HYDROGEOLOGICAL IMPACT APPRAISAL OF OPEN CUT CROSSING, ALLTAMI BROOK

HyNet Carbon Dioxide Pipeline DCO

Planning Act 2008

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EXECUTIVE SUMMARY

An open-cut crossing across the Alltami Brook is proposed as part of the HyNet North West project. The crossing is required to allow for a pipeline to be installed which will be used to transport carbon dioxide. The planning consent for the project is being applied for under a Development Consent Order (DCO) that has been submitted to the Secretary of State (SoS) for the Department of Energy Security and Net Zero under Section 37 of the Planning Act 2008 (‘the PA 2008’). The Application relates to the Carbon Dioxide (CO_2) pipeline which constitutes the DCO Proposed Development.

During the consultation process for the DCO, Natural Resources Wales (NRW) has expressed concerns regarding the potential effects that the open-cut approach may have on water resources, and subsequently the possibility of a detrimental impact to the Water Framework Directive (WFD) status of the Wepre Brook surface water body. NRW’s primary concern is that the proposed open-cut crossing method could ultimately result in a loss of flow from the Alltami Brook to bedrock, (e.g., through cracks, faults, fissures, and joints), either in the short or long term. NRW also considers that any former mine workings in the vicinity of the proposed crossing point may also be a potential receptor of flow which is lost from the Alltami Brook. In turn, this loss of flow could cause a deterioration of hydromorphology, water quality and ecological elements downstream. resulting in the negative impact to WFD status.

To address NRW’s concerns a Hydrogeological Impact Appraisal (HIA) has been prepared. The objectives of the HIA are to develop a conceptual understanding of the groundwater flow regime at the Alltami Brook; to consider the potential effects from construction and operation of the pipeline; and to identify key uncertainties in the understanding of site conditions under different flow scenarios.   The HIA is informed by baseline information that was collected from multiple, relevant sources including geological maps, memoirs, reports, online resources, historic borehole logs, and field information (observations and photos from walkovers).

The preliminary conceptual site model indicates that, based on the current level of understanding, there is likely to be an upwards hydraulic gradient from the bedrock aquifers into the Alltami Brook. The key lines of evidence for this are as follows:

- site walkover observations indicating that the made ground (which sits above the bedrock) is discharging water into the Alltami Brook;
- recorded water levels in nearby historic boreholes in the bedrock (same or similar geology) indicating an upwards water pressure following water strikes;
- literature information states that the bedrock aquifers are primarily driven by fracture flow which is laterally discontinuous leading to a ‘compartmentalised’ groundwater flow regime;
- there is no evidence of flow loss along the fault line (running perpendicular and parallel) that follows the route of the Alltami Brook, where fracturing would be expected to be substantial; and
- there is a widening of the watercourse in the area of the fault, without any surface water tributary contributing to flow in the watercourse i.e., there is a groundwater baseflow contribution (site observation).

The presence of nearby mine historic mine workings is also discounted as a possible receptor in terms of acting as a recipient of discharge. The age and shallow depth of the workings suggest any remaining mine voids would be saturated or otherwise have returned to a state of equilibrium. Unsaturated mine voids (i.e., which could act as a recipient of flow) situated hydraulically downgradient of the preferred open cut crossing point are very unlikely based on available information. Additionally, geophysical survey undertaken offers no indication of open mine voids being present.

The conceptual site model considers the potential effects of the preliminary design of the open-cut crossing, which will be excavated into the bedrock. At this stage, there is no evidence of fracturing or fissuring in the bedrock at the preferred crossing point. Based on the conceptual site model, any groundwater flow encountered during the excavation of the trench would be upwards from the underlying bedrock, rather than vertically downwards from the watercourse.

Given NRW's concerns in relation to loss of flow in the watercourse through fractures and fissures, a geotechnical ground investigation will be implemented as part of the detailed design. Should the findings of the ground investigation demonstrate that there is evidence of fracturing etc. with potential high permeability flow zones, then the scheme design will incorporate additional mitigation to reduce the risk of 'flowing features'. Such works would normally include a form of grouting (permeation grouting or jet grouting) to effectively 'cut-off' flow in the targeted bedrock zone. The design of such works will depend on the findings of the investigation but is a commonly applied method of ground treatment.

The risk of washout of grout, also highlighted as a concern by NRW, can be reduced by using appropriate grout materials and/or accelerators during construction. The long-term performance (degradation) of the grout within a fissure is also considered unlikely as the grout will within the rock mass surrounding the structure, and fractures and fissures will be sealed. Effectively, a low permeability plug within the bedrock would be created, eliminating flow zones in the bedrock at the open-cut crossing location. A concrete slab placed over the pipeline installation and a reinstated riverbed would reduce potential scour / erosion effects. The reconstituted riverbed would be monitored in accordance with an agreed inspection plan during the lifespan of the project to confirm the integrity of the structure.

The conceptual site model identifies some uncertainties, such as the exact relationship between the Alltami Brook and the surrounding groundwater level of the bedrock aquifer in terms of its seasonal variability and any possible change in hydraulic gradient which may occur. However, due to the laterally discontinuous fracture flow conditions and the design mitigation this is considered to have limited consequences at this stage. Additionally, under normal conditions the relationship is expected to be that of a gaining watercourse in term of groundwater baseflow component. The presence (and extent) of fracturing at the preferred crossing location is also currently not confirmed, however is also considered manageable due to the design features and grouting approach.

The HIA is sufficiently developed at this stage to demonstrate that there is not considered to be a mechanism present that would allow a significant loss of flow from the Alltami Brook, either in the short or long term.

For this reason, the DCO Proposed Development is not considered by the Applicant to be a risk to impacting the WFD status of the Wepre Brook surface water body and is considered by the Applicant to be WFD compliant.

A ground investigation which is sufficiently scoped to address the uncertainties in the current conceptual understanding could be undertaken to inform the detailed design if required.

This would be informed through consultation with NRW and the design team, including specialist geotechnical contractors with an expertise in dewatering and geotechnical grouting.

1. INTRODUCTION

1.1. BACKGROUND

1.1.1. This document has been prepared on behalf of Liverpool Bay CCS Limited ('the Applicant') and relates to an application ('the Application') for a Development Consent Order (DCO) that has been submitted to the Secretary of State (SoS) for Energy Security and Net Zero under Section 37 of the Planning Act 2008 ('the PA 2008'). The Application relates to the Carbon Dioxide (CO_2) pipeline which constitutes the DCO Proposed Development.

1.2. REPORT CONTEXT

1.2.1. During the consultation process, Natural Resources Wales (NRW) has expressed concerns about the proposed open cut crossing at the Alltami Brook, the potential effects that this may have on water resources, and the possibility of that impacting Water Framework Directive (WFD) status of the Wepre Brook surface water body.

1.2.2. In particular, reference 2.5 of their Written Representations and Response to ExA's ExQ1 submission received for Deadline 1 **[REP1-071]**, states *'Specifically, NRW considers that there is a risk that excavating bedrock for the proposed Alltami Brook open-cut crossing could create a pathway for surface water to be lost to the ground/contaminated mine workings via disturbance, cracks, faults and joints between proposed bedrock removal and concrete backfill, even with the grouting of any fissures/fractures found and backfill of existing bed material; this could cause water courses to dry up downstream of the open-cut crossing, including Wepre Brook. This loss of flow may occur in the short- or long-term, for example if the grouting was to deteriorate over many years. Such flow losses, and any resultant contaminated mine water upwelling elsewhere, are difficult to address in the long term and could cause deterioration of hydromorphology, water quality and ecological elements downstream'.* Section 2.9 of their Written Representation **[REP1-071]** goes on to advise that '*The applicant proposes to address these concerns through assessment, monitoring, and adaptive mitigation at the detailed design phase, and argues that the mitigation measures would be technically and financially feasible. Based on the lack of available site-specific information for Alltami Brook NRW cannot currently advise whether or not this is correct*'.

1.2.3. With regards to the potential dewatering required during construction of the crossing, Section 7.4 of the NRW Written Representations submitted at Deadline 1 **[REP1-071]** states that '*the hydrogeological relationship between the made ground, the bedrock, and the superficial sediments in the vicinity of the Alltami Brook crossing point are therefore currently undefined'*, and that '*an understanding of local hydrogeological conditions is relevant to understanding the nature of dewatering works that may be required at this location*'.

1.2.4. The Applicant has acknowledged these concerns in its response to the Written Representations at Deadline 2 **[REP2-041]** and recognises that further work is required to support this aspect of the DCO Proposed Development. Consequently, and in order to promote further dialogue with NRW, this report has been prepared to present the current understanding of the hydrogeological conditions, to identify key areas of uncertainty in this understanding, and to explore the consequences of these in relation to potential impacts on surface water flow in the Alltami Brook (and other potential associated impacts as described in NRW's responses).

1.3. OBJECTIVES

1.3.1. The objectives of the hydrogeological appraisal are to develop the conceptual understanding of the groundwater flow regime in and around the catchment of the Alltami Brook; to highlight key areas of uncertainty in this understanding; and to consider the potential effects on the watercourse from the proposed construction (and subsequent operation) of an open cut crossing in the channel bed of the Alltami Brook.

1.3.2. It is intended that the report is used to clearly set out the Applicant's reasoning for why the proposed open cut crossing approach does not represent a risk to WFD status of the Wepre Brook waterbody. Additionally, it will aim to identify the uncertainties in the conceptual understanding in order for them to be addressed through the commitment for site-specific ground investigation and monitoring (at the detailed design stage).

1.4. APPROACH

1.4.1. The approach to developing the conceptual understanding of the groundwater regime has been undertaken in general accordance with established principles for developing conceptual models as published in regulatory guidance (**Ref 3**). The conceptual model considers the DCO Proposed Development during construction and operational stages, with reference to NRW's concerns relating to the current understanding of hydrogeological conditions at the site.

1.4.2. The conceptual model is the framework for identifying and describing the uncertainties in our understanding and will help determine the requirements for further data collection and assessment. It recognises that the information used will often be incomplete and that realistic and justifiable assumptions need to be made. In line with published guidance, the development of the conceptual model is an iterative process, which will be updated as more site-specific information becomes available through ground investigation or surveys undertaken at detailed design. The HIA review process will be progressed through commitment D-WR-035 of the OCEMP **[REP4-237]** which requires a Dewatering Management Plan. This will be secured through Requirement 5 of the dDCO **[REP4-008]**.

1.5. INFORMATION EXAMINED

1.5.1. The information used to inform this report includes:

- Technical Note – Wepre Brook Crossing, EniProgetti, April 2022 **[REP4-120 to [REP4-129]**
- D.6.3.11.2 Environmental Statement (ES) – Appendix 11.2 Coal Mining Risk Assessment – Part 9 **[REP4-128]**
- D.6.3.11.2 Environmental Statement (ES) – Appendix 11.2 Coal Mining Risk Assessment – Part 1 **[REP4-120]**
- Geological maps (1:10,000 and 1:50,000 scale), British Geological Survey (BGS), 1990 and 1999 **(Ref 4 and Ref 5)**
- Geological memoir for the country around Flint (map sheet 108), BGS, 2004 **(Ref 8)**
- Deeside (North Wales) thematic geological mapping, technical report, BGS, 1988 **(Ref 7)**
- Hydrogeology of Wales technical report, BGS, 2015 **(Ref 1)**
- Field information from site visits undertaken on the 14th and 27th of March 2023
- Parrys Quarry Landfill Hydrogeological Risk Assessment. Rep. White Rock Geo-Environmental Ltd. 2020 **(Ref 2)**

1.6. LIMITATIONS

1.6.1. This report is based on preliminary designs and mitigation based on details available at the end of May 2023. Should the assumptions and/or understanding of the site conditions stated within the report materially change as new information or data is presented, then this report should be reviewed and updated accordingly.

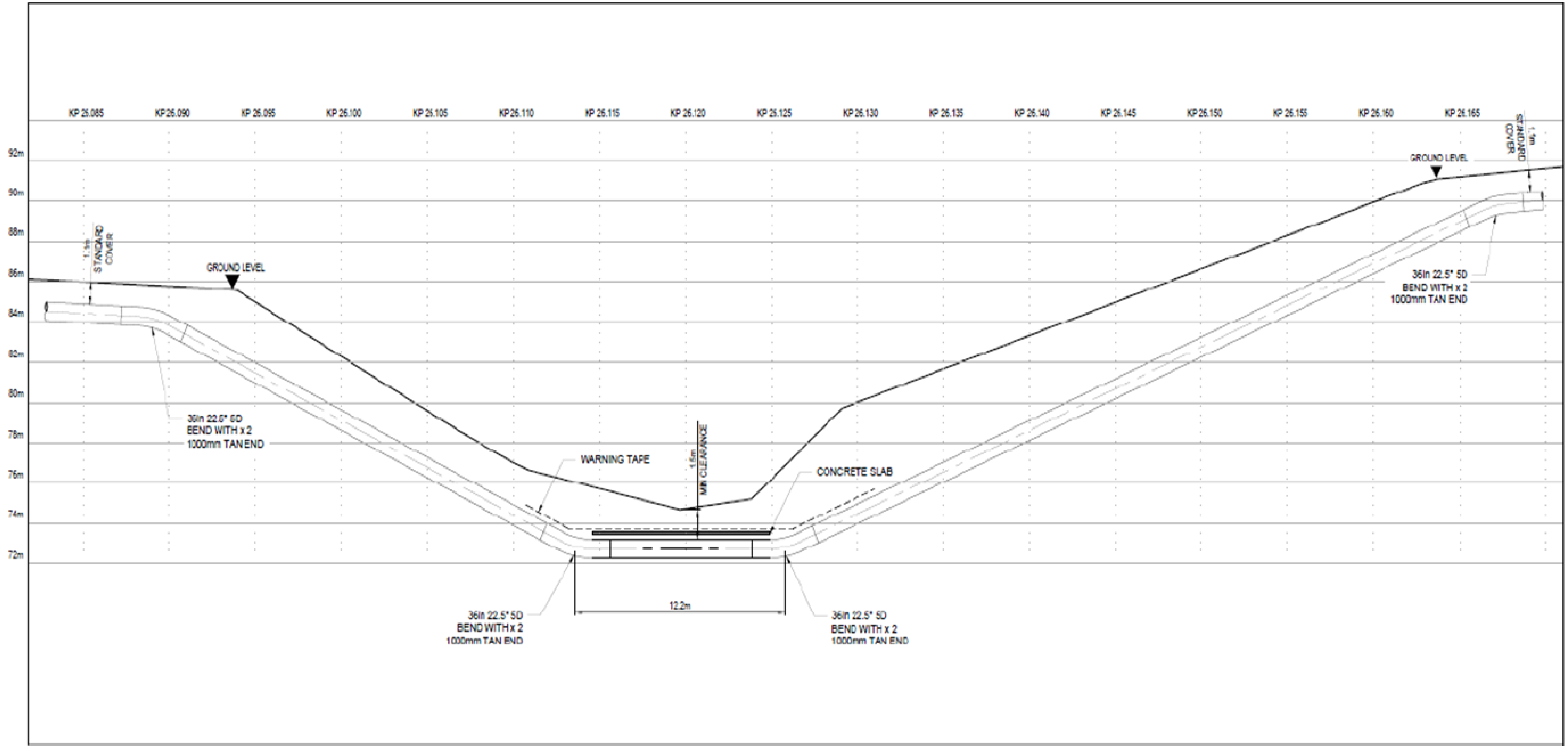
1.6.2. It should be noted that this report does not assess the potential impact of the embedded pipe bridge crossing option (PS25) as this option has been assessed separately in the 2023 Environmental Statement Addendum Change Request 2 **[CR2-017]**.

1.7. SUMMARY OF PROPOSED DEVELOPMENT

1.7.1. Various methods have been considered for the construction of the pipeline crossing of Alltami Brook, including the open cut option, which is the preferred option by the Applicant. It is noted that open cut methods are usually simpler, safer, and require less complex construction tools and planning to execute than other pipeline installation methods as outlined in Technical Note – Wepre Brook Crossing, EniProgetti, April 2022 **[REP4-120 to REP4-129].**

1.7.2. An indicative preliminary design is presented in **Figure 1.1**.

Figure 1.1: Preliminary design for open-trenched Alltami Brook crossing approach



CONSTRUCTION STAGE

1.7.3. During the construction stage, excavations will be required along the banks and within the Alltami Brook to lay the pipeline. The likely maximum depth of the excavation beneath the watercourse is approximately 4 metres below ground level (mbgl) and the maximum width of the excavation parallel to the pipeline is expected to be 4 m.

1.7.4. The pipeline will be laid upon bedrock and surrounded by bedding material (i.e., sand/gravel). Any visibly identified significant fractures within the excavation would be sealed with grout to prevent any future water ingress. Potential washout of grout would be controlled by appropriate grout materials and/or accelerators to ensure rapid gel setting and strength gain. A concrete slab will be constructed in-situ above the pipeline to protect it from scour over its lifetime. The slab will then be covered with the reinstated bedrock from the watercourse to recreate the natural bed of the watercourse as closely as possible. During detailed design the Construction Contractor will consider the most appropriate specifications for concrete design and any permeation grouting in accordance with industry standards (e.g., BS EN 12715:2020).

1.7.5. During construction, the stream flow would be maintained by installing a temporary culvert across the open cut or diverting the stream to the side and sequencing excavations. The temporary diversion will prevent water from entering the works area, allowing excavation of the bedrock under ‘dry’ conditions. Any minor residual seeps entering the working area will be pumped to a settling tank from where it will be re-introduced to the stream. Appropriate consents/permits will be obtained from NRW prior to works commencing. After reinstatement, the stream would be returned to its original hydraulic conditions.

OPERATIONAL STAGE

1.7.6. In the operational stage, the top of the pipeline is expected to lie approximately 1.5 m below the base of the watercourse with the concrete slab placed above the pipeline. It is expected that the concrete slab would be integrated with the new riverbed. The fill material surrounding the pipeline is expected to be sand/gravel backfill.

2. SITE SETTING AND CHARACTERISTICS

2.1. INTRODUCTION

2.1.1. This section presents the baseline information and site setting, including the location, topography, details of site walkovers, geology, hydrogeology, and hydrology as well as relevant anthropogenic influences i.e., coal mining history.

2.2. SITE LOCATION

2.2.1. The preferred location for crossing the Alltami Brook via open cut construction is located northwest of land at Pinfold Lane, Hawarden, Northop Hall, Flintshire, Wales, CH7 6LE.

2.2.2. The preferred crossing location is in a rural setting between the villages of Northop Hall and Mold and is approximately 200 m northeast of the A55. The preferred crossing location and setting are shown in Figure 2.1.

2.2.3. There is an approximately 200 m stretch of the Alltami Brook within which the river crossing could be built within the Newbuild Infrastructure Boundary (shown in Figure 2.1). Within the Newbuild Infrastructure Boundary the preferred open cut crossing location from an engineering perspective is near NGR SJ 27650 67144. This is the crossing location that is considered within this report although the crossing could be located anywhere within the Newbuild Infrastructure Boundary.

2.3. TOPOGRAPHY

2.3.1. The preferred crossing location is located at the bottom of a steep sided valley with an elevation of approximately 78 metres above Ordnance Datum (mAOD). The ground elevation rises to 92 mAOD in the northwest and 87 mAOD in the southeast towards Pinfold Lane.

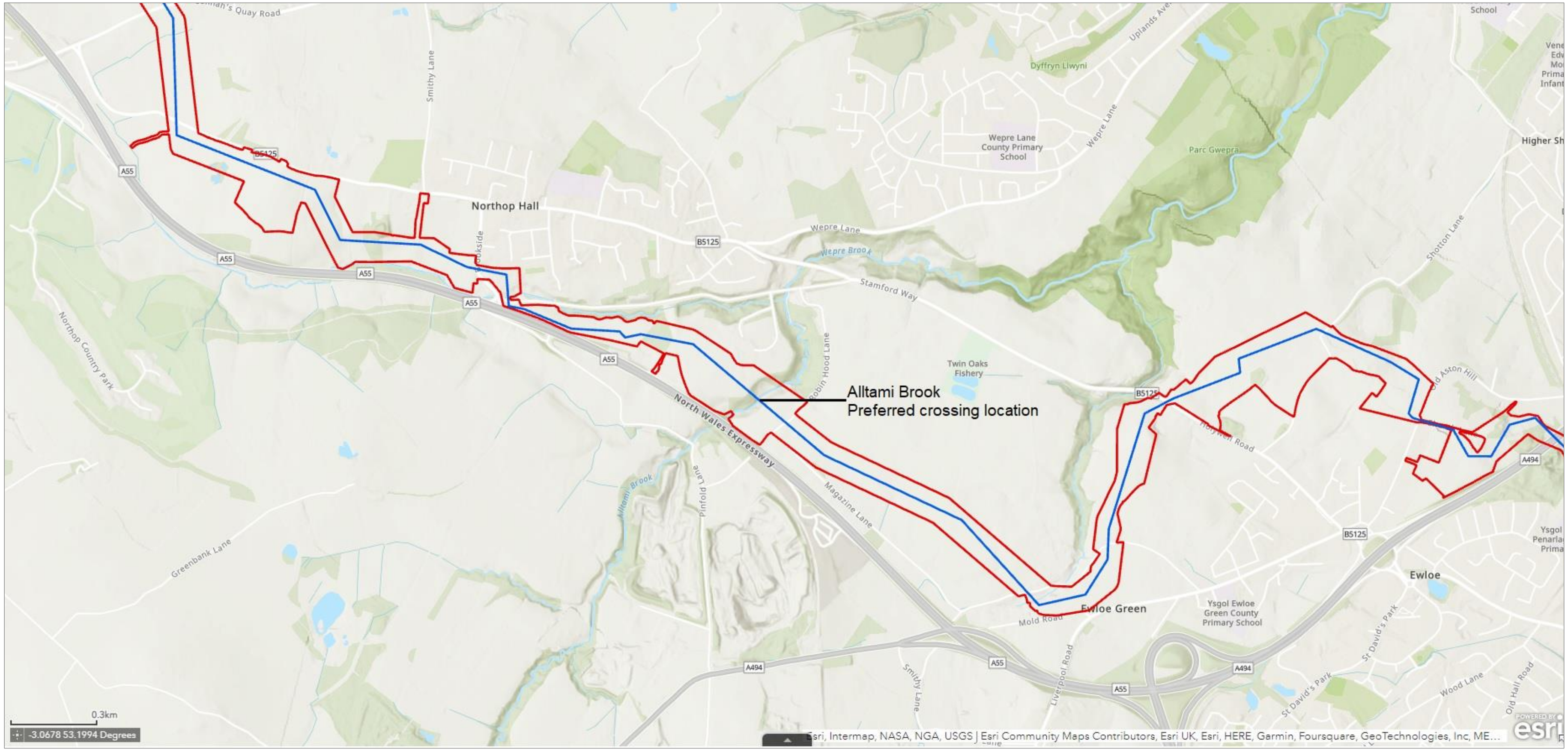


Figure 2.1. Preferred crossing location and setting around the Alltami Brook

2.4. SITE OBSERVATIONS

2.4.1. Two site walkovers were undertaken by the Applicant on the 14th and 27th March 2023. The photographs and details are provided in Annex A and the main outcomes of the site visits are discussed throughout this report.

2.5. GEOLOGY

INFORMATION USED

2.5.1. The geological setting has been characterised using the 1:50,000 scale geological map sheet 108 (Flint) (**Ref 5**), 1:10,000 scale geological map sheet no. SJ26NE (**Ref 4**), the geological memoir associated with map sheet 108 (**Ref 8**), and various BGS technical reports (**Ref 7 and Ref 1**).

MADE GROUND AND SUPERFICIAL DEPOSITS

2.5.2. The BGS geological maps do not record made ground at the preferred crossing location. However, made ground was observed to be present during the site walkovers along the eastern bank (see walkover photos in Annex A) and whilst it is assumed to be material resulting from the construction of the A55, the origin of this is not confirmed.

2.5.3. The geological map indicates that there are no superficial deposits underlying the Alltami Brook in the reach that is situated within the Newbuild Infrastructure Boundary (bedrock shown to be present at outcrop in site walkover photos – see Annex A). There are none recorded until approximately 0.7 km upstream of the Newbuild Infrastructure Boundary, and none downstream, until close to the edge of the Newbuild Infrastructure Boundary, where glaciofluvial deposits are recorded as present. Further up the banks to the northwest and southeast (30-40 m uphill from the preferred crossing location), glacial till (a mixture of clay, sand, gravel, and boulders) is present and as shown on the maps, is widespread in the region.

2.5.4. Landslide features are also present approximately 150 m southeast of the preferred crossing location according to BGS map data. These are formed by the relatively rapid movement of a mass of rock, earth or debris down a slope. The material of landslip is dependent on the nature of the upslope material and the type of slip failure (**Ref 6**).

BEDROCK GEOLOGY

2.5.5. According to the geological map, the preferred crossing location overlies the Gwespyr Sandstone, which is further underlain by the Bowland Shale Formation (both form part of the Millstone Grit Group).

2.5.6. Further upstream and downstream (15-20 m) of the preferred crossing location and in the surrounding area, the Pennine Lower Coal Measures Formation is situated beneath the made ground and superficial deposits.

The Middle and Lower Coal Measures Formations of the Pennine Coal Measures Group in the region were formerly targeted for coal mining (see Section 2.6).

2.5.7. The region is heavily faulted and the closest mapped geological fault to the preferred crossing location is located approximately 50 m upstream of the preferred crossing location (within the Order Limits, towards the A55). This fault dips towards the southwest and uplifts the older Pennine Lower Coal Measures Formation. There is another fault located approximately 135 m downstream of the preferred crossing location (slightly north of the Order Limits), which dips towards the southeast and uplifts the Gwespyr Sandstone. This fault runs approximately along the corridor of the Alltami Brook for approximately 80 m.

2.5.8. The BGS geological maps and the Coal Authority's (CA) coal mining report indicate that there are no faults expected to be present at the preferred open cut crossing location. However, it is recognised that there may be unmapped faults or faults beneath the surface where difficult to ascertain.

2.5.9. The Hollin Rock Member of the Pennine Middle Coal Measures Formation and the Etruria Formation of the Warwickshire Group (formerly known as the Red Measures) both outcrop beneath the superficial deposits approximately 50 m southwest of the preferred crossing location, west of the closest fault.

2.5.10. The geological sequence and lithological description of the strata is summarised in Table 2.1.

Table 2.1: Geological sequence and lithological descriptions

Group	Formation	Lithological Description	Expected Thickness*
Warwickshire Group	Etruria Formation – mudstone, sandstone, and conglomerate	Red, purple, brown, ochreous, green, grey and commonly mottled mudstone, with lenticular sandstones and conglomerates (generally lacking coal)	~100 m
	Etruria Formation – sandstone		
Pennine Coal Measures Group	Pennine Middle Coal Measures Formation	Interbedded grey mudstone, siltstone, pale grey sandstone and commonly coal seams	~100 m
	Hollin Rock Member (sandstone) of the Middle Coal Measures Formation	Sandstone locally interbedded with thin mudstones. The Hollin Rock Member represents a widespread deltic sandstone body, or series of bodies, within the Flintshire Coalfield	~100 m

Group	Formation	Lithological Description	Expected Thickness*
	Pennine Lower Coal Measures Formation	Interbedded grey mudstone, siltstone and pale grey sandstone, commonly with mudstones and more numerous and thicker coal seams	~100 m
Millstone Grit Group	Gwespyr Sandstone Formation	Fine-grained, feldspathic and micaceous sandstones, cross-stratified on a variety of scales, with conglomerate-lined scours and intercalated siltstone and mudstone beds.	~150 m
	Bowland Shale Formation	Mainly dark grey fissile and blocky mudstone, weakly calcareous, with subordinate sequences of interbedded limestone and sandstone	~120 m

*Based on BGS Map Sheet 108 Flint

CROSS AND LONG SECTIONS

2.5.11. Cross and long sections of the geology are included in Annex B.

2.6. COAL MINING HISTORY

OVERVIEW

2.6.1. The preferred crossing location is located within the North Wales Coalfield, which includes the Park Hill Colliery and Magazine Lane Colliery located east of the Alltami Brook. BGS borehole records indicate that the two collieries were present in this area at different times. The collieries were located east and west of Pinfold Lane and along Magazine Lane.

2.6.2. Appendix 11.2: Coal Mining Risk Assessment - Part 1 of the ES **[REP4-120]** indicates that the mines were developed in the 1930s and 1940s. The mine abandonment plan for Park Hill Colliery shows the entrance adit north of the route corridor (Appendix 11.2: Coal Mining Risk Assessment – Part 9 of the ES **[REP4-128]**). The adit extends northwards and targets coal seams at several depths. The total depth of the mine below ground is not confirmed; however, a newspaper article from 1947 records that operations were undertaken at the Park Hill Colliery to a depth of 150 ft (~45 m) below ground level.

2.6.3. Other adits are shown on the BGS 1:10 000 geological map to the northeast of the preferred crossing location. However, these were not observed during the site walkovers. Furthermore, there was no visual evidence of mine water discharges (i.e., iron ochre) occurring as groundwater seepages either along the landslip zone, or in the actual river valley. On this basis, it is considered that the adits shown on the map are possibly buried beneath the made ground and in the absence of any discharges could be ‘dry’ and/or capped off. There are no mine water treatment schemes in the area that would indicate active groundwater management in these mine workings.

2.6.4. The mine plans for the Magazine Lane Colliery indicate an adit access parallel to Magazine Lane and running north-eastwards. The majority of this mine extends out under Magazine Lane in the direction of the A55. Mining of this area occurred in the 1940s and with an adit predominantly targeting the Premier Coal at 7.3 mbgl (Appendix 11.2: Coal Mining Risk Assessment – Part 1 of the ES **[REP4-120]**).

GEOPHYSICAL SITE INVESTIGATION

2.6.5. A geophysical ground investigation was undertaken by the Applicant in January and February 2022 to identify the presence of void spaces resulting from historical mining activity. Surveys were undertaken within the field to the northeast of the preferred crossing location, where made ground is present, and along Pinfold Lane.

2.6.6. BGS maps (**Ref 5, 6)** and the CA’s Consultants Coal Mining Report (appended to Appendix 11.2: Coal Mining Risk Assessment – Part 1 of the ES **[REP4-120]**), however, indicate that there are no faults, shallow workings, or probable shallow workings at the preferred crossing location. Further, the results of the geophysics provide no indication of voids of shallow coal mining across the area. However, the Northop Hall Mine Workings Geophysical Ground Investigation report **[REP4-128]** notes that if the workings have been backfilled with the same material as the surface material, then it may be difficult to differentiate between natural and made ground areas.

2.6.7. An area of fenced off trees is present towards the northeast corner of the field in which geophysical surveys were undertaken (northeast of the preferred crossing location), which was the suspected location of mine adits **[REP4-128]** (Geophysical Ground Investigation. This correlates with the historic mine plans of an adit/shaft location, although, this area is located over 100 m northeast of the crossing location and is not expected to be of concern for the purposes of this report. Additionally, the presence of trees in this area is not conducive to the presence of open mine voids.

2.6.8. The geophysical survey did not find any evidence that there are shallow mining related void spaces beneath the Alltami Brook. This is considered unlikely in any case, as mines did not normally extend directly beneath rivers due to the risk of flooding and difficulties in controlling potential inflows to the mine.

2.7. HYDROGEOLOGY

AQUIFER PROPERTIES AND GROUNDWATER FLOW

Made Ground and Superficial Deposits

2.7.1. The made ground present to the east of Alltami Brook at the preferred crossing location does not have an aquifer designation. Additionally, its composition and hydraulic properties are not currently known, though due to the prevalence of glacial till in the area it may have comparable composition and hydraulic properties. However, during the site walkover by the Applicant on the 14th of March 2023 (photos provided in Annex A), it was observed that the made ground was near-saturated with evidence of extensive surface water puddling. This suggests that a perched water table is present within the made ground, which is likely to be responsive to rainfall events. In areas of made ground where the material predominantly comprises low permeability clays, recharge may also runoff e.g., via the observed areas of surface water puddling. Although the composition of glacial till predominantly comprises low permeability clays, perched water is expected to be present within sand and gravel lenses.

2.7.2. Glacial till is designated as a Secondary (undifferentiated) aquifer, which is a classification given to aquifers that are generally unproductive. The glacial till predominately comprises low permeability clays and typically does not support local water supplies or provide significant baseflow. The glacial till can act as a layer which inhibits recharge to the Permo-Triassic Sandstone aquifer.

2.7.3. The glacial till is also a limiting factor for recharge to the bedrock aquifers underlying it, though some recharge is expected to occur (especially in areas of elevated permeability).

Warwickshire Group – Etruria Formation

2.7.4. The mudstones and sandstones of the Etruria Formation generally have low primary permeabilities. This means that water movement occurs within joints and fractures. Recharge to the sandstones occurs via infiltration of rainfall where the formation outcrops at surface or through fault blocks.

Pennine Coal Measures Group – Lower and Middle Coal Measures Formations

2.7.5. The Lower Coal Measures Formation and Middle Coal Measures Formation of the Pennine Coal Measures Group are also designated as Secondary A aquifers in the region (**Ref 1**). These strata are expected to behave as a multi-layered aquifer system in which lower permeability mudstones act as aquicludes between sandstone aquifer horizons. Both the mudstones and sandstones are expected to be well cemented with minimal primary porosity (**Ref 12**). Groundwater flow within these strata will therefore predominately occur within joints, fractures and fissures. Such flow may occur at depths up to 250 mbgl with fracturing often having been enhanced by mining subsidence (**Ref 12**). Groundwater movement will be controlled by the connectivity of these features, and in some instances will be compartmentalised (due to faulting).

2.7.6. Recharge is via rainfall where the formation outcrops or through fault blocks and former mine workings that may by-pass natural pathways. It is considered that direct recharge is limited where there is widespread glacial till coverage. Lateral groundwater movement and recharge is also considered to be limited as the hydraulic continuity is restricted by extensive faulting, which divides the aquifer into isolated blocks (**Ref 12**). Historic coal mine workings may also act as sinks and pathways for groundwater movement to occur.

2.7.7. There is limited information on groundwater levels for the Coal Measures Group at the preferred crossing location. However, the Applicant is aware of groundwater monitoring information available for a site approximately 830 m southwest of the preferred crossing location, which indicates that groundwater levels are between 85 and 100 mAOD and the groundwater flow direction towards the Alltami Brook (**Ref 5**).

Millstone Grit Group – Gwespyr Sandstone

2.7.8. The Gwespyr Sandstone directly underlies the proposed crossing location and is designated as a Secondary A aquifer (**Ref 6**). The Gwespyr Sandstone is part of the Millstone Grit Group. The Millstone Grit Group is well cemented with very low primary porosity and intergranular permeability, and, therefore, groundwater flow is expected to occur predominantly within the joints, fissures and fractures (**Ref 12**).

2.7.9. Springs occur at the junctions of the jointed sandstone with underlying mudstones and shales (**Ref 12**). During the site walkover, groundwater seepage issuing from the bedrock was observed at NGR SJ 27726 67182 (see photos in Annex A). This is located at the boundary of the Lower Coal Measures Formation (mudstone) and the Gwespyr Sandstone according to the geological map. This observation suggests that the Gwespyr Sandstone in the area is likely to be saturated and may contribute baseflow to the Alltami Brook.

2.7.10. It was noted on a walkover in March 2023 that the Alltami Brook visually appears to widen further downstream of the preferred crossing location (visible from the bridge over the Alltami Brook on Chester Road). This approximately corresponds to where the Alltami Brook flows along the path of a fault.

HISTORIC BOREHOLE LOGS (BGS)

2.7.11. A search for relevant historic borehole logs was undertaken for the purpose of gathering relevant site-specific information (or as near to site as possible). Several borehole logs were obtained, which are for boreholes all within 0.5 km of the preferred crossing location.

2.7.12. The locations of these are shown in Figure 2.2. The relevant information from these borehole logs is shown in Table 2.2 and the borehole logs are presented in Annex C.

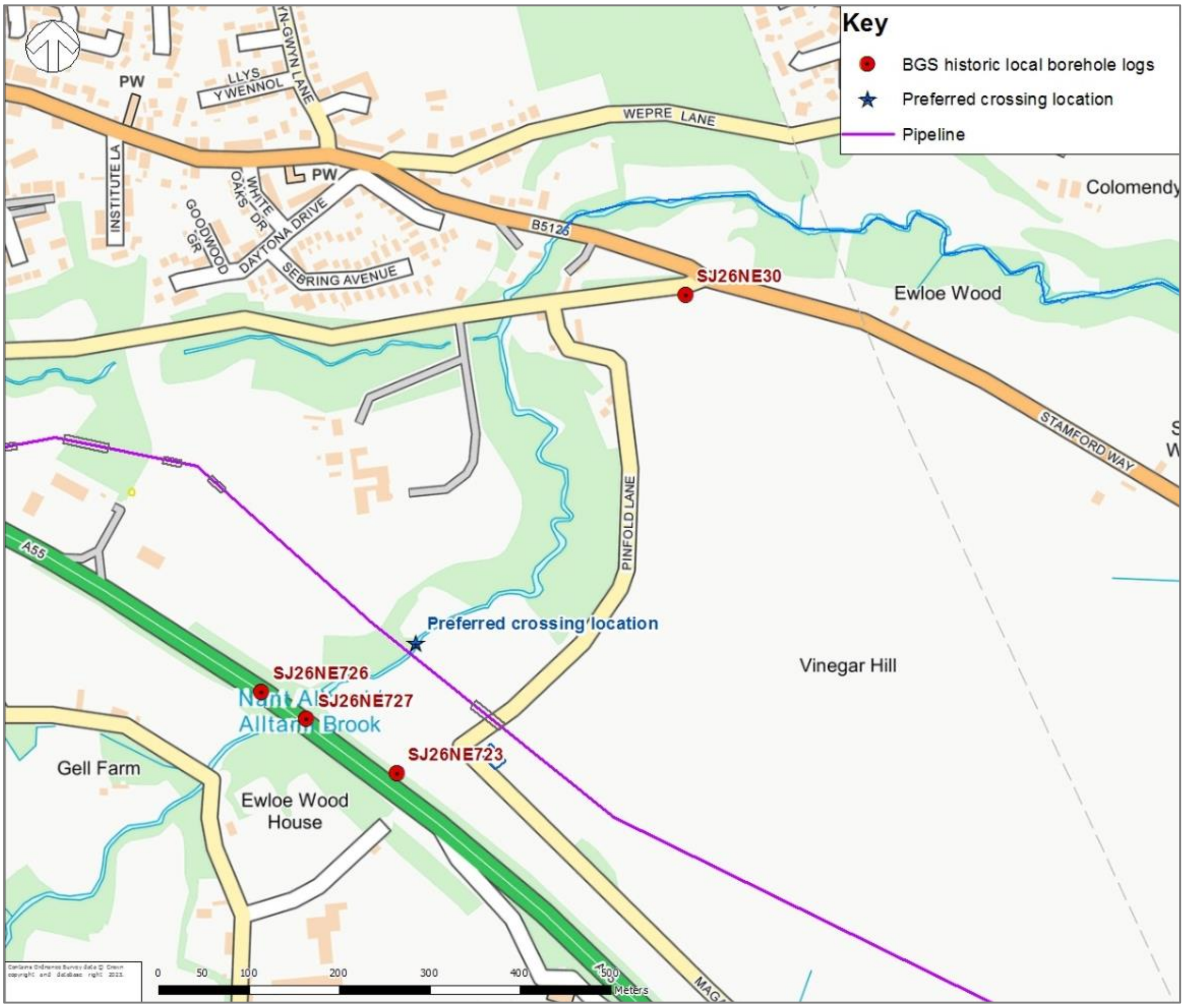


Figure 2.2. Nearby historic boreholes (source: BGS GeoIndex, 2023)

Table 2.2. BGS historic borehole information

Borehole / Information	SJ26NE726	SJ26NE727	SJ26NE723	SJ26NE30
Well NGR:	SJ 27480 67090	SJ 27530 67060	SJ 27630 67000	SJ 27950 67530
Easting/Northing	327480, 367090	327530, 367060	327630, 367000	327950, 367530
Ground Elevation	89 mAOD	79.5 mAOD	90.5 mAOD	84 m AoD
Distance from preferred crossing location	~180 m WSW	~150 m SW	~140 m S	~490 m NE
Name	HAWARDEN BY-PASS, (EXPLORATION ASSOCIATES). NO.15	HAWARDEN BY-PASS, (EXPLORATION ASSOCIATES). NO.16	HAWARDEN BY-PASS, (EXPLORATION ASSOCIATES). NO.5	NEAR EWLOE WOOD
Completion Date	April 1975	April 1975	April 1975	October 1979
Completion Depth	21.3 m	15.1 m	14.5 m	14.5 m
Aquifer	Hollin Rock (presumed). Lower Coal Measures Formation	Hollin Rock (presumed). Lower Coal Measures Formation	Hollin Rock (presumed). Lower Coal Measures Formation	Coal Measures
Rest water level after completion	0 mBGL	0.3 mAGL (above ground level)	0 mBGL	Well dry
Comments	The borehole was dry to 11.2 m. After reaching 18.5 water was struck and rose to 6.9 mBGL. When completed to total depth the water level had	Water strike noted to have occurred at 14.3 mBGL (in sandstone). Possibly a productive fracture with water held under pressure was	No details of water strikes given however groundwater level was noted to be 0 mBGL upon completion.	No water encountered. Elevation of Alltami Brook at nearest point is ~ 67 mAOD.

Borehole / Information	SJ26NE726	SJ26NE727	SJ26NE723	SJ26NE30
	risen to match ground level (0 mBGL).	encountered. Upon completion the water level had risen to 0.3 mAGL (slightly artesian).		

2.7.13. Each of the historic boreholes drilled for the A55 GI in 1975 (Hawarden Bypass) presented in Table 2.2 were drilled to a range of depths from 14.5 to 21.3 m bgl (with SJ26NE26 being the deepest) and encountered similar geology. The ground elevation ranges from 79.5 to 90.5 mAOD. Upon completion, the final recorded groundwater level at these three boreholes was found to be at, or slightly above, ground surface level. The elevation of the Alltami Brook nearest to these boreholes is approximately 81 mAOD.

2.7.14. A fourth borehole to the northeast of the preferred crossing location is included for comparison (SJ26NE30). This borehole was drilled into the Coal Measures. The ground level at this borehole is recorded at approx. 84 mAOD and the borehole was drilled to a depth of 14.5 m (or 69.5 mAOD). It was found to be dry throughout. The elevation for the Alltami Brook at the nearest point to this borehole is approx. 67 mAOD.

2.8. HYDROLOGY

2.8.1. The surface water catchment area for the Alltami Brook is approximately 6.25 km^2 and drains in a northerly direction towards the Wepre Brook, which ultimately discharges into the River Dee (**Ref 9**). The Alltami Brook is expected to be fed by rainfall with small inputs from groundwater baseflow. Additionally, the Applicant is aware of a permitted discharge activity to the Alltami Brook from a landfill further upstream.

2.8.2. During the site walkover undertaken on 14th March 2023, a small surface water inflow was observed to be discharging into the Alltami Brook from the eastern bank upstream of the A55 at approximate NGR SJ 27793 67229 (see walkover photo in Annex A). A small waterfall discharging from the right bank was also observed to be discharging into the Alltami Brook at NGR SJ 27786 67196 (see photographs in Annex A). To cross the A55 (upstream of the Newbuild Infrastructure Boundary) the Alltami Brook flows through a large culvert which discharges onto a concrete slab perched above the bed level (photos in Annex A). The bedrock channel immediately downstream of the concrete culvert was observed to have boulders and gravel deposits.

3. HYDROGEOLOGICAL CONCEPTUAL MODEL

3.1. INTRODUCTION

3.1.1. This section presents a conceptual understanding of the groundwater regime in and around the Alltami Brook. It presents the current baseline conditions and examines the potential changes beyond baseline that may be encountered during construction and operational stages, accounting for the concerns raised by NRW.

3.1.2. A preliminary hydrogeological conceptual model is presented in . This is a simplified representation of a complex geological and hydrogeological setting, which is based on the data and information presented in Section 2.0 and the application of hydrogeological expertise in identifying and assessing groundwater flow conditions.

3.1.3. The conceptual model illustrates the key physical relationships and interactions that are assessed as primary controls for groundwater-surface water interactions in and around the Alltami Brook. Using this interpretation, the baseline conditions are described in Section 3.2.

3.1.4. Whilst the conceptual model is derived largely on published information and site observations, it does provide the framework for considering the how the proposed construction using the open cut method and subsequent operation of the pipeline may impact the baseline conditions. This is discussed in Section 3.3.

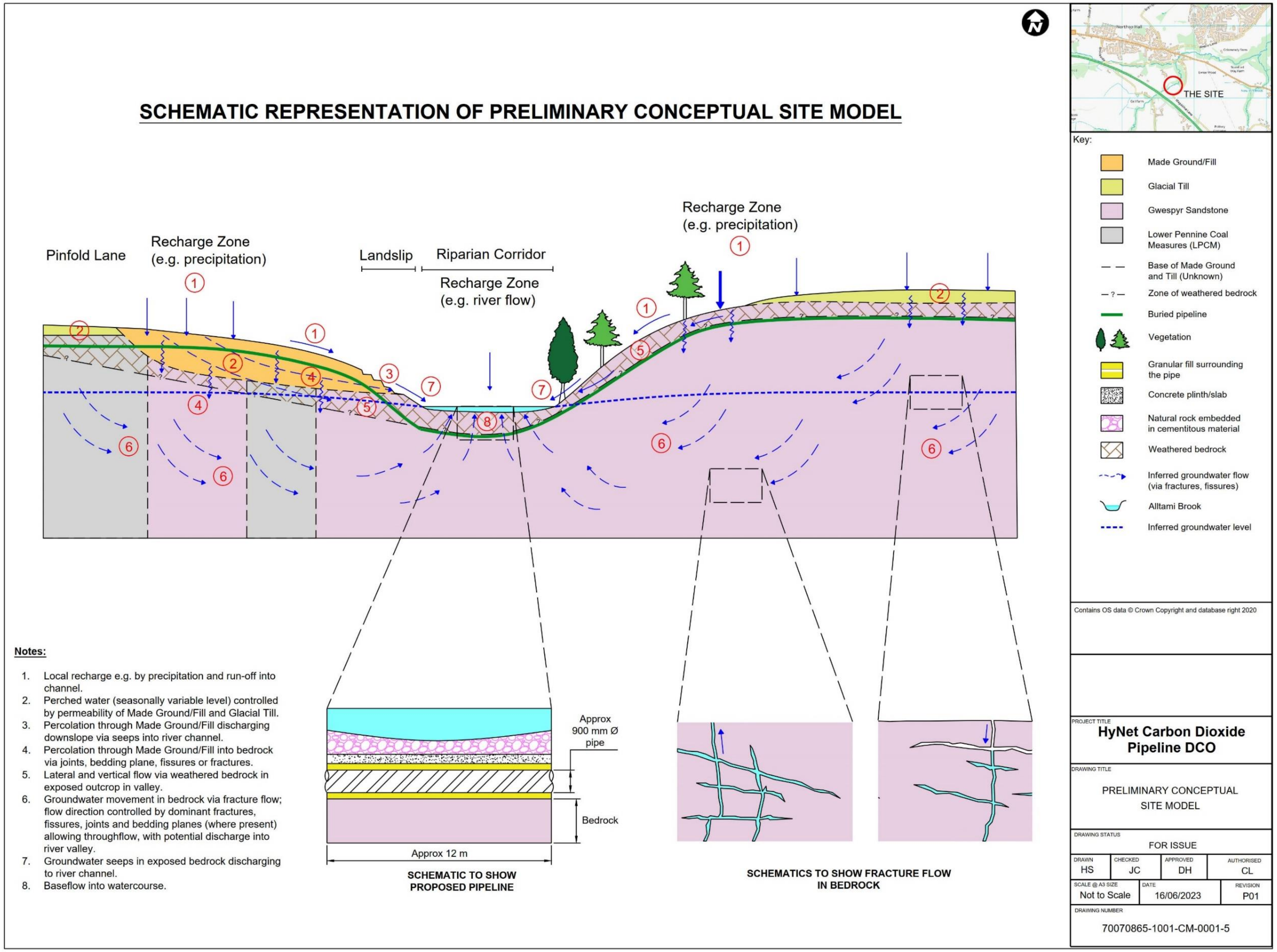


Figure 3.1. Preliminary Hydrogeological Conceptual Model

3.2. UNDERSTANDING OF BASELINE CONDITIONS

3.2.1. Considering the cross and long sections in Annex B, and following the course of the Alltami Brook from the upstream side of the Newbuild Infrastructure Boundary, then the geological conditions are characterised as follows:

- the Middle Coal Measures, which here is comprised of the Hollin Rock;
- downstream, and at the location of the preferred crossing location, is an outcrop of the Gwespyr Sandstone (part of the Millstone Grit Group);
- downstream of this location, and in the lower portion of the stretch of the Alltami Brook within the Newbuild Infrastructure Boundary are the Pennine Lower Coal Measures at outcrop.

3.2.2. Each of these formations have similar lithology, characterised by inter-bedded grey mudstones, siltstones, sandstones, with coal seams in the coal measures. The Hollin Rock and the Gwespyr Sandstone are more sandstone dominant.

3.2.3. There are two faults of note, one cutting across the Alltami Brook perpendicular to it which separates the Hollin Rock/Middle Coal Measures from the Gwespyr Sandstone. Then slightly downstream of the Newbuild Infrastructure Boundary for an approximately 80 m stretch, there is a fault running parallel to the Alltami Brook that is either along or very near to the watercourse (where we would expect fracturing to be present).

3.2.4. At the preferred crossing location, shown on Figure 5 (Preliminary Hydrogeological Conceptual Model), the geology at outcrop is the Gwespyr Sandstone. At ground surface and for the initial several metres below weathered bedrock is anticipated, which is also expected to become increasingly competent at greater depth i.e., where the effects of weathering are not evident.

3.2.5. Recharge to the bedrock aquifer occurs regionally; however, this is limited through the glacial till superficial deposits. Recharge is expected to be increased in the areas immediately surrounding the Alltami Brook where bedrock is at outcrop.

3.2.6. The stream flow within the Alltami Brook is considered to be largely influenced by regional surface water recharge, potentially with inputs from localised land and road drainage.

There is a secondary baseflow component to the river from groundwater where there are seepages and sufficient fracturing allows it, as groundwater movement in the bedrock is largely controlled by secondary porosity resulting from fissures, joints and cracks in bedrock (see

3.2.7. **Figure 3.1**). These conditions are likely to be laterally and vertically discontinuous.

3.2.8. There are known former collieries near to Pinfold Lane. On the abandonment plans **[Appendix 11.2: Coal Mining Risk Assessment – Part 9** of the **ES, REP4-128]** these are indicated to be approximately 100 m northeast of the preferred crossing point on the Alltami Brook.

3.2.9. There are some mine adits shown on historic maps for these abandoned mines indicated to be buried beneath an area of made ground which forms the eastern slope of the valley of Alltami Brook. The mines were known to extend to a depth of 45 m below ground level. Due to this relatively shallow depth and considering the duration of time (75 years approximately) since abandonment, it is considered that mine water levels have likely recovered to natural equilibrium.

3.3. SCENARIOS FOR RIVER FLOW CHANGE

CONSTRUCTION PHASE

3.3.1. During construction the approach will be to redirect the flow in the Alltami Brook through a temporary culvert which collects all of the river flow upstream of the excavation and redirects it around the excavation whilst the works are ongoing. The culvert will be made of impermeable material, therefore not allowing any flow to be lost. The flow will not be allowed to continue back along the natural route