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A47/A11 Thickthorn Junction

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6.3 Environmental Statement Appendices
Appendix 13.3 – Groundwater Assessment

APFP Regulation 5(2)(a)

Planning Act 2008

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Infrastructure Planning

Planning Act 2008

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

The A47/A11 Thickthorn Junction Development Consent Order 202[x]

ENVIRONMENTAL STATEMENT APPENDICES
Appendix 13.3 – Groundwater Assessment

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1. Introduction

1.1.1. This appendix report supports Environmental Statement (ES) Chapter 13 Road drainage and water environment **(TR010037/APP/6.1)**. It provides a hydrogeological conceptual model for the Proposed Scheme and its study area, based on a ground investigation undertaken in the current stages 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 identify potentially significant impacts and inform the assessment of significant effects presented in ES Chapter 13 Road drainage and the water environment **(TR010037/APP/6.1)**, 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 generally comprises a 1km corridor surrounding the Proposed Scheme DCO boundary, focussing on the main features of the Proposed Scheme that are likely to have a potential impact (see Section 1.2.1). The groundwater study area is shown in Annex A. Location plan 1 for the Proposed Scheme are provided in ES Figures 13.1 to 13.8 **(TR010037/APP/6.2).**

1.2. Proposed scheme overview

1.2.1. ES Chapter 2 **(TR010037/APP/6.1)** provides a detailed description of the Proposed Scheme. The junction improvements briefly comprise the construction of a new A11–A47 connector road and the Cantley Lane link road, as well as the following associated below-ground structures which are shown in Annex A Location plan 2:

- Cantley Wood link road overbridge (S42)
- Cantley Wood overbridge (S41)
- Cuttings associated with the A11 – A47 connector road
- Drainage attenuation tank (S18)
- Wards Wood underpass (S02)
- Cantley Lane underpass (S04)
- Cantley Lane footbridge (Cringleford) (S45)
- Cantley Stream underpass (S01A)
- Cantley Lane south culvert (S46)

1.2.2. There are utility diversions throughout the entire Proposed Scheme. In particular diversions below the A11-A47 connector road and across the Cantley Stream are expected to be completed via directional drilling.

1.2.3. The proposed drainage design includes unlined road drainage in the form of filter drains.

1.2.4. Key potential construction and operation effects upon the water environment include:

- Groundwater levels and flow changes through potential construction dewatering activities (or other forms of groundwater control) and redirection of flows around permanent placement of structures
- Contamination of groundwater by generation of suspended solids, direct contact with construction materials, or polluted construction runoff
- Discharge of metalloid and organic compounds from road drainage to surface water and groundwater

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

1.3.2. The report is set out in the following structure:

- Section 2 presents the hydrogeological baseline conditions based on ground investigation results and other freely available sources of information. This informs a conceptual model and receptors, in line with the Groundwater Levels and Flows assessment method set out in LA113.
- Section 3 provides details of construction and operation activities and a description of the potential hydrogeological impact, prior to mitigation.
- Section 4 assesses the significance of risk to receptors, in line the assessment methods set out in LA113 (Groundwater Dependent Terrestrial Ecosystems (GWDTE), groundwater quality and routine runoff and spillage assessments).
- Section 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.

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 and 1:625,000 superficial and bedrock geological maps (British Geological Survey, 2021)
- DEFRA's 'Magic' interactive map (DEFRA, 2021)
- Environment Agency (EA) Catchment Data Explorer (Environment Agency, 2021)
- Highways Agency Drainage Data Management System (HADDMS), Drainage Data Management System v5.12. (Highways England, 2021)

Ground investigation

1.4.2. A 2018 geotechnical and geoenvironmental investigation was undertaken around the A47/A11 Thickthorn Junction in 2018.

1.4.3. The objective of the investigation was to obtain information on the ground and groundwater conditions relating to the design of the Proposed Scheme. The investigation comprised cable percussive boreholes, dynamic sample boreholes, trial pits and dynamic probes. In situ permeability and soakaway testing, groundwater level monitoring, and laboratory testing of soil and groundwater, was also undertaken. Details of the results from this investigation are summarised in section 2.

1.4.4. There are a total of 22 boreholes completed for groundwater monitoring, 12 of which have dual installations.

1.4.5. Two soakaway infiltration tests and one rising head permeability test were completed during investigation works.

1.4.6. Groundwater levels were recorded between July 2018 and January 2019 through a series monthly monitoring visits. 12 boreholes were installed with groundwater level loggers from which data was downloaded in January 2020. Manual groundwater dip measurements were taken at the time of download to calibrate the logger data.

1.4.7. Groundwater quality analyses were undertaken for 15 samples, which were collected between 17 and 19 July 2018.

2. Hydrogeological baseline conditions

2.1. Topography and drainage

2.1.1. The study area follows a general slope from north to south between 33 m above ordnance datum (aOD) and 15 maOD. The land is drained by Cantley Stream at the southern extent of the study area, which marks a topographic low point.

2.1.2. The majority of the site comprises agricultural fields, alongside the A47 and A11 carriageways. There are also urbanised areas within the study area, in particular Cringleford in the west and a service station and park and ride facility immediately west of Thickthorn Junction between the A11 and B1172 Norwich Road.

2.2. Geology

2.2.1. The regional superficial geology at 1:50,000 scale is presented in Annex A: Location Plan 1. The descriptions provided below are based on the 2018 ground investigation and the spatial extents as presented in Annex B: Mainline Geological Sections. Note that that geological sections show the design as of April 2020.

2.2.2. The study area has extensive Pleistocene superficial deposits that overlie the Cretaceous Chalk bedrock. The superficial deposits are predominantly cohesive glacial till (Lowestoft Formation) and glacial sands and gravels (Sheringham Cliffs Formation). The bedrock and superficial geology are described in further detail below.

Alluvium

2.2.3. Alluvium comprising clay, silt, sand and gravel is present along the line of the Cantley Stream, in the south-eastern corner of the site, which flows eastwards along the southern boundary of the site towards the River Yare. Adjacent to the A47, and Cantley Stream, in the south-eastern corner of the Site (Annex A) coarse-grained alluvium was encountered in BH31 (0.3m thickness) and BH33 (2.2m thickness).

Lowestoft Formation

2.2.4. The cohesive glacial till of the Lowestoft Formation is approximately 8 to 10 m thick and typically described as soft to firm, slightly sandy slightly gravelly clay. The gravel is angular of flint and chalk. Bands of sand and gravel are noted locally.

Sheringham Cliffs Formation

2.2.5. The glacial sands and gravels of the Sheringham Cliffs Formation are approximately 5 to 6 m in thickness and typically described as medium dense fine to medium sand, and slightly clayey with some gravel. These deposits generally underlie the Lowestoft Formation and are shown to outcrop in the southern half of the site where the ground falls towards Cantley Stream.

Cretaceous Chalk

2.2.6. The Proposed Scheme extents are underlain by the White Chalk Subgroup, formerly known as the Upper Chalk Formation. The BGS lexicon states that the sub-group includes the Lewes Nodular Chalk Formation, Seaford Chalk Formation, Newhaven Chalk Formation, Culver Chalk Formation and Portsdown Chalk Formation. BGS geological maps shows that the Chalk outcrops in the southeast of the site adjacent to the Cantley Stream. A possible exposure of Chalk was also observed in the Cantley Stream riverbed during an early geomorphological site visit further west upstream, just north of where the Cantley Stream flows underneath the A11.

2.2.7. The top of the Chalk ranges in depth from 9.5maOD (3.2mbGL) in boreholes closest to Cantley Stream (BH31) to 18.2maOD (13.5mbGL) in those furthest north (BH19). The upper Chalk was recovered during the ground investigation as structureless silty chalk with comminuted clasts of sand, gravel and cobbles. This has been interpreted as “putty” chalk, and as such the upper profile may be highly undulating due to weathering and erosion processes (British Geological Survey, 1997).

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 ES Figure 13.3 **(TR010037/APP/6.2)**. Where geological units are not present at surface, an assumed aquifer designation has been used.

Table 2.1 Aquifer designations

Geological Unit	EA Aquifer Designation	Approximate Extents
Alluvium	Secondary (undifferentiated) aquifer	Present along the line of the watercourse (Cantley stream) some 700m south west of the interchange under the A11 and under the A47 to the south east. This tract of Alluvium follows the course of the Cantley stream which flows alongside the railway line eastwards towards the River Yare.
Sheringham Cliffs Formation - Sands and gravels	Secondary A aquifer	Underlying topsoil or made ground in the southern, eastern and western extents of the Scheme. In the northern extents of the Proposed Scheme the sands and gravels of the Sheringham Cliffs Formation are overlain by cohesive glacial till of the Lowestoft formation.
Lowestoft Formation - Diamicton	Secondary (undifferentiated) aquifer	Cohesive glacial till comprising the Lowestoft Formation encountered at shallow depths and in significant thicknesses (up to 8.5m) underlying the topsoil or made ground at the northern extent of the Proposed Scheme.
Chalk	Principal aquifer	Underlies the entire study area. The Chalk is shown on 1:50,000 mapping to outcrop in the lower valley sides where the A47 crosses Cantley stream south of Thickthorn interchange and is indicated to extend at least 30m below ordinance datum.

2.3.2. The chalk bedrock is known to be 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 is classified as a Secondary 'A' aquifer. 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 alluvium and Lowestoft Formation are classified as a Secondary (undifferentiated) aquifers. 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 bedrock and superficial aquifers have a combined groundwater vulnerability classification of medium risk. There are also areas of medium to low risk in the south east of the study area. Soluble rock risk associated with the Chalk is also noted.

Groundwater levels and flows

Regional groundwater level monitoring

2.3.6. The nearest Environment Agency groundwater monitoring point is at Hethersett Lane, Colney (TG10/7750) approximately 2km to the north west of the study area. This monitors the Chalk. Groundwater level monitoring between 1995 and 2004 ranged from 7maOD to 15maOD. The seasonal groundwater level range in the Chalk where glacial sands and gravels are present is between 0.8 to 1.2m (Environment Agency, 2017). Groundwater modelling carried out by the Environment Agency has suggested that this regional groundwater level range has slightly decreased to between 7 and 12maOD in 2011 to 2012 (Environment Agency, 2017). Regionally, groundwater flow in the Chalk is broadly from west to east across Norfolk.

Site groundwater level monitoring

2.3.7. Groundwater strikes recorded during fieldworks were primarily in the Sheringham Cliffs Formation and the underlying upper structureless Chalk. A single strike was noted in alluvium (BH31) and one seepage in made ground (BH27).

2.3.8. The 2018 groundwater monitoring installations were completed primarily to monitor the Sheringham Cliffs Formation, the Lowestoft Formation and the Chalk. One borehole installation (BH27) was constructed to monitor made ground. Groundwater level data was collected over 9 months between April 2018 and January 2019 with a follow up visit in January 2020. 12 standpipes were installed with groundwater level loggers which recorded groundwater levels between July 2018 and January 2020. A table summarising available groundwater level monitoring data is presented below in Table 2.2. Borehole locations are shown in Annex A Location Plan 1.

Table 2.2 Groundwater level monitoring summary

Borehole Reference Number	Ground Elevation (m aOD)	Response Zone Depths (m bDAT)	Monitoring Horizon	Min GW level (m bGL)	Min GW level (m aOD)	Date	Max GW level (m bGL)	Max GW level (m aOD)	Date	Logger Install?
BH01	17.34	1 – 9.5	Sheringham Cliffs (S&G)	2.20	15.15	24/09/19	1.13	16.21	03/01/20	Y
BH02_P1	17.25	4 – 19.5	Chalk	1.73	15.53	23/09/19	0.63	16.62	03/01/20	Y
BH02_P2	17.25	1 – 2	Sheringham Cliffs (G)	1.20	16.05	25/06/18	0.66	16.59	18/10/18	
BH06_P1	22.77	1.5 – 5	Sheringham Cliffs (S&G)	DRY	DRY		DRY	DRY		
BH06_P2	22.77	9 – 24.5	Chalk	8.36	14.41	23/09/19	7.22	15.55	03/01/20	Y
BH08_P1	18.20	1.5 – 3	Sheringham Cliffs (G)	DRY	DRY		DRY	DRY		
BH08_P2	18.20	5.5 – 24.5	Chalk	4.69	13.51	24/09/19	3.35	14.85	08/01/20	Y
BH09_P1	20.11	6.5 – 24.5	Chalk	5.75	14.36	17/12/18	4.47	15.64	29/05/18	
BH09_P2	20.11	1.5 – 4.5	Sheringham Cliffs (S&G)	DRY	DRY		DRY	DRY		
BH09A_P1	20.83	1.5 – 5	Sheringham Cliffs (S&G)	DRY	DRY		DRY	DRY		
BH09A_P2	20.83	7.5 – 24.5	Chalk	5.80	15.03	22/11/18	5.23	15.60	18/06/18	
BH14_P1	27.37	12.5 – 29.5	Chalk	14.61	12.76	23/09/19	13.12	14.25	08/01/20	Y
BH14_P2	27.37	1.5 – 8.5	Sheringham Cliffs (S&G)	DRY	DRY		DRY	DRY		
BH15_P1	29.40	5.5 – 11.5	Sheringham Cliffs (S&G)	DRY	DRY		DRY	DRY		
BH15_P2	29.40	14.5 – 29.5	Chalk	16.46	19.94	24/09/19	14.98	14.42	08/01/20	Y
BH17_P1	30.68	2 - 11	Lowestoft (Clay) / Sheringham Cliffs (G)	DRY	DRY		DRY	DRY		
BH18	31.54	1.5 – 12.5	Lowestoft (Clay) / Sheringham Cliffs (G)	DRY	DRY		DRY	DRY		
BH19_P1	31.70	14.2 - 25	Chalk	19.33	12.37	22/11/18	18.10	13.60	02/05/18	
BH19_P2	31.70	1.5 – 12.7	Lowestoft (Clay) / Sheringham Cliffs (S&G)	DRY	DRY		DRY	DRY		
BH20_P1	30.40	6.5 – 11	Sheringham Cliffs (S&G)	DRY	DRY		DRY	DRY		
BH20_P2	30.40	13.5 – 29.5	Chalk	18.80	11.60	24/09/19	17.54	12.86	08/01/20	Y
BH24_P1	31.15	15.5 – 29.5	Chalk	19.74	11.41	23/09/19	18.52	12.63	08/01/20	Y
BH24_P2	31.15	1.5 – 12.5	Lowestoft (Clay) / Sheringham (S&G)	DRY	DRY		DRY	DRY		
BH25A_P1	31.18	1.5 – 12.5	Sheringham Cliffs (S) / Lowestoft (Clay)	DRY	DRY		DRY	DRY		
BH25A_P2	31.18	14.5 – 29.5	Chalk	19.84	11.34	24/09/19	18.62	12.56	08/01/20	Y
BH26_P1	31.69	15.9 – 29.5	Chalk	20.20	11.49	24/09/19	18.98	12.71	09/01/20	Y
BH26_P2	31.69	1.5 – 13.9	Sheringham Cliffs (S) / Lowestoft (Clay)	DRY	DRY		DRY	DRY		

Borehole Reference Number	Ground Elevation (m aOD)	Response Zone Depths (m bDAT)	Monitoring Horizon	Min GW level (m bGL)	Min GW level (m aOD)	Date	Max GW level (m bGL)	Max GW level (m aOD)	Date	Logger Install?
BH27	26.13	1.5 – 6.5	Made Ground	DRY	DRY		DRY	DRY		
BH31	12.7	4.5 – 24.5	Chalk	1.49	11.21	23/09/19	0.33	12.37	06/01/20	Y
BH33	11.74	2.5 - 10	Sheringham Cliffs (G) / Chalk	0.72	11.02	18/10/18	0.05	11.69	12/06/20	
BH36	25.63	1.5 – 9.5	Lowestoft (Clay) / Sheringham Cliffs (S)	7.92	17.71	02/11/19	7.32	18.31	21/12/19	Y, water level dips below logger
WS03	25.11	1.5 – 3.0	Sheringham Cliffs (S&G)	DRY	DRY		DRY	DRY		
WS14	22.03	1.5 – 8.0	Sheringham Cliffs (S) / Lowestoft (Clay)	DRY	DRY		DRY	DRY		

2.3.9. Groundwater levels are plotted on the hydrograph in Figure 1. Groundwater levels range from 18.9maOD (12.71mbGL) to 11.7maOD (0.05mbGL) across the site. The groundwater table was found to lie predominantly within the Upper Structureless Chalk at approximately 14 – 16maOD (13.11 to 7.00mbGL) at the Thickthorn Junction and the A11 approach. The groundwater table reduces to approximately 11maOD (0.15mbGL) in the Chalk at the Cringleford Railway Bridge.

