A303 Amesbury to Berwick Down

TR010025

6.3 Environmental Statement Appendices

Appendix 10.6 Land Instability Risk Assessment Report

Volume 6

APFP Regulation 5(2)(a)

Planning Act 2008

Infrastructure Planning (Applications: Prescribed Forms and Procedure) Regulations 2009

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Foreword

The A303 Amesbury to Berwick Down scheme (the Scheme) forms part of a package of proposals for the A303/A30/A358 corridor, improving this vital connection between the South West and London and the South East and including the upgrade of remaining single carriageway sections on the route to dual carriageway. This investment is stated as a priority project in the National Infrastructure Plan and government's commitment is confirmed in the Road Investment Strategy (2015-2020). Subject to achieving an approved Development Consent Order (DCO), enabling works are planned to start in early 2020 with the main construction works following in late 2021, and with the Scheme due to open to traffic in late 2026.

Objectives for the Scheme have been formulated both to address identified problems and to take advantage of the opportunities that new infrastructure would provide. The objectives are defined in the Department for Transport's (DfT) Client Scheme Requirements:

- **Transport** - To create a high quality reliable route between the South East and the South West that meets the future needs of traffic;
- **Economic Growth** - to enable growth in jobs and housing by providing a free flowing and reliable connection between the South East and the South West.
- **Cultural Heritage** - To help conserve and enhance the World Heritage Site and to make it easier to reach and explore; and
- **Environment and Community** - To improve biodiversity and provide a positive legacy for nearby communities.

The objectives would be achieved by providing a high quality dual two lane all-purpose carriageway on the A303 trunk road between Amesbury and Berwick Down in Wiltshire.

The Scheme would resolve traffic problems and, at the same time, protect and enhance the WHS. Key components comprise:

a) A bypass to the north of Winterbourne Stoke with a viaduct over the River Till valley
b) A new junction between the A303 and A360 to the west of (outside) the World Heritage Site, replacing the existing Longbarrow roundabout
c) A twin-bore tunnel 3km in length past Stonehenge
d) A new flyover at Countess roundabout

Executive Summary

A number of the proposed elements to be constructed as part of the A303 Amesbury to Berwick Down Scheme will cause ground movements. This report serves as a preliminary risk assessment for potential land instability, identifying key features, highlighting the risks of land instability, discussing preliminary assessments and suggesting further work at future stages of the PCF process. This report has been carried out in accordance with the Department for Transport's National Policy Statement for National Networks with regards to Land Instability.

Ground conditions, historical activity and construction techniques can all influence the risk of ground movement associated with a project. The A303 Amesbury to Berwick Down Scheme has the potential to affect a number of structures and infrastructure in the vicinity of the Scheme. As such, it is important to assess the risk that construction poses to them.

An Esso pipeline underlies a section of proposed Scheme embankment and a landscape fill area. The potential to protect this or to divert it is to be determined.

The rural setting of the Scheme means that the only existing buildings within the area of interest are Custodian Cottages, which are directly above the proposed tunnel alignment. Preliminary analysis indicates that the impact on these buildings will not be significant.

In order to further mitigate the risk of ground instability in the region, additional ground investigation is proposed. The entire site is underlain by chalk of the White Chalk subgroup, therefore features of dissolution, folding, faulting, fracturing and natural cavities may be present. At present, there is no clear evidence of significant dissolution features or natural cavities. However, faults and fractures have been logged at points throughout the scheme and the potential effects of the phosphatic chalk deposits cannot be discarded. It is therefore essential to obtain further ground investigation data in order to conclude the assessment of risks to potential land instability.

1 Introduction

1.1 Scope and Objective of the Report

1.1.1 AECOM-Mace-WSP (AmW) has been commissioned by Highways England to carry out the requirements of the Project Control Framework (PCF) Stage 3 for the A303 Amesbury to Berwick Down scheme, hereafter referred to as “the Scheme”.

1.1.2 The scope of works for the AmW commission comprises Preliminary Design for the Scheme and the provision of services to support the preparation of the Development Consent Order (DCO) Application scheduled towards the end of September 2018.

1.1.3 The Scheme will have associated ground movements, caused by:

- Potential natural cavities;
- Potential faulting and fractures;
- Potential historical mining activity;
- Tunnel construction;
- Deep excavations;
- Formation of retaining structures;
- Embankment and cutting slopes, and other landscaping.

1.1.4 Ground movements can be caused by a wide range of factors, such as geology, construction methodology and quality, and underground obstructions. It is essential to understand the potential ground movements associated with the construction of the Scheme in order to identify the risks to assist in determining the technical feasibility of the Scheme and to determine appropriate mitigation strategies.

1.1.5 The purpose of this report is to provide a preliminary risk assessment of potential ground instability in relation to the Scheme. A brief review of the existing information is provided, followed by an assessment of potential risks to surrounding areas from land instability.

1.1.6 This report has been carried out in accordance with the guidelines as set out by the Department for Transport’s National Policy Statement for National Networks (NPSNN) [1] with regards to Land Instability (paragraphs 5.116 to 5.119).

2 Review of Existing Sources of Information

2.1 Site Description

2.1.1 The Scheme covers an approximately 13km long section of the existing A303 carriageway between Amesbury and Berwick Down in Wiltshire. The current A303 carriageway passes through the Stonehenge part of the Stonehenge, Avebury and Associated Sites World Heritage Site (WHS); including the stone circle which lies 165m from the carriageway.

2.1.2 The existing A303 currently experiences severe road traffic congestion and has a poor road traffic accident record.

2.1.3 The Scheme proposes an upgrade of the current single carriageway to a high quality dual carriageway including passing through the WHS in a twin bored tunnel.

2.2 Site History

2.2.1 There is a long history of proposed improvement to the A303, with earliest announcements dating back to 1971 when an upgrade was announced for the entire length under the new roads programme to improve the national network by 1980. Studies and consultations into alternatives for the A303 between Amesbury and Berwick Down section have been underway since 1991.

2.2.2 In 1999 a first preferred route announcement was made by the Highways Agency, which for the first time, had the backing of the National Trust and English Heritage. Several phases of Ground Investigation were commissioned in order to inform design.

2.2.3 In 2007, following the identification of a number of cost increases following developments arising from the ground investigations, the former published scheme put forward at that time was cancelled.

2.2.4 The Government’s National Infrastructure Plan announced that the Scheme had become a priority in 2010, and in 2014 work on the design of the current Scheme began.

2.2.5 A review of the ground investigation history of the A303 between Amesbury and Berwick down and its surrounding region is presented in Section 2.3. More detailed reviews can be found in the Preliminary Sources Study Report (PSSR) [2].

2.3 Ground Investigation History

2.3.1 A series of targeted intrusive ground investigations has been carried out within the region, both as part of various stages of development of the Scheme (or previous iterations) or as part of surrounding projects.

2.3.2 The earliest ground investigation information is dated from 1965. The ground investigation was carried out for a proposed bypass in the area of the existing Countess Roundabout.

2.3.3 A series of ground investigations were carried out between 2000 and 2004 to support the design development of the former published scheme. The ground investigations were carried out in three major phases:

- A preliminary ground investigation took place in 2000 and comprised three boreholes. The boreholes were located within 70m from the centreline of the tunnel section of the proposed route.

- A main ground investigation was carried out in two phases. The locations of the majority of exploratory holes in general follow the alignment of the proposed route. The combined two phases are considered to contribute the most geotechnical information in terms of exploratory hole numbers and area coverage.

  - Phase 1 started in February 2001 and investigated the route between Countess Roundabout and Longbarrow junction.

  - Phase 2 was carried out between August and September 2001. It investigated the area to the west of Longbarrow as well as the locations of two alternative routes both for a northern bypass at Winterbourne Stoke.

- A supplementary ground investigation was carried out between 2002 and 2004 with early contractor involvement in three phases:

  - Phase 1A took place from 2002 to 2003. The exploratory hole locations in general distributed along the proposed route. Higher densities of exploratory holes are noted in the areas of the Countess Roundabout, proposed tunnel and the Winterbourne Stoke northern bypass.

  - Phase 1B comprised two pumping tests, carried out between 2002 and 2004. The pumping tests took place in the areas of Stonehenge Down and Stonehenge Bottom. Both test locations are close to the proposed tunnel alignment on the proposed route. The pumped water was discharged into a series of recharge holes located approximately 700m to the south of the proposed tunnel.

  - Phase 2 comprised site trial of four numbers of CPT gamma cone in the area of the Proposed Route tunnel in 2004.

2.3.4 A ground investigation was carried out in 2002 for a proposed Stonehenge Visitors Centre located to the north of Countess Roundabout.

2.3.5 A ground investigation was carried out for improvement works at the Countess Roundabout in 2009. It comprised two boreholes and sixteen trial pits.

