surcharge of the embankment (kPa)	34,00
Static surcharge (kPa)	0,00
Sr (kPa)	34,00

Embankment geometry for calculating the influence factor at the axis

distance to the axis (m):	0
c1	6,85
c2	6,85
d1	9,55
d2	9,55

Groundwater level 5,38 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Kz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σ'v0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (= total settlement x geological correction factor)	Immediate Settlement (mm) (= total - consolidation settlement)
E&R	0	0,3	1,000	34,0	19	3	0,2	5,3	0,9	0,0	0,0	0,0
TILMP - CZ	0,3	3,5	0,996	33,9	21	40	0,2	9,0	0,5	12,0	6,0	6,0
GFDMP - S.V BV	0,3	7,8	0,969	32,9	19	77	0,2	42,0	0	5,9	0,0	5,9
CKC - CZ ut1	7,8	15,5	0,742	25,2	21	249	0,2	15,7	0,5	12,4	6,2	6,2
CKC - CZ ut2	15,5	20,5	0,572	19,4	21	319	0,2	23,0	0,3	4,2	1,3	3,0
KLB - CZ MDST	20,5	26	0,472	16,1	20	350	0,2	146,0	0,4	0,6	0,2	0,4
									Total settlement at 0 m from the axis (mm) :	35	14	21
									Impact of surcharge	0	0	0
			Stress inc. / σ'v0	5%					Impact of landscape	0	0,0	0,0
									Settlement with surcharge			
									Internal settlement (mm)	1		

Post-construction Total settlement 15 mm

2 - CONSOLIDATION BY TIME (without vertical drains)

Time

month	1
number of days / mo	30,5
secondes	2628000

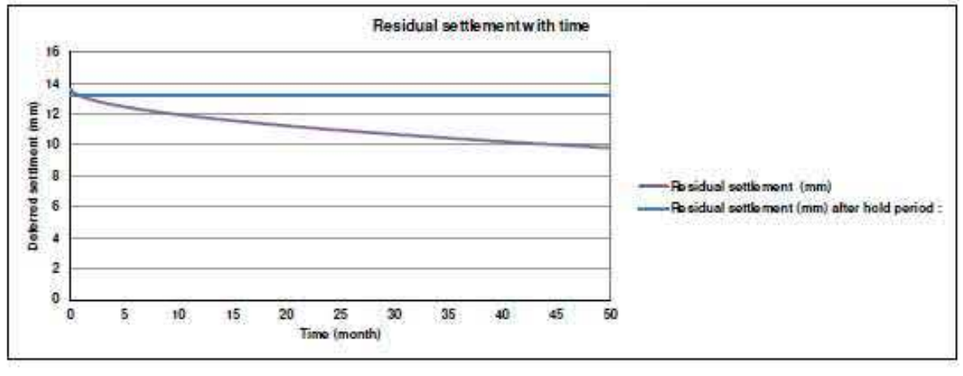
Consolidation settlement

Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ABSI)	2,20E-07	21,40	0,001	4,02	0,6	4%

Total settlement at 0 m from the axis in 1 months (mm): 0,6 4%

Residual settlement

Residual settlement (mm) after hold period :	13,2
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	0,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design
Chetwode Cutting - MC01 School End Road Realignment
Ch. 360.00
Initial Case E&R 0,3 m

γ (kN/m³)	20,00
Hf (m)	1,22
Hr (m)	1,22
Side slope (H/V)	4,00
Width PF (m)	12,55
Surcharge of the embankment (kPa)	24,40
Static surcharge (kPa)	0,00
Sr (kPa)	24,40

Embankment geometry for calculating the influence factor at the axis

	distance to the axis (m): 0
c1	4,99
c2	4,99
d1	8,72
d2	8,72

Groundwater level 5,48 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Kz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σV0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (= total settlement x geological correction factor)	Immediate Settlement (mm) (= total - consolidation settlement)
E&R	0	0,3	1,000	24,5	19	3	0,2	5,3	0,9	0,0	0,0	0,0
TILMP - CZ	0,3	3,5	0,995	24,3	21	40	0,2	9,0	0,5	8,7	4,3	4,3
GFDMP - S V SV	0,3	7,8	0,962	23,5	19	77	0,2	42,0	0	4,2	0,0	4,2
OKC - CZ u1	7,8	15,5	0,707	17,3	21	250	0,2	15,7	0,5	8,5	4,2	4,2
OKC - CZ u2	15,5	20,5	0,533	13,0	21	320	0,2	23,0	0,9	2,8	0,9	2,0
KLB - CZ MDST	20,5	25	0,435	10,7	20	351	0,2	145,0	0,4	0,4	0,2	0,2
									Total settlement at 0 m from the axis (mm) :	25	10	15
									Impact of surcharge	0	0	0
				Stress inc. / σV0	3%				Impact of landscape	0	0,0	0,0
									Settlement with surcharge			
									Internal settlement (mm)	1		

2 - CONSOLIDATION BY TIME (without vertical drains)

Post-construction Total settlement 11 mm

	Time
month	1
number of days / mo	30,5
secondes	2635200

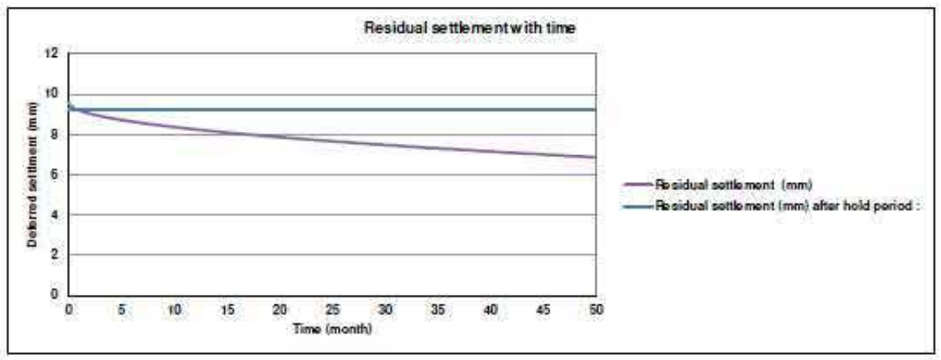
Consolidation settlement

Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ABSI)	2,20E-07	21,40	0,061	4,02	0,4	4%

Total settlement at 0 m from the axis in 1 months (mm): 0,4 4%

Residual settlement

Residual settlement (mm) after hold period :	9,2
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	9,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design

Chetwode Cutting - MC02 Maintenance Access Road to Pond (Off School End Road - South)

Ch. 12,779

Initial Case E&R 0,3 m

γ (kN/m³)	20,00
Hf (m)	6,00
Ht (m)	6,00
Side slope (H/V)	4,00
Width PF (m)	11,30
Surcharge of the embankment (kPa)	120,00
Static surcharge (kPa)	0,00
Sr (kPa)	120,00

Embankment geometry for calculating the influence factor at the axis

distance to the axis (m):	0
c1	24,00
c2	24,00
d1	17,65
d2	17,65

Groundwater level 0 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Kz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σv0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (= total settlement x geological correction factor)	Immediate Settlement (mm) (= total - consolidation settlement)
E&R	0	0,3	1,000	120,0	19	3	0,2	5,3	0,9	0,0	0,0	0,0
TILMP - CZ	0,3	4,5	0,997	119,6	21	26	0,2	9,0	0,5	55,8	27,9	27,9
GFDMP - S V tV	0,3	7,4	0,988	118,6	19	35	0,2	42,0	0	20,0	0,0	20,0
OKC - CZ ut	7,4	12	0,908	108,9	21	195	0,2	15,7	0,5	31,9	16,0	16,0
OKC - CZ ut2	12	15,5	0,835	100,3	21	239	0,2	23,0	0,3	15,3	4,6	10,7
KLB - CZ MOST	15,5	21,5	0,752	90,3	20	269	0,2	145,0	0,4	3,7	1,5	2,2
									Total settlement at 0 m from the axis (mm) :	127	50	77

Stress inc. / σv0 44%

Impact of surcharge	0	0	0
Impact of landscape	0	0,0	0,0
Settlement with surcharge			
Internal settlement (mm)	6		
Post-construction Total settlement	56 mm		

2 - CONSOLIDATION BY TIME (without vertical drains)

Time

month	1
number of days / mo	30,5
secondes	2628000

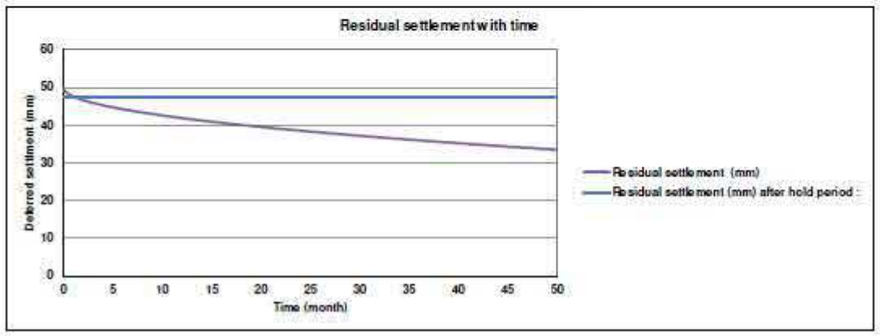
Consolidation settlement

Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ABS)	2,17E-07	19,30	0,002	4,87	2,8	5%

Total settlement at 0 m from the axis in 1 months (mm): 2,8 5%

Residual settlement

Residual settlement (mm) after hold period :	47,6
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	0,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design
Chetwode Cutting - MC02 Maintenance Access Road to Pond (Off School End Road - South)
Ch. 635.00
Initial Case E&R 2,3 m

γ (kN/m³)	20,00
Ht (m)	2,70
Hr (m)	2,70
Side slope (H/V)	2,00
Width PF (m)	13,00
Surcharge of the embankment (kPa)	54,00
Static surcharge (kPa)	0,00
Sr (kPa)	54,00

Embankment geometry for calculating the influence factor at the axis

distance to the axis (m):	0
c1	5,40
c2	5,40
d1	0,20
d2	0,20

Groundwater level 0 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Iiz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σ'v0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (= total settlement x geological correction factor)	Immediate Settlement (mm) (= total - consolidation settlement)
ESR - CL2 (TILMP/GFD/MP)	0	2,3	0,999	53,9	20	12	0,2	12,0	0,5	0,0	0,0	0,0
CB -LMST	2,3	4,3	0,980	52,9	20	33	0,2	150,0	0,3	0,7	0,2	0,5
KJB - CZ MDST	4,3	21,5	0,688	37,1	20	129	0,2	145,0	0,4	4,4	1,8	2,6
									Total settlement at 0 m from the axis (mm) :	5	2	3

Stress Inc. / σ'v0 29%

Impact of surcharge	0	0	0
Impact of landscape	0	0,0	0,0
Settlement with surcharge			
Informal settlement (mm)	2		
Post-construction Total settlement	4 mm		

2 - CONSOLIDATION BY TIME (without vertical drains)

	Time
month	1
number of days / mo	30,5
secondes	2635200

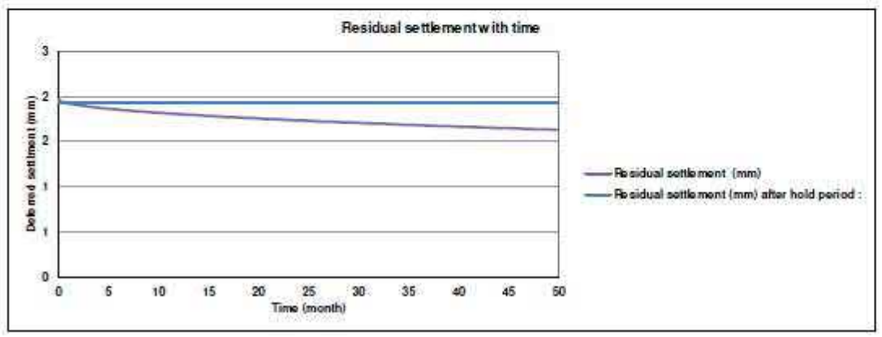
Consolidation settlement

Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ABS)	8,29E-08	21,50	0,000	2,46	0,0	3%

Total settlement at 0 m from the axis in 1 months (mm):	0,0	3%

Residual settlement

Residual settlement (mm) after hold period :	1,9
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	0,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design

Chetwode Cutting - MC04 Maintenance Access Road to GSMR (off School End Road Realignment) and Compound

Ch: 64,00

Initial Case E&R 0,3 m + Landcape bunds

γ (kN/m³)	20,00
Hf (m)	6,50
Hr (m)	6,50
Side slope (H/V)	4,00
Width PF (m)	6,50
Surcharge of the embankment (kPa)	100,00
Static surcharge (kPa)	0,00
Sr (kPa)	100,00

Embankment geometry for calculating the influence factor at the axis

distance to the axis (m):	0
c1	26,00
c2	26,00
d1	19,25
d2	19,25

Groundwater level 0 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Kz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σ'V0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (= total settlement x geological correction factor)	Immediate Settlement (mm) (= total - consolidation settlement)
E&R	0	0,3	1,000	130,0	19	1	0,2	5,3	0,9	0,0	0,0	0,0
TILMP - CZ	0,3	4,5	0,992	129,0	21	26	0,2	9,0	0,5	50,2	36,1	36,1
GFDMP - S.V. SV	0,3	7,5	0,975	126,7	19	35	0,2	42,0	0	21,7	0,0	21,7
GKC - CZ u1	7,5	14	0,849	110,4	21	206	0,2	15,7	0,5	45,7	22,9	22,9
GKC - CZ u2	14	17	0,760	98,7	21	259	0,2	23,0	0,3	12,9	3,9	9,0
KLB - CZ MDST	17	22	0,691	89,8	20	279	0,2	146,0	0,4	3,1	1,2	1,9
									Total settlement at 0 m from the axis (mm) :	144	58	86
									Impact of surcharge	0	0	0
									Impact of landscape	25	10,0	6,8
									Settlement with surcharge			
									Informal settlement (mm)	7		
									Post-construction Total settlement	75 mm		

Stress inc. / σV0 32%

2 - CONSOLIDATION BY TIME (without vertical drains)

Time

month	1
number of days / mo	30,5
secondes	2630160

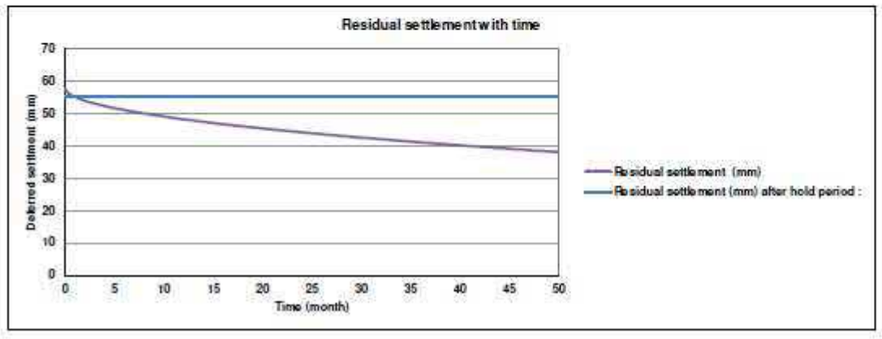
Consolidation settlement

Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ABS)	2,45E-07	18,70	0,069	4,00	2,9	8%

Total settlement at 0 m from the axis in 1 months (mm) 2,9 8%

Residual settlement

Residual settlement (mm) after hold period	58,0
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm) :	0,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design

Chetwode Cutting - MC04 Maintenance Access Road to GSMR (off School End Road Realignment) and Compound

Ch. 80,00

Initial Case E&R 0,3 m + Landscape bunds

γ (kN/m³)	20,00
Hf (m)	2,85
Hr (m)	2,85
Side slope (H/V)	4,00
Width PF (m)	6,50
Surcharge of the embankment (kPa)	57,00
Static surcharge (kPa)	0,00
Sr (kPa)	57,00

Embankment geometry for calculating the influence factor at the axis

distance to the axis (m):	0
c1	11,40
c2	11,40
d1	0,05
d2	0,05

Groundwater level 0 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Iz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σV0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (= total settlement x geological correction factor)	Immediate Settlement (mm) (= total - consolidation settlement)
E&R	0	0,3	1,000	57,0	19	3	0,2	5,3	0,9	0,0	0,0	0,0
TILMP - CZ	0,3	4,5	0,983	56,0	21	26	0,2	9,0	0,5	26,1	13,1	13,1
GFDMP - S.V SV	0,3	7,5	0,946	53,9	19	35	0,2	42,0	0	9,2	0,0	9,2
CKC - CZ u1	7,5	14	0,714	40,7	21	206	0,2	15,7	0,5	16,8	8,4	8,4
CKC - CZ u2	14	17	0,582	33,2	21	255	0,2	23,0	0,3	4,3	1,3	3,0
KLB - CZ MDST	17	22	0,497	28,3	20	279	0,2	146,9	0,4	1,0	0,4	0,6
									Total settlement at 0 m from the axis (mm) :	58	23	34
				Stress Inc. / σV0	10%				Impact of surcharge	0	0	0
									Impact of landscape	0	0,0	0,0
									Settlement with surcharge			
									Informal settlement (mm)	2		
									Post-construction Total settlement	35 mm		

2 - CONSOLIDATION BY TIME (without vertical drains)

Time

month	1
number of days / mo	30,5
secondes	2628200

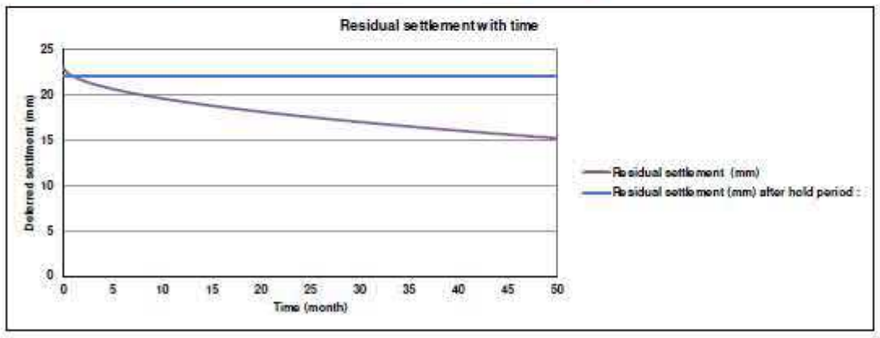
Consolidation settlement

Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ABS1)	2,45E-07	19,70	0,002	4,86	1,1	5%

Total settlement at 0 m from the axis in 1 months (mm): 1,1 5%

Residual settlement

Residual settlement (mm) after hold period :	22,3
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	0,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design
Chetwode Cutting - MC01 Footpath CHW18 Accommodation Access Realignement
Ch. 66,00
Initial Case E&R 0,3 m

γr (kN/m³)	20,00
Hf (m)	2,00
Hr (m)	3,00
Side slope (H/V)	4,00
Width PF (m)	10,17
Surcharge of the embankment (kPa)	40,00
Static surcharge (kPa)	0,00
Sr (kPa)	40,00

Embankment geometry for calculating the influence factor at the axis

distance to the axis (m):	0
c1	8,00
c2	8,00
d1	0,00
d2	0,00

Groundwater level 26,5 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Kz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σV0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (= total settlement x geological correction factor)	Immediate Settlement (mm) (= total - consolidation settlement)
E&R	0	0,3	1,000	40,0	21	3	0,2	5,3	0,9	0,0	0,0	0,0
TILMP - CZ	0,3	2	0,999	39,9	21	24	0,2	9,0	0,5	7,5	3,8	3,8
GFDMP - S V SV	2	5	0,972	38,9	19	67	0,2	42,0	0	2,8	0,0	2,8
OKC - CZ w	5	6	0,919	36,8	19	105	0,2	7,0	0,5	5,3	2,6	2,6
OKC - CZ u1	6	11	0,818	32,7	21	179	0,2	15,7	0,5	10,4	5,2	5,2
OKC - CZ u2	11	17	0,643	25,7	21	294	0,2	23,0	0,3	6,7	2,0	4,7
KLB - CZ MDST	17	23	0,503	20,1	20	400	0,2	145,0	0,4	0,8	0,3	0,5
									Total settlement at 0 m from the axis (mm) :	34	14	20
									Impact of surcharge	0	0	0
			Stress inc. / σv0	5%					Impact of landscape	0	0,0	0,0
									Settlement with surcharge			
									Internal settlement (mm)	1		
									Post-construction Total settlement :	15 mm		

2 - CONSOLIDATION BY TIME (without vertical drains)

Time

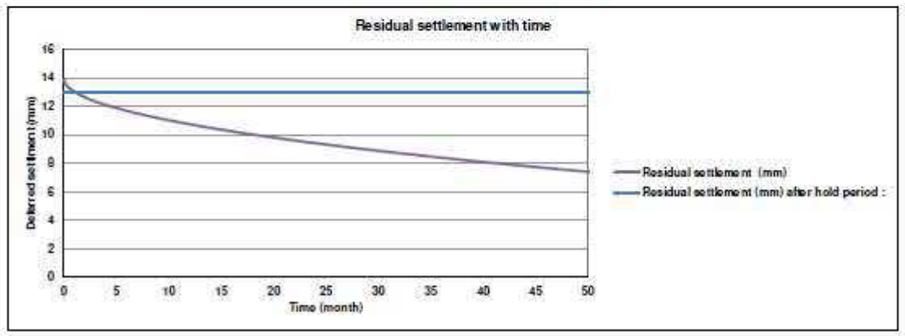
month	1
number of days / m	30,5
secondes	2630250

Consolidation settlement

Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ABS)	6,10E-07	19,70	0,000	6,84	0,9	7%
	0,00E+00	0,00				
	0,00E+00	0,00				
	0,00E+00	0,00				
	0,00E+00	0,00				
	0,00E+00	0,00				
	0,00E+00	0,00				
Total settlement at 0 m from the axis in 1 months (mm):					0,9	7%

Residual settlement

Residual settlement (mm) after hold period :	13,0
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	0,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design
Chetwode Cutting - MC01 Footpath CH-W18 Accommodation Access Realignement
Ch. 69,20
Initial Case E&R 0,3 m

γr (kN/m³)	20,00	Embankment geometry for calculating the influence factor at the axis	
Ht (m)	2,21	distance to the axis (m):	0
Hr (m)	2,21	c1	8,82
Side slope (H/V)	4,00	c2	8,82
W idth PF (m)	12,30	d1	10,61
Surcharge of the embankment (kPa)	44,10	d2	10,61
Static surcharge (kPa)	0,00		
Sr (kPa)	44,10		

Groundwater level 20,5 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Kz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σ'v0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (ν total settlement x geological correction factor)	Immediate Settlement (mm) (ν total - consolidation settlement)
E&R	0	0,3	1,000	44,1	21	31	0,2	5,3	0,9	0,0	0,0	0,0
TILMP - CZ	0,3	2	0,999	44,1	21	24	0,2	9,0	0,5	8,3	4,2	4,2
GFDMP - S V SV	2	5	0,982	43,3	19	67	0,2	42,0	0	3,1	0,0	3,1
OKC - CZ w	5	6	0,944	41,6	19	105	0,2	7,0	0,5	5,9	3,0	3,0
OKC - CZ u1	6	11	0,862	38,0	21	179	0,2	15,7	0,5	12,1	6,1	6,1
OKC - CZ u2	11	17	0,703	31,0	21	294	0,2	23,0	0,3	9,1	2,4	5,7
KLB - CZ MOST	17	23	0,564	24,9	20	400	0,2	145,0	0,4	1,0	0,4	0,6
									Total settlement at 0 m from the axis (mm)	39	15	23
									Impact of surcharge	0	0	0
				Stress inc. / σ'v0	6%				Impact of landscape	0	0,0	0,0
									Settlement with surcharge			
									Internal settlement (mm)	2		
									Post-construction Total settlement	18 mm		

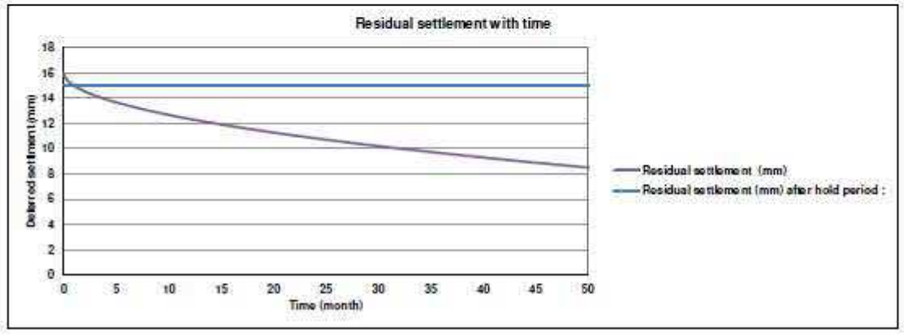
2 - CONSOLIDATION BY TIME (without vertical drains)

Time		
month	1	
number of days / mo	30,5	
secondes	2630016	

Consolidation settlement						
Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ABSI)	5,10E-07	19,70	0,003	6,84	1,1	7%

Total settlement at 0 m from the axis in 1 months (mm):	1,1

Residual settlement	
Residual settlement (mm) after hold period	16,8
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	0,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design
Chetwode Cutting - MC01 Footpath CHW19 Accommodation Access Realignement
Ch. 163,30
Initial Case E&R 0,3 m

γr (kN/m³)	20,00
Ht (m)	5,20
Hr (m)	3,20
Side slope (H/V)	4,00
Width PF (m)	9,03
Surcharge of the embankment (kPa)	64,00
Static surcharge (kPa)	0,00
Sr (kPa)	64,00

Embankment geometry for calculating the influence factor at the axis

distance to the axis (m):	0
c1	12,90
c2	12,90
d1	19,91
d2	19,91

Groundwater level 20,8 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Kz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σV0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (= total settlement x geological correction factor)	Immediate Settlement (mm) (= total - consolidation settlement)
E&R	0	0,3	1,000	64,0	21	3	0,2	5,3	0,9	0,0	0,0	0,0
TILMP - CZ	0,3	2	0,999	63,9	21	24	0,2	9,0	0,5	12,1	0,0	6,0
GFDMP - S V SV	0,3	5	0,988	63,3	19	50	0,2	42,0	0	7,1	0,0	7,1
OKC - CZ w	5	6	0,933	59,7	19	137	0,2	7,0	0,5	8,5	4,3	4,3
OKC - CZ u1	6	11	0,850	54,4	21	214	0,2	15,7	0,5	17,3	8,7	8,7
OKC - CZ u2	11	17	0,697	44,6	21	330	0,2	23,0	0,3	11,6	3,5	8,1
KLB - CZ MDST	17	23	0,565	36,1	20	434	0,2	145,0	0,4	1,5	0,6	0,9
									Total settlement at 0 m from the axis (mm) :	58	23	35
				Stress inc. / σV0	8%				Impact of surcharge	0	0	0
									Impact of landscape	0	0,0	0,0
									Settlement with surcharge			
									Inferred settlement (mm)	2		

Post-construction Total settlement 25 mm

2 - CONSOLIDATION BY TIME (without vertical drains)

Time

month	1
number of days / mo	30,5
secondes	2630000

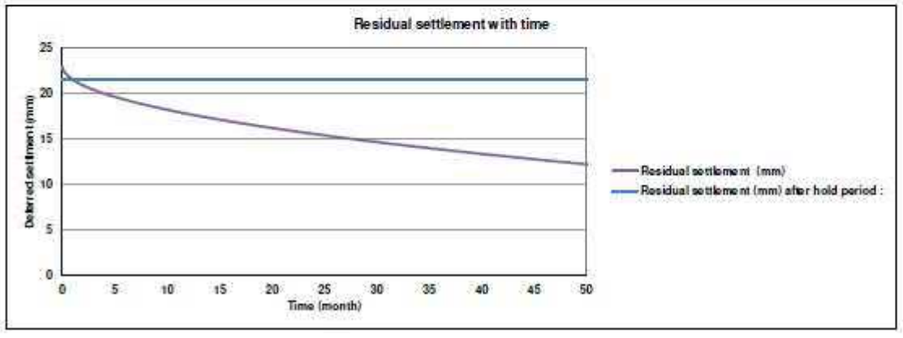
Consolidation settlement

Layers	Cv (m²/s)	drainage height H (m)	TV	UV (%)	w (mm)	percentage
Layer Eq (ABS)	5,10E-07	19,70	0,003	6,54	1,5	7%

Total settlement at 0 m from the axis in 1 months (mm):	1,5	7%

Residual settlement

Residual settlement (mm) after hold period :	21,5
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	0,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design
Chetwode Cutting - MC01 Footpath CHW18 Accommodation Access Realignement
Ch. 170,00
Initial Case E/R 0,3 m

γ (kN/m³)	20,00
Ht (m)	2,99
Hr (m)	2,99
Side slope (H/V)	4,00
W idth PF (m)	9,03
Surcharge of the embankment (kPa)	57,80
Static surcharge (kPa)	0,00
Sr (kPa)	57,80

Embankment geometry for calculating the influence factor at the axis

distance to the axis (m):	0
c1	11,56
c2	11,56
d1	10,29
d2	10,29

Groundwater level 20,5 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Kz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σV0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (= total settlement x geological correction factor)	Immediate Settlement (mm) (= total - consolidation settlement)
E&R	0	0,3	1,000	57,8	21	3	0,2	5,3	0,9	0,0	0,0	0,0
TILMP - CZ	0,3	2	0,999	57,7	21	24	0,2	9,0	0,5	10,9	5,5	5,5
GFDMP - S V SV	0,3	5	0,987	57,1	19	50	0,2	42,0	0	6,4	0,0	6,4
CKC - CZ w	5	6	0,928	53,6	19	137	0,2	7,0	0,5	7,7	3,8	3,8
CKC - CZ ut1	6	11	0,838	48,5	21	214	0,2	15,7	0,5	15,4	7,7	7,7
CKC - CZ ut2	11	17	0,679	39,2	21	330	0,2	23,0	0,3	10,2	3,1	7,2
KLB - CZ MDST	17	23	0,544	31,4	20	434	0,2	145,0	0,4	1,3	0,5	0,8
									Total settlement at 0 m from the axis (mm) :	52	21	31
									Impact of surcharge	0	0	0
									Impact of landscape	0	0,0	0,0
									Settlement with surcharge			
									Internal settlement (mm)	2		

Stress inc. / σV0 7%

Post-construction Total settlement	23 mm

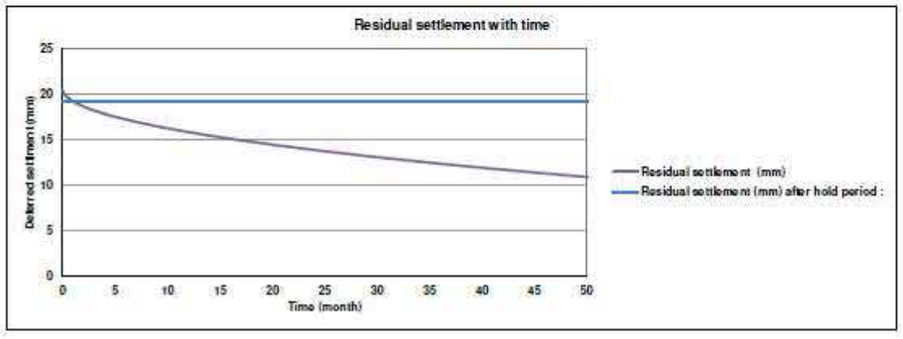
2 - CONSOLIDATION BY TIME (without vertical drains)

Time	
month	1
number of days / mo	30,5
secondes	2635200

Consolidation settlement						
Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ABS1)	5,10E-07	19,70	0,003	6,64	1,4	7%

Total settlement at 0 m from the axis in 1 months (mm):	1,4

Residual settlement	
Residual settlement (mm) after hold period :	18,2
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	0,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design
Chetwode Cutting - MC02 Footpath CHW/18 Diversion
Ch.30,00
Initial Case + Embankment on the Landscape bund

γr (kN/m³)	20,00
Ht (m)	1,60
Hr (m)	1,60
Side slope (H/V)	3,00
Width PF (m)	4,00
Surcharge of the embankment (kPa)	32,00
Static surcharge (kPa)	0,00
Sr (kPa)	32,00

Embankment geometry for calculating the influence factor at the axis

distance to the axis (m)	0
c1	4,00
c2	4,80
d1	4,40
d2	4,40

Groundwater level 20,5 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Iz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σ'v0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (= total settlement x geological correction factor)	Immediate Settlement (mm) (= total - consolidation settlement)
Landscape Fill	0	1,6	0,993	31,8	21	17	0,2	9,0	0,5	5,7	2,8	2,8
TILMP - CZ	1,6	3,6	0,913	29,2	21	55	0,2	9,0	0,5	6,5	3,2	3,2
GFDMP - S V SV	3,6	6,6	0,737	23,6	19	97	0,2	42,0	0	1,7	0,0	1,7
OKC - CZ w	6,6	7,6	0,616	19,7	19	135	0,2	7,0	0,5	2,8	1,4	1,4
OKC - CZ u1	7,6	12,6	0,483	15,4	21	212	0,2	15,7	0,5	4,9	2,5	2,5
OKC - CZ u2	12,6	19,6	0,328	10,5	21	338	0,2	23,0	0,3	3,2	1,0	2,2
KLB - CZ MDST	19,6	25,6	0,240	7,7	20	431	0,2	145,0	0,4	0,3	0,1	0,2
									Total settlement at 0 m from the axis (mm) :	25	11	14
									Impact of surcharge	0	0	0
									Impact of landscape	0	0,0	0,0
									Settlement with surcharge			
									Internal settlement (mm)	1		

Stress inc. / σ'v0 2%

Post-construction Total settlement	12 mm

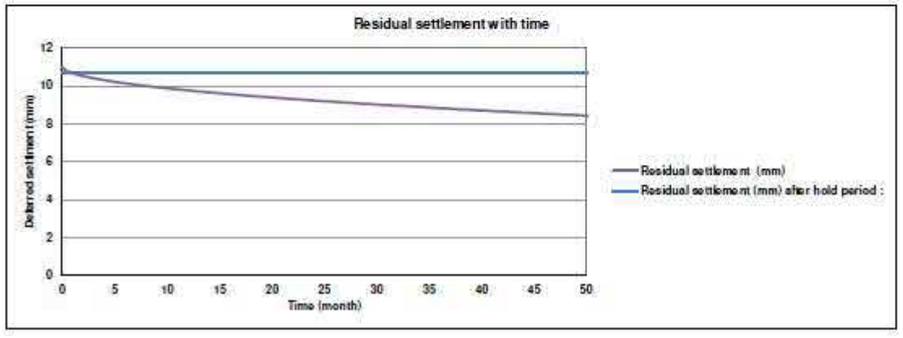
2 - CONSOLIDATION BY TIME (without vertical drains)

Time	
month	1
number of days / mo	30,5
secondes	2628200

Consolidation settlement						
Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ABSI)	1,70E-07	22,60	0,001	3,36	0,4	3%

Total settlement at 0 m from the axis in 1 months (mm):	0,4	3%

Residual settlement	
Residual settlement (mm) after hold period :	10,7
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	0,0



HS2 Ltd - Code 1 - Accepted

HS2 – C2 – T2G – Detailed Design
Chetwode Cutting - MC02 Footpath CHW/18 Diversion
Ch.60,00
Initial Case + Embankment on the Landscape bund

γr (kN/m³)	20,00
Ht (m)	1,60
Hr (m)	1,60
Side slope (H/V)	3,00
Width PF (m)	4,87
Surcharge of the embankment (kPa)	32,00
Static surcharge (kPa)	0,00
Sr (kPa)	32,00

Embankment geometry for calculating the influence factor at the axis

distance to the axis (m):	0
c1	4,80
c2	4,80
d1	4,83
d2	4,83

Groundwater level 20,5 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Iz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σ'v0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) (ι: total settlement x geological corrector factor)	Immediate Settlement (mm) (ι: total - consolidation settlement)
Landscape Fill	0	3,71	0,969	31,0	21	39	0,2	9,0	0,5	12,8	6,4	6,4
TILMP - CZ	3,71	5,71	0,799	25,6	21	99	0,2	9,0	0,5	5,7	2,8	2,8
GFDMP - S V SV	5,71	8,71	0,650	20,8	19	137	0,2	42,0	0	1,5	0,0	1,5
GKC - CZ w	8,71	9,71	0,555	17,8	19	175	0,2	7,0	0,5	2,5	1,3	1,3
GKC - CZ u1	9,71	14,71	0,450	14,4	21	236	0,2	15,7	0,5	4,6	2,3	2,3
GKC - CZ u2	14,71	21,71	0,320	10,2	21	382	0,2	23,0	0,3	3,1	0,9	2,2
KLB - CZ MDST	21,71	27,71	0,242	7,7	20	452	0,2	145,0	0,4	0,3	0,1	0,2
									Total settlement at 0 m from the axis (mm) :	31	14	17
									Impact of surcharge	0	0	0
			Stress inc. / σ'v0	2%					Impact of landscape	0	0,0	0,0
									Settlement with surcharge			
									Internal settlement (mm)	1		
									Post-construction Total settlement	15 mm		

2 - CONSOLIDATION BY TIME (without vertical drains)

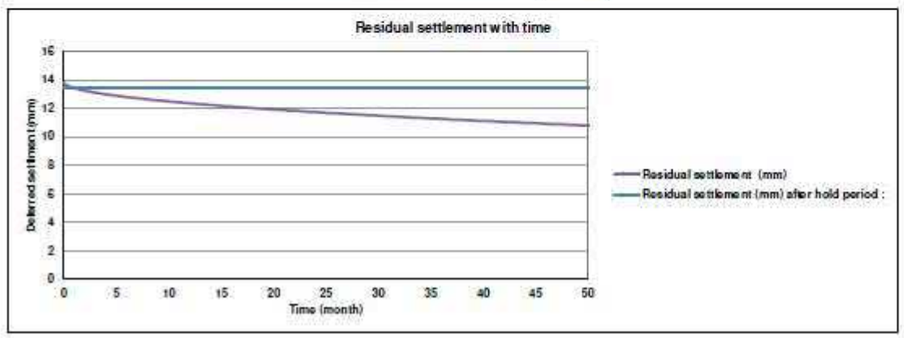
	Time
month	1
number of days / mo	30,5
seconds	2630016

Consolidation settlement

Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ABSI)	1,77E-07	24,71	0,001	3,14	0,4	3%

Total settlement at 0 m from the axis in 1 months (mm):	0,4

Residual settlement	
Residual settlement (mm) after hold period :	13,4
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	0,0



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HS2 – C2 – T2G – Detailed Design
Chetwode Cutting - MC05 Green HW Realignement
Ch.127,00
Initial Case E&R 0,3 m

γ' (kN/m³)	20,00
Ht (m)	2,00
Ht (m)	2,00
Side slope (H/V)	4,00
Width PF (m)	5,50
Surcharge of the embankment (kPa)	40,00
Static surcharge (kPa)	0,00
Sr (kPa)	-40,00

Embankment geometry for calculating the influence factor at the axis

distance to the axis (m):	0
c1	0,00
c2	0,00
d1	7,25
d2	7,25

Groundwater level 20,5 m

1 - ESTIMATED SETTLEMENT

Layers	Top (m)	Base (m)	Influence factor at the center of the layer Kz	Stress increase at the center of the layer (kPa)	γ (kN/m3)	σV0 (kPa)	Poisson ratio	Characteristic Oedometer Modulus (MPa)	ICE/MGE Factor (ratio of consolidation to total settlement)	Total settlement ΔH (mm)	Consolidation settlement ΔH (mm) i= total settlement x geological correction factor	Immediate Settlement (mm) i= total - consolidation settlement
E/R	0	0,3	1,000	40,0	21	3	0,2	9,0	0,5	1,3	0,7	0,7
TILMP - CZ	0,3	2	0,997	39,9	21	24	0,2	9,0	0,5	7,5	3,8	3,8
GFDMP - S V SV	0,3	5	0,970	38,8	19	50	0,2	42,0	0	4,3	0,0	4,3
OKC - CZ w	5	6	0,861	34,4	19	137	0,2	7,0	0,5	4,9	2,5	2,5
OKC - CZ u1	6	11	0,733	29,3	21	214	0,2	15,7	0,5	9,3	4,7	4,7
OKC - CZ u2	11	17	0,547	21,9	21	330	0,2	23,0	0,3	5,7	1,7	4,0
KLB - CZ MDST	17	23	0,417	16,7	20	434	0,2	145,0	0,4	0,7	0,3	0,4
									Total settlement at 0 m from the axis (mm) :	34	14	20
									Impact of surcharge	0	0	0
									Impact of landscape	0	0,0	0,0
									Settlement with surcharge			
									Internal settlement (mm)	1		

Stress inc. / σV0 4%

Post-construction Total settlement 15 mm

2 - CONSOLIDATION BY TIME (without vertical drains)

	Time
month	1
number of days / m	30,5
seconds	2632200

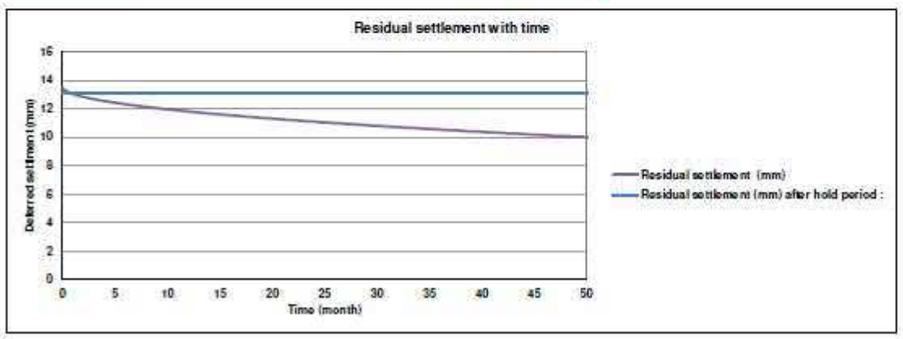
Consolidation settlement

Layers	Cv (m²/s)	drainage height H (m)	Tv	Uv (%)	w (mm)	percentage
Layer Eq (ABSI)	1,58E-07	19,70	0,001	3,71	0,5	4%

Total settlement at 0 m from the axis in 1 months (mm): 0,5 4%

Residual settlement

Residual settlement (mm) after hold period :	13,0
Settlement without surcharge anticipation over 12 after a hold period of 1 months (mm):	0,0



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Data

Project title : Raft - GSMR Platform
Project number : 1
Comments : N/A
Project dimension : 3D
X-coordinate of the plate (m) : 0.00
Y-coordinate of the plate (m) : 0.00
Plate elevation (m) : 0,00
Plate orientation (°) : 0,0
Project symmetries : None
Unsticking threshold (kPa) : 5
Plastification threshold (kPa) : 2000
Automatic unsticking/plastification : No
Recovery of stiffness matrix : No
Save matrix : No
Printing type : Detailed printing
Manual unsticking/plastification of nodes : No
Resolution method : Direct

Soil layers definition

No	Name	Colour	base	Esoil	v	Slope-x	Slope-y
1	TILMP-C Z		-4,50	6.00E03	0,20	0.000	0,000
2	GFOMP-S V SV		-7,50	9.00E03	0,20	0.000	0,000
3	OXC-C Z u1		-9,00	1.40E04	0,20	0.000	0,000
4	OXC-C Z u2 (MDST)		-15,50	1.64E04	0,20	0.000	0,000
5	KLB- C Z MDST		-21,70	1.21E04	0,20	0.000	0,000

Initial surface stress (kPa) : 0.00

Plate

Area #	Xmin	Xmax	Ymin	Ymax	Eplate	v	h
1	0,00	6.50	0,00	3.50	1,70E07	0,20	0,50

Distributed load

Load #	Xmin	Xmax	Ymin	Ymax	Load	kz
1	0.00	6.50	0.00	3.50	20.00	0.00E00

Maximum step (m) : 1.00

Refinements along X axis

No	Min	Max	Ratio
1	0.00	6.50	2.0

Refinements along Y axis

No	Min	Max	Ratio
1	0.00	3.50	2.0

User-defined crossover points along X axis

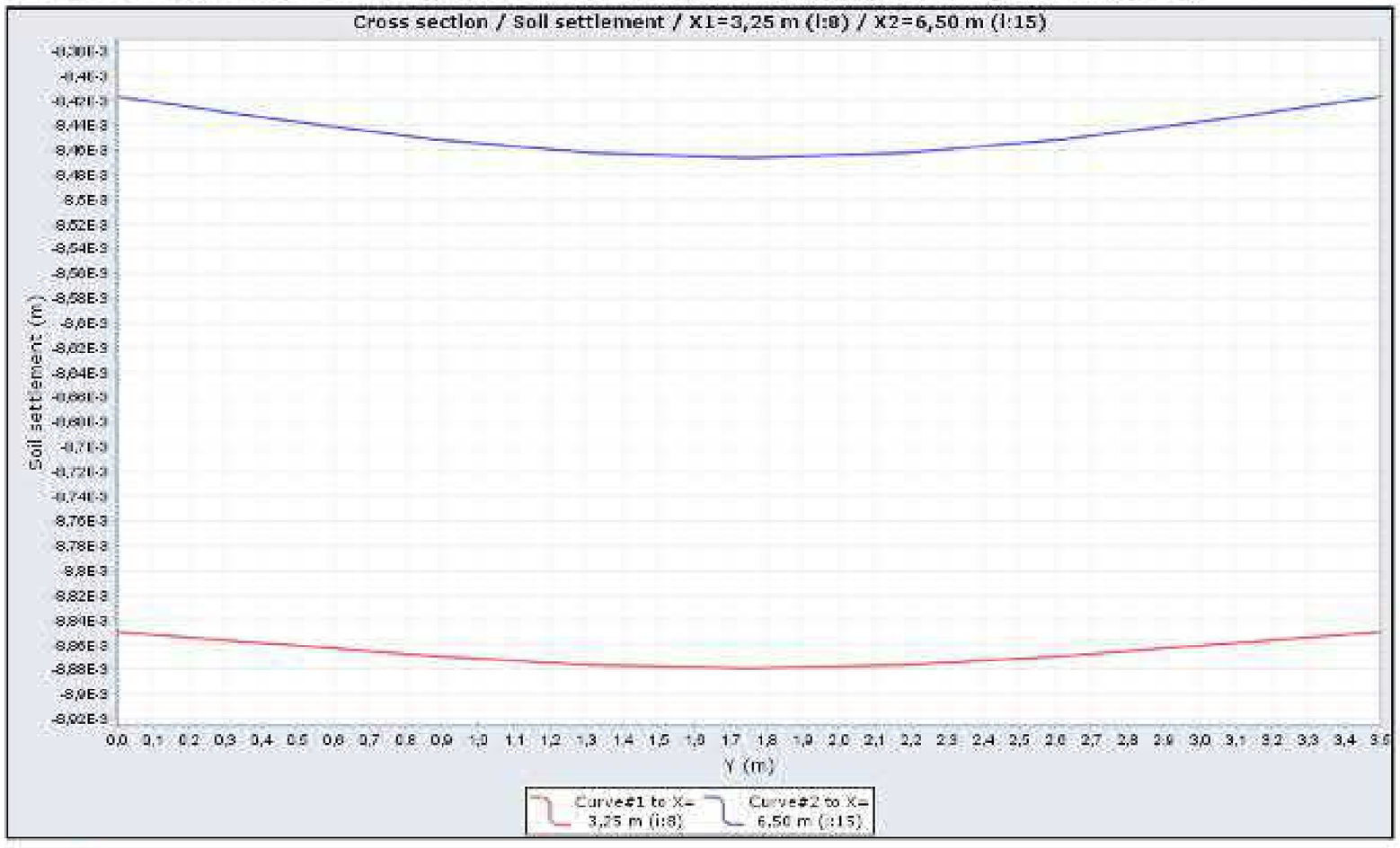
No	Coord.
1	3.25

User-defined crossover points along Y axis

No	Coord.
1	1.75

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Cross section / Soil settlement / X1=3,25 m (i:8) / X2=6,50 m (i:15)



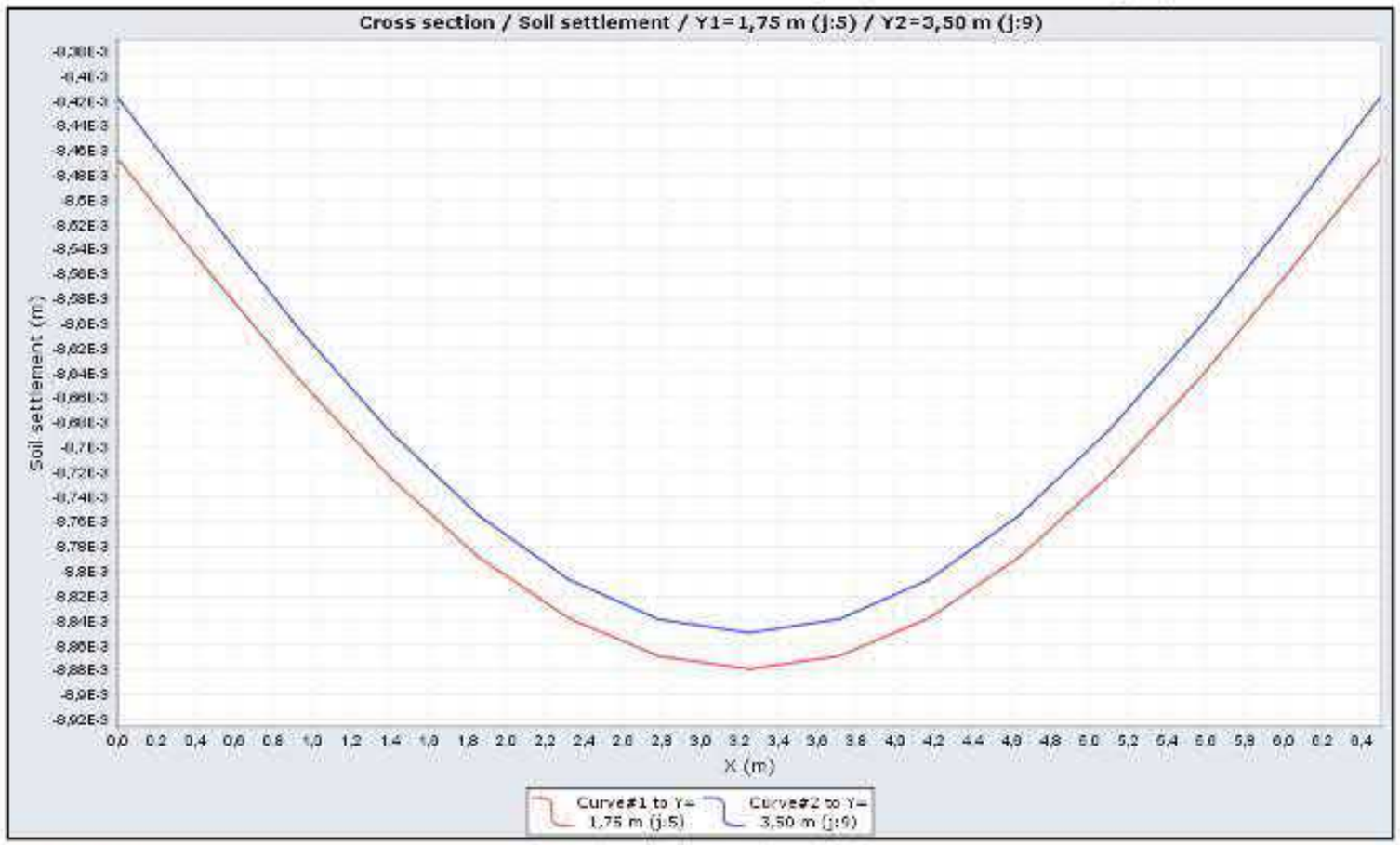
FoXta v3
v3.3.8

Printed on : 10/11/2022 - 10:25:22
Calculation made by : SEITEC ALS

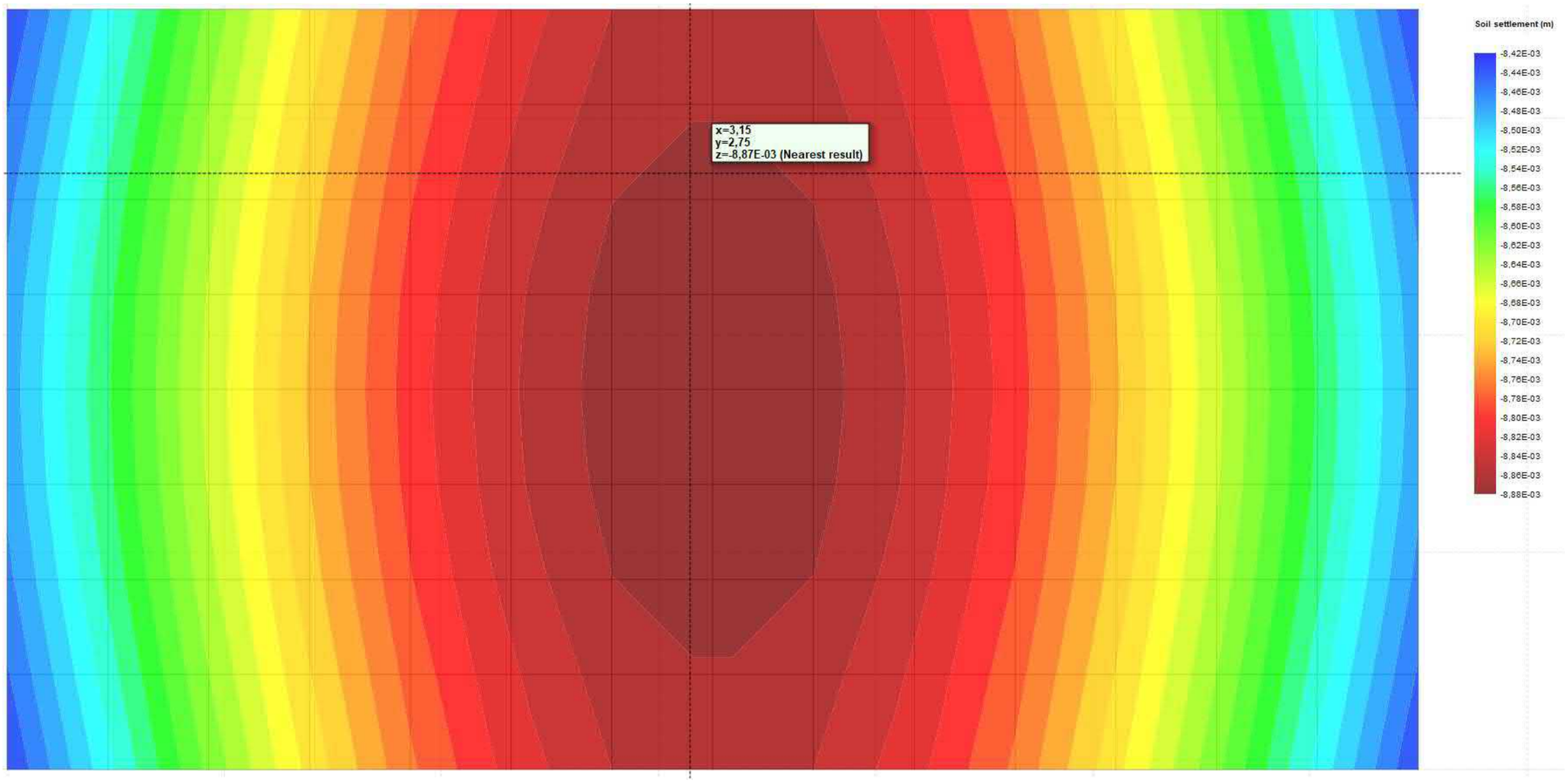
Project : Settlement GSMR Platform V2
Module : fasplax

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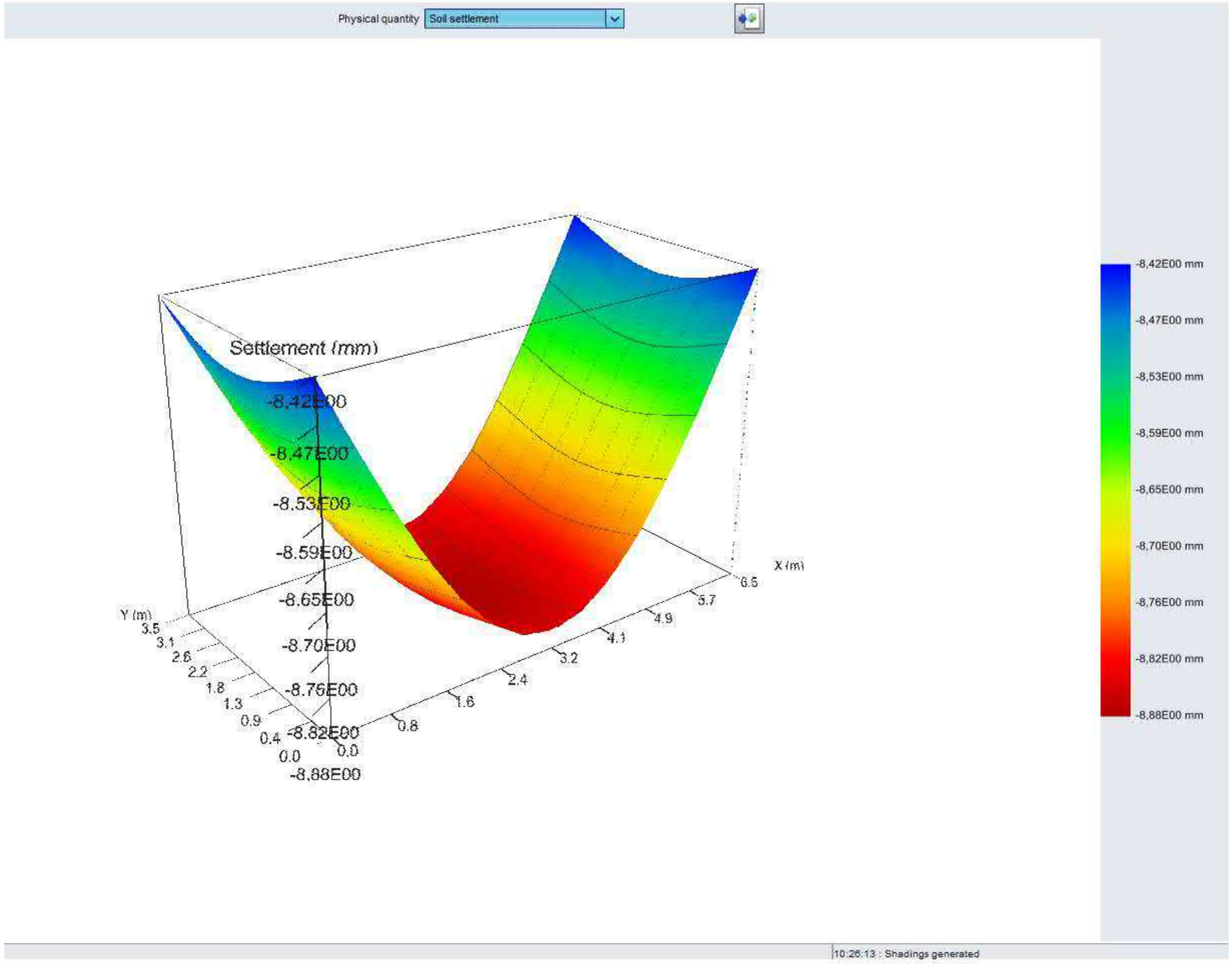
Cross section / Soil settlement / Y1=1,75 m (j:5) / Y2=3,50 m (j:9)



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APPENDIX E

Geotechnical Risk Register–

Number of Pages: 21

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IDR 221.1 - Chet–ode Cutting, Chetwode Cutting Landscape Earthworks, Chet–ode ATS
Extract 03/03/2022

HS2-00000105– - Chetwode Cutting

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_2312	CDM_40103 CDM_45854	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Soft ground or interbedded soils with varying stiffness at transitions and/or within the cutting, which could cause instability of embankment slopes and/or unacceptable total or differential settlements /subgrade performance	Weathered compressible strata on the top of OXC (up to 5 m deep)	1. Slope instability 2. Bearing capacity requirements not achived 3. Delay to works / longer hold periods / rutting / traffcability 4. Higher maintenance and associated costs 5. Temporary slope instabilities	6	Reduce	1. Appropriate gentle slopes : 1V/4H to 1V/3H wich have taken into account additional load due to presence of embankments at cutting crest (ATS platform, OB, Landscapes) (refer to stability calculation) [Complete] 2. Ground improvement of founding soils : excavate and replace 2 to 2.5 m bFl [complete] 3. Use acceptable backfill materials to ensure adequate compaction and stiffness support : a class 1 material is planned as replacement fill with minimum EV2> 60 MPa [Complete] 4. Construction during rainy period : use adequate haul road [transfered to EK] 5. Verification testing during works (refer to specifications for minimum EV2 requirements at formation level) [transfered to EK] 6. Site inspection of excavations by competent geotechnical engineer to confirm complete removal of soft pocket [transfered to EK]	Construction and Manufacture	2
GEO_2314	CDM_43364	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Soil volume may change significantly (shrink-swell) with water content	Susceptibility of highly plastic fine grained soils (TILMP + OXC) to changes in volume arising from the changes in water content from seasonal variation from the action of vegetation and climate	1. Shrinkage and swelling of formation soils and causing changes in ground stress and the development of earth pressures, ground movement and cracking in soil deposits. 2. Longitudinal and lateral shrinkage / swelling in subgrade formation leading to uneven track profile and unacceptable total and differential settlements 3. Differential ground movements causing damage to track support 4. Cracking of formation leading to deformation of track drainage 5. Strain softening of soils in cutting slopes or excavations	10	Reduce	1. According to HS Railways design and construction international standards, the shrink/swell behaviour of high plasticity clays is mastered through compliance with the suitability rules of soils for substructure works. 2. Slope stability to adopt vadose zones and use of conservative parameters [Complete] 3. Control drainage to limit change in water content of soil, particularly at track level [Transfered to EK] 4. Excavate and replace susceptible soils, particularly at track level [Complete] 5. Use adequate temporary (haul) roads during works [transfered to EK] 6. Take the necessary constructive measures in rainy days and/or to proceed to dewatering measures (pumping, drainage, etc.) at the base of excavations in temporary works to manage potential water ingress [transfered to EK]	Construction and Manufacture	3
GEO_2316	CDM_45855 CDM_45856	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Elevated sulphate levels leading to lower reuse	1. Inherent ground conditions due to the mineralogy of clay soils 2. Inadequate/insufficient ground investigation information (OXC)	1. Chemical attack on concrete slab of adjacent structure leading to higher maintenance frequency and associated costs 2. Limited reuse of site-won materials resulting in an increase in imported materials 3. Increase in volumes of landscape fill 4. Limiting use of as-dug or stabilised materials resulting in increased costs due to large haulage distances or importation of selected fill material	8	Reduce	1. Recommend BRE Special Digest SD1 suite of testing to determine levels of aggressivity during Ground Investigation. [Complete] 2. Adopt correct concrete class accordingly [Complete] 3. Undertake material specific durability and volumetric stability testing where soil re-use or soil stabilisation is proposed [Transfered to EK_depend on mass haul strategy] 4. Use adequate material for dig-out and replace : proposed replacement fill material is class 1 [Complete] 5. OXC assumed to be reused as off-line (landscape bunds) [Complete] 6. Modify mass haul accordingly	Construction and Manufacture	2
GEO_2325	CDM_45861 CDM_45862 CDM_45866	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Periglacial shear in Clay-rich materials leading to weakened in-situ geology and increased risk of slope instability such as mudslides, solifluction or gelifluction	1. Presence of OXC Formation 2. Slope gradient higher than 5° at some locations 3. Existing natural slope do not cross the mainline lengthwise 4. Perched water in OXC	1. Reactivation of possible periglacial shear slips 2. Slope instability and progressive slope failure on cutting slopes which may require re-design 3. Delay or cessation of works	6	Reduce	1. Perform stability calculations with reduced cohesion to ensure safe slope angle and required bearing capacity [Complete] 2. Adopt gentle slope gradients : 1V/4H to 1V/3H [Complete] 3. Observational approach to follow potential ground movement during works and inspection of temporary/permanent excavation during works : [Transfered to EK] 4. Instrumentation in order to monitor potential slope instability [Complete] 5. Provision for rock butress between 84+150 and 84+575 to be deployed during construction, if necessary [Transfered to EK] 6. Apply slope protection (vegetalisation) [Complete]	Construction and Manufacture	2
GEO_3739	CDM_45863	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	During operation : Long term heave movement developing over time at the base of the cutting exceeding the allowable heave limits (total heave and distortion)	1. Stress relief due to the excavation of the cutting with H> 5m 2. Presence of Oxford Clay Formation which has been identified as heave prone strata (high plastic overconsolidated clay) below the excavation level of the cutting	1. Unacceptable total or differential heave compared to HS2 slab track tolerances during operation, affecting rail alignment and rail infrastructure 2. Changes in drainage gradients and geometry 3. Increase of maintenance costs and frequency 4. Disruption to operation (ride quality, speed restriction, major remedial works)	9	Reduce	1. Trial cutting is being undertaken to increase the confidence in the geotechnical parameters considered for design [completed] 2. Additional Ground Investigations (boreholes, in situ tests, laboratory tests) in Oxford Clay Formation and a GI impact assessment is panned to be performed as a part of the detail design study [completed] 3. Monitoring of ground movement and verification of ground movement estimates during the construction works [Transfered to EK] 4. Minor adjustments in the slab track systems where required [Transfered to HS2]	Construction and Manufacture	4
					Possible relation to the nearby LQ 13.07 (Dismantled Rugby to Quainton Great Central Railway). Made Ground	1. Potential risk to human health, controlled waters and infrastructure.			1. Correct characterisation of soils by verification during works. 2.Made ground and unforseen contamination (if encountered during the works) will be segregated from natural soils and		

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Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_4108	CDM_45857 CDM_45858	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Potential risk of encountering soil and groundwater contamination.	Possible relation to the nearby LQ 13.07 (Dismantled Rugby to Quainton Great Central Railway). Made Ground has been encountered in one location on site (ML086-TP438) within the LQ 13.07. Exceedances against Water Quality Standards for metals identified in leachate and groundwater samples.	1. Potential risk to human health, controlled waters and infrastructure. 2. Reduction in water quality (controlled waters) 3. Risk of delays to the programme - potentially from additional GI to classify material and from remediation.	6	Reduce	1. Correct characterisation of soils by verification during works. 2.Made ground and unforseen contamination (if encountered during the works) will be segregated from natural soils and tested accordingly. 4. Materials Management Plan (MMP) to be adopted. 5. Use of appropriate PPE and standard Health and Safety practices during the works. 6. Discharge consents, de-watering, collect and treat/tanker contamination if necessary	Construction and Manufacture	4
GEO_4162	CDM_45865 CDM_45861 CDM_45862 CDM_45866 CDM_43405	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Presence of high / shallow groundwater identified by the ground investigations and short and long term instrumentation monitoring in GFDMP.	Due to a combination of water bearing soil , topography and seasonal fluctuations in the groundwater table through the GFDMP.	Groundwater inflow into cuttings and if not mitigated could cause : 1. Slope instability 2. Flooding of temporary excavations 3. Reduce in bearing capacity	9	Reduce	1. Design gentle slope (1V/4Hto 1V/3H) and use conservative assumptions for groundwater level [Complete] 2. Instrumentation and monitoring planned to confirm ground water assumptions and notice instability [Complete] 3. Observational approach to be planned during the construction [Transfered to EK] 4. Include a provision for slope drainage [Transfered to EK] 5. Dewatering measures to be planned in temporary excavations : To take the necessary constructive measures in rainy days and/or to proceed to dewatering measures (pumping, drainage, etc.) at the base of excavations in temporary works to manage potential water ingress [Transfered to EK] 6. Excavations to be done during low groundwater period (usually during dry season or as per groundwater monitoring data) [transfered to EK] 7. Design of temporary slopes (E&R) to ensure stability if water ingress [transfered to EK] 8. The ground improvement should be backfilled immediately to protect the subgrade and prevent instability issues. [transfered to EK]	Construction and Manufacture	4
GEO_4677	CDM_45884 CDM_45868	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	1. The dynamic performance of the completed earthworks does not achieve the Very Short Term (Instantaneous) performance criteria set out in Table 4.2/1 in the HS2 Standard Doc No. HS2-HS2-GT-STD-000-000001	Inadequate subgrade support due to presence of soft ground materials (OXC, TILMP) inducing Rayleigh Waves effect	This could result in excessive vibration and deflection of the combined slab track and earthworks, impacting the safe operation and maintenance of the Railway	12	Reduce	1. Geophysical survey performed before Datadrop 14 has been used in the design of the Rayleigh Waves mitigations. [Complete] 2. Mitigation will comprise excavate and replace (various depths) [Complete] 3. Construction validation testing (MASW, CSW) to confirm performance criteria has been achieved especially at the cutting / embankment transition (Asset Specific) [transfered to EK] 4. Use acceptable backfill materials to ensure adequate compaction and stiffness support : a class 1 material is planned as replacement fill with minimum Vs > 250 m/s [transfered to EK]	Construction and Manufacture	4
GEO_4688	N/A	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Impacts on groundwater resources identified by the GIR, which provides details of hydrogeology including aquifer characteristics. This risk was identified by undertakings and assurances (U&A's).	The presence of groundwater abstractions in the vicinity of Chetwode Cutting	The excavation could have an impact on the groundwater level at the nearby groundwater abstractions	12	Reduce	1. Develop and update hydrogeological model as more data becomes available. 2. Initiate trial pumping tests and long term monitoring of groundwater levels and surface water flows [Transfered to EK] 3. Design mitigation which could include cut-off walls and/or recharge to the aquifers. 4. In worst case scenario, many need to provide alternative water supply	Construction and Manufacture	8
GEO_T2G_0019	CDM_45883	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Risk of ground gases migrating onto the site during construction works (methane, carbon dioxide, depleted oxygen, carbon monoxide and hydrogen sulphide)	Ground gas monitoring undertaken to date has indicated a low risk (CS1). Potential sources of ground gases exist from the (mostly offsite) Dismantled Rugby to Quainton Great Central Railway Line (LQ 13.07). As a result there is potential for preferential pathways to be created during construction works for ground gas to migrate onto site.	1. Risk to human health during excavation. 2. Potential risk to construction workers entering confined spaces if elevated gas concentrations/depleted oxygen concentrations are encountered. 3. Risk of creation of preferential pathways for gas migration	4	Reduce	1. Excavations and confined spaces should be monitored for gas and depleted oxygen prior to worker entry in line with recommendations of HSE guidance.	Construction and Manufacture	4
GEO_T2G_0048	CDM_45863	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	During operation : Long term heave movement developing over time at the base of the cutting exceeding the allowable heave limits (total heave and distortion)	1. Stress relief due to the excavation of the cutting 2. Presence of Oxford Clay Formation which has been identified as heave prone strata (high plastic overconsolidated clay) below the excavation level of the cutting	1. Unacceptable total or differential heave compared to HS2 slab track tolerances during operation, affecting rail alignment and rail infrastructure 2. Changes in drainage gradients and geometry 3. Increase of maintenance costs 4. Disruption to operation (ride quality, speed restriction, major remedial works)	4	Control	1. Monitoring of track movement during operation [Complete] 2. Minor adjustments in the slab track systems where required [Transfered to HS2]	Operations and Maintenance	2
GEO_T2G_0050	CDM_45859 CDM_45860	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Risk of encountering UXO and UXB during excavation works.	Upon viewing the ASC GIS Viewer 2 locations of Unexploded Bombs (UXB) are located nearby the LLAU with the closest UXB located approx. 20 m east from the LLAU at Ch 85 +800 (offsite).	1.) Potential risk to construction workers encountering UXB who are involved with below ground excavations 2.) Risk of delays to the programme if UXO is encountered and increased costs	8	Reduce	UXO safety awareness briefings to be given prior to the works. UXB risk is located outisde of LLAU, but awarenss should be incorporated due to its close proximity to site. Geophysical survey to be performed at crictical locations	Construction and Manufacture	2

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Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0050	CDM_45859 CDM_45860	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Risk of encountering UXO and UXB during excavation works.	Upon viewing the ASC GIS Viewer 2 locations of Unexploded Bombs (UXB) are located nearby the LLAU with the closest UXB located approx. 20 m east from the LLAU at Ch 85 +800 (offsite).	1.) Potential risk to construction workers encountering UXB who are involved with below ground excavations 2.) Risk of delays to the programme if UXO is encountered and increased costs	8	Reduce	UXO safety awareness briefings to be given prior to the works. UXB risk is located outisde of LLAU, but awarenss should be incorporated due to its close proximity to site. Geophysical survey to be performed at crictical locations	Construction and Manufacture	2
GEO_T2G_0051	N/A	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Co-seismic soil slope instability	Induce earthquake seismic wave through ground. Risk expected to be very low.	1. Ground displacement and slope instability 2. Unacceptable total or differential ground movements 3. Delay to works 4. Higher maintenance	4	Reduce	Risk assumed to be low. 1. Slope stability analysis with seismic conditions and propsed suitable slope angles. [Complete] 2. Area of the asset within a very low seismic hazard area (Midland Microcraton M3) according to the Eurocode 8 seismic hazard zoning maps for the UK	Construction and Manufacture	3
GEO_T2G_0052	CDM_40103 CDM_45854	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Weathering profile in OXC	Erosion and alteration at the top of the strata	1. Softening soil in top of strata which could cause slope instability (refer to soft soil risk in OXC) 2. Variable base depth of the weathered strata wich could cause unacceptable distorsion/ bearing capacity 3. Higher maintenance frequency and associated costs 4. Delay to works in rainy period (soft soils)	6	Reduce	1. Ground improvement of founding soils : Foundation treatment include excavation and replacement of OXC beneath tracks [Complete] 2. Regarding additional GI obtained after the freeze date (datadrop2), the GI Impact assessement (cf. 1MC06-CEK-GT-REP-CS06_CL10-000036) confirm the geological ground model proposed in the design. [Completed] 3. Construction during rainy period : use adequate haul roads [transfered to EK] 4. Provision to remove remaining soft pocket of OXC [transfered to EK] 5. Site inspection to control the complete removal of soft soil [transfered to EK]	Construction and Manufacture	2
GEO_T2G_0053	CDM_45861 CDM_45862 CDM_45866	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Slope movement identified in the HS2 Geomorphological Inspection Report (GZA229) - potentially related to relic slip surfaces. Ch. 85800 to85880	Solifluxion or gelifluxion in superficial soils (up to 5 m deep)	1. Instability of cutting slopes due to mobilisation of existing landslide 2. Impact on rail operation 3. HSE, time and cost implications	4	Control	Risk is low due to the feature has not been identified as geohazard 1. Design gentle slope gradients [Complete] 2. Instrumentation planned to monitor potential slope instabilities [Complete] 3. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction : inspection of slopes by competent geologist for indication of landslides [Tranfered to EK]	Construction and Manufacture	4
GEO_T2G_0054	CDM_45861 CDM_45862 CDM_45866	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Slope movement identified in the HS2 Geomorphological Inspection report (GZA230) - potentially related to relic slip surfaces. Ch. 86140 to 86160	Solifluxion or gelifluxion in superficial soils (up to 5 m deep)	1. Instability of cutting slopes due to mobilisation of existing landslide 2. Impact on rail operation 3. HSE, time and cost implications	4	Control	Risk is low due to the feature has not been identified as geohazard 1. Design gentle slope gradients [Complete] 2. Instrumentation planned to monitor potential slope instabilities [Complete] 3. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction : inspection of slopes by competent geologist for indication of landslides [Tranfered to EK]	Construction and Manufacture	4
GEO_T2G_0055	CDM_45861 CDM_45862 CDM_45866	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Slope movement identified in the HS2 Geomorphological Inspection Report (GZA231) - potentially related to relic slip surfaces. Ch. 86260 to 86280	Solifluxion or gelifluxion in superficial soils (up to 5 m deep)	1. Instability of cutting slopes due to mobilisation of existing landslide 2. Impact on rail operation 3. HSE, time and cost implications	4	Control	Risk is low due to the feature has not been identified as geohazard 1. Design gentle slope gradients [Complete] 2. Instrumentation planned to monitor potential slope instabilities [Complete] 3. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction : inspection of slopes by competent geologist for indication of landslides [Tranfered to EK]	Construction and Manufacture	4
GEO_T2G_0056	CDM_45861 CDM_45862 CDM_45866	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls towards HS2. Ch. 85.100 to Ch. 86300	1. Presence of OXC Formation 2. Slope gradient higher than 5° transversal to the HS2 route 3. Existing natural slope do not crossing mainline lengthwise 4. Perched water in OXC	1. Slope instability and progressive slope failure on cutting slopes which may require re-design 2. Delay or cessation of works	12	Reduce	Risk is potential level 1 but low residual risk due to gentle slope gradient adopted in the design and limited cutting height. 1. Design gentle slope gradients (1V/4H to 1V/3H) [Complete] 2. Observational approach to follow potential ground movement during works and inspection of temporary/permanent excavation during works : [Transfered to EK] 3. The options for mitigation = provision for risk could include: shear keys, rock butress or counterforts [Transfered to EK] 4. Instrumentation planned at high risk location [Complete]	Construction and Manufacture	6
GEO_T2G_0057	CDM_45861 CDM_45862 CDM_45866	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls towards HS2. Ch. 86450 to Ch. 86852	1. Presence of OXC Formation 2. Slope gradient higher than 5° transversal to the HS2 route 3. Existing natural slope do not crossing mainline lengthwise 4. Perched water in OXC	1. Slope instability and progressive slope failure on cutting slopes which may require re-design 2. Delay or cessation of works	8	Reduce	Risk is potential level 1 but low residual risk due to gentle slope gradient adopted in the design and limited cutting height. 1. Design gentle slope gradients (1V/4H to 1V/3H) [Complete] 2. Observational approach to follow potential ground movement during works and inspection of temporary/permanent excavation during works : [Transfered to EK] 3. The options for mitigation = provision for risk could include: shear keys, rock butress or counterforts [Transfered to EK] 4. Instrumentation planned at high risk location [Complete]	Construction and Manufacture	6

HS2 Ltd - Code 1 - Accepted

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0058	N/A	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	1. Displaced geological units (approx. Ch. 86+400) 2. Unexpected variable ground conditions 3. Locally weakened ground conditions 4. Locally higher permeability	Natural geological faulting processes	2. Unsuitable geotechnical solution given unexpected ground conditions 3. Differential movements more likely within a fault zone 4. Risk of softer /weaker ground at platform level	3	Eliminate	Low risk due to the bedrock strata depth located beneath the track level. Refer to the structure foundation for further risks and mitigation	Construction and Manufacture	3
GEO_T2G_0059	N/A	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	1. Displaced geological units (between Ch. 86550 et 87+000) 2. Unexpected variable ground conditions 3. Locally weakened ground conditions 4. Locally higher permeability	Natural geological faulting processes	1. Slope instability 2. Unsuitable geotechnical solution given unexpected ground conditions 3. Differential movements more likely within a fault zone 4. Risk of softer /weaker ground at platform level	3	Eliminate	Low risk due to the bedrock strata depth located beneath the track level. Refer to the structure foundation for further risks and mitigation	Construction and Manufacture	3
GEO_T2G_0061	N/A	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Exact fault position assumed between Ch. 86350 and Ch. 86700	Lack of GI	1. Low impact on design 2. Impact on geological long section	2	Eliminate	1. Risk is tolerate due to the low impact on design : The cutting base is planned above the top of the bedrock	Construction and Manufacture	1
GEO_T2G_0062	CDM_45865 CDM_45861 CDM_45862 CDM_45866 CDM_43405	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Water ingress from potential perched water table (seasonal) in OXC Formation	1. Presence of OXC Formation (with sand interbeds) with high permeability, related with the potential for water run-off in rainy weather conditions. 2. Inadequate monitoring installation/information - groundwater inflow in rainy period	1. Could case instability of slopes due to water ingress into cutting 2. Reduced soil stiffness 3. Flooding on temporary excavation	6	Reduce	1.Observational approach during construction [Transfered to EK] 2. Temporary works slope to insure stability if water [Transfered to EK] 3. Provision for mitigation measures if the observational approach during construction show a water inflow : blanket layer / countrefort drain with appropriate drainage [Transfered to EK] 4. To take the necessary constructive measures in rainy days and/or to proceed to dewatering measures (pumping, drainage, etc.) at the base of excavations in temporary works to manage potential water ingress [Transfered to EK]	Construction and Manufacture	4
GEO_T2G_0063	CDM_45865 CDM_45861 CDM_45862 CDM_45866 CDM_43405	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Threat of water ingress in permeable strata in OXC and GFDMP formation	1. Presence of OXC Formation (with sand interbeds) & sandy GFDMP with high permeability, related with the potential for water run-off in rainy weather conditions. 2. Inadequate monitoring installation/information - groundwater inflow in rainy period	1. Could case instability of slopes due to water ingress into cutting 2. Reduced soil stiffness 3. Flooding on temporary excavation	12	Reduce	1. Design gentle slope (1V/4H to 1V/3H) and use conservative assumptions for groundwater level [Complete] 2. Instrumentation and monitoring planned to confirm ground water assumptions and notice instability [Complete] 3. Observational approach to be planned during the construction [Transfered to EK] 4. Include a provision for slope drainage [Transfered to EK] 5. Update CDM register and provide an updated risk to the drainage and temporary works designer. [To be completed] 6. Dewatering measures to be planned in temporary excavations : To take the necessary constructive measures in rainy days and/or to proceed to dewatering measures (pumping, drainage, etc.) at the base of excavations in temporary works to manage potential water ingress [Transfered to EK] 7. Excavations to be done during low groundwater period (usually during dry season or as per groundwater monitoring data) [transfered to EK] 8. Design of temporary slopes (E&R) to ensure stability if water ingress [transfered to EK]	Construction and Manufacture	6
GEO_T2G_0064	CDM_40103 CDM_45854	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Compressible ground, characterised as having a low strength and high compressibility, is encountered beneath the EW	Compressible TILMP	1. Slope instability 2. Bearing capacity requirements not achived 3. Delay to works / longer hold periods / rutting / trafficability 4. Higher maintenance and associated costs 5. Temporary slope instabilities	6	Reduce	1. Appropriate gentle slopes wich have taken into account additional load due to presence of embankments at cutting crest (ATS platform, OB, Landscapes) (refer to stability calculation) [Complete] 2. Ground improvement of founding soils : excavate and replace 2 to 2.5 m bFI [complete] 3. Use acceptable backfill materials to ensure adequate compaction and stiffness support : a class 1 material is planned as replacement fill with minimum EV2> 60 MPa [Complete] 4. Construction during rainy period : use adequate haul road [Transfered to EK] 5. Verification testing during works (refer to specifications for minimum EV2 requirements at formation level) [Transfered to EK] 6. Site inspection of excavations by competent geotechnical engineer to confirm complete removal of soft pocket [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0065	CDM_45857 CDM_45858	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Poor quality materials (possibly contaminated) present on site	Existing Made Ground related with dismantled road and drains and embankment within footprint of the earthwork, due to current and historical land use : - Dismantled drain : Ch. 85670 - 85720 - Dismantled Rosehill Cottage and road : Ch. 85470 - Dismantled Manthorn Farm : Ch. 85800 - Dismantled School En road : Ch. 86420 - Dismantled Drain : Ch. 86780	1. Excessive volumes of material for disposal 2. If not removed then would undermine cutting stability 3. If not removed then would result in unachieved bearing capacity	9	Reduce	1. Mitigation measure include provision for total removal of made ground [Complete] 2. Suitable testing during works to determine suitability for re-use and/or disposal off site [Transfered to EK] 3. HSE implications required for handling of contaminated materials and environmental protection during disposal. [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0066	N/A	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Encountering Potential hard ground band in local Made Ground	Obstructions associated with current and historical land use below Presence of made ground related with exiting infrastructures : - Dismantled drain : Ch. 85670 - 85720 - Dismantled Rosehill Cottage and road : Ch. 85470 - Dismantled Manthorn Farm : Ch. 85800 - Dismantled School En road : Ch. 86420 - Dismantled Drain : Ch. 86780	1. Extra time to remove and break out existing concrete structures. 2. Impact on programme and cost. 3. Damage to plant	4	Reduce	1. Using adequate engine during works [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0071	N/A	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Instabilities on existing building : - Rosehill Farm : Ch; 85200 - 85250 - 50m upside HS2 - Manthorn Farm : Ch. 85750 - 85810 - 50 m down side HS2 - Hermitage : Ch. 85800 - 86350 - 100 m upside from HS2 - Presence of existing bridge down side at Ch. 86+390	Potential cutting slope instability due to the additional load from existing buildings	Building destruction and ground movement	6	Reduce	1.Design completed with additional load impact on slope stability. [Complete] 2. Impact on 3rd party asset detailed in the GMIA report [Complete] 3. No need for instrumentation and monitoring for 3rd party asset but inspection of these buildings during works is recommanded [tranfered to EK] NOTA: Some buiding are far enough to avoid mitigations	Construction and Manufacture	3
GEO_T2G_0073	CDM_45865	HS2-000001054 - Chetwode Cutting	Risk Reduction in Progress	Loose and instable ground of GFDMP sandy strata if water ingress and steep temporary slopes	1. Low cohesion and high permeability in sandy GFDMP strata 2. Water ingress through GFDMP 3. Temporary E&R with steep slope angle in GFDMP	1. Slope instability 2. Water ingress through permeable strata (GFDMP) 3. Flooding of temporary excavations	12	Reduce	1. Appropriate Design slopes (1V/3H in GFDMP) to ensure long term stability [Complete] 2. Provision for mitigation measures if the observational approach during construction show a water inflow : blanket layer / countrefort drain with appropriate drainage [Transfered to EK] 3. Temporary slopes in GFDMP not stable without mitigation measures during works. Adequate mitigation measure to be planned by EKFB to ensure temporary slope stability [Transfered to EK] 4. Sequential excavation over limited length [transfered to EK] 5.The ground improvement should be backfilled immediately to protect the subgrade and prevent instability issues. [transfered to EK]	Construction and Manufacture	4

