ALIGN Working in partnership with HS2

Periglacial Geohazards at the Colne Valley South Embankment and Chiltern Tunnel Ventilation Shaft Design

West Midlands Regional Group of The Geological Society

April 2024

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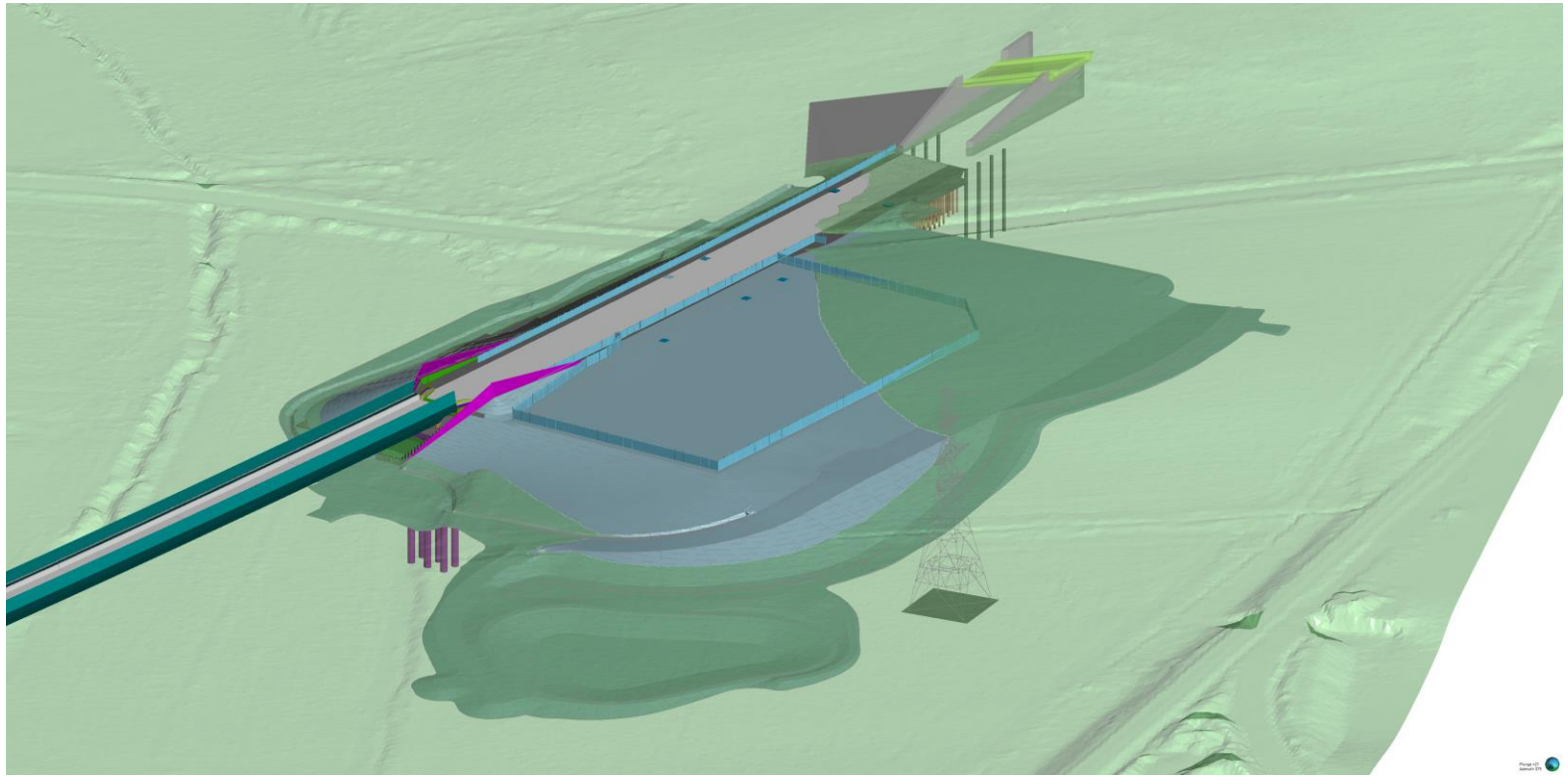
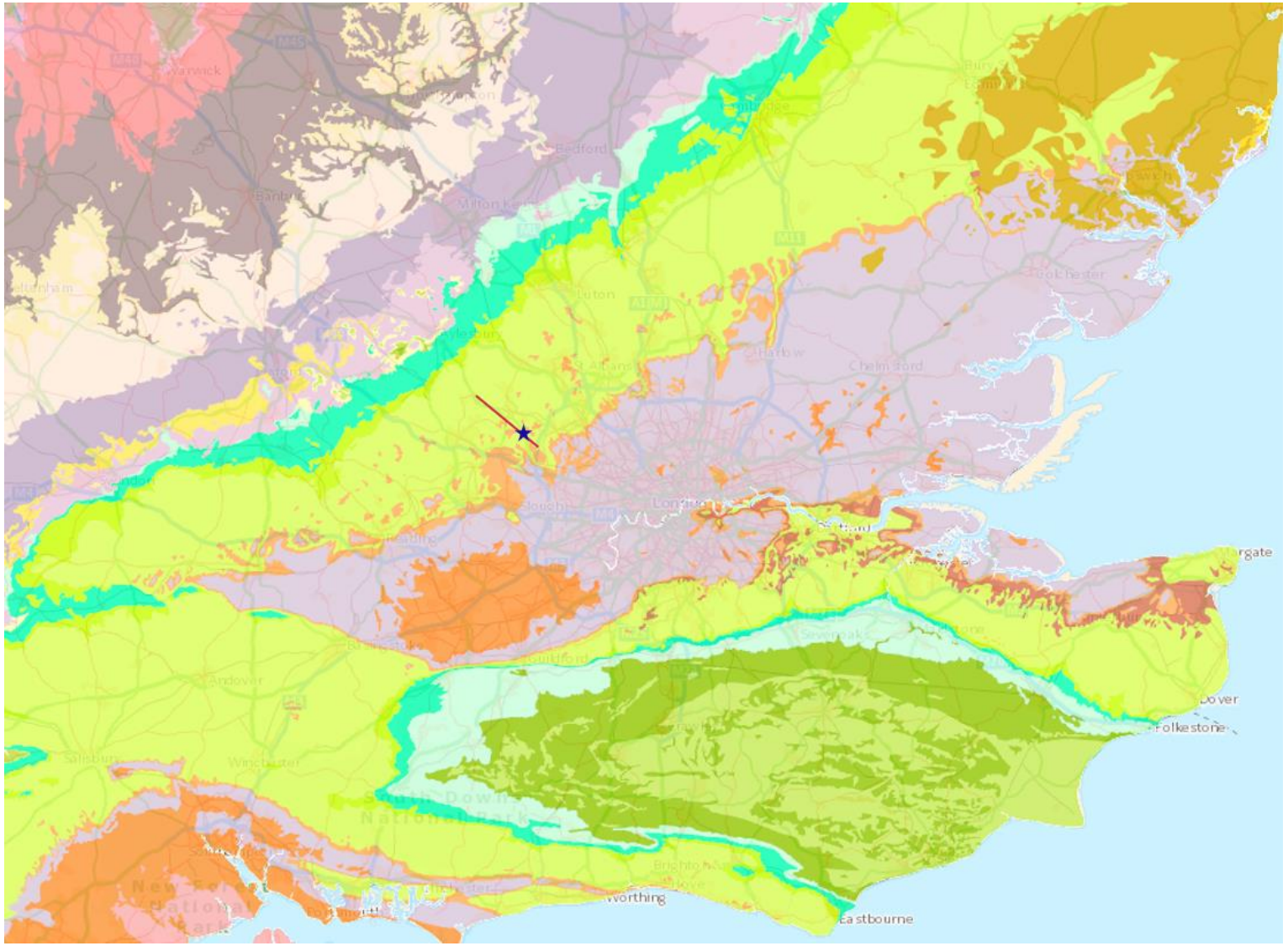
Agenda

- Introduction to Contract C1
- Colne Valley South Embankment
  - Abstract
  - Site Location / Setting
  - Site Investigation and Testing
  - Geology and Ground Model
  - Relic Shear Surfaces
  - Design Evolution and Implications
  - Engineering Solution
- Chiltern Tunnel Ventilation Shafts
  - Ground Conditions
  - Geotechnical Design
  - Construction & Performance



C1 Works Overview

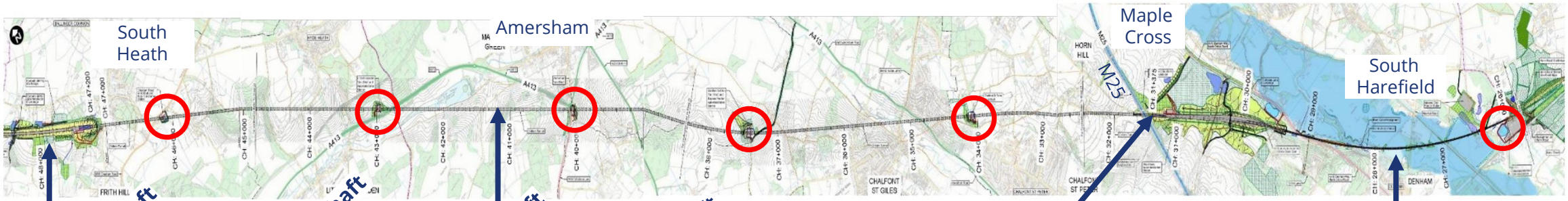
C1 Align – A Truly Integrated Project Team



C1 Works Overview

- Colne Valley Viaduct, Earthworks and Tunnelling through the chalk geology of the Chiltern Hills
- The tunnel alignment cuts across the north limb of the London Basin geological syncline

C1 Works Overview

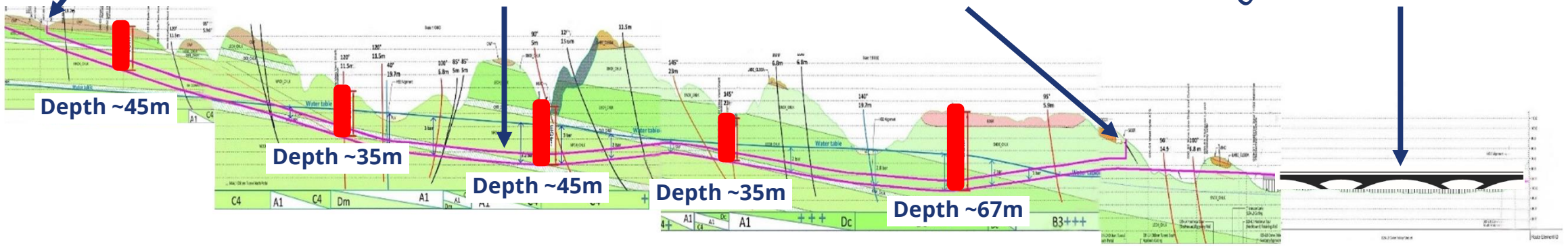


5 shafts

4 for Intervention and tunnel ventilation / 1 for Intervention only

North Portal

Colne Valley Viaduct



Periglacial Geohazards at the Colne Valley South Embankment

Abstract

Periglacial slip surfaces have different causes and mechanisms, but all present a potential geohazard to engineering works, in this case, embankment construction. Periglaciation can result in the presence of a mantle of material at or near the ground surface characterised by poor compressibility and strength characteristics, including the presence of shear surfaces with potential residual shear strength values. There are significant periglacial shear surfaces recorded in the Denham area (particularly associated with the construction of the M25). The most well-publicised are solifluction shears recorded in the London Clay.

