VARIABLE GLACIAL GROUND AND LIQUEFIABLE SOIL CONDITIONS

RYAN BEECH

14 DECEMBER, 2021

Background

2009-2011

- AS / A-Level Geology

2011-2014

- BSc (Hons) Geology – University of Birmingham

2014-2015

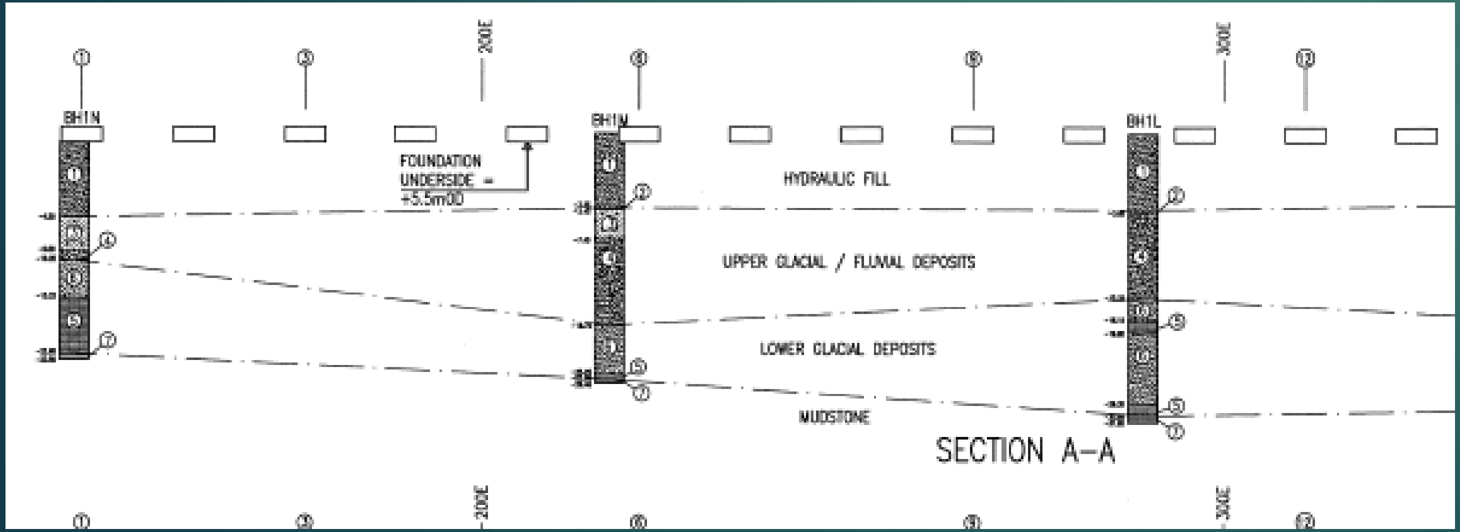
- MSc Engineering Geology – University of Leeds

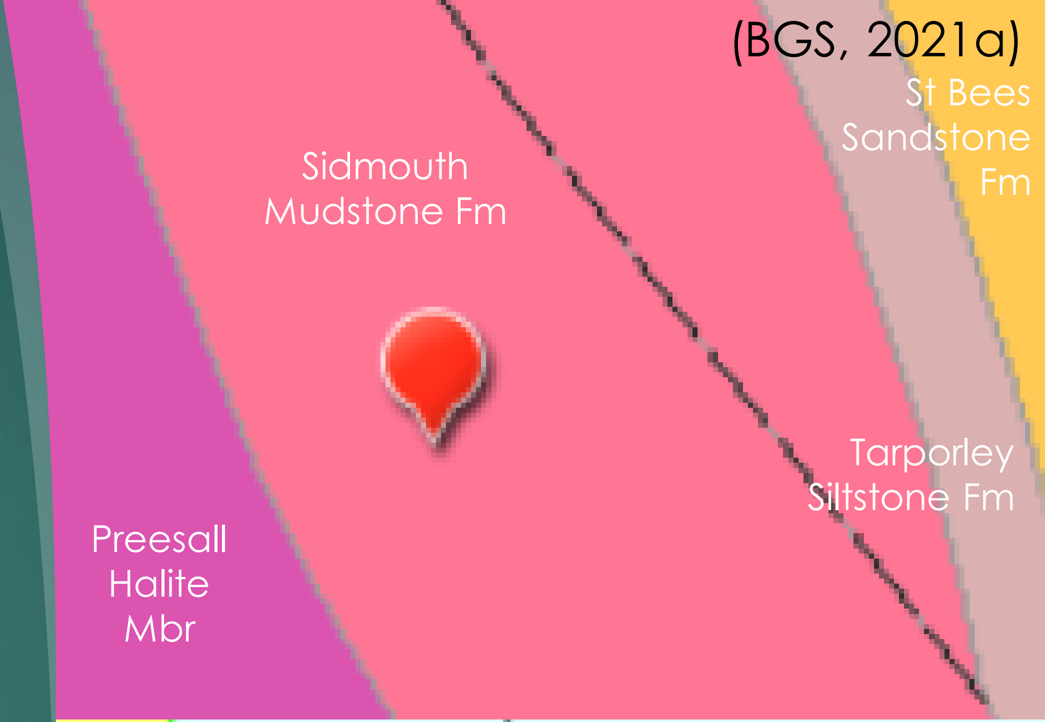
2015-Present

- Joined Civil Engineering industry
    - Preparation of Desk Studies
    - Ground Investigation Scoping
    - Site Supervision
    - Ground Modelling / Geotechnical Design
        - Utilities, Highways, Waste Remediation, Aviation, Nuclear sectors
- Fellow of Geological Society
- Member of Midlands' Geotechnical Society

Project

- New (~40m x 190m) Dock Quay Wall
- Nuclear (MoD) Facility
- Sensitive project with confidentiality constraints
- Geotechnical Category 3 project (BS EN 1997-1) requiring a seismic assessment





Involvement

2015

- Preliminary GI

2017

- Ground Investigation Report
- Preliminary Liquefaction Assessment and Strategy Document
- Data Gap Analysis
- GI Specification

2020

- Liquefaction GI
- Detailed Liquefaction Assessment and Outline Ground Treatment Specification
- Liaison with Principal Contractor & Ground Treatment Specialist & Value Engineering

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- Ground Investigation Report
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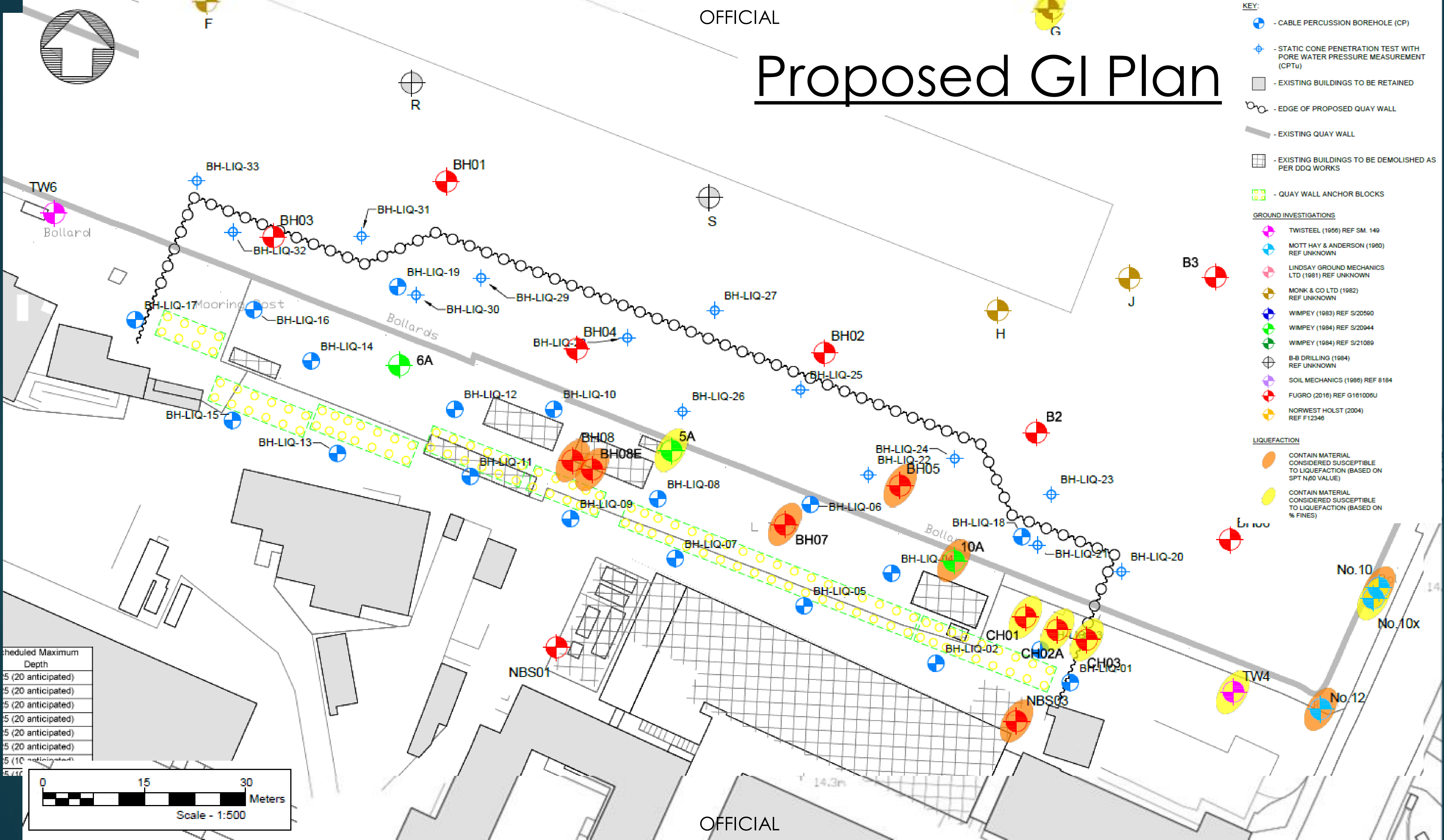
Proposed GI Plan



Liquefaction Assessment - Grading

Balkema (1997)