HS2 Ltd - Code 1 - Accepted

HS2-00002BVHU - Chetwode Cutting Landscape Earthworks

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0588	CDM_40173	HS2-00002BVHU - Chetwode Cutting Landscape Earthworks	Risk Reduction in Progress	Slope movement identified in the HS2 Geomorphological Inspection Report (GZA229) - potentially related to relic slip surfaces. Ch. 85800 to85880	Solifluxion or gelifluxion in superficial soils (up to 5 m deep)	1. Instability beneath the landscape due to mobilisation of existing landslide 2. Impact on rail operation 3. HSE, time and cost implications	4	Control	Risk is low due to the feature has not been identified as geohazard 1. Design gentle slope gradients [Complete] 2. Instrumentation planned to monitor potential slope instabilities [Complete] 3. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction : inspection of slopes by competent geologist for indication of landslides [Tranfered to EK]	Construction and Manufacture	4
GEO_T2G_0589	CDM_40173	HS2-00002BVHU - Chetwode Cutting Landscape Earthworks	Risk Reduction in Progress	Slope movement identified in the HS2 Geomorphological Inspection report (GZA230) - potentially related to relic slip surfaces. Ch. 86140 to 86160	Solifluxion or gelifluxion in superficial soils (up to 5 m deep)	1. Instability beneath the landscape due to mobilisation of existing landslide 2. Impact on rail operation 3. HSE, time and cost implications	4	Control	Risk is low due to the feature has not been identified as geohazard 1. Design gentle slope gradients [Complete] 2. Instrumentation planned to monitor potential slope instabilities [Complete] 3. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction : inspection of slopes by competent geologist for indication of landslides [Tranfered to EK]	Construction and Manufacture	4
GEO_T2G_0590	CDM_40173	HS2-00002BVHU - Chetwode Cutting Landscape Earthworks	Risk Reduction in Progress	Slope movement identified in the HS2 Geomorphological Inspection Report (GZA231) - potentially related to relic slip surfaces. Ch. 86260 to 86280	Solifluxion or gelifluxion in superficial soils (up to 5 m deep)	1. Instability beneath the landscape due to mobilisation of existing landslide 2. Impact on rail operation 3. HSE, time and cost implications	4	Control	Risk is low due to the feature has not been identified as geohazard 1. Design gentle slope gradients [Complete] 2. Instrumentation planned to monitor potential slope instabilities [Complete] 3. Adopt a risk management strategy and include a risk provision for slope drainage/reinforcement with an observational approach during construction : inspection of slopes by competent geologist for indication of landslides [Tranfered to EK]	Construction and Manufacture	4
GEO_T2G_0591	CDM_40173	HS2-00002BVHU - Chetwode Cutting Landscape Earthworks	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls towards HS2. Ch. 85.100 to Ch. 86300	1. Presence of OXC Formation 2. Slope gradient higher than 5° transversal to the HS2 route 3. Existing natural slope do not crossing mainline lengthwise 4. Perched water in OXC	1. Instability beneath the landscape due to mobilisation of existing landslide 2. Delay or cessation of works	9	Reduce	Risk is potential level 1 but low residual risk due to gentle slope gradient adopted in the design and limited cutting height. 1. Design gentle slope gradients (1V/4H to 1V/3H) [Complete] 2. Observational approach to follow potential ground movement during works and inspection of temporary/permanent excavation during works : [Transfered to EK] 3. The options for mitigation = provision for risk could include: shear keys, rock butress or counterforts [Transfered to EK] 4. Instrumentation planned at high risk location [Complete]	Construction and Manufacture	4
GEO_T2G_0592	CDM_40173	HS2-00002BVHU - Chetwode Cutting Landscape Earthworks	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls towards HS2. Ch. 86450 to Ch. 86852	1. Presence of OXC Formation 2. Slope gradient higher than 5° transversal to the HS2 route 3. Existing natural slope do not crossing mainline lengthwise 4. Perched water in OXC	1. Instability beneath the landscape due to mobilisation of existing landslide 2. Delay or cessation of works	6	Reduce	Risk is potential level 1 but low residual risk due to gentle slope gradient adopted in the design and limited cutting height. 1. Design gentle slope gradients (1V/4H to 1V/3H) [Complete] 2. Observational approach to follow potential ground movement during works and inspection of temporary/permanent excavation during works : [Transfered to EK] 3. The options for mitigation = provision for risk could include: shear keys, rock butress or counterforts [Transfered to EK] 4. Instrumentation planned at high risk location [Complete]	Construction and Manufacture	3

HS2 Ltd - Code 1 - Accepted

HS2-000020864 - Chetwode ATS – part 1

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0148	CDM_45855 CDM_45856	HS2-000020864 - Chetwode ATS	Risk Reduction in Progress	Elevated sulphate levels leading to lower reuse	1. Inherent ground conditions due to the mineralogy of clay soils 2. Inadequate/insufficient ground investigation information (OXC)	1. Chemical attack on concrete slab of adjacent structure leading to higher costs 2. Limited of reuse resulting on increase in imported materials 3. Increase in volumes of landscape fill 4. Limiting the use of as-dug or stabilised materials resulting in increased costs due to large haulage distances or importation of selected fill material	8	Reduce	1. Recommend BRE Special Digest SD1 suite of testing to determine levels of aggressivity during Ground Investigation. [Complete] 2. Adopt correct concrete class accordingly [Complete] 3. Undertake material specific durability and volumetric stability testing where soil re-use or soil stabilisation is proposed [Transfered to EK_depend on mass haul strategy] 4. Use adequate material for dig-out and replace : proposed replacement fill material is class 1 [Complete] 5. OXC assumed to be reused as off-line (landscape bunds) [Complete] 6. Modify mass haul accordingly	Construction and Manufacture	2
GEO_T2G_0149	CDM_43364	HS2-000020864 - Chetwode ATS	Risk Reduction in Progress	Soil volume may change significantly (shrink-swell) with water content	Susceptibility of highly plastic fine grained soils (TILMP + OXC) to changes in volume arising from the changes in water content from seasonal variation from the action of vegetation and climate	1. Shrinkage and swelling of formation soils and causing changes in ground stress and the development of earth pressures, ground movement and cracking in soil deposits. 2. Longitudinal and lateral shrinkage / swelling in subgrade formation leading to uneven track profile and unacceptable total and differential settlements 3. Differential ground movements causing damage to track support 4. Cracking of formation leading to deformation of track drainage 5. Strain softening of soils in cutting slopes or excavations	10	Reduce	Risk assumed to be tolerate for unbound access road 1. Control drainage to limit change in water content of soil [Transfered to EK] 2. Subgrade improvement where needed (E&R) [Transfered to EK] 3. Use adequate temporary (haul) roads during works [transfered to EK]	Construction and Manufacture	3
GEO_T2G_0150	CDM_40103 CDM_45854	HS2-000020864 - Chetwode ATS	Risk Reduction in Progress	Weathering profile in OXC	Erosion and alteration at the top of the strata	1. Softening soil in top of strata which could cause slope instability (refer to soft soil risk in OXC) 2. Variable base depth of the weathered strata wich could cause unacceptable distorsion/ bearing capacity 3. Higher maintenance frequency and associated costs 4. Delay to works in rainy period (soft soils)	6	Reduce	1. Ground improvement of founding soils : Foundation treatment include excavation and replacement of OXC beneath tracks [Complete] 2. Regarding additional GI obtained after the freeze date (datadrop2), the GI Impact assessement (cf. 1MC06-CEK-GT-REP-CS06_CL10-000036) confirm the geological ground model proposed in the design. [Complete] 3. Construction during rainy period : use adequate haul roads [transfered to EK] 4. Provision to remove remaining soft pocket of OXC [transfered to EK]	Construction and Manufacture	2
GEO_T2G_0151	CDM_45861 CDM_45862 CDM_45866	HS2-000020864 - Chetwode ATS	Risk Reduction in Progress	Periglacial shear in Clay-rich materials leading to weakened in-situ geology and increased risk of slope instability	1. Presence of clay-rich bedrock (OXC)	1. Slope failure and/or lack of bearing capacity which may require re-design 2. Delay to works 3. Loss and cessation of works	6	Reduce	1. Perform stability calculations with reduced cohesion to ensure safe slope angle and required bearing capacity [Complete] 2. Adopt gentle slope gradients [Complete] 3. Observational approach to follow potential ground movement during works and inspection of temporary excavation during works [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0152	CDM_45861 CDM_45862 CDM_45866	HS2-000020864 - Chetwode ATS	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls towards HS2. Ch. 85.100 to Ch. 86300	1. Presence of OXC Formation 2. Slope gradient higher than 5° transversal to the HS2 route 3. Existing natural slope do not crossing mainline lengthwise 4. Perched water in OXC	1. Reactivation of shear slip (GZA229, 230, 231) 2. Slope instability 3. Delay or cessation of works	8	Reduce	Risk is potential level 1 but low residual risk due to gentle slope gradient adopted in the design and limited cutting height. 1. Design gentle slope gradients [Complete] 2. Observational approach during construction [Transfered to EK] 3. The options for mitigation = provision for risk could include: shear keys, rock butress or counterforts [Transfered to EK]	Construction and Manufacture	3
GEO_T2G_0154	CDM_45865 CDM_45861 CDM_45862 CDM_45866 CDM_43405	HS2-000020864 - Chetwode ATS	Risk Reduction in Progress	Presence of high / shallow groundwater identified by the ground investigations and short and long term instrumentation monitoring in GFDMP.	Due to a combination of water bearing soil , topography and seasonal fluctuations in the groundwater table through the GFDMP.	Groundwater inflow into cuttings and if not mitigated could cause : 1. Slope instability 2. Flooding of temporary excavations 3. Reduce in bearing capacity	9	Reduce	1. Design gentle slope and use conservative assumptions for groundwater level [Complete] 2. Observational approach to be planned during the construction [Transfered to EK] 3. Include a provision for slope drainage [Transfered to EK] 4. Update CDM register and provide an updated risk to the drainage and temporary works designer. [To be completed] 5. Excavations to be done during low groundwater period (usually during dry season or as per groundwater monitoring data) [transfered to EK]	Construction and Manufacture	2
GEO_T2G_0155	CDM_45865 CDM_45861 CDM_45862 CDM_45866 CDM_43405	HS2-000020864 - Chetwode ATS	Risk Reduction in Progress	Water ingress from potential perched water table (seasonal) in OXC Formation	1. Presence of OXC Formation (with sand interbeds) with high permeability, related with the potential for water run-off in rainy weather conditions. 2. Inadequate monitoring installation/information - groundwater inflow in rainy period	1. Could case instability of slopes due to water ingress into cutting 2. Reduced soil stiffness 3. Flooding on temporary excavation	6	Reduce	1.Observational approach during construction [Transfered to EK] 2. Temporary works slope to insure stability if water [Transfered to EK] 3. Provision for mitigation measures if the observational approach during construction show a water inflow : blanket layer / countrefort drain with appropriate drainage [Transfered to EK]	Construction and Manufacture	4

HS2 Ltd - Code 1 - Accepted

HS2-000020864 - Chetwode ATS – part 2

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0156	CDM_45865 CDM_45861 CDM_45862 CDM_45866 CDM_43405	HS2-000020864 - Chetwode ATS	Risk Reduction in Progress	Threat of water ingress in permeable strata in OXC and GFDMP formation	1. Presence of OXC Formation (with sand interbeds) & sandy GFDMP with high permeability, related with the potential for water run-off in rainy weather conditions. 2. Inadequate monitoring installation/information - groundwater inflow in rainy period	1. Could case instability of slopes due to water ingress into cutting 2. Reduced soil stiffness 3. Flooding on temporary excavation	9	Reduce	1. Design gentle slope and use conservative assumptions for groundwater level [Complete] 2. Instrumentation and monitoring planned to confirm ground water assumptions and notice instability [Complete] 3. Observational approach to be planned during the construction [Transfered to EK] 4. Include a provision for slope drainage [Transfered to EK] 5. Update CDM register and provide an updated risk to the drainage and temporary works designer. [To be completed] 6. Dewatering measures to be planned in temporary excavations [Transfered to EK] 7. Excavations to be done during low groundwater period (usually during dry season or as per groundwater monitoring data) [transfered to EK] 8. Design of temporary slopes (E&R) to ensure stability if water ingress [transfered to EK]	Construction and Manufacture	4
GEO_T2G_0157	CDM_40103 CDM_45854	HS2-000020864 - Chetwode ATS	Risk Reduction in Progress	Soft ground or interbedded soils with varying stiffness at transitions and/or within the cutting, which could cause instability of embankment slopes and/or unacceptable total or differential settlements /subgrade performance	Weathered compressible strata on the top of OXC (up to 5 m deep)	1. Instability slopes and/or unacceptable total or differential settlements 2. Unacceptable subgrade performance 3. Reconstruction of road pavement and adverse impact on drainage/utilities. 4. Risk of unsafe driving conditions at bridge interface. 5. Delay to works in rainy period 6. Higher maintenance and associated costs	6	Reduce	1. Appropriate gentle slopes (refer to stability calculation) [Complete] 2. Adequate subgrade stiffness achieved in the design through adequate subbase thickness : 0.60 m subgrade imporvement planned at ATS platform [Complete] 3. Use acceptable backfill materials to ensure adequate compaction and stiffness support. [Complete] 4. Construction during rainy period : use adequate works road and methodology [Transfered to EK] 5. Site inspection of excavations by competent geotechnical engineer to confirm complete removal of soft pocket [transfered to EK]	Construction and Manufacture	2
GEO_T2G_0158	CDM_40103 CDM_45854	HS2-000020864 - Chetwode ATS	Risk Reduction in Progress	Compressible ground, characterised as having a low strength and high compressibility, is encountered beneath the EW	Compressible TILMP	1. Instability slopes and/or unacceptable total or differential settlements 2. Unacceptable subgrade performance 3. Reconstruction of road pavement and adverse impact on drainage/utilities. 4. Risk of unsafe driving conditions at bridge interface. 5. Delay to works in rainy period 6. Higher maintenance and associated costs	6	Reduce	1. Appropriate gentle slopes (refer to stability calculation) [Complete] 2. Adequate subgrade stiffness achieved in the design through adequate subbase thickness : 0.60 m subgrade imporvement planned at ATS platform [Complete] 3. Use acceptable backfill materials to ensure adequate compaction and stiffness support. [Complete] 4. Construction during rainy period : use adequate works road and methodology [Transfered to EK] 5. Site inspection of excavations by competent geotechnical engineer to confirm complete removal of soft pocket [transfered to EK]	Construction and Manufacture	2
GEO_T2G_0159	CDM_45857 CDM_45858	HS2-000020864 - Chetwode ATS	Risk Reduction in Progress	Soft ground potentially contaminated	Presence of made ground related with exiting infrastructures : - Dismantled drain : Ch. 85670 - 85720 - Dismantled Rosehill Cottage and road : Ch. 85470	1. Excessive volumes of material for disposal 2. If not removed then would undermine cutting stability 3. If not removed then would result in unachieved bearing capacity	6	Reduce	1. Mitigation measure include provision for totla removal of made ground [Complete] 2. Suitable testing during works to determine suitability for re-use and/or disposal off site [Transfered to EK] 3. HSE implications required for handling of contaminated materials and environmental protection during disposal. [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0161	CDM_45865	HS2-000020864 - Chetwode ATS	Risk Reduction in Progress	Loose and instable ground of GFDMP sandy strata if water ingress and steep temporary slopes	1. Low cohesion and high permeability in sandy GFDMP strata 2. Water ingress through GFDMP 3. Temporary E&R with steep slope angle in GFDMP	1. Slope instability 2. Water ingress through permeable strata (GFDMP)	12	Reduce	1. Appropriate Design slopes (1V/3H in GFDMP) to ensure long term stability [Complete] 2. Provision for mitigation measures if the observational approach during construction show a water inflow : blanket layer / countrefort drain with appropriate drainage [Transfered to EK] 3. Temporary slopes in GFDMP not stable without mitigation measures during works. Adequate mitigation measure to be planned by EKFB to ensure temporary slope stability [Transfered to EK]	Construction and Manufacture	4

HS2 Ltd - Code 1 - Accepted

GRR extr–ct relative to Footpath CHW18 accommodation overbrid–e (27/07/2022)

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_1967		HS2-000001321 - Footpath CHW/18 Accommodation Overbridge	Risk Reduced ALARP	Heave	The ground within this earthwork is likely to heave due to stress relief from removal of cut soil	Bridge piles may be subject to additional loading, including tensile forces, and deflections (lateral and vertical) which will affect the overall performance of the bridge	12	Reduce	1. Heave effects are assessed through a complete modelling. Additonnal heave induced forces and displacements are calculated and taken into account in the structural design of the piles and the structure. 2. Instrumentation implemented in order to measure displacements during the excavation. These measurements help validate the calculation models and input data.	Construction and Manufacture	4
GEO_1969		HS2-000001321 - Footpath CHW/18 Accommodation Overbridge	Risk Reduced ALARP	Shear Surfaces (relic)	relic shear surfaces being common in Oxford Clay Formation.	Local slips which may destabilise shallow foundations, slipped material causing an increased lateral load on the piles, shallow slopes needing to be stabilised.	9	Reduce	Gentle excavation slope (4H/1V). Slope stability has been verified along the level 1 asset (Chetwode cutting)	N/A	3
GEO_2056		HS2-000001321 - Footpath CHW/18 Accommodation Overbridge	Risk Reduced ALARP	Parent earthwork is classed as medium risk with respect to heave	The ground within this earthwork is likely to heave due to stress relief from removal of cut soil	Bridge piles may be subject to additional loading, including tensile forces, and deflections (lateral and vertical) which will affect the overall performance of the bridge.	10	Reduce	1. Heave effects are assessed through a complete modelling. Additonnal heave induced forces and displacements are calculated and taken into account in the structural design of the piles and the structure. 2. Instrumentation implemented in order to measure displacements during the excavation. These measurements help validate the calculation models and input data.	Construction and Manufacture	2
GEO_4110		HS2-000001321 - Footpath CHW/18 Accommodation Overbridge	Risk Reduction in Progress	Potential risk of soil and groundwater contamination associated with Dismantled Rugby to Quainton Great Central Railway adjacent to route (LQ 13.07) (approx. 120 m southwest of asset).	Previous land use / site history.	Potential risk to human health, controlled waters and infrastructure. Reduction in water quality (controlled waters) / contaminated groundwater encountered may also result in increased costs and delays to the programme due to obtaining consent and remediation costs.	9	Reduce	Further GI including groundwater sampling and testing has been proposed. Appropriate risk assessment and PPE. Discharge consents, de-watering, collect and treat/tanker contamination if necessary	Detailed Design	3

GRR extract relative to School end overbridge (27/07/2022)

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_2063		HS2-000001322 - School End Overbridge	Risk Reduced ALARP	Parent earthwork is classed as medium risk with respect to heave	The ground within this earthwork is likely to heave due to stress relief from removal of cut soil	Bridge piles may be subject to additional loading, including tensile forces, and deflections (lateral and vertical) which will affect the overall performance of the bridge.	10	Reduce	1. Heave effects are assessed through a complete modelling. Additonnal heave induced forces and displacements are calculated and taken into account in the structural design of the piles and the structure. 2. Instrumentation implemented in order to measure displacements during the excavation. These measurements help validate the calculation models and input data.	Construction and Manufacture	2
GEO_2482		HS2-000001322 - School End Overbridge	Risk Reduced ALARP	Risk of higher groundwater levels than monitored during GI, or absence of groundwater level data.	Absence of groundwater data, seasonal variations in groundwater levels which have not been recorded in existing monitoring, or presence of perched water levels not captured in existing monitoring.	1. Resulting in an increase in pile loads. 2. Reduction in pile capacity.	6	Reduce	A conservative value is taken for the groundwater level (1 mbgl) based on supplementary and recent monitoring results). The slope stability is verified.	N/A	1
GEO_4111		HS2-000001322 - School End Overbridge	Risk Reduction in Progress	Potential risk of soil and groundwater contamination associated with Dismantled Rugby to Quainton Great Central Railway adjacent to route (LQ 13.07) (crosses western access road of asset).	Previous land use / site history. Prediction of the ground condition is not accurately assessed within the available ground investigation data.	Potential risk to human health, controlled waters and infrastructure. Reduction in water quality (controlled waters) / contaminated groundwater encountered may also result in increased costs and delays to the programme due to obtaining consent and remediation costs.	9	Reduce	Further GI including soil, leachate and groundwater sampling and testing has been proposed. Appropriate risk assessment and PPE. Discharge consents, de-watering, collect and treat/tanker contamination if necessary. Trial pitting at foundation locations to confirm ground conditions.	Detailed Design	6
GEO_T2G_0623		HS2-000001322 - School End Overbridge	Risk Reduced ALARP	Heave	The ground within this earthwork is likely to heave due to stress relief from removal of cut soil	Bridge piles may be subject to additional loading, including tensile forces, and deflections (lateral and vertical) which will affect the overall performance of the bridge	12	Reduce	1. Heave effects are assessed through a complete modelling. Additonnal heave induced forces and displacements are calculated and taken into account in the structural design of the piles and the structure. 2. Instrumentation implemented in order to measure displacements during the excavation. These measurements help validate the calculation models and input data.	Construction and Manufacture	4
GEO_T2G_0624		HS2-000001322 - School End Overbridge	Risk Reduced ALARP	Shear Surfaces (relic)	relic shear surfaces being common in Oxford Clay Formation.	Local slips which may destabilise shallow foundations, slipped material causing an increased lateral load on the piles, shallow slopes needing to be stabilised.	9	Reduce	Gentle excavation slope (4H/1V). Slope stability has been verified along the level 1 asset (Chetwode cutting)	N/A	3

HS2 Ltd - Code 1 - Accepted

HS2-000020357 - Th– Green Highway Realignment

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0112	N/A	HS2-000020357 - The Green Highway Realignment	Risk Reduction in Progress	Elevated sulphate levels leading to lower reuse	1. Inherent ground conditions due to the mineralogy of clay soils 2. Inadequate/insufficient ground investigation information (OXC)	1. Chemical attack on concrete slab of adjacent structure leading to higher costs 2. Limited of reuse resulting on increase in imported materials 3. Increase in volumes of landscape fill 4. Limiting the use of as-dug or stabilised materials resulting in increased costs due to large haulage distances or importation of selected fill material	8	Reduce	1. Use adequate material for embankment fill which will be not impacted by aggressive ground :proposed replacement fill material is Class 1 [Complete] 2. Design concrete resistance following BRE Special Digest SD1	Construction and Manufacture	3
GEO_T2G_0113	CDM_47038 CDM_47039	HS2-000020357 - The Green Highway Realignment	Risk Reduction in Progress	1. Soil volume may change significantly (shrink-swell) with water content 2. Shrinking and swelling of soil underlying pavement	1. Presence of high plasticity clays (OXC, TILMP) 2. Presence of frost susceptible soils	1. Unacceptable total or differential settlements/ground movement which could impact earthwork, pavement and/or, drainage	8	Control	Risk assumed to be tolerated for an unbound access road 1. Control drainage to limit change in water content of soil [Transfered to EK] 2. Inspection of the subrage by a geotechnical engineer during works and plan for soft spot removal [transfered to EK] 3. Verification testing before works to control moisture content of the subgrade and CBR [transfered to EK] 4. Subgrade improvement if CBR design not achieved [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0114	CDM_47012	HS2-000020357 - The Green Highway Realignment	Risk Reduction in Progress	Periglacial shear in Clay-rich materials leading to weakened in-situ geology and increased risk of slope instability	1. Presence of clay-rich bedrock (OXC)	1. Progressive slope failure and ground movement beneath the embankment which may require re-design. 2. Reduced bearing capacity 3. Slope instability	2	Eliminate	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	3
GEO_T2G_0115	CDM_47012	HS2-000020357 - The Green Highway Realignment	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls is longitudinal to the HW	1. Presence of OXC Formation 2. Slope gradient higher than 5° transversal to the HS2 route 3. Existing natural slope do not crossing mainline	1. Slope instability 2. Delay or cessation of works	4	Reduce	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	2
GEO_T2G_0117	CDM_47012 CDM_47049	HS2-000020357 - The Green Highway Realignment	Risk Reduction in Progress	Compressible ground, characterised as having a low strength and high compressibility, is encountered beneath the EW	Compressible TILMP ansd weathered OXC	1. Unacceptable sugrade performance 2. Reconstruction of road pavement and adverse impact on drainage/utilities. 3. Delay to works in rainy period 4. Higher maintenance	2	Control	1. Data and calculations shows no need for subgrade improvement [Complete] 2. Avoid circulation during works, in order to preserve the subgrade performance [transfered to EK] 3. Use adequate temporary works roads [transfered to EK] 4. Field trial before works to control water content and CBR design [transfered to EK] 5. Routine inspections during operation. [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0118	N/A	HS2-000020357 - The Green Highway Realignment	Risk Reduction in Progress	Soft ground potentially contaminated	Presence of Made Ground related with existing infrastructures : - Dismantled drain : Ch. 85670 - 85720 - Dismantled Rosehill Cottage and road : Ch. 85470	1. Excessive volumes of material for disposal 2. If not removed then would undermine stability of excavations 3. If not removed then would result in unsatisfactory bearing capacity	9	Reduce	1. Mitigation measure include provision for total removal of Made Ground [Complete] 2. Suitable testing during works to determine suitability for re-use and/or disposal off site [Transfered to EK] 3. HSE implications required for handling of contaminated materials and environmental protection during disposal. [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0119	CDM_47012	HS2-000020357 - The Green Highway Realignment	Risk Reduction in Progress	Encountering Potential hard ground band in local Made Ground	Presence of made ground related with exiting infrastructures : - Dismantled drain : Ch. 85670 - 85720	1. Obstruction when excavating 2. Delay to works / longer hold periods	4	Reduce	1. Using adequate engine during works [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0120	N/A	HS2-000020357 - The Green Highway Realignment	Risk Reduction in Progress	Connection to effect of the interaction with the existing pavement structure	Existing pavement structure unknown (Insuficient GI)	1. Possible detrimental effect during construction to existing assets 2. Possible degradation of the existing road pavement, due to differential behaviour with the existing HW	6	Reduce	1. Perform additional GI under existing roads before works to confirm road structure [Transfered to EK] 2. Refer to typicall cross section for connection with existing road [Complete]	Construction and Manufacture	2
GEO_T2G_0632	N/A	HS2-000020357 - The Green Highway Realignment	Risk Reduction in Progress	Co-seismic soil slope instability	Induce earthquake seismic wave through ground. Risk expected to be very low.	1. Ground displacement and slope instability 2. Unacceptable total or differential ground movements 3. Delay to works 4. Higher maintenance	4	Reduce	Risk assumed to be low. 1. Slope stability analysis with seismic conditions and propsed suitable slope angles. [Complete] 2. Area of the asset within a very low seismic hazard area (Midland Microcraton M3) according to the Eurocode 8 seismic hazard zoning maps for the UK	Construction and Manufacture	3
GEO_T2G_0646	CDM_47012	HS2-000020357 - The Green Highway Realignment	Risk Reduction in Progress	Weathering profile in OXC	Erosion and alteration at the top of the strata	1. Softening soil in top of strata which could cause slope instability (refer to soft soil risk in OXC) 2. Variable base depth of the weathered strata wich could cause unacceptable distorsion/ bearing capacity 3. Higher maintenance frequency and associated costs 4. Delay to works in rainy period (soft soils)	6	Reduce	1. Ground improvement of founding soils where needed [Complete] 2. Instrumentation planned to monitor ground movements (settlement) at transition zone with the structure [Complete] 3. Construction during rainy period : use adequate works road and methodology [Transfered to EK] 4. Provision to remove remaining soft pocket of OXC [transfered to EK]	Construction and Manufacture	2

HS2 Ltd - Code 1 - Accepted

HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road –o Pond (P-RAI-0846) – part 1

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0134	N/A	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	Elevated sulphate levels leading to lower reuse	1. Inherent ground conditions due to the mineralogy of clay soils 2. Inadequate/insufficient ground investigation information (OXC)	1. Limited reuse of site-won materials and resulting of an increase in imported materials 2. Limiting the use of as-dug or stabilised materials resulting in increased costs due to large haulage distances or importation of selected fill material	8	Reduce	1. Use adequate material for embankment fill which will be not impacted by aggressive ground :proposed replacement fill material is Class 1 [Complete] 2. Design concrete resistance following BRE Special Digest SD1	Construction and Manufacture	3
GEO_T2G_0135	CDM_47037 CDM_47228	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	1. Soil volume may change significantly (shrink-swell) with water content 2. Shrinking and swelling of soil underlying pavement	1. Presence of high plasticity clays (OXC, TILMP) 2. Presence of frost susceptible soils	1. Unacceptable total or differential settlements/ground movement which could impact earthwork, pavement and/or, drainage	8	Control	Risk assumed to be tolerated for an unbound access road 1. Control drainage to limit change in water content of soil [Transfered to EK] 2. Inspection of the subrage by a geotechnical engineer during works and plan for soft spot removal [transfered to EK] 3. Verification testing before works to control moisture content of the subgrade and CBR [transfered to EK] 4. Subgrade improvement if CBR design not achieved [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0137	CDM_47011	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	Periglacial shear in Clay-rich materials leading to weakened in-situ geology and increased risk of slope instability	1. Presence of clay-rich bedrock (OXC)	1. Slope failure and/or lack of bearing capacity which may require re-design 2. Delay to works 3. Loss and cessation of works	6	Reduce	1. Perform stability calculations with reduced cohesion to ensure safe slope angle and required bearing capacity [Complete] 2. Adopt gentle slope gradients [Complete] 3. Observational approach to follow potential ground movement during works and inspection of temporary excavation during works [Transfered to EK] 4. Provision for rock butress between 83+150 and 83+575 to be deployed during construction, if necessary [Transfered to EK] 5. Limit/avoid heavy loads (vehicles, strockpile) on top of excavation [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0138	CDM_47011	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls towards HS2. Ch. 85.100 to Ch. 86300	1. Presence of OXC Formation 2. Slope gradient higher than 5° transversal to the HS2 route 3. Existing natural slope do not crossing mainline lengthwise 4. Perched water in OXC	1. Reactivation of shear slip (GZA229, 230, 231) 2. Slope instability 3. Delay or cessation of works	4	Reduce	Risk is potential level 1 but low residual risk due to gentle slope gradient adopted in the design and limited cutting height. 1. Design gentle slope gradients [Complete] 2. Observational approach during construction [Transfered to EK]	Construction and Manufacture	3
GEO_T2G_0140	CDM_46995	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	Presence of high / shallow groundwater identified by the ground investigations and short and long term instrumentation monitoring in GFDMP.	Due to a combination of water bearing soil , topography and seasonal fluctuations in the groundwater table through the GFDMP.	Groundwater inflow into excavation and if not mitigated could cause : 1. Slope instability (HW in cutting) 2. unacceptable bearing capacity (and so reduction in CBR design)	6	Reduce	1. Design gentle slope and use conservative assumptions for groundwater level [Complete] 2. Instrumentation and monitoring planned to confirm ground water assumptions and notice instability [Complete] 3. Observational approach to be planned during the construction [Transfered to EK] 4. Include a provision for slope drainage [Transfered to EK] 5. Update CDM register and provide an updated risk to the drainage and temporary works designer. [To be completed]	Construction and Manufacture	2
GEO_T2G_0142	CDM_46995	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	Threat of water ingress in permeable strata in OXC and GFDMP formation	1. Presence of OXC Formation (with sand interbeds) & sandy GFDMP with high permeability, related with the potential for water run-off in rainy weather conditions. 2. Inadequate monitoring installation/information - groundwater inflow in rainy period	1. Could case instability of slopes due to water ingress into cutting 2. Reduced soil stiffness 3. Flooding on temporary excavation	3	Reduce	1. Design gentle slope and use conservative assumptions for groundwater level [Complete] 2. Observational approach to be planned during the construction [Transfered to EK] 4. Include a provision for slope drainage [Transfered to EK]	Construction and Manufacture	4
GEO_T2G_0143	CDM_47011 CDM_47048	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	Soft ground or interbedded soils with varying stiffness at transitions and/or within the cutting, which could cause instability of embankment slopes and/or unacceptable total or differential settlements /subgrade performance	Weathered compressible strata on the top of OXC (up to 5 m deep)	1. Instability slopes and/or unacceptable total or differential settlements 2. Unacceptable subgrade performance 3. Reconstruction of road pavement and adverse impact on drainage/utilities. 4. Risk of unsafe driving conditions at bridge interface. 5. Delay to works in rainy period 6. Higher maintenance and associated costs	4	Reduce	1. Adequate subgrade stiffness and ground improvement where needed [Complete] 2. Use acceptable backfill materials to ensure adequate compaction and stiffness support. [Transfered to EK] 3. Construction during rainy period : use adequate works road and methodology [Transfered to EK] 4. Avoid circulation on theaccess road during works, in order to preserve the subgrade performance [transfered to EK] 5. Use adequate temporary works roads [transfered to EK] 6. Field trial before works to control water content and CBR design [transfered to EK] 5. Routine inspections during operation. [Transfered to EK]	Construction and Manufacture	2

HS2 Ltd - Code 1 - Accepted

HS2-000020NLY - Chetwode ATS Ac–ess Road and Maintenance Access Road to Pond (P-RAI-08–6) – part 2

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0144	CDM_47011 CDM_47048	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	Compressible ground, characterised as having a low strength and high compressibility, is encountered beneath the EW	Compressible TILMP	1. Instability slopes and/or unacceptable total or differential settlements 2. Unacceptable subgrade performance 3. Reconstruction of road pavement and adverse impact on drainage/utilities. 4. Risk of unsafe driving conditions at bridge interface. 5. Delay to works in rainy period 6. Higher maintenance and associated costs	4	Reduce	1. Appropriate gentle slopes (refer to stability calculation) [Complete] 2. Adequate subgrade stiffness and ground improvement where needed [Complete] 3. Use acceptable backfill materials to ensure adequate compaction and stiffness support. [Transfered to EK] 4. Construction during rainy period : use adequate works road and methodology [Transfered to EK] 5. Avoid circulation on theaccess road during works, in order to preserve the subgrade performance [transfered to EK] 6. Use adequate temporary works roads [transfered to EK] 7. Field trial before works to control water content and CBR design [transfered to EK] 5. Routine inspections during operation. [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0145	N/A	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	Soft ground potentially contaminated	Presence of Made Ground related with existing infrastructures : - Dismantled drain : Ch. 85670 - 85720 - Dismantled Rosehill Cottage and road : Ch. 85470	1. Excessive volumes of material for disposal 2. If not removed then would undermine stability of excavations 3. If not removed then would result in unsatisfactory bearing capacity	9	Reduce	1. Mitigation measure include provision for total removal of Made Ground [Complete] 2. Suitable testing during works to determine suitability for re-use and/or disposal off site [Transfered to EK] 3. HSE implications required for handling of contaminated materials and environmental protection during disposal. [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0146	CDM_47011	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	Encountering Potential hard ground band in local Made Ground	Presence of made ground related with exiting infrastructures : - Dismantled drain : Ch. 85670 - 85720 - Dismantled Rosehill Cottage and road : Ch. 85470	1. Obstruction when excavating 2. Delay to works / longer hold periods	4	Reduce	1. Using adequate engine during works [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0147	CDM_47011	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	Loose and unstable ground of GFDMP sandy strata if water ingress and steep temporary slopes	1. Low cohesion and high permeability in sandy GFDMP strata 2. Water ingress through GFDMP 3. Temporary E&R with steep slope angle in GFDMP	1. Slope instability 2. Water ingress through permeable strata (GFDMP)	6	Reduce	1. Appropriate Design slopes to ensure long term stability [Complete] 2. Provision for mitigation measures if the observational approach during construction show a water inflow : blanket layer / countrefort drain with appropriate drainage [Transfered to EK] 3. Temporary slopes in GFDMP not stable without mitigation measures during works. Adequate mitigation measure to be planned by EKFB to ensure temporary slope stability [Transfered to EK]	Construction and Manufacture	4
GEO_T2G_0633	N/A	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	Co-seismic soil slope instability	Induce earthquake seismic wave through ground. Risk expected to be very low.	1. Ground displacement and slope instability 2. Unacceptable total or differential ground movements 3. Delay to works 4. Higher maintenance	4	Reduce	Risk assumed to be low. 1. Slope stability analysis with seismic conditions and propsed suitable slope angles. [Complete] 2. Area of the asset within a very low seismic hazard area (Midland Microcraton M3) according to the Eurocode 8 seismic hazard zoning maps for the UK	Construction and Manufacture	3
GEO_T2G_0645	CDM_47011	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	Weathering profile in OXC	Erosion and alteration at the top of the strata	1. Softening soil in top of strata which could cause slope instability (refer to soft soil risk in OXC) 2. Variable base depth of the weathered strata wich could cause unacceptable distorsion/ bearing capacity 3. Higher maintenance frequency and associated costs 4. Delay to works in rainy period (soft soils)	6	Reduce	1. Ground improvement of founding soils where needed [Complete] 2. Instrumentation planned to monitor ground movements (settlement) at transition zone with the structure [Complete] 3. Construction during rainy period : use adequate works road and methodology [Transfered to EK] 4. Provision to remove remaining soft pocket of OXC [transfered to EK]	Construction and Manufacture	2
GEO_T2G_0658	CDM_47011	HS2-000020NLY - Chetwode ATS Access Road and Maintenance Access Road to Pond (P-RAI-0846)	Risk Reduction in Progress	The existing slopes of the dismantled railway line could be affected by an instability due to the proposed earthworks	Interface with the existing slopes of the dismantled railway line	1. Ground instabilities beneath the proposed embankment	6	Reduce	The proposed earthwork is an embankment and will stabilise potential slope instailities of the existing cutting, inducing a low risk of instability. The risk is assumed to be tolerated. [Complete]	Construction and Manufacture	4

HS2 Ltd - Code 1 - Accepted

HS2-000020NLZ - Fo–tpath CHW/18 Accommodation Access Realignment

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0121	N/A	HS2-000020NLZ - Footpath CHW/18 Accommodation Access Realignment	Risk Reduction in Progress	Elevated sulphate levels leading to lower reuse	1. Inherent ground conditions due to the mineralogy of clay soils 2. Inadequate/insufficient ground investigation information (OXC)	1. Chemical attack on concrete slab of adjacent structure leading to higher costs 2. Limited of reuse resulting on increase in imported materials 3. Increase in volumes of landscape fill 4. Limiting the use of as-dug or stabilised materials resulting in increased costs due to large haulage distances or importation of selected fill material	8	Reduce	1. Use adequate material for embankment fill which will be not impacted by aggressive ground :proposed replacement fill material is Class 1 [Complete] 2. Design concrete resistance following BRE Special Digest SD1	Construction and Manufacture	3
GEO_T2G_0122	CDM_47032 CDM_47227	HS2-000020NLZ - Footpath CHW/18 Accommodation Access Realignment	Risk Reduction in Progress	1. Soil volume may change significantly (shrink-swell) with water content 2. Shrinking and swelling of soil underlying pavement	1. Presence of high plasticity clays (OXC, TILMP) 2. Presence of frost susceptible soils	1. Unacceptable total or differential settlements/ground movement which could impact earthwork, pavement and/or, drainage	8	Control	Risk assumed to be tolerated for an unbound access road 1. Control drainage to limit change in water content of soil [Transfered to EK] 2. Inspection of the subrage by a geotechnical engineer during works and plan for soft spot removal [transfered to EK] 3. Verification testing before works to control moisture content of the subgrade and CBR [transfered to EK] 4. Subgrade improvement if CBR design not achieved [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0123	CDM_47009	HS2-000020NLZ - Footpath CHW/18 Accommodation Access Realignment	Risk Reduction in Progress	Weathering profile in OXC	Erosion and alteration at the top of the strata	1. Softening soil in top of strata which could cause slope instability (refer to soft soil risk in OXC) 2. Variable base depth of the weathered strata wich could cause unacceptable distorsion/ bearing capacity 3. Higher maintenance frequency and associated costs 4. Delay to works in rainy period (soft soils)	6	Reduce	1. Ground improvement of founding soils where needed [Complete] 2. Instrumentation planned to monitor ground movements (settlement) at transition zone with the structure [Complete] 3. Construction during rainy period : use adequate works road and methodology [Transfered to EK] 4. Provision to remove remaining soft pocket of OXC [transfered to EK]	Construction and Manufacture	2
GEO_T2G_0124	CDM_47009	HS2-000020NLZ - Footpath CHW/18 Accommodation Access Realignment	Risk Reduction in Progress	Periglacial shear in Clay-rich materials leading to weakened in-situ geology and increased risk of slope instability	1. Presence of clay-rich bedrock (OXC)	1. Progressive slope failure and ground movement beneath the embankment which may require re-design. 2. Reduced bearing capacity 3. Slope instability	2	Eliminate	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	2
GEO_T2G_0125	CDM_47009	HS2-000020NLZ - Footpath CHW/18 Accommodation Access Realignment	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls is longitudinal to the HW	1. Presence of OXC Formation 2. Slope gradient > 5° transversal to the HS2 route 3. Perched groundwater in OXC	1. Slope instability 2. Delay or cessation of works	4	Reduce	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	2
GEO_T2G_0128	CDM_47009 CDM_47045	HS2-000020NLZ - Footpath CHW/18 Accommodation Access Realignment	Risk Reduction in Progress	Compressible ground, characterised as having a low strength and high compressibility, is encountered beneath the EW	Compressible TILMP ansd weathered OXC	1. Unacceptable sugrade performance 2. Reconstruction of road pavement and adverse impact on drainage/utilities. 3. Delay to works in rainy period 4. Higher maintenance	6	Reduce	1. Ground improvement of founding soils where needed (E&R or stabilisation) [Complete] 2. Monitoring of settlement during construction (at transition with structures only) [Complete] 3. Extend wait period for earthworks if required. [Transfered to EK] 4. Routine inspections during operation. [Transfered to EK] 5. Construction during rainy period : use adequate works road and methodology [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0129	N/A	HS2-000020NLZ - Footpath CHW/18 Accommodation Access Realignment	Risk Reduction in Progress	Soft ground potentially contaminated	Presence of Made Ground related with existing infrastructures : - Dismantled drain : Ch. 85670 - 85720 - Dismantled Rosehill Cottage and road : Ch. 85470	1. Excessive volumes of material for disposal 2. If not removed then would undermine stability of excavations 3. If not removed then would result in unsatisfactory bearing capacity	9	Reduce	1. Mitigation measure include provision for total removal of Made Ground [Complete] 2. Suitable testing during works to determine suitability for re-use and/or disposal off site [Transfered to EK] 3. HSE implications required for handling of contaminated materials and environmental protection during disposal. [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0130	CDM_47009	HS2-000020NLZ - Footpath CHW/18 Accommodation Access Realignment	Risk Reduction in Progress	Encountering Potential hard ground band in local Made Ground	Presence of made ground related with exiting infrastructures : - Dismantled drain : Ch. 85670 - 85720 - Dismantled Rosehill Cottage and road : Ch. 85470	1. Obstruction when excavating 2. Delay to works / longer hold periods	4	Reduce	1. Using adequate engine during works [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0131	CDM_47009 CDM_47045	HS2-000020NLZ - Footpath CHW/18 Accommodation Access Realignment	Risk Reduction in Progress	Magnitude of settlement and/or time for consolidation greater than expected at OB or culvert transitions.	1. Soft ground 2. Low tolerances to ground movements 3. High groundwater table	1. Differential settlements and longitudinal distortion 2. Longer construction hold periods 3. Higher maintenance and associated costs 4. Embankment side slope instability.	6	Reduce	1. Ground improvement of founding soils defined by calculation (1 m bgl at some location) [Complete] 2. Instrumentation and monitoring planned to manage settlement issues beneath the embankment. [Complete] 3. Construction during rainy period : use adequate works road [transfered to EK] 4.Monitoring data to analyse during construction works to validate the duration of the hold period and to verify that the consolidations settlements have occurred and are stabilised [transfered to EK]	Construction and Manufacture	1
GEO_T2G_0132	N/A	HS2-000020NLZ - Footpath CHW/18 Accommodation Access Realignment	Risk Reduction in Progress	Connection to effect of the interaction with the existing pavement structure	Existing pavement structure unknown (Insuficient GI)	1. Possible detrimental effect during construction to existing assets 2. Possible degradation of the existing road pavement, due to differential behaviour with the existing HW	6	Reduce	1. Perform additional GI under existing roads before works to confirm road structure [Transfered to EK] 2. Refer to typicall cross section for connection with existing road [Complete]	Construction and Manufacture	2
GEO_T2G_0133	CDM_47009 CDM_47045	HS2-000020NLZ - Footpath CHW/18 Accommodation Access Realignment	Risk Reduction in Progress	Internal settlement of the embankments made with high plasticity clay	Material used for the construction difficult to be compacted. Internal creeping.	Additional settlement which coul cause innacceptable distortion	4	Reduce	1. Perform trial embankment before works to obtain adequate compaction requirement [Transfered to EK] 2. Design take into acount internal settlement [Complete]	Construction and Manufacture	2
GEO_T2G_0634	N/A	HS2-000020NLZ - Footpath CHW/18 Accommodation Access Realignment	Risk Reduction in Progress	Co-seismic soil slope instability	Induce earthquake seismic wave through ground. Risk expected to be very low.	1. Ground displacement and slope instability 2. Unacceptable total or differential ground movements 3. Delay to works 4. Higher maintenance	4	Reduce	Risk assumed to be low. 1. Slope stability analysis with seismic conditions and propsed suitable slope angles. [Complete] 2. Area of the asset within a very low seismic hazard area (Midland Microcraton M3) according to the Eurocode 8 seismic hazard zoning maps for the UK	Construction and Manufacture	3

HS2 Ltd - Code 1 - Accepted

HS2-0–0020NM2 - Maintenance Access Road to–Pond (Off School End Road - South) – part 1

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0024		HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	Potential risk of soil and groundwater contamination associated with Dismantled Rugby to Quainton Great Central Railway within LOD (LQ 13.07).	No Made Ground (MGR) has been encountered within the realignment to date. While the realignment is situated within greenfield agricultural land, there also remains a potential to encounter further unforeseen areas of MGR. There is potential for contaminated soil & groundwater to be associated with the Dismantled Rugby to Quainton Great Central Railway Line (LQ 13.07) which is partially within the LOD.	1. Risk to human health and controlled waters during the works. 2. Risk of delays to the programme - potentially from additional GI to classify material and from remediation 3. Risk of encountering contaminated groundwater during excavation which will need to be disposed of appropriately	9	Reduce	1. Further GI has been scoped and is ongoing. 2. Further contamination assessment to be undertaken once information is available. 3. Contaminated GW exceeding screening values may require de-watering, collect and treat/tanker and discharge consents. 4. Management of potentially contaminated soils to be in line with the Remediation Outline Strategy and Verification Plan reports.	Construction and Manufacture	4
GEO_T2G_0025		HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	Risk of ground gases (methane, carbon dioxide, depleted oxygen, carbon monoxide and hydrogen sulphide - Radon assessed separately).	Ground gas monitoring undertaken to date has indicated a low risk (CS1) from ground gas migration, however this is based on limited data. Elevated methane concentrations were identified in two locations within agricultural land which is not considered to be representative of the whole site and further assessment is recommended. Potential sources of ground gases exist including the Dismantled Rugby to Quainton Great Central Railway Line (LQ 13.07). As a result there is potential for ground gas to have migrated onto site. However, it is assumed that confined spaces are not proposed in which gas could accumulate, however the	1. Risk to human health during excavation. 2. Potential health risk to construction workers entering confined spaces if elevated gas concentrations/depleted oxygen concentrations are encountered. 3. Risk of creation of preferential pathways for gas migration	4	Reduce	1. Further GI has been scoped and is ongoing. 2. Further gas assessment to be undertaken once information is available. 3. Excavations and confined spaces should be monitored for gas and depleted oxygen prior to man entry in line with recommendations of HSE guidance.	Construction and Manufacture	2
GEO_T2G_0026		HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	Limitations to where material can be re-used in view of its chemical characteristics/re-use criteria and material incorrectly segregated cannot be reused	No Made Ground (MGR) has been encountered within the realignment to date. While the realignment is situated within greenfield agricultural land, there also remains a potential to encounter further unforeseen areas of MGR. There is potential for contaminated soil & groundwater to be associated with the Dismantled Rugby to Quainton Great Central Railway Line (LQ 13.07) which is partially within the LOD.	1. Failure to comply with regulatory guidance/MMP 2. Increased costs with having to re-do segregation of stockpiled material 3. Increased costs with having to disposal of material 4. Potential Environmental harm to receptors 5. Delay to programme	9	Reduce	1. Further GI has been scoped and is ongoing. [Transfered to EK] 2. Correct characterisation of soils 3. Management of potentially contaminated soils to be in line with the Remediation Outline Strategy and Verification Plan reports.[Transfered to EK] 4. Materials Management Plan (MMP) to be adopted [Complete]	Construction and Manufacture	4
GEO_T2G_0089	N/A	HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	Elevated sulphate levels leading to lower reuse	1. Inherent ground conditions due to the mineralogy of clay soils 2. Inadequate/insufficient ground investigation information (OXC)	1. Chemical attack on concrete slab of adjacent structure leading to higher costs 2. Limited of reuse resulting on increase in imported materials 3. Increase in volumes of landscape fill 4. Limiting the use of as-dug or stabilised materials resulting in increased costs due to large haulage distances or importation of selected fill material	8	Reduce	1. Use adequate material for embankment fill which will be not impacted by aggressive ground :proposed replacement fill material is Class 1 [Complete] 2. Design concrete resistance following BRE Special Digest SD1	Construction and Manufacture	3
GEO_T2G_0090	CDM_47023 CDM_47030	HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	1. Soil volume may change significantly (shrink-swell) with water content 2. Shrinking and swelling of soil underlying pavement	1. Presence of high plasticity clays (OXC, TILMP) 2. Presence of frost susceptible soils	1. Unacceptable total or differential settlements/ground movement which could impact earthwork, pavement and/or, drainage	8	Control	Risk assumed to be tolerated for an unbound access road 1. Control drainage to limit change in water content of soil [Transfered to EK] 2. Inspection of the subrage by a geotechnical engineer during works and plan for soft spot removal [transfered to EK] 3. Verification testing before works to control moisture content of the subgrade and CBR [transfered to EK] 4. Subgrade improvement if CBR design not achieved [Transfered to EK]	Construction and Manufacture	2

HS2 Ltd - Code 1 - Accepted

HS2-00–020NM2 - Maintenance Access–Road to Pond (Off School End Road - South) – part 2

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0091	CDM_47007	HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	Periglacial shear in Clay-rich materials leading to weakened in-situ geology and increased risk of slope instability	1. Presence of clay-rich bedrock (OXC)	1. Progressive slope failure and ground movement beneath the embankment which may require re-design. 2. Reduced bearing capacity 3. Slope instability	2	Eliminate	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	1
GEO_T2G_0092	CDM_47007	HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls is longitudinal to the HW	1. Presence of OXC Formation 2. Slope gradient > 5° transversal to the HS2 route 3. Perched groundwater in OXC	1. Slope instability 2. Delay or cessation of works	4	Reduce	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	2
GEO_T2G_0093	N/A	HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	1. Displaced geological units 2. Unexpected variable ground conditions 3. Locally weakened ground conditions 4. Locally higher permeability	Natural geological faulting processes	1. Slope instability 2. Unsuitable geotechnical solution given unexpected ground conditions 3. Differential movements more likely within a fault zone	2	Reduce	Low risk due to the depth of bedrock strata location beneath the track level. However, Contractor to supervise the excavations for potential faulting. Refer to the structure foundation for further risks and mitigation	Construction and Manufacture	2
GEO_T2G_0096	CDM_47007 CDM_47043	HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	Compressible ground, characterised as having a low strength and high compressibility, is encountered beneath the EW	Compressible TILMP ansd weathered OXC	1. Unacceptable sugrade performance 2. Reconstruction of road pavement and adverse impact on drainage/utilities. 3. Delay to works in rainy period 4. Higher maintenance	2	Control	1. Data and calculations shows no need for subgrade improvement [Complete] 2. Avoid circulation during works, in order to preserve the subgrade performance [transfered to EK] 3. Use adequate temporary works roads [transfered to EK] 4. Field trial before works to control water content and CBR design [transfered to EK] 5. Routine inspections during operation. [Transfered to EK]	Construction and Manufacture	1
GEO_T2G_0097	N/A	HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	Soft ground potentially contaminated	Presence of Made Ground related with existing infrastructures : - Dismantled railay line - Dismantled School En road : Ch. 86420 - Dismantled Drain : Ch. 86780	1. Excessive volumes of material for disposal 2. If not removed then would undermine stability of excavations 3. If not removed then would result in unsatisfactory bearing capacity	9	Reduce	1. Mitigation measure include provision for total removal of Made Ground [Complete] 2. Suitable testing during works to determine suitability for re-use and/or disposal off site [Transfered to EK] 3. HSE implications required for handling of contaminated materials and environmental protection during disposal. [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0098	CDM_47007	HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	Encountering Potential hard ground band in local Made Ground	Presence of made ground related with exiting infrastructures : - Dismantled railay line - Dismantled School En road : Ch. 86420 - Dismantled Drain : Ch. 86780	1. Obstruction when excavating 2. Delay to works / longer hold periods	4	Reduce	1. Using adequate engine during works [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0099	CDM_47007 CDM_47043	HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	Internal settlement of the embankments made with high plasticity clay	Material used for the construction difficult to be compacted. Internal creeping.	Additional settlement which coul cause innacceptable distortion	4	Reduce	1. Design take into acount internal settlement [Complete]	Construction and Manufacture	2
GEO_T2G_0100	CDM_47007	HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	The existing slopes of the dismantled railway line could be affected by an instability due to the proposed earthworks	Interface with the existing slopes of the dismantled railway line	1. Ground instabilities beneath the proposed embankment	6	Reduce	The proposed earthwork is an embankment and will stabilise potential slope instailities of the existing cutting, inducing a low risk of instability. The risk is assumed to be tolerated. [Complete]	Construction and Manufacture	4
GEO_T2G_0635	N/A	HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	Co-seismic soil slope instability	Induce earthquake seismic wave through ground. Risk expected to be very low.	1. Ground displacement and slope instability 2. Unacceptable total or differential ground movements 3. Delay to works 4. Higher maintenance	4	Reduce	Risk assumed to be low. 1. Slope stability analysis with seismic conditions and propsed suitable slope angles. [Complete] 2. Area of the asset within a very low seismic hazard area (Midland Microcraton M3) according to the Eurocode 8 seismic hazard zoning maps for the UK	Construction and Manufacture	3
GEO_T2G_0723		HS2-000020NM2 - Maintenance Access Road to Pond (Off School End Road - South)	Risk Reduction in Progress	There is a threat of flood risk associated with the Padbury Brook (approx. Ch.87+000) which can impact the proposed access road to pond.	Embankment located in flood plain related with Tributary of Padbury Brook	1.Erosion of the structure of the access road 2.Higher maintenance frequency and associated costs. 3. Interuption of the vehicule acess during flooding events	4	Control	No action required	Operations and Maintenance	4

HS2 Ltd - Code 1 - Accepted

–HS2-000020NM3 - Maintenance Access Road to Pond (Off Sch–ol End Road - North)

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0101	N/A	HS2-000020NM3 - Maintenance Access Road to Pond (Off School End Road - North)	Risk Reduction in Progress	Elevated sulphate levels leading to lower reuse	1. Inherent ground conditions due to the mineralogy of clay soils 2. Inadequate/insufficient ground investigation information (OXC)	1. Chemical attack on concrete slab of adjacent structure leading to higher costs 2. Limited of reuse resulting on increase in imported materials 3. Increase in volumes of landscape fill 4. Limiting the use of as-dug or stabilised materials resulting in increased costs due to large haulage distances or importation of selected fill material	8	Reduce	1. Use adequate material for embankment fill which will be not impacted by aggressive ground :proposed replacement fill material is Class 1 [Complete] 2. Design concrete resistance following BRE Special Digest SD1	Construction and Manufacture	3
GEO_T2G_0102	CDM_47024 CDM_47028	HS2-000020NM3 - Maintenance Access Road to Pond (Off School End Road - North)	Risk Reduction in Progress	1. Soil volume may change significantly (shrink-swell) with water content 2. Shrinking and swelling of soil underlying pavement	1. Presence of high plasticity clays (OXC, TILMP) 2. Presence of frost susceptible soils	1. Unacceptable total or differential settlements/ground movement which could impact earthwork, pavement and/or, drainage	8	Control	Risk assumed to be tolerated for an unbound access road 1. Control drainage to limit change in water content of soil [Transfered to EK] 2. Inspection of the subrage by a geotechnical engineer during works and plan for soft spot removal [transfered to EK] 3. Verification testing before works to control moisture content of the subgrade and CBR [transfered to EK] 4. Subgrade improvement if CBR design not achieved [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0103	CDM_47008	HS2-000020NM3 - Maintenance Access Road to Pond (Off School End Road - North)	Risk Reduction in Progress	Periglacial shear in Clay-rich materials leading to weakened in-situ geology and increased risk of slope instability	1. Presence of clay-rich bedrock (OXC)	1. Progressive slope failure and ground movement beneath the embankment which may require re-design. 2. Reduced bearing capacity 3. Slope instability	2	Eliminate	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	2
GEO_T2G_0104	CDM_47008	HS2-000020NM3 - Maintenance Access Road to Pond (Off School End Road - North)	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls is longitudinal to the HW	1. Presence of OXC Formation 2. Slope gradient > 5° transversal to the HS2 route 3. Perched groundwater in OXC	1. Slope instability 2. Delay or cessation of works	4	Reduce	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	2
GEO_T2G_0105	CDM_47008 CDM_47044	HS2-000020NM3 - Maintenance Access Road to Pond (Off School End Road - North)	Risk Reduction in Progress	1. Displaced geological units 2. Unexpected variable ground conditions 3. Locally weakened ground conditions 4. Locally higher permeability	Natural geological faulting processes	1. Slope instability 2. Unsuitable geotechnical solution given unexpected ground conditions 3. Differential movements more likely within a fault zone	2	Reduce	Low risk due to the depth of bedrock strata location beneath the track level. However, Contractor to supervise the excavations for potential faulting.	Construction and Manufacture	2
GEO_T2G_0108	CDM_47008 CDM_47044	HS2-000020NM3 - Maintenance Access Road to Pond (Off School End Road - North)	Risk Reduction in Progress	Compressible ground, characterised as having a low strength and high compressibility, is encountered beneath the EW	Compressible TILMP ansd weathered OXC	1. Unacceptable sugrade performance 2. Reconstruction of road pavement and adverse impact on drainage/utilities. 3. Delay to works in rainy period 4. Higher maintenance	2	Control	1. Data and calculations shows no need for subgrade improvement [Complete] 2. Avoid circulation during works, in order to preserve the subgrade performance [transfered to EK] 3. Use adequate temporary works roads [transfered to EK] 4. Field trial before works to control water content and CBR design [transfered to EK] 5. Routine inspections during operation. [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0109	N/A	HS2-000020NM3 - Maintenance Access Road to Pond (Off School End Road - North)	Risk Reduction in Progress	Soft ground potentially contaminated	Presence of Made Ground related with existing infrastructures : - Dismantled School En road : Ch. 86420 - Dismantled Drain : Ch. 86780	1. Excessive volumes of material for disposal 2. If not removed then would undermine stability of excavations 3. If not removed then would result in unsatisfactory bearing capacity	9	Reduce	1. Mitigation measure include provision for total removal of Made Ground [Complete] 2. Suitable testing during works to determine suitability for re-use and/or disposal off site [Transfered to EK] 3. HSE implications required for handling of contaminated materials and environmental protection during disposal. [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0110	CDM_47008	HS2-000020NM3 - Maintenance Access Road to Pond (Off School End Road - North)	Risk Reduction in Progress	Encountering Potential hard ground band in local Made Ground	Presence of made ground related with exiting infrastructures : - Dismantled School En road : Ch. 86420 - Dismantled Drain : Ch. 86780	1. Obstruction when excavating 2. Delay to works / longer hold periods	4	Reduce	1. Using adequate engine during works [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0111	CDM_47008 CDM_47044	HS2-000020NM3 - Maintenance Access Road to Pond (Off School End Road - North)	Risk Reduction in Progress	Internal settlement of the embankments made with high plasticity clay	Material used for the construction difficult to be compacted. Internal creeping.	Additional settlement which coul cause innacceptable distortion	4	Reduce	1. Design take into acount internal settlement [Complete]	Construction and Manufacture	2
GEO_T2G_0636	N/A	HS2-000020NM3 - Maintenance Access Road to Pond (Off School End Road - North)	Risk Reduction in Progress	Co-seismic soil slope instability	Induce earthquake seismic wave through ground. Risk expected to be very low.	1. Ground displacement and slope instability 2. Unacceptable total or differential ground movements 3. Delay to works 4. Higher maintenance	4	Reduce	Risk assumed to be low. 1. Slope stability analysis with seismic conditions and propsed suitable slope angles. [Complete] 2. Area of the asset within a very low seismic hazard area (Midland Microcraton M3) according to the Eurocode 8 seismic hazard zoning maps for the UK	Construction and Manufacture	3

HS2 Ltd - Code 1 - Accepted

HS2-00002BJUR - Scho–l End Road Realignment – part 1

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that…)	Risk Cause (Due to….)	Risk Impact (Resulting in….)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0021		HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	Potential risk of soil and groundwater contamination associated with Dismantled Rugby to Quainton Great Central Railway within LOD (LQ 13.07).	No Made Ground (MGR) has been encountered within the realignment to date. While the realignment is situated within greenfield agricultural land, there also remains a potential to encounter further unforeseen areas of MGR. There is potential for contaminated soil & groundwater to be associated with the Dismantled Rugby to Quainton Great Central Railway Line (LQ 13.07) which is partially within the LOD.	1. Risk to human health and controlled waters during the works. 2. Risk of delays to the programme - potentially from additional GI to classify material and from remediation 3. Risk of encountering contaminated groundwater during excavation which will need to be disposed of appropriately	9	Reduce	1. Further GI has been scoped and is ongoing. 2. Further contamination assessment to be undertaken once information is available. 3. Contaminated GW exceeding screening values may require de-watering, collect and treat/tanker and discharge consents. 4. Management of potentially contaminated soils to be in line with the Remediation Outline Strategy and Verification Plan reports.	Construction and Manufacture	4
GEO_T2G_0022		HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	Risk of ground gases (methane, carbon dioxide, depleted oxygen, carbon monoxide and hydrogen sulphide - Radon assessed separately).	Ground gas monitoring undertaken to date has indicated a low risk (CS1) from ground gas migration, however this is based on limited data. Elevated methane concentrations were identified in two locations within agricultural land which is not considered to be representative of the whole site and further assessment is recommended. Potential sources of ground gases exist including the Dismantled Rugby to Quainton Great Central Railway Line (LQ 13.07). As a result there is potential for ground gas to have migrated onto site. However, it is assumed that confined spaces are not proposed in which gas could accumulate, however the	1. Risk to human health during excavation. 2. Potential health risk to construction workers entering confined spaces if elevated gas concentrations/depleted oxygen concentrations are encountered. 3. Risk of creation of preferential pathways for gas migration	4	Reduce	1. Further GI has been scoped and is ongoing. 2. Further gas assessment to be undertaken once information is available. 3. Excavations and confined spaces should be monitored for gas and depleted oxygen prior to man entry in line with recommendations of HSE guidance.	Construction and Manufacture	2
GEO_T2G_0023		HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	Limitations to where material can be re-used in view of its chemical characteristics/re-use criteria and material incorrectly segregated cannot be reused	No Made Ground (MGR) has been encountered within the realignment to date. While the realignment is situated within greenfield agricultural land, there also remains a potential to encounter further unforeseen areas of MGR. There is potential for contaminated soil & groundwater to be associated with the Dismantled Rugby to Quainton Great Central Railway Line (LQ 13.07) which is partially within the LOD.	risk of: 1. Failure to comply with regulatory guidance/MMP 2. Increased costs with having to re-do segregation of stockpiled material 3. Increased costs with having to disposal of material 4. Potential Environmental harm to receptors 5. Delay to programme	9	Reduce	1. Further GI has been scoped and is ongoing. [Transfered to EK] 2. Correct characterisation of soils 3. Management of potentially contaminated soils to be in line with the Remediation Outline Strategy and Verification Plan reports.[Transfered to EK] 4. Materials Management Plan (MMP) to be adopted [Complete]	Construction and Manufacture	4
GEO_T2G_0074	N/A	HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	Elevated sulphate levels leading to lower reuse	1. Inherent ground conditions due to the mineralogy of clay soils 2. Inadequate/insufficient ground investigation information (OXC)	1. Chemical attack on concrete slab of adjacent structure leading to higher costs 2. Limited reuse resulting on increase in imported materials 3. Increase in volumes of landscape fill 4. Limiting the use of as-dug or stabilised materials resulting in increased costs due to large haulage distances or importation of selected fill material	8	Reduce	1. Use adequate material for embankment fill which will not be impacted by aggressive ground :proposed replacement fill material is Class 1 [Complete] 2. Design concrete resistance following BRE Special Digest SD1	Construction and Manufacture	3
GEO_T2G_0075	CDM_47022 CDM_47026	HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	1. Soil volume may change significantly (shrink-swell) with water content 2. Shrinking and swelling of soil underlying pavement	1. Presence of high plasticity clays (OXC, TILMP) 2. Presence of frost susceptible soils	1. Unacceptable total or differential settlements/ground movement which could impact earthwork, pavement and/or, drainage	8	Control	Risk assumed to be tolerated for an unbound access road 1. Control drainage to limit change in water content of soil [Transfered to EK] 2. Inspection of the subrage by a geotechnical engineer during works and plan for soft spot removal [transfered to EK] 3. Verification testing before works to control moisture content of the subgrade and CBR [transfered to EK] 4. Subgrade improvement if CBR design not achieved [Transfered to EK]	Construction and Manufacture	2

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HS2-00002BJUR - School End Road Realignment – part 2

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0077	CDM_47006	HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	Periglacial shear in Clay-rich materials leading to weakened in-situ geology and increased risk of slope instability	1. Presence of clay-rich bedrock (OXC)	1. Progressive slope failure and ground movement beneath the embankment which may require re-design. 2. Reduced bearing capacity 3. Slope instability	2	Eliminate	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	2
GEO_T2G_0078	CDM_47006	HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls towards the HW	1. Presence of OXC Formation 2. Slope gradient > 5° transversal to the HS2 route 3. Perched groundwater in OXC	1. Slope instability 2. Delay or cessation of works	4	Reduce	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	2
GEO_T2G_0079	N/A	HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	1. Displaced geological units 2. Unexpected variable ground conditions 3. Locally weakened ground conditions 4. Locally higher permeability	Natural geological faulting processes	1. Slope instability 2. Unsuitable geotechnical solution given unexpected ground conditions 3. Differential movements more likely within a fault zone	2	Reduce	Low risk due to the depth of bedrock strata location beneath the track level. However, Contractor to supervise the excavations for potential faulting.	Construction and Manufacture	2
GEO_T2G_0082	CDM_47006 CDM_47042	HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	Compressible ground, characterised as having a low strength and high compressibility, is encountered beneath the EW	Compressible TILMP ansd weathered OXC	1. Instability slopes and/or unacceptable total and/or differential settlements 2. Unacceptable subgrade performance 3. Reconstruction of road pavement and adverse impact on drainage/utilities. 4. Risk of unsafe driving conditions at bridge interface. 5. Delay to works in rainy period 6. Higher maintenance and associated costs	6	Reduce	1. Ground improvement of founding soils where needed (E&R or stabilisation) [Complete] 2. Monitoring of settlement during construction (at transition with structures only) [Complete] 3. Extend wait period for earthworks if required. [Transfered to EK] 4. Routine inspections during operation. [Transfered to EK] 5. Construction during rainy period : use adequate works road and methodology [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0083	N/A	HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	Soft ground potentially contaminated	Presence of Made Ground related with existing infrastructures : - Dismantled railay line - Dismantled School En road : Ch. 86420	1. Excessive volumes of material for disposal 2. If not removed then would undermine stability of excavations 3. If not removed then would result in unsatisfactory bearing capacity	9	Reduce	1. Mitigation measure include provision for total removal of Made Ground [Complete] 2. Suitable testing during works to determine suitability for re-use and/or disposal off site [Transfered to EK] 3. HSE implications required for handling of contaminated materials and environmental protection during disposal. [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0084	CDM_47006	HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	Encountering Potential hard ground band in local Made Ground	Presence of made ground related with exiting infrastructures : - Dismantled railay line - Dismantled School En road : Ch. 86420	1. Obstruction when excavating 2. Delay to works / longer hold periods	4	Reduce	1. Using adequate/appropriate machinery ~~engine~~ during works [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0086	N/A	HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	Connection to effect of the interaction with the existing pavement structure	Existing pavement structure unknown (Insuficient GI)	1. Possible detrimental effect during construction to existing assets 2. Possible degradation of the existing road pavement, due to differential behaviour with the existing HW	6	Reduce	1. Perform additional GI under existing roads before works to confirm road structure [Transfered to EK] 2. Refer to typicall cross section for connection with existing road [Complete]	Construction and Manufacture	2
GEO_T2G_0087	CDM_47006 CDM_47042	HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	Internal settlement of the embankments made with high plasticity clay	Material used for the construction difficult to be compacted. Internal creeping.	Additional settlement which coul cause innacceptable distortion	4	Reduce	1. Perform trial embankment before works to obtain adequate compaction requirement [Transfered to EK] 2. Design take into acount internal settlement [Complete]	Construction and Manufacture	2
GEO_T2G_0088	CDM_47006	HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	The existing slopes of the dismantled railway line could be affected by an instability due to the proposed earthworks	Interface with the existing slopes of the dismantled railway line	1. Ground instabilities beneath the proposed embankment	6	Reduce	The proposed earthwork is an embankment and will stabilise potential slope instailities of the existing cutting, inducing a low risk of instability. The risk is assumed to be tolerated. [Complete]	Construction and Manufacture	4
GEO_T2G_0637	N/A	HS2-00002BJUR - School End Road Realignment	Risk Reduction in Progress	Co-seismic soil slope instability	Induce earthquake seismic wave through ground. Risk expected to be very low.	1. Ground displacement and slope instability 2. Unacceptable total or differential ground movements 3. Delay to works 4. Higher maintenance	4	Reduce	Risk assumed to be low. 1. Slope stability analysis with seismic conditions and propsed suitable slope angles. [Complete] 2. Area of the asset within a very low seismic hazard area (Midland Microcraton M3) according to the Eurocode 8 seismic hazard zoning maps for the UK	Construction and Manufacture	3

HS2 Ltd - Code 1 - Accepted

HS2-00002QH92 - Footpath CHW/18 Diversion

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0076	CDM_47010	HS2-00002QH92 - Footpath CHW/18 Diversion	Risk Reduction in Progress	Weathering profile in OXC	Erosion and alteration at the top of the strata	1. Softening soil in top of strata which could cause slope instability (refer to soft soil risk in OXC) 2. Variable base depth of the weathered strata wich could cause unacceptable distorsion/ bearing capacity 3. Higher maintenance frequency and associated costs 4. Delay in programme/works in rainy period (soft soils)	6	Reduce	1. Ground improvement of founding soils where needed [Complete] 2. Instrumentation planned to monitor ground movements (settlement) at transition zone with the structure [Complete] 3. Construction during rainy period : use adequate works road and methodology [Transfered to EK] 4. Provision to remove remaining soft pocket of OXC [transfered to EK]	Construction and Manufacture	2
GEO_T2G_0630	N/A	HS2-00002QH92 - Footpath CHW/18 Diversion	Risk Reduction in Progress	Co-seismic soil slope instability	Induce earthquake seismic wave through ground. Risk expected to be very low.	1. Ground displacement and slope instability 2. Unacceptable total or differential ground movements 3. Delay to works 4. Higher maintenance	4	Reduce	Risk assumed to be low. 1. Slope stability analysis with seismic conditions and propsed suitable slope angles. [Complete] 2. Area of the asset within a very low seismic hazard area (Midland Microcraton M3) according to the Eurocode 8 seismic hazard zoning maps for the UK	Construction and Manufacture	3
GEO_T2G_0638	N/A	HS2-00002QH92 - Footpath CHW/18 Diversion	Risk Reduction in Progress	Elevated sulphate levels leading to lower reuse	1. Inherent ground conditions due to the mineralogy of clay soils 2. Inadequate/insufficient ground investigation information (OXC)	1. Chemical attack on concrete slab of adjacent structure leading to higher costs 2. Limited of reuse resulting on increase in imported materials 3. Increase in volumes of landscape fill 4. Limiting the use of as-dug or stabilised materials resulting in increased costs due to large haulage distances or importation of selected fill material	8	Reduce	1. Use adequate material for embankment fill which will be not impacted by aggressive ground :proposed replacement fill material is Class 1 [Complete] 2. Design concrete resistance following BRE Special Digest SD1	Construction and Manufacture	3
GEO_T2G_0641	CDM_47010 CDM_47047	HS2-00002QH92 - Footpath CHW/18 Diversion	Risk Reduction in Progress	Compressible ground, characterised as having a low strength and high compressibility, is encountered beneath the EW	Compressible TILMP ansd weathered OXC	1. Unacceptable sugrade performance 2. Reconstruction of road pavement and adverse impact on drainage/utilities. 3. Delay to works in rainy period 4. Higher maintenance	4	Reduce	Refer to the structure foundation for further risks and mitigation	Construction and Manufacture	2
GEO_T2G_0642	CDM_47010 CDM_47047	HS2-00002QH92 - Footpath CHW/18 Diversion	Risk Reduction in Progress	Internal settlement of the embankments made with high plasticity clay	Material used for the construction difficult to be compacted. Internal creeping.	Additional settlement which coul cause innacceptable distortion	4	Reduce	1. Design take into acount internal settlement [Complete]	Construction and Manufacture	2
GEO_T2G_0647	CDM_47034 CDM_47035	HS2-00002QH92 - Footpath CHW/18 Diversion	Risk Reduction in Progress	1. Soil volume may change significantly (shrink-swell) with water content 2. Shrinking and swelling of soil underlying pavement	1. Presence of high plasticity clays (OXC, TILMP) 2. Presence of frost susceptible soils	1. Unacceptable total or differential settlements/ground movement which could impact earthwork, pavement and/or, drainage	8	Control	Risk assumed to be tolerated for an unbound access road 1. Control drainage to limit change in water content of soil [Transfered to EK] 2. Inspection of the subrage by a geotechnical engineer during works and plan for soft spot removal [transfered to EK] 3. Verification testing before works to control moisture content of the subgrade and CBR [transfered to EK] 4. Subgrade improvement if CBR design not achieved [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0650	CDM_47010	HS2-00002QH92 - Footpath CHW/18 Diversion	Risk Reduction in Progress	Encountering Potential hard ground band in local Made Ground	Presence of made ground related with exiting infrastructures : - Dismantled drain : Ch. 85670 - 85720	1. Obstruction when excavating 2. Delay to works / longer hold periods	4	Reduce	1. Using adequate engine during works [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0652	CDM_47010	HS2-00002QH92 - Footpath CHW/18 Diversion	Risk Reduction in Progress	Periglacial shear in Clay-rich materials leading to weakened in-situ geology and increased risk of slope instability	1. Presence of clay-rich bedrock (OXC)	1. Progressive slope failure and ground movement beneath the embankment which may require re-design. 2. Reduced bearing capacity 3. Slope instability	2	Eliminate	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	2
GEO_T2G_0653	CDM_47010	HS2-00002QH92 - Footpath CHW/18 Diversion	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls is longitudinal to the	1. Presence of OXC Formation 2. Slope gradient > 5° transversal to the HS2 route 3. Perched groundwater in OXC	1. Slope instability 2. Delay or cessation of works	4	Reduce	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	2
GEO_T2G_0656	N/A	HS2-00002QH92 - Footpath CHW/18 Diversion	Risk Reduction in Progress	Soft ground potentially contaminated	Presence of Made Ground related with existing infrastructures : - Dismantled drain : Ch. 85670 - 85720 - Dismantled Rosehill Cottage and road : Ch. 85470	1. Excessive volumes of material for disposal 2. If not removed then would undermine stability of excavations 3. If not removed then would result in unsatisfactory bearing capacity	9	Reduce	1. Mitigation measure include provision for total removal of Made Ground [Complete] 2. Suitable testing during works to determine suitability for re-use and/or disposal off site [Transfered to EK] 3. HSE implications required for handling of contaminated materials and environmental protection during disposal. [Transfered to EK]	Construction and Manufacture	2

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HS2-00002VXUC - Maintenance Access Road to GSMR and Compound (off School E–d Road Realignment)

Geotechnical Risk ID	Associated CDM Register Risk ID	Level 2 Asset	Risk Status	Risk Description (There is a threat that...)	Risk Cause (Due to....)	Risk Impact (Resulting in....)	Risk Rating	Primary Risk Mitigation Strategy	Mitigation Description / Notes	Next Action Due	Residual Risk Rating
GEO_T2G_0631	N/A	HS2-00002VXUC - Maintenance Access Road to GSMR and Compound (off School End Road Realignment)	Risk Reduction in Progress	Co-seismic soil slope instability	Induce earthquake seismic wave through ground. Risk expected to be very low.	1. Ground displacement and slope instability 2. Unacceptable total or differential ground movements 3. Delay to works 4. Higher maintenance	4	Reduce	Risk assumed to be low. 1. Slope stability analysis with seismic conditions and propsed suitable slope angles. [Complete] 2. Area of the asset within a very low seismic hazard area (Midland Microcraton M3) according to the Eurocode 8 seismic hazard zoning maps for the UK	Construction and Manufacture	3
GEO_T2G_0639	N/A	HS2-00002VXUC - Maintenance Access Road to GSMR and Compound (off School End Road Realignment)	Risk Reduction in Progress	Elevated sulphate levels leading to lower reuse	1. Inherent ground conditions due to the mineralogy of clay soils 2. Inadequate/insufficient ground investigation information (OXC)	1. Chemical attack on concrete slab of adjacent structure leading to higher costs 2. Limited of reuse resulting on increase in imported materials 3. Increase in volumes of landscape fill 4. Limiting the use of as-dug or stabilised materials resulting in increased costs due to large haulage distances or importation of selected fill material	8	Reduce	1. Use adequate material for embankment fill which will be not impacted by aggressive ground :proposed replacement fill material is Class 1 [Complete] 2. Design concrete resistance following BRE Special Digest SD1	Construction and Manufacture	3
GEO_T2G_0640	CDM_47203 CDM_47207	HS2-00002VXUC - Maintenance Access Road to GSMR and Compound (off School End Road Realignment)	Risk Reduction in Progress	1. Displaced geological units 2. Unexpected variable ground conditions 3. Locally weakened ground conditions 4. Locally higher permeability	Natural geological faulting processes	1. Slope instability 2. Unsuitable geotechnical solution given unexpected ground conditions 3. Differential movements more likely within a fault zone	2	Reduce	Low risk due to the depth of bedrock strata location beneath the track level. However, Contractor to supervise the excavations for potential faulting.	Construction and Manufacture	2
GEO_T2G_0643	CDM_47203 CDM_47207	HS2-00002VXUC - Maintenance Access Road to GSMR and Compound (off School End Road Realignment)	Risk Reduction in Progress	Compressible ground, characterised as having a low strength and high compressibility, is encountered beneath the EW	Compressible TILMP	1. Unacceptable sugrade performance 2. Reconstruction of road pavement and adverse impact on drainage/utilities. 3. Delay to works in rainy period 4. Higher maintenance	4	Reduce	1. Ground improvement of founding soils where needed (E&R or stabilisation) [Complete] 2. Monitoring of settlement during construction (at transition with structures only) [Complete] 3. Extend wait period for earthworks if required. [Transfered to EK] 4. Routine inspections during operation. [Transfered to EK] 5. Construction during rainy period : use adequate works road and methodology [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0644	CDM_47203 CDM_47207	HS2-00002VXUC - Maintenance Access Road to GSMR and Compound (off School End Road Realignment)	Risk Reduction in Progress	Internal settlement of the embankments made with high plasticity clay	Material used for the construction difficult to be compacted. Internal creeping.	Additional settlement which coul cause innacceptable distortion	4	Reduce	1. Design take into acount internal settlement [Complete]	Construction and Manufacture	2
GEO_T2G_0648	CDM_47036 CDM_47025	HS2-00002VXUC - Maintenance Access Road to GSMR and Compound (off School End Road Realignment)	Risk Reduction in Progress	1. Soil volume may change significantly (shrink-swell) with water content 2. Shrinking and swelling of soil underlying pavement	1. Presence of high plasticity clays (OXC, TILMP) 2. Presence of frost susceptible soils	1. Unacceptable total or differential settlements/ground movement which could impact earthwork, pavement and/or, drainage	8	Control	Risk assumed to be tolerated for an unbound access road 1. Control drainage to limit change in water content of soil [Transfered to EK] 2. Inspection of the subrage by a geotechnical engineer during works and plan for soft spot removal [transfered to EK] 3. Verification testing before works to control moisture content of the subgrade and CBR [transfered to EK] 4. Subgrade improvement if CBR design not achieved [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0651	CDM_47203	HS2-00002VXUC - Maintenance Access Road to GSMR and Compound (off School End Road Realignment)	Risk Reduction in Progress	Encountering Potential hard ground band in local Made Ground	Presence of made ground related with exiting infrastructures : - Dismantled drain : Ch. 85670 - 85720 - Dismantled Rosehill Cottage and road : Ch. 85470	1. Obstruction when excavating 2. Delay to works / longer hold periods	4	Reduce	1. Using adequate engine during works [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0654	CDM_47203	HS2-00002VXUC - Maintenance Access Road to GSMR and Compound (off School End Road Realignment)	Risk Reduction in Progress	Periglacial shear in Clay-rich materials leading to weakened in-situ geology and increased risk of slope instability	1. Presence of clay-rich bedrock (OXC)	1. Progressive slope failure and ground movement beneath the embankment which may require re-design. 2. Reduced bearing capacity 3. Slope instability	2	Eliminate	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	2
GEO_T2G_0655	CDM_47203	HS2-00002VXUC - Maintenance Access Road to GSMR and Compound (off School End Road Realignment)	Risk Reduction in Progress	Potential for relic slip shear surfaces and cut slope instability in the OXC where the slope gradient is > 5° and falls is longitudinal to the HW	1. Presence of OXC Formation 2. Slope gradient > 5° transversal to the HS2 route 3. Perched groundwater in OXC	1. Slope instability 2. Delay or cessation of works	4	Reduce	Risk is assumed to be low for the asset, however, Contractor to supervise the excavations for potential relict shear surfaces No mitigation measure is planned	Construction and Manufacture	2
GEO_T2G_0657	N/A	HS2-00002VXUC - Maintenance Access Road to GSMR and Compound (off School End Road Realignment)	Risk Reduction in Progress	Soft ground potentially contaminated	Presence of Made Ground related with existing infrastructures : - Dismantled School En road : Ch. 86420 - Dismantled Drain : Ch. 86780	1. Excessive volumes of material for disposal 2. If not removed then would undermine stability of excavations 3. If not removed then would result in unsatisfactory bearing capacity	9	Reduce	1. Mitigation measure include provision for total removal of Made Ground [Complete] 2. Suitable testing during works to determine suitability for re-use and/or disposal off site [Transfered to EK] 3. HSE implications required for handling of contaminated materials and environmental protection during disposal. [Transfered to EK]	Construction and Manufacture	2
GEO_T2G_0659	CDM_47203	HS2-00002VXUC - Maintenance Access Road to GSMR and Compound (off School End Road Realignment)	Risk Reduction in Progress	The existing slopes of the dismantled railway line could be affected by an instability due to the proposed earthworks	Interface with the existing slopes of the dismantled railway line	1. Ground instabilities beneath the proposed embankment	6	Reduce	The proposed earthwork is an embankment and will stabilise potential slope instailities of the existing cutting, inducing a low risk of instability. The risk is assumed to be tolerated. [Complete]	Construction and Manufacture	4

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GEO_T2G_0749		HS2-000001321 - Footpath CHW/18 Accommodation Overbridge	Risk Reduction in Progress	Mechanical non conformity of the piles base, supposed to be founded in medium strong limestone of the Cornbrash formation	local variation of the Cornbrash top level and thickness	1. Insufficiency of the pile bearing resistance 2. Additionnal settlements of the piles	6	Reduce	1. During piles boring, it is requested to identify the level of the Cornbrash formation top. 2. If the CB formation top is such as the embedded length of the pile in this formation is less than its diameter, it is required to increase the pile length. 3. The pile length is increased until an embedded length of the pile in CB formation is equal to its diameter at least	Construction and Manufacture	2
GEO_T2G_0750		HS2-000001322 - School End Overbridge	Risk Reduction in Progress	Mechanical non conformity of the piles base, supposed to be founded in medium strong limestone of the Cornbrash formation	local variation of the Cornbrash top level and thickness	1. Insufficiency of the pile bearing resistance 2. Additionnal settlements of the piles	6	Reduce	1. During piles boring, it is requested to identify the level of the Cornbrash formation top. 2. If the CB formation top is such as the embedded length of the pile in this formation is less than its diameter, it is required to increase the pile length. 3. The pile length is increased until an embedded length of the pile in CB formation is equal to its diameter at least	Construction and Manufacture	2

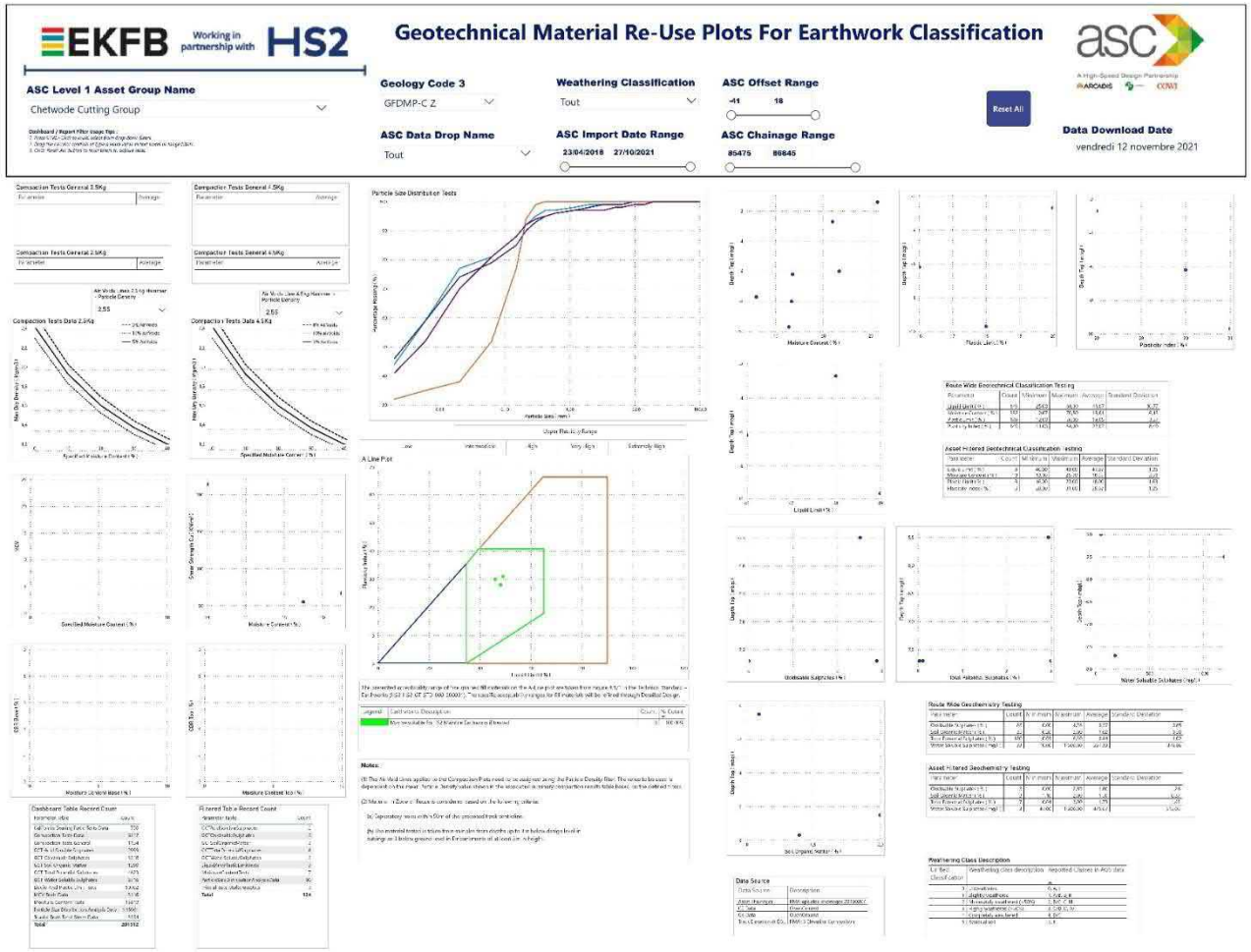
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APPENDIX F

