E53

High Speed Rail (West Midlands - Crewe)

Environmental Statement

Volume 5: Technical appendices

Ecology and biodiversity

Habitats Regulations Assessment screening report for Midland Meres and Mosses Phase 1 Ramsar site addendum - Betley Mere Site of Special Scientific Interest component (EC-017-002)

July 2017

ES 3.5.0.11.2

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Department for Transport

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Contents

Executive Summary

This document forms an addendum to the Habitats Regulations Assessment (HRA) screening report for the Midland Meres and Mosses Phase 1 Ramsar site which was undertaken for the Phase 2 Appraisal of Sustainability (AoS).

It is required because there have been changes to the Proposed Scheme, including the proposal to extract gravel from a borrow pit to the north of Checkley Lane in the South Cheshire area (CA5), which is approximately 280m from Betley Mere. It considers the findings of a hydrological assessment to consider further possible impacts due to the borrow pit.

As a result of the measures that will be put in place, it is not likely that there will be a significant effect on the Betley Mere SSSI element of the Midland Meres and Mosses Phase 1 Ramsar site due to the construction of HS2 Phase 2a, either alone or in combination with other plans or projects.

1 Introduction

1.1.1 This document forms an addendum to the Habitats Regulations Assessment (HRA) screening report for the Midland Meres and Mosses Phase 1 Ramsar site, part of which contains Betley Mere Site of Special Scientific Interest (SSSI)[1], which was undertaken for the Phase 2 Appraisal of Sustainability (AoS)[2] in 2013.

1.1.2 This addendum is required because there have been changes to the Proposed Scheme since that time, including the proposal to extract gravel from a borrow pit to the north of Checkley Lane in the South Cheshire area (CA5), which is approximately 280m south of Betley Mere. The intention is to reinstate this borrow pit using appropriate cohesive excavated material from elsewhere along the Proposed Scheme.

1.1.3 This addendum includes a summary of the findings of a hydrogeological assessment to consider further possible impacts on the Betley Mere SSSI component of the Midlands Meres and Mosses Phase 1 Ramsar Site.

[1] *Habitats Regulations Assessment screening report for Midland Meres and Mosses Phase 1 Ramsar Site*, see Appendix EC-017-001
[2] HS2, (2013), *Phase Two Appraisal of Sustainability Appendix E4 – Biodiversity*, http://assets.hs2.org.uk/sites/default/files/consulation_library/pdf/P2C12d%20Appendix%20E4%20Biodiversity%20050713.pdf

2 Context

2.1.1 Midland Meres and Mosses Phase 1 Ramsar site is made up of 16 constituent SSSIs, each with its own specific Conservation Objectives. At the AoS stage for Phase Two, a HRA screening report was undertaken for the two constituent SSSIs that were closest to the Proposed Scheme. These were Betley Mere SSSI (0.4km) and The Mere, Mere SSSI (1.2km). All of the other constituent SSSIs are over 2km from the Proposed Scheme. The main interest of the Ramsar site is the wide range of lowland wetland types and successional stages present within a distinct biogeographical area, which identify it as a wetland of international importance.

2.1.2 Hydrological impacts to the Betley Mere SSSI were screened out at the end of the initial screening process in January 2012 as no hydrological impacts to the site were predicted. However, during the subsequent design development it has become necessary to extract gravel from five borrow pits along the Phase 2a route. One of these, which is to the north of Checkley Lane in the South Cheshire area (CA5), is approximately 280m from Betley Mere at its nearest point. This addendum considers the potential effects on hydrology and hydrogeology resulting from the extraction of gravel from this borrow pit.

2.1.3 In order to inform the assessment of likely significant effects, a baseline hydrogeological report has been prepared (Baseline Hydrogeology – Betley Mere SSSI and Surrounding Area C861-ARP-EV-REP-000-123581) and this is included in Appendix 1.

2.1.4 Betley Mere is located within the Water Framework Directive water body GB31234330 and has a current overall water body status of poor as of 2015 cycle 2. This has declined from 2009 cycle 1 where it achieved an overall water body status of moderate. It has an overall objective of reaching good ecological potential by 2027 (Environment Agency, 2016)[3].

2.1.5 The Water Framework Directive (2000/60/EC) lake typology based on alkalinity and mean depth for Betley Mere is classified as High for alkalinity (>1 mequiv L^{-1}) and for mean depth Very Shallow (<3m) (Environment Agency, 2016).

2.1.6 Water levels in the mere have fallen significantly over the past few decades for reasons unknown. However, it is speculated that the decrease in levels may be related to changes in the drainage pattern (Environment Agency, 2015)[4].

2.1.7 High sediment loads to Betley Mere from inflowing streams to the north and north-east and from runoff from nearby farms has resulted in a decline in water quality with increased turbidity (Environment Agency, 2015). Natural England has assessed all units within the SSSI as being either unfavourable or unfavourable recovering. The

[3] Environment Agency (2016), *Nitrate Vulnerable Zone (NVZ) designation, 2017 Eutrophication (lakes), Betley Mere*, NVZ ID: EL128
[4] Environment Agency (2015), *Betley Mere Diffuse Water Pollution Plan*, Version 4

Natural England condition surveys confirm the influence of effluent from the nearby waste water treatment works in contributing to this unfavourable condition[5].

[5] Natural England (2015), *Betley Mere SSSI condition assessment*, https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=s1002384

3 Findings

3.1 Potential Surface Water Drainage Effects

3.1.1 Existing topographical information indicates that the northern half of the proposed borrow pit is within the surface water catchment of Betley Mere and Mere Gutter. The proposed borrow pit has a potential maximum surface area of approximately 40ha. The southern half is within the catchment of the Checkley Brook, which flows away from the mere.

3.1.2 The whole of the proposed borrow pit is at a higher elevation (70m-95m AOD) than Betley Mere (65m AOD).

3.1.3 A surface water drain to the south of the quarry pond which is part of the Water Framework Directive waterbody 'Unnamed tributary of Mere Gutter 6', carries runoff and potentially some groundwater below the West Coast Main Line (WCML) and towards the drains which discharge to Betley Mere SSSI.

3.1.4 The catchment area for Betley Mere is approximately 8.2km^2. Only about half of the 40ha borrow pit area extends into the surface water catchment. This equates to approximately 2.5% of the total catchment.

3.1.5 Betley Mere has a surface area of about 9.3 ha and is shallow, with a maximum water depth of about 1.8m (Reynolds, 1979)[6]. The estimated inflow into the mere typically exceeds the outflow which suggests there is substantial loss of water either to groundwater or to the adjacent wetland areas (Moss et al, 1992)[7], in addition to evaporation. The mere is highly eutrophic and well mixed with the main source of water from surface flows. However, there is some maintenance of the water table by recharge from precipitation. The mere is also known to have interaction with the superficial aquifer as both a source and sink of water dependent on the groundwater table within the aquifer (Reynolds, 1992).

3.1.6 The baseline hydrology and hydrogeology report concludes that surface water runoff is likely to contribute substantially to Betley Mere as it sits in a valley like structure and is the low point within the surface water catchment. Much of the surface water flow entering Betley Mere is likely to come from the higher reaches of the catchment to the south-east where low permeability Glacial Till will inhibit infiltration and direct runoff towards surface watercourses.

3.1.7 The proportion of surface water flow entering Betley Mere from the 20ha section that lies within the proposed borrow pit area is therefore likely to be less than 2.5% of the total.

[6] Reynolds, C.C (1979), *The limnology of the eutrophic meres of the Shropshire-Cheshire Plain. Field Studies*, 5(1), 93-173
[7] Moss B, Mcgowan S., Kilinic S. & Carvalho L. (1992), *Current limnological condition of a group of the West Midland meres that bear SSSI status*, P85

3.1.8 Without mitigation, excavation and lowering of the ground surface in the northern half of the proposed borrow pit to allow gravel extraction to take place there would be a risk of disruption to the surface water flow towards Betley Mere for this part of the catchment.

3.2 Groundwater volume

3.2.1 The hydrology and hydrogeology report has considered the geology of the area around the proposed borrow pit and Betley Mere in order to understand the potential effects on the mere due to potential changes in groundwater flow.

3.2.2 Geological cross-sections were developed on the basis of existing geological maps and historical borehole records. However, the information available from existing boreholes is very limited, and hence the understanding of the hydrogeology of the area also has limitations. It has not been possible to undertake specific site investigations due to land-ownership and timing considerations.

3.2.3 In the absence of detailed cross-sections, it has not been possible to confirm that there is no hydrological connectivity between the superficial deposits within the proposed borrow area and Betley Mere.

3.2.4 Groundwater levels have been assumed to be near surface within the topographic depressions of the Glaciofluvial deposits. The direction of groundwater flow would therefore be towards local depressions such as watercourses, the disused quarry and Betley Mere. Due to the nature of the geology, groundwater levels and flow within the superficial deposits will be dependent on the layering of deposits with potentially perched horizons.

3.2.5 The potential for extraction of the gravels to cause an effect on water levels in Betley Mere is dependent on the depth to which gravels would be extracted. If excavation takes place below the water table, the potential for this to affect the groundwater supply to Betley Mere cannot be discounted.

3.3 Groundwater quality

3.3.1 No groundwater quality data has been provided for the borrow pit area.

3.3.2 Betley Mere is known to be highly eutrophic (Environment Agency, 2016) with an overall WFD ecological status of poor although the confidence in that status is uncertain. Nitrate is significantly elevated (>2mg/l). Phosphorous and to a lesser extent nitrogen are also elevated within the SSSI.

3.3.3 Due to the potential hydraulic connection between the borrow pit area and the SSSI through the Glaciofluvial Deposits, there is a pathway for contamination via groundwater.

3.4 Further research and mitigation measures

3.4.1 Approximately half of the proposed borrow pit at Checkley Lane will be excavated into the Glaciofluvial Deposits, within the surface water catchment of Betley Mere

SSSI. There is a potential surface water connection between the borrow pit and the drains discharging to the mere. The mere is also believed to have interaction with the Glaciofluvial Deposit aquifer as both a source and sink of water. Therefore excavation of the borrow pit within the Betley Mere catchment could disrupt surface and groundwater flows towards the mere, without appropriate avoidance measures. It is therefore proposed to carry out the excavation of this borrow pit in accordance with the following measures:

- provision of a one metre vertical buffer between the base of the borrow pit excavations and the groundwater level. This will ensure that there are no significant impacts on groundwater flows;
- adherence to the measures described in the draft Code of Construction Practice (CoCP) for Phase 2a;
- treatment and recirculation of any surface water runoff intercepted by the borrow pit into the downstream catchment at an appropriate rate and location, therefore ensuring that there is no significant impact on the volume or quality of water reaching the mere; and
- such reasonable ancillary measures as may be required.

3.4.2 The details of this mitigation will be agreed with the Environment Agency in consultation with Natural England.

3.4.3 Before the extraction of gravels commences, detailed hydrological and hydrogeological investigations will be undertaken using boreholes to establish the safe depth of the extraction to ensure there are no effects on the groundwater and, therefore, to avoid groundwater effects on Betley Mere.

3.4.4 A groundwater and surface water monitoring programme would need to be developed to ensure that there is no significant impact on groundwater and that the correct volume and quality of discharge to surface water is maintained.

3.4.5 There is the possibility that alternative methods of avoidance to those specified in paragraph 3.4.1 above may be developed in the period prior to excavation that would be equally effective in preventing the likelihood of significant effects. If that were to be the case, HS2 Ltd would secure the Environment Agency's approval to such an alternative prior to excavation commencing

3.4.6 The mitigation measures will ensure that there will be no significant impact to the flow or quality of groundwater and surface water reaching Betley Mere and therefore it is not likely that there will be a significant effect on the Betley Mere SSSI element of the Midland Meres and Mosses Phase 1 Ramsar site due to the construction of HS2 Phase 2a.

4 In-combination effects

4.1.1 Potential in-combination effects from other plans and projects were assessed in the findings of the initial HRA for Midland Meres and Mosses Phase 1 Ramsar site. While there may be emerging proposals to improve the quality of water flowing into Betley Mere in order to improve water quality in the longer term, none of these can be considered a confirmed project. There are no known plans or projects in the vicinity that would affect direction of surface water flows and/or would affect groundwater flows. On this basis, it is assessed that it is not likely that there will be any significant in combination effect.

5 Conclusions

5.1.1 Further to the initial HRA screening report for the Midland Meres and Mosses Phase 1 Ramsar site, it has become necessary to extract material from a borrow pit north of Checkley Lane in the South Cheshire area (CA5). This HRA addendum considers the potential for hydrological and hydrogeological effects on the Betley Mere SSSI component of the Ramsar site, which is approximately 280m from the borrow pit.

5.1.2 The mitigation measures, described in Section 3.4, that will be put in place will ensure that there is no significant impact on the groundwater and surface water flow and quality to Betley Mere.

5.1.3 This HRA screening report addendum therefore concludes that it is not likely there will be a significant effect on the Betley Mere SSSI element of the Midland Meres and Mosses Phase 1 Ramsar site due to the construction of HS2 Phase 2a, either alone or in combination with other plans or projects.

6 References

Environment Agency (2015), *Betley Mere Diffuse Water Pollution Plan,* Version 4.

Environment Agency (2016), *Nitrate Vulnerable Zone (NVZ) designation, 2017 Eutrophication (lakes), Betley Mere*, NVZ ID: EL128.

HS2 Ltd (2013), *Phase Two Appraisal of Sustainability Appendix E4 – Biodiversity*. Available online at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/400842/p2c12d_appendix_e4_biodiversity_050713.pdf.

Moss B., Mcgowan S., Kilinc S. & Carvalho L. (1992), *Current limnological condition of a group of the West Midland meres that bear SSSI status*, p. 85.

Natural England (2015), *Betley Mere SSSI condition assessment.* Available online at: https://designatedsites.naturalengland.org.uk/SiteDetail.aspx?SiteCode=s1002384.

Reynolds, C. S. (1979), *The limnology of the eutrophic meres of the Shropshire-Cheshire Plain*, Filed Studies, 5(1), 93-173.

Appendix 1

Baseline hydrology and hydrogeology –

Betley Mere SSSI and surrounding area

Contents

List of tables

List of figures

1 Introduction

1.1 Objectives

1.1.1 This report brings together existing information to summarise and develop the baseline geological, hydrogeological and hydrology understanding within Betley Mere SSSI, and the surrounding area of the surface water catchment (the study area, Figure 1).