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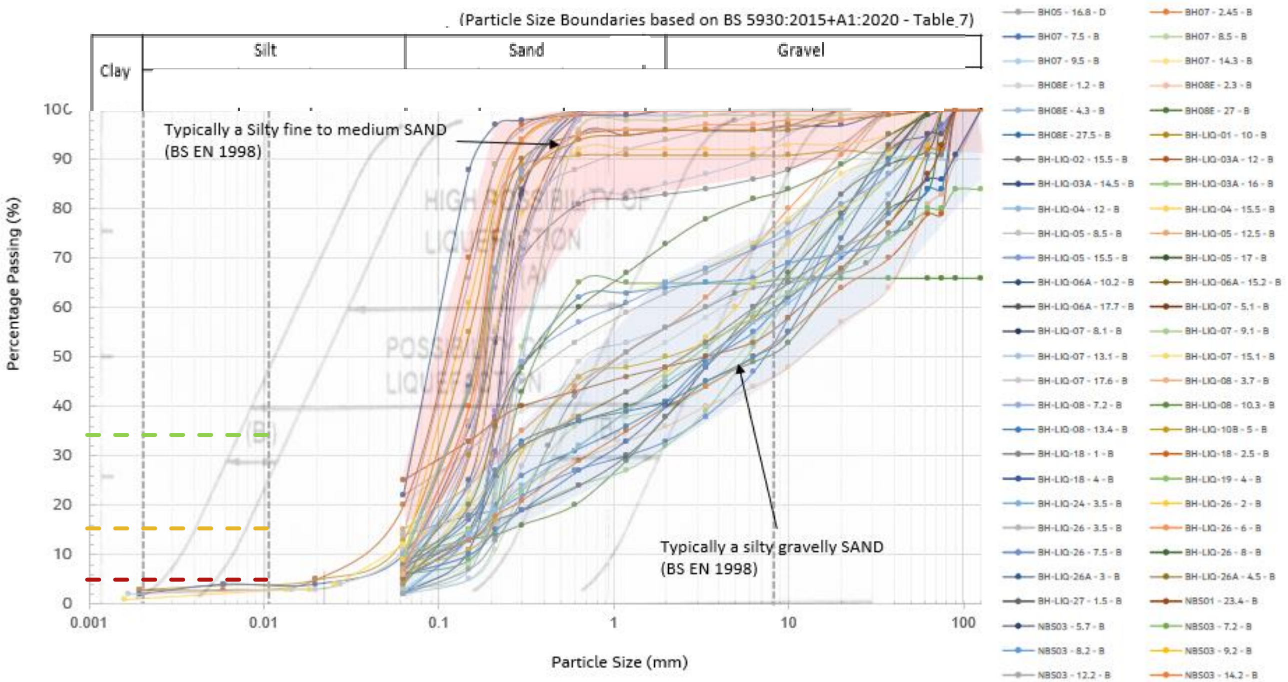

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Jacobs

Particle Size Distribution (Balkema 1997)	Figure Reference	A.1.4
Curve 3 (Refe	ty Coefficient Cu =	>3

Key

τ_e/σ'_{vo} – cyclic stress ratio

A – clean sands; B – silty sands

curve 1: 35 % fines

curve 2: 15% fines

curve 3: < 5% fines

Figure B.1 — Relationship between stress ratios causing liquefaction and $N_1(60)$ values for clean and silty sands for M_S=7,5 earthquakes.

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CALCULATION SHEET

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	Page No.	1	Cont'n Page No.		
	Originator	RB	Date	08/09/2020	
Section: Design Base Event (DBE) - Evaluation of Liquefaction Susceptibility by Grading and SPT	Checker	SCP	Date	16/09/2020	

Hole ID: BH-LIQ-05

PGA (a_g): 0.25 g
Importance Factor (γ_1): 1.4
Earthquake Magnitude (M): 5

Max Depth of SPT (m): 17.2
Groundwater Level (mbgl): 3.00

(BS EN 1998-5)
(EN 1998-5 Cl. 4.4.1(10) Expression for τ_e not applicable to depths >20m)