2.3.6 A separate ground investigation, comprising five trial pits, was carried out for the improvement works at the Longbarrow Roundabout.

2.3.7 Results from the ground investigations summarised above are presented in the Preliminary Ground Investigation Report (PGIR) [3].

2.4 Recent Ground Investigations

2.4.1 During PCF Stages 1 and 2, Highways England commissioned the design, planning and procurement of a ground investigation with the intention to provide initial information for the Preliminary Design and DCO planning requirements in the follow-on PCF Stage 3. The scope of the ground investigation was based on the route options that were published at the time of non-statutory public consultation in early 2017.

2.4.2 The fieldworks were carried out between January and April 2017 by ground investigation contractor Structural Soils Ltd (SSL).

3 Ground Conditions

3.1.1 A detailed summary of engineering ground conditions is provided in the Preliminary Ground Investigation Report (GIR) [3]. Ground conditions vary along the route. However, the stratigraphy typically comprises the following:

- Made Ground;
- Superficial Deposits;
- Structureless/Weathered Chalk;
- Structured/Intact Chalk.

3.1.2 The composition of superficial deposits varies along the route, with Alluvium and River Terrace Deposits dominant around river valleys and Head Deposits prevalent around higher interfluvial regions. Peat has been encountered around Countess Roundabout, although this was effectively removed by previous road construction activities.

3.1.3 Chalk formations encountered are of the White Chalk Subgroup, comprising a succession of chalk of the Newhaven, Seaford and Lewes Nodular formations. Structureless, or weathered, Chalk is typically less than 1m thick throughout higher elevations, reaching up to 3m in the River Till Valley north of Winterbourne Stoke, up to 7m in the dry valleys and reaching a maximum of 10m in the Avon Valley at Countess Roundabout and around the River Till Valley.

3.1.4 Phosphatic Chalk deposits have been identified in part of the region of the proposed tunnel, around Stonehenge Bottom. Mortimore [4] suggests that the phosphatic deposits were formed either by a single or multiple northbound flowing channels, with two potential northerly trending fault zones in the region. The composition of the phosphatic chalk deposits is thought to vary greatly throughout the region, and some zones can be described as very weak, poorly bonded sand and silt grade phosphates. Phosphatic Chalk is discussed in more detail in the PGIR [3].

4 Key Elements of the Scheme

4.1 Existing Structures

4.1.1 The proposed route passes over an existing Esso pipeline at a sub-perpendicular angle, to the north-west of Winterbourne Stoke at approximately Ch2350. At this point, the pipeline is currently 1.2m below ground level and the proposed carriageway is intended to be on an embankment up to 18m in height, with additional landscaping using arisings from tunnel excavation and road cuttings in order to taper slopes into the surroundings.

4.1.2 Three structures at Custodian Cottages are located in close proximity to the proposed tunnel (approximately Ch9800 to Ch9900), to the east of Stonehenge monument.

4.1.3 An underpass currently exists beneath the existing alignment at approximately Ch10770, known as Cattle Creep Underpass.

4.1.4 The remaining structures along the route comprise elements of the existing A303.

4.2 The Proposed Tunnel

4.2.1 The proposed tunnel closely follows the current A303 alignment, spanning a length of approximately 3000m. The western tunnel portal is proposed at Ch7400, situated to the east of the existing Longbarrow Roundabout, with the eastern tunnel portal to be constructed at Ch10400, to the west of Countess Roundabout. The above chainages refer to the start and end of the bored tunnel only. Cut and cover elements extend beyond this and are covered in section 4.3.

4.2.2 It is proposed to use a Tunnel Boring Machine (TBM) to construct the twin bored tunnel, with each of the two tunnels measuring approximately 14m in external diameter and reaching a maximum tunnel crown depth of approximately 40m below ground level.

4.3 Retaining Walls

4.3.1 Retaining walls are proposed along each carriageway verge to support excavations at the two tunnel portals and the carriageway approaches to the tunnel. It is proposed that some of the retaining wall length will have a “soft top” landscaped slope at the head.

4.3.2 Retaining walls supporting the approach to the western tunnel portal cover a length of approximately 1400m of the Proposed Route. The maximum retained height is proposed to be approximately 23m during construction (including 5m for tunnel excavation), with a finished maximum retained height of approximately 18m.

4.3.3 Retaining walls supporting the approach to the eastern tunnel portal cover a length of approximately 260m of the Proposed Route. The proposed maximum retained height reaches approximately 17m.

4.4 Cuttings

4.4.1 The majority of the proposed alignment is within cutting, the majority of which do not exceed a height of 6m.

4.4.2 The maximum height difference is noted at approximately Ch2800, west of the River Till Valley, where the cutting height reaches approximately 13m. Cutting heights also reach up to approximately 11m (approximately Ch6600 to Ch6700), around the proposed junction at Longbarrow Roundabout.

4.5 Embankments and Landscaping

4.5.1 Landscape fill is proposed as part of the Scheme, most notably at Parsonage Down (approximately Ch3030 to Ch3950). The re-use of chalk arisings from tunnel construction is being considered as a landscaping material to produce a chalk grassland environment.

4.5.2 Embankments are proposed around the B3083 underbridge (approximately Ch3400 to Ch3600), with a maximum proposed height of approximately 18m. Here, it is anticipated that the ground conditions that the embankments are constructed on will be Structureless Chalk.

4.5.3 Proposed embankments around the River Till viaduct (approximately Ch3900 to Ch4200) are anticipated to reach a maximum height of approximately 11m, where they are likely to be constructed over Head Deposits or Alluvial Deposits.

4.5.4 The Scheme passes over proposed embankments up to 7.3m in height around Countess Junction (approximately Ch11500 to Ch12000), where a grade separated junction is proposed to replace the current at-grade roundabout. Embankments are proposed to incorporate reinforced earth walls and are expected to be constructed over river gravel deposits, and in the unlikely event of any limited pockets having survived previous road construction, any remnant alluvial deposits will be excavated and replaced.

5 Potential Sources of Ground Movement

5.1 Natural Cavities and Dissolution Features

5.1.1 Natural cavities can often be found present within Chalk in the form of dissolution features. These can be present as sinkholes, dissolution pipes and swallow holes.

5.1.2 As discussed in CIRIA C574 [5], the prediction of the extent of natural dissolution features is not yet reliable. However, an understanding of the processes and types of dissolution feature is presented in CIRIA C574. They can be caused either during the sedimentation process, as a result of pressure after cementation or as late dissolution after uplift due to erosion and weathering, and can lead to sinkholes, dissolution pipes and swallow holes, thereby having a major impact on potential ground movements.

5.2 Mining Workings

5.2.1 Historical industrial mining activity is not uncommon within chalk beds in the UK. This typically involves mining for chalk or flint workings, leading to artificial cavities and a potential risk of sinkholes and collapse.

5.3 Faulting and Fractures

5.3.1 Faulting and fractures occur naturally within chalk, largely due to tectonic activity and the effects of groundwater on the sedimentary rock.

5.3.2 CIRIA C574 [5] states that an effect of the local tectonic controls on the engineering behaviour of chalk is changed engineering performance, as fracture style influences slope stability, block size and ease of excavation.

5.4 Tunnel Construction

5.4.1 Tunnel construction results in ground movement at surface and sub-surface levels due to ground volume loss during formation of the tunnel bore. The extent of these movements depends on a number of factors, including the size and depth of the construction works, existing ground conditions and construction methodology.

5.4.2 Any groundwater dewatering as a requirement for tunnel construction activities would also be a factor contributing to potential land instability.

5.5 Retaining Wall Construction

5.5.1 Horizontal and vertical ground movements are associated both with retaining wall construction and following excavation in front of the retaining wall due to lateral deflections of the wall.

5.5.2 Local groundwater dewatering could be required during retaining wall construction and can be a factor influencing land instability and ground movements.

5.6 Cutting Construction

5.6.1 Cuttings can influence ground movements at slope crests through potential destabilisation failure mechanisms and localised changes in groundwater levels and regimes. The formation of cuttings also reduces loadings on the remaining ground.

5.7 Embankment Construction and Landscaping

5.7.1 Embankment construction results in ground movements due to the application of increased loading over a given area, resulting in ground settlement, including consolidation within softer cohesive deposits. This can impact assets immediately beneath the embankment and in close proximity.

5.7.2 The Scheme involves the construction of embankments to support the proposed carriageway, as well as additional landscaping in surrounding areas within the site boundaries.

5.7.3 Landscaping is proposed around Parsonage Down. The re-use of chalk arisings from tunnel construction is being considered as landscaping material. The addition of landscaping around proposed earthworks will impose increased stress on the ground and thereby increase the risk of ground movement within the area of application.