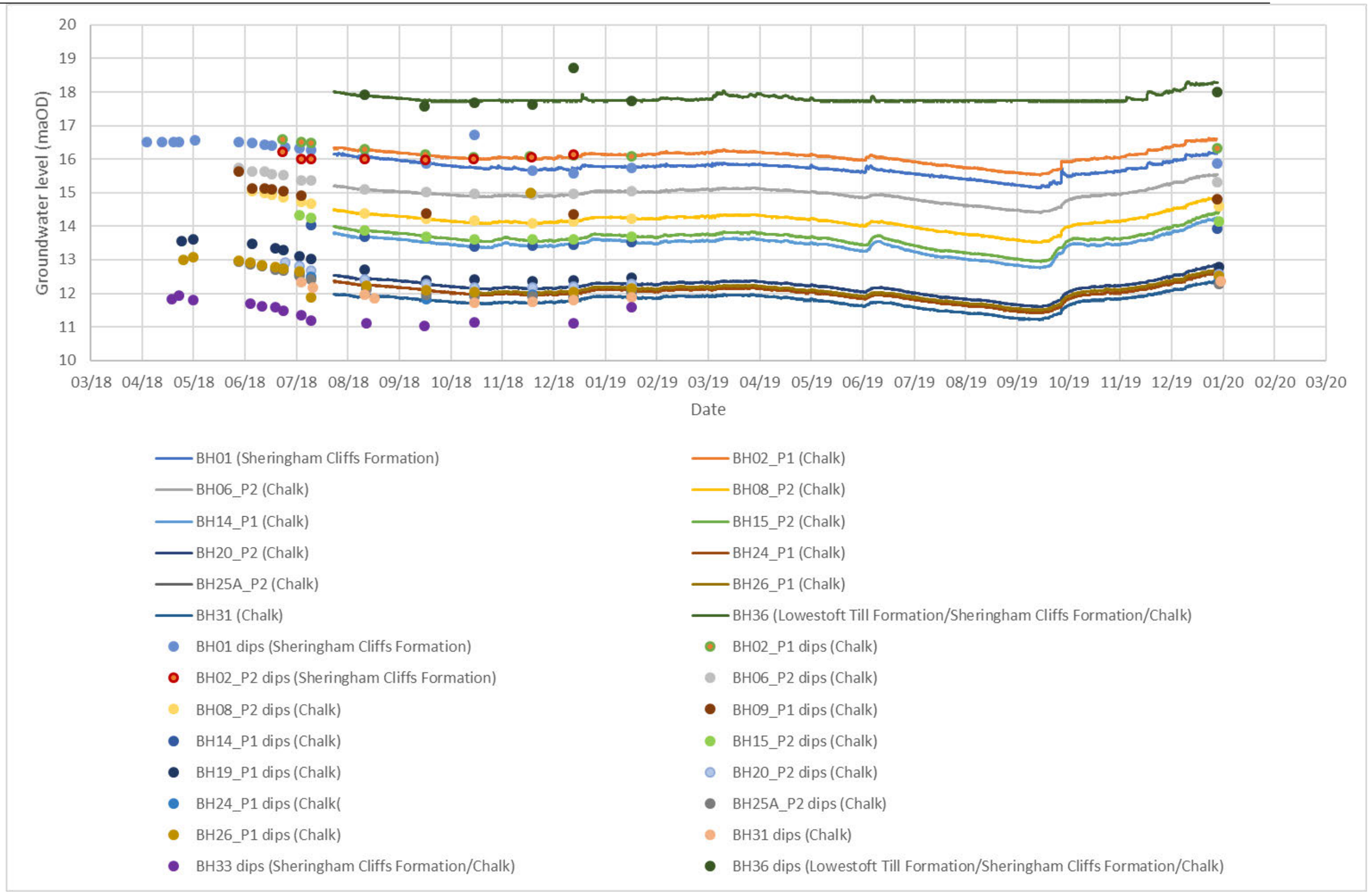

Figure 1 Groundwater level datalogger and manual dips hydrograph

Discussion of groundwater level monitoring

2.3.10. Chalk groundwater levels across the study area are sub-artesian, especially in proximity of the Cringleford Railway Bridge and along the line of Cantley Stream (BH1, BH2, BH31 and BH33, as per Annex A Location Plan 1).

2.3.11. The groundwater table across the site is within the range of 12 to 16maOD (19.74 to 14.11mbGL) at the Thickthorn Junction and the A11 approach. This reduces to approximately 11maOD (0.05mbGL) in the Chalk at the Cringleford Railway Bridge. This is indicative of local hydraulic gradients within the Sheringham Cliffs Formation and the Chalk being toward the south and Cantley Stream. It is assumed that to the south of Cantley Stream, groundwater levels flow to the northeast to diverge on the stream. The overall highest groundwater levels were recorded during May to June 2018 and January 2020.

2.3.12. Groundwater levels recorded in the overlying permeable deposits of the Sheringham Cliffs Formation (BH01, BH02_P2 and BH33) reflect those recorded in the Chalk and indicate a level of continuity between the aquifers. Broadly, the Sheringham Cliffs Formation is dry in the study area but is saturated in the vicinity of Cantley Stream where Chalk groundwater levels are highest and are sub-artesian. BH02, adjacent to Cantley Stream, has a dual installation to monitor both the Sheringham Cliffs Formation and the Chalk. At this location during the monitoring period, groundwater levels in the Chalk were slightly higher than those in the Sheringham Cliffs Formation suggesting an upwards hydraulic gradient between the two aquifer units. It is likely that there are pathways through the Sheringham Cliffs Formation and alluvium, where groundwater from the Chalk supplies baseflow to Cantley Stream.

2.3.13. Long term regional groundwater monitoring suggests that, where glacial sands and gravels are present, the seasonal range in the Chalk groundwater levels is between 0.8 to 1.2m (Environment Agency, 2017). This is broadly comparable to Chalk groundwater levels range recorded on site, approximately 1.5m, and suggests that seasonal maximum groundwater levels may have been captured.

2.3.14. Groundwater levels in BH36 appear to flatline for much of the monitoring period. It is likely that groundwater levels dropped below the datalogger and were not recorded during the times. This would reflect the trend seen in other boreholes.

Aquifer properties

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

2.3.16. The Lowestoft Formation is impermeable within the study area and semi-confines the underlying the Sheringham Cliffs Formation and the Chalk. The Lowestoft Formation has been found to be dry in the study area.

2.3.17. The Sheringham Cliffs Formation is a locally important Secondary A aquifer. In the study area it is approximately 5 to 6 m in thickness. It consists of sand and gravels and, in some areas, clayey gravels. These deposits generally underlie the Lowestoft Formation and are known to outcrop towards the Cantley Stream.

2.3.18. Permeability in the Sheringham Cliffs Formation is likely to be variable depending on local characteristics; with high permeability in layers with a high sand content, but lower permeability in areas where clay content is higher. No permeability testing was undertaken in the superficial deposits. Based on published literature it is possible that within the Sheringham Cliffs Formation permeability may be in the range of 10^{-5} m/s to 10^{-3} m/s (Freeze & Cherry, 1979). However, this is based on an assumption of high sand content and may be as low as 10^{-7} m/s to 10^{-9} m/s in areas where clay content is higher.

2.3.19. The Chalk is a locally important Principal aquifer, and in the study area it ranges from less than 1m to more than 35m in thickness as structureless fine chalk. This is underlain by structureless coarse chalk, the thickness of which is not proven. The Chalk is sub-artesian, especially adjacent to the Cantley Stream.

2.3.20. The permeability of the Chalk is likely to have significant variability depending on its local structure and characteristics (including fracturing), which vary with depth. It is possible that in areas where there are significant thicknesses of putty chalk, groundwater flow may actually be impeded. Adjacent to the Cantley Stream this is unlikely to be the case, however, as groundwater levels show a hydraulic connection between superficial deposits and the Chalk.

2.3.21. One rising head permeability test was undertaken during the 2018 ground investigation. This was carried out in BH28, found to the east of the main A47 carriageway and immediately south of Cantley Lane, between 15.7 and 25.1 mbGL within the structureless chalk. This borehole is approximately 300m north of Cantley Stream. Insufficient measurements of groundwater level were taken during the elapsed time of the test, therefore no permeability result has been calculated. During the test, the water level recovered by 0.65m over 120 minutes. It is likely that this failed test reflects the low permeability associated with putty chalk which is often encountered in upper chalk horizons.

2.3.22. Two soakaway tests were carried out during the 2018 ground investigation. These were within the Sheringham Cliffs Formation and the Lowestoft formation in TP04 and TP12 at a depth of 2.5mbGL in both. No infiltration rate was

calculated for either test as a result of slow water dissipation rate (Geotechnics, 2018).

Groundwater quality

2.3.23. Surface water, groundwater and soil quality sampling was carried out as part of the 2018 ground investigation and is presented in the Ground Investigation Report (Sweco, 2020b). A total of 10 groundwater samples were analysed for suites including metals, inorganics, polycyclic aromatic hydrocarbons and total petroleum hydrocarbons, phenols, volatile organic compounds and semi-volatile organic carbons. Nine groundwater samples exceeded the screening limits for inorganics including cyanide (total), nitrate, and nitrite at relatively low levels. The assessment of risk to controlled waters in the Ground Investigation Report concluded that there is no unacceptable risk to controlled waters. It is possible that high nitrates reported are due to the largely agricultural land use in the area.

2.3.24. Table 2.3 provides groundwater and surface water sampling results from the 2018 ground investigation and subsequent surface water quality sampling for key road drainage pollutants, comprising copper, zinc and chloride.

Table 2.3 Summary of groundwater and surface water quality results

Location	Sample date	Sample lithology	Copper (µg/l)	Zinc (µg/l)	Chloride (mg/l)
BH01	26 July 2018	Sheringham Cliffs Formation	0.34	8.00	44.17
BH02	26 July 2018	n/k	1.12	23.00	36.55
BH06	26 July 2018	Chalk	1.07	45.00	58.96
BH08	26 July 2018	Chalk	0.93	10.00	50.29
BH09A	26 July 2018	Chalk	1.07	45.00	94.93
BH14	26 July 2018	Chalk	0.76	30.00	240.90
BH19	26 July 2018	Chalk	0.86	14.00	30.26
BH26	26 July 2018	Chalk	0.75	48.00	71.67
BH31	26 July 2018	Chalk	3.32	30.00	71.81
BH36	26 July 2018	Lowestoft Formation /Sheringham Cliffs Formation	0.44	13.00	49.11
Cantley Stream	23 January 2019	-	2.69	17.72	61.92
Cantley Stream	3 September 2020 – 12 January 2021	-	1 – 2	2 – 3	n/a

2.3.25. Dissolved copper concentrations in groundwater samples across the site were low (<0.4 to 1.1µg/l) and dissolved zinc concentrations ranged between 8 and 48µg/l, exceeding the environmental quality standards (EQS) for dissolved bioavailable zinc. The zinc concentrations are in agreement with the range observed within the Chalk in north Norfolk, however (0.25 – 114mg/l; Ander et al, 2006).

2.3.26. A surface water sample was also taken during the 2018 GI and also had high zinc concentrations (18µg/l), although subsequent surface water quality sampling undertaken over a six month period in 2020 and 2021 with significantly lower dissolved zinc concentrations (2 to 3µg/l).

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

2.4. Groundwater resources

Groundwater abstractions

2.4.1. The entire Study Area is within a source protection zone (SPZ) 3 (Total Catchment). This is associated with groundwater abstractions for public water supply in Norwich, 5km to the east and 2.5km to the north.

2.4.2. There are 10 licensed groundwater abstractions within 1km of the Proposed Scheme. These are used for agricultural and domestic water supply purposes and are listed below in Table 2.4 and presented in Annex A Location Plan 1. No licensed abstractions have been identified to be directly down hydraulic gradient of the Scheme.

Table 2.4 Summary of licensed groundwater abstractions

Licensed groundwater abstraction Location	Abstraction Type	Grid reference	Location description	Geology	Use	Max annual abstracted quantity (m3)	Max daily abstracted quantity (m3)
Intwood Hall, Keswick	Borehole	619350 304240	1km south east of S45.	Chalk	Drink, cooking, sanitary-Household	112300	1209
Intwood Hall, Keswick	Borehole	619120 304130		Chalk	Spray irrigation-Direct		
Hall Farm, Keswick	Borehole	618880 304130		Chalk	General farming & domestic		
Little Melton	Borehole	617001 306601	2km north west of S02 and S04 cutting.	Chalk	Spray irrigation-Direct	44000	1200
Training ground, Colney	Borehole	617260 306669		Chalk	Spray irrigation-Direct	18700	180
Hethersett	Borehole	616500 304960	1.5km to the west of S41 and S42.	Chalk	Spray irrigation-Storage	14000	655
Hethersett	Borehole	616330 305020		Chalk	General farming & domestic	6800	23

Licensed groundwater abstraction Location	Abstraction Type	Grid reference	Location description	Geology	Use	Max annual abstracted quantity (m3)	Max daily abstracted quantity (m3)
Hethersett	Borehole	616330 305020		Chalk	General use relating to secondary category (medium loss)		
Thickthorn Farm	Well	617210 305880	1.2km north west of S42.	Glacial sands/gravels	General farming & domestic	109509.14	1501.14
Thickthorn Farm	Borehole	617680 305750	0.8km north north west of S42.	Chalk	Spray irrigation-Direct		

2.4.3. A request was made to the South Norfolk Council (July 2020) for information on private water supplies (unlicensed groundwater and surface water abstractions) within the study area. Exact locations could not be provided due to General Data Protection Regulations, however abstractions in relation to their general directions are provided below.

2.4.4. Private water supplies identified to be close to, and specifically down-gradient of, the Proposed Scheme are as follows:

- four abstractions around 450m south of the A11 – A47 connector road
- one abstraction around 150m south of the A11 – A47 connector road
- four abstractions around 300m east of the Cantley Lane pedestrian bridge
- one abstraction around 1km south west of the A11 – A47 connector road

2.4.5. Other private water supplies within the 1km study area include:

- one abstraction around 600m north east of the A11 – A47 connector road
- one abstraction 1km north of Norwich Road, Hethersett

Consented discharges to groundwater

2.4.6. There are two consented discharges to groundwater and land within the study area:

- Discharge of surface water runoff from the hard standing (concrete slab) at Ketteringham Household Waste Recycling Centre via groundwater infiltration (after treatment of settlement) at grid reference 617296, 303981 (easting and northing)
- Discharge of biologically treated sewage effluent to land at grid reference 617250, 303850 (easting and northing)

2.4.7. A request has been made to the South Norfolk Council (July 2020) to supply information on unconsented discharges to groundwater within the study area. As of January 2021, no information has been provided.

2.5. Water Framework Directive

2.5.1. The study area is located 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. Details of the WFD groundwater body is summarised below in Table 2.5.

Table 2.5 Summary of WFD groundwater bodies within the study area

WFD Groundwater body	Description/Quality
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 GW Management Catchment
River Basin District	Anglian
Type	Groundwater Body
Hydromorphological Status	N/A
Overall Classification (Cycle 2 – 2016)	Poor
Current Chemical Quality (Cycle 2 – 2016)	Poor
Chemical Objective	Good (by 2027)
Protected Area	Nitrates Directive and Drinking Water Protected Area

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 (GWDTE) 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 Chemical status is limited by the Chemical Drinking Water Protected Area criteria, which scored poorly. With specific relevance to the Thickthorn Junction, there is a drinking water safeguard zone situated along the southern and south eastern boundary of the study area. This relates to a public water supply abstraction outside the study area at Bixley (Trowse Newton), which suffers from high nitrates. Objectives are to achieve 'Good Chemical Status by 2027 by natural recovery.

2.6. Groundwater Dependent Terrestrial Ecosystems

2.6.1. Designated sites are illustrated in Annex A Location Plan 1.

Chalk stream

2.6.2. Cantley Stream flows south east from the western boundary to the south eastern boundary of the study area. It is a chalk stream that receives baseflow from the underlying Chalk and Sheringham Cliffs Formation.

Priority habitats

2.6.3. Lowland Fen Priority Habitats are located along Cantley Stream in the south-eastern corner of the Site. Lowland fens receive water and nutrients from the underlying soil, rock and groundwater. They are recognised as a priority habitat under the UK Biodiversity Action Plan (Joint Nature Conservation Committee, 2016). The following Priority Habitats are closest to the Proposed Scheme:

- A Lowland Fen (TG 19315 04877) is located within the south east of the study area. This is immediately east of the main A47 carriageway where the railway line is found. It is underlain by Alluvium and may be in hydraulic continuity with the underlying Secondary A and Principal Aquifer.
- A Lowland Fen (TG 20133 05040) is located within the study area, a further 0.5km east along Cantley Stream. At this location, the fen is also underlain by Alluvium.

2.6.4. County wildlife sites have been identified within the study area. The nearest are Meadow Farm Meadow County Wildlife Site (CWS) and Intwood Carr CWS. Both sites are underlain by Alluvium that is likely to be in hydraulic continuity with the underlying Secondary A aquifer, if present, and the Principal Aquifer. Whilst Meadow Farm Meadow CWS is located adjacent to Cantley Stream, Intwood Carr is located adjacent to Intwood Stream, a northwards flowing tributary of Cantley Stream.

2.6.5. As there is a likely hydrogeological connection between the Proposed Scheme and the lowland fens and CWS, these are considered further in the Groundwater Dependent Terrestrial Ecosystems assessment (Section 4.2).

2.6.6. There is one further Lowland Fen Priority Habitat and one further CWS situated further east. As these are more than 1km from the main construction footprint of the Proposed Scheme, however, they have not been considered further.

SSSIs

2.6.7. There are no Sites of Special Scientific Interest (SSSIs) or sites of geological interest within 2km of the Proposed Scheme.

2.7. Groundwater flooding

2.7.1. There is potential for groundwater flooding to occur at surface in the south west and south east of the study area generally along the line of Cantley Stream. Chalk is found close to surface in these topographic low points and is thought to outcrop in the riverbed. Sub-artesian groundwater conditions have been noted in BHs 1, 2, 31 and 33. Susceptibility to groundwater flooding is shown in ES Figure 13.7 **(TR010037/APP/6.2)**.

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 shorter period, leading to more variable groundwater levels and a greater drought vulnerability.

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 required by LA 113.

2.10. Hydrogeological conceptual model

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

2.10.2. 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.

2.10.3. The main aquifer units in the study area are the Sheringham Cliffs Formation and the Chalk. The Chalk is semi-confined by overlying deposits of till of the Lowestoft Formation. The Chalk is sub-artesian, close to Cantley Stream. The study area is within a source protection zone (SPZ) 3 (Total Catchment) associated with groundwater abstractions for public water supply in Norwich, 5km to the east and 2.5km to the north.

2.10.4. The Lowestoft Formation and Made Ground are dry.

2.10.5. Permeability in the Sheringham Cliffs Formation is likely variable depending on local characteristics. Based on published literature it is possible that within the

Sheringham Cliffs Formation permeability may be in the range of 10^{-5} m/s to 10^{-3} m/s. However, this is based on an assumption of high sand content. It may be as low as 10^{-7} m/s to 10^{-9} m/s in areas where clay content is higher (Freeze & Cherry, 1979).

