A47 North Tuddenham to Easton Dualling

Scheme Number: TR010038

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Appendix 13.4 - Groundwater Assessment

APFP Regulation 5(2)(a)

Planning Act 2008

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

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Infrastructure Planning

Planning Act 2008

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

The A47 North Tuddenham to Easton Development Consent Order 202[x]

ENVIRONMENTAL STATEMENT APPENDICES
Appendix 13.4 – Groundwater Assessment

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1. Introduction

1.1.1. This appendix report supports Chapter 13 Road Drainage and Water Environment of the Environmental Statement for the A47 North Tuddenham to Easton Dualling Scheme. It provides a hydrogeological conceptual model for the Scheme and its study area, based on a ground investigation undertaken by Highways England (the Applicant) in the current stage of the Proposed Scheme, and the necessary groundwater-specific environmental assessments as described in the Design Manual for Roads and Bridges (DMRB) LA 113 Road Drainage and the Water Environment (Highways England, 2020) . These assessments inform the assessment of significant impacts presented in Chapter 13 Road Drainage and the Water Environment, which follows the assessment methodology described in LA 104 Environmental Assessment and Monitoring (Highways England, 2019).

1.1.2. The study area encompasses groundwater and surface water features that could be affected by the Proposed Scheme. The study area is based on professional judgement to ensure that effects are sufficiently identified. It comprises a 1km corridor surrounding the Site, extended to include features further down-gradient that may also be impacted. The groundwater study area is shown in the figures contained in Annex A Location Plan. The site extension between Breck Barn and Ringland, and associated extension of the study area, is due to traffic management requirements during construction. There are no planned intrusive works in this area, therefore this is not considered in this assessment report.

1.2. Scheme overview

1.2.1. Chapter 2 of the Environmental Statement provides detailed description of the Proposed Scheme. The design briefly includes the following intrusive structures and temporary works, which are considered in this report:

- construction of a new dualling
- A new drainage design which incorporates outfalls to surface water and infiltration to ground via filter drains
- connection roads with underpasses between the A47 and;
  - Norwich Road (S07) at the eastern extent of the Proposed Scheme,
  - Wood Lane (S03) west of Honingham,
  - Hall Farm (S04) north of Honingham,
  - Honingham Church underpass (S18) east of Honingham
  - and Mattishall Lane Link Road underbridge (S16) southwest of Hockering
- an overbridge across the River Tud (S05) east of Honingham

- ground improvements for the east culvert where the Proposed Scheme is underlain by soft ground crossing the River Tud floodplain at S01, south of Hockering, and S05.
- utilities diversions, including works to a high-pressure gas pipeline adjacent to the proposed Wood Lane Junction (S03) and a sewer diversion at S05.

1.2.2. Structure S04 is immediately to the east of S03, and subsequently these have been assessed as a combined structure due to similar ground conditions and design.

1.2.3. Key potential construction and operation effects upon the water environment identified in Chapter 13 Road Drainage and the Water Environment (**TR010038/APP/6.1**) include:

- Changes to groundwater levels and/or flow through groundwater control during construction.
- Changes to groundwater levels and/or flow through redirection and / or reduction of flows around permanent subsurface structures.
- Contamination of groundwater by generation of suspended solids, direct contact with construction materials, or polluted construction run off.
- Contamination of surface water by discharge of untreated dewatering volumes, if required.
- Contamination of groundwater due to routine road runoff or accidental spillages infiltrating to ground via filter drains or receiving watercourses with low flows.

1.3. Aims and Objectives

1.3.1. This report aims to:

- provide a hydrogeological conceptual model and identify key direct and indirect receptors within the study area
- identify construction and operation activities specific to the Proposed Scheme that have the potential to impact on the groundwater environment
- present simple qualitative assessments to identify which activities may result in a significant impact, and therefore require further consideration and mitigation

1.3.2. The report is set out in the following structure to achieve these aims:

- Chapter 2 presents the hydrogeological baseline conditions, based on ground investigation results and other freely available sources of information, to provide a conceptual model and identify receptors, in line with the Groundwater Levels and Flows assessment method set out in LA113.
- Chapter 3 provides details of construction and operation activities and a description of the potential hydrogeological impact, prior to mitigation.

- Chapter 4 assesses the significance of risk to receptors, in line the assessment methods set out in LA113, comprising Groundwater Dependent Terrestrial Ecosystems (GWDTE), and routine road runoff risk assessments. Routine road runoff assessments were undertaken for all catchments where drainage to groundwater may occur via infiltration from filter drains. Assessments were also undertaken for outfalls within catchments S1 and M2, where flows within the receiving watercourse are classed as low flows (less than 1 l/s), pose a risk to groundwater through infiltration. These assessments are included within Section 4.3. Spillages assessments were undertaken for all catchments and are presented in Appendix 13.3 (Water quality assessment) (**TR010038/APP/6.3**).
- Chapter 5 summarises the activities that may result in a potentially significant impact, prior to mitigation, and that are taken forward for further consideration in the assessment of significant effects in Chapter 13 Road Drainage and the Water Environment (**TR010038/APP/6.1**).

1.4. Data sources

1.4.1. This technical report has been produced utilising the following sources of information:

- British Geological Survey (BGS) 1:50,000 superficial and bedrock geological maps (BGS, 2020a) and regional groundwater monitoring (BGS, 2020b)
- DEFRA's 'Magic' interactive map (DEFRA, 2020)
- Environment Agency (EA) Catchment Data Explorer (Environment Agency, 2020)
- Highways Agency Drainage Data Management System (HADDMS), Drainage Data Management System v5.12. (Highways England, 2020b)
- 2020 ground investigation by the Applicant
- 2020 Geomorphology Assessment Report (Sweco, 2020b)
- 2019 River Tud Aquatic Invertebrate Survey Report (EMEC Ecology, 2019)
- 2019 Botanical Survey Report (Wild Frontier Ecology, 2019)
- Information provided by the Environment Agency in April and May 2020

Ground investigation

1.4.2. A geotechnical and geoenvironmental investigation was undertaken by the Applicant at the site of the Proposed Scheme between North Tuddenham and Easton, Norfolk, between March 2020 and August 2020.

1.4.3. 46 boreholes were installed for groundwater monitoring with 50mm diameter standpipes. 5 of these were also installed with a 19mm piezometer.

1.4.4. The ground investigation also included 51 window samples, 49 dynamic (windowless) samples, 38 static cone penetrometer tests (CPT) and 81 Trial pits.

1.4.5. Exploratory holes were placed along the mainline route of the Proposed Scheme, with a focussed group of boreholes where the route crosses the River Tud floodplain. Design changes following the commencement of the 2020 ground investigation necessitate a supplementary ground investigation. Significant design changes include the inclusion of Mattishall Lane and Honingham Church underpasses and changes to the Norwich Road Junction.

1.4.6. A number of boreholes and dynamic samples were not included due to the COVID-19 pandemic and resultant delays to the investigation programme. Details of the exploratory holes will be updated during the detiall design stage.

2. Hydrogeological baseline conditions

2.1. Topography and drainage

2.1.1. The topography of the study area gently undulates, with ground elevations between 20mAOD at the River Tud crossing and 50mAOD at valley slopes. The land is drained by the River Tud and its tributaries.

2.2. Geology

2.2.1. The bedrock and superficial geology within the study area are presented in Annex A Location Plan and in cross sections along the mainline of the Proposed Scheme (Annex B).

2.2.2. The study area is predominantly underlain by glacial till of the Lowestoft Formation, with patches of glacial sands and gravels of the Sheringham Cliffs Formation that become more dominant towards the east of the study area around Easton. The Lowestoft Formation is absent in the incised valleys, with post glacial deposits of River Terrace Deposits and Alluvium present and directly overlying Chalk bedrock. Discrete patches of Alluvial Fan Deposits and Happisburgh Glacigenic Formation are also found within the study area, as described below.

Alluvium

2.2.3. Alluvium present within the Study Area follows the line of the River Tud and incised valleys. It is described from the 2020 ground investigation as predominantly granular, however cohesive and organic fractions (peat) were also present. Where present, cohesive Alluvium including organic units are limited to shallow depths (<3.0m) with the granular Alluvium generally infilling former and existing river channels to a more significant depth, such as that observed at the River Tud where granular Alluvium directly overlaid the Chalk.

2.2.4. The Alluvium was proven to a maximum thickness of 19.50m (average 3.0m) however it should be noted that the base of the granular Alluvium described in DS233 was not proven.

Alluvial Fan Deposits

2.2.5. The Alluvial Fan Deposits, comprising clay and silt, is mapped on BGS mapping as a small outcrop area located along the line of the River Tud at Berrys Lane, west of Honingham.

2.2.6. Granular layers classified as Alluvial Fan Deposits were also observed south of the proposed Wood Lane Junction in TP335 during the 2020 ground

investigation. The layers comprise coarse sub-angular to sub-rounded gravel of chalk and flint. The presence of the Alluvial Fan Deposits within TP335 indicates that it extends beyond that indicated by the BGS mapping, although does not extend as far as to intersect the Proposed Scheme.

River Terrace Deposits

2.2.1. River Terrace Deposits outcrop on BGS mapping along the course of the River Tud, within the floodplain.

2.2.2. The River Terrace Deposits were identified during the 2020 ground investigation at a location east of Mattishall Lane, associated with the River Tud. The deposits here comprise sand and gravel to depths of between 5.70 and 9.60m. The River Terrace Deposits are proven to a maximum depth of 9.60m (BH104) with an average proven thickness of 2.10m.

Lowestoft Formation

2.2.3. The Lowestoft Formation is found across Scheme up to the roundabout at Easton on both the BGS mapping and during the 2020 ground investigation, where it was proven to a depth of up to 23.5mbgl. This formation either outcrops or directly underlies the Alluvium and Sheringham Cliff Formation, where present. The Lowestoft Formation overlies Happisburgh Formation, where present, and the Chalk.

2.2.4. The Lowestoft Formation is described as a “chalky till” and displays a full range of grain sizes comprising clay, silt, sand and gravel that is typically clayey near the surface becoming gravelly and increasingly chalky at depth, significantly such that initially it may appear to be weathered Chalk. The formation was found to become increasingly inter-bedded with granular layers within exploratory holes located to the east of the proposed River Tud crossing. Interbeds of granular deposits are typically dense, very clayey silty sands.

Sheringham Cliffs Formation

2.2.5. The Location Plan within Annex A shows the Sheringham Cliffs Formation to outcrop as patches within the Study Area west of the Proposed Scheme between North Tuddenham and Hockering, north of the River Tud east of Hockering, and at Honingham. Eastwards of Church Farm there is a more extensive coverage of the Sheringham Cliffs Formation present.

2.2.6. The Sheringham Cliffs Formation was identified during the 2020 ground investigation at the western extents of the Proposed Scheme and as a ‘wedge’ at the east of the Proposed Scheme near Church Lane. The deposits are predominantly granular, however thin bands of clay and silt were noted at areas

east of Church Lane. It is present to a maximum depth of 13m. The Sheringham Cliffs Formation was found to overlie the Lowestoft Formation within the study area.

Happisburgh Glacigenic Formation

2.2.7. The Happisburgh Glacigenic Formation is included on BGS mapping as an undifferentiated formation with the Lowestoft Formation (see Annex A Location Plan). It is present north of Hockering and at a location within the River Tud floodplain north of Mattishall.

2.2.8. Further east, the Leet Hill Sand and Gravel Member is present within the River Tud floodplain at Taverham Road. It was encountered during the 2020 ground investigation and is noted to extend further southwards than as depicted on the BGS published mapping. The depth of the Happisburgh Glacigenic Formation increases southwards beneath the proposed Mainline and Norwich Road Junction westbound merge where it is present from a depth of 8.10mbgl. The Happisburgh Glacigenic Formation comprises both cohesive and granular units, and directly overlies the Chalk where present.

Cretaceous Chalk

2.2.9. Chalk bedrock is present across the entire Scheme and is generally overlain by superficial deposits, with the exception of two small outcrop areas adjacent to the River Tud and to the north of the Site to the east of Honingham. The Chalk profile is variable, noted to be present from a depth of 1.8mbgl at locations east of Hockering and towards Church Lane, and from a depth of 25.5mbgl at the western extent of the Scheme. The average depth to the Chalk rockhead is 12mbgl. A maximum thickness of 36.5m was encountered at locations close to the River Tud. However, the base of the Chalk was not proven.

2.2.10. In general, the Chalk profile varies roughly between elevations of 20 to 30m AOD west of Honingham, to between 10 and 20m AOD eastwards of the Honingham, with a reducing thickness of superficial deposits eastwards.

2.2.11. The Chalk encountered is ‘putty’ Chalk, classified as Grade Dm (matrix-dominant) and Grade Dc (clast-dominant). It was recovered predominantly as silty sandy gravel, and sandy, slightly gravelly silt. Competent, structured Chalk was not proven to a maximum depth of 50mbgl.

2.3. Hydrogeology

Aquifer designations

2.3.1. Table 2.1 summarises Environment Agency aquifer designations, along with their approximate extents within the study area, as per Annex A Location Plan.

Table 2.1 Environment Agency aquifer designations (DEFRA, 2020)

Geological Unit	EA Aquifer Designation	Approximate Extents
Lowestoft Formation - Diamicton	Secondary (undifferentiated) aquifer	Found at the higher elevations across the scheme, within the interfluves and valley sides.
Lowestoft Formation - Sand	Secondary A aquifer	A 1 x 0.5 km^2 outcrop is mapped between the River Tud and Mattishall, to the south of the Site.
Happisburgh Glacigenic Formation and Lowestoft Formation (Undifferentiated) – Sand and Gravel	Secondary A aquifer	Three patches of outcrop are located south of the existing A47 mainline west of Easton. The outrcrops are approximately up 0.35 x 0.15km^2.
Sheringham Cliffs Formation - Sands and gravels	Secondary A aquifer	Underlying topsoil or the Lowestoft Formation, within the interfluves and valley sides. Patches of the Sheringham Cliffs Formation outcrop across the scheme.
Alluvium and River Terrace Deposits	Secondary A aquifer	Present along the line of the River Tud and within incised valleys.
Alluvial Fan Deposits	Unproductive	A 0.2km^2 outcrop is located along the line of the River Tud at Berrys Lane, west of Honingham.
Chalk	Principal aquifer	Underlies the entire Study Area. The Chalk is shown on 1:50,000 mapping to outcrop north of the River Tud northwest of Easton.

2.3.2. The chalk bedrock is a Principal aquifer. Principal aquifers are strata that have high intergranular and/or fracture permeability, and as such usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale.

2.3.3. The superficial Sheringham Cliffs Formation, Lowestoft Formation – Sand, Happisburgh and Lowestoft (Undifferentiated), Alluvium, and River Terrace Deposits are classified as Secondary 'A' aquifers. Secondary A aquifers are permeable layers capable of supporting water supplied at a local, rather than strategic scale, and in some cases, form an important source of baseflow to rivers.

2.3.4. The Lowestoft Formation - Diamicton is classified as a Secondary (undifferentiated) aquifer. Secondary (undifferentiated) aquifers are classified as such due to the formation previously having been designated as both a minor

aquifer and non-aquifer (now defined as Secondary A and Secondary B respectively) in different locations, due to variable characteristics of the rock type. As such Secondary (undifferentiated) aquifers are likely to contain lower permeability layers and perched aquifers.

2.3.5. The Alluvial Fan Deposits are classed as unproductive and are impermeable.

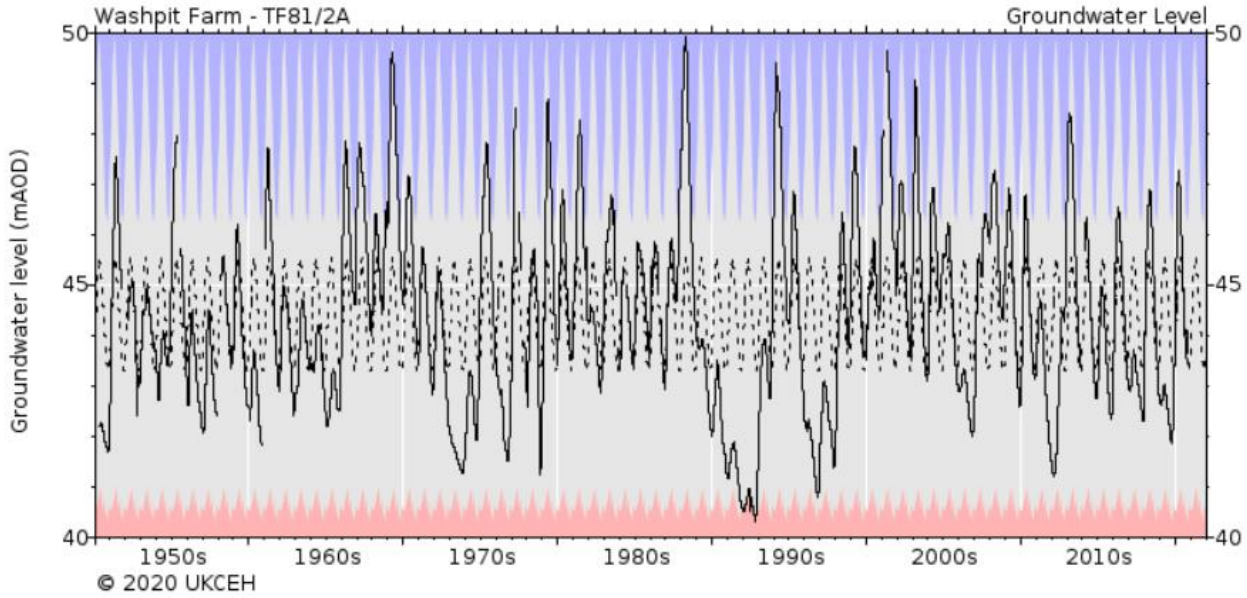
2.3.6. The bedrock and superficial deposits have a combined groundwater vulnerability classification of primarily Medium risk to the west and south of Honingham. The area underlain with the Alluvial Fan Deposits has a classification of Low risk. To the east and north of Honingham, the groundwater vulnerability classification is Medium – High risk. An area where the Chalk outcrops at Osier Carr, east of Honingham, has a classification of Medium – Low risk, although the reason for the classification here is unclear.

Groundwater levels and flows

Regional groundwater level monitoring and modelling

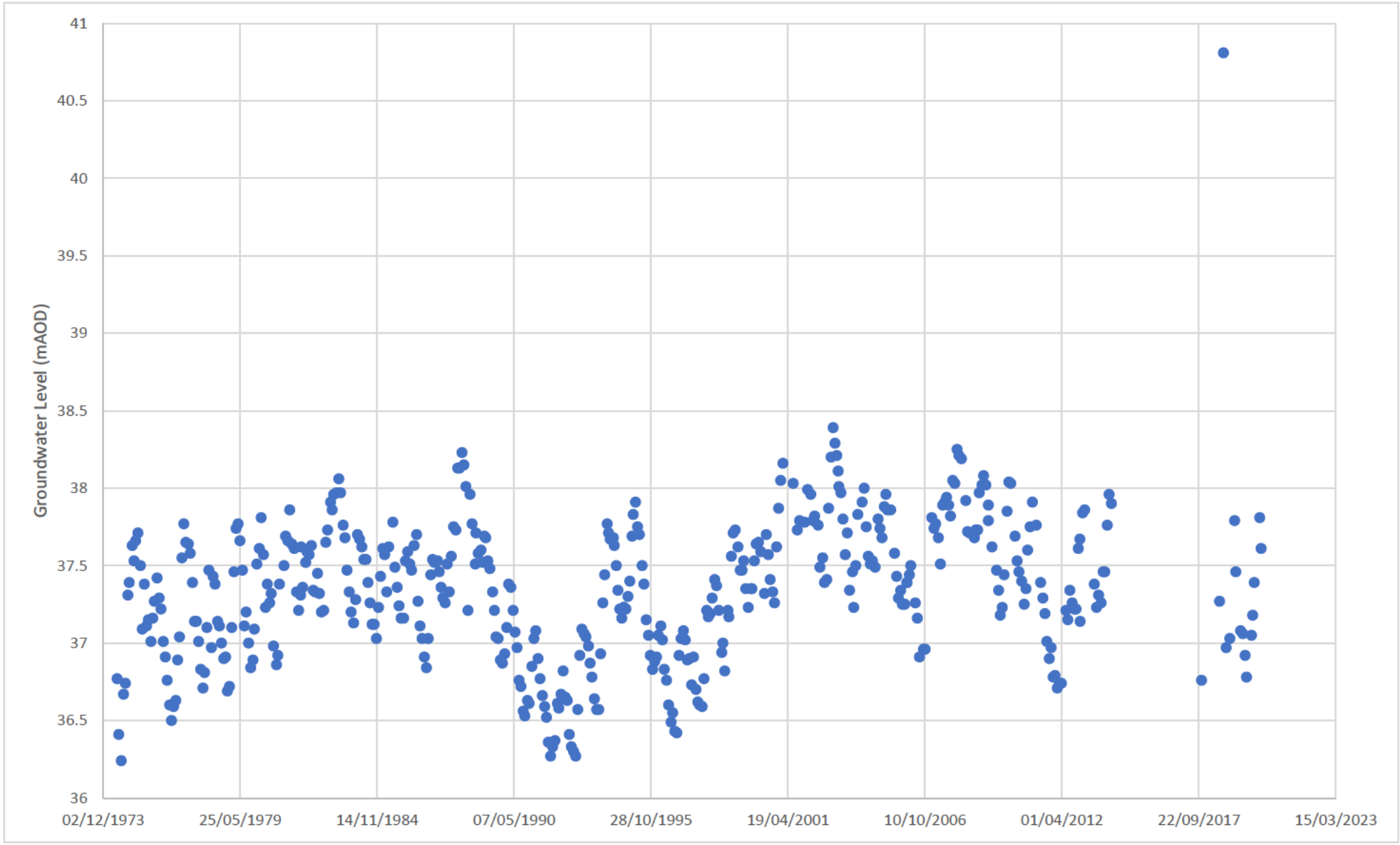
2.3.7. BGS groundwater monitoring has been undertaken within the unconfined Chalk of the Broadland Rivers Chalk and Crag waterbody at Washpit Farm, Rougham, approximately 20km northwest of the Proposed Scheme, between 1950 and 2020 (BGS, 2020b). The monitoring hydrograph (Figure 2.1) shows a groundwater level range of approximately 9.5m, between 40.5mAOD and 50mAOD, although a more typical seasonal range is 2m. The monitoring data from 2020 indicates a wetter than average spring and early summer, followed by average groundwater conditions over the later summer and autumn months.

Figure 2.1 Washpit Farm Chalk groundwater levels (BGS, 2020b)



2.3.8. Groundwater monitoring provided by the Environment Agency at the Council House site within the 1km study area north of Hockering is available between 1974 and 2020. The groundwater monitoring hydrograph is shown in Figure 2.2. It is assumed that this location monitors Chalk groundwater, based on nearby historical borehole logs (BGS, 2020a). Groundwater levels have ranged between 36.24 and 40.81mAOD with a seasonal range of around 1m and a long-term range of 2.15m, excluding the outlier from September 2018. As with the Washpit Farm observation borehole, groundwater monitoring at the Council House site suggests that recent groundwater levels are representative of average conditions, and that long-term maximum may be around 0.5m higher than those experienced in 2020.

Figure 2.2 Environment Agency groundwater monitoring at Council House, 1974 - 2020



2.3.9. The Northern East Anglia Chalk Groundwater Investigation Report for the Wensum and Tud catchments undertaken by the Environment Agency (EA, 2017) indicates that groundwater flow within the study area is primarily to the north and east, towards the River Wensum. Local variations in groundwater flow direction are also apparent, with groundwater controlled by both topography and local hydrology, including headwater streams.

2.3.10. Modelled groundwater flow in the Chalk within the Tud catchment strongly converges to the River Tud, although this becomes less apparent further east in the catchment where closer to the River Wensum, which has a greater control on groundwater levels and flow.

2.3.11. Modelling indicates that baseflow to the River Tud is perennial between Dereham, approximately 5km to the west of the study area, and Honingham. Further east and downstream, the modelling suggests that River Tud loses water to the Chalk during dry conditions, and flow is drawn to the River Wensum and also presumably the major public water supply abstractions in the Wensum catchment.

Site groundwater level monitoring

2.3.12. Groundwater strikes recorded during the 2020 ground investigation were encountered within the Alluvium, River Terrace Deposits, Sheringham Cliffs Formation, and the Chalk.

2.3.13. Groundwater monitoring installations primarily targeted the Chalk and the Lowestoft Formation, with the exception of BH104, BH133 and DS234 that were installed to monitor the Alluvium, and DS212, DS216 and DS218 that were installed to monitor the Sheringham Cliffs Formation.

2.3.14. Artesian groundwater was encountered in boreholes BH108A, BH108, BH127, BH128 and BH129, and CPT604, CPT605, CPT606, CPT503I, CPT503J, and CPT503K. Any monitoring installations in artesian boreholes were extended above ground to prevent flooding and ensure aquifer protection.

2.3.15. A summary of the ground investigation groundwater monitoring is provided in Table 2.2.

Table 2.2 2020 ground investigation groundwater monitoring summary

Borehole Reference Number	Ground Elevation (m aOD)	Response Zone Depths (m bDAT)	Response Zone Stratigraphy	Min GW level (m bGL)	Min GW level (m aOD)	Date	Max GW level (m bGL)	Max GW level (m aOD)	Date
BH101	43.50	26.50 – 28.50	Chalk	3.62	39.88	25/08/20	3.02	40.48	21/05/20
BH101	43.50	11.00 – 13.00	Lowestoft Formation	3.66	39.84	06/07/20	2.3	41.20	28/05/20

Borehole Reference Number	Ground Elevation (m aOD)	Response Zone Depths (m bDAT)	Response Zone Stratigraphy	Min GW level (m bGL)	Min GW level (m aOD)	Date	Max GW level (m bGL)	Max GW level (m aOD)	Date
BH102	43.34	13.00 – 18.00	Lowestoft Formation	11.05	32.29	02/09/20	10.86	32.48	21/05/20
BH103	40.02	8.00 – 11.00	Lowestoft Formation	8.22	31.80	02/09/20	6.61	33.41	21/05/20
BH104	34.11	1.00 – 5.00	Alluvium	3.38	30.73	18.08.20	2.9	30.85	18/05/20
BH106		1.00 – 5.00	Lowestoft Formation	DRY	DRY		DRY	DRY	
BH107		1.00 – 5.00	Lowestoft Formation	DRY	DRY		DRY	DRY	
BH108	29.93	4.00 – 7.00	Lowestoft Formation	1.37	28.56	26/08/20	-0.2	30.13	12/05/20
BH108	29.93	11.00 – 13.00	Chalk	1.02	28.91	12/05/20	-0.31	30.24	21/05/20
BH108A	28.52	4.50 – 5.50	Chalk	-0.66	29.18	12/05/20	-0.75	29.27	03/09/20
BH108A	28.52	8.00 – 10.00	Chalk	-0.7	29.22	07/07/20	-1.32	29.84	12/05/20
BH109	32.20	1.00 – 3.00	Lowestoft Formation	DRY	DRY		DRY	DRY	
BH111	35.53	5.50 – 6.50	Lowestoft Formation	5.1	30.23	25/08/20	4.61	30.72	21/05/20
BH113	35.83	5.50 – 8.50	Lowestoft Formation	6.42	29.41	21/05/20	5.48	30.35	28/05/20
BH115	36.07	18.00 – 30.00	Chalk	4.89	31.18	02/09/20	4.61	31.46	27/07/20
BH117	49.20	13.00 – 14.70	Lowestoft Formation	DRY	DRY	22/07/20	12.38	36.83	27/07/20
BH119	49.92	11.00 – 15.00	Lowestoft Formation	12.53	37.40	07/05/20	12.00	37.93	20/03/20
BH120	43.09	2.00 – 5.00	Lowestoft Formation	DRY	DRY		DRY	DRY	
BH121	44.29	20.00 – 22.00	Chalk	11.65	32.64	07/05/20	10.54	33.75	09/04/20
BH122	45.61	6.00 – 9.00	Lowestoft Formation	DRY	DRY		8.52	37.08	20/03/20
BH125	33.21	10.00 – 13.00	Chalk	5.37	27.84	03/09/20	4.69	28.52	31/03/20
BH125	33.21	4.00 – 6.00	Lowestoft Formation	4.38	28.83	03/09/20	3.35	29.86	31/03/20
BH127	22.51	15.00 – 20.00	Chalk	0.31	22.20	07/07/20	-0.25	22.76	07/05/20
BH128	22.26	41.00 – 50.00	Chalk	-0.54	22.80	26/08/20	-0.92	23.18	21/08/20
BH133	27.05	6.00 – 11.00	Alluvium	5.35	21.70	25/08/20	5.03	22.02	28/05/20

Borehole Reference Number	Ground Elevation (m aOD)	Response Zone Depths (m bDAT)	Response Zone Stratigraphy	Min GW level (m bGL)	Min GW level (m aOD)	Date	Max GW level (m bGL)	Max GW level (m aOD)	Date
BH134	35.77	5.00 – 10.00	Lowestoft Formation	8.03	27.74	03/09/20	6.96	28.81	15/05/20
BH136	41.18	4.00 – 6.00	Lowestoft Formation	DRY	DRY		DRY	DRY	
BH137	23.36	5.00 – 8.00	Chalk	2.77	20.59	03/09/20	1.64	21.72	20/03/20
BH138	31.81	3.00 – 6.00	Lowestoft Formation	DRY	DRY	-	5.96	25.85	21/05/20
BH140	38.40	3.00 – 6.00	Lowestoft Formation	DRY	DRY		DRY	DRY	
BH140	38.40	14.50 – 16.50	Chalk	DRY	DRY		15.31	23.01	14/04/20
BH141	45.25	5.00 – 8.00	Lowestoft Formation	DRY	DRY		DRY	DRY	
DS201	48.53	5.00 – 10.00	Lowestoft Formation	6.47	42.06	02/09/20	5.27	43.26	12/05/20
DS205	44.84	1.00 – 5.00	Lowestoft Formation	5.18	39.66	25/08/20	2.1	42.74	02/09/20
DS206	45.43	0.30 – 6.30	Lowestoft Formation	3.56	41.87	02/09/20	1.86	43.57	18/05/20
DS207	50.39	1.00 – 3.00	Lowestoft Formation	DRY	DRY	-	2.3	48.09	02/09/20
DS209	38.21	5.00 – 7.00	Lowestoft Formation	DRY	DRY		DRY	DRY	
DS212	44.74	3.00 – 6.00	Sheringham Cliffs Formation	DRY	DRY		DRY	DRY	
DS216	49.76	2.00 – 5.00	Sheringham Cliffs Formation	DRY	DRY		DRY	DRY	
DS218	51.50	3.00 – 6.00	Sheringham Cliffs Formation	DRY	DRY		DRY	DRY	
DS221	51.04	7.00 – 9.00	Lowestoft Formation	DRY	DRY		DRY	DRY	
DS223	49.98	1.00 – 5.00	Lowestoft Formation	DRY	DRY		DRY	DRY	
DS229	34.93	9.00 – 11.00	Lowestoft Formation	7.24	27.69	03/09/20	5.71	29.22	31/03/20
DS231	40.44	4.00 – 5.00	Lowestoft Formation	3.00	37.44	03/09/20	1.97	38.47	21/05/20
DS234	28.45	8.00 – 12.00	Alluvium	6.64	21.81	25/08/20	6.27	22.18	21/05/20
DS236	32.57	1.00 – 3.00	Lowestoft Formation	DRY	DRY		1.35	31.22	18/05/20
DS238	28.86	8.00 – 11.00	Chalk	6.34	22.52	20/03/20	7.45	21.41	03/09/20

Borehole Reference Number	Ground Elevation (m aOD)	Response Zone Depths (m bDAT)	Response Zone Stratigraphy	Min GW level (m bGL)	Min GW level (m aOD)	Date	Max GW level (m bGL)	Max GW level (m aOD)	Date
DS241	37.93	6.00 – 10.00	Lowestoft Formation	DRY	DRY		DRY	DRY	
DS242	41.18	1.00 – 3.00	Lowestoft Formation	DRY	DRY		DRY	DRY	
DS244	36.26	3.00 – 6.00	Lowestoft Formation	DRY	DRY		5.3	30.96	30/03/20
DS245	29.32	4.00 – 5.00	Lowestoft Formation	DRY	DRY		DRY	DRY	

2.3.16. Groundwater levels were recorded over the summer of 2020 and are plotted on the hydrograph in Figure 2.3. Groundwater levels range between around 48mAOD and 20mAOD across the site and show a generally eastwards groundwater flow direction.