Chart 1 - Required SPT N1,60 Value vs Depth

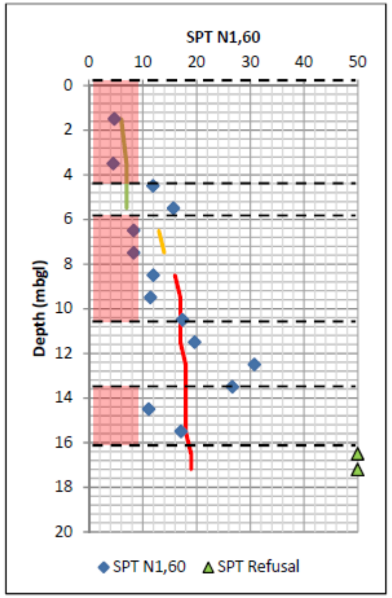

Chart 2 - Seismic Stress Ratio vs SPT N1,60 Value

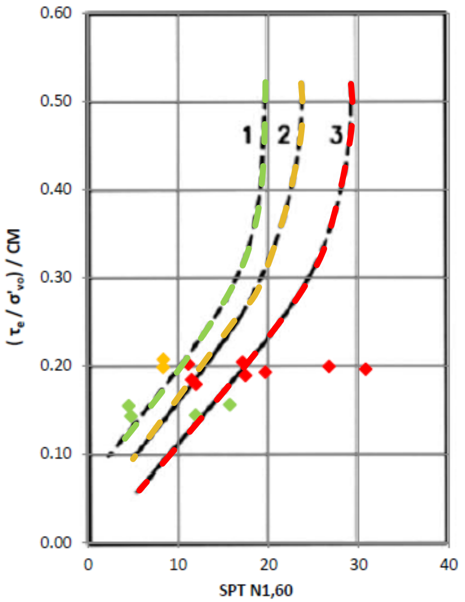

Chart 3 - Stratigraphic (Soil) Profile

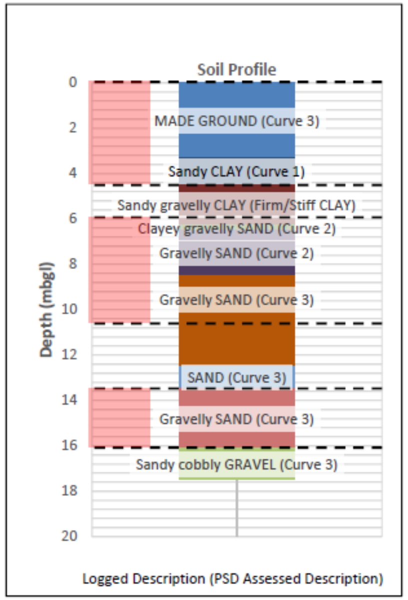

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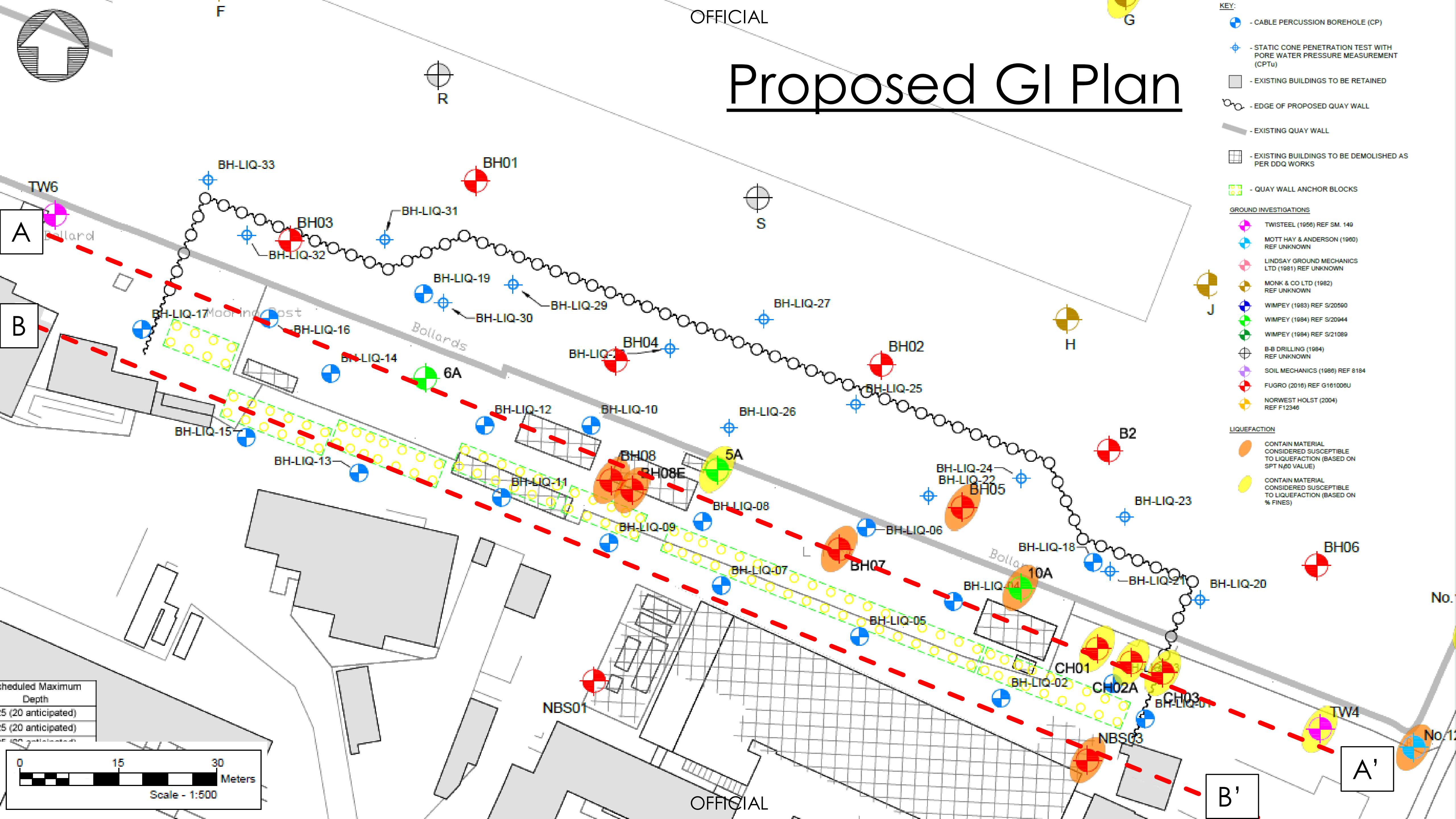
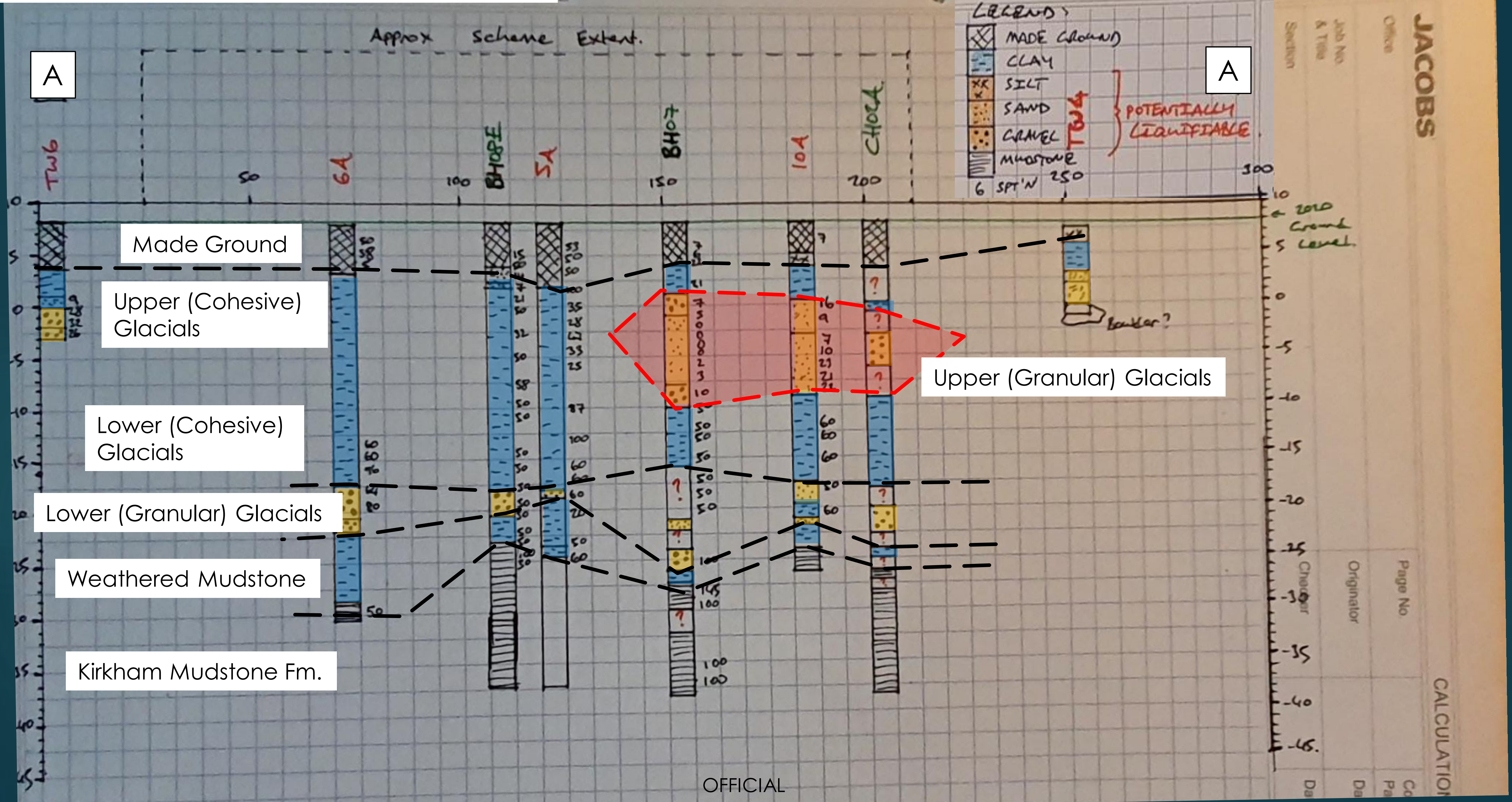
Figure B.1 — Relationship between stress ratios causing liquefaction and $N_1(60)$ values for clean and silty sands for M_S=7,5 earthquakes.

Liquefaction Assessment - SPT

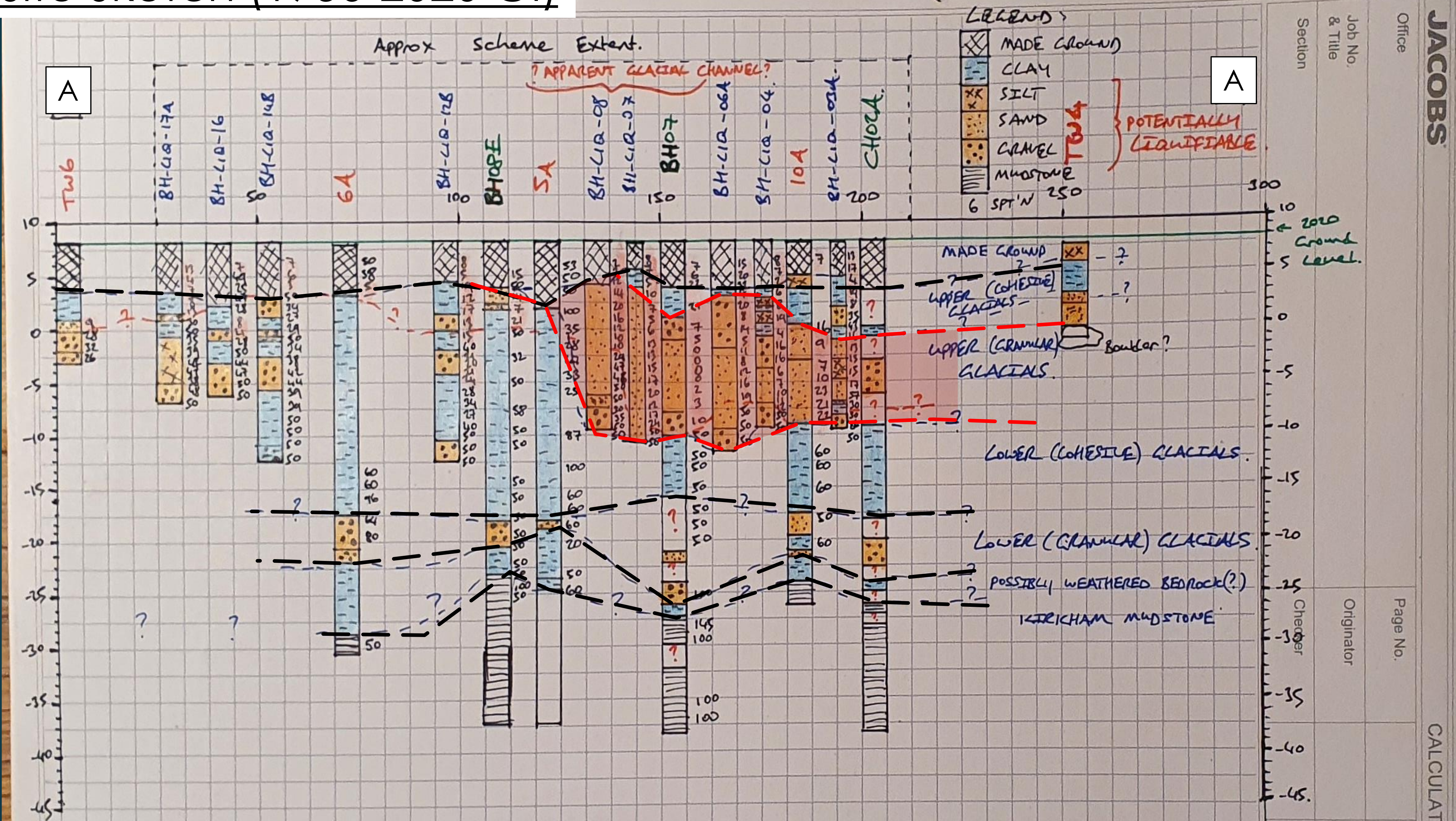
Proposed GI Plan



Site Sketch (1956-2015 GI)



Site Sketch (1956-2020 GI)



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Job No. & Title

Section

Page No.