During the interpretation of the ground investigation, and subsequent ground modelling for the detailed design of the High Speed 2 Colne Valley South Embankment, Jacobs confirmed the presence of periglacial Head Deposits and relic shear surfaces occurring within the Head Deposits and underlying Reading Formation (Lambeth Group). Test data demonstrated poor engineering characteristics including residual strength values lower than those assumed during the ‘preliminary’ and ‘scheme’ design phases which required reconsideration for the detailed design and construction proposals

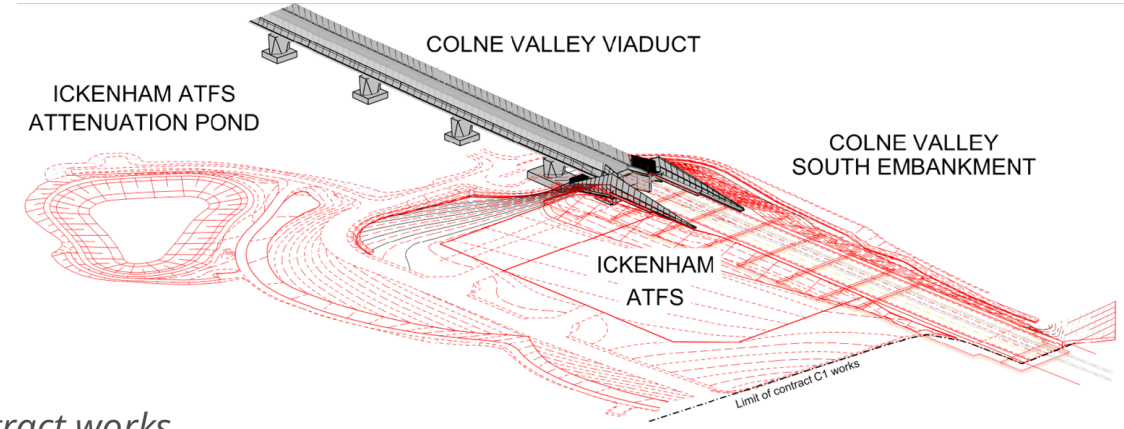
Site Location / Setting

Site Location / Setting

Colne Valley South Embankment (CVSE):

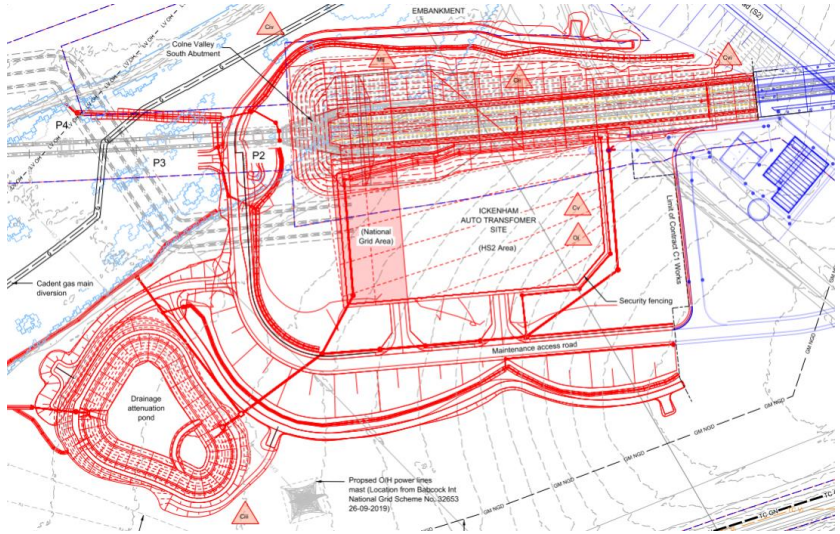
- Southern approach to the Colne Valley Viaduct to the North
- Transitions into Copthall Tunnel portal to the south (S2 Contract)
- HS2 Chainage from 025+810 to 026+010
- 200m long
- 10m high

Requires the permanent diversion of Harvill Road. as part of separate S2 contract works which also include the construction of the Copthall Tunnel portal and Copthall Tunnel portal building, located east of the Ickenham ATFS.



Ickenham Auto-Transformer Feeder Station (ATFS)

- Earthworks platform south of the CVSE between approximate Ch. 025+885 and Ch. 026+010.
- 125m x 65m (level with the CVSE).
- Includes the construction of a drainage attenuation pond permanent maintenance access roads / tracks serving the Ickenham ATFS, CVSE and CVV.



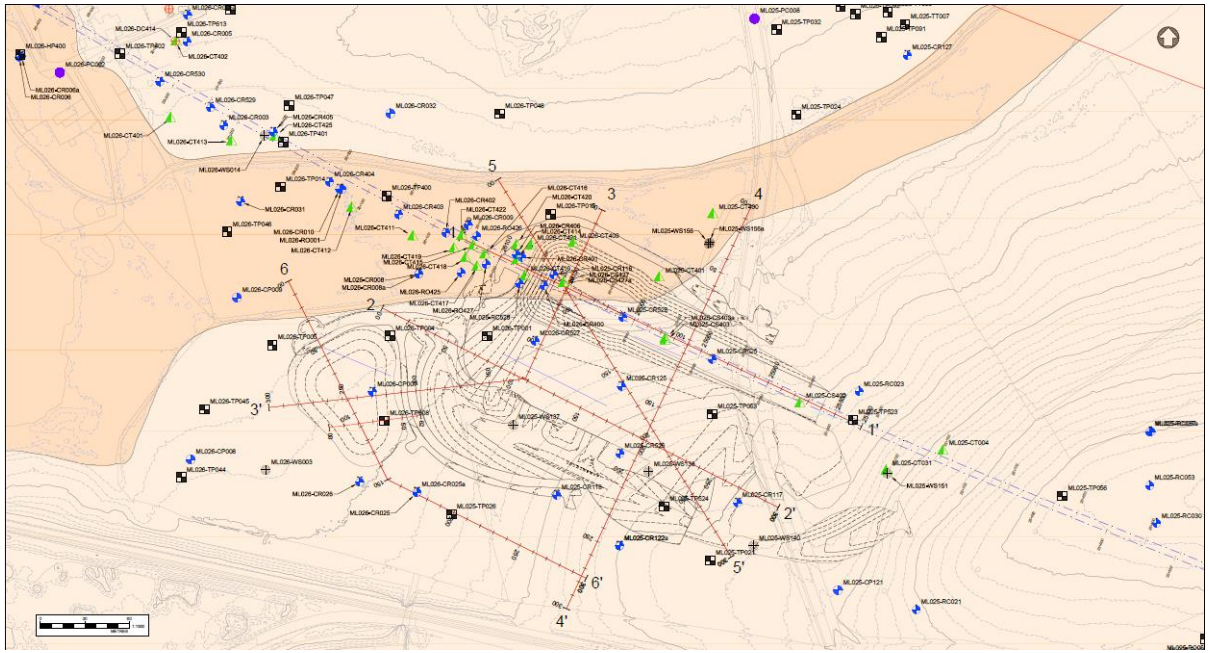
Site Investigation and Testing

Site Investigation and Testing

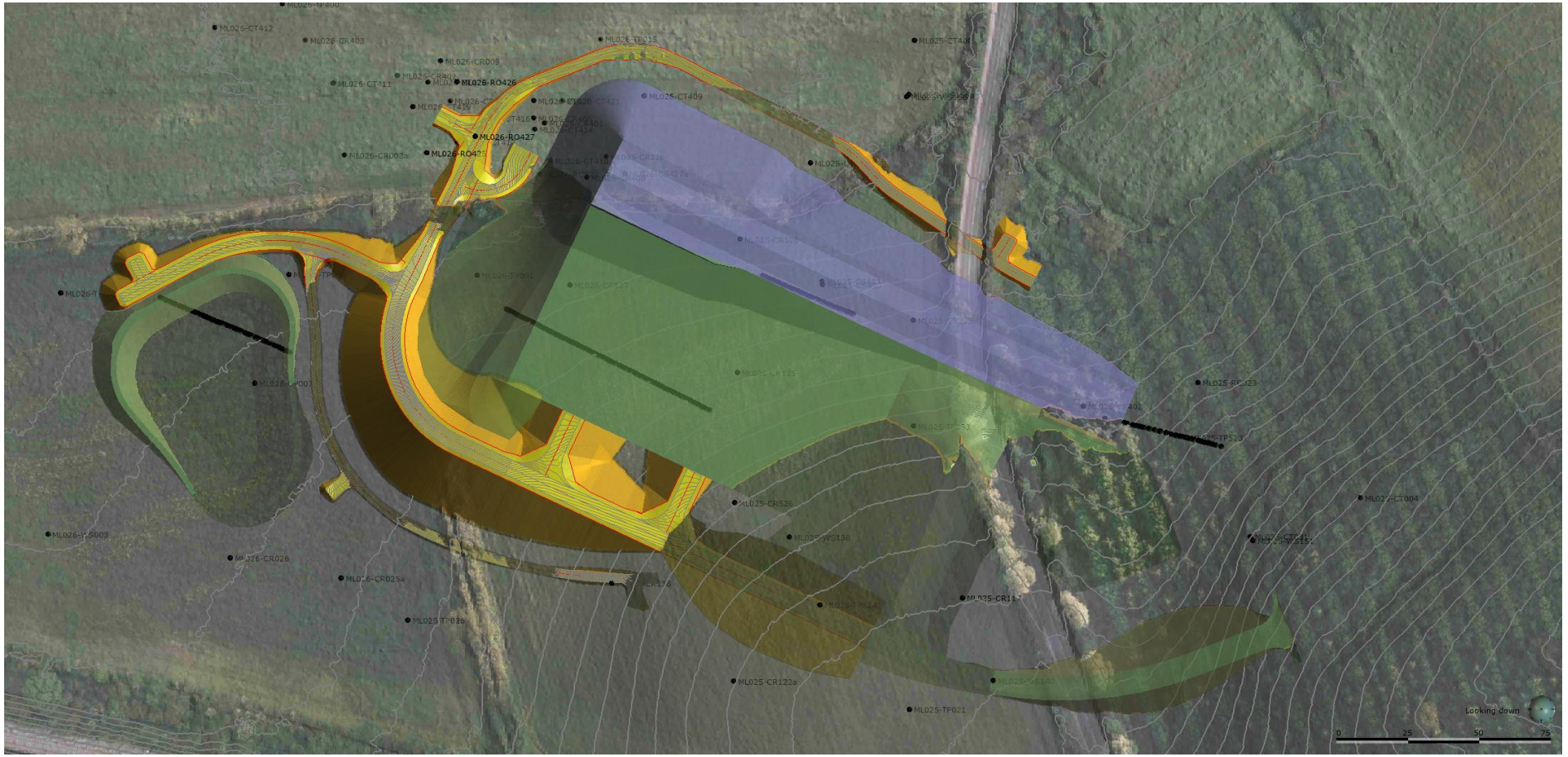
1. **HS2 Main GI in this area was limited by protester activities, resulted in limited preliminary GI**

2. **Supplementary C1 GI Phase 1 limited by protester activity, archaeology, and viaduct compound area**

3. **Supplementary C1 GI Phase 5 Boreholes and Trial pits completed summer 2020**
   - Laboratory testing
     - 254 Laboratory Test Completed
   - Surface MASW Geophysics undertaken in September 2020
     - RSK (1 Geophysical Surveys)
     - Zetica (3 Geophysical Surveys)



Site Investigation and Testing



Geology and Ground Model

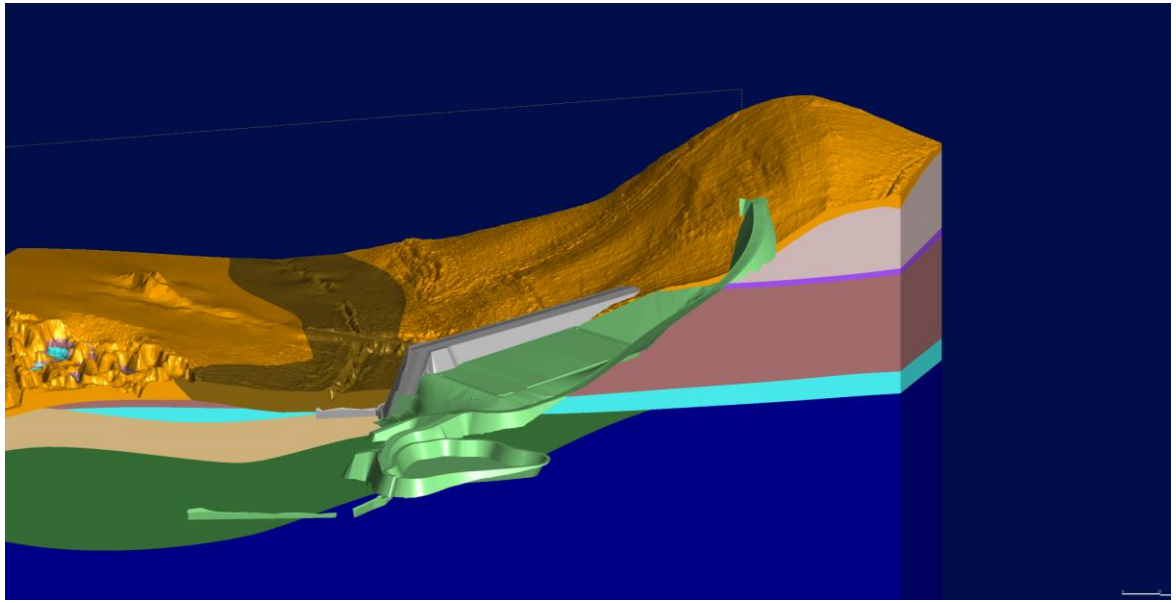
Geology and Ground Model

Superficial Deposits:

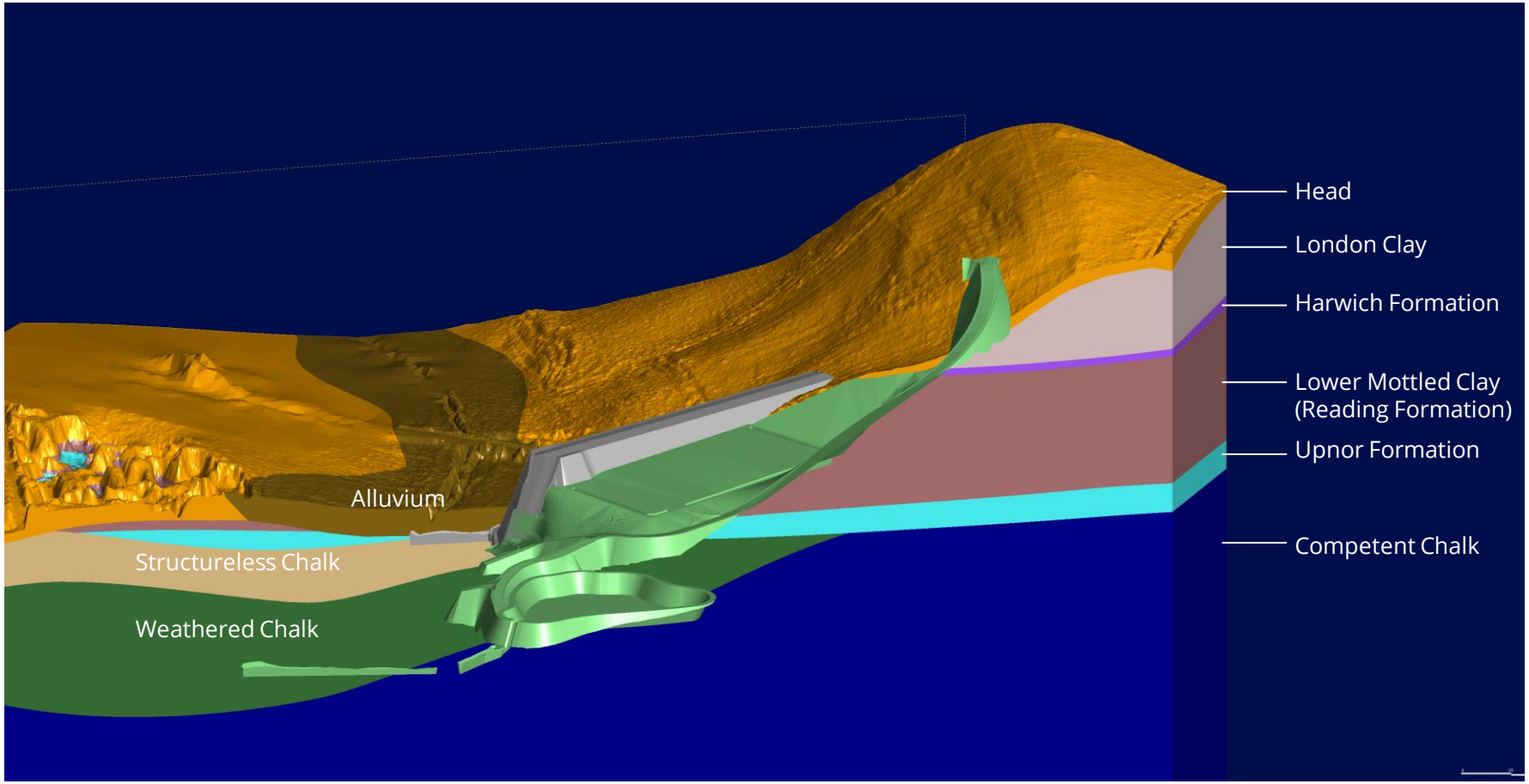
- Alluvium (ALV) at the viaduct southern abutment and across the valley floor
- Head forming a blanket over the slope

Solid Geology

- London Clay (LC) forms the upper part of the hill,
- Harwich Formation (HWH) is a thin relatively granular layer
- Reading Formation - Lower Mottled Clay (LMCL)
- Upnor Formation (UPR), thin layer of sand and clay,
- Upper Chalk weathering sequence underlying the valley floor:
  - Structureless chalk
  - Weathered chalk
  - Competent chalk



Geology and Ground Model



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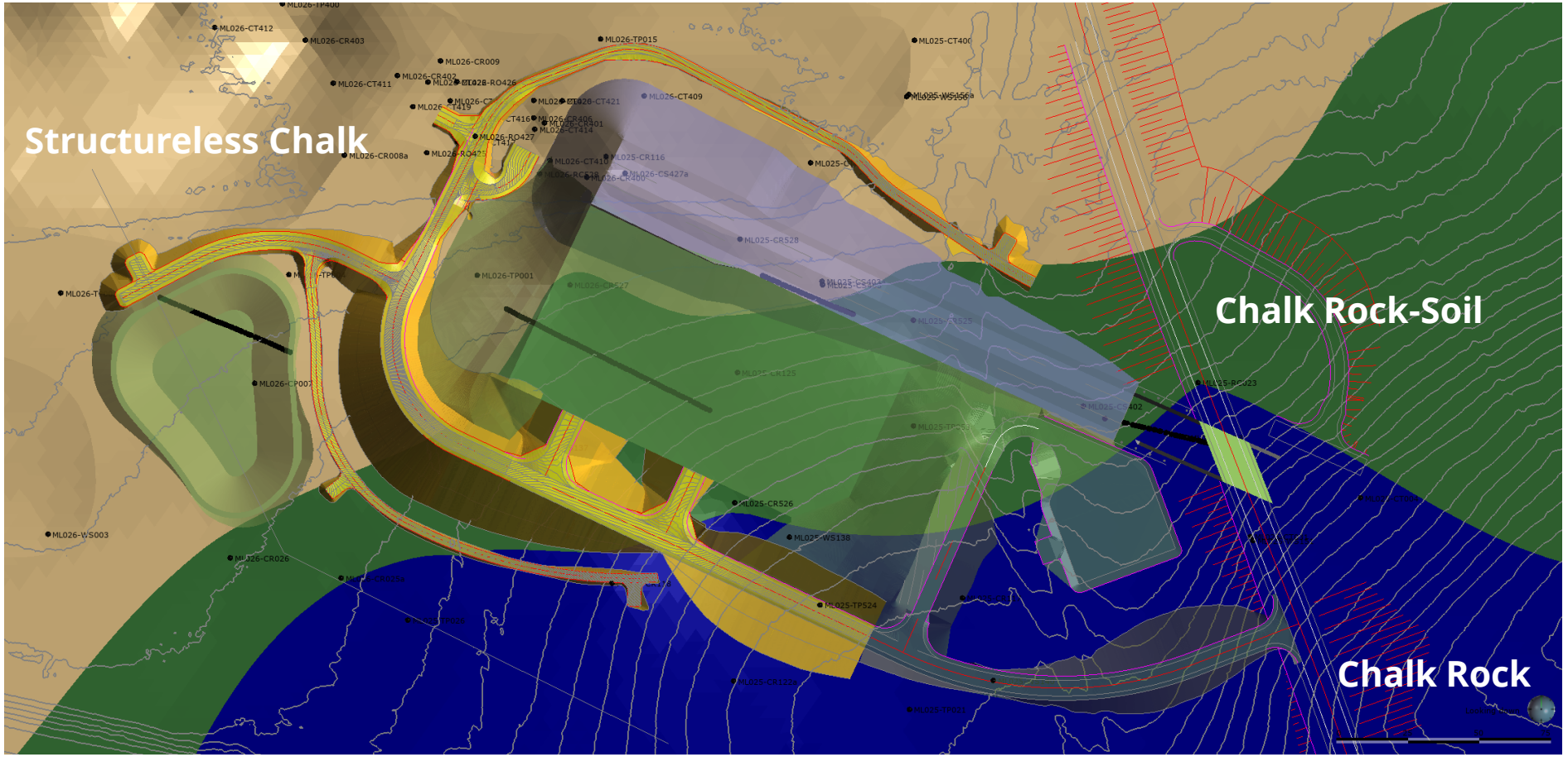

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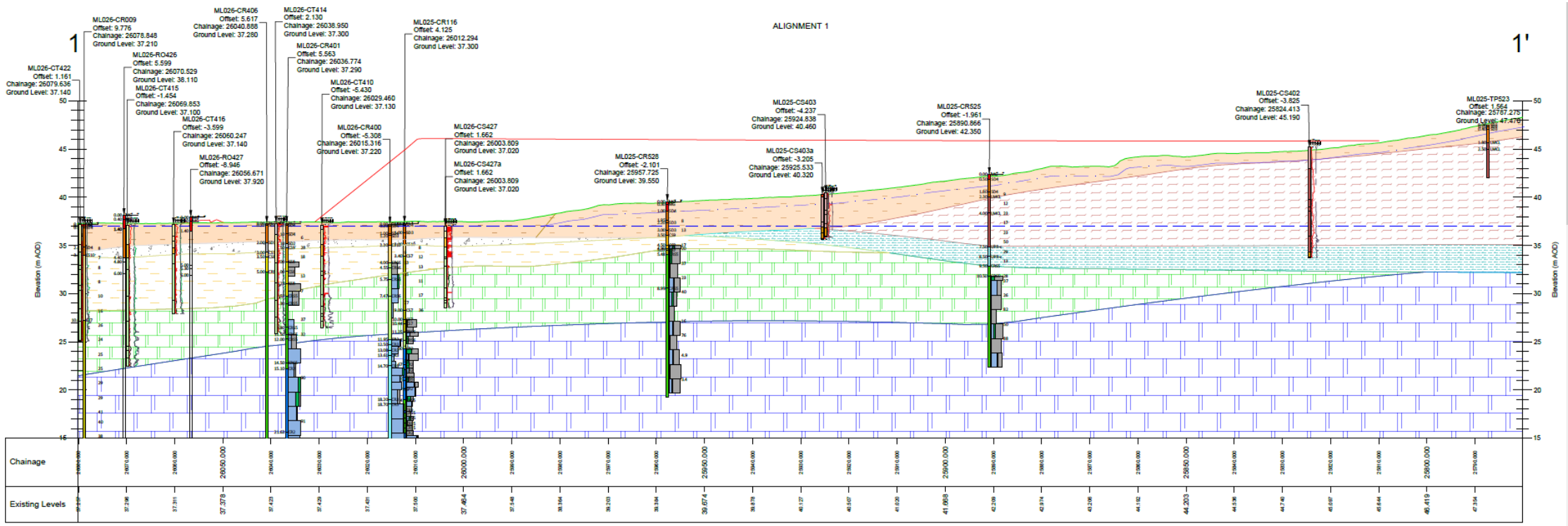
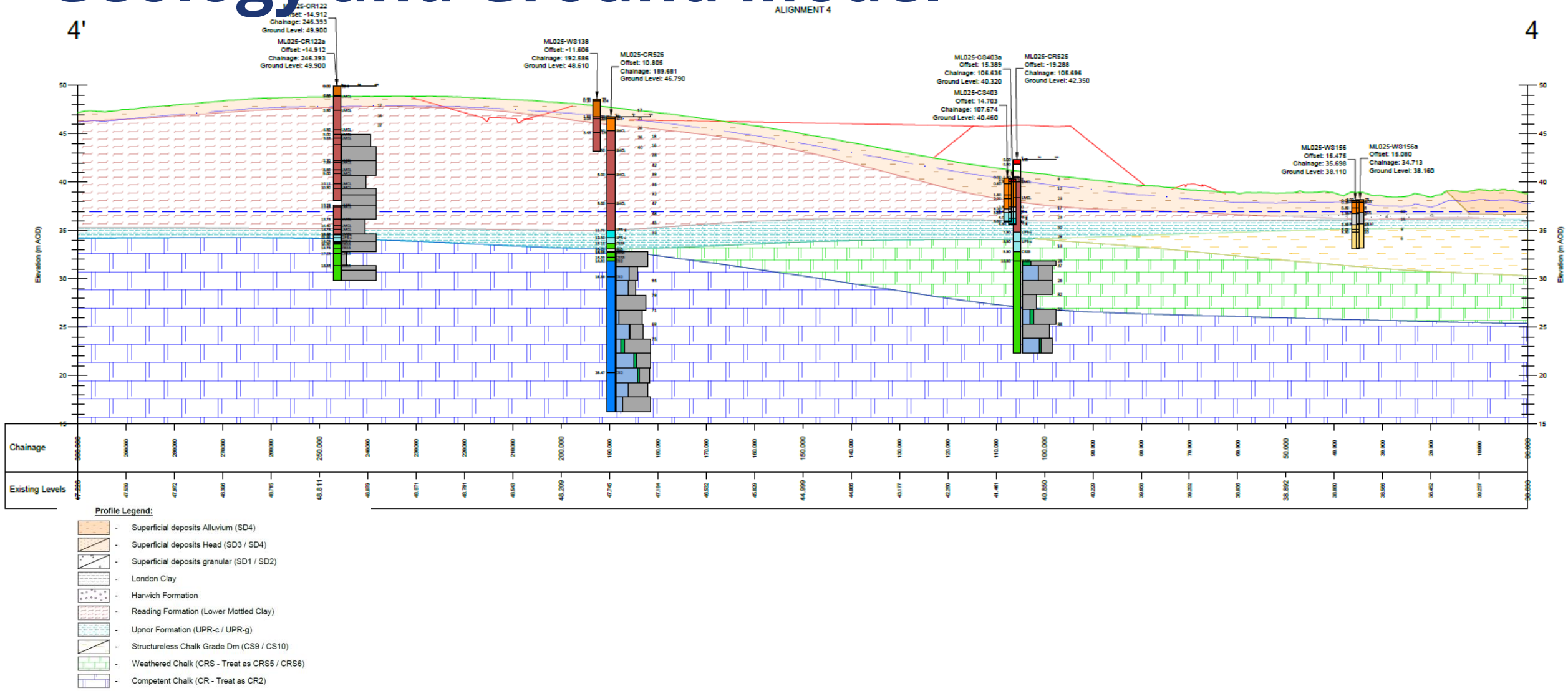