2.3.17. Shallow and artesian groundwater levels were recorded in the Chalk aquifer during the 2020 ground investigation, notably where the Proposed Scheme crosses the River Tud at Honingham and a tributary of the River Tud southeast of Hockering.

2.3.18. Interactions between the artesian Chalk groundwater and the groundwater levels within the overlying Alluvium within the River Tud floodplain are shown in Figure 2.4. The groundwater within these boreholes strongly follow the same trend.

2.3.19. In the interfluves, groundwater levels within Chalk groundwater and the overlying Lowestoft Formation (Figure 2.5) show a strong matching trend, with Chalk groundwater level generally 1m below the Lowestoft Formation.

Figure 2.3 2020 ground investigation groundwater monitoring hydrograph from manual dip data

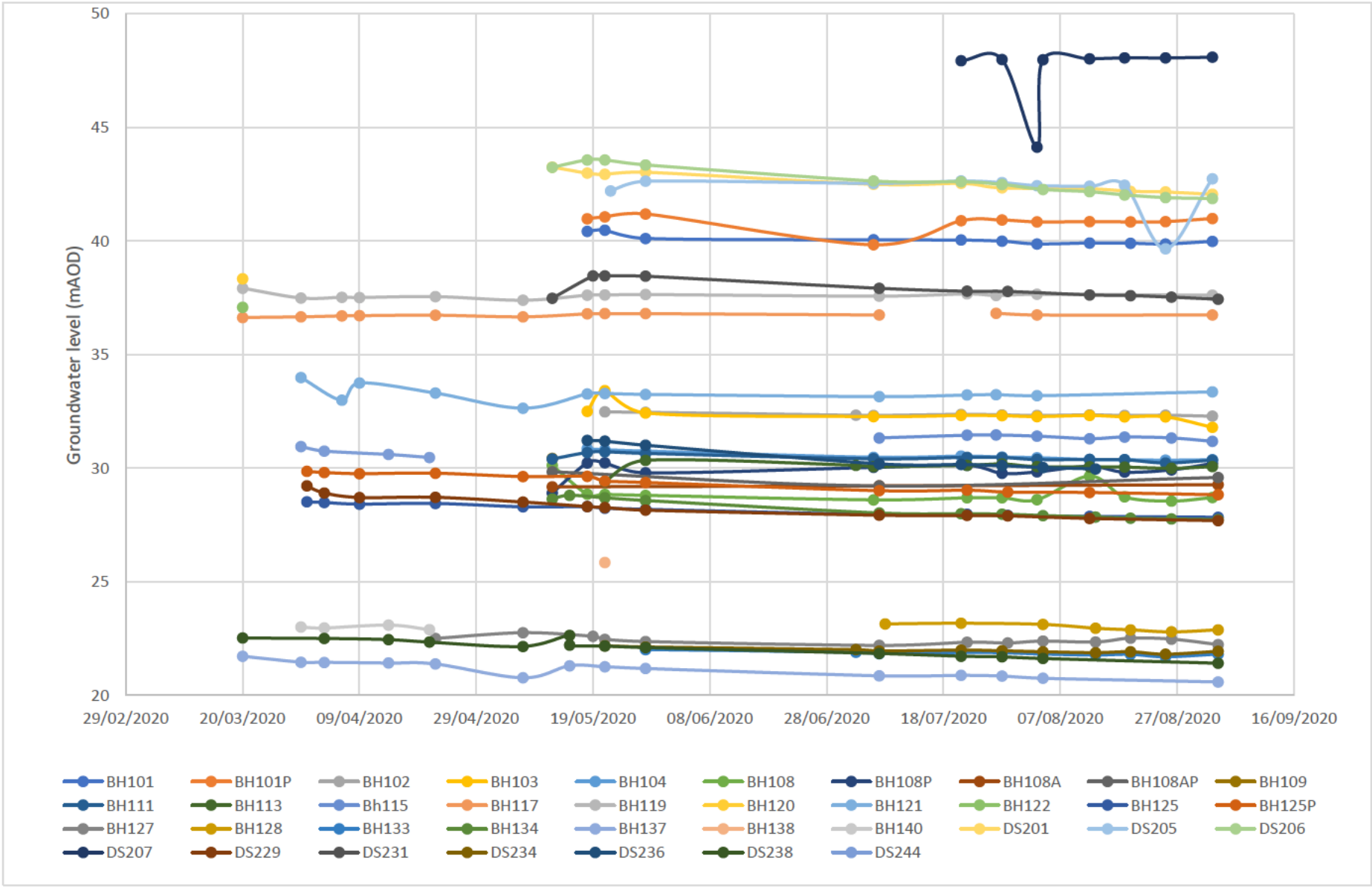


Figure 2.4 2020 ground investigation groundwater monitoring data hydrograph - interactions between Chalk and Alluvium groundwater

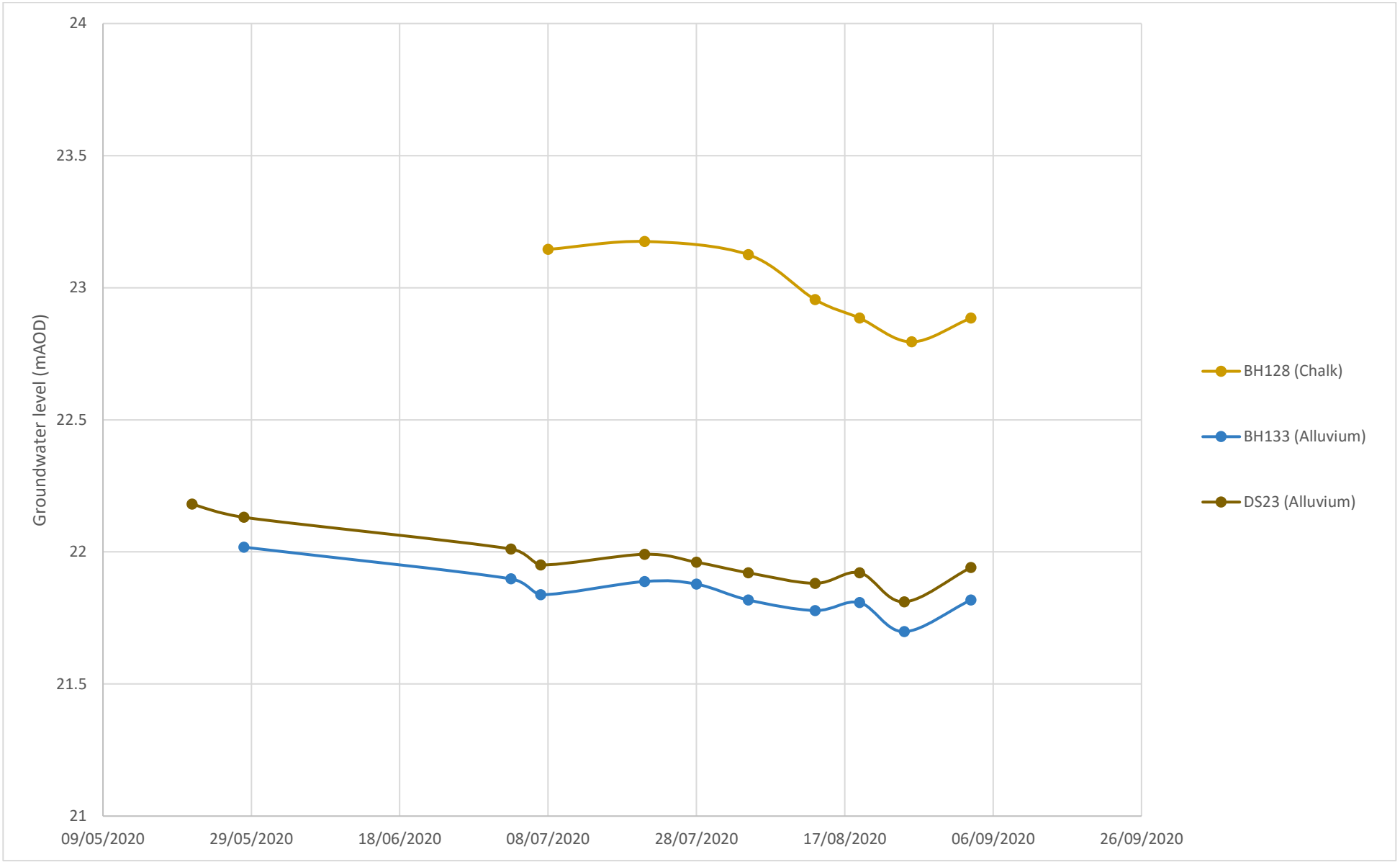
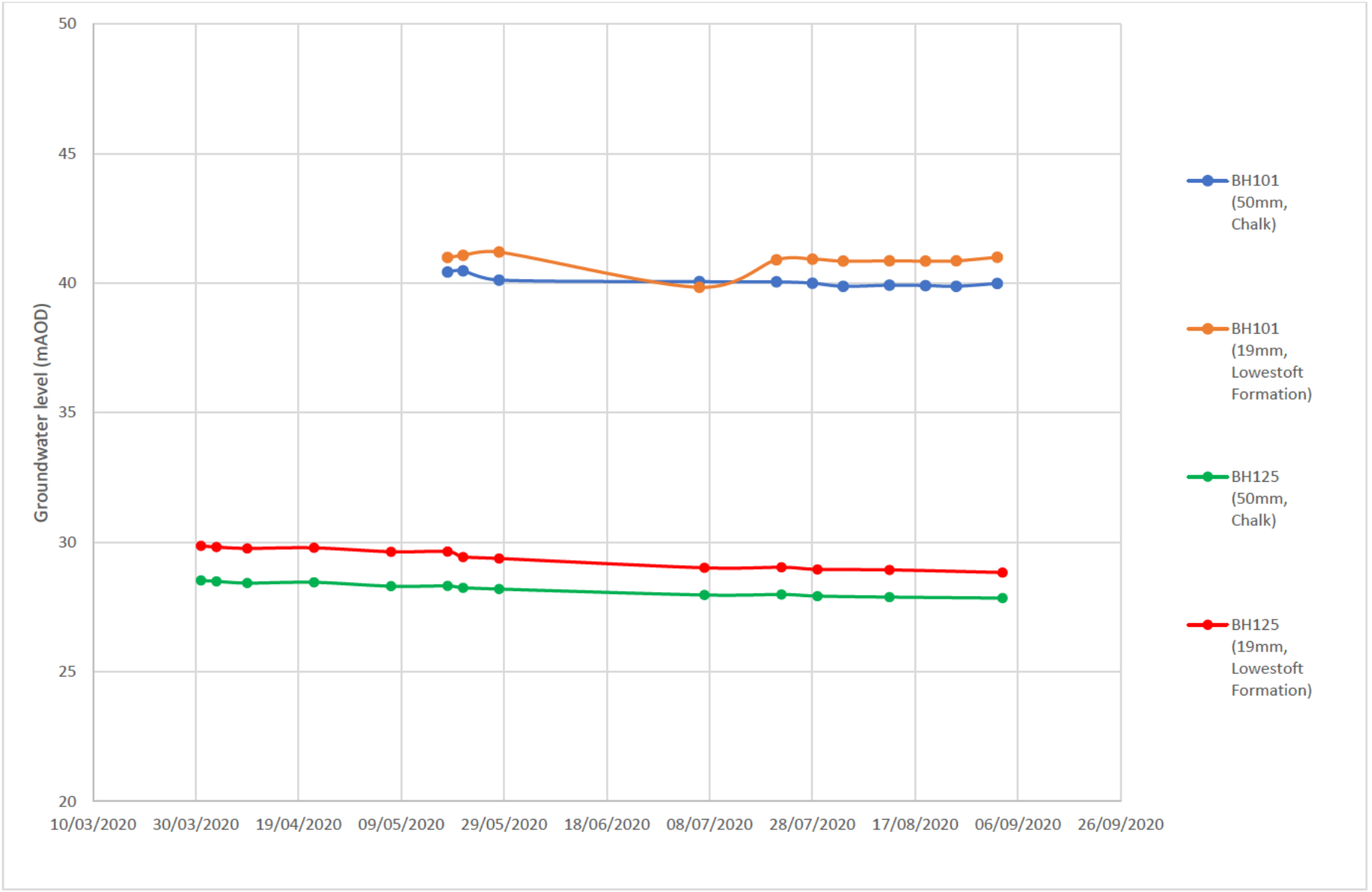


Figure 2.5 2020 ground investigation groundwater monitoring data hydrograph - interactions between Chalk and Lowestoft Formation groundwater



Discussion of site groundwater level monitoring

2.3.20. The groundwater within the study area is semi-confined by peat and low permeability layers within the River Tud floodplain and confined by low permeability layers of the Lowestoft Formation within the interfluves.

2.3.21. Figure 2.4 shows that artesian Chalk and Alluvium groundwater levels at the location of the River Tud Bridge crossing follow the same trend indicating that close to the River Tud there is a component of upward leakage into the superficial deposits, and which also likely provides baseflow to the River Tud.

2.3.22. This relationship is also noted in a tributary of the River Tud that flows southwards through Hockering, at BH108A. However, groundwater monitoring at at tributary of the River Tud at Oak Farm (BH101 and DS205), at the western extent of the Scheme and underlain by clay dominated Lowestoft Formation, indicates that there is a disconnect between the watercourse and the groundwater level.

2.3.23. In the interfluves, groundwater levels differ by 1m between Chalk and the overlying Lowestoft Formation (Figure 2.5), possibly due to different hydraulic properties between the two aquifers.

2.3.24. Groundwater flow within the Study Area is shown to be driven by the Chalk and is predominantly towards the east, locally controlled by the River Tud. It is likely that there are is an enhanced pathway through the superficial deposits within the incised valleys, and therefore flow converges towards the river.

2.3.25. Although the regional groundwater modelling indicates that there may be a component of groundwater flow towards the River Wensum to the east of Honingham, the groundwater monitoring data shows artesian groundwater conditions in the location of the new River Tud bridge, and therefore the River Wensum's control on groundwater flow within the study area is likely to occur much further east of this location. Although not confirmed specifically by groundwater monitoring, it is assumed that there may also be some local control on groundwater flows adjacent to licensed groundwater abstractions and private water supplies.

2.3.26. Groundwater level monitoring has been undertaken throughout the summer of 2020 only, and therefore it is unlikely that the seasonal maximum groundwater level has been recorded. It is assumed at present that groundwater levels may be approximately 1m higher than the maximum recorded level in Table 2.2, based on the seasonal range from Environment Agency monitoring data at Council House.

Aquifer Properties

2.3.27. The properties of the aquifer define its capacity to release water and the ability of groundwater flow to be transmitted with ease.

2.3.28. The Lowestoft Formation largely confines the underlying Chalk aquifer within the study area. However, the formation includes permeable horizons which contain groundwater which may be perched or fed by upward leakage from the Chalk.

2.3.29. The Secondary A Alluvium aquifer was saturated where found within the River Tud floodplain and is likely hydraulically linked to the Chalk aquifer via upward leakage, and the River Tud. The Sheringham Cliffs Formation Secondary A aquifer was found to be dry where intersected.

2.3.30. The Chalk aquifer is fully saturated and under artesian pressure within the incised valley at the proposed crossing of the River Tud. Transmissivity values from historical pumping tests for the Chalk within the Tud catchment average 275m^2/day (Allen et al, 1997). The full thickness of the structureless upper chalk is unknown and was not proved to 50 metres below ground level (mbgl) during the 2020 ground investigation.

2.3.31. The permeable superficial deposits are interpreted to be in hydraulic continuity with the Chalk, and baseflow to surface watercourses from the Chalk likely flows primarily through permeable layers within the Alluvium and River Terrace Deposits. The River Tud is assessed to have a baseflow index of 0.64 at Costessey Park suggesting a high degree of groundwater supply to river flows (Centre for Ecology and Hydrology, 2020b).

2.3.32. Ten permeability tests were undertaken within selected boreholes monitoring the superficial deposits during the 2020 ground investigation. Results from these permeability tests are summarised in Table 2.3. The permeability of the Chalk aquifer was not tested.

2.3.33. Permeability test results range between $7.33x10^{-6}$ m/s and $1.21x10^{-4}$ m/s within the cohesive Lowestoft Formation and $2.61x10^{-5}$m/s and $1.48x10^{-4}$m/s within the granular Lowestoft Formation. The cohesive Lowestoft Formation has a large range, over two magnitudes. It is possible that the permeability test undertaken in DS231 is anomalous or may be due to a higher than anticipated gravel content within the monitored lithology.

Table 2.3 2020 ground investigation permeability test results

Borehole	Response Zone (mbgl)	Response Zone lithology	Test type	Permeability (m/s)
BH102	13.00 – 18.00	Sand and gravel (Lowestoft Formation)	Falling head	$1.48x10^{-4}$
BH106*	1.00 – 5.00	Sand and gravel (Lowestoft Formation)	Falling head	$8.87x10^{-5}$
BH108	4.00 – 7.00	Sand and gravel (Lowestoft Formation)	Rising head	$7.41x10^{-5}$
BH109	1.00 – 3.00	Clayey sand (Lowestoft Formation)	Falling head	$7.33x10^{-6}$
BH111	5.50 – 6.50	Sandy clay (Lowestoft Formation)	Falling head	$2.78x10^{-5}$
BH119	11.00 – 15.00	Sand and gravel (Lowestoft Formation)	Rising head	$5.65x10^{-5}$
BH134	5.00 – 10.00	Sand and gravel (Lowestoft Formation)	Rising head	$2.61x10^{-5}$
BH136*	4.00 – 6.00	Sand and gravel (Lowestoft Formation)	Falling head	$5.03x10^{-5}$
DS218*	3.00 – 6.00	Sand and gravel (Sheringham Cliffs Formation)	Falling head	$3.64x10^{-5}$
DS231	4.00 – 5.00	Gravelly silty clay (Lowestoft Formation)	Falling head	$1.21x10^{-4}$

*Borehole not saturated during test

Groundwater quality

2.3.34. Groundwater and soil quality sampling were carried out as part of the 2020 ground investigation. Surface water quality monitoring was also undertaken at Oak Farm Stream which will receive road drainage as part of the proposed design.

2.3.35. Groundwater sampling results reported from laboratory analyses were compared against WFD and EQS screening values in terms of risk to surface water and groundwater. Exceedances of NH4, Mercury, Nickel and Zinc were noted. However, the exceedances were negligible and therefore do not pose an unacceptable risk to controlled waters. A summary of the sampling results of key road drainage pollutants, comprising copper, zinc and chloride are provided in Table 2.4

Table 2.4 Summary of groundwater and surface water quality results from the 2020 ground investigation and surface water sampling

Location	Depth (mbgl) / Date	Sample lithology	Copper (µg/l)	Zinc (µg/l)	Chloride (mg/l)
BH108	1.04	Cohesive Lowestoft Formation	<5	<2	949
BH119	12.37	Granular Lowestoft Formation	<5	5	63
BH125	10	Chalk	<5	2	22
BH127	0.1	Alluvium	<5	54	58
DS206	2.19	Cohesive Lowestoft Formation	<5	<2	949
DS234	8	Alluvium	<5	<2	18
DS238	8	Chalk	<5	8	29
Oak Farm Stream	24/09/2020	-	12	13	-
Oak Farm Stream	29/10/2020	-	1	3	-
Oak Farm Stream	01/12/2020	-	1	2	-
Oak Farm Stream	16/12/2020	-	1	2	-
Oak Farm Stream	12/01/2021	-	1	2	-

2.3.36. Soil leachability results reported from laboratory analyses were compared against WFD and EQS screening values in terms of risk to groundwater. Exceedances of nitrogen as NH_4, metals, PAHs and TPHs were recorded. Of these exceedances, only PAH and TPH is considered as a potential risk to controlled waters, both from DP419.

2.3.37. There are no known Environment Agency groundwater quality network monitoring points within the study area.

2.4. Groundwater resources

Groundwater abstractions

2.4.1. The Proposed Scheme crosses a source protection zone (SPZ) 3 (Total Catchment) between Honingham and Easton. This is associated with major groundwater abstractions to the northeast, south and southeast of the scheme.

2.4.2. The Proposed Scheme also crosses an SPZ 1 (Inner Zone) for a new public water supply east of Hockering, at Church Lane. The extents of the SPZ for this

source have not, as yet, been confirmed by the Environment Agency, although a 1km stretch of the Proposed Scheme immediately to the north of the public water supply is assumed to represent the SPZ 1.

2.4.3. A further SPZ 3 is present within the 1km study area boundary, located approximately 250m to 1000m north of the Proposed Scheme. This SPZ is associated with public water supply abstractions 4km north of the study area at Lyng and includes a drinking water safeguard zone for groundwater.

2.4.4. There are two known licensed groundwater abstractions within the study area at Easton. These abstractions are summarised in Table 2.5.

Table 2.5 Licensed abstractions within the 1km study area, provided by the Environment Agency in 2020

License number	Use	Abstraction point name	Source of supply
7/34/13/*G/0166	Make-Up Or Top Up Water	Borehole at Easton	Groundwater
7/34/13/*G/0166	Spray Irrigation - Direct	Borehole at Easton	Groundwater

2.4.5. The district councils have been contacted for details of unlicensed private water supplies. At time of writing, only Breckland Council have provided details of private water supplies near to the scheme. South Norfolk and Broadland district councils are yet to respond.

2.4.6. There are 26 unlicensed abstractions within the part of the 1km study area belonging to Breckland Council. The locations are shown within Annex A Location Plan and are generally clustered in the following locations:

- Fox Lane Junction, and the wider study area east of Hockering
- Blois Bridge and Church Lane
- south of the Scheme at Berrys Lane

2.4.7. Details of the abstraction uses, and aquifer units abstracted, have not been provided.

Consented discharges to groundwater

2.4.8. According to data received from the Environment Agency in April 2020 there are 6 active consented discharges to groundwater within the study area (see Table 2.6). These are situated between 0.25km and 1.1km from the Site.

Table 2.6 Consented discharges to groundwater within the 1km study area, provided by the Environment Agency in 2020

Consent number	Use	Receiving water body
EPR-KB3995WJ	Discharge into land of secondary treated sewage effluent	Groundwater via an infiltration system
PR4LF84215	Discharge of domestic sewage from a septic tank and soakaway system	Groundwater via an infiltration system
EPR-AB3099AM	Discharge into land of secondary treated sewage effluent	Groundwater
EPR-MP3724GQ	Discharge into land of secondary treated sewage effluent	Groundwater
NPSWQD009058	Trade effluent derived from heat exchange use of abstracted groundwater	Groundwater
PR4LF69	Discharge of sewage effluent from a septic tank soakaway system	Groundwater via an infiltration system

2.5. Water Framework Directive

2.5.1. The study area is within the Broadland Rivers Chalk and Crag WFD groundwater body (GB40501G400300) and is part of the Broadland Rivers Chalk and Crag Operational Catchment and the Anglian Groundwater Management Catchment (EA, 2020). A summary of the groundwater body is given in Table 2.7.

Table 2.7 Summary of WFD groundwater bodies within the study area

Feature	Designation
Water body ID	GB40501G400300
Water body name	Broadland Rivers Chalk and Crag Groundwater Body
Operational catchment	Broadland Rivers Chalk and Crag Operational Catchment
Management catchment	Anglian Groundwater Management Catchment
River basin district	Anglian
Type	Groundwater Body
Hydromorphological status	N/A
Overall classification (cycle 2 – 2019)	Poor
Current chemical quality (cycle 2 – 2019)	Poor
Overall objective	Good (by 2027)
Protected area (within the study area)	Yes, Nitrates Directive

2.5.2. The Broadland Rivers Chalk and Crag groundwater body (GB40501G400300) has poor chemical and quantitative status (2019 cycle 2). The quantitative status is limited by the Groundwater Dependent Terrestrial Ecosystems test which scored poorly due to agricultural abstractions lowering the natural flow and levels of the groundwater. The objective is to achieve 'good' quantitative status by

2021. The site is located within the Norwich Crag and Gravels groundwater Nitrate Vulnerable Zone and is a Drinking Water Protected Area.

2.6. Groundwater dependent terrestrial ecosystems

Sites of special scientific interest

2.6.1. Hockering Wood Site of Special Scientific Interest (SSSI) is the sole SSSI located within the 1km study area. This ancient woodland includes surface water features within its boundary comprising ponds and streams which may be fed by groundwater. Ponds within the area of the SSSI support breeding Great Crested Newts (DEFRA, 2020).

2.6.2. The SSSI woodland is located up hydraulic gradient of the Proposed Scheme. It is therefore not at risk of impact and is not considered in the assessment.

2.6.3. The River Wensum SSSI and Special Area of Conservation (SAC) is located within the study area, approximately 1.6km north of the Proposed Scheme at its closest point. The River Wensum is a chalk river and receives a significant portion of supply from baseflow from the underlying Chalk aquifer.

2.6.4. It is interpreted from groundwater monitoring that the River Tud, a chalk stream, receives baseflow from the underlying artesian Chalk via upward leakage within the study area. The River Tud feeds into the River Wensum SSSI east of Costessey. The River Tud is considered to be of equal ecological value as the River Wensum by the Norfolk Wildlife Trust (NWT, 2020).

2.6.5. The River Wensum SSSI and SAC is at a sufficient distance from the Proposed Scheme however, and furthermore is not directly down hydraulic gradient of the Proposed Scheme. It is therefore not considered to be at risk of impact and is not considered further in the assessment as an indirect groundwater receptor.

Priority Habitats

2.6.6. The River Tud is a Chalk Stream supplied by high groundwater levels driven by the Chalk principal aquifer. Groundwater dependent Priority Habitats Wetlands comprising Lowland Fens are located within the 1km Study Area, predominantly along the course of the River Tud but also 1km north of Honingham.

County Wildlife Sites

2.6.7. There are a number of County Wildlife Sites (CWS) located within the study area that are potentially fed by groundwater. These are summarised in Table 2.8.

Table 2.8 County wildlife sites (Norfolk Biodiversity Information Service, 2018)

Name	Grid Reference	Priority Habitat	Description
Gravel pits, East Tuddenham	TG 075118	N/A	Gravel pits used for trout fishing
Fen west of East Tuddenham	TG 090123	Lowland Fen	Marshy grasslands and stream
Adjacent to River Tud	TG128116	Floodplain Grazing Marsh	Wet meadow
Church meadow, Alder Carr, here Corner Thicket and Nursery Plantation	TG 114117	Lowland Fen and Floodplain Grazing Marsh	Unimproved wet pasture, spring fed ditches, wet woodland, wetland
The Waterfence	TG 106132	Lowland Fen and Floodplain Grazing Marsh	Wet grassland within a spring-fed valley
Fen Plantation	TG 098117	Lowland Fen	Damp semi-natural woodland on the south bank of the River Tud

2.7. Groundwater flooding

2.7.1. The BGS Susceptibility to groundwater flooding mapping dataset indicates that the majority of the Site lies within areas that has limited potential for groundwater flooding to occur. However, there is potential for groundwater flooding to above ground structures within the site boundary to the south and east of Hockering and north-east of Honingham. This occurs along the route of the River Tud at a ground level of approximately 25-35mAOD. This has been confirmed by the ground investigation as artesian Chalk groundwater levels have been observed in both locations.

2.7.2. Within the same area, there is also potential for groundwater flooding to subsurface structures. This corresponds to a ground level of approximately 35-40mAOD along the route of the River Tud.

2.8. Climate change

2.8.1. Climate change predictions suggest that the future annual recharge volumes for groundwater are broadly stable although the groundwater recharge season is likely to condense into a shortened period, leading to more variable groundwater levels and a greater drought vulnerability (Environment Agency, 2019).

2.9. Groundwater levels and flows assessment

2.9.1. This section provides a summary of findings, in the form of a conceptual hydrogeological model, and also highlights receptors and uncertainties relating to the datasets considered. This forms the basis of the Groundwater Levels and Flows assessment (as per the Design Manual for Roads and Bridges guidance document LA 113).

Hydrogeological conceptual model

2.9.2. The default study area comprises a 1km buffer zone of the Scheme based on professional judgement of the groundwater flow pathways this is considered appropriate.

2.9.3. The Study Area is found within the Broadland Rivers Chalk and Crag groundwater body (GB40501G400300) and is part of the Broadland Rivers Chalk and Crag Operational Catchment and the Anglian GW Management Catchment.

2.9.4. The main aquifer units in the study area are the granular layers within the Lowestoft Formation, the Sheringham Cliffs Formation, Alluvium, River Terrace Deposits, and the Chalk.

2.9.5. The Chalk is semi-confined by overlying deposits of cohesive Lowestoft Formation within the interfluves where groundwater levels are sub-artesian and is semi-confined by cohesive layers of Alluvium and peat within the River Tud floodplain where groundwater levels are artesian.

2.9.6. Chalk groundwater levels from the limited 2020 monitoring period range between 40.5mAOD and 20.5mAOD. Groundwater levels within the superficial deposits range between 48 and 21.8mAOD

2.9.7. The groundwater level monitoring indicates that levels are predominantly controlled by the Chalk. Groundwater from the Chalk feeds into the overlying superficial deposits by upward leakage, and to the River Tud via baseflow.

2.9.8. Groundwater monitoring and modelling across the site shows the groundwater flow direction to be predominantly to the east and north, towards the River Tud and the River Wensum.

2.9.9. Although not indicated by the current monitoring, it is anticipated that the licensed and unlicensed abstractions also act as local controls on groundwater levels and flow.

2.9.10. Permeability test results from the 2020 ground investigation range between $7.33x10^{-6}$ m/s and $1.21x10^{-4}$ m/s within the cohesive Lowestoft Formation and $2.61x10^{-5}$m/s and $1.48x10^{-4}$m/s within the granular Lowestoft Formation.

2.9.11. The Chalk within the study area is entirely ‘putty’ structureless Chalk. Competent Chalk with structures was not proven to a maximum depth of 50mbgl. Permeability in the Chalk was not tested during the ground investigation as it is anticipated to be too large to determine from single well tests in 50mm diameter

installations. The average transmissivity of the Chalk within the Tud catchment is 275m^2/day (Allen et al, 1997).

2.9.12. The Study Area is within a source protection zone (SPZ) 3 (Total Catchment) between Honingham and Easton for public water supply abstractions. The Proposed Scheme also crosses an SPZ1 (Inner Zone) east of Hockering for a new public water supply abstraction at East Tuddenham.