Originator

Checker

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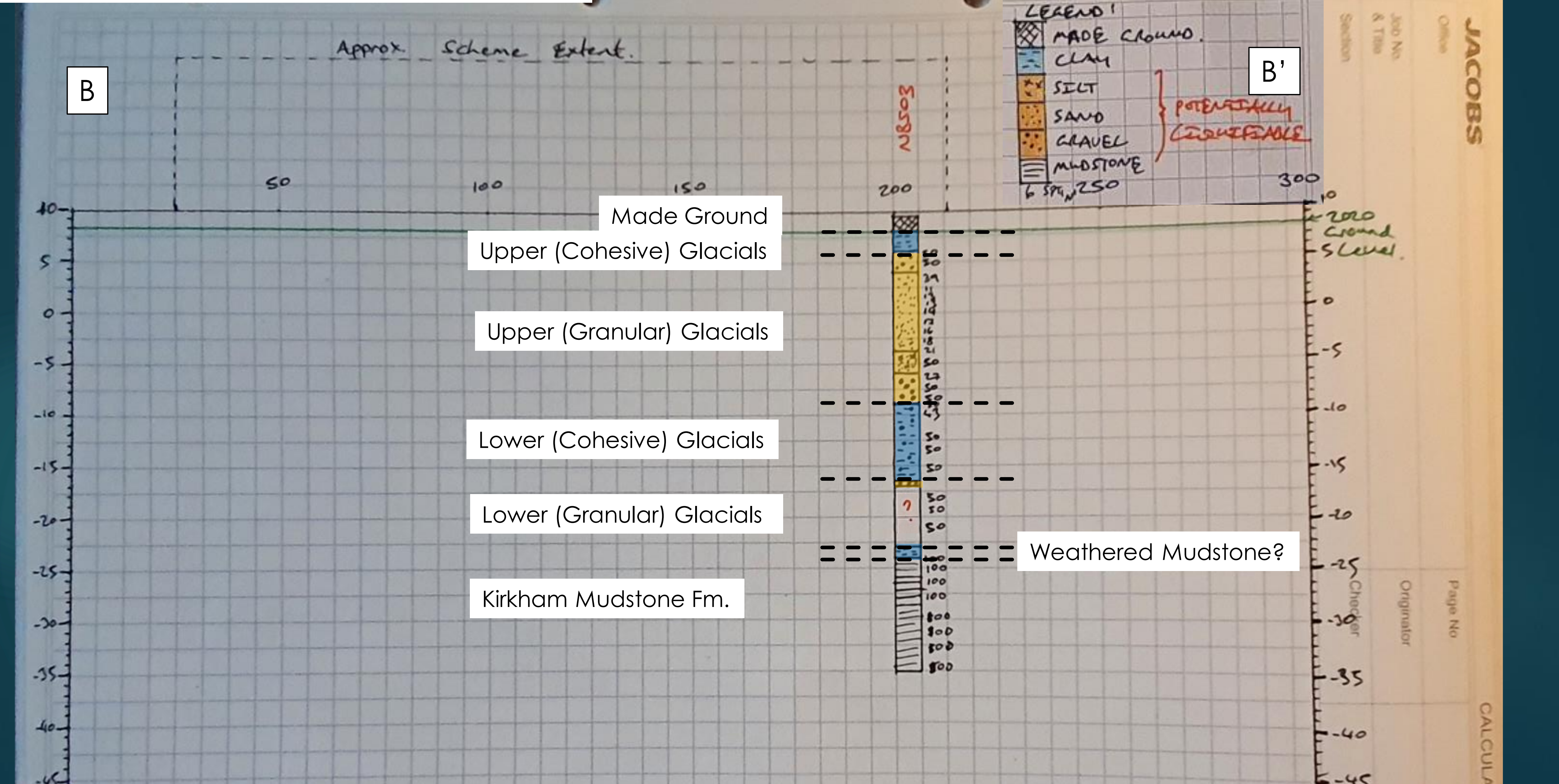
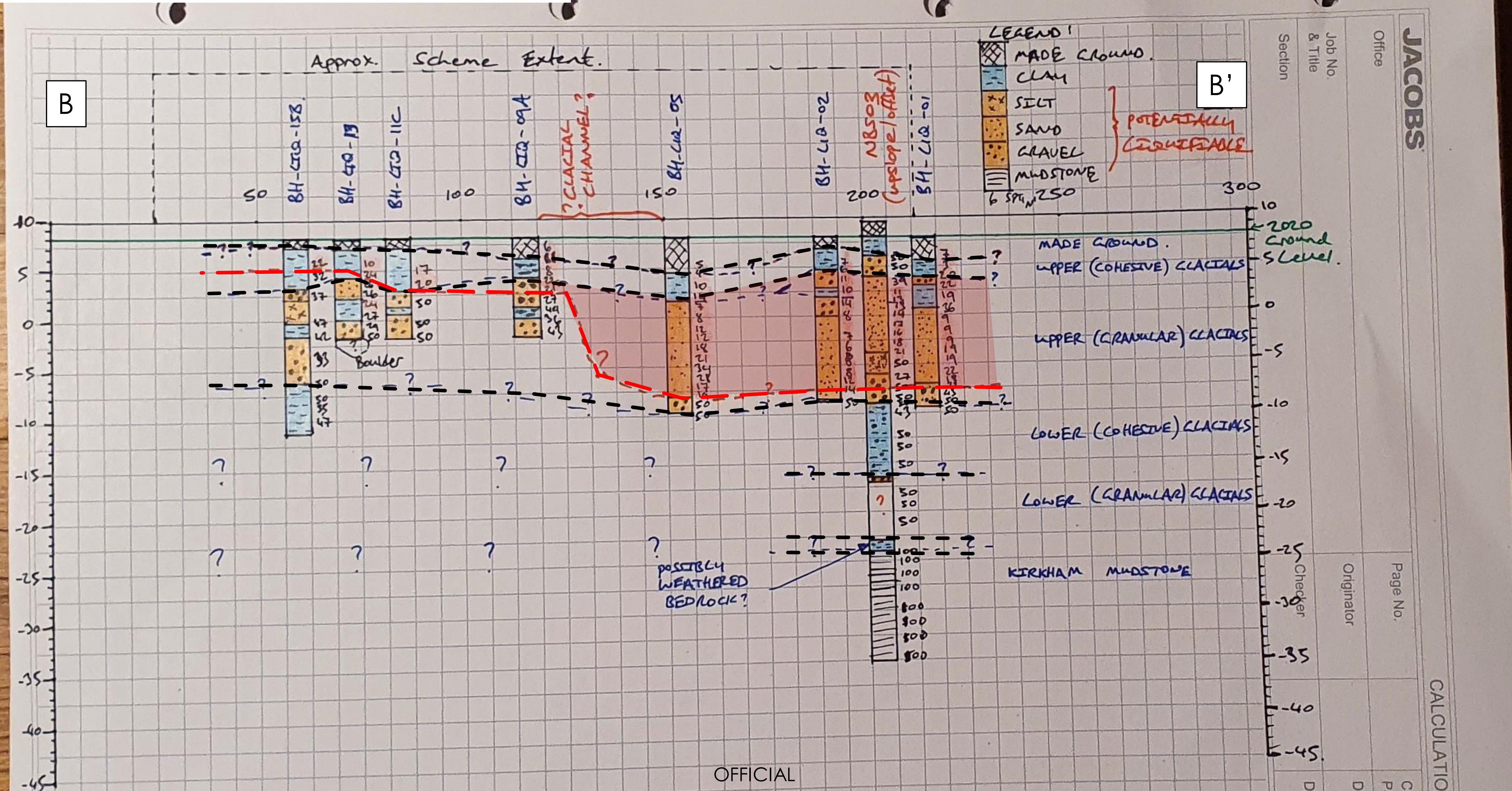
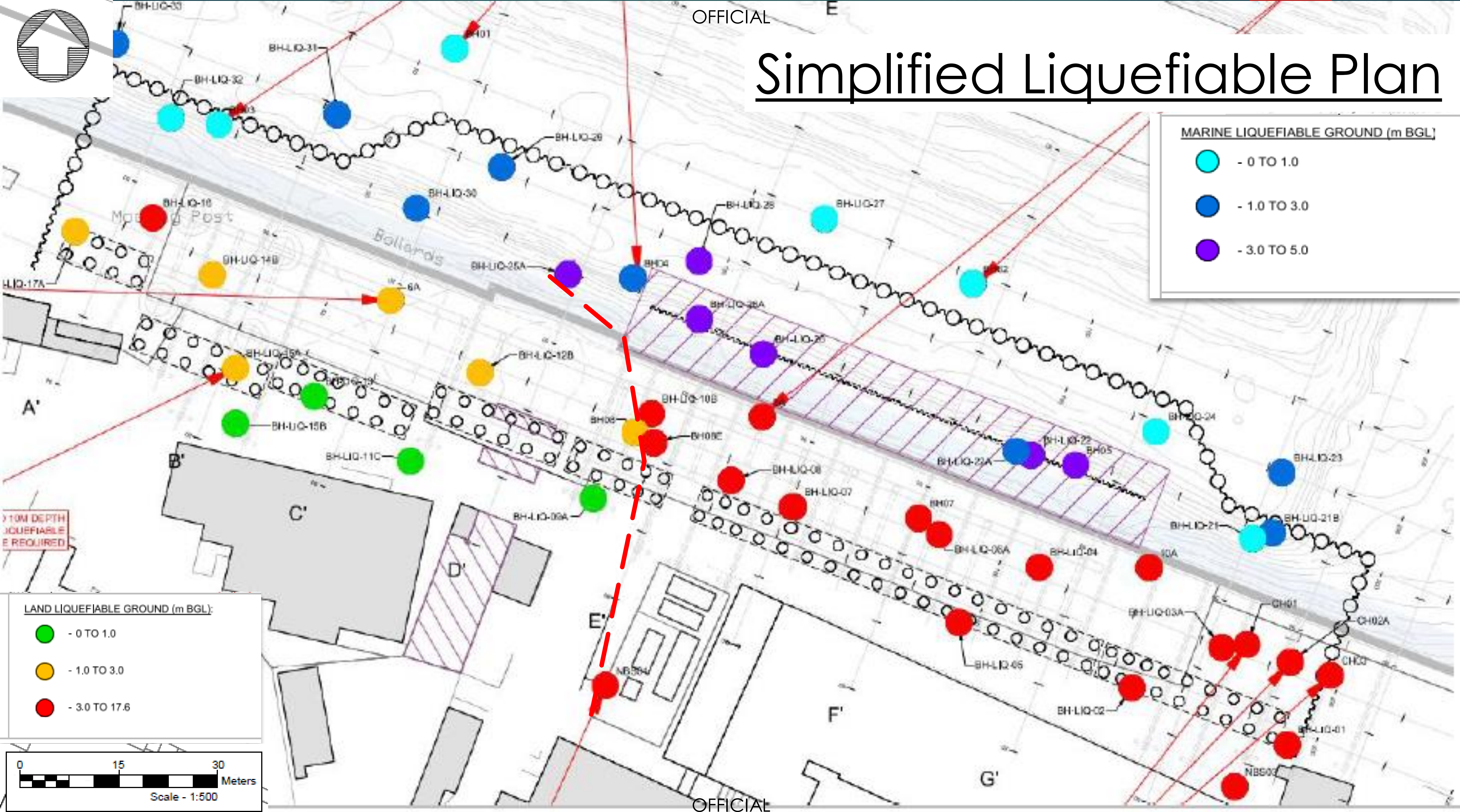
Site Sketch (1956-2015 GI)