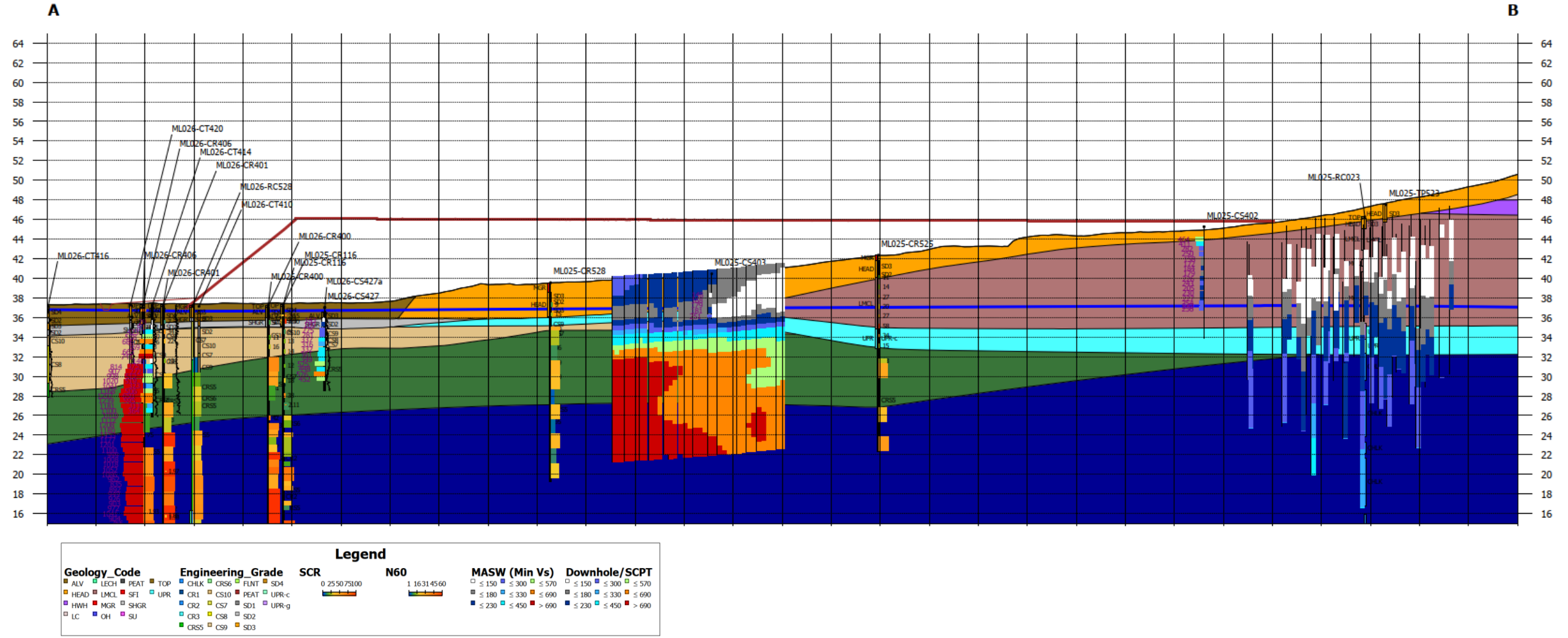
Profile Legend:

- Superficial deposits Alluvium (SD4)
- Superficial deposits Head (SD3 / SD4)
- Superficial deposits granular (SD1 / SD2)
- London Clay
- Harwich Formation
- Reading Formation (Lower Mottled Clay)
- Upnor Formation (UPR-c / UPR-g)
- Structureless Chalk Grade Dm (CS9 / CS10)
- Weathered Chalk (CRS - Treat as CRS5 / CRS6)
- Competent Chalk (CR - Treat as CR2)

Geology and Ground Model



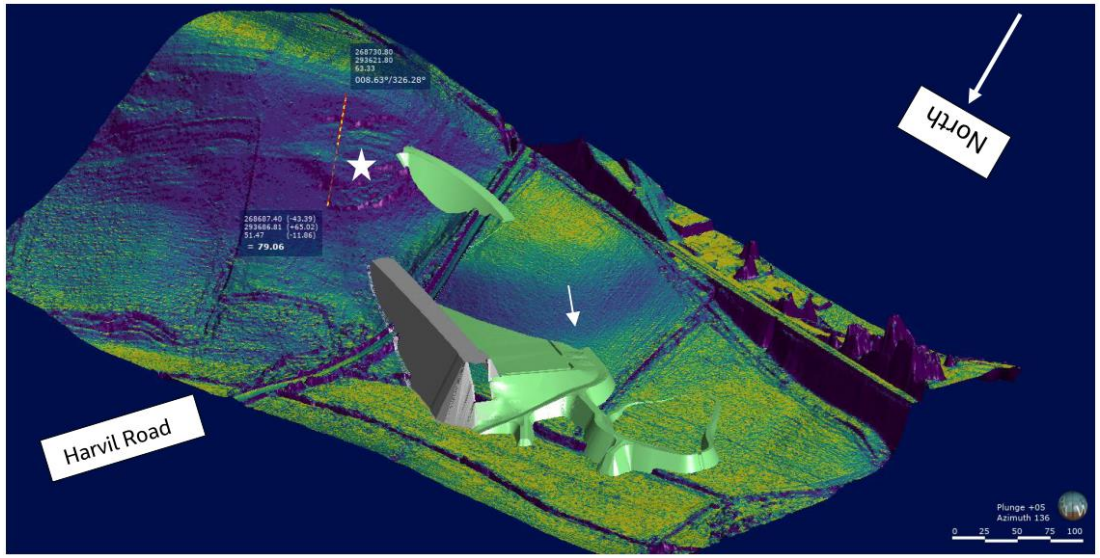
Geology and Ground Model



Relic Shear Surfaces

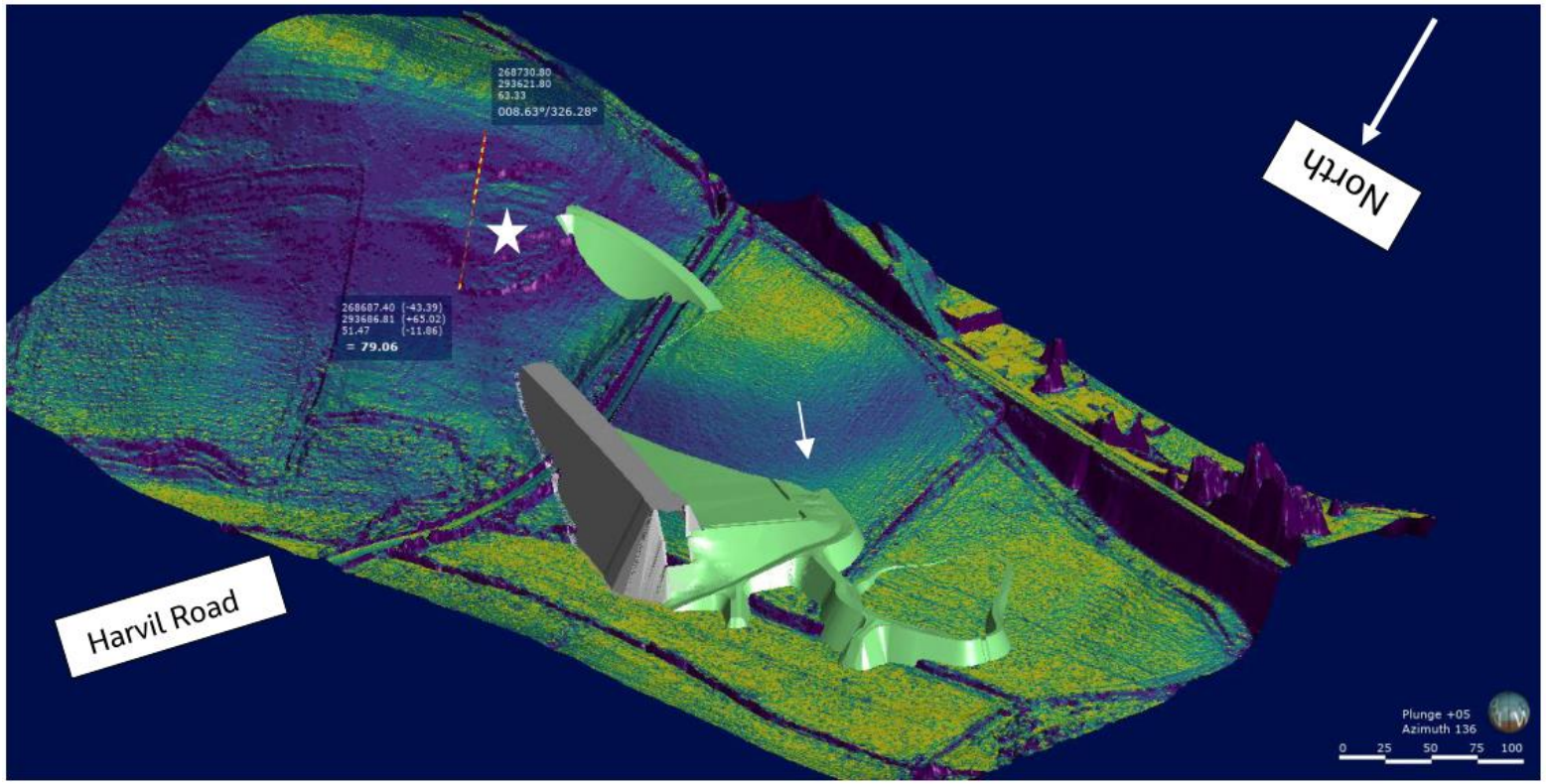
Relic Shear Surfaces

- **Detailed interpretation of the available LiDAR topographical surface allowed to reveal relict landslips within the site area**
- **Features were found on a natural hillside slope of around 9 degrees from horizontal**
- **The gradient of the slope to be considered stable was only 5 degrees.**
- **The sub-surface ground model clearly showed the depth of Head deposits gradually increasing towards the toe of the slope, suggesting significant downslope movement during periglacial climatic conditions of the Late Pleistocene.)**



5x Vertical Scale

Relic Shear Surfaces



5x Vertical Scale

Polished slip surface at 2.0m depth, showing the morphology of the slip surfaces

Relict Landslip feature identified at 4.5 to 5.0m depth

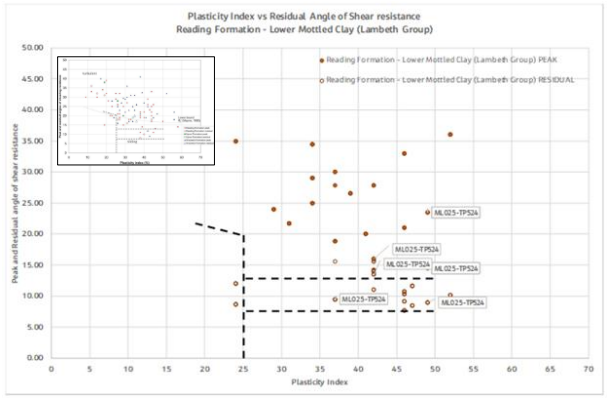
Relic Shear Surfaces

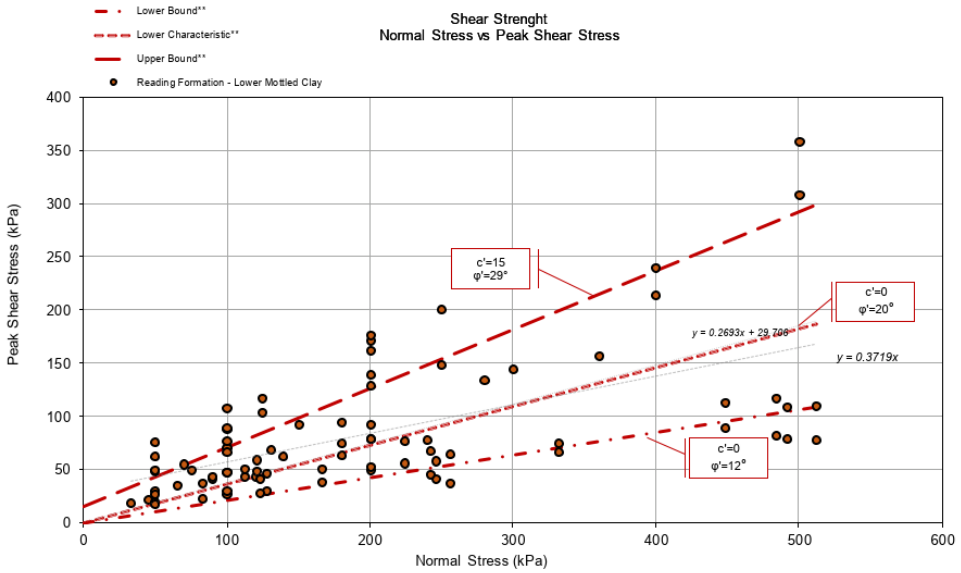
It was concluded that the data validated design values to be set based on lower characteristic values compared to preliminary design.