2.9.13. There are two licensed abstractions from the Chalk within the study area and 26 known unlicensed private water supplies. It is not known what aquifer units the private water supplies abstraction from. The locations of these abstractions are shown within Annex A Location Plan.

2.9.14. Groundwater dependent terrestrial ecosystems within the Study Area comprise the River Tud Chalk Stream, and Lowland Fen Priority Habitats predominantly within the River Tud Floodplain.

Receptors

2.9.15. The identified direct groundwater receptors within the Study Area are as follows:

- Aquifer units of the Broadland Rivers Chalk and Crag groundwater body (GB40501G400300), comprising:
  - Alluvium
  - River Terrace Deposits
  - Lowestoft Formation
  - Happisburgh Glacigenic Formation
  - Chalk Group

2.9.16. The 2020 ground investigation exploratory holes were placed at key structures of the Proposed Scheme. These exploratory holes proved the Sheringham Cliffs Formation was not present at these locations and are therefore not considered to be direct receptor of risk from the Proposed Scheme.

2.9.17. The identified indirect groundwater receptors within the Study Area are:

- The River Tud Chalk Stream
- Lowland Fen Priority Habitats
- Groundwater abstractions located east of, and including, private water supply P227CO0141 approximately 1km west of Hockering, as per Annex A Location Plan.

2.9.18. The known private water supplies west of P227CO0141 are at present considered to not be at risk from the Scheme, due to being located up-hydraulic

gradient of, and at a sufficient distance from, structures that pose risk to groundwater resources. This will be reviewed following receipt of the addendum ground investigation report, private water supply details from South Norfolk and Breckland councils, confirmation of the SPZ for the newly proposed public water supply abstraction at East Tuddenham, and completion of the baseline groundwater level monitoring and detailed dewatering assessments, if required.

Limitations and Uncertainty

2.9.19. Proposed structures may require works to be undertaken intersecting the Chalk aquifer. Further investigations are required to ascertain accurate hydraulic properties of this aquifer in order to understand any potential dewatering requirements and subsequent impacts of construction. Further details of construction methods will also be required to assess the associated dewatering requirements.

2.9.20. The groundwater monitoring information from the ground investigation is limited to the summer of 2020, and therefore is unlikely to have captured the maximum seasonal groundwater levels. Furthermore, groundwater monitoring data from some borehole locations is yet to be received at the time of writing.

2.9.21. Information on private water supplies has been requested from local councils. At present, only Breckland Council have responded with information. Therefore, no risk assessments have been undertaken on private water supplies within these districts.

3. Potential impacts

3.1.1. The key intrusive structures that may have the potential to impact on groundwater are summarised in Table 3.1, along with their maximum depths. There are also a number of cuttings across the Proposed Scheme up to a maximum depth of 8m.

Table 3.1 A summary of the key proposed intrusive structures that pose risk to the groundwater environment

Structure	Activities	Maximum structure depth (mbgl)
Utilities	Pipeline diversions	2
Gas main pipeline	Horizontal direction drilling	10
Cutting west of S05, located at DS231 (Annex B)	Cutting intersecting groundwater	2.36
S01 Culvert/embankment	Ground improvement and sewer diversion	3
S03 & S04 Wood Lane junction / Hall Farm underpass	Underpass construction and piling	4.06
S05 River Tud Crossing overbridge	Overbridge construction, piling and ground improvement	25
S07 Norwich Road junction underpass	Underpass construction and piling	7.1
S16 Mattishall Lane underpass	Underpass construction	8
S18 Honingham Church underpass	Underpass construction intersecting groundwater	4.5

3.1.2. There are a number of utilities diversions in the study area, which mainly occur around road junctions. The depth of utilities diversion excavations is likely to be less than 2m where open cut methods are to be used, but may be more than 10m where directional drilling is used, such as for the gas main works adjacent to the Wood Lane junction. In addition to the road junction locations listed above, utilities diversions will also be required at the Church Lane junction, in the area identified as a preliminary SPZ1 for the new Anglian Water public water supply.

3.1.3. The proposed drainage design includes filter drains in all drainage catchments, which have the potential to discharge to ground. The filter drains are anticipated to include a permeable geotextile membrane filter. Discharge to ground is also anticipated at Oak Farm tributary, which will receive road drainage via outfall but has been assessed as an infiltration feature due to low flows.

3.1.4. The existing A47 road will be retained as an access road. As such, the existing drainage will be retained where possible. Eight of the existing ten soakaways are anticipated to superseded by the proposed drainage design where the proposed route follows the existing mainline, and may therefore be

decommissioned. Two soakaways are anticipated to be retained, where the existing mainline is to be retained as an access road.

3.1.5. A simple hydrogeological assessment of the construction and operational activities relating to these structures is presented in Table 3.2 and 3.3. This includes the results of simple Sichardt empirical calculations was used to estimate the potential radius of influence of excavations that may intersect groundwater. Based on the available information, the two areas that are confirmed to intersect groundwater are the cutting to the west of the River Tud overbridge (adjacent to DS231; maximum depth 2.63m), and the Honingham Church underpass. The results of these calculations are presented in Annex E Sichardt calculations of Radius of Influence. The radius of influence for these locations, using worst case permeability of $1.21x10^{-4}$ m/s, are 76.7m and 26.3m respectively.

3.1.6. The use of the Sichardt formula is discussed within the Environment Agency's guidance document Hydrogeological Impact Appraisal for Dewatering Abstractions (2007). Whilst the formula provides an estimate of the radius of influence, it is limited due to not being consistent with the principle of the impact of an abstraction spreading until it has captured sufficient water (EA, 2007). Therefore, the radius of influence results is a preliminary assessment of risk to nearby receptors. The radius of influence will be considered further at the detailed design stage following completion of the baseline groundwater level monitoring, addendum factual report and the supplementary ground investigation.

3.1.7. Intercepting groundwater may necessitate groundwater control measures to be incorporated in the construction methodology and operation design. Temporary dewatering will be subject to licensing, which requires a detailed Hydrogeological Impact Assessment (HIA) to be undertaken. The potential dewatering requirements will be considered further at the detailed design stage following completion of the baseline groundwater level monitoring, addendum factual report and the supplementary ground investigation.

3.1.8. Consultation with Anglian Water commenced in January 2021 regarding the new public water supply abstraction at East Tuddenham. Discussions focused on the ground conditions determined from the 2020 ground investigation, potential impacts from intrusive structures and the essential and embedded mitigation measures incorporated to date. Anglian Water noted the following;

- The abstraction at East Tuddenham is the only public water supply abstraction of concern, although there are significant number of private water supplies within the study area

- Turbidity generation from excavation works and future ground investigations are the impact of greatest potential concern
- Structures west of the abstraction pose the greatest risk to the East Tuddenham abstraction
- Diversions for utilities located within the Inner Source Protection Zone (SPZ1) for the abstraction do not pose a risk to the abstraction, as they are not anticipated to intersect the aquifer.

3.1.9. Anglian Water have requested assurances that additional monitoring boreholes will not result in contamination risks and that aquifer protection measures have been incorporated into the design, citing unexpected artesian conditions within the River Tud floodplain. Anglian Water have also requested that appropriate measures are taken to decommission the monitoring points at the end of the monitoring period. Discusions with Anglian Water are ongoing.

Table 3.2 Potential risk to the groundwater environment from construction activities

Activity	General Description of Potential Impact	Structure	Direct Receptor	Indirect receptor	Site specific potential impact	Potential impact?
Construction						
Drainage from construction areas, including site compounds	Removal of topsoil during construction works has the potential to increase the vulnerability of underlying aquifers. Accidental spillages / leakage of construction materials in such areas may result in contamination of groundwater	General & site compounds	Lowestoft Formation	River Tud Chalk downgradient abstractions GWDTEs	Satellite compounds at the proposed underpass at structures S16, S03 and S18, where underlain by the Secondary undifferentiated aquifer is potentially in direct hydraulic continuity with the Principal Chalk Aquifer. However, due to the variable permeability characteristics of the Lowestoft Formation, and the large unsaturated zone, this impact is considered negligible.	No
Drainage from construction areas, including excavations and cuttings	Excavations reduce the thickness of unsaturated zone above the receptor aquifer, thus increasing its vulnerability to groundwater contamination risks as a result of accidental spillages / leakage	S16 / S03 / S04 / S18 / S07 / ground improvement at S01 / all mainline cuttings	Lowestoft Formation Chalk	River Tud Downgradient abstractions GWDTEs	A significant proportion of the unsaturated thickness will be removed at S16, S03, S18 and S07, significantly increasing the vulnerability of the Chalk. S16 and S07 may intersect groundwater within the superficial deposits overlying the Chalk.	Yes
Excavations and piling	Potential creation of contamination transport pathways between ground & aquifers. Contamination of groundwater through direct contact with contaminated construction materials	Ground improvement at S01 / S05 Utilities diversions near S05 and Norwich Road junction Piling into the top of the Chalk at S03, S05 and S07	Alluvium Lowestoft Formation Chalk	River Tud Downgradient abstractions GWDTEs	Design of S05 overbridge foundations to comprise box sheet pile walls that will be embedded into Chalk bedrock. The design of underbridges at S03 and S07 may also require piles into the top of the Chalk. Ground improvement works at S01 may intersect shallow chalk bedrock (3.5mbgl) with artesian groundwater. Utilities diversions in the same location may intersect shallow groundwater in the Lowestoft Formation. Gas pipeline diversions near Wood Lane junction require directional drilling at depths of more than 10m, and there is a risk that the Chalk aquifer may be encountered. No excavations are anticipated to intersect contaminated land.	Yes
		Utilities diversions at all other junctions, including Church Lane	None	None	Utilities diversions likely to require shallow (~2m) excavations – with the exception of diversions near the S05 structure, these are unlikely to intersect groundwater in the superficial deposits.	No
	Potential creation of pathways and groundwater	Ground improvement at S01	Lowestoft Formation	River Tud	The release of artesian groundwater from the Chalk has the potential to cause	Yes

Activity	General Description of Potential Impact	Structure	Direct Receptor	Indirect receptor	Site specific potential impact	Potential impact?
	flooding from artesian pressure	/ S05 / Utilities diversion near S06		Downgradient abstractions GWDTEs	flooding problems, and potentially contaminate surface water bodies if this contains high suspended solids / turbidity.	
	Groundwater control requirements during any excavation works (including construction of cuttings and underpasses) resulting in a reduction in local groundwater levels and therefore a loss of groundwater flow / resource to nearby receptors	S18 / cutting west of S05	Lowestoft Formation	River Tud GWDTEs Nearby abstractions Chalk	Cuttings at this location are likely to intersect the groundwater, necessitating the need for groundwater control. At S18, the minimum design level is 30mAOD, and the maximum recorded groundwater level at nearby borehole DS236 is 31.2mAOD. Therefore, the cutting may require 1.2m drawdown. The cutting west of S05 has a minimum design level of 35mAOD, and a maximum recorded groundwater level at DS231 of 38.5mAOD. Therefore, the cutting may require 3.5m drawdown. A Sichardt empirical formula was used to estimate the radius of influence based on the drawdown and maximum recorded permeability value of $1.21x10^{-4}$ m/s. The radius of influence was calculated to be 76.7m for and 26.3m respectively.	Yes
		Ground improvement at S01 / S05	Alluvium Lowestoft Formation Chalk	River Tud Nearby abstractions GWDTEs	Artesian groundwater noted at proposed structure. Risk of dewatering if any excavations are required.	Yes
		S16 / S03 / S04 / S07	Lowestoft Formation	River Tud Nearby abstractions GWDTEs Chalk	The maximum groundwater level, plus the potential seasonal variation of 2.15m identified from regional groundwater monitoring, was compared to the minimum design level of the proposed structure to determine the risk of groundwater control being required. At S16, the minimum design level is 38.88mAOD, and the maximum recorded groundwater level at nearby borehole is 32.48mAOD. With the addition of the seasonal variation, the maximum anticipated groundwater level is 34.63mAOD. Therefore, there is negligible risk that the groundwater level will intercept the base of the cutting.	No

Activity	General Description of Potential Impact	Structure	Direct Receptor	Indirect receptor	Site specific potential impact	Potential impact?
					At S03 & S04, the minimum design level is 40.97mAOD, and the maximum groundwater level is 37.09mAOD. Adding the seasonal variation, the maximum anticipated groundwater level is 39.24mAOD. Therefore, there is negligible risk that the groundwater level will intercept the base of the cutting. At S07, the minimum design level is 27.20mAOD, and the maximum groundwater level recorded in BH140 is 23.1mAOD. Adding the seasonal variation, the maximum anticipated groundwater level is 25.60mAOD. Therefore, there is negligible risk that the groundwater level will intercept the base of the cutting. The above assessments will be revisited following completion of the baseline groundwater monitoring, the addendum report, and the 2021 supplementary GI. The above cuttings may intercept pockets of perched groundwater during construction, but this are not anticipated to be significant.	
	Construction dewatering discharges may contain suspended solids and may therefore result in contamination of receiving waterbody	S05 / S18 / ground improvement at S01 / cutting west of S05	River Tud	River Wensum Downgradient abstractions GWDTEs	Dewatering discharge points to be confirmed following confirmation of dewatering requirements, but may either be direct to River Tud or its tributaries. Untreated dewatering discharges would have significant water quality impact on receiving water body, especially if they contain chalky water.	Yes
Decommissioning of existing soakaways	Soakaway acts as a potential pathway for construction contamination	HADDMS soakaway ID TG0513-8061b, TG0513_9259c, TG1211_1805c, TG1311_0903f, TG1311_0904h, TG1311_0904i, TG1311_1502f, TG1311_1802e.	Lowestoft Formation Sheringham Cliffs Formation	Chalk aquifer GWDTE Downgradient abstractions	There is a risk of accidental spillages / leakage of construction materials in these areas during construction may result in contamination of groundwater.	Yes

Table 3.3 Potential risk to the groundwater environment from the operation of the Scheme

Activity	General Description of Potential Impact	Structure	Direct Receptor	Indirect receptor	Site specific potential impact	Potential impact?
Operation						
Road drainage	Routine road drainage may result in contamination of receiving aquifer	Filter drains proposed in all drainage catchments, Oak Farm tributary outfall (low flows)	Superficial aquifers	Chalk aquifer GWDTE Downgradient abstractions	Oak Farm watercourse has low flows and was observed to have no flow during summer months and there is therefore a risk of infiltration to ground. Filter drains will allow infiltration to ground, including areas of shallow groundwater, and a preliminary SPZ1 associated with the new public water abstraction at East Tuddenham. Results for the groundwater quality assessments are presented in Section 4.3.	Yes
	Accidental spillages collected by road drainage may result in contamination of receiving aquifer		Superficial aquifers	Chalk aquifer GWDTE Downgradient abstractions	Spillage assessments, undertaken as part of Appendix 13.3 Water Quality, show the risk of impact from spillage pass the assessment.	No
	Retained soakaways may result in contamination or receiving aquifer	HADDMS soakaway ID TG0912-7519f, and TG0912_7918b, located west of Honingham.	Lowestoft Formation	Chalk aquifer GWDTE Downgradient abstractions	Soakaways located on section of existing A47 that is to be retained as access road, resulting AADT will reduce significantly from 20,000 – 30,000 to less than 5000. Soakaways previously assessed as low risk and therefore will not pose a risk to groundwater quality.	No
Increase in impermeable area	Reduction in aquifer recharge due to increase in impermeable area from roads, embankments and bunding	New road layout	Lowestoft Formation Chalk	GWDTE Downgradient abstractions	Groundwater within the area is largely semi-confined, infiltration to ground via filter drains included in the drainage design.	No
Permanent subsurface drainage of cuttings / underpasses	Permanent drainage may result in a local reduction in groundwater levels around the structure	S18 / cutting west of S05	Lowestoft Formation	River Tud GWDTEs Nearby abstractions Chalk	Cuttings at this location are likely to intersect the groundwater, necessitating the need for groundwater control. At S18, the minimum design level is 30mAOD, and the maximum recorded groundwater level at nearby borehole DS236 is 31.2mAOD. Therefore, the cutting may require 1.2m drawdown. The cutting west of S05 has a minimum design level of 35mAOD, and a maximum recorded groundwater level at DS231 of 38.5mAOD. Therefore, the cutting may require 3.5m drawdown. A Sichardt empirical formula was used to estimate the radius of influence based on the drawdown and maximum recorded permeability value of 1.21×10^{-4} m/s. The	Yes

Activity	General Description of Potential Impact	Structure	Direct Receptor	Indirect receptor	Site specific potential impact	Potential impact?
					radius of influence was calculated to be 76.7m for and 26.3m respectively.	
		S03 / S04 / S07 / S16	Lowestoft Formation	River Tud Nearby abstractions GWDTEs Chalk	The maximum groundwater level, plus the potential seasonal variation of 2.15m identified from regional groundwater monitoring, was compared to the minimum design level of the proposed structure to determine the risk of groundwater control being required. At S16, the minimum design level is 38.88mAOD, and the maximum recorded groundwater level at nearby borehole is 32.48mAOD. With the addition of the seasonal variation, the maximum anticipated groundwater level is 34.63mAOD. Therefore, there is negligible risk that the groundwater level will intercept the base of the cutting. At S03 & S04, the minimum design level is 40.97mAOD, and the maximum groundwater level is 37.09mAOD. Adding the seasonal variation, the maximum anticipated groundwater level is 39.24mAOD. Therefore, there is negligible risk that the groundwater level will intercept the base of the cutting. At S07, the minimum design level is 27.20mAOD, and the maximum groundwater level recorded in BH140 is 23.1mAOD. Adding the seasonal variation, the maximum anticipated groundwater level is 25.60mAOD. Therefore, there is negligible risk that the groundwater level will intercept the base of the cutting. The above assessments will be revisited following completion of the baseline groundwater monitoring, the addendum report, and the 2021 supplementary GI. The above cuttings may intercept pockets of perched groundwater during construction, but this are not anticipated to be significant.	No
Permanent placement of below-ground piles	Redirection of flows around permanent underground structures	S05	Lowestoft Formation Chalk	River Tud Downgradient abstractions GWDTEs	Groundwater mounding may occur, resulting in a reduction in groundwater flows immediately down-gradient of the underpass.	Yes

Activity	General Description of Potential Impact	Structure	Direct Receptor	Indirect receptor	Site specific potential impact	Potential impact?
		S03 / S07	Lowestoft Formation Chalk	River Tud Downgradient abstractions GWDTEs	Piles for other underpasses are not likely to be continuous and therefore do not pose a risk.	No

4. Risk assessments

4.1. Introduction

4.1.1. Groundwater dependent terrestrial ecosystems (GWDTEs) have been identified as receptors to construction and operation activities. These are therefore considered further in Section 4.2.

4.1.2. A routine runoff assessment for the proposed outfall to a tributary of the River Tud at Oak Farm at the western extent of the Scheme has been undertaken due to low flows of less than 1 l/s. Routine runoff and spillage assessments were undertaken for filter drains in all drainage catchments. These assessments are presented in Section 4.3, and the spillage assessments are contained within Appendix 13.3 (Water quality) (**TR010038/APP/6.3**).

4.2. Groundwater dependent terrestrial ecosystems assessment

4.2.1. Identified groundwater dependent terrestrial ecosystems (GWDTE) have been assessed following the guidance set out in the LA 113 guidance document to determine hydrogeological links with the Scheme, the importance of each GWDTE, the magnitude of any potential impact on the GWDTE and thereby the overall significance of risk to the GWDTE prior to mitigation.

4.2.2. GWDTE sites comprise Lowland Fen Priority Habitats, and the River Tud as per Annex A Location Plan.

Assessment of GWDTE importance

4.2.3. Table 4.1 presents the overall importance for the GWDTEs. This is taken as highest of the 'flora and fauna' and 'habitat' receptors, based on UKTAG guidance for national vegetation classification (UKTAG, 2009).

4.2.4. Flora and fauna details and importance are based on information compiled from SSSI citations, MAGIC map, and the 2020 biodiversity survey where applicable. The surveyed land parcels are as per Figure 4.1 (Wild Frontier Ecology, 2019). Where no information is available, a worst-case value of Moderate was assigned based on professional judgement.

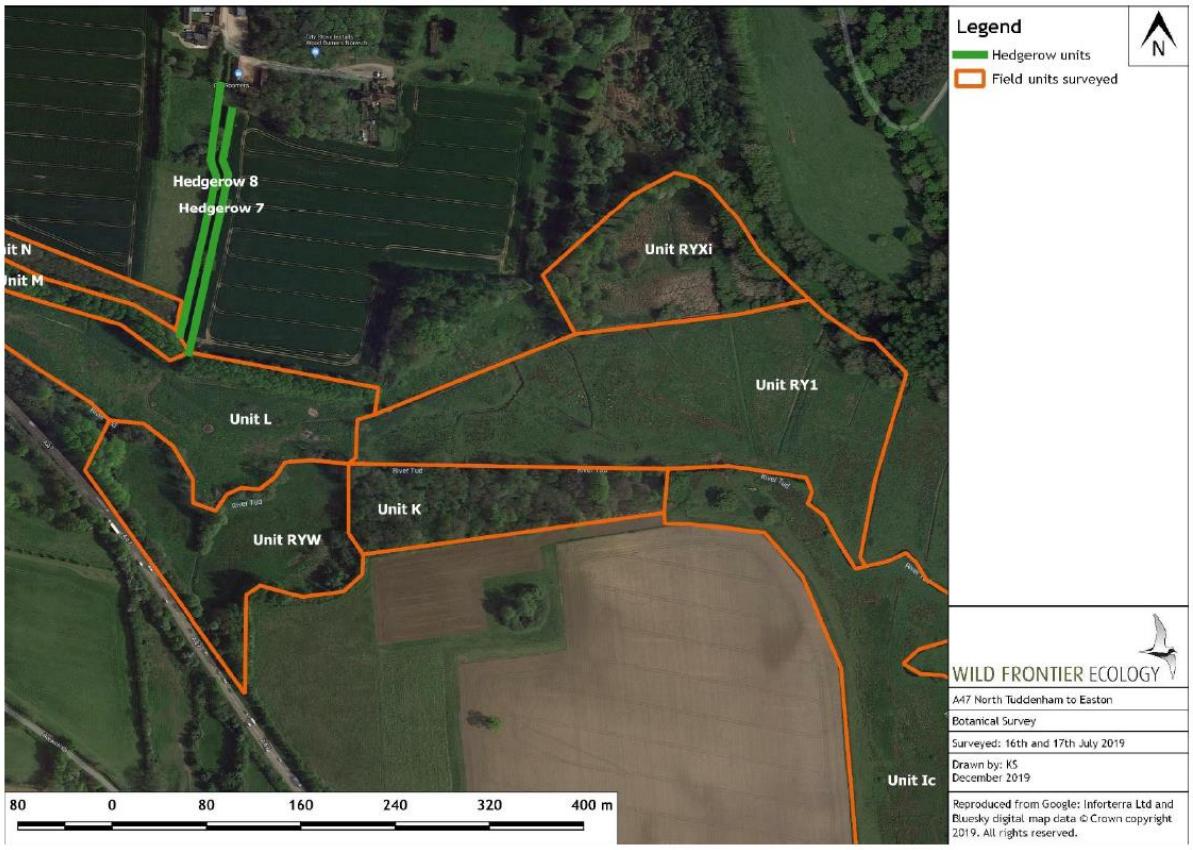
Table 4.1 GWDTE importance assessment

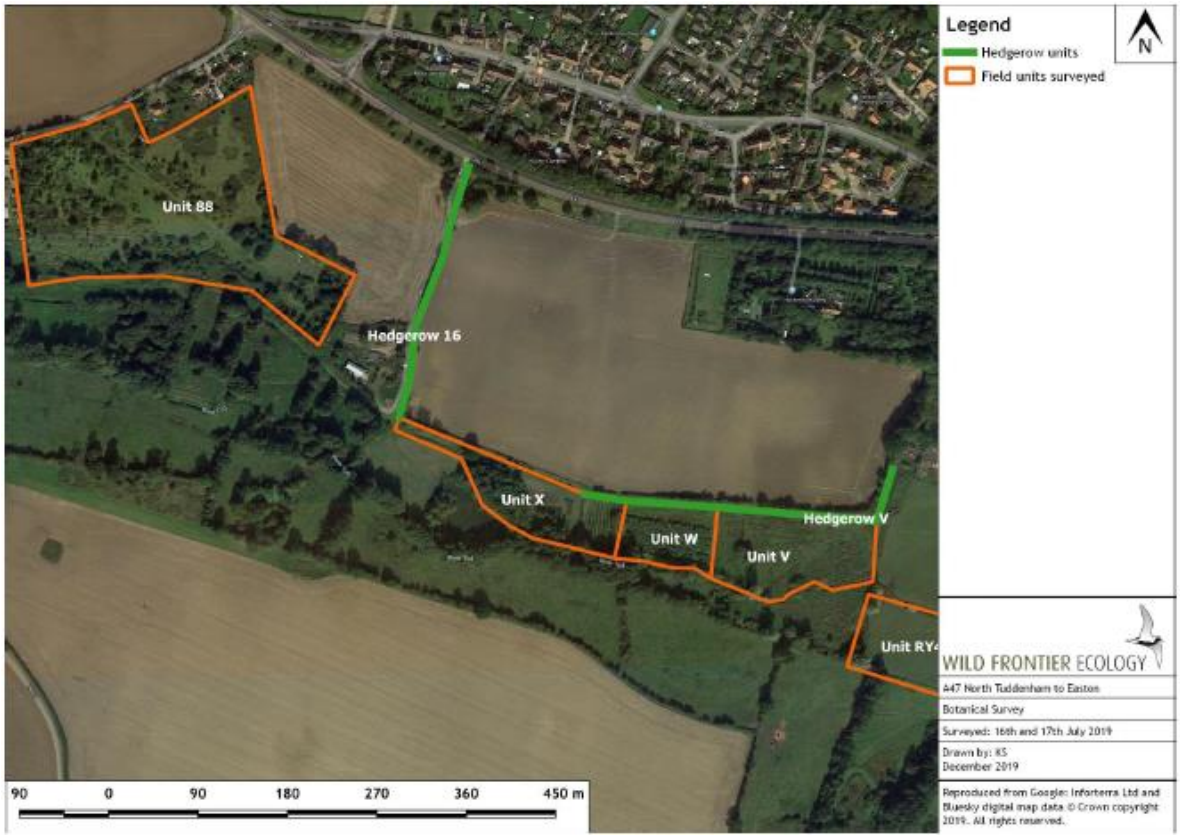
GDTWE	Flora and fauna receptor	Flora and fauna importance	Habitat receptor	Habitat importance	Overall importance
Priority Habitat (Unit K, TG1112711686)	W8a *Fraxinus – Acer – Mercurialis* woodland,	-	Lowland Fen / Broadleaved Forest	Low	Low

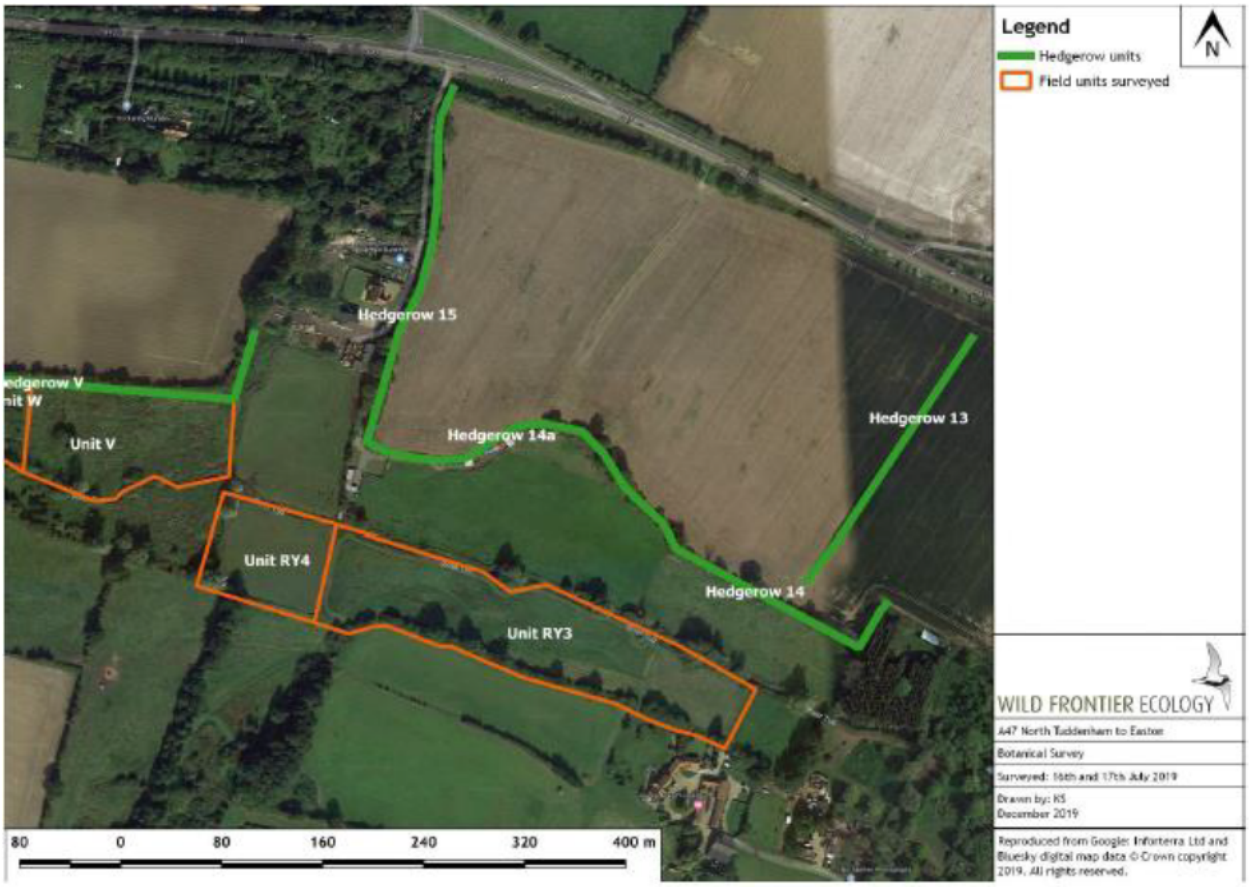
GDTWE	Flora and fauna receptor	Flora and fauna importance	Habitat receptor	Habitat importance	Overall importance
	Primula sub-community.				
Priority Habitat (Unit RYXi, TG1127111805)	S26 *Phragmites australis – Urtica dioica* tall-herb fen	Moderate (NVC Level 2)	Lowland Fen	Low	Moderate
Priority Habitat (Unit RY1, TG1127111805)	S7 *Carex acutiformis* swamp	Moderate (NVC Level 2)	Lowland Fen	Low	Moderate
River Tud / River Wensum	S25 *Phragmites australis - Eupatorium cannabinum* tall-herb fen S3 *Carex paniculata* swamp S4 *Phragmites australis* swamp and reed-beds S5 *Glyceria maxima* swamp S7 *Carex acutiformis* swamp	High (NVC 1)	SSSI/SAC with significant baseflow, supporting populations of [redacted] was also found during a biodiversity survey undertaken by EMEC Ecology in 2019. It is noted in the Geomorphology Assessment Report (Sweco, 2020b) that the River Tud, as a Chalk Stream, is particularly sensitive to sediment loading.	High	High
Hockering Wood	W10 *Quercus robur – Pteridium aquilinium* Rubus fruticosus woodland W8 *Fraxinus excelsior – Acer campestre – Mercurialis perennis* Woodland	-	SSSI with ponds supporting [redacted] population.	High	High
Priority Habitat (TG1006811663)	Not surveyed	Moderate (NVC 2)	Lowland Fen (declining / destroyed)	Low	Moderate
Priority Habitat (TG0973311647)	Not surveyed	Moderate (NVC 2)	Lowland Fen	Low	Moderate
Priority Habitat (TG0952811830)	Not surveyed	Moderate (NVC 2)	Lowland Fen / Floodplain Grazing Marsh	Low	Moderate
Priority Habitat (TG0888412289)	W4 *Betula pubescens - Molinia*	High (NVC 1)	Lowland Fen / Floodplain Grazing Marsh	Low	High

GDTWE	Flora and fauna receptor	Flora and fauna importance	Habitat receptor	Habitat importance	Overall importance
	caerulea woodland W8 *Fraxinus excelsior – Acer campestre – Mercurialis perennis* Woodland				
Priority Habitat (TG0879312222)	Not surveyed	Moderate (NVC 2)	Lowland Fen	Low	Moderate
Priority Habitat (TG0882212233)	Not surveyed	Moderate (NVC 2)	Lowland Fen	Low	Moderate
Priority Habitat (TG1050313321)	Not surveyed	Moderate (NVC 2)	Lowland Fen (declining / destroyed)	Low	Moderate
Priority Habitat (TG1053513363)	Not surveyed	Moderate (NVC 2)	Lowland Fen (declining / destroyed)	Low	Moderate
County Wildlife Site (Gravel Pits, East Tuddenham) (TG 075 118)	W8 *Fraxinus excelsior – Acer campestre – Mercurialis perennis* Woodland	-	Mesotrophic lake, potentially groundwater fed and supporting trout populations	Moderate	Moderate
Priority Habitat (Unit X, Unit W, Unit V, Unit RY4, Unit RY3, TG0733812657)	MG9 *Holcus lanatus - Deschampsia cespitosa* grasslands / No classification	-	Floodplain grazing marsh.	Low	Low
Priority Habitat (Unit RYW, TG1093911643)	MG9 *Holcus lanatus - Deschampsia cespitosa* grasslands	-	Floodplain grazing marsh. Wet grassland, likely improved by agriculture	Low	Low
Priority Habitat (TG1153211631)	Not surveyed	Unknown	Floodplain grazing marsh. Wet grassland, likely improved by agriculture	Low	Low
Priority Habitat (TG1106912735)	Not surveyed	Unknown	Floodplain grazing marsh. Wet grassland, likely improved by agriculture	Low	Low

Figure 4.1 Land parcels surveyed during the 2019 botanical survey (Wild Frontier Ecology, 2019)







Assessment of potential impacts

4.2.5. Table 4.2 summarises the GWDTEs identified within the study area that are considered to be hydraulically connected, and therefore most sensitive, to the Proposed Scheme.