1.1.2 The purpose of this report is to set out the current baseline understanding of the geology, hydrogeology and hydrology of the SSSI site to provide the basis for review of works in relation to the borrow pit north of Checkley Lane to the west of Betley Mere as shown in Figure 1.

1.2 Data sources

1.2.1 The preparation of this document has involved the review of the following information (full references given at the end of this report):

- British Geological Survey (BGS) 1:50,000 and 1:10,000 scale solid (bedrock) and superficial geological mapping and associated explanatory notes;
- BGS on-shore borehole records (BGS GeoIndex);
- Environment Agency records for groundwater levels, water abstractions and river flows;
- review of 2m resolution Lidar elevation data and 5m resolution topographic Ordnance Survey mapping; and
- review of open source literature.

1.3 Data assumptions and limitations

1.3.1 It is assumed that:

- the BGS geological mapping and borehole records are representative of the solid and superficial geology within the study area;
- the BGS geological mapping and explanatory notes are representative of the position and nature of geological faults within the study area; and
- the surface water features are in connection with groundwater and are indicative of the groundwater table at those locations. Where surface water is not present, it has been assumed that groundwater is at or near surface at the location of topographic depressions within the superficial aquifers.

1.3.2 The key limitations for the geological, hydrogeological and hydrology understanding are as follows:

- there are limited borehole records available within the study area to give an indication as to the depth and nature of the superficial deposits, Professional geological and hydrogeological judgement has been used to interpret these

data and generate the conceptual ground model;

- there has been no land access available to view the surface water features and watercourses in the vicinity of the borrow pit north of Checkley Lane; and
- there has been no monitoring of levels, flows or quality for groundwater or surface water undertaken by HS2 Ltd and no site specific ground investigation to confirm local geology and groundwater assumptions to date within the study area.

1.3.3 Within the limitations identified, the information obtained is considered to represent an improvement in the baseline geological, hydrogeological and hydrology understanding.

2 Site location

2.1 Location

2.1.1 The study area is shown within the solid and dashed red lines on Figure 1. The study area has been defined based on the surface water catchment area of Betley Mere (within the solid red line) which has been delineated primarily from Lidar data and 'Functional Ecological Units' as defined by Shropshire Wildlife Trust Methodology for Mapping Meres and Mosses (Shropshire Wildlife Trust, 2016). The study area also includes the area of the borrow pit north of Checkley Lane (BP241) which falls partly outside of the surface water catchment and is indicated by the dashed red line in Figure 1. The HS2 route alignment and proposed borrow pit area (BP241) have been superimposed onto this figure to show the borrow pit in relation to Betley Mere and the surface water catchment.

2.1.2 The surface water catchment area has been included within the study area as groundwater flow is likely to be highly dependent of surface topography. Groundwater within the study area is likely near surface and therefore surface water and groundwater are likely to have a high degree of interaction.

2.2 Land use

2.2.1 Figure 2 shows the aerial photography of the study area.

2.2.2 The land use within and around the study area consists primarily of arable and semi-improved pasture for cattle as well as numerous mosses, natural grassland and woodland. Most notable of these features is Stockings Cote which has a number of springs, issues and streams which feed into Stockings Pond, the outflow of which flows into Betley Mere. The town of Betley is located to the west and northwest of Betley Mere at an elevation of approximately 80mAOD.

2.2.3 Betley Mere Wastewater Treatment Works (WwTW) is located just to the west of Betley Mere. The outfall location of the treated water from the WwTW is into Mere Gutter via a pipeline which runs adjacent to Betley Mere SSSI. To the southwest of the SSSI is the West Coast Main Line (WCML) which intersects the lower southwest section of the surface water catchment. Along the western side of the WCML is a disused assumed sand and gravel quarry, the base of which is at approximately 65mOD and is in-filled with water.

2.2.4 The M6 corridor runs north to south approximately 200m to the east of the study area. Black Firs and Cranberry Bog SSSI which includes Black Mere is located approximately 2km to the north of Betley Mere. A number of ponds which are used as fish ponds for Bay Malton Border Fisheries are located 1.5km to the northwest of the study are.

3 Topography and drainage

3.1.1 The topography and main surface watercourses in the study area are shown on Figure 3, including the approximate topographic drainage catchment for Betley Mere SSSI for both 2000 which was defined within the Meres and mosses conservation plans report prepared for English Nature and the Environment Agency (ECUS, 2001) and in 2016 which was redefined by Shropshire Wildlife Trust (Shropshire Wildlife Trust, 2016). There has been little change in the catchment area between these dates however, the 2016 boundary has been slightly redefined along the northern and southern boundaries. The catchment area ranges in elevation from approximately 160mOD along the eastern and southern boundaries to a low of 60mOD within the valley bottom in the vicinity of Betley Mere. Elevations along the side of the valley rise to the east, west and south of the SSSI to approximately 85 to 100mOD.

3.1.2 The predominant drainage of the Shropshire-Cheshire Plain is northwards through the Dee, Gowy and Mersey-Weaver systems (Reynolds, 1979). Betley Mere receives water primarily from two streams. The first of the streams is the outflow from the spring fed Stockings Pond located at elevations of 80 to 85mOD. The overflow from the pond flows southwest towards the mere where it collects behind a sluice gate and travels through a series of weirs before entering Betley Mere at the northwest corner. The second stream which feeds into Betley Mere is a collection of artificial drains within the wetlands along the southern bank of the mere which are mostly spring fed.

3.1.3 There are numerous small ponds and water features throughout the study area, many of these are shown on the OS map in Figure 1. These are mostly found in local depressions within the higher topography.

3.1.4 The existing ground surface in the borrow pit area is undulating with most of the borrow pit area having a surface elevation of 85 to 95 mAOD. The lowest existing ground level in the borrow pit area is approximately 70 mAOD in the northern extent. At the southern end of the borrow pit, the lowest existing ground level is approximately 80 mAOD. The northern part of the borrow pit area falls within the catchment of Betley Mere SSSI and Mere Gutter, and the southern half is within the catchment of Checkley Brook.

3.1.5 There are a number of small artificial drains within the wetland area that are in connection to the mere. Most notably, approximately 500m to the southwest of the Mere is a disused sand and gravel quarry marked on the OS map, in proximity to the borrow pit location with a pond marked 'Quarry'. The base of which is at an elevation of approximately 65mOD.

3.1.6 A surface water drain to the south of the quarry pond which is part of the WFD waterbody 'Unnamed tributary of Mere Gutter 6', carries runoff and potentially some groundwater below the WCML and towards the drains which discharge to Betley Mere SSSI. As the quarry sits at a higher elevation than the mere it may act as a source of water to the wetlands and the mere itself.

3.1.7 Outflow from the study area is via Mere Gutter which flows from south to north through the low lying marshland along the northern bank of the mere. Mere Gutter flows northeast where it is partially diverted into drainage and also flows into Basford

Brook near Weston. The brook continues northwards where it then turns westwards at Crewe and flows into Gesty Brook. The brook continues to flow through Wistaston Brook and into Valley Brook where it eventually enters the River Weaver near Worleston.

4 Hydrology

4.1 Introduction

4.1.1 The study area for Betley Mere has been defined as the borrow pit area north of Checkley Lane and the surface water catchment. The catchment area is approximately 8.2km^2 (820ha) whilst the area of Betley Mere SSSI is approximately 9.3ha. Only about half of the 40ha borrow pit extends into the surface water catchment. This equates to approximately 2.5% of the total catchment. For comparison, if the entire borrow pit were within the surface water catchment this would equate to 5% of the total catchment area.

4.1.2 The mere is shallow with a maximum water depth of about 1.8m and an area of about 9.3ha (Reynolds, 1979). The estimated inflow into the mere typically exceeds the outflow which suggests there is substantial loss of water either to groundwater or to the adjacent wetland areas (Moss, 1992), with likely losses also from open water evaporation. The mere is highly eutrophic and well mixed with the main source of water from surface flows. However, there is some maintenance of the water table by recharge from precipitation. The mere is also known to have interaction with the superficial aquifer as both a source and sink of water dependent on the groundwater table within the aquifer (Reynolds, 1992).

4.1.3 From the topographic maps it is difficult to define the interaction of the drains with Betley Mere. Some of the drainage may bypass the mere and flow directly into Mere Gutter. The valley bottom is relatively flat and the surrounding area around the mere is primarily wetland. A site walkover would allow for proper assessment of the contributing drainage network around Betley Mere.

4.2 Water Framework Directive (WFD)

4.2.1 Betley Mere is located within the WFD water body GB31234330 and has a current overall water body status of poor as of 2015 cycle 2. This has declined from 2009 cycle 1 where it achieved an overall water body status of moderate. It has an overall objective of reaching good ecological potential by 2027 (Environment Agency, 2016).

4.2.2 The Water Framework Directive (2000/60/EC) lake typology based on alkalinity and mean depth for Betley Mere is classified as High for alkalinity (>1 mequiv L^{-1}) and for mean depth Very Shallow (<3m) (Environment Agency, 2016).

4.2.3 Water levels in the mere have fallen significantly over the past few decades for reasons unknown. However, it is speculated that the decrease in levels may be related to changes in the drainage pattern (Environment Agency, 2015).

4.2.4 High sediment loads to Betley Mere from inflowing streams to the north and north-east and from runoff from nearby farms has resulted in a decline in water quality with increased turbidity (Environment Agency, 2015).

4.3 Rainfall

4.3.1 Long term rainfall is shown on Figure 4 showing both daily and annual trends.

4.3.2 Rainfall data has been provided by the Environment Agency from a rain gauge at Alsager (NGR SJ 7862 5449), for the period 2000 to 2015. The gauge site is approximately 4.3km to the northeast of the surface water catchment boundary. This station is the closest rainfall station to the site.

4.3.3 The long term average annual rainfall between 2000 and 2015 was 752mm. This excludes the year of 2006 where data is missing from June to December.

4.3.4 Larger rainfall events (exceeding 25mm per day) are fairly common with some very large events noted in 2007/2008, 2012 and 2015. The wettest year within this period was 2002, however 2007 and 2012 are similar and suggest the 2002 year is not uncommon. The years 2009 through 2011 stand out as being low in comparison to the annual trends. As the years were consecutive this would likely have impacted groundwater levels within the catchment area if it resulted in a reduction in aquifer recharge.

5 Geology

5.1 Geology

5.1.1 The 1:50,000 scale geological maps of the study area are presented on Figure 5 (Superficial Geology) and Figure 6 (Solid Geology). Figure 7 shows the interpreted geological long-section along the route alignment between Chainage 236+250 to 242+250 (drawing number C861-ARP-GT-DPP-000-010009). In addition, several conceptual cross sections through Betley Mere and the borrow pit north of Checkley Lane are presented in Figures 9 through 13.The location of the cross sections are shown on Figure 8.

5.1.2 The geological cross-sections are based on interpretation of the 1:10,000 and 1:50,000 scale geological maps and accompanying explanatory notes as well as reference to historical borehole records available from the BGS onshore borehole archive. The distribution of BGS onshore borehole archive records are extremely limited within the study area. For the purpose of this report up to date lithostratigraphic terminology provided by the BGS (Ambrose et. al., 2014) has been used.

5.1.3 The geology of the study area is summarised below.

5.2 Superficial geology

5.2.1 Solid rock within the Shropshire-Cheshire basin is mostly buried under a blanket of unconsolidated glacial drift deposits from the Pleistocene ice advances. The most substantial ice sheet originated from the Lake District and southwest Scotland which passed southwards via the Irish Sea and Lancashire Plain (Reynolds, 1979). The lesser ice sheet originated in North Wales, and migrated towards the basin via the Severn, Vyrnwy and Dee valleys.

5.2.2 The superficial deposits can be classified structurally into two major types. The first being the Glacial Diamicton (Till) comprising unstratified boulder clay laid down at the base of an advancing ice sheet. The second being the glacial silts, sands and gravels carried out and re-deposited by meltwater issuing from the decaying ice fronts, or in subglacial channels beneath the ice sheet (Reynolds, 1979).

5.2.3 Within the Shropshire-Cheshire basin and present at the study area, younger superficial deposits are present including Glaciolacustrine, Alluvium and Peat deposits. These can be attributed to the last glacial stage of the British Pleistocene known as the Devensian. The dominant feature of this are Late-Devensian till superimposed upon a series of Middle Devensian gravels incorporating numerous lenses of organic silts and Peats which have been dated to be between 30,000 and 40,000 years old (Reynolds,1979).

5.2.4 There are three main morainic complexes located along the edge of the Cheshire Basin, the Wrinehall Moraine, the Foxley Moraine, and the Woore Moraine. Betley Mere lies within the Woore Moraine. The Woore Moraine is attributed to the late-Devensian glaciation. Most of the morainic surface is composed of Glacial Till, which commonly overlies pods or beds of underlying sand and gravel. However, some of the sand and gravel forms prominent hills in the area which appear to rest on the till (BGS,

1998). The area of the borrow pit north of Checkley Lane is located on the Wrinehall Moraine.

5.2.5 There are only four borehole logs within the vicinity of the study area which provide any information on the thickness of the superficial deposits. These logs suggest that rockhead is likely some 40 to 46mbgl within the catchment area. This relates to the superficial deposits having an approximate thickness of 20m within the valley bottom in the vicinity of Betley Mere. No information on the thickness of the Peat, Glaciolacustrine and Alluvial deposits has been identified to date. The BGS borehole log approximately 400m to the north of the quarry pond suggests the superficial deposits, which are shown as Glacial Till on the geological maps, may be 45.7m thick at this location. The log also suggests that the deposits are mainly sands and silts, though the records do not provide a high level of detail. Further ground investigation is required to confirm the nature of the superficial deposits in the study area. The superficial deposits within the study area are summarised in Table 1.

Table 1: Superficial deposits within the study area

Geology	Distribution	Formation Description
Peat	Covers nearly the full SSSI area. Located within the flat low-lying ground of Betley Mere and the surrounding wetlands.	Peat
Lacustrine Deposits	Distributed along the western and northern low lying land of the study area associated with Betley Mere and from the fish pond.	Deposits of silt and clay of lacustrine origin
Alluvium	Narrow band along the eastern boundary of the study area associated with Betley Mere, Mere Gutter and the outflow from the fish pond and Stockings Pond.	Deposits of clay, silt, sand and gravel of fluvial origin
Glaciofluvial Deposits	Located throughout the study area beneath the deposits listed above.	Sand and gravel of Devensian age
Glacial Till	Located primarily to the west of the study area at higher elevations where it is at surface.	Boulder clay of Devensian age

5.3 Solid geology and geological structure

5.3.1 The current BGS nomenclature divides the strata present into Period, Group and Formations, this is outlined in Table 2 below, listing the various solid geological components present within the study area.