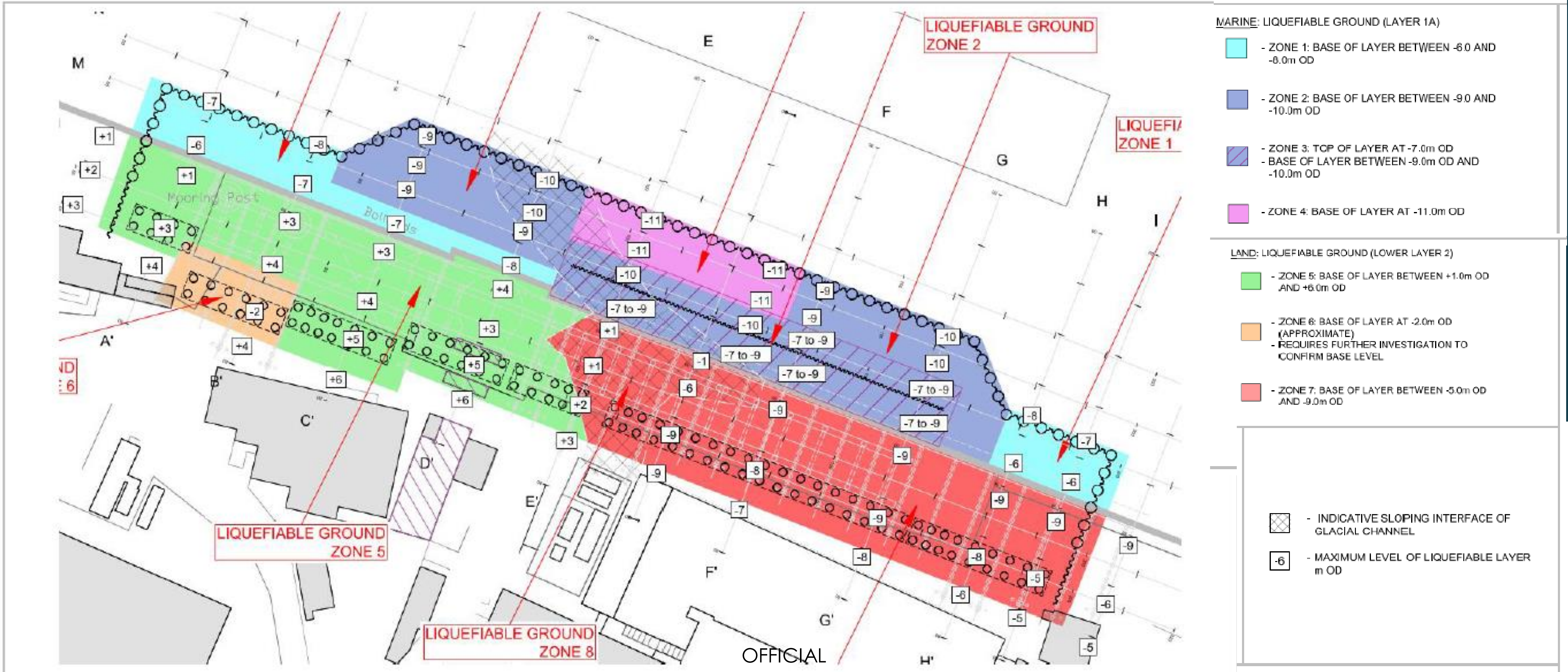
Site Sketch (1956-2020 GI)



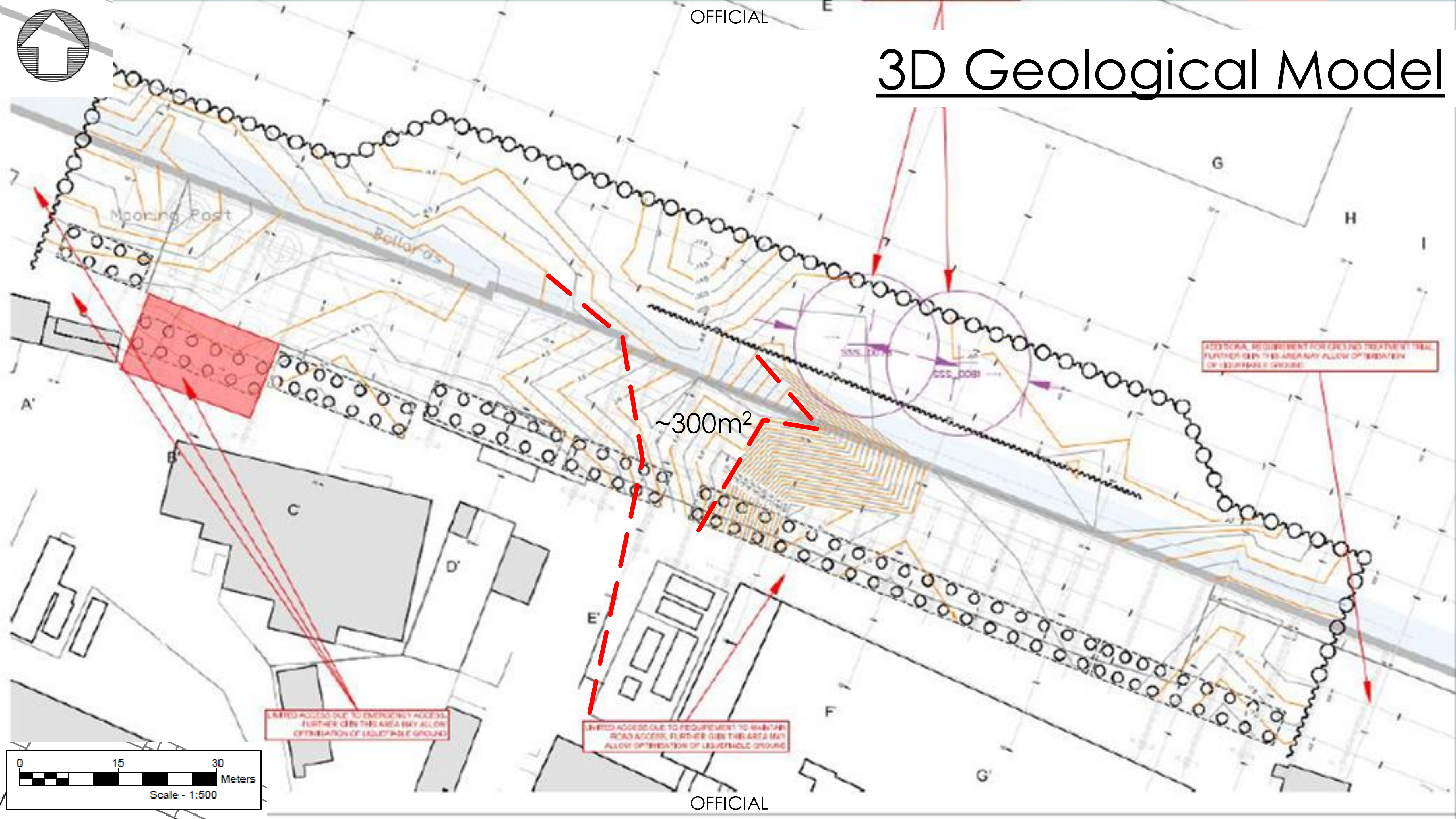
Simplified Liquefiable Plan



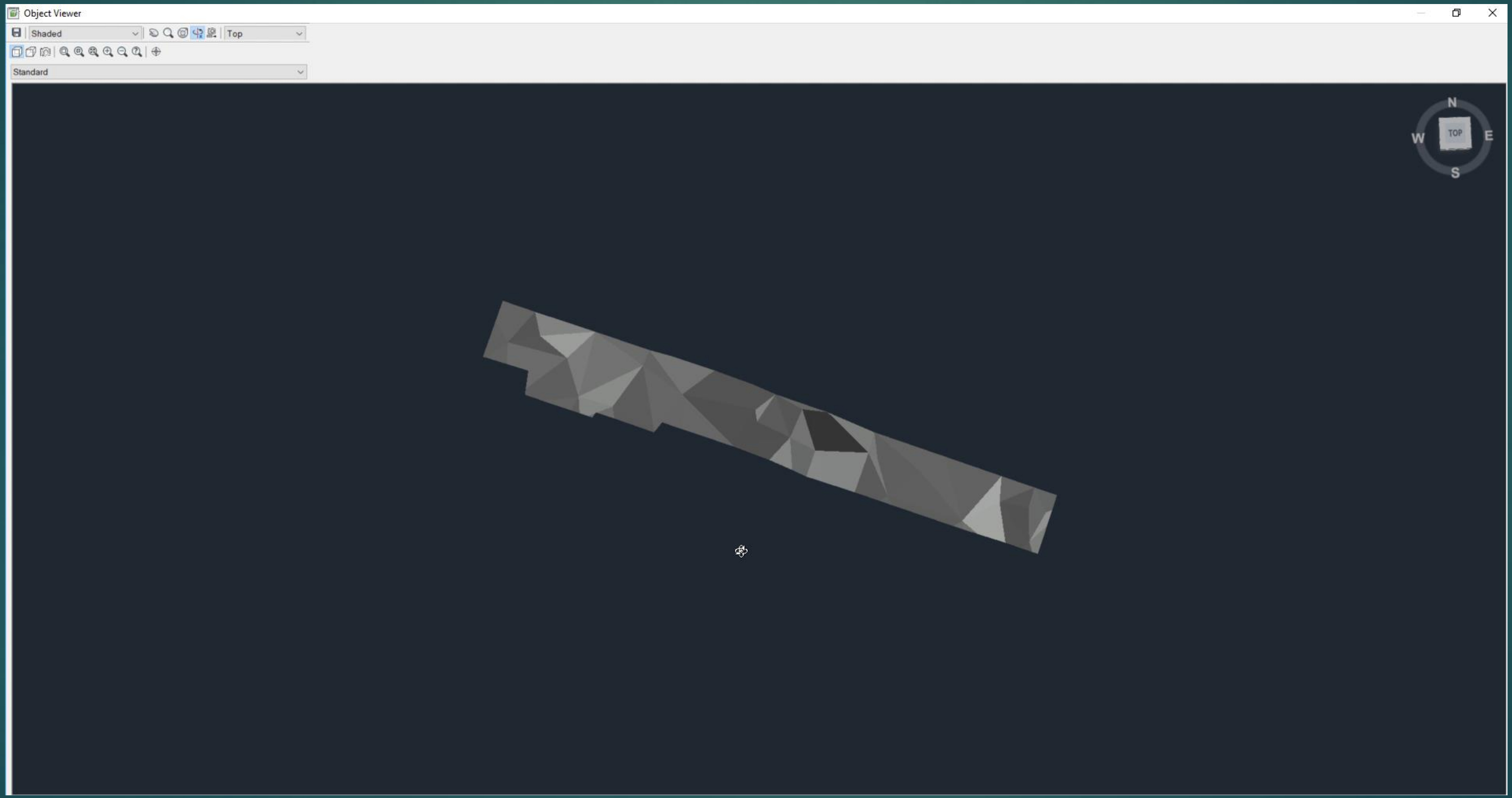
Ground Treatment Plan



3D Geological Model



3D Modelling / Design Integration



Future Work

- Development of Sitewide 3D Model
  - Geology
  - Liquefiable Layers
  - Obstructions
- Ground Treatment
  - Value Engineering and Outline Solution to Mitigate GeoHazard
  - Trials
  - Further GI to reduce ground risk
  - Construction
  - Verification

References

- Balkema 1997 Handbook on liquefaction remediation of reclaimed land. Port and Harbour Research Institute, PHRI, Rotterdam, Brookfield, Netherlands.
- BGS 2021a: GeoIndex 1:50,000 Superficial Deposits
- BGS 2021b: GeoIndex 1:50,000 Bedrock / Linear Features
- BSI, 2004a. BS EN 1997-1: 2004: Eurocode 7: Geotechnical design–Part 1: General rules.
- BSI, 2004b. BS EN 1998-1, 2004: Eurocode 8: Design of Structures for Earthquake Resistance
- BSI, 2004c. BS EN 1998-5: 2004: Eurocode 8: Design of structures for earthquake resistance. Foundations, retaining structures and geotechnical aspects

Any Questions?