Table 4.2 GWDTEs hydraulically connected to the scheme

GWDTE	Overall importance	Hydraulic connection between scheme and GWDTE
Priority Habitat (Unit K, TG1112711686)	Low	Yes, due to the proximity of proposed River Tud Crossing
Priority Habitat (Unit RYXi, TG1127111805)	Moderate	Yes, due to the proximity of proposed River Tud Crossing
Priority Habitat (Unit RY1, TG1127111805)	Moderate	Yes, due to the proximity of proposed River Tud Crossing
River Tud / River Wensum	High	Yes, due to the proposed River Tud Crossing and below ground structures across the route
Hockering Wood	High	No, due to being located hydraulically upgradient of the scheme
Priority Habitat (TG1006811663)	Moderate	Yes, within the River Tud floodplain down gradient of subsurface structures

GWDTE	Overall importance	Hydraulic connection between scheme and GWDTE
Priority Habitat (TG0973311647)	Moderate	Yes, within the River Tud floodplain down gradient of subsurface structures
Priority Habitat (TG0952811830)	Moderate	Yes, within the River Tud floodplain down gradient of subsurface structures
Priority Habitat (TG0888412289)	High	Yes, within the River Tud floodplain down gradient of subsurface structures
Priority Habitat (TG0879312222)	Moderate	Yes, within the River Tud floodplain down gradient of subsurface structures
Priority Habitat (TG0882212233)	Moderate	Yes, within the River Tud floodplain down gradient of subsurface structures
Priority Habitat (TG1050313321)	Moderate	No, due to being located hydraulically upgradient of the scheme
Priority Habitat (TG1053513363)	Moderate	No, due to being located hydraulically upgradient of the scheme
County Wildlife Site (Gravel Pits, East Tuddenham) (TG 075 118)	Moderate	Yes, subject to a water features survey
Priority Habitat (Unit X, Unit W, Unit V, Unit RY4, Unit RY3, TG0733812657)	Low	Yes, within the River Tud floodplain down gradient of subsurface structures
Priority Habitat (Unit RYW, TG1093911643)	Low	Yes, within the River Tud floodplain down gradient of subsurface structures
Priority Habitat (TG1153211631)	Low	Yes, within the River Tud floodplain down gradient of subsurface structures
Priority Habitat (TG1106912735)	Low	No, due to being located hydraulically upgradient of the scheme

4.2.6. Potential impacts specifically to GWDTEs from construction and operation of the scheme prior to mitigation, based on identified hydrogeological impacts as summarised in Tables 3.2 and 3.3, are described in Table 4.3 below.

4.2.7. It is possible that on-site construction and operation activities could result in a reduction in groundwater quantity and quality which may negatively impact upon the GWDTE sites listed above. The overall risk depends on the importance of the GWDTE combined with the magnitude of the potential impact, as per the LA 113.

4.2.8. The radius of influence calculations presented in Section 3 and Annex E confirm that the risk to GWDTEs from temporary dewatering and permanent slope drainage is negligible. The nearest GWDTEs to the mainline cutting to the west of S05 and Honingham Church underpass are at 500m and therefore outside of the radius of influence.

4.2.9. The radius of influence calculations will be reassessed for the above structures, and others where required, following completion of the full baseline groundwater level monitoring and the 2021 supplementary ground investigation.

Table 4.3 GWDTE risk assessment

Impact type	Activity	Description of potential impact	Magnitude of impact on GWDTE	Overall risk to GWDTE
Groundwater quantity • Groundwater flow / flux • Groundwater level • Soil saturation / soil moisture	Excavations, including underpass construction, ground improvement and associated dewatering requirements	Removal of groundwater from the aquifer, as a result of groundwater control for excavations, has the potential to impact on groundwater levels in the immediate area surrounding excavation, and also on groundwater supply to receptors including the River Tud and associated Lowland Fen habitats. Any dewatering activities resulting in abstractions of >50m^3 will be subject to further impact assessments and consultation with the EA. Dewatering rates to be confirmed following supplementary ground investigation and an abstraction license will be applied for following further hydrogeological impact assessments.	Negligible, due to distance of structures that may require dewatering to GWDTEs. This will be reassessed following completion of the full baseline groundwater monitoringand the 2021 supplementary ground investigation.	Negligible risk
	Permanent subsurface drainage of cuttings / underpasses	Permanent drainage may result in a local reduction in groundwater levels around the structure, altering the groundwater flow regime. However, if required, volumes are likely to be low, seasonal, and diverted using passive drainage systems. This will be reassessed upon completion of supplementary GI and finalisation of drainage design.	Negligible, due to distance of structures that may require permanent slope drainage to GWDTEs. This will be reassessed following completion of the full baseline groundwater monitoring and the 2021 supplementary ground investigation.	Negligible risk
	Permanent placement of below-ground piles	Redirection of flows around permanent underground structures resulting in a potential reduction in supply to River Tud and associated Lowland Fen habitats.	Minor adverse (worst case). This will be reassessed following completion of the full baseline groundwater monitoring and the 2021 supplementary ground investigation.	Moderate risk – negligible risk
Groundwater quality as a result of construction activities • Nutrients (Nitrate / Phosphate) • Metalloid and organic compounds	Drainage from construction areas including site compounds, excavations and cuttings.	Satellite compound along the proposed route likely underlain by Lowestoft Formation. Removal of topsoil during construction works and/or a reduction in the thickness of the unsaturated zone has the potential to increase the vulnerability of underlying aquifers. Accidental spillages / leakage of construction materials in such areas may result in	Minor / Moderate .	Moderate risk – negligible risk

Impact type	Activity	Description of potential impact	Magnitude of impact on GWDTE	Overall risk to GWDTE
		contamination of groundwater which in turn has the potential to impact the groundwater quality. The cuttings for the underpasses, and for ground improvement, may intersect the saturated superficial aquifers and the top of the Chalk.		
	Excavations, including underpass construction	Potential for contamination of groundwater through direct contact with contaminated construction materials which may migrate to the River Tud and associated Lowland Fen habitats.	Moderate	Moderate risk – negligible risk
	Permanent placement of below-ground structures, i.e. piles, underpasses.	Potential for contamination of groundwater through smearing of contaminants from surface / creation of pathway for migration of artesian groundwater which could migrate to the River Tud and associated Lowland Fen habitats.	Minor	Moderate risk – negligible risk
	Discharge of metalloid and organic compounds to groundwater from proposed road drainage to both surface water and groundwater	Road drainage discharges to groundwater. Any pollution (including accidental spillages) in routine runoff may have the potential to migrate to River Tud and associated Lowland Fen habitats	Negligible – see Section 4.3	Negligible risk

Assessment outcomes and actions

4.2.10. Prior to any mitigation the risk to GWDTE sites is moderate to negligible.

4.2.11. Construction activities that may have a significant impact upon the quality and quantity of groundwater available for the identified GWDTEs are subject to further investigation during the supplementary ground investigation. It is anticipated that best practise mitigation measures set out in the Environment Management Plan (**TR010038/APP/7.4**) will address these risks. No further detailed assessment is therefore required. Any risk will be reassessed when the supplementary ground investigation is complete.

4.3. Groundwater quality and runoff

Simple assessment

4.3.1. A groundwater quality and runoff risk assessment for routine runoff was completed to assess the risk of impact upon groundwater quality from unlined drainage (filter drains) and potential infiltration from the receiving watercourse, a tributary of the Rive Tud at Oak Farm, which has particularly low flows. The assessment is based on the 'source-pathway-receptor' model, as per Appendix C of LA 113.

4.3.2. Unlined road drainage in the form of filter drains are proposed in a number of locations throughout the Proposed Scheme and are located in all drainage catchments (see Annex C). Where necessary, catchments have either been combined or further sub-divided to consider filter drains by different hydrogeological conditions in the assessments.

4.3.3. Input parameters were derived from ground investigation data and publicly available information. These are in line with the conceptualisation outlined above in Section 2.10 and are summarised below in Table 4.4. Results are presented in Figure 4.2 and show that infiltration of untreated routine road runoff presents a medium risk to groundwater. This is primarily due to the depth to water table and low organic matter content in the unsaturated zone.

4.3.4. The results of the routine runoff assessments, including details of the parameters used, are presented in Annex D.

Table 4.4 Summary of HEWRAT risk assessment input parameters

Input parameter	Detail
Traffic flow	AADT traffic flow provided by traffic modelling data
Rainfall depth (annual averages)	Average based on warm/dry climatic region from nearest UK rainfall monitoring site (Huntingdon).

Input parameter	Detail
Drainage area ratio	Determined as 'drainage area of road'/'active surface area of infiltration device', where the surface area is that part of the device through which most downward discharge will occur.
Infiltration method	shallow linear (e.g. unlined ditch, swale, grassed channel) – selected to reflect overall dimensions of the stream
Unsaturated zone	Determined from the available groundwater level monitoring from boreholes within the catchment.
Flow type	(e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)" was selected to represent the variability within the Lowestoft Formation, Sheringham Cliffs Formation and the Happisburgh Glacigenic Formation.
Unsaturated zone clay content	Determined from particle size distribution results available for a number of ground investigation borehole samples in each catchment.
Organic carbon	Organic matter results were determined from ground investigation borehole samples in each catchment. Where no data was available, worst case values were applied.
Unsaturated zone soil pH	Organic matter results were determined from ground investigation borehole samples in each catchment. Where no data was available, worst case values were applied.

Detailed assessment

4.3.5. As the HEWRAT assessment for infiltration to ground produced a medium risk result, consultation was undertaken with the Environment Agency, in line with the assessment guidance.

4.3.6. The key concerns raised by the Environment Agency were as follows:

- The treatment train prior to discharge needs to be suitable in terms of treatment steps and efficacy (bearing in mind the environmental sensitivity), and the area for soakage and soakage rates.
- Consideration for an increase in chloride in winter, along with how the system would cope with a catastrophic spill from a road accident, and how/the extent to which it will be maintained over time.
- The groundwater assessment should specifically consider the new Anglian Water Services public water abstraction at East Tuddenham.

4.3.7. To address the Environment Agency's concerns, the further hydrogeological assessment has followed guidance provided at www.susdrain.org, and specifically the SuDS Manual (Woods Ballard et al, 2015). This is presented in the sections below and considers the ground conditions, baseline water quality and environmental sensitivity of the road drainage catchments, and treatment measures embedded into the drainage design. A water quality assessment has also been undertaken, based on the HEWRAT tool, to assess the potential for road drainage to impact on the water quality of groundwater receptors.

4.3.8. Consultation has also been undertaken with Anglian Water Services on the discharges with proposals for treatment presented.

Baseline hydrogeological conditions

4.3.9. Baseline conditions are summarised for each medium risk catchment in Table 4.5. These are based on details presented in Section 2. The catchment locations are shown in Annex C.

4.3.10. The SuDS manual provides evidence of the extents to which surface water runoff can pose a risk to groundwater. This states that whilst the overall risk to groundwater from the key contaminants associated with highways runoff is low and the vast majority of heavy metals, PAHs, and TPHs are retained within the top 10m of soil, organic matter with the unsaturated zone forms an important barrier to the movement and attenuation of contamination. As organic matter content within the Lowestoft Formation, Happisburgh Glacigenic Formation and Sheringham Cliffs Formation is low, natural attenuation of any potential contaminants within the unsaturated zone beneath most of the Proposed Scheme is likely to be limited.

Table 4.5 Hydrogeological baseline conditions of medium risk catchments

Catchment	Boreholes used in assessment	Geology	Infiltration capacity	Groundwater levels	Baseline groundwater quality	Environmental receptors
M2 & S1 (including Oak Farm watercourse)	BH101, DS205	Cohesive Lowestoft Formation to 25mbGL underlain by Chalk. Small patch of alluvium overlies the Lowestoft Formation at DS205.	Infiltration testing in Lowestoft Formation across scheme range between 7.33 x 10^{-6} and 1.21 x 10^{-4}m/s.	Maximum groundwater level DS205 2.1 mbgl (42.74 mAOD) Tributary bed assumed to be 0.5mbGL, therefore unsaturated zone ~1.5m below base of stream. Insufficient monitoring information to comment on seasonal variation in groundwater levels. Chalk: 3.02 – 3.62mbGL (BH101; May – Sep-20) indicating downwards hydraulic gradient.	Borehole zinc concentrations: <2 – 5µg/l. Nearest borehole copper concentrations: below level of detection (5µg/l). Surface water sampling in Oak Farm watercourse: range between 1 – 12 µg/l copper and between 13 – 2 µg/l zinc.	Lowestoft Formation (direct receptor) Chalk (indirect receptor) Unlicensed groundwater abstraction <500m downgradient of Oak Farm watercourse. AWS licensed groundwater abstraction at North Tuddenham (3km downgradient) River Tud and adjacent priority habitats
M3 (Mattishall Lane underpass)	BH102	20m thickness of Granular Lowestoft Formation overlying Chalk	Infiltration within the Granular Lowestoft Formation ranges between 2.61x10^{-5} m/s and 1.48x10^{-4} m/s.	Maximum groundwater level 10.86 mbgl (32.481 mAOD).	Nearest borehole copper concentrations: below level of detection (5µg/l). Nearest borehole zinc concentrations <2 – 5 µg/l	Lowestoft Formation (direct receptor) Chalk (indirect receptor) River Tud and adjacent priority habitats AWS licensed groundwater abstraction at North Tuddenham (2km downgradient)
M3 (mainline), S2, & S3a	BH103	Granular Alluvium (5m thick) overlying Granular Lowestoft Formation to 23mbgl, underlain by Chalk	Infiltration within the Granular Lowestoft Formation ranges between 2.61x10^{-5} m/s and 1.48x10^{-4} m/s.	Maximum groundwater level 6.61mbgl (33.412 mAOD)	Borehole zinc concentrations: <2 – 5µg/l. Nearest borehole copper concentrations: below level of detection (5µg/l).	Lowestoft Formation (direct receptor) Chalk (indirect receptor) River Tud and adjacent priority habitats AWS licensed groundwater abstraction at North Tuddenham (2km downgradient)
M4	BH104, BH108, BH111	Alluvium, River Terrace Deposits (BH104 only) overlying Cohesive and Granular Lowestoft Formation. Chalk between 10 and 25 mbgl.	Infiltration testing in Lowestoft Formation across scheme range between 7.33 x 10^{-6} and 1.21 x 10^{-4}m/s. No data available for the Alluvium or River Terrace Deposits.	Maximum groundwater level 2.9 mbgl (30.85 mbgl)	Borehole zinc concentrations: <2 – 54 µg/l. Nearest borehole copper concentrations: below level of detection (5µg/l).	Alluvium, River Terrace Deposits and Lowestoft Formation (direct receptors) Chalk (indirect receptor) River Tud and adjacent priority habitats AWS licensed groundwater abstraction at North Tuddenham (1km downgradient), catchment partially within preliminary SPZ1. Downgradient unlicensed abstractions.
M5	BH115, BH116	Sheringham Cliffs Formation (Granular) overlying Cohesive and Granular Lowestoft Formation to 23mbgl, underlain by Chalk.	Infiltration testing within the Sheringham Cliffs Formation indicates a rate of 3.64x10^{-5} m/s. Infiltration testing in Lowestoft Formation across scheme range between 7.33 x 10^{-6} and 1.21 x 10^{-4}m/s.	Maximum groundwater level 4.61 mbgl (31.46 mAOD)	Borehole zinc concentrations: <2 – 5µg/l. Nearest borehole copper concentrations: below level of detection (5µg/l).	Sheringham Cliffs Formation and Lowestoft Formation (direct receptors) Chalk (indirect receptor) River Tud and adjacent priority habitats AWS licensed groundwater abstraction at North Tuddenham (1km downgradient), catchment partially within preliminary SPZ1. Downgradient unlicensed abstractions.
NW	BH120, BH121, BH122	Lowestoft Formation (Granular and Cohesive) to	Infiltration testing in Lowestoft Formation across scheme	Maximum groundwater level 8.52 mbgl (38.09 mAOD)	Borehole zinc concentrations: <2 – 5µg/l.	Lowestoft Formation (direct receptor)

Catchment	Boreholes used in assessment	Geology	Infiltration capacity	Groundwater levels	Baseline groundwater quality	Environmental receptors
		18mbgl, underlain by Chalk.	range between 7.33 x 10^{-6} and 1.21 x 10^{-4}m/s.		Nearest borehole copper concentrations: below level of detection (5µg/l).	Chalk (indirect receptor) River Tud and adjacent priority habitats
M6	BH121, BH122, BH125	Lowestoft Formation (Granular and Cohesive) to 18mbgl, underlain by Chalk.	Infiltration testing in Lowestoft Formation across scheme range between 7.33 x 10^{-6} and 1.21 x 10^{-4}m/s.	Maximum groundwater level 8.52 mbgl (38.09 mAOD)	Borehole zinc concentrations: <2 – 5µg/l. Nearest borehole copper concentrations: below level of detection (5µg/l).	Lowestoft Formation (direct receptor) Chalk (indirect receptor) River Tud and adjacent priority habitats
M7	DS231, BH127	Lowestoft Formation (Granular and Cohesive) (DS231) to 15mbgl, overlying Chalk. Granular Alluvium (BH127) to 10mbgl, overlying Chalk.	Infiltration testing in Lowestoft Formation across scheme range between 7.33 x 10^{-6} and 1.21 x 10^{-4}m/s. No data for Alluvium.	Maximum groundwater level 1.97 mbgl (38.47 mAOD)	Borehole zinc concentrations: <2 – 54 µg/l. Nearest borehole copper concentrations: below level of detection (5µg/l).	Lowestoft Formation (direct receptor) Chalk (indirect receptor) River Tud and adjacent priority habitats
M8	BH134	Lowestoft Formation (Granular and Cohesive) to 20mbgl, overlying chalk (not proven).	Infiltration testing in Lowestoft Formation across scheme range between 7.33 x 10^{-6} and 1.21 x 10^{-4}m/s.	Maximum groundwater level 6.96 mbgl (28.81 mAOD)	Borehole zinc concentrations: <2 – 5µg/l. Nearest borehole copper concentrations: below level of detection (5µg/l).	Lowestoft Formation (direct receptor) Chalk (indirect receptor) River Tud and adjacent priority habitats
M9 & NE	DS236, DS238, BH140	Lowestoft Formation (Granular and Cohesive) to between 10 mbgl and 20 mbgl, overlying Chalk.	Infiltration testing in Lowestoft Formation across scheme range between 7.33 x 10^{-6} and 1.21 x 10^{-4}m/s.	Maximum groundwater level 1.35 mbgl (31.22 mAOD)	Borehole zinc concentrations: <2 – 5µg/l. Nearest borehole copper concentrations: below level of detection (5µg/l).	Lowestoft Formation (direct receptor) Chalk (indirect receptor) River Tud and adjacent priority habitats
Access to St Andrews Church (catchment M9) and link to Taverham Road (catchment NE)	BH137, DS238	Lowestoft Formation (Granular and Cohesive) to 12 mbgl, overlying Chalk (DS238). Cohesive Alluvium and Cohesive Happisburgh Glacigenic Formation overlying Chalk <5 mbgl.	Infiltration testing in Lowestoft Formation across scheme range between 7.33 x 10^{-6} and 1.21 x 10^{-4}m/s. No data available for the Happisburgh Glacigenic Formation or Alluvium.	Maximum groundwater level 6.22 mbgl (21.15 mAOD)	Borehole zinc concentrations: <2 – 54 µg/l. Nearest borehole copper concentrations: below level of detection (5µg/l).	Alluvium, Happisburgh Glacigenic Formation, and Lowestoft Formation (direct receptors) Chalk (indirect receptor) River Tud and adjacent priority habitats
M10	DS244	Patches of Granular Happisburgh Glagicenic Formation overlying Lowestoft Formation (Granular and Cohesive) to 10mbgl, underlain by chalk (not proven).	Infiltration testing in Lowestoft Formation across scheme range between 7.33 x 10^{-6} and 1.21 x 10^{-4}m/s. No data available for the Happisburgh Glacigenic Formation.	Maximum groundwater level 5.30 mbgl (30.95 mAOD)	Borehole zinc concentrations: <2 – 5µg/l. Nearest borehole copper concentrations: below level of detection (5µg/l).	Lowestoft Formation (direct receptor) Chalk (indirect receptor) River Tud and adjacent priority habitats
W1	BH134, DS236	Lowestoft Formation (Granular and Cohesive) to 20mbgl, overlying chalk (not proven).	Infiltration testing in Lowestoft Formation across scheme range between 7.33 x 10^{-6} and 1.21 x 10^{-4}m/s.	Maximum groundwater level 1.35 mbgl (31.22 mAOD)	Borehole zinc concentrations: <2 – 5µg/l. Nearest borehole copper concentrations: below level of detection (5µg/l).	Lowestoft Formation (direct receptor) Chalk (indirect receptor) River Tud and adjacent priority habitats

Road drainage design

4.3.11. The road drainage has been designed in accordance with Design Manual for Roads and Bridges (DMRB), and specifically CG 501 Design of highway drainage systems, CD 532 Vegetated drainage systems for highway runoff and CIRIA: The SUDS manual (C753). Full details of the drainage strategy are provided in Appendix 13.2 (Drainage Strategy) (**TR010038/APP/6.3**).

4.3.12. The treatment incorporated into the road drainage system has been designed to be protective of receiving watercourses at the point of outfall, of which the filter drains form an important part. The overall efficacy of the road drainage treatment train for discharges to surface waterbodies, including the Oak Farm watercourse, has also been assessed in Appendix 13.3 (Water quality assessment) of the Environmental Statement (**TR010038/APP/6.3**).

4.3.13. Filter drains are designed to attenuate flows and therefore promote sedimentation. They include a geotextile wrap whereby ensuring that any sediment laden pollutants do not enter the unsaturated zone. CG501 specifies 60% efficacy for removal of suspended solids and 45% removal of dissolved zinc concentrations.

4.3.14. In the case of catchments S1 and M2, road drainage includes filter drains, swales and a wetland in order to protect discharges to the Oak Farm watercourse. Swales are grassed channels used to convey and treat runoff from both large and small events providing 80% efficacy in removal of suspended solids and 50% removal of dissolved pollutants. Wetlands are used to further facilitate the treatment of runoff. They provide 60% removal of suspended solids, 30% removal of dissolved copper and 50% removal of dissolved zinc.

4.3.15. Flow control devices, such as hydrobrakes and orifice plates, have been included in the road drainage design, which along with the attenuation provisions within each treatment component, will reduce the peak flows to the outfall locations.

4.3.16. Protection from spillages is included through the road drainage design, in the form of catchpits, kerb and gullies (to a lesser degree), and penstocks on the inlets and outlets to the wetland. Penstocks are considered to be a reliable measure over the long-term.

4.3.17. Details of maintenance requirements are provided in Appendix 13.2 (Drainage Strategy) of the Environmental Statement (**TR010038/APP/6.3**), and include regular inspections for blockages and to ensure mechanical devices such as penstocks are in working order, removal of litter, sediment accumulation and unwanted vegetation growth, and replacement of filter material where required.

4.3.18. Although infiltration to ground through the filter drains is generally not included in the hydraulic design of the road drainage, it is necessary to consider as groundwater mounding beneath the filter drains as a result of low permeability may result in discharges direct to the groundwater.

4.3.19. Table 4.5 highlights that there is no road runoff will discharge directly to the Chalk Principal aquifer. Road drainage will discharge to the overlying superficial deposits across the scheme via filter drains. Further ground investigation is to be undertaken, which will improve the understanding of the hydraulic properties of the superficial deposits, including organic matter, and groundwater levels and quality across the scheme. The risk that road runoff poses to the underlying aquifers will therefore be reassessed once further information is available.

4.3.20. It is shown that the current drainage design includes filter drains in catchments M2 (DS205), M7 (DS231) and the access to St Andrew's Church (catchment M9) and link to Taverham Road (catchment NE) (BH137) where shallow groundwater levels are present within the Lowestoft Formation and Happisburgh Glacigenic Formation overlying Chalk. It is unclear from the available monitoring whether these groundwater levels are perched groundwater within the Lowestoft Formation, or controlled by the underlying Chalk aquifer. However, the groundwater levels are within 1m of the proposed drainage design. The existing drainage design includes filter drains within the preliminary SPZ1 for the new East Tuddenham public water supply abstraction (as shown in Annex A), between catchments M4 and M5. Stakeholder and design consultation is ongoing regarding the above drainage design elements, and filter drains are to be removed from the SPZ1 area during detailed design.

Water quality risk assessment

Filter drains

4.3.21. The HEWRAT assessment tool models road drainage runoff as annual average concentrations that can be compared to WFD environmental quality standards (EQS) for copper (1μg/l) and zinc (10.9μg/l), for protection of indirect surface water receptors, and in addition the drinking water standard (DWS) for copper (2mg/l) for protection of the aquifers and groundwater abstractions.

4.3.22. The assessment considers the impact of dissolved copper and zinc as indicators as they are generally the main metallic pollutants associated with road drainage and can be toxic to aquatic life. Consideration of event mean concentrations in comparison to runoff specific thresholds is not appropriate for groundwater receptors, and chronic impacts from sediment laden pollutants are not required as filter drains include geotextile membranes to capture sediment.

4.3.23. The modelled annual average concentrations are indicative of runoff recharging to the aquifer at the water table and do not include for any attenuation that may occur in the unsaturated zone or dilution within the aquifer itself. Although filter drains are considered to be a form of treatment for dissolved zinc, no treatment effectiveness for soluble contaminants has been included in the assessment. Furthermore, the assessment assumes a point source discharge, whereas discharges from filter drains are more diffuse. The resulting annual average concentrations therefore present a worst-case.

4.3.24. The results of the adapted HEWRAT assessment are provided in Annex D and show that for all medium risk catchments with an AADT of between 50,000 and 100,000 the anticipated routine runoff water quality entering the drainage network will be 4.59 µg/l copper and 10.44µg/l zinc. For catchment W1, which has an AADT of <50,000, the anticipated routine runoff water quality is 3.78µg/l copper and 8.3µg/l zinc. The anticipated copper concentrations exceed the 1µg/l Freshwater EQS but does not exceed the 2mg/l DWS value. With the anticipated dilution within the aquifer, the risk to groundwater is assessed to be negligible. Concentrations of Zinc are not anticipated to exceed the 10.9µg/l EQS.

Oak Farm watercourse

4.3.25. The HEWRAT assessment for the Oak Farm watercourse is summarised in Table 4.6, with full details provided in Appendix 13.3 (Water quality) of the Environmental Statement (**TR010038/APP/6.3**). This considers the whole treatment train included in the road drainage within catchments S1 and M2 and assesses the water quality at the outfall point into the Oak Farm watercourse.

Table 4.6 Summary of HEWRAT assessment for surface water at the Oak Farm watercourse

	Copper	Zinc	Comments
Freshwater EQS limits (bioavailable, dissolved phase)	1 µg/l	10.9 µg/l	
HEWRAT Step 2 – annual average concentrations	2.34 µg/l	8.07 µg/l	Concentrations consider dilution within the Oak Farm watercourse (1l/s)
HEWRAT Step 3 – annual average concentrations following treatment	0.47 µg/l	1.61 µg/l	Takes into account the treatment effectiveness (see CG 501, Table 8.6.4N3)

4.3.26. The ambient background copper concentrations from the water quality sampling were not included as part of the HEWRAT assessments, the background bioavailable copper concentrations found in the samples would not alter the outcome of the HEWRAT assessment.

4.3.27. The results for Step 2 consider dilution within the Oak Farm watercourse, albeit with low flows (1l/s). Although this minimal dilution included in the second step may not always be occurring, especially in situations when the Oak Farm watercourse is not flowing and infiltration through the base of the stream may be more pronounced, the reductions in concentrations between steps 2 and 3 are considered to be sufficiently protective of groundwater quality, as is apparent by comparison to the drinking water standard for copper (2mg/l). The baseline water quality highlights very low concentrations of copper and zinc that are not likely to impact the overall result of the HEWRAT assessment.

4.3.28. Although the HEWRAT assessment does not specifically consider chloride, the treatment efficiencies for dissolved metals and sediment are considered appropriate of this also. These give an indication of the likely reductions in chloride as a result of filtration occurring in the treatment train. The use of salt on roads is seasonal and this only tends to be washed off the roads during a thaw event. Under these circumstances the salt is generally diluted relatively quickly both within the road drainage system itself (such as in catchpits and the wetland) as well as within the receiving watercourse. Flow control devices may also help to mitigate against the potential impacts of large discharges of salt-laden runoff entering natural watercourses during a thaw event. Therefore, any chlorides infiltrating through the base of the Oak Farm watercourse will be sufficiently diluted that these are unlikely to impact on groundwater quality.