2.10.6. Permeability in the Chalk has not been determined from testing during the ground investigation but is likely to have significant variability depending on local characteristics and the degree of degradation of the Chalk, which varies with depth. It is possible that in areas of low permeability the chalk may impede groundwater flow at the top of the Chalk which has potential to confine the lower aquifer or restrict flow of groundwater between the overlying sand and gravels and the Chalk (British Geological Survey, 1997).

2.10.7. The permeability of the Chalk is likely to have significant variability depending on the local structure, characteristics and levels of degradation or fracturing of the Chalk.

2.10.8. Groundwater levels are driven by the Chalk and occasionally recorded in overlying permeable superficial deposits of the Sheringham Cliffs Formation, indicating a degree of hydraulic continuity between the units. Boreholes where this is evident (BH01, 02, 31 and 33) are closest to Cantley Stream and are sub-artesian, indicating a degree of baseflow from the Chalk to the watercourse.

2.10.9. Groundwater flow within the Sheringham Cliffs Formation and the Chalk is predominantly toward the south and Cantley Stream. To the south of Cantley Stream it is assumed that groundwater levels flow towards the northeast and diverge on the stream.

2.10.10. There are 10 licensed groundwater abstractions and 12 private water supplies (unlicensed groundwater abstractions) within the study area. It is noted that only one licensed abstraction takes water from the sand and gravels. All other licensed abstractions take from the underling chalk aquifer. It is unknown what aquifer any of the unlicensed abstractions take water from. None of the licensed groundwater abstractions are located down-hydraulic gradient of the Proposed Scheme. 10 of the unlicensed abstractions are identified to be down-hydraulic gradient of the Proposed Scheme.

2.10.11. Groundwater dependent terrestrial ecosystems identified within the study area comprise Cantley Stream, a chalk stream, Meadow Farm Meadow CWS, Intwood Carr CWS and two areas of Lowland Fen Priority Habitat.

Receptors

2.10.12. The main direct groundwater receptors within the study area are as follows:

- Aquifer units of the Broadland Rivers Chalk and Crag groundwater body (GB40501G400300), comprising:
  - Sheringham Cliffs Formation
  - Chalk Group

2.10.13. The main indirect groundwater receptors within the study area are:

- 10 licensed groundwater abstractions and 10 unlicensed groundwater abstractions. Two unlicensed abstractions of the 12 identified in the study area have been discounted as one is up-gradient of the Proposed Scheme and the other is south of Cantley Stream. It is noted that only one licensed abstraction takes water from the sand and gravels. Licensed abstractions are shown in Annex A. Location Plan 1 and unlicensed abstractions are listed in section 2.4.4. All other licensed abstractions take from the underling chalk aquifer. It is unknown what aquifer any of the unlicensed abstractions take water from.
- Designated sites associated with groundwater dependent terrestrial ecosystems, include Meadow Farm Meadow CWS, Intwood Carr CWS and two areas of Lowland Fen Priority Habitat. These are all likely to be dependent on groundwater quantity and quality.
- Cantley Stream which likely receives baseflow from the Chalk where it outcrops at surface or through hydraulic pathways in the Sheringham Cliffs Formation.

2.10.14. The designated sites are considered further in Section 4.2. All direct and indirect receptors listed above are considered further in the assessment of significant effects provided in Chapter 13 Road Drainage and the Water Environment (**TR010037/APP/6.1**).

Limitations and uncertainty

2.10.15. Proposed structures may require excavation into the Chalk bedrock. 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 groundwater control (i.e. dewatering) requirements.

2.10.16. This groundwater assessment is constrained by the information available; the ground investigation has provided comprehensive data relating to the geology and hydrogeology within the Site (the Proposed Scheme DCO boundary), but data is limited outside of this. The data collected may therefore not necessarily fully represent the regional hydrogeological conditions, particularly with respect to hydraulic gradients and direction of regional groundwater flow. In addition, whilst almost two years of groundwater level monitoring data has been collected,

there is the possibility that this does not reflect long term seasonal maximums and minimums. Although Environment Agency groundwater level monitoring suggests that observed groundwater levels in the Chalk reflect long term trends further groundwater level monitoring would be required to confirm this.

2.10.17. Further limitations in the datasets used include the extents of the groundwater flooding susceptibility dataset, which is limited to a 500m corridor around the existing road, and restricted location descriptions for unlicensed groundwater abstractions due to General Data Protection Regulations.

3. Potential impacts

3.1.1. A summary of the potential construction and operational activities relating to the Proposed Scheme that may have a hydrogeological impact on identified receptors is in Table 3.1 and Table 3.2. A list of relevant structures being completed as part of the Proposed Scheme is given below:

- Cantley Wood link road overbridge (S42)
- Cantley Wood overbridge (S41)
- Cuttings associated with the A11 – A47 connector road
- Drainage attenuation tank (S18)
- Wards Wood underpass (S02)
- Cantley Lane underpass (S04)
- Cantley Lane footbridge (Cringleford) (S45)
- Cantley Stream underpass (S01A)
- Cantley Lane south culvert (S46)

3.1.2. Additionally, there are utility diversions throughout the entire Proposed Scheme. In particular diversions below the A11-A47 connector road and adjacent to Cantley Stream are expected to be completed via directional drilling.

3.1.3. The proposed drainage design includes unlined road drainage in the form of filter drains in a number of locations across the Proposed Scheme, specifically catchments A, B, F, H and E2 (see Figure C.1, Annex C).

Table 3.1 Summary of hydrogeological impacts to identified receptors from potential activities during construction of the Proposed Scheme

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	Sheringham Cliffs Formation	Chalk downgradient abstractions GWDTEs	Satellite compound between A11 and Cantley Lane is underlain by Sheringham Cliffs Formation. Here, the Secondary A aquifer is unconfined and is potentially in direct hydraulic continuity with the Principal Chalk Aquifer. Other site compounds are underlain by Lowestoft Fm (~4m at the satellite compound to the east of the A47 and ~3m at the primary site compound west of the Thickthorn Park and Ride) and therefore do not pose a significant risk.	Yes, where Sheringham Cliffs outcrops
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	Cutting / S01 / S02 / S04 / S46 / utilities diversions	Sheringham Cliffs Formation Chalk	Cantley Stream downgradient abstractions GWDTEs	Cutting and S02 intercepts the top of the Chalk at its southwestern extents. Elsewhere (including S04) a significant proportion of the Sheringham Cliffs Formation thickness is removed, significantly increasing the vulnerability of the Chalk. S01 and S46 may also intercept the top of the Chalk.	Yes
Excavations, including underpass construction	Potential for contamination of groundwater through direct contact with contaminated construction materials	S02 (preferred option) and utilities diversions below underpass and potentially adjacent to Cantley Stream	Chalk	Cantley Stream downgradient abstractions GWDTEs	Construction methods may include the use of slurries / grouts. Fracturing in Chalk may result in grout losses to the wider environment, and contamination of down-gradient receptors.	Yes
	Potential for contamination of groundwater through direct contact with contaminated construction materials	S01 / S46 / utilities diversions adjacent to Cantley Stream	Sheringham Cliffs Formation Chalk	Cantley Stream Downgradient abstractions GWDTEs	S01 and S46 require excavations that may expose both the Sheringham Cliffs Formation and the Chalk thus potentially creating a pathway between aquifers.	Yes
	Potential for contamination of groundwater through creation of pathways between potentially contaminated ground & underlying aquifers	All structures	Sheringham Cliffs Formation Chalk	Cantley Stream Downgradient abstractions GWDTEs	No excavations intercept contaminated land.	No
	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	S02 / S18 / cutting (western extents)	Chalk	Cantley Stream Downgradient abstractions GWDTEs	There is a risk that Chalk groundwater may be intercepted during the construction of S02 and the southwestern extents of the Connector road cutting. (NB Sheringham Cliffs Formation is dry in this location).	Yes
		S01 / S46 / utilities diversions adjacent to Cantley Stream	Sheringham Cliffs Formation Chalk	Cantley Stream Downgradient abstractions GWDTEs	Groundwater control (i.e. dewatering) within the Sheringham Cliffs Formation will be required. Groundwater control (i.e. dewatering) within the Chalk may also be required if the Chalk is encountered in the excavation. This is likely to have a direct impact on baseflow to the adjacent Cantley Stream.	Yes

Activity	General Description of Potential Impact	Structure	Direct Receptor	Indirect receptor	Site specific potential impact	Potential impact?
Construction						
		S04 / cutting (eastern extents)	N/A	N/A	S04 and cutting at eastern extents of the connector road intercept the Sheringham Cliffs Formation only, which is dry in this location	No
	Construction dewatering discharges may contain suspended solids and may therefore result in contamination of receiving waterbody	S02 / S18 / cutting / S01 / S46	Sheringham Cliffs Fm / Cantley Stream (depending on discharge point)	Cantley stream Downgradient abstractions GWDTEs	Dewatering discharge points to be confirmed following confirmation of dewatering requirements but may either be direct to ground via infiltration galleries or to Cantley Stream.	Yes
Piled foundations	Potential for contamination of groundwater through smearing of contaminants from surface / creation of pathway for migration of groundwater between different aquifer units / direct contact with construction materials, etc	S42, S41, S45 & S02 (alternative option)	Sheringham Cliffs Formation Chalk	Cantley Stream Downgradient abstractions GWDTEs	The Sheringham Cliffs Formation is saturated in boreholes closest to Cantley Stream (BH1 and BH2). Structures (S01 and S46) will intercept the saturated Sheringham Cliffs Formation in this area. It is also possible that Chalk groundwater will also be encountered in this location and a pathway between the aquifers is created as a result. Foundations for all structures intercept Chalk groundwater.	Yes

Table 3.2 Summary of hydrogeological impacts to identified receptors from potential activities during operation of the Proposed 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 in catchments A, B, F, H and E2	Sheringham Cliffs Formation Chalk	Cantley Stream Downgradient abstractions	Routine road runoff may discharge to the Sheringham Cliffs Formation and potentially also the Chalk via filter drains, impacting on water quality. Results for the groundwater quality and routine runoff assessments are presented in Section 4.1.	Yes
	Accidental spillages collected by road drainage may result in contamination of receiving aquifer	Filter drains in catchments A, B, F, H and E2	Sheringham Cliffs Formation Chalk	Cantley Stream Downgradient abstractions	Spillage assessments, undertaken as part of Appendix 13.4 Water Quality, show the risk of impact from spillage pass the assessment.	No
Increase in impermeable area	Reduction in aquifer recharge due to increase in impermeable area from roads, embankments and bunding	New road layout	Sheringham Cliffs Formation	N/A	Within the area where the Sheringham Cliffs outcrops there is a limited increase in impermeable area in relation to the extents of the outcrop. Furthermore, existing road drainage currently discharges to surface waterbodies (therefore no change).	No
Permanent subsurface drainage of cuttings / underpasses	Permanent drainage may result in a local reduction in groundwater levels around the structure	S02 / S04 / S18 / cutting	Chalk	N/A	The southwestern extents of the cutting may intercept the top of the Chalk and therefore require permanent drainage. However, the likely zone of influence is likely to be small. The nearest groundwater abstraction is 400m south of the S02 and S04 cuttings and therefore unlikely to be affected. Reduction in groundwater flows to downgradient receptors is considered to be small.	No
Permanent placement of below-ground structures, i.e. piles, underpasses	Redirection of flows around permanent underground structures.	S02 (preferred option)	Chalk	N/A	S02 intercepts the top of the Chalk only and does not create a continuous vertical barrier - groundwater likely to flow around and below underpass box. Therefore, the zone of influence is likely to be minimal.	No

Activity	General Description of Potential Impact	Structure	Direct Receptor	Indirect receptor	Site specific potential impact	Potential impact?
Operation						
	Groundwater mounding may occur, resulting in a reduction in groundwater flows immediately down-gradient of the underpass.	S41 / S42, S45 / S02 (alternative option) / utilities diversions below underpass	Chalk	N/A	Piles encounter the top of the Chalk but do not create a continuous vertical barrier - groundwater likely to flow around and below piles. Therefore, zone of influence is likely to be minimal.	No
		S01 / S46 / utilities diversions adjacent to Cantley Stream	Sheringham Cliffs Formation	Cantley Stream Downgradient abstractions GWDTEs	Placement of foundations (S01 and S46) will intercept saturated areas of the Sheringham Cliffs Formation and may result in groundwater mounding. However immediately downstream the Sheringham Cliffs Formation increases in thickness and the underpass is unlikely to create a continuous vertical barrier. Where groundwater mounding may occur there is also the potential for a reversal of the hydraulic gradient between the Sheringham Cliffs Formation and the Chalk which subsequently could impact upon baseflow to Cantley Stream.	Yes

4. Risk assessment

4.1. Groundwater quality and routine runoff assessment

Simple assessment

4.1.1. Groundwater quality and runoff risk assessments for routine runoff were completed to assess the risk of impact upon groundwater quality from unlined road drainage. The assessment is based on the 'source-pathway-receptor' model, as per Appendix C of LA 113.

4.1.2. Unlined road drainage in the form of filter drains are proposed in a number of locations throughout the Proposed Scheme, and specifically catchments A, B, F, H and E2 (see Annex C). Filter drains in other catchments take runoff from the surrounding areas only and do not receive any road drainage, therefore they do not require assessment. Where necessary, catchments have either been combined or further sub-divided to consider filter drains by different hydrogeological conditions in the assessments.

4.1.3. 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 4.1. Results are presented in Table C1, Annex C and show that infiltration of untreated routine road runoff presents a low risk to groundwater in catchments B (east of the Wards Wood underpass), B/H, F and J, and a medium risk to groundwater in catchments A, B (west of Wards Wood underpass), and E2. This is primarily due to the depth to water table.

Table 4.1 Summary of HEWRAT risk assessment input parameters

Input parameter	Detail
Traffic flow	AADT traffic flow selected for individual road to be serviced by filter drains
Rainfall depth (annual averages)	Average based on warm/dry climatic region from nearest UK rainfall monitoring site (Huntingdon).
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. Filter drains assumed to be 1.2m deep and 0.3m wide.
Infiltration method	shallow linear (e.g. unlined ditch, swale, grassed channel) – selected to reflect overall dimensions of filter drains
Unsaturated zone	Taken from nearest monitoring borehole
Flow type	"Dominantly intergranular" (e.g. non-fractured consolidated deposits or unconsolidated deposits of fine-medium sand or finer)" selected to represent the variability within the Lowestoft Formation and Sheringham Cliffs Formation. "Flow dominated by fractures and fissures" selected where catchments intercept the Chalk
Unsaturated zone clay content	Particle size distribution results were available for a number of ground investigation borehole samples in the area and results ranged from 0 to 59% clay content. Results from the nearest appropriate boreholes selected – where this is a large range, a lower value is selected to provide a conservative result.
Organic carbon	Soil organic matter results from ground investigation borehole samples at depths representative of unsaturated zone are generally below 1% across the Proposed Scheme.
Unsaturated zone soil pH	pH results from ground investigation borehole samples in the area at depths representative of the unsaturated zone range between 7.5 and >8.

Detailed assessment

4.1.4. As HEWRAT assessments for catchments A, parts of B and E2 produced a medium risk result, a detailed hydrogeological assessment is required. This has been completed in line with guidance provided at www.susdrain.org, and specifically the SuDS Manual (Woods Ballard *et al,* 2015) and considers the baseline ground and groundwater conditions and environmental sensitivity of the receiving waterbodies, as well as the baseline and road runoff water quality.

4.1.5. In addition, a comment on the road drainage design has been provided in terms of treatment provided prior to the point of discharge, its efficacy, and infiltration capacity. 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.

4.1.6. Consultation is ongoing with the Environment Agency on the road drainage design and potential impacts to groundwater.

Baseline hydrogeological conditions

4.1.7. Baseline conditions are summarised for each medium risk catchment in Table 4.2, and are based on details presented in Section 2.

Table 4.2 Hydrogeological baseline conditions of medium risk catchments

Catchment	Location description	Geology	Infiltration capacity	Groundwater levels	Baseline groundwater quality	Environmental receptors
A	A11 northbound diverge, south of Cantley Stream	Sheringham Cliffs Formation overlying Chalk. Exact depths unknown (no nearby exploratory boreholes).	The Sheringham Cliffs Formation is expected to be relatively permeable due to high sand content.	Nearest groundwater monitoring information used in HEWRAT assessment is further east and adjacent to the Cantley Stream. Here, groundwater levels are less than 5m below ground level and around 4m below the proposed road levels. As the filter drains are further away from the Cantley Stream and at higher elevations, the underlying groundwater table may be at a greater depth, and with groundwater flowing towards Cantley Stream. Dual piezometer in BH02 suggests an upwards hydraulic gradient between the Sheringham Cliffs Formation and Chalk – this may protect the Chalk aquifer.	Dissolved zinc concentrations range between 8 and 23µg/l in nearest boreholes Dissolved copper: <0.4 – 1.1µg/l Chloride: 36 – 44mg/l	Sheringham Cliffs Formation – secondary A aquifer (receiving aquifer) Cantley Stream. NB designated sites are at a significant distance downstream of the filter drains, and are unlikely to be impacted from road drainage due to dilution in the aquifer and the river.
B	A11 – A47 connector road cutting between its southwestern extents and the Wards Wood underpass	The proposed A11 – A47 connector road cutting between its southwestern extents and the Wards Wood underpass intercepts the top of the Chalk.	HEWRAT assessment assumes flow dominated by fracture and fissure flow as a conservative approach, although a failed permeability test in the study area suggests that putty chalk may be present at the top of the Chalk. Permeability of upper horizons of Chalk in area of cutting to be confirmed during supplementary GI.	Maximum Chalk groundwater level recorded at around 14maOD and close to the top of the Chalk – risk of road runoff discharging direct to aquifer.	Dissolved zinc concentrations in nearest borehole: 30µg/l Dissolved copper: 0.8µg/l Chloride: 241mg/l	Chalk – principal aquifer Unlicensed abstractions located approximately 150m to the south of the connector road (NB it is not known which aquifer unit these abstractions exploit) Cantley Stream NB designated sites are at a significant distance downstream of the filter drains, and are unlikely to be impacted from road drainage due to dilution in the aquifer and the river.
E2	Cantley Lane South, to south of Cantley Stream	Sheringham Cliffs Formation overlying Chalk – exact depths unknown (no nearby exploratory boreholes).	The Sheringham Cliffs Formation is expected to be relatively permeable due to high sand content.	No nearby monitoring boreholes – due to location adjacent to Cantley Stream, similar conditions to those described for catchment A are expected.	No nearby monitoring boreholes.	Sheringham Cliffs Formation – secondary A aquifer (receiving aquifer) Cantley Stream

Road drainage design

4.1.8. 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 ES Appendix 13.2 (Drainage Strategy) **(TR010037/APP/6.3)**.