Contact: Ryan.Beech@jacobs.com

West Midland Regional Group

14/12/2021

Rock Slope Modelling

Hamish Strachan

Contents

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Scope

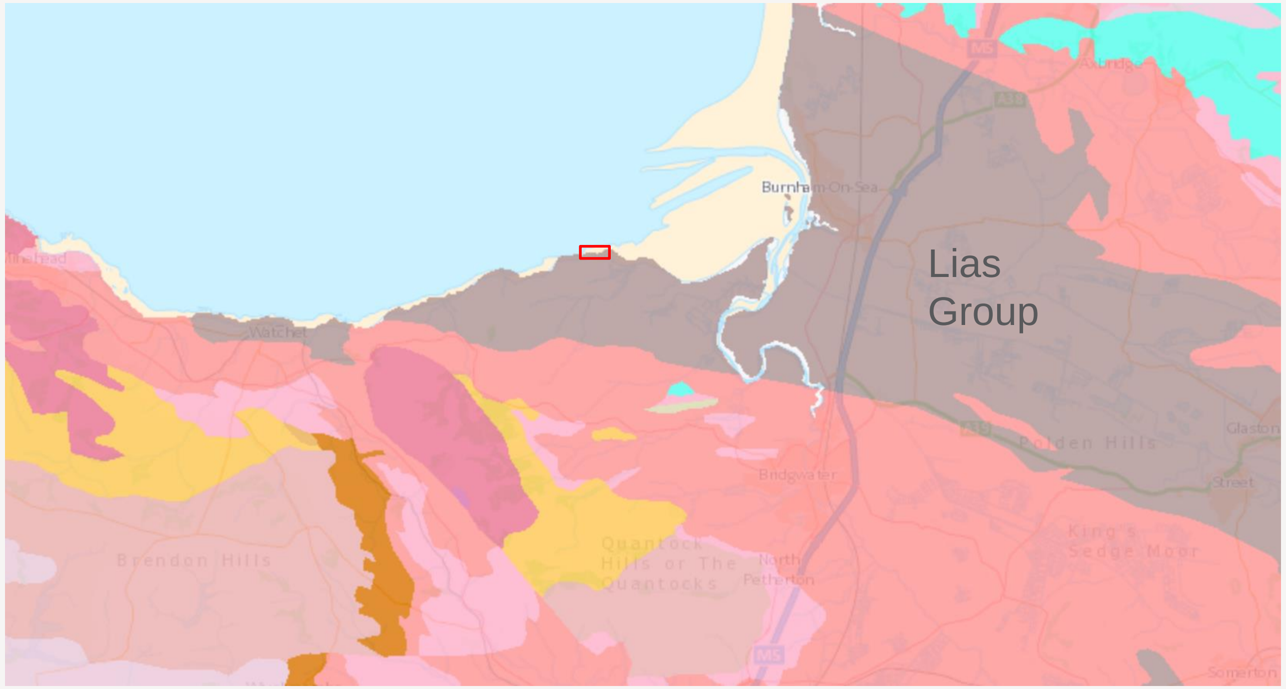
- Undertake a review of the stability of two rock slopes
- Assess deformation and adequacy of installed support as well as likely levels of movement for trigger level purposes
- Summarise findings in a Technical Note

Previous Work

- Design Study
- Face Logs

Geology

- Lias Group and Penarth Group:
- Blue Lias Formation
- Lilstock Formation and Westbury Formation



GeoIndex - British Geological Survey (bgs.ac.uk)

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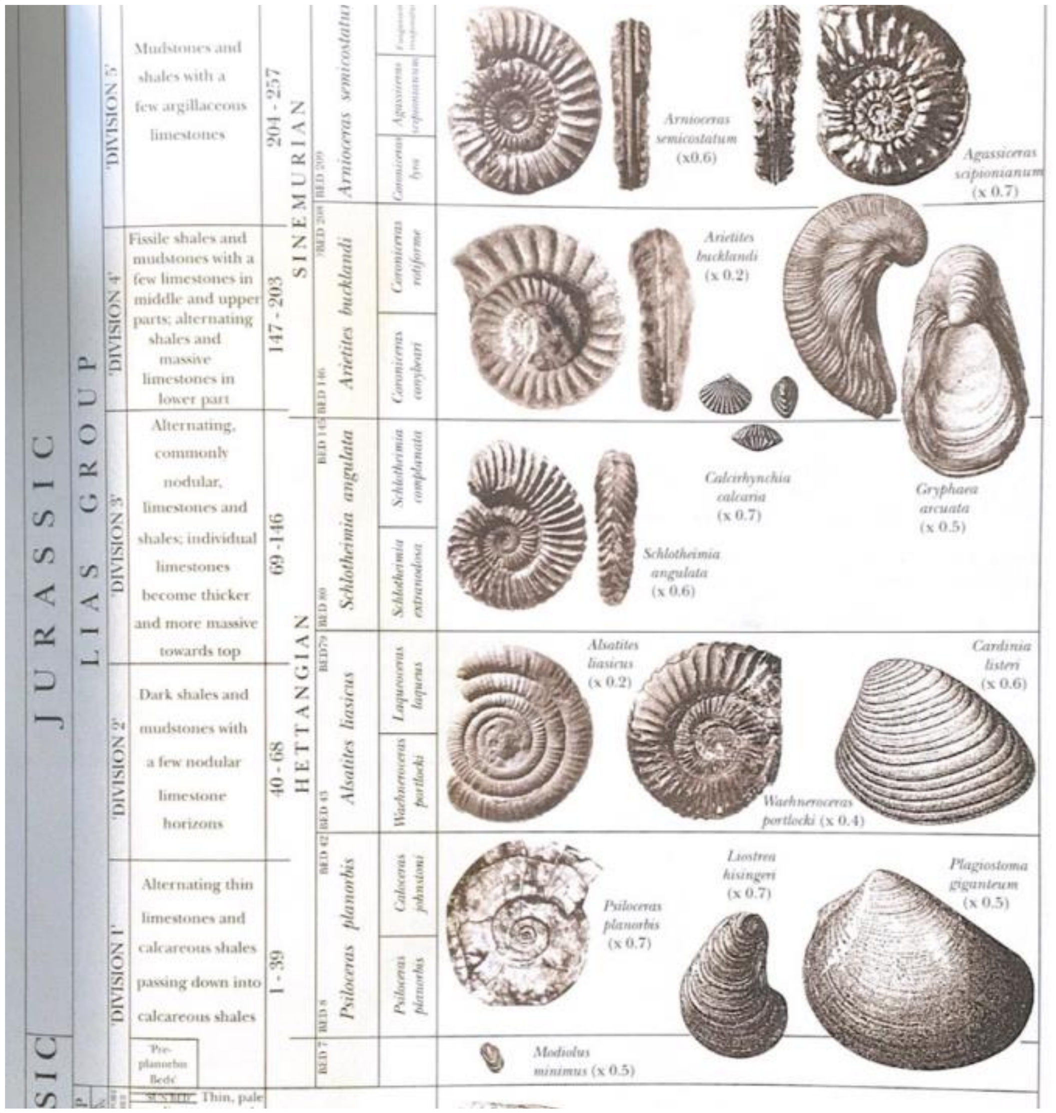
Geology

- Blue Lias Formation sub divided based on biozones:
  - Planorbis
  - Lower Liasicus
  - Upper Liasicus / Angulata



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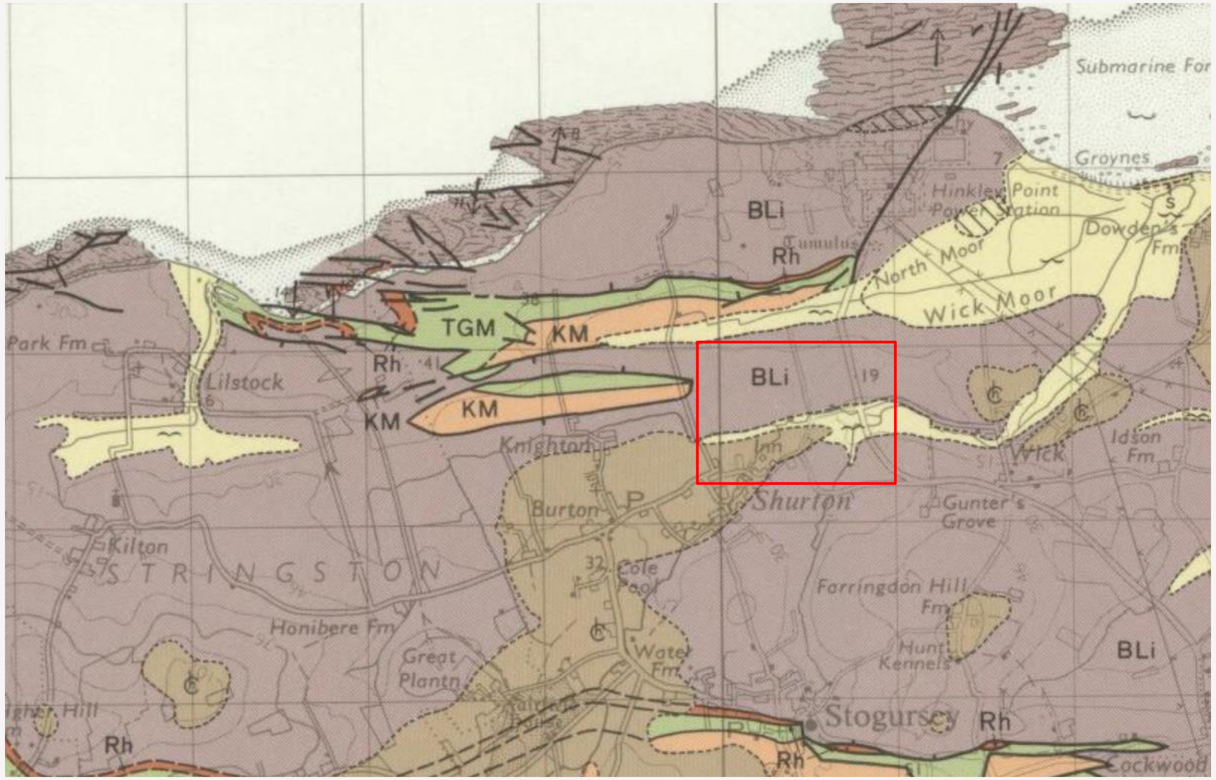
› In situ stress regime – K0 = 1.5