Table 2: Solid geological strata of the study area

Period	Group	Formation	Member	Typical Strata
Triassic	Mercia Mudstone	Sidmouth Mudstone	Wilkesley Halite	Halite with mudstone partings
			Northwich Halite	Halite stone and mudstone
Triassic	Sherwood Sandstone[1]	Helsby Sandstone Wilmslow Sandstone Chester	-	Sandstone

Note: 1. The Sherwood Sandstone Group was formerly divided into a series of regional formations reflecting the various depositional areas, e.g. the Knowle Basin (Warrington et al 1980). However, this has recently been revised by the British Geological Survey, and the Cheshire Basin nomenclature has now been applied across the whole of the Sherwood Sandstone Group in England, Wales and South West Scotland (Ambrose et al 2014).

5.3.2 The following provides a geological summary of the Mercia Mudstone Group geological units and associated Formations.

Mercia Mudstone Group

5.3.3 The Mercia Mudstone Group outcrops in a broad, down-faulted tract of the Knowle Basin and comprises a thick sequence of red brown mudstones deposited in an arid continental alluvial and lacustrine floodplain. The Mercia Mudstone Group typically comprises a weak red brown silty mudstone, with a minor amount of carbonate (dolomite) and gypsum when unweathered. The Mercia Mudstone typically weathers by the dissolution of the carbonate and gypsum component to stiff friable silty clay. This weathered zone is often diffuse, and may be 10m or more thick.

5.3.4 Occasional beds of dolomitic siltstone or sandstone (skerries) occur within the Mercia Mudstone, these beds are generally thin (0.1m to 1.0m).

5.3.5 The BGS Research Report RR/08/04 (Howard et. al., 2008) has divided the Mercia Mudstone into five formations. The Blue Anchor Formation, the Branscombe Mudstone Formation, the Arden Sandstone Formation, the Sidmouth Mudstone Formation and the Tarporley Siltstone Formation. The proposed route alignment traverses a part of the Knowle Basin, where the lower part of the Branscombe Mudstone Formation, the Arden Sandstone Formation and the Sidmouth Mudstone is present. Within the study area, the Sidmouth Mudstone Formation is predominant.

Sidmouth Mudstone Formation

5.3.6 The Sidmouth Mudstone Formation of the Mercia Mudstone Group is present at depth under a thick cover of superficial deposits along the route alignment in the study area as shown in cross-section in Figure 7. The Sidmouth Mudstone Formation includes several members which formerly had 'formation' status including the Northwich Halite and the Wilkesley Halite Members which are present within the study area.

5.3.7 The Sidmouth Mudstone consists of dominantly red-brown mudstone and siltstone. Elsewhere in the country the Sidmouth Mudstone ranges in thickness from 120 to 165m however, in the Cheshire basin the Sidmouth Mudstone is up to 1,600m in thickness (BGS, 1998).

5.3.8 The Northwich Halite Member of the Sidmouth Mudstone Formation is present to the south of the study area along the upthrown side of the King Street fault which runs northwest to southeast and downthrown to the northwest. A small fault running northwest to southeast with a downthrow to the southwest bounds the Northwich Halite to the southwest. The Northwich Halite Member is up to 280m thick and comprises 25% mudstone and 75% halite. Mudstones and siltstones are interbedded with the halite and contain laminated gypsum or anhydrite and microcrystalline dolomite (BGS, 1998).

5.3.9 The mineralogy of the Wilkesley Halite Member is similar to that of the Northwich Halite Formation. The Wilkesley Halite Member is present beneath all of Betley Mere SSSI where it is downthrown by the King Street Fault. The Wilkesley Halite as well as the other halite members of the Sidmouth Mudstone Formation, can be prone to salt dissolution and gives rise to dissolution hollows and collapse breccias. The 1:10,000 geological mapping indicates that Betley Mere is a probable infilled subsidence hollow which was formed by these processes.

Sherwood Sandstone Group

5.3.10 The Triassic Sherwood Sandstone Group is present beneath the Glacial Till deposits along the eastern edge of the study area where it has been up-thrown by the Wem Fault. It is also present at depth below the Mercia Mudstone Group within the study area.

5.3.11 However, within the study area, the group is not in hydraulic connection or in the direct vicinity of Betley Mere and therefore the Triassic Sherwood Sandstone Group has not been discussed in further detail within this report.

5.4 Desk study / local detail and cross sections

5.4.1 There is no site specific investigation data available for the study area and therefore the thickness and geological boundaries of the superficial deposits at depth in the cross-sections presented in Figures 9 through 13 are largely inferred. From the geological mapping, the Glaciofluvial deposits appear to be deposited on the tops of hills such as evidence from the sand and gravel quarry to the southwest of Betley Mere. The thickness of the Glaciofluvial deposits beneath Betley Mere is unknown. However, the cross-sections show that the mere lies within a valley like structure where the valley sides are comprised of the Glaciofluvial sands and gravels.

6 Hydrogeology

6.1 Aquifer classification

6.1.1 Figure 14 and 15 present the aquifer classification of the superficial and solid geology of the study area.

6.1.2 The strata identified in Section 5 have been classified using the Environment Agency aquifer classification framework which is consistent with the Water Framework Directive. Aquifer designations for each stratum are included in Table 3.

Table 3: Aquifer designations

Geological Unit	Geological Description	Aquifer Designation
Peat	Peat	Unproductive strata
Lacustrine Deposits	Deposits of silts and clays	Unproductive strata
Alluvium	Deposits of clay, silt, sand and gravel	Secondary A aquifer
Glaciofluvial Deposits	Poorly sorted, sand, clayey sand, pebbly sand and gravel	Secondary A aquifer
Till	Boulder clay	Secondary (undifferentiated) aquifer
Sidmouth Mudstone Formation - Wilkesley Halite Member, of the Mercia Mudstone Group	Halite with mudstone partings	Unproductive strata
Sidmouth Mudstone Formation - Northwhich Halite Member, of the Mercia Mudstone Group	Halite stone and mudstone	Secondary B aquifer
Triassic Sherwood Sandstone Group	Sandstone	Principal aquifer

6.1.3 The key features for each of the aquifer classifications:

- Principal aquifers: These are layers of rock or drift deposits that have high intergranular and/or fracture permeability – meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases principal aquifers are those designated extensive and highly productive aquifers; and
- Secondary aquifers: These include a wide range of rock layers or drift deposits with an equally wide range or permeability and storage. Secondary aquifers are subdivided:
  - Secondary A - permeable layers capable of supporting water supplies at a local rather than strategic scale and in some cases forming an important source of base flow to rivers;
  - Secondary B - predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of

non-aquifers; and

- Secondary undifferentiated - where it is not possible to attribute to either A or B, often due to the variable characteristics of the rock type.

- Unproductive strata: These are rock layers or drift deposits with low permeability that have negligible significance for water supply and river base flow.

6.2 Aquifer Characteristics

Superficial geology

6.2.1 For the glacially derived superficial deposits, Knipe, et al. (1993) distinguished four broad lithological types within the greater Birmingham area which are similar in composition to those found within and surrounding the study area. They are described as follows:

- Diamicton deposits - unsorted rock debris in a sandy clay matrix, generally on the higher ground and lining the sides and base of the main depressions. These deposits are predominantly 'till' deposited under and from melting glaciers but include unsorted stony clays within glacial lake deposits and also some solifluxion ('head') deposits. They tend to have low permeabilities;
- Glacial lake deposits - mainly clays, silts and fine sands with some peat, deposited in ice-dammed lakes that formed in the valleys of the proto-Tame and proto-Rea. The permeability of these deposits tends to be poor vertically but better laterally;
- Glacial sand and gravel - deposited by melt-water flowing from or beneath the glaciers. These have relatively higher permeabilities; and
- Interglacial deposits - organic clays and silts with beds of peat, also formed in shallow lakes and marshes between periods of ice advance.

6.2.2 The following Table 4 summarises the superficial deposits mapped within the study area and the associated permeabilities, based on the Knipe, et al. (1993) classification.

Table 4: Summary of superficial deposit hydraulic properties

Type	Permeability
Peat	Variable
Glaciolacustrine	Low
Alluvium	Low to Moderate
Glaciofluvial sands and gravels	High
Glacial Till	Low

Solid geology - Mercia Mudstone Group

6.2.3 The Mercia Mudstone Group is water-bearing in places by virtue of thin laterally impersistent but fractured skerries (siltstones and sandstones), which are interbedded with the impermeable or low permeability mudstones (BGS, 2000). Groundwater contained in these skerries is generally confined by the overlying mudstones. These

skerries are present throughout most of the mudstone sequence, except in the uppermost unit of the Mercia Mudstone Group.

6.2.4 The Mercia Mudstone Group can also appear water-bearing where boreholes are drilled through overlying permeable superficial deposits, such as alluvium or glacial sands and gravels, and into the mudstones (BGS, 2000). A significant portion of the yield may be derived from these overlying deposits.

6.2.5 Transmissivity values for the Mercia Mudstone Group in the Midlands have been derived from fifty-nine (59) records and range from 0.75 to 402m^2/d with a geometric mean of 12.3m^2/d (BGS, 2000). While there are no results of hydraulic conductivity testing on mudstone samples reported in the BGS publication "The physical properties of major aquifers in England and Wales" (BGS, 1997) states that the Mercia Mudstones may be regarded as effectively impermeable, with a hydraulic conductivity in the order of 0.01m/d (BGS, 2000). The permeability of the Mercia Mudstone Group is summarised in Table 5. The permeability of the Mercia Mudstone Group across the site is likely to be similar.

Table 5: Summary of Mercia Mudstone Group hydraulic properties

Parameter	Values (BGS, 2000)
Transmissivity	0.75 to 402m2/d (mean 12.3m2/d)
Hydraulic conductivity	On the order of 0.01m/d

6.3 Groundwater levels and flows

6.3.1 Figure 16 presents the study area with the available hydrogeologically relevant information such as the location of springs and issues (potential springs), water features and wells. Figure 17 shows the hydrogeological conceptual model of the study area.

6.3.2 There are no long-term groundwater level monitoring boreholes maintained by the Environment Agency within the study area. There is also no groundwater level data available for the study area in relation to the superficial geology from BGS borehole records within the study area.

6.3.3 There has been no site investigation or groundwater monitoring in the vicinity of the study area carried out as part of the HS2 ground investigations to date.

6.3.4 With no other data available, it is assumed that the permeable superficial deposits are in hydraulic connection with the surface water features and water level at the sand and gravel quarry and the water level at Betley Mere is representative of the groundwater table within the adjacent superficial deposits.

6.3.5 Reynolds (1979) states that the typical maximum depth of water within Betley Mere is 1.8m which, based on the Lidar data is at an elevation of approximately 62mOD. It has been assumed that where there are marsh lands surrounding the mere, groundwater level is at or near surface level. By geo-referencing the imagery OS mapping and aerial imagery over Lidar data, an estimate of the water level within the sand and gravel quarry has been made. This suggests that water levels within the disused quarry are at approximately 68mOD.

6.3.6 The Glaciofluvial Deposits are the predominant water bearing strata within the superficial deposits in the study area. There could be perched water within sand and gravel lenses within the Till but these are unlikely to contribute significantly to the water supply to Betley Mere. As the nature of the Glaciofluvial Deposits has not been confirmed in the study area, it is possible that there are different horizons of permeability within the deposits and there is uncertainty in the range of groundwater levels in these deposits. Further investigation and seasonal monitoring will be required to confirm groundwater levels in the areas of the borrow pit north of Checkley Lane.

6.3.7 The aquifer is assumed to be unconfined and groundwater flow is likely to be largely controlled by the local topography as demonstrated in the cross-sections and Figure 17. Groundwater levels within this assessment have been assumed to be near surface within the topographic depressions of the Glaciofluvial deposits. This results in steep hydraulic gradients which may not be a correct representation of an unconfined clean sand and gravel aquifer. However, as no ground investigation data is available to confirm the composition of the Glaciofluvial deposits, it has been assumed that a high clay content or lenses could be present within the aquifer which would result in increased hydraulic gradients.

6.3.8 The direction of groundwater flow would therefore be towards local depressions such as watercourses, the disused quarry and Betley Mere.

6.3.9 Surface water runoff is likely to contribute substantially to Betley Mere as it sits in a valley structure and is the low point within the surface water catchment. Surface water runoff will be enhanced within the higher reaches of the catchment where low permeability Glacial Till will inhibit infiltration and direct runoff towards surface watercourses.

6.4 Springs and issues

6.4.1 The presence of springs, seepages and issues indicates the discharge of groundwater. Figures 16 and 17 show the location of springs and issues within the study area.

6.4.2 The springs and issues correlate to the geological boundaries of the superficial deposits which in turn tend to correlate to changes in topography as shown in Figure 17, most of these occur to the east of Betley Mere. Most of the springs occur at the boundary between the Glacial Till and the Glaciofluvial Deposits as well as the Glacial Till and the Alluvium suggesting the groundwater levels are at or near surface at these locations.

6.4.3 A number of springs feed into Stockings Pond which is the primary watercourse flowing into Betley Mere. The springs arise along the fringe of Stockings Cote, up-gradient of Stockings Pond. There are two springs to the southwest of Betley Mere which appear to feed into minor watercourses which drain into the wetland area to the south of the mere. Within the vicinity of the disused quarry, there are no springs or issues mapped or referenced.

6.5 Borrow pit – groundwater levels and flow

6.5.1 The cross-sections and Figure 17 demonstrate that the existing surface elevation of the borrow pit location is at a higher elevation than both Betley Mere and the sand

and gravel quarry. Cross-section C and E demonstrate that there may be a connection between the Glaciofluvial Deposits present around the quarry and those present at Betley Mere.

6.6 Groundwater abstraction

6.6.1 Groundwater abstraction can change groundwater levels. As groundwater abstraction patterns can change over time, it can be an important aspect of understanding why groundwater levels are where they are and how they might change should rates of abstraction change.

6.6.2 From Environment Agency records, there are no groundwater abstraction licences within the study area. Figure 16 shows the closest abstraction to the study is the licensed groundwater abstractions at The Grange, which is 420m south east of the borrow pit north of Checkley Lane. This includes two groundwater abstractions the first of which is a borehole (Abstraction number: NW/068/0001/007) which abstracts from a horizon between 28 mbgl and 53 mbgl (approximately 52 mAOD to 27 mAOD). The material above this is cased off but consists of potentially permeable sandy layers. During drilling of this borehole, water was struck at 8.5 mbgl and rest water level on completion of the borehole was recorded at 7.5 mbgl (approximately 72.5 mAOD) at the time of drilling.

6.6.3 The second is a well, the abstraction horizon details for the second licensed abstraction (number 2568001067) are not known, though it is in close proximity to the abstraction NW/068/0001/007, so it is assumed that the geology is similar.

6.6.4 Approximately 250m north of the Betley Mere catchment boundary is a groundwater abstraction belonging to Severn Trent Water Ltd. This borehole abstracts water from the Sherwood Sandstone Group. There is also a surface water abstraction approximately 750m outside of the study area which abstracts water from Checkley Brook.

6.6.5 Private groundwater abstractions registered with local councils within the study area have not yet been collected beyond 1km of the HS2 route alignment. Figure 16 shows the location of two water wells indicated on the BGS geoindex (2017), details of which are summarised in Table 6. It is not known whether or not the wells are used for private abstraction. If they are in use it is assumed that abstraction quantities are less than 20 m^3/d (the upper abstraction limit for unlicensed water abstractions).

6.6.6 Figure 16 shows the locations of where OS mapping indicates the presence of four further 'wells' within the study area however, there is no reference to these wells on the BGS or Environment Agency mapping which may indicate that these wells are no longer in use.

Table 6: Details of potential unlicensed private groundwater abstractions

Reference	Location	Depth	Year of installation	Aquifer type
SJ74/43	Plum tree park farm	150	1982	Triassic Sherwood Sandstone Group
SJ74/44	Plum tree farm	180	Unknown	Triassic Sherwood Sandstone Group

6.6.8 The Environment Agency have defined Groundwater Source Protection Zones (SPZ) around all public water supply sources (boreholes, wells and springs) and large industrial users, to guide development and land use activities away from sensitive groundwater recharge areas. These zones are divided as follows:

- Zone 1 (Inner): Defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50m;
- Zone 2 (Outer): Defined by a 400 day travel time from a point below the water table and has a minimum radius of 250 or 500m around the source depending on the size of the abstraction; and
- Zone 3 (Total Catchment Zone): Defined as the area around the source within which all groundwater recharge is presumed to be discharged at the source. In confined aquifers the source catchment may be displaced some distance from the source.

6.6.9 The location of SPZ's are shown on Figure 16. The HS2 route and borrow pit north of Checkley Lane do not pass through any SPZ.

6.6.10 The nearest SPZs (SPZ2 Outer, and SPZ3 Total Catchment) is located within the northwest of the study area in relation to the Environment Agency licenced groundwater abstraction from the Sherwood Sandstone Group.

6.6.11 Due to the depth and source of abstraction, known and potential groundwater abstractions summarised above would not be expected to influence groundwater levels in Betley Mere or in the area of the borrow pit north of Checkley Lane.

6.7 Groundwater quality

6.7.1 No groundwater quality data has been provided for the borrow pit area.

6.7.2 Betley Mere is known to be highly eutrophic (Environment Agency, 2016) with an overall WFD ecological status of poor although the confidence in that status in uncertain (Environment Agency, 2016). Nitrate is significantly elevated (>2mg/l). Phosphorous and to a lesser extent nitrogen are also elevated within the SSSI.

6.7.3 The 2015 Environment Agency source apportionment assessment estimated that 74% of the nitrogen comes from agricultural sources. The effects of the sewage treatment works is apparent in the elevated phosphorous levels of the water and sediment. The WFD total phosphorus classification for the mere is bad status (Environment Agency, 2016)

6.8 Borrow pit - groundwater quality

6.8.1 Due to the borrow pit being topographically higher than the SSSI coupled with a potential hydraulic connection between the borrow pit area and the SSSI through the Glaciofluvial Deposits, there is a potential pathway for contamination via groundwater.

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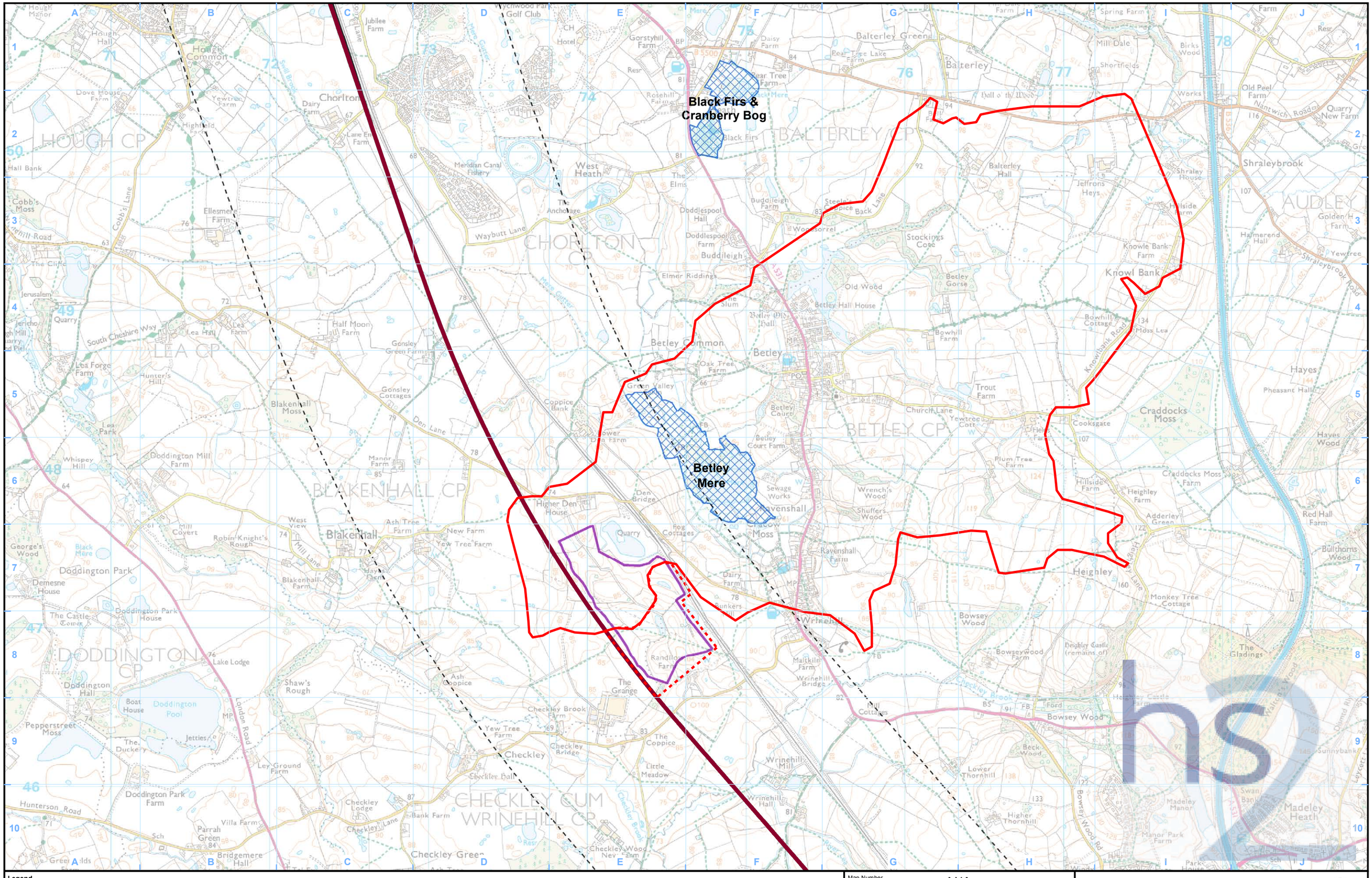
Figures



Legend

- HS2 route alignment
- HS2 route alignment 1km buffer
- Surface water catchment 2016 (Study Area)
- Borrow pit study area
- Temporary borrow pit (BP241)
- *Sites of Special Scientific Interest (SSSI)*

Map Number: N/A

Map Name: Study Area

Figure 01

Registered in England. Registration number 06791686.
Registered office: 2 Snowhill, Queensway, Birmingham B4 6GA.

Scale at A3: 1:21,690

0 220 440 660 880 Metres

Doc Number:

Date: 04/05/17

Legend

- HS2 route alignment
- HS2 route alignment 1km buffer
- Surface water catchment 2016 (Study Area)
- Borrow pit study area
- Temporary borrow pit (BP241)
- *Sites of Special Scientific Interest (SSSI)*

Map Number: N/A

Map Name: Land Use

Figure 02

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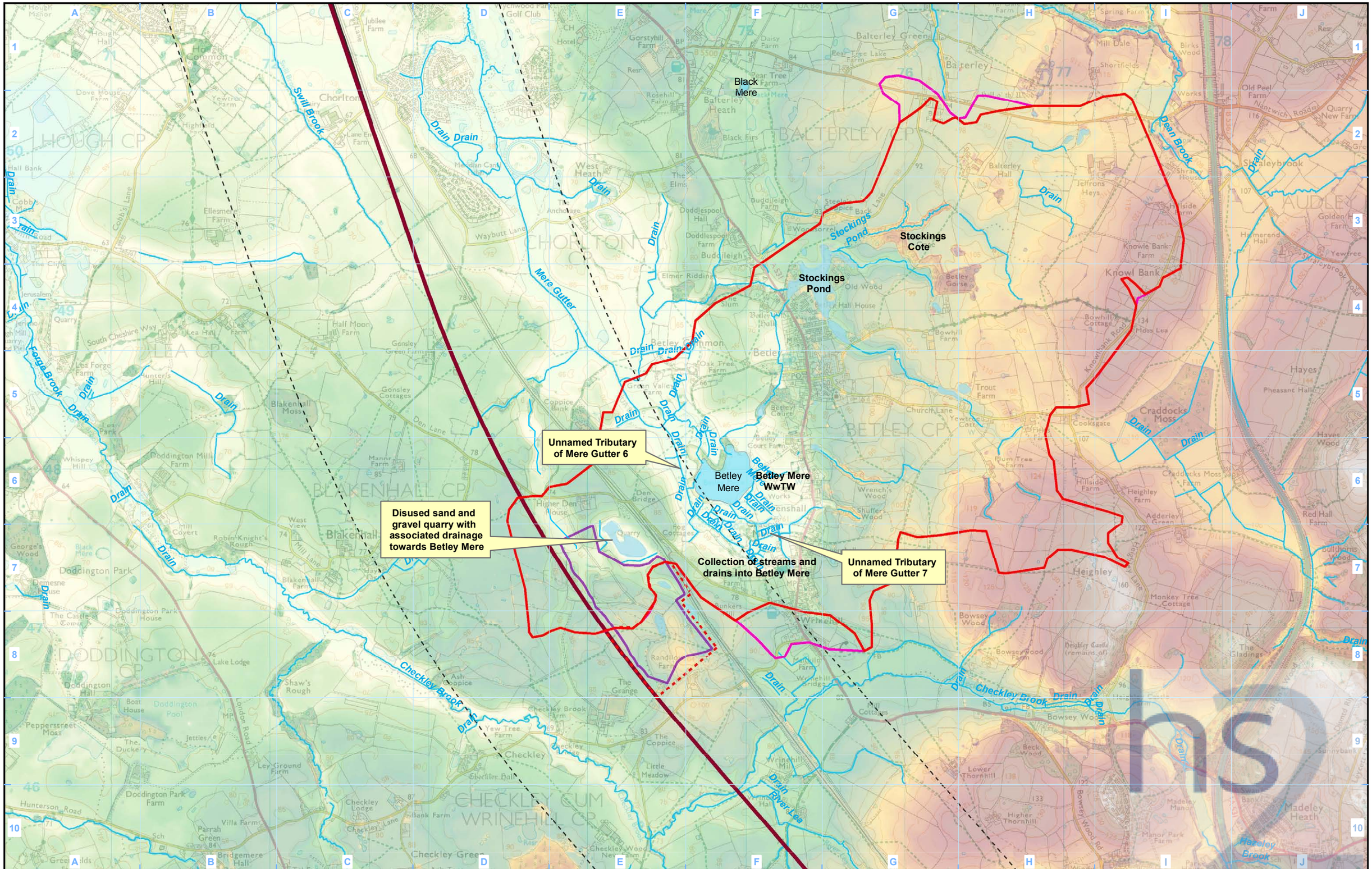
Scale at A3: 1:21,690

0 220 440 660 880
Metres

Doc Number:

Date: 05/05/17



Legend

- HS2 route alignment
- HS2 route alignment 1km buffer
- Surface water catchment 2016 (Study Area)
- Borrow pit study area
- Surface water catchment 2000
- Temporary borrow pit (BP241)
- Surface waterbodies

EA river network

- Watercourse
- Culverted watercourse
- Canal
- Canal tunnel

Surface Topography

Value

High : 181.18

Low : 47.03

Map Number: N/A

Map Name: Topography and Drainage

Figure 03

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Scale at A3: 1:21,690

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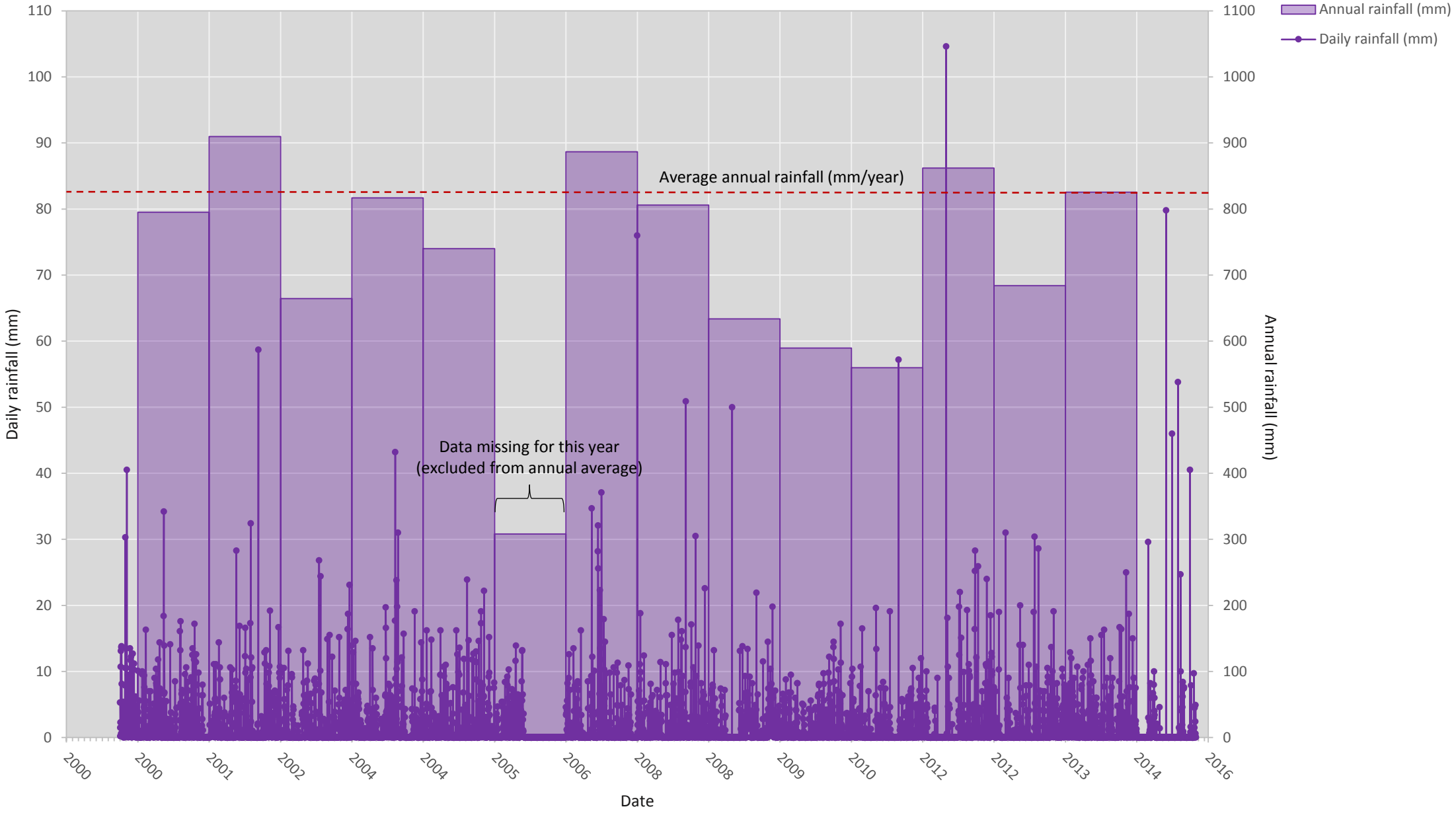
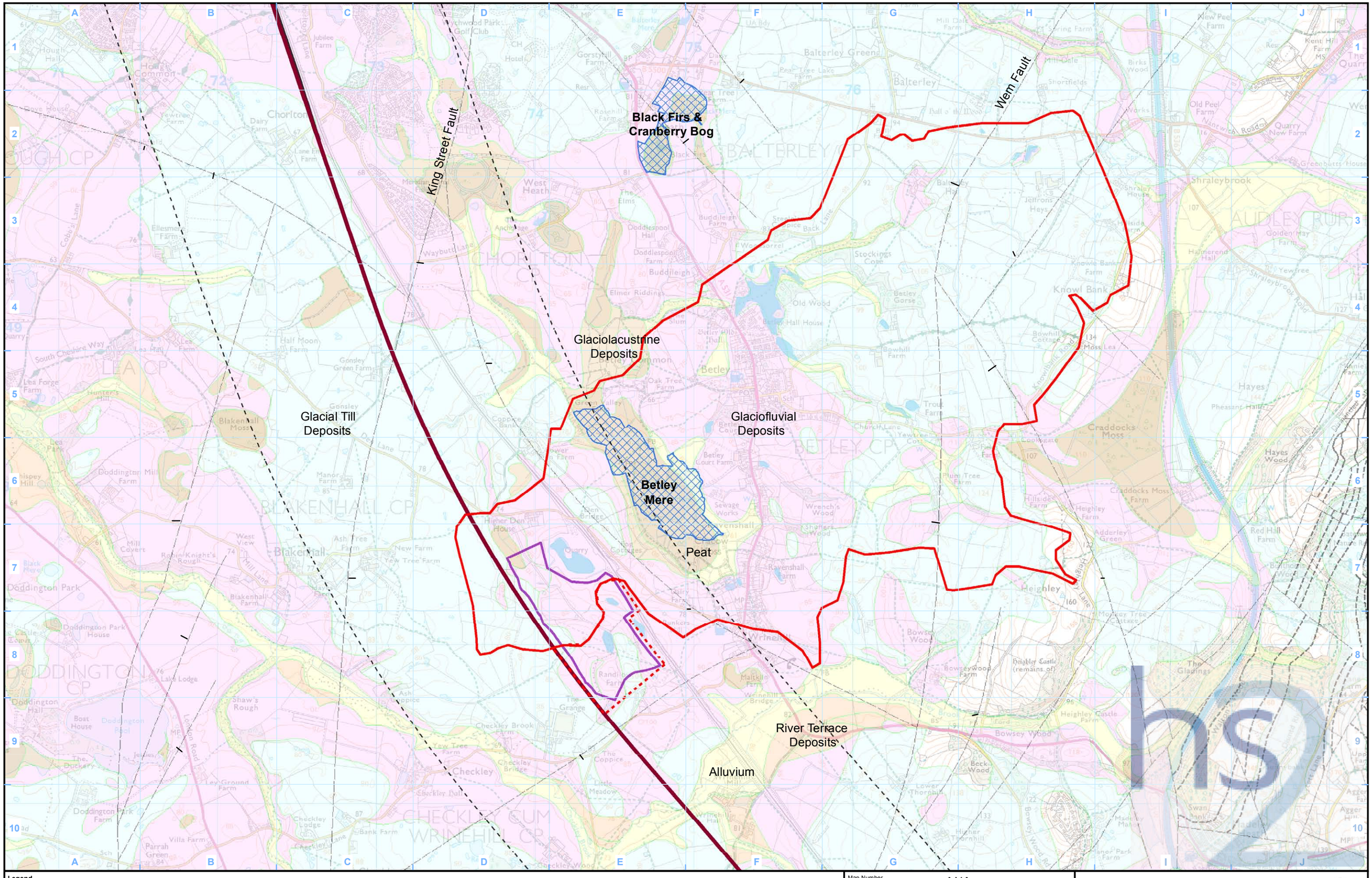
Doc Number:

Date: 04/05/17

Figure 4 - Rainfall data for monitoring station number 553230 near Alsager





Legend

- HS2 route alignment
- HS2 route alignment 1km buffer
- Surface water catchment 2016 (Study Area)
- Borrow pit study area
- Temporary borrow pit (BP241)
- *Sites of Special Scientific Interest (SSSI)*

Map Number: N/A

Map Name: Superficial Deposits

Figure 05

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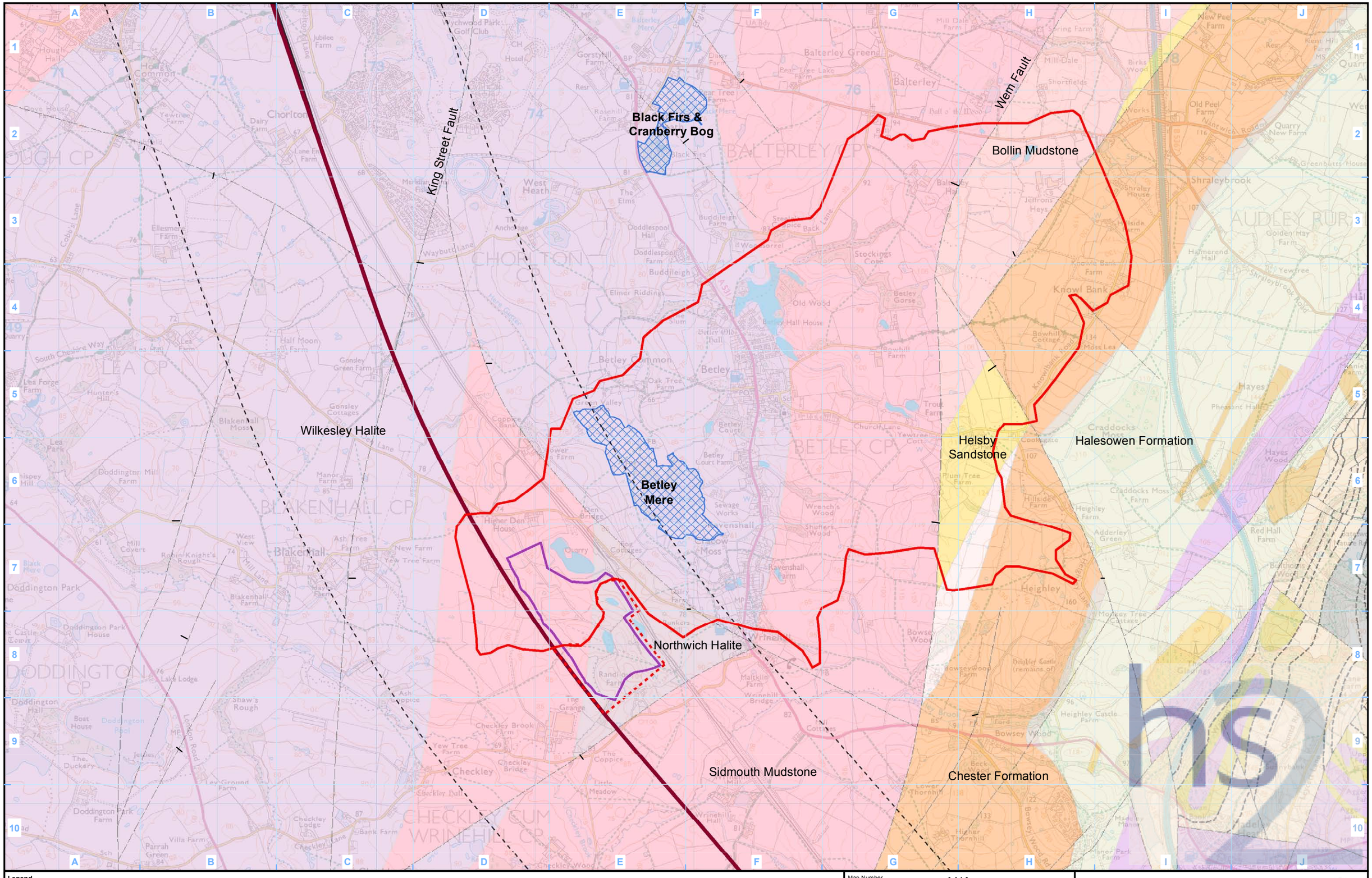
Doc Number:

Date: 05/05/17



Legend

- HS2 route alignment
- HS2 route alignment 1km buffer
- Surface water catchment 2016 (Study Area)
- Borrow pit study area
- Temporary borrow pit (BP241)
- *Sites of Special Scientific Interest (SSSI)*

Map Number: N/A

Map Name: Solid Geology

Figure 06

Registered in England. Registration number 06791686.
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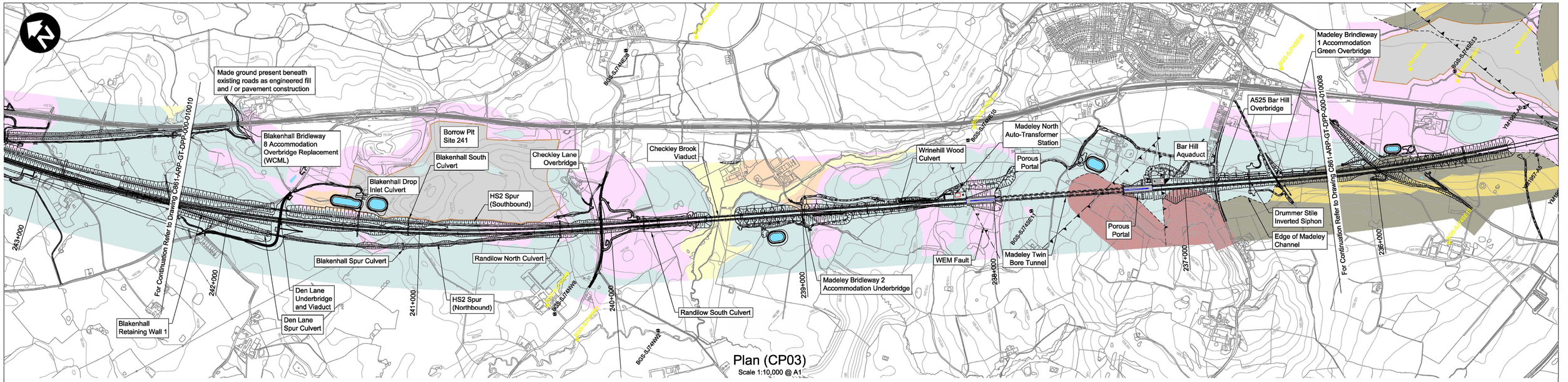
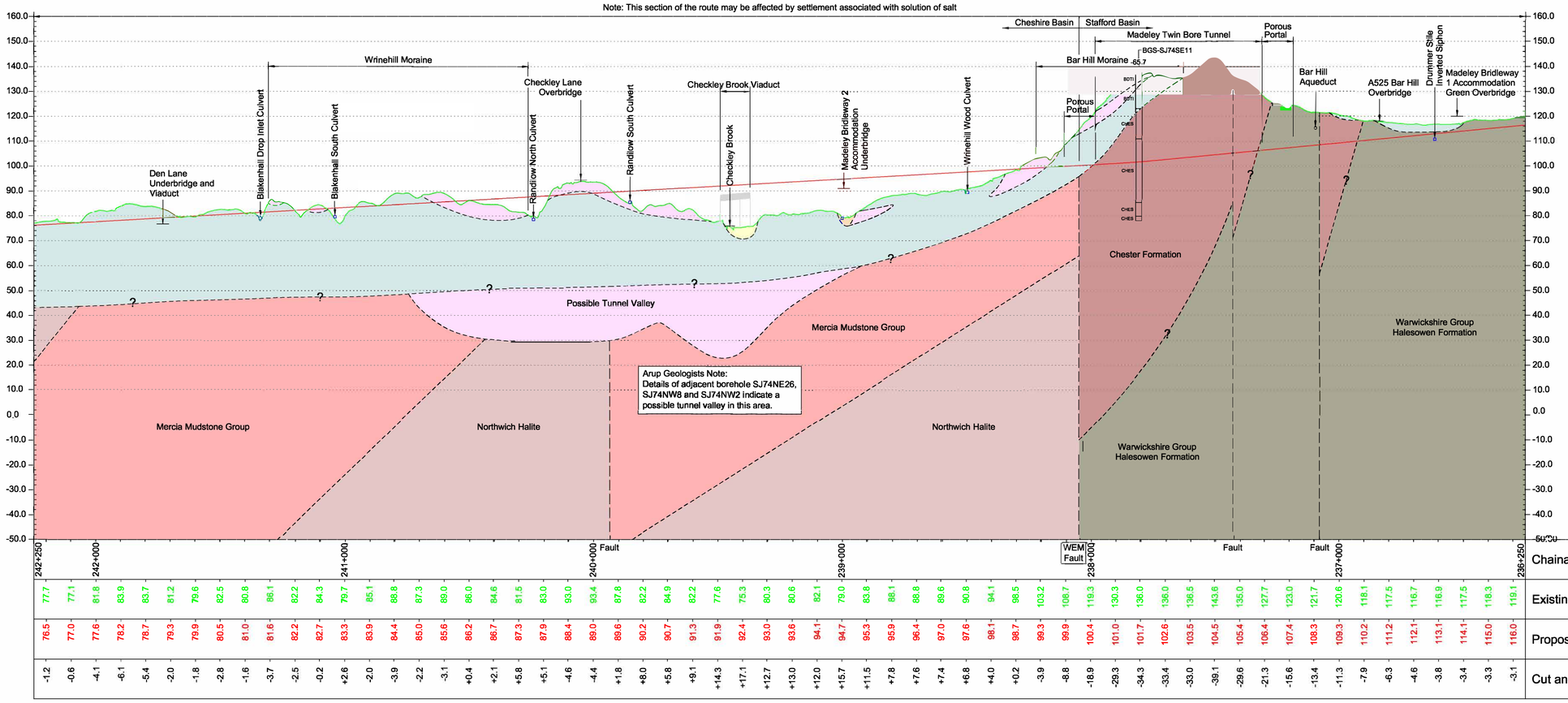
Doc Number:

Date: 05/05/17



Note: This section of the route may be affected by settlement associated with solution of salt



Chainage	242+250	242+000	241+000	Fault	240+000	239+000	WEM Fault	238+000	Fault	Fault	237+000	236+250
Existing Level	77.7	81.8	79.7	85.1	88.8	87.3	89.0	86.0	84.6	81.5	83.0	93.0	93.4	87.8	82.2	84.9	82.2	77.6	75.3	80.3	80.6	82.1	79.0	83.8	88.1	88.8	89.6	90.8	94.1	98.5	103.2	108.7	119.3	130.3	136.0	136.0	136.5	143.6	135.0	127.7	123.0	121.7	120.6	118.1	117.5	116.7	116.9	117.5	118.3	119.1
Proposed Rail Level	78.5	77.6	82.7	83.3	83.9	84.4	85.0	85.6	86.2	86.7	87.3	87.9	88.4	89.0	89.6	90.2	90.7	91.3	91.9	92.4	93.0	93.6	94.1	94.7	95.3	95.9	96.4	97.0	97.6	98.1	98.7	99.3	99.9	100.4	101.0	101.7	102.6	103.5	104.5	105.4	106.4	107.4	108.3	109.3	110.2	111.2	112.1	113.1	114.1	115.0	116.0
Cut and Fill	-1.2	-4.1	+2.6	-2.0	-3.9	-2.2	-3.1	+0.4	+2.1	+5.8	+5.1	-4.6	-4.4	+1.8	+8.0	+5.8	+9.1	+14.3	+17.1	+12.7	+13.0	+12.0	+15.7	+11.5	+7.8	+7.6	+7.4	+6.8	+4.0	+0.2	-3.9	-8.8	-18.9	-29.3	-34.3	-33.4	-33.0	-39.1	-29.6	-21.3	-15.6	-13.4	-11.3	-7.9	-6.3	-4.6	-3.8	-3.4	-3.3	-3.1

METRES @ 1:10000 0 100 200 500 1000

METRES @ 1:1000 0 10 20 50 100

Scale H:1:10,000 V:1:1000 @ A1

Rev	Description	Drawn	Checked	Con App	HS2 App
P02	For Information	RT 29/06/2017	AP 29/06/2017	DE 29/06/2017	
P01	For Information	KE 12/07/2016	AP 12/07/2016	TH 12/07/2016	

Legends/Notes:

Geology - Bedrock:
- Mercia Mudstone Group
- Chester Formation
- Saliferous Beds
- Carboniferous Warwickshire Group
- Northwich and Wilkesley Halite Member
- Helsby Sandstone Formation
- Wilmslow Formation

Geology - Superficial:
- Made Ground
- Head
- Alluvium
- Glaciofluvial
- Peat
- Glaciolacustrine Deposits
- River Terrace 1
- Glacial Till
- River Terrace 2

BGS Borehole Key

Plan:
- BGS Borehole

Profile:
- Borehole Reference
- Offset from Centreline
- Borehole Log

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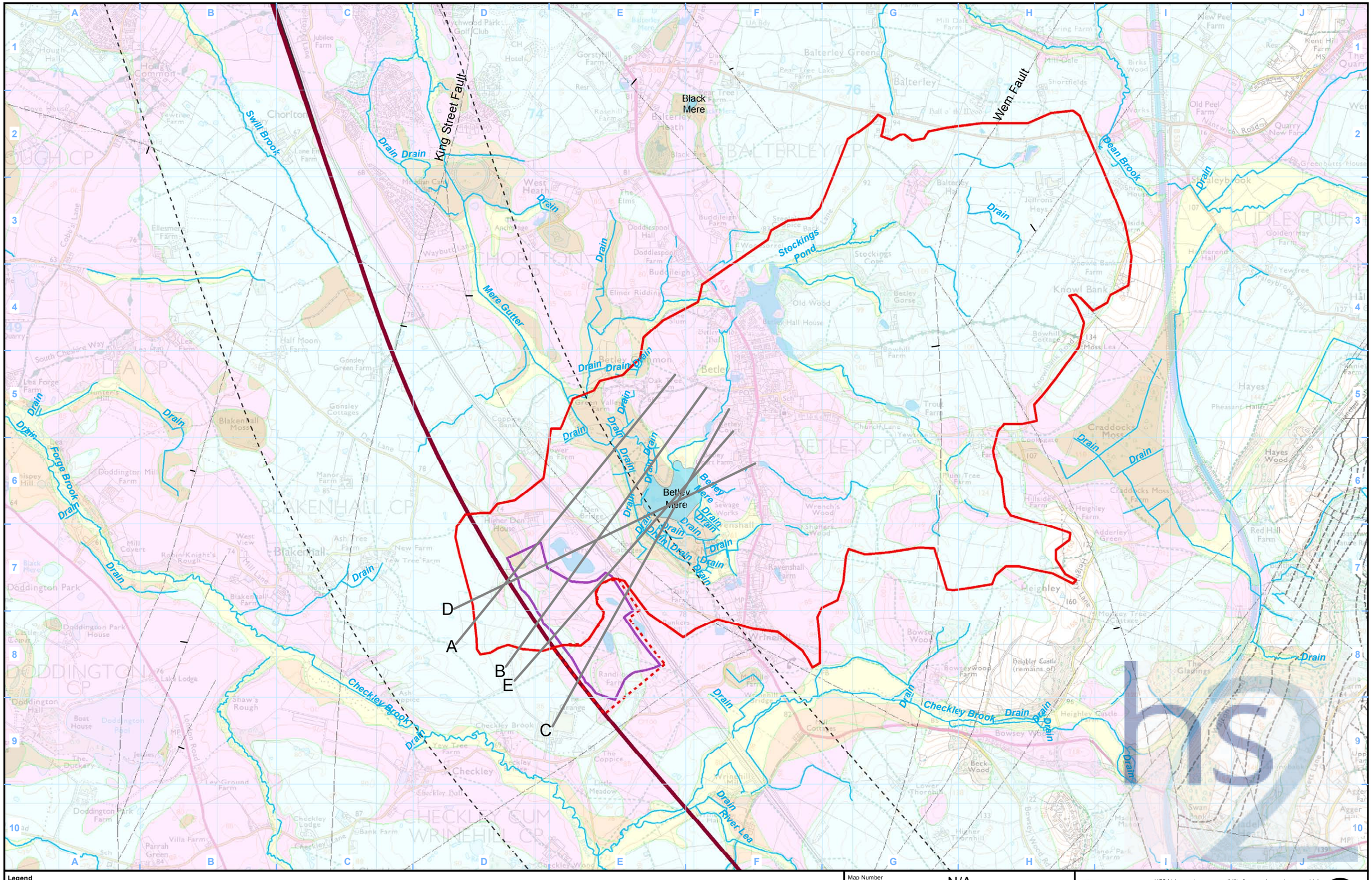
Registration No. 06791686
Registered office:
2 Snow Hill,
Queensway,
Birmingham, B4 6GA

Creator/Originator
Ove Arup & Partners International Ltd

Zone	Route Wide
Design Stage	Hybrid Bill
Drawing Title	Figure 07 Geological Plan and Profile
Project/Contract	Phase 2A Civils & Environmental Services
Discipline/Function	Geotechnical
Drawn / Checked / Approved	KE / AP / TH
Date / Scale / Size	10/03/2016 / AS SHOWN / A1
Drawing No. / Rev.	C861- ARP-GT-DPP-000-010009 / P02



Legend

- HS2 route alignment
- HS2 route alignment 1km buffer
- Surface water catchment 2016 (Study Area)
- Borrow pit study area
- Temporary borrow pit (BP241)
- Cross-section
- Surface waterbodies

EA river network

- Watercourse
- Culverted watercourse
- Canal
- Canal tunnel

Map Number: N/A

Map Name: Plan of Geological Cross-sections

Figure 08

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Scale at A3: 1:21,690

0 220 440 660 880 Metres

Doc Number:

Date: 05/05/17

Figure 9 - Section A

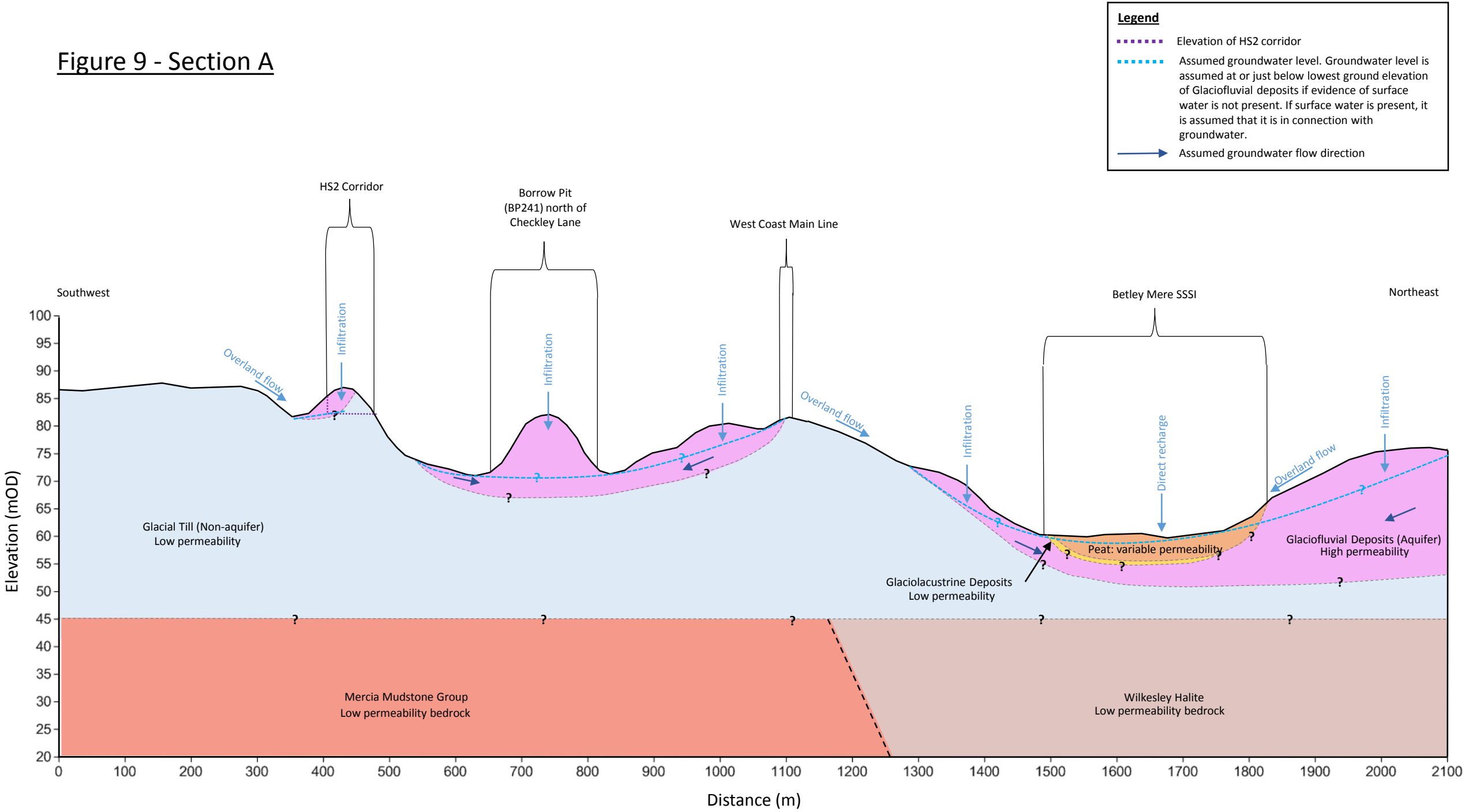


Figure 10 - Section B

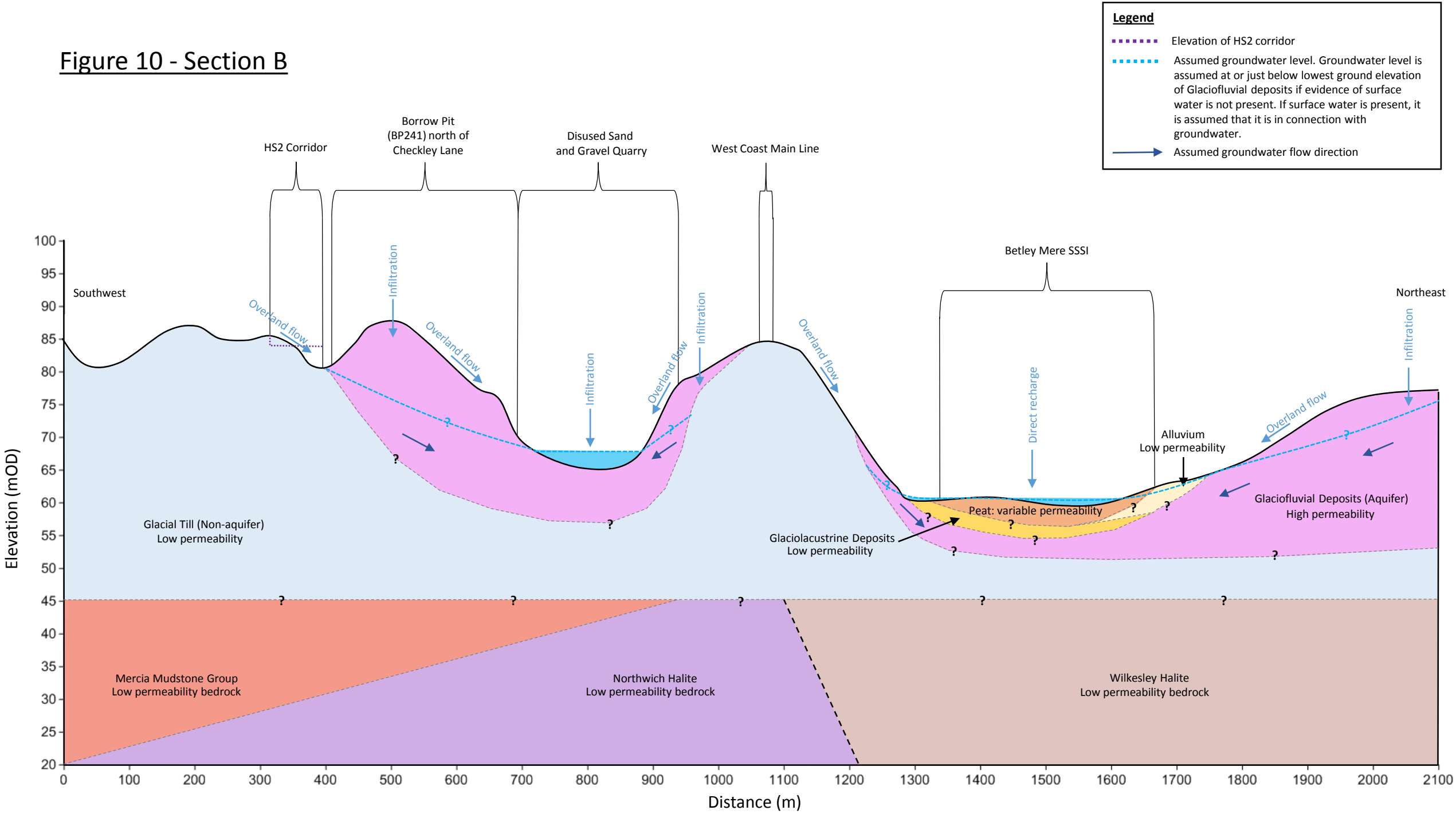


Figure 11 - Section C

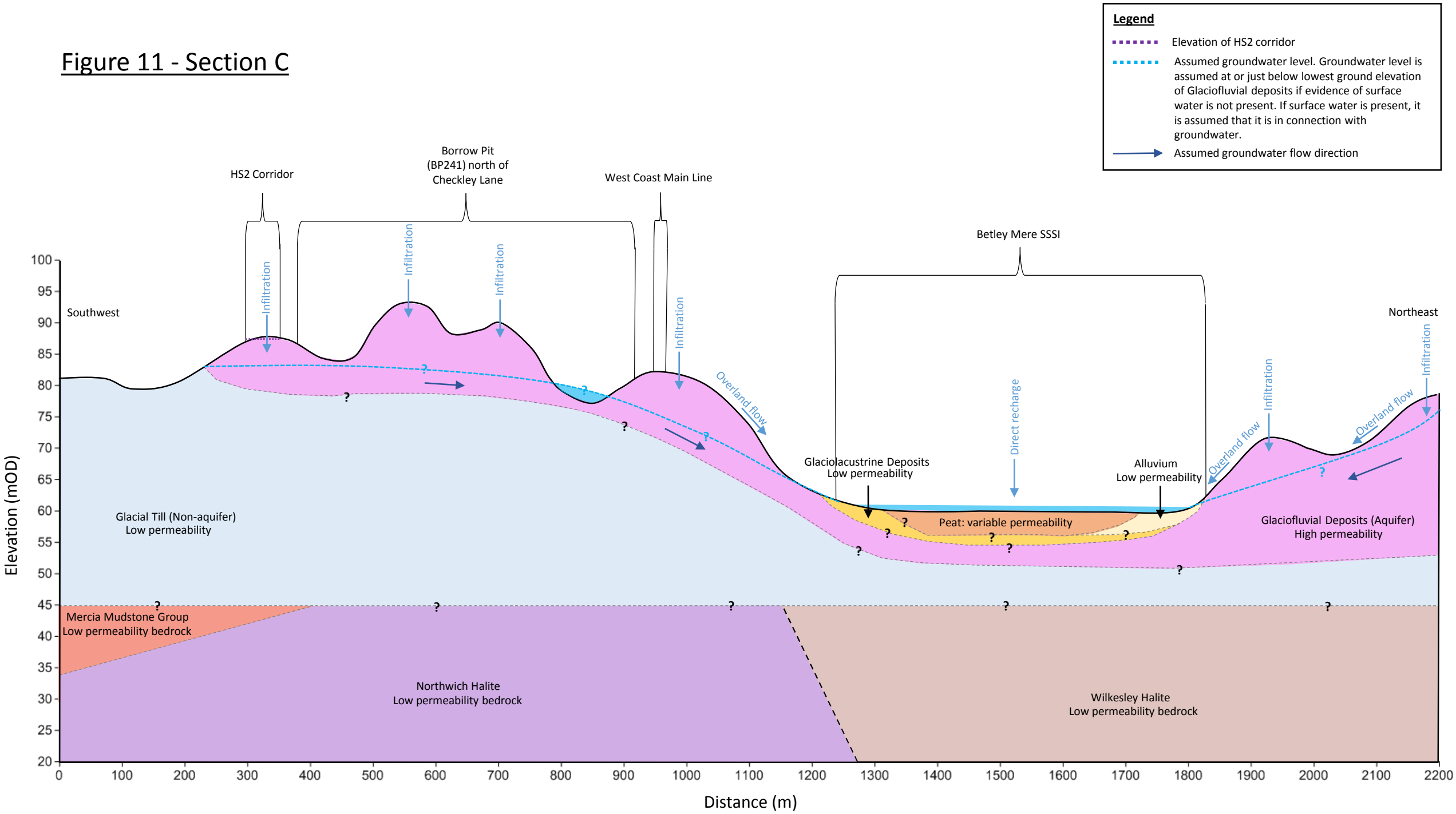


Figure 12 - Section D

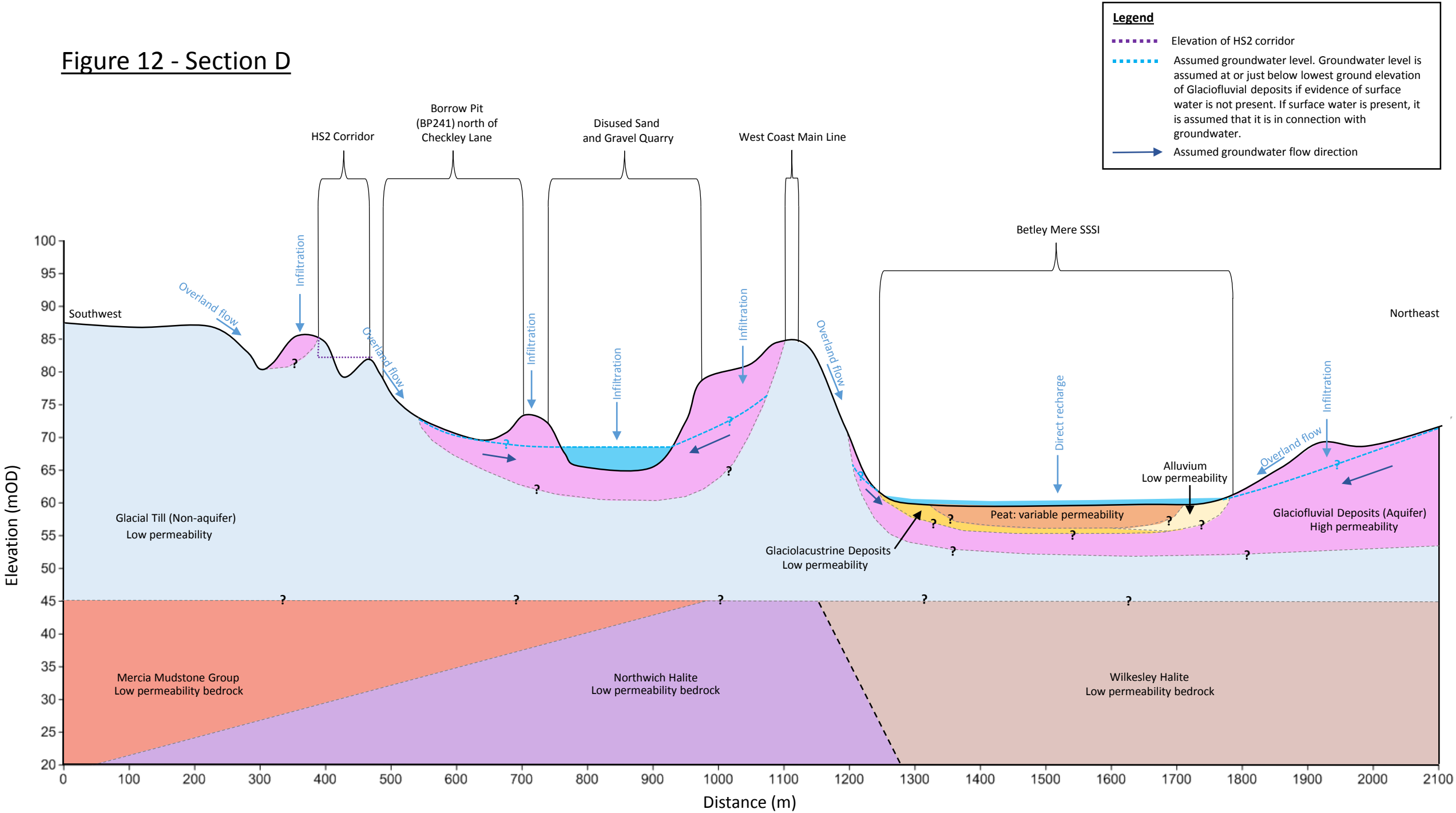
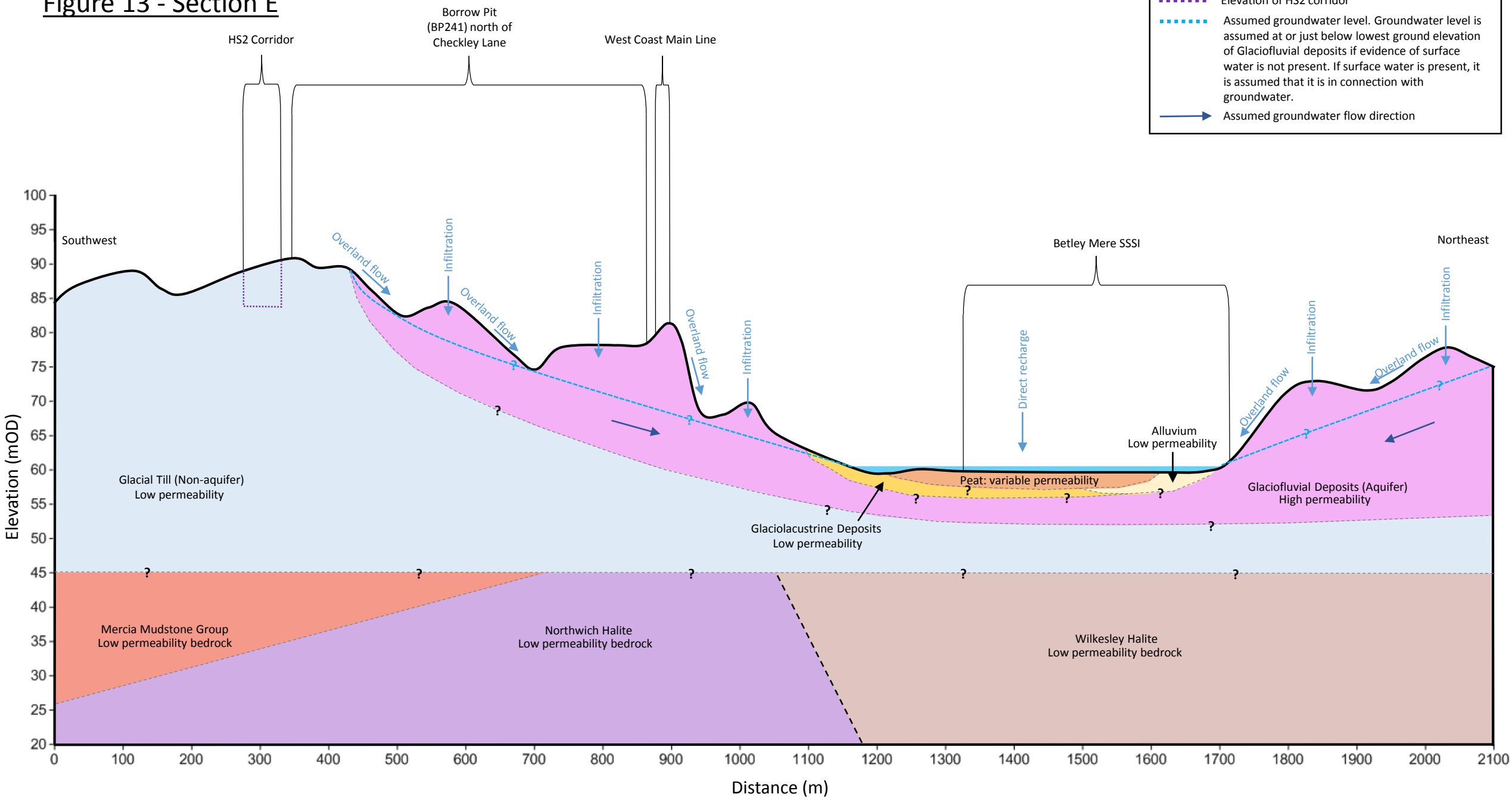
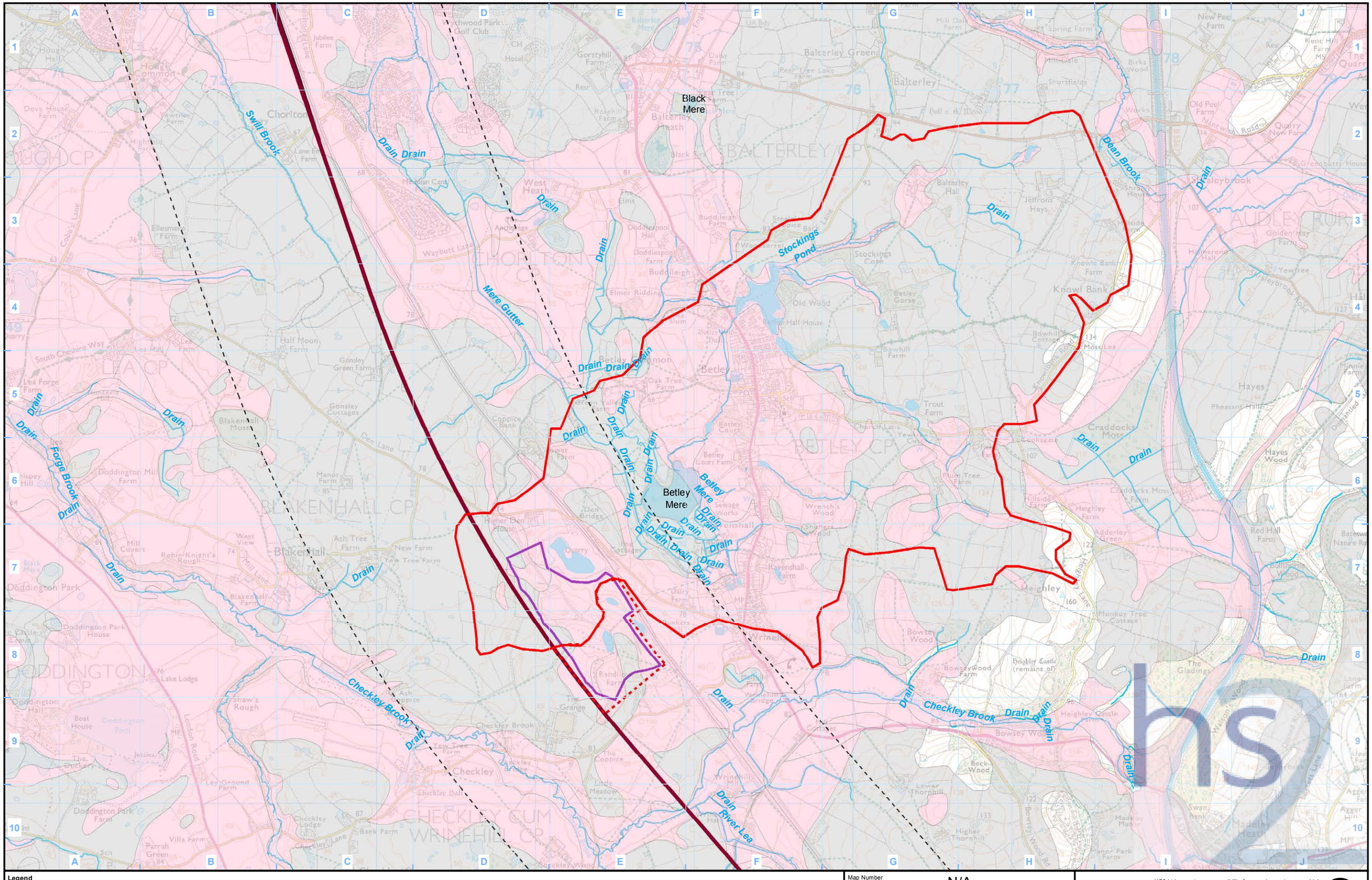


Figure 13 - Section E





Legend

- HS2 route alignment
- HS2 route alignment 1km buffer
- Surface water catchment 2016 (Study Area)
- Borrow pit study area
- Temporary borrow pit (BP241)
- Surface waterbodies

EA river network

- Watercourse
- Culverted watercourse
- Canal
- Canal tunnel

BGS Aquifer Designation - Superficial

Category

- Principal
- Secondary (undifferentiated)
- Secondary A
- Secondary B
- Unknown (lakes+landslip)
- Unproductive

Map Number: N/A

Map Name: Aquifer Designation - Superficial Geology

Figure 14

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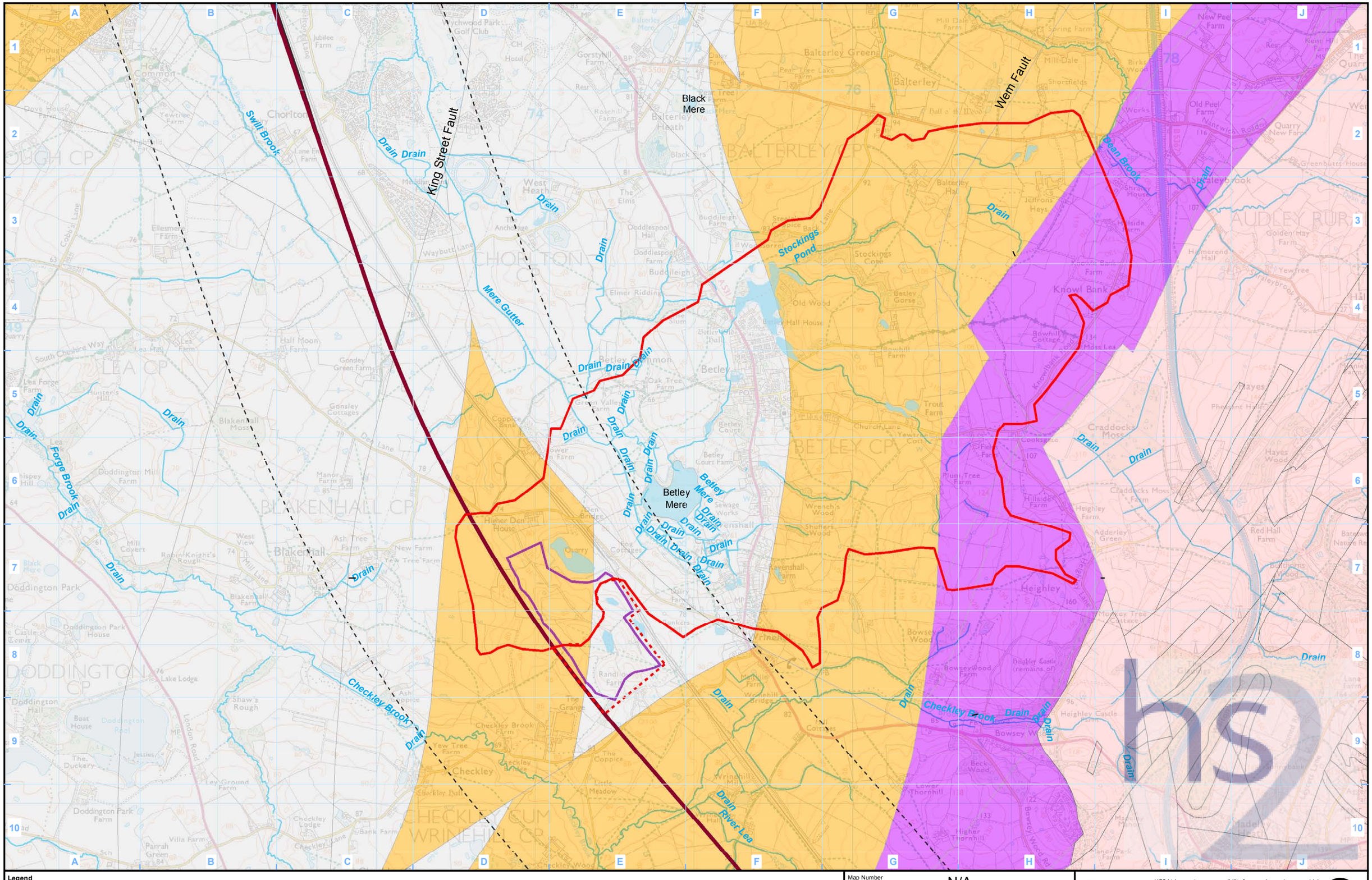
Scale at A3: 1:21,690

0 220 440 660 880 Metres

Doc Number:

Date: 05/05/17



Legend

- HS2 route alignment
- HS2 route alignment 1km buffer
- Surface water catchment 2016 (Study Area)
- Borrow pit study area
- Temporary borrow pit (BP241)

- Surface waterbodies

EA river network

- Watercourse
- Culverted watercourse
- Canal
- Canal tunnel

BGS Aquifer Designation - Bedrock

Category

- Principal
- Secondary (undifferentiated)
- Secondary A
- Secondary B
- Unproductive

Map Number: N/A

Map Name: Aquifer Designation - Solid Geology

Figure 15

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Registered office: 2 Snowhill, Queensway, Birmingham B4 6GA.

Scale at A3: 1:21,690

0 220 440 660 880 Metres

Doc Number:

Date: 05/05/17

Severn Trent Water Ltd
PWS abstraction

2568001100

Black Mere

Betley Mere

NW/068/0001/007
2568001067
2568001258

BALTERLEY CP
CHORLTON CP
BLAKENHALL CP
BETLEY CP
AUDLEY RURAL CP
CHECKLEY CUM WRINEHILL CP

Swill Brook
Stockings Pond
Mere Gutter
Dean Brook
Checkley Brook
River Lee
Hazeley Brook

Legend

- HS2 route alignment
- HS2 route alignment 1km buffer
- Surface water catchment 2016 (Study Area)
- Borrow pit study area
- Temporary borrow pit (BP241)
- Surface waterbodies
- Springs and issues
- OS water wells
- BGS water well record
- Licensed groundwater abstraction
- Licensed surface water abstraction
- BGS borehole record

EA river network

- Watercourse
- Culverted watercourse
- Canal
- Canal tunnel

Groundwater Source Protection Zones

Zone

- 1
- 2
- 3

Map Number: N/A

Map Name: Hydrogeological Features

Figure 16

Registered in England. Registration number 06791686.
Registered office: 2 Snowhill, Queensway, Birmingham B4 6GA.

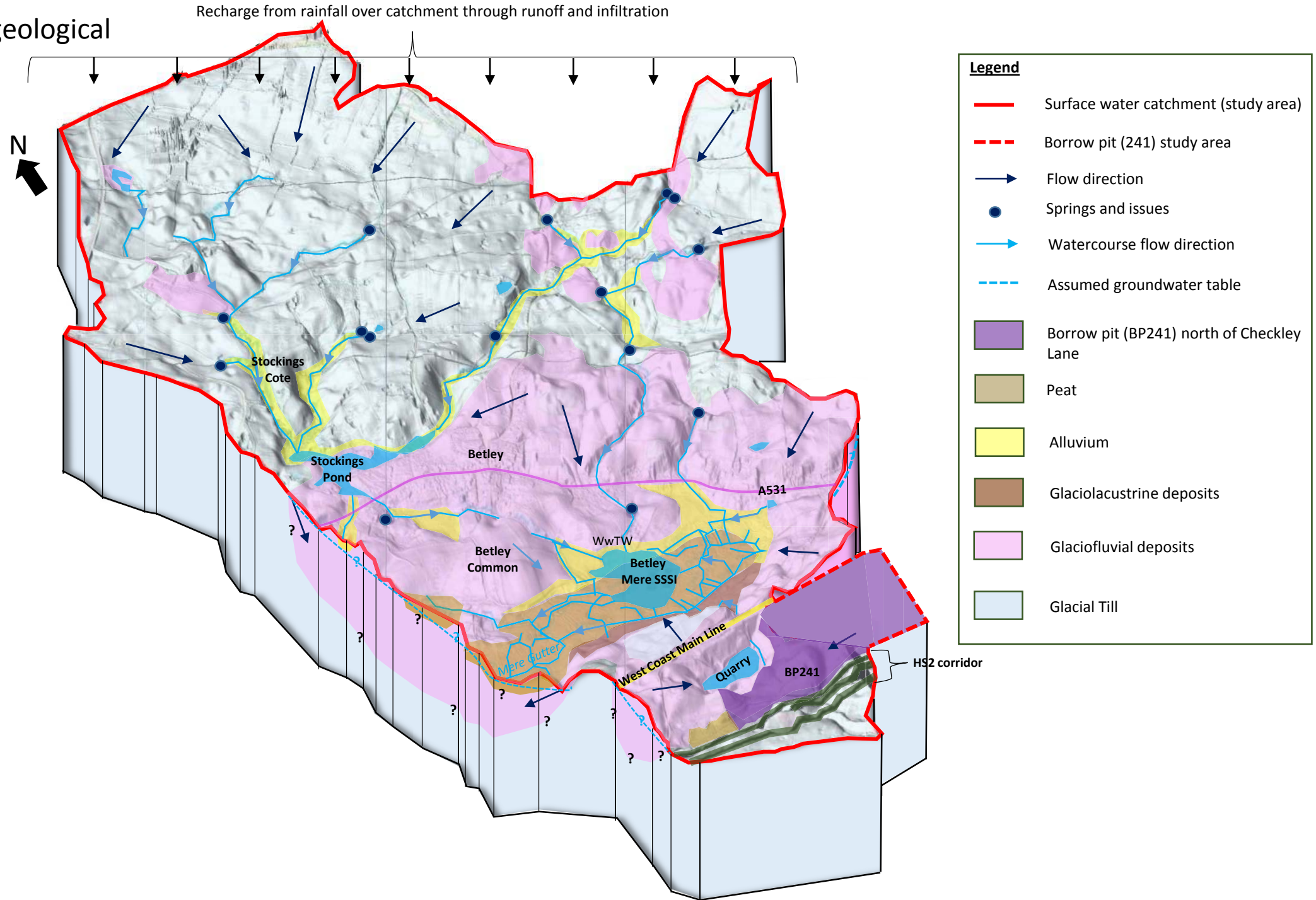
Scale at A3: 1:21,690

0 220 440 660 880
Metres

Doc Number:

Date: 05/05/17

Figure 17 – Hydrogeological Conceptual model



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