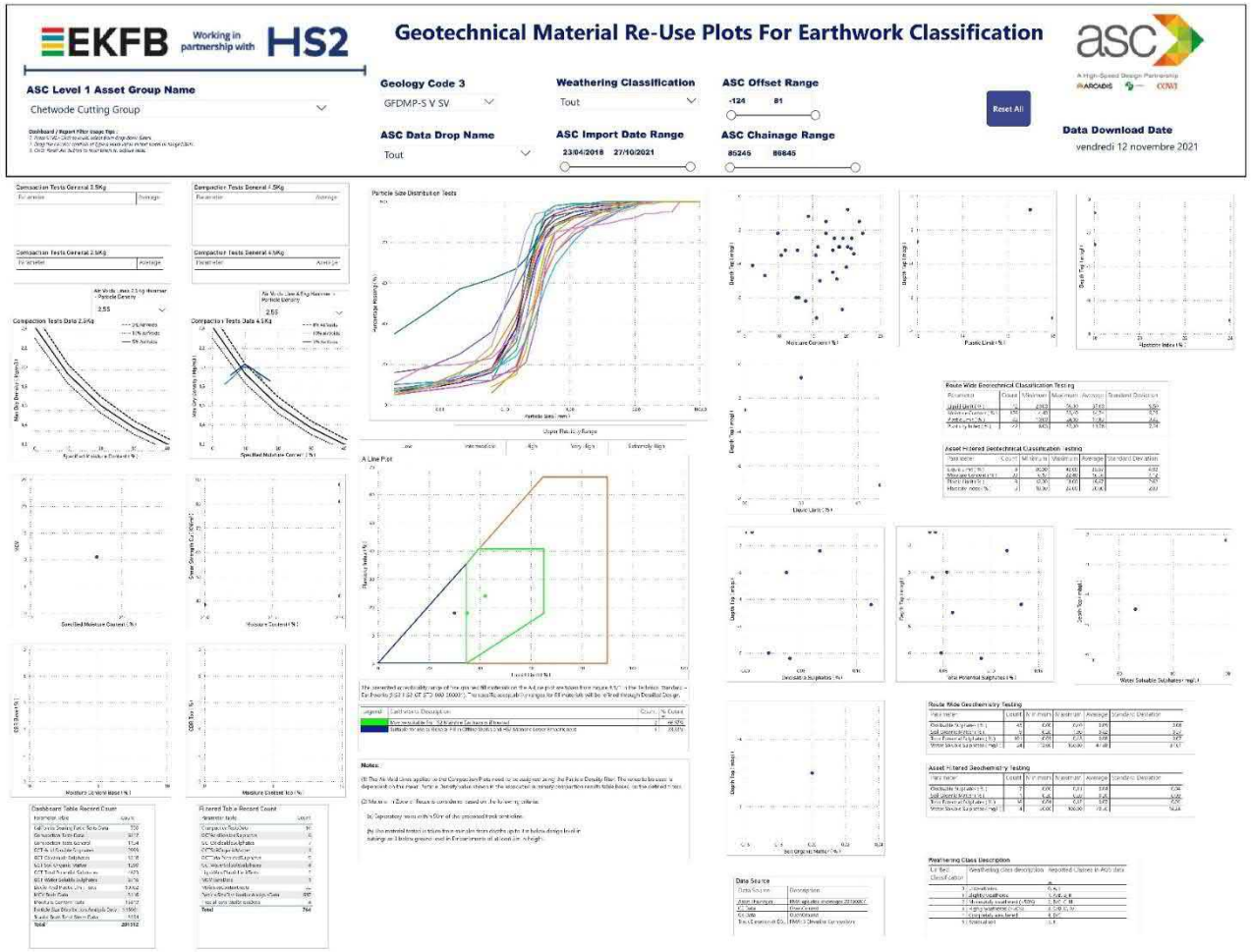
E-GDR Dashboards

Number of Pages: 4

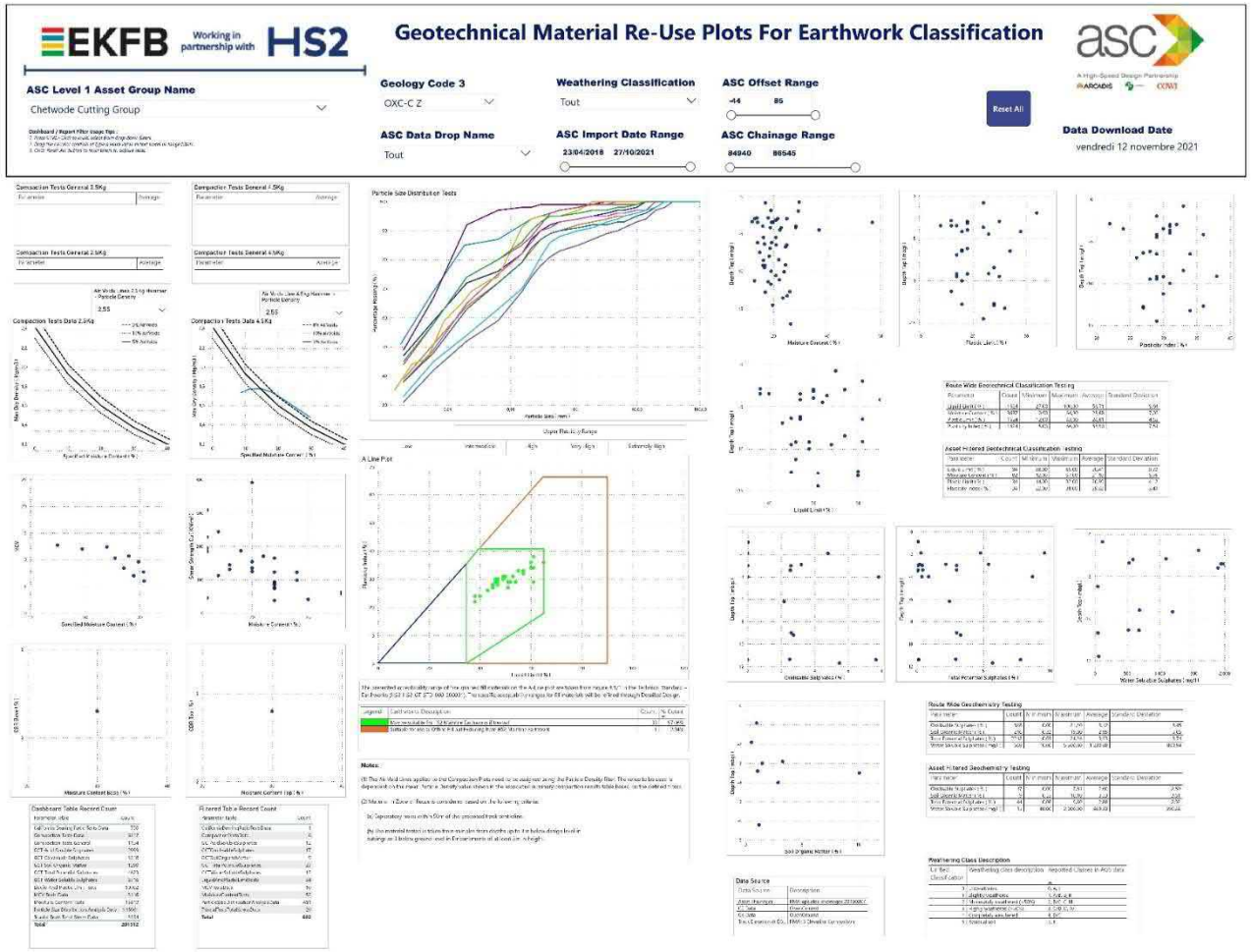
HS2 Ltd - Code 1 - Accepted



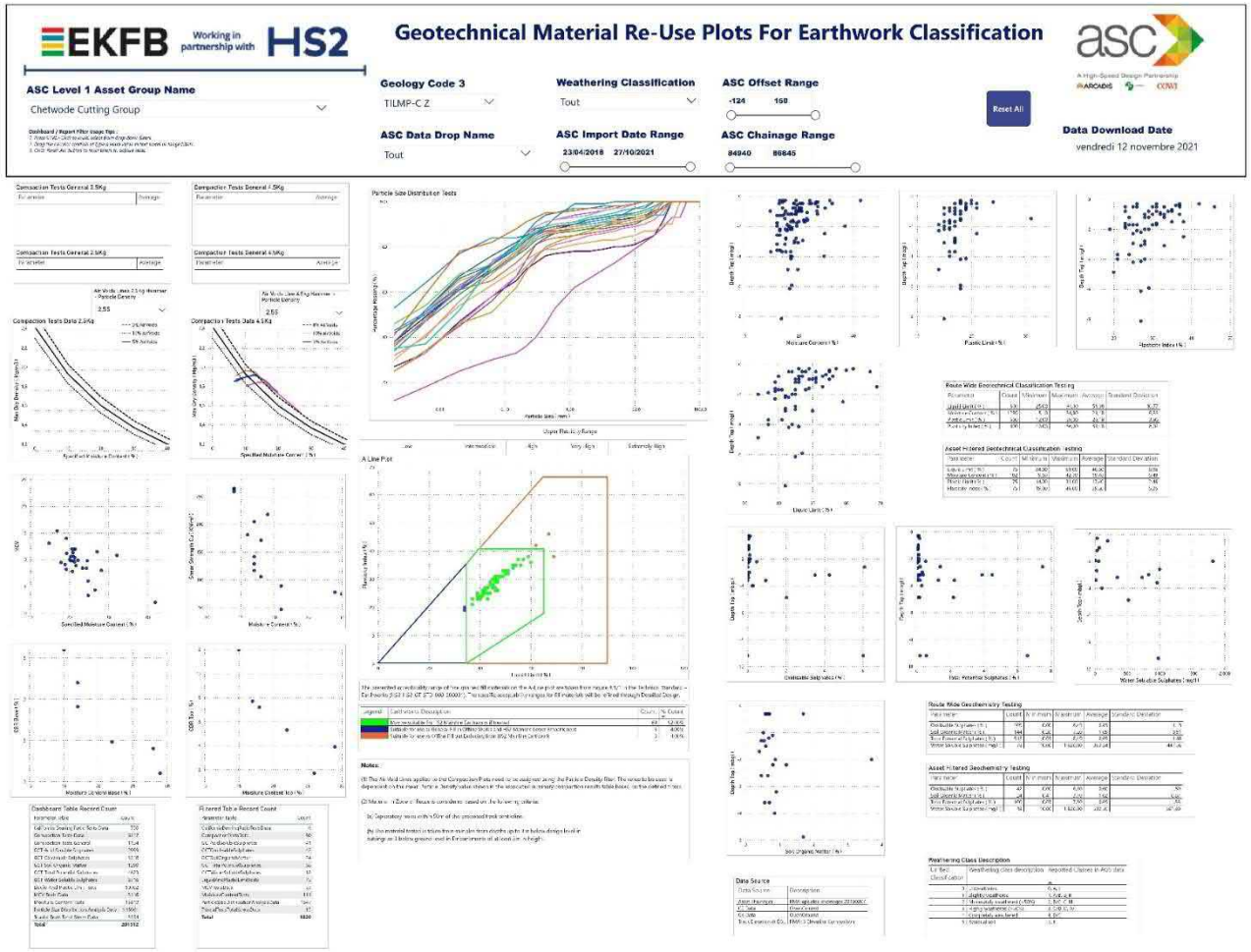
HS2 Ltd - Code 1 - Accepted



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APPENDIX G

GI Impact Assessment plots

Number of pages: 22

HS2 Ltd - Code 1 - Accepted

A- Glacial Till Deposits TILMP - CZ

Table 17.95 – Impact of new GI between Data Drop 3 and Data Drop 17 on design parameters

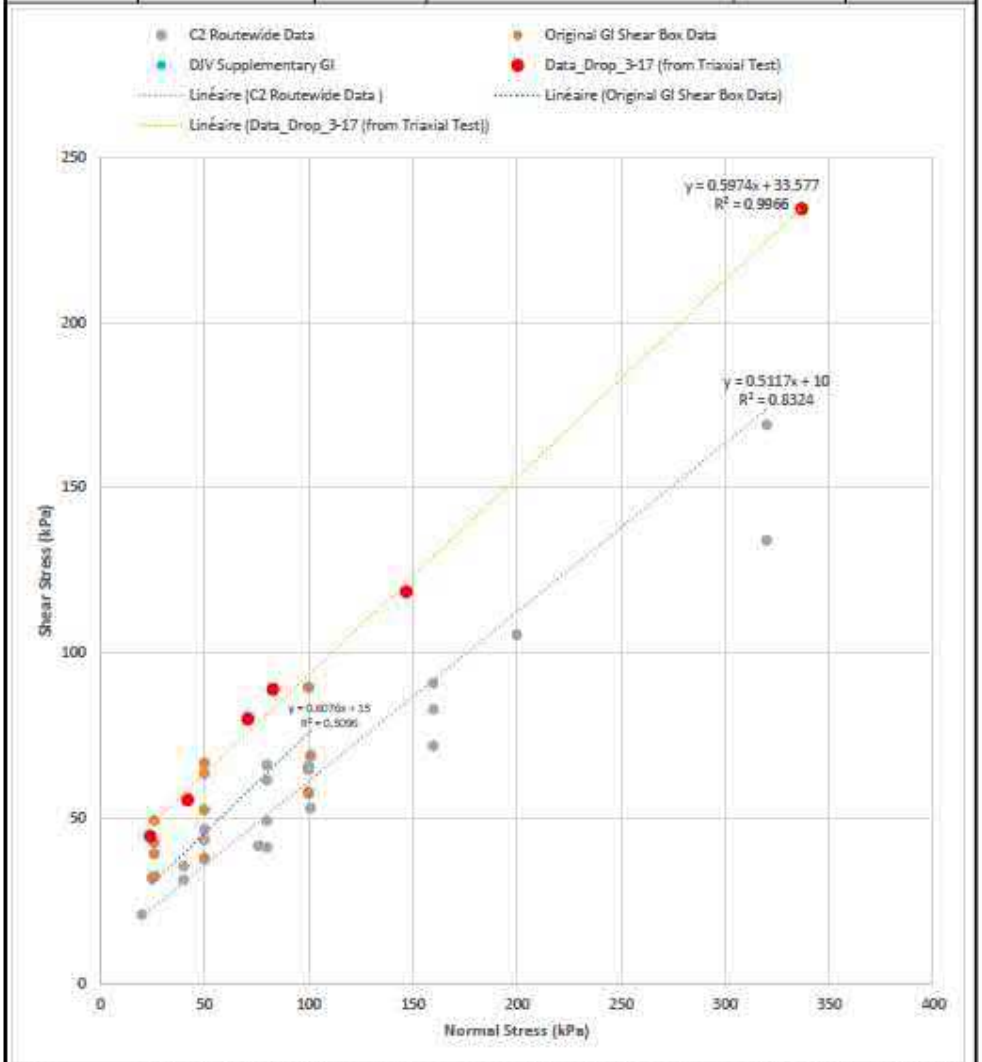
Parameter	Symbol	Additional value Data Drop 3-17	Observation
Blow N number from SPT, corrected to 60% test energy	N_{60}	Yes	confirms the design value chosen in the current GDR
Cone resistance from CPT	q_c	Yes	confirms'the'design value chosen in the current GDR
Undrained shear strength	c_u	Yes	confirms the design value chosen in the current GDR
Drained shear strength	c', ϕ'	Yes	confirms the conservative design value chosen in the current GDR
Young/Effective Deformation Modulus	E'	Yes	Confirms the conservative design value chosen in the current GDR.
Oedometer Deformation Modulus	E_{oed}	Yes	• The values derived from SPT tests confirms the design parameter chosen in the current GDR. • The values coming from Oedometer test are located at depth greater than the ground models adopted in the current GDR: therefore, they are considered irrelevant.
Coefficient of consolidation	Cv	Yes	Confirm the conservative design value chosen in this GDR (considering the average value)

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HS2

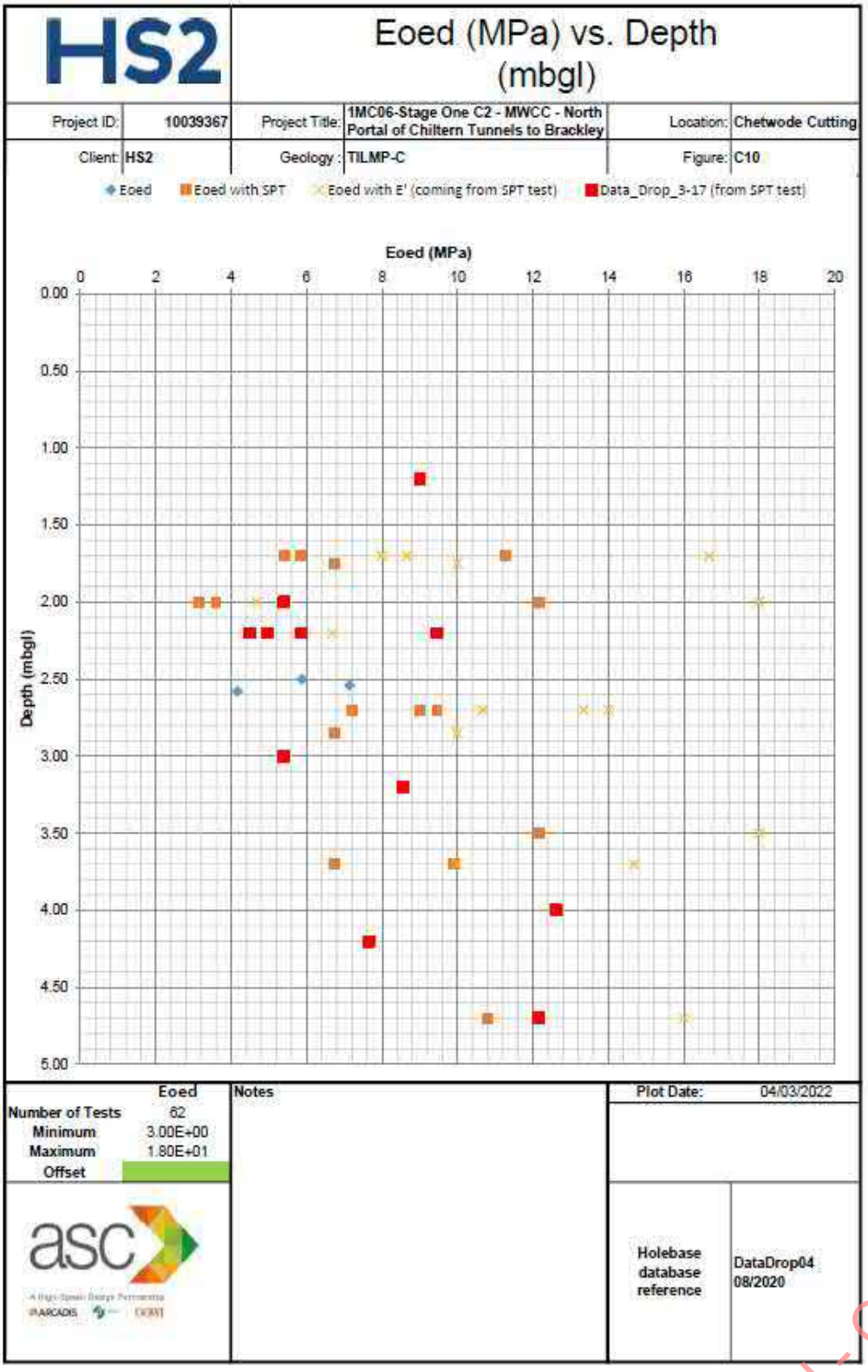
Shear Box Shear Stress vs. Normal Stress

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	TILMP-C Z	Figure:	C.8

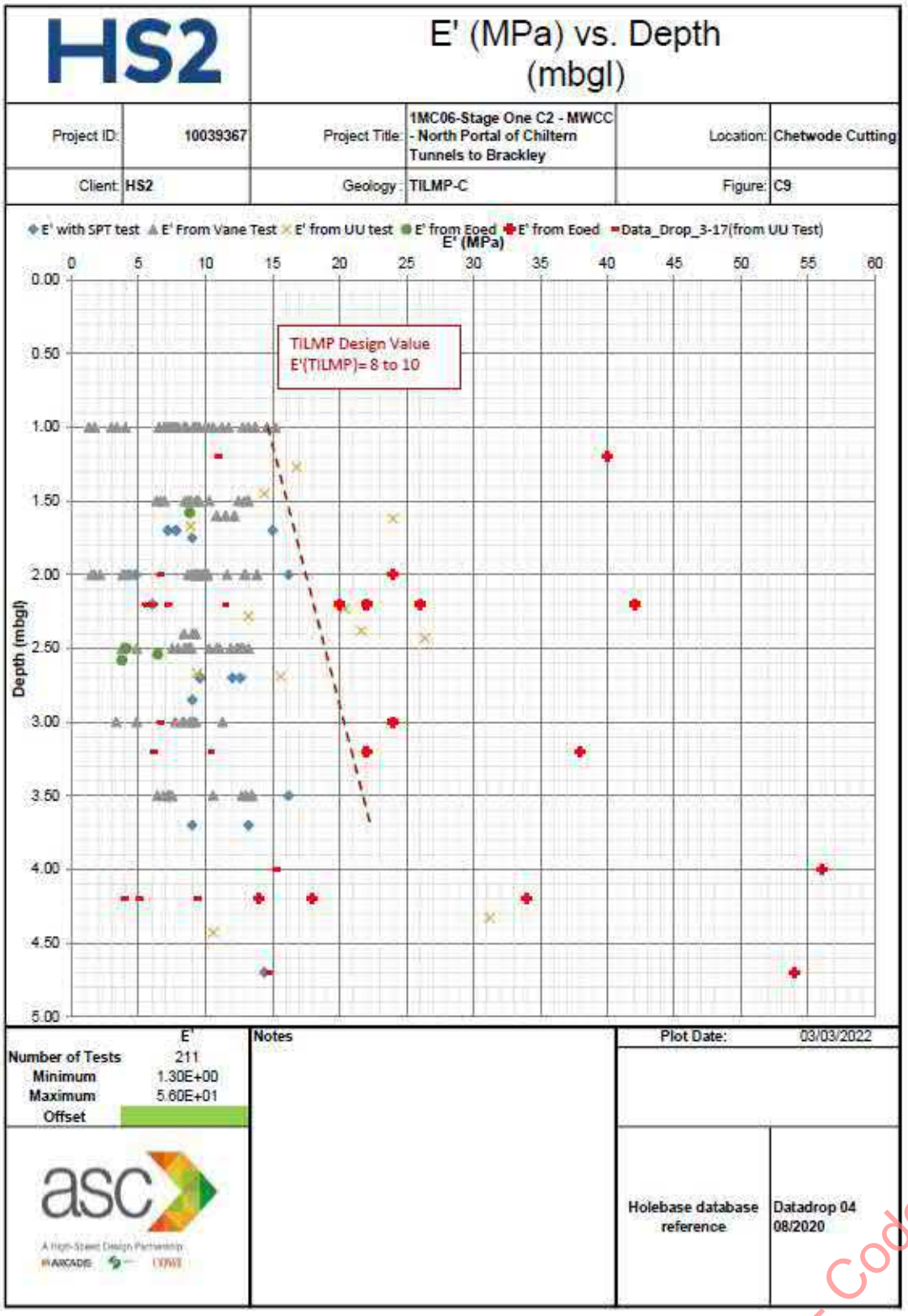


Notes:	Background C2 Routewide data shown are based on holebase database geology codes dated 26/01/2021 (c'; phi') routewide = (10kPa ; 28°) (c' ; phi') Chetwode Cutting = (15 kPa ; 31°) (c' ; phi') Chetwode Cutting - Data Drop 3 to 17 = (33 kPa ; 30°)	Plot Date:	04/03/2022
Offset			
Holebase database reference	DataDrop 04 - Published 08/2020		

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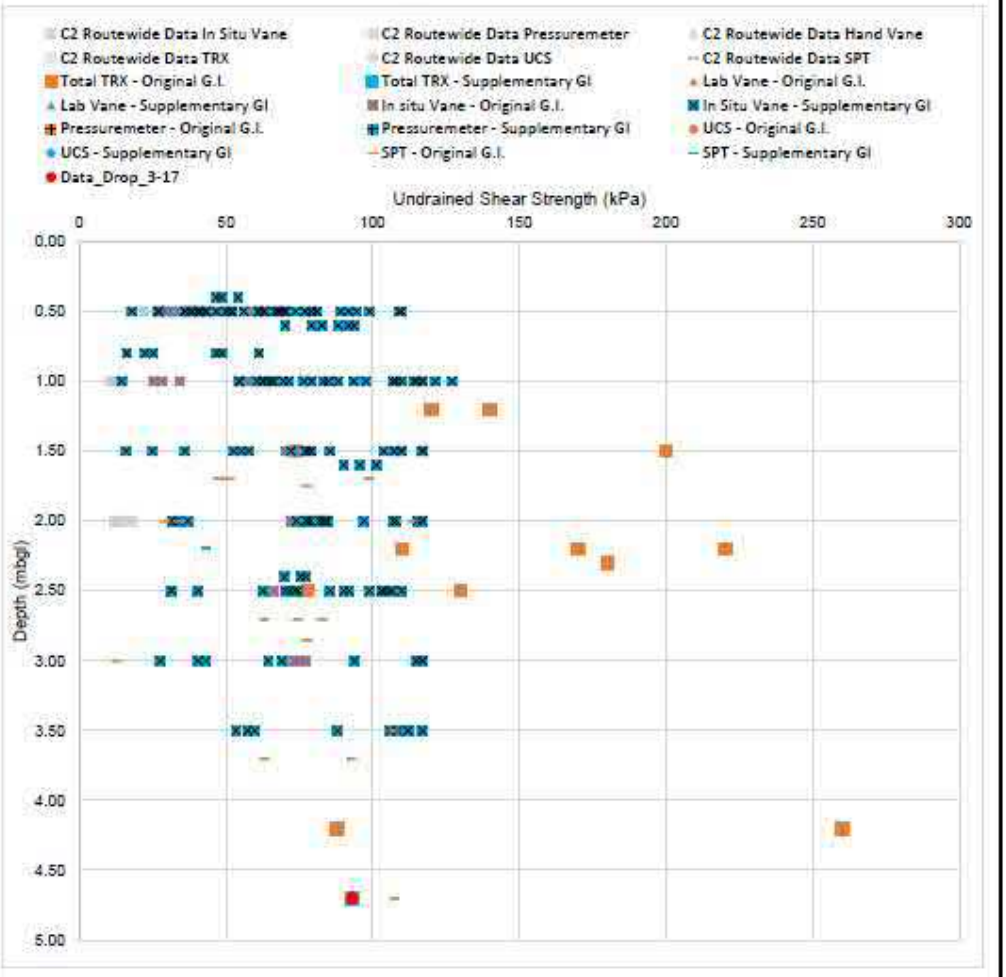


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HS2

Undrained Shear Strength vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	TILMP-C Z	Figure:	A6



	Total
Number of Tests	220
Minimum	14
Maximum	260
Offset	

Notes

Background C2 Routewide data shown are based on Holebase database geology codes dated 08/04/2021. Background routewide data on the graph are limited to the Clay vale asset (Ch.82+349 to Ch.87+204)

Inferred ground conditions applied to CPT Cu profiles are based on review of exploratory hole information adjacent to the CPT position.

Plot Date: 25/01/2022

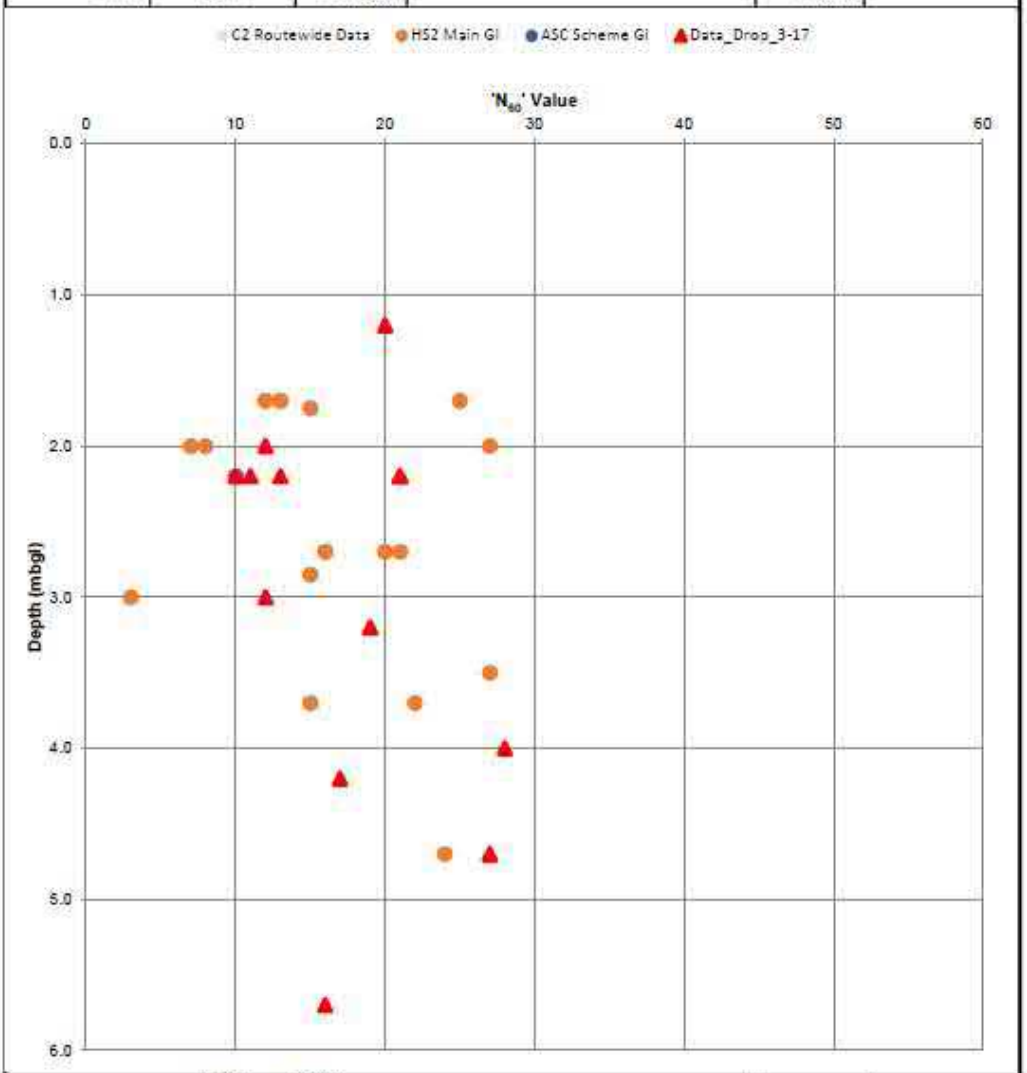
Holebase database reference	Datadrop 02 Published 03/2020

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HS2

SPT-N_{60} vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	TILMP-C Z	Figure:	A7



N Value	
Number of Tests	20
Minimum	3
Maximum	27
Offset	

Notes
Background C2 Routewide data shown are based on Holebase database geology codes dated 08/04/2021. Background routewide data on the graph are limited to the Clay vale asset (Ch.82+349 to Ch.87+204)

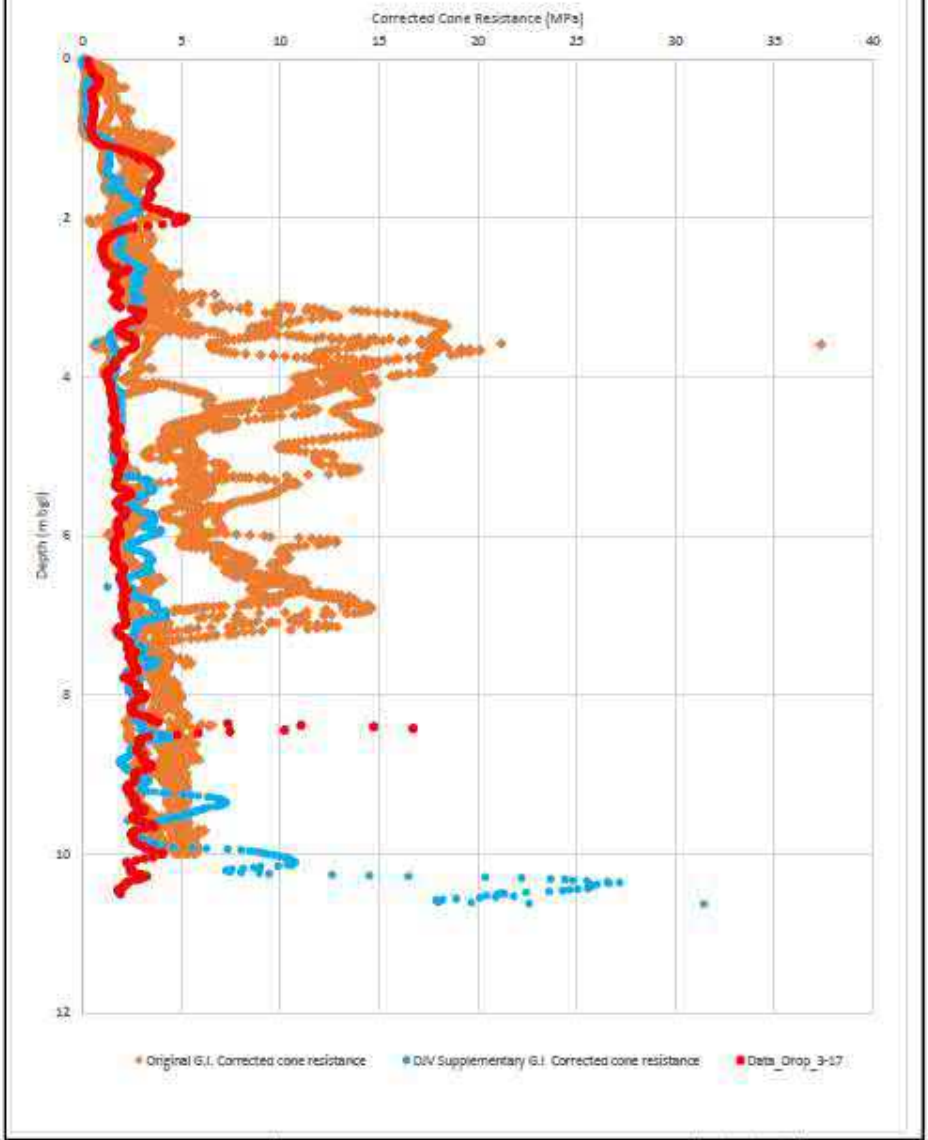
Plot Date:	03/03/2022
Holebase Database Reference	Datadrop 02. Published 03/2020

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HS2

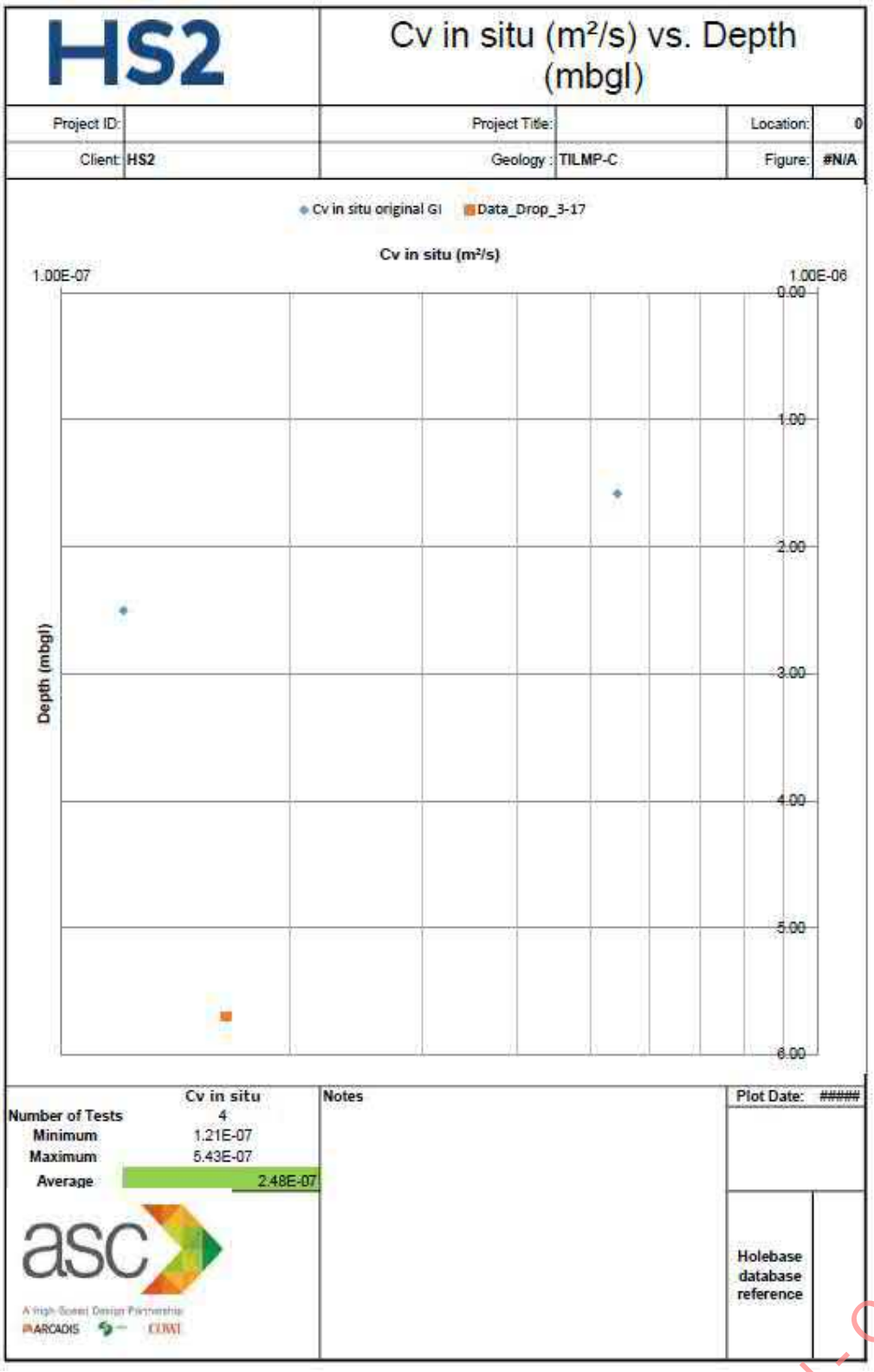
CPT Cone Resistance vs Depth

Project ID:	10033367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Figure:	20
Client:	HS2	Location :	Chetwode Cutting Group		



Notes:	Plot Date:	25/01/2022
	Holebase database reference	Datadrop 02 Published 03/2020

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B- Glacio-Fluvial Deposits – GFDMP S SV

Table 17.96 – Impact of new GI between Data Drop 3 and Data Drop 17 on design parameters

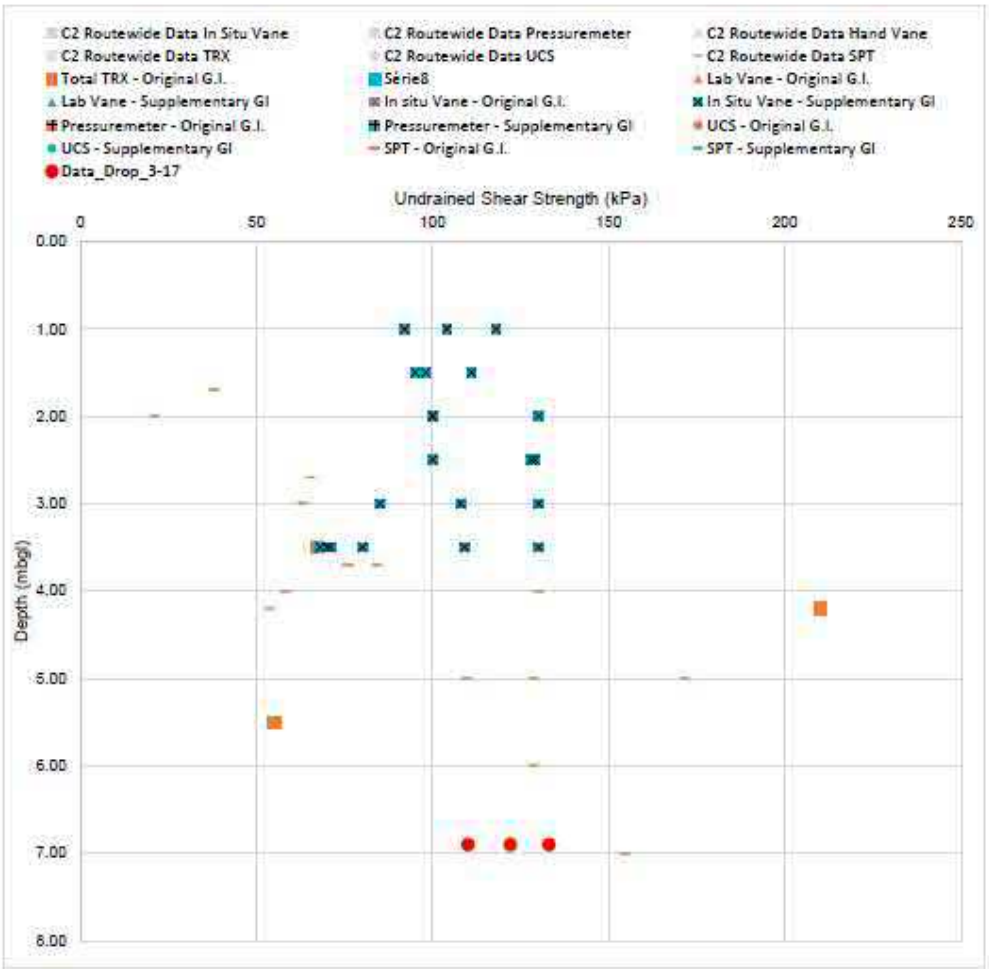
Parameter	Symbol	Additional value Data Drop 3-17	Observation
Blow N number from SPT, corrected to 60% test energy	N_{60}	Yes	confirms the design value chosen in the current GDR
Cone resistance from CPT	q_c	No	No impact'on 'esign parameters
Undrained shear strength	c_u	Yes	confirms the design value chosen in the current GDR (Cu from derived SPT)
Drained shear strength	c', ϕ'	No	No impact on design parameters
Young/Effective Deformation Modulus	E'	No	No impact on design parameters
Oedometer Deformation Modulus	E_{oed}	No	No impact on design parameters
Coefficient of consolidation	Cv	No	No impact on design parameters

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HS2

Undrained Shear Strength vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	GFDMP-C Z	Figure:	C6



	Total
Number of Tests	49
Minimum	21
Maximum	210
Offset	

Notes

Background C2 Routewide data shown are based on Holebase database geology codes dated 08/04/2021. Background routewide data on the graph are limited to the Clay vale asset (Ch.82+349 to Ch.87+204)

Inferred ground conditions applied to CPT Cu profiles are based on review of exploratory hole information adjacent to the CPT position.

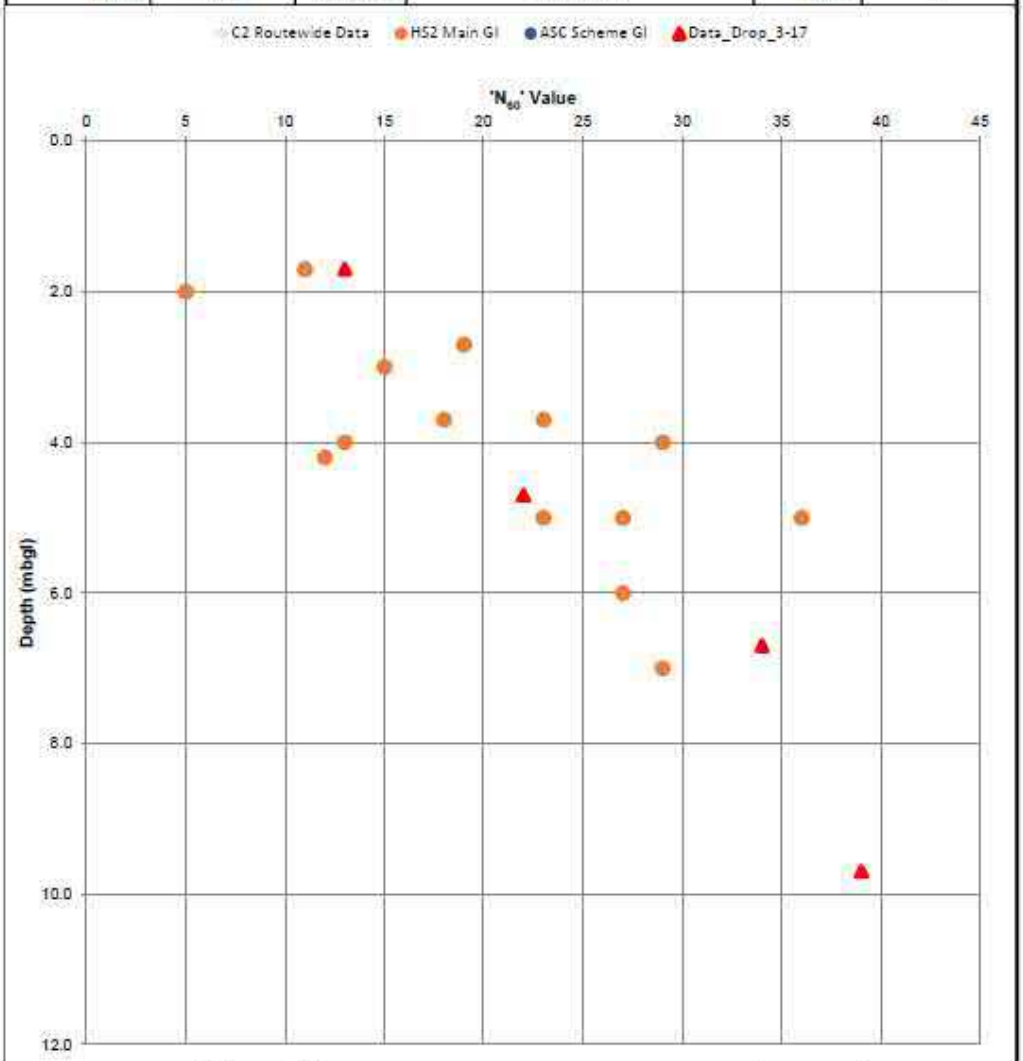
Plot Date:	25/01/2022
Holebase database reference	Datadrop 02 Published 03/2020

HS2 Ltd - Code 1 - Accepted

HS2

SPT-N_{60} vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	GFDMP-C Z	Figure:	C7



	N Value
Number of Tests	14
Minimum	5
Maximum	36
Offset	

Notes
Background C2 Routewide data shown are based on Holebase database geology codes dated 08/04/2021. Background routewide data on the graph are limited to the Clay vale asset (Ch.82+349 to Ch.87+204)

Plot Date:	25/01/2022
Holebase Database Reference	Datadrop 02. Published 03/2020

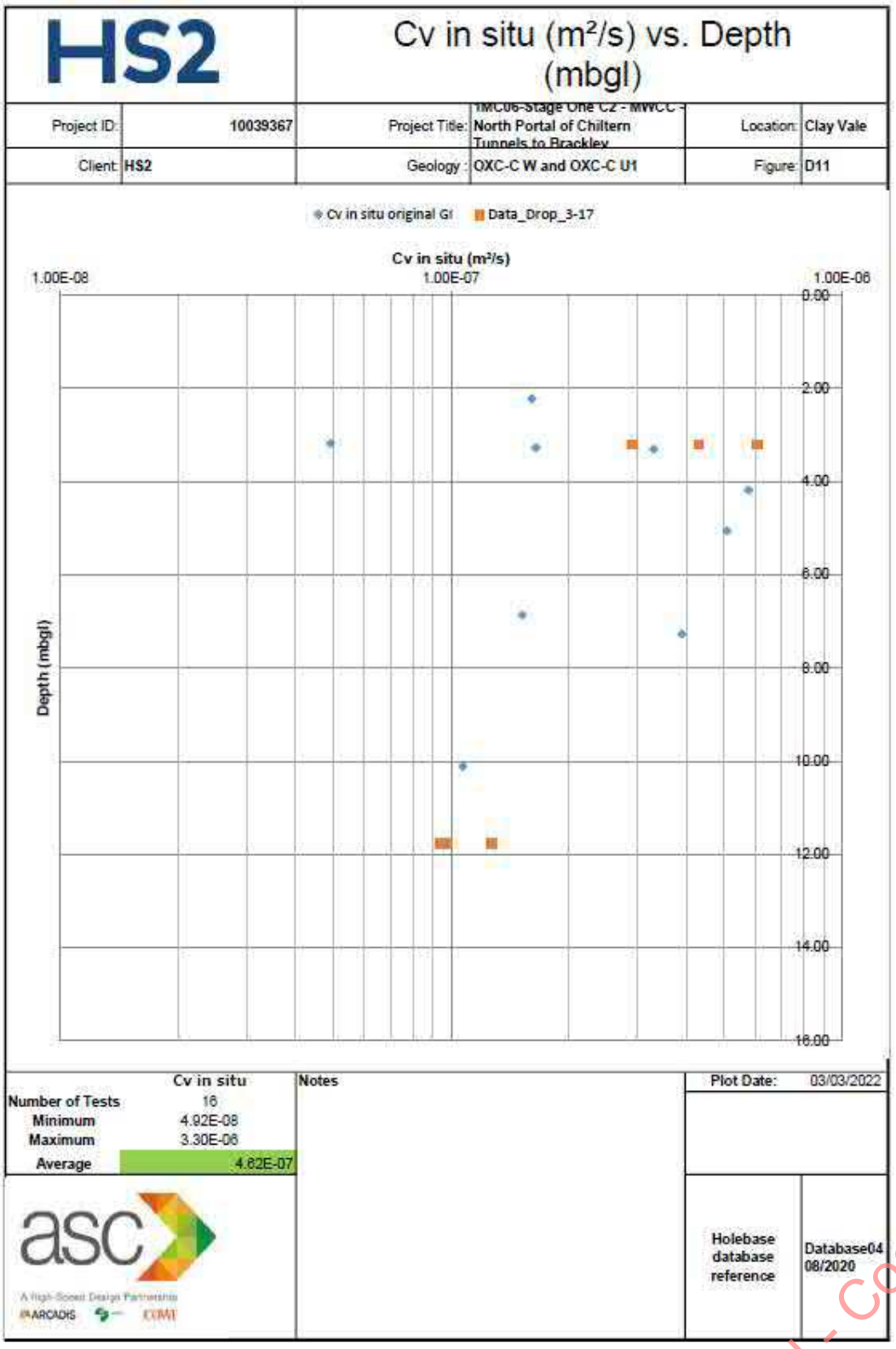
HS2 Ltd - Code 1 - Accepted

C- Oxford Clay Formation (OXC): OXCw, OXCu1, OXCu2

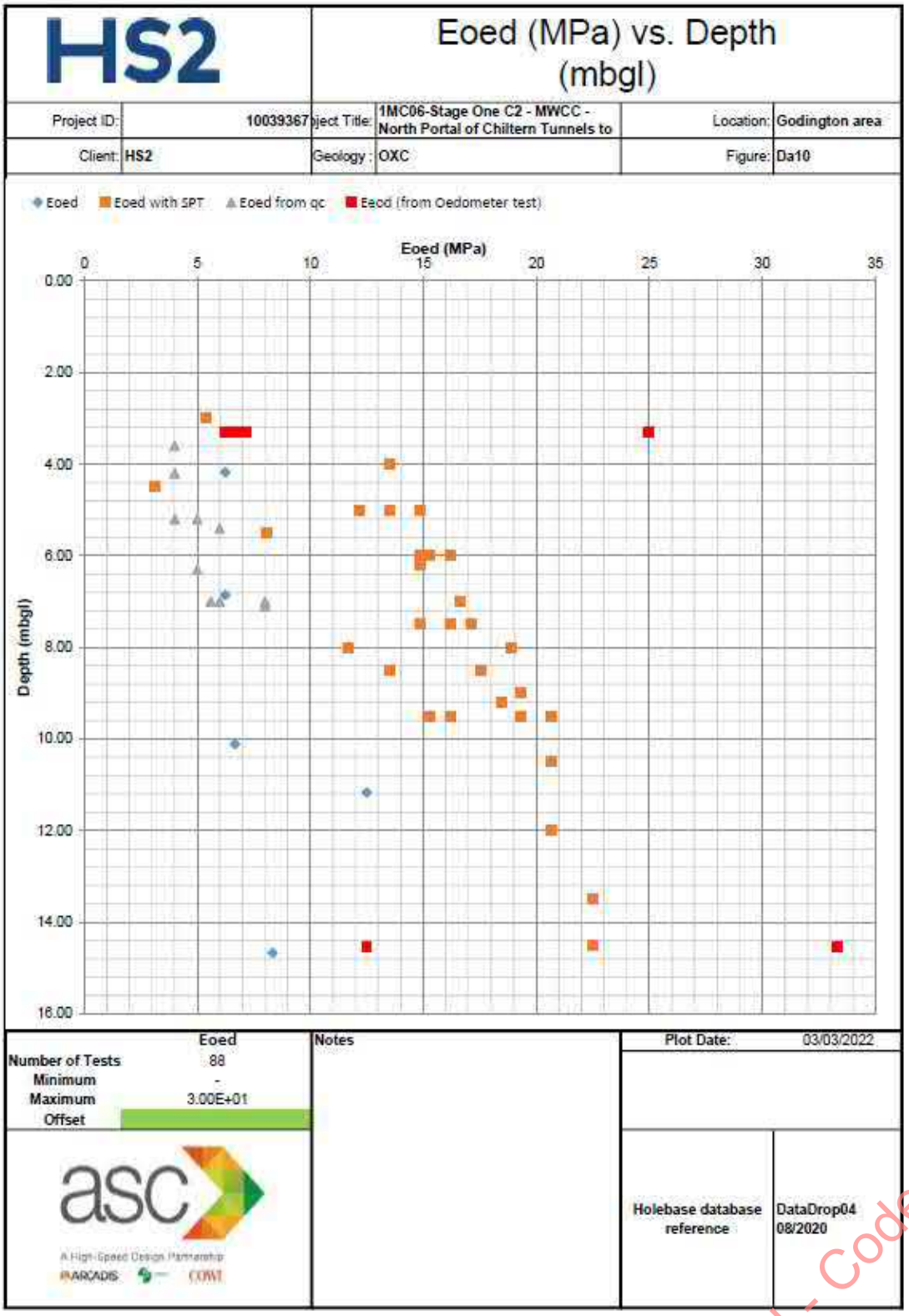
Table G.97 – Impact of new GI between Data Drop 3 and Data Drop 17 on design parameters

Parameter	Symbol	Additional value Data Drop 3-17	Observation
Blow N number from SPT, corrected to 60% test energy	N_{60}	Yes	confirms the design value chosen in the current GDR
Cone resistance from CPT	q_c	Yes	confirms'the'design value chosen in the current GDR
Undrained shear strength	c_u	Yes	confirms the design value chosen in the current GDR
Drained shear strength	c', ϕ'	No	No impact on design parameters
Young/Effective Deformation Modulus	E'	Yes	Confirms the design value chosen in the current GDR
Oedometer Deformation Modulus	E_{oed}	Yes	Additional value obtained from oedometer tests are few and scattered and they do not have any impact on the parameters.
Coefficient of consolidation	Cv	Yes	The average value confirms the conservative parmater chosen in the current GDR.

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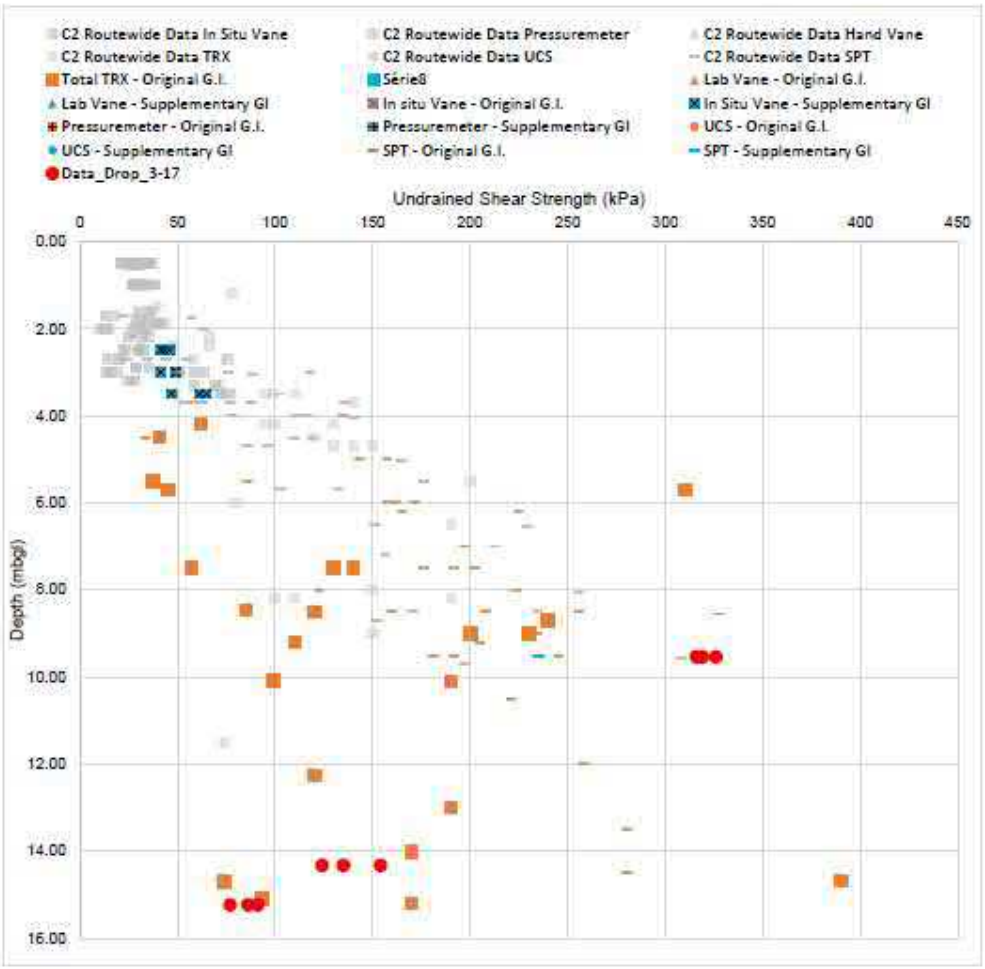


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HS2

Undrained Shear Strength vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	OXC-C Z	Figure:	E6



	Total
Number of Tests	96
Minimum	33
Maximum	390
Offset	

Notes

Background C2 Routewide data shown are based on Holebase database geology codes dated 06/04/2021. Background routewide data on the graph are limited to the Clay vale asset (Ch.82+349 to Ch.87+204)

Inferred ground conditions applied to CPT Cu profiles are based on review of exploratory hole information adjacent to the CPT position.

Plot Date: 25/01/2022

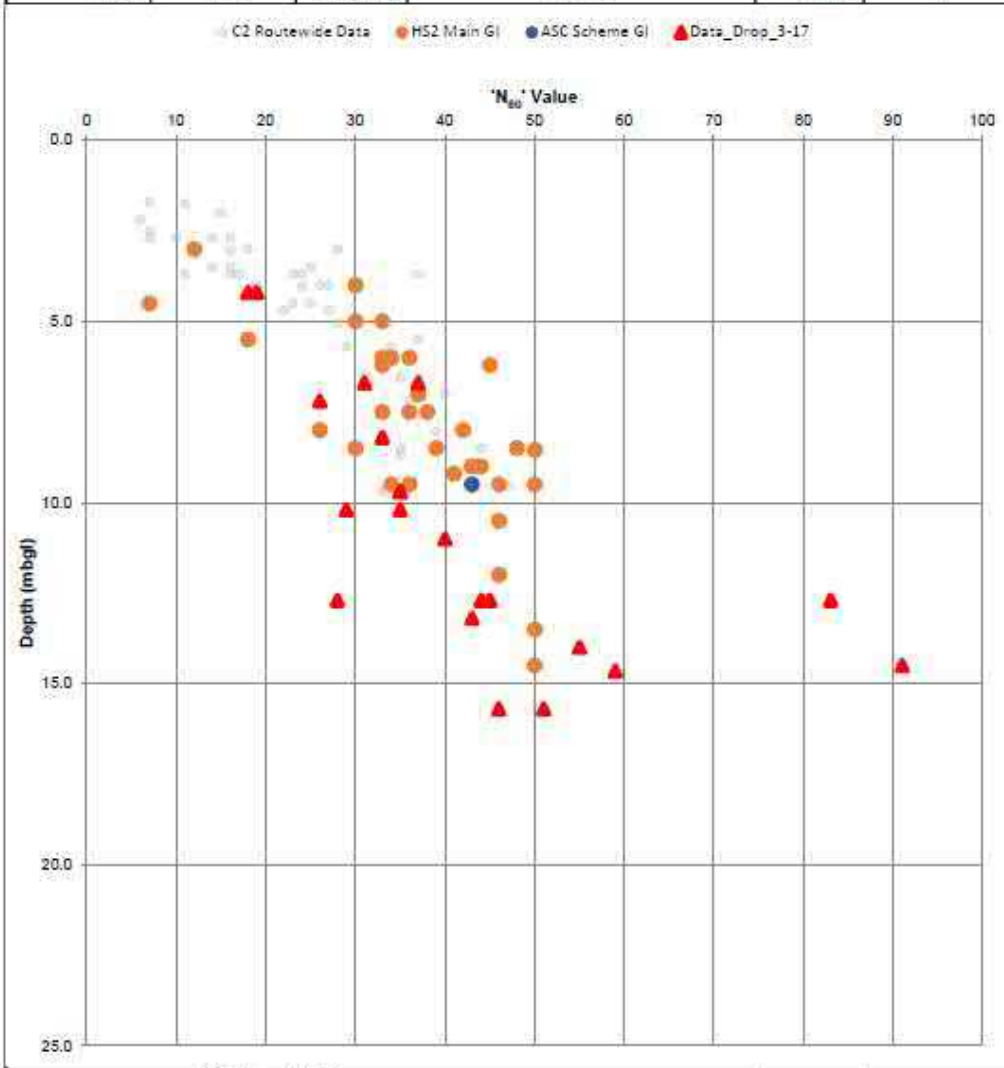
Holebase database reference	Datadrop 02. Published 03/2020

HS2 Ltd - Code 1 - Accepted

HS2

SPT-N_{60} vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	OXC-C Z	Figure:	E7



N Value	
Number of Tests	35
Minimum	7
Maximum	50
Offset	

Notes
Background C2 Routewide data shown are based on Holebase database geology codes dated 08/04/2021. Background routewide data on the graph are limited to the Clay vale asset (Ch.82+349 to Ch.87+204)

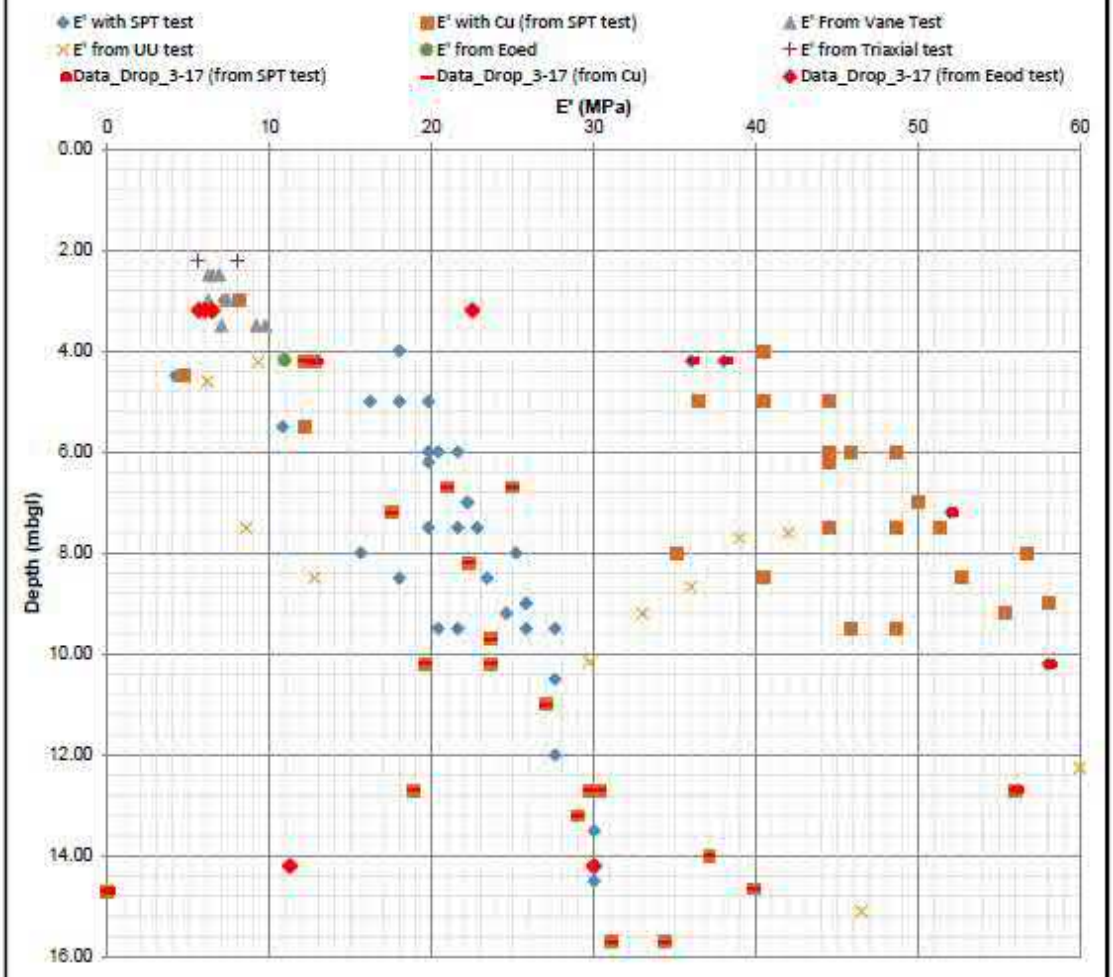
Plot Date:	25/01/2022
Holebase Database Reference	Datadrop 02. Published 03/2020

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HS2

E' (MPa) vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC06-Stage One C2 - MWCC - North	Location:	Godington area
Client:	HS2	Geology :	OXC	Figure:	Da9



	E'
Number of Tests	143
Minimum	-
Maximum	1.95E+02
Offset	

Notes

Plot Date: 03/03/2022

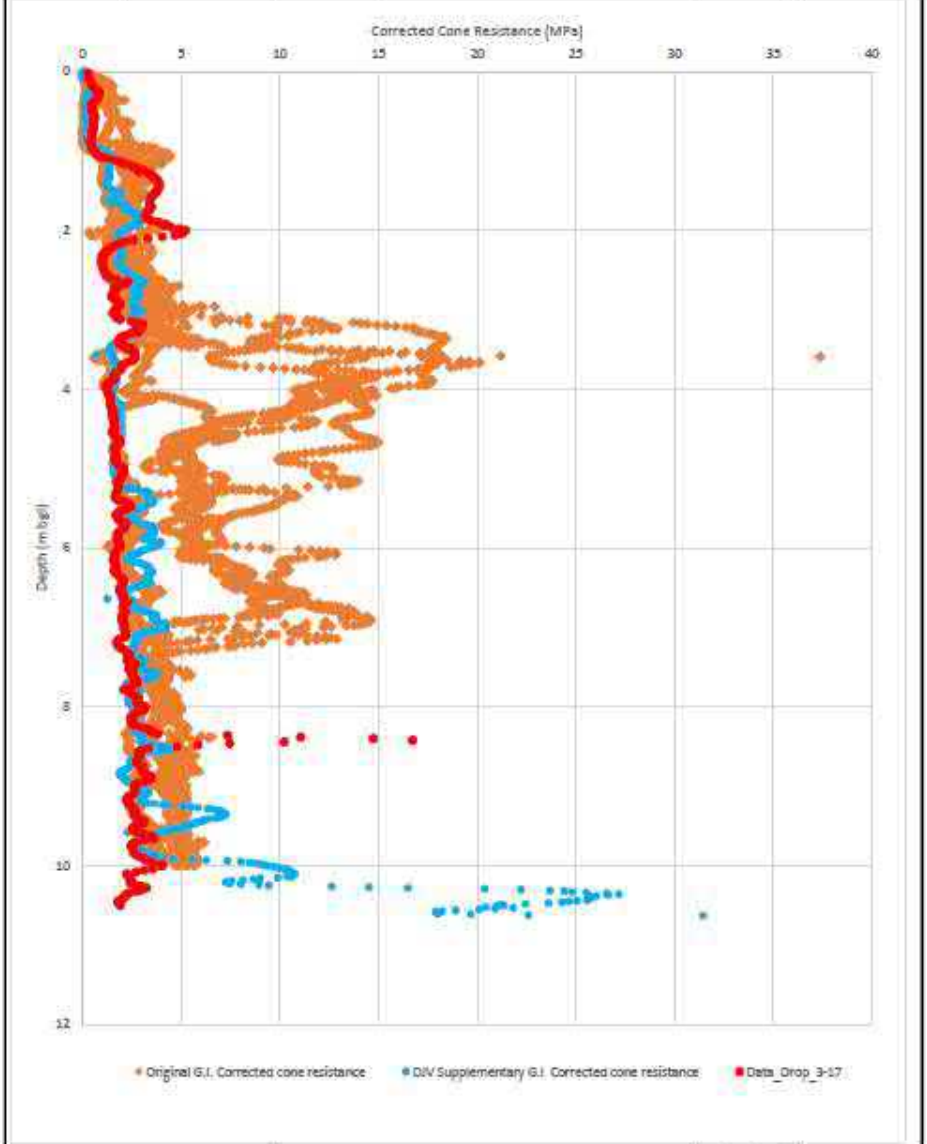
Holebase database reference: Datadrop 04 08/2020

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HS2

CPT Cone Resistance vs Depth

Project ID:	10033367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Figure:	20
Client:	HS2	Location :	Chetwode Cutting Group		



Notes:	Plot Date:	25/01/2022
	Holebase database reference	Datadrop 02 Published 03/2020

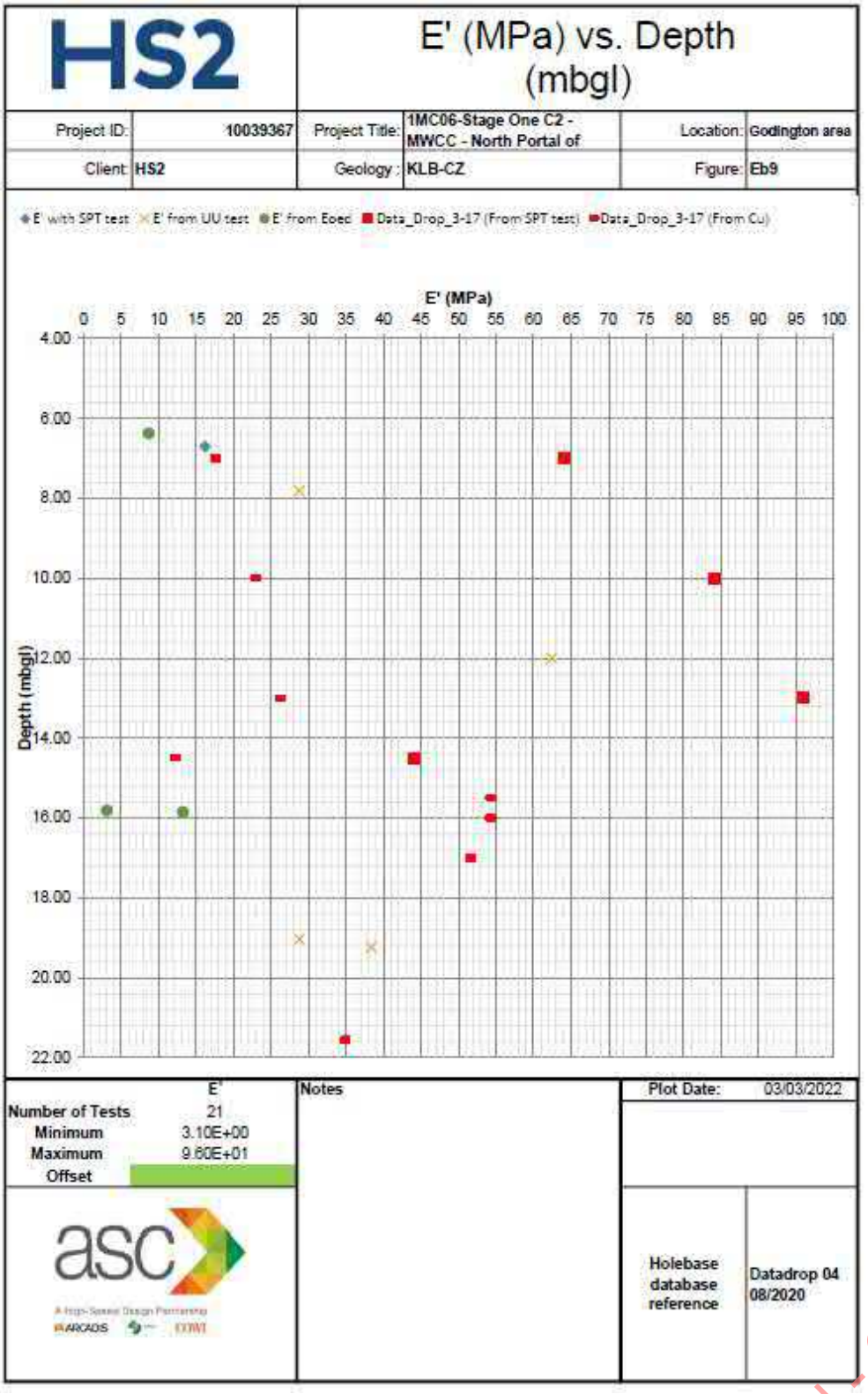
HS2 Ltd - Code 1 - Accepted

D- Kellaways Formation – KLB-S & KLB- CZ

Table G.98 – Impact of new GI between Data Drop 3 and Data Drop 17 on design parameters

Parameter	Symbol	Additional value Data Drop 3-17	Observation
Blow N number from SPT, corrected to 60% test energy	N_{60}	Yes	confirms the design value chosen in the current GDR
Cone resistance fr'm C'T	q_c	No	No impact on design parameters
Undrained shear strength	c_u	Yes	confirms the design value chosen in the current GDR
Drained shear strength	c', ϕ'	No	No impact on design parameters
Young/Effective Deformation Modulus	E'	Yes	Confirms the conservative value used in the current GDR.
Oedometer Deformation Modulus	E_{oed}	Yes	The design value has directly been derived from E'. There is no impact as the E' is confirmed.
Coefficient of consolidation	Cv	Yes	Only one value in the stress range (due to the cutting): there is no impact.

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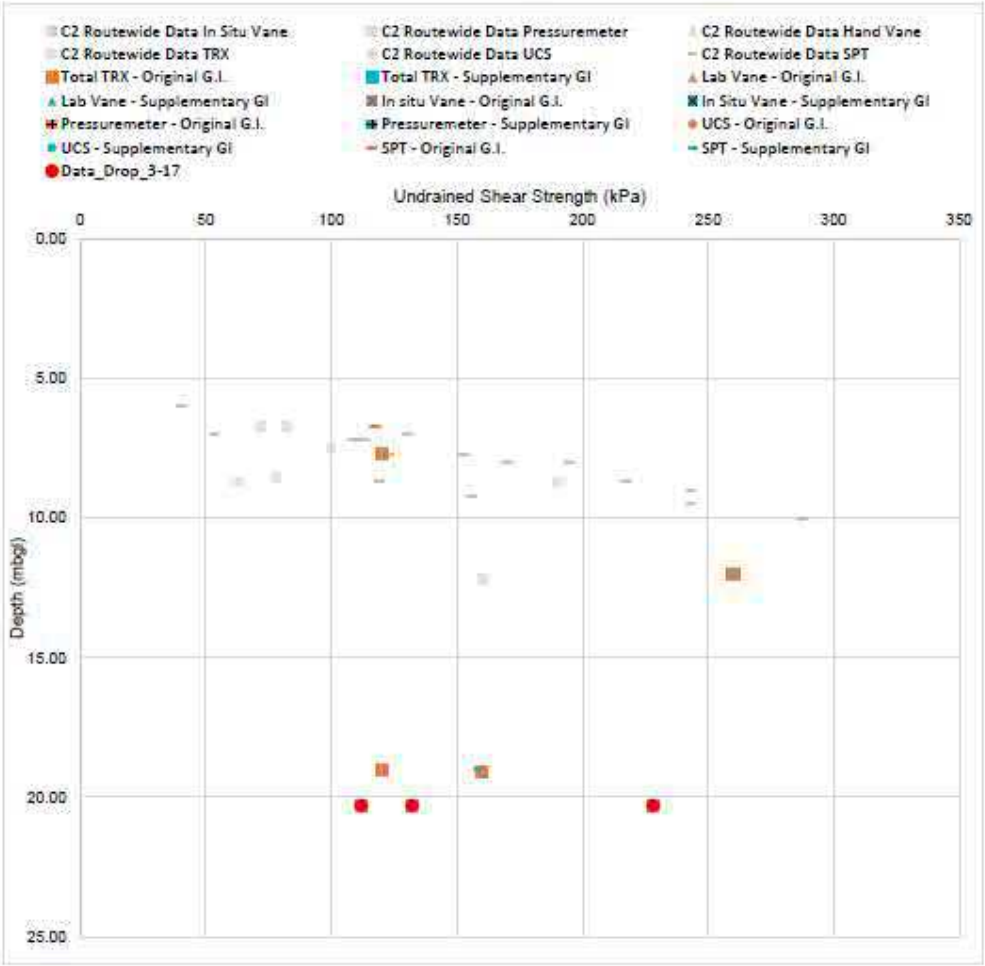


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HS2

Undrained Shear Strength vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	KLB-C Z	Figure:	H6



	Total
Number of Tests	8
Minimum	117
Maximum	260
Offset	

Notes

Background C2 Routewide data shown are based on Holebase database geology codes dated 06/04/2021. Background routewide data on the graph are limited to the Clay vale asset (Ch.82+349 to Ch.87+204)

Inferred ground conditions applied to CPT Cu profiles are based on review of exploratory hole information adjacent to the CPT position.

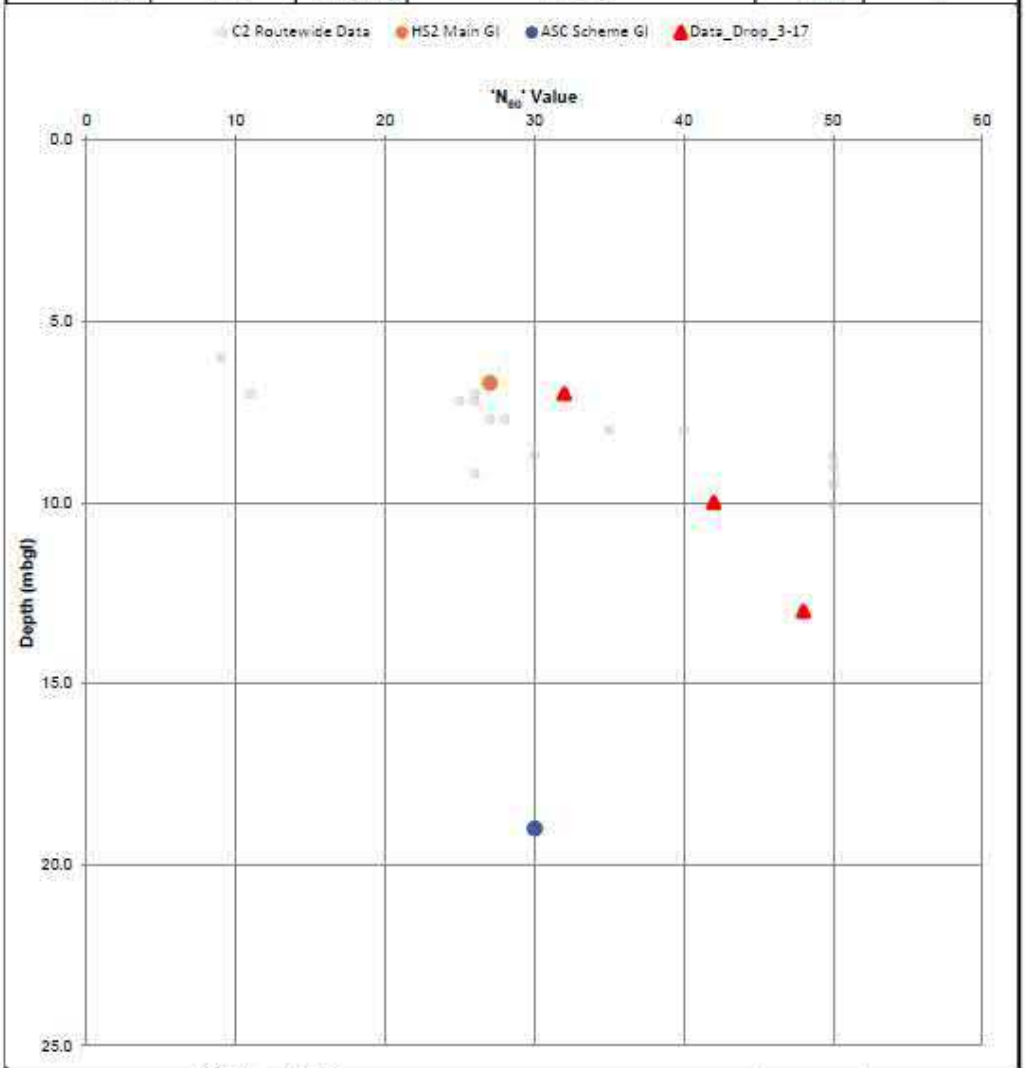
Plot Date:	25/01/2022
Holebase database reference	Datadrop 02 Published 03/2020

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HS2

SPT-N_{60} vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	KLB-C Z	Figure:	H7



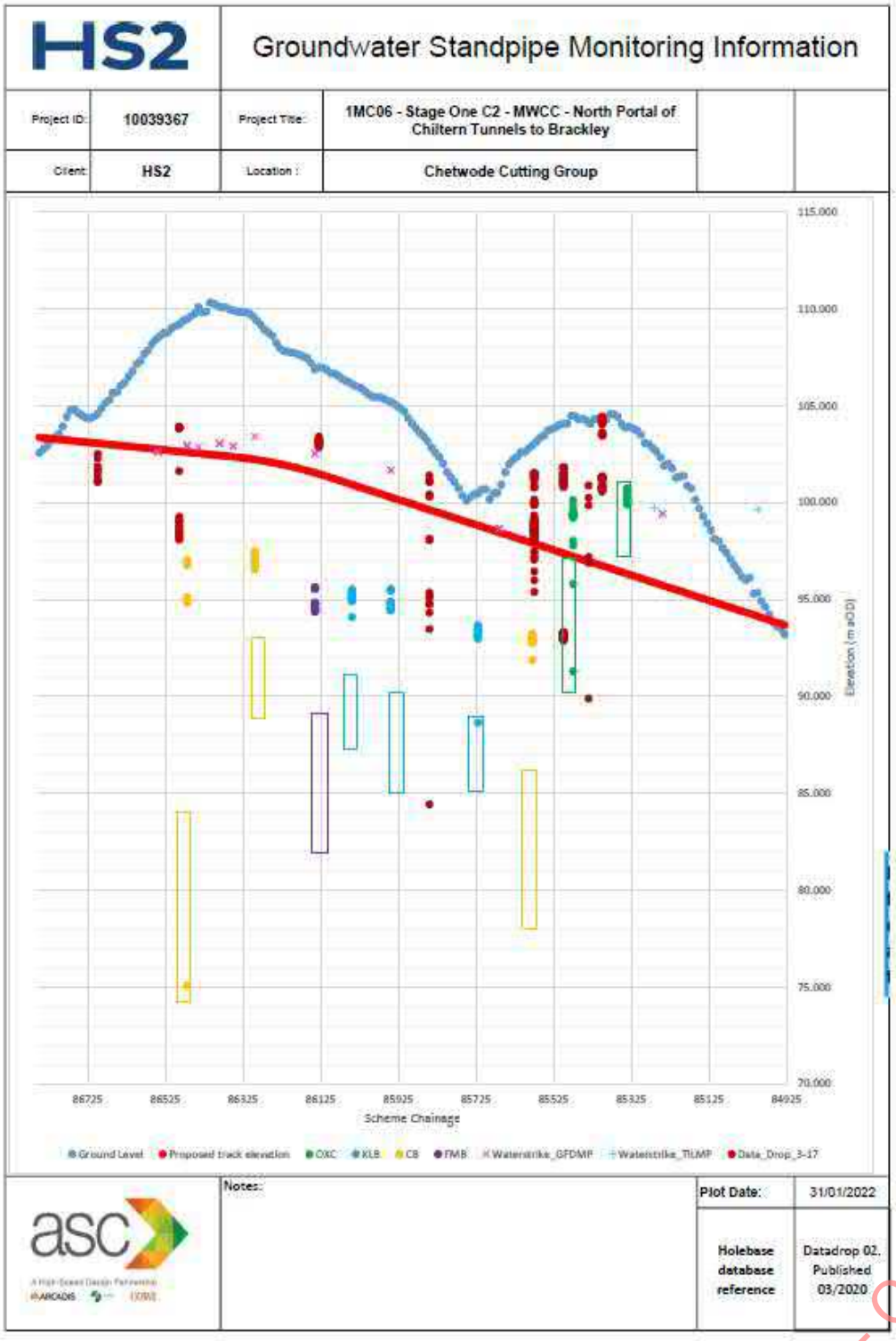
	N Value
Number of Tests	2
Minimum	27
Maximum	30
Offset	

Notes
Background C2 Routewide data shown are based on Holebase database geology codes dated 08/04/2021. Background routewide data on the graph are limited to the Clay vale asset (Ch.82+349 to Ch.87+204)

Plot Date:	25/01/2022
Holebase Database Reference	Datadrop 02. Published 03/2020

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Groundwater level



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APPENDIX H

Footpath CHW18 accommodation overbridge geotechnical calculations

Number of pages: 58

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1 Ground model

The definition of the ground model was based on local GI in the direct vicinity of the asset, as well as on tests conducted on samples from GIs along the Clay Vale zone (1MC06-CEK-GT-REP-CS06_CL10-000015 – P01).

The elements presented here were originally based on GI up to datadrop 02, lately completed by GI up to datadrop 17.

1.1 Stratigraphy

The definition of the stratigraphy is mainly based on the observations from the cable percussion boreholes ML085-CR004, ML085-CR413, ML085-CR414 and ML085-CR425, located along the axis of the overbridge (Figure 1). The observations from other exploratory holes located within 100-200 m from the overbridge are used to confirm this stratigraphy (Figure 2).

The following table summarizes the GI that were used for the definition of the stratigraphy. The geotechnical elevation of the Figure 3 shows the relative position of these boreholes to the axis of the overbridge and their logs.