4.1.9. 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 has also been assessed in ES Appendix 13.4 (Water quality assessment) **(TR010037/APP/6.3)**.

4.1.10. 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% efficacy for removal of dissolved zinc concentrations.

4.1.11. Catchpits, and also to a lesser degree kerb and gullies, are included throughout the road drainage design in order to reduce any pollution that may occur in the event of a spillage. Details of maintenance requirements are provided in ES Appendix 13.2 (Drainage Strategy) **(TR010037/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.

4.1.12. 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.

4.1.13. Table 4.2 highlights that road runoff may discharge directly to the Chalk Principal aquifer in catchment B. The hydraulic properties of the Chalk in this location are not well understood and putty chalk may be present. If this is the case, the putty chalk may provide some protection to the Chalk aquifer itself. Further ground investigation is to be undertaken in this area, which will confirm the hydraulic properties of the Chalk. The risk that road runoff poses to the Chalk aquifer will therefore be reassessed once further information is available and the road drainage design updated as appropriate.

4.1.14. At catchments A and E2 there is a lack of site specific information, and therefore ground and groundwater conditions have been assumed, based on the nearest available data. Although the infiltration capacity of the Sheringham Cliffs

Formation is likely to be acceptable for infiltration to ground, further ground investigations will confirm conditions in these locations. The risk that road runoff poses to groundwater in these areas will therefore be reassessed once further information is available.

Water quality risk assessment

4.1.15. 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 Cantley Stream, and in addition the drinking water standard (DWS) for copper (2mg/l) for protection of the aquifers and unlicensed abstractions.

4.1.16. 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.

4.1.17. 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.

4.1.18. The results of the adapted HEWRAT assessment are provided in Table C2 (Annex C) and show that the modelled annual average concentrations for copper and zinc are 3.78 and 8.3µg/l respectively in all three catchments.

4.1.19. Although the results exceed the EQS for copper, baseline copper concentrations within groundwater are low and it is likely that dilution within the aquifer will sufficiently reduce concentrations to below the EQS. The road runoff discharging to ground therefore does not pose a risk to indirect groundwater receptors such as Cantley Stream or its associated priority habitats.

4.1.20. The modelled dissolved zinc concentrations do not exceed the EQS. Baseline groundwater contains zinc concentrations in excess of the EQS, although this does not appear to have impacted the water quality of the Cantley Stream, where zinc concentrations are low (2 – 3 µg/l).

4.1.21. The HEWRAT assessment does not specifically consider chloride. 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) as well as within the receiving aquifer. Baseline groundwater quality sampling indicated that all samples were below the DWS for chloride (250mg/l). Therefore, any chlorides infiltrating through the base filter drains are likely to be sufficiently diluted that these are unlikely to impact on groundwater quality.

4.1.22. Spillage assessments have been carried out for the catchments at the point of outfall, which is also considered applicable to discharges to groundwater. These are presented in ES Appendix 13.4 (Water quality assessment) **(TR010037/APP/6.3)**. The outfall passed the accidental spillage assessment with the results indicating that the drainage area would have <0.5% annual risk of pollution.

Summary of risk to groundwater

4.1.23. The detailed assessments highlight that where filter drains pose a medium risk to groundwater there are generally data limitations, and the use of filter drains will therefore require further reassessment following the supplementary GI at detailed design stage. Should the supplementary GI confirm that the intercepted Chalk may effectively allow infiltration of road runoff into the saturated aquifer, filter drains may have to be removed from catchment B.

4.1.24. A water quality assessment has been completed using the HEWRAT assessment tool and results are contained in Table 6.2, Annex C. This highlights that road runoff does not pose a risk to groundwater receptors. Although baseline zinc concentrations within the aquifer are high, these are not impacting on river water quality in Cantley Stream.

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 Appendix B of LA 113 to determine hydrogeological links with the Proposed 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.

4.2.2. Designated sites and priority habitats with a potential hydrogeological link to the study area have been within the 1km study area. These are:

- Lowland Fen priority habitat (TG 19315 04877)
- Lowland Fen priority habitat (TG 20133 05040)
- Meadow Farm Meadow CWS
- Intwood Carr CWS.
- Cantley Stream is considered to be a groundwater dependent terrestrial ecosystem, as it received baseflow from the Chalk, but it is not designated. However, it is likely to be in hydraulic continuity with the adjacent fen habitats to a certain degree. Therefore, assessment of the fen habitats is also considered to be representative of the river itself.

4.2.3. County Wildlife Sites are categorised as Local Sites by Natural England's Designations Strategy (Natural England, 2020). These are sites that support locally and nationally threatened wildlife and may contain habitats and species that are priorities under the county or UK Biodiversity Action Plans (BAP).

Potential hydrogeological link between the Proposed Scheme and GWDTE

4.2.4. Groundwater flow within the study area is primarily towards the south and the Cantley Stream, which receives baseflow from the permeable superficial deposits and the Chalk. Both the Lowland Fen Priority Habitats areas and Meadow Farm Meadow CWS are located adjacent to Cantley Stream. The priority habitats and Meadow Farm Meadow CWS are underlain by Alluvium which is likely to be in hydraulic continuity with the underlying Sheringham Cliffs Formation Secondary A aquifer, where present, and the Chalk Principal aquifer and there is therefore a potential hydrogeological connection between the sites and the Proposed Scheme.

4.2.5. Intwood Carr CWS is located adjacent to Intwood Stream, a northwards flowing tributary of Cantley Stream, and a section of the Cantley Stream around the confluence. The site is underlain by Alluvium, River Terrace Deposits, Sheringham Cliffs Formation, where present, and the Chalk. Local groundwater levels are likely to follow topography, especially within the superficial deposits, and therefore fall towards the north and the confluence with the Cantley Stream.

Whilst a potential hydrogeological connection is likely between the site and the Proposed Scheme at the northern part of the site and adjacent to Cantley Stream, the hydrogeological connection is not considered to extend to the southern section of the site.

Assessment of GWDTE importance

4.2.6. Table 4.3 presents the overall importance for the County wildlife sites and fen priority habitats, which are also considered representative of the Cantley Stream. This is taken as highest of the 'flora and fauna' and 'habitat' receptors, which are based on UKTAG guidance for national vegetation classification (UKTAG, 2009), details included in the citations for Meadow Farm Meadow and Intwood Carr CWS (see Annex D, Consultation with Norfolk Wildlife Trust) and the 2020 botanical survey undertaken for the Proposed Scheme (Appendix 8.1 Botanical survey report **(TR010037/APP/6.3)**).

4.2.7. The Botanical Survey recognised Meadow Farm Meadow CWS as a groundwater dependent ecosystem. Although Lowland Fen priority habitat (TG 19315 04877) could not be accessed, this was identified remotely to be poor semi-improved grassland. This habitat survey did not cover Intwood Carr CWS or the other lowland fen priority habitat (TG 20133 05040).

Table 4.3 Summary of GWDTE classification and importance based on flora and fauna, and habitat receptors

GWDTE	Flora and fauna receptor	Flora and fauna importance	Habitat receptor	Habitat importance	Overall importance
Meadow Farm Meadow County Wildlife Site	M22 - Juncus subnodulosus - Cirsium palustre fen meadow (2) M27 - Filipendula ulmaria - Angelica sylvestris mire (3) (Norfolk County Council, 1998a)	Moderate (NVC Level 2)	County Wildlife Site – site of local biodiversity value but not intact	Low	Moderate
Intwood Carr County Wildlife Site	M27 - Filipendula ulmaria - Angelica sylvestris mire (3) S25 - Phragmites australis - Eupatorium cannabinum tall-herb fen (3) (Norfolk County Council, 1998b)	Low (NVC Level 3)	County Wildlife Site – site of local biodiversity value but condition unknown, therefore conservative importance rating assigned	Moderate	Moderate
Lowland Fen priority habitat	S26 Urtica dioica	Moderate (NVC Level 2)	Biodiversity Action Plan Priority Habitat – condition	Moderate	Moderate

GWDTE	Flora and fauna receptor	Flora and fauna importance	Habitat receptor	Habitat importance	Overall importance
(TG 19315 04877)			unknown, assumed habitat has high species number / habitat diversity / 'naturalness'		
Lowland Fen priority habitat (TG 20133 05040)	No details available	-	Biodiversity Action Plan Priority Habitat – condition unknown, assumed habitat has high species number / habitat diversity / 'naturalness'	Moderate	Moderate

Assessment of potential impacts and establishment of risk to GWDTE

4.2.8. Based on identified hydrogeological impacts as summarised in Table 3.1 and Table 3.2, 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. A summary of these activities, resulting impacts prior to mitigation and the overall risk to GWDTE sites is given below in Table 4.4.

Table 4.4 Summary of overall risk to GWDTE

Impact type	Activity	Description of potential impact	Magnitude of impact on a GWDTE	Overall risk to GWDTE
Groundwater quantity • Groundwater flow / flux • Groundwater level • Soil saturation / soil moisture	Excavations, including underpass construction	The distance between the underpass S02 cutting and the nearest GWDTE is approximately 0.9km. The distance between the Cantley Lane south culvert (S46) and the nearest GWDTE is approximately 0.7km. Removal of groundwater from the aquifer has the potential to impact on groundwater levels in the immediate area surrounding excavation, and also on groundwater supply to down-gradient receptors including Intwood Carr, Meadow Farm Meadow and both Lowland Fen Priority Habitats. Any dewatering activities resulting in abstractions of >50m^3 will be subject to further impact assessments and consultation with the EA. This will be reassessed following supplementary ground investigation and an abstraction license will be applied for following further hydrogeological impact assessments.	Minor adverse	Moderate risk

Impact type	Activity	Description of potential impact	Magnitude of impact on a GWDTE	Overall risk to GWDTE
	Permanent subsurface drainage of cuttings / underpasses	The distance between the underpass S02 which will require permanent drainage and the nearest GWDTE is approximately 0.9km Permanent drainage may result in a local reduction in groundwater levels around the structure and a potential reduction in supply to Intwood Carr, Meadow Farm Meadow and both Lowland Fen Priority Habitats. The southwestern extents of the S02 cutting may intercept the top of the Chalk and require permanent drainage. However, the zone of influence is likely to be small and reduction of flows to downgradient receptors including the GWDTE sites also small. This will be reassessed upon completion of further ground investigation and finalisation of drainage design.	Negligible	Negligible risk
	Permanent placement of below-ground structures, i.e. piles, underpasses	The distance between the underpass S02 which will require permanent drainage and the nearest GWDTE is approximately 0.9km Redirection of flows around permanent underground structures resulting in a potential reduction in supply to Intwood Carr, Meadow Farm Meadow and both Lowland Fen Priority Habitats. Pile foundations are not continuous and the underpass structure (S02) only intercepts the top of the Chalk. Groundwater will likely be able to flow around and below these structures as a result. The zone of influence relating to these is likely to be minimal.	Negligible	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.	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 contamination of groundwater which in turn has the potential to reduce groundwater quality supplied to Intwood Carr, Meadow Farm Meadow and both Lowland Fen Priority Habitats. Satellite compound between A11 and Cantley Lane is likely underlain by glacial sands and gravels where the secondary aquifer is unconfined and	Minor / Moderate .	Moderate risk

Impact type	Activity	Description of potential impact	Magnitude of impact on a GWDTE	Overall risk to GWDTE
		potentially has a direct pathway down to the principal Chalk Aquifer. The cutting intercepts the top of the Chalk at its southwestern extents. Elsewhere a significant proportion of the Sheringham Cliffs Formation thickness is removed, which may increase the vulnerability of the Chalk		
	Excavations, including underpass construction	The distance between the underpass S02 and the nearest GWDTE is approximately 0.9km Potential for contamination of groundwater through direct contact with contaminated construction materials which has the potential to migrate to Intwood Carr, Meadow Farm Meadow and both Lowland Fen Priority Habitats. Construction methods may include the use of slurries / grouts. Fracturing in Chalk may result in grout losses to the wider environment, and contamination of down-gradient receptors including GWDTE sites.	Moderate	Moderate risk
	Permanent placement of below-ground structures, i.e. piles, underpasses	The distance between the underpass S02 and the nearest GWDTE is approximately 0.9km Potential for contamination of groundwater through smearing of contaminants from surface / creation of pathway for migration of groundwater between different aquifer units which could migrate to Intwood Carr, Meadow Farm Meadow and both Lowland Fen Priority Habitats.	Minor	Moderate risk
	Discharge of metalloid and organic compounds to groundwater from proposed road drainage to both surface water and groundwater	The distance between the nearest filter drains (low risk) and the nearest GWDTE is 0.25km. Road drainage discharges to the Sheringham Cliffs Formation and potentially also the Chalk. Results of the groundwater quality and routine runoff assessments are presented in Section 4.1	Negligible	Negligible risk

Assessment outcomes

4.2.9. Prior to any mitigation the risk to GWDTE sites is moderate to negligible. Construction activities that may have a moderate risk impact upon the quality and quantity of groundwater available for the identified GWDTEs are subject to further investigation during the supplementary GI and any risk will be reassessed when the supplementary GI is complete. Best practise mitigation measures shall

be included in the Environment Management Plan (TR**010037/APP/7.4**) to address the risks to the GWDTEs. For example, where groundwater control is required for below-ground construction works, isolation techniques will be adopted in preference of dewatering, especially adjacent to Cantley Stream. Furthermore, groundwater level and quality monitoring prior to and during the construction phase. No further detailed assessment is therefore required.

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 ES Chapter 13 Road drainage and the water environment **(TR010037/APP/6.1)**:

- Construction activities:
  - Drainage of construction areas including excavations, cuttings and site compounds
  - Excavations, including construction of underpasses and footbridge foundations
  - Dewatering activities associated with construction of underpasses and foundations
  - Placement of piled foundations
- Operation activities:
  - Permanent placement of below-ground structures, i.e. piles, underpasses

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:
    - Sheringham Cliffs Formation
    - Chalk Group
- The main indirect groundwater receptors within the study area are:
  - 10 licensed groundwater abstractions and 12 unlicensed groundwater abstractions, it is noted that only one licensed abstraction takes water from the sand and gravels. All other licensed abstractions take from the underling chalk aquifer. It is unknown what aquifer any of the unlicensed abstractions take water from.
  - Designated sites associated with groundwater dependent terrestrial ecosystems, including the two areas of Lowland Fen Priority Habitat, Meadow Farm Meadow County Wildlife Site (TG 193 046) and Intwood Carr County Wildlife Site (TG 198 048).
  - Cantley stream which likely receives baseflow from the superficial deposits

5.1.3. A summary of hydrogeological impacts on identified receptors relating to potential construction and operation activities from the Proposed 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 GI, 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. The detailed assessment identified that although road runoff does not pose a risk to groundwater receptors in terms of water quality, there is a potential risk of runoff discharging directly to saturated aquifer units. The use of filter drains will therefore require further reassessment following the supplementary GI at detailed design stage to confirm the risk.

5.1.6. The simple GWDTE assessment considered potential hydraulic links between the Proposed Scheme and designated sites to the south east. The assessment concluded moderate to negligible risk to the sites in terms of groundwater quality and quantity. Best practise mitigation measures set out in the Environment Management Plan **(TR010037/APP/7.4)** address these risks and no further detailed assessment is required.