5.8 Construction Vehicles and Plant Operation

5.8.1 Where the Proposed Route and associated construction phase routes are proposed, loading and vibration from vehicles could potentially have an adverse effect on below ground pressures.

6 Assessment of Land Instability

6.1 Natural Cavities and Dissolution Features

6.1.1 Desk studies and ground investigations typically assist in identifying and interpreting the potential risk of natural cavities on a site. The studies and investigations conducted throughout the development of the proposed scheme to date have aided understanding and are referenced in the PSSR [2].

6.1.2 Dissolution features have been identified regionally and several features have been identified during preliminary excavations within the footprint of the Proposed Route. The features within the footprint of the proposed route are within proposed cuttings, so will not have any impact on construction. Small scale features have also been identified in interpretative reports; however, the evidence is deemed to be limited and inconclusive.

6.2 Mining Workings

6.2.1 The risk of land instability as a result of mining activity in a given area is typically ascertained through liaising with local authorities and the use of desk studies.

6.2.2 The Wiltshire Country Council Minerals Planning Office was consulted as part of a study in 1994 regarding mining activity, and at subsequent stages of the Scheme’s development.

6.2.3 The absence of authorised mining activity in the vicinity of the Proposed Route was confirmed in a 1994 discussion between Halcrow-Gifford and Wiltshire County Council.

6.2.4 Further interrogation of the Coal Authority and BGS non-coal Mining Plans have confirmed that no further mineral extractions have taken place since 1994.

6.2.5 The Wiltshire County Council Minerals Core Strategy Development Plan Document for 2006-2026 has been interrogated, and no potential mining areas or safeguarding zones are present in the vicinity of the Scheme.

6.3 Faulting and Fractures

6.3.1 Evidence of faulting and fractures within chalk has been identified as part of ground investigations carried out to date, utilising the following information:

- Observations within borehole cores;
- Observations within deep trials pits;
- Data outputs from geophysical surveys, including optical televiewer and natural gamma logs;
- Published data.

6.3.2 Confidence in ascertaining trends in faulting and fractures in chalk is predominantly determined by the availability of exposures in the rock face. The lack of availability of evidence of such activity through the observation of a cliff face or recent mining activity local to the Scheme means that difficulties in interpreting such trends with confidence remain.

6.3.3 Faults have been mapped on the surface regionally. In the vicinity of the Scheme, a north-south trending fault is indicated to be present crossing the existing A303 within Stonehenge Bottom. At this point the Scheme passes at a sub-surface level.

6.3.4 Potential faulting has been logged and discussed in the PSSR [2] and PGIR [3]. Discontinuities have been identified around the proposed tunnel area and have typically varied in nature. Further discontinuities may be present in other areas, however existing data is currently densest around the region of the proposed tunnel.

6.4 Tunnel Construction Movement Assessment

6.4.1 In order to assess the potential impact of the proposed tunnel on local assets and the landscape, analysis has been carried out using the following:

- Modelling in Xdisp software by Oasys, using empirical methods;
- Finite element modelling at specific cross sections through the proposed tunnel;
- Published data from previous examples of tunnelling in chalk.

6.4.2 Results have been presented in settlement contour plots, information from which has been used to visualise impacts and risk in the drawings present in Appendix A.

6.4.3 From preliminary ground movement assessment vertical settlements as a result of tunnelling are anticipated to be 20-30mm based on expected construction methods. Of these, peak movements would be located along the centreline of the proposed alignment. The 1mm settlement contour line extends to a maximum of 55m from the centreline of the proposed tunnel alignment based on worst case assumptions.

6.5 Retaining Wall Ground Movement Assessment

6.5.1 Assessments have been carried out in order to estimate potential lateral and vertical ground movements for preliminary retaining wall designs, with vertical settlement and lateral movement contours plotted. The approach is based on guidance provided in CIRIA report 760 [6].

6.5.2 Results from preliminary ground movement analyses as a result of retaining wall construction are presented in the form of settlement contour plots, as shown in the drawings presented in Appendix A.

6.5.3 Ground movements cannot be predicted exactly. However, preliminary assessments and an adequate monitoring strategy during construction and maintenance can mitigate the effects of construction on land instability.

6.5.4 Vertical settlement troughs based on preliminary assessments do not extend beyond a distance of 45m from the outside of the proposed retaining walls, calculated at each tunnel portal.

6.5.5 Lateral settlement troughs based on preliminary assessments do not extend beyond a distance of 90m from the outside of the proposed retaining walls, calculated at each tunnel portal.

6.6 Effects of Cuttings

6.6.1 SigmaW software by Geostudio has been used to carry out a preliminary assessment of ground movements as a result of the formation of the deepest proposed cutting of 13m at approximate chainage Ch2800 and providing a conservative estimate for movements at this preliminary stage. Stages of cutting excavation are modelled in 1m height increments, with horizontal and vertical displacements at ground surface plotted against distance from the slope crest.

6.6.2 The maximum vertical settlement calculated is 8mm during cutting excavation, which occurs during excavation of the first 1m and occurs at the slope crest. The maximum heave is anticipated at the final excavation stage, with a magnitude of 5mm at approximately 8m from the slope crest. This suggests that vertical ground movements as a result of cutting excavation should not exceed 10mm, however this should be confirmed with additional analysis at Detailed Design stage.

6.6.3 The settlement contours produced from preliminary analyses are presented in Appendix A.

6.7 Effects of Embankment Construction and Landscaping

6.7.1 SigmaW software by Geostudio has been used to model potential ground movements as a result of proposed embankment construction at the following three locations, considered to be examples of the most significant embankments:

- Proposed earthworks at Ch3280;
- Proposed earthworks at Ch4150;
- Proposed reinforced earth walls and embankment at Ch11700 (Countess Roundabout).

6.7.2 A preliminary assessment has been conducted to predict potential ground movement as a result of proposed landscaping around Parsonage Down, serving as part of the impact assessment of the Esso oil pipeline. The resulting settlement contours are presented in Appendix A.

6.7.3 Preliminary embankment design proposes conservative embankment slope gradients slacker than 1:2.5 (*v:h*). Embankments have been modelled and analysed with a staged construction of 1m height increments, followed by the application of loading to represent traffic.

6.7.4 At Ch3280, the modelled embankment height is 18m, with landscaping proposed over and around the structural earthworks. Preliminary analyses suggest that maximum settlements beneath the embankment are high (up to 370mm), however the settlement trough is not extensive. The 10mm settlement contour due to embankment construction is anticipated to be 6m from the embankment toe. Additional load from proposed landscaping works will increase settlement. The 10mm settlement contour due to landscaping works is expected to be at a distance of up to 165m from the centreline of the proposed carriageway (as shown in drawing HE551506-AMW-HGT-SW-ML-M00-Z-DR-CE-0097 presented in Appendix A).

6.7.5 Preliminary analyses suggest that ground settlement as a result of earthwork construction and associated landscaping could reach up to 370mm over the existing Esso oil pipeline. Assessment and mitigation of the risk of ground movement with respect to the Esso oil pipeline is discussed further in Section 0.

6.7.6 At Ch4150, the modelled embankment height is 18m. Preliminary analyses suggest that settlements are anticipated to be less than 10mm at the toe of the proposed embankment, and the 1mm settlement contour is at a distance of approximately 60m from the toe of the embankment.

6.7.7 In the case of the reinforced earth embankment at Countess Roundabout, ground improvement is proposed to reduce potential settlement. For the purpose of this assessment, it has been conservatively assumed that natural ground conditions are to be maintained for a conservative estimate of potential ground movements. From analyses, it is anticipated that vertical ground settlement will be less than 10mm at a distance of 2m from the toe of the proposed embankment, and the 1mm settlement contour is at a distance of approximately 28m from the toe of the embankment.

6.7.8 At Countess Roundabout, ground investigations have indicated that peat has effectively been removed within the footprint of the existing Countess Roundabout and its approach roads. However, further ground investigation has been proposed in this area in order to confirm this in relation to the proposed embankment construction.

6.8 Oil Pipeline Damage Impact Assessment

6.8.1 A preliminary assessment has been carried out regarding settlement of the proposed embankment over the Esso pipeline if this was to remain in place. Preliminary settlement contours as a result of embankment construction over the Esso pipeline and associated landscaping are incorporated and presented as part in Appendix A (drawing HE551506-AMW-HGT-SW-ML-M00-Z-DR-CE-0097).

7 Evaluation of Potential Impacts on Receptors

7.1 Natural Cavities

7.1.1 Known sinkholes have been identified within the study area. Wilsford Shaft (a suspected dissolution feature) is located around 90m south of the proposed alignment, and 200m south west of the proposed Western Tunnel Portal. Three further features have been identified during trial trenching, two within the proposed A360 approach to Longbarrow Junction and one within the footprint of the Western Tunnel Portal.