4.3.29. Spillage assessments have been carried out for the catchments as a whole, which is also considered applicable to discharges to groundwater. This is presented in Appendix 13.3 (Water quality) of the Environmental Statement (**TR010038/APP/6.3**). The outfalls passed the accidental spillage assessment with the results indicating that the drainage area would have <0.5% annual risk of pollution.

Summary of residual risk to groundwater

4.3.30. Despite the uncertainty in the relationship between groundwater and the stream bed, and the limited capacity for natural attenuation of pollutants within the unsaturated zone, the HEWRAT assessment for surface water highlights that treatment embedded into the drainage design and dilution within the surface watercourse provides a sufficient level of protection to groundwater receptors, including the nearest unlicensed groundwater abstraction less than 500m downgradient of the Oak Farm watercourse and the AWS public water supply groundwater abstraction at East Tuddenham.

4.3.31. Out of the 15 routine runoff assessments undertaken for the proposed drainage catchments, 13 were assessed to be medium risk at simple assessment, primarily due to the AADT or shallow groundwater. A detailed assessment was

undertaken assessing the baseline ground conditions, groundwater levels and quality, and receptors. This also included an adapted HEWRAT assessment to assess the anticipated runoff water quality. The baseline assessment has shown that there are sections of the proposed drainage within catchments M2, M7 and the access to St Andrew's Church (catchment M9) and link to Taverham Road (catchment NE) (BH137) that may have an insufficient unsaturated zone (<1m) below the drainage design, and that elsewhere filter drains are proposed within the preliminary SPZ1 for a new public water supply at East Tuddenham. The HEWRAT assessment has shown that the anticipated runoff water quality will not exceed the DWS for copper (2mg/l) or the EQS for zinc (10.9µg/l). Although anticipated runoff water quality exceeds the EQS for copper, dilution within the aquifer is likely to sufficiently dilute copper concentrations so as not to impact on the River Tud or downgradient GWDTE receptors.

5. Conclusions

5.1.1. This section summarises the activities that may result in a potentially significant impact, prior to mitigation, and are therefore taken forward for further consideration in the assessment of significant effects in Chapter 13 Road Drainage and the Water Environment of the Environmental Statement (**TR010038/APP/6.1**):

- Construction activities:
  - Drainage of construction areas including excavations, cuttings and site compounds
  - Excavations, including construction of underpasses and for ground improvement
  - Groundwater control requirements associated with construction of underpasses and foundations
  - Placement of piled foundations for the River Tud Crossing
- Operation activities:
  - Permanent placement of below-ground structures, i.e. piles, underpasses
  - Infiltration of routine runoff to ground via filter drains, and via outfall to Oak Farm stream

5.1.2. The groundwater levels and flows assessment identified the following receptors for consideration in the assessment of significant impacts:

- The main direct groundwater receptors within the Study Area are:
  - Aquifer units of the Broadland Rivers Chalk and Crag groundwater body (GB40501G400300), comprising:
    - Alluvium
    - River Terrace Deposits
    - Lowestoft Formation
    - Chalk Group
  - River Tud which likely receives baseflow from the superficial deposits
- The main indirect groundwater receptors within the Study area are:
  - Licensed and unlicensed groundwater abstractions east of and including P227CO0141 1km west of Hockering (Annex A Location Plan). It is unknown what aquifer any of the unlicensed abstractions take water from.
  - Designated sites associated with groundwater dependent terrestrial ecosystems, including the River Tud and associated Lowland Fen Priority Habitats (Annex A Location Plan).

5.1.3. A summary of hydrogeological impacts on identified receptors relating to potential construction and operation activities from the scheme is given.

5.1.4. The groundwater levels and flows assessment identified limitations within the conceptual understanding in key areas of the Proposed Scheme. These areas of uncertainty are to be addressed by a supplementary ground investigation and the completion of 12 months baseline groundwater level monitoring, following which the impact to groundwater receptors will be reassessed.

5.1.5. Groundwater quality and runoff risk assessments for routine runoff were completed to assess the risk of impact upon groundwater quality from unlined road drainage and infiltration through the base of low flows watercourses. The detailed assessment identified that road runoff does not pose a risk to groundwater receptors in terms of water quality, however filter drains are proposed within a preliminary SPZ1 for a new public water supply located at East Tuddenham. Furthermore, sections of the drainage design within catchments M2, M7, and the access to St Andrew's Church (catchment M9) and link to Taverham Road (catchment NE) do not have a minimum of 1m unsaturated zone beneath them. Areas containing filter drains are subject to further investigation in the supplementary ground investigation, and assessments will be updated once further information is available. The drainage design will be updated at detailed design to remove filter drains from the SPZ1.

5.1.6. The simple GWDTE assessment considered potential hydraulic links between the scheme and designated sites. The assessment concluded moderate to negligible risk to the sites in terms of groundwater quality and quantity. It is anticipated that best practise mitigation measures set out in the Environment Management Plan (**TR010038/APP/7.4**) will address these risks and no further detailed assessment is required.

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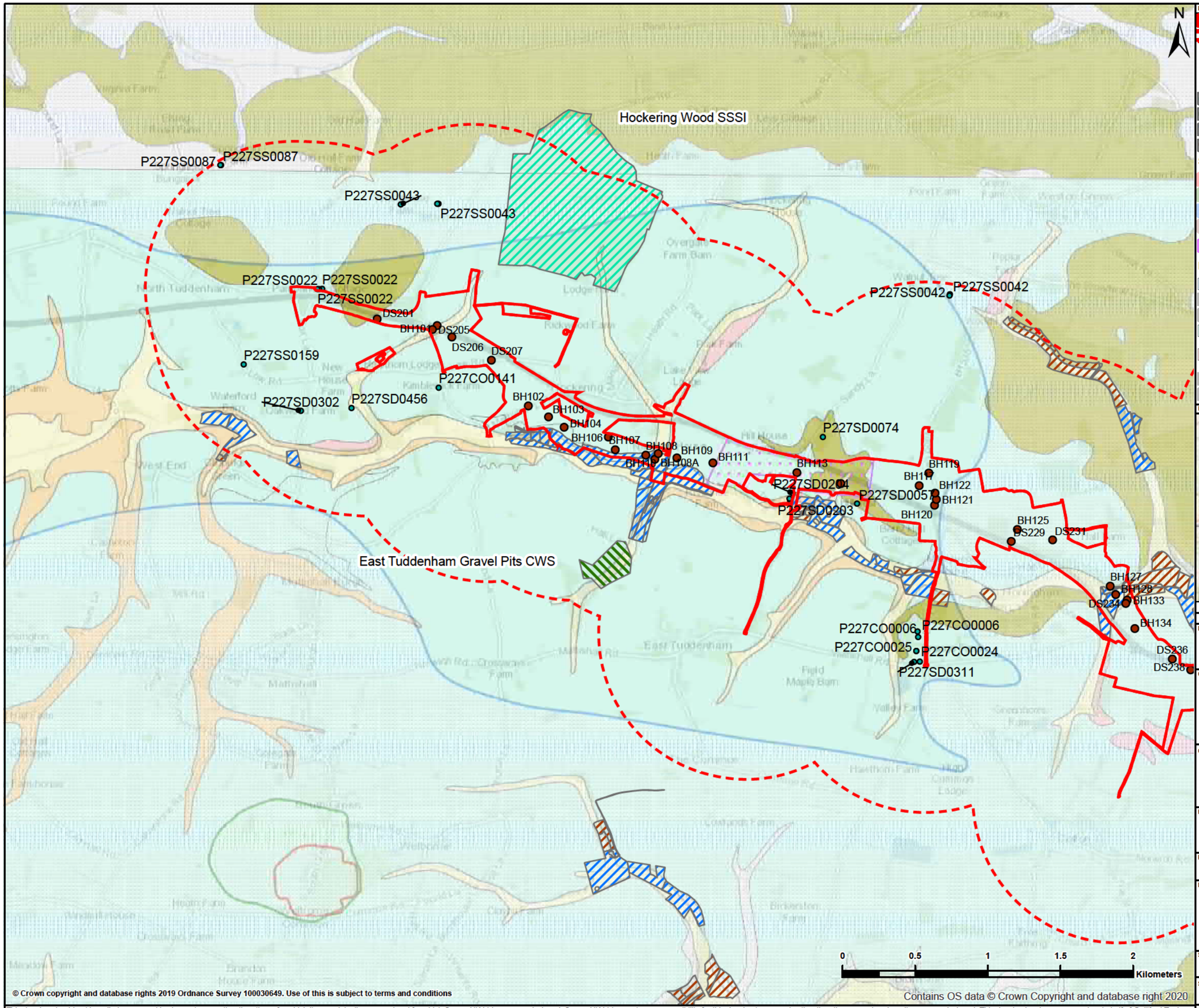
Annex A Location Plan



LEGEND

- DCO boundary
- Study area
- Licensed groundwater abstractions
- Unlicensed groundwater abstractions
- GI groundwater monitoring boreholes
- Site of Scientific Interest
- County Wildlife Site
- Coastal and floodplain grazing marsh
- Lowland fens

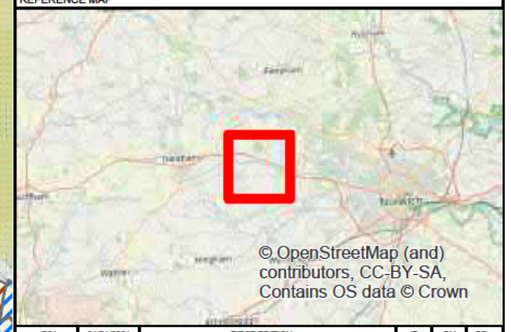
Source protection zones

- Zone I - Inner Protection Zone
- Zone II - Outer Protection Zone
- Zone III - Total Catchment
- Zone of Special Interest
- Potential Source Protection Zone I - Inner Protection Zone

BGS superficial deposits (50k)

- ALLUVIAL FAN DEPOSITS
- ALLUVIUM
- RIVER TERRACE DEPOSITS, 1
- LOWESTOFT FORMATION
- HAPPISBURGH GLACIGENIC FORMATION AND LOWESTOFT FORMATION (UND FFERENTIATED)
- SHERINGHAM CLIFFS FORMATION
- LEET HILL SAND AND GRAVEL MEMBER

REFERENCE MAP



REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	21/01/2021	FIRST EDITION	JB	CM	CB

DESIGNER

CONTRACTOR

CLIENT

PROJECT TITLE
A47 North Tuddenham to Easton

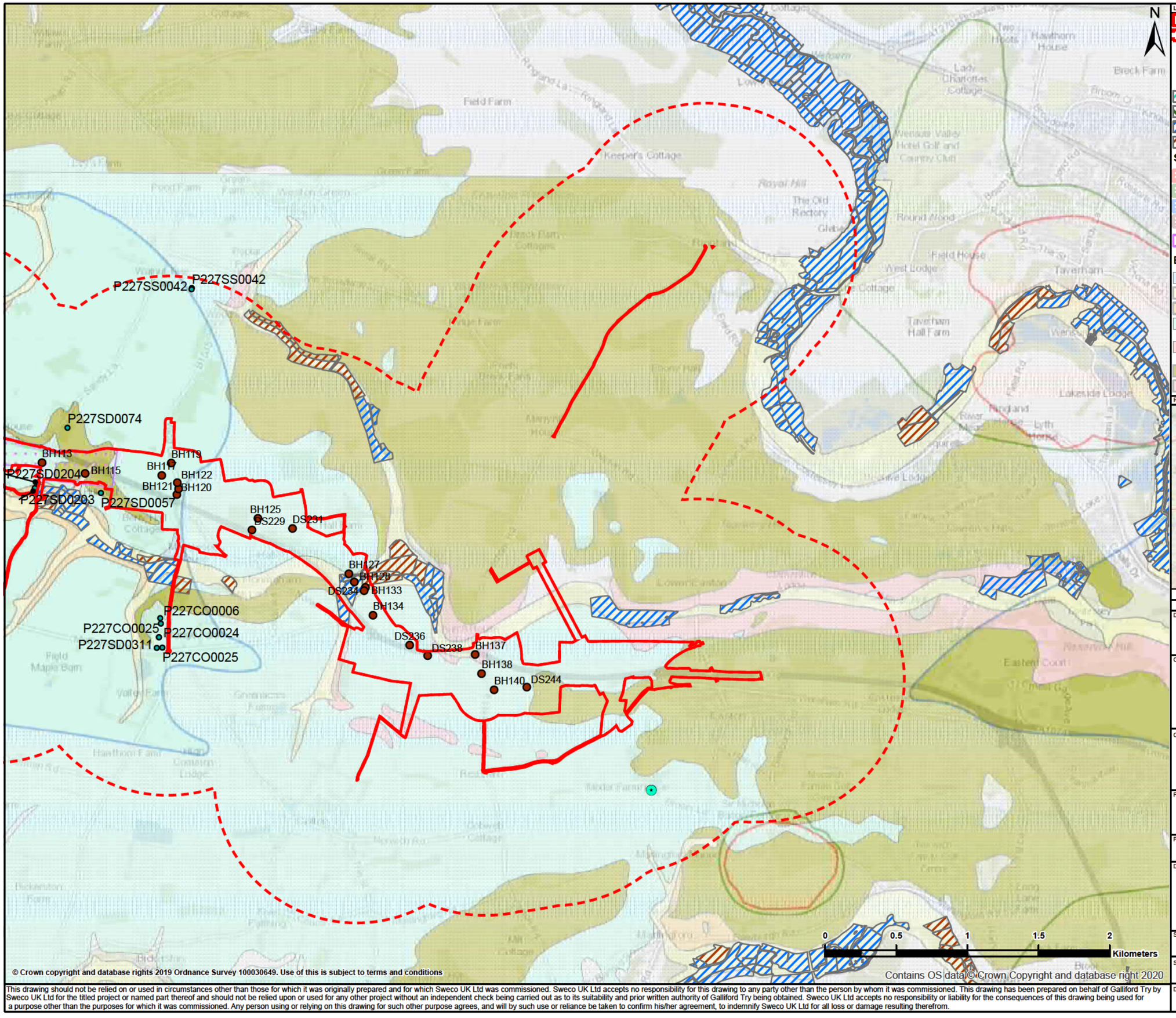
PROJECT STAGE
PROJECT STAGE

DRAWING TITLE
GROUNDWATER APPENDIX: LOCATION PLAN
SHEET 1 OF 2

SUITABILITY
FOR INFORMATION

SHEET SIZE	SCALE	STATUS
A3	1:25,000	S0

DRAWING NUMBER
HE551489-GTY-EWE-000-DR-LE-30001



LEGEND

- DCO boundary
- Study area
- Licensed groundwater abstractions
- Unlicensed groundwater abstractions
- GI groundwater monitoring boreholes
- Site of Scientific Interest
- County Wildlife Site
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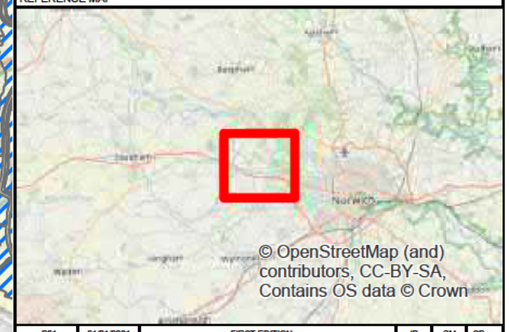
- Potential Source Protection Zone I - Inner Protection Zone

BGS superficial deposits (50k)

- ALLUVIAL FAN DEPOSITS
- ALLUVIUM
- RIVER TERRACE DEPOSITS, 1
- LOWESTOFT FORMATION
- HAPPISBURGH GLACIGENIC FORMATION AND LOWESTOFT FORMATION (UND FFERENTIATED)
- SHERINGHAM CLIFFS FORMATION
- LEET HILL SAND AND GRAVEL MEMBER

REFERENCE MAP



REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	21/01/2021	FIRST EDITION	JB	CM	CB

DESIGNER

CONTRACTOR

CLIENT

PROJECT TITLE
A47 North Tuddenham to Easton

PROJECT STAGE
PROJECT STAGE

DRAWING TITLE
GROUNDWATER APPENDIX: LOCATION PLAN
SHEET 2 OF 2

SUITABILITY
FOR INFORMATION

SHEET SIZE	SCALE	STATUS
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DRAWING NUMBER
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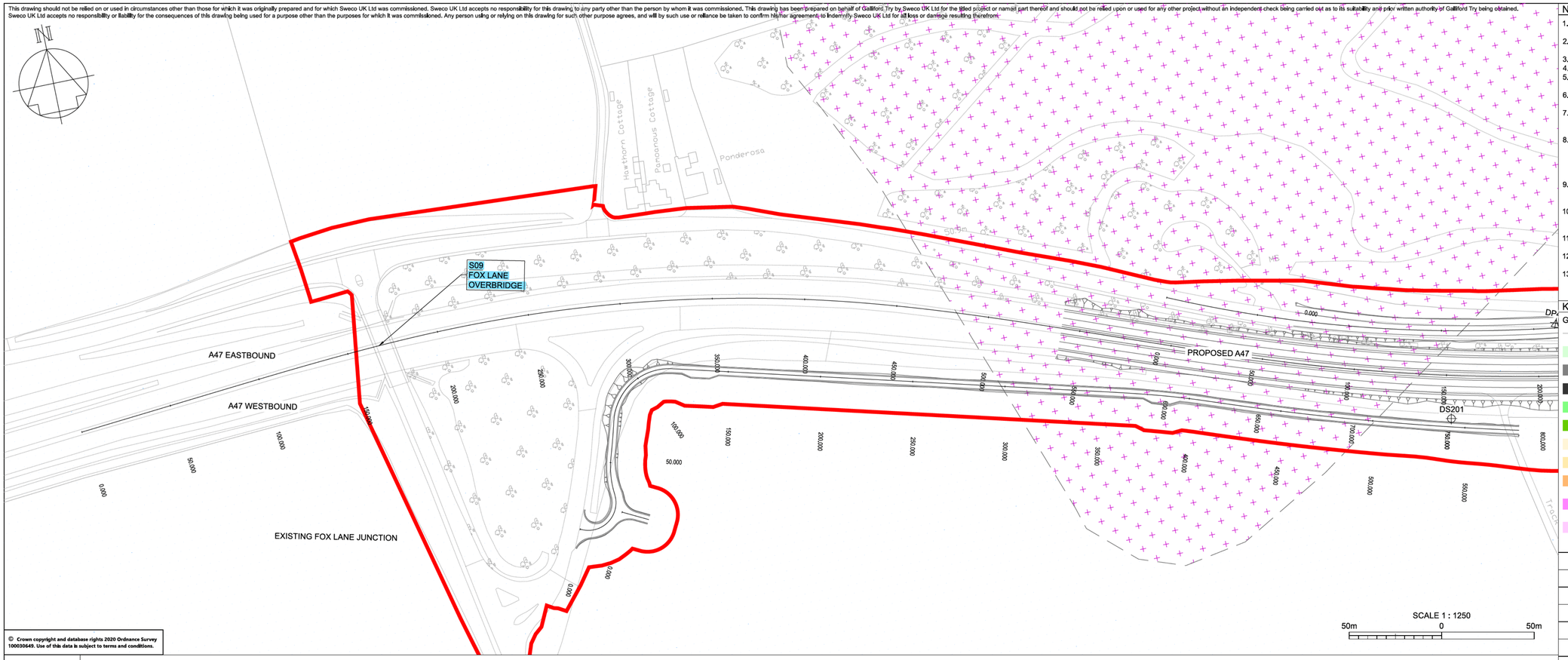
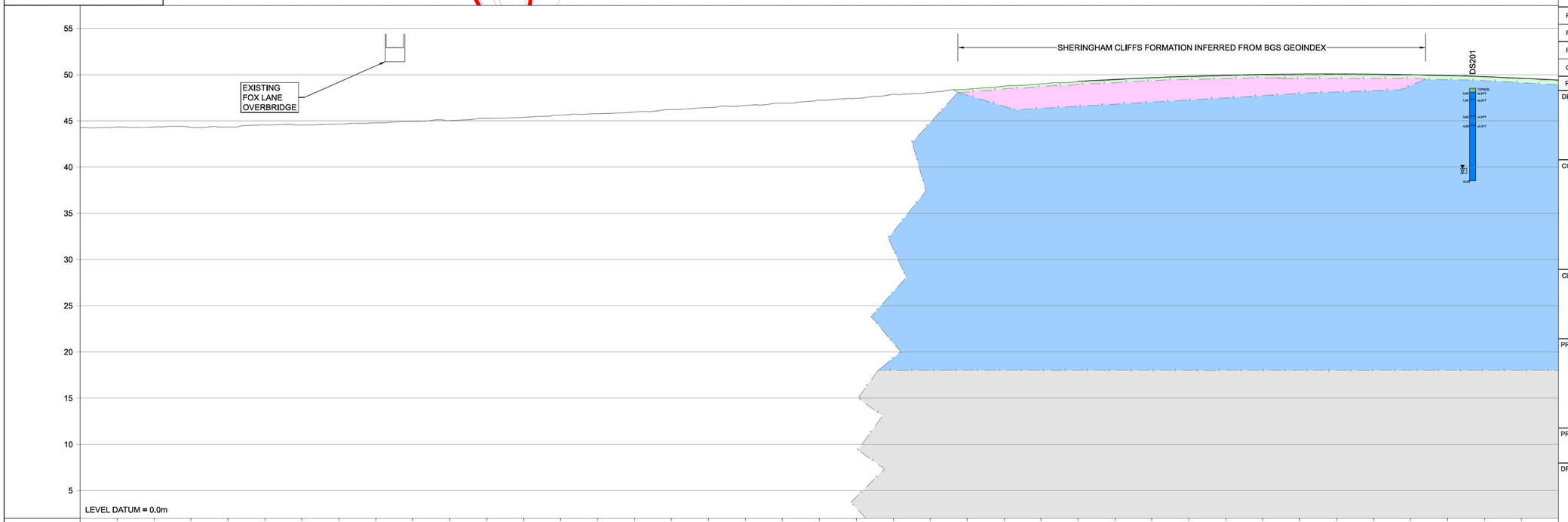
Annex B Geological Long Sections





CHAINAGE	EXISTING LEVELS	DESIGN LEVELS
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20.000	44.335	
40.000	44.335	
60.000	44.308	
80.000	44.332	
100.000	44.561	
120.000	44.558	
140.000	44.646	
160.000	44.782	
180.000	44.938	
200.000	45.030	
220.000	45.257	
240.000	45.387	
260.000	45.610	
280.000	45.781	
300.000	45.958	
320.000	46.217	
340.000	46.443	
360.000	46.674	
380.000	46.908	
400.000	47.252	
420.000	47.433	
440.000	47.865	
460.000	48.086	
480.000	48.408	
500.000	48.757	
520.000	49.008	
540.000	49.261	49.274
560.000	49.431	49.494
580.000	49.661	49.679
600.000	49.796	49.830
620.000	49.897	49.946
640.000	49.990	50.026
660.000	49.956	50.072
680.000	49.999	50.084
700.000	49.998	50.060
720.000	49.976	50.002
740.000	49.874	49.909
760.000	49.788	49.781
780.000	49.588	49.619
800.000	49.345	49.421

NOTES

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P01	18/09/20	DRAFT - FOR INFORMATION	SF	JH	MD
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P03	29/01/21	FOR STAGE APPROVAL	SFln	JHas	MDlg
C01	29/01/21	FOR STAGE APPROVAL	SFln	JHas	MDlg

DESIGNER: SWECO

CONTRACTOR: GallifordTry

CLIENT: highways england

PROJECT TITLE: A47 NORTH TUDDENHAM TO EASTON DUALLING

PROJECT STAGE: PCF STAGE 3

DRAWING TITLE: MAINLINE PLAN AND GEOLOGICAL LONG SECTION SHEET 1 OF 12

SUITABILITY: AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
N/A	1:1250	A3	C01

DRAWING NUMBER: HE551489-GTY-HGT-000-DR-CE-30001

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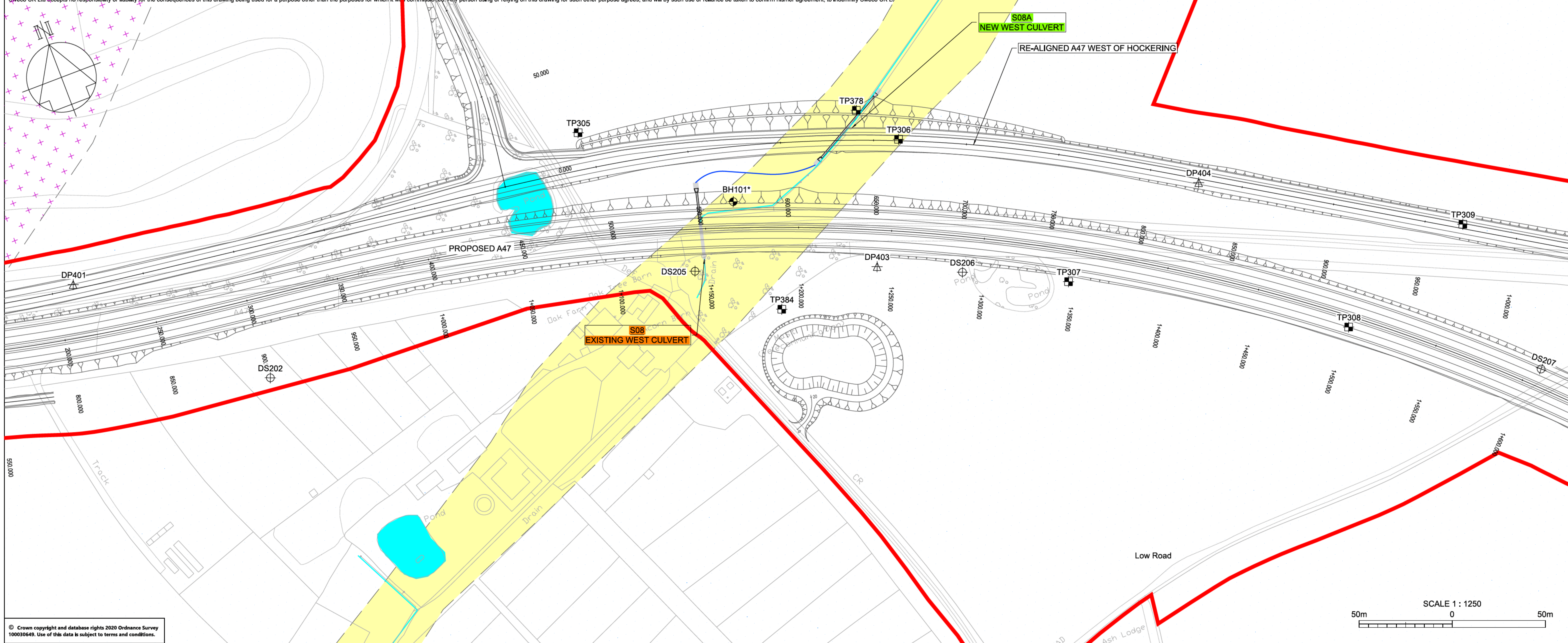

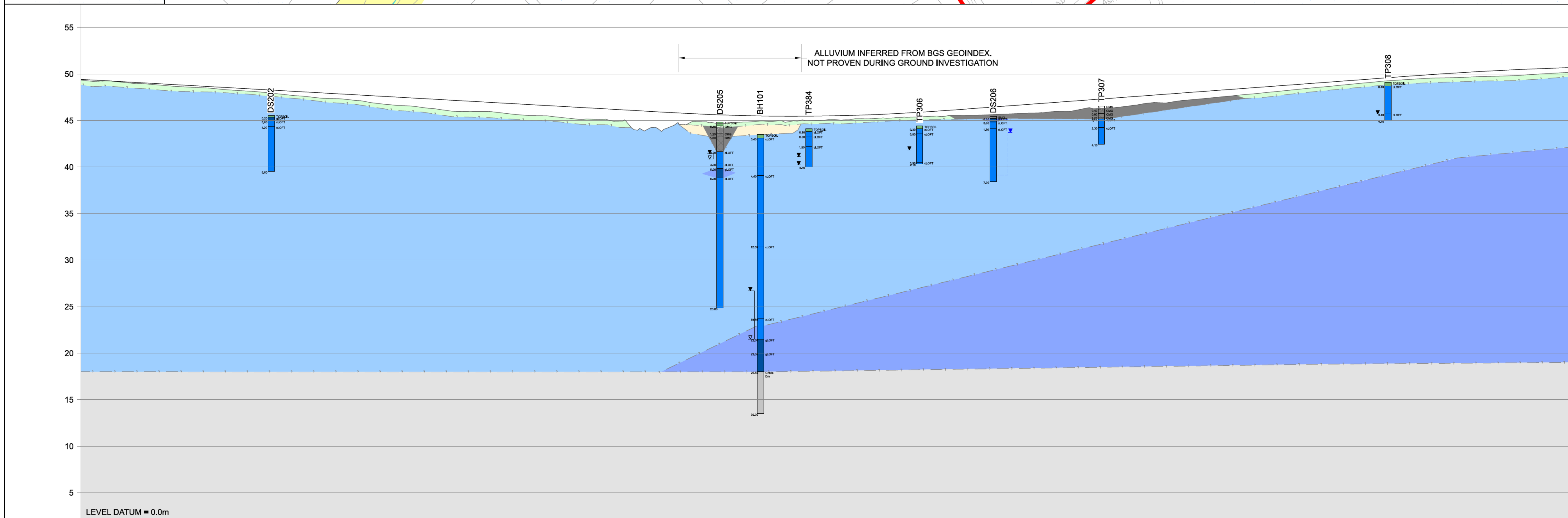

CHAINAGE	DESIGN LEVELS	EXISTING LEVELS
800.000	49.421	49.345
820.000	49.198	49.148
840.000	48.973	48.851
860.000	48.748	48.568
880.000	48.523	48.280
900.000	48.298	47.985
920.000	48.073	47.599
940.000	47.848	47.320
960.000	47.623	46.822
980.000	47.398	46.499
1000.000	47.173	45.997
1020.000	46.948	45.960
1040.000	46.723	45.544
1060.000	46.498	45.277
1080.000	46.273	45.123
1100.000	46.048	44.120
1120.000	45.823	44.675
1140.000	45.631	44.744
1160.000	45.512	44.864
1180.000	45.466	44.864
1200.000	45.492	45.047
1220.000	45.591	45.196
1240.000	45.763	45.332
1260.000	46.007	45.481
1280.000	46.302	45.570
1300.000	46.598	45.719
1320.000	46.895	45.919
1340.000	47.191	46.318
1360.000	47.488	46.487
1380.000	47.784	46.909
1400.000	48.081	47.296
1420.000	48.377	47.683
1440.000	48.674	48.069
1460.000	48.970	48.473
1480.000	49.266	48.856
1500.000	49.563	49.233
1520.000	49.858	49.491
1540.000	50.126	49.624
1560.000	50.353	49.755
1580.000	50.540	49.946
1600.000	50.688	50.183

NOTES

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P01	18/09/20	DRAFT - FOR INFORMATION	SF	JH	MD
P02	27/11/20	FOR REVIEW & COMMENT	SFin	JHas	MDig
P03	29/01/21	FOR STAGE APPROVAL	SFin	JHas	MDig
C01	29/01/21	FOR STAGE APPROVAL	SFin	JHas	MDig