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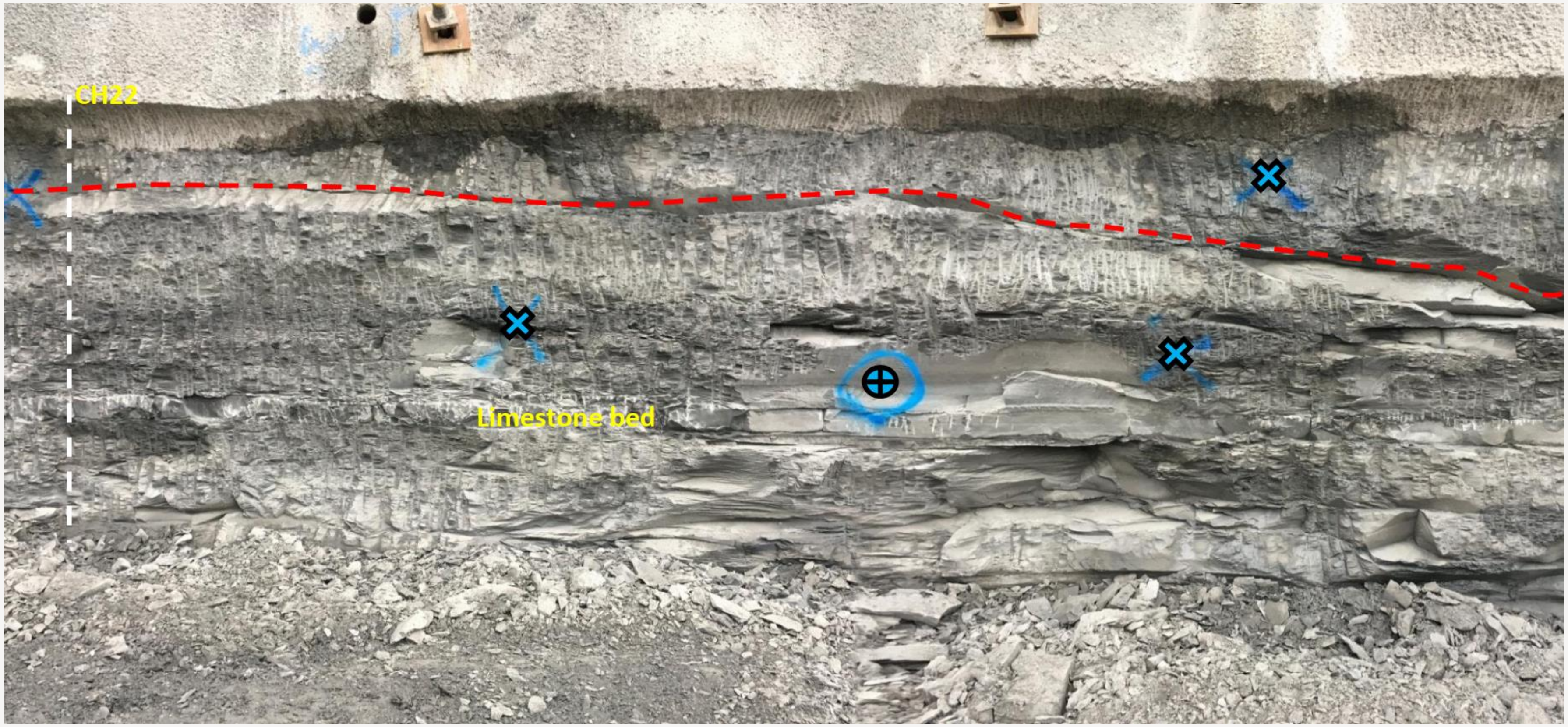
Geology

Geology



Interbedded units of calcareous MUDSTONE and LIMESTONE. Very weak to weak Calcareous Mudstone makes up most of the cut faces and is interbedded with medium strong to strong LIMESTONE.

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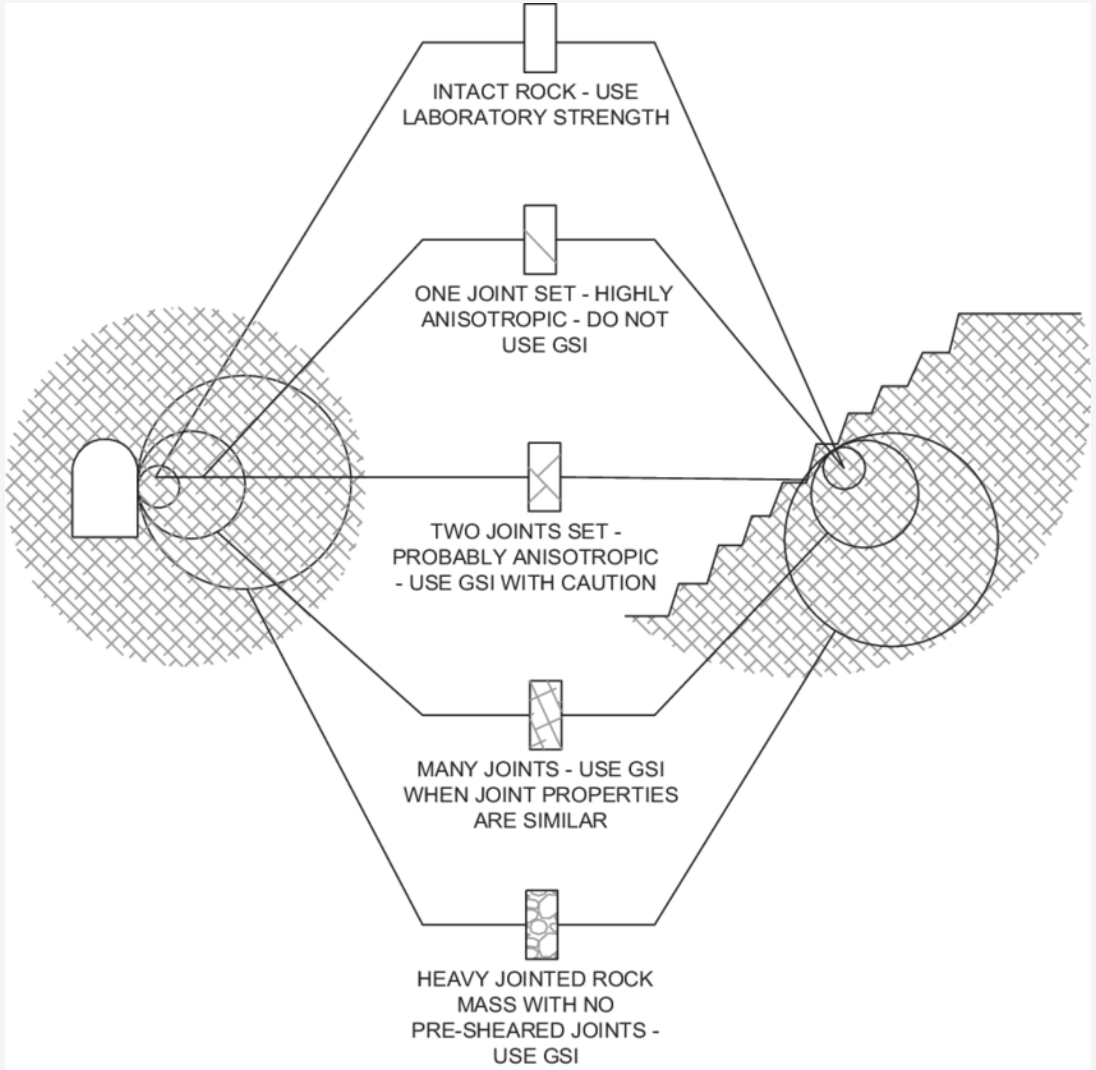
Parameter Derivation

Rock Mass Parameters

- Hoek-Brown rock mass strength criterion
- GSI selected from logging or previous reports
- Em derived using the recommendations of Hoek and Diederichs (2006)

$$E_{\mathrm{rm}} = E_{\mathrm{i}}\left(0.02 + \frac{1 - D/2}{1 + e^{((60+15D-\mathrm{GSI})/11)}}\right)$$



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Parameter Derivation

Rock Mass Parameters

› Hoek-Brown rock mass strength criterion

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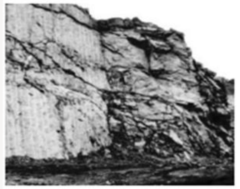
$$E_{rm} = E_i \left(0.02 + \frac{1 - D/2}{1 + e^{((60+15D-GSI)/11)}} \right)$$

› Disturbance factor of 0.5 was applied to a depth of 1m

Table 4.6 Guidelines for estimating disturbance factor D

Appearance of rock mass	*Description of rock mass*	*Suggested value of D*
	Excellent quality controlled blasting or excavation by Tunnel Boring Machine results in minimal disturbance to the confined rock mass surrounding a tunnel.	$D = 0$
	Mechanical or hand excavation in poor quality rock masses (no blasting) results in minimal disturbance to the surrounding rock mass.	$D = 0$
	Where squeezing problems result in significant floor heave, disturbance can be severe unless a temporary invert, as shown in the photograph, is placed.	$D = 0.5$ No invert
	Very poor quality blasting in a hard rock tunnel results in severe local damage, extending 2 or 3 m, in the surrounding rock mass.	$D = 0.8$