7.1.2 The other identified features are within proposed cuttings, so will be excavated out during construction. However, it is possible that pre-existing dissolution features are present closer to the proposed alignment, therefore the possible influence of dissolution features cannot be discounted. If additional features are discovered, further investigation and treatment will be required. Investigation of such features will be more effective in early stages of construction when formation materials can be expected over large areas.

7.2 Faulting and Fractures

7.2.1 A region in which chalk discontinuities have been logged is located at approximately Ch7500 to Ch7700. These are varied in nature, but generally relate to relatively shallow joint and vein discontinuities. Discontinuities have been logged around the proposed Eastern Tunnel Portal (approximately Ch10500), These are varied in nature. The discontinuity dips are typically associated with shallow joint and vein discontinuities, with the exception of three steep south-dipping joint/vein discontinuities logged at shallow depths.

7.2.2 The inferred model in drawing HE551506-AA-HGT-D_SWI-DR-CX-000081 (PSSR [2]) suggests that faulting may be present around the Amesbury Conservation Area and associated listed buildings.

7.3 Mining Activity

7.3.1 With reference to the PSSR [2], minor unauthorised excavations are known to have taken place in the area but are thought to be localised to the area of the River Till Valley and are understood to be superficial in nature.

7.3.2 Reference has been made to the presence of a small quarry to the west of Countess Roundabout at around 1971-1972, shown on historical maps to sit on the alignment of the existing A303. It is therefore assumed that the quarry has since been infilled.

7.3.3 Based on the above, it is considered that the risk of ground movement associated with historical mining activities is low to negligible.

7.4 Proposed Tunnel Construction

7.4.1 The proposed twin bored tunnels run in close proximity to the three cottage buildings at Custodian Cottages, situated on King Barrow Ridge around Ch9800 to Ch9900. A preliminary assessment has been carried out regarding the influence of the proposed tunnel on the existing structures. Potential ground movements have been analysed and corresponding risk of movement of the structures has been assessed.

7.4.2 A preliminary Stage 1 damage assessment has been carried out on the cottage structures based on a method similar to that defined in Crossrail's report "Crossrail: A Technical Guide for Developers" [7]. The assessed damage category of the structures at Custodian Cottages does not exceed Category 0. Category 0 indicates negligible tensile strains within the structure of between 0.0 and 0.05%.

7.5 Retaining Wall Construction

7.5.1 Preliminary ground movement analyses indicate that the impact of retaining wall construction on surrounding ground may be limited. However, ground movement predictions are based on empirical approaches from existing literature and applied using conservative assumptions. Current ground investigation data is particularly limited in the region of the proposed Western Tunnel Portal, and as such further investigation to determine ground conditions is proposed (as summarised in Section 8.2). Following the proposed ground investigation, ground movement assessments should be revised using finite element analyses informed by targeted ground investigation data.

7.5.2 Design amendments could be proposed in order to mitigate the risk of potential ground movement due to excavation for retaining wall construction. Increased embedment depth could be adopted to reduce potential deflections, and the construction sequence could adopt methods to minimise the effects of any groundwater drawdown on surface settlement. Temporary propping could be introduced into the sequence although this is not a preferred option due to the space requirements for operation and construction of the Tunnel Boring Machine.

8 Proposed Further Work

8.1 Monitoring

8.1.1 The mitigation strategy for ground movements associated with construction works should include the development of a monitoring regime. This will be developed through discussion with stakeholders in order to identify specific monitoring requirements, with a typical regime as follows:

- Identification of the monitoring system objectives and stakeholders;
- Definition of monitoring system scope and output requirements;
- Drafting of specification;
- Design and rationalisation (review, assess and revise);
- Procure and commission monitoring system;
- Baseline Monitoring;
- Baseline Construction Monitoring;
- Construction Monitoring;
- Post-construction Monitoring;
- Decommissioning of monitoring system.

8.1.2 For retaining walls, ground movement monitoring is advised before, during and following construction. Typical measurements and instrumentation are given in Table 1, however a targeted and site-specific strategy should be implemented.

Table 1. Typical monitoring measurements and instrumentation for ground movements as a result of retaining wall construction (after Dunnicliff, 2012 [8]).

Measurement	Instrumentation to Consider
Settlement of ground surface, structures and top of supporting wall	• Surveying methods
Horizontal deformation of ground surface, structures, and exposed part of supporting wall	• Surveying methods (convergence gauges
Change in width of cracks in structures and utilities	• Crack gauges
Subsurface horizontal deformation of ground	• Inclinometers • In-place inclinometers • (fixed borehole extensometers) (fibre-optic instruments)
Subsurface settlement of ground and utilities	• Probe extensometers (fixed borehole extensometers)
Load in props/struts	• Surface-mounted strain gauges
Load in ground anchors	• Load cells • (calibrated hydraulic jacks and load cells, lift-off tests) • Surface mounted strain gauges
Groundwater pressure	• Open standpipe piezometers • Vibrating wire piezometers installed by the fully grouted method (pneumatic piezometers)
Base heave	• Probe extensometers

8.1.3 A suitable ground movement monitoring strategy is advised for proposed cuttings, potentially incorporating inclinometers around slope crests with movement acceptance limits agreed with relevant authorities and owners of assets.

8.1.4 It is advised to implement a ground movement monitoring strategy prior to, during and following embankment construction. This could involve:

- Taking benchmark level readings before construction;
- Implementing surface settlement markers around embankments;
- Installing inclinometers within and around embankments;
- Implementing monitoring equipment to measure pore water pressures of underlying cohesive superficial deposits to determine the stage of consolidation;
- Settlement or inclination limits should be determined in accordance with the requirements of local authorities and owners of relevant assets.

8.2 Future Ground Investigation

8.2.1 An outline of proposed further ground investigation work is summarised briefly below and is specified in more detail within the Phase 6 Ground Investigation Specification [9]:

- Boreholes advanced by rotary coring and rotary open hole techniques;
- In situ geotechnical testing including self-boring pressuremeter testing, gamma cone penetration testing and downhole wireline logging;
- In-situ hydrogeological testing including packer testing, constant head testing and constant rate pumping tests;
- Geotechnical and geo-environmental sampling;
- Laboratory geotechnical testing and chemical analysis; and construction of groundwater monitoring wells, including the supply, installation, maintenance and handover of automated logging systems.

8.2.2 The proposed further ground investigation may aid the understanding of any potential presence of natural cavities within the vicinity of the scheme.

8.2.3 The area around the Western Tunnel Portal is to be targeted as part of the proposed ground investigation. This could aid in providing greater understanding of the distribution of potential lines of faulting and potential ground movements associated with proposed retaining wall construction in advance of Detailed Design.

8.2.4 Hydrogeological testing should help to ascertain groundwater flow regimes within the chalk aquifer around the Scheme, providing information assisting in the design of dewatering systems for tunnelling and retaining wall excavation.

8.2.5 In addition, to the planned phase 6 ground investigation further investigation for detailed design purposes will be required.

Abbreviations List

AAJV	Arup-Atkins Joint Venture (PCF Phase 2 Consultant)
AmW	AECOM-Mace-WSP Joint Venture (PCF Phase 3 Consultant)
CSR	Client Scheme Requirements
CPT	Cone Penetration Test
DCO	Development Consent Order
GIR	Ground Investigation Report
NPSNN	national Policy Statement for National Networks
PCF	Project Control Framework
PSSR	Preliminary Sources Study Report
SSL	Structural Soils Ltd
TBM	Tunnel Boring Machine
UNESCO	United Nations Educational, Scientific and Cultural Organisation

References

[1] Department for Transport, “National Policy Statement for National Networks,” 2014.

[2] AAJV, “A303 Amesbury to Berwick Down, Preliminary Sources Study Report [HAGDMS Ref: 29300],” 2016.

[3] AmW, “A303 Amesbury to Berwick Down, Preliminary Ground Investigation Report [HAGDMS Ref: 30465],” 2018.

[4] R. N. Mortimore, “Making sense of Chalk: A total rock approach in Engineering Geology,” BGS, London, 2012.

[5] J. A. C. C. R. &. M. R. N. Lord, “Engineering in chalk,” CIRIA, 2002.

[6] A. Gaba, S. Hardy, L. Doughty, W. Powrie and D. Selemetas, “CIRIA C760: Guidance on Embedded Retaining Wall Design,” CIRIA, London, 2017.

[7] Crossrail, “Crossrail: A Technical Guide for Developers,” 2015.

[8] J. Dunnicliff, “Types of Geotechnical Instrumentation and their Usage,” ICE Publishing, 2012.