DESIGNER: SWECO

CONTRACTOR: Galliford Try

CLIENT: highways england

PROJECT TITLE
A47 NORTH TUDDENHAM TO EASTON DUALLING

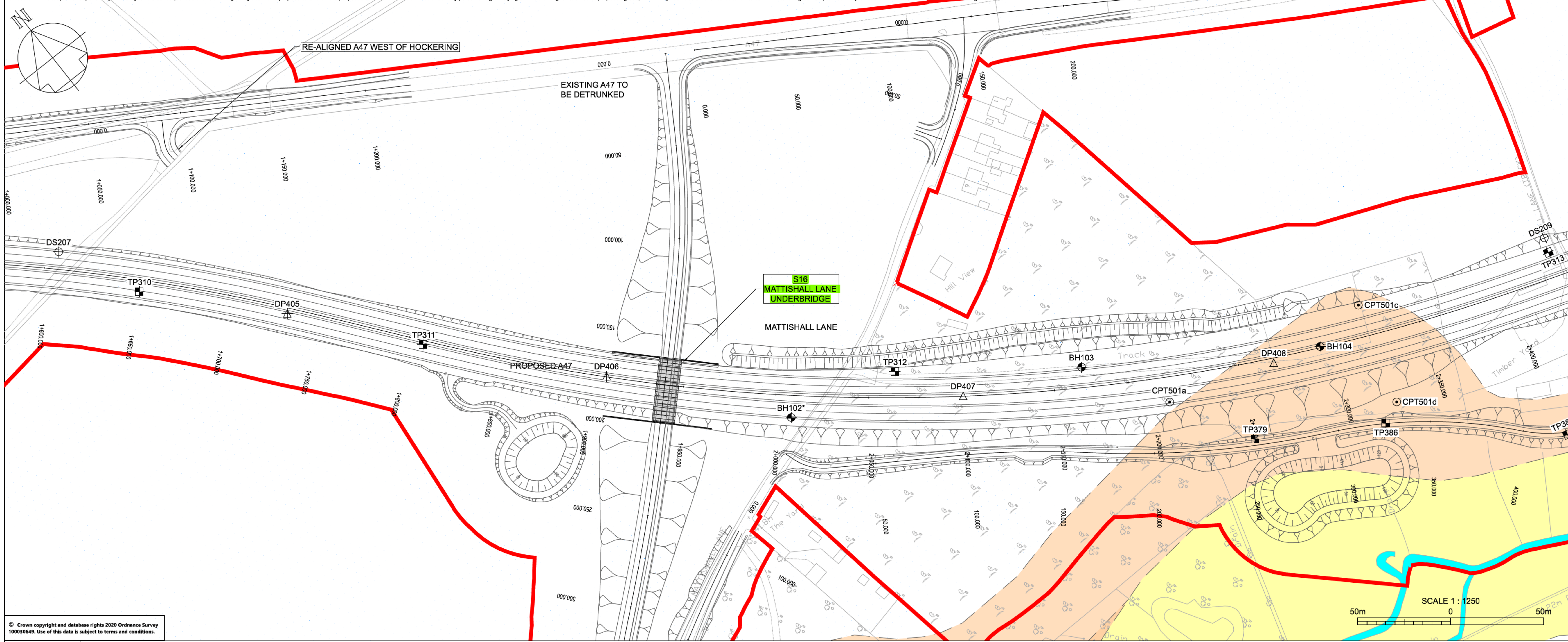
PROJECT STAGE
PCF STAGE 3

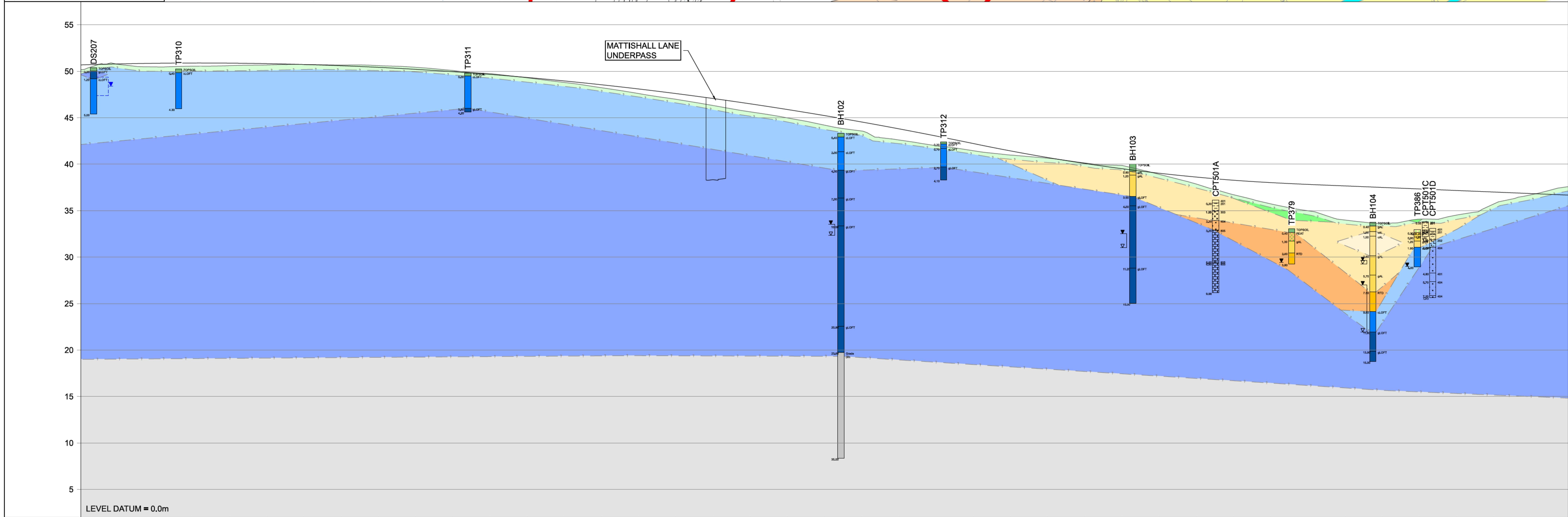
DRAWING TITLE
MAINLINE PLAN AND GEOLOGICAL LONG SECTION SHEET 2 OF 12

SUITABILITY
AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	A3	C01

DRAWING NUMBER
HE551489-GTY-HGT-000-DR-CE-30002





DESIGN LEVELS	50.688	50.795	50.862	50.889	50.877	50.824	50.731	50.598	50.426	50.213	49.960	49.668	49.335	48.962	48.549	48.097	47.604	47.071	46.499	45.886	45.233	44.540	43.808	43.035	42.222	41.432	40.718	40.079	39.516	39.028	38.615	38.278	38.016	37.829	37.664	37.499	37.335	37.170	37.005	36.841	36.676
EXISTING LEVELS	50.183	50.750	50.475	50.552	50.609	50.681	50.722	50.674	50.612	50.429	50.087	49.754	49.301	48.801	48.233	47.605	46.991	46.320	45.637	44.986	44.205	43.572	42.609	41.991	41.452	40.986	40.649	40.138	39.871	38.911	37.864	36.716	35.731	34.990	33.990	33.642	34.086	34.526	35.725	36.711	37.585
CHAINAGE	1600.000	1620.000	1640.000	1660.000	1680.000	1700.000	1720.000	1740.000	1760.000	1780.000	1800.000	1820.000	1840.000	1860.000	1880.000	1900.000	1920.000	1940.000	1960.000	1980.000	2000.000	2020.000	2040.000	2060.000	2080.000	2100.000	2120.000	2140.000	2160.000	2180.000	2200.000	2220.000	2240.000	2260.000	2280.000	2300.000	2320.000	2340.000	2360.000	2380.000	2400.000

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REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	18/09/20	DRAFT - FOR INFORMATION	SF	JH	MD
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C01	29/01/21	FOR STAGE APPROVAL	SFin	JHas	MDig

DESIGNER: SWECO

CONTRACTOR: Galliford Try

CLIENT: highways england

PROJECT TITLE
A47 NORTH TUDDENHAM TO EASTON DUALLING

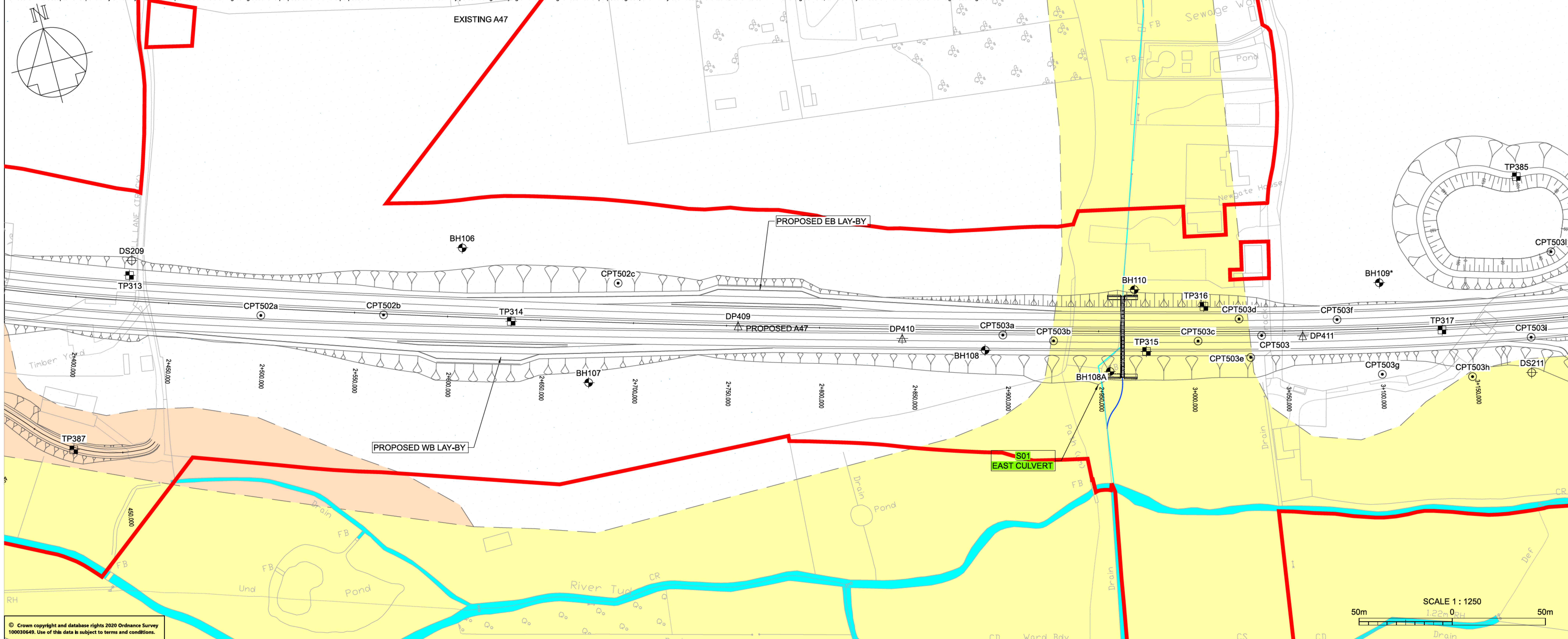
PROJECT STAGE
PCF STAGE 3

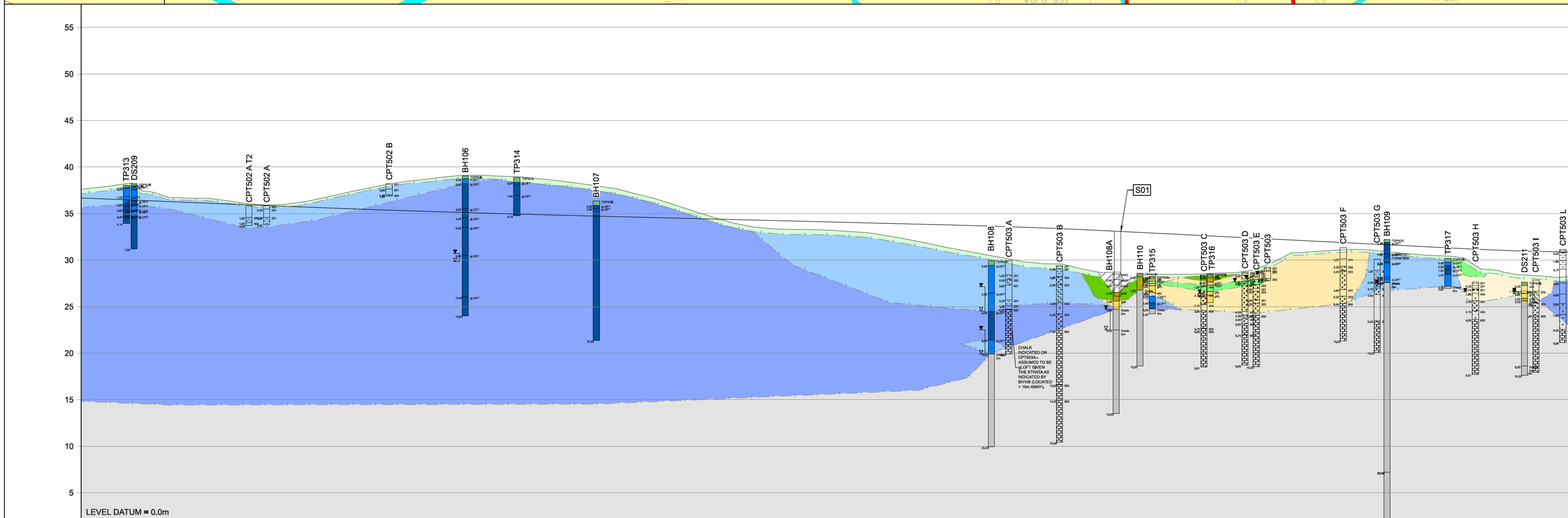
DRAWING TITLE
MAINLINE PLAN AND GEOLOGICAL LONG SECTION SHEET 3 OF 12

SUITABILITY
AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	A3	C01

DRAWING NUMBER
HE551489-GTY-HGT-000-DR-CE-30003





CHAINAGE	DESIGN LEVELS	EXISTING LEVELS
2400.000	36.676	37.585
2420.000	36.511	38.090
2440.000	36.347	37.210
2460.000	36.182	36.645
2480.000	36.018	36.340
2500.000	35.855	35.915
2520.000	35.699	36.277
2540.000	35.550	37.125
2560.000	35.408	37.963
2580.000	35.274	38.568
2600.000	35.147	39.022
2620.000	35.028	39.066
2640.000	34.915	38.871
2660.000	34.810	38.441
2680.000	34.710	37.887
2700.000	34.610	37.031
2720.000	34.510	35.867
2740.000	34.410	34.589
2760.000	34.310	33.608
2780.000	34.210	33.309
2800.000	34.110	33.227
2820.000	34.010	32.978
2840.000	33.910	32.387
2860.000	33.810	31.581
2880.000	33.704	30.809
2900.000	33.576	30.076
2920.000	33.427	29.599
2940.000	33.255	28.968
2960.000	33.062	27.974
2980.000	32.863	28.478
3000.000	32.663	28.495
3020.000	32.463	28.640
3040.000	32.263	29.736
3060.000	32.063	30.886
3080.000	31.863	31.133
3100.000	31.663	30.941
3120.000	31.463	30.575
3140.000	31.263	30.311
3160.000	31.076	28.922
3180.000	30.946	28.351
3200.000	30.878	28.235

NOTES

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DESIGNER
SWECO

CONTRACTOR
Galliford Try

CLIENT
highways england

PROJECT TITLE
A47 NORTH TUDDENHAM TO EASTON DUALLING

PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
MAINLINE PLAN AND GEOLOGICAL LONG SECTION SHEET 4 OF 12

SUITABILITY
AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	A3	C01

DRAWING NUMBER
HE551489-GTY-HGT-000-DR-CE-30004

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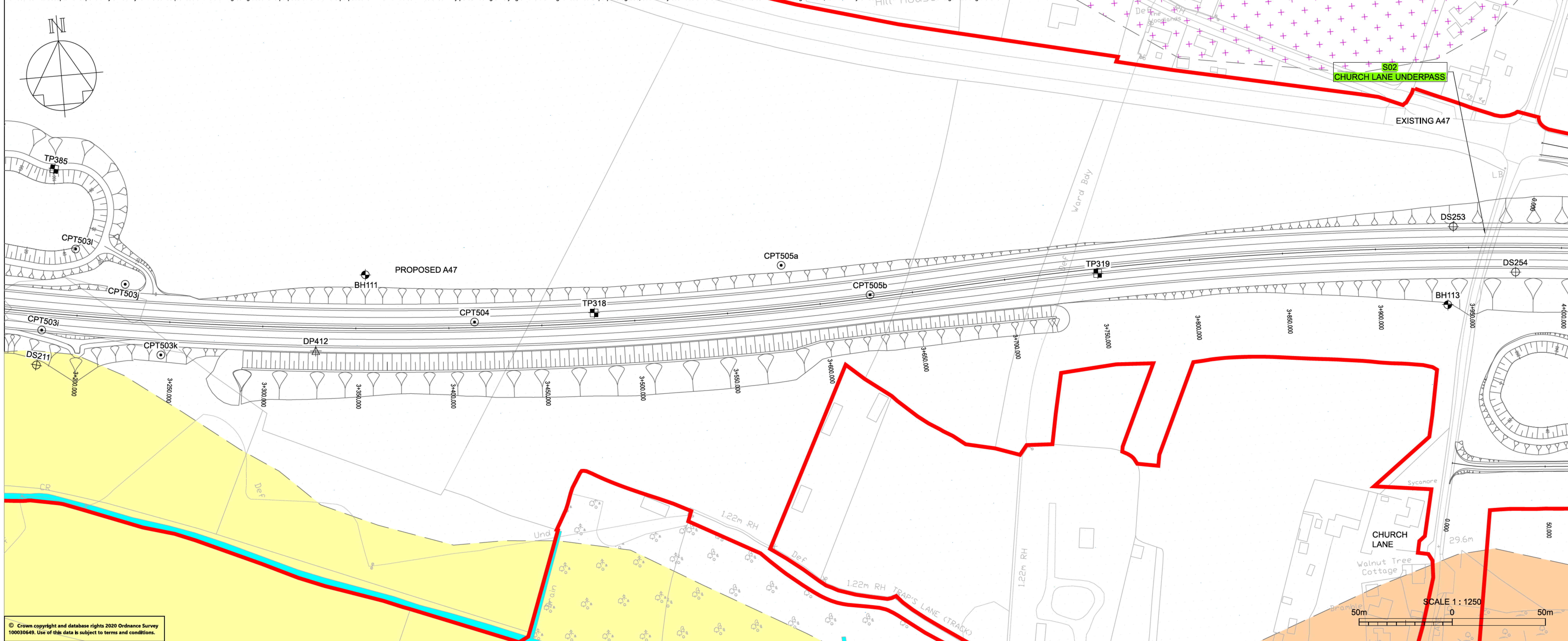

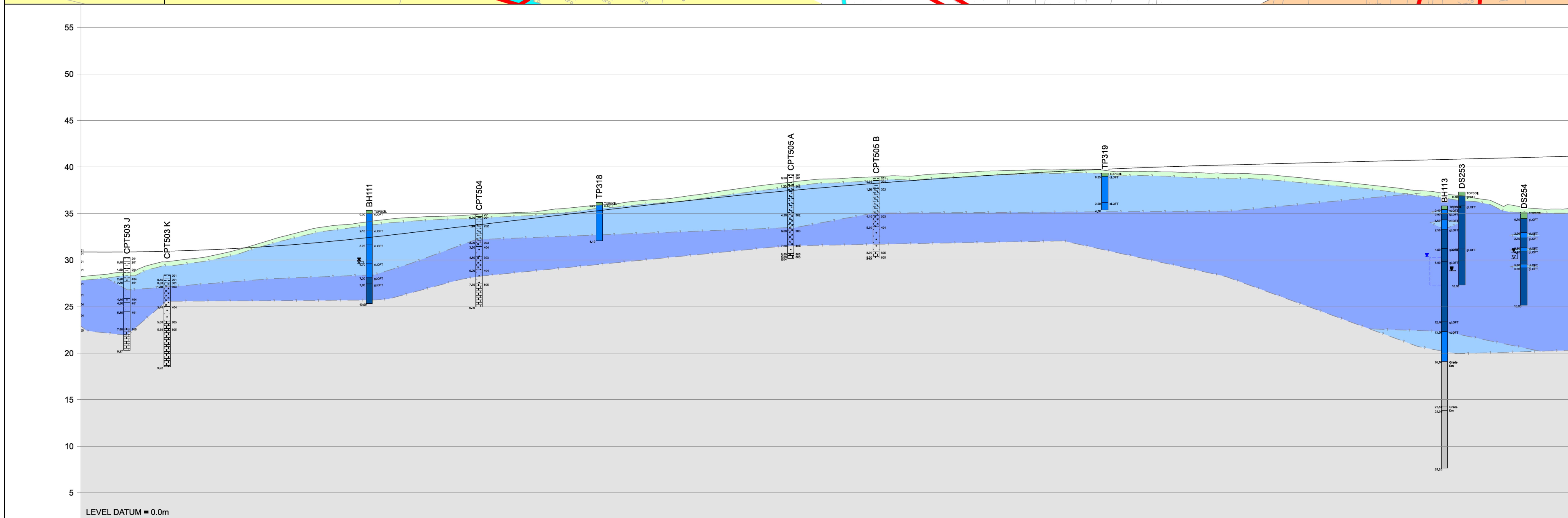

CHAINAGE	DESIGN LEVELS	EXISTING LEVELS
3200.000	30.878	28.235
3220.000	30.871	28.678
3240.000	30.926	29.638
3260.000	31.042	30.159
3280.000	31.220	30.900
3300.000	31.460	32.046
3320.000	31.761	33.138
3340.000	32.123	33.787
3360.000	32.547	34.275
3380.000	33.014	34.600
3400.000	33.482	34.753
3420.000	33.950	34.985
3440.000	34.419	35.156
3460.000	34.887	35.562
3480.000	35.355	35.936
3500.000	35.818	36.372
3520.000	36.260	36.721
3540.000	36.680	37.287
3560.000	37.078	37.860
3580.000	37.454	38.349
3600.000	37.808	38.714
3620.000	38.140	38.898
3640.000	38.450	39.047
3660.000	38.738	39.268
3680.000	39.004	39.486
3700.000	39.249	39.637
3720.000	39.471	39.696
3740.000	39.671	39.733
3760.000	39.849	39.523
3780.000	40.005	39.493
3800.000	40.140	39.400
3820.000	40.252	39.291
3840.000	40.352	39.145
3860.000	40.452	38.747
3880.000	40.552	38.357
3900.000	40.652	37.906
3920.000	40.752	37.451
3940.000	40.852	36.956
3960.000	40.952	36.172
3980.000	41.052	35.566
4000.000	41.158	35.556

NOTES

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- GRANULAR MADE GROUND
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P01	18/09/20	DRAFT - FOR INFORMATION	SF	JH	MD
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P03	29/01/21	FOR STAGE APPROVAL	SFin	JHas	MDig
C01	29/01/21	FOR STAGE APPROVAL	SFin	JHas	MDig

DESIGNER

SWECO

CONTRACTOR

GallifordTry

CLIENT

highways england

PROJECT TITLE

A47 NORTH TUDDENHAM TO EASTON DUALLING

PROJECT STAGE

PCF STAGE 3

DRAWING TITLE

MAINLINE PLAN AND GEOLOGICAL LONG SECTION SHEET 5 OF 12

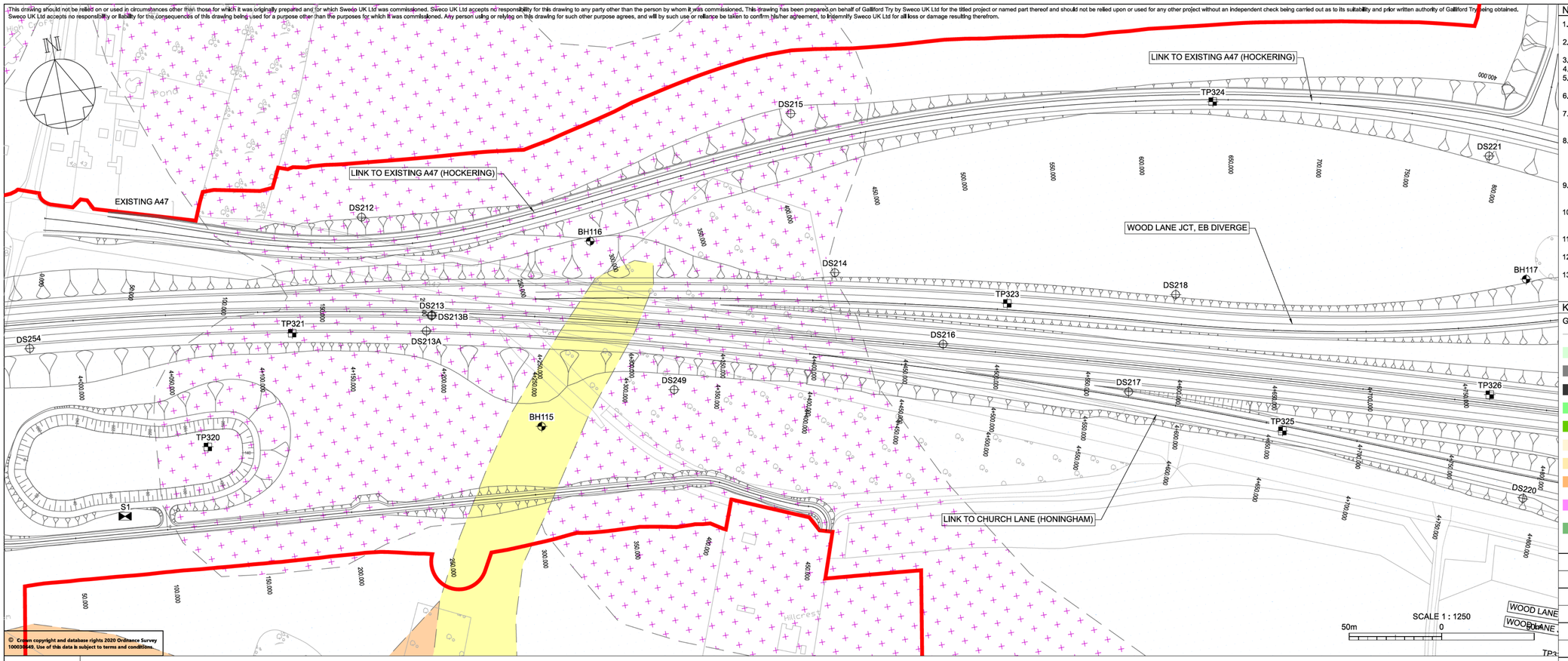
SUITABILITY

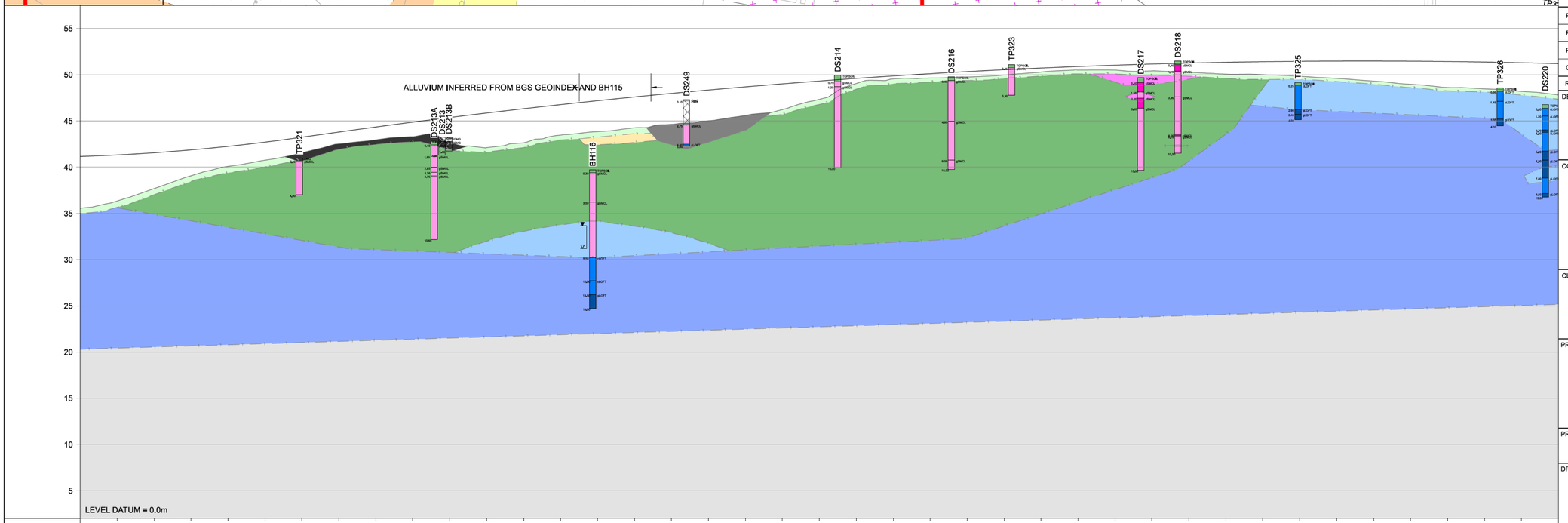
AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	A3	C01

DRAWING NUMBER

HE551489-GTY-HGT-000-DR-CE-30005





CHAINAGE	DESIGN LEVELS	EXISTING LEVELS
4000.000	41.158	35.556
4020.000	41.322	36.343
4040.000	41.560	37.684
4060.000	41.870	39.068
4080.000	42.253	40.085
4100.000	42.708	40.753
4120.000	43.237	41.556
4140.000	43.800	42.518
4160.000	44.344	42.961
4180.000	44.869	43.303
4200.000	45.373	42.645
4220.000	45.857	42.116
4240.000	46.321	42.635
4260.000	46.765	43.463
4280.000	47.190	43.844
4300.000	47.594	44.257
4320.000	47.978	44.632
4340.000	48.342	45.021
4360.000	48.686	45.588
4380.000	49.011	46.225
4400.000	49.315	47.333
4420.000	49.599	49.051
4440.000	49.863	49.541
4460.000	50.107	49.636
4480.000	50.332	49.749
4500.000	50.536	49.959
4520.000	50.720	50.279
4540.000	50.884	50.499
4560.000	51.028	50.501
4580.000	51.152	50.406
4600.000	51.257	50.258
4620.000	51.341	50.060
4640.000	51.405	50.001
4660.000	51.449	49.828
4680.000	51.473	49.597
4700.000	51.478	49.311
4720.000	51.462	48.962
4740.000	51.426	48.619
4760.000	51.370	48.469
4780.000	51.294	48.198
4800.000	51.199	47.812

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C01	29/01/21	FOR STAGE APPROVAL	SFln	JHas	MDlg