Table H.99: Used GI

Exploratory hole	Type	Ground level (m AOD)	Depth (m)
ML085-CR004	Cable percussion borehole with rotary cored follow on	102.79	35
ML085-CR413		102.55	30
ML085-CR414		103.32	30
ML085-CR425		103.05	30

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Figure 1: Boreholes along the axis of the overbridge

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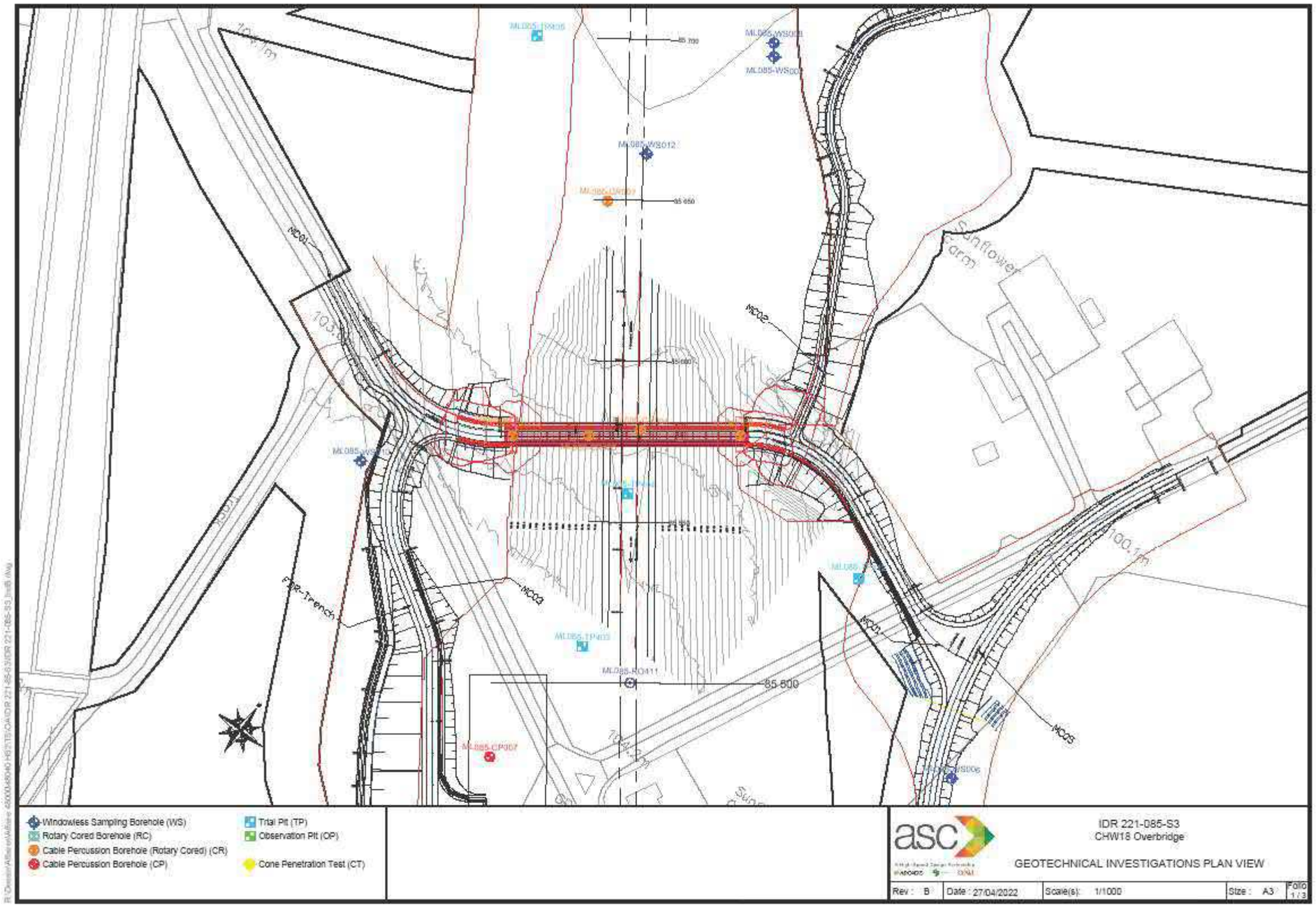


Figure 2 Exploratory holes located around the overbridge

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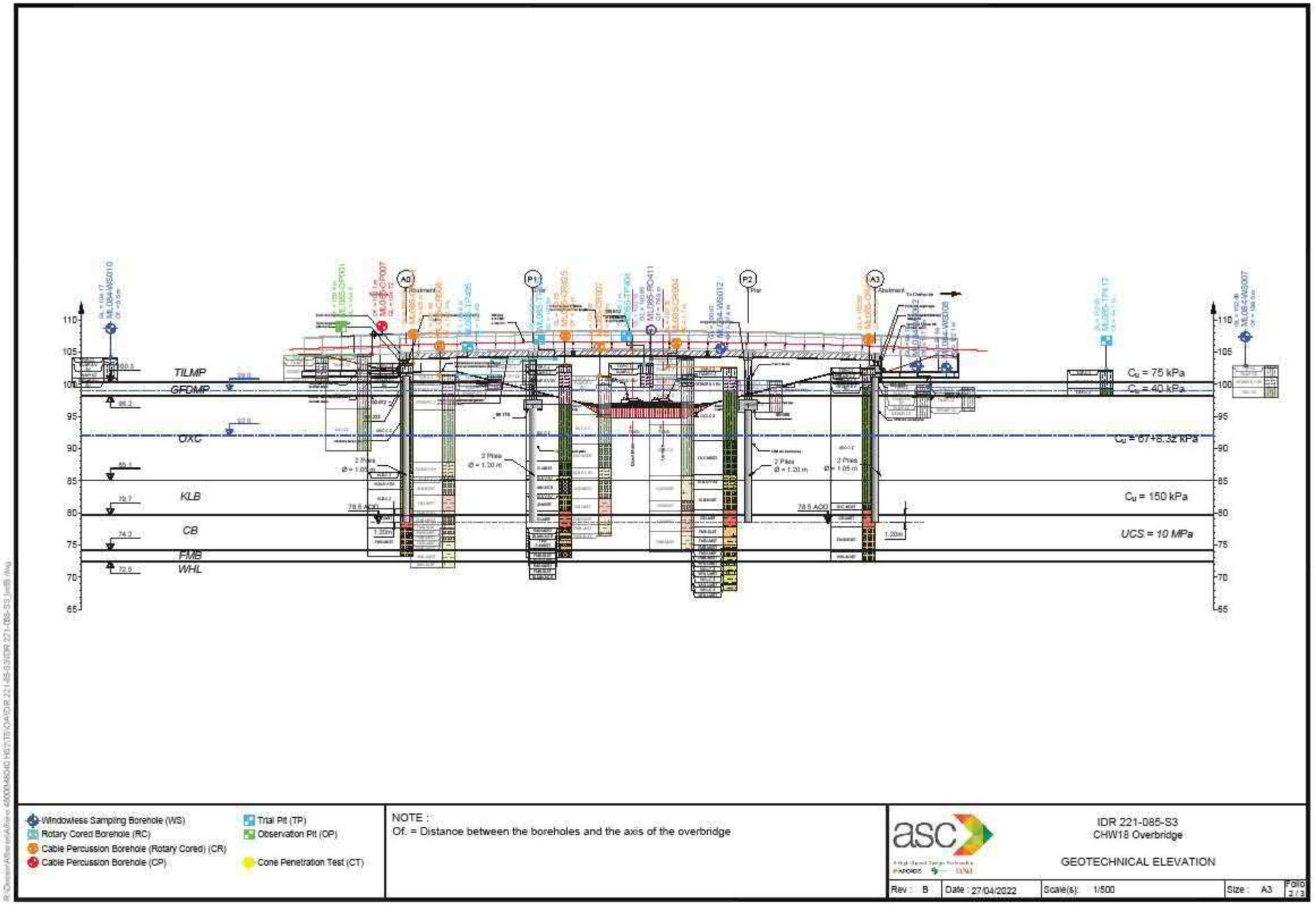


Figure 3 Geotechnical elevation

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The Table H.100 summarizes the stratigraphy for this overbridge. The Existing Ground Level is estimated at 102 m AOD. The stratigraphy is composed of the following layers:

- firm sandy clay of 1.7 m in thickness (till),
- loose gravely fine sand of 2.1 m in thickness (Glaciofluvial deposits),
- 13.1 m of the Oxford Clay formation composed of 7.8 m of firm to very stiff sandy clay and 5.3 m of weak mudstone,
- 5.1 m of the Kellaways formation composed of extremely weak sandstone and mudstone,
- and a substratum of the Great Oolite Group, composed of:
  - medium strong to strong limestone of the Cornbrash formation, of 5.5 m in thickness,
  - 1.7 m of the Forest Marble formation composed of weak mudstone with siltstone interbeds. Very locally, this formation is composed of medium strong limestone (ML085-CR004: 28.25 → 28.69 m and ML085-CR425: 27.4 → 27.77 m).
  - and medium strong limestone of the White Limestone formation, with sublayers of firm laminated clay.

Table H.100 Detailed design stratigraphy

Geological formation	Design top level (m AOD)	Design thickness (m)	Design bottom level (m AOD)
Till	102	1.7	100.3
Glaciofluvial deposits	100.3	2.1	98.2
Oxford Clay formation	98.2	13.1	85.1
Kellaways formation	85.1	5.4	79.7
Cornbrash formation	79.7	5.5	74.2
Forest marble formation	74.2	1.7	72.5
White Limestone formation	72.5	>5.5	<67

1.2 Geotechnical parameters

Static geotechnical parameters are defined from a cross analysis of tests conducted on samples and in situ tests from the aforementioned exploratory holes. A cross analysis of tests conducted on samples from along the Clay Vale zone is also performed in order to verify the relevance of the defined parameters for this overbridge and other assets in this zone.

1.2.1 Undrained shear strength

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Undrained shear strength values are estimated for Till, Glaciofluvial deposits, Oxford Clay formation and Kellaways formation. These values are either directly measured in triaxial tests or correlated from NSPT values (≈ 5 NSPT). For each formation, measured and correlated values are plotted, and a representative value or linear variation is defined accordingly.

Till (firm sandy clay)

Measured values and correlated values, from samples at depths ranging from 1 to 5 m are plotted on Figure 5. The values of the undrained shear strength ranges mostly from 50 to 140 kPa in samples from boreholes near the overbridge, and from 15 to 250 kPa routewide.

A representative mean value of 75 kPa is selected, based on the various correlations from SPT, as well as in situ vane measurements, especially in the depth range 0-1.7 m (the depth at which the formation is encountered near the overbridge).

Glaciofluvial deposits (sand)

Although this formation is sandy, an undrained shear strength value is estimated from SPT values.

This choice is justified by the fact that the formation is composed of fine sand, and interbeds of sandy clay (for example ML085-CR007: 1.4-6 m, ML085-CR413: 1-2.2 m, ML085-CR414: 1.4-1.7 m, ML085-CR425: 3.45-6.2 m).

SPT correlated values, from samples at depths ranging from 1 to 9 m are plotted on Figure 6, with values mostly ranging from 25 to 150 kPa. A representative mean value of 40 kPa is selected.

Oxford Clay formation (firm to very stiff clay and weak mudstone)

Two sublayers of Oxford Clay are encountered: firm to stiff clay and weak mudstone.

Figure 7 illustrates the measured and correlated values for the clayey sublayer.

For the firm to stiff clay, the values are overall increasing with depth. A trendline is constructed to reflect this increase in a conservative way:

- the slope of the trendline is defined according to the general tendency of the values,
- and the zero ordinate value account for smaller values measured around 5 m of depth.

This leads to an equation for the undrained shear strength variation with depth: $C_u = 67 + 8.3z$ with a maximum value of Cu = 150 kPa (z is the depth from the existing ground level).

For the mudstone sublayer, encountered at the base of the sublayer (below the clayey sublayer), the maximum value of undrained shear strength that was taken for the clayey part is selected (150 kPa).

Kellaways formation

Measured values and correlated values, from samples at depths ranging from 15 to 25 m are plotted on Figure 8. The values are mostly comprised within the range 120-250 kPa. According to these observations, a representative mean value of 150 kPa is selected.

1.2.2 Uniaxial Compressive Strength

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Due to its rocky nature, the Great Oolite group is concerned by the determination of Uniaxial Compressive Strength. The Great Oolite group at this overbridge is mostly composed of limestone (Cornbrash formation and Forest Marble formation) and mudstone with siltstone interbeds (Forest Marble formation).

Cornbrash formation (medium strong to strong limestone)

Measured values are plotted on Figure 9. The values are quite scattered.

Based on the apparent good quality of the rock in this formation (RQD > 60%, see Figure 4) and on the usual resistance values for strong limestone formations, a value of 10 MPa is selected.

Forest Marble formation (weak mudstone with siltstone interbeds)

Measured and correlated values are plotted on Figure 10 for the weak mudstone part of the formation. The values are mostly comprised between 0.5 and 2 MPa, with some outlier values around 5-6 MPa and 8 MPa. A representative average value of 1 MPa is selected.

For the siltstone interbeds, measured and correlated values are plotted on Figure 11. The values are mostly divided in two parts (around 1 MPa and greater than 10 MPa). For safety reasons, and to ensure the continuity with the values of the mudstone sublayer containing these siltstone interbeds, a value of 1 MPa is selected.

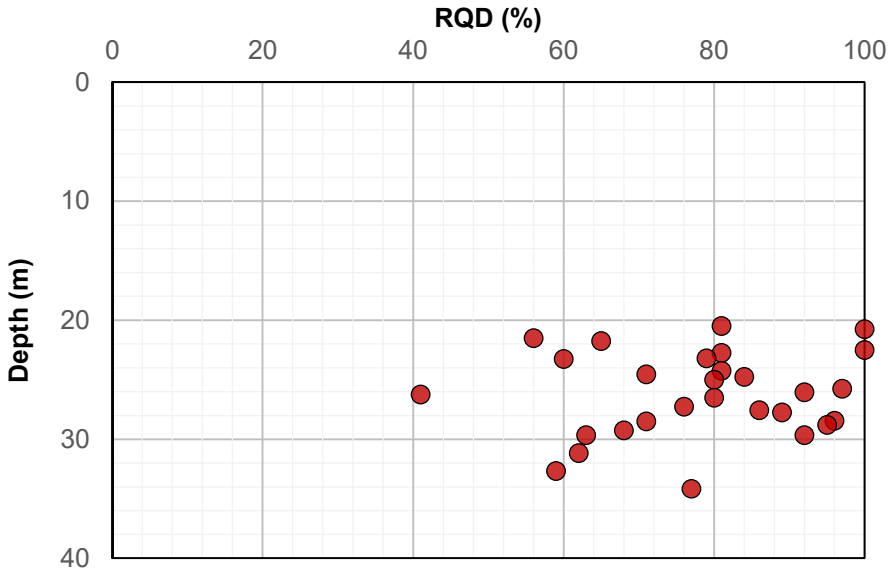


Figure 4 RQD values in Cornbrash formation and Forest Marble formation

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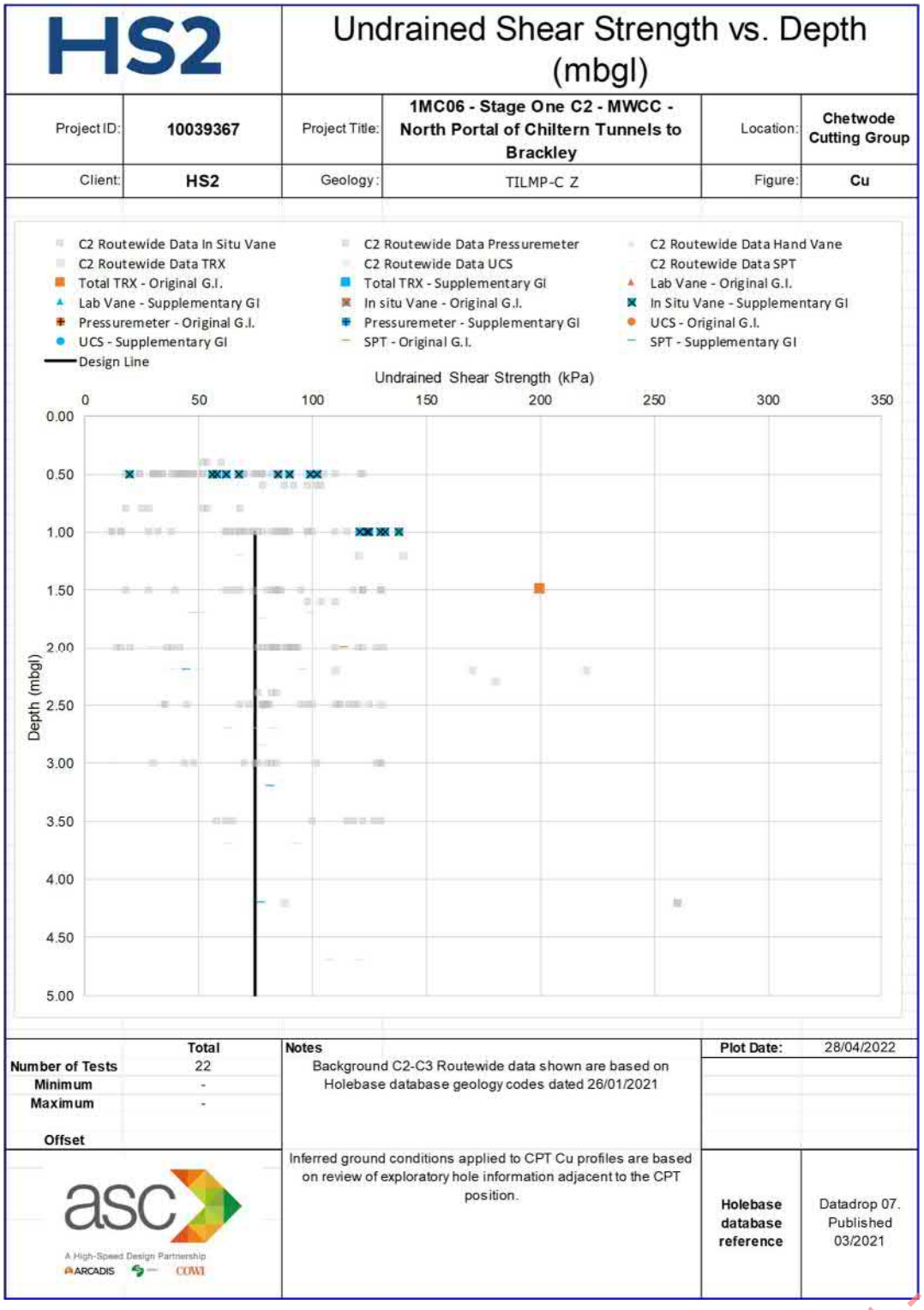


Figure 5 Undrained shear strength in Till

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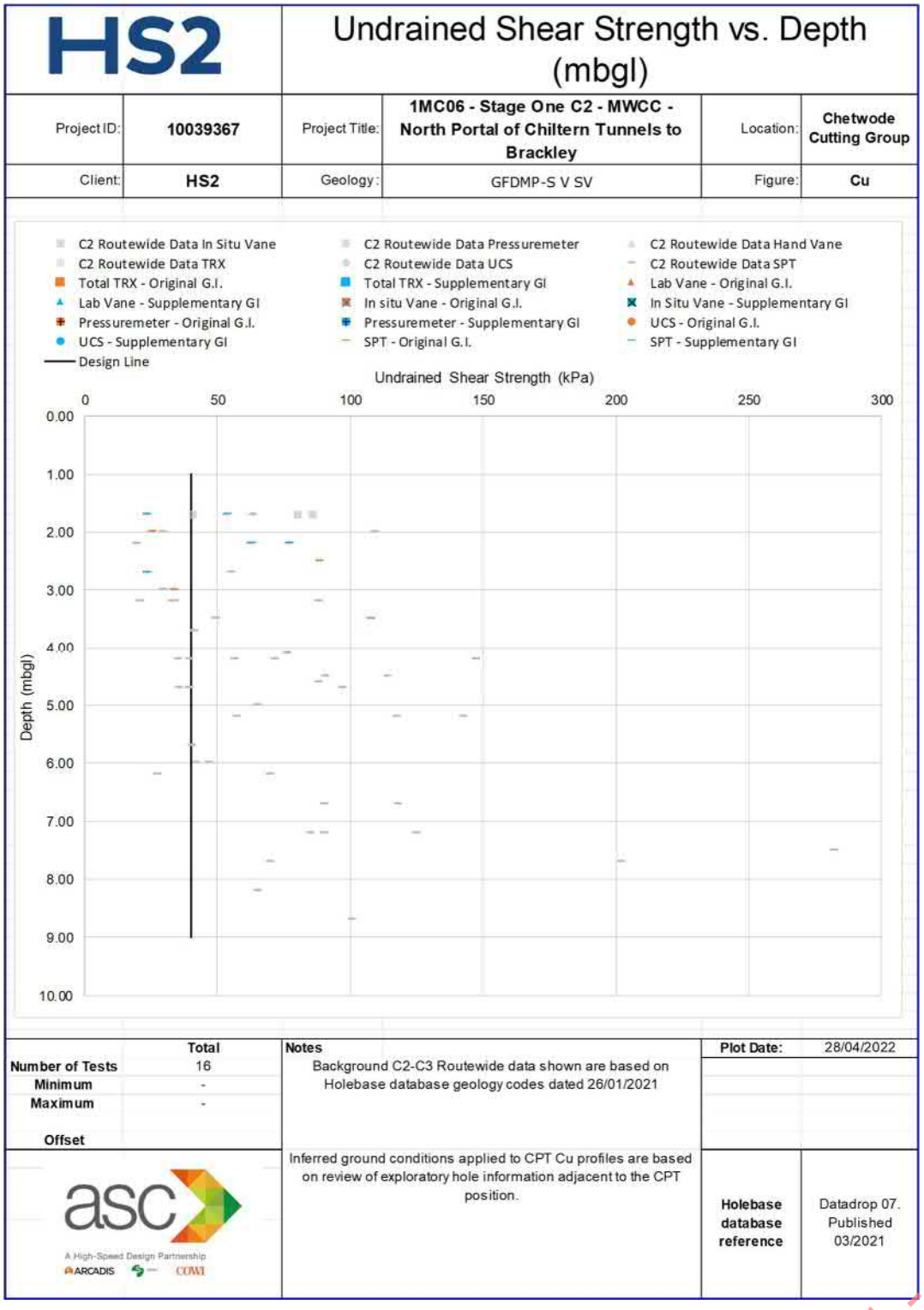


Figure 6 Undrained shear strength in Glaciofluvial Deposits

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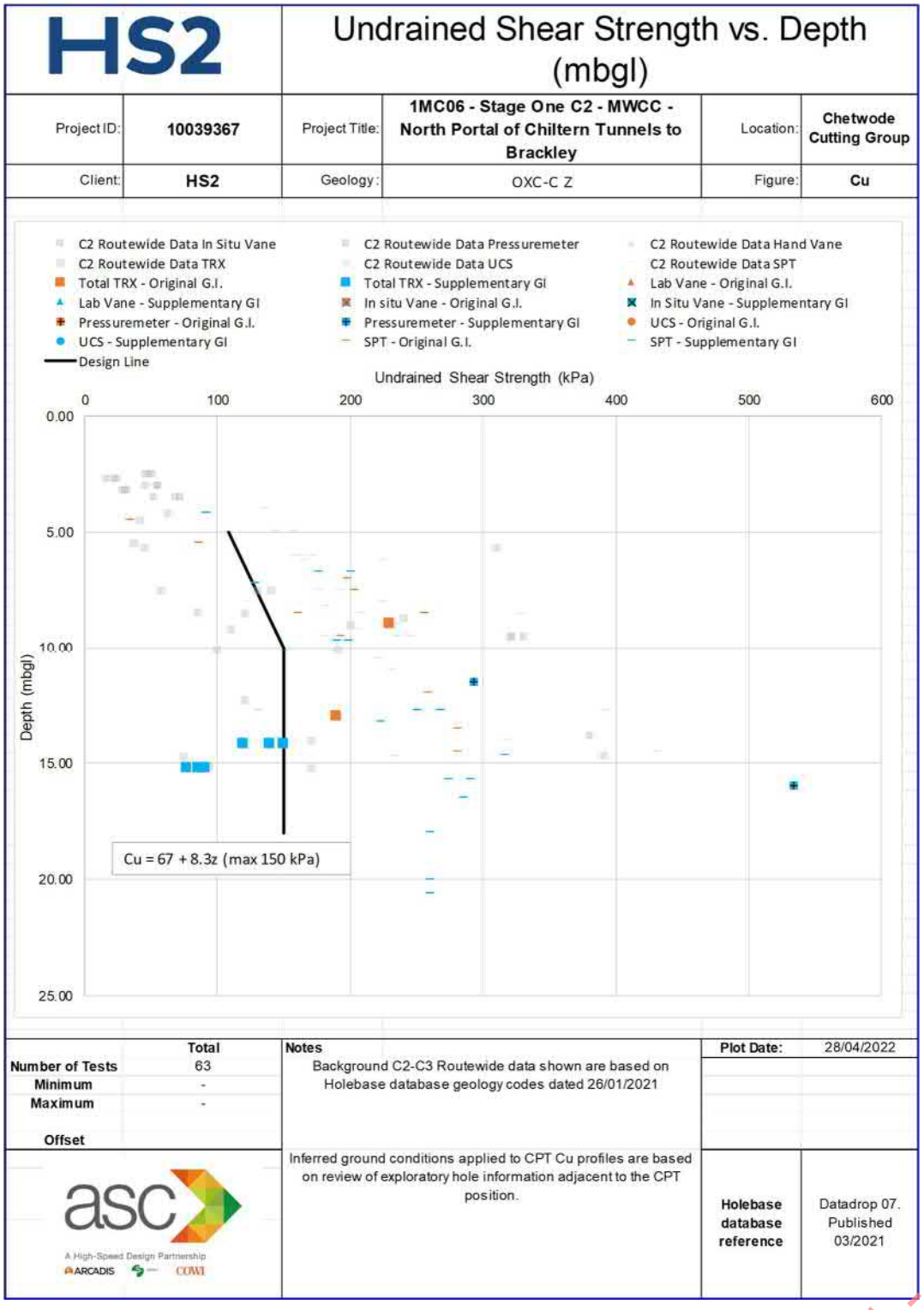


Figure 7 Undrained shear strength in Oxford Clay formation – stiff clay

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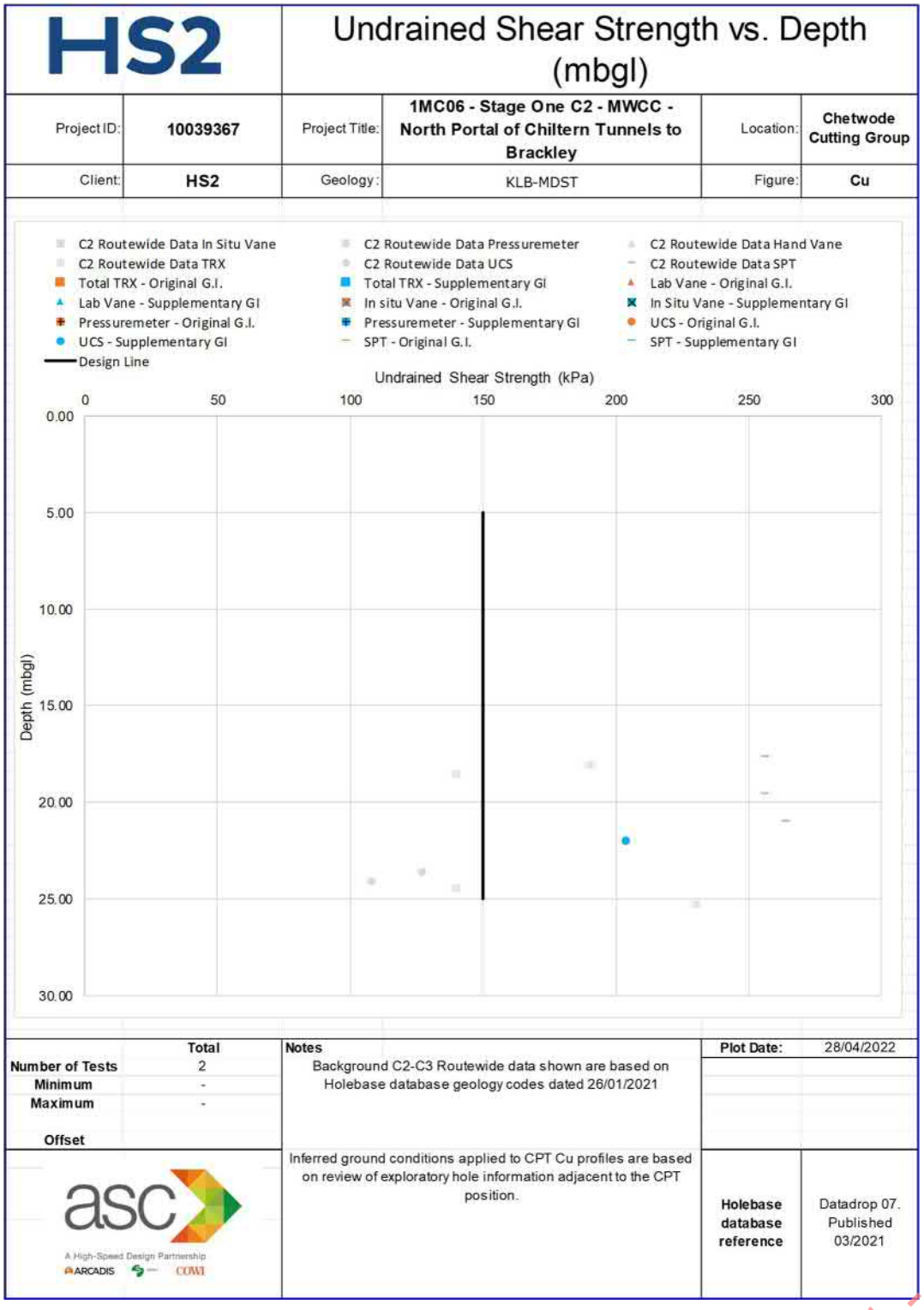


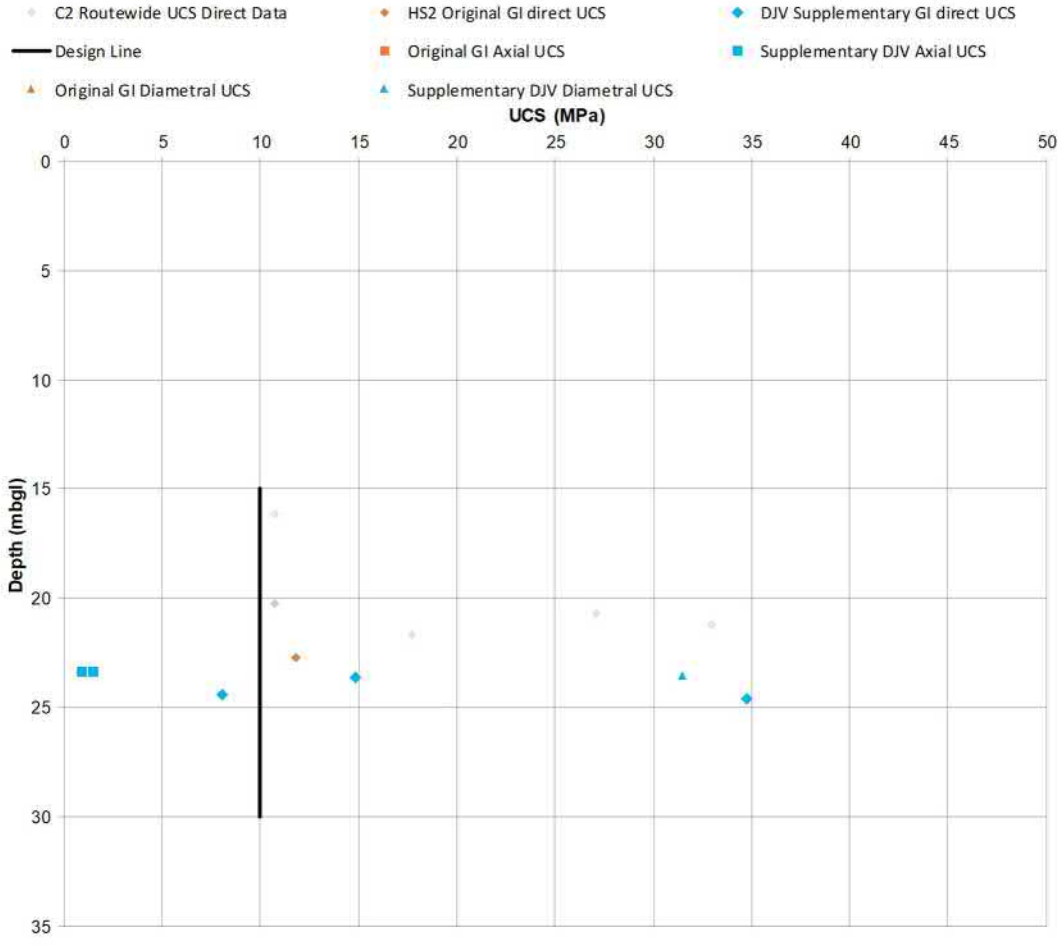
Figure 8 Undrained shear strength in Kellaways formation

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HS2

Uniaxial Compressive Strength vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Location:	Chetwode Cutting Group
Client:	HS2	Geology:	CB-LMST	Figure:	UCS



	UCS Direct data
Number of Tests	6
Minimum	8
Maximum	35

Notes
Background C2-C3 Routewide data shown are based on Holebase database geology codes dated 26/01/2021

Plot Date:	28/04/2022
Offset	
Holebase database reference	Datadrop 07. Published 03/2021

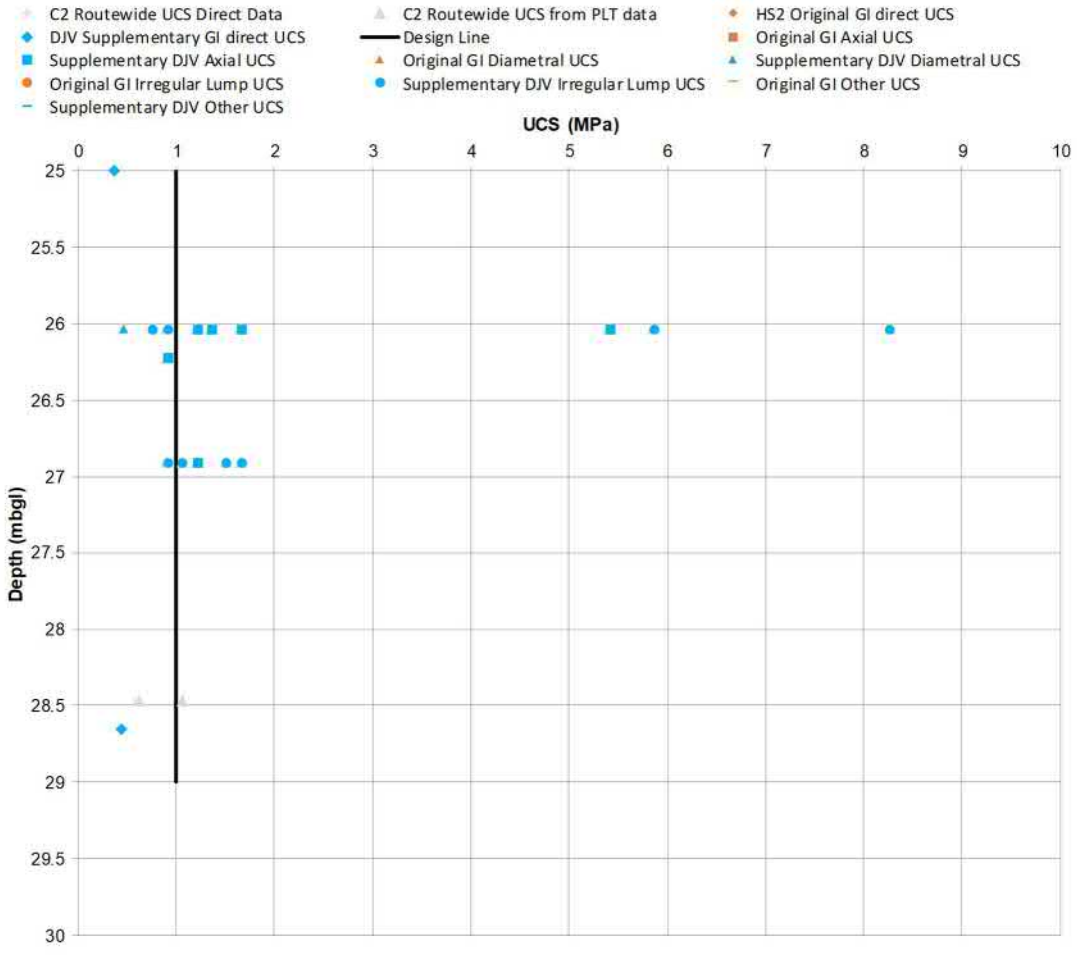
Figure 9 Uniaxial Compressive Strength in Cornbrash formation – Limestone

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Uniaxial Compressive Strength vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC06 - Stage One C2 - MWCC - North Portal of Chiltern Tunnels to Brackley	Location:	Chetwode Cutting Group
Client:	HS2	Geology:	FMB-MDST	Figure:	UCS



	UCS Direct data
Number of Tests	3
Minimum	0
Maximum	34

Notes
Background C2-C3 Routewide data shown are based on Holebase database geology codes dated 26/01/2021

Plot Date:	28/04/2022
Offset	
Holebase database reference	Datadrop 07. Published 03/2021

Figure 10 Uniaxial Compressive Strength in Forest Marble formation – Mudstone

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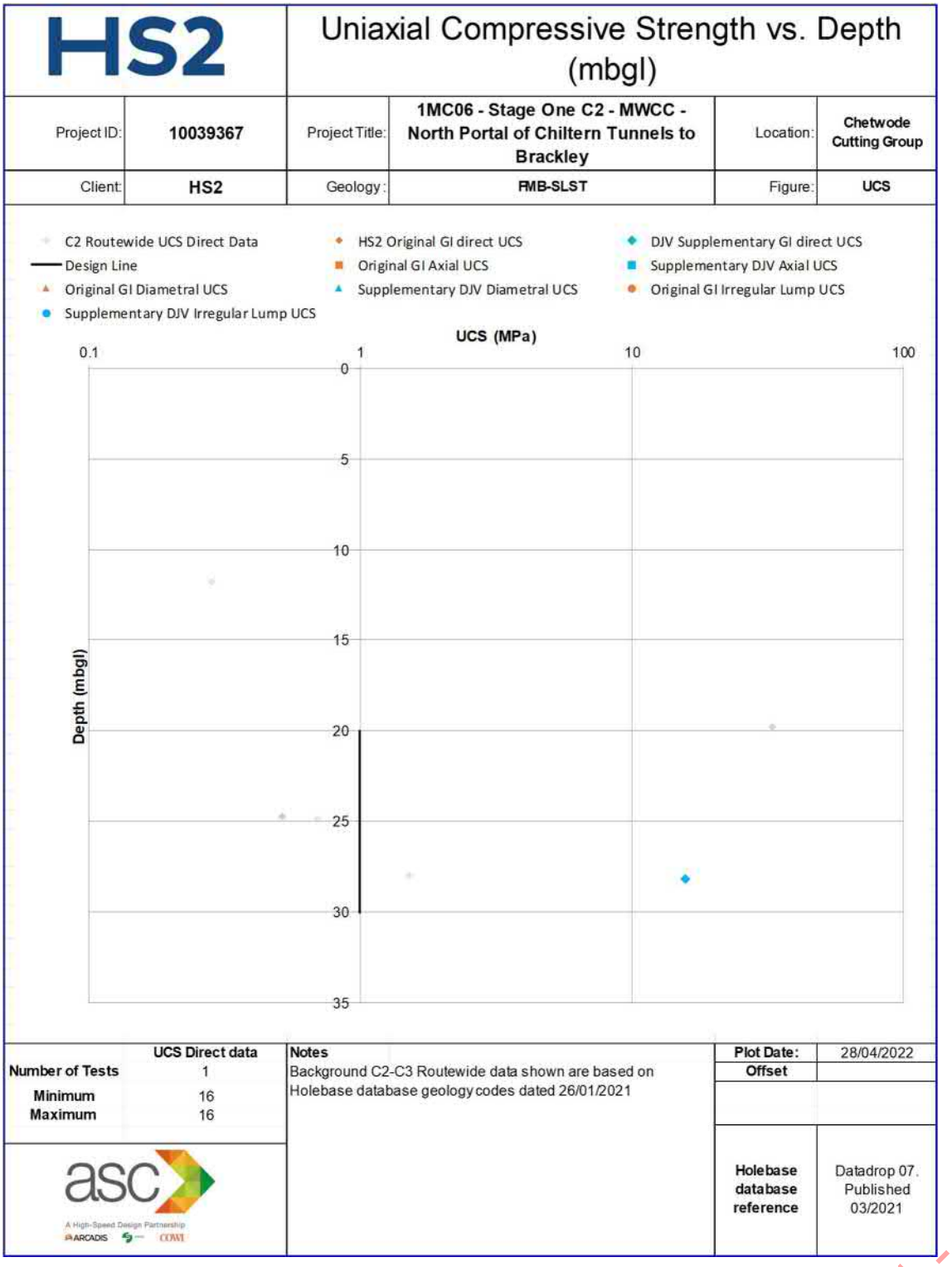


Figure 11 Uniaxial Compressive Strength in Forest Marble formation – Siltstone interbeds

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1.2.3 Young modulus

The Young modulus for each deformable layer is estimated through series of post treatment of oedometer tests, and correlations from NSPT values ($E = 2 \times SPT$) or from C_u values ($E = 300 \times C_u$).

The Young modulus in the rocky layers is estimated from correlations with UCS values as follows:

$$E = 300 \times \beta \times UCS$$

The coefficient β depends on the discontinuity of the rock layer. For all the formations, β is estimated to 0.5.

The following figure shows SPT values for the different formations.

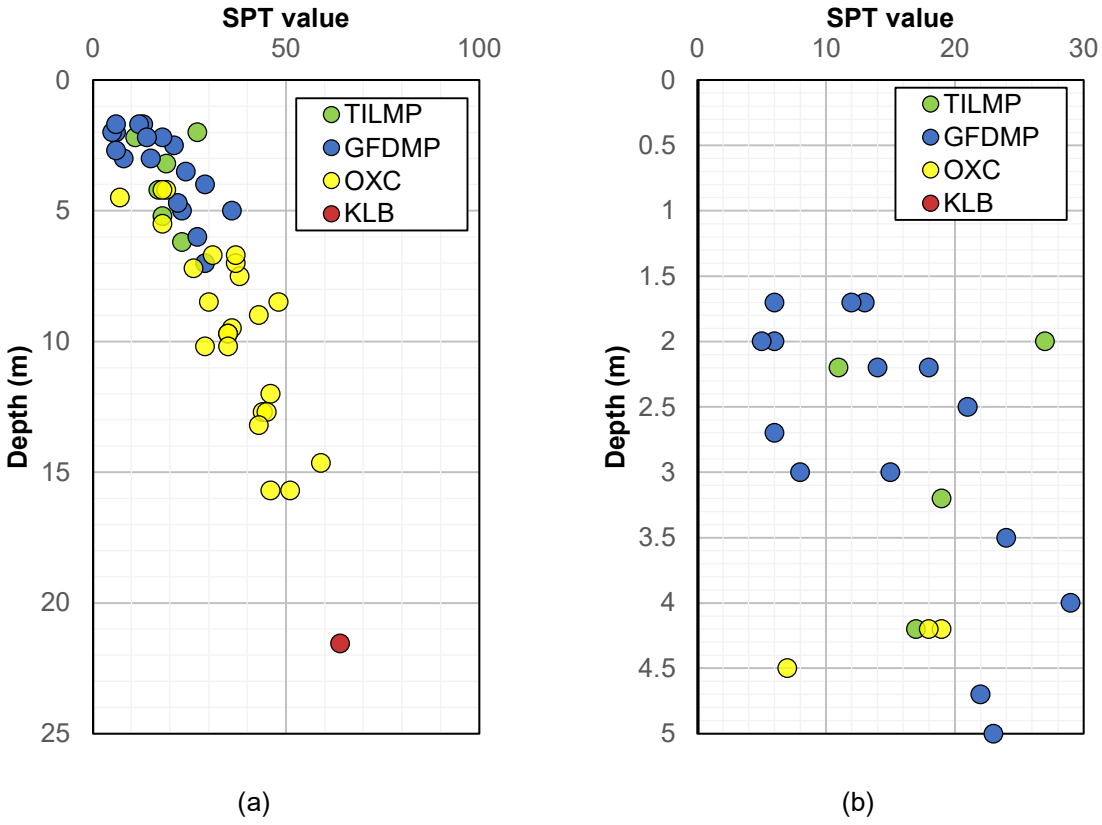


Figure 12 SPT values (a) all values, (b) shallower than 5 m

For each layer, a conservative, yet representative value is selected. The values of Young moduli are thus listed in the table below.

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Table H.101 Soil Young moduli

Formation	Base elevation (m AOD)	E' (MPa)	Notes
Till	100.3	14	Correlated from SPT values NSPT = 11, but NSPT=7 considered instead to keep the value lesser than the underlying formation. E=2*NSPT=14 MPa
Glaciofluvial deposits	98.2	18	Correlated from SPT values Average NSPT = 9 ⇒ E=2*NSPT=18 MPa
Oxford Clay formation	85.1	16-20	Correlated from SPT values Minimal SPT=7, greater values at 18-19. Average values 8-10 ⇒ E=2*NSPT=16-20 MPa
Kellaways formation	79.7	20	Conservative value of 20 MPa equal to E of the overlying formation

1.2.4 Drained shear resistance properties (c and ϕ)

The drained shear strength properties are calculated through a cross analysis of tests on samples collected from exploratory holes in the Chetwode cutting. The following values are selected for the non-rocky formations.

Table H.102 Drained shear resistance properties

Formation	Base elevation (m AOD)	c' (kPa)	Notes	Φ(°)	Notes
Till	100.3	0	No data available, hence c'=0 selected	27	Defined from experience feedback, since the value from shear tests (34°) is high
Glaciofluvial deposits	98.2	0	Low fine content	30*	Defined as the lower estimate from 7 direct shear tests. Range of values from tests is 30°-35°
Oxford Clay formation	85.1	5	Estimated from 2 CU+u triaxial tests and	28	Estimated from 3 Cu+u triaxial tests

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Formation	Base elevation (m AOD)	c' (kPa)	Notes	Φ(°)	Notes
			experience feedback		
Kellaways formation	79.7	5	Estimated from 1 triaxial test	27	Estimated from 1 triaxial test

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1.3 Soil model summary

Based on the paragraphs 1.1 and 1.2, the used soil model is summarized in the following table.

Table H.103 Detailed design soil model summary

Geological group	Geological formation	Design top level (m AOD)	Design thickness (m)	Design bottom level (m AOD)	Undrained shear strength (kPa)	Uniaxial Compressive Strength (MPa)	Young modulus (MPa)	c' (kPa)	ϕ (°)
Till	Till	102	1.7	100.3	**Clay: 75 kPa**	-	14	0	27
Glaciofluvial deposits	Glaciofluvial deposits	100.3	2.1	98.2	**Sand: 40 kPa**	-	18	0	30
Oxford Clay formation	Oxford Clay formation	98.2	13.1	85.1	**Clay: 67+8.3z** (max. 150 kPa) **Mudstone: 150 KPa**	-	16-20	5	28
Kellaways formation	Kellaways formation	85.1	5.4	79.7	**Mudstone: 150 kPa**	-	20	5	27
Great Oolite Group	Cornbrash formation	79.7	5.5	74.2	-	**Limestone: 10 MPa**	Assumed substratum	-	-
	Forest marble formation	74.2	1.7	72.5	-	**Mudstone: 1 MPa** *Siltstone: 1 MPa*	-	-	-
	White Limestone formation	72.5	>5.5	<67		*Not used in design*	-	-	-

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1.4 Seismic parameters

Based on the Ground Engineering Design Basis Statement – Seismic Design (*1MC06-CEK-GT-REP-C002-000096*) The design value of the PGA is equal to 0.05 g. This value corresponds to a return period of 2500 years (2% probability of exceedance in 50 years) and to an ultimate limit state.

For seismic calculations, soil moduli are multiplied by a factor of 3 to account for short term behaviour effects. Soil resistance properties are unchanged between static and seismic analysis.

On the other side, the ground type in accordance with Eurocode 8 is B. The description of this type (Deposits of very dense sand, gravel, or very stiff clay, at least several tens of meters in thickness, characterized by a gradual increase of mechanical properties with depth) is compatible with the encountered stratigraphy.

1.5 Ground water

Ground water monitoring at the overbridge (standpipe installed in the ML085-CR004) identifies the groundwater level at 10 m depth below EGL, at 92 m AOD.

However, standpipes installed in holes along the chainage (ML085-CP007, ML085-CR004, ML085-CR008, ML085-RC009, ML086-CR005, ML086-CR009, ML086-CR010 and ML086-CR014) show a varying water level between 88 and 99 m AOD (Figure 13).

Given that, a higher calculation level is also defined at 99 m AOD. Both levels (92 and 99 m AOD) will be used in the design, and the level leading to more conservative results will be chosen on a case-by-case basis.

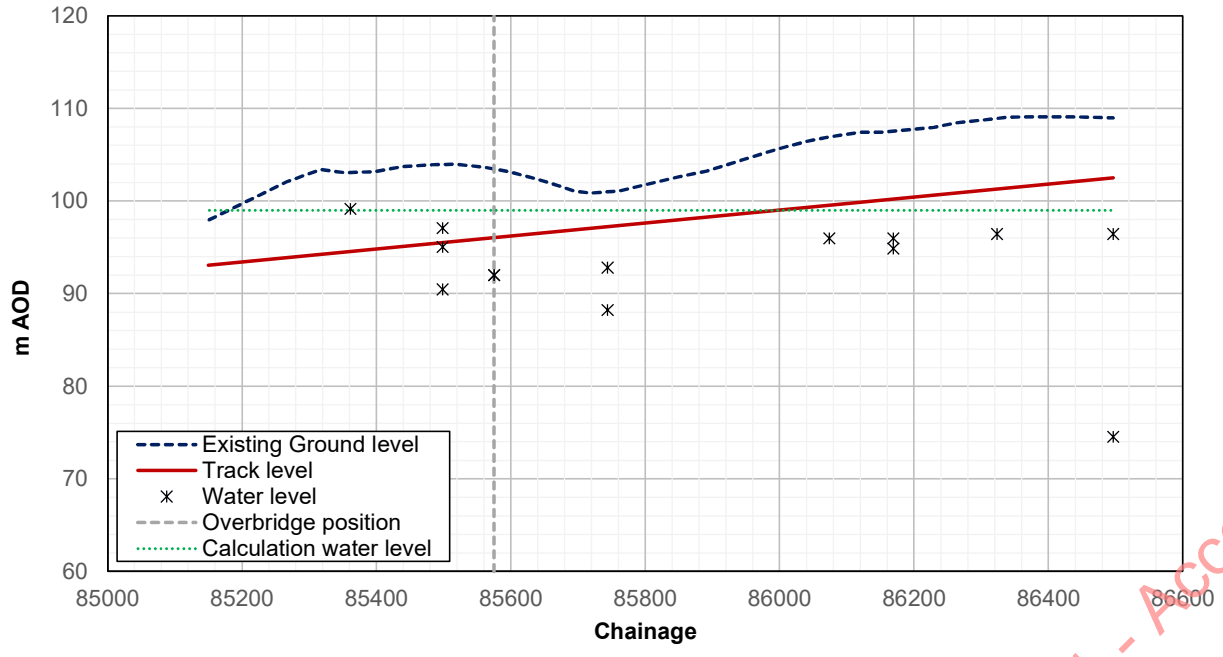


Figure 13 Water level measurements around the overbridge

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1.6 Ground Aggressivity and Concrete Classification

The concrete classes are defined considering the level of ground aggressivity. The ground aggressivity class is determined according to the BS 8500-1, based on the results of chemical tests conducted on samples from each formation.

In accordance with BS 8500-1 (2015), the aggressivity of the ground toward concrete is defined from the following characteristics:

- Total Sulphur (TS)
- Acid-Soluble Sulphates (AS)
- Water-Soluble Sulphates (WS)
- pH

The analysis is conducted as follows: for each concerned formation of a certain nature, a representative value for each chemical characteristic is defined from lab tests results on samples collected in this formation in the vicinity of the overbridge or along the level 1 asset (Chetwode Cutting in this case). Then, the Design Sulfate Class and Aggressive Chemical Environment for Concrete (ACEC) classification are defined accordingly.

Next, for each foundation component (pile, pile cap or spread foundation), the Design Sulfate class and the ACEC is taken as the most unfavourable along those of the soil formations it interacts with.

Characteristic values are given in the following table. Detailed laboratory testing results are plotted below.

Table H.104. Chemical characteristic values

	Till (CZ)	Glaciofluvial deposits (SV)	Oxford Clay (CZ)	Kellaways formation (MDST)	Cornbrash formation (LMST)
WS_k (mg/L SO4)	800	180	1500	1400	570
pH_k	8.8	8.6	8.1	8.3	8.6
AS_k (% SO4)	0.24	0.19	2	0.35	0.45
TS_k (% S)	0.5	0.07	4.5	3.7	2.3
TPS = 3 × TS_k (% SO4)	1.5	0.21	13.5	11.1	6.9

Following the guidelines from BS 8500-1 (2015), the Design Sulfate Class, the groundwater conditions affecting the structure and the Aggressive Chemical Environment for Concrete (ACEC) classification are as follows.

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Table H.105 Concrete classification

		Ground water conditions	DS Class	AC Class
Piles cap	Abutments	mobile	DS-4	AC-4
	Piers	mobile	DS-5	AC-4s
Piles	Abutments	mobile	DS-2	AC-2
	Piers	mobile	DS-2	AC-2

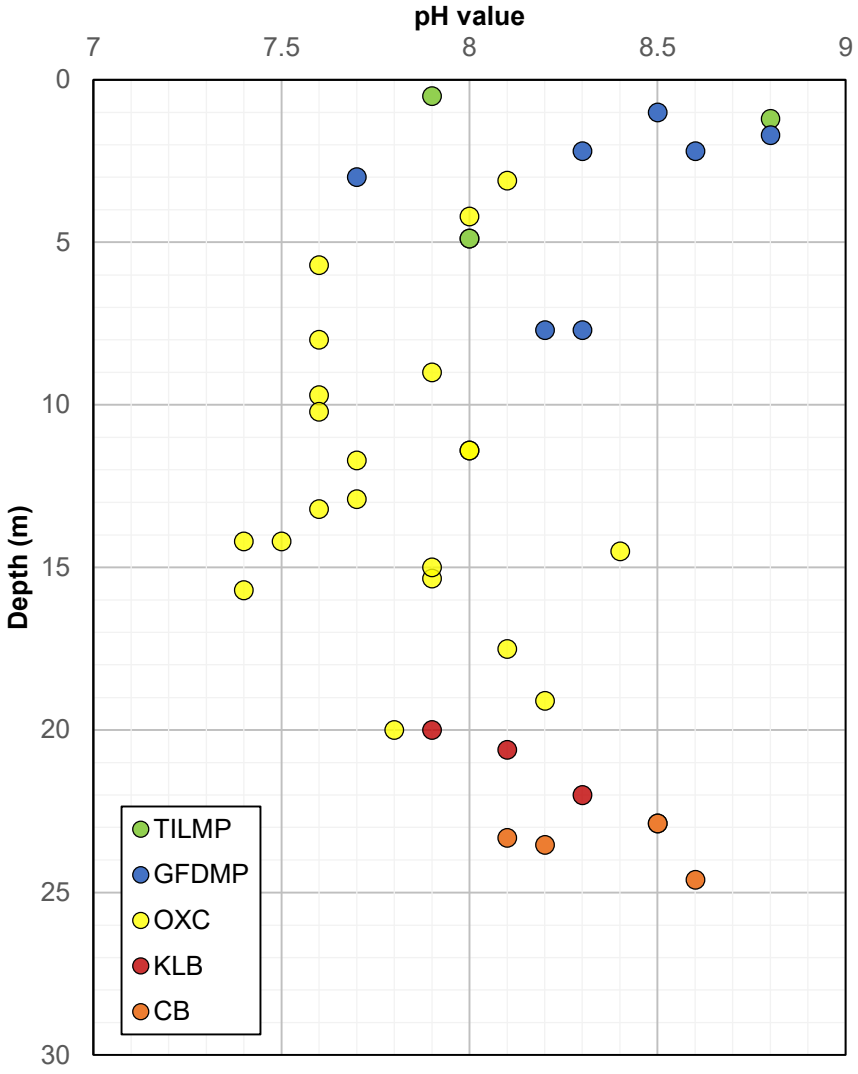
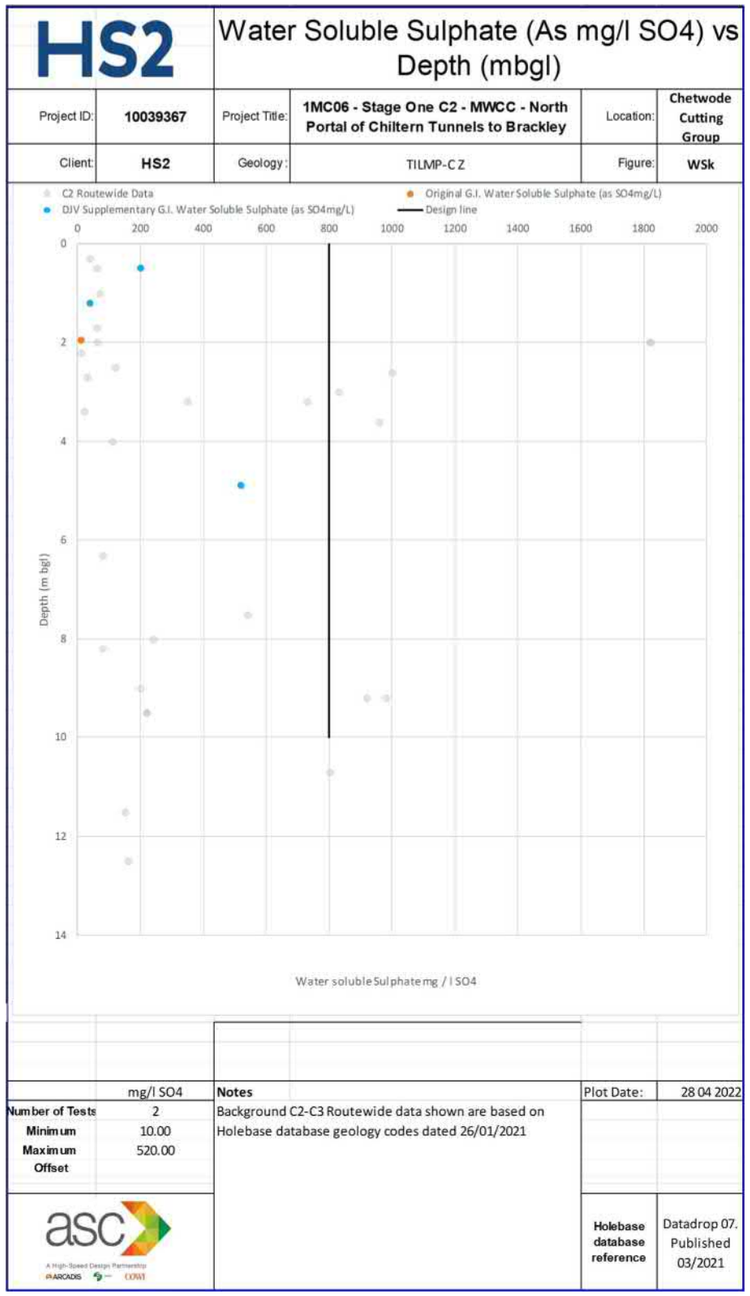
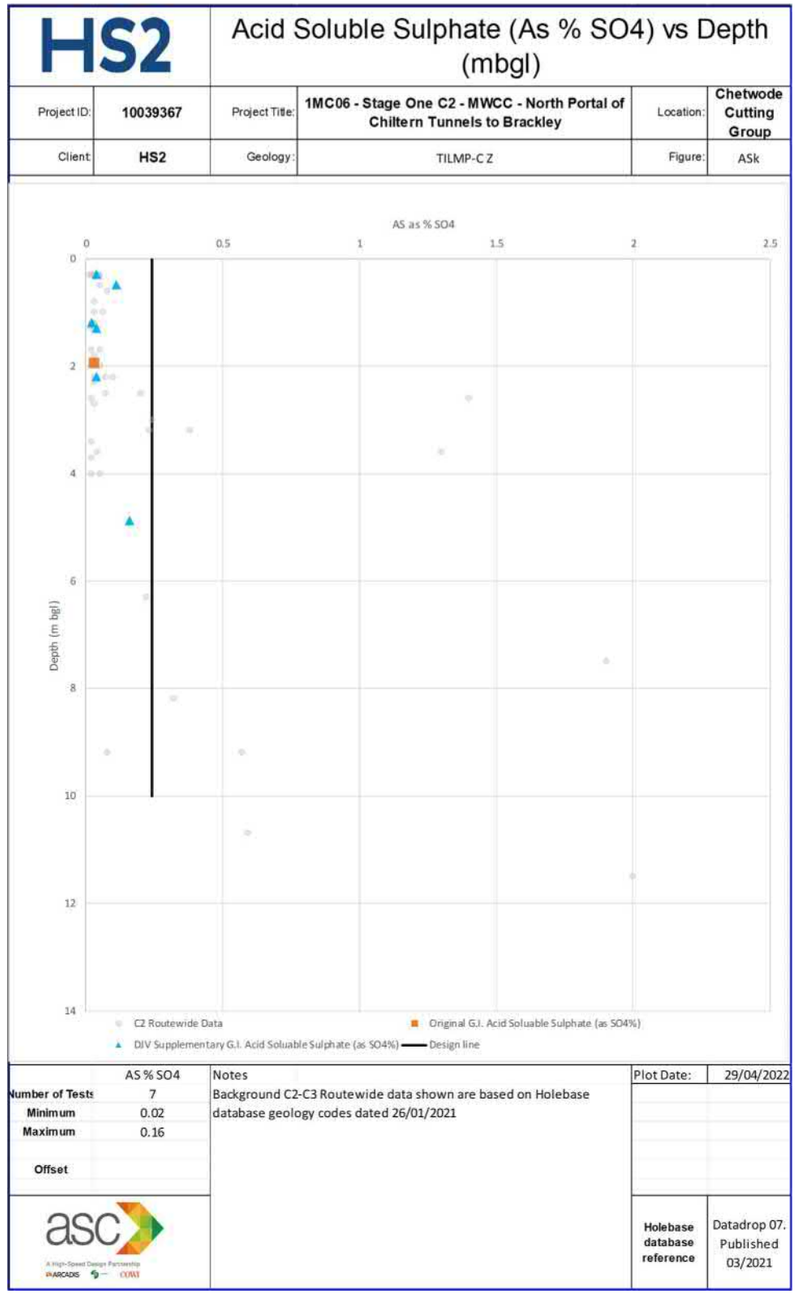


Figure 14 pH values in the encountered formation in function of depth – tests in ML085-RO411, ML085-CR413, ML085-CR425 and ML085-CR414

HS2 Ltd - Code 1 - Accepted



(a)



(b)

Figure 15 Till (clay): (a) Water soluble sulfate concentration, (b) Acid soluble sulfate percentage

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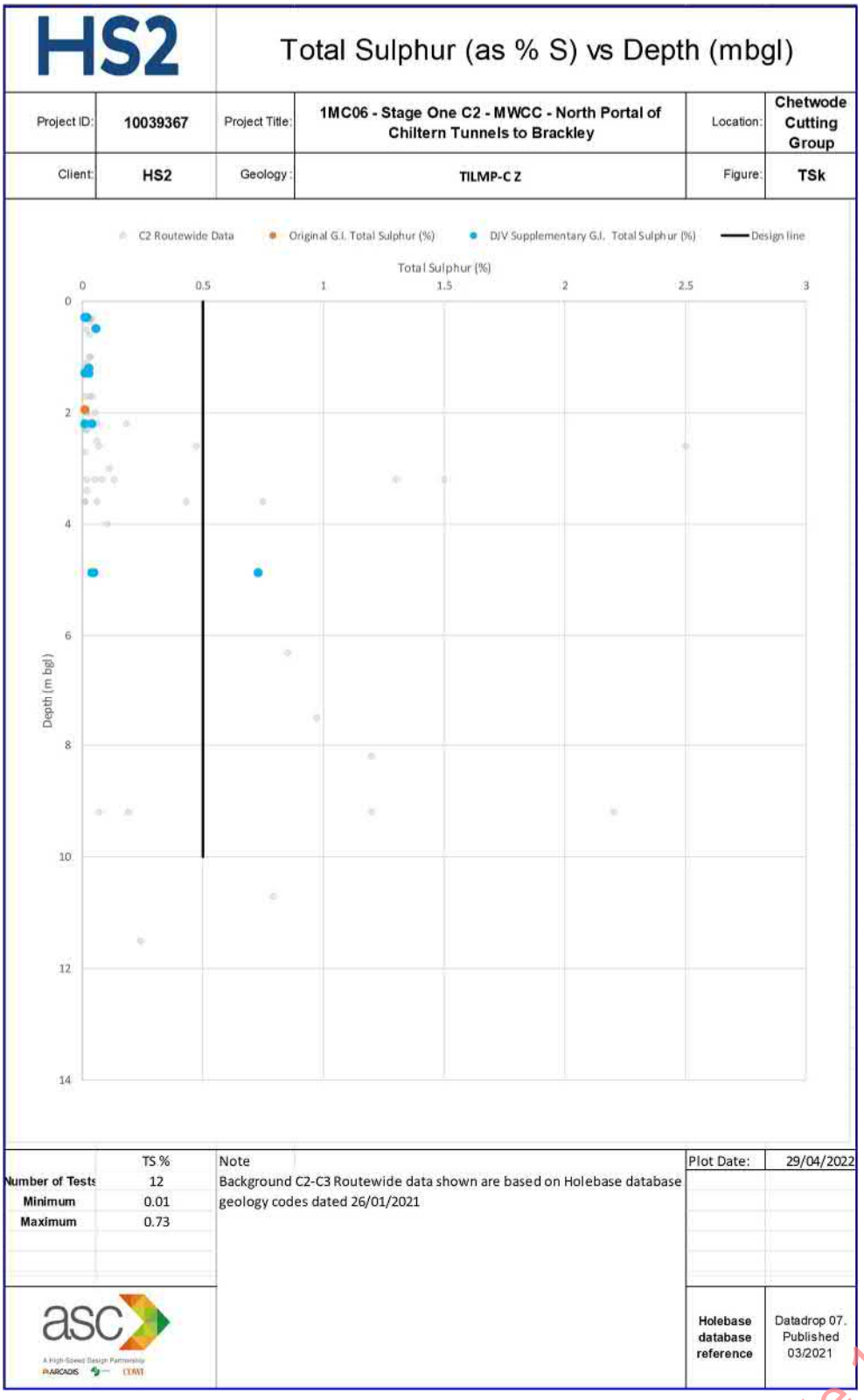
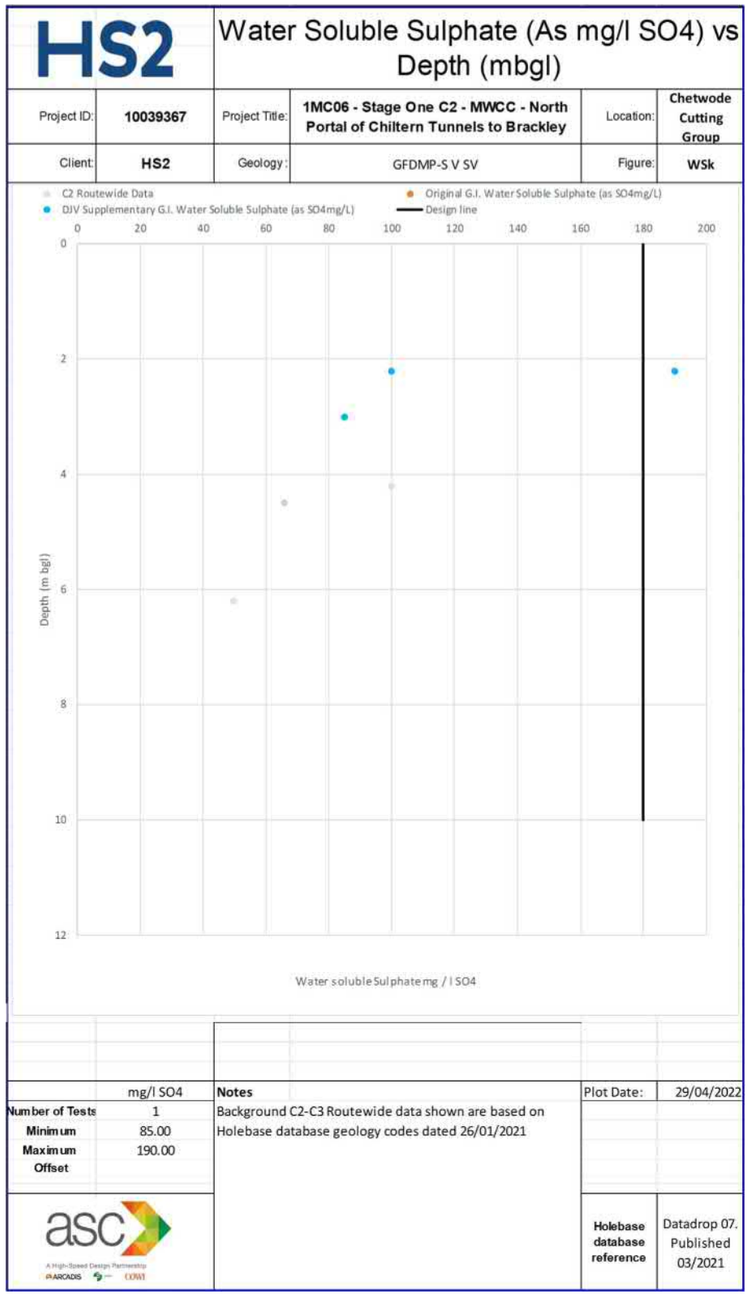
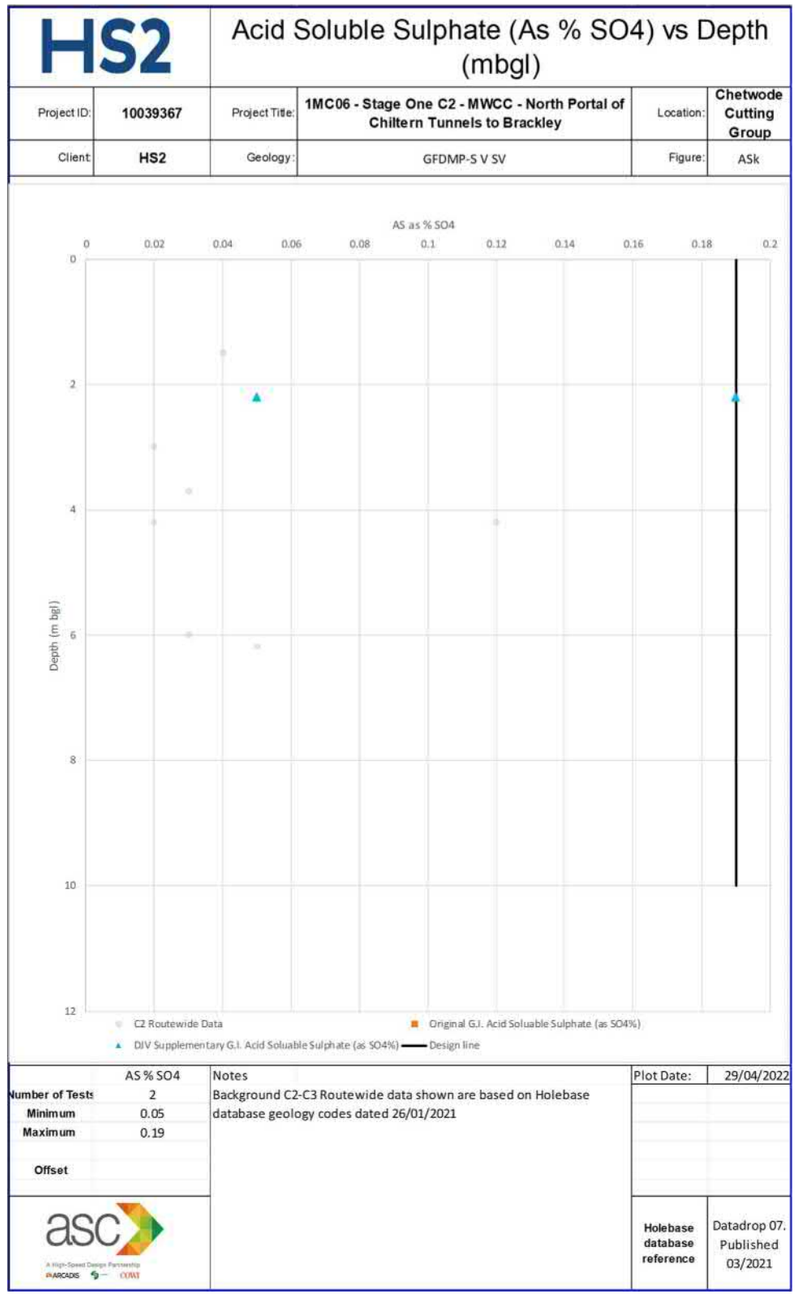


Figure 16 Till (clay): Total sulfur

HS2 Ltd - Code 1 - Accepted



(a)



(b)

Figure 17 Glaciofluvial deposits (sand): (a) Water soluble sulfate concentration, (b) Acid soluble sulfate percentage

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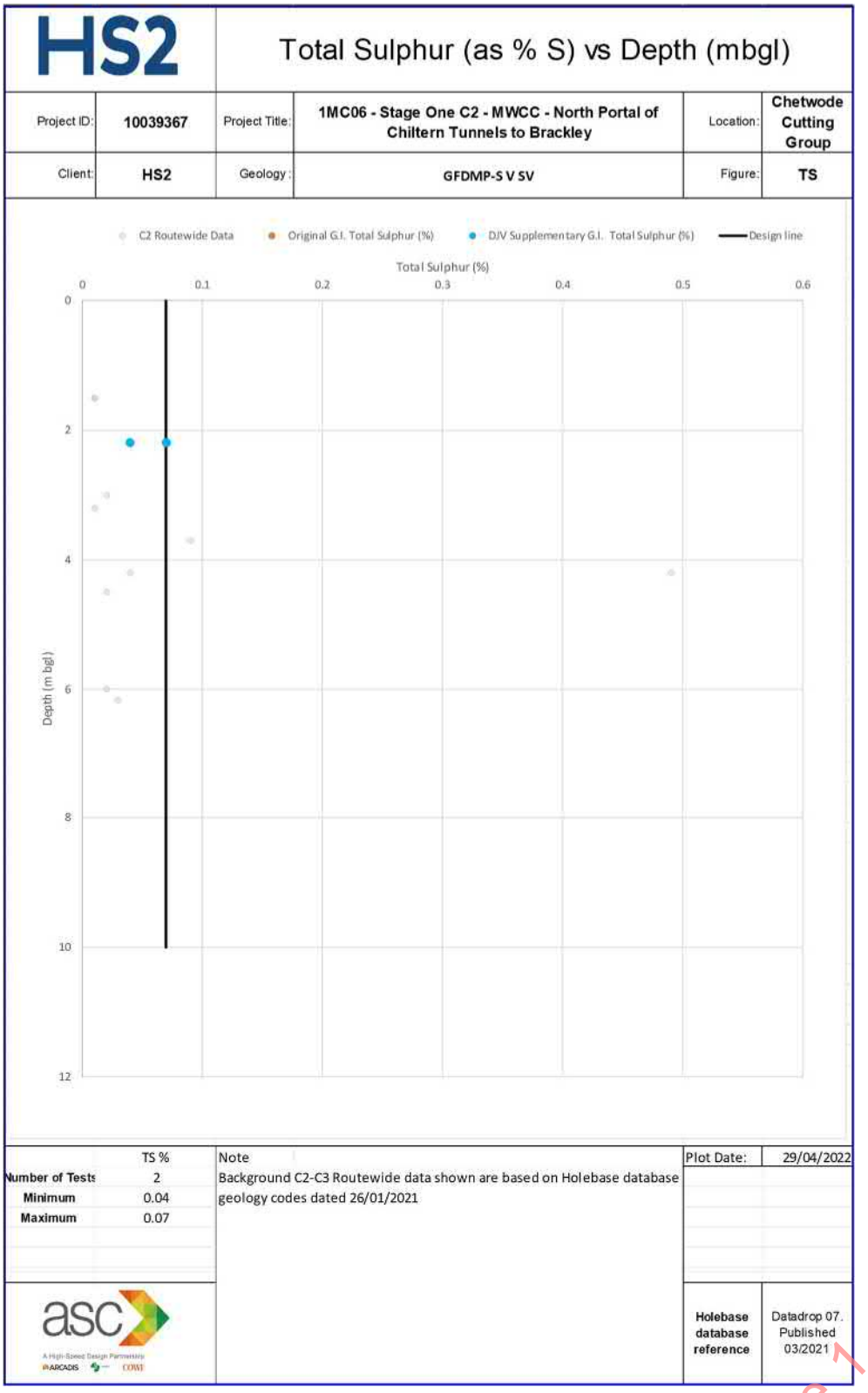
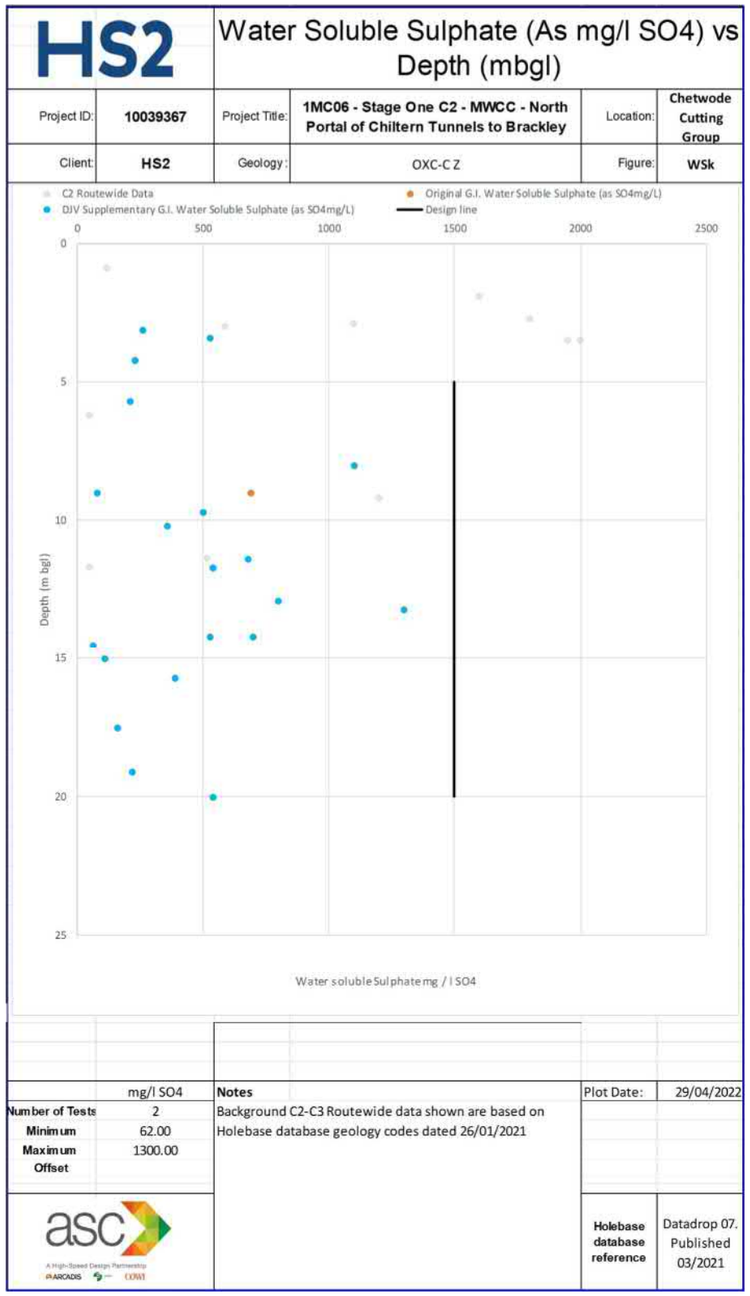
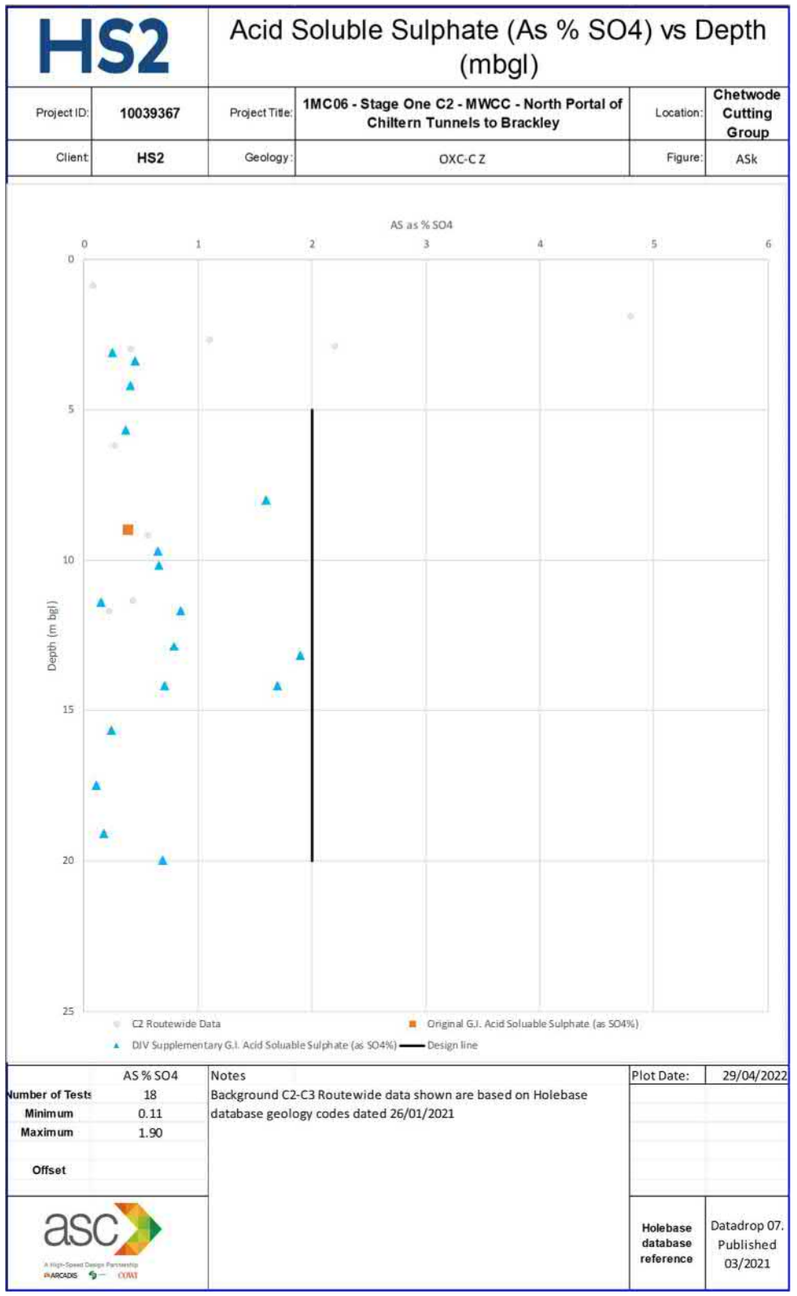


Figure 18 Glaciofluvial deposits (sand): Total sulfur

HS2 Ltd - Code 1 - Accepted



(a)



(b)

Figure 19 Oxford Clay: (a) Water soluble sulfate concentration, (b) Acid soluble sulfate percentage

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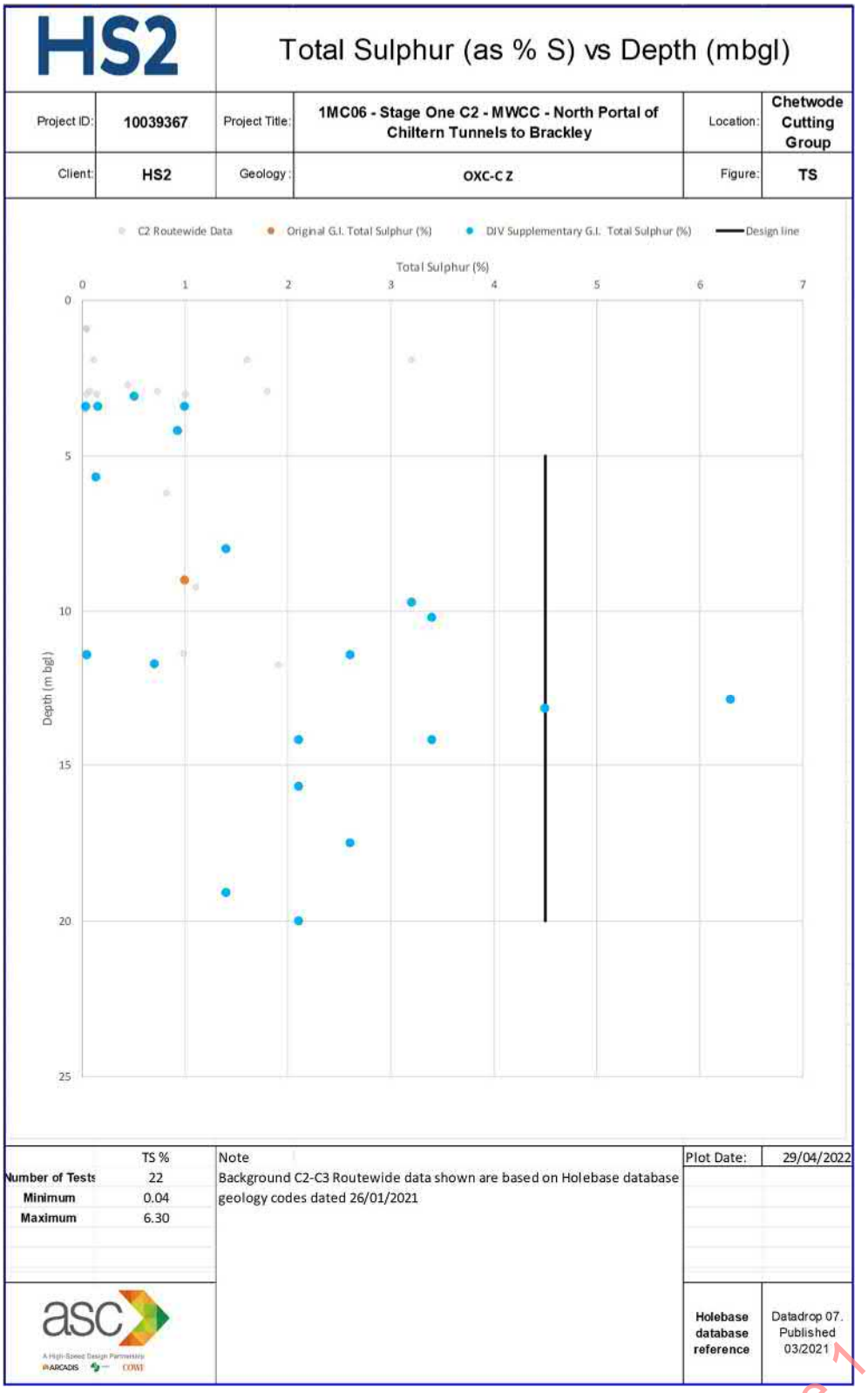
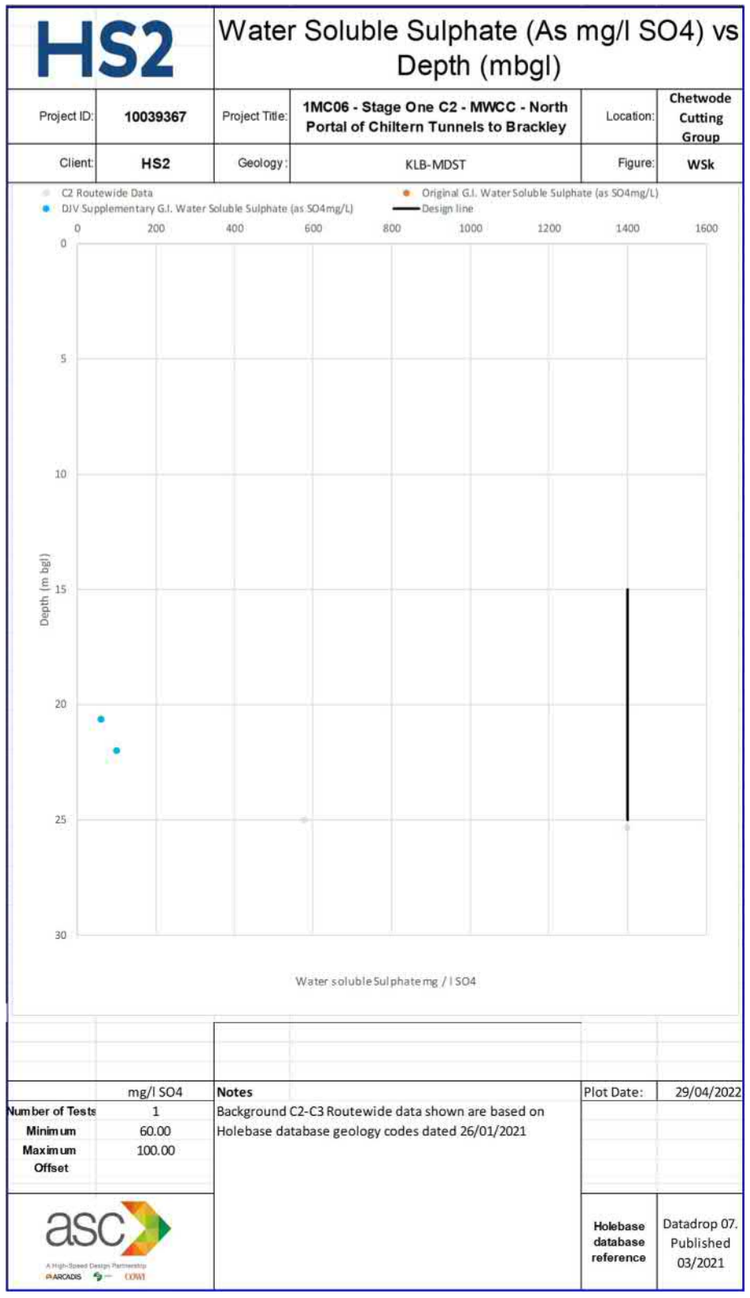
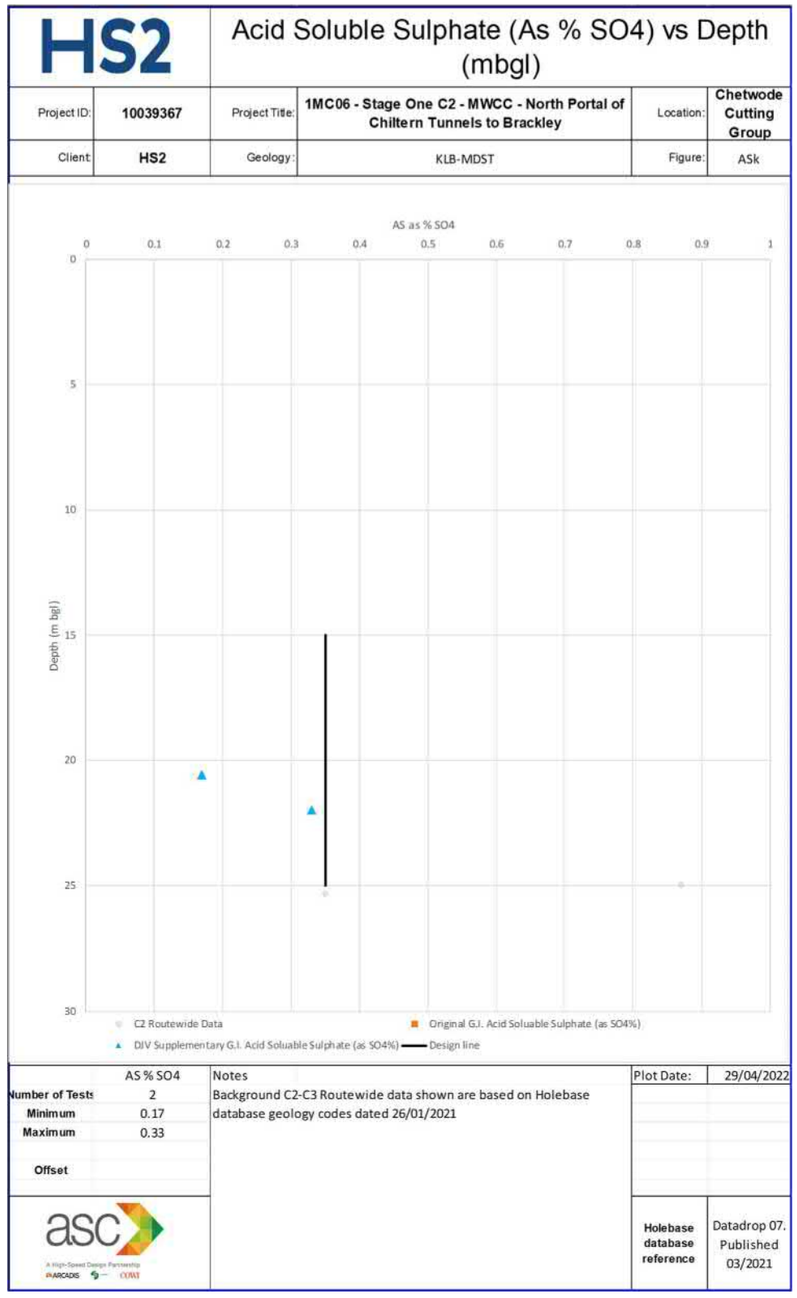