[9] AmW, “A303 Amesbury to Berwick Down - Phase 6 Ground Investigation Specification,” 2018.

[10] AAJV, “A303 Stonehenge, Amesbury to Berwick Down. 2016/17 Ground Investigation Close Out Report. HE551506-AA-HGT-X_SWI-RP-CX-000001,” 2017.

Appendices

Appendix A Anticipated Ground Movement Drawings

A.1 Land Instability Risk Assessment Drawings

A.1.1.1 HE551506-AMW-HGT-SW-ML-M00-Z-DR-CE-0097 – Anticipated Ground Movement – Sheet 1 of 8

A.1.1.2 HE551506-AMW-HGT-SW-ML-M00-Z-DR-CE-0097 – Anticipated Ground Movement – Sheet 2 of 8

A.1.1.3 HE551506-AMW-HGT-SW-ML-M00-Z-DR-CE-0097 – Anticipated Ground Movement – Sheet 3 of 8

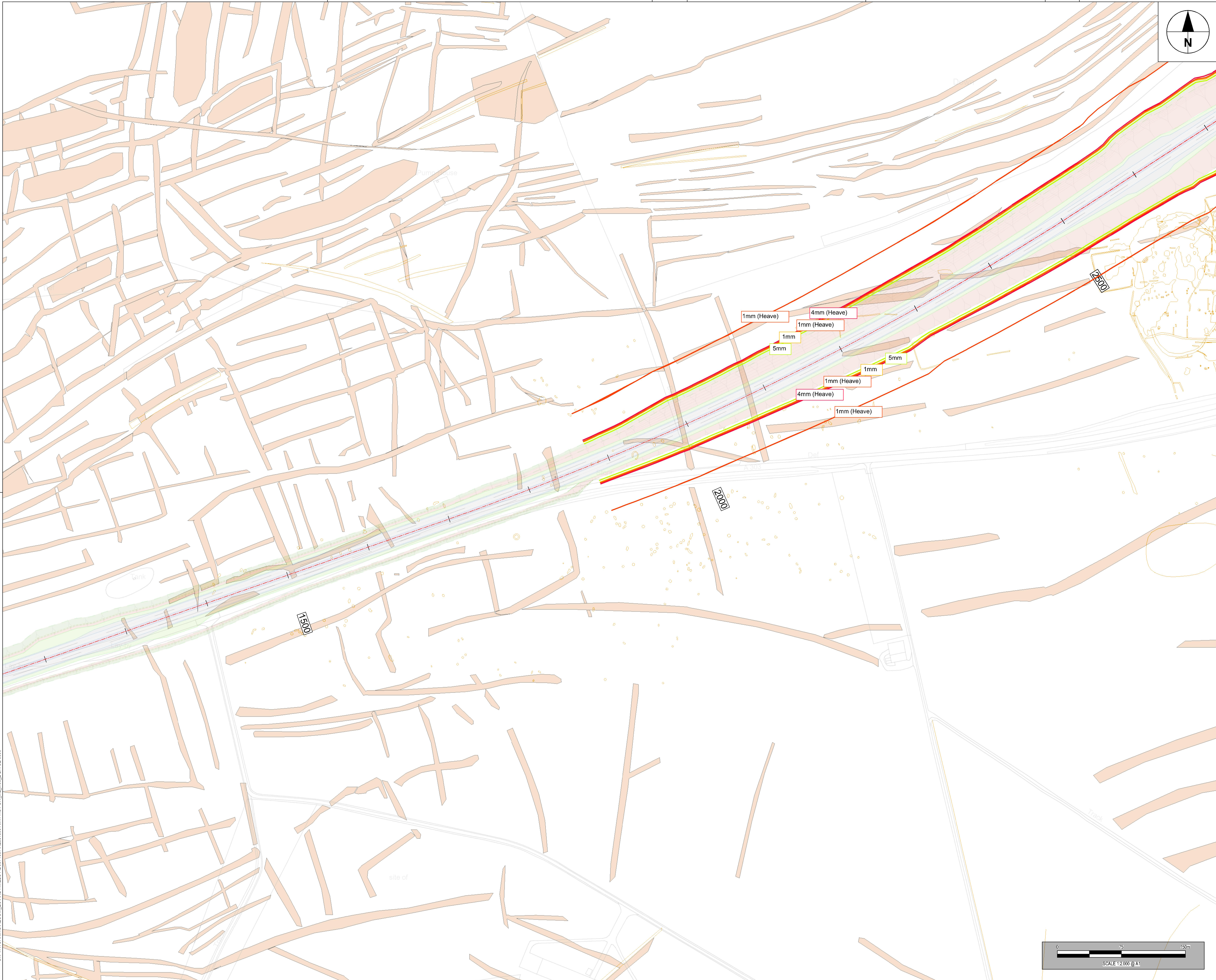
A.1.1.4 HE551506-AMW-HGT-SW-ML-M00-Z-DR-CE-0097 – Anticipated Ground Movement – Sheet 4 of 8

A.1.1.5 HE551506-AMW-HGT-SW-ML-M00-Z-DR-CE-0097 – Anticipated Ground Movement – Sheet 5 of 8

A.1.1.6 HE551506-AMW-HGT-SW-ML-M00-Z-DR-CE-0097 – Anticipated Ground Movement – Sheet 6 of 8

A.1.1.7 HE551506-AMW-HGT-SW-ML-M00-Z-DR-CE-0097 – Anticipated Ground Movement – Sheet 7 of 8

A.1.1.8 HE551506-AMW-HGT-SW-ML-M00-Z-DR-CE-0097 – Anticipated Ground Movement – Sheet 8 of 8



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LEGEND

PROPOSED A303 CARRIAGEWAY
CUTTING
EMBANKMENT

SETTLEMENT CONTOURS

4mm HEAVE
1mm HEAVE
1mm SETTLEMENT
5mm SETTLEMENT

Revision Details	By / Check	Date	Suffix
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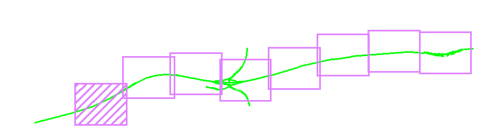

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Location | Type | Role | Number

Rev
P01

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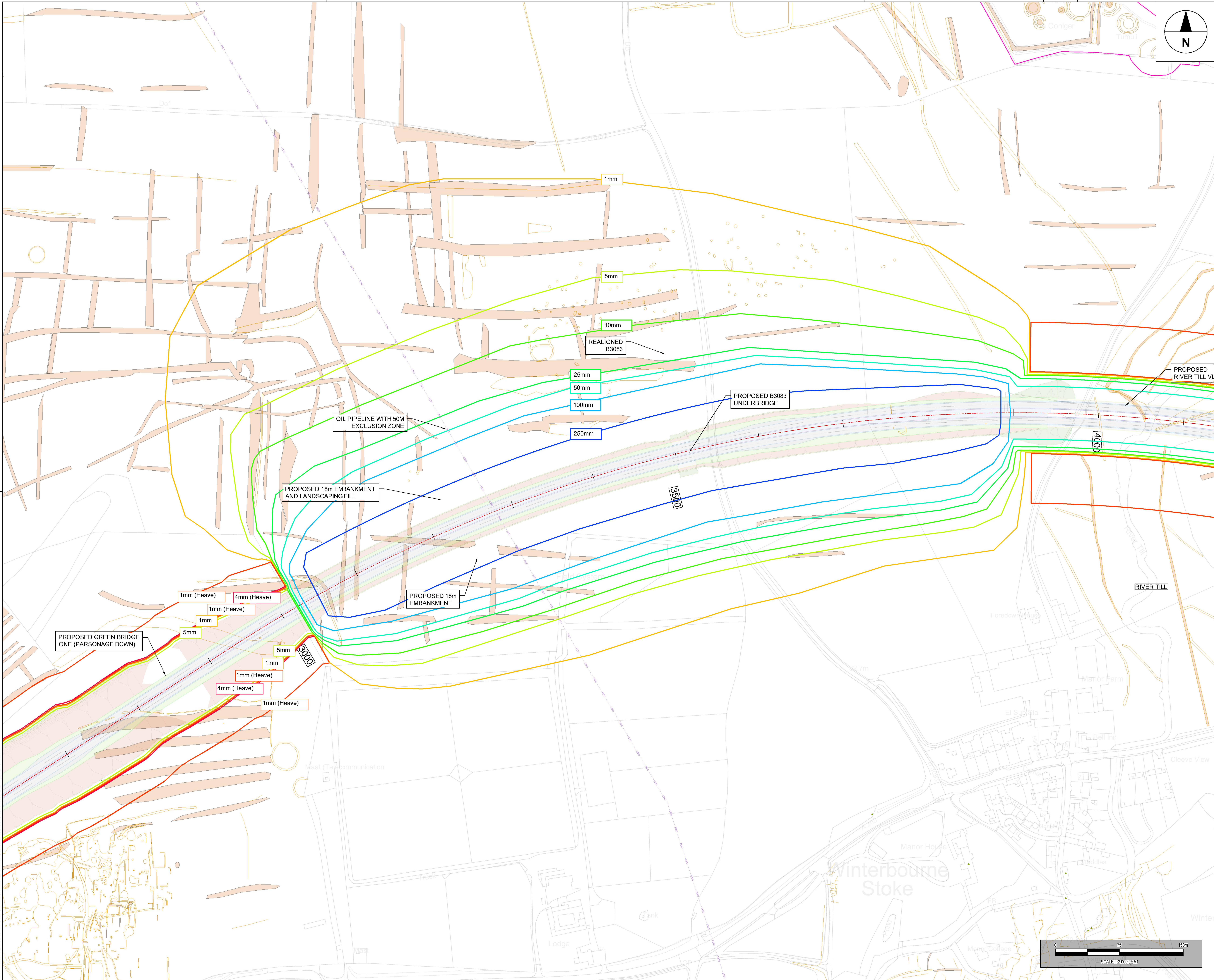