6. References

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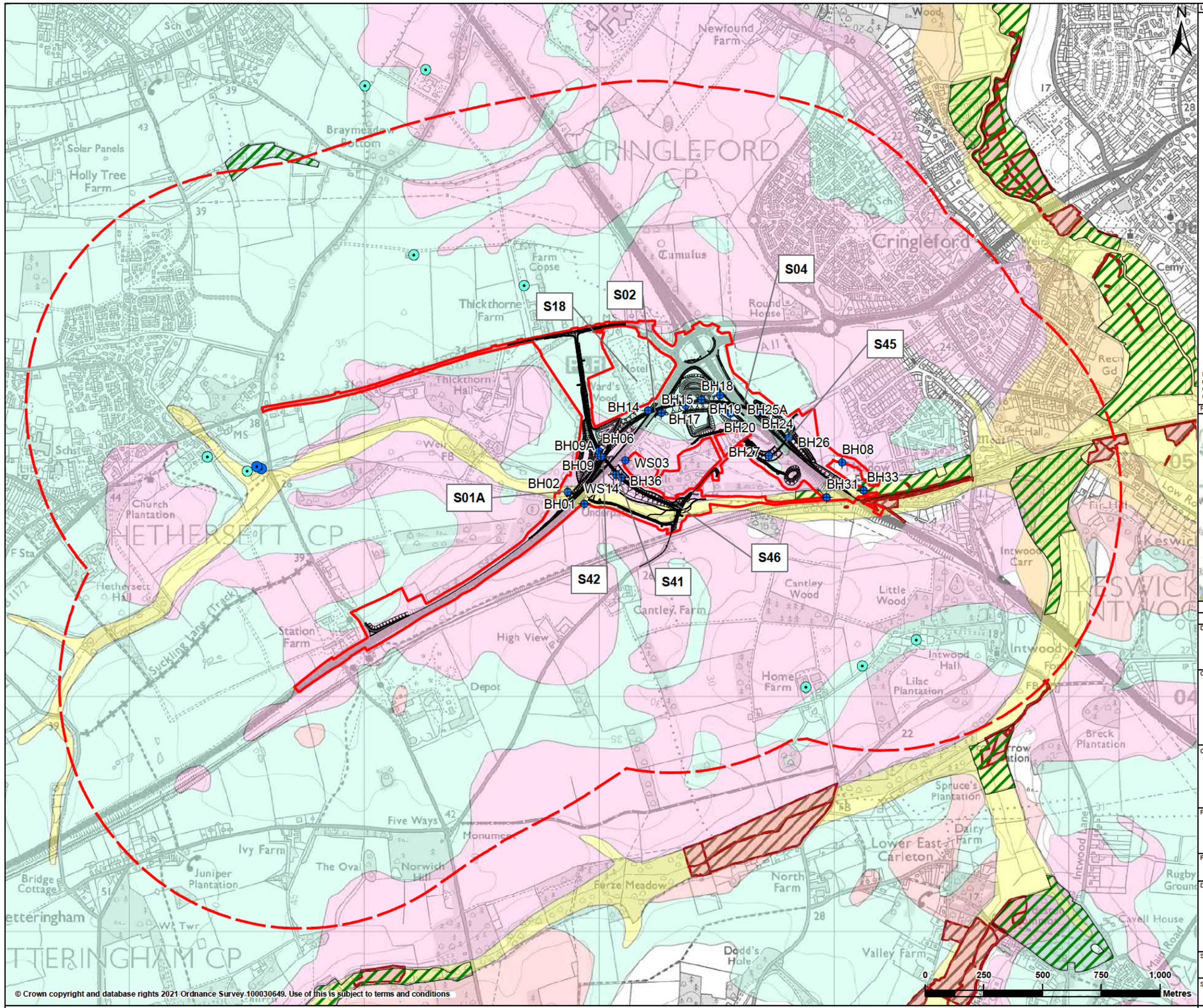
Annex A. Location plans



LEGEND

- DCO boundary
- Study area
- Proposed scheme design
- Ground water monitoring locations
- County wildlife site
- Lowland fens

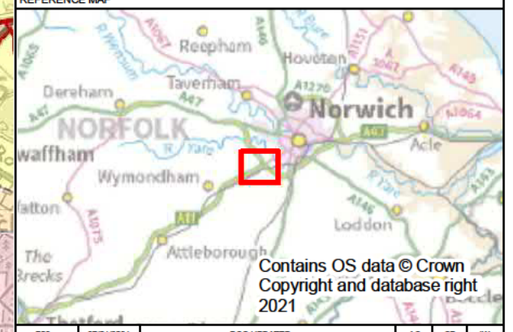
Licensed Groundwater Abstractions

- Groundwater source of supply
- Surface water source of supply

BGS Superficial Geology (50k)

- Alluvium - Clay, silt, sand and gravel
- River Terrace Deposits, 1 - Sand and gravel
- Lowestoft Formation - Diamicton
- Happisburgh Glacigenic Formation And Lowestoft Formation (Undifferentiated) - Sand and gravel
- Sheringham Cliffs Formation - Sand and gravel
- Leet Hill Sand And Gravel Member - Sand and gravel

REFERENCE MAP



REV	DATE	REVISION NOTE	ORG	CHK D	APP'D
P02	27/01/2021	DCO UPDATED	AC	CB	JW

DESIGNER: SWECO

CONTRACTOR: GallifordTry

CLIENT: highways england

PROJECT TITLE: A47/A11 THICKTHORN JUNCTION

PROJECT STAGE: PCF STAGE 3

DRAWING TITLE: FIGURE 2.1 - LOCATION PLAN
TR010037/APP/6.2

SUITABILITY: FOR INFORMATION

SHEET SIZE	SCALE	STATUS
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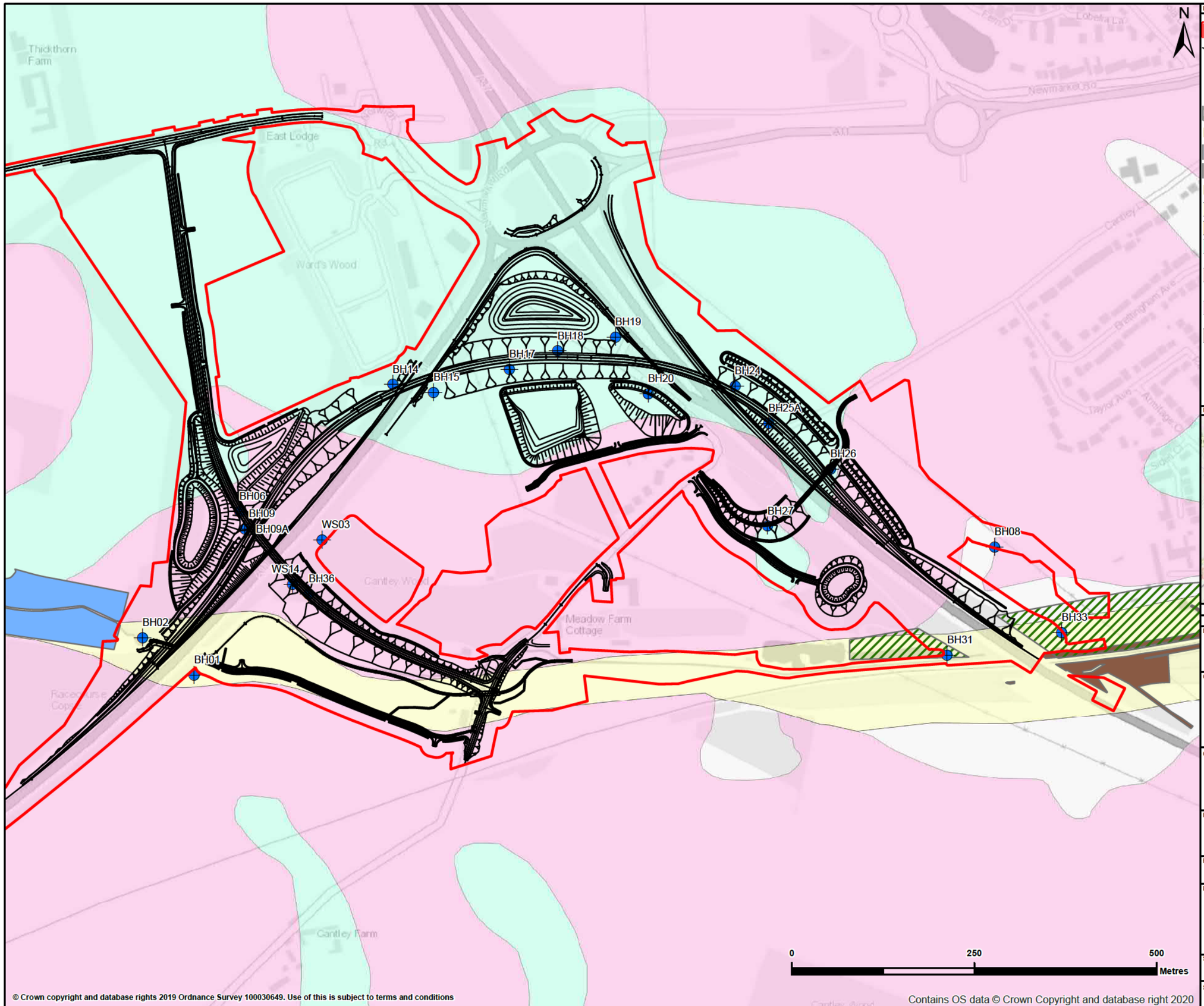
DRAWING NUMBER: HE551492-GTY-EWE-000-DR-GI-30009



LEGEND

- DCO boundary
- Scheme design
- Groundwater monitoring boreholes
- Licensed groundwater abstractions
- County wildlife site

Priority habitat

- Coastal and floodplain grazing marsh
- Lowland fens

BGS superficial geology (50k)

- Alluvium - Clay, silt, sand and gravel
- River Terrace Deposits, 1 - Sand and gravel
- Lowestoft Formation - Diamicton
- Happisburgh Glacigenic Formation And Lowestoft Formation (Undifferentiated) - Sand and gravel
- Sheringham Cliffs Formation - Sand and gravel
- Leet Hill Sand And Gravel Member - Sand and gravel

REFERENCE MAP

REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	24/03/2021	FIRST EDITION	AA	BB	CC

DESIGNER

CONTRACTOR

CLIENT

PROJECT TITLE
A47/A11 THICKTHORN JUNCTION

PROJECT STAGE
PCF STAGE 3

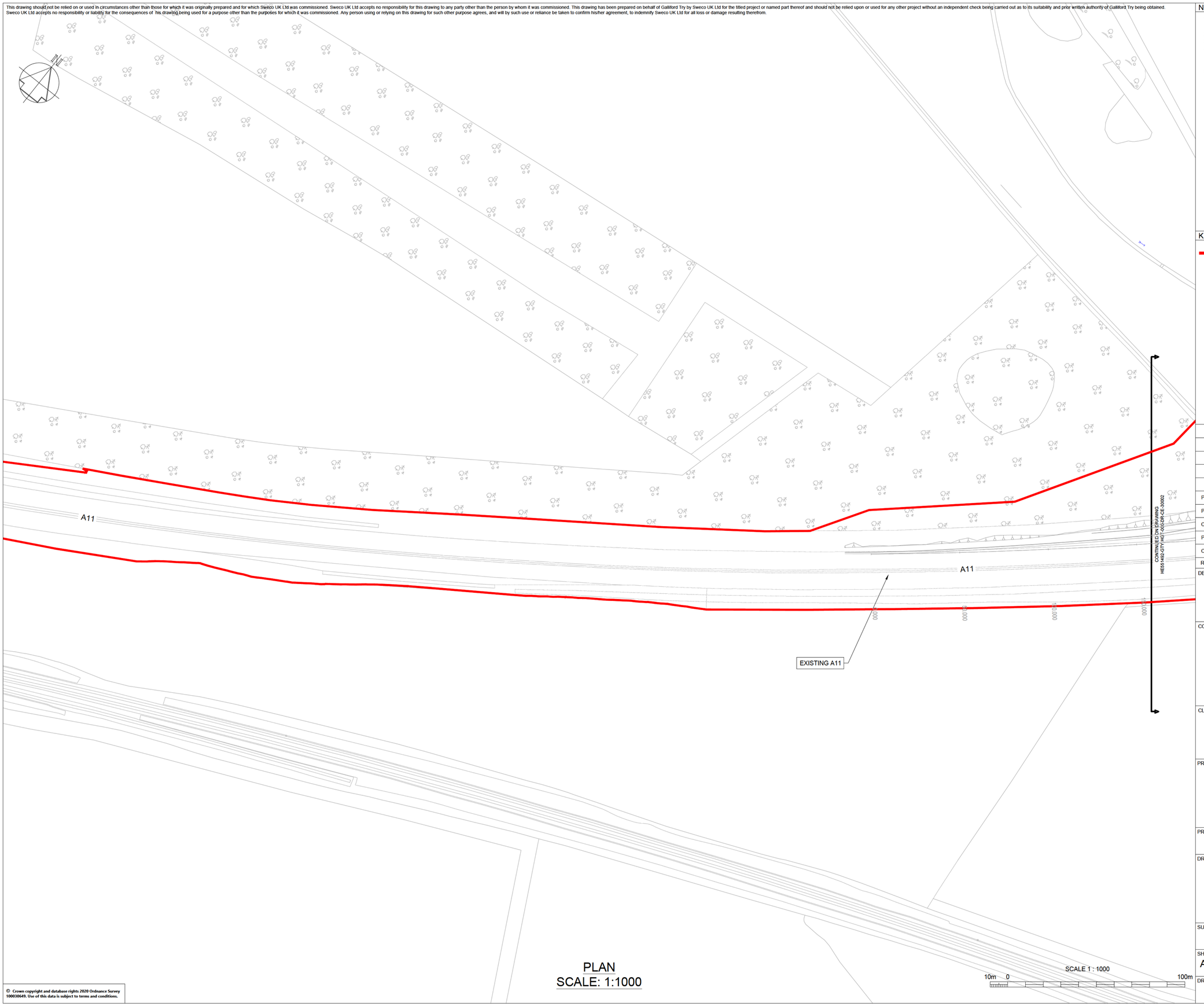
DRAWING TITLE
GROUNDWATER ASSESSMENT
ANNEX A: LOCATION PLAN

SUITABILITY
FOR INFORMATION

SHEET SIZE	SCALE	STATUS
A3	1:5,000	S0

DRAWING NUMBER
HE551489-GTY-V**********

Annex B. Mainline geological sections from 2018 ground investigation



PLAN
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NOTES

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5. DUE TO THE EXTENTS OF THE PROPOSED EARTHWORKS ASSOCIATED WITH THE SLIP ROAD TO THE A11 - A47 CONNECTOR ROAD SHOWN ON THIS DRAWING BEING MINOR, AND THE LACK OF INTRUSIVE INVESTIGATION (HISTORICAL OR FROM THE 2018 GI), NO INTERPRETED GEOLOGICAL SECTION IS PRESENTED.

KEY TO SYMBOLS

DCO BOUNDARY

REV	DATE	REVISION NOTE	ORG	CHK'D	APP'D
P01	14/04/20	DRAFT FOR COMMENT	JP	AL	MA
P02	20/07/20	FOR INFORMATION	JP	AL	MA
C01	20/07/20	FOR INFORMATION	JP	AL	MA
P03	10/03/21	UPDATED FOR DCO BOUNDARY/PLAN AT DFC	MWat	ALow	NT
C02	10/03/21	UPDATED FOR DCO BOUNDARY/PLAN AT DFC	MWat	ALow	NT

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47/A11 THICKTHORN JUNCTION

PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
A11 TO A47 INTERCHANGE - DFB.2
GEOLOGICAL LONGITUDINAL SECTION
SHEET 1 OF 5

SUITABILITY
AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
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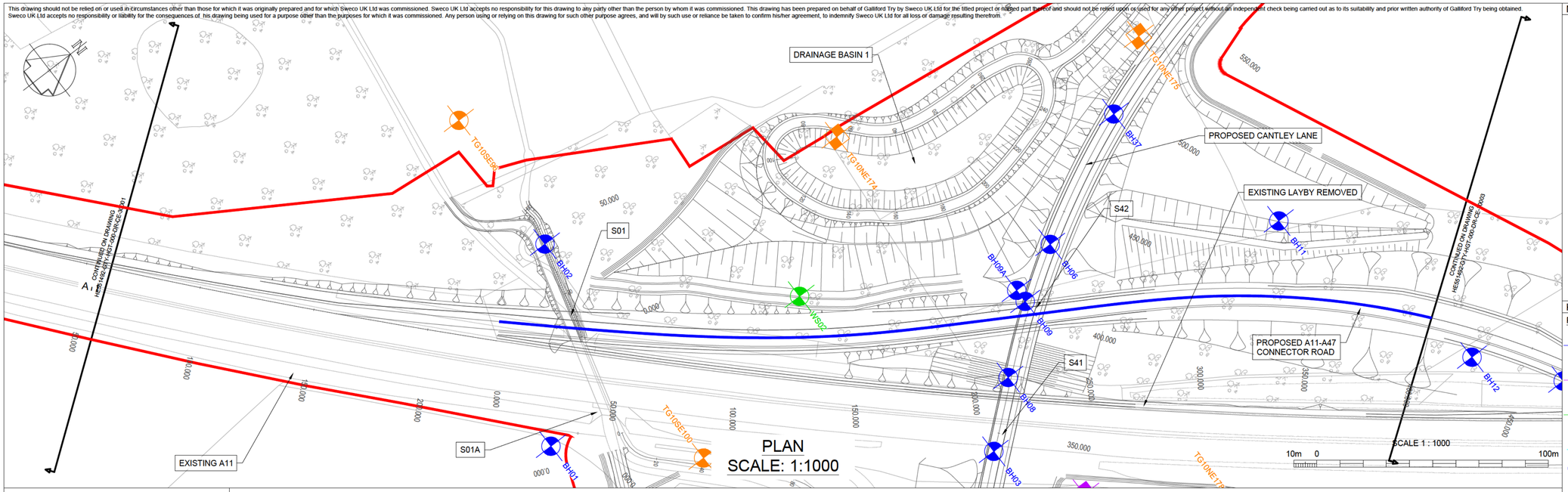
HE551492-GTY-HGT-000-DR-CE-30001



NOTES

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3. DO NOT SCALE FROM THIS DRAWING.
4. DRAWING SHOULD BE READ IN CONJUNCTION WITH THE GROUND INVESTIGATION REPORT (DOCUMENT NUMBER HE551492-GTY-HGT-000-RP-VG-00001).
5. LONG SECTIONS ARE PREDOMINANTLY BASED ON THE CENTRELINE OF THE PROPOSED/EXISTING CARRIAGEWAYS.
6. VERTICAL PROFILE LEVELS ARE GIVEN IN METRES ABOVE ORDNANCE DATUM (M AOD). DEPTHS GIVEN ON EXPLORATORY HOLE STICKS ARE IN METRES BELOW GROUND LEVEL (M BGL).
7. STANDARD PENETRATION TESTS (SPT), DYNAMIC PROBE (DP) LOCATIONS AND DYNAMIC CONE PENETRATION (DCP) TEST LOCATIONS HAVE BEEN OMITTED FROM THE LONG SECTION FOR CLARITY. LOCATIONS OF EXPLORATORY HOLE STICKS ARE INDICATIVE ONLY AND, IN SOME LOCATIONS, HAVE BEEN SEPARATED FOR CLARITY.
8. THE GEOLOGICAL LONGITUDINAL SECTION PRESENTS INTERPRETED GEOLOGICAL SEQUENCES WITH INFERRED STRATA BOUNDARIES BASED ON THE AVAILABLE GROUND INVESTIGATION INFORMATION.