Figure 20 Oxford Clay: Total sulfur

HS2 Ltd - Code 1 - Accepted



(a)



(b)

Figure 21 Kellaways formation (mudstone): (a) Water soluble sulfate concentration, (b) Acid soluble sulfate percentage

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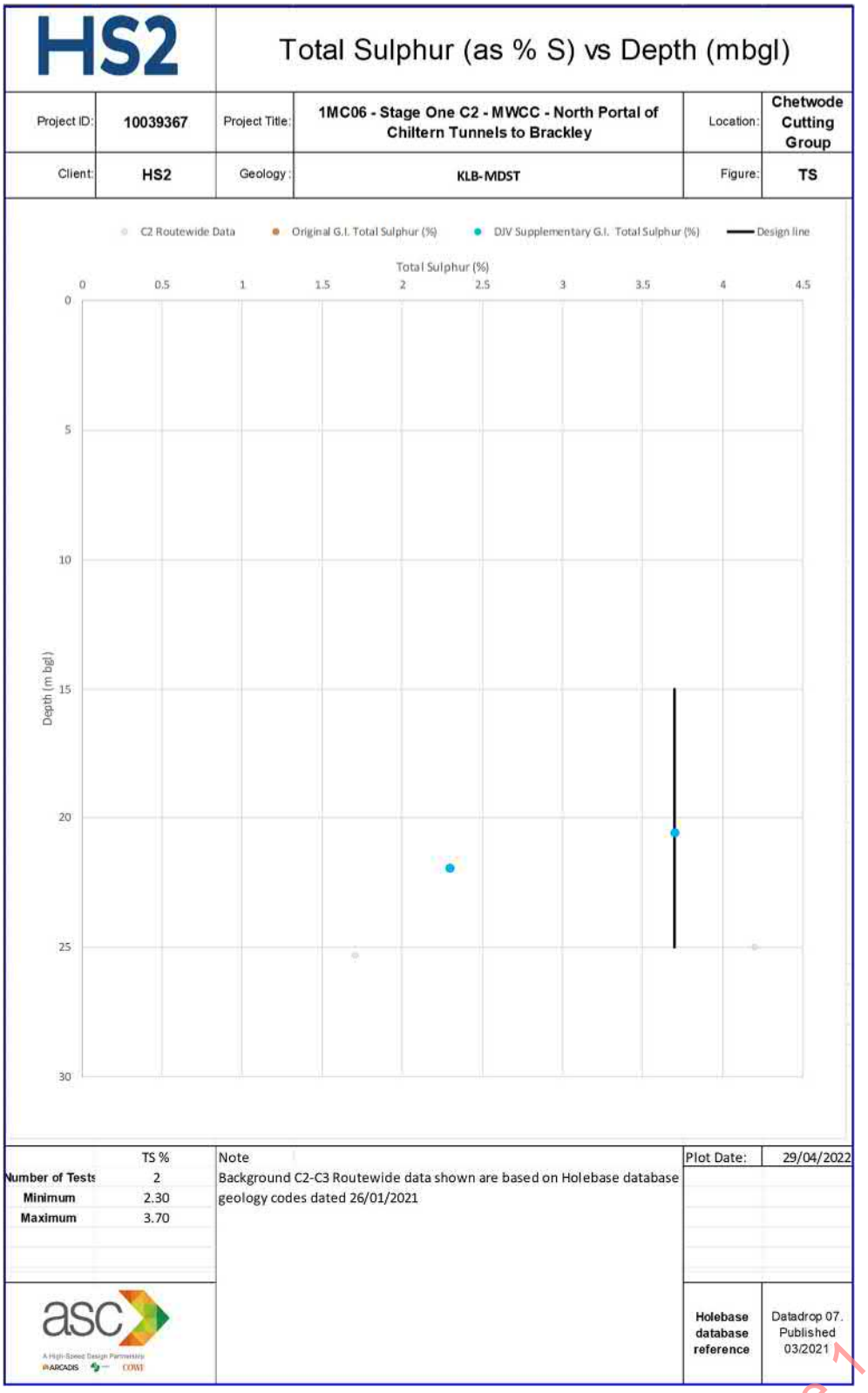
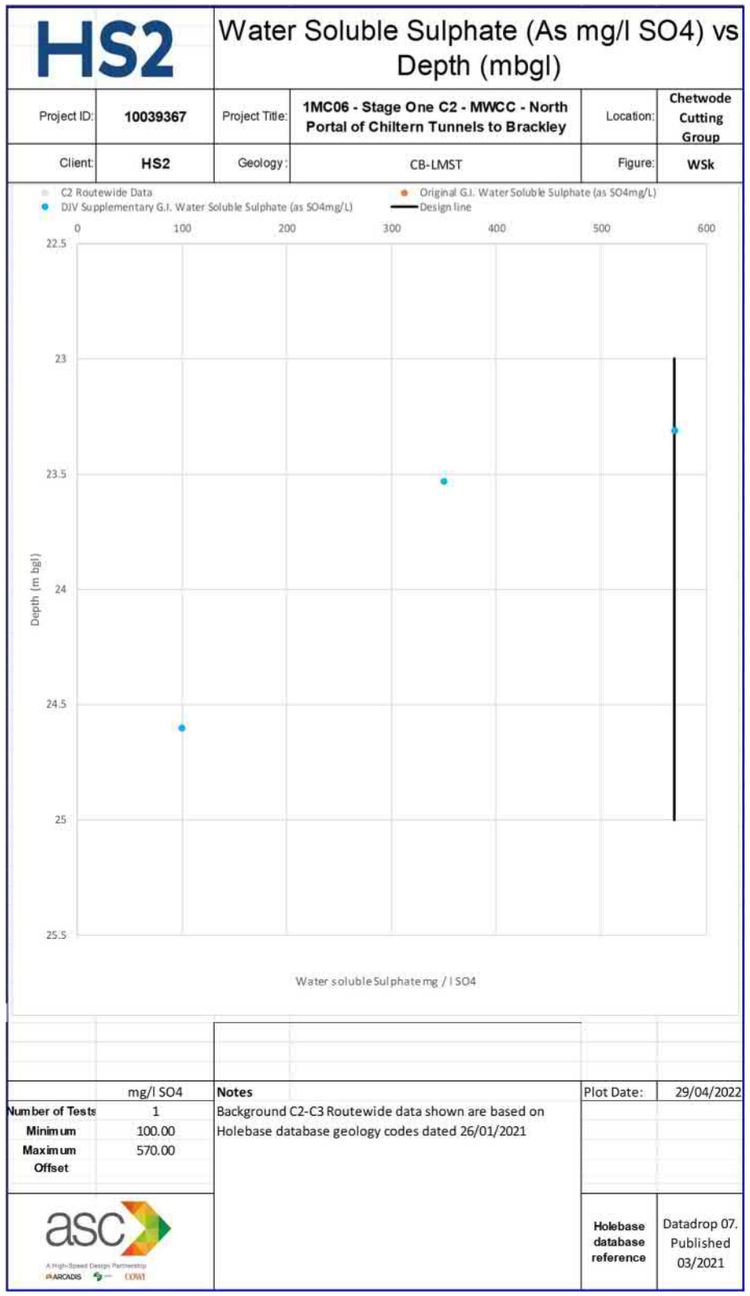
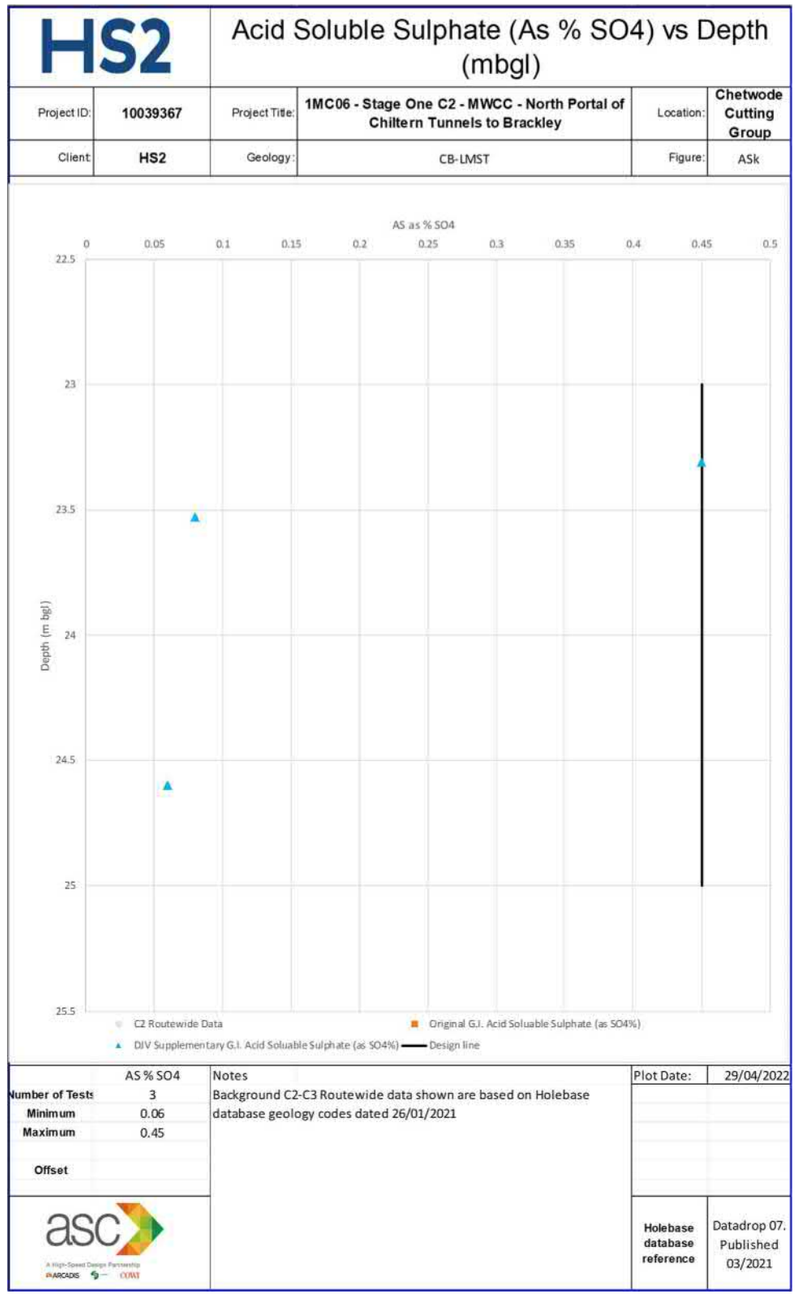


Figure 22 Kellaways formation (mudstone): Total sulfur

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(a)



(b)

Figure 23 Cornbrash formation (limestone): (a) Water soluble sulfate concentration, (b) Acid soluble sulfate percentage

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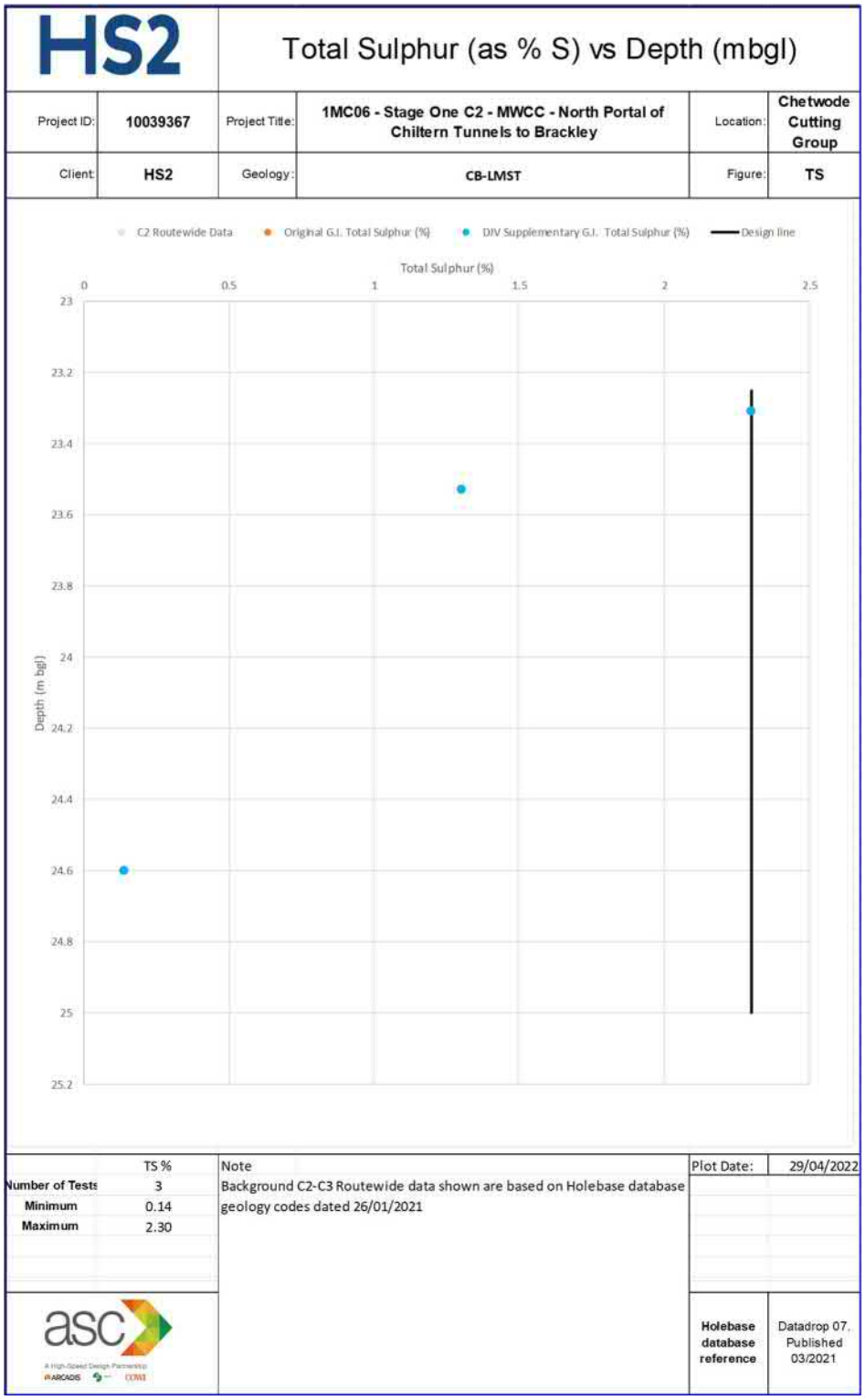


Figure 24 Cornbrash formation (limestone): Total sulfur

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2 Study of foundations

The foundation design was carried out in accordance with BS EN 1997. It takes into account the loading from the structure, as well as heave effects induced by the excavation of the cutting.

2.1 Foundations features

The proposed foundation system is composed of

- 2ϕ1050 piles for each abutment
- 2ϕ1200 piles for each pier

The table below presents the proposed design for the piles.

Table H.106 Pile foundations properties

Support	Piles layout	Diameter (mm)	Pile head elevation (m AOD)	Pile base elevation (m AOD)	Pile length (m)
West abutment	2 piles d = 4.1 m	1050	101.2	78.5	22.7
West pier	2 piles d = 4.1 m	1200	96.2	78.5	17.7
East pier	2 piles d = 4.1 m	1200	96.1	78.5	17.6
East abutment	2 piles d = 4.1 m	1050	101.1	78.5	22.6

Note: d is the centre-to-centre distance

2.2 Earthworks behind abutments

The earthworks behind abutment are illustrated on Figure 25. 6N5 material will be used behind the abutments since the abutments are not integral. The properties of the fill materials are listed in the following table.

Table H.107 Friction angle ranges for 6N5 fill material

	Lower value
φ'_{peak} (°)	35

The soil pressures behind abutments are determined according to PD6694 in function of the aforementioned values of friction angles. The resulting active pressure coefficients is equal to 0.27.

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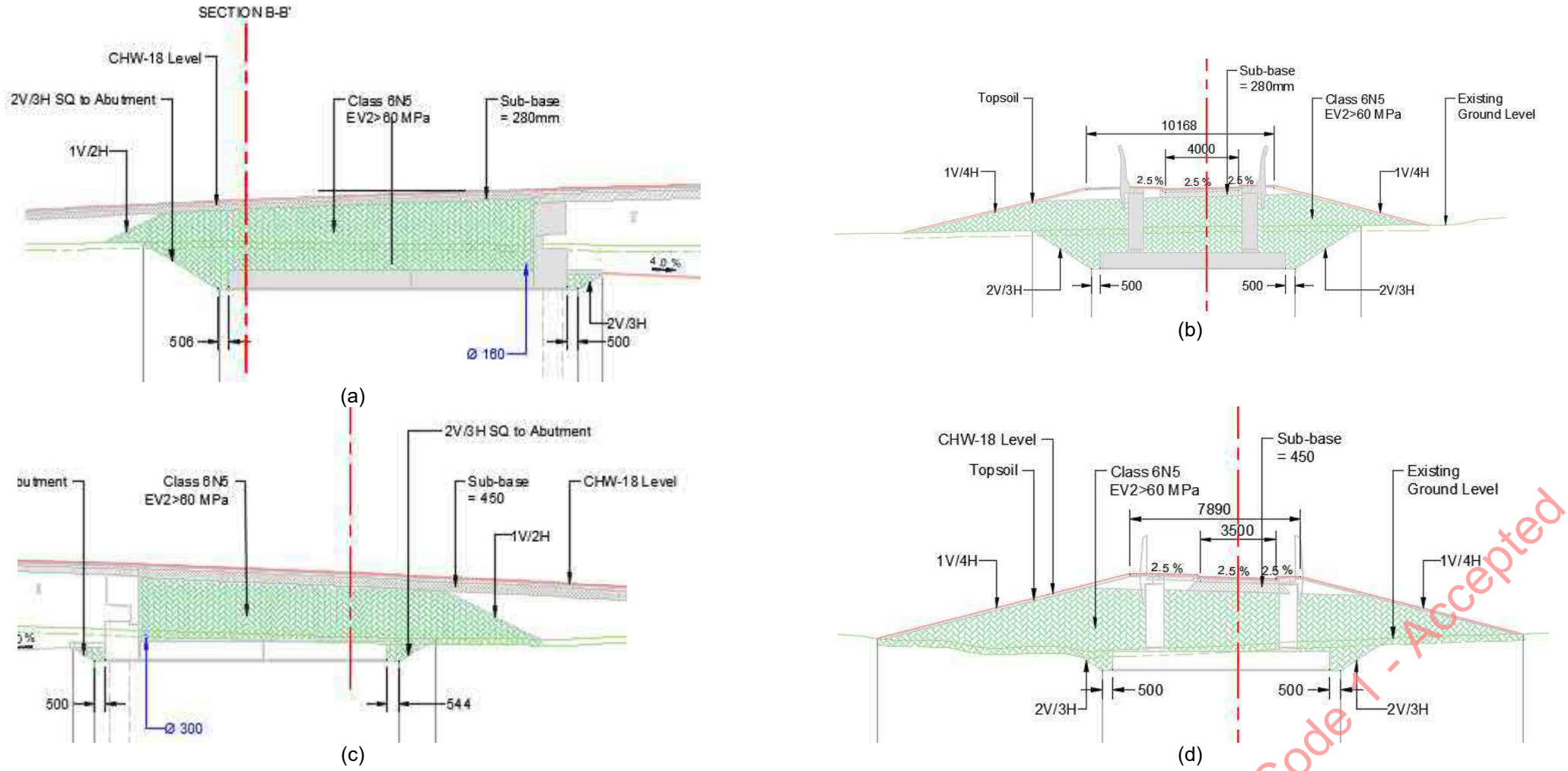


Figure 25 Earthworks behind abutments: (a) West abutment elevation view, (b) West abutment cross section, (c) East abutment elevation view and (d) East abutment cross section

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2.3 p-y and t-z curves

The interaction between the piles and the soil is modelled through p-z and t-z curves. These are interaction laws, formulated in the form of bilinear laws, with a flat part representing total plastification of the soil.

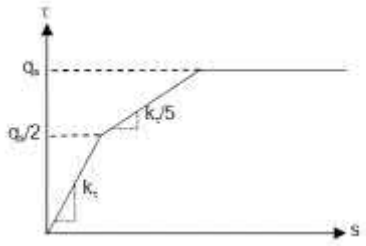


Figure 26 Schematic illustration of a t-z law

The slopes of the linear parts and the flat part are calculated in a way to fit equivalent laws in BS EN 1997. Figures in Appendix G illustrates these interaction laws.

In order to take into account the variation of the undrained shear strength with depth, the Oxford Clay formation is divided in 4 sublayers, and a set of t-z p-y laws is calculated for each sublayer (with the corresponding value of C_u).

The values calculated in the present case are the following for the piers and abutments piles, according to M1 and M2 approach.

For seismic calculations, according to §1.4, the modules K are multiplied with a factor of 3.

Table H.108 Soil structure interaction laws - Piers piles - M1

Piers – M1	Base level	Shaft friction t-z		Base resistance q-b		Lateral interaction p-y	
Soil	m AOD	K_{t1} (kN/m/m)	q_s (kN/m)	K_{p1} (kN/m)	q_p (kN)	K_{s1} (kN/m/m)	P (kN/m)
OXC 1	95.6	2.3E+04	1.7E+02	5.8E+04	1.1E+03	7.7E+04	1.5E+03
OXC 2	93	2.7E+04	2.0E+02	6.8E+04	1.3E+03	9.6E+04	1.7E+03
OXC 3	90.4	3.2E+04	2.3E+02	7.9E+04	1.5E+03	1.2E+05	2.0E+03
OXC 4	85.1	3.2E+04	2.3E+02	7.9E+04	1.5E+03	1.2E+05	2.0E+03
KLB	79.7	3.2E+04	2.3E+02	7.9E+04	1.5E+03	1.2E+05	2.0E+03
CB	78.5	3.3E+05	2.4E+03	8.8E+05	1.7E+04	9.6E+06	1.3E+05

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Table H.109 Soil structure interaction laws - Piers piles - M2

Piers – M2	Base level	Shaft friction t-z		Base resistance q-b		Lateral interaction p-y	
Soil	m AOD	K_{t1} (kN/m/m)	q_s (kN/m)	K_{p1} (kN/m)	q_p (kN)	K_{s1} (kN/m/m)	P (kN/m)
OXC 1	95.6	1.7E+04	1.2E+02	4.1E+04	8.0E+02	1.5E+04	5.4E+02
OXC 2	93	2.0E+04	1.4E+02	4.9E+04	9.5E+02	2.3E+04	7.8E+02
OXC 3	90.4	2.3E+04	1.6E+02	5.6E+04	1.1E+03	7.5E+04	1.4E+03
OXC 4	85.1	2.3E+04	1.6E+02	5.6E+04	1.1E+03	7.5E+04	1.4E+03
KLB	79.7	2.3E+04	1.6E+02	5.6E+04	1.1E+03	7.5E+04	1.4E+03
CB	78.5	2.8E+05	2.0E+03	7.4E+05	1.4E+04	6.8E+06	9.4E+04

Table H.110 Soil structure interaction laws - Abutments piles - M1

Abutments – M1	Base level	Shaft friction t-z		Base resistance q-b		Lateral interaction p-y	
Soil	m AOD	K_{t1} (kN/m/m)	q_s (kN/m)	K_{p1} (kN/m)	q_p (kN)	K_{s1} (kN/m/m)	P (kN/m)
Till	100.3	1.6E+04	9.9E+01	3.5E+04	5.8E+02	8.8E+03	2.8E+02
GFD	98.2	8.4E+03	5.3E+01	1.8E+04	3.1E+02	4.2E+03	2.1E+02
OXC 1	95.6	2.3E+04	1.5E+02	5.1E+04	8.6E+02	7.7E+04	1.3E+03
OXC 2	93	2.7E+04	1.7E+02	6.0E+04	1.0E+03	9.6E+04	1.5E+03
OXC 3	90.4	3.2E+04	2.0E+02	6.9E+04	1.2E+03	1.2E+05	1.7E+03
OXC 4	85.1	3.2E+04	2.0E+02	6.9E+04	1.2E+03	1.2E+05	1.7E+03
KLB	79.7	3.2E+04	2.0E+02	6.9E+04	1.2E+03	1.2E+05	1.7E+03

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CB	78.5	3.3E+05	2.1E+03	7.7E+05	1.3E+04	9.6E+06	1.2E+05

Table H.111 Soil structure interaction laws - Abutments piles - M2

Abutments – M1	Base level	Shaft friction t-z		Base resistance q-b		Lateral interaction p-y	
Soil	m AOD	K_{t1} (kN/m/m)	q_s (kN/m)	K_{p1} (kN/m)	q_p (kN)	K_{s1} (kN/m/m)	P (kN/m)
Till	100.3	1.1E+04	7.1E+01	2.5E+04	4.2E+02	4.7E+03	2.0E+02
GFD	98.2	6.0E+03	3.8E+01	1.3E+04	2.2E+02	2.1E+03	1.3E+02
OXC 1	95.6	1.7E+04	1.0E+02	3.6E+04	6.1E+02	1.6E+04	5.0E+02
OXC 2	93	2.0E+04	1.2E+02	4.3E+04	7.2E+02	2.4E+04	7.3E+02
OXC 3	90.4	2.3E+04	1.4E+02	4.9E+04	8.3E+02	7.5E+04	1.2E+03
OXC 4	85.1	2.3E+04	1.4E+02	4.9E+04	8.3E+02	7.5E+04	1.2E+03
KLB	79.7	2.3E+04	1.4E+02	4.9E+04	8.3E+02	7.5E+04	1.2E+03
CB	78.5	2.8E+05	1.8E+03	6.5E+05	1.1E+04	6.8E+06	8.2E+04

2.4 Stiffness matrixes

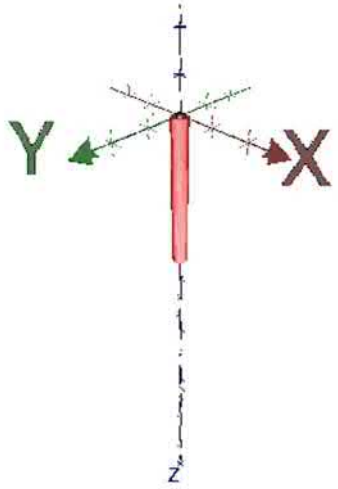
The stiffness matrices of the piles set for each support are listed in following tables. They have been calculated with the software FoxTa\Groupie+, considering that the pile caps are rigid.

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Table H.112 Stiffness matrices of abutments piles

		Static											
		Short term						Long term					
		HX	MY	HY	MX	V	MZ	HX	MY	HY	MX	V	MZ
K/2	HX	1.0E+05	2.9E+05					7.3E+04	1.8E+05				
	MY	2.9E+05	1.3E+06					1.8E+05	7.2E+05				
	HY			1.0E+05	-2.9E+05					7.3E+04	-1.8E+05		
	MX			-2.9E+05	4.2E+06					-1.8E+05	2.8E+06		
	V					9.9E+05						7.1E+05	
	MZ						3.0E+05						2.2E+05
Kx2	HX	2.6E+05	5.2E+05					1.9E+05	3.2E+05				
	MY	5.2E+05	1.7E+06					3.2E+05	9.6E+05				
	HY			2.6E+05	-5.2E+05					1.9E+05	-3.2E+05		
	MX			-5.2E+05	7.4E+06					-3.2E+05	4.7E+06		
	V					1.9E+06						1.3E+06	
	MZ						7.7E+05						5.5E+05

		Seismic					
		Short term					
		HX	MY	HY	MX	V	MZ
K/2	HX	2.2E+05	5.5E+05				
	MY	5.5E+05	2.2E+06				
	HY			2.2E+05	-5.5E+05		
	MX			-5.5E+05	8.5E+06		
	V					2.1E+06	
	MZ						6.5E+05
Kx2	HX	5.6E+05	9.7E+05				
	MY	9.7E+05	2.9E+06				
	HY			5.6E+05	-9.7E+05		
	MX			-9.7E+05	1.4E+07		
	V					3.8E+06	
	MZ						1.7E+06

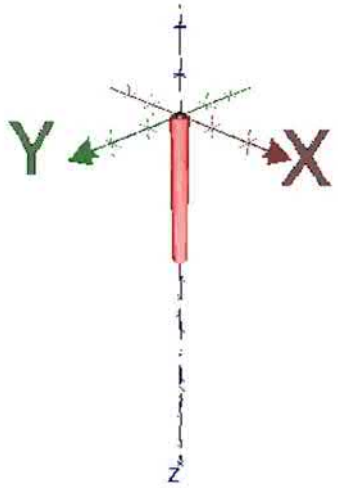


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Table H.113 Stiffness matrices of piers piles

Static														
		Short term							Long term					
		HX	MY	HY	MX	V	MZ		HX	MY	HY	MX	V	MZ
K/2	HX	3.4E+05	6.5E+05					HX	2.9E+05	4.5E+05				
	MY	6.5E+05	2.3E+06					MY	4.5E+05	1.4E+06				
	HY			3.4E+05	-6.5E+05			HY			2.9E+05	-4.5E+05		
	MX			-6.5E+05	5.4E+06			MX			-4.5E+05	3.5E+06		
	V					1.1E+06		V					7.3E+05	
	MZ						1.0E+06	MZ						8.4E+05
Kx2	HX	1.3E+06	1.5E+06					HX	1.1E+06	1.1E+06				
	MY	1.5E+06	3.6E+06					MY	1.1E+06	2.1E+06				
	HY			1.3E+06	-1.5E+06			HY			1.1E+06	-1.1E+06		
	MX			-1.5E+06	1.1E+07			MX			-1.1E+06	7.3E+06		
	V					2.6E+06		V					1.8E+06	
	MZ						3.8E+06	MZ						3.1E+06

Seismic							
		Short term					
		HX	MY	HY	MX	V	MZ
K/2	HX	8.5E+05	1.4E+06				
	MY	1.4E+06	4.1E+06				
	HY			8.5E+05	-1.4E+06		
	MX			-1.4E+06	1.2E+07		
	V					2.8E+06	
	MZ		#####				2.5E+06
Kx2	HX	3.2E+06	3.2E+06				
	MY	3.2E+06	6.3E+06				
	HY			3.2E+06	-3.2E+06		
	MX			-3.2E+06	2.2E+07		
	V					5.3E+06	
	MZ		#####				9.4E+06



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2.5 Pile loads

The load induced on the supports for each combination are listed in detail in Appendix H.

2.6 Bearing capacity

The bearing capacity of piles is verified in accordance to BS EN 1997-1, BS EN 1997-1\NA and BS 8004_2015.

The characteristic pile axial resistance is calculated using the shear resistance values defined in §1.2, while the design pile resistance is calculated for three limit states: SLS, ULS/DA1-C1 and ULS/DA1-C2.

The input parameters of the calculation are listed in the following table.

Table H.114 Input parameters for the bearing capacity check of piles

Geological formation	Soil type	γ (kN/m³)	C_u (kPa)	UCS (MPa)
Glaciofluvial deposits	Coarse soil	21	50	-
Oxford clay	Fine soil	21	67 + 8.3z (max. 150 kPa)	-
Kellaways formation	Mudstone	21	150	-
Cornbrash formatiob	Limestone	21	-	10

General parameters	
Static load tests	No
SLS verification	Covered by ULS due to the embedment in WHL (settlements < 5 mm)
Execution	Replacement, Bored pile, without stabilizing fluid

These parameters lead to the following values for the characteristic shaft friction resistance and base resistance.

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Table H.115 Characteristic shaft friction resistance and base resistance of the formations

Geological formation	C_u (kPa)	UCS (MPa)	q_s (kPa)	q_b (MPa)
Glaciofluvial deposits	50	-	16	0.36
Oxford clay	67 + 8.3z (max. 150 kPa)	-	27 + 3.3z (max.60 kPa)	0.6 + 0.075 z (max. 1.35 MPa)
Kellaways formation	150	-	60	1.35
Cornbrash formatiob	-	10	630	15

Based on these results, the pile design resistance is calculated and summarized in the following table, along with the maximal normal force by pile for each combination. Bearing capacity is verified for all combinations.

Table H.116 Bearing capacity check

Pile	Limit state	Maximal axial force on pile (kN)	Design resistance force (kN)	Check
Piers	SLS	5387	6841	OK
	ULS/DA1-C1	7074	18959	OK
	ULS/DA1-C2	5724	9479	OK
	ULS/SEISMIC	5994	13406	OK
Abutments	SLS	2061	5486	OK
	ULS/DA1-C1	2786	14054	OK
	ULS/DA1-C2	2300	7027	OK
	ULS/SEISMIC	1678	9938	OK

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2.7 Structural forces

The structural forces are calculated using the foundation layout, the interaction laws detailed in §2.3 and the loading from structure analysis. The calculation is done for 4 load combinations: SLS QP, SLS C, ULS STR/GEO and ULS Seismic.

The maximal values of the structural forces in the piles for each load combination are listed in the table below.

Table H.117 Maximal structural forces in piles

Pile		N_{max} (kN)	M_{max} (kN.m)	T_{max} (kN)	N_{min} (kN)
Piers	SLS C	5387	1056	575	899
	SLS F	5143	685	422	1198
	SLS QP	4586	466	230	1202
	ULS Seismic	5994	1267	509	791
	ULS STR/GEO (DA1-C1)	7074	1413	751	629
	ULS STR/GEO (DA1-C2)	5724	1207	649	956
Abutments	SLS C	2061	588	201	120
	SLS F	1687	553	177	157
	SLS QP	1361	496	152	161
	ULS Seismic	1678	526	207	97
	ULS STR/GEO (DA1-C1)	2786	798	282	31
	ULS STR/GEO (DA1-C2)	2300	768	257	45

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3 Heave assessment

Heave effects are assessed through a mixed numerical and analytical approach. The heave induced displacements are calculated from a 2D FE model of the cutting in the vicinity of the overbridge. Then, these displacements are used to estimate the supplementary displacements and forces in the piles and the deck, using an analytical approach featuring interaction laws detailed in §4.3.

3.1 Additional parameters

The heave induced displacements are calculated through a 2D finite element modelling of the cutting, using Plaxis 2D. The soil behaviour is modelled through the Hardening Soil Small constitutive law for the Oxford Clay and Kellaways formations, and through linear elastic law for the till and glaciofluvial deposits; the layers beneath the Kellaways formation are considered as substratum. The displacements are calculated in free field conditions, i.e. in the absence of the structure.

3.1.1 HSS parameters definition

The Hardening Soil Small constitutive law main parameters are secant stiffness (E_{50}), unloading/reloading stiffness (E_{ur}), shear modulus at very small strain (G_0) and the threshold shear strain at which $G_s = 0.722G_0$ ($\gamma_{0.7}$). These parameters are defined through specific tests: triaxial and pressuremeter tests, as well as shear wave measurements and resonant column tests. In the present case, these parameters are defined from a cross analysis of tests conducted on Oxford Clay samples collected from boreholes located along the construction area. This analysis is detailed in a proper note (1MC07-CEK-GT-REP-CS07_CL14-000013 – 18/02/2020).

In order to account for the variation of the parameters values with depth, the OXC formation is divided in three virtual sublayers defined in terms of the depth relative to the soil surface: 0-10 m, 10-15 m and 15-25 m. For each range of depth, lower and higher boundary values are defined to account for the scatter distribution of the test points.

Figure 27, Figure 28 and Figure 29 illustrate respectively the calculated properties from measurement in function of depth, for E_{50}, E_{ur}, and G_0. Lower and higher boundary values are marked in dotted red lines.

The value of $\gamma_{0.7}$ for each range is estimated based on the experimental results and the Santos and Correia theoretical correlation between G_s/G_0 γ and $\gamma_{0.7}$. This equation is written as follows.

$$\frac{G_s}{G_0} = \frac{1}{1 + 0.385\left|\frac{\gamma}{\gamma_{0.7}}\right|}$$

For each range of depth (0-10 m, 10-15 m, 15-25 m), triaxial tests results were plotted as G/G_0 versus shear strain γ, G_0 being the maximum shear modulus measured for each triaxial test. Then, the Santos & Correia theoretical equation has then been plotted over these experimental results, for various values of $\gamma_{0.7}$ and a best-fitting curve has been derived. An example of this fitting for the 0-10 m range is illustrated on Figure 30. The value of $\gamma_{0.7} = 0.015$ corresponds to the best fitting curve for these data points in this case.

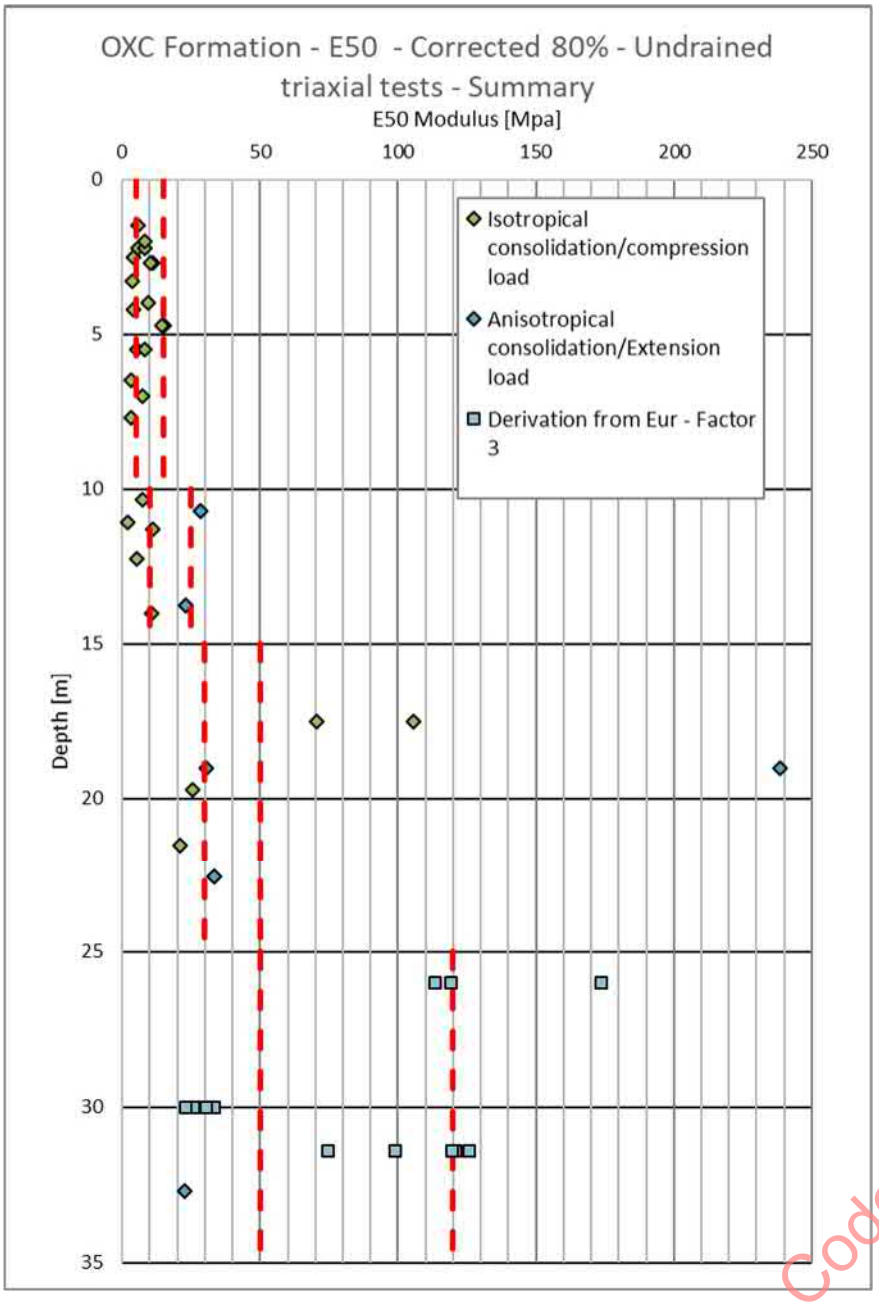
Hence, the HSS parameters can be summarized in the following table.

Table H.118 HSS model properties

Layer	E_{50} (MPa)	E_{ur} (MPa)	G_0 (MPa)	$\gamma_{0.7}$

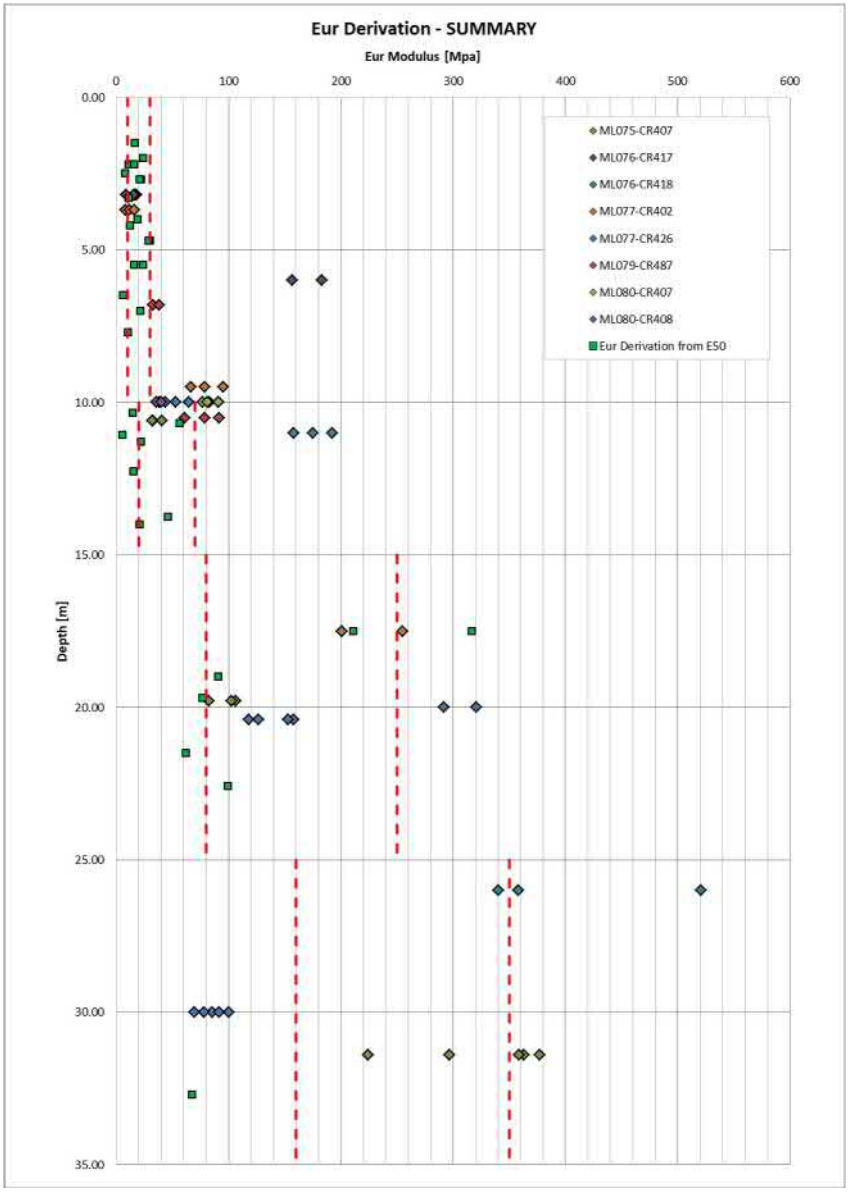
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Oxford clay (0-10m)	5-15	10-30	25-100	0.015
Oxford clay (10-15m)	10-25	20-70	80-200	0.010
Oxford clay (15-25m)	30-50	80-250	150-350	0.010



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Figure 27 Secant stiffness E50 versus depth – Lower and Upper boundaries



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Figure 28 Unloading/reloading stiffness Eur versus depth

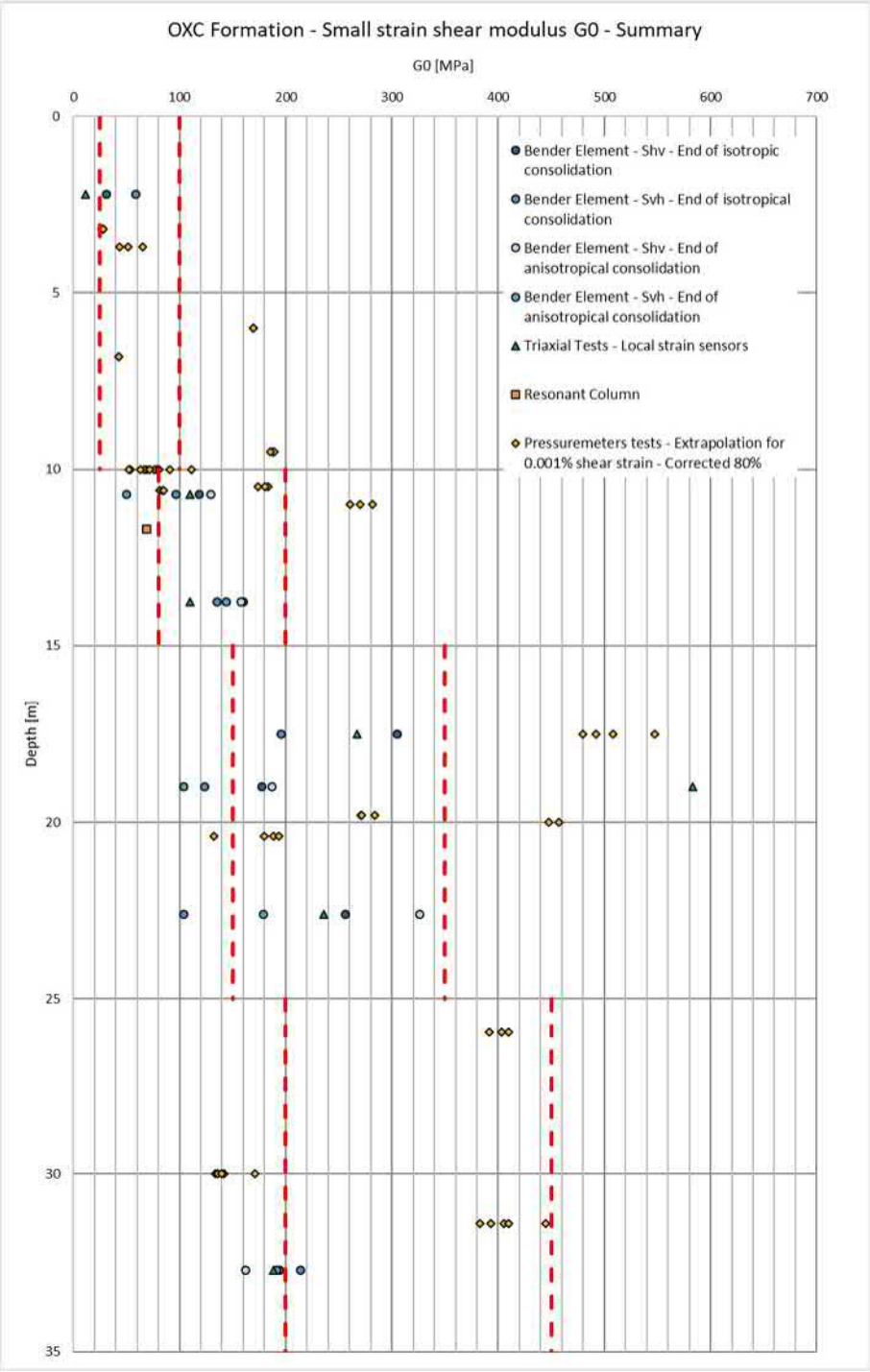


Figure 29 Shear modulus at very small strain G0 versus depth

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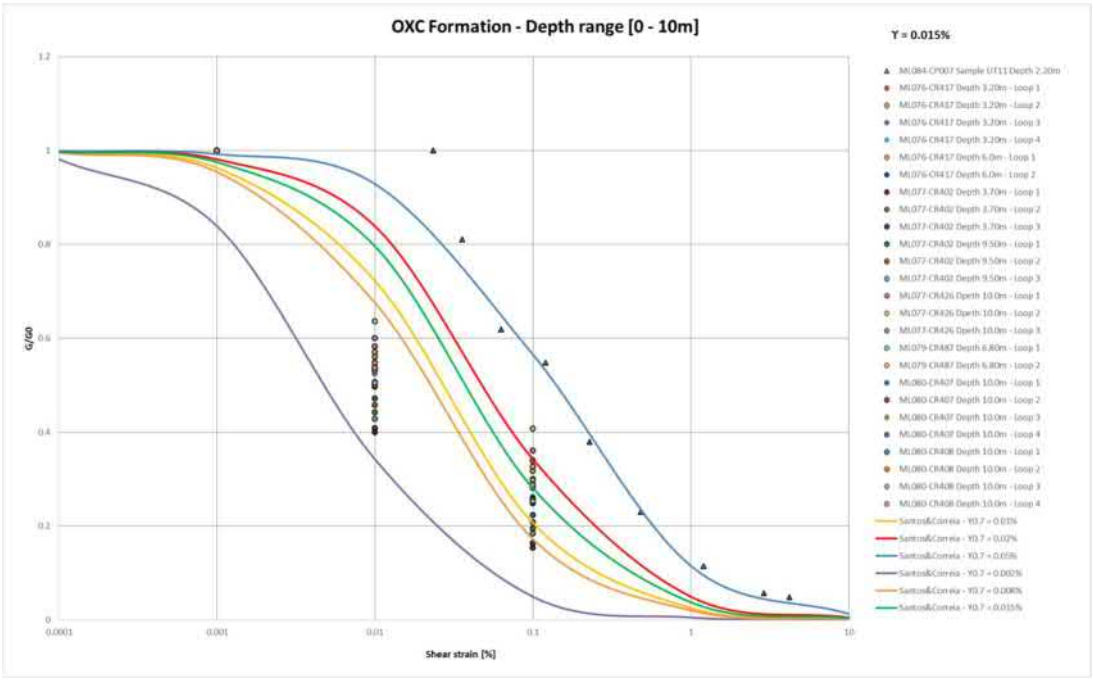


Figure 30 G/G_0 vs shear strain experimental results and Santos & Correia hyperbolic law – Depth range [0 – 10 m]

In accordance with the assumptions for the undrained shear strength definition, the parameters relative to the Kellaways formation are assumed to be equal to those of the overlying Oxford Clay sublayer.

Two separate calculations using higher and lower boundary values for each layer are conducted. The most conservative values for horizontal and vertical displacements are taken for each one.

3.1.2 Water level

Two separate calculations using the two water levels established in §1.5 are conducted. The most conservative values for horizontal and vertical displacements are taken for each one.

3.1.3 Construction sequence

The following construction sequence for the earthworks and foundations construction works is used as a base for the phasing of the model. The construction methodology is bottom-up.

- Excavate to the level of the abutments piles
- Construct the piles starting from this level: 21 days
- Total excavation of the cutting: 19 days
- Wait period after the total excavation of the cutting: 138 days

Construct the deck (concrete works): 138 days after the end of the total excavation. The construction of the overground elements of the supports such as piers, abutments and other structural elements can be done during the 138 days wait period).

Figure 31 illustrates a general view of the FE model in the final phase (complete depth excavation).

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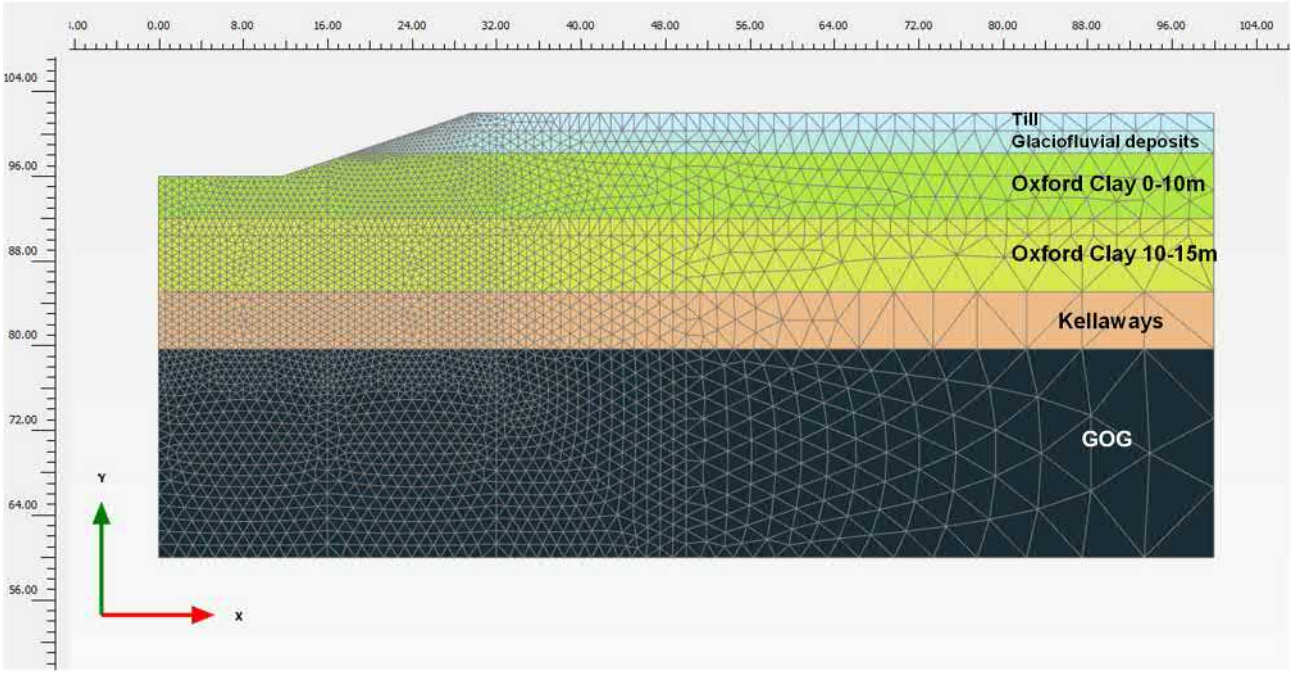


Figure 31 General view of the FE model

3.1.4 Time dependant behaviour

Time dependant behaviour is characterised through the definition of non-zero permeability in the Oxford clay formation, and by extension, in the Kellaways formation.

The value is defined from routewide measurement in Oxford Clay formation along the Chetwode cutting. The horizontal permeability can be estimated by a constant value with depth, equal to 1 x 10^{-8} m/s (K_h = 8.64 x 10^{-4} m/day). The vertical permeability is equal to 1/5 of the horizontal permeability K_v = 1.73 x 10^{-4} m/day. The same values are used by extension for the Kellaways formation.

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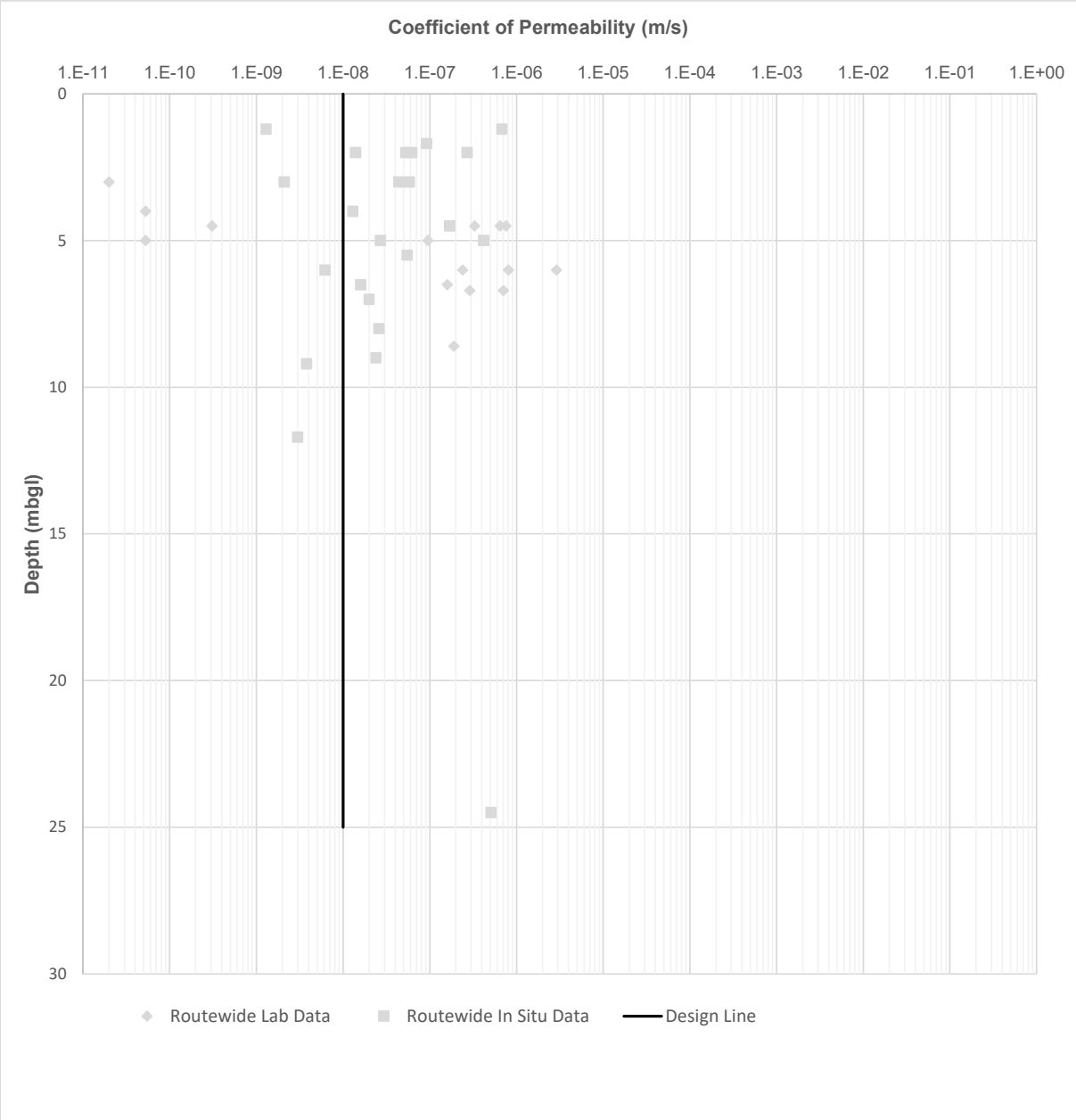


Figure 32 Permeability values in the Oxford Clay formation

3.2 Heave induced displacements

The construction sequence is detailed in the following table. In order to assess the heave effects on the structure, the heave induced displacements during the phases where the latter is present have to be considered. The table outlines also the correspondence between construction phases and the state of the structure at each phase.

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Table H.119 Construction sequence

Phase no	Description	Duration	State of the structure at the end of the phase
1	Excavate to the level of the abutments piles	-	-
2	Construct the piles	21 days	Piles only
3	Total excavation of the cutting	19 days	Piles only
4	Wait period	138 days	Piles only
5	Construct the deck	-	Complete structure
6	Service period	120 years	Complete structure

Thus, the effects of the heave induced displacements during phases 2 to 4 have to be considered on the piles individually; while the heave effects induced during and after phase 5 have to be considered on the complete structure (piles + piers + deck).

Figures below illustrate the resulting displacements near the supports piles.
Note that these displacements were obtained in the calculation with the lower boundary value of soil modules.
For each support, the free field horizontal and vertical displacements, expected to be applied to the piles, are plotted in function of the AOD level. Three plots are presented:

- the induced displacement between the construction of the piles and the construction of the deck (noted “before deck construction”). It corresponds to the displacements that occur during phases 2 to 4.
- the induced displacement starting from the construction of the deck (noted “after deck construction”). It corresponds to the displacements that occur during and after phase 5.
- the sum of the two aforementioned displacements (noted “Total”).

Note that a positive vertical displacement corresponds to an upwards heave of the soil, and a negative displacement corresponds to a displacement towards the excavation centre.

Near abutments piles

The heave induced soil displacements expected to be applied at the abutments piles are as follows.

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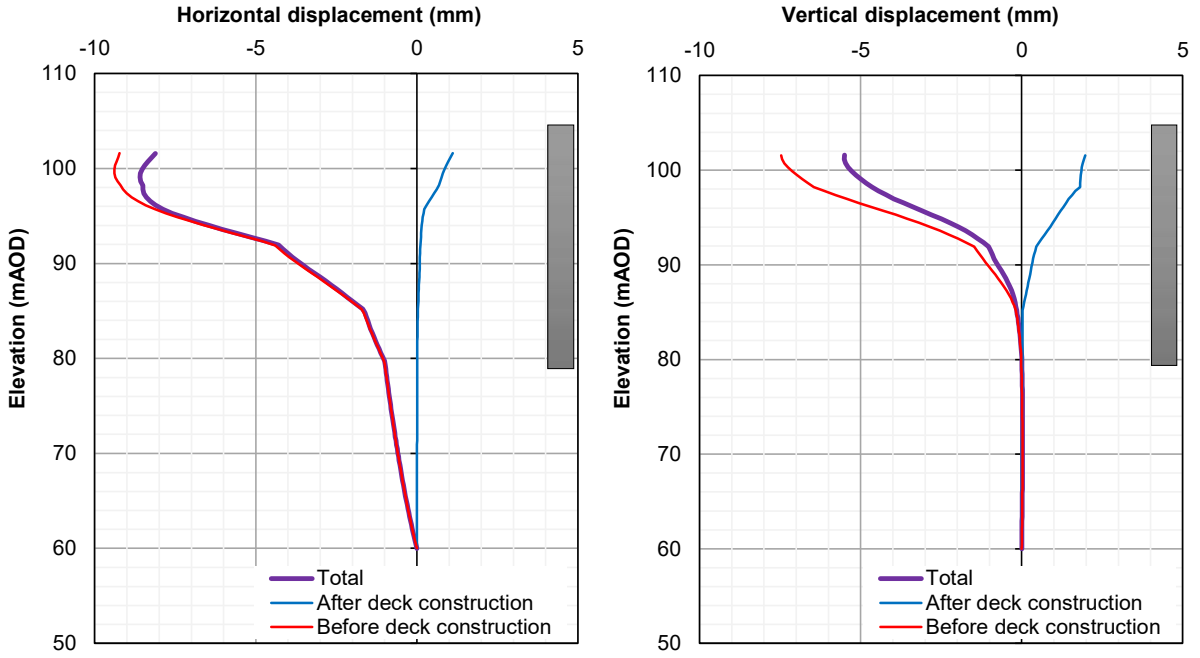


Figure 33 Heave induced displacements near the abutments piles

Near piers piles

The heave induced soil displacements expected to be applied at the pier piles are as follows.

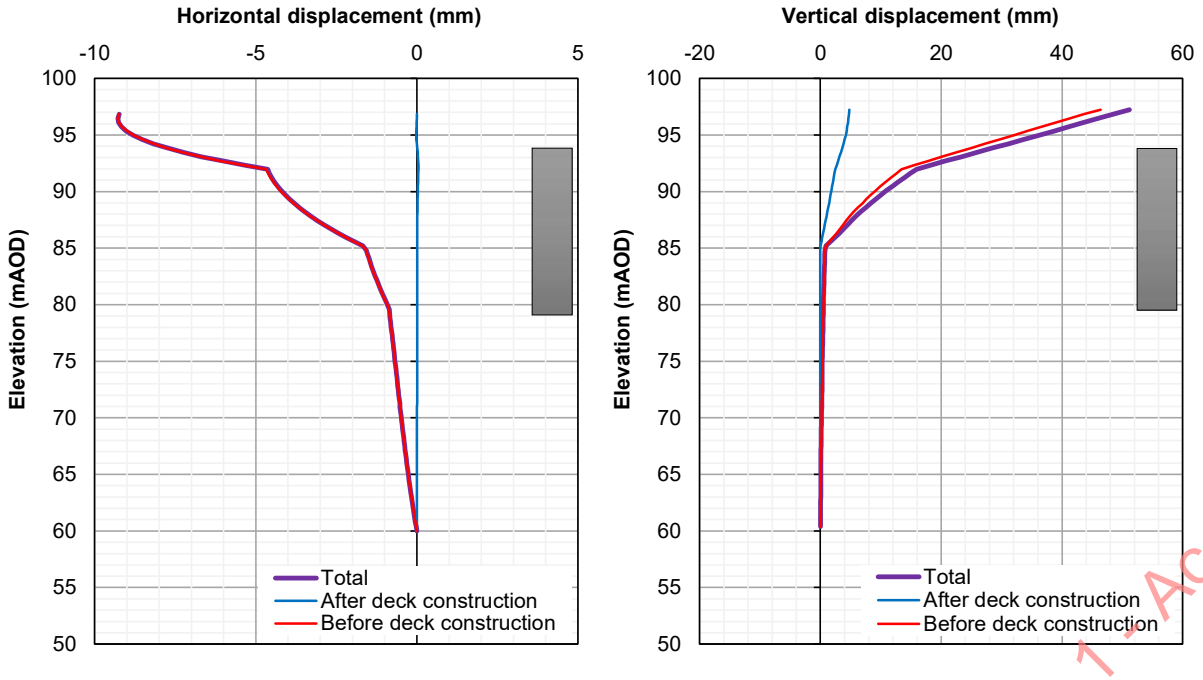


Figure 34 Heave induced displacements near the piers piles

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3.3 Heave consequences on piles

3.3.1 Calculation models

The effects of the heave induced displacements on the individual piles are assessed through calculations using Foxta v4, a software for shallow and deep foundations design, developed by Terrasol. In this model, the piles are directly modelled along with the interaction with the surrounding soil, with load transfer approaches. The heave induced displacements (in this case, displacements induced in phases 2 to 4) are applied as a soil displacement and the resulting force and displacement of the pile are obtained from the model.

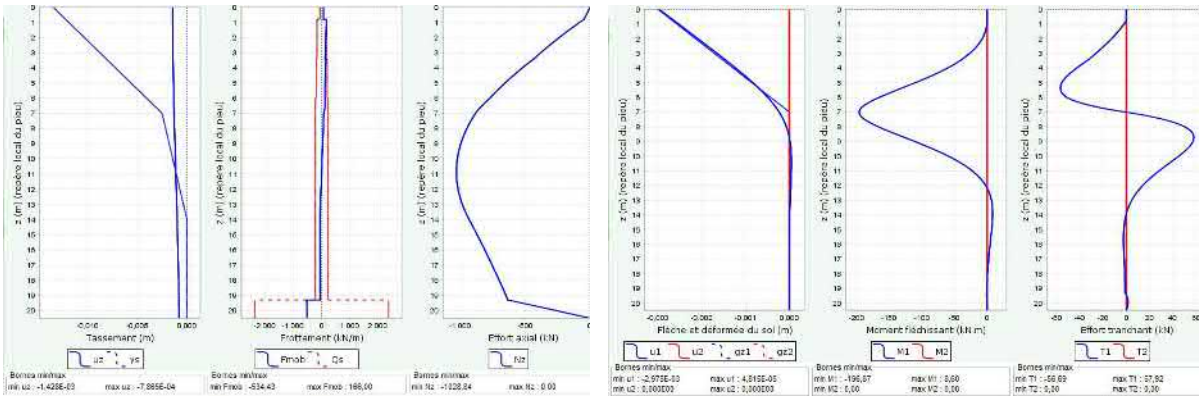


Figure 35 Typical output from Foxta v4

On the other side, the effects of the heave induced displacements on the complete structure are assessed through a calculation using Poutre2D, an analytical software developed by Terrasol. In this software, the piles, piers and abutments, deck are modelled through beam elements, and connections between all these elements are customizable. The interaction between the piles and the soil is modelled through load transfer approaches (similarly to Foxta v4). The heave induced displacement (in this case, displacements induced during and after phase 5) is applied as a soil displacement of the embedded part of the pile and the resulting forces (and displacements) in the piles, piers and deck are obtained.

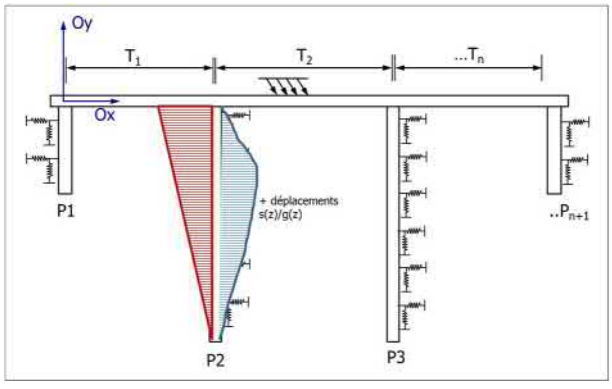


Figure 36 Typical output from Poutre2D

3.3.2 Heave induced forces

Phases 4 and 5

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The heave induced forces on the piles during these phases are summarized in the table below. These values represent around 10-20% of the SLS loading to be applied on the pile during its lifetime.

Table H.120 Heave induced forces on structure during piles and piers construction

	Normal force (kN)	Shear force (kN)	Moment (kN.m)
Piers piles	-1677	202	364
Abutments piles	790	120	175

Phase 6 and beyond

The heave induced forces on the piles during and after this phase, as well as the forces induced in the deck are summarized in the table below. These values represent at most 5% of the forces induces by the deck weight only. The maximal heave induced displacements of the deck, piers and abutments remain lesser that 1 mm.

Table H.121 Heave induced forces on structure during and after deck construction

	Normal force (kN)	Shear force (kN)	Moment (kN.m)
Piers piles	-1000	5	10
Abutments piles	-350	20	30
Deck	-	~0	-52

These values were transferred to the structures teams in order to be included in the structural verification of the whole overbridge.

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4 Wingwalls

The stiffness of the wing walls foundation is calculated and the bearing capacity and sliding resistance are verified in accordance with BS EN 1997-1, BS EN 1997-1\NA and BS 8004_2015.

4.1 Features

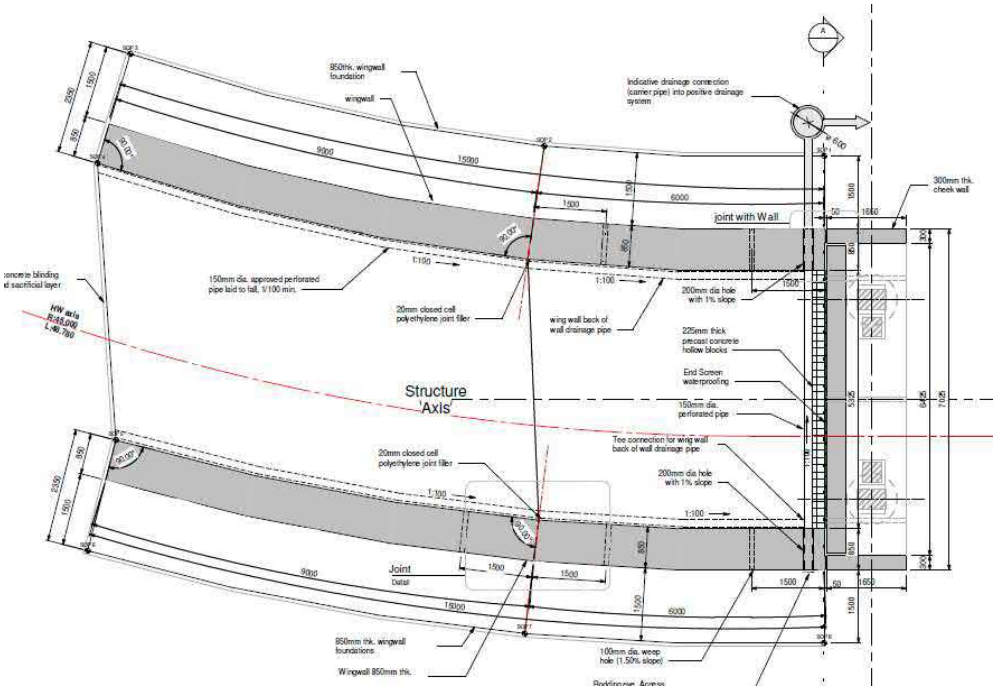
The wingwalls are constructed in two U-shaped panels for each. The geometrical properties are listed below.

Table H.122 Geometrical properties of abutments wingwalls

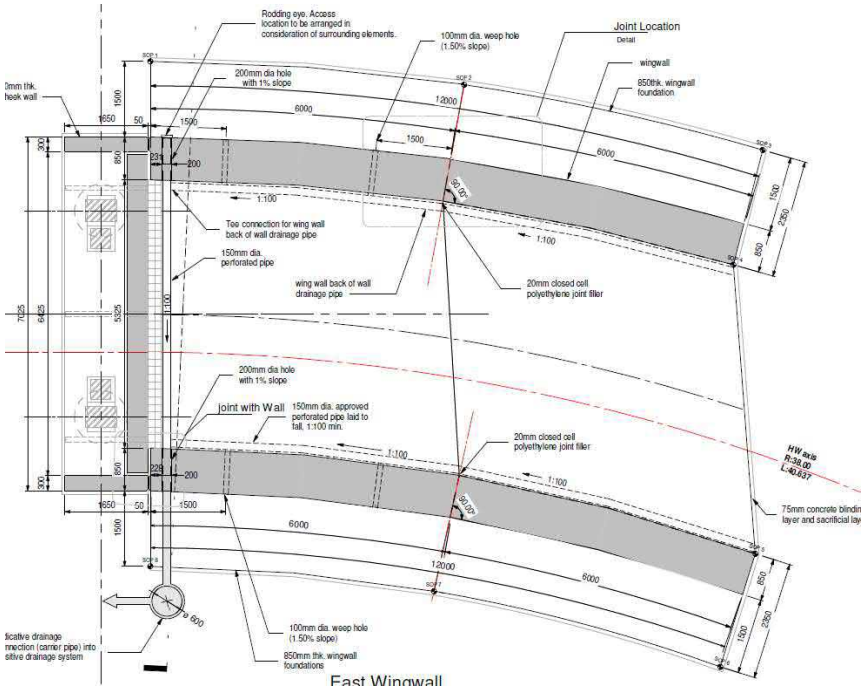
	A0 and A3 (U-shaped panel)
Number of panels	2 (for each abutment)
Panel length (m)	6 m and 9 m for A0 6 m both panels for A3
Foundation width (m)	10 m
Foundation thickness (m)	85 cm
Foundation base level (m AOD)	101.2 m AOD for West abutment A0 101.1 m AOD for West abutment A0
Backfill height (m)	Around 4.5 m

The schematic cross sections of the wingwall are illustrated on the figure below.

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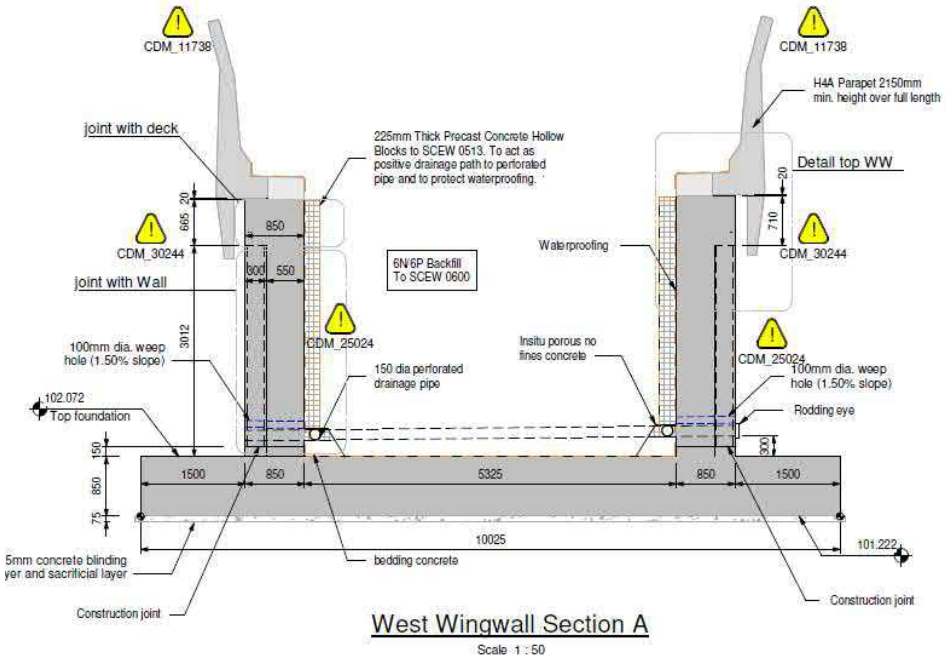


(a) West abutment (A0) wingwall plan view

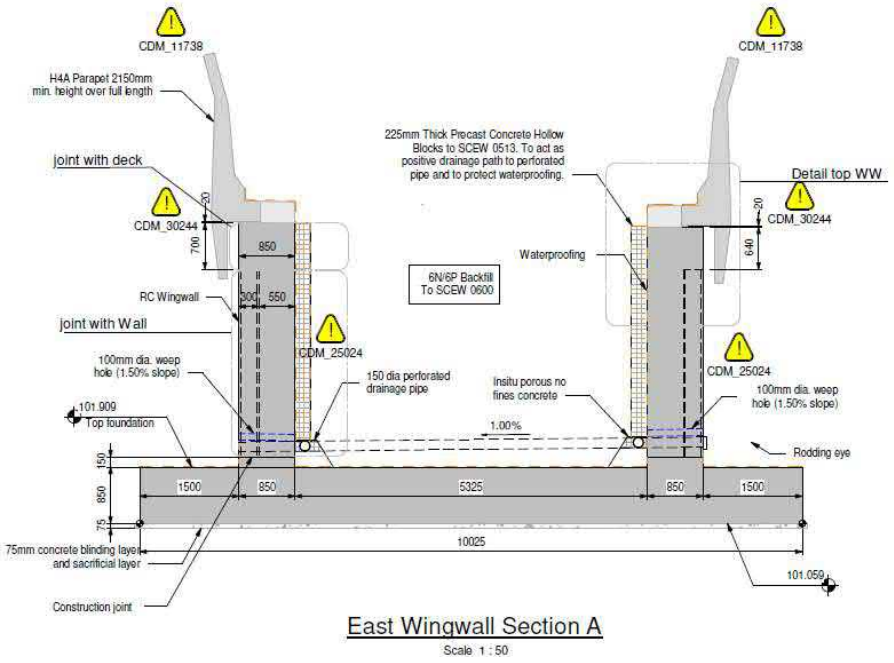


(a) East abutment (A3) wingwall plan view

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(a) West abutment (A0) wingwall elevation view



(a) East abutment (A3) wingwall elevation view

Figure 37 Wingwalls geometry

4.2 Ground properties

The stratigraphy for each abutment is defined from the local GI as listed in the previous paragraphs. The same soil model is used for both abutments

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Table H.123 Detailed design stratigraphy

Geological formation	Design thickness (m)
Glaciofluvial deposits	2.4
Oxford Clay formation 1	7.8
Oxford Clay formation 2	5.3
Kellaways formation	5.4

The ground properties are listed in the §1.3.

4.3 Stiffnesses

The stiffnesses of the soil beneath the foundations of one panel of the wingwall is calculated using conventional formulae. The equivalent soil modulus of the soil layers is equal to 18 MPa, it is calculated as the harmonic mean value of the soil moduli beneath the foundation.

The effect of the substratum situated at a depth of 21.17 m is considered via an increase of the vertical stiffness. The increase factor is calculated in function of the substratum depth H and the width of the foundation B:

$$\frac{K_{v,substratum}}{K_v} = 1 + \alpha \frac{B}{H} \quad \alpha = 1.4 - 1.6 \; depending \; on \; the \; foundation \; shape$$

Thus, the stiffnesses of the foundation are equal to the following.

Stiffness				
	Global		Surfacic	
Vertical	Kv (MN/m)	265.1	kv (MPa/m)	2.2
Horizontal	Kh (MN/m)	204.5	kh (MPa/m)	1.7

Kv with substratum at 21.17 m				
Vertical	Kv,sub	455	kv,sub	3.8

4.4 Bearing capacity

The bearing capacity is calculated in accordance with BS EN 1997, taking into consideration a fine soil beneath the foundation.

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The value of 110 kPa is considered for the undrained shear strength of the soil. This value is chosen as a representative value along the soil depth where the bearing capacity mechanism will be developed; this depth is approximately equal to 1.5B.

In this case, this significant depth is equal to 9 m. The average value of the undrained bearing capacity is thus equal to 110 kPa. The bearing capacity of the foundation is equal to the following.

Bearing capacity		
		$q_{u;d}$ (kPa)
ULS	DA1C1	566
	DA1C2	346
SLS		189

The bearing capacity is then verified considering the maximum values of stress beneath the foundation for both ULS and SLS. The table below summarizes this verification.

Combination	Maximum pressure	Bearing capacity		Check
	kPa	*Limit state*	*kPa*	
ULS STR/GEO Set B	120	ULS-DA1C1	566	✓ 4.71
ULS Accidental	175	ULS-DA1C1	566	✓ 3.23
ULS STR/GEO Set C	91	ULS-DA1C2	346	✓ 3.81
ULS Seismic	92	ULS-DA1C2	346	✓ 3.77
SLS Characteristic	89	SLS	189	✓ 2.12
SLS QP	77	SLS	189	✓ 2.45

4.5 Sliding resistances

The sliding resistance is verified in accordance with BS EN 1997. The characteristic friction angle of the soil beneath the foundation is equal to 27°. The design friction angles are thus equal to the following.

Sliding		
		ϕ'k (°)
ULS	DA1C1	27
	DA1C2	22

The stability vis-à-vis sliding is verified for two cases of loads:

- Shock load of 600 kN per panel: The resistant force is equal to the total weight multiplied by tan(ϕ'k) = tan(22°)=0.404.

  The total weight is equal to the weight of concrete and backfill on one panel, equal to 4450 kN. Since 4450 x 0.404 = 1800 > 600, the stability is verified.
- Note that the shock load includes a vertical component of 175 kN that was neglected in this verification for security reasons.
- Seismic load defined by horizontal and vertical coefficients: k_h = 0.076 and k_v = 0.025.

  The condition to be verified is the following, W_h is the total weight of concrete and backfill:

$$\frac{W_t(1-k_v)\tan(\phi'_d)}{1.25} \geq W_t k_h$$

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$$\frac{(1-0.025)\tan(22°)}{1.25} = 0.315 \geq 0.076$$

- The stability is hence verified.

4.1 Settlement in the transition zone

The settlement in the transition zone corresponds to the settlement below the wingwall foundations.

This settlement is estimated from a coupled analysis where the wingwall foundations are modelled through plate elements, and the multi-layered soil is modelled through analytical stiffness functions.

For the sake of simplification, wing wall panels are considered to be all rectangular.

The calculation is performed using the component Tasplaq of Foxta v4 (a software for shallow and deep foundations design, developed by Terrasol).

The loads acting on the foundations are composed of a the backfill weight (slightly different value for each panel) and a service load of 20 kPa.

The resulting total maximum settlement is estimated at 33 mm for abutment A0 and 30 mm for abutment A3. It is expected that half of this settlement will occur immediately at the end of the construction of the wingwalls. The differential settlement is approximately 1/500. These values are quite acceptable according to the project standards.