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LEGEND

- PROPOSED A303 CARRIAGEWAY
- CUTTING
- EMBANKMENT
- ESSO PIPELINE

SETTLEMENT CONTOURS

- 4mm HEAVE
- 1mm HEAVE
- 1mm SETTLEMENT
- 5mm SETTLEMENT
- 10mm SETTLEMENT
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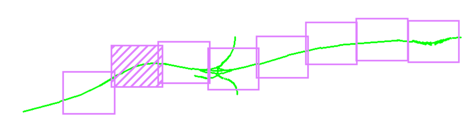

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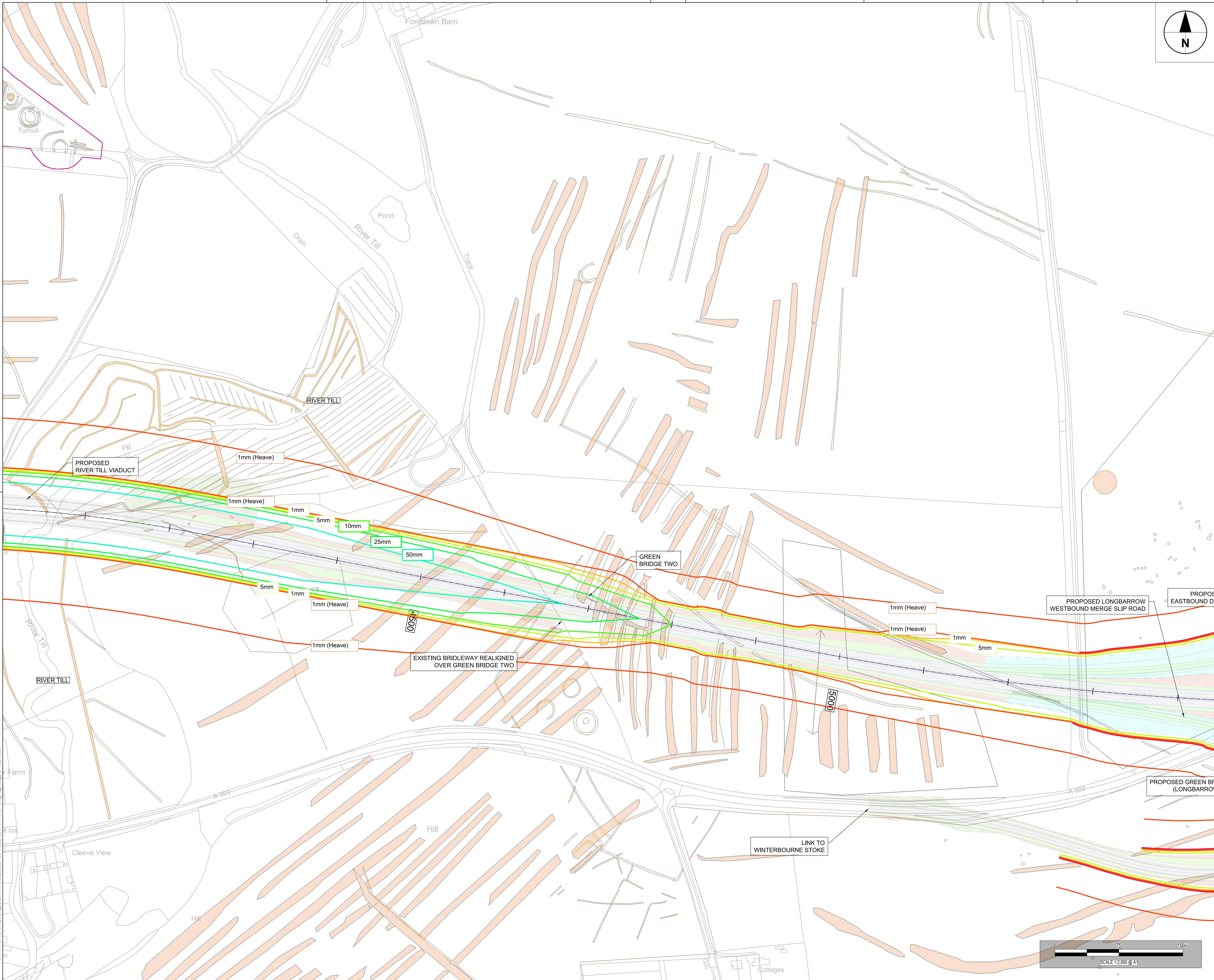

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LEGEND

- PROPOSED A303 CARRIAGEWAY
- CUTTING
- EMBANKMENT

SETTLEMENT CONTOURS

- 4mm HEAVE
- 1mm HEAVE
- 1mm SETTLEMENT
- 5mm SETTLEMENT
- 10mm SETTLEMENT
- 25mm SETTLEMENT
- 50mm SETTLEMENT

Revision Details	By / Check	Date	Suffix
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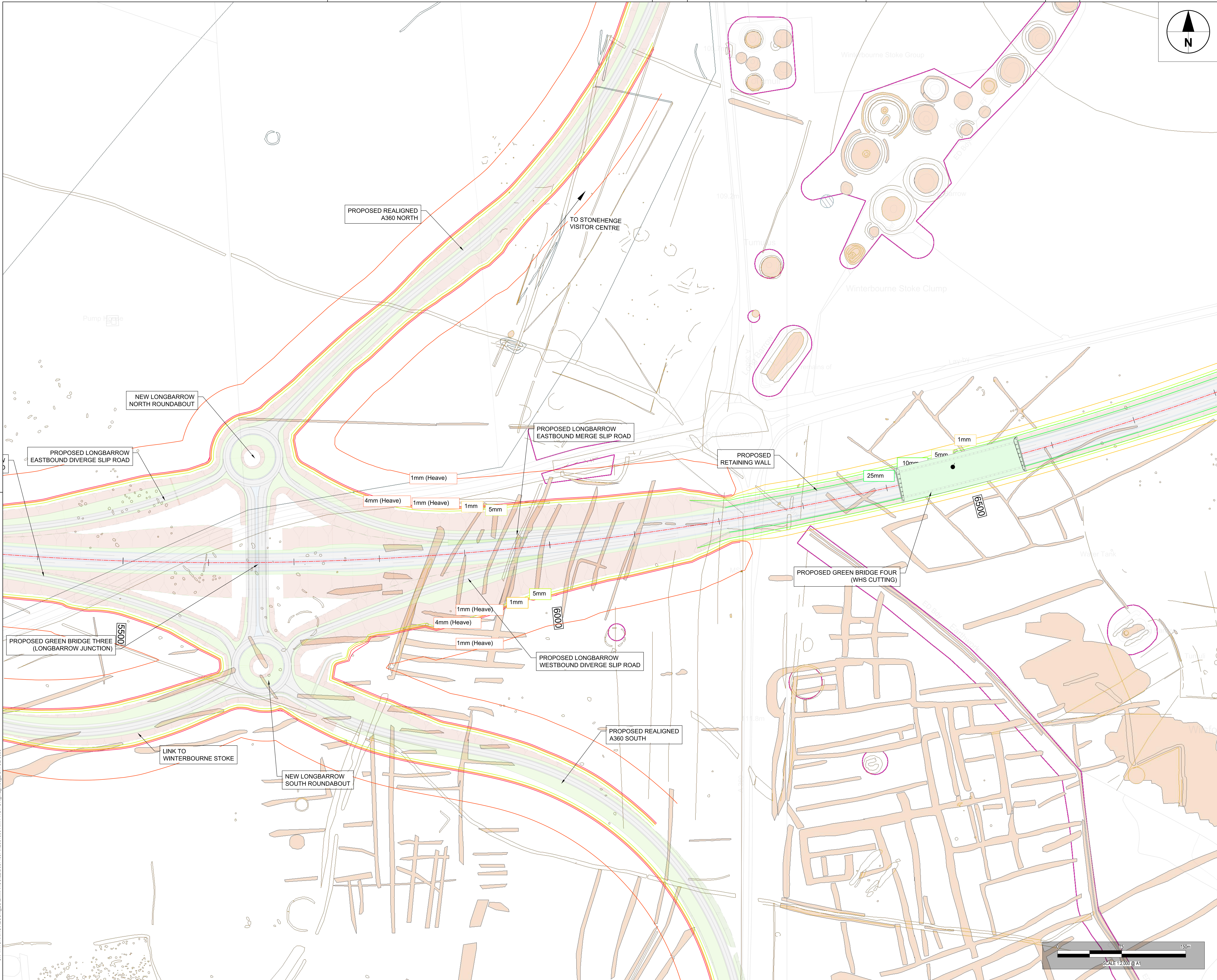