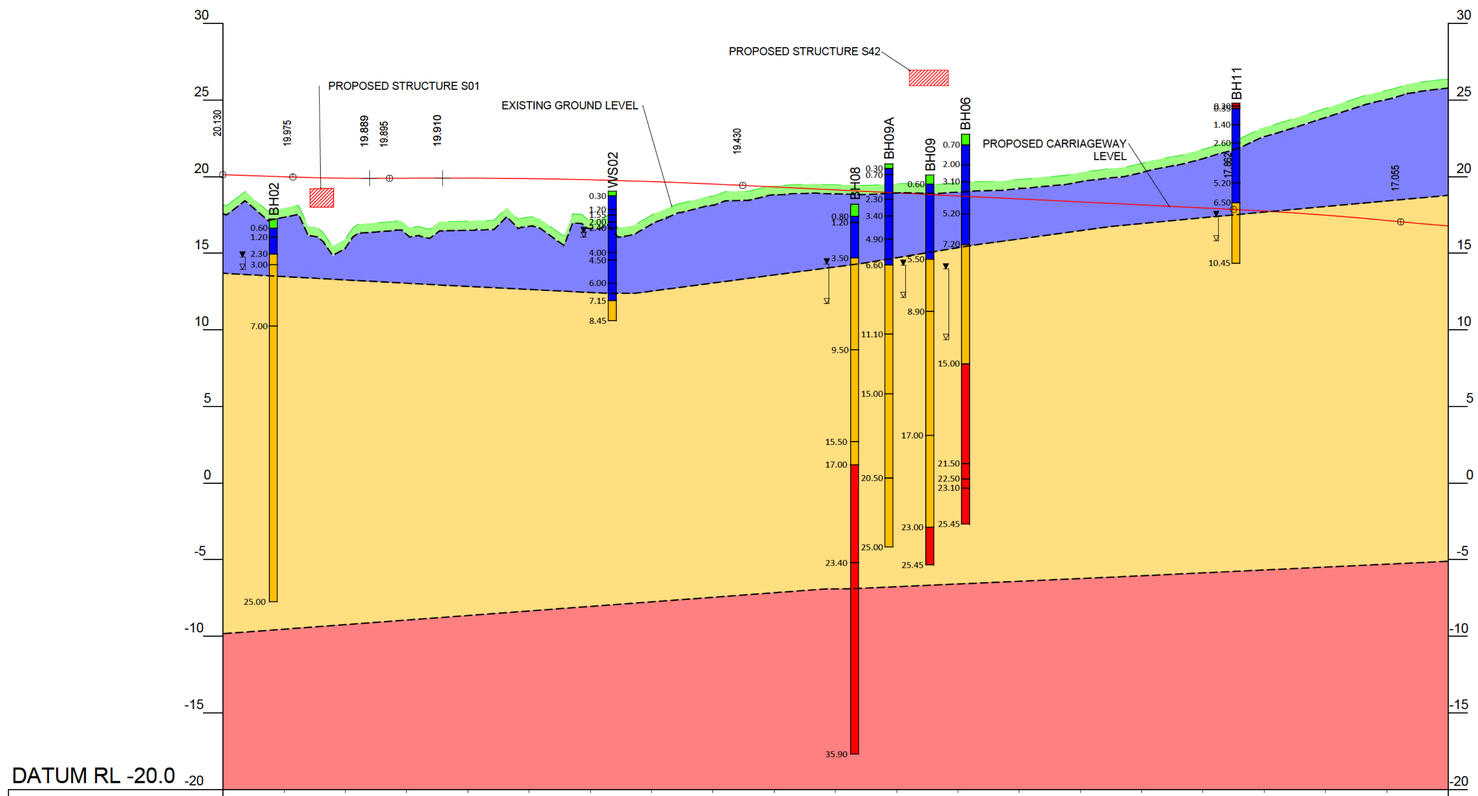
KEY TO SYMBOLS

PLAN LEGEND:

- BHxx BOREHOLE
- TG10xx HISTORICAL BOREHOLE (BGS)
- TPxx TRIAL PIT
- TG10xx HISTORICAL TRIAL PIT (BGS)
- WSxx DYNAMIC SAMPLE BOREHOLE
- DCPTPxx DYNAMIC CONE PENETRATION
- DPWSxx DYNAMIC PROBE
- DCO BOUNDARY
- ALIGNMENT REFERENCE STRING

SECTION LEGEND:

- PROPOSED GROUND LEVEL
- EXISTING GROUND LEVEL
- INFERRED GEOLOGICAL BOUNDARY
- GROUNDWATER STRIKE
- TOPSOIL
- MADE GROUND
- ALLUVIUM
- COHESIVE GLACIAL TILL
- GLACIAL SAND AND GRAVEL
- STRUCTURELESS FINE CHALK
- STRUCTURELESS COARSE CHALK



DESIGN LEVELS	20.130	19.994	19.898	19.903	19.907	19.870	19.794	19.677	19.521	19.330	19.134	18.938	18.742	18.546	18.350	18.155	17.959	17.754	17.485	17.143	16.783
EXISTING LEVELS	18.177	17.946	15.930	16.835	17.097	17.358	17.226	17.493	18.737	19.405	19.474	19.532	19.581	19.828	20.269	20.674	21.780	23.211	24.455	25.637	26.380
CHAINAGE	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340	360	380	400

PROFILE
SCALE: 1:1000H, 1:200V

REV	DATE	REVISION NOTE	ORG	CHKD	APP'D
P01	14/04/20	DRAFT FOR COMMENT	JP	AL	MA
P02	20/07/20	FOR INFORMATION	JP	AL	MA
C01	20/07/20	FOR INFORMATION	JP	AL	MA
P03	10/03/21	UPDATED FOR DCO BOUNDARY/PLAN AT DFC	MWat	ALow	NT
C02	10/03/21	UPDATED FOR DCO BOUNDARY/PLAN AT DFC	MWat	ALow	NT

DESIGNER: SWECO

CONTRACTOR: GallifordTry

CLIENT: highways england

PROJECT TITLE: A47/A11 THICKTHORN JUNCTION

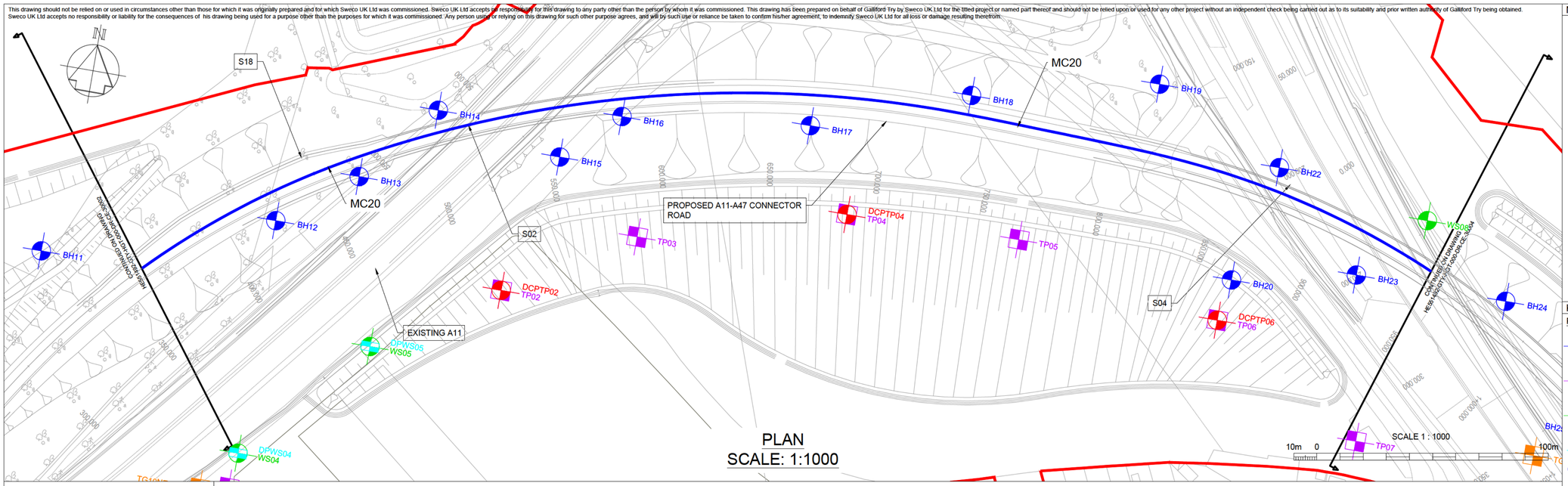
PROJECT STAGE: PCF STAGE 3

DRAWING TITLE: A11 TO A47 INTERCHANGE - DFB.2 GEOLOGICAL LONGITUDINAL SECTION SHEET 2 OF 5

SUITABILITY: AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	AS SHOWN	A3	C02

DRAWING NUMBER: HE551492-GTY-HGT-000-DR-CE-30002



PLAN
SCALE: 1:1000

SECTION LEGEND:
- PROPOSED GROUND LEVEL
- EXISTING GROUND LEVEL
- INFERRED GEOLOGICAL BOUNDARY
- GROUNDWATER STRIKE
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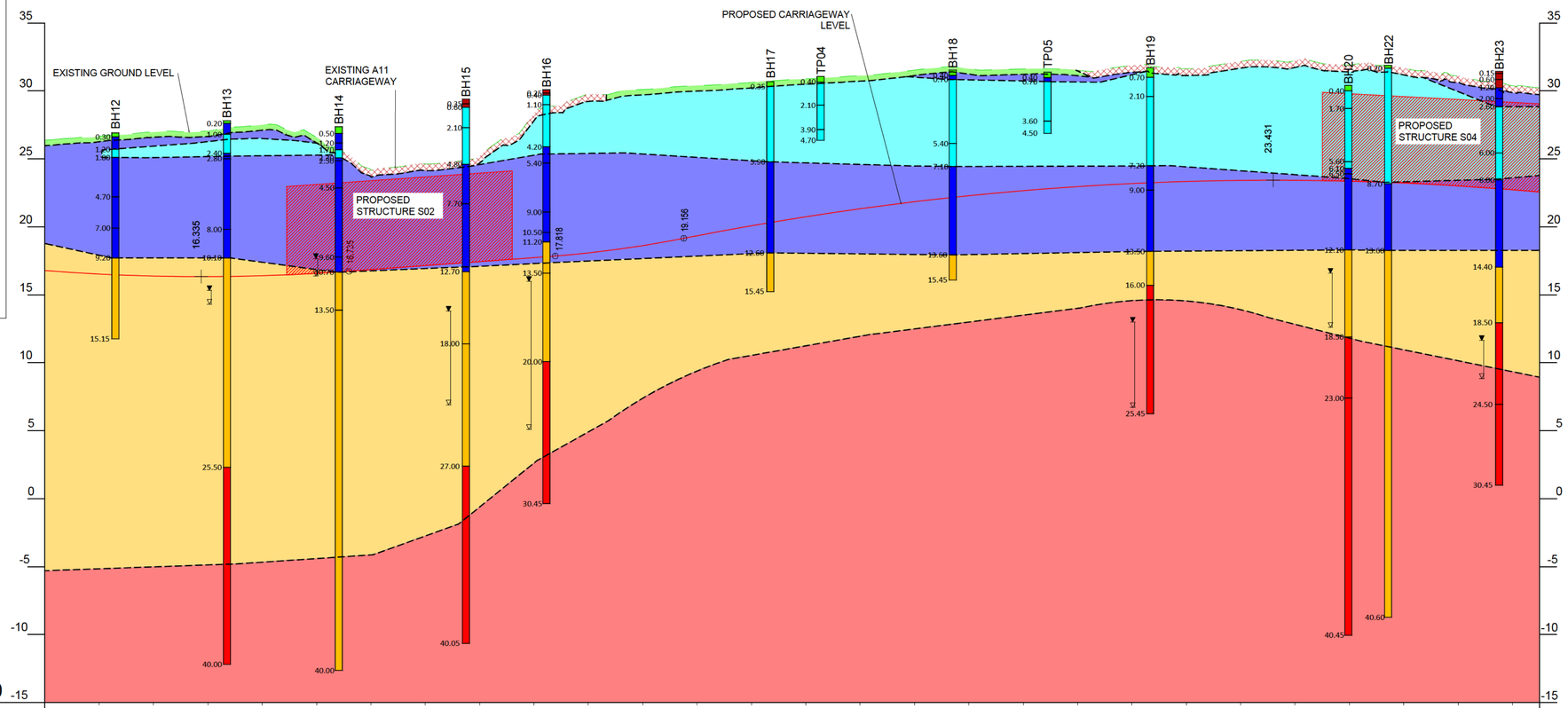
- ALLUVIUM
- COHESIVE GLACIAL TILL
- GLACIAL SAND AND GRAVEL
- STRUCTURELESS FINE CHALK
- STRUCTURELESS COARSE CHALK



DATUM RL -15.0

DESIGN LEVELS	16.783	16.525	16.377	16.336	16.403	16.578	16.853	17.147	17.441	17.735	18.080	18.618	19.347	20.082	20.743	21.332	21.848	22.292	22.662	22.960	23.186	23.338	23.418	23.425	23.359	23.221	23.010	22.726	22.557
EXISTING LEVELS	26.380	26.661	26.990	27.048	27.507	26.591	24.193	24.625	25.199	28.309	29.726	30.112	30.394	30.618	30.893	31.122	31.531	31.637	31.623	31.516	31.875	31.638	32.176	32.228	31.900	31.679	31.122	30.380	30.222
CHAINAGE	400	420	440	460	480	500	520	540	560	580	600	620	640	660	680	700	720	740	760	780	800	820	840	860	880	900	920	940	950

PROFILE
SCALE: 1:1000H, 1:200V

NOTES
1. THIS DRAWING SHALL ONLY BE USED FOR THE DESIGN ELEMENT STATED IN THE DRAWING TITLE.
2. ALL DIMENSION IN METRES (m) UNLESS OTHERWISE STATED.
3. DO NOT SCALE FROM THIS DRAWING.
4. DRAWING SHOULD BE READ IN CONJUNCTION WITH THE GROUND INVESTIGATION REPORT (DOCUMENT NUMBER HE551492-GTY-HGT-000-RP-VG-30001).
5. LONG SECTION PREDOMINANTLY BASED ON THE CENTRELINE OF THE PROPOSED/EXISTING CARRIAGEWAYS.
6. VERTICAL PROFILE LEVELS ARE GIVEN IN METRES ABOVE ORDNANCE DATUM (M AOD). DEPTHS GIVEN ON EXPLORATORY HOLE STICKS ARE IN METRES BELOW GROUND LEVEL (M BGL).
7. STANDARD PENETRATION TESTS (SPT), DYNAMIC PROBE (DP) LOCATIONS AND DYNAMIC CONE PENETRATION (DCP) TEST LOCATIONS HAVE BEEN OMITTED FROM THE LONG SECTION FOR CLARITY. LOCATIONS OF EXPLORATORY HOLE STICKS ARE INDICATIVE ONLY AND, IN SOME LOCATIONS, HAVE BEEN SEPARATED FOR CLARITY.
8. THE GEOLOGICAL LONGITUDINAL SECTION PRESENTS INTERPRETED GEOLOGICAL SEQUENCES WITH INFERRED STRATA BOUNDARIES BASED ON THE AVAILABLE GROUND INVESTIGATION INFORMATION.

KEY TO SYMBOLS

PLAN LEGEND:
- BHxx BOREHOLE
- TG10xx HISTORICAL BOREHOLE (BGS)
- TPxx TRIAL PIT
- TG10xx HISTORICAL TRIAL PIT (BGS)
- WSxx DYNAMIC SAMPLE BOREHOLE
- DCPTPxx DYNAMIC CONE PENETRATION
- DPWSxx DYNAMIC PROBE
- DCO BOUNDARY
- ALIGNMENT REFERENCE STRING

REV	DATE	REVISION NOTE	ORG	CHKD	APP'D
P01	14/04/20	DRAFT FOR COMMENT	JP	AL	MA
P02	20/07/20	FOR INFORMATION	JP	AL	MA
C01	20/07/20	FOR INFORMATION	JP	AL	MA
P03	10/03/21	UPDATED FOR DCO BOUNDARY/PLAN AT DFC	MWat	ALow	NT
C02	10/03/21	UPDATED FOR DCO BOUNDARY/PLAN AT DFC	MWat	ALow	NT

DESIGNER: SWECO

CONTRACTOR: GallifordTry

CLIENT: highways england

PROJECT TITLE: A47/A11 THICKTHORN JUNCTION

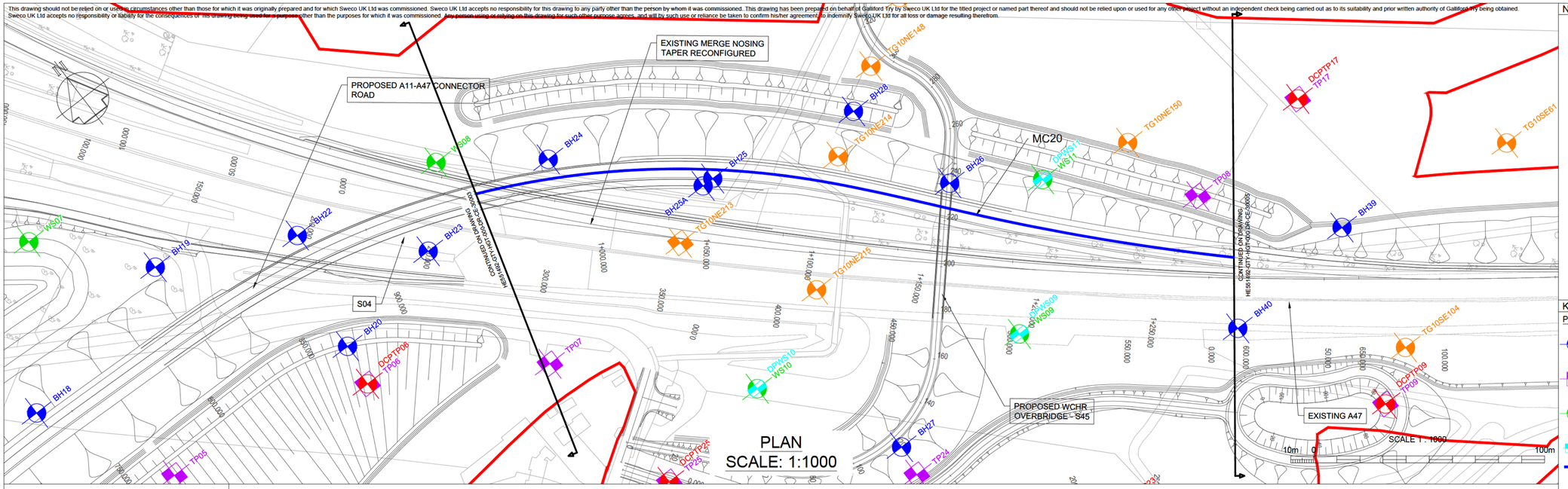
PROJECT STAGE: PCF STAGE 3

DRAWING TITLE: A11 TO A47 INTERCHANGE - DFB.2 GEOLOGICAL LONGITUDINAL SECTION SHEET 3 OF 5

SUITABILITY: AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	AS SHOWN	A3	C02