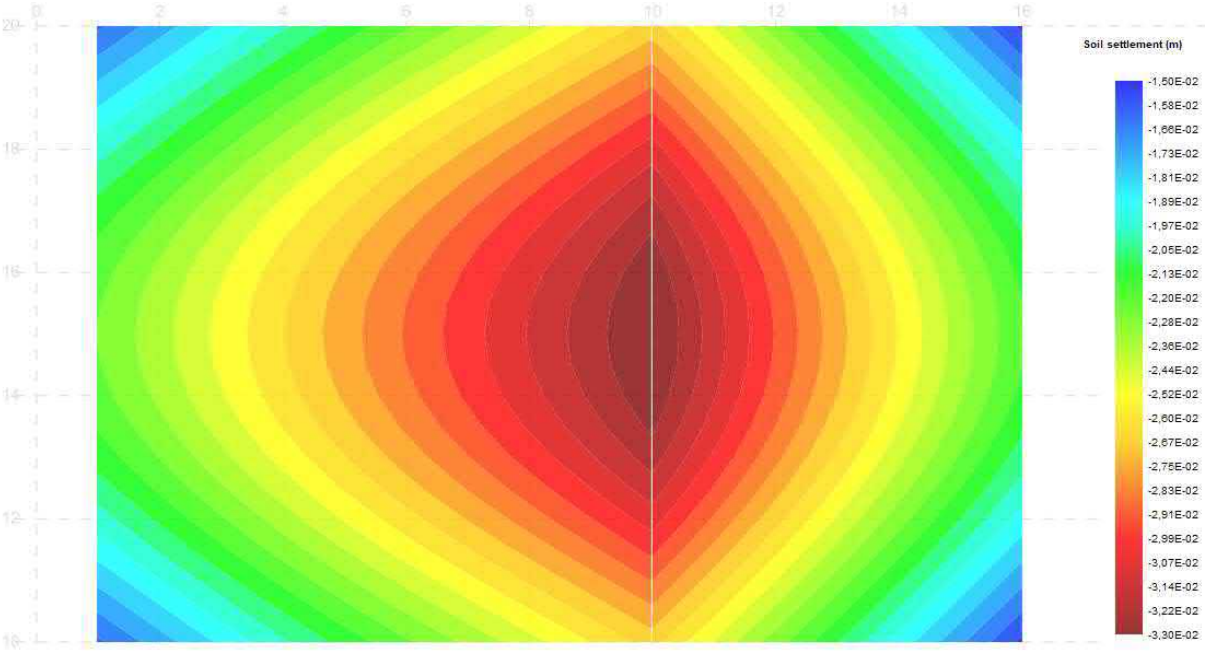


Image H-17 : Settlements in the transition zone behind the A0 abutment

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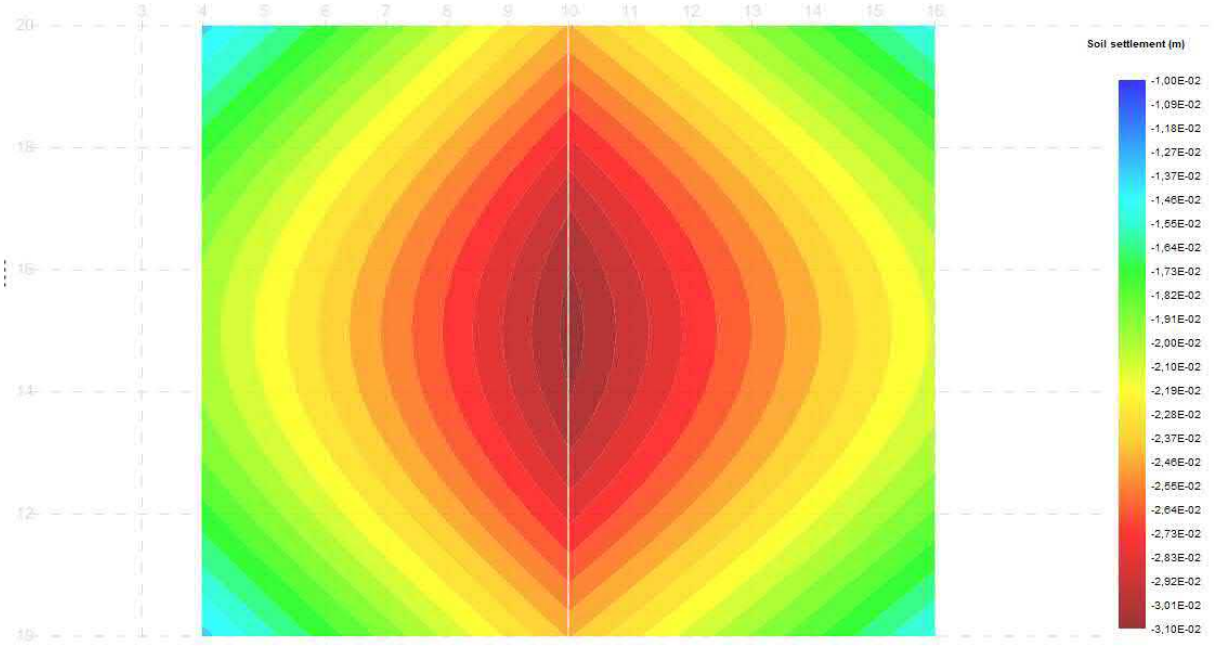


Image H-18 : Settlements in the transition zone behind the A3 abutment

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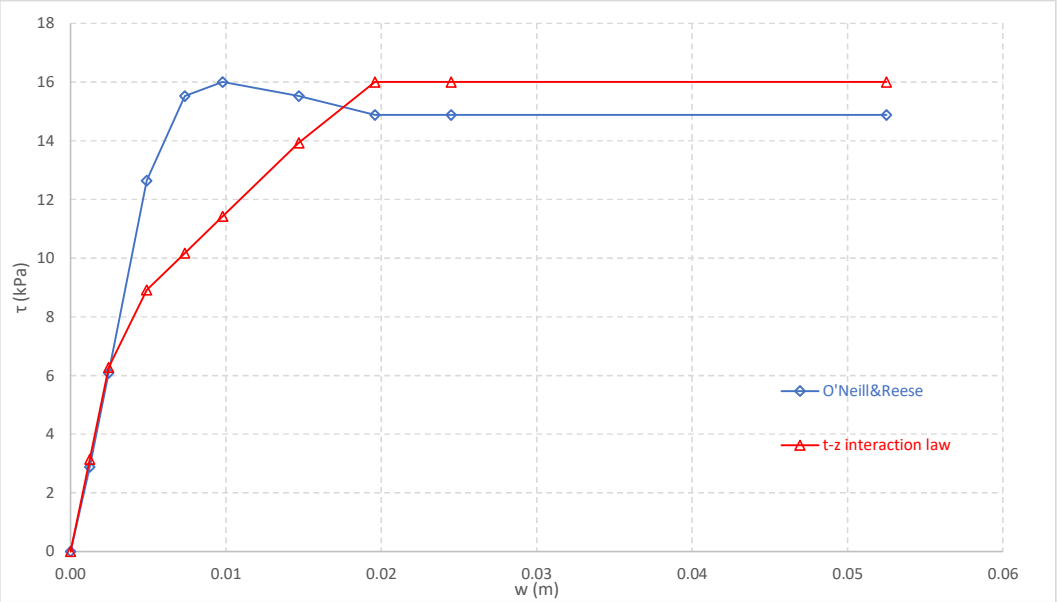
APPENDIX I

Footpath CHW18 accommodation overbridge interaction laws

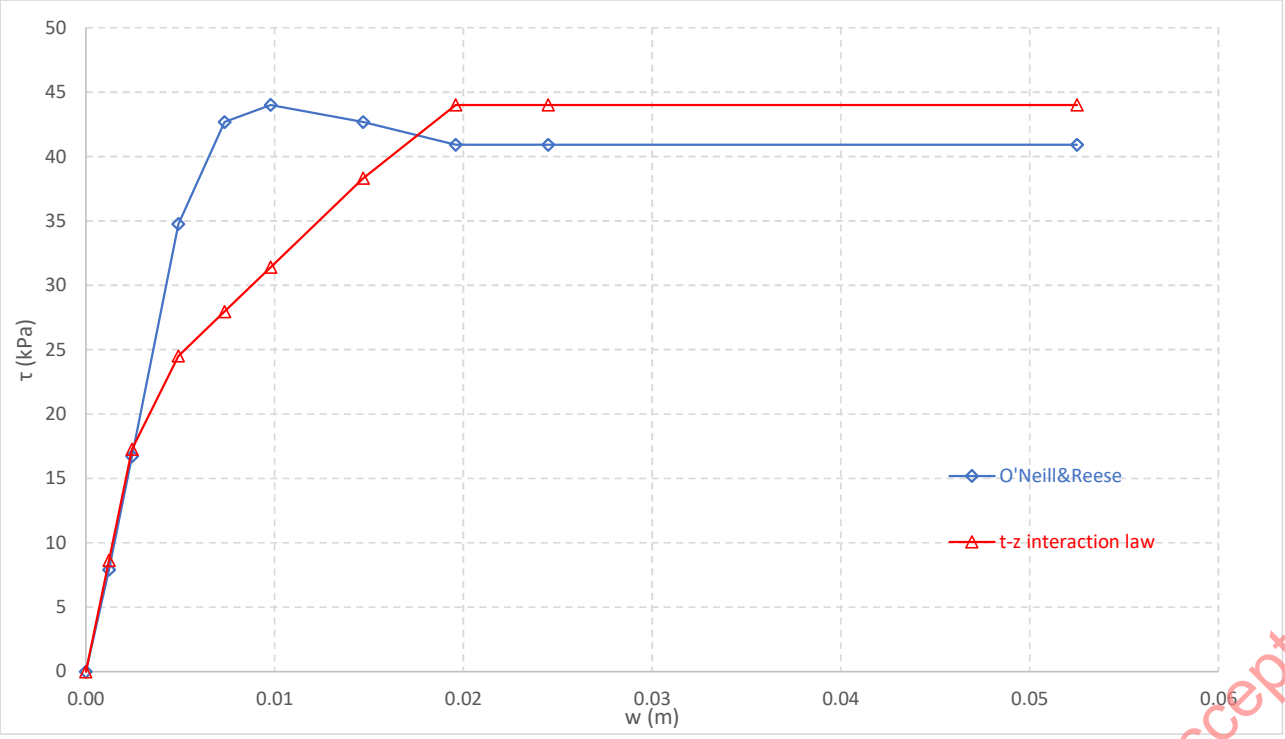
Number of pages: 4

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Shaft friction (t-z) in Glaciofluvial deposits

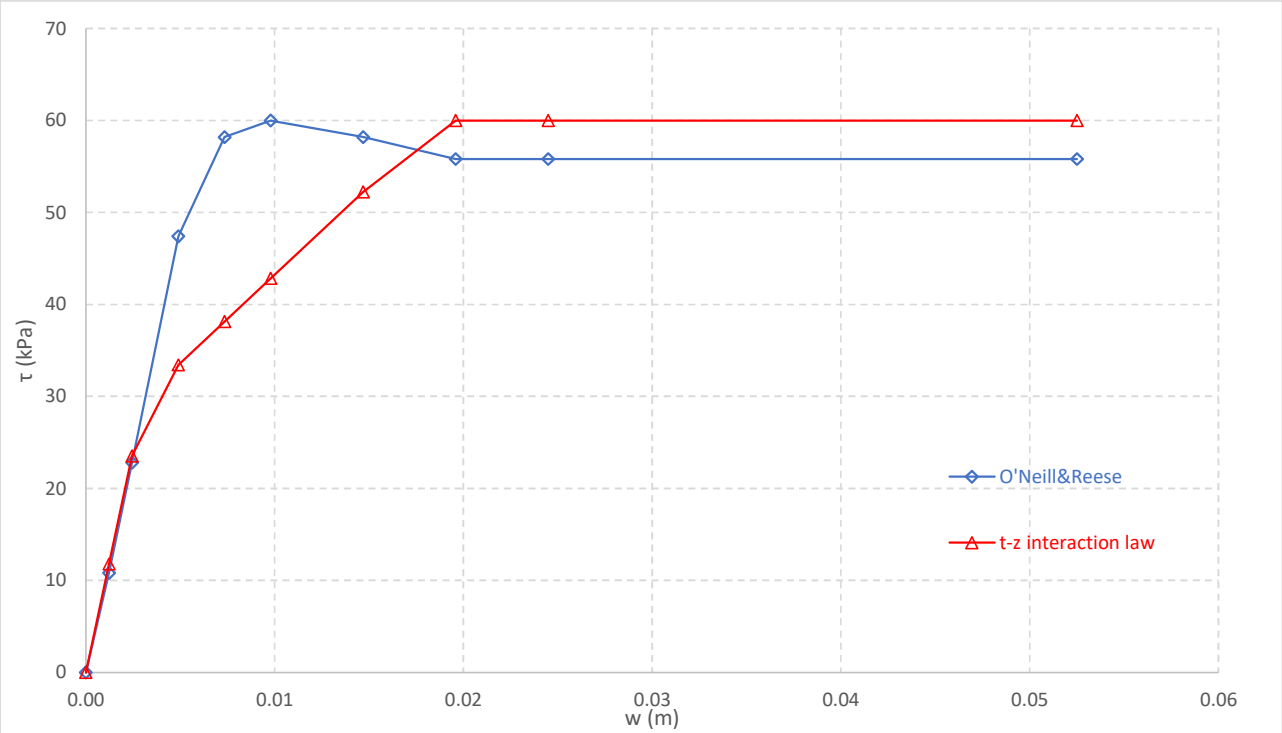


Shaft friction (t-z) in Oxford clay (sublayer 1 of 4)

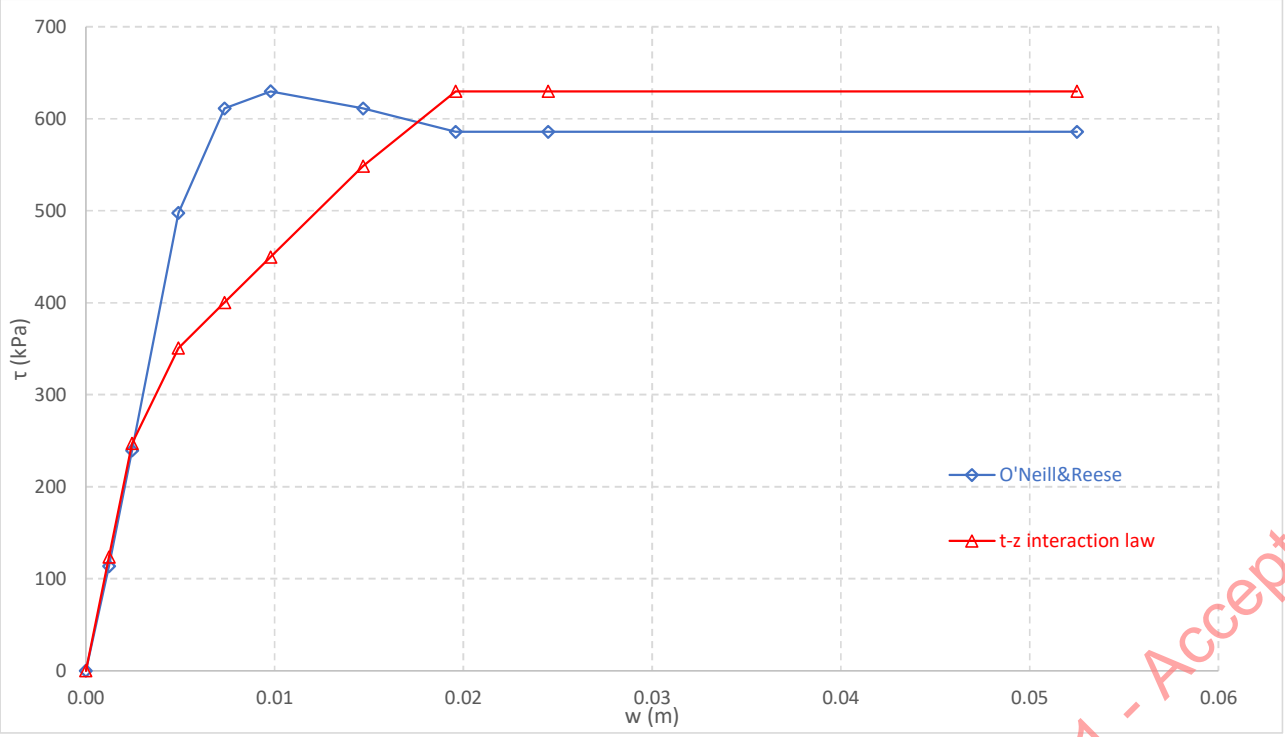


Shaft friction (t-z) in Kellaways formation

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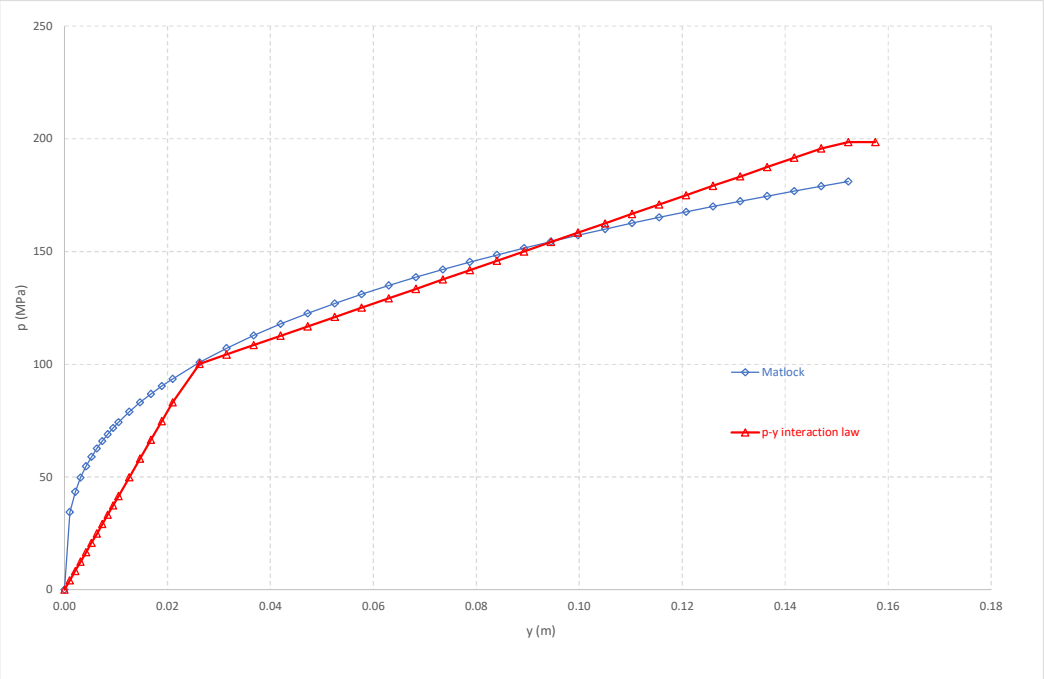


Shaft friction (t-z) in Cornbrash formation

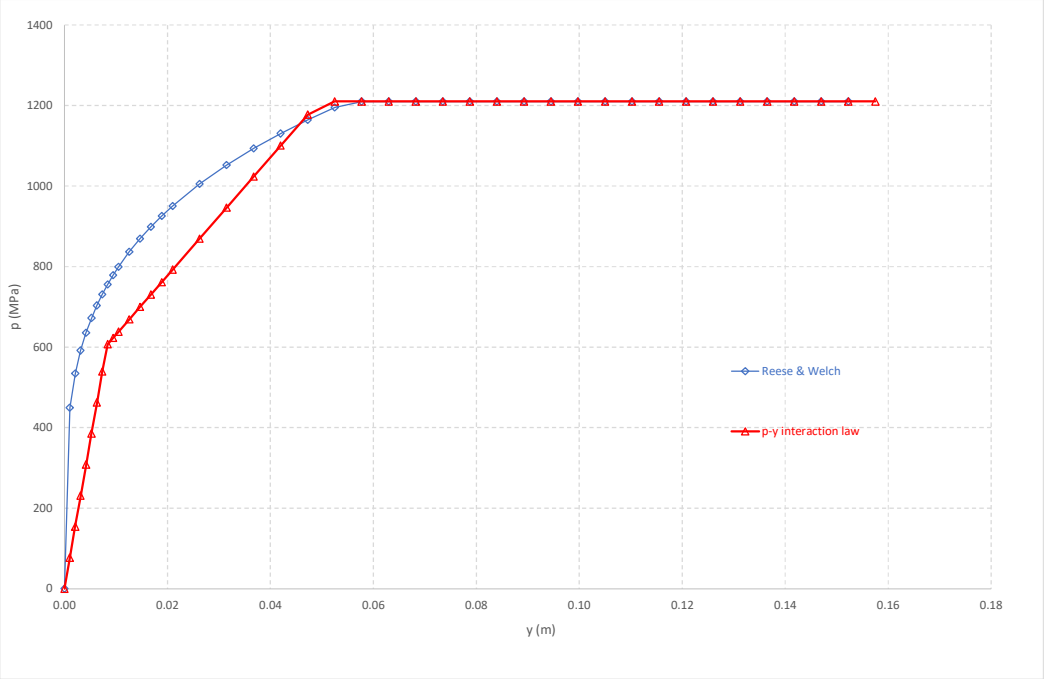


Lateral interaction (p-y) in Glaciofluvial deposits

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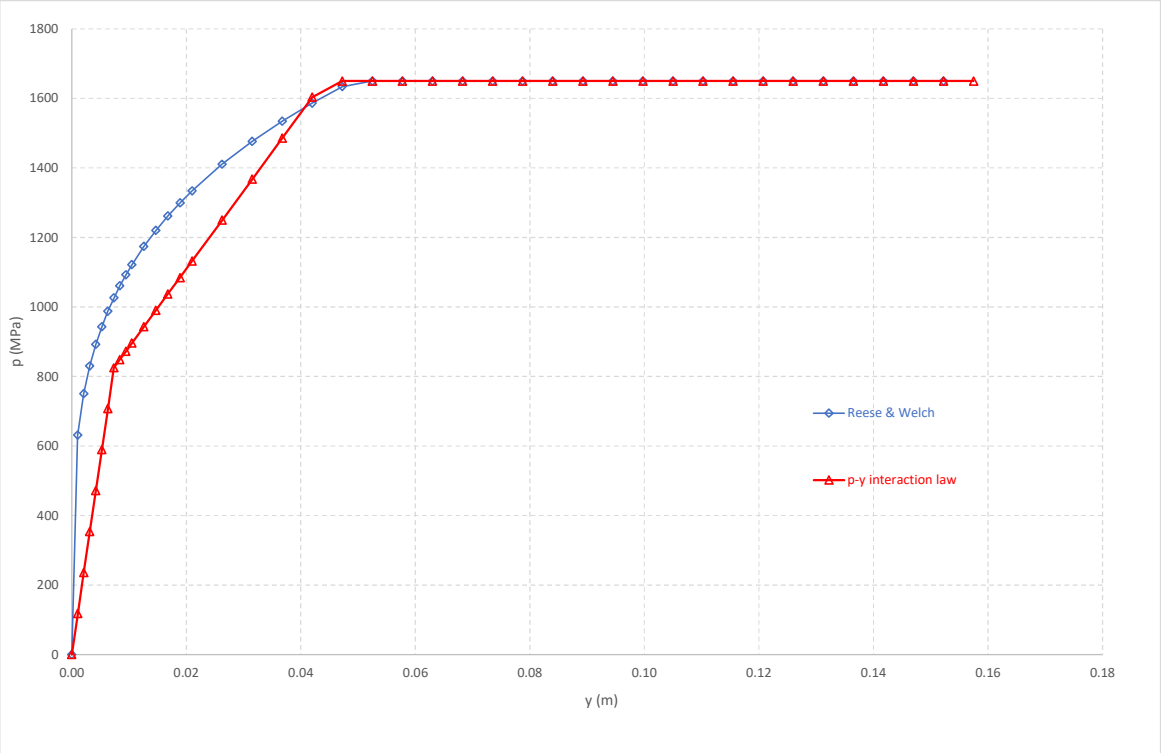


Lateral interaction (p-y) in Oxford clay (sublayer 1 of 4)

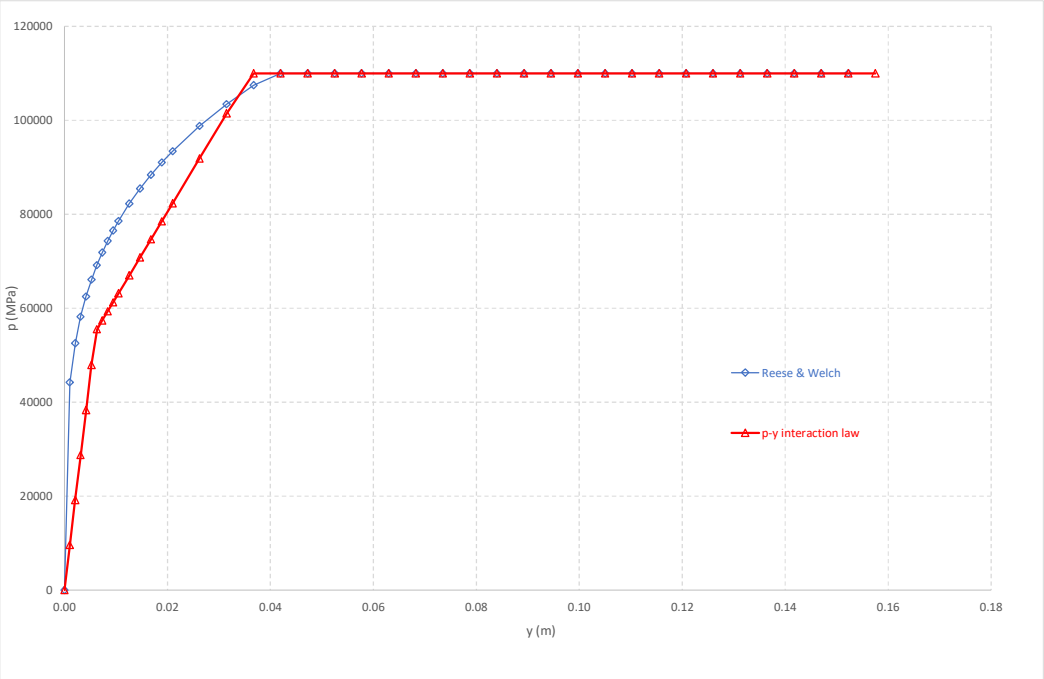


Lateral interaction (p-y) in Kellaways formation

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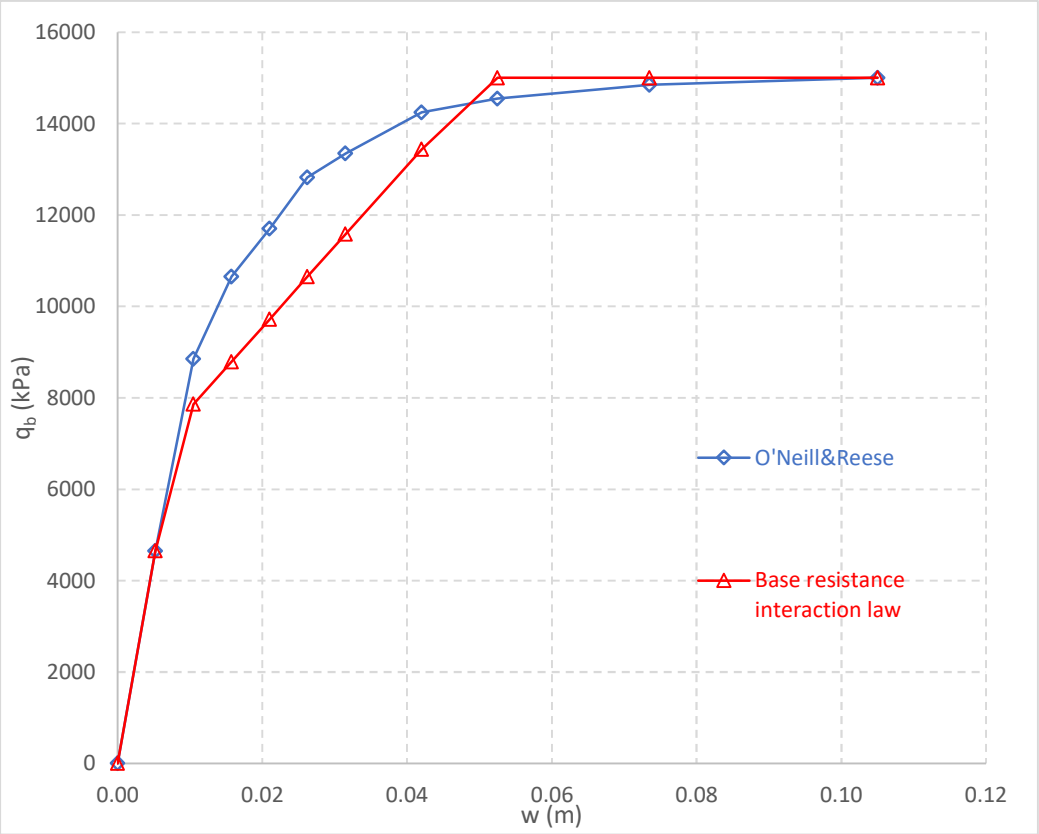


Lateral interaction (p-y) in Cornbrash formation



Base resistance interaction law in Cornbrash formation

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APPENDIX J

School end overbridge geotechnical calculations

Number of pages: 66

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1 Ground model

The definition of the ground model was based on local GI in the direct vicinity of the asset, as well as on tests conducted on samples from GIs along the HS2 line when needed, in particular the Clay Vale zone (1MC06-CEK-GT-REP-CS06_CL10-000015 – P01).

The elements presented here were originally based on GI up to datadrop 02, a first impact assessment has been made on GI from Datadrops 14 (ML086-CR443, 16 (ML086-CR443a and ML086-CR444) and 21 (ML086-CR442), indicating that assumptions made for the design (geological long section, design values, mitigation measures) of the overbridges are confirmed and validated.

1.1 Stratigraphy

The definition of the stratigraphy is mainly based on the observations from the 25-40 m deep cable percussion boreholes ML086-CR005, ML086-CR400 and ML086-CR002, and trial pits ML086-TP404 and ML086-TP405. These boreholes are located near the overbridge (Figure 38). The observations from other exploratory holes located within 100-200 m from the overbridge are used to confirm this stratigraphy. These boreholes are ML086-CR012 and ML086-CR004.

The following table summarizes the GI that were used for the definition of the stratigraphy. The geotechnical elevation of the Figure 39 shows the relative position of these boreholes to the axis of the overbridge and their logs.

Table J.124 Used GI

Exploratory hole	Type	Ground level (m AOD)	Depth (m)
ML086-CR002	Cable percussion borehole with rotary cored follow on	108.4	30
ML086-CR005		109.54	40
ML086-CR400		109.48	25
ML086-CR012		109.81	35
ML086-CR004		109.94	40
ML086-TP404	Trial pit	110.22	3
ML086-TP405		109.27	4

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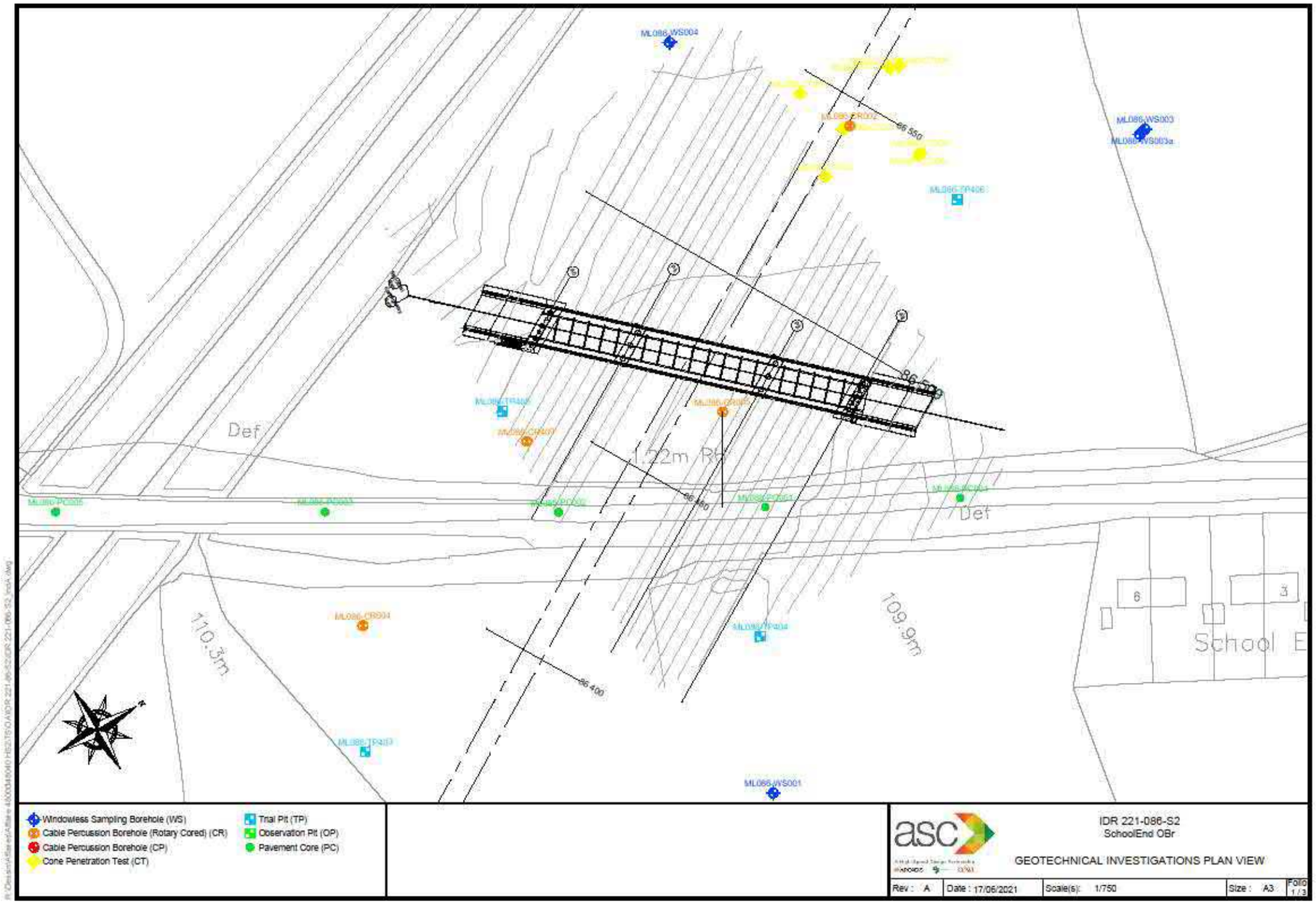


Figure 38: Location of GIs along the overbridge

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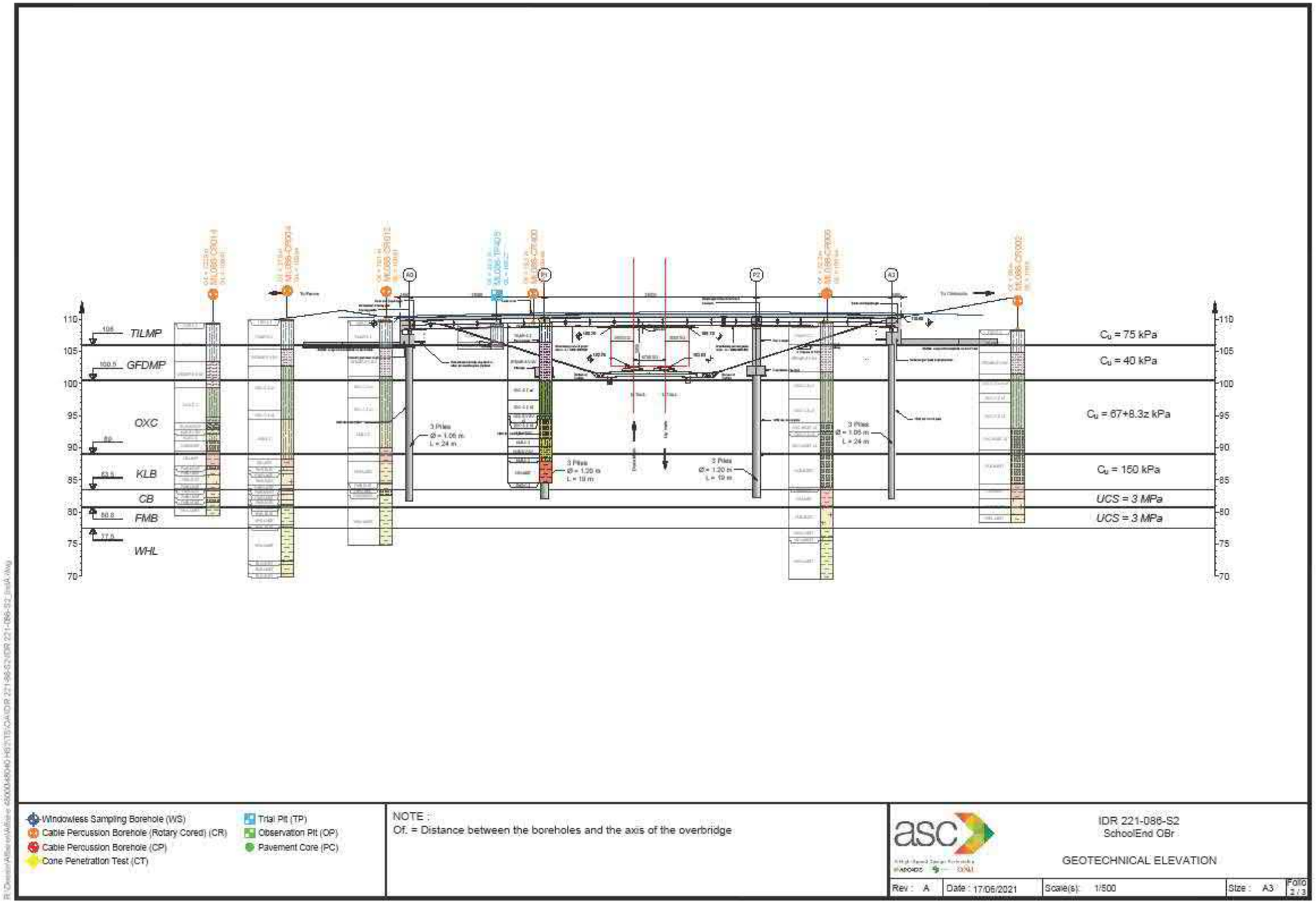


Figure 39: Geotechnical elevation

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The Table J**.125** summarizes the stratigraphy for this overbridge. The Existing Ground Level is estimated at 109.5 m AOD. The stratigraphy is composed of the following layers:

- Firm to stiff sandy gravelly clay of 3.5 m in thickness (Till formation)
- Loose to medium dense fine to medium sand of 5.5 m in thickness (Glaciofluvial deposits),
- 11.5 m of stiff to very stiff clay of the Oxford Clay formation

  In the boreholes ML086-CR005 and ML086-CR002, a sublayer of weak mudstone is found in the last 3-5 m of this formation. The properties of this sublayer will be determined and used in the design.
- 5.5 m of extremely weak mudstone of the Kellaways formation. This formation contains interbeds of stiff clay and fine sand (especially in ML086-CR400). The presence of these interbeds will be accounted for in the definition of the resistance properties of the formation.
- and a substratum of the Great Oolite Group, composed of:
  - 2.7 m of medium strong to strong limestone of the Cornbrash formation,
  - 3.3 m of alterations of medium strong limestone and weak silstone of the Forest Marble formation,
  - And around 17.5 m of weak to medium strong limestone of the White Limestone formation, including very small layers of weak siltstone and mudstone (20-40 cm).

Table J.125 Detailed design stratigraphy

Geological group	Geological formation	Design top level (m AOD)	Design thickness (m)	Design bottom level (m AOD)
Till formation	Till formation	109.5	3.5	106
Glaciofluvial deposits	Glaciofluvial deposits	106	5.5	100.5
Oxford Clay formation	Oxford Clay formation	100.5	11.5	89
Kellaways formation	Kellaways formation	89	5.5	83.5
Great Oolite Group	Cornbrash formation	83.5	2.7	80.8
	Forest Marble formation	80.8	3.3	77.5
	White Limestone formation	77.5	8.0	69.5

Main upcoming GI are 3 cable percussion boreholes, ML086-CR442, ML086-CR443 and ML086-CR444, located along the overbridge axis, near the west abutment, west pier and east abutment respectively.

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Figure 40 Upcoming GIs

1.2 Geotechnical parameters

Static geotechnical parameters are defined from a cross analysis of tests conducted on samples from the aforementioned exploratory holes and from in situ tests. A cross analysis of tests conducted on samples from along the Clay Vale zone is also performed in order to verify the relevance of the defined parameters for this overbridge and other assets in this zone.

1.2.1 Undrained shear strength

Undrained shear strength values are estimated for Till, Glaciofluvial deposits, Oxford Clay formation and Kellaways formation. These values are either directly measured in triaxial tests or correlated from NSPT values (≈ 5 NSPT). For each formation, measured and correlated values are plotted, and a representative value or linear variation is defined accordingly.

Till formation (Firm to stiff sandy gravelly clay)

Measured values and correlated values, from samples at depths ranging from 1 to 8 m are plotted on Figure 5. The values of the undrained shear strength ranges from 15 to 260 kPa.

A representative mean value of 75 kPa is selected, based on the various correlations from SPT, as well as in situ vane measurements. This value is coherent with the value that was selected for another asset in the same zone (CHW18 Overbridge, located around 1 km upstream, included in both the clay vale zone and the Chetwode cutting).

Glaciofluvial deposits (Loose to medium dense fine to medium sand)

Although this formation is sandy, an undrained shear strength value is estimated from SPT values.

This choice is justified by the fact that the formation is mostly composed of fine sand which is clayey in some places (for example in ML086-CR004:4.5-5.2 m, ML086-CR400:3.15-3.7 m and ML086-CR400:3.7-6.2 m).

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SPT correlated values, from samples at depths ranging from 1 to 9 m are plotted on Figure 6, with values mostly ranging from 25 to 300 kPa (for deep samples). A representative mean value of 40 kPa is selected.

This value is also coherent with the value that was selected for the CHW18 Overbridge.

Oxford clay formation (stiff to very stiff clay)

Figure 7 illustrates the measured and correlated values for the stiff to very stiff clay.

The values are overall increasing with depth. The trendline equation for the undrained shear strength variation with depth: $C_u = 67 + 8.3z$ with a maximum value of Cu = 150 kPa (z is the depth relative to the existing ground level). This equation is the same that was used for the assets in the clay vale zone. It is selected for this asset as well since it fits the variation of the measured and correlated values.

Kellaways formation (stiff clay)

Measured values and correlated values, from samples at depths ranging from 5 to 35 m are plotted on Figure 8. The values for samples shallower than 15 m are quite scattered (50-300 kPa), but for deeper samples (>15 m), an average value of 150 kPa can be identified.

This value is thus selected, since the Kellaways formation is encountered at depths greater than 20 m.

Kellaways formation (extremely weak mudstone)

Measured values are plotted on Figure 9. From direct measurements in samples around 25 m (the Kellaways formation is encountered at depths greater than 20 m), a representative value of 150 kPa can be selected.

The value selected for both the extremely weak mudstone part and the stiff clay interbeds of the Kellaways formation (= 150 kPa) is identical to the maximum value of undrained shear strength that was taken for the clayey part of the Oxford Clay formation, overlying the Kellaways formation.

1.2.2 Uniaxial Compressive Strength

For each of the rocky layers (or sublayers), the values of Uniaxial Compressive Strength are calculated from measurements on samples from the aforementioned GIs as well as other GIs along the Chetwode Cutting

Oxford clay formation (weak mudstone)

Measured values are plotted on Figure 9. The values are quite scattered; nevertheless, from direct measurements in samples at 19 m, a representative value of 400 kPa can be selected.

This value is consistent with the maximum value of undrained shear strength that was taken for the clayey part of the Oxford Clay formation (150 kPa).
In fact, the undrained shear strength is equal to half the uniaxial compressive strength. If this correlation is applied to this case, the orders of magnitude are logical ($C_u = \frac{UCS}{2} = 200\ kPa$) not far from 150 kPa.

However, in order to preserve the continuity of the strength variation with depth in the Oxford formation, a value of 150 kPa of undrained shear strength will be used for this sublayer. This value is conservative.

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Kellaways formation (extremely weak mudstone)

Measured values are plotted on Figure 9. The values are quite scattered.

Although a representative average value of 0.5 MPa can be selected, the undrained shear strength value of 150 kPa previously defined for both the extremely weak mudstone part and the stiff clay interbeds will be used in the design.

Cornbrash formation (medium strong to strong limestone)

Measured values are plotted on Figure 9.

Based on the apparent good quality of the rock in this formation, as described in the logs description (medium strong to strong limestone) and illustrated on Figure 39 (RQD > 60%, see Figure 41) and on the usual resistance values for strong limestone formations, a value of 10 MPa is selected.

Forest Marble formation (medium strong limestone)

Measured values are plotted on Figure 9. A value of 15 MPa is selected, based on:

- the apparent good quality of the rock in this formation, as described in the logs description (medium strong to strong limestone) and illustrated on Figure 39 (RQD > 60%, see Figure 41),
- the measured values in samples around 25 m, leading to values between 15 and 40 MPa,
- and on the usual resistance values for strong limestone formations.

Forest Marble formation (weak silstone)

Measured values are plotted on Figure 9. Although the values are quite scattered, a value of 0.8 MPa is selected.

White Limestone formation (medium strong limestone)

Measured values are plotted on Figure 9. A conservative value of 10 MPa is selected, based on the measured values between 30 and 40 m.

This value is not directly used in the design, but it does confirm the good resistance parameters of this layer, allowing it to be considered as a substratum layer.

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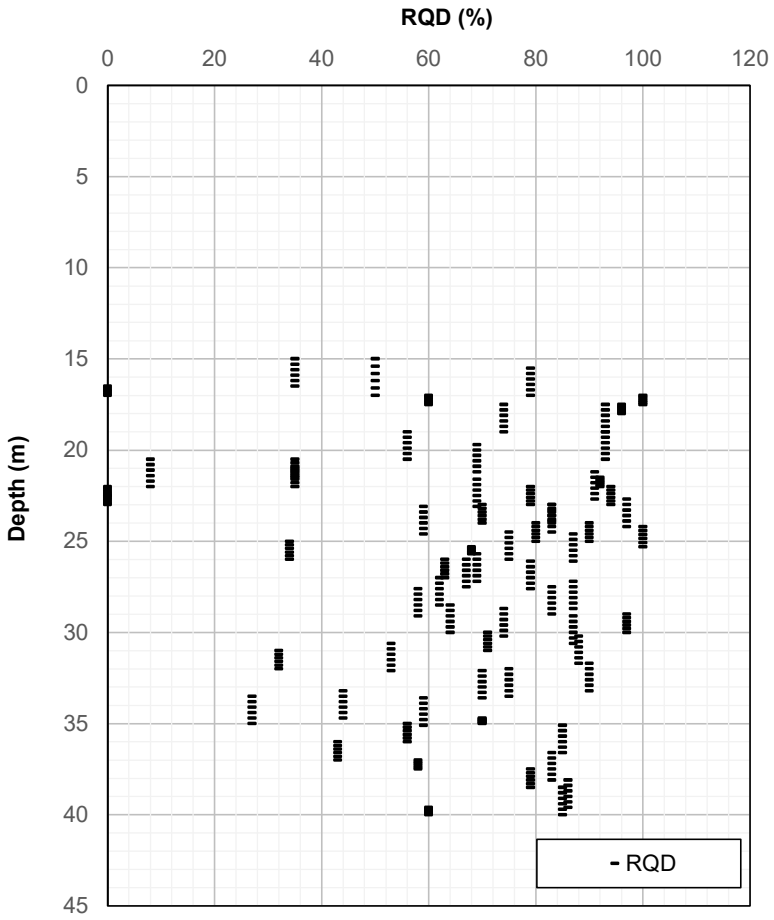


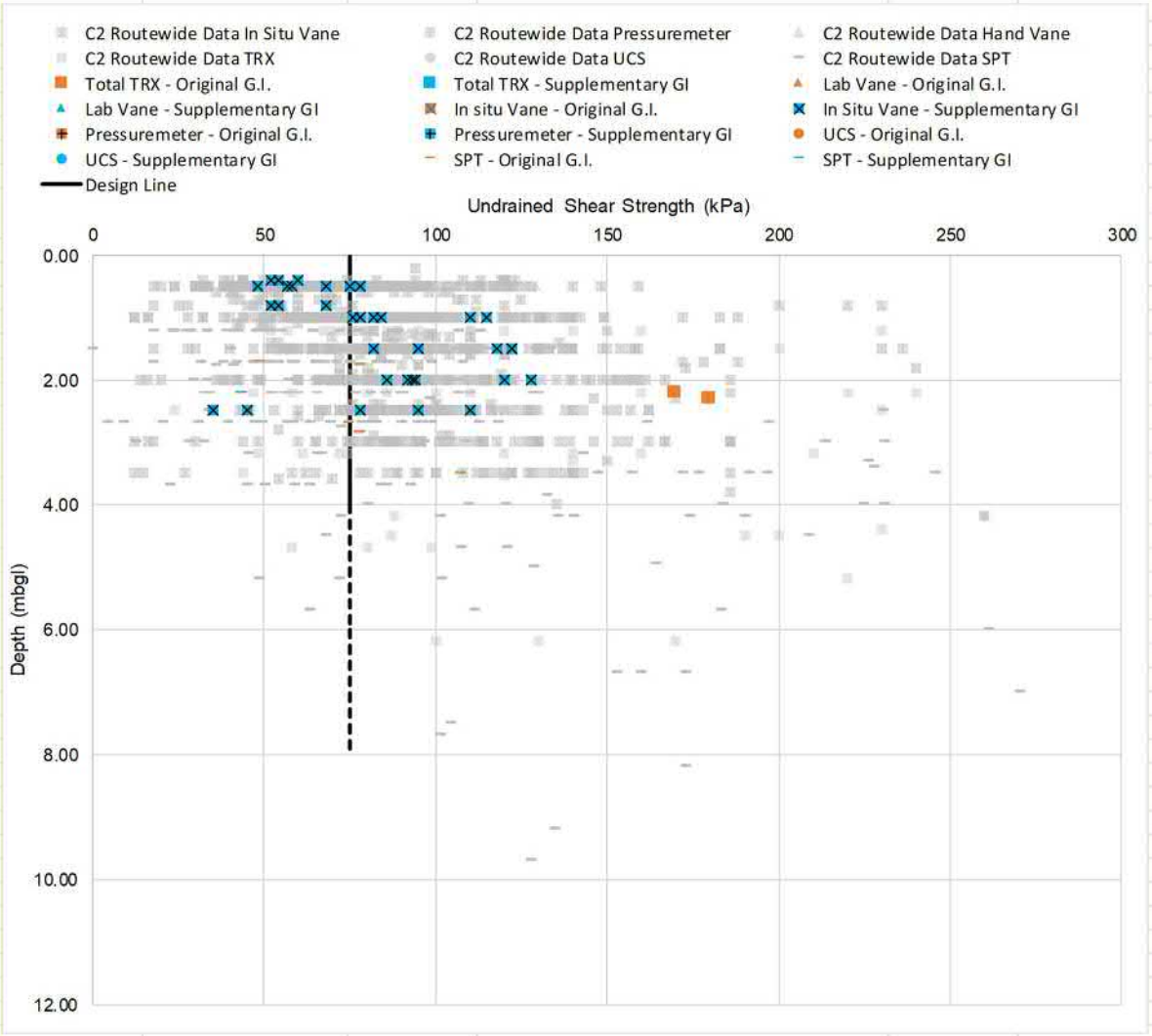
Figure 41 RQD in rocky formations

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HS2

Undrained Shear Strength vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC07 - Stage One C3 -MWCC – Brackley to South Portal of Long Itchington Tunnel	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	TILMP-C Z	Figure:	TILMP-C Z Cu



	Total	Notes	Plot Date:	13/07/2021
Number of Tests	47	Background Routewide data shown are based on Holebase database geology codes dated 30/06/2021 from C2 and C3 Routewide		
Minimum	-			
Maximum	-			
Offset		Inferred ground conditions applied to CPT Cu profiles are based on review of exploratory hole information adjacent to the CPT position.	Holebase database reference	Datadrop 11. Published 06/2021

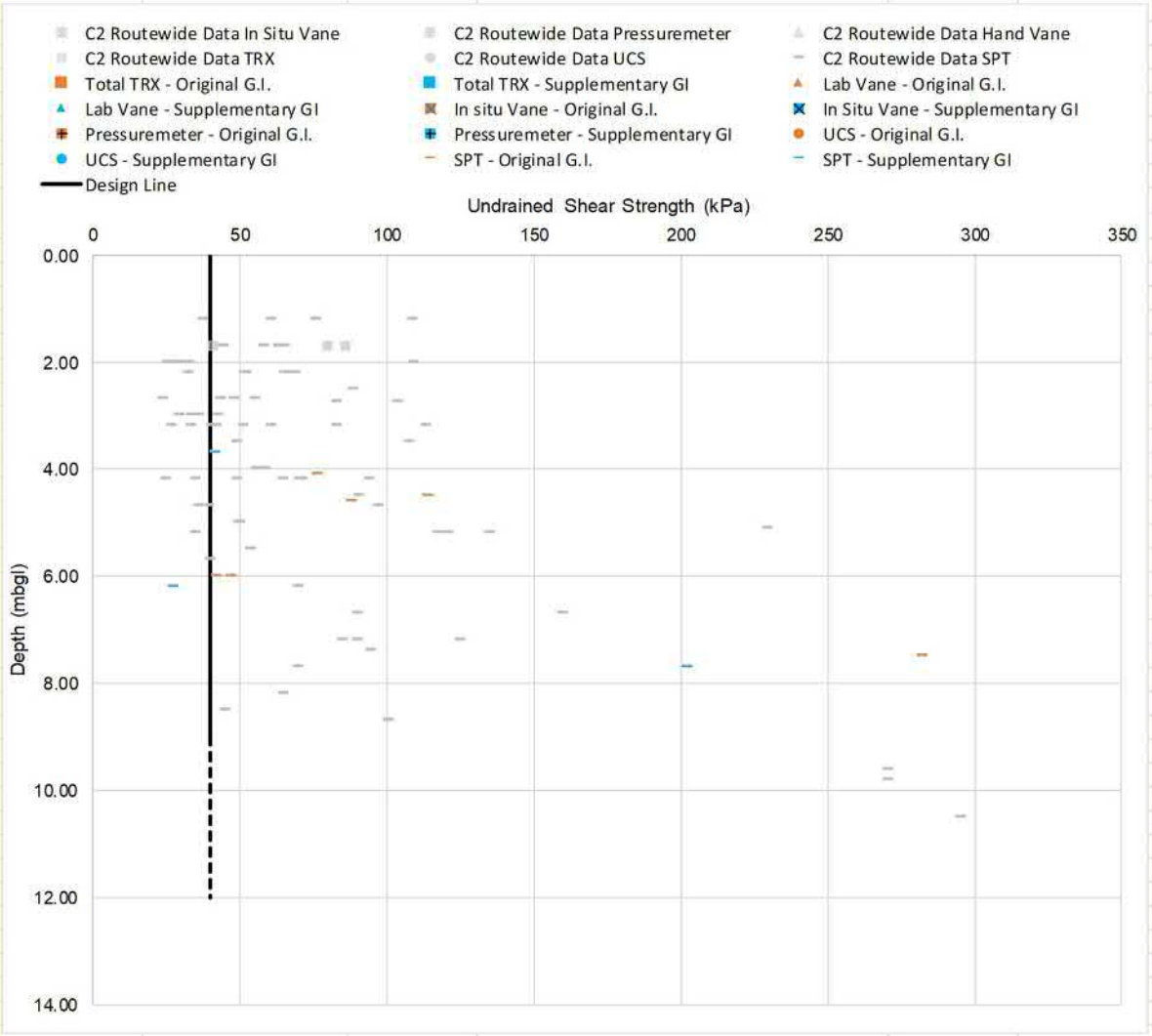
Figure 42 Undrained shear strength in till (Firm to stiff clay)

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HS2

Undrained Shear Strength vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC07 - Stage One C3 -MWCC – Brackley to South Portal of Long Itchington Tunnel	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	GFDMP-S V SV	Figure:	GFDMP-S V SV Cu



	Total	Notes	Plot Date:	13/07/2021
Number of Tests	16	Background Routewide data shown are based on Holebase database geology codes dated 30/06/2021 from C2 and C3 Routewide		
Minimum	-			
Maximum	-			
Offset		Inferred ground conditions applied to CPT Cu profiles are based on review of exploratory hole information adjacent to the CPT position.	Holebase database reference	Datadrop 11. Published 06/2021

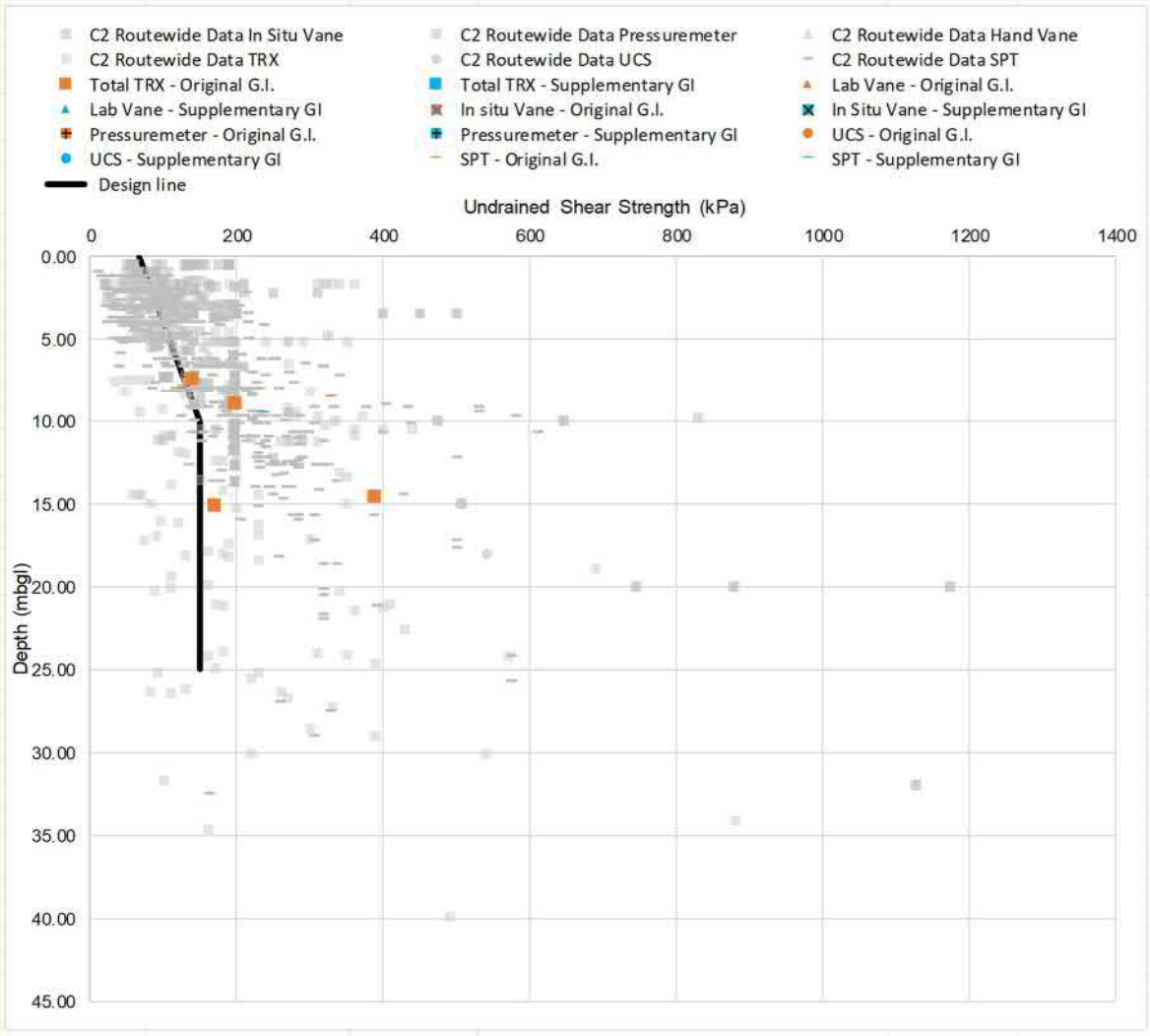
Figure 43 Undrained shear strength in Glaciofluvial Deposits (Loose to medium sand)

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HS2

Undrained Shear Strength vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC07 - Stage One C3 -MWCC – Brackley to South Portal of Long Itchington Tunnel	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	OXC-C Z	Figure:	OXC-CZ Cu



	Total
Number of Tests	10
Minimum	-
Maximum	-
Offset	

Notes

Background Routewide data shown are based on Holebase database geology codes dated 30/06/2021 from C2 and C3 Routewide

Inferred ground conditions applied to CPT Cu profiles are based on review of exploratory hole information adjacent to the CPT position.

Plot Date: 02/05/2022

Holebase database reference	Datadrop 11. Published 06/2021

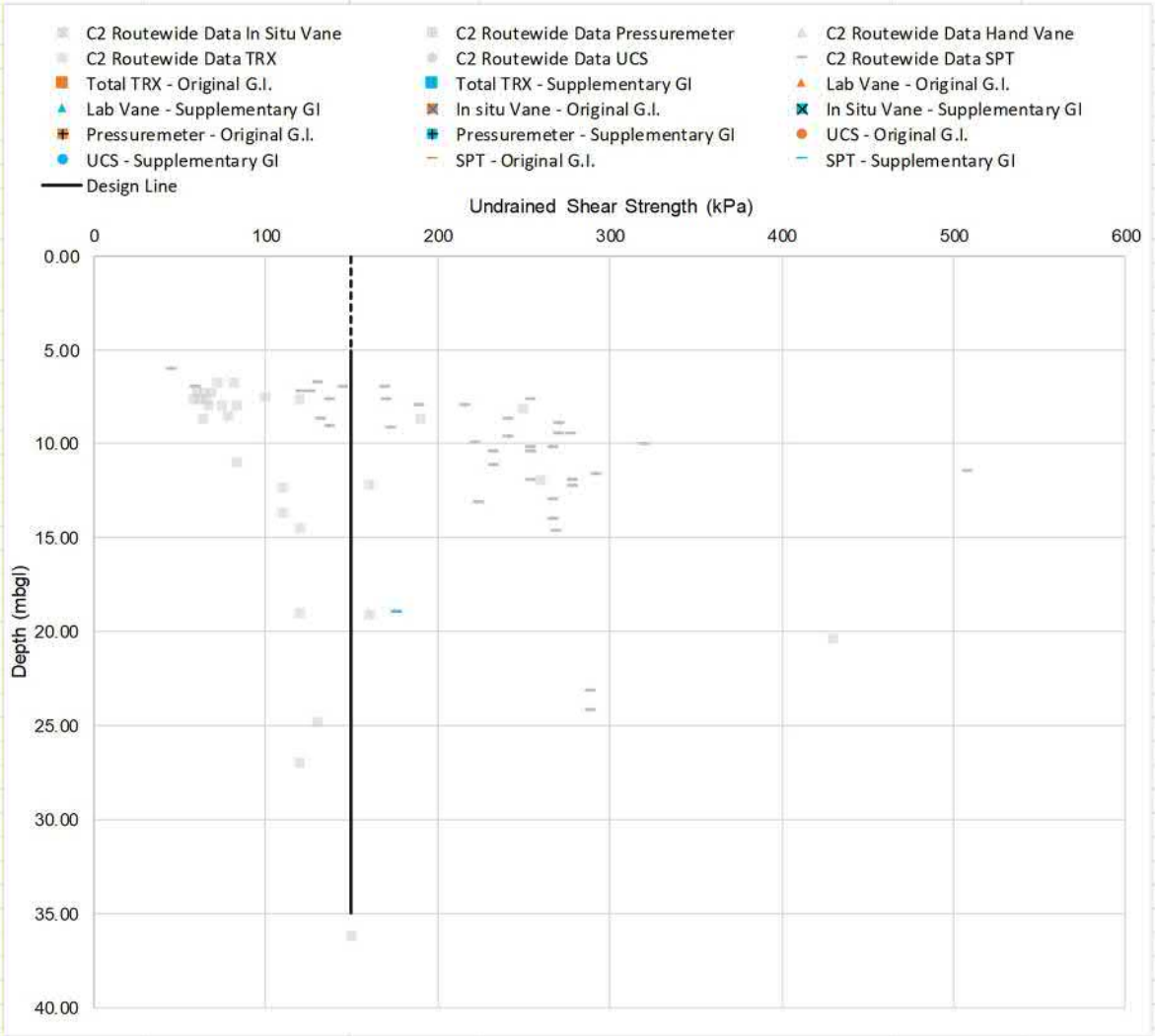
Figure 44 Undrained shear strength in Oxford Clay (stiff clay)

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HS2

Undrained Shear Strength vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC07 - Stage One C3 -MWCC – Brackley to South Portal of Long Itchington Tunnel	Location:	Chetwode Cutting Group
Client:	HS2	Geology :	KLB-C Z	Figure:	KLB-C Z Cu



	Total
Number of Tests	2
Minimum	-
Maximum	-
Offset	

Notes

Background Routewide data shown are based on Holebase database geology codes dated 30/06/2021 from C2 and C3 Routewide

Inferred ground conditions applied to CPT Cu profiles are based on review of exploratory hole information adjacent to the CPT position.

Plot Date:	13/07/2021
Holebase database reference	Datadrop 11. Published 06/2021

Figure 45 Undrained shear strength in Kellaways formation (stiff clay)

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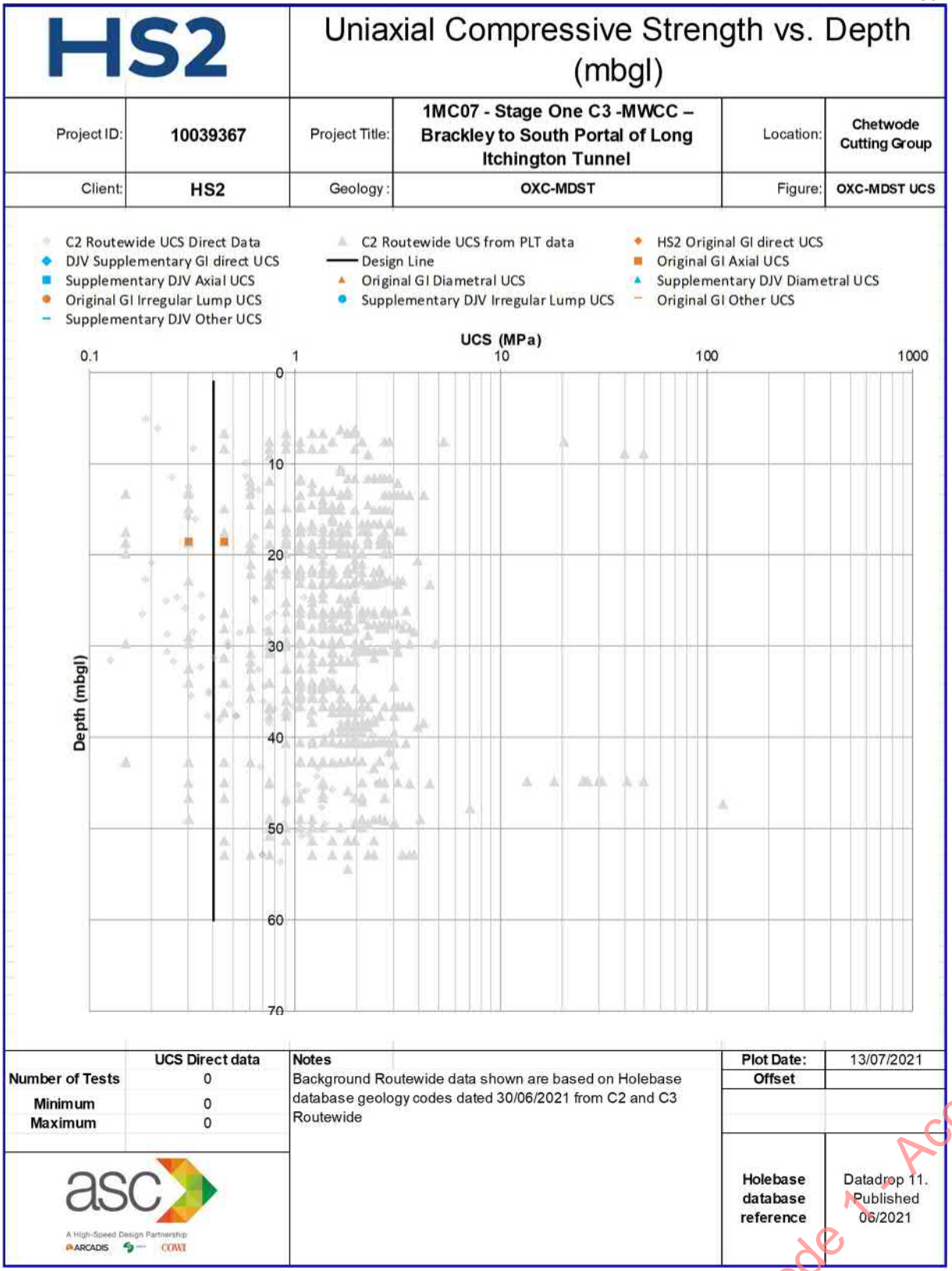
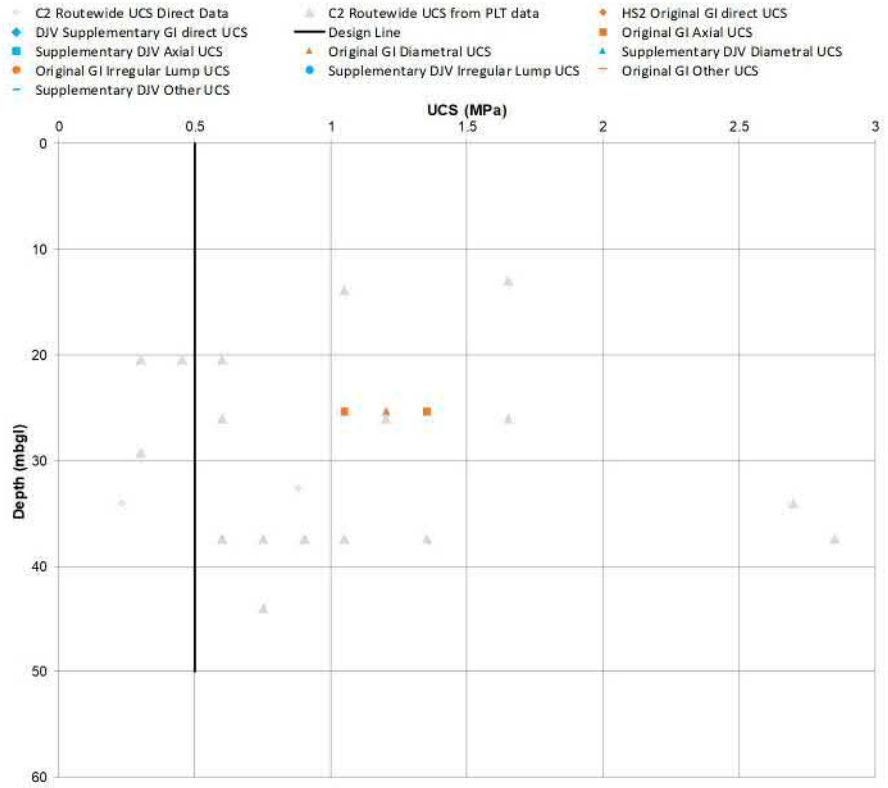


Figure 46 Uniaxial Compressive Strength in Oxford Clay formation (weak mudstone)

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Uniaxial Compressive Strength vs. Depth (mbgl)

Project ID:	10039367	Project Title:	1MC07 - Stage One C3 -MWCC – Brackley to South Portal of Long Itchington Tunnel	Location:	Chetwode Cutting Group
Client:	HS2	Geology:	KLB-MDST	Figure:	KLB-MDST UCS



	UCS Direct data
Number of Tests	0
Minimum	0
Maximum	0

Notes

Background Routewide data shown are based on Holebase database geology codes dated 30/06/2021 from C2 and C3 Routewide

Plot Date:	13/07/2021
Offset	

Holebase database reference	Datadrop 11. Published 06/2021

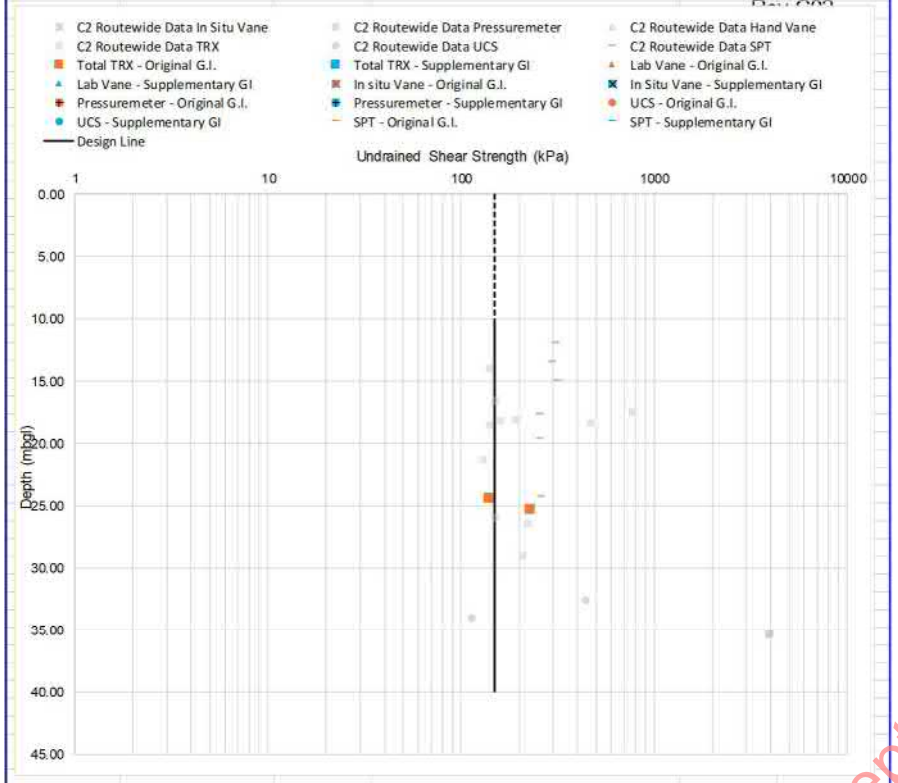
Undrained Shear Strength vs. Depth (mbgl)

High Speed 2 - 1MC06 Stage One C2 - MWCC – North Portal of Chiltern Tunnels to Brackley

Chetwode Cutting Geotechnical Design Report

1MC06-CEK-GT-REP-CS06_CL10-000031

Project ID:	10039367	Project Title:	1MC07 - Stage One C3 -MWCC – Brackley to South Portal of Long Itchington Tunnel	Location:	Chetwode Cutting Group
Client:	HS2	Geology:	KLB-MDST	Figure:	KLB-MDST Cu



	Total
Number of Tests	2
Minimum	-
Maximum	-
Offset	

Notes

Background Routewide data shown are based on Holebase database geology codes dated 30/06/2021 from C2 and C3 Routewide

Inferred ground conditions applied to CPT Cu profiles are based on review of exploratory hole information adjacent to the CPT position.

Plot Date:	13/07/2021

Holebase database reference	Datadrop 11. Published 06/2021

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Figure 47 Uniaxial Compressive Strength and Undrained shear strength in Kellaways formation (weak mudstone)

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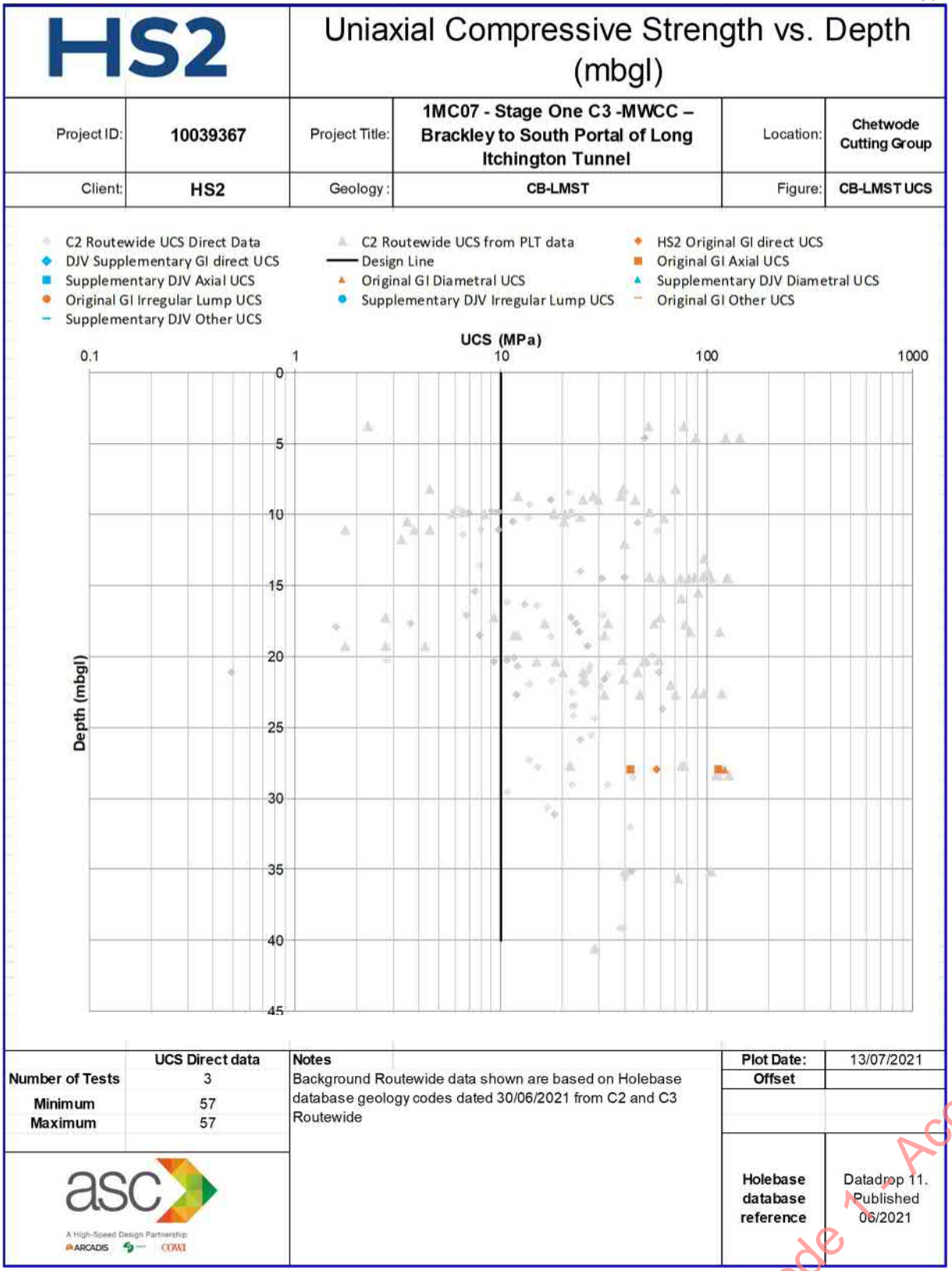


Figure 48 Uniaxial Compressive Strength in Cornbrash formation (medium strong limestone)

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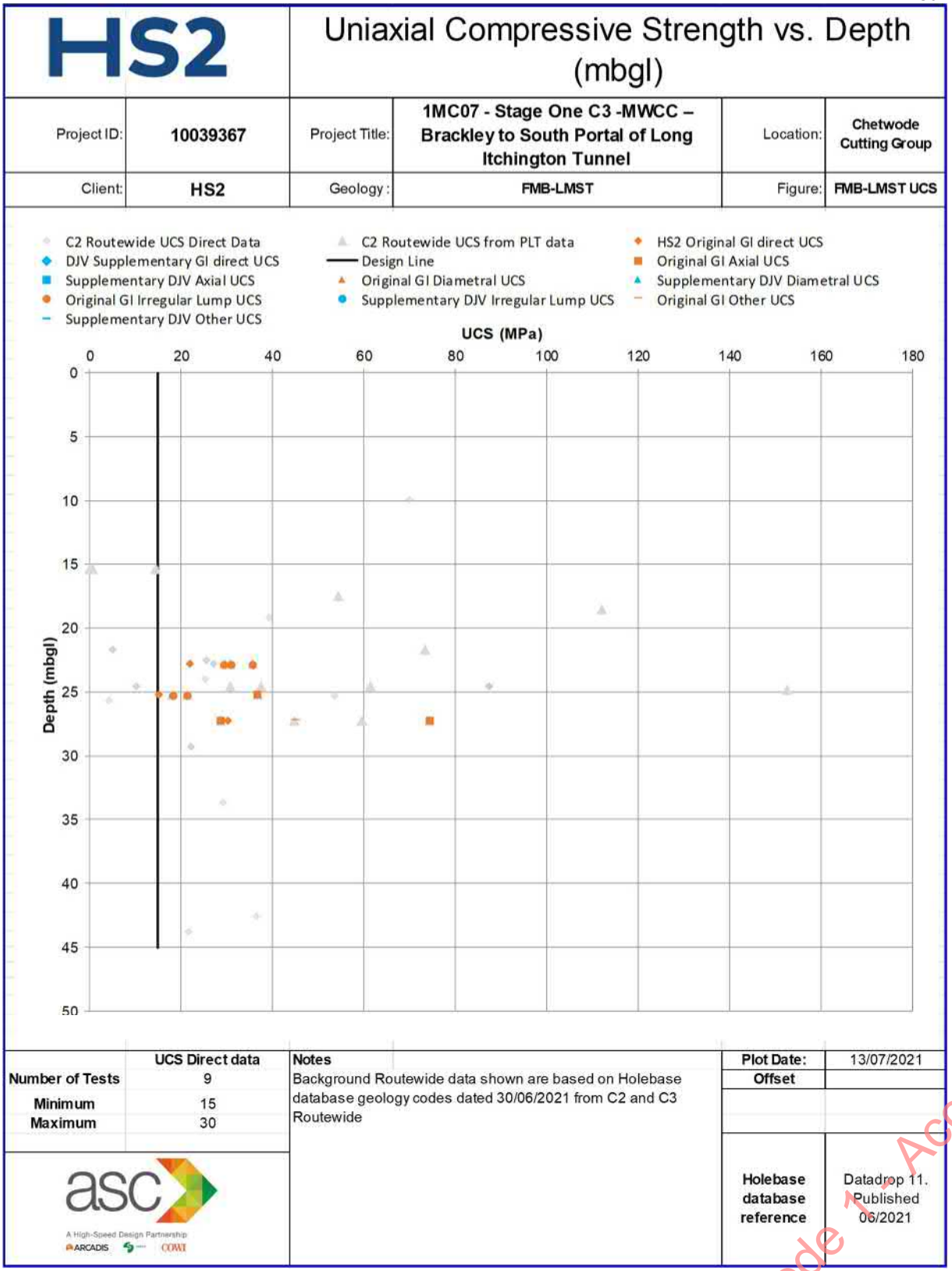


Figure 49 Uniaxial Compressive Strength in Forest Marble formation (strong limestone)

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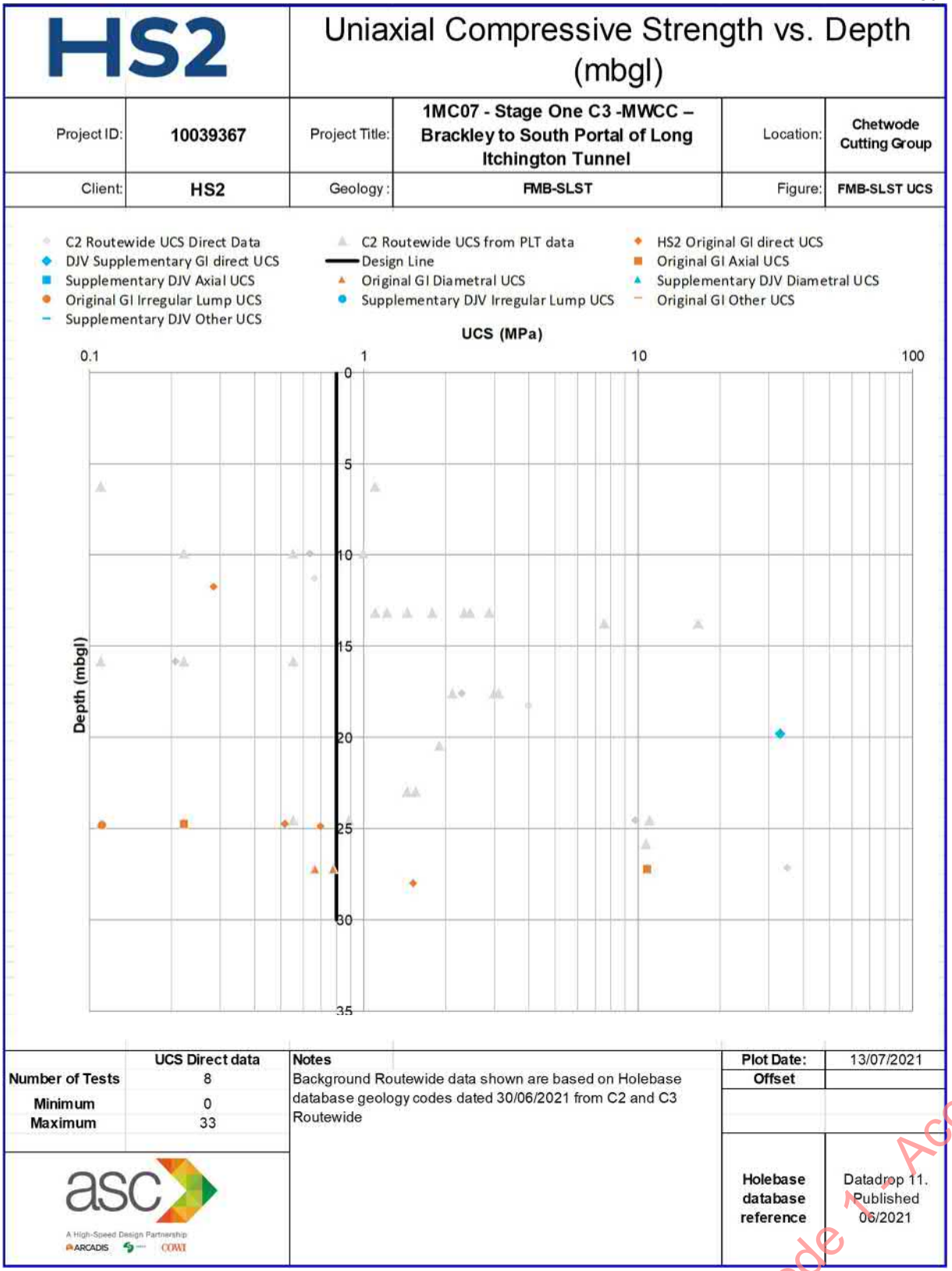


Figure 50 Uniaxial Compressive Strength in Forest Marble formation (weak siltstone)

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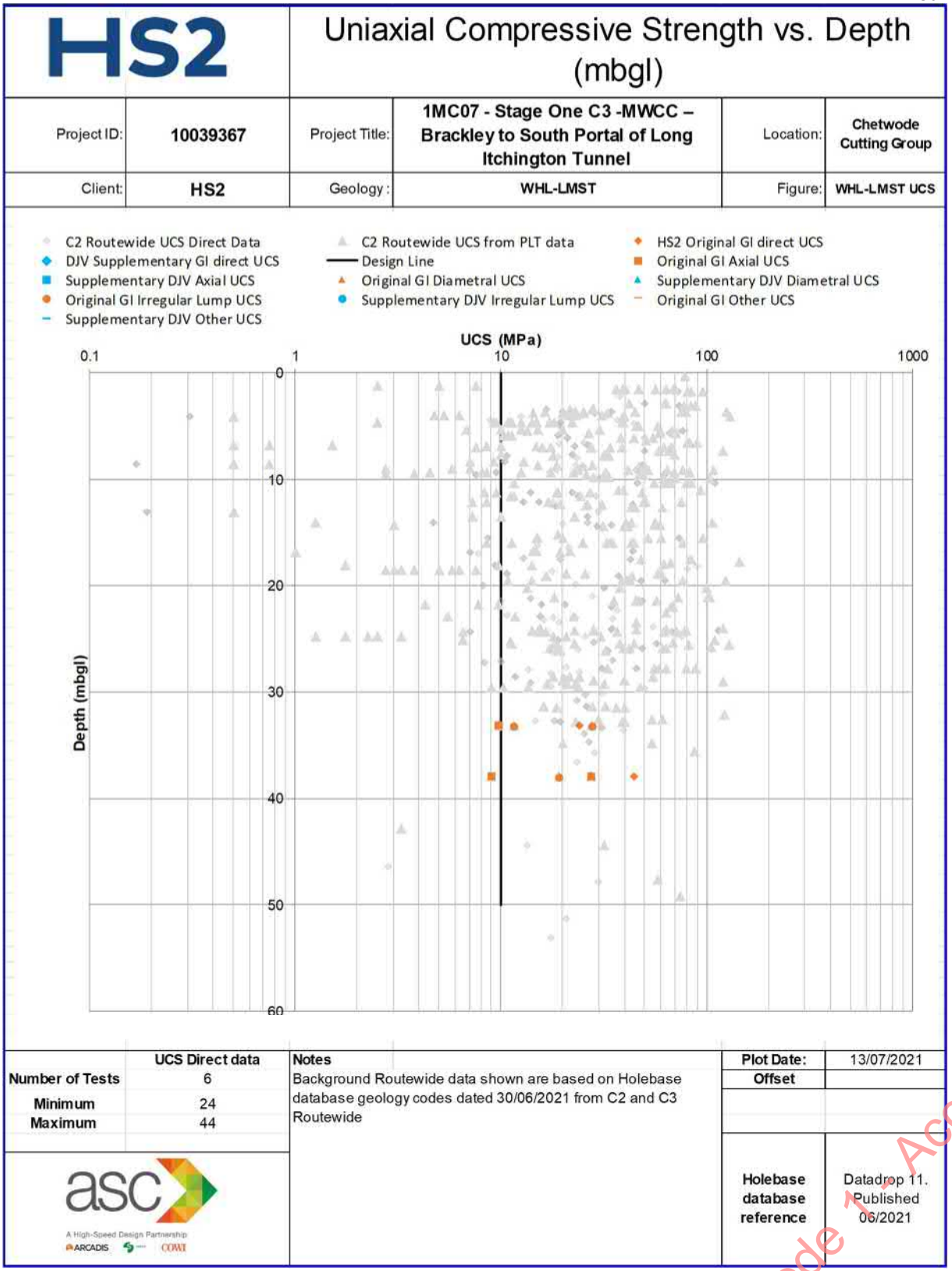


Figure 51 Uniaxial Compressive Strength in White Limestone formation (medium strong limestone)

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1.2.3 Young modulus

The Young modulus values that were defined for CHW18 Overbridge are used for this overbridge. This assumption is taken because both overbridges are located in the Clay Vale zone and Chetwode cutting, less than 1 km apart. These values are thus listed in the table below.