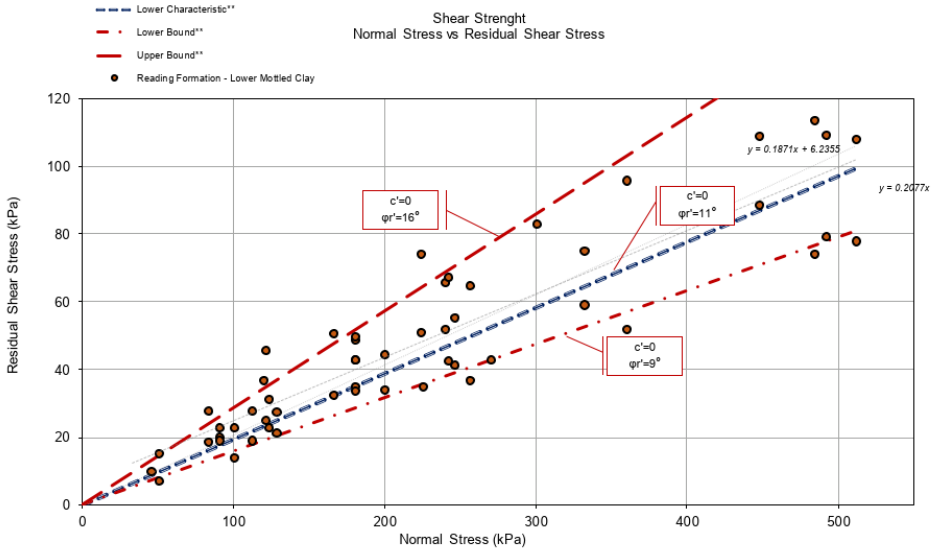
GL to 8m depth design on residual shear strength properties:

- C'r = 0kPa
- Phi'r = 11 degrees

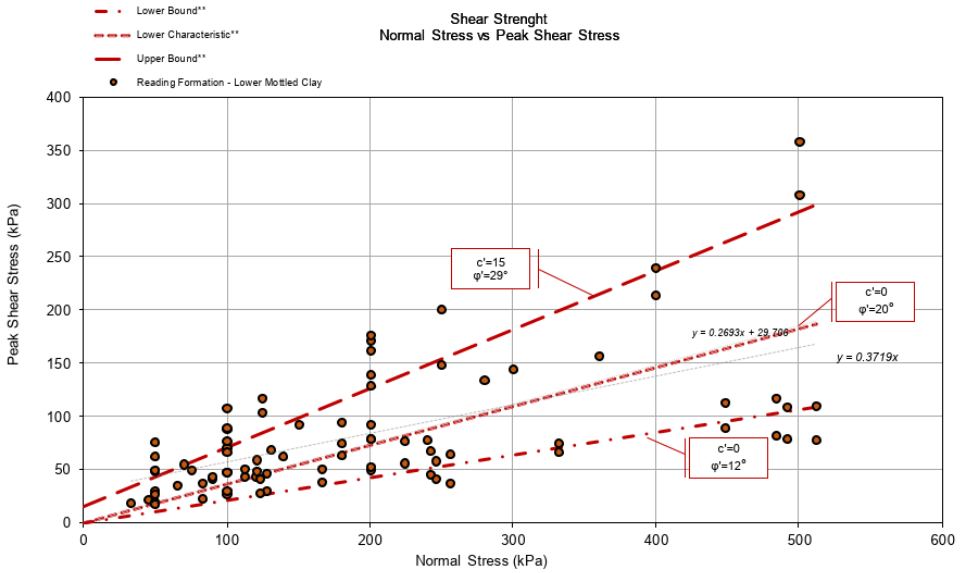
- >8m depth design on peak shear strength properties:
  - C'p = 0kPa
  - Phi'p = 20 degrees

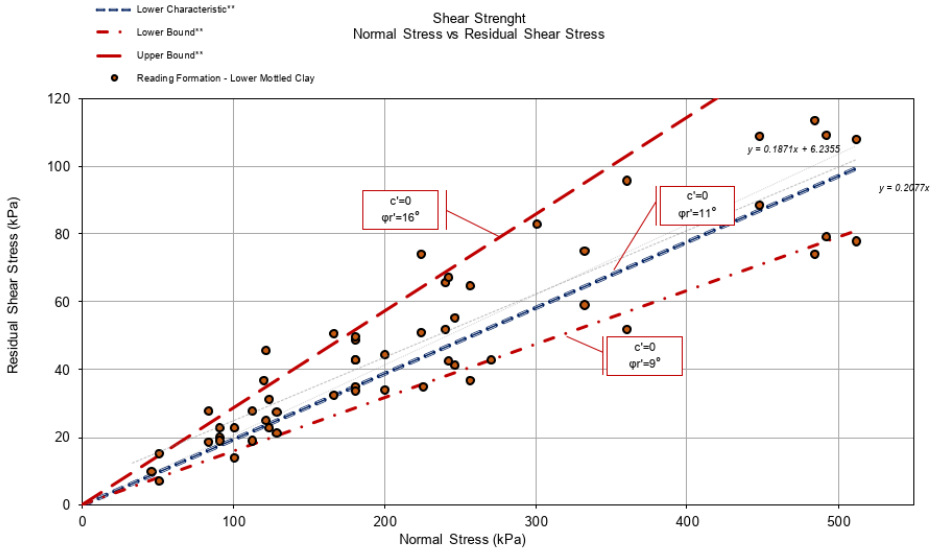






Relic Shear Surfaces





The BGS report Engineering Geology of British Rocks and Soils - Lambeth Group (Open Report OR/13/006) reviews both triaxial test results and shear box data for the various strata of the Lambeth Group including the Reading Formation that includes the Lower Mottled Clay. It comments that "Only a few residual shear strength values were available

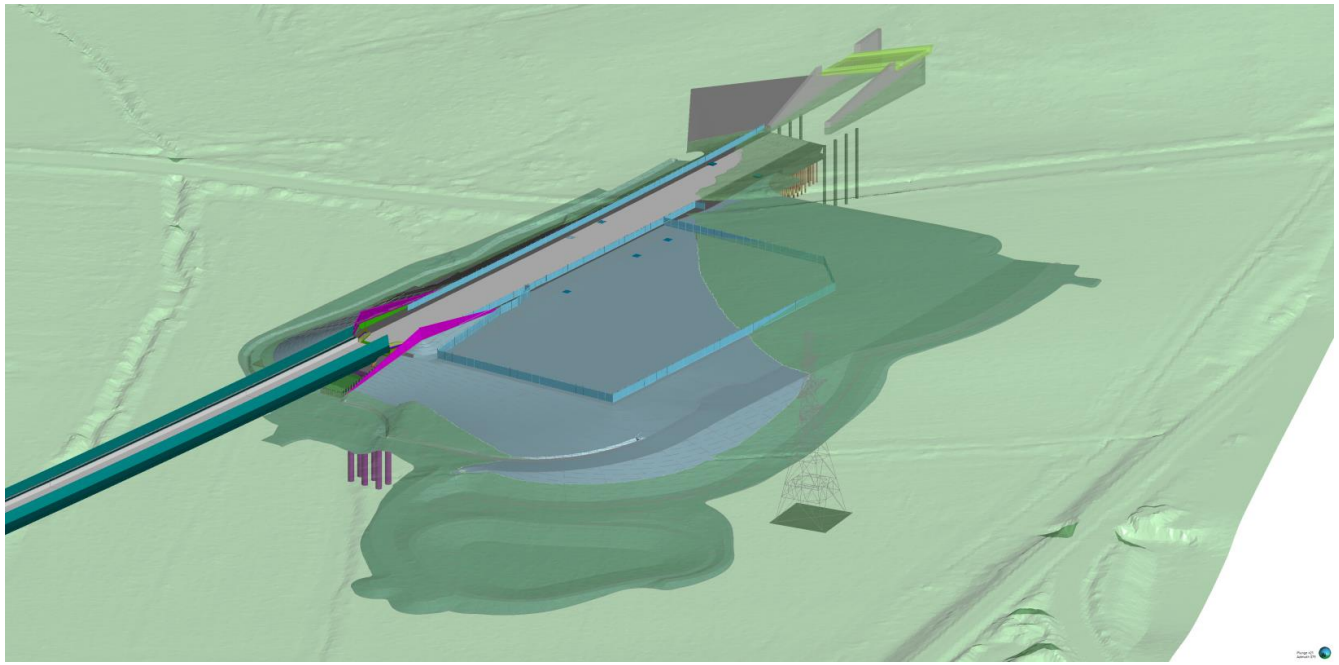
Design Evolution and Implications

Design Evolution and Implications

1. Preliminary design assumed slope stability relying on residual strength for the superficial deposits and Lambeth group considering relict slip surfaces were likely to be present
2. Phi’r was set at a typical average value of 16 degrees, with limited testing and data to confirm this assumption
3. Subsequent laboratory test data demonstrated a lower Phi’r value of 11 degrees was appropriate (a reduction of 31%).

Implications on the scheme:

- **Increase in Foundation Treatment by extending length and distribution of driven piles including piles under the west shoulder of CVSE**
- **Lower embankment fill to be formed of cement stabilised chalk**
- **Extensive Geotechnical Instrumentation**



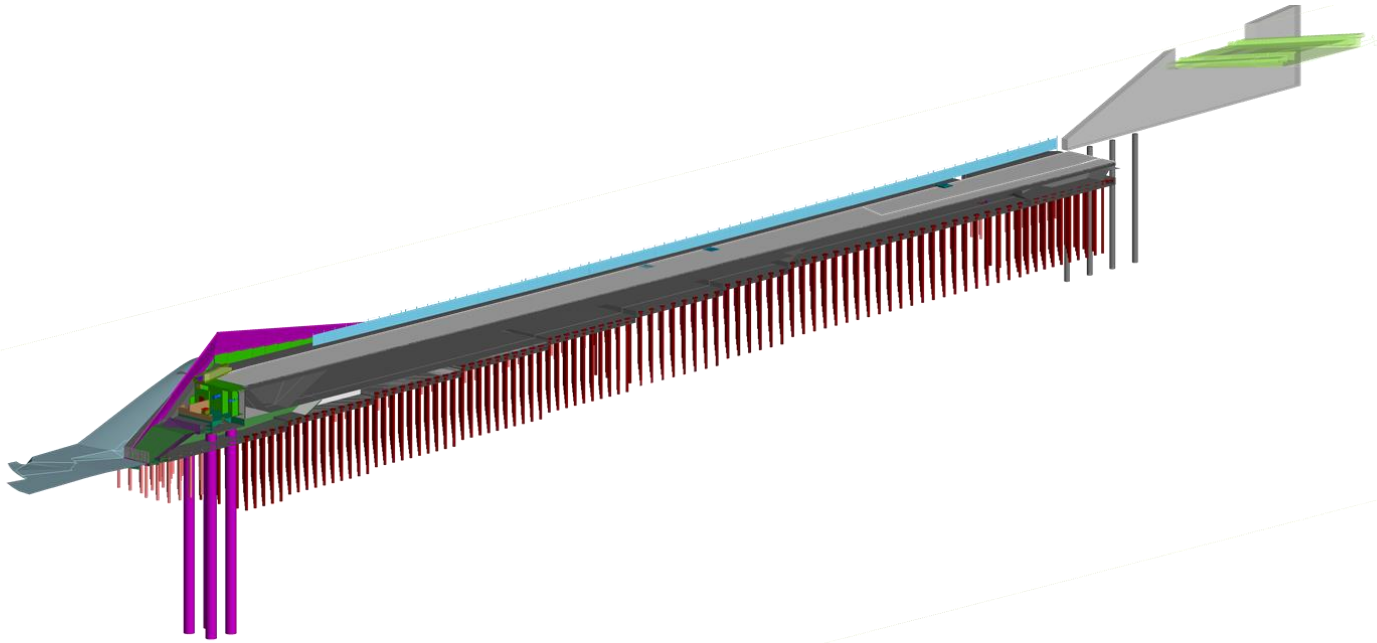
Engineering Solution

Engineering Solution

To mitigate the risk of excessive total / differential settlement and also instability associated the potential presence of relic shear surfaces, the CVSE is supported on piled foundation.