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LEGEND

PROPOSED A303 CARRIAGEWAY
CUTTING
EMBANKMENT

SETTLEMENT CONTOURS

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1mm HEAVE
1mm SETTLEMENT
5mm SETTLEMENT
25mm SETTLEMENT

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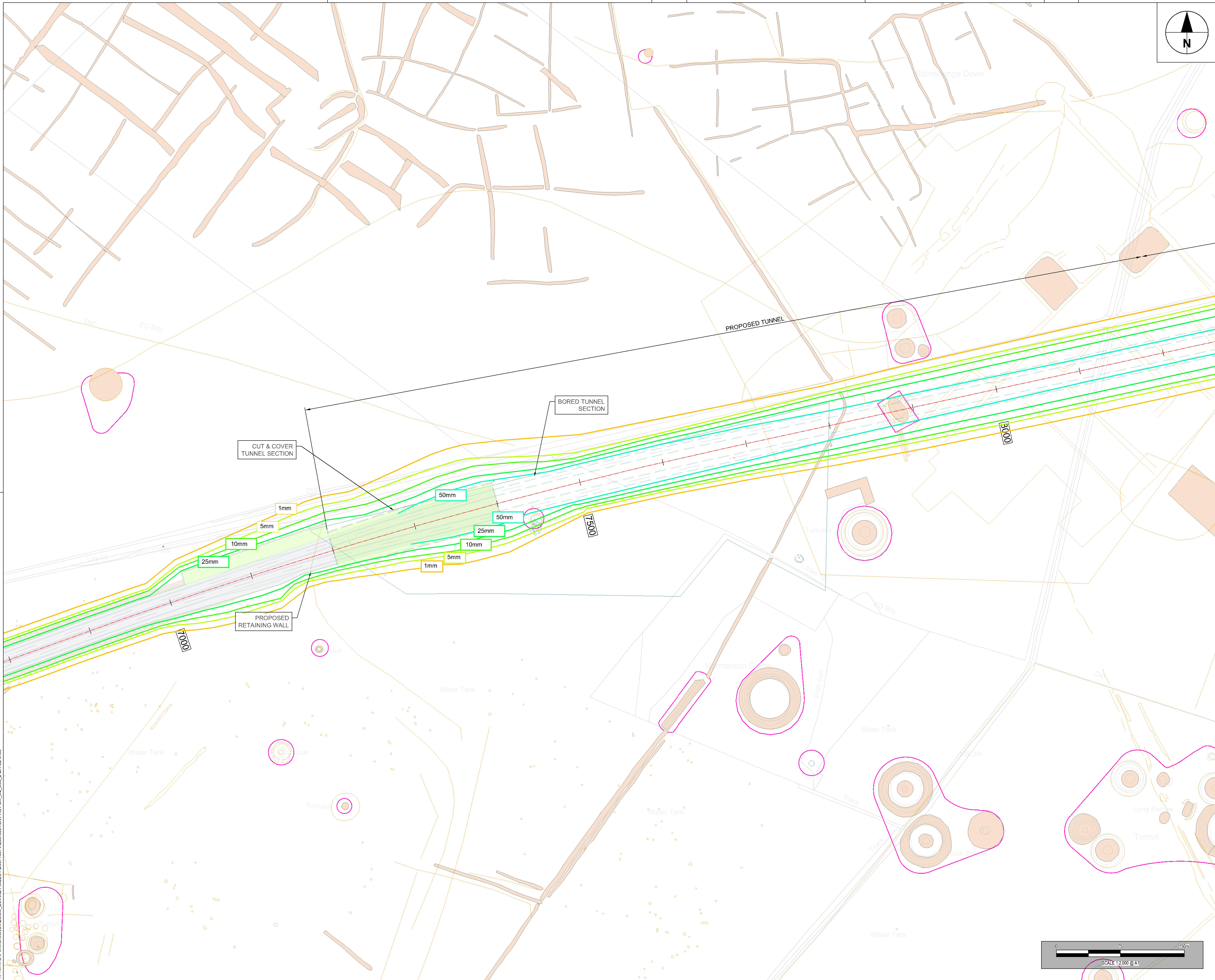

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LEGEND

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EMBANKMENT

SETTLEMENT CONTOURS

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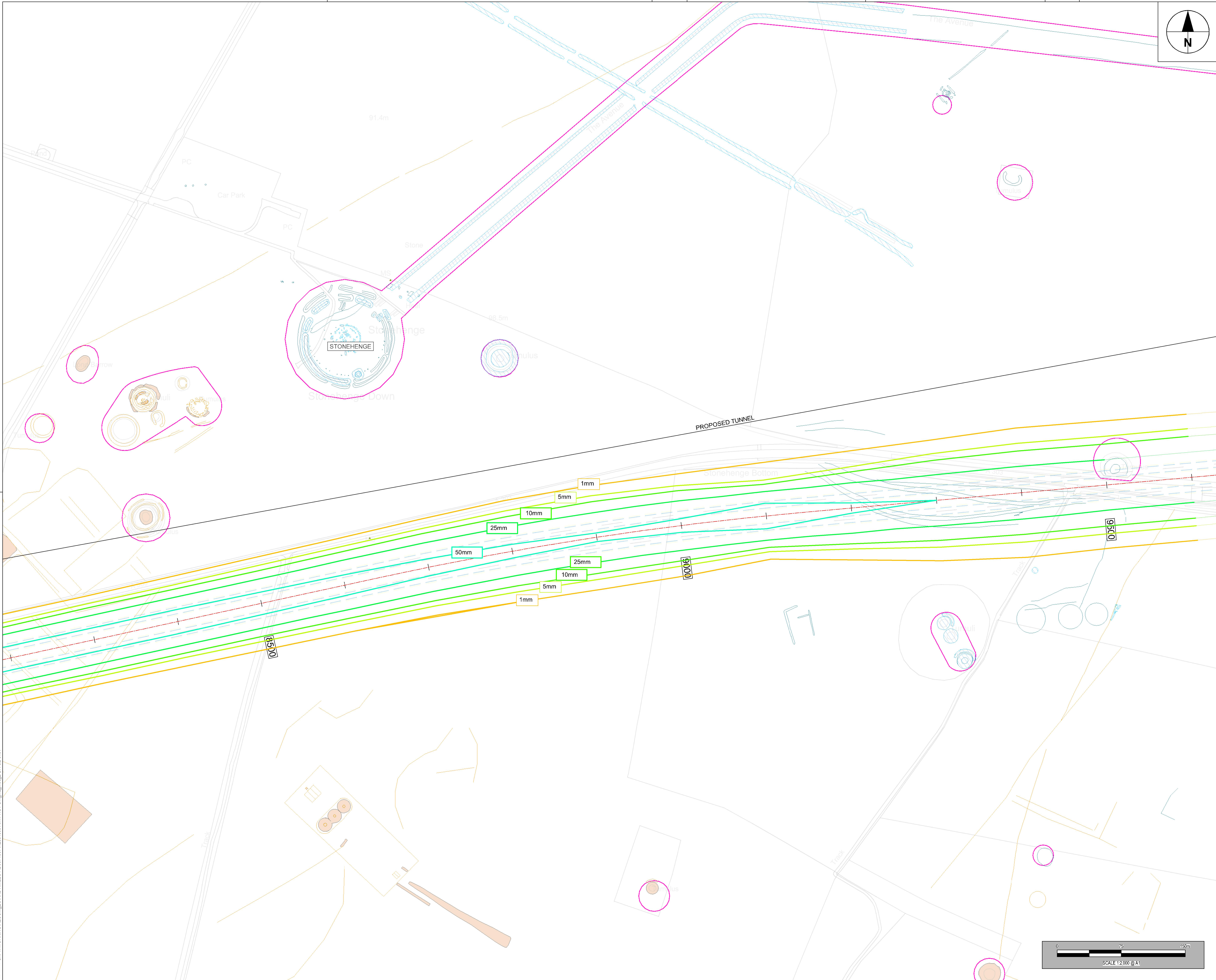

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- CUTTING
- EMBANKMENT

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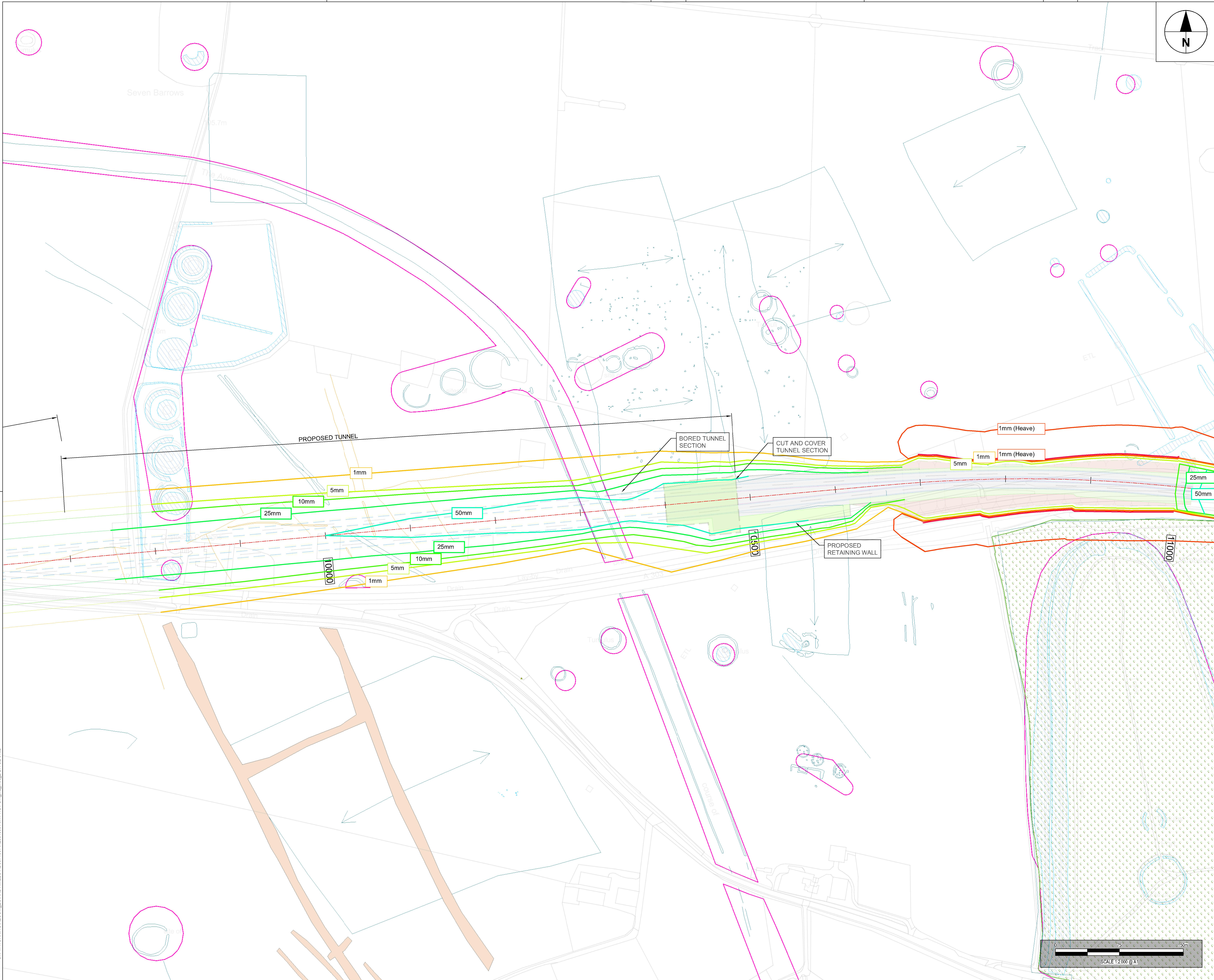

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LEGEND

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- CUTTING
- EMBANKMENT

SETTLEMENT CONTOURS

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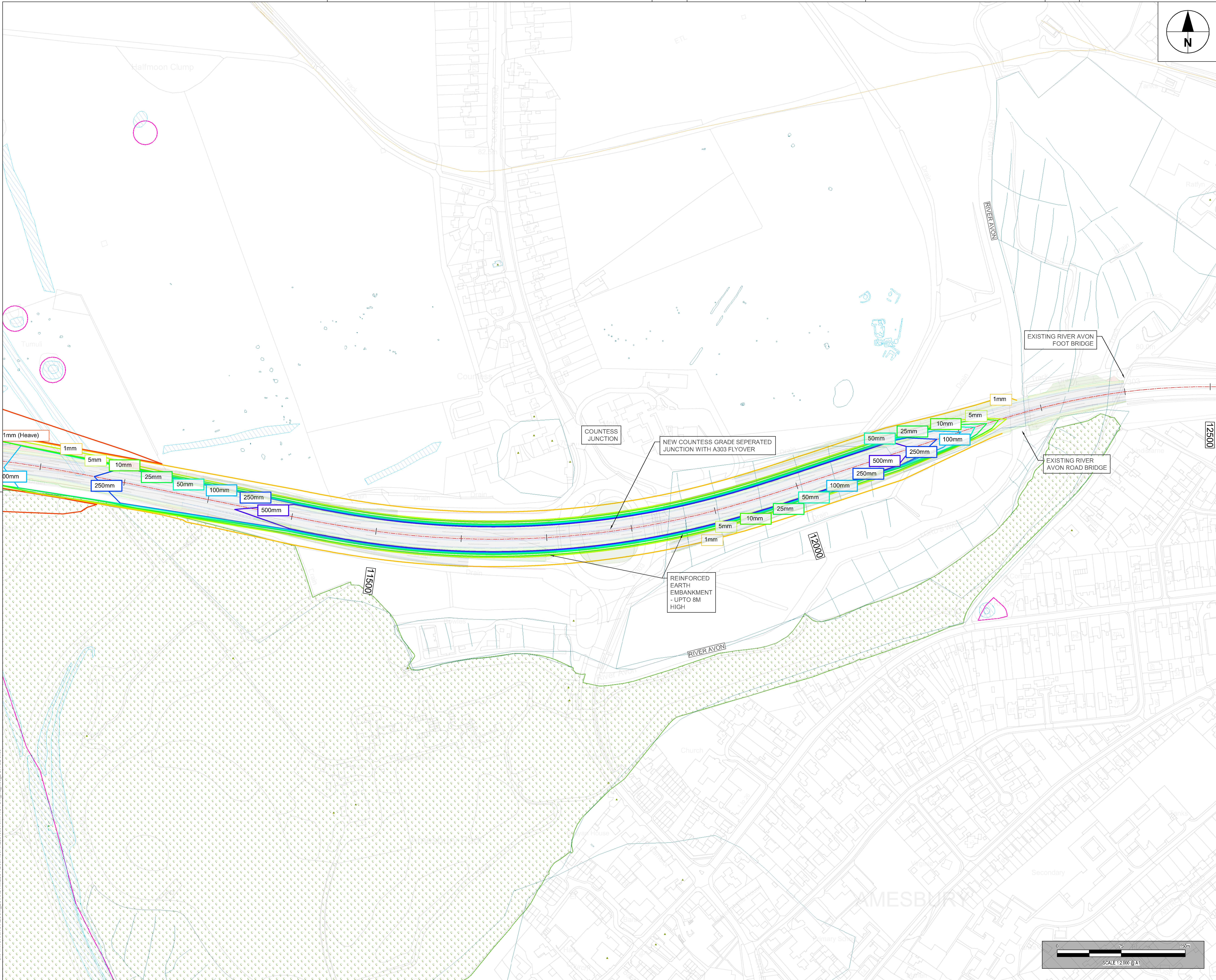

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LEGEND

PROPOSED A303 CARRIAGEWAY
CUTTING
EMBANKMENT

SETTLEMENT CONTOURS

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1mm SETTLEMENT
5mm SETTLEMENT
10mm SETTLEMENT
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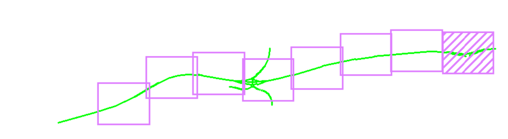

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