Table J.126 Soil Young moduli

Formation	Base elevation (m AOD)	E' (MPa)	Notes
Till	100.3	14	Correlated from SPT values NSPT = 11, but NSPT=7 considered instead to keep the value lesser than the underlying formation. E=2*NSPT=14 MPa
Glaciofluvial deposits	98.2	18	Correlated from SPT values Average NSPT = 9 ⇒ E=2*NSPT=18 MPa
Oxford Clay formation	85.1	16-20	Correlated from SPT values Minimal SPT=7, greater values at 18-19. Average values 8-10 ⇒ E=2*NSPT=16-20 MPa
Kellaways formation	79.7	20	Conservative value of 20 MPa equal to E of the overlying formation

1.2.4 Drained shear resistance properties (c and ϕ)

The drained shear strength properties are calculated through a cross analysis of tests on samples collected from exploratory holes in the Chetwode cutting. The following values are selected for the non-rocky formations.

Table J.127 Drained shear resistance properties

Formation	Base elevation (m AOD)	c' (kPa)	Notes	Φ(°)	Notes
Till	106	0	No data available, hence c'=0 selected	27	Defined from experience feedback, since the value from shear tests (34°) is high
Glaciofluvial deposits	100.5	0	Low fine content	30*	Defined as the lower estimate from 7 direct shear tests. Range of values from

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Formation	Base elevation (m AOD)	c' (kPa)	Notes	Φ(°)	Notes
					tests is 30°-35°
Oxford Clay formation	89	5	Estimated from 2 CU+u triaxial tests and experience feedback	28	Estimated from 3 Cu+u triaxial tests
Kellaways formation	83.5	5	Estimated from 1 triaxial test	27	Estimated from 1 triaxial test

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1.3 Soil model summary

Based on the paragraphs 0 and 1.2, the used soil model is summarized in the following table.

Table J.128 Detailed design soil model summary

Geological group	Geological formation	Design top level (m AOD)	Design thickness (m)	Design bottom level (m AOD)	Undrained shear strength (kPa)	Uniaxial Compressive Strength (MPa)	Young modulus (MPa)	c' (kPa)	ϕ (°)
Till	Till formation	109.5	3.5	106	**Clay: 75 kPa**	-	14	0	27
Glaciofluvial deposits	Glaciofluvial deposits	106	5.5	100.5	**Sand: 40 kPa**	-	18	0	30
Oxford Clay formation	Oxford Clay formation	100.5	11.5	89	**Clay: 67+8.3z** (max. 150 kPa) **Mudstone: 150 KPa**	-	16-20	5	28
Kellaways formation	Kellaways formation	89	5.5	83.5	**Mudstone: 150 kPa**	-	20	5	27
Great Oolite Group	Cornbrash formation	83.5	2.7	80.8	-	**Limestone: 10 MPa**	Assumed substratum	-	-
	Forest Marble formation	80.8	3.3	77.5	-	**Siltstone: 0.8 MPa** *Limestone: 15 MPa*	-	-	-

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Geological group	Geological formation	Design top level (m AOD)	Design thickness (m)	Design bottom level (m AOD)	Undrained shear strength (kPa)	Uniaxial Compressive Strength (MPa)	Young modulus (MPa)	c' (kPa)	ϕ (°)
	White Limestone formation	77.5	8.0	69.5		*Limestone: 10 MPa not used in the design*	-	-	-

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1.4 Seismic parameters

Based on the Ground Engineering Design Basis Statement – Seismic Design (*1MC06-CEK-GT-REP-C002-000096*) The design value of the PGA is equal to 0.05 g. This value corresponds to a return period of 2500 years (2% probability of exceedance in 50 years) and to an ultimate limit state.

For seismic calculations, soil moduli are multiplied by a factor of 3 to account for short term behaviour effects. Soil resistance properties are unchanged between static and seismic analysis.

On the other side, the ground type in accordance with Eurocode 8 is B. The description of this type (Deposits of very dense sand, gravel, or very stiff clay, at least several tens of meters in thickness, characterized by a gradual increase of mechanical properties with depth) is compatible with the encountered stratigraphy.

1.5 Ground water

Ground water monitoring near the overbridge is done through standpipes installed in the ML086-CR005 and ML086-CR444. The readings show varying water level between 95 and 97 m AOD (ML086-CR005), and between 98 and 103.5 m AOD, with a peak value at 108 m AOD (ML086-CR444). identifies the groundwater level at 10 m depth below EGL, at 92 m AOD. In the calculations, the water level is conservatively taken at 1 m below natural ground level, at 108 m AOD.

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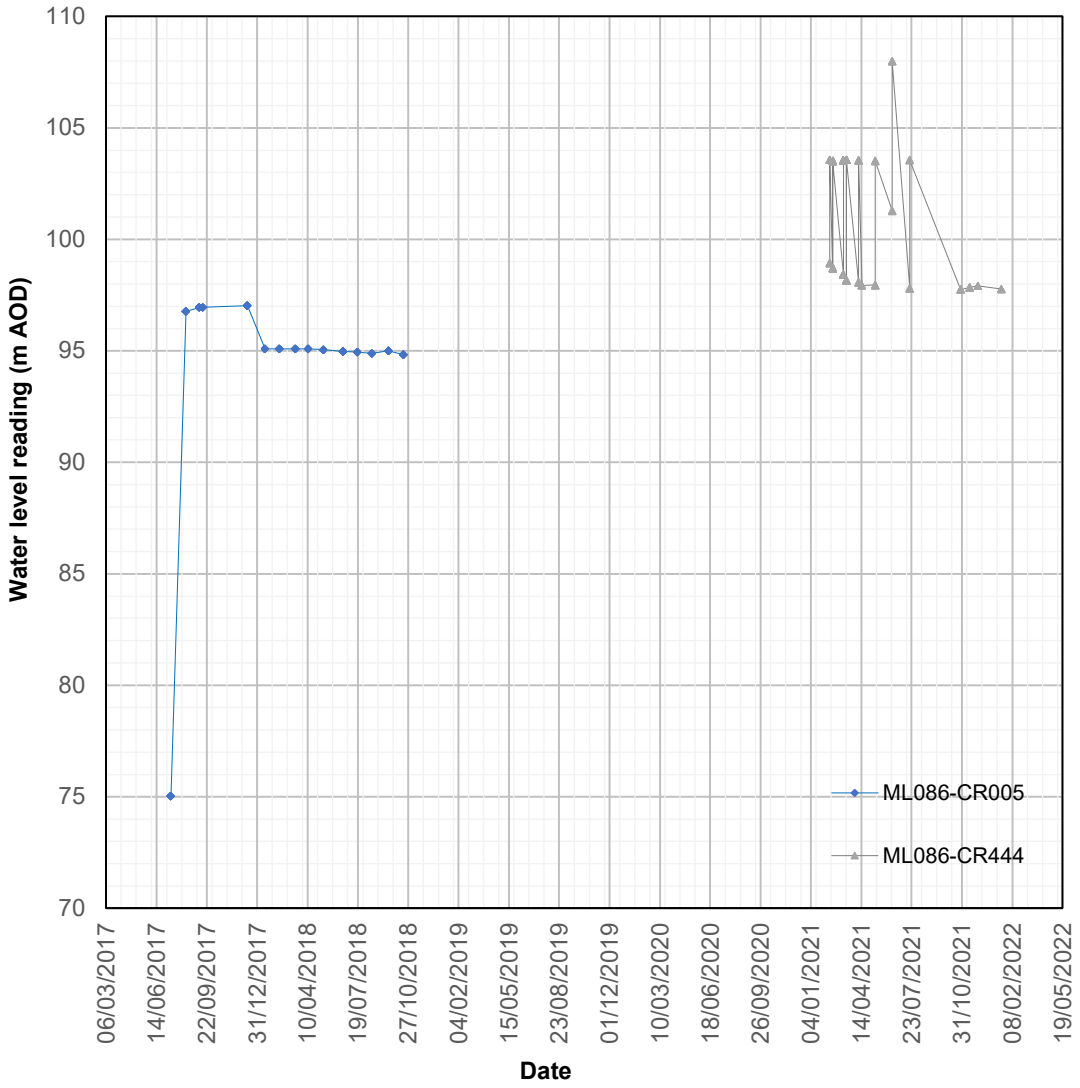


Figure 52 Water level measurements around the overbridge

1.6 Ground Aggressivity and Concrete Classification

The concrete classes are defined considering the level of ground aggressivity. The ground aggressivity class is determined according to the BS 8500-1, based on the results of chemical tests conducted on samples from each formation.

In accordance with BS 8500-1 (2015), the aggressivity of the ground toward concrete is defined from the following characteristics:

- Total Sulphur (TS)
- Acid-Soluble Sulphates (AS)
- Water-Soluble Sulphates (WS)
- pH

The analysis is conducted as follows: for each concerned formation of a certain nature, a representative value for each chemical characteristic is defined from lab tests results on samples collected in this formation in the vicinity of the overbridge or along the level 1 asset (Chetwode Cutting in this case).

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Then, the Design Sulfate Class and Aggressive Chemical Environment for Concrete (ACEC) classification are defined accordingly.

Next, for each foundation component (pile, pile cap or spread foundation), the Design Sulfate class and the ACEC is taken as the most unfavourable along those of the soil formations it interacts with.

Characteristic values are given in the following table. Detailed laboratory testing results are plotted below.

Table J.129. Chemical characteristic values

	Till (CZ)	Glaciofluvial deposits (SV)	Oxford Clay (CZ)	Kellaways formation (MDST)	Cornbrash formation (LMST)*
WS_k (mg/L SO4)	800	50	1200	1400	570
pH_k	8.8	9	7.8	8	8.6
AS_k (% SO4)	1.9	0.05	3.7	0.87	0.45
TS_k (% S)	1	0.04	2.6	4.2	2.3
TPS = 3 × TS_k (% SO4)	3	0.12	7.8	12.6	6.9

*No data available near the overbridge, values taken identical to CHW18 overbridge (both in Chetwode cutting).

Following the guidelines from BS 8500-1 (2015), the Design Sulfate Class, the groundwater conditions affecting the structure and the Aggressive Chemical Environment for Concrete (ACEC) classification are as follows.

Table J.130 Concrete classification

		Ground water conditions	DS Class	AC Class
Piles cap	Abutments	mobile	DS-5	AC-4s
	Piers	mobile	DS-5	AC-4s
Piles	Abutments	mobile	DS-2	AC-2
	Piers	mobile	DS-2	AC-2

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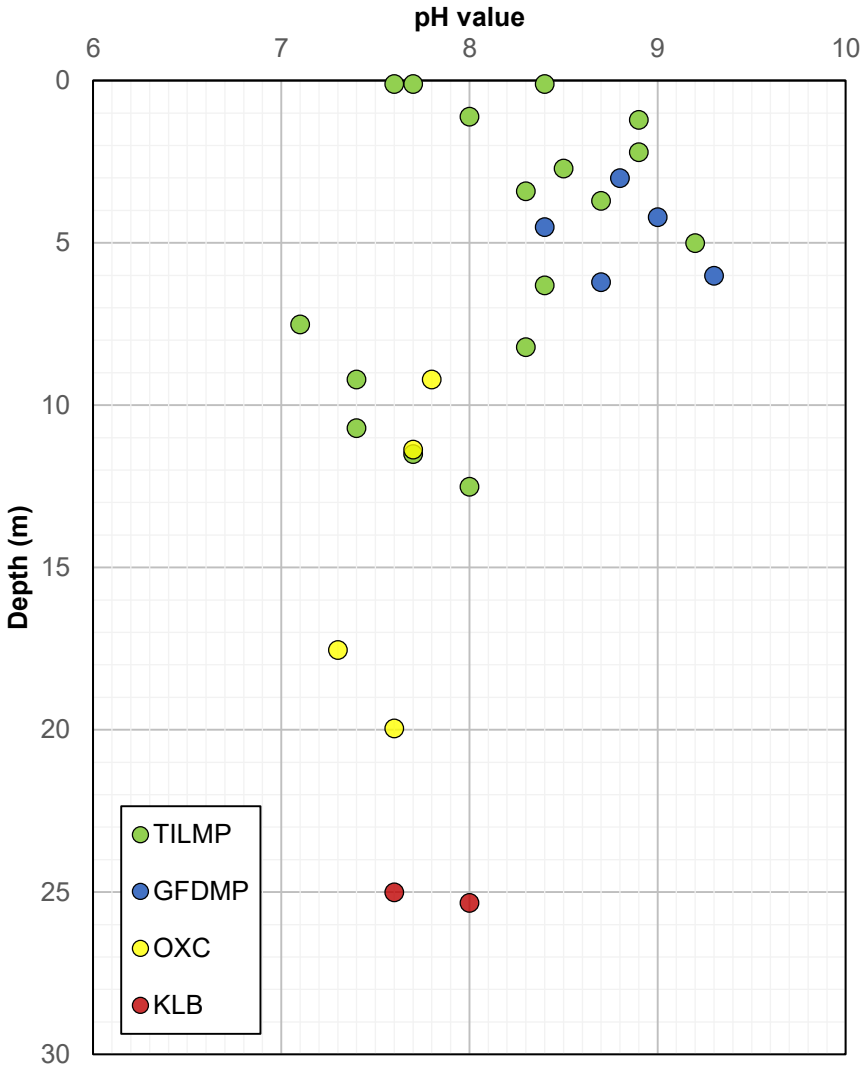
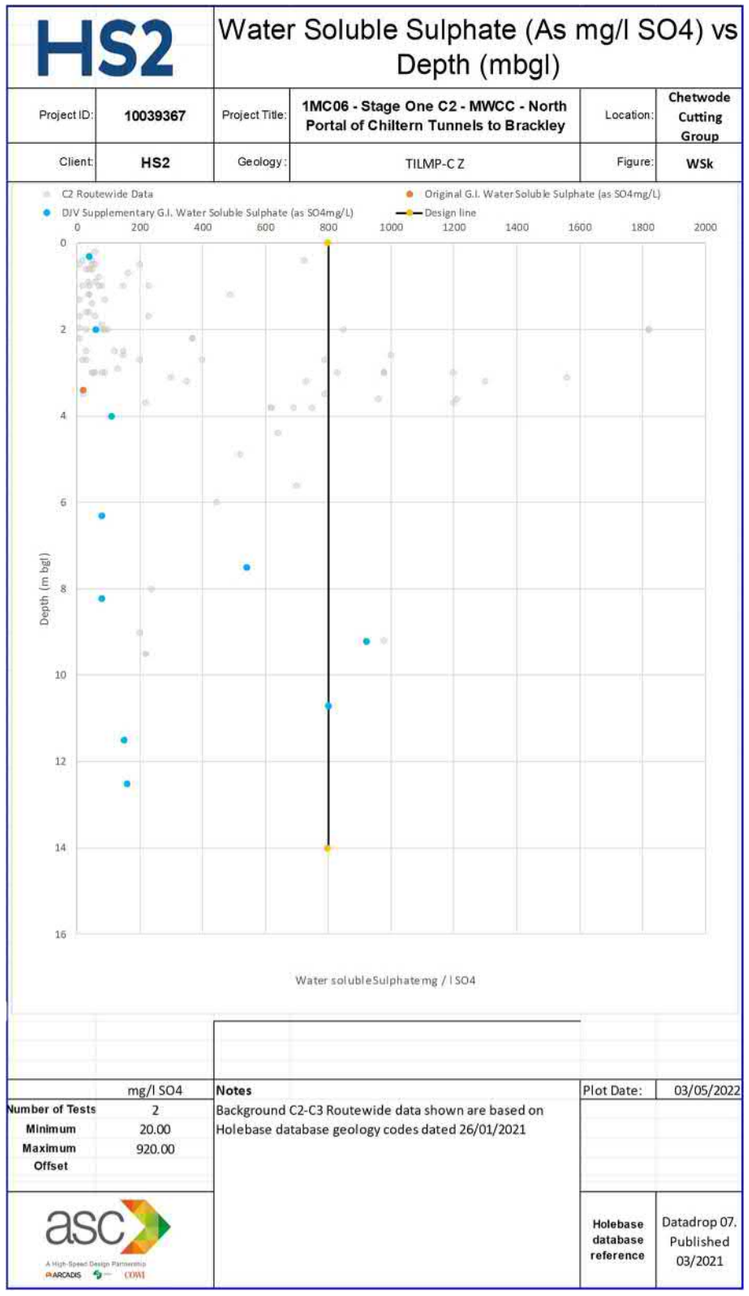
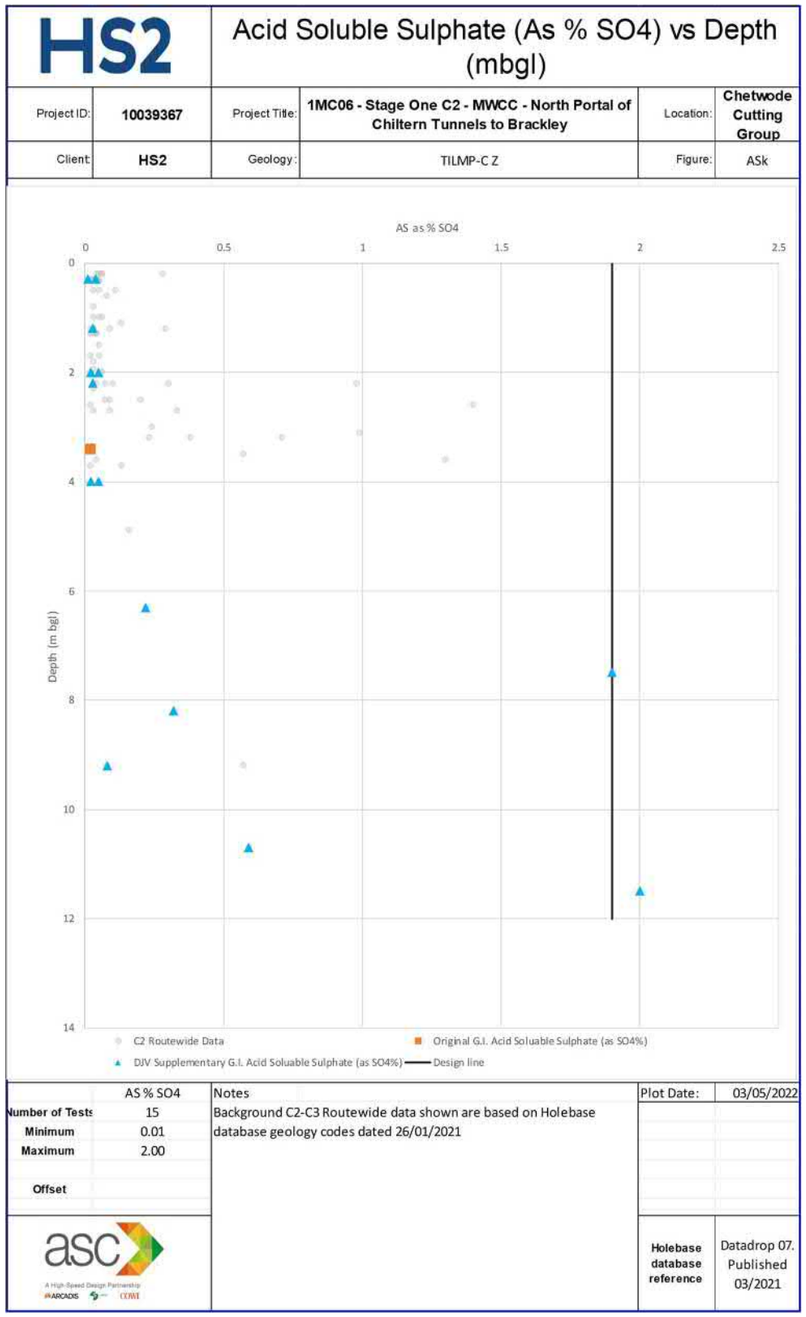


Figure 53 pH values in the encountered formation in function of depth – tests in ML086-CR443a, ML086-CR004, ML086-CR443, ML086-CR400, ML086-CR005 and ML086-CR444

HS2 Ltd - Code 1 - Accepted



(a)



(b)

Figure 54 Till (clay): (a) Water soluble sulfate concentration, (b) Acid soluble sulfate percentage

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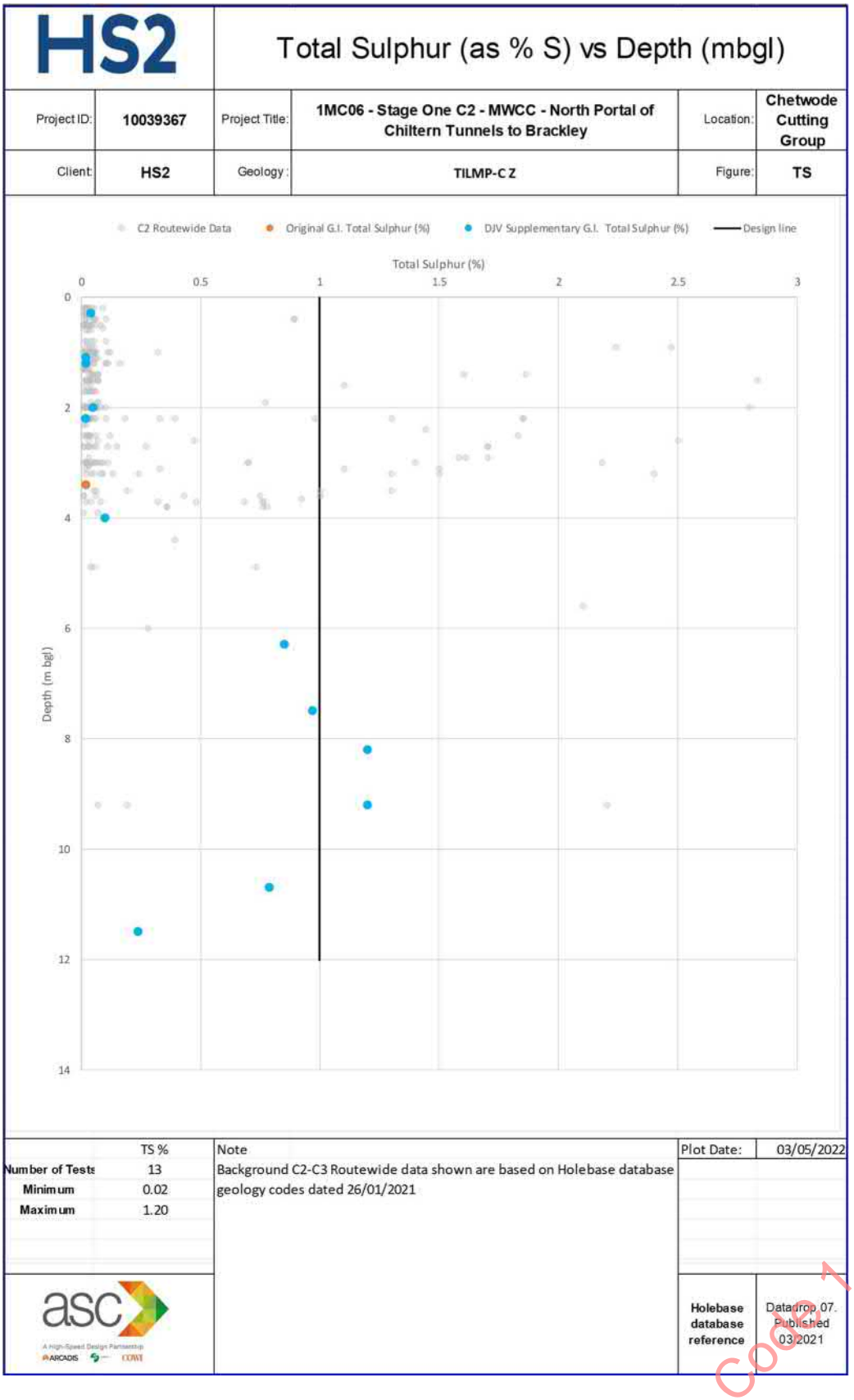
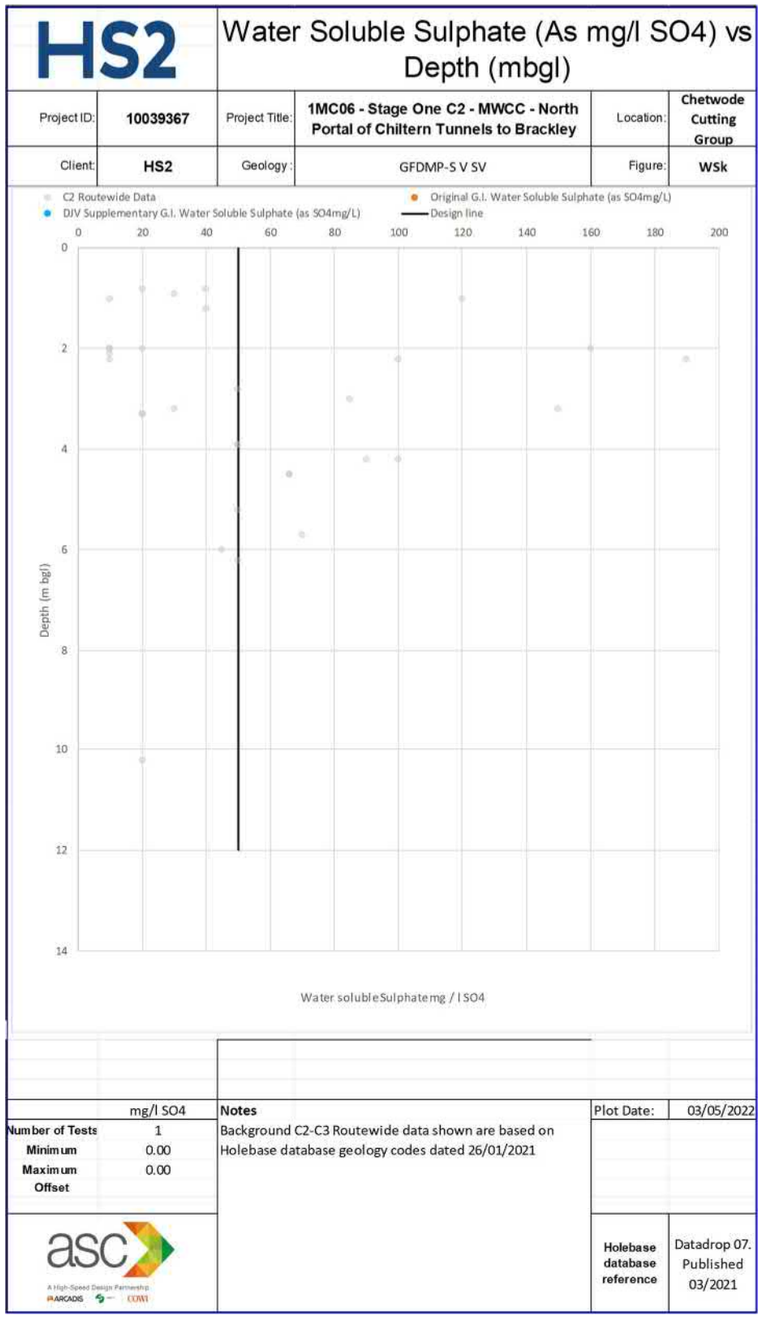
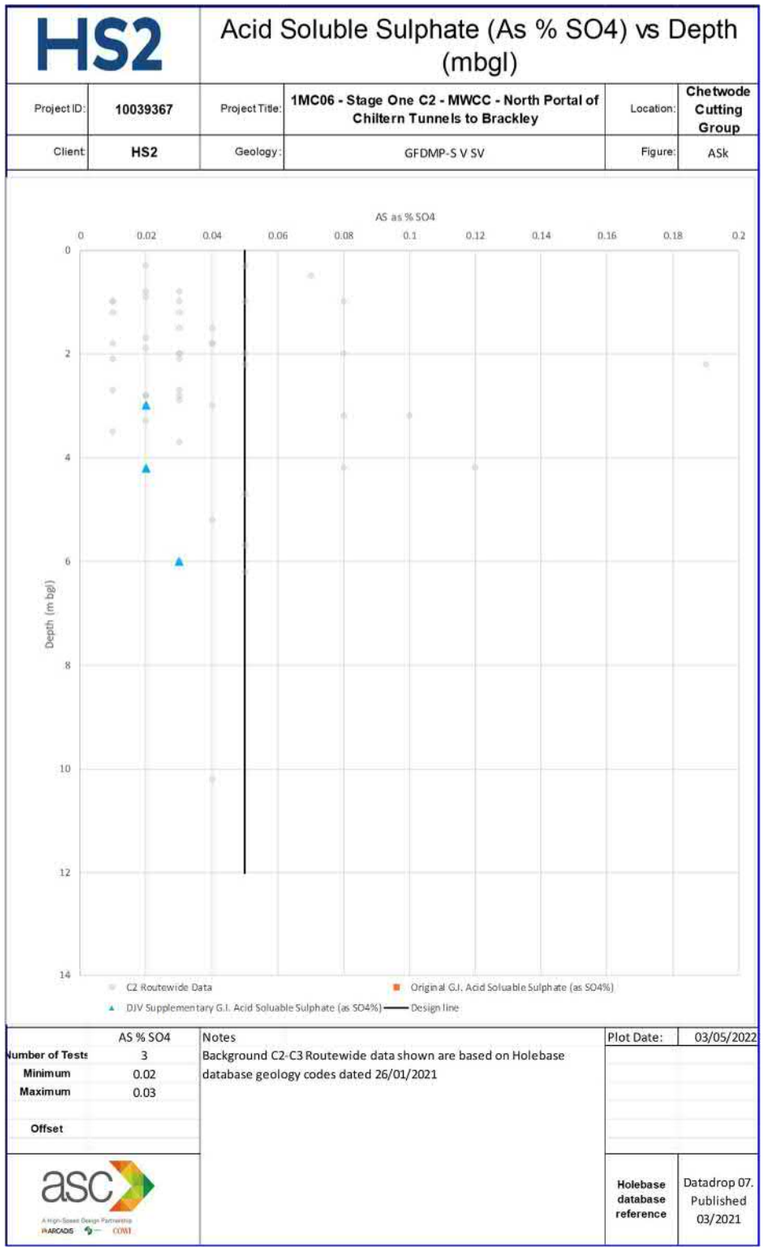


Figure 55 Till (clay): Total sulfur

HS2 Ltd - Code 1 - Accepted



(a)



(b)

Figure 56 Glaciofluvial deposits (sand): (a) Water soluble sulfate concentration, (b) Acid soluble sulfate percentage

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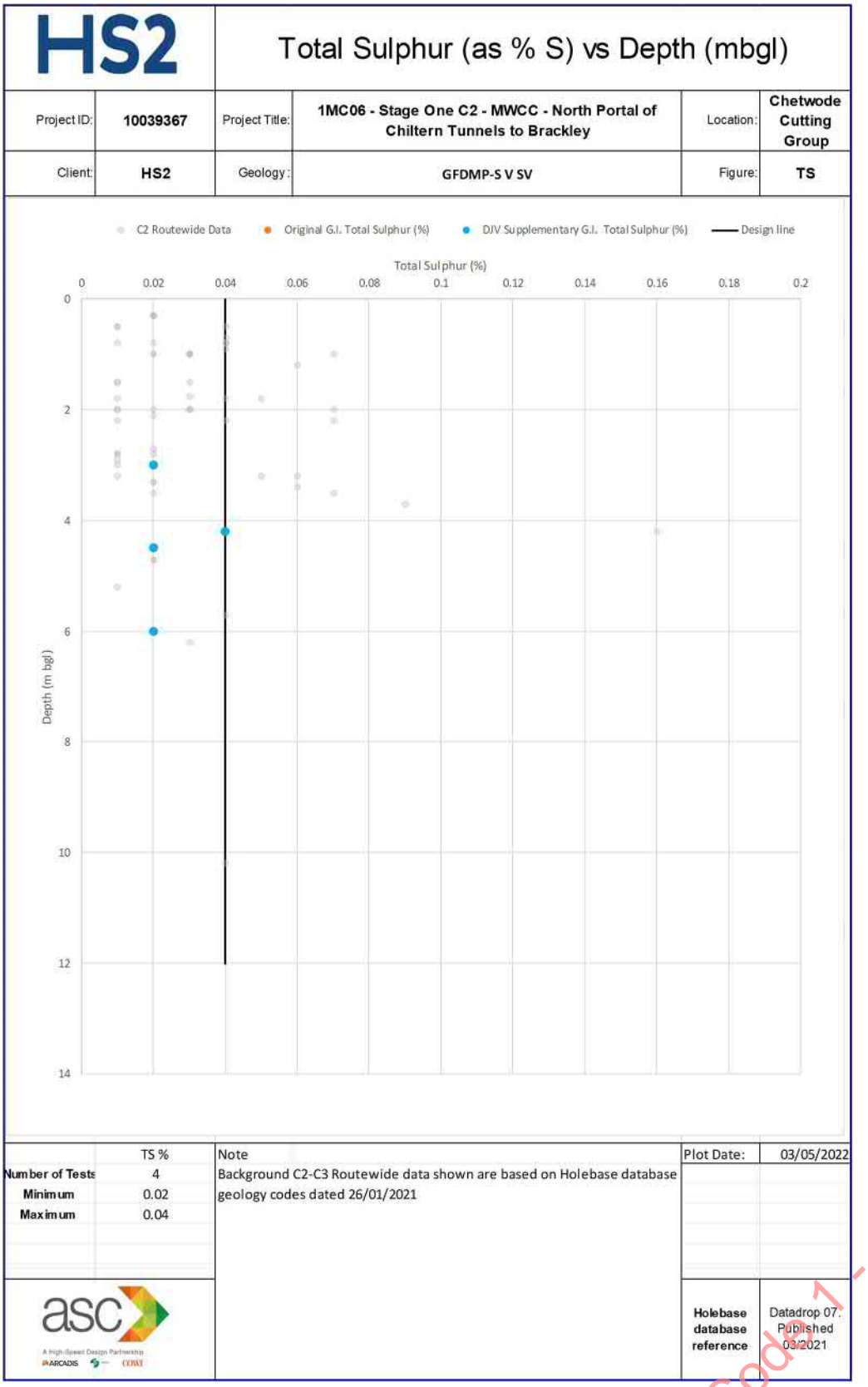
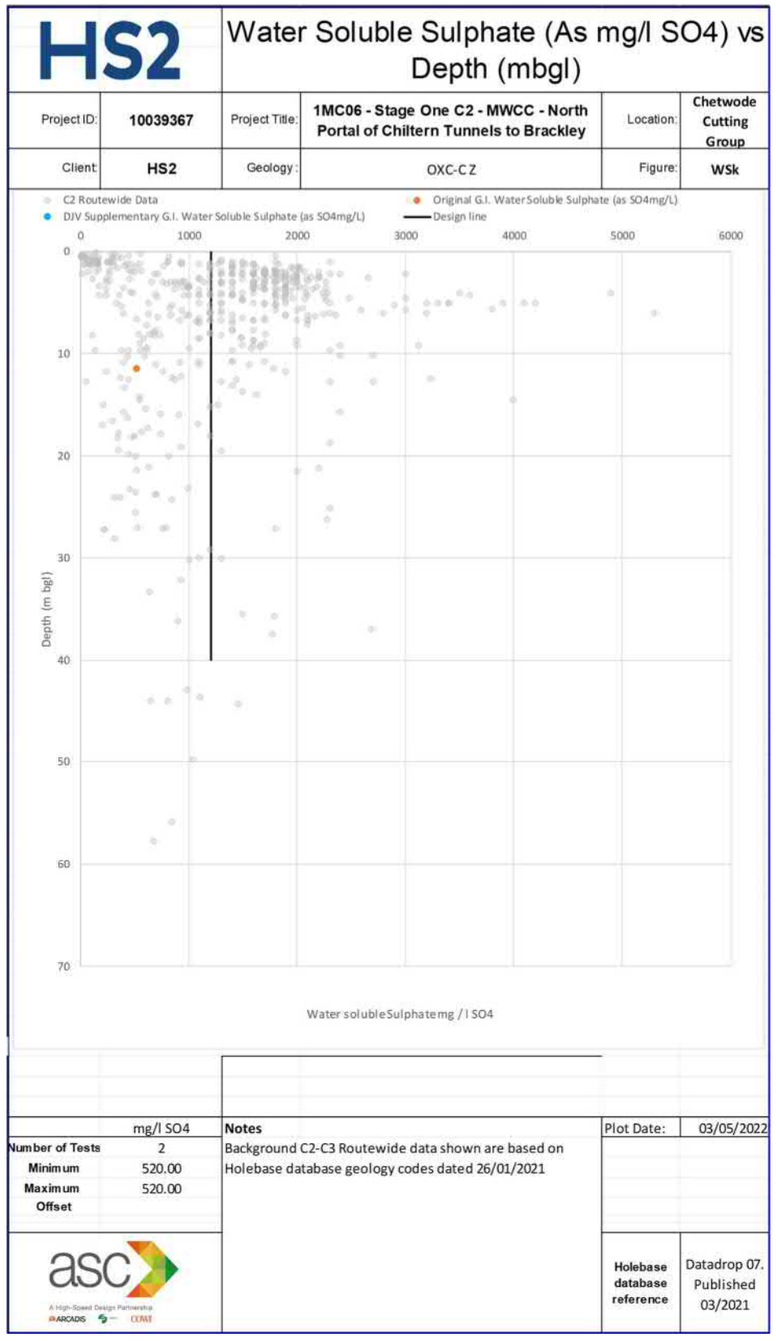
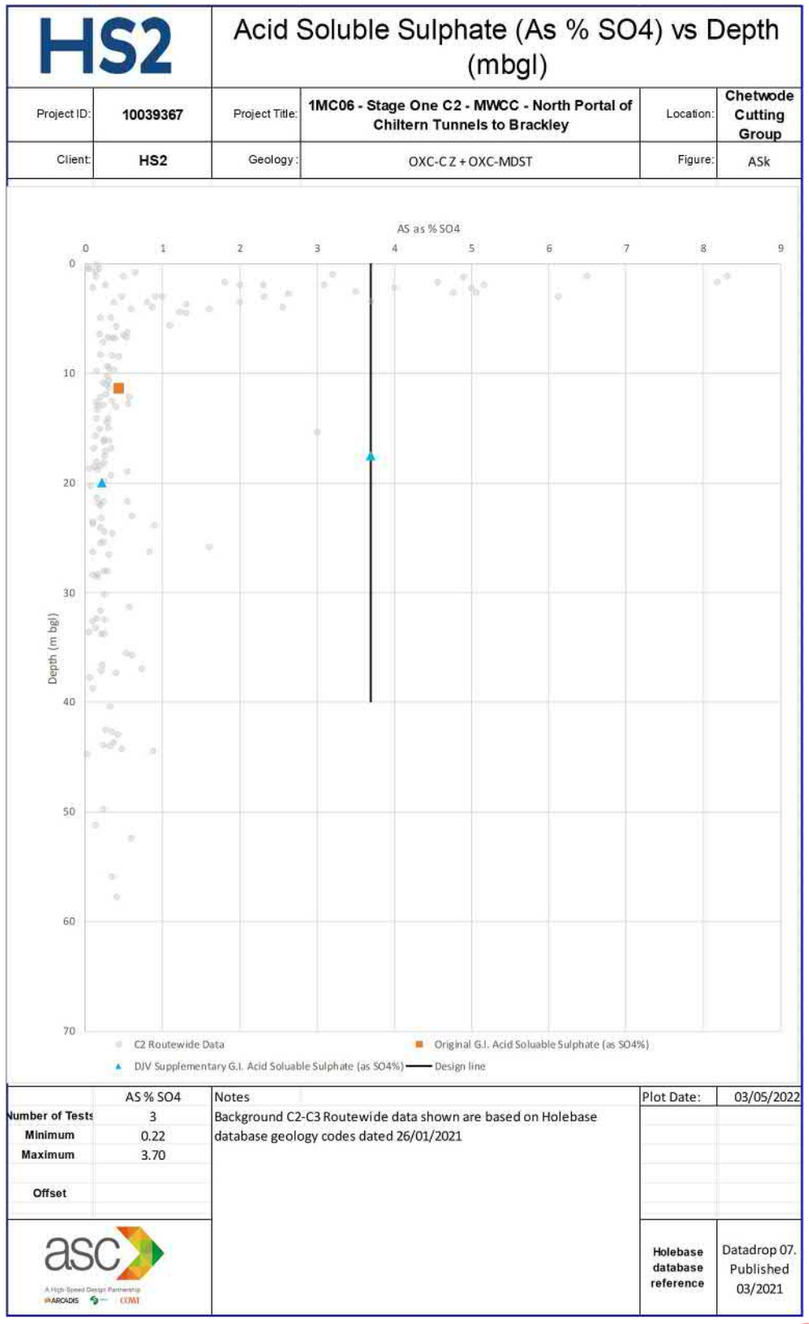


Figure 57 Glaciofluvial deposits (sand): Total sulfur

HS2 Ltd - Code 1 - Accepted



(a)



(b)

Figure 58 Oxford Clay: (a) Water soluble sulfate concentration, (b) Acid soluble sulfate percentage

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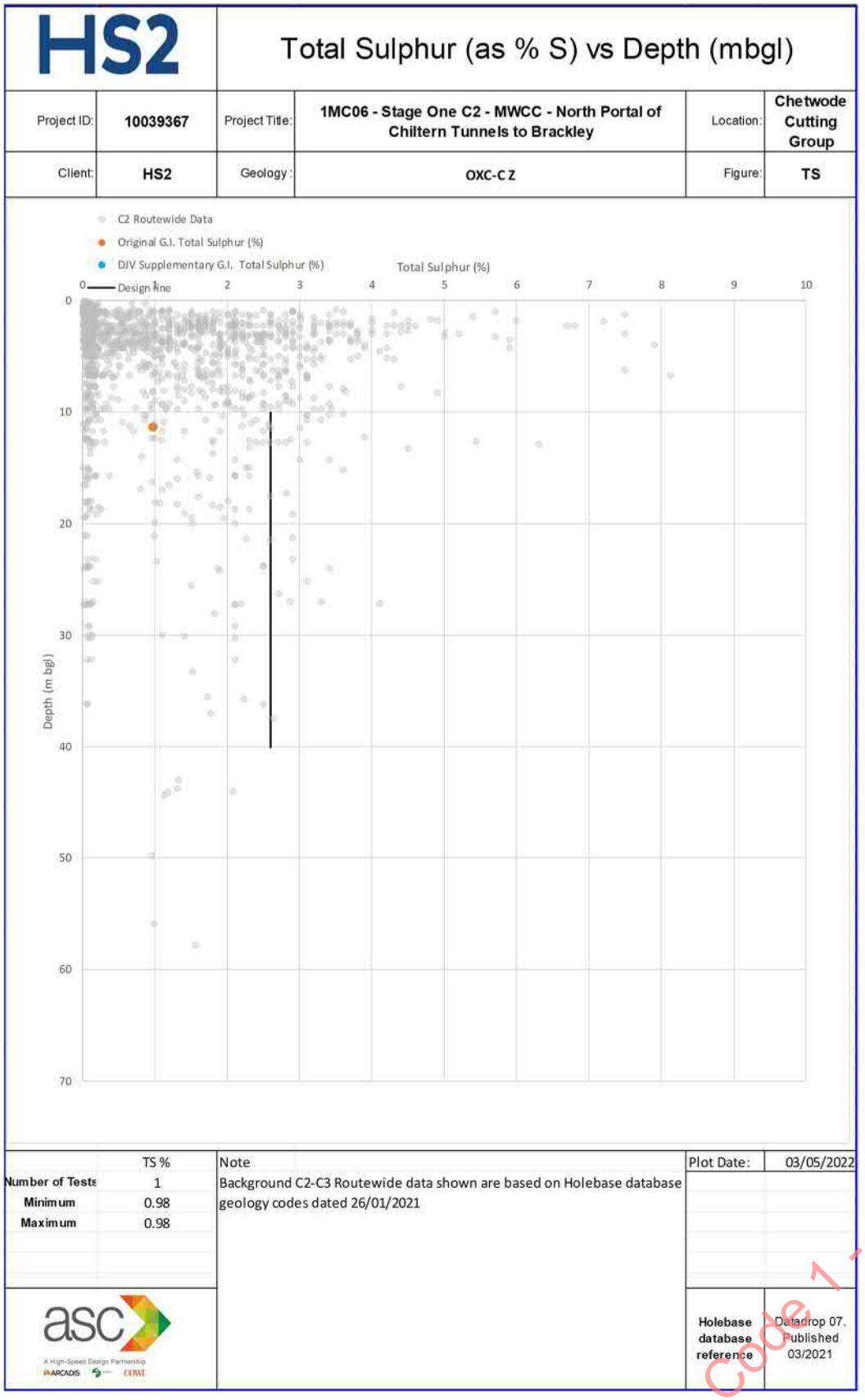
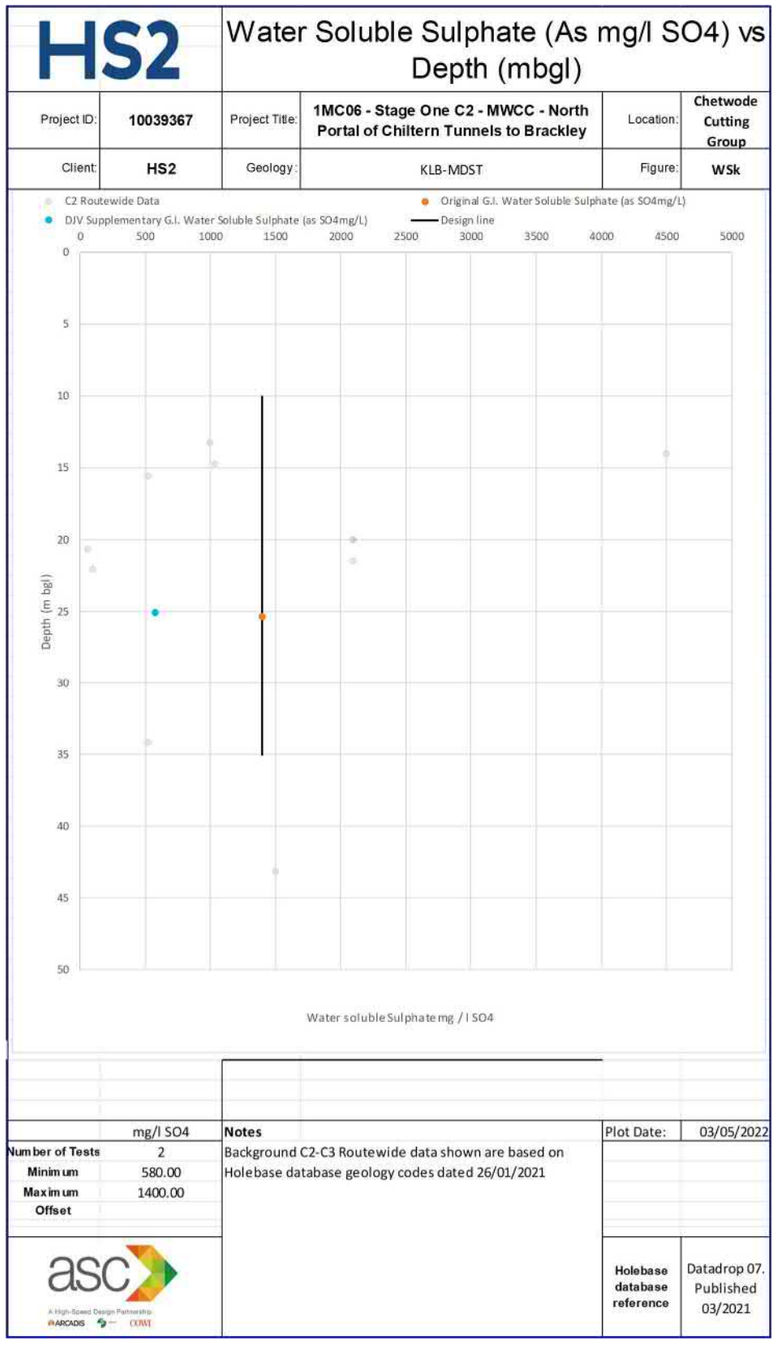
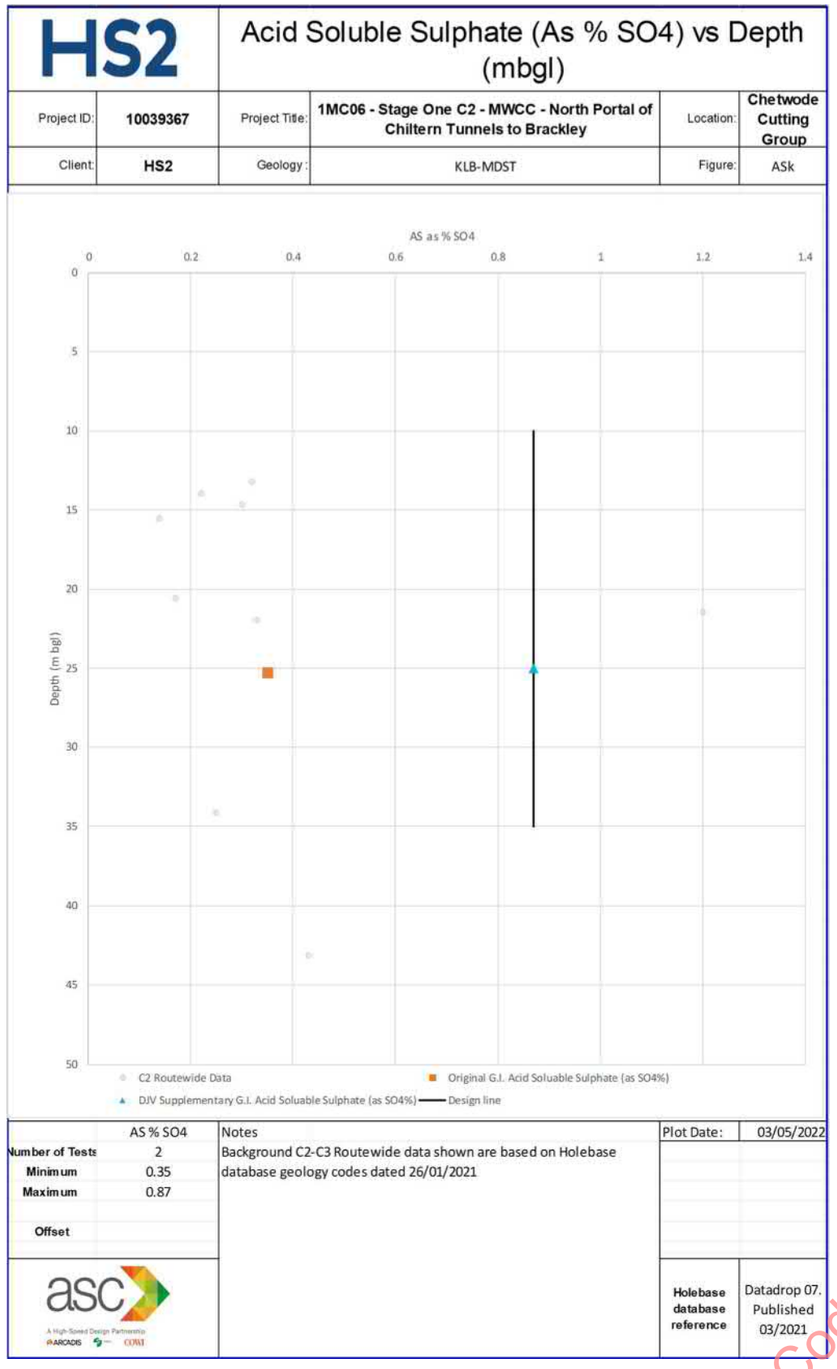


Figure 59 Oxford Clay: Total sulfur

HS2 Ltd - Code 1 - Accepted



(a)



(b)

Figure 60 Kellaways formation (mudstone): (a) Water soluble sulfate concentration, (b) Acid soluble sulfate percentage

HS2 Ltd - Code 1 - Accepted

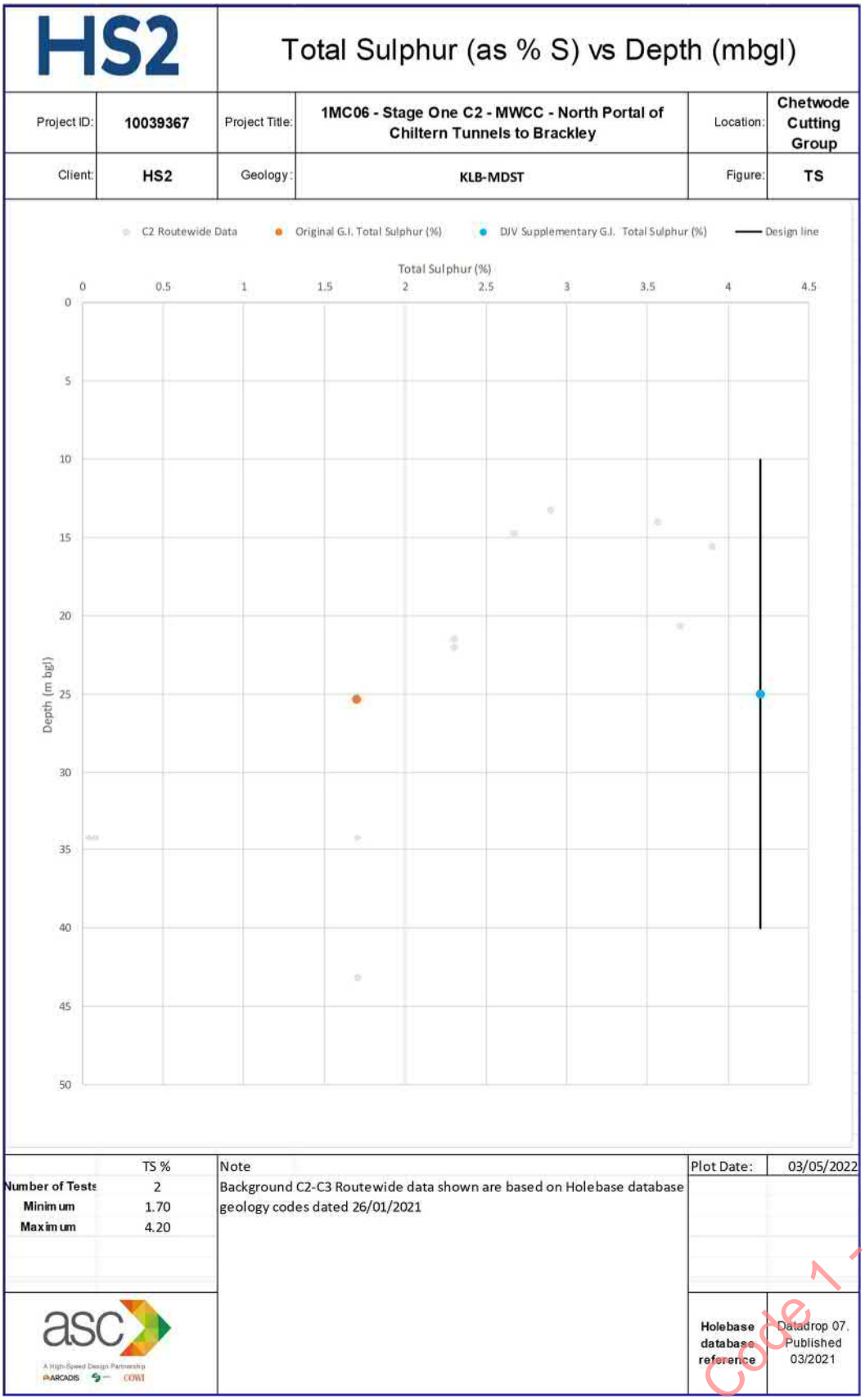
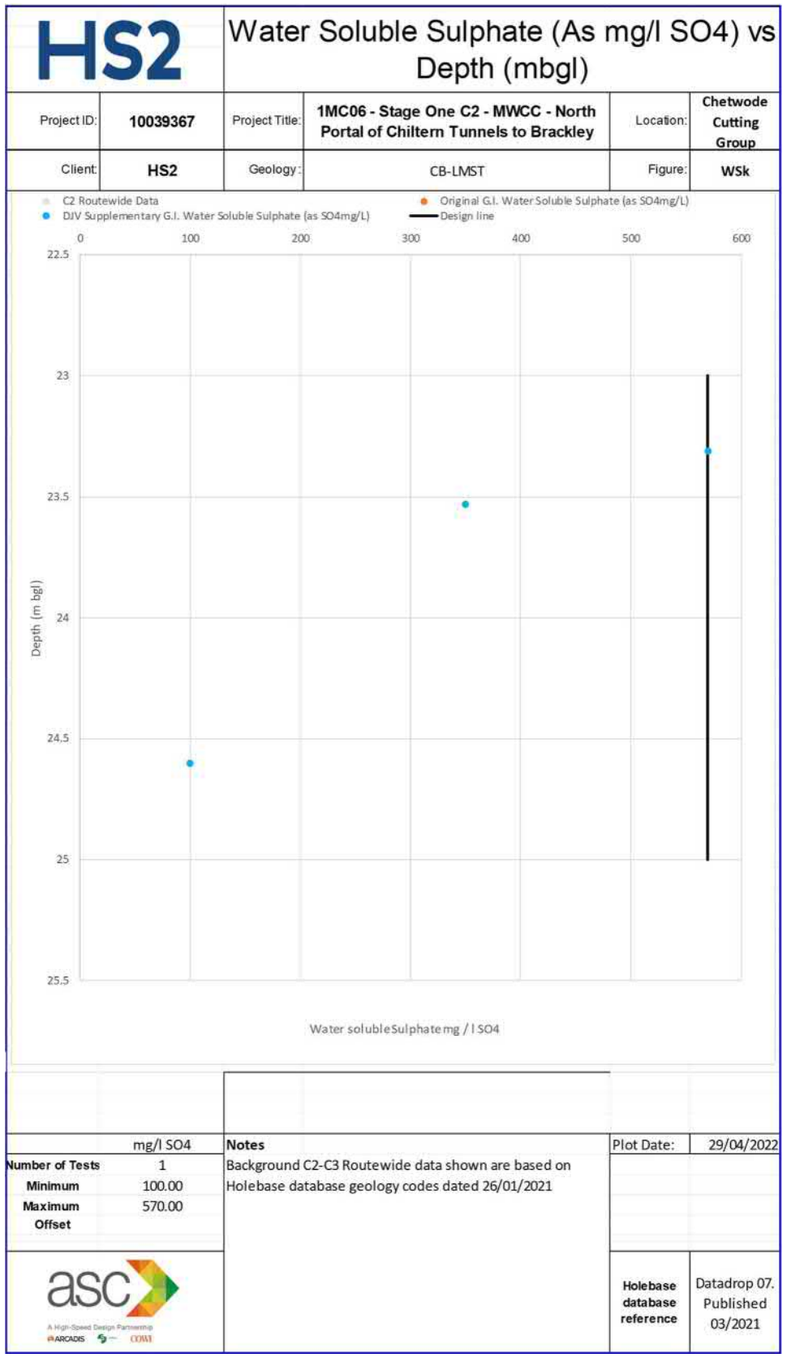
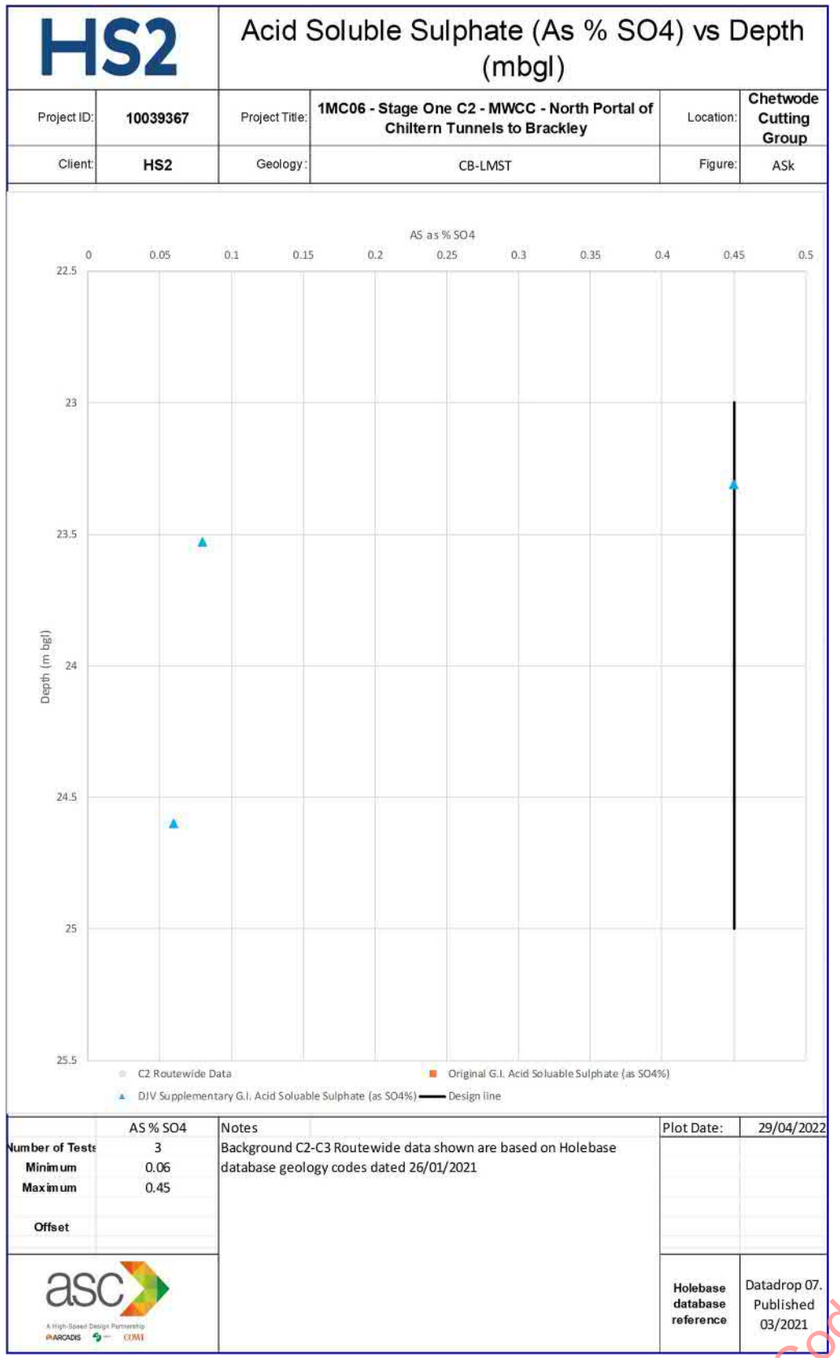


Figure 61 Kellaways formation (mudstone): Total sulfur

HS2 Ltd - Code 1 - Accepted



(a)



(b)

Figure 62 Cornbrash formation (limestone): (a) Water soluble sulfate concentration, (b) Acid soluble sulfate percentage

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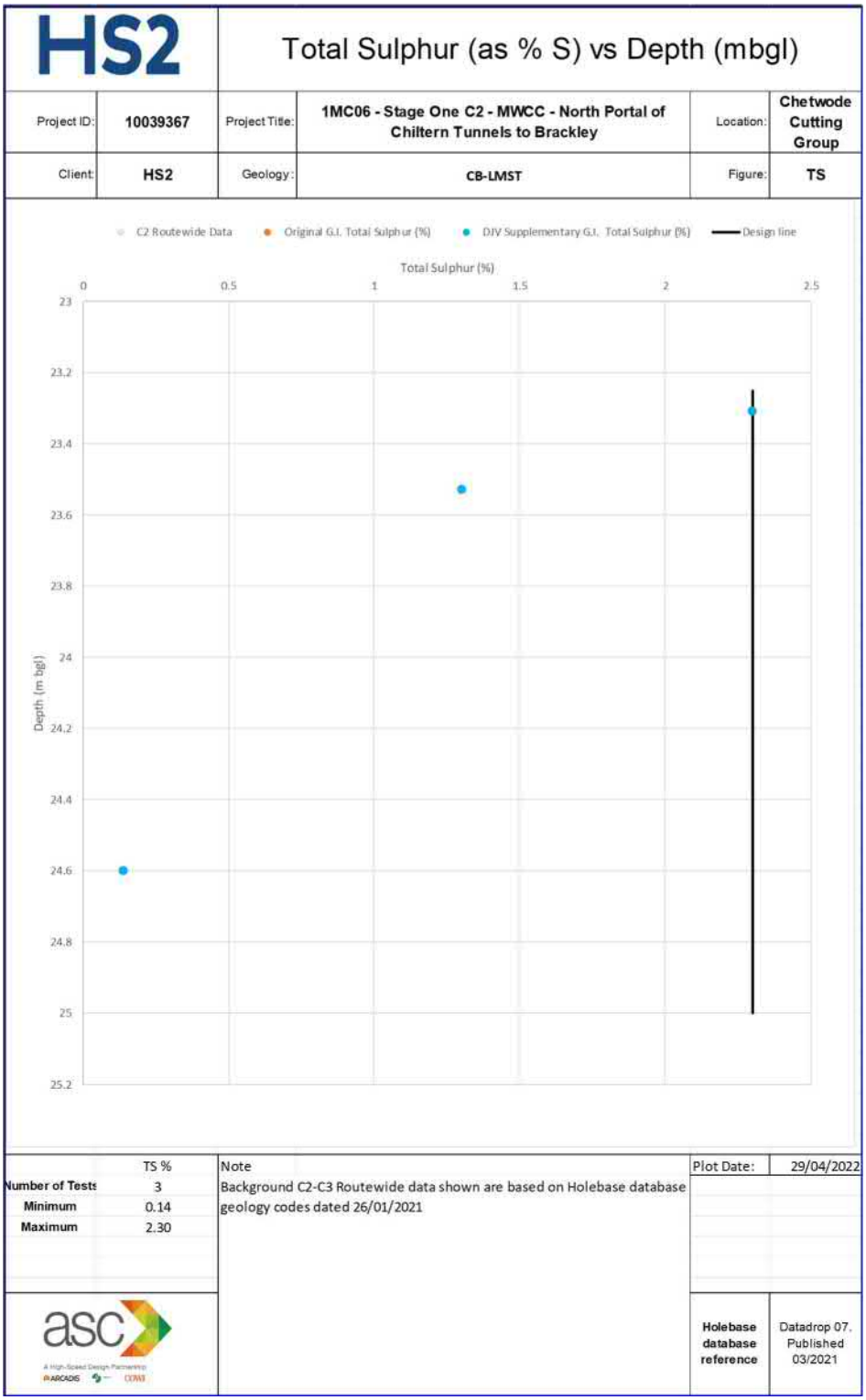


Figure 63 Cornbrash formation (limestone): Total sulfur

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2 Study of foundations

The foundation design was carried out in accordance with BS EN 1997. It takes into account the loading from the structure, as well as heave effects induced by the excavation of the cutting.

2.1 Foundations features

The proposed foundation system is a set of three piles for each support. The table below presents the proposed design for the piles.

Table J.131 Pile foundations properties

Support	Piles layout	Diameter (mm)	Pile head elevation (m AOD)	Pile base elevation (m AOD)	Pile length (m)
West abutment	3 piles d = 3.3 m	1500	105.7	82.1	23.6
West pier	3 piles d = 3.3 m	1200	101.1	82.2	18.9
East pier	3 piles d = 3.3 m	1200	101.3	82.2	19.1
East abutment	3 piles d = 3.3 m	1500	106.1	82.1	24

Note: d is the centre-to-centre distance

2.2 Earthworks behind abutments

The earthworks behind abutment are illustrated on Figure 25. 6N8 material will be used behind the abutments. The properties of the fill materials are listed in the following table.

Table J.132 Friction angle ranges for 6N8 fill material

	Lower value	Upper value
φ'_{peak} (°)	40	45
φ'_{cv} (°)	35	38
$\varphi'_{triaxial}$	*35*	42*

*(as proposed by PD6694)

The soil pressures behind abutments are determined according to PD6694 in function of the aforementioned values of friction angles, in accordance with PD6694. The Figure 64 illustrates the calculation principle : The soil pressure coefficient in M1 approach is equal to 0.426, while it is equal to 0.511 in M2 approach. These calculations are done considering an average value of $\phi'_{triaxial,k}$ = 0.6x45° + 0.4 x 38° = 42°.

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The soil passive pressure coefficients are reduced in order to take into account the skew angle of the bridge.

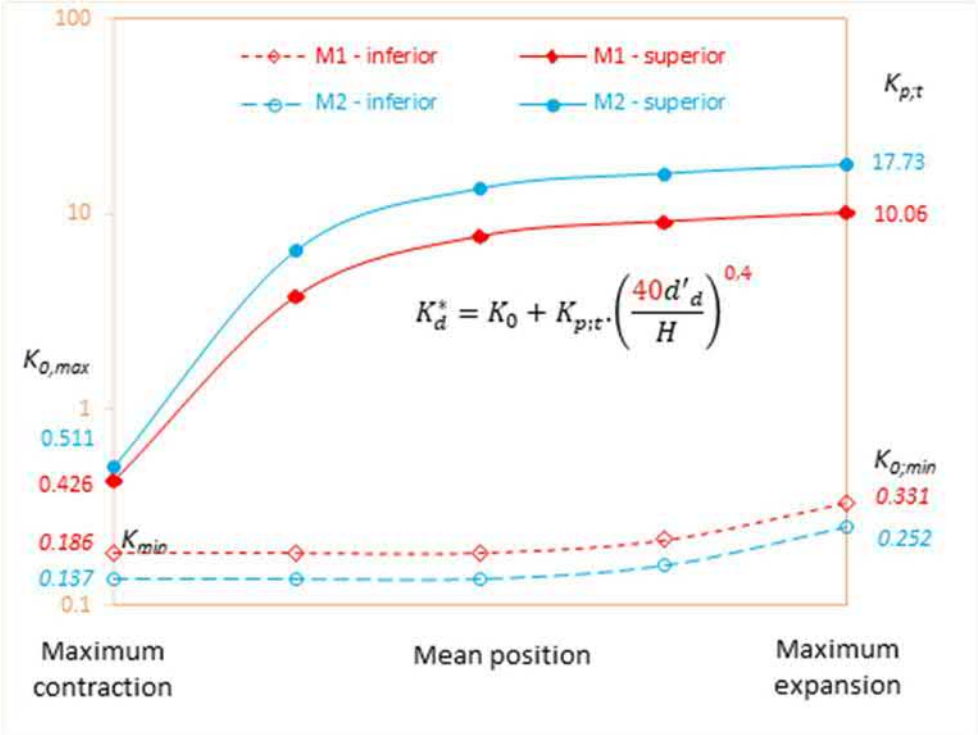


Figure 64 Soil pressures behind abutments

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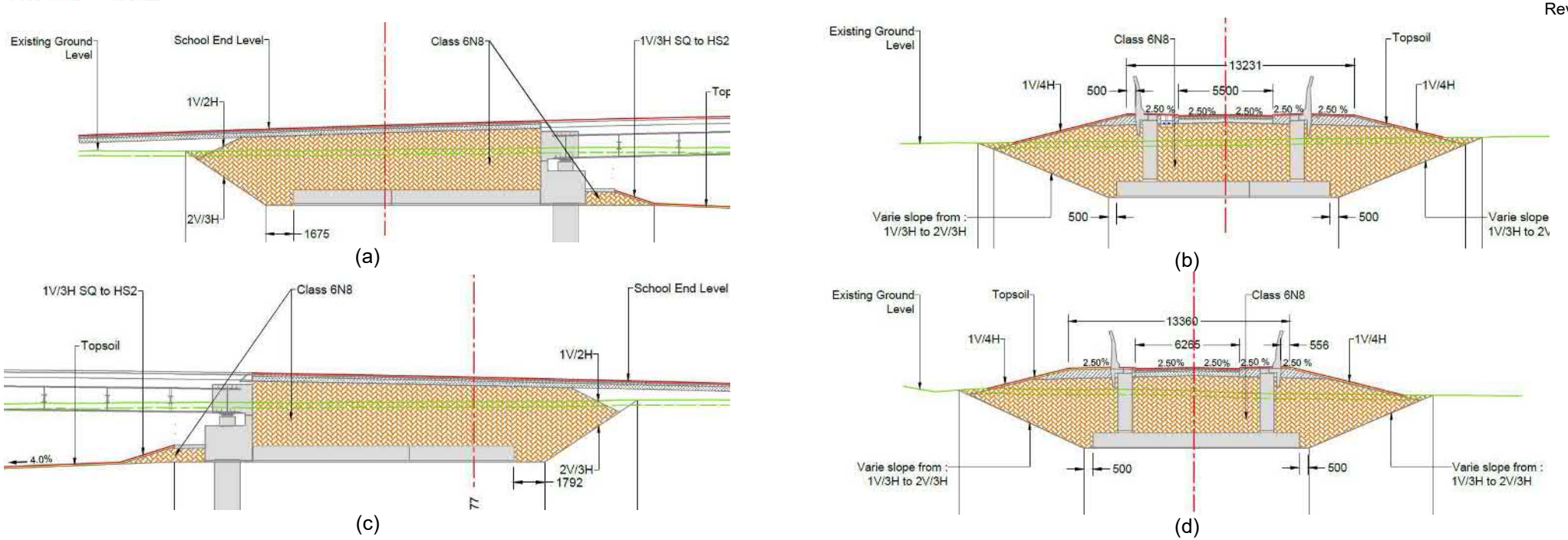


Figure 65 Earthworks behind abutments: (a) West abutment elevation view, (b) West abutment cross section, (c) East abutment elevation view and (d) East abutment cross section

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2.3 p-y and t-z curves

The interaction between the piles and the soil is modelled through p-z and t-z curves. These are interaction laws, formulated in the form of bilinear laws, with a flat part representing total plastification of the soil.

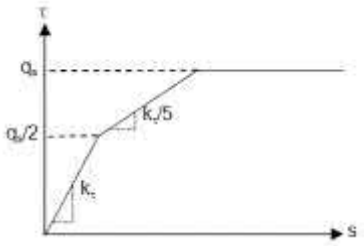


Figure 66 Schematic illustration of a t-z law

The slopes of the linear parts and the flat part are calculated in a way to fit equivalent laws in BS EN 1997. Figures in Appendix G illustrates these interaction laws.

In order to take into account the variation of the undrained shear strength with depth, the Oxford Clay formation is divided in 2 sublayers, and a set of t-z p-y laws is calculated for each sublayer (with the corresponding value of C_u).

The values calculated in the present case are the following for the piers and abutments piles, according to M1 and M2 approach.

For seismic calculations, according to §1.3, the modules K are multiplied with a factor of 3.

Table J.133 Soil structure interaction laws - Piers piles - M1

Piers – M1	Base level	Shaft friction t-z		Base resistance q-b		Lateral interaction p-y	
Soil	**m AOD**	**Kt1 (kN/m/m)**	**qs (kN/m)**	**Kp1 (kN/m)**	**qp (kN)**	**Ks1 (kN/m/m)**	**P (kN/m)**
GFD	100.5	8.45E+03	6.03E+01	2.10E+04	4.07E+02	2.70E+03	1.55E+02
OXC1	97.5	2.96E+04	2.11E+02	7.36E+04	1.43E+03	7.08E+04	1.23E+03
OXC2	89	3.17E+04	2.26E+02	7.89E+04	1.53E+03	1.18E+05	1.98E+03
KLB	83.5	3.17E+04	2.26E+02	7.89E+04	1.53E+03	1.18E+05	1.98E+03
CB	82.2	1.82E+05	1.30E+03	4.80E+05	9.29E+03	1.44E+06	1.98E+04

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Table J.134 Soil structure interaction laws - Piers piles - M2

Piers – M2	Base level	Shaft friction t-z		Base resistance q-b		Lateral interaction p-y	
Soil	**m AOD**	**Kt1 (kN/m/m)**	**qs (kN/m)**	**Kp1 (kN/m)**	**qp (kN)**	**Ks1 (kN/m/m)**	**P (kN/m)**
GFD	100.5	6.0E+03	4.31E+01	1.5E+04	2.9E+02	1.3E+03	9.2E+01
OXC1	97.5	2.1E+04	1.51E+02	5.3E+04	1.0E+03	4.6E+04	8.9E+02
OXC2	89	2.3E+04	1.62E+02	5.6E+04	1.1E+03	7.5E+04	1.4E+03
KLB	83.5	2.3E+04	1.62E+02	5.6E+04	1.1E+03	7.5E+04	1.4E+03
CB	82.2	1.5E+05	1.10E+03	4.1E+05	7.9E+03	1.0E+06	1.4E+04

Table J.135 Soil structure interaction laws - Abutments piles - M1

Abutments – M1	Base level	Shaft friction t-z		Base resistance q-b		Lateral interaction p-y	
Soil	**m AOD**	**Kt1 (kN/m/m)**	**qs (kN/m)**	**Kp1 (kN/m)**	**qp (kN)**	**Ks1 (kN/m/m)**	**P (kN/m)**
Till	106	1.6E+04	1.41E+02	4.9E+04	1.1E+03	7.6E+03	3.4E+02
GFD	100.5	8.4E+03	7.54E+01	2.6E+04	6.1E+02	3.9E+03	2.8E+02
OXC1	97.5	3.0E+04	2.64E+02	9.2E+04	2.1E+03	1.1E+05	2.3E+03
OXC2	89	3.2E+04	2.83E+02	9.9E+04	2.3E+03	1.2E+05	2.5E+03
KLB	83.5	3.2E+04	2.83E+02	9.9E+04	2.3E+03	1.2E+05	2.5E+03
CB	82.2	1.8E+05	1.63E+03	6.0E+05	1.4E+04	1.4E+06	2.5E+04

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Table J.136 Soil structure interaction laws - Abutments piles - M2

Abutments – M1	Base level	Shaft friction t-z		Base resistance q-b		Lateral interaction p-y	
Soil	**m AOD**	**Kt1 (kN/m/m)**	**qs (kN/m)**	**Kp1 (kN/m)**	**qp (kN)**	**Ks1 (kN/m/m)**	**P (kN/m)**
Till	106	1.1E+04	1.01E+02	3.5E+04	8.1E+02	4.0E+03	2.4E+02
GFD	100.5	6.0E+03	5.39E+01	1.9E+04	4.3E+02	2.0E+03	1.7E+02
OXC1	97.5	2.1E+04	1.88E+02	6.6E+04	1.5E+03	6.8E+04	1.7E+03
OXC2	89	2.3E+04	2.02E+02	7.0E+04	1.6E+03	7.5E+04	1.8E+03
KLB	83.5	2.3E+04	2.02E+02	7.0E+04	1.6E+03	7.5E+04	1.8E+03
CB	82.2	1.5E+05	1.37E+03	5.1E+05	1.2E+04	1.0E+06	1.8E+04

2.4 Stiffness matrixes

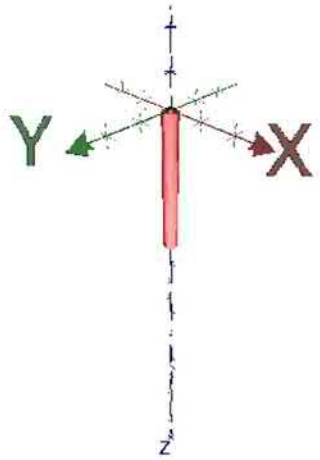
The stiffness matrices of the piles set for each support are listed in following tables. They have been calculated with the software FoxTa\Groupie+, considering that the pile caps are rigid.

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Table J.137 Stiffness matrices of abutments piles

		Static												
		Short term						Long term						
		HX	MY	HY	MX	V	MZ		HX	MY	HY	MX	V	MZ
K/2	HX	5.4E+04	2.5E+05					HX	3.7E+04	1.5E+05				
	MY	2.5E+05	1.8E+06					MY	1.5E+05	9.8E+05				
	HY			5.9E+04	-2.7E+05			HY			4.0E+04	-1.6E+05		
	MX			-2.7E+05	1.8E+06			MX			-1.6E+05	1.0E+06		
	V					7.4E+05		V					5.5E+05	
	MZ						1.0E+00	MZ						1.0E+00
Kx2	HX	1.2E+05	4.2E+05					HX	8.4E+04	2.5E+05				
	MY	4.2E+05	2.3E+06					MY	2.5E+05	1.2E+06				
	HY			1.3E+05	-4.4E+05			HY			9.2E+04	-2.6E+05		
	MX			-4.4E+05	2.3E+06			MX			-2.6E+05	1.3E+06		
	V					1.3E+06		V					8.9E+05	
	MZ						1.0E+00	MZ						1.0E+00

		Seismic					
		Short term					
		HX	MY	HY	MX	V	MZ
K/2	HX	1.1E+05	4.6E+05				
	MY	4.6E+05	2.9E+06				
	HY			1.2E+05	-4.9E+05		
	MX			-4.9E+05	3.0E+06		
	V					1.3E+06	
	MZ						1.0E+00
Kx2	HX	2.5E+05	7.5E+05				
	MY	7.5E+05	3.7E+06				
	HY			2.8E+05	-7.9E+05		
	MX			-7.9E+05	3.8E+06		
	V					2.7E+06	
	MZ						1.0E+00

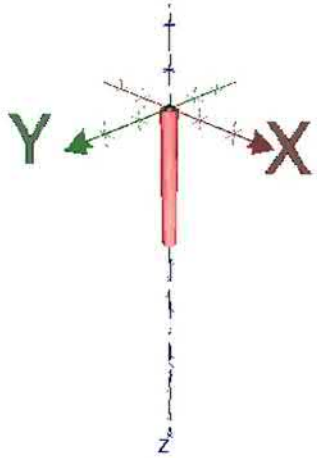


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Table J.138 Stiffness matrices of piers piles

		Static												
		Short term						Long term						
		HX	MY	HY	MX	V	MZ		HX	MY	HY	MX	V	MZ
K/2	HX	1.2E+05	2.8E+05					HX	9.7E+04	1.9E+05				
	MY	2.8E+05	1.1E+06					MY	1.9E+05	6.5E+05				
	HY			1.2E+05	-2.8E+05			HY			9.7E+04	-1.9E+05		
	MX			-2.8E+05	1.1E+06			MX			-1.9E+05	6.5E+05		
	V					3.5E+05		V					2.6E+05	
	MZ						1.0E+00	MZ						1.0E+00
Kx2	HX	4.0E+05	6.3E+05					HX	3.1E+05	4.3E+05				
	MY	6.3E+05	1.7E+06					MY	4.3E+05	9.7E+05				
	HY			4.0E+05	-6.3E+05			HY			3.1E+05	-4.3E+05		
	MX			-6.3E+05	1.7E+06			MX			-4.3E+05	9.7E+05		
	V					1.2E+06		V					8.3E+05	
	MZ						1.0E+00	MZ						1.0E+00

		Seismic					
		Short term					
		HX	MY	HY	MX	V	MZ
K/2	HX	2.9E+05	5.8E+05				
	MY	5.8E+05	1.9E+06				
	HY			2.9E+05	-5.8E+05		
	MX			-5.8E+05	1.9E+06		
	V					1.2E+06	
	MZ						1.0E+00
Kx2	HX	9.3E+05	1.3E+06				
	MY	1.3E+06	2.9E+06				
	HY			9.3E+05	-1.3E+06		
	MX			-1.3E+06	2.9E+06		
	V					2.5E+06	
	MZ						1.0E+00



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2.5 Pile loads

The load induced on the supports for each combination are listed in detail in appendix.

2.6 Bearing capacity

The bearing capacity of piles is verified in accordance to BS EN 1997-1, BS EN 1997-1\NA and BS 8004_2015.

The characteristic pile axial resistance is calculated using the shear resistance values defined in §**1.2**, while the design pile resistance is calculated for three limit states: SLS, ULS/DA1-C1 and ULS/DA1-C2.

The input parameters of the calculation are listed in the following table.

Table J.139 Input parameters for the bearing capacity check of piles

Geological formation	Soil type	γ (kN/m³)	C_u (kPa)	UCS (MPa)
Glaciofluvial deposits	Coarse soil	21	40	-
Oxford clay	Fine soil	21	67 + 8.3z (max. 150 kPa)	-
Kellaways formation	Mudstone	21	150	-
Cornbrash formation	Limestone	21	-	3

General parameters	
Static load tests	No
SLS verification	Covered by ULS due to the embedment in WHL (settlements < 5 mm)
Execution	Replacement, Bored pile, without stabilizing fluid

These parameters lead to the following values for the characteristic shaft friction resistance and base resistance.

Table J.140 Characteristic shaft friction resistance and base resistance of the formations

Geological formation	C_u (kPa)	UCS (MPa)	q_s (kPa)	q_b (MPa)

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Glaciofluvial deposits	40	-	16	0.36
Oxford clay	67 + 8.3z (max. 150 kPa)	-	27 + 3.3z (max.60 kPa)	0.6 + 0.075 z (max. 1.35 MPa)
Kellaways formation	150	-	60	1.35
Cornbrash formatiob	-	3	345	8.2

Based on these results, the pile design resistance is calculated and summarized in the following table, along with the maximal normal force by pile for each combination. Bearing capacity is verified for all combinations.