The piles along the CVSE fall into two categories:

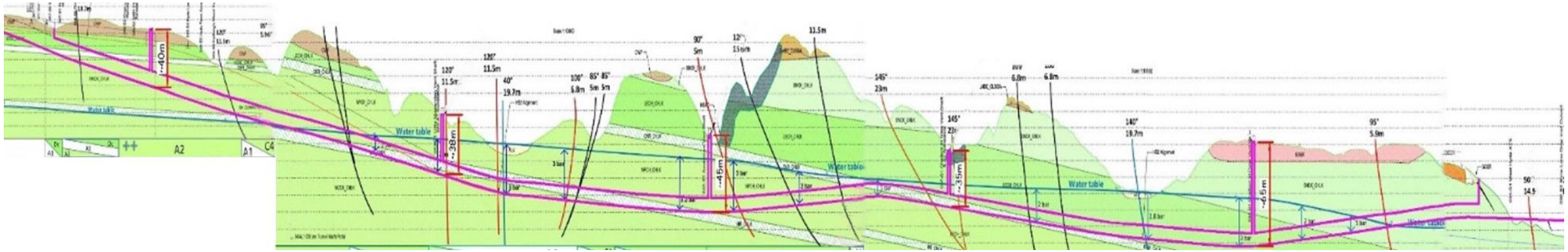
- Settlement reducing piles: Piles located beneath the embankment that carry the permanent and variable actions.
- Slope stabilising piles: Piles located beneath the edges of the embankment slopes to increase overall stability and vertical loads associated with the embankment shoulders.



Chiltern Tunnel Ventilation Shaft Design

Geological Setting

Geological Setting



Desk Study Long Section

- Shafts located to limit the amount of excavation
- Typically located in chalk dry valleys with variable thickness of Clay-with-Flints and high presence of dissolution features within the Chalk
- Example from Chalfont St Giles – Junction of 3 dry valleys

Geological Setting at Chalfont St Giles

Ground Investigation

Ground Investigation

Ground Investigation in chalk is complicated by chalk weathering and tendency to breakup during drilling. Shaft design required clear identification of chalk condition:

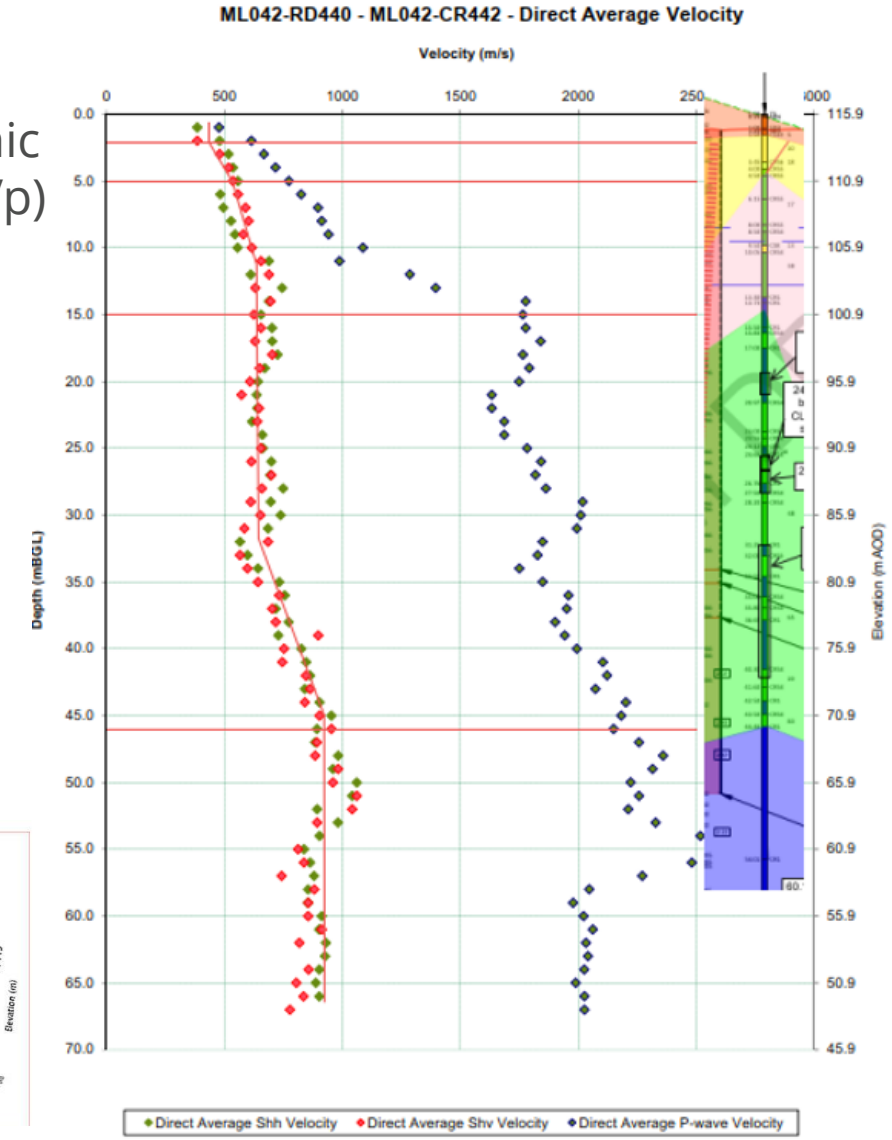
- Completely weathered chalk soil
- Weathered chalk with some structure but open / infilled joints
- Competent chalk with closed fissures
- Geological fault zones & dissolution features

Chalfont St Giles – Televiewer looking horizontally

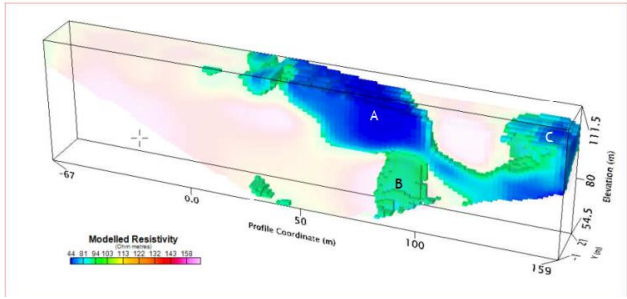
Ground Investigation

Chalfont St Giles

Cross-hole seismic geophysics (Vs, Vp)



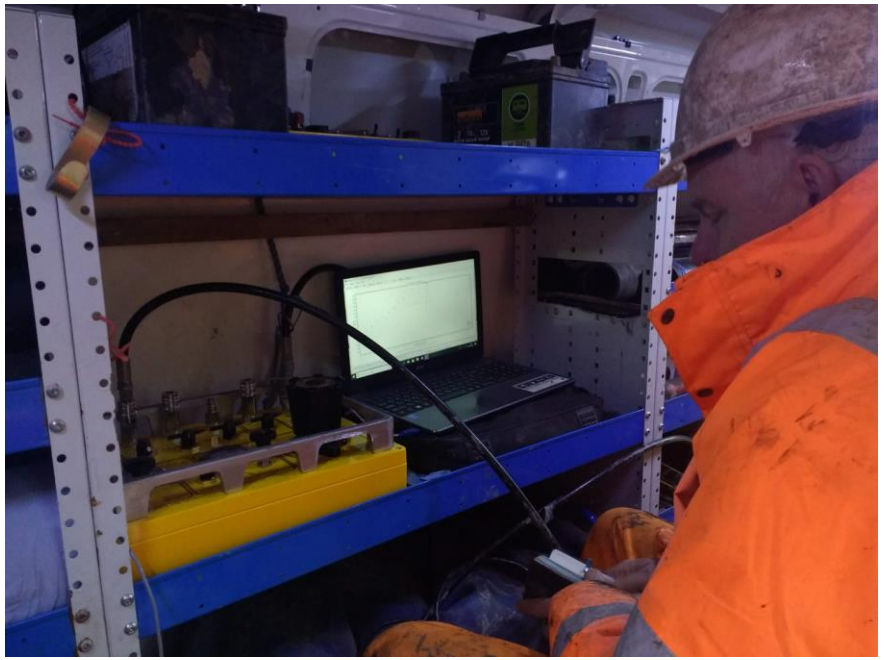
HPD

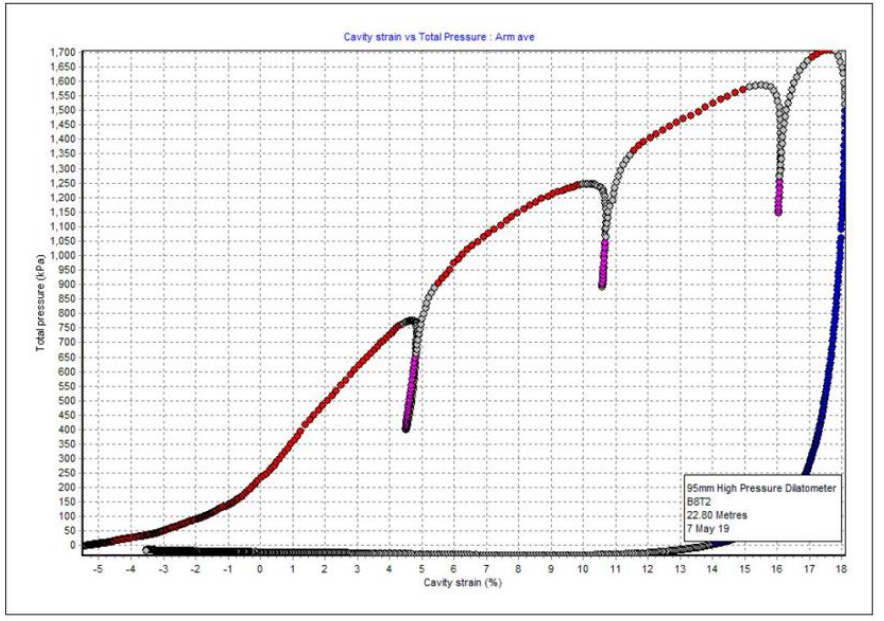


3D Resistivity

Soil properties for design

- Pumping well tests: mass permeability (before & after D-wall)
- Pressuremeter testing: Es50 &horizontal earth pressure for K_0
- Cross-hole geophysics: small strain stiffness