DESIGNER

SWECO

CONTRACTOR

GallifordTry

CLIENT

highways england

PROJECT TITLE

A47 NORTH TUDDENHAM TO EASTON DUALLING

PROJECT STAGE

PCF STAGE 3

DRAWING TITLE

MAINLINE PLAN AND GEOLOGICAL LONG SECTION SHEET 6 OF 12

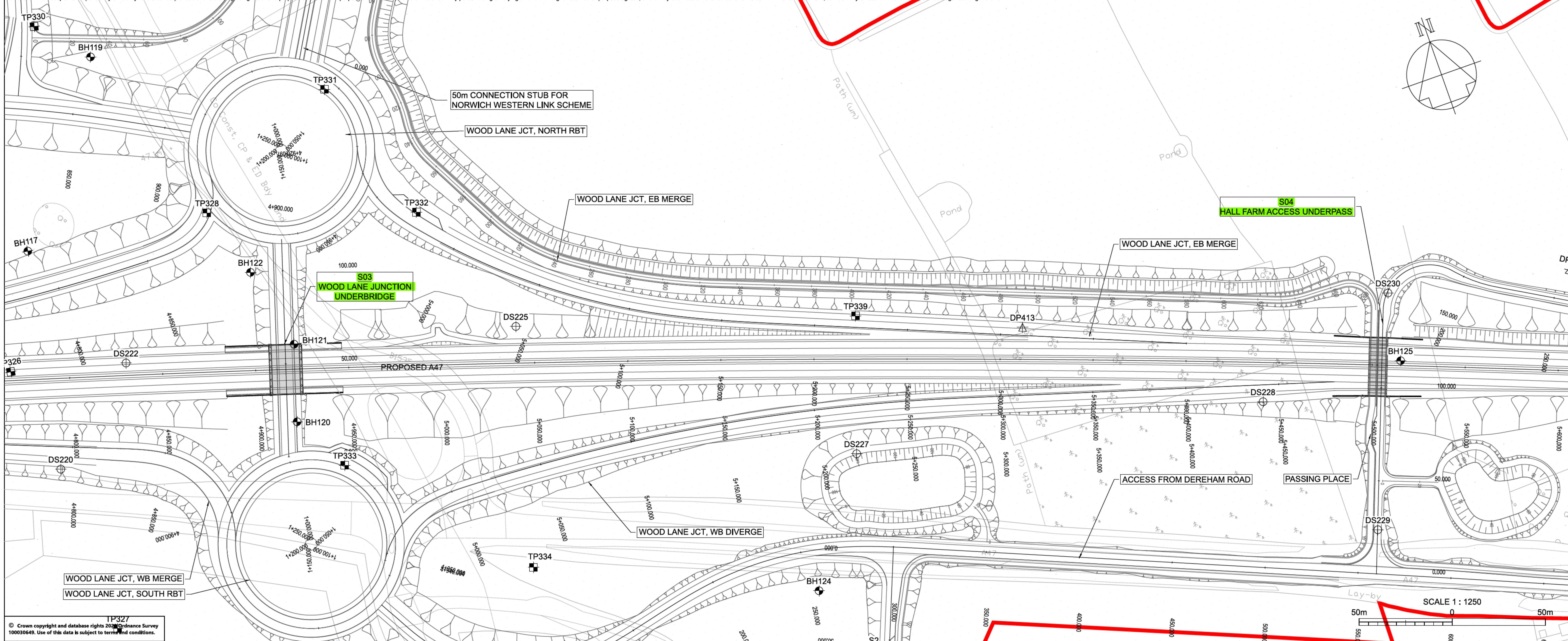
SUITABILITY

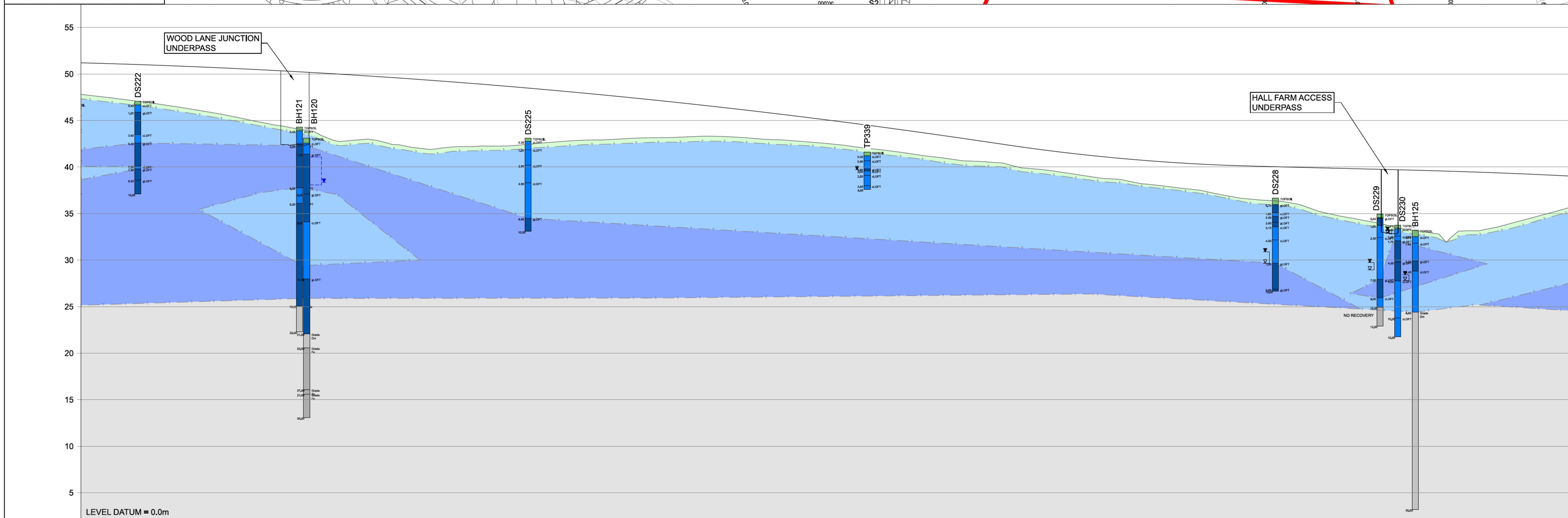
AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	A3	C01

DRAWING NUMBER

HE551489-GTY-HGT-000-DR-CE-30006





CHAINAGE	4800.000	4820.000	4840.000	4860.000	4880.000	4900.000	4920.000	4940.000	4960.000	4980.000	5000.000	5020.000	5040.000
DESIGN LEVELS	51.199	51.083	50.947	50.791	50.615	50.420	50.204	49.968	49.712	49.436	49.140	48.825	48.489
EXISTING LEVELS	47.812	47.333	46.811	46.200	45.497	44.679	43.970	42.756	42.808	42.067	42.169	42.246	42.436

CHAINAGE	5060.000	5080.000	5100.000	5120.000	5140.000	5160.000	5180.000	5200.000	5220.000	5240.000	5260.000	5280.000	5300.000
DESIGN LEVELS	48.133	47.757	47.361	46.946	46.510	46.054	45.578	45.082	44.567	44.031	43.475	42.899	42.308
EXISTING LEVELS	42.775	42.918	43.115	43.196	43.304	43.100	42.862	42.543	42.062	41.598	41.054	40.626	40.184

CHAINAGE	5320.000	5340.000	5360.000	5380.000	5400.000	5420.000	5440.000	5460.000	5480.000	5500.000	5520.000	5540.000	5560.000	5580.000	5600.000
DESIGN LEVELS	41.767	41.299	40.904	40.582	40.332	40.155	40.044	39.944	39.844	39.744	39.642	39.523	39.381	39.218	39.032
EXISTING LEVELS	39.640	39.045	38.605	38.008	37.537	36.760	36.385	35.602	34.607	33.841	33.079	33.076	33.513	34.563	35.655

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DESIGNER
SWECO

CONTRACTOR
Galliford Try

CLIENT
highways england

PROJECT TITLE
A47 NORTH TUDDENHAM TO EASTON DUALLING

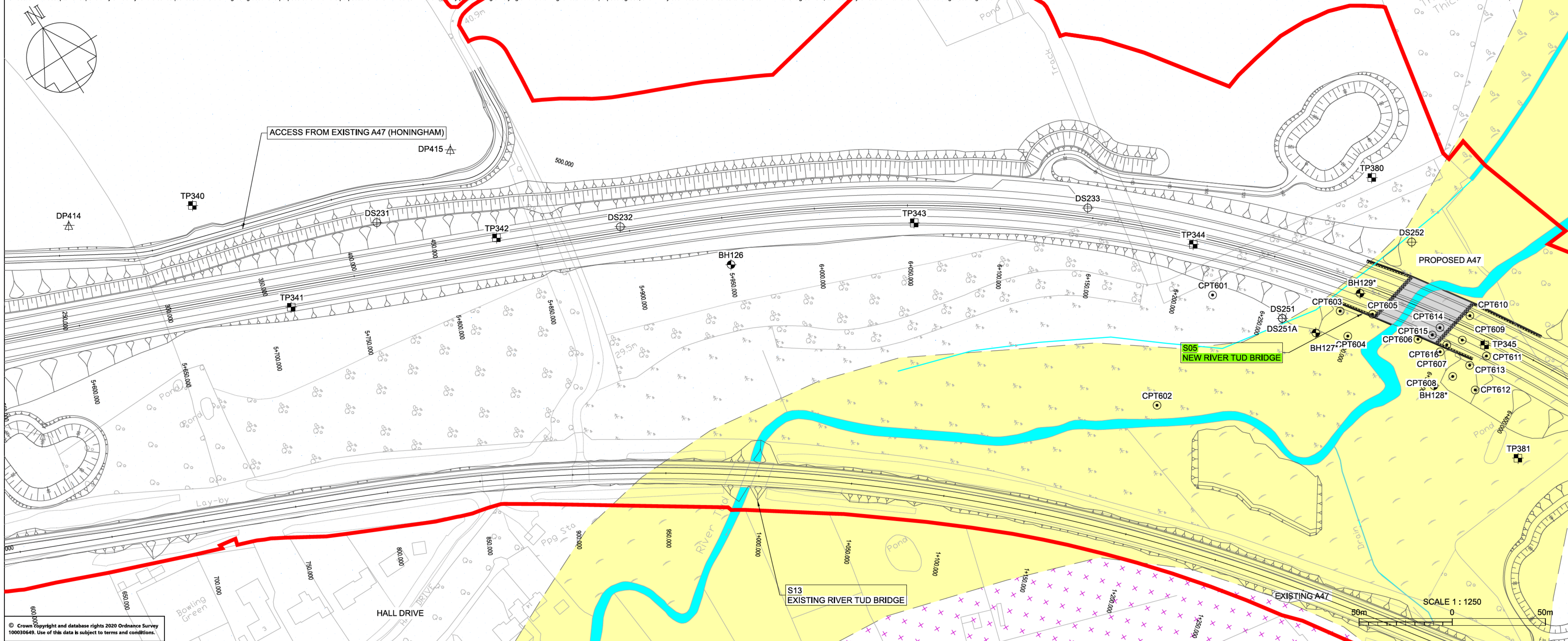
PROJECT STAGE
PCF STAGE 3

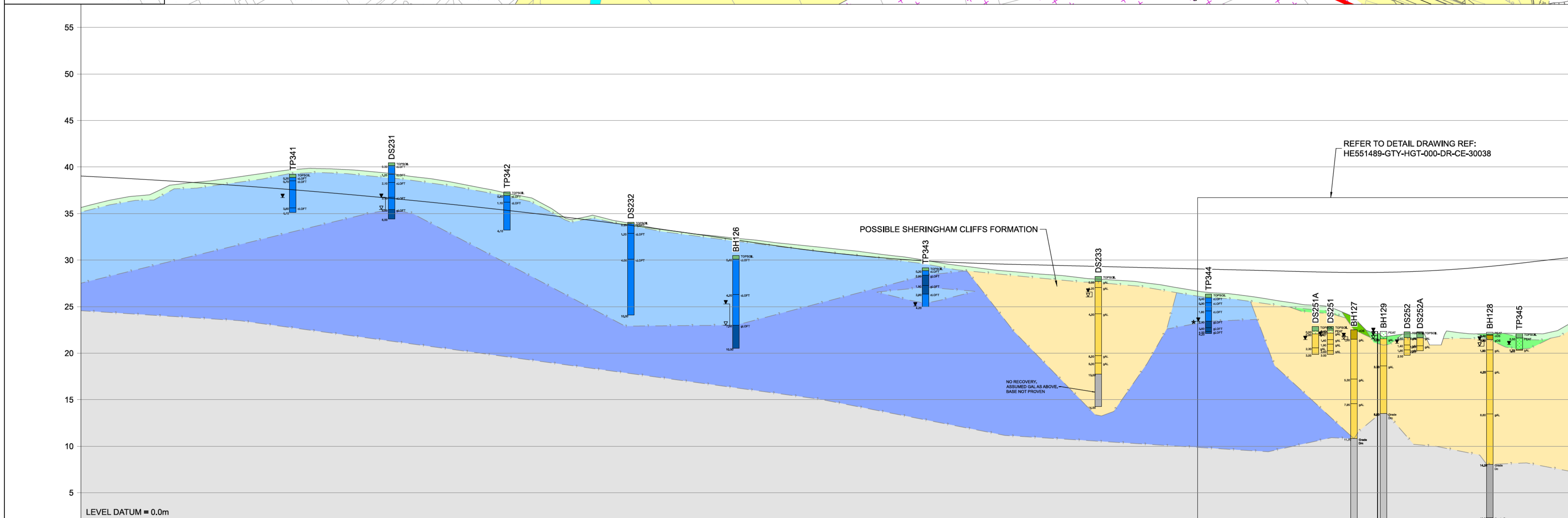
DRAWING TITLE
MAINLINE PLAN AND GEOLOGICAL LONG SECTION SHEET 7 OF 12

SUITABILITY
AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	A3	C01

DRAWING NUMBER
HE551489-GTY-HGT-000-DR-CE-30007





DESIGN LEVELS	39.032	38.825	38.596	38.344	38.071	37.776	37.458	37.119	36.758	36.374	35.969	35.542	35.093	34.622	34.129	33.613	33.076	32.517	31.936	31.360	30.861
EXISTING LEVELS	35.655	36.605	37.311	38.341	38.805	39.386	39.818	39.751	39.436	38.929	38.348	37.580	36.762	34.546	34.577	33.762	33.086	32.616	32.200	31.737	31.325
CHAINAGE	5600.000	5620.000	5640.000	5660.000	5680.000	5700.000	5720.000	5740.000	5760.000	5780.000	5800.000	5820.000	5840.000	5860.000	5880.000	5900.000	5920.000	5940.000	5960.000	5980.000	6000.000

DESIGN LEVELS	30.441	30.101	29.841	29.662	29.552	29.452	29.352	29.252	29.152	29.052	28.952	28.852	28.752	28.669	28.685	28.834	29.107	29.380	29.821	30.272
EXISTING LEVELS	30.885	30.393	29.764	29.214	28.775	28.438	28.034	27.793	27.356	26.670	26.316	25.741	25.176	24.230	21.751	22.216	22.212	22.118	22.103	23.184
CHAINAGE	6020.000	6040.000	6060.000	6080.000	6100.000	6120.000	6140.000	6160.000	6180.000	6200.000	6220.000	6240.000	6260.000	6280.000	6300.000	6320.000	6340.000	6360.000	6380.000	6400.000

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CLIENT
highways england

PROJECT TITLE
A47 NORTH TUDDENHAM TO EASTON DUALLING

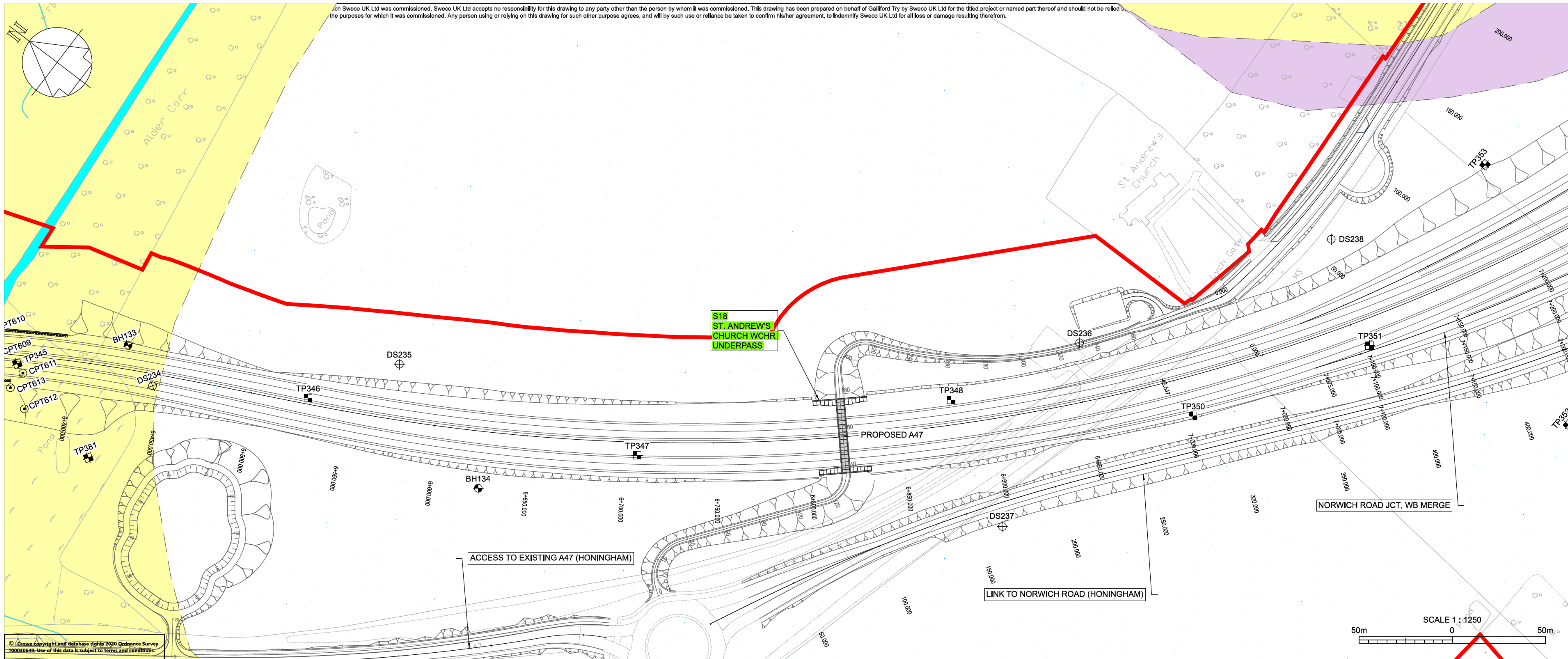
PROJECT STAGE
PCF STAGE 3

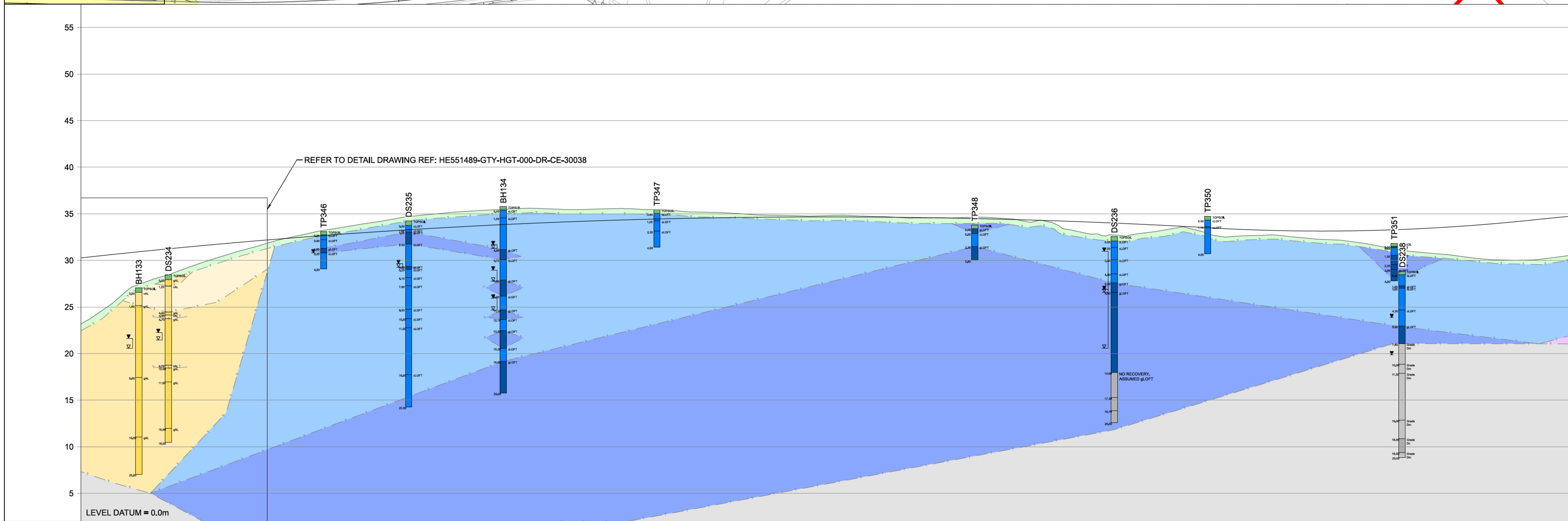
DRAWING TITLE
MAINLINE PLAN AND GEOLOGICAL LONG SECTION SHEET 8 OF 12

SUITABILITY
AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	A3	C01

DRAWING NUMBER
HE551489-GTY-HGT-000-DR-CE-30008





CHAINAGE	DESIGN LEVELS	EXISTING LEVELS
6400.000	30.272	23.184
6420.000	30.701	25.943
6440.000	31.107	28.056
6460.000	31.492	29.417
6480.000	31.855	30.701
6500.000	32.195	31.838
6520.000	32.514	32.798
6540.000	32.811	33.529
6560.000	33.086	34.167
6580.000	33.338	34.784
6600.000	33.569	35.168
6620.000	33.778	35.415
6640.000	33.965	35.596
6660.000	34.130	35.462
6680.000	34.273	35.531
6700.000	34.394	35.492
6720.000	34.493	35.320
6740.000	34.570	35.151
6760.000	34.625	34.933
6780.000	34.658	34.818
6800.000	34.669	34.802
6820.000	34.658	34.756
6840.000	34.625	34.608
6860.000	34.570	34.582
6880.000	34.493	34.633
6900.000	34.394	34.454
6920.000	34.273	34.147
6940.000	34.131	32.919
6960.000	33.966	32.641
6980.000	33.779	33.188
7000.000	33.570	33.213
7020.000	33.360	32.575
7040.000	33.220	32.743
7060.000	33.154	32.358
7080.000	33.165	32.088
7100.000	33.250	31.445
7120.000	33.412	30.865
7140.000	33.648	30.473
7160.000	33.960	30.059
7180.000	34.345	30.049
7200.000	34.735	30.544

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P02	27/11/20	FOR REVIEW & COMMENT	SFin	JHas	MDig
P03	29/01/21	FOR STAGE APPROVAL	SFin	JHas	MDig
C01	29/01/21	FOR STAGE APPROVAL	SFin	JHas	MDig

DESIGNER

SWECO

CONTRACTOR

Galliford Try

CLIENT

highways england

PROJECT TITLE

A47 NORTH TUDDENHAM TO EASTON DUALLING

PROJECT STAGE

PCF STAGE 3

DRAWING TITLE

MAINLINE PLAN AND GEOLOGICAL LONG SECTION SHEET 9 OF 12

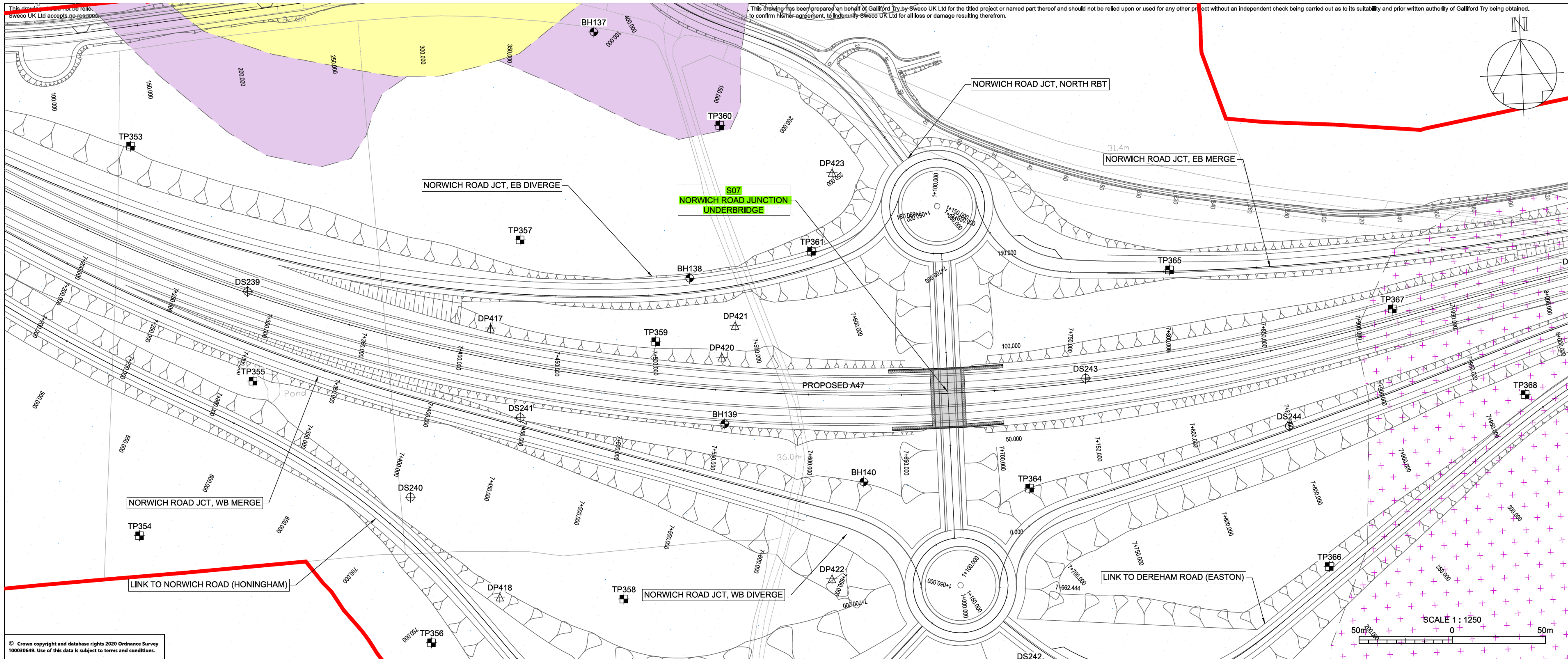
SUITABILITY

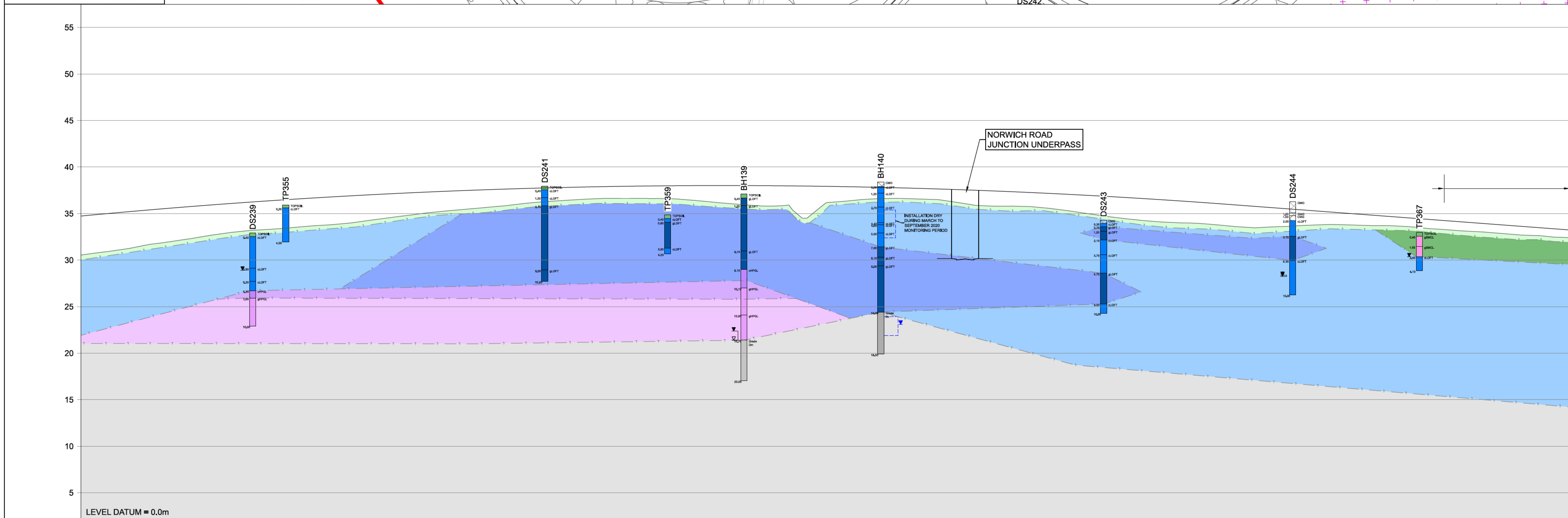
AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	A3	C01

DRAWING NUMBER

HE551489-GTY-HGT-000-DR-CE-30009





DESIGN LEVELS	34.735	35.104	35.450	35.775	36.077	36.358	36.616	36.853	37.067	37.260	37.431	37.579	37.706	37.810
EXISTING LEVELS	30.544	31.081	31.767	32.341	32.957	33.291	33.607	33.900	34.404	34.919	35.347	35.703	36.121	36.416
CHAINAGE	7200.000	7220.000	7240.000	7260.000	7280.000	7300.000	7320.000	7340.000	7360.000	7380.000	7400.000	7420.000	7440.000	7460.000

DESIGN LEVELS	37.893	37.954	37.993	38.009	38.004	37.977	37.928	37.857	37.763	37.648	37.511	37.352	37.171	36.968
EXISTING LEVELS	36.622	36.633	36.573	36.225	35.898	35.909	36.106	36.515	36.631	36.505	35.901	35.797	35.568	35.021
CHAINAGE	7480.000	7500.000	7520.000	7540.000	7560.000	7580.000	7600.000	7620.000	7640.000	7660.000	7680.000	7700.000	7720.000	7740.000

DESIGN LEVELS	36.743	36.496	36.227	35.936	35.636	35.336	35.036	34.736	34.436	34.136	33.836	33.536	33.236
EXISTING LEVELS	34.476	34.101	33.949	33.607	33.570	33.749	33.789	33.704	33.473	33.169	32.916	32.651	32.416
CHAINAGE	7760.000	7780.000	7800.000	7820.000	7840.000	7860.000	7880.000	7900.000	7920.000	7940.000	7960.000	7980.000	8000.000

NOTES

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C01	29/01/21	FOR STAGE APPROVAL	SFin	JHas	MDig