DRAWING NUMBER: HE551492-GTY-HGT-000-DR-CE-30003



PLAN
SCALE: 1:1000

SECTION LEGEND:
- PROPOSED GROUND LEVEL
- EXISTING GROUND LEVEL
- INFERRED GEOLOGICAL BOUNDARY
- GROUNDWATER STRIKE
- TOPSOIL
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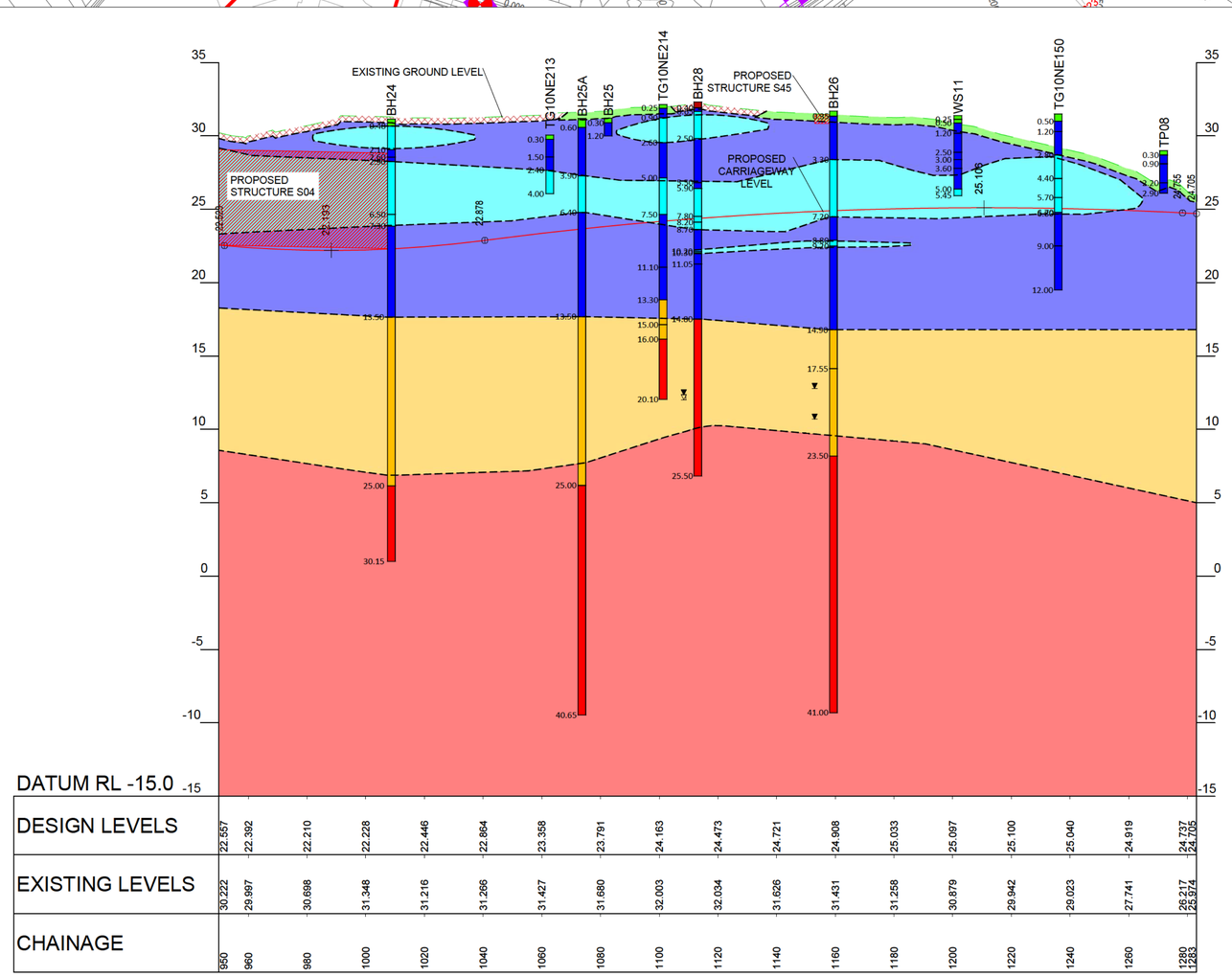

DATUM RL -15.0

DESIGN LEVELS	22.557	22.392	22.210	22.228	22.446	22.864	23.358	23.791	24.163	24.473	24.721	24.908	25.033	25.097	25.100	25.040	24.919	24.737 / 24.705
EXISTING LEVELS	30.222	29.997	30.698	31.348	31.216	31.266	31.427	31.680	32.003	32.034	31.626	31.431	31.258	30.879	29.942	29.023	27.741	26.217 / 25.974
CHAINAGE	950	960	980	1000	1020	1040	1060	1080	1100	1120	1140	1160	1180	1200	1220	1240	1260	1280 / 1283

PROFILE
SCALE: 1:1000H, 1:200V

NOTES

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P03	10/03/21	UPDATED FOR DCO BOUNDARY/PLAN AT DFC	MWat	ALow	NT
C02	10/03/21	UPDATED FOR DCO BOUNDARY/PLAN AT DFC	MWat	ALow	NT

DESIGNER: SWECO

CONTRACTOR: GallifordTry

CLIENT: highways england

PROJECT TITLE: A47/A11 THICKTHORN JUNCTION

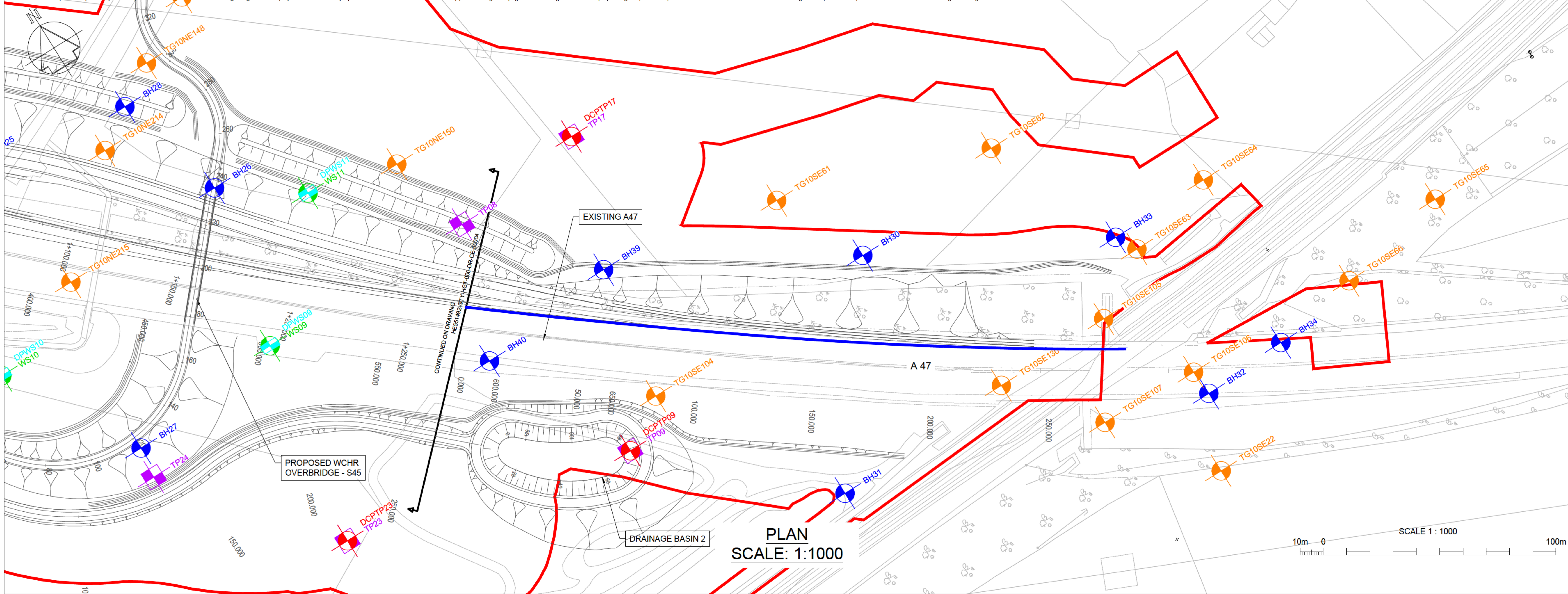
PROJECT STAGE: PCF STAGE 3

DRAWING TITLE: A11 TO A47 INTERCHANGE - DFB.2
GEOLOGICAL LONGITUDINAL SECTION
SHEET 4 OF 5

SUITABILITY: AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	AS SHOWN	A3	C02

DRAWING NUMBER: HE551492-GTY-HGT-000-DR-CE-30004



PLAN
SCALE: 1:1000

SECTION LEGEND:

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- EXISTING GROUND LEVEL
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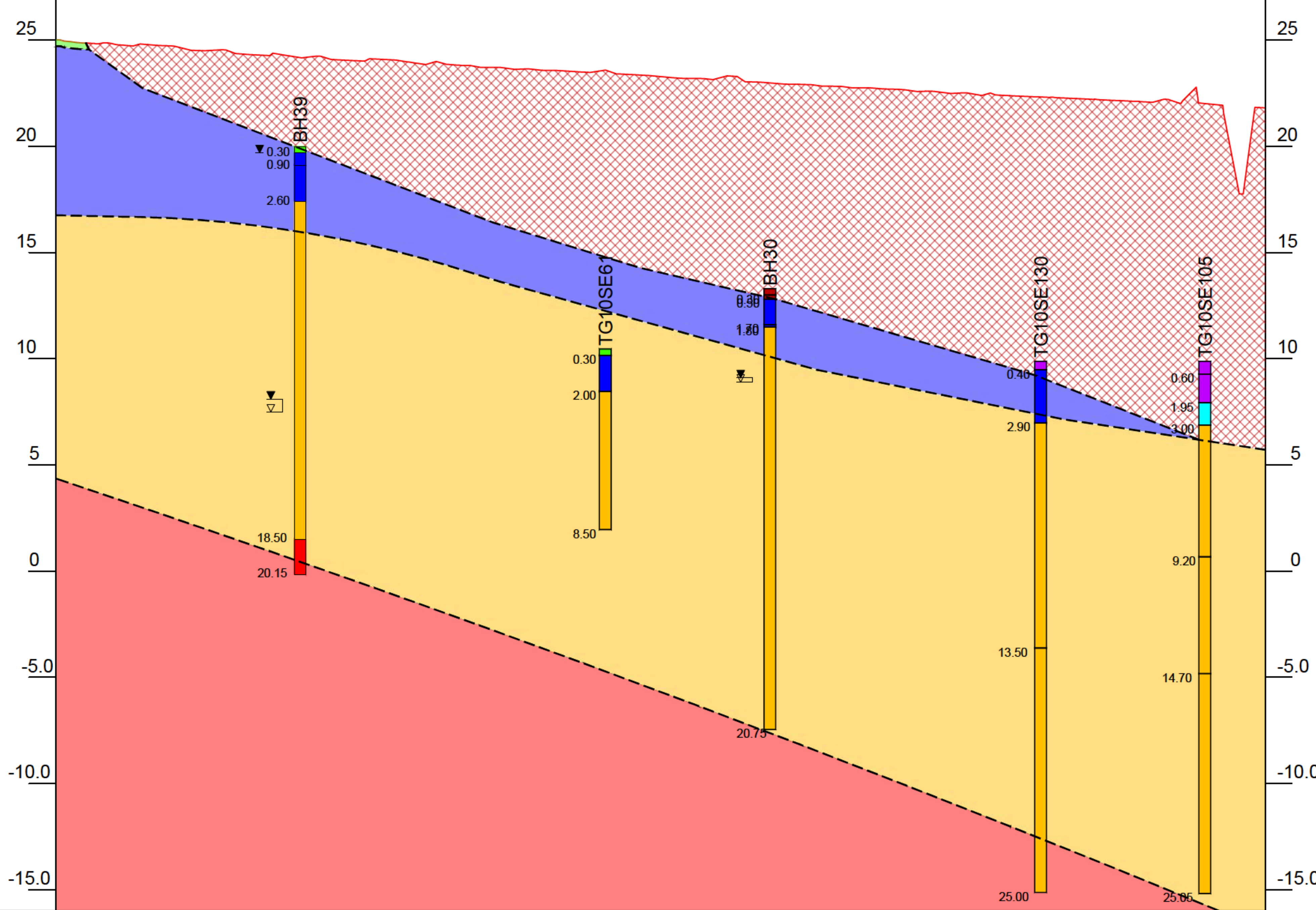

DATUM RL -16.0

DESIGN LEVELS	-999.000	-999.000	-999.000	-999.000	-999.000	-999.000	-999.000	-999.000	-999.000	-999.000	-999.000	-999.000	-999.000	-999.000	-999.000	-999.000
EXISTING LEVELS	25.016	24.814	24.532	24.214	24.058	23.717	23.544	23.322	23.293	22.839	22.653	22.500	22.250	22.170	18.510	21.809
CHAINAGE	0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	285

PROFILE
SCALE: 1:1000H, 1:200V

NOTES

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C01	20/07/20	FOR INFORMATION	JP	AL	MA
P03	10/03/21	UPDATED FOR DCO BOUNDARY/PLAN AT DFC	MWat	ALow	NT
C02	10/03/21	UPDATED FOR DCO BOUNDARY/PLAN AT DFC	MWat	ALow	NT

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47/A11 THICKTHORN JUNCTION

PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
A11 TO A47 INTERCHANGE - DFB.2
GEOLOGICAL LONGITUDINAL SECTION
SHEET 5 OF 5

SUITABILITY
AUTHORISED AS STAGE 3 COMPLETED

SHEET SIZE	SCALE	STATUS	REVISION
A1	AS SHOWN	A3	C02

DRAWING NUMBER
HE551492-GTY-HGT-000-DR-CE-30005

Annex C. Proposed road drainage catchments and HEWRAT assessment results

IMPORTANT

SAFETY, HEALTH & ENVIRONMENTAL INFORMATION

TO BE READ IN CONJUNCTION WITH HAZARD REGISTER
DOC. REF: HE551492-GTY-GHS-000-HS-ZZ-30002.

HAZARD REF AND BRIEF DESCRIPTION OF HAZARD:-

	HAZARD REF	CATCHMENT INFO ONLY
⚠		

Catchment Reference	*Post development Catchment Area (m2)	*Post development Catchment Area (Ha)
Catchment A (existing retained)	15476	1.548
Catchment A (new)	14728	1.473
Catchment B	141464	14.146
Catchment E	4479	0.448
Catchment E2	2980	0.298
Catchment F	63456	6.346
Catchment F2	17042	1.704
Catchment H	12473	1.247
Catchment I	3811	0.381
Catchment J	16580	1.658
Catchment K	1738	0.174
Natural A	81222	8.122
Natural A2	128346	12.835
Natural B	81402	8.140
Natural B1	1549251	154.925
Natural C	148213	14.821
Natural C2	32954	3.295
Natural D	53850	5.385

* These are whole unfactored areas

NOTES

KEY TO SYMBOLS

- DIRECTION OF SURFACE WATER DRAINAGE
- ATTENUATION TANK
- PUMPING CHAMBER
- PUMP SHAFT
- FLOW CONTROL DEVICE
- SHUT-OFF VALVE
- CATCHMENT A (existing)
- CATCHMENT A (new)
- CATCHMENT B
- CATCHMENT E
- CATCHMENT E2
- CATCHMENT F
- CATCHMENT F2
- CATCHMENT H
- CATCHMENT I
- CATCHMENT J
- CATCHMENT K
- NATURAL CATCHMENT A & A1
- NATURAL CATCHMENT B & B1
- NATURAL CATCHMENT C
- NATURAL CATCHMENT C 2
- NATURAL CATCHMENT D
- DCO BOUNDARY
- OVERLAND FLOW PATHS