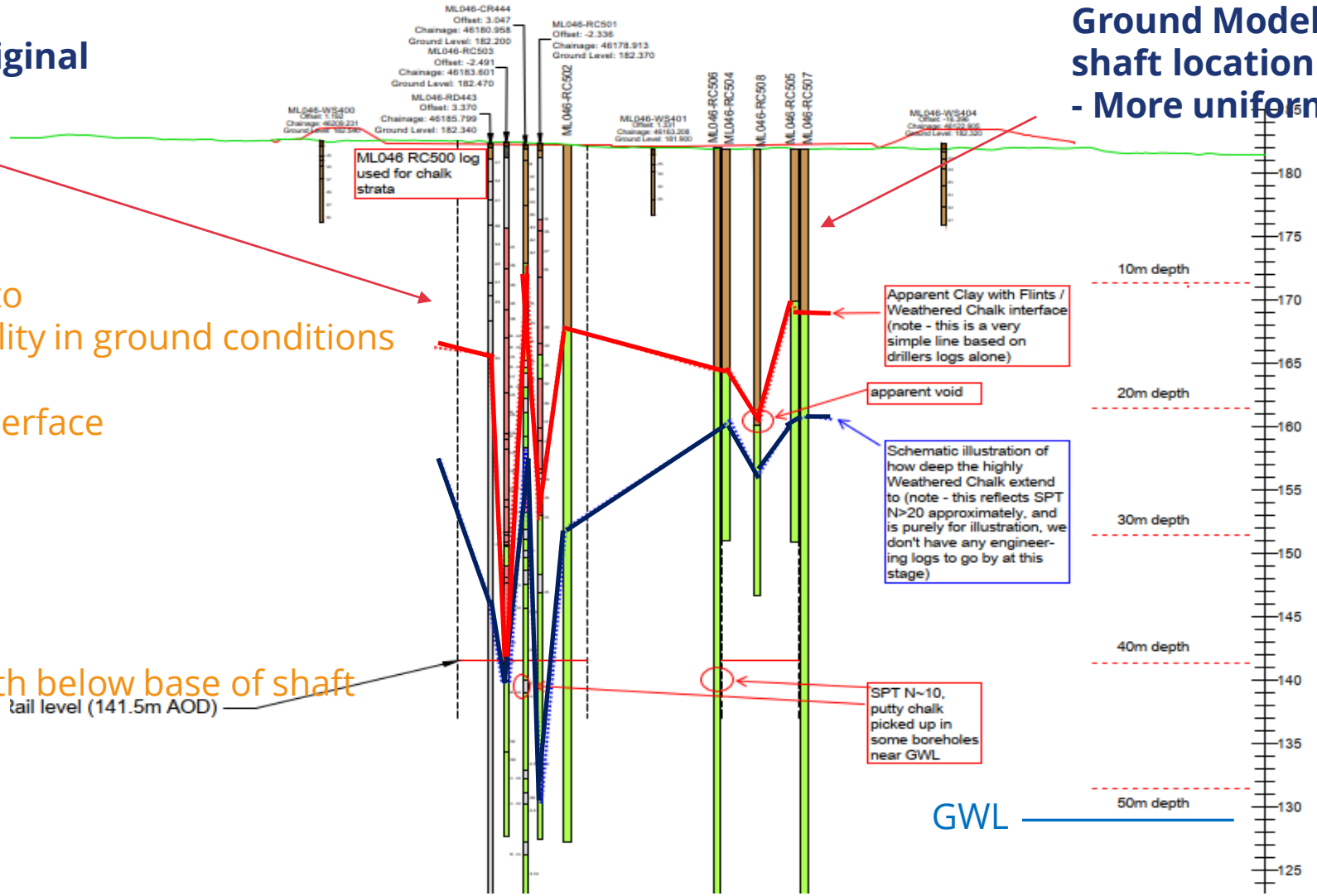




Ground conditions at Chesham

Ground Model at original shaft location
- More variation

Ground Model at new shaft location
- More uniform

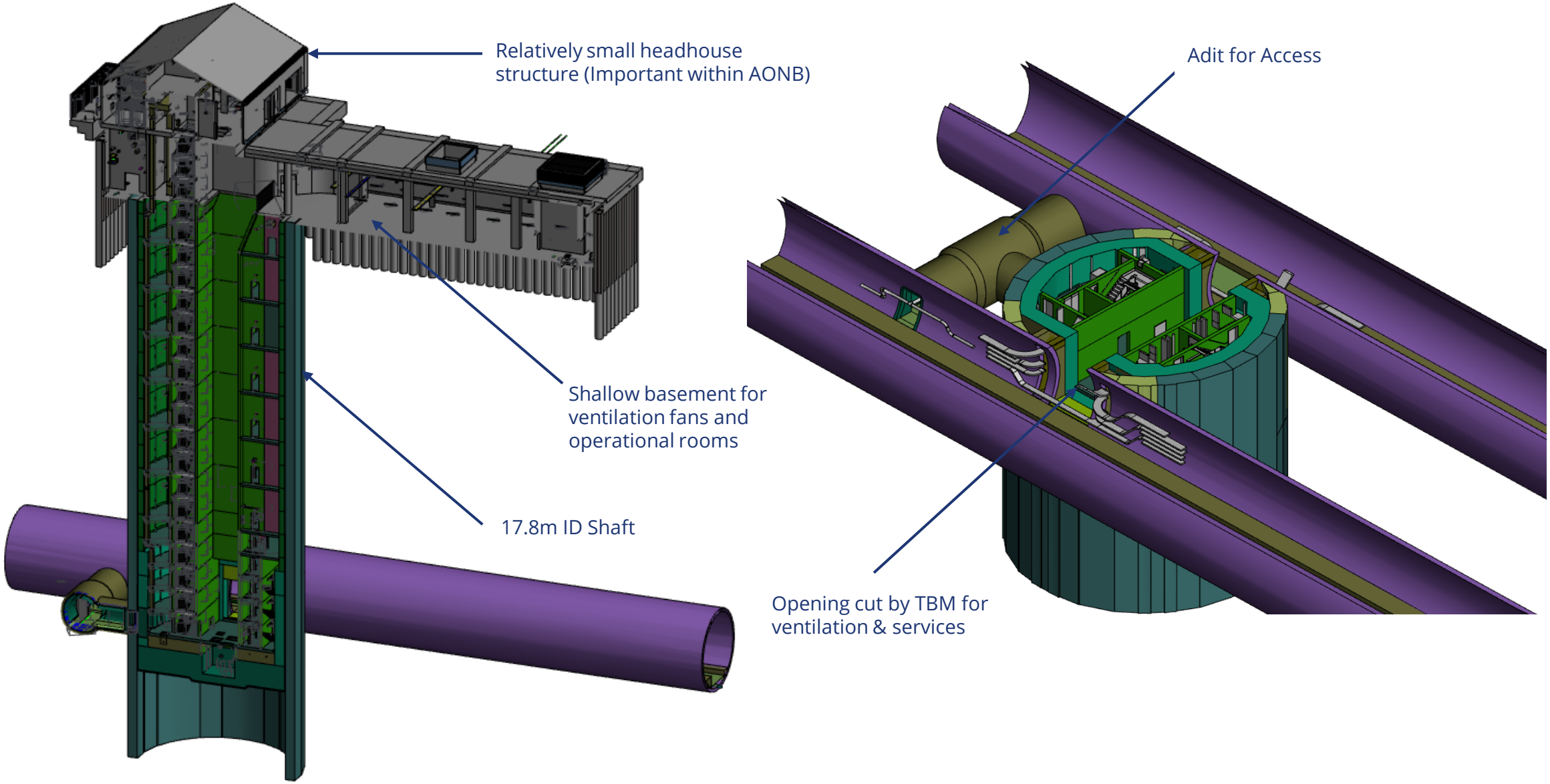


Shaft relocated due to
- significant variability in ground conditions
- Presence of fault
- Depth of chalk interface

Groundwater at depth below base of shaft

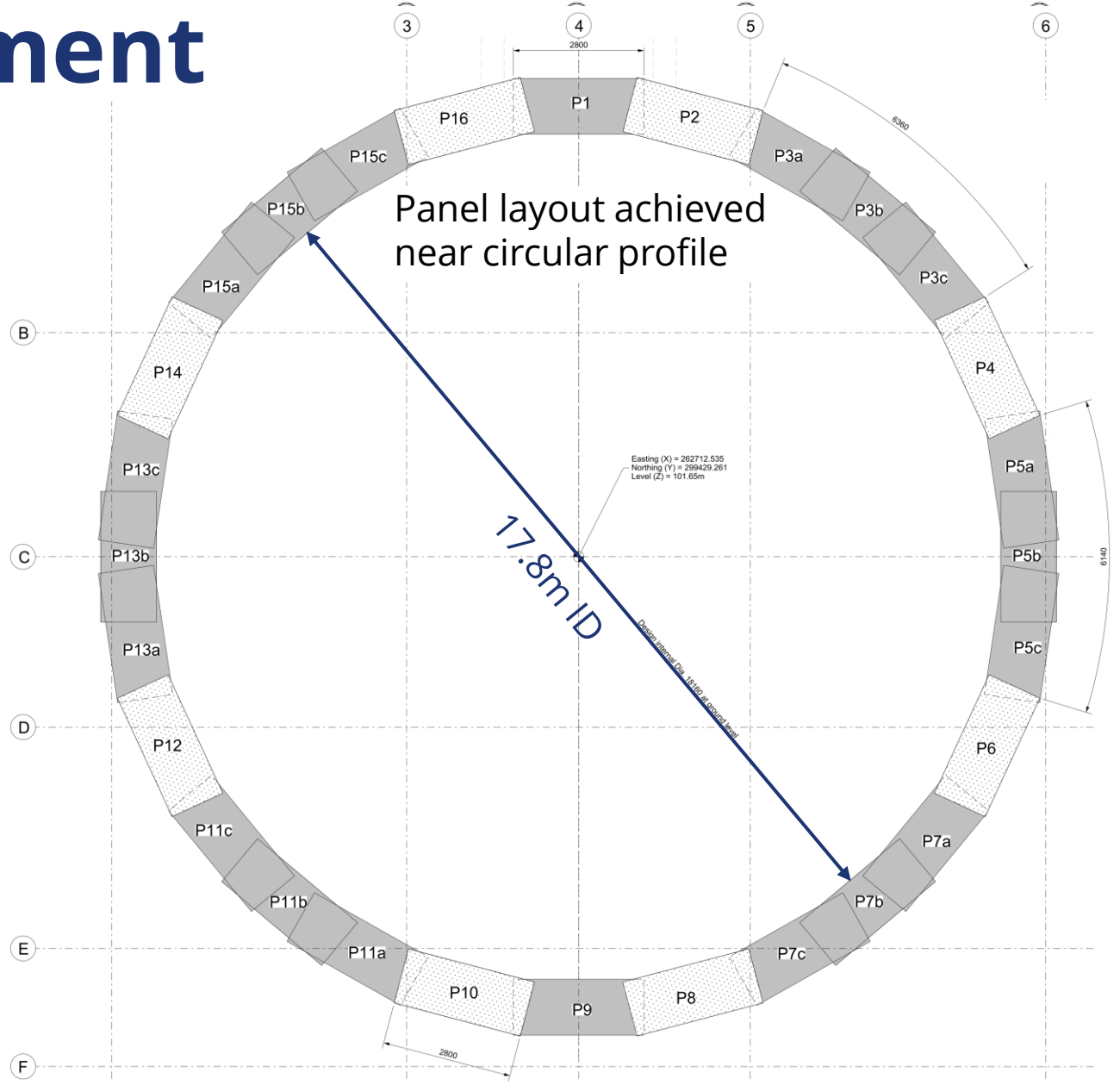
Design Solution

New / Innovative Design Solution



CSP D-Wall Arrangement

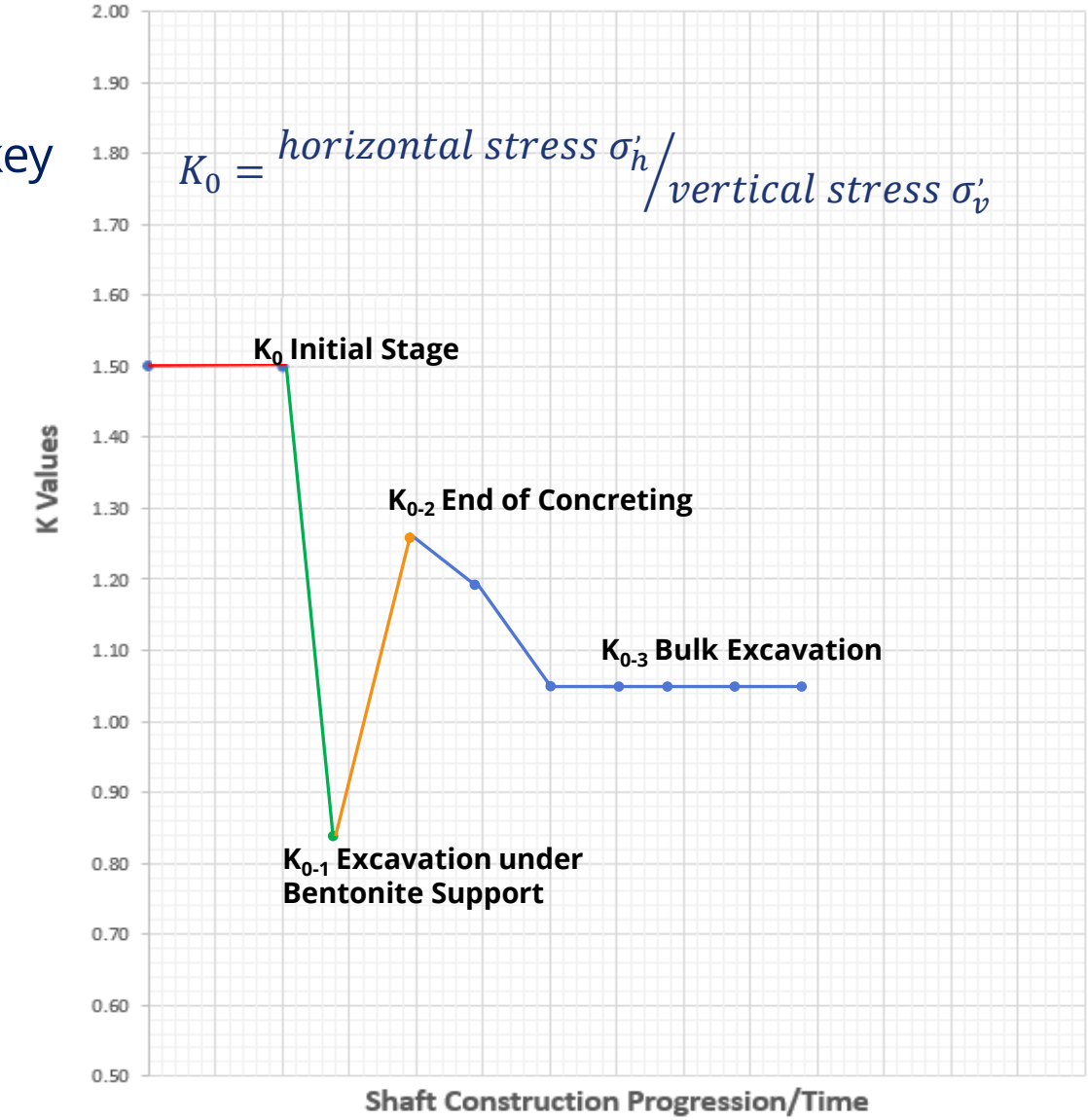
- Design developed in collaboration with KVJV
- Diaphragm Wall Depth: 78m
- D-wall thickness: 1.2m
- Construction tolerance 1 in 400 vertical plus 25mm positional
- I&M comprised:
  - Inclinometers within D-Walls
  - Surface monitoring points
  - Vibrating wire stain gauges
  - Vibrating wire Piezo-meters
  - Trigger values determined by design