Table J.141 Bearing capacity check

Pile	Limit state	Maximal axial force on pile (kN)	Design resistance force (kN)	Check
Piers	SLS	5090	5679	OK
	ULS/DA1-C1	6572	12316	OK
	ULS/DA1-C2	5247	6158	OK
	ULS/SEISMIC	5650	8709	OK
Abutments	SLS	2918	5531	OK
	ULS/DA1-C1	3950	12168	OK
	ULS/DA1-C2	3624	6084	OK
	ULS/SEISMIC	3560	8604	OK

2.7 Structural forces

The structural forces are calculated using the foundation layout, the interaction laws detailed in §2.3 and the loading from structure analysis. The calculation is done for 4 load combinations: SLS QP, SLS C, ULS STR/GEO and ULS Seismic.

The maximal values of the structural forces in the piles for each load combination are listed in the table below.

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Table J.142 Maximal structural forces in piles

Pile		N_{max} (kN)	M_{max} (kN.m)	T_{max} (kN)	N_{min} (kN)
Piers	SLS C	5090	1805	580	754
	SLS F	4851	1374	449	816
	SLS QP	4445	900	254	830
	ULS Seismic	5650	2564	741	654
	ULS STR/GEO (DA1-C1)	6572	2527	782	-59
	ULS STR/GEO (DA1-C2)	5247	2339	722	-69
Abutments	SLS C	2918	1493	420	69
	SLS F	2719	1385	389	103
	SLS QP	2374	1135	320	162
	ULS Seismic	3560	2166	631	-1077
	ULS STR/GEO (DA1-C1)	3950	2071	578	-989
	ULS STR/GEO (DA1-C2)	3624	2292	636	-1090

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3 Heave assessment

Heave effects are assessed through a mixed numerical and analytical approach. The heave induced displacements are calculated from a 2D FE model of the cutting in the vicinity of the overbridge. Then, these displacements are used to estimate the supplementary forces in the piles and the deck, using an analytical approach featuring interaction laws detailed in §**2.3**.

3.1 Additional parameters

The heave induced displacements are calculated through a 2D finite element modelling of the cutting, using Plaxis 2D. The soil behaviour is modelled through the Hardening Soil Small constitutive law for the Oxford Clay and Kellaways formations, and through linear elastic law for the till and glaciofluvial deposits; the layers beneath the Kellaways formation are considered as substratum. The displacements are calculated in free field conditions, i.e. in the absence of the structure.

3.1.1 HSS parameters definition

The Hardening Soil Small constitutive law main parameters are secant stiffness (E_{50}), unloading/reloading stiffness (E_{ur}), shear modulus at very small strain (G_0) and the threshold shear strain at which $G_s = 0.722G_0$ ($\gamma_{0.7}$). These parameters are defined through specific tests: triaxial and pressuremeter tests, as well as shear wave measurements and resonant column tests. In the present case, these parameters are defined from a cross analysis of tests conducted on Oxford Clay samples collected from boreholes located along the construction area. This analysis is detailed in a proper note (1MC07-CEK-GT-REP-CS07_CL14-000013 – 18/02/2020).

In order to account for the variation of the parameters values with depth, the OXC formation is divided in three virtual sublayers defined in terms of the depth relative to the soil surface: 0-10 m, 10-15 m and 15-25 m. For each range of depth, lower and higher boundary values are defined to account for the scatter distribution of the test points.

Figure 67, Figure 68 and Figure 69 illustrate respectively the calculated properties from measurement in function of depth, for E_{50}, E_{ur}, and G_0. Lower and higher boundary values are marked in dotted red lines.

The value of $\gamma_{0.7}$ for each range is estimated based on the experimental results and the Santos and Correia theoretical correlation between G_s/G_0 γ and $\gamma_{0.7}$. This equation is written as follows.

$$\frac{G_s}{G_0} = \frac{1}{1 + 0.385\left|\frac{\gamma}{\gamma_{0.7}}\right|}$$

For each range of depth (0-10 m, 10-15 m, 15-25 m), triaxial tests results were plotted as G/G_0 versus shear strain γ, G_0 being the maximum shear modulus measured for each triaxial test. Then, the Santos & Correia theoretical equation has then been plotted over these experimental results, for various values of $\gamma_{0.7}$ and a best-fitting curve has been derived. An example of this fitting for the 0-10 m range is illustrated on Figure 70. The value of $\gamma_{0.7}$ = 0.015 corresponds to the best fitting curve for these data points in this case.

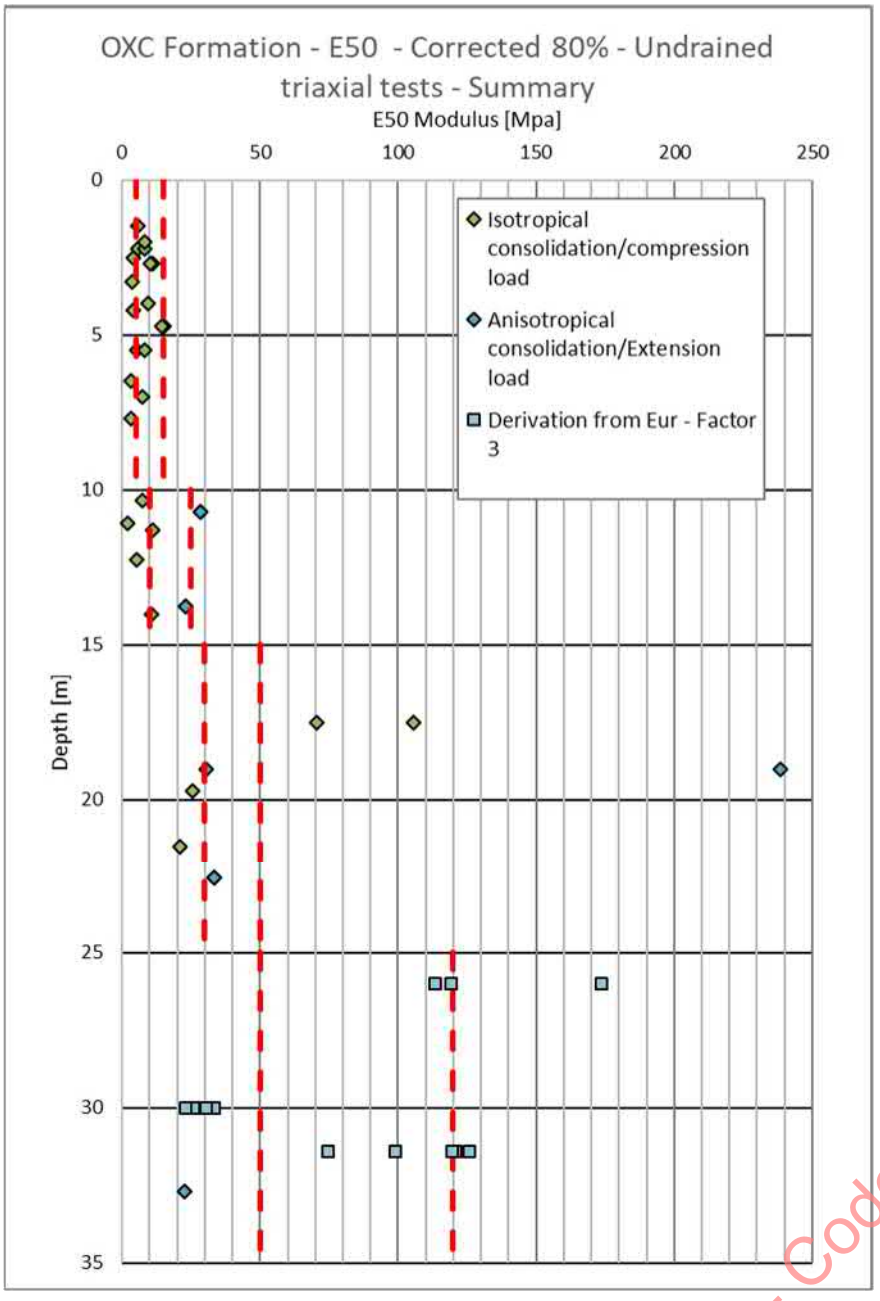
Hence, the HSS parameters can be summarized in the following table.

Table J.143 HSS model properties

Layer	E_{50} (MPa)	E_{ur} (MPa)	G_0 (MPa)	$\gamma_{0.7}$

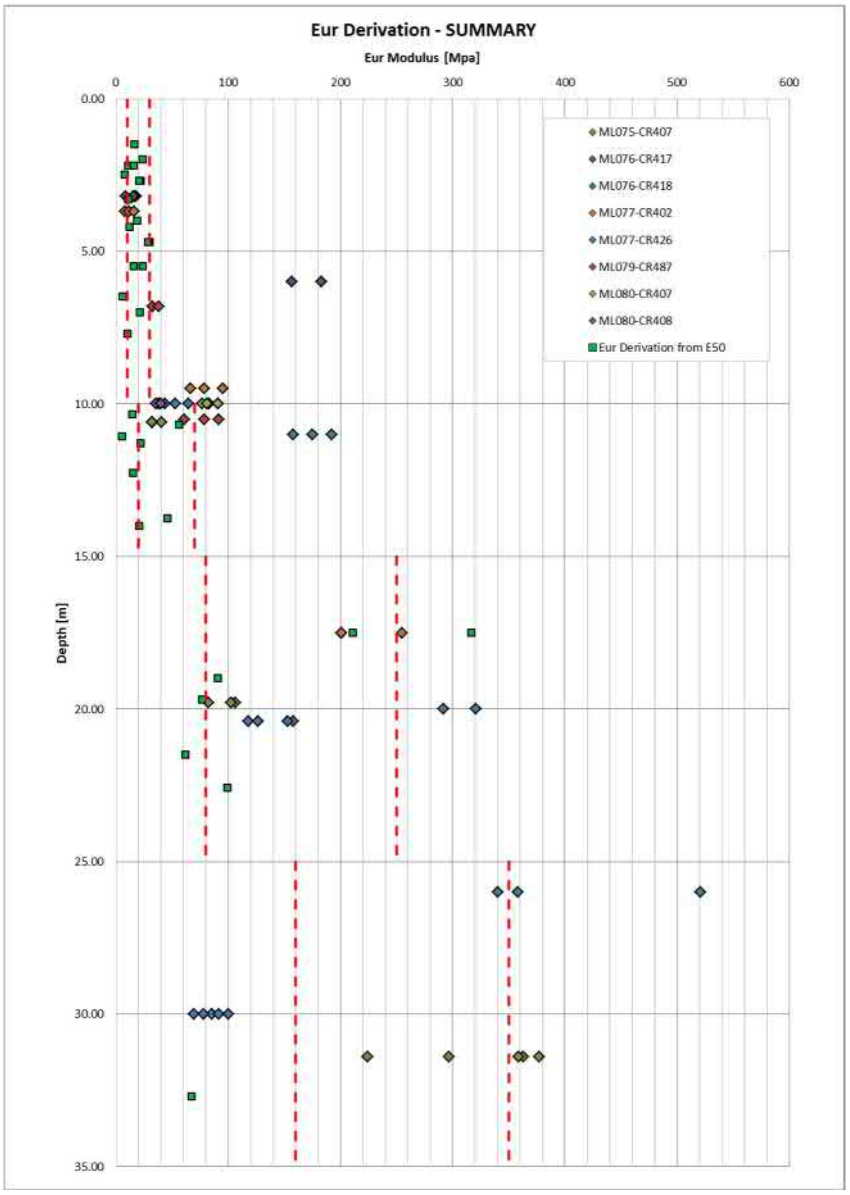
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Oxford clay (0-10m)	5-15	10-30	25-100	0.015
Oxford clay (10-15m)	10-25	20-70	80-200	0.010
Oxford clay (15-25m)	30-50	80-250	150-350	0.010



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Figure 67 Secant stiffness E50 versus depth – Lower and Upper boundaries



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Figure 68 Unloading/reloading stiffness Eur versus depth

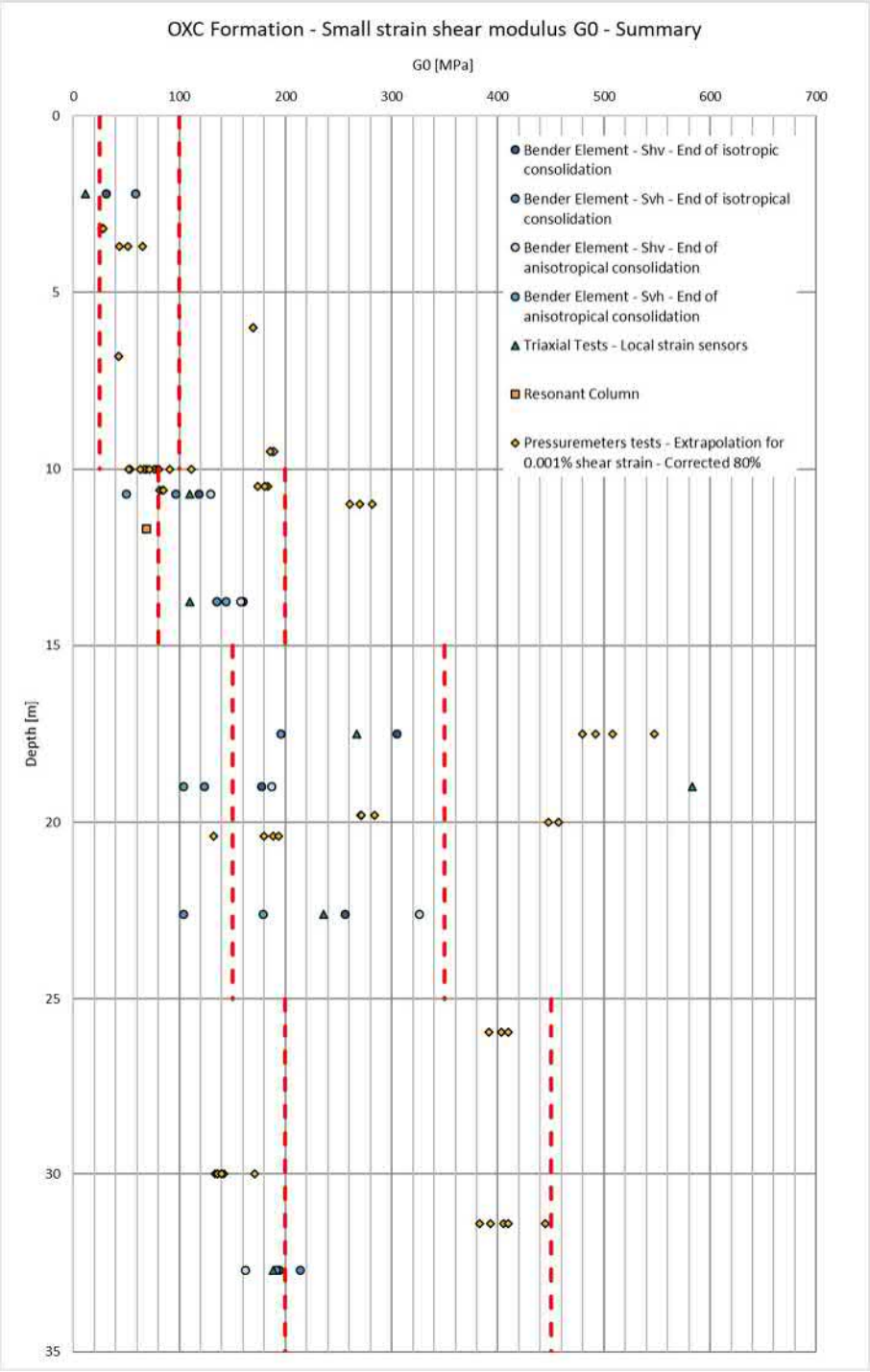


Figure 69 Shear modulus at very small strain G0 versus depth

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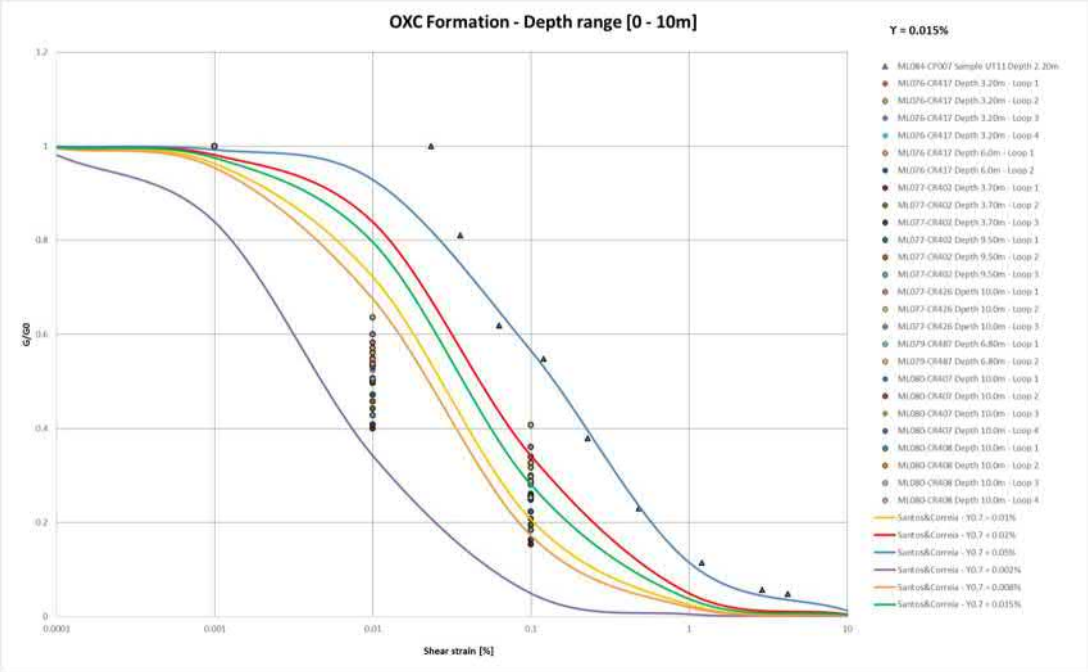


Figure 70 G/G_0 vs shear strain experimental results and Santos & Correia hyperbolic law – Depth range [0 – 10 m]

In accordance with the assumptions for the undrained shear strength definition, the parameters relative to the Kellaways formation are assumed to be equal to those of the overlying Oxford Clay sublayer.

Two separate calculations using higher and lower boundary values for each layer are conducted. The most conservative values for horizontal and vertical displacements are taken for each one.

3.1.2 Water level

The water level defined in §1.5 is used in the calculations.

3.1.3 Construction sequence

The following construction sequence for the earthworks and foundations construction works is used as a base for the phasing of the model. The construction methodology is bottom-up.

- Excavate to the level of the abutments piles: 13 days
- Construct the piles starting from this level: 25 days
- Total excavation of the cutting: 13 days
- Wait period after the total excavation of the cutting: 112 days
- Construct the deck (concrete works): 112 days after the end of the total excavation. The construction of the overground elements of the supports such as piers, abutments and other structural elements can be done during the 112 days wait period).

Figure 71 illustrates a general view of the FE model in the final phase (complete depth excavation).

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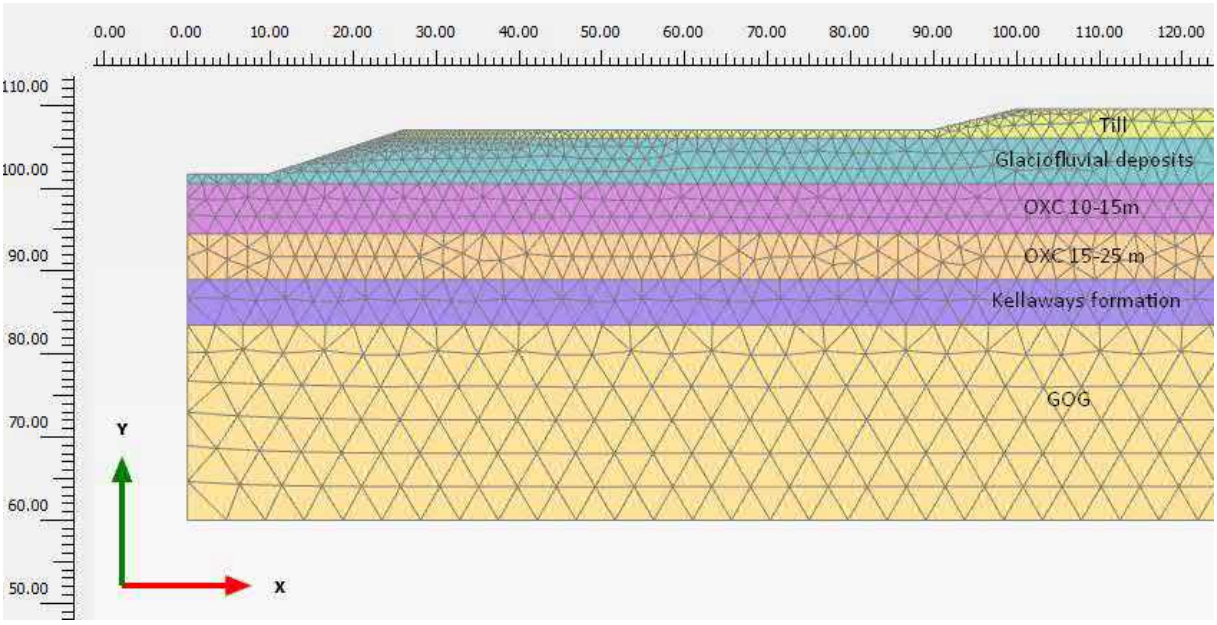


Figure 71 General view of the FE model

3.1.4 Time dependant behaviour

Time dependant behaviour is characterised through the definition of non-zero permeability in the Oxford clay formation, and by extension, in the Kellaways formation.

The value is defined from routewide measurement in Oxford Clay formation along the Chetwode cutting. The horizontal permeability can be estimated by a constant value with depth, equal to 1 x 10^{-8} m/s (K_h = 8.64 x 10^{-4} m/day). The vertical permeability is equal to 1/5 of the horizontal permeability K_v = 1.73 x 10^{-4} m/day. The same values are used by extension for the Kellaways formation.

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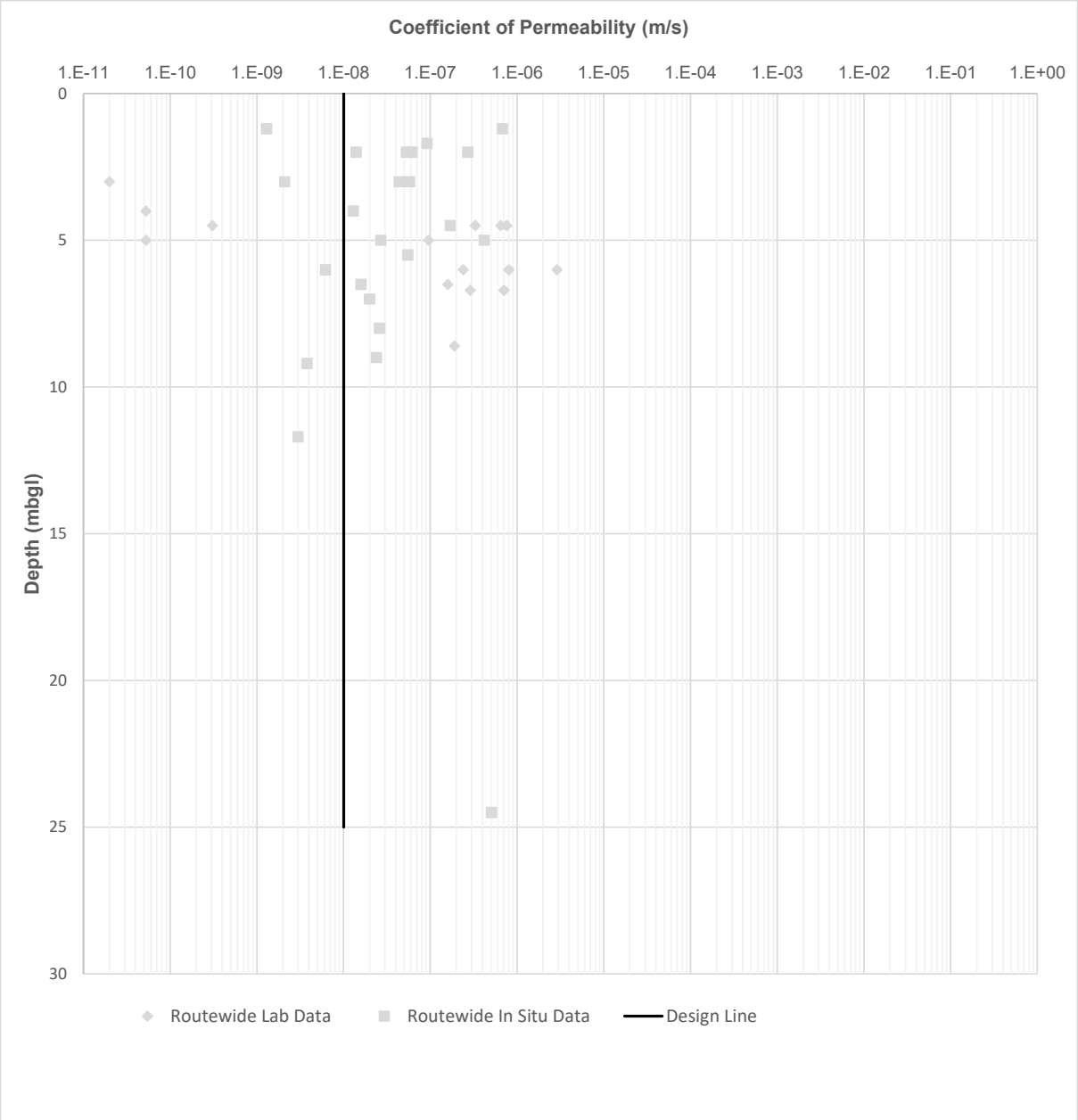


Figure 72 Permeability values in the Oxford Clay formation

3.2 Heave induced displacements

The construction sequence is detailed above. In order to assess the heave effects on the structure, the heave induced displacements during the phases where the latter is present have to be considered. The table below resumes the correspondence between construction phases and the state of the structure at each phase.

Table J.144 Construction sequence

Phase no	Description	Duration	State of the structure at the end of the phase

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1	Excavate to the level of the abutments piles	13 days	-
2	Construct the piles	25 days	Piles only
3	Excavate the remaining depth of the cutting	13 days	Piles only
4	Wait period after the total excavation of the cutting	112 days	Piles only
5	Construct the deck	-	Complete structure
6	Service period	120 years	Complete structure

Thus, the effects of the heave induced displacements during phases 2 to 4 have to be considered on the piles individually; while the heave effects induced during and after phase 5 have to be considered on the complete structure (piles + piers + deck).

Figures below illustrate the resulting displacements near the supports piles.
Note that these displacements were obtained in the calculation with the lower boundary value of soil modules.
For each support, the free field horizontal and vertical displacements, expected to be applied to the piles, are plotted in function of the AOD level. Three plots are presented:

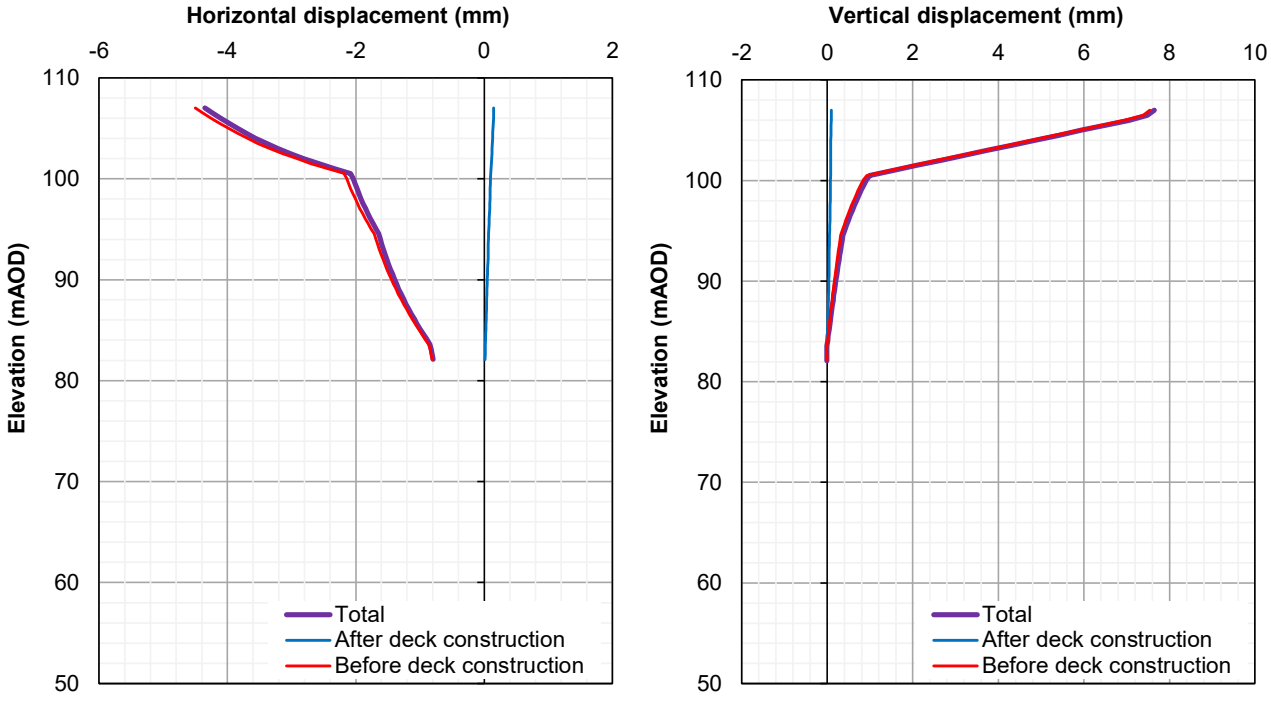
- the induced displacement between the construction of the piles and the construction of the deck (noted “before deck construction”). It corresponds to the displacements that occur during phases 2 to 4.
- the induced displacement starting from the construction of the deck (noted “after deck construction”). It corresponds to the displacements that occur during and after phase 5.
- the sum of the two aforementioned displacements (noted “Total”).

Note that a positive vertical displacement corresponds to an upwards heave of the soil, and a negative displacement corresponds to a displacement towards the excavation centre.

Near abutments piles

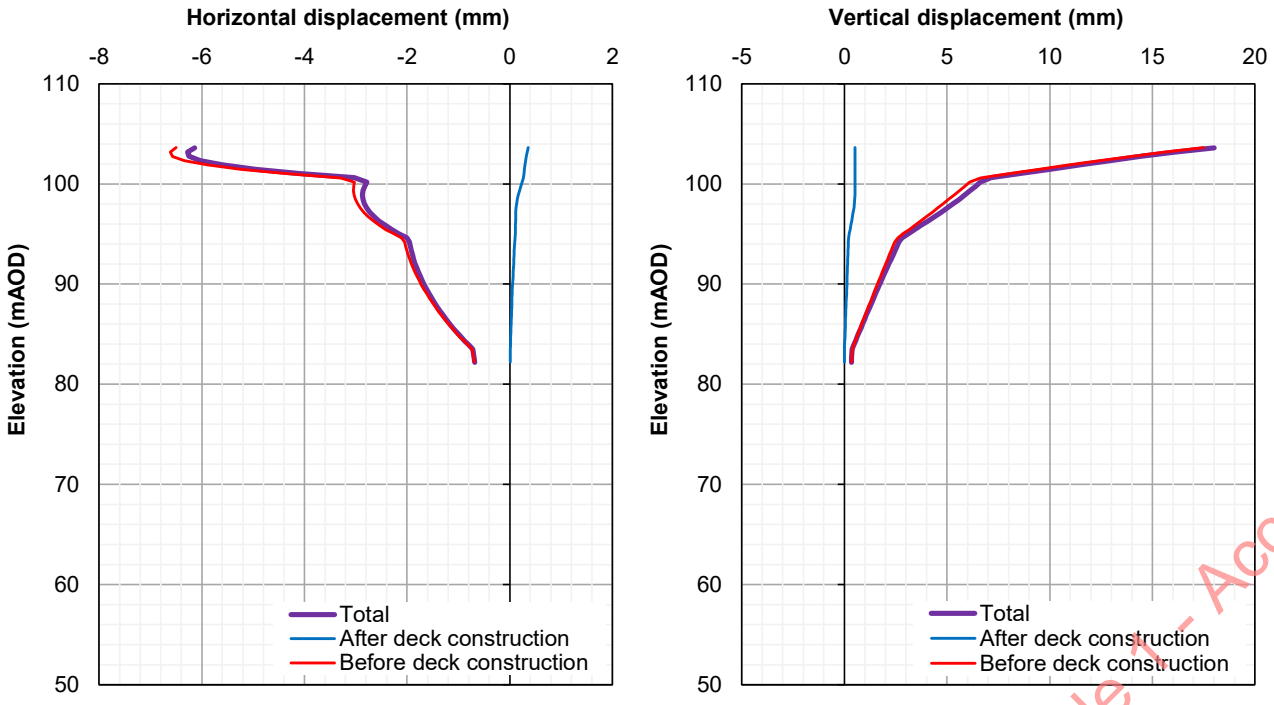
The heave induced soil displacements expected to be applied at the abutments piles are as follows.

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Near piers piles

The heave induced soil displacements expected to be applied at the pier piles are as follows.



3.3 Heave results

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3.3.1 Calculation models

The effects of the heave induced displacements on the individual piles are assessed through calculations using Foxta v4, a software for shallow and deep foundations design, developed by Terrasol. In this model, the piles are directly modelled along with the interaction with the surrounding soil, with load transfer approaches. The heave induced displacements (in this case, displacements induced in phases 2 to 4) are applied as a soil displacement and the resulting force and displacement of the pile are obtained from the model.

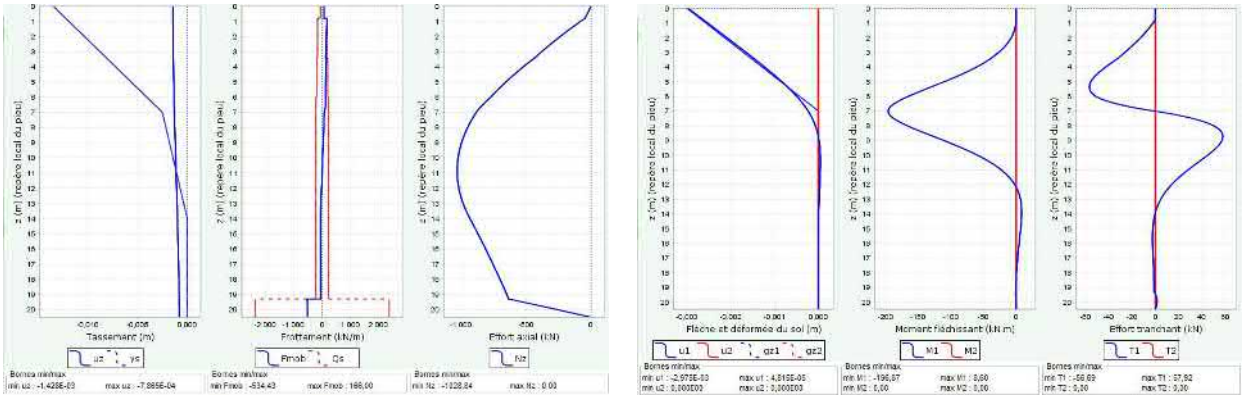


Figure 73 Typical output from Foxta v4

On the other side, the effects of the heave induced displacements on the complete structure are assessed through a calculation using Poutre2D, an analytical software developed by Terrasol. In this software, the piles, piers and abutments, deck are modelled through beam elements, and connections between all these elements are customizable. The interaction between the piles and the soil is modelled through load transfer approaches (similarly to Foxta v4). The heave induced displacement (in this case, displacements induced during and after phase 5) is applied as a soil displacement of the embedded part of the pile and the resulting forces (and displacements) in the piles, piers and deck are obtained.

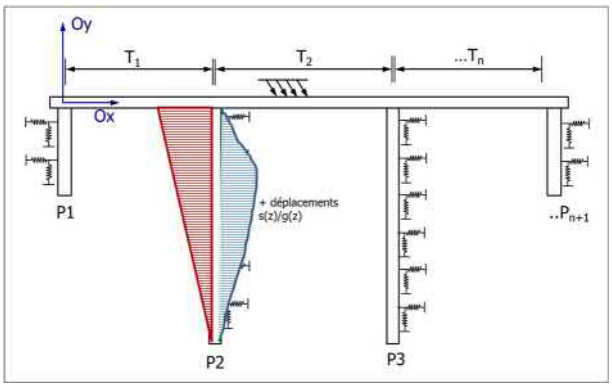


Figure 74 Typical output from Poutre2D

3.3.2 Heave consequence on piles

Phases 2 to 4

The heave induced forces on the piles during these phases are summarized in the table below.

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Table J.145 Heave induced forces on structure during piles and piers construction

	Normal force (kN)	Shear force (kN)	Moment (kN.m)
Piers piles	-780	69	-67
Abutments piles	-280	36	-115

Phase 5 and beyond

The heave induced forces on the piles during and after this phase, as well as the forces induced in the deck are summarized in the table below. The maximal heave induced displacements of the deck, piers and abutments remain lesser that 1 mm.

Table J.146 Heave induced forces on structure during and after deck construction

	Normal force (kN)	Shear force (kN)	Moment (kN.m)
Piers piles	-90	8	20
Abutments piles	-20	~0	~0
Deck	-	~0	-64

These values were taken into account by to the structures teams in the structural verification of the whole overbridge

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4 Wingwalls

The stiffness of the wing walls foundation is calculated and the bearing capacity and sliding resistance are verified in accordance with BS EN 1997-1, BS EN 1997-1\NA and BS 8004_2015.

4.1 Features

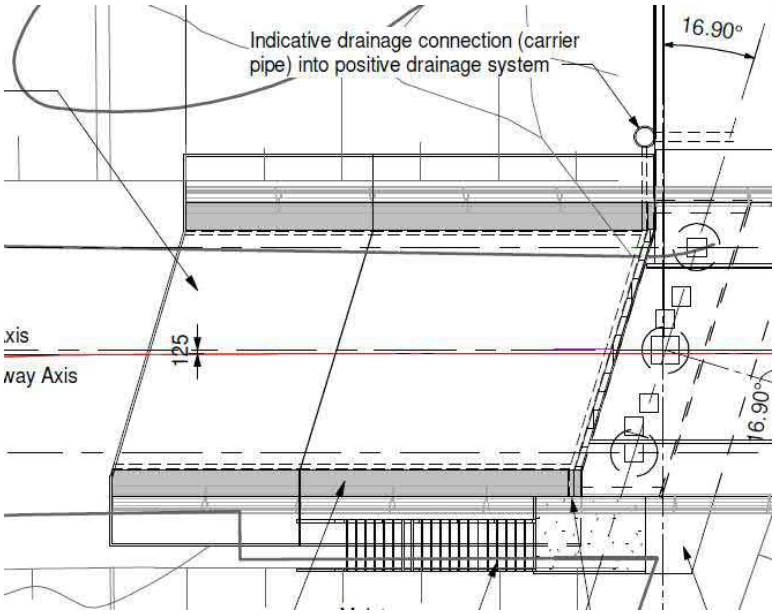
The wingwalls are constructed in two U-shaped panels for each abutment. The geometrical properties are listed below.

Table J.147 Geometrical properties of abutments wingwalls

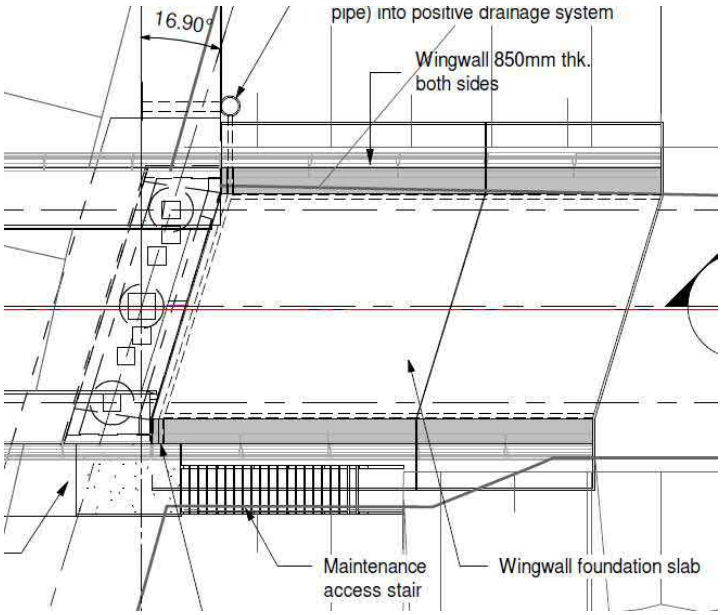
	A0 and A3 (U-shaped panel)
Number of panels	2 (for each abutment)
Panel length (m)	First panel: 6 m Second panel: 9 m
Foundation width (m)	12.4 m
Foundation thickness (m)	85 cm
Foundation base level (m AOD)	106.54 m AOD for West abutment A0 106.14 m AOD for East abutment A3
Backfill height (m)	3.5 m

The schematic cross sections of the wingwall are illustrated on the figure below.

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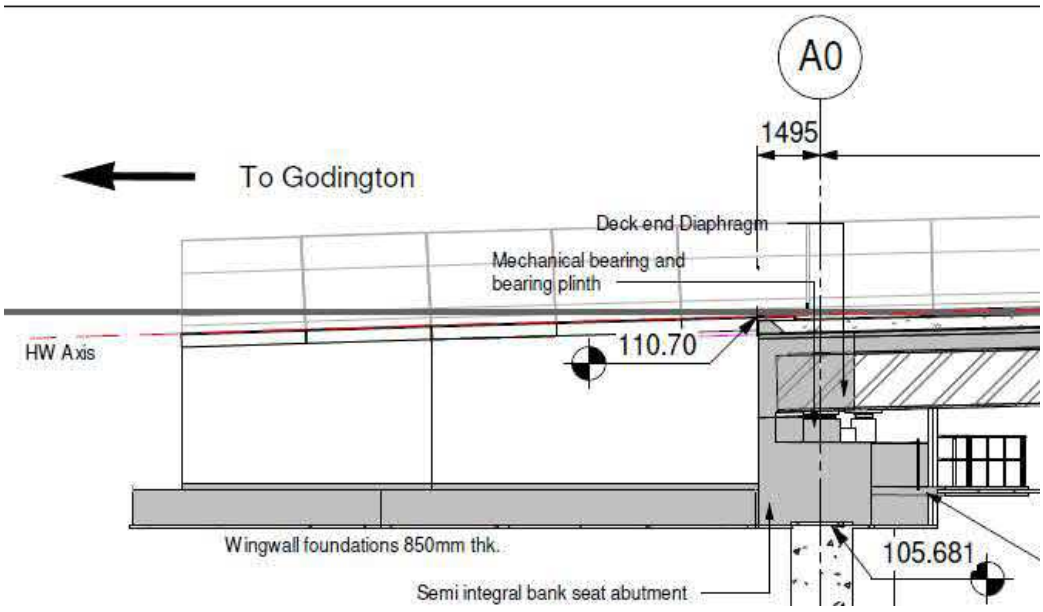


(a) West abutment (A0) wingwall plan view

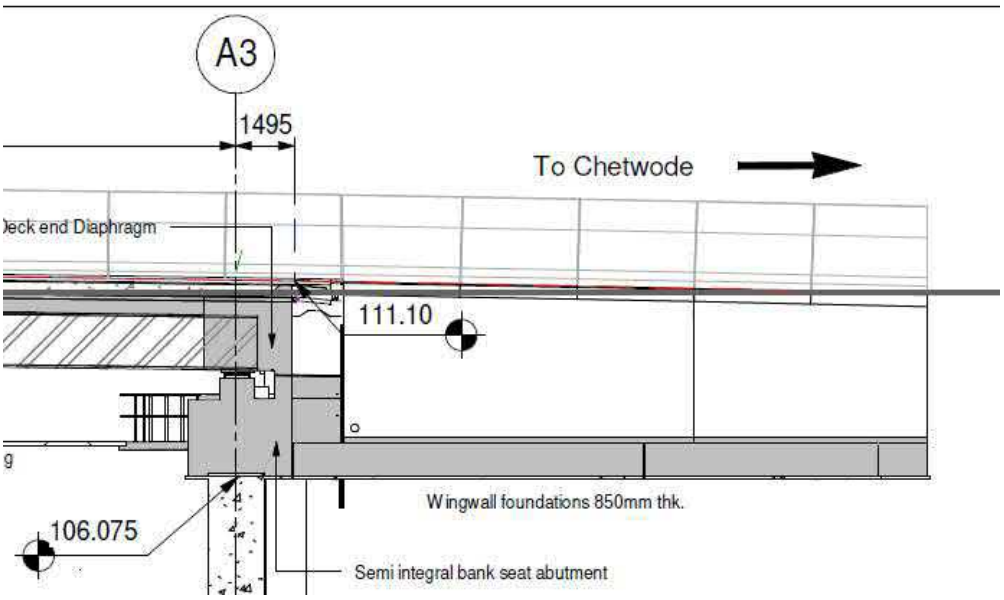


(a) East abutment (A3) wingwall plan view

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(c) West abutment (A0) wingwall elevation view



(d) East abutment (A3) wingwall elevation view

Figure 75 Wingwalls geometry

4.2 Ground properties

The stratigraphy for each abutment is defined from the local GI as listed in the previous paragraphs. The same soil model is used for both abutments

Table J.148 Detailed design stratigraphy

Geological formation	Design thickness (m)

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Till formation	0.54
Glaciofluvial deposits	5.5
Oxford Clay formation 1	3
Oxford Clay formation 2	8.5
Kellaways formation	5.5

The ground properties are listed in the §1.3.

4.3 Stiffnesses

The stiffnesses of the soil beneath the foundations of one panel of the wingwall is calculated using conventional formulae. The equivalent soil modulus of the soil layers is equal to 19 MPa, it is calculated as the harmonic mean value of the soil moduli beneath the foundation.

Stiffness				
	Global		Surfacic	
Vertical	Kv (MN/m)	261.9	kv (MPa/m)	2.4
Horizontal	Kh (MN/m)	206.2	kh (MPa/m)	1.9

4.4 Bearing capacity

The bearing capacity is calculated in accordance with BS EN 1997-1, BS EN 1997-1\NA and BS 8004_2015, taking into consideration a fine soil beneath the foundation.

The value of 75 kPa is considered for the undrained shear strength of the soil. This value is chosen as a representative value along the soil depth where the bearing capacity mechanism will be developed; this depth is approximately equal to 1.5B. In this case, this significant depth is equal to 9 m.

The bearing capacity of the foundation is equal to the following.

Bearing capacity		
		$q_{u;d}$ (kPa)
ULS	DA1C1	445
	DA1C2	335
SLS		188

These values are used by the structures design team to verify the bearing capacity of the wingwalls foundations. This verification is presented in the structural design report.

4.5 Sliding resistances

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The sliding resistance is verified in accordance with BS EN 1997-1, BS EN 1997-1\NA and BS 8004_2015. Since the soil beneath the foundation is of a clayey nature, the sliding resistance is expressed in the terms of undrained cohesion. For a conservative approach, the value of undrained shear strength of the glaciofluvial deposits (40 kPa) is considered as a characteristic value. The design sliding resistance values are thus equal to the following.

Sliding		
		Cu,d (kPa)
ULS	DA1C1	40
	DA1C2	29

These values are used by the structures design team to verify the stability vis à vis sliding of the wingwalls foundations. This verification is presented in the structural design report.

4.1 Settlement in the transition zone

The settlement in the transition zone corresponds to the settlement below the wingwall foundations.

This settlement is estimated from a coupled analysis where the wingwall foundations are modelled through plate elements, and the multi-layered soil is modelled through analytical stiffness functions.

The calculation is performed using the component Tasplaq of Foxta v4 (a software for shallow and deep foundations design, developed by Terrasol).

The loads acting on the foundations are composed of a the backfill weight (different value for each panel) and a service load of 20 kPa.

The resulting total maximum settlement is estimated at 17 mm for abutment A0 and A3. It is expected that half of this settlement will occur immediately at the end of the construction of the wingwalls. The differential settlement is approximately 1/1000. These values are quite acceptable according to the project standards.

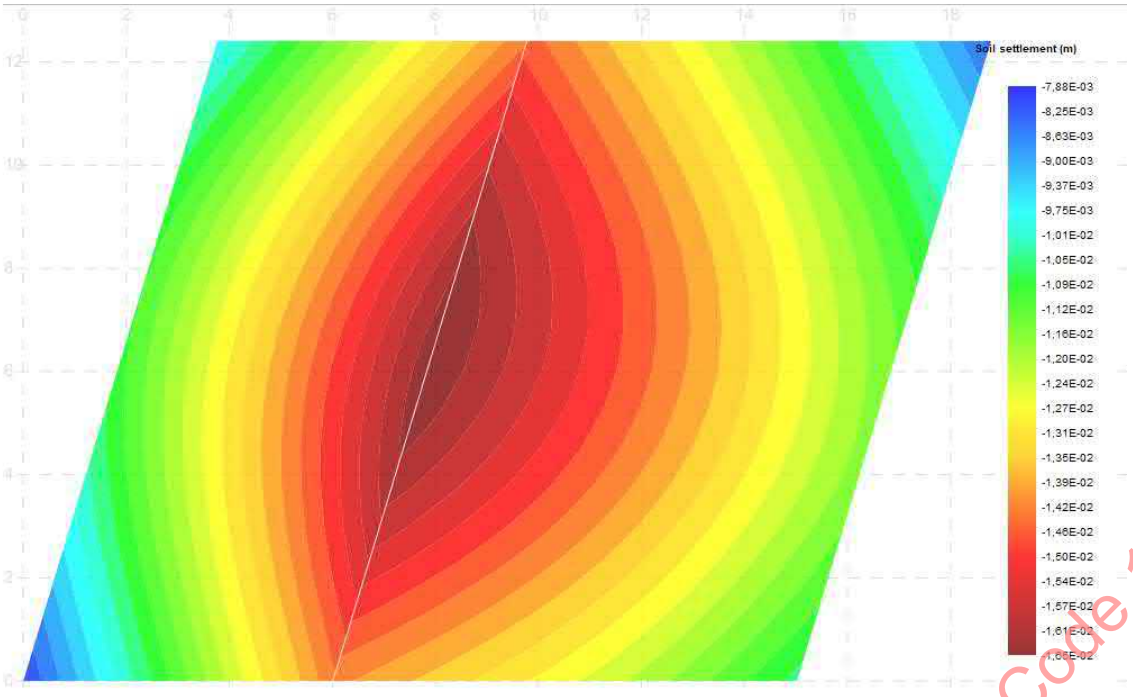


Image J-19 : Settlements in the transition zone behind the A0 and A3 abutments

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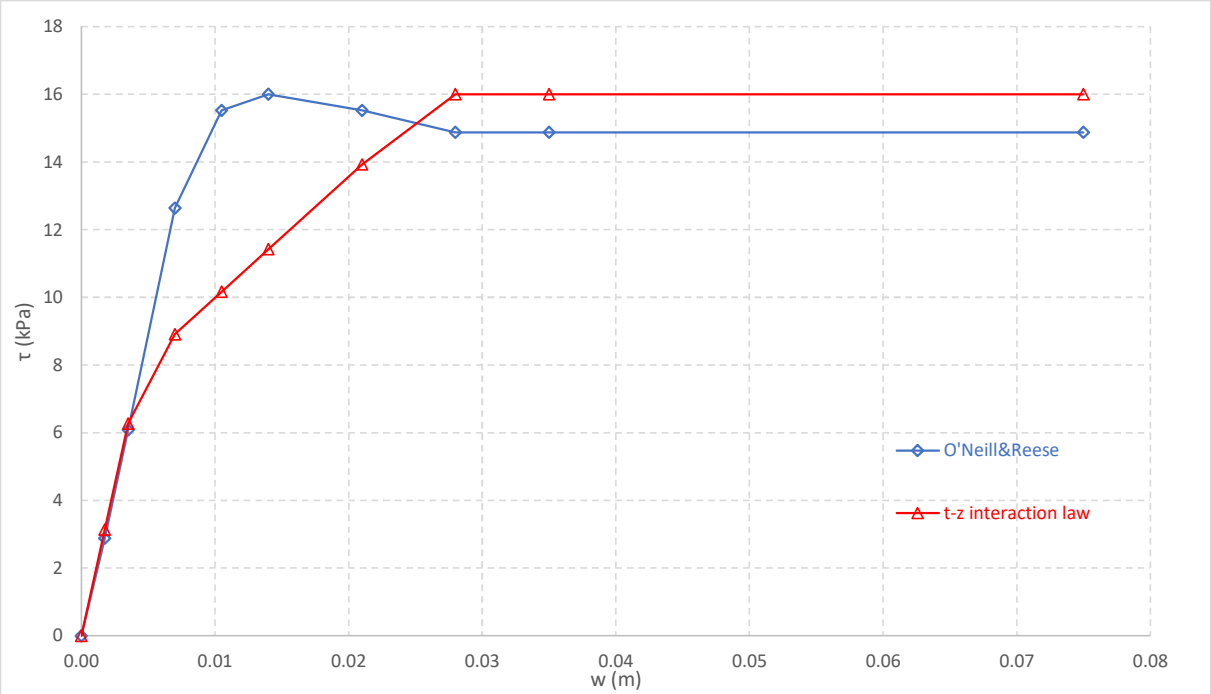
APPENDIX K

School end overbridge geotechnical interaction laws

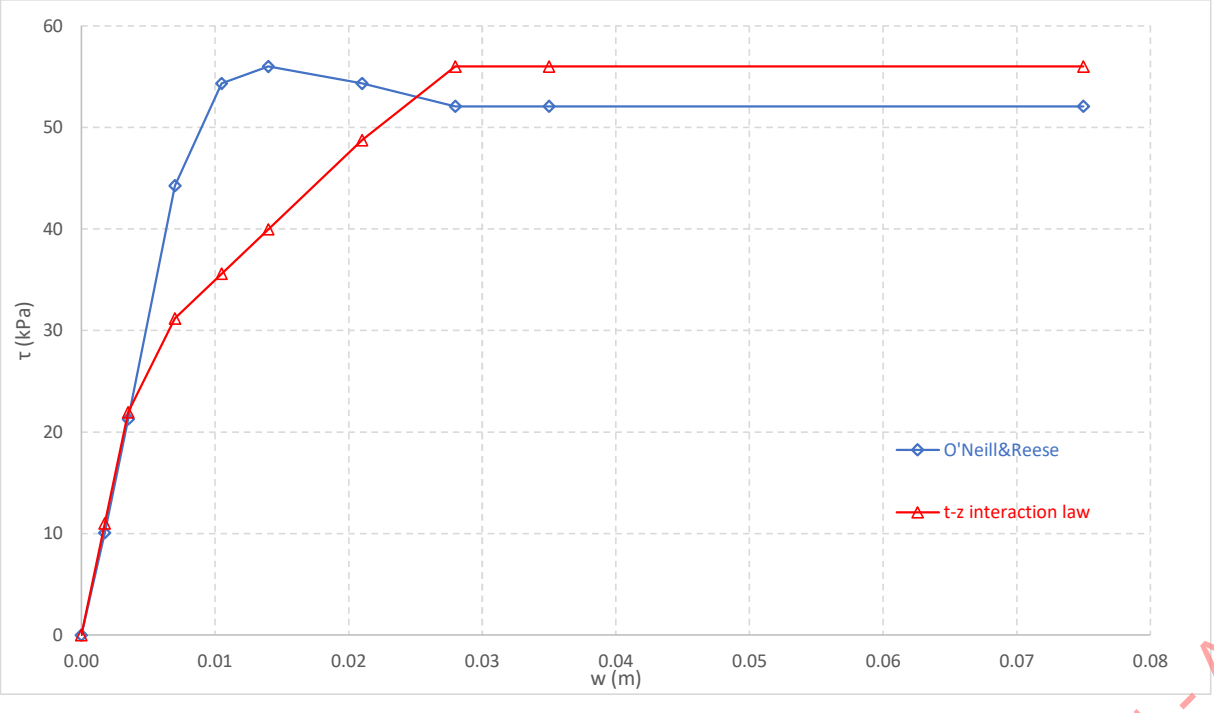
Number of pages: 5

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Shaft friction (t-z) in Glaciofluvial deposits

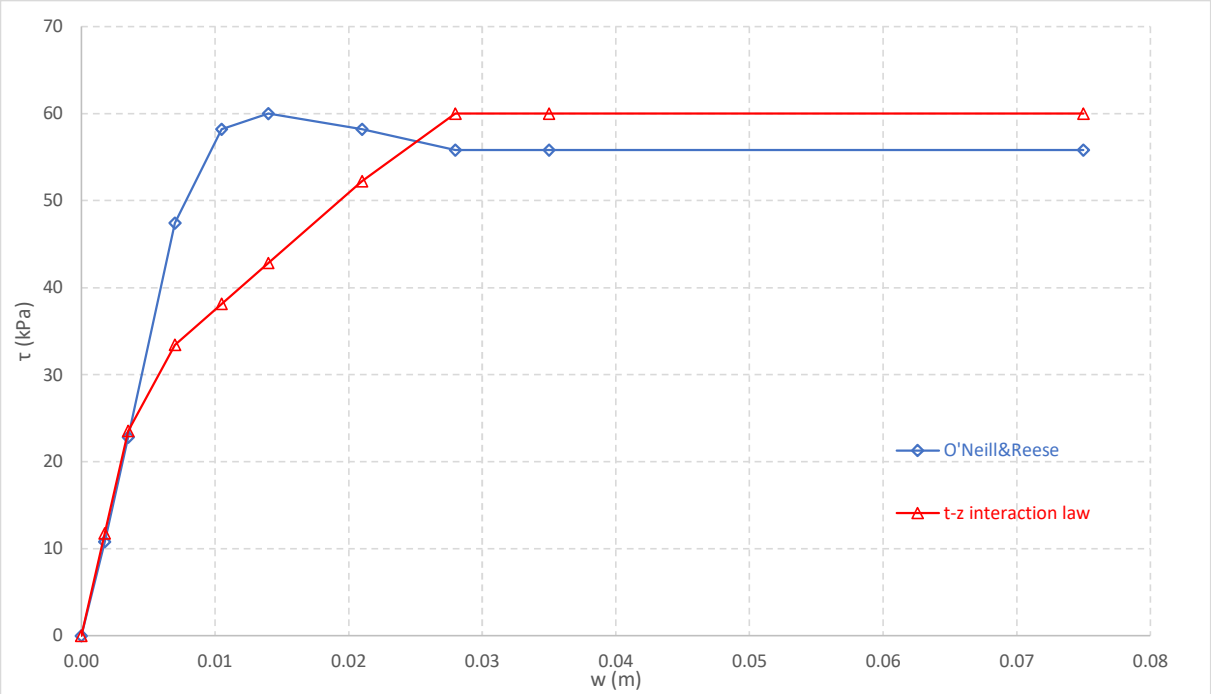


Shaft friction (t-z) in Oxford clay (sublayer 1 of 4)

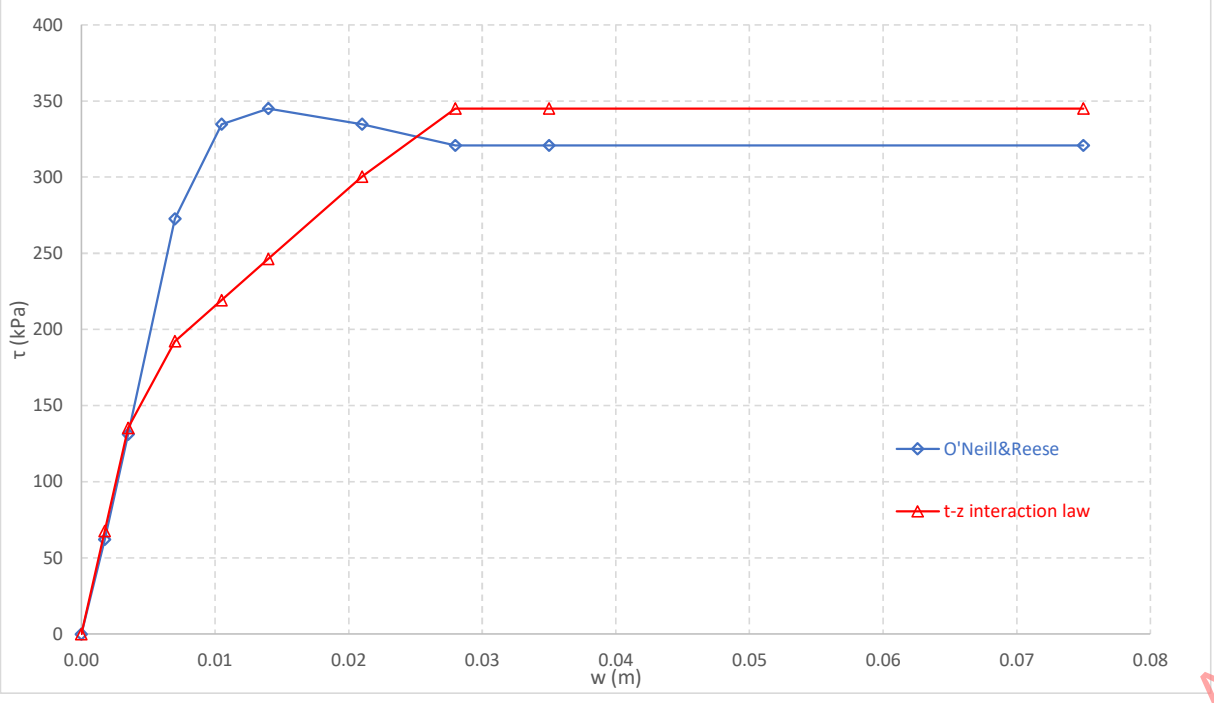


Shaft friction (t-z) in Kellaways formation

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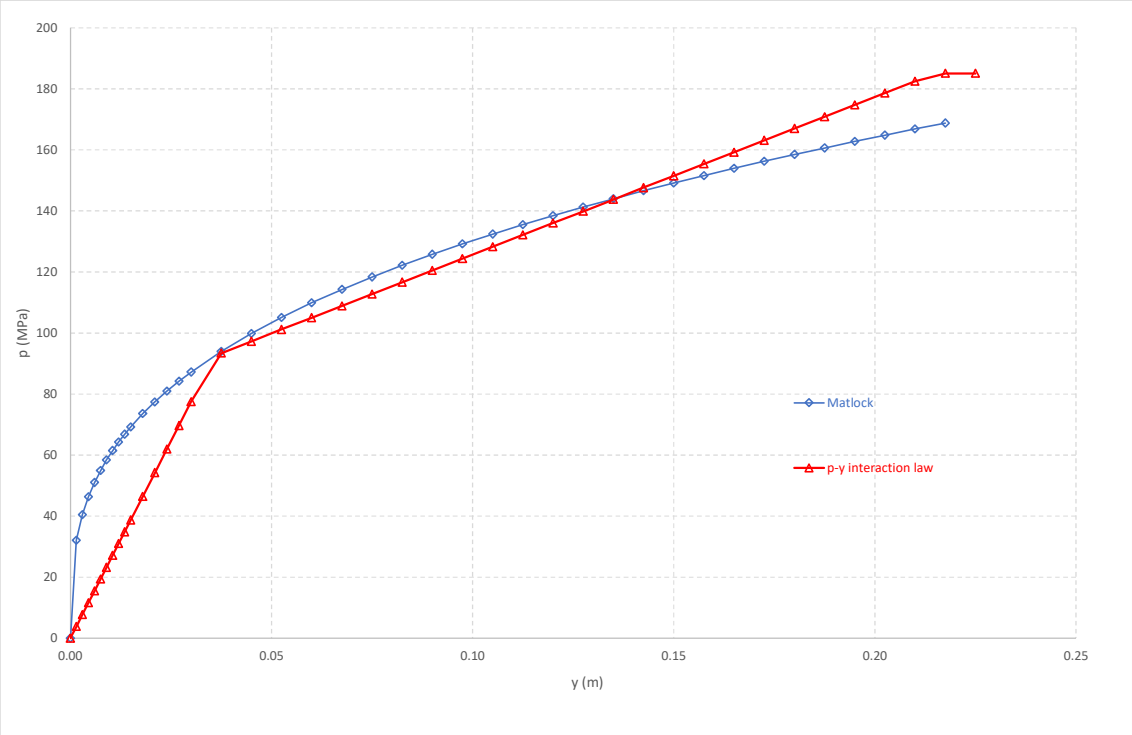


Shaft friction (t-z) in Cornbrash formation

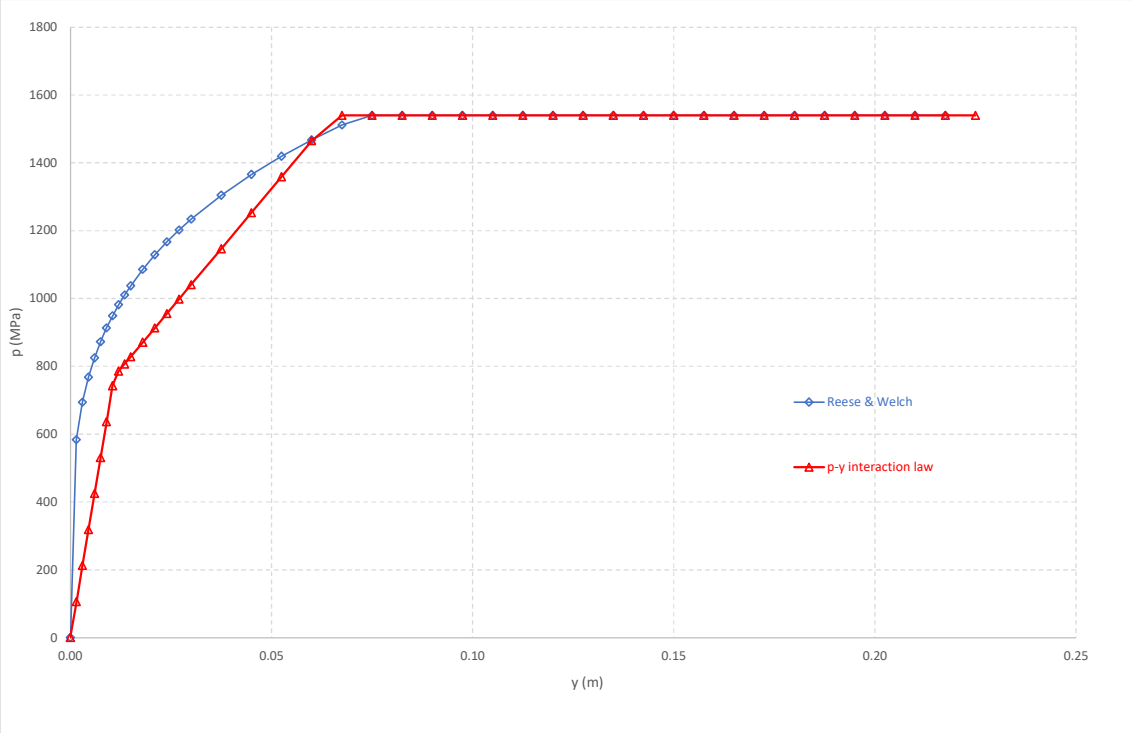


Lateral interaction (p-y) in Glaciofluvial deposits

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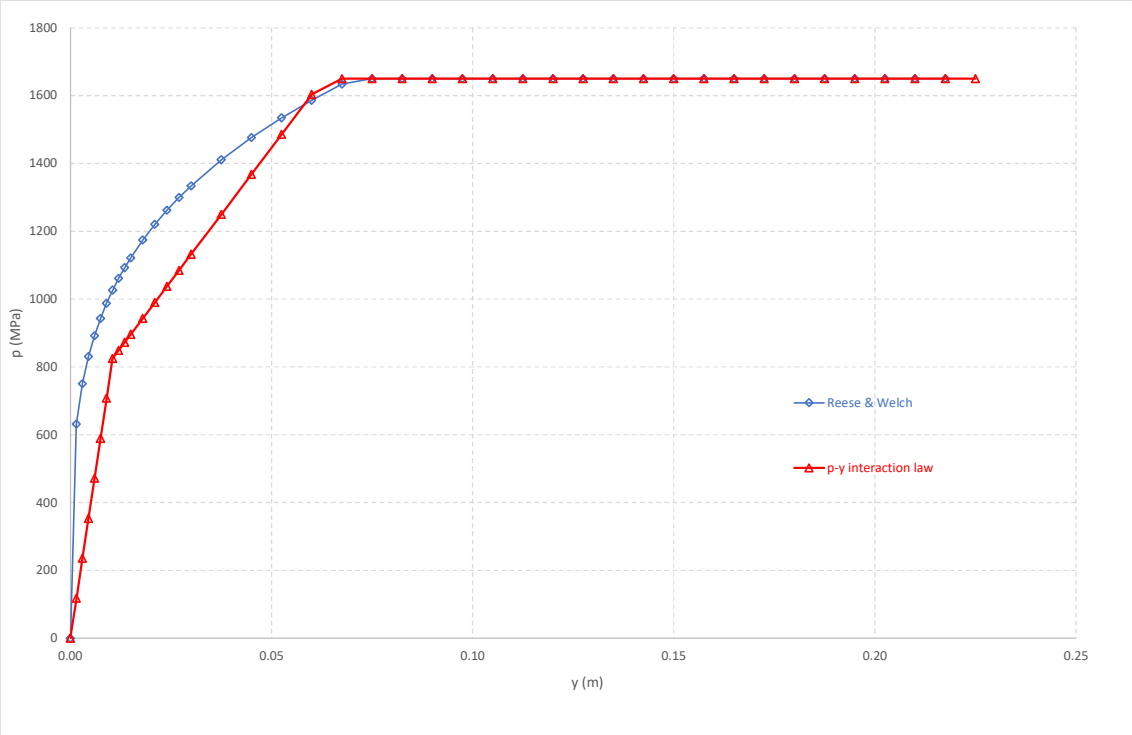


Lateral interaction (p-y) in Oxford clay (sublayer 1 of 4)

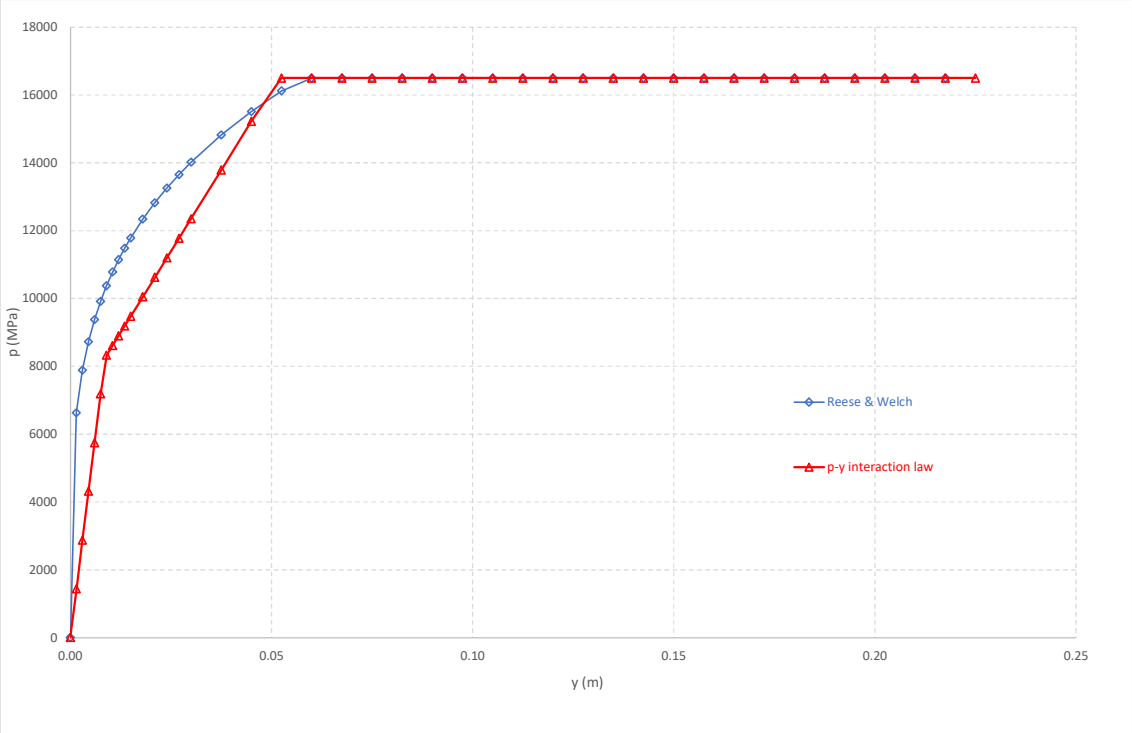


Lateral interaction (p-y) in Kellaways formation

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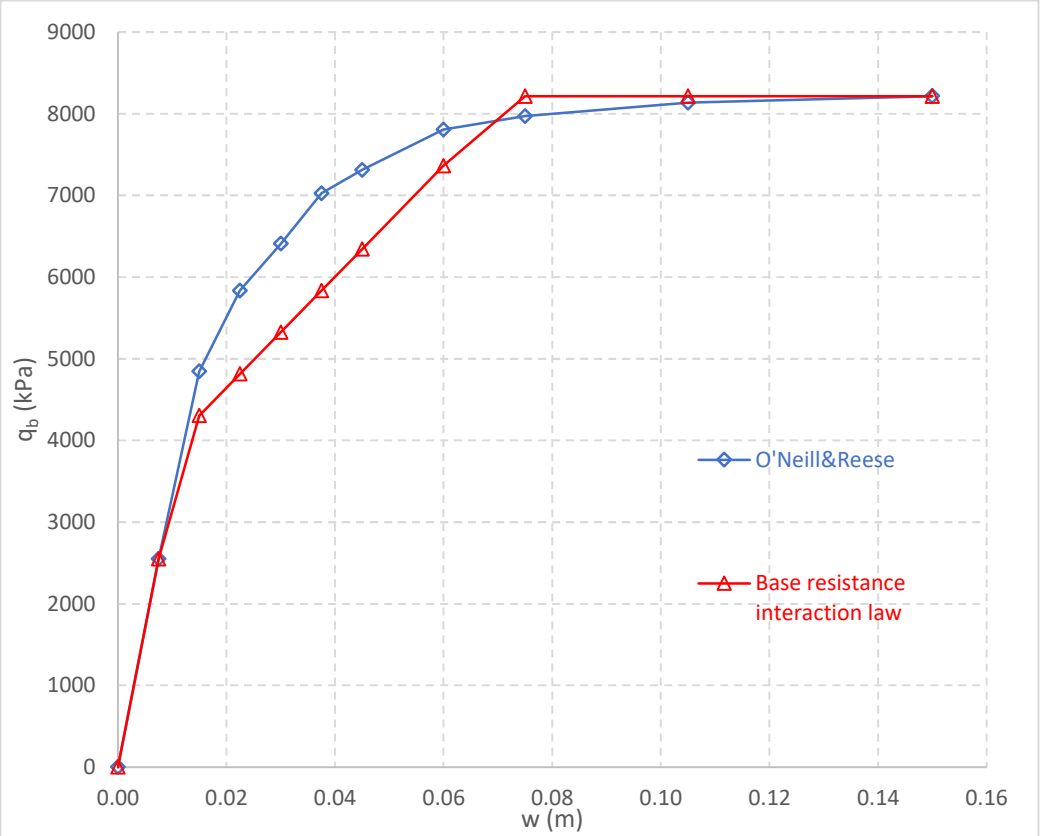


Lateral interaction (p-y) in Cornbrash formation



Base resistance interaction law in Cornbrash formation

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APPENDIX L

School end overbridge GI impact assessment

Number of pages: 10

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Part A – Current Design and Construction Information

Asset Name	School End overbridge
Asset ID	HS2-000001322
Design Status	IDR held on 07/06/2022
Construction Status	Not Started
Uncertainty in Ground Conditions Classification	3
Agreed Mitigation for Uncertainty in Ground Conditions	Proceed with Design – Review new GI Data when available

The School End overbridge is a three-span overbridge located at chainage 86+475.

The structure is composed of three spans: two side spans of 21.0 m each and a central span of 33.0 m. The deck is supported on two integral piers and two non-integral abutments.

For the detailed design, the freeze date for this asset is fixed in January 2021 (Data drop 2).

Piled foundations are proposed for both piers and abutments.
The features of the supports piled foundations are given in the following table.

School End overbridge piled foundation features

Support	Piles layout	Diameter (mm)	Pile head elevation (m AOD)	Pile base elevation (m AOD)	Pile length (m)
West abutment	3 piles d = 3.3 m	1500	105.7	82.1	23.6
West pier	3 piles d = 3.3 m	1200	101.1	82.2	18.9
East pier	3 piles d = 3.3 m	1200	101.3	82.2	19.1
East abutment	3 piles d = 3.3 m	1500	106.1	82.1	24

On the other side, the structural backfill height in the transition zone behind each abutment is around 3.5 m, of which 2.0 m are above the initial ground level and thus generate settlements. This settlement is estimated at around 8 mm. It is estimated that half of the settlements will be generated immediately at the end of the construction of the wingwalls. The differential settlement is around 1/1000. These values are quite acceptable according to the project standards.

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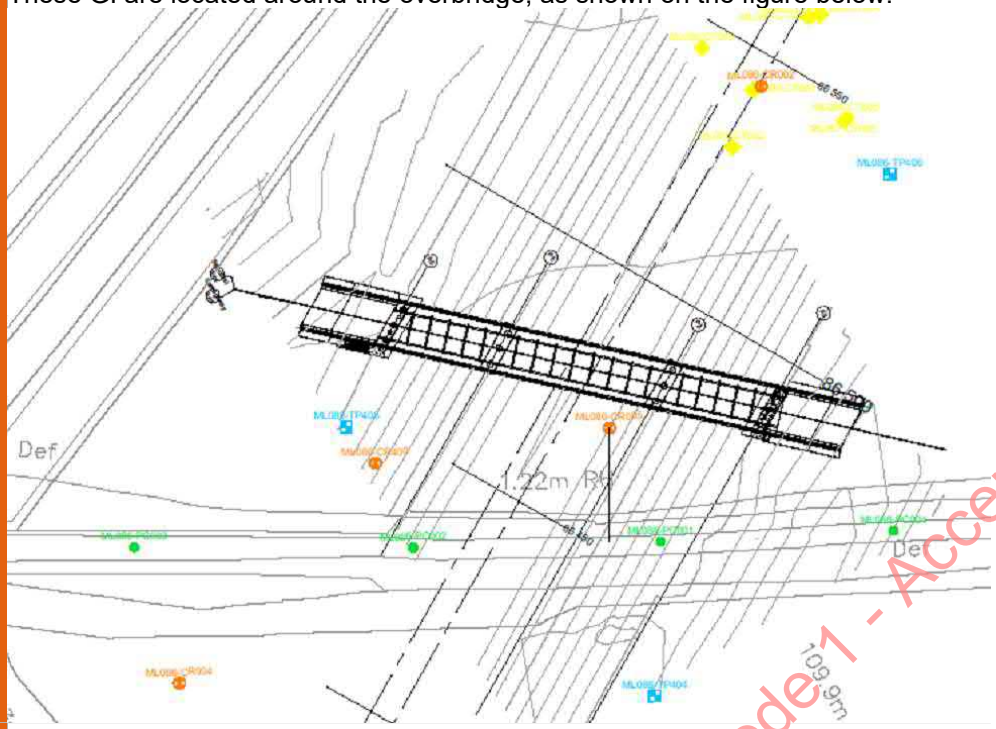
Part B – New GI and Field Trial Data

Current GI Database ID

For the detailed design, the freeze date for this asset is fixed in January 2021 (Data drop 2). The available GIs at this date are listed in the following table.

Exploratory hole	Type	Ground level (m AOD)	Depth (m)
ML086-CR002	Cable percussion borehole with rotary cored follow on	108.4	30
ML086-CR005		109.54	40
ML086-CR400		109.48	25
ML086-CR012		109.81	35
ML086-CR004		109.94	40
ML086-TP404	Trial pit	110.22	3
ML086-TP405		109.27	4

These GI are located around the overbridge, as shown on the figure below.



Current GI data and ground properties

Stratigraphy

The stratigraphy is composed of the following layers:

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- Firm to stiff sandy gravelly clay of 3.5 m in thickness (Till formation)
- Loose to medium dense fine to medium sand of 5.5 m in thickness (Glaciofluvial deposits),
- 11.5 m of stiff to very stiff clay of the Oxford Clay formation

  In the boreholes ML086-CR005 and ML086-CR002, a sublayer of weak mudstone is found in the last 3-5 m of this formation. The properties of this sublayer will be determined and used in the design.
- 5.5 m of extremely weak mudstone of the Kellaways formation. This formation contains interbeds of stiff clay and fine sand (especially in ML086-CR400). The presence of these interbeds will be accounted for in the definition of the resistance properties of the formation.
- and a substratum of the Great Oolite Group, composed of:
  - 2.7 m of medium strong to strong limestone of the Cornbrash formation,
  - 3.3 m of alterations of medium strong limestone and weak silstone of the Forest Marble formation,
  - And around 17.5 m of weak to medium strong limestone of the White Limestone formation, including very small layers of weak siltstone and mudstone (20-40 cm).

Detailed design stratigraphy

Geological formation	Design top level (m AOD)	Design thickness (m)	Design bottom level (m AOD)
Till formation	109.5	3.5	106
Glaciofluvial deposits	106	5.5	100.5
Oxford Clay formation	100.5	11.5	89
Kellaways formation	89	5.5	83.5
Cornbrash formation	83.5	2.7	80.8
Forest Marble formation	80.8	3.3	77.5
White Limestone formation	77.5	8.0	69.5

Ground properties

The detailed design soil model is summarized in the following table:

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Geological formation	Undrained shear strength (kPa)	Uniaxial Compressive Strength (MPa)	Young modulus (MPa)	c' (kPa)	ϕ (°)
Till formation	**Clay: 75 kPa**	-	14	0	27
Glaciofluvial deposits	**Sand: 40 kPa**	**-**	18	0	30
Oxford Clay formation	**Clay: 67+8.3z** (max. 150 kPa) **Mudstone: 150 KPa**	**-**	16-20	5	28
Kellaways formation	**Mudstone: 150 kPa**	**-**	20	5	27
Cornbrash formation	-	**Limestone: 10 MPa**	Assumed substratum	-	-
Forest Marble formation	-	**Siltstone: 0.8 MPa** *Limestone: 15 MPa*	-	-	-
White Limestone formation		*Limestone: 10 MPa not used in the design*	-	-	-

New GI Database ID	The new GI relevant to the overbridge are 3 cable percussion boreholes, ML086-CR442, ML086-CR443, ML086-CR443a and ML086-CR444, located along the overbridge axis, near the west abutment, west pier and east abutment respectively. These GIs are included in Datadrops 14 (ML086-CR443), 16 (ML086-CR443a and ML086-CR444) and 21 (ML086-CR442).

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New GI data and ground properties

Stratigraphy:

The analysis of the geological description of the new GI logs leads to the following stratigraphy.

ML086-CR442	Base depth (m)	Base elevation (AOD)	Soil description	Detailed design assumptions
Till formation	2.3	107.08	Firm sandy clay	• Firm to stiff sandy gravelly clay • Base at 106mAOD
Glaciofluvial deposits	8.2	101.18	• Fine to coarse sand	• Loose to medium dense fine to medium sand • Base at 100.5mAOD
Oxford Clay formation	19	90.38	Very stiff sandy clay	• Stiff to very stiff clay • Base at 89mAOD
Kellaways formation	24.2	85.18	• Extremely weak mudstone • Extremely weak sandstone	• Extremely weak mudstone • Interbeds of stiff clay and fine sand • Base at 83.5mAOD
Cornbrash formation	>25	<84.38	• Medium strong to strong limestone	• Medium strong to strong limestone • Base at 80.8mAOD

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ML086-CR443	Base depth (m)	Base elevation (AOD)	Soil description	Detailed design assumptions
Till formation	3	106.18	Firm to stiff clay	• Firm to stiff sandy gravelly clay • Base at 106mAOD
Glaciofluvial deposits	>7.5	<101.68	• Loose sand • Stiff clay (may be the top of OXC)	• Loose to medium dense fine to medium sand • Base at 100.5mAOD

ML086-CR443a	Base depth (m)	Base elevation (AOD)	Soil description	Detailed design assumptions
Till formation	3	106.6	Firm gravelly clay	• Firm to stiff sandy gravelly clay • Base at 106mAOD
Glaciofluvial deposits	7.2	102.4	Loose to medium dense sand	• Loose to medium dense fine to medium sand • Base at 100.5mAOD
Oxford Clay formation	20.52	89.08	• Stiff to very stiff clay • Extremely weak mudstone	• Stiff to very stiff clay • Base at 89mAOD
Kellaways formation	26.7	82.9	Very weak mudstone	• Extremely weak mudstone • Interbeds of stiff clay and fine sand • Base at 83.5mAOD
Cornbrash formation	28	81.6	Strong limestone	• Medium strong to strong limestone • Base at 80.8mAOD
Forest Marble formation	>30	79.6	• Very weak to weak mudstone • Very weak to weak siltstone • Strong limestone • Weak to medium strong siltstone.	• Medium strong limestone and weak siltstone • Base at 77.5mAOD

ML086-CR444	Base depth (m)	Base elevation (AOD)	Soil description	Detailed design assumptions

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Till formation	3.3	106.03	Soft to firm gravelly clay	• Firm to stiff sandy gravelly clay • Base at 106mAOD
Glaciofluvial deposits	6.3	103.03	Fine to coarse sand	• Loose to medium dense fine to medium sand • Base at 100.5mAOD
Oxford Clay formation	20.6	88.73	Very stiff clay	• Stiff to very stiff clay • Base at 89mAOD
Kellaways formation	>25	<84.33	• Extremely weak mudstone • Extremely weak sandstone	• Extremely weak mudstone • Interbeds of stiff clay and fine sand • Base at 83.5mAOD

The geological descriptions given in the new GIs for each soil are identical to those considered in detailed design.

The comparison of soil formations levels is summarized in the following table.

	Base elevation (AOD)					
	ML086-CR442	**ML086-CR443**	**ML086-CR443a**	**ML086-CR444**	**Detailed design assumptions**	**Observations**
Till	107.08	106.18	106.6	106.03	106	Design model conservative (thicker layer of till)
GFD	101.18	<101.68	102.4	103.03	100.5	Design model conservative (thicker layer of GFD)
OXC	90.38		89.08	88.73	89	Design value within the range given by the new GIs
KLB	85.18		82.9	<84.33	83.5	Design value within the range given by the new GIs
CB	<84.38		81.6		80.8	Base of CB lower in design model New GIs value still ~1m below pile base level
FMB			<79.6		77.5	New GIs do not give exact value

Soil and rock tests

The main tests and measurements conducted on samples from the new GIs are listed in the following table.

Test	Formation	Description	Detailed design assumptions
UCS measurement	KLB	• 0.221 MPa at 22.31 m in ML086-CR442 • 13.7 MPa at 24.42 m in ML086-CR442	Cu=200 kPa

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		• 0.254 MPa at 23.65 m in ML086-CR443a • 34.2 MPa at 26.68 m in ML086-CR443a • 34.2 MPa at 26.68 m in ML086-CR443a • 0.216 MPa at 24.13 m in ML086-CR444	
UCS measurement	CB	• 13.7 MPa at 24.42 m in ML086-CR442	UCS=10 MPa
RQD estimation	OXC KLB CB FMB	• Values within the range of values considered for detailed design	

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Part C – First Pass SWOT Impact Assessment

Strengths	Weakness
• The observation from the new GIs conforms with the soil model used in the detailed design. Small differences are seen for soil formations levels, but they do not affect the relevance of the defined soil model. UCS measurements give comparable values to those considered in the design.	• No weakness remaining
Opportunities	**Threats**
• None	• None

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Part D – Conclusions of First Pass Impact Assessment

Regarding the piles of the overbridge:

Potential Impact	None
ASC Recommendations subject to review and agreement with EKFB/HS2	The new GI do not change the piles design

Regarding the transition zone:

ASC Recommendations subject to review and agreement with EKFB/HS2	The new GI do not change the transition zone design. No impact on the calculated settlements.

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