EXISTING ROAD & COMMERCIAL CATCHMENT UNDEFINED; 11849m² & 19788m²
B1172 Norwich Rd
A47
A11 New market Rd
EXISTING CAR PARK OUTFALLS TO SOAKAWAY
NATURAL CATCHMENT A (SPLIT BY NEW ROAD) CONVEYED TO EXISTING OUTFALL IA NEW DRAINAGE SYSTEM 81222m²
NATURAL CATCHMENT A2 CONVEYED TO EXISTING OUTFALL VIA NEW DRAINAGE SYSTEM 128346m²
New Cantley Lane Link
A11
CATCHMENT B CONTINUES THROUGH UNDERPASS
New A11 A47 Link
A47 UNDERPASS
A11 UNDERPASS
EXISTING NATURAL CATCHMENT D REDUCED AREA 53850m²
NATURAL CATCHMENT A & A2 COLLECTION POINT AND NEW DRAINAGE OUTFALL
New A11-A47 Link
PROPOSED NETWORK J 5470m²
NATURAL CATCHMEN C2 DISCHARGES TO CANTLEY STREAM VIA NEW COLLECTION SYSTEM AND NEW OUTFALL
BASIN 1
EXISTING CATCHMENT F2 REDUCED AREA 17042m²
CATCHMENT B OUTFALL VIA BASIN 1 TO CANTLEY STREAM
EXIST NG CATCHMENT J REDUCED AREA 12500m²
Cantley Lane South
NATURAL CATCHMENT B COLLECTION POINT AND NEW DRAINAGE OUTFALL
BASIN 2
CATCHMENT F2 OUTFALL TO EXISTING DRAINAGE
NETWORK A OUTFALL
New Cantley Lane Link
CATCHMENT F OUTFALL TO CANTLEY STREAM VIA BASIN 2
E ISTING CATCHMENT J OUTFALL RETAINED
CATCHMENT E OUTFALL
BRECKLAND RAILWAY BRIDGE
EXISTING CATCHMENT A OUTFALL RETAINED
NEW CANTLEY LANE CULVERT
CATCHMENT E2 OUTFALL
EXISTING CATCHMENT A REDUCED AREA 15476m²
REDUCED NATURAL CATCHMENT B1 1431655m²
A11 Hethersett Bypass
CANTLE LANE RAILWAY BRIDGE
Inset X-X
PROPOSED NETWORK K 5160m²
Inset X-X

REV	DATE	REVISION NOTE	ORG	CHKD	APP'D
P01	02/02/21	GENERAL UPDATES	SG	CBuc	BWil
P02	12/03/21	area updated	SG	CBuc	BWil

DESIGNER
SWECO

CONTRACTOR
GallifordTry

CLIENT
highways england

PROJECT TITLE
A47/A11 THICKTHORN JUNCTION

PROJECT STAGE
PCF STAGE 3

DRAWING TITLE
DRAINAGE OUTFALL CATCHMENTS
SCHEME LAYOUT PLAN
SHEET 1 OF 1

SUITABILITY
SUITABLE FOR INFORMATION

SHEET SIZE	SCALE	STATUS	REVISION
A1	1:2500	S2	P02

DRAWING NUMBER
HE551492-GTY-HDG-000-DR-CD-30009

Table C1 HEWRAT groundwater assessment of catchments containing filter drains

Catchment	A	B (underpass, east of Wards Wood underpass)	B (underpass, west of Wards Wood underpass)	B/H	F	E2	J
Traffic flow	<50,000	<50,000	<50,000	>50,000	<50,000	<50,000	<50000
Rainfall depth	<740mm (nearest rainfall site: Huntingdon)						
Drainage ratio	<50						
Infiltration method	Continuous						
Unsaturated zone	<5	>5 and <15m	<5	>5 and <15m	>5 and <15m	<5	>15
Monitoring borehole	BH01, BH02	BH19	BH14	BHs15 - 20	BHs24 & 26	No nearby boreholes (BH01 / BH02 used)	BHs15 - 20
Flow Type	Dominantly intergranular	Dominantly intergranular	Flow dominated by fractures and fissures	Dominantly intergranular	Dominantly intergranular	Dominantly intergranular	Dominantly intergranular
Geological description	Sheringham Cliffs Formation overlying Chalk	Sheringham Cliffs Formation overlying Chalk	Chalk	Lowestoft Formation overlying Chalk	Sheringham Cliffs Formation overlying Chalk	Assume Sheringham Cliffs Formation overlying Chalk	Lowestoft Formation overlying glacial sands and gravels (Sheringham Cliffs Formation)
Unsaturated zone clay content	<1%	<1%	<1%	>15%	>1% and <15%	<1%	<1%
Justification	Nearest boreholes: 0%	Nearest boreholes: 0 %		nearest boreholes: 17 - 27%	Nearest boreholes: 1 - 59% - due to the large range the worst case option is selected.	No nearby boreholes (BH01 / BH02 used)	Nearest boreholes: 0 - 25%. Due to large range the worst case option is selected.
Organic Carbon	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Justification	Nearest borehole: 2.4% SOM	No data - assume worst case	Chalk	nearest boreholes:0.1 - 0.9% SOM	No data - assume worst case	No nearby boreholes (BH01 / BH02 used)	No data - assume worst case
pH	>pH5 and <pH8	>pH8	>pH8	>pH8	>pH5 and <pH8	>pH5 and <pH8	>pH8
Justification	Nearest boreholes: pH7.56 - 8.42	nearest boreholes: pH8.3 - 8.8	Assumed for Chalk	Nearest boreholes: pH7.88 - 8.9. Majority >8	nearest boreholes: pH7.4	No nearby boreholes (BH01 / BH02 used)	Nearest boreholes: pH7.88 - 8.9. Majority >8
Risk score	**165**	140	**180**	140	140	**165**	120
	Medium	Low	**Medium**	Low	Low	**Medium**	Low

Table C2 Water quality risk assessment of medium risk catchments

Catchment	A	B (underpass, east of Wards Wood underpass)	B (underpass, west of Wards Wood underpass)	B/H	F	E2	J
Annual average copper concentration (Ug/l)	**3.78**		**3.78**			**3.78**	
Annual average zinc concentration (Ug/l)	8.3		8.3			8.3	

Annex D. Consultation with Norfolk Wildlife Trust

From: [redacted]
Sent: 27 June 2018 14:21
To: [redacted]
Subject: RE: A47 A11 Thickthorn Junction
Attachments: 199.doc; 200.doc; 199.pdf; 200.pdf

Follow Up Flag: Follow up
Flag Status: Flagged

Hi [redacted]

I have included citations and original survey forms for the two sites. As you can see, we haven't been able to visit either for several years. Meadow Farm (199) looks to have become degraded over the years. Intwood Carr (200) has small amount of fen habitat present but we don't have any information on the quality of this habitat or whether it is drying out.

I hope this is useful

Kind regards

[redacted]

From [redacted]
Sent: 27 June 2018 12:20
To [redacted]

Subject: A47 A11 Thickthorn Junction

Hi [redacted]

As part of the scoping opinion received for the proposed A47 A11 junction at Thickthorn and subsequent consultations, the Environment Agency have suggested that we consider lowland fens at NGR TG190048 (Meadow Farm and Intwood Carr) in our groundwater assessment.

As discussed, any site survey information you might have on these sites would help us to inform our preliminary baseline understanding.

Also, if there is any existing surface water or groundwater monitoring on site that you know of (i.e. gauge boards, weirs, dipwells etc), this would also be valuable information to us.

Many thanks.

Kind Regards

[redacted]

SWECO

[redacted]

County Wildlife Site
(Ref. No: 199)

Site Name: Meadow Farm Meadow **Parish: Cringleford/Keswick**

Grid Reference: TG 193 046 **Area: 4.4 ha**

Site Description:

This is an interesting and diverse area of marshy grassland which is grazed by horses and contains areas of spring activity, tall fen and scrub and woodland. A stream runs along the southern edge of the site and the Norwich Bypass crosses to the west.

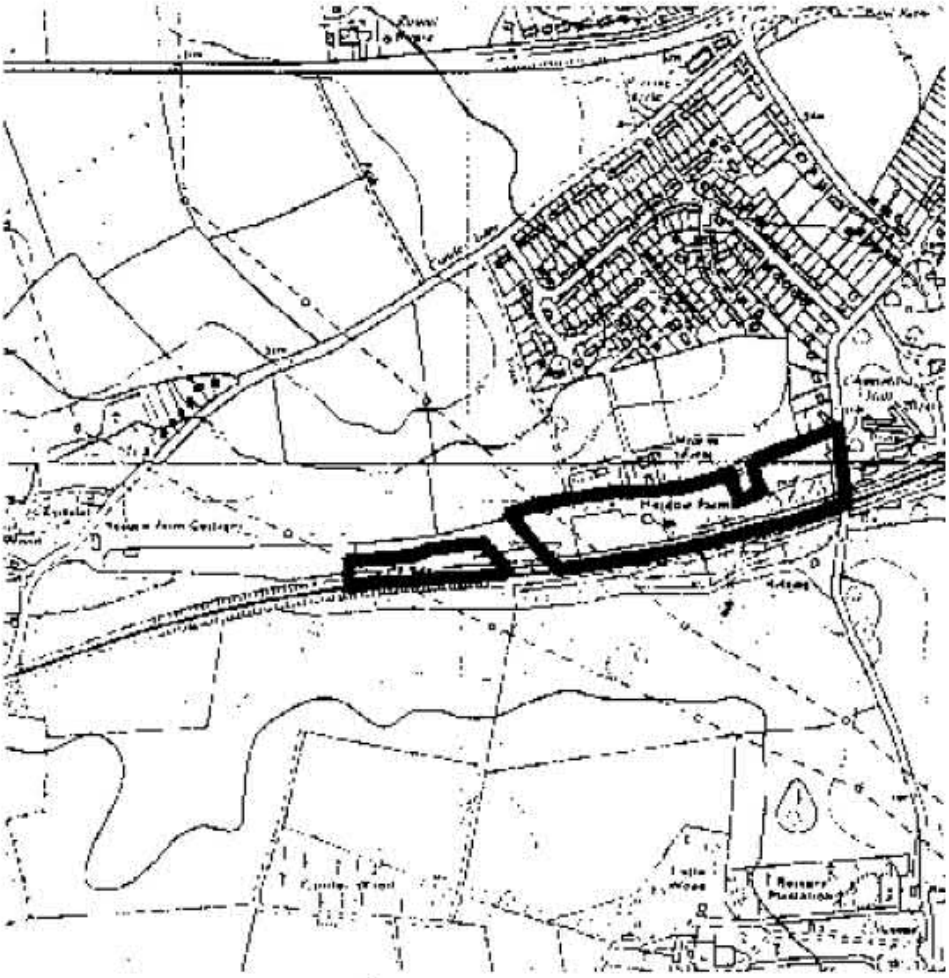
The grassland is quite variable but where short-grazed the sward is dominated by creeping bent *(Agrostis stolonifera)* with Yorkshire fog *(Holcus lanatus).* Drier patches support common bent *(Agrostis capillaris)* and red fescue *(Festuca rubra).* Forbs are frequent and include creeping buttercup *(Ranunculus repens),* selfheal *(Prunella vulgaris)* and hare's-foot clover *(Trifolium arvense).* Wetter ground supports ragged-robin *(Lychnis flos-cuculi)*, fleabane *(Pulicaria dysentrica)*, water mint *(Mentha aquatica)*, marsh-orchids *(Dactylorhiza sp.)* and yellow rattle *(Rhinanthus minor).* In one dry area there is a colony of hoary mullein *(Verbascum pulverulentum).*

Fen areas occur on the wettest ground and include great willowherb *(Epilobium hirsutum)*, meadowsweet *(Filipendula ulmaria),* jointed rush *(Juncus articulatus)* and brown sedge *(Carex disticha).* The section south of the A47 includes marshy grassland along an impeded ditch and along the stream which forms the southern boundary. Species here include creeping and marsh thistle (*Cirsium arvense* and *Cirsium palustre*), common sorrel (*Rumex acetosa*), marsh horsetail (*Equisetum palustre*) and greater birds foot trefoil (*Lotus corniculatus*). Finer, more open patches support common sorrel, meadow buttercup (*Ranunculus acris*), creeping cinquefoil (*Potentilla reptans*) and cuckooflower (*Cardamine pratensis*). In the south east, a drier, well drained area supports ground ivy (*Glechoma hederacea*), common bird's foot trefoil, square stalked St John's wort (*Hypericum tetrapterum*) and field wood rush (*Luzula campestris*).

Water figwort (*Scrophularia auriculata*) is occasional in the shallow drain which flows through the site; floating sweet grass (*Glyceria fluitans*)and hairy sedge (*Carex hirta*) also occur. The mesotrophic stream has little aquatic vegetation, other than occasional water starwort (*Callitriche* sp), water mint, bur reed (*Sparganium* sp) and patches of fool's watercress (*Apium nodiflorum*); water figwort is occasional

Scrub is abundant young sallow *(Salix cinerea)* and crack willow *(Salix fragilis)*; the marginal woodland areas have the same species, plus hazel (*Corylus avellana*), ash (*Fraxinus excelsior*), pedunculate oak (*Quercus robur*) and goat willow (*Salix caprea* sp.).

Survey date: 21/9/95 & 5/6/98



Local Authority No. 078759

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Norfolk County Council
County Hall
Norwich Date .....

County Wildlife Site
(Ref No: 200)

Site Name: Intwood Carr **Parish: Keswick**

Grid Reference: TG 198 048 **Area: 10.4 ha**

Site Description:

A moderately large area of predominantly damp broad-leaved semi-natural carr woodland.

A small tributary stream of the River Yare flows through part of the site, dividing the woodland from a small area of tall-herb fen. To the north of a narrow thinned strip, the ground becomes progressively more waterlogged and the woodland grades into carr over a ground layer of tall-herb fen crossed by an extensive network of water-filled drains.

A proportion of the woodland has been converted to conifer plantation and hybrid black-poplars (*Populus* x *canadensis*) are interspersed throughout the semi-natural woodland. There is evidence of past management with coppice-stool regrowths and a row of large veteran oak pollards adjacent to the eastern boundary.

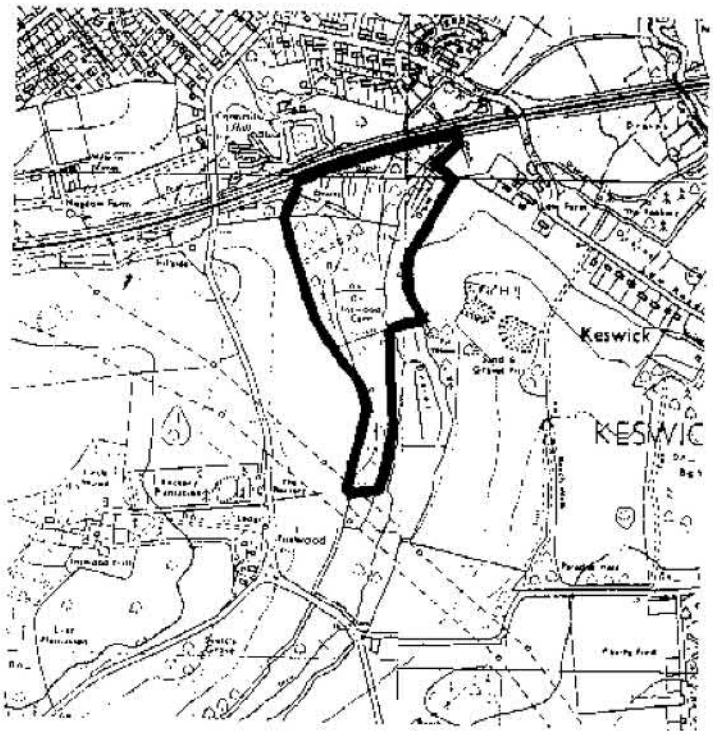
The woodland canopy is dominated by ash (*Fraxinus excelsior*) and hybrid black-poplar, with a sub-canopy of alder (*Alnus glutinosa*) throughout the northern section. Oak (*Quercus robur*), silver birch (*Betula pendula*) and hornbeam (*Carpinus betulus*) are also present. The shrub layer is well-developed and dense in places. It is dominated by hazel (*Corylus avellana*) in drier areas and bird cherry (*Prunus padus*) in the wetter carr. Hawthorn (*Crataegus monogyna*), wych elm (*Ulmus glabra*), hornbeam and occasional silver birch, holly (*Ilex aquifolium*) and spindle (*Euonymus europaeus*) also occur.

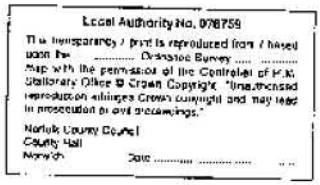
The ground flora is well-developed throughout. Monospecific patches of dog's mercury (*Mercurialis perennis*) dominate large areas with lesser periwinkle (*Vinca minor*), bluebell (*Hyacinthoides non-scripta*), wood anemone (*Anemone nemorosa*), nettle (*Urtica dioica*) and bramble (*Rubus fruticosus* agg.) also dominant in parts. There are frequent patches of black currant (*Ribes nigrum*). Enchanter's-nightshade (*Circaea lutetiana*) is abundant, with frequent lords-and-ladies (*Arum maculatum*), common twayblade (*Listera ovata*), primrose (*Primula vulgaris*), ivy (*Hedera helix*) and false brome (*Brachypodium sylvaticum*). Other characteristic species include moschatel (*Adoxa moschatellina*), bugle (*Ajuga reptans*), pignut (*Conopodium majus*), sanicle (*Sanicula europaea*), common figwort (*Scrophularia nodosa*) and hairy brome (*Bromus ramosus*). Bird's-nest orchid (*Neottia nidus-avis*) is found under the dense, shaded shrub layer of hazel and bird cherry. Waterlogged areas along the drains support wild angelica (*Angelica sylvestris*), hemp-agrimony (*Eupatorium cannabinum*), meadowsweet (*Filipendula ulmaria*), water figwort (*Scrophularia auriculata*) and pond-sedge (*Carex*).

A Scots pine (*Pinus sylvestris*) plantation occupies a higher, sandier area along the western boundary where the ground layer is dominated by bracken (*Pteridium aquilinum*) with frequent bluebell and occasional wood sage (*Teucrium scorodonia*), heath bedstraw (*Galium saxatile*), sheep's sorrel (*Rumex acetosella*) and honeysuckle (*Lonicera periclymenum*).

A small area of tall-herb fen lies to the east of the main woodland, separated from it by a small stream. Woodland is encroaching from the eastern side and parts show evidence of drying out with dominant great willowherb (*Epilobium hirsutum*) and bramble. There are patches of common reed (*Phragmites australis*), reed sweet-grass (*Glyceria maxima*) and greater pond-sedge (*Carex riparia*), with occasional wild angelica, marsh thistle (*Cirsium palustre*), meadowsweet, greater bird'sfoot-trefoil (*Lotus uliginosus*), Ragged Robin (*Lychnis flos-cuculi*) and common valerian (*Valeriana officinalis*).

Survey date: 5.6.98





Survey date: 5.6.98