Design Consideration

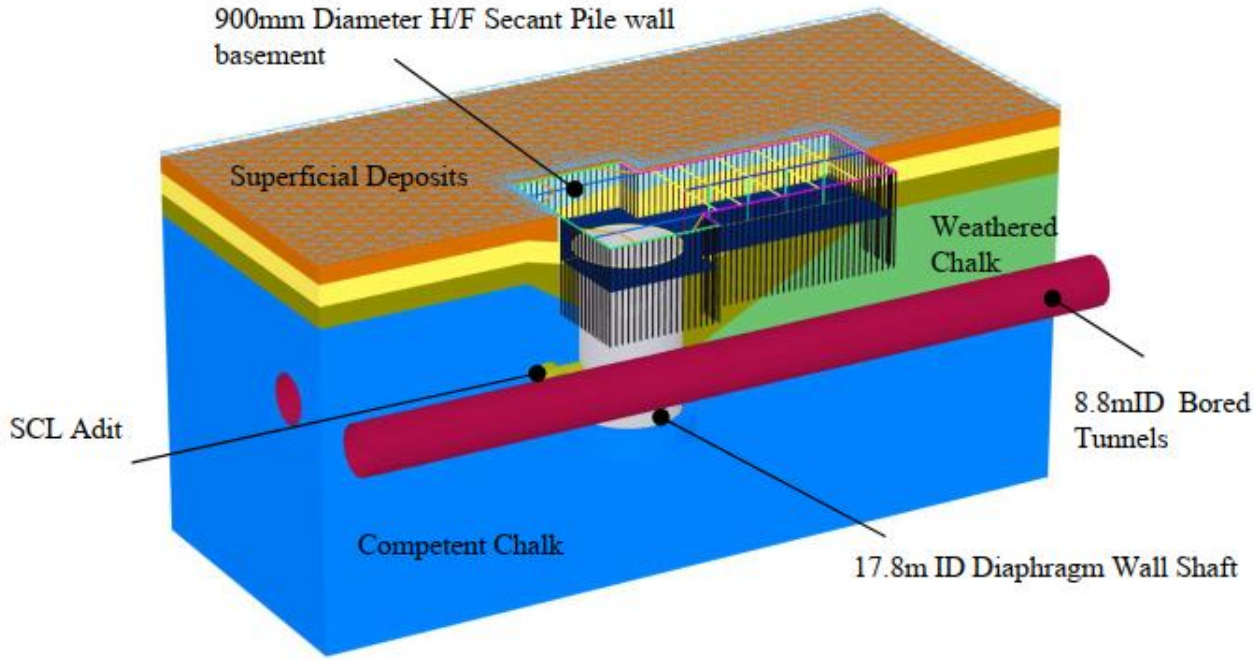
- Lateral Earth Pressure Coefficient at rest $K_0 = {}^{\sigma'_h}/_{\sigma'_v}$ a key parameter for shaft design
- Initial value (pre-construction) from insitu testing
- Lateral earth pressure coefficient, K changes during;
  - D-wall excavation
  - D-Wall concreting
  - Bulk Excavation

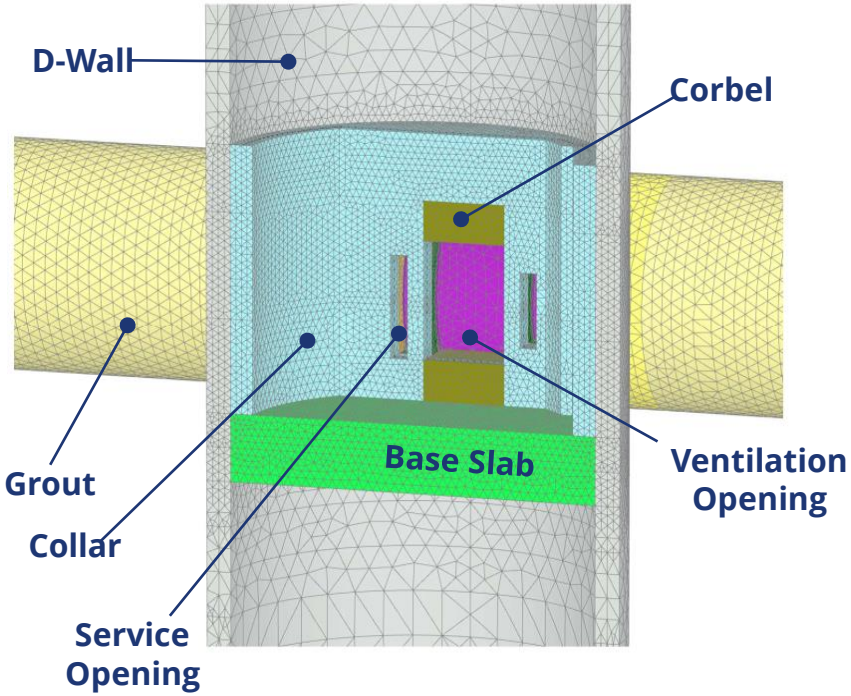
3D numerical modelling of soil structure interaction used to predict changes



K_0 variation in Chalk Rock during construction

Geotechnical Design and Analysis

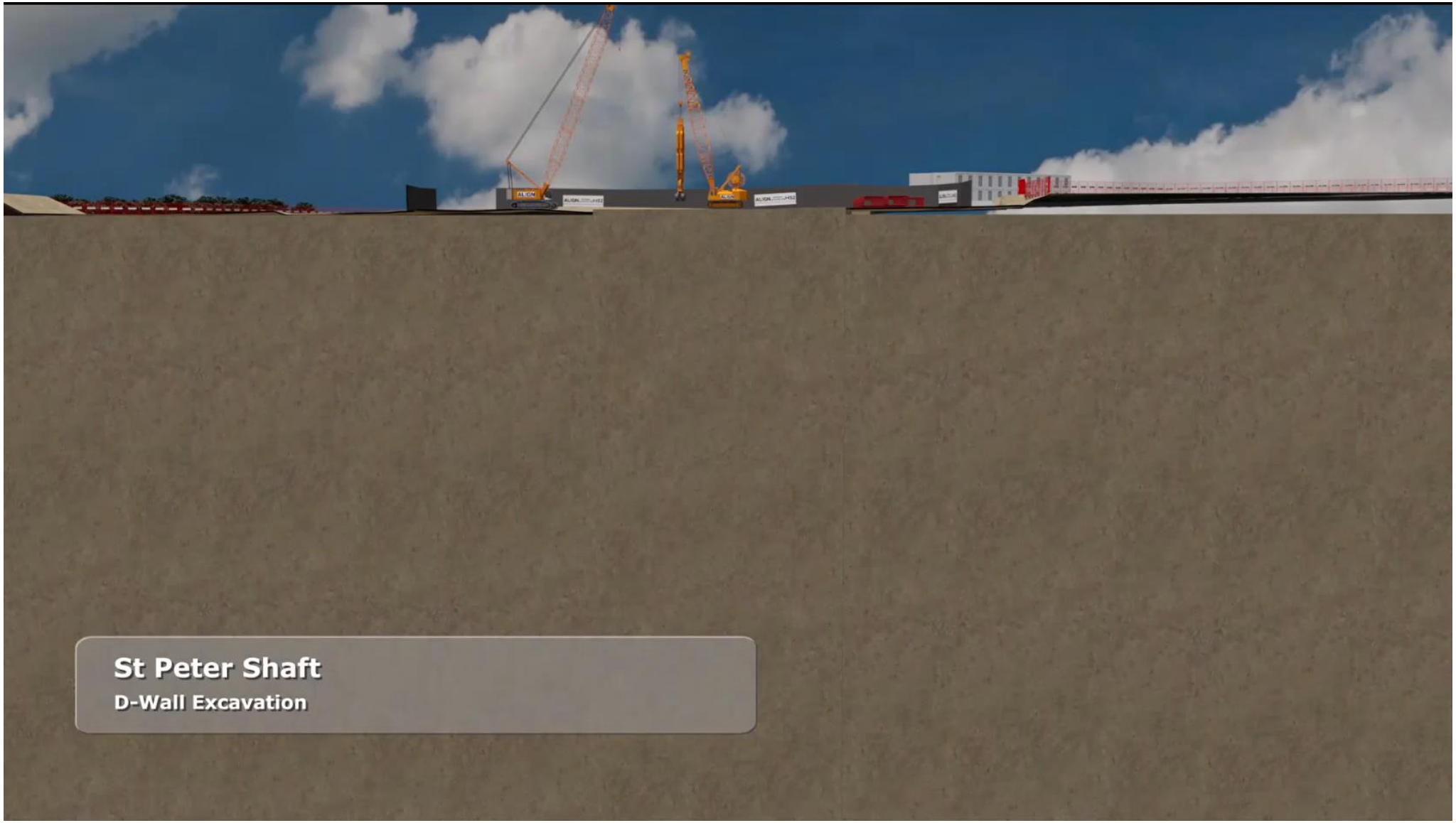




Ground-Shaft-Tunnel interaction analysis enabled us to:

- Understand the clear load path and the arching/relaxation effects of the surrounding ground
- Determine forces on the structural elements at different construction stages
- Optimise diaphragm wall thickness & collar structure.

Construction Methods Planning



Construction

Chalfont St Giles September 2022

Chalfont St Peter Ground Treatment

Chalfont St Peter Collar Installation

Actual v Predicted

Hoop forces are key to shaft stability

Geotechnical design set instrumentation trigger values

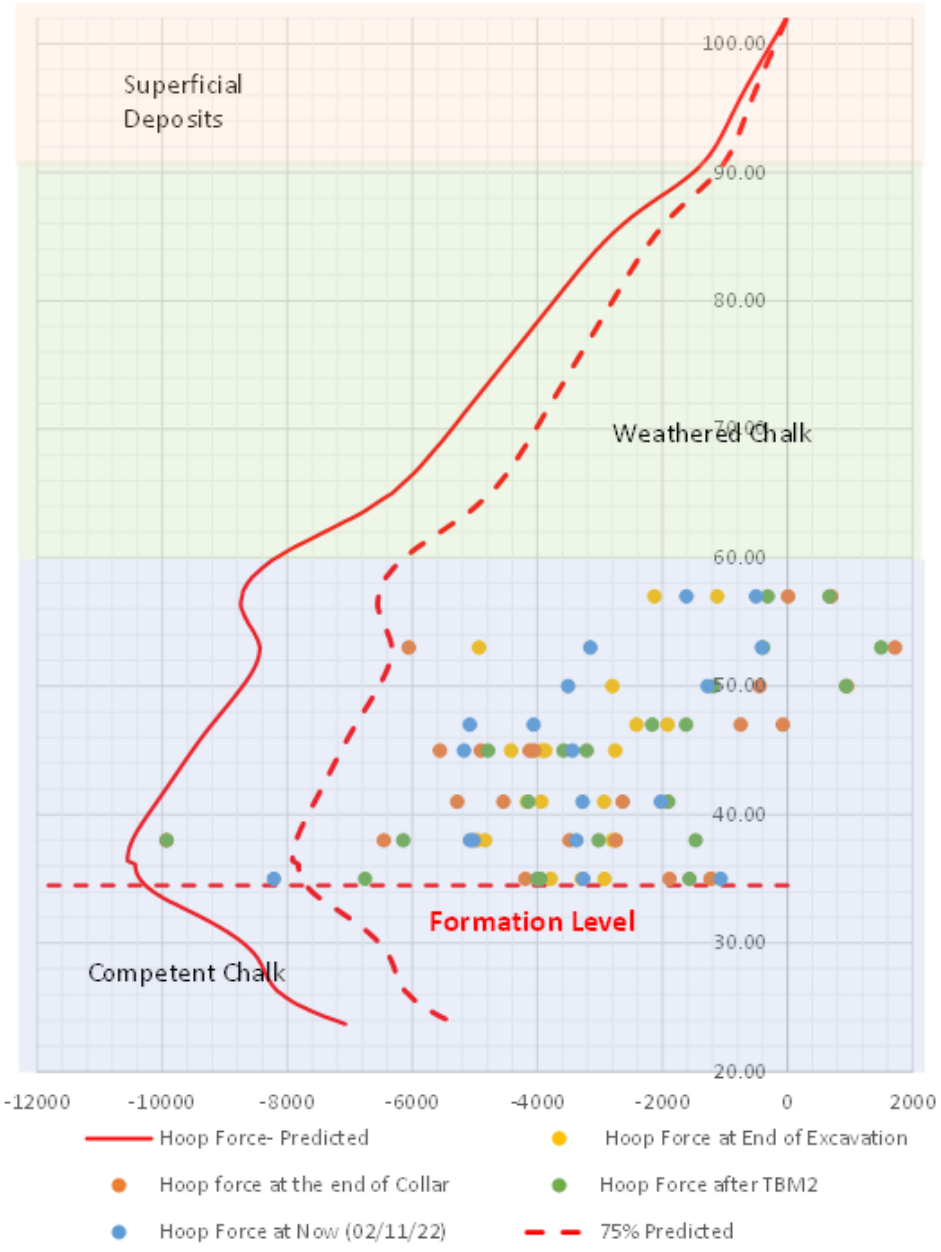
- Stresses
- Strain

Monitoring demonstrated:

- compliance with trigger values
- also validated the design parameters used

  $K_{0-3} = {}^{\sigma'_h}/_{\sigma'_v}$ = *1.05 affecting the shafts during excavation*

- provides data for research & development



Thank you