Table 4.6 Continued

Appearance of rock mass	*Description of rock mass*	*Suggested value of D*
	Small-scale blasting in civil engineering slopes results in modest rock mass damage, particularly if controlled blasting is used as shown on the left hand side of the photograph. However, stress relief results in some disturbance.	$D = 0.7$ Good blasting $D = 1.0$ Poor blasting
	Very large open pit mine slopes suffer significant disturbance due to heavy production blasting, and also due to stress relief from overburden removal.	$D = 1.0$ Production blasting
	In some softer rocks, excavation can be carried out by ripping and dozing, and the degree of damage to the slopes is less.	$D = 0.7$ Mechanical excavation

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Parameter Derivation

Rock Mass Parameters

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- Disturbance factor of 0.5 was applied to a depth of 1m

Parameter		Source
Unit Weight (kN/m3)		Design study
Unconfined Compressive Strength, UCS (MPa)		Design study
Geological Strength Index, GSI		Logging / Design Study
Poisson's Ratio		Design Study
Intact Rock Stiffness, Ei (MPa)		Design Study
Rock Mass Stiffness (MPa)		Calculated
Hoek brown material constants	m_i	Design Study
	m_b	Calculated
	s	Calculated
	a	Calculated

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Parameter Derivation

Joint Strength Parameters

- Barton-Bandis rock joint strength formulation
- Joint stiffnesses calculated equations below

$$k_n = \frac{E_m E_r}{s\,(E_r - E_m)}$$

$$k_s = \frac{G_m G_r}{s\,(G_r - G_m)}$$

Joint Set	Source
Dip	Logging
Dip Direction	Logging
JRC	Logging
JCS	Design Study
Residual Friction Angle	Design Study
Spacing	Logging
Persistence	Logging
Joint Normal Stiffness Undisturbed	Calculated
Joint Shear Stiffness Disturbed	Calculated

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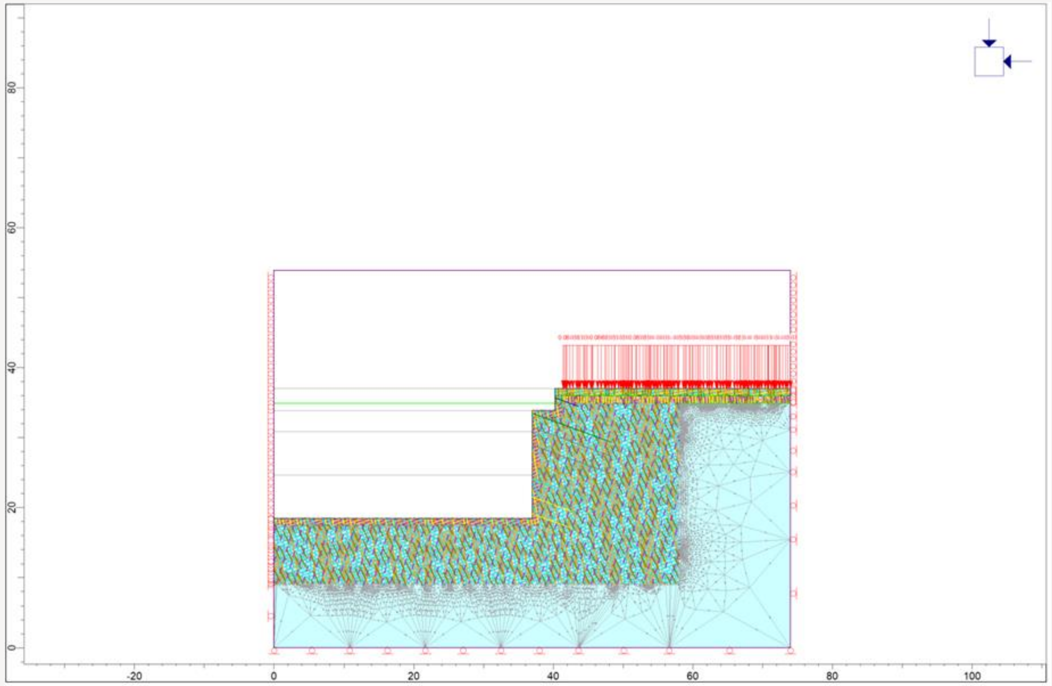
Numerical Modelling

Key Points:

- 2D model
- No groundwater modelled
- 4 material zones with 4 joint sets
- Modelled in stages to replicate excavation sequence
- Support consisting of fully bonded rock dowels wished in place
- Shotcrete not modelled as primary purpose is to prevent weathering of excavated face
- Area of focus modelled as a discontinuum with extents modelled as a continuum



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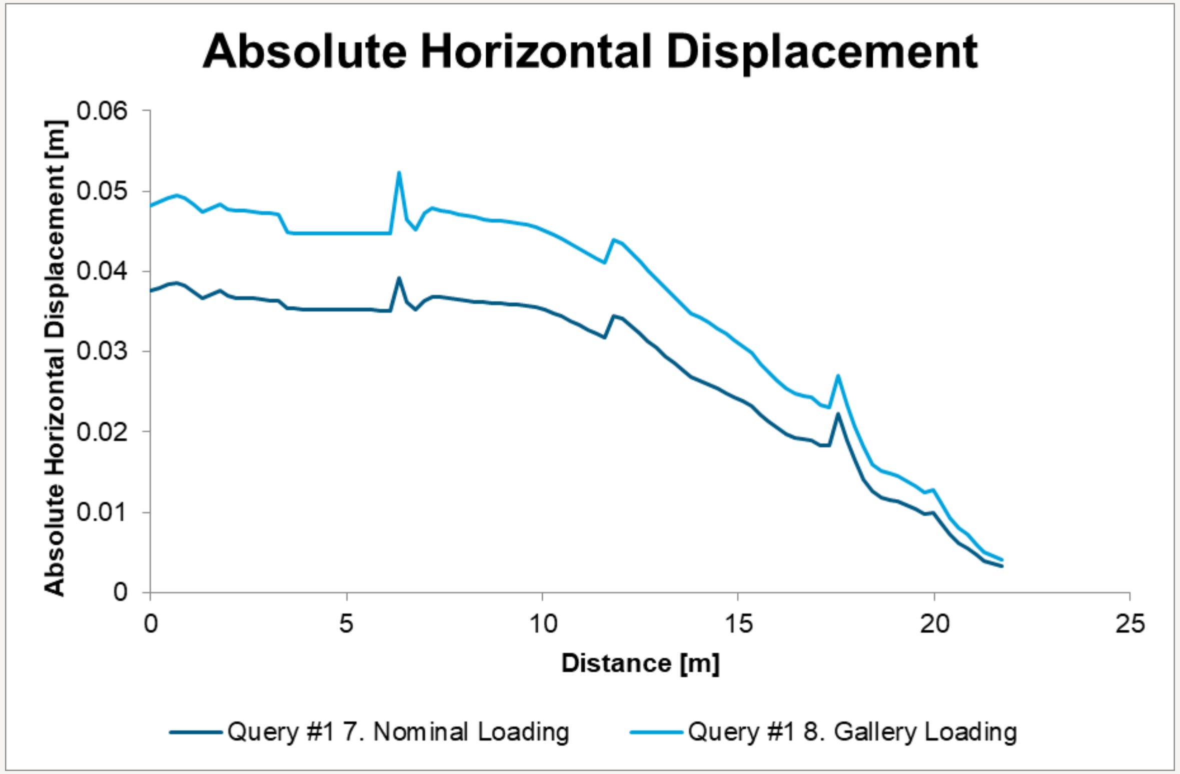
Results

- Differential horizontal displacement upon loading was less than 13mm
- Bolt capacity utilisation less than 100% for all



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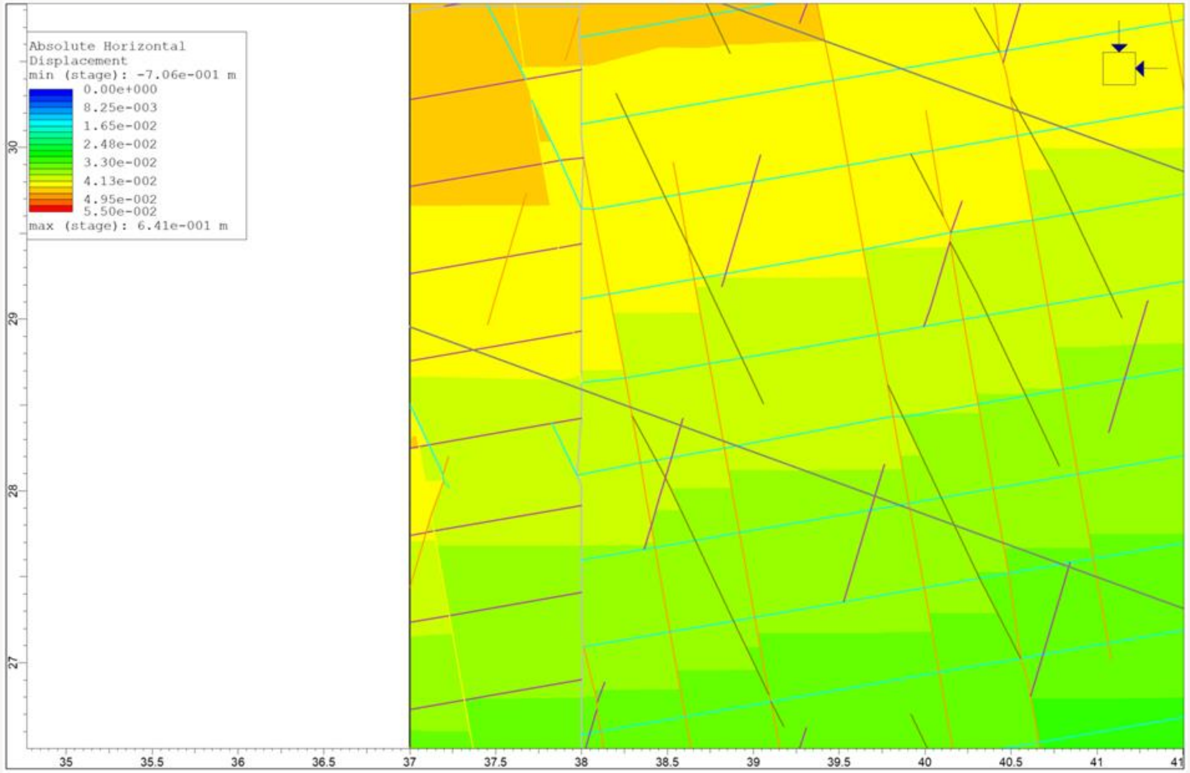

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Any Questions?

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