DESIGNER: SWECO

CONTRACTOR: GallifordTry

CLIENT: highways england

PROJECT TITLE: A47 NORTH TUDDENHAM TO EASTON DUALLING

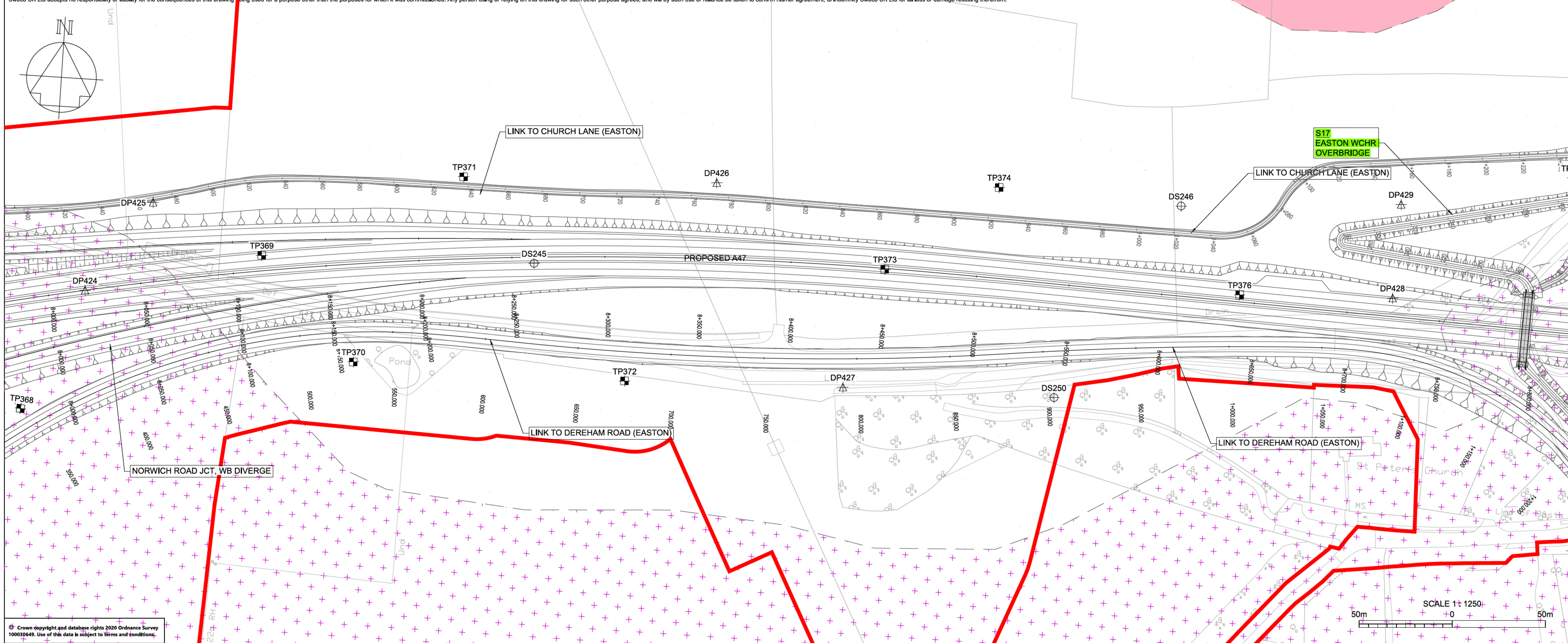
PROJECT STAGE: PCF STAGE 3

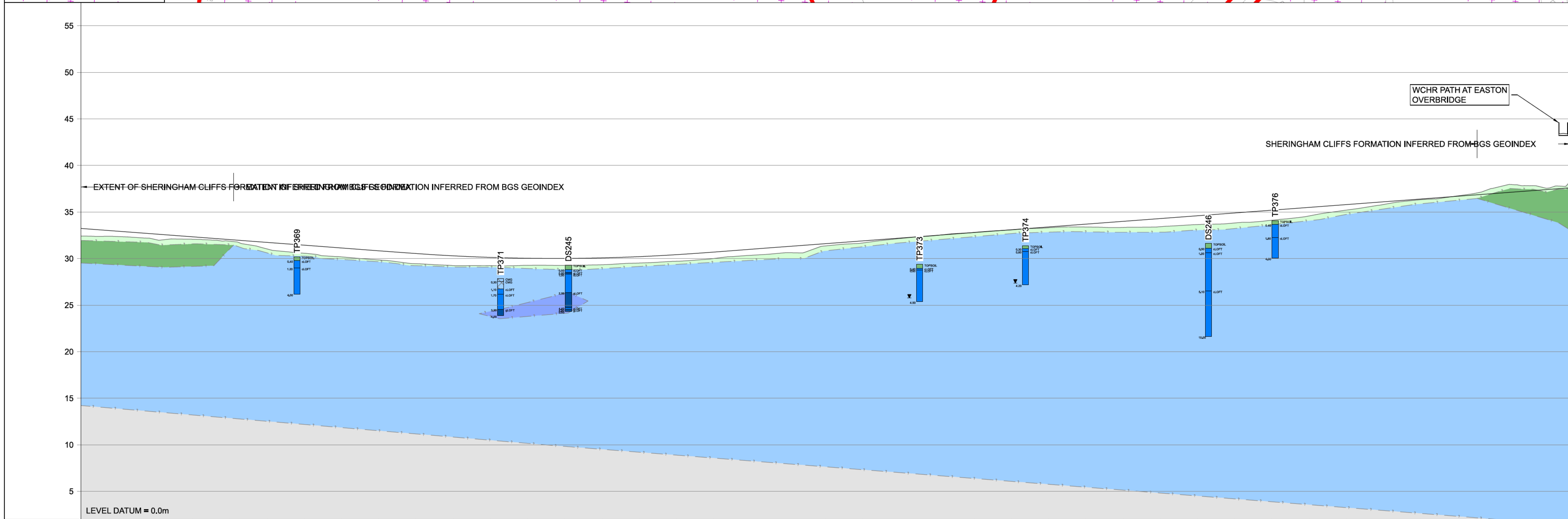
DRAWING TITLE: MAINLINE PLAN AND GEOLOGICAL LONG SECTION SHEET 10 OF 12

SUITABILITY: AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	A3	C01

DRAWING NUMBER: HE551489-GTY-HGT-000-DR-CE-30010





DESIGN LEVELS	33.236	32.936	32.636	32.336	32.036	31.736	31.436	31.136	30.836	30.539
EXISTING LEVELS	32.416	32.366	32.047	32.079	31.866	31.034	30.576	30.185	29.851	29.452
CHAINAGE	8000.000	8020.000	8040.000	8060.000	8080.000	8100.000	8120.000	8140.000	8160.000	8180.000

DESIGN LEVELS	30.295	30.127	30.034	30.017	30.075	30.209	30.418	30.700	31.000	31.300
EXISTING LEVELS	29.251	29.246	29.276	29.270	29.340	29.523	29.711	30.010	30.352	30.634
CHAINAGE	8200.000	8220.000	8240.000	8260.000	8280.000	8300.000	8320.000	8340.000	8360.000	8380.000

DESIGN LEVELS	31.600	31.900	32.200	32.500	32.800	33.100	33.400	33.700	34.000	34.300
EXISTING LEVELS	31.359	31.677	32.153	32.489	32.819	33.082	33.311	33.391	33.347	33.426
CHAINAGE	8400.000	8420.000	8440.000	8460.000	8480.000	8500.000	8520.000	8540.000	8560.000	8580.000

DESIGN LEVELS	34.600	34.900	35.200	35.500	35.800	36.100	36.400	36.700	37.000	37.300	37.600
EXISTING LEVELS	33.656	33.826	34.124	34.584	35.211	35.814	36.326	36.744	37.613	37.831	38.149
CHAINAGE	8600.000	8620.000	8640.000	8660.000	8680.000	8700.000	8720.000	8740.000	8760.000	8780.000	8800.000

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DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47 NORTH TUDDENHAM TO EASTON DUALLING

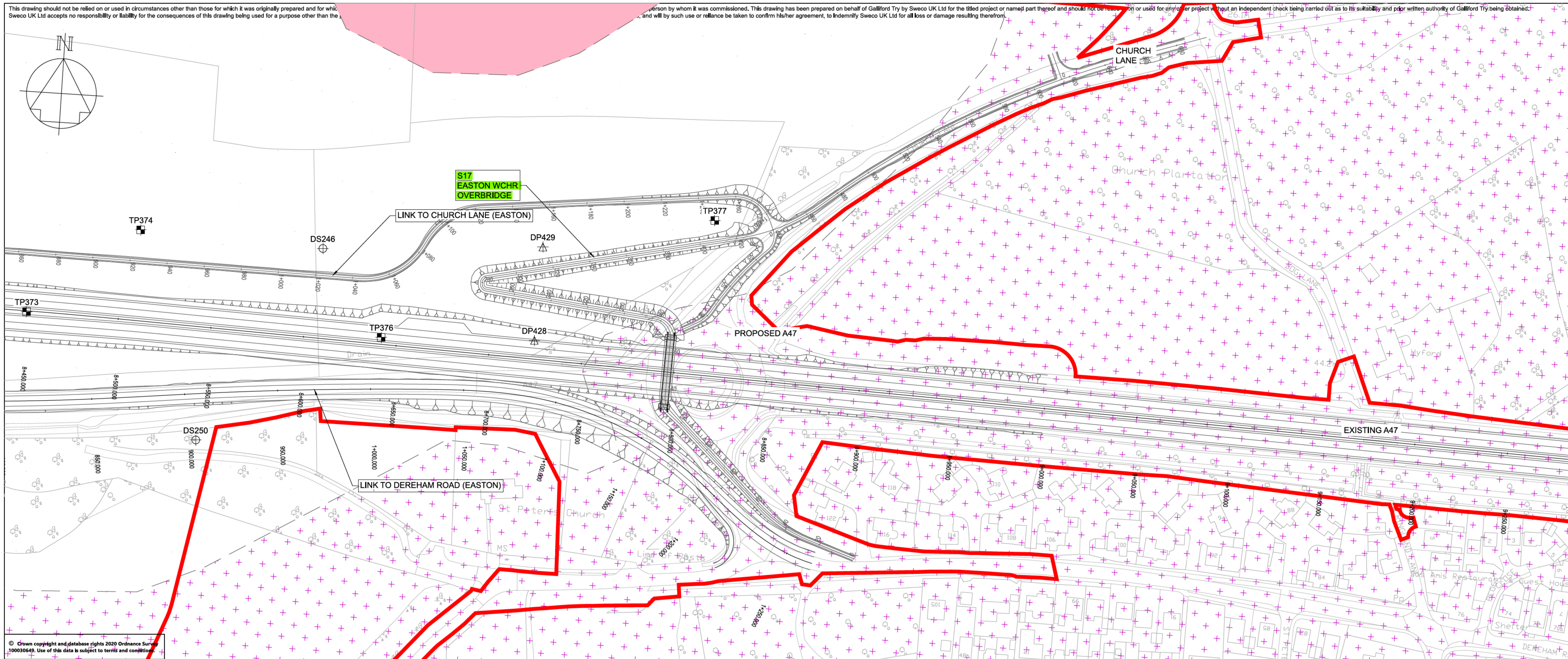
PROJECT STAGE
PCF STAGE 3

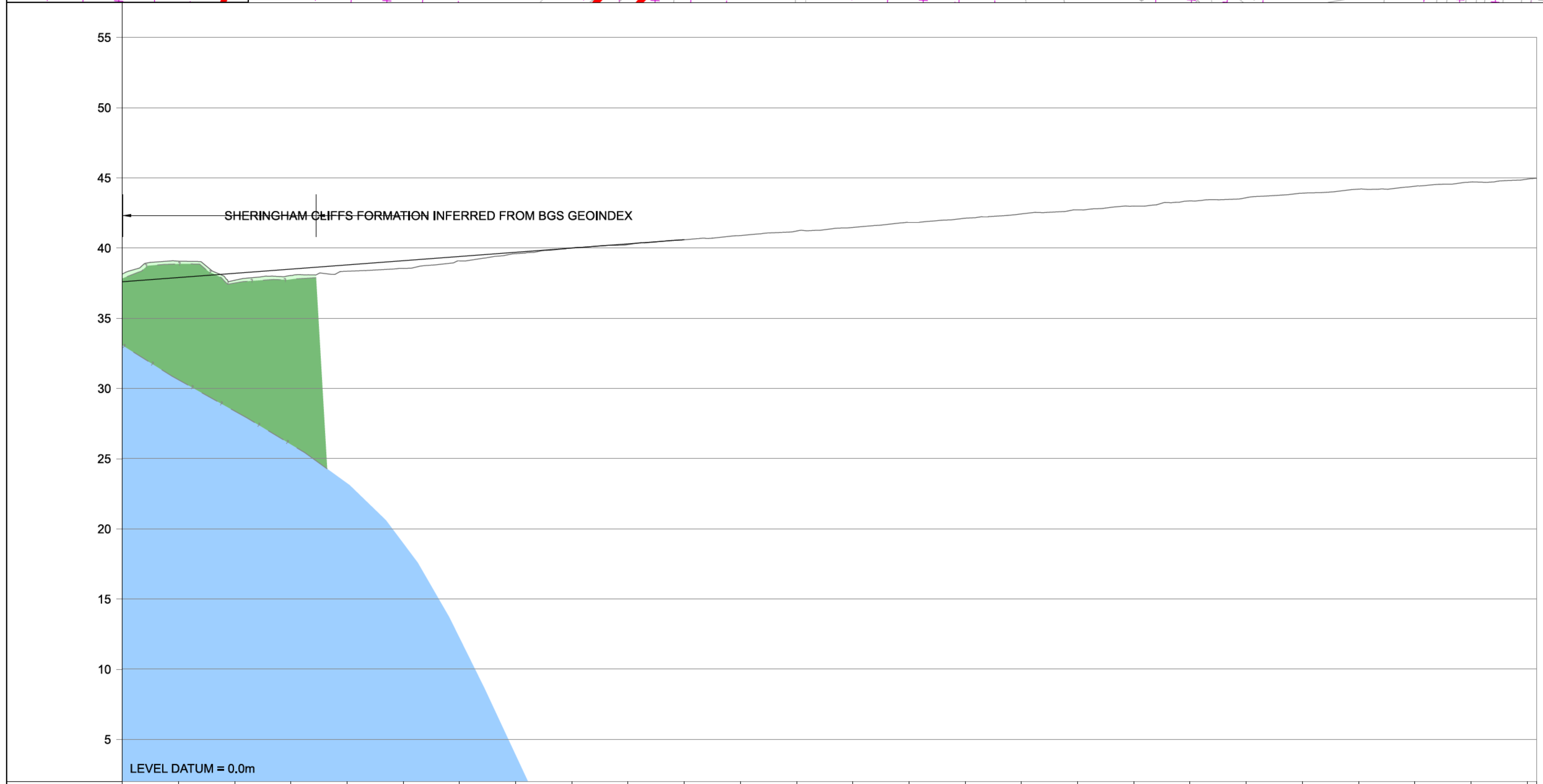
DRAWING TITLE
MAINLINE PLAN AND GEOLOGICAL LONG SECTION SHEET 11 OF 12

SUITABILITY
AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	A3	C01

DRAWING NUMBER
HE551489-GTY-HGT-000-DR-CE-30011





DESIGN LEVELS	37.600	37.900	38.200	38.500	38.800	39.100	39.400	39.700	40.000	40.300	40.600	40.888	41.214	41.468	41.836	42.128	42.433	42.721	42.980	43.362	43.586	43.907	44.198	44.402	44.703	44.911	45.070
EXISTING LEVELS	38.149	39.066	37.706	38.041	38.348	38.553	39.078	39.600	40.014	40.246	40.588	40.888	41.214	41.468	41.836	42.128	42.433	42.721	42.980	43.362	43.586	43.907	44.198	44.402	44.703	44.911	44.965
CHAINAGE	8800.000	8820.000	8840.000	8860.000	8880.000	8900.000	8920.000	8940.000	8960.000	8980.000	9000.000	9020.000	9040.000	9060.000	9080.000	9100.000	9120.000	9140.000	9160.000	9180.000	9200.000	9220.000	9240.000	9260.000	9280.000	9300.000	9303.455

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DESIGNER: SWECO

CONTRACTOR: Galliford Try

CLIENT: highways england

PROJECT TITLE
A47 NORTH TUDDENHAM TO EASTON DUALLING

PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
MAINLINE PLAN AND GEOLOGICAL LONG SECTION
SHEET 12 OF 12

SUITABILITY
AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:1250	A3	C01

DRAWING NUMBER
HE551489-GTY-HGT-000-DR-CE-30012

Annex C Drainage catchments

Annex D Routine runoff and HEWRAT assessments

Catchment M1

highways england | Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	<=50,000 AADT	1	10
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <15 m to >5 m	2	40
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	>=15% clay minerals	1	5
8		5	Organic Carbon	<15% to >1% SOM	2	10
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	125
RISK SCREENING LEVEL	Low

Catchments M2 & S1

highways england | Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <=5 m	3	60
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	>=15% clay minerals	1	5
8		5	Organic Carbon	<15% to >1% SOM	2	10
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	155
RISK SCREENING LEVEL	Medium

Catchment M3 (Mattishall Lane underpass)

highways england | Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <15 m to >5 m	2	40
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	150
RISK SCREENING LEVEL	Medium

Catchments M3 (mainline), S2 and S3a

highways england | Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <=5 m	3	60
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	170
RISK SCREENING LEVEL	Medium

Catchment M4

highways england | Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <=5 m	3	60
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH <8 to >5	2	10

TOTAL SCORE	175
RISK SCREENING LEVEL	Medium

Catchment M5

highways england | Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <15 m to >5 m	2	40
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH <8 to >5	2	10

TOTAL SCORE	155
RISK SCREENING LEVEL	Medium

Catchment NW

highways england

Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	<=50,000 AADT	1	10
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <=5 m	3	60
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	>=15% clay minerals	1	5
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH <8 to >5	2	10

TOTAL SCORE	155
RISK SCREENING LEVEL	Medium

Catchment M6

highways england

Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <15 m to >5 m	2	40
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	<15% to >1% clay minerals	2	10
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH <8 to >5	2	10

TOTAL SCORE	150
RISK SCREENING LEVEL	Medium

Catchment S3

highways england

Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	<=50,000 AADT	1	10
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <15 m to >5 m	2	40
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	<=1% clay minerals	3	15
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH <8 to >5	2	10

TOTAL SCORE	145
RISK SCREENING LEVEL	Low

Catchment M7

highways england

Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <=5 m	3	60
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	<15% to >1% clay minerals	2	10
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH <8 to >5	2	10

TOTAL SCORE	170
RISK SCREENING LEVEL	Medium

Catchment M8

highways england

Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <=5 m	3	60
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	<15% to >1% clay minerals	2	10
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH <8 to >5	2	10

TOTAL SCORE	170
RISK SCREENING LEVEL	Medium

Catchments M9 & NE

highways england

Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <=5 m	3	60
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	<15% to >1% clay minerals	2	10
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH <8 to >5	2	10

TOTAL SCORE	170
RISK SCREENING LEVEL	Medium

Access road to St Andrews Church (catchment M9) and link to Taverham Road (catchment NE)

highways england

Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <=5 m	3	60
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	>=15% clay minerals	1	5
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH <8 to >5	2	10

TOTAL SCORE	165
RISK SCREENING LEVEL	Medium

Catchment M10

highways england

Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>50,000 to <100,000 AADT	2	20
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <=5 m	3	60
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	>=15% clay minerals	1	5
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH <8 to >5	2	10

TOTAL SCORE	165
RISK SCREENING LEVEL	Medium

Catchment W1

highways england

Reset GW Assessment | Go To Interface

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	<=50,000 AADT	1	10
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	<=50	1	10
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <=5 m	3	60
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	>=15% clay minerals	1	5
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH <8 to >5	2	10

TOTAL SCORE	155
RISK SCREENING LEVEL	Medium

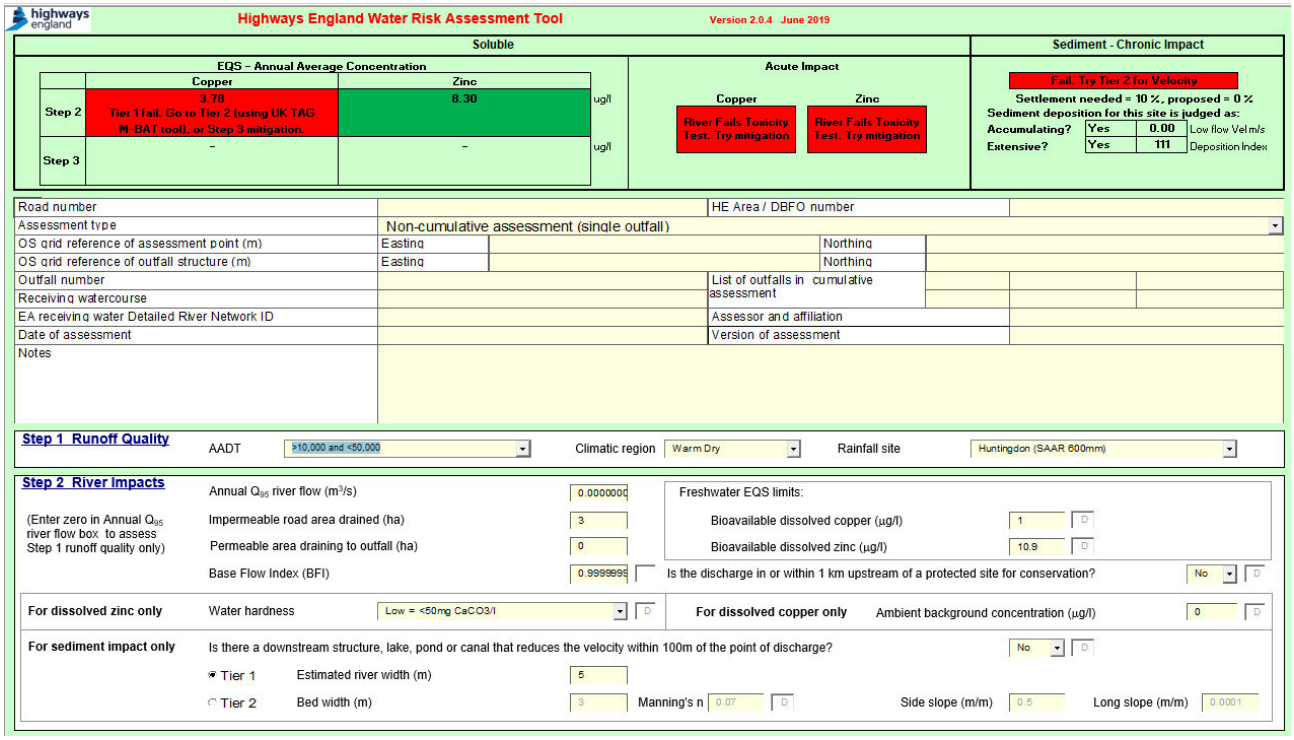
Oak Farm Watercourse

Groundwater Assessment

Component Number		Weighting Factor	Property or Parameter	Risk Score	Component score	Weighted component score
1	SOURCE	10	Traffic flow	>=100,000 AADT	3	30
2		10	Rainfall depth (annual averages)	<=740 mm rainfall	1	10
3		10	Drainage area ratio	>=150	3	30
4	PATHWAY	15	Infiltration method	"Continuous", shallow linear (e.g. unlined ditch, swale, grassed channel)	1	15
5		20	Unsaturated zone	Depth to water table <=5 m	3	60
6		20	Flow type (Incorporates flow type an effective grain size)	Dominantly intergranular flow (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)	1	20
7		5	Unsaturated Zone Clay Content	>=15% clay minerals	1	5
8		5	Organic Carbon	<=1% SOM	3	15
9		5	Unsaturated zone soil pH	pH >=8	1	5

TOTAL SCORE	190
RISK SCREENING LEVEL	Medium

HEWRAT assessment for catchments with an AADT of <50,000



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Soluble				Sediment - Chronic Impact
EQS – Annual Average Concentration			Acute Impact	
	Copper	Zinc		Fail. Try Tier 2 for Velocity
Step 2	3.78 Tier 1 fail. Go to Tier 2 (using UK TAG M-BAT tool), or Step 3 mitigation.	8.30 ug/l	Copper: River Fails Toxicity Test. Try mitigation	Settlement needed = 10 %, proposed = 0 %
Step 3	–	– ug/l	Zinc: River Fails Toxicity Test. Try mitigation	Sediment deposition for this site is judged as:
				Accumulating? Yes 0.00 Low flow Vel m/s
				Extensive? Yes 111 Deposition Index

Road number		HE Area / DBFO number			
Assessment type	Non-cumulative assessment (single outfall)				
OS grid reference of assessment point (m)	Easting		Northing		
OS grid reference of outfall structure (m)	Easting		Northing		
Outfall number		List of outfalls in cumulative assessment			
Receiving watercourse					
EA receiving water Detailed River Network ID		Assessor and affiliation			
Date of assessment		Version of assessment			
Notes					

Step 1 Runoff Quality — AADT: ≥10,000 and <50,000 — Climatic region: Warm Dry — Rainfall site: Huntingdon (SAAR 600mm)

Step 2 River Impacts

(Enter zero in Annual Q_{95} river flow box to assess Step 1 runoff quality only)

- Annual Q_{95} river flow (m^3/s): 0.0000000
- Impermeable road area drained (ha): 3
- Permeable area draining to outfall (ha): 0
- Base Flow Index (BFI): 0.9999999
- Freshwater EQS limits:
  - Bioavailable dissolved copper (µg/l): 1
  - Bioavailable dissolved zinc (µg/l): 10.9
- Is the discharge in or within 1 km upstream of a protected site for conservation? No

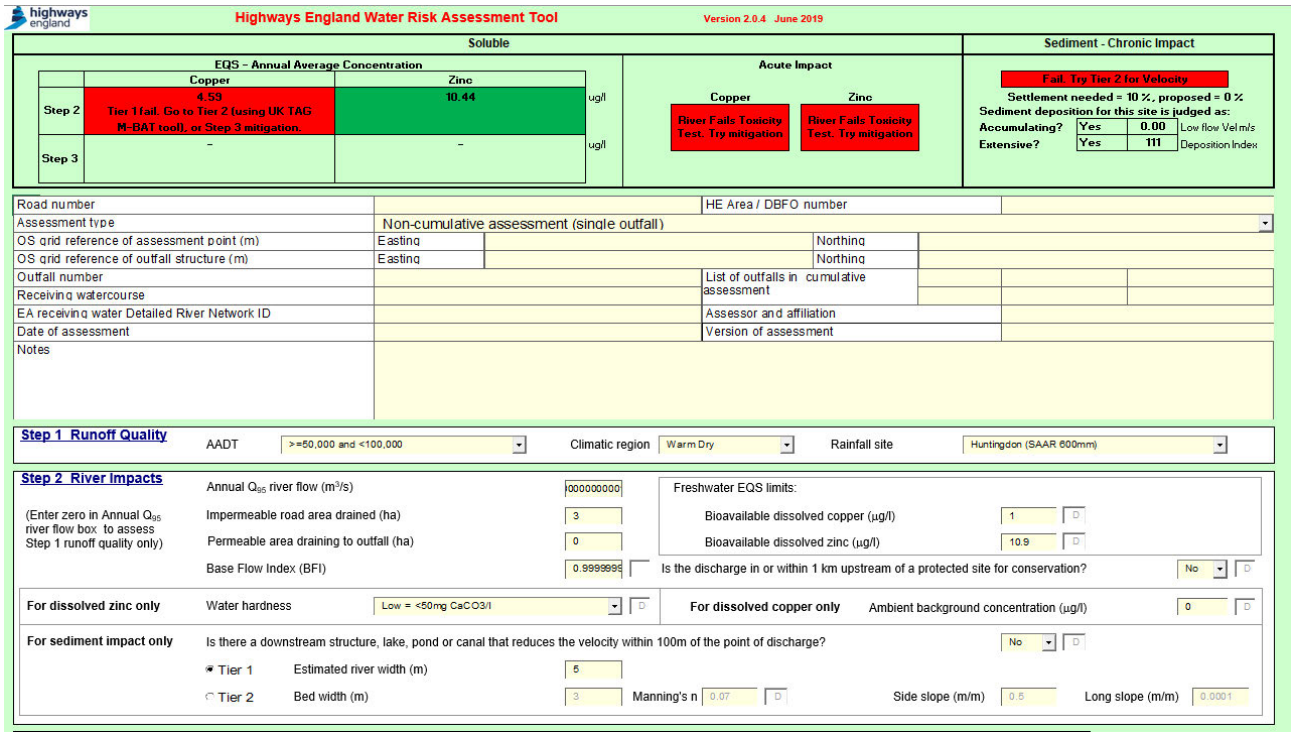
For dissolved zinc only — Water hardness: Low = <50mg CaCO3/l

For dissolved copper only — Ambient background concentration (µg/l): 0

For sediment impact only — Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge? No

- Tier 1 — Estimated river width (m): 5
- Tier 2 — Bed width (m): 3 — Manning's n: 0.07 — Side slope (m/m): 0.5 — Long slope (m/m): 0.0001

HEWRAT assessment for catchments with an AADT of >50,000 and <100,000



highways england — Highways England Water Risk Assessment Tool — Version 2.0.4 June 2019

Soluble				Sediment - Chronic Impact
EQS – Annual Average Concentration			Acute Impact	
	Copper	Zinc		Fail. Try Tier 2 for Velocity
Step 2	4.59 Tier 1 fail. Go to Tier 2 (using UK TAG M-BAT tool), or Step 3 mitigation.	10.44 ug/l	Copper: River Fails Toxicity Test. Try mitigation	Settlement needed = 10 %, proposed = 0 %
Step 3	–	– ug/l	Zinc: River Fails Toxicity Test. Try mitigation	Sediment deposition for this site is judged as:
				Accumulating? Yes 0.00 Low flow Vel m/s
				Extensive? Yes 111 Deposition Index

Road number		HE Area / DBFO number			
Assessment type	Non-cumulative assessment (single outfall)				
OS grid reference of assessment point (m)	Easting		Northing		
OS grid reference of outfall structure (m)	Easting		Northing		
Outfall number		List of outfalls in cumulative assessment			
Receiving watercourse					
EA receiving water Detailed River Network ID		Assessor and affiliation			
Date of assessment		Version of assessment			
Notes					

Step 1 Runoff Quality — AADT: >=50,000 and <100,000 — Climatic region: Warm Dry — Rainfall site: Huntingdon (SAAR 600mm)

Step 2 River Impacts

(Enter zero in Annual Q_{95} river flow box to assess Step 1 runoff quality only)

- Annual Q_{95} river flow (m^3/s): 000000000
- Impermeable road area drained (ha): 3
- Permeable area draining to outfall (ha): 0
- Base Flow Index (BFI): 0.9999999
- Freshwater EQS limits:
  - Bioavailable dissolved copper (µg/l): 1
  - Bioavailable dissolved zinc (µg/l): 10.9
- Is the discharge in or within 1 km upstream of a protected site for conservation? No

For dissolved zinc only — Water hardness: Low = <50mg CaCO3/l

For dissolved copper only — Ambient background concentration (µg/l): 0

For sediment impact only — Is there a downstream structure, lake, pond or canal that reduces the velocity within 100m of the point of discharge? No

- Tier 1 — Estimated river width (m): 5
- Tier 2 — Bed width (m): 3 — Manning's n: 0.07 — Side slope (m/m): 0.5 — Long slope (m/m): 0.0001

Annex E Radius of Influence (Sichardt) assessment

The empirical Sichardt formula presented in both CIRIA (2000) and EA (2007) is a very commonly used method for estimating the radius of influence (R_0) under steady state conditions and assuming radial flow:

$$R_0 = C\ (H_0 - h_w)\ \sqrt{K}$$

where:

H_0 = water level above the base of the aquifer prior to dewatering (i.e. at R_0)

h_w = water level at the equivalent radius (r_e) of the excavation (i.e. the water level required to dewater the excavation)

Therefore $H_0 - h_w$ = target drawdown

K = hydraulic conductivity of the aquifer

C = an empirical calibration factor.

Table 1 details the parameters used and the result for radius of influence for the cutting west of the River Tud overbridge (S05), and at S18 (St Andrew's Church underpass access).

Table 1 Radius of influence formula parameters

Structure	Minimum Design Level (mAOD)	Borehole	Maximum recorded groundwater level (mAOD)	C	$H_0 - h_w$ (m)	K (m/s)	R_0 (m)
Cutting west of the River Tud overbridge (S05)	35	DS231	38.5	2000*	3.5	1.21×10^{-4}	76.68
St Andrew's Church access underpass (S18)	30	DS236	31.2	2000*	1.2	1.21×10^{-4}	26.29

*recommended value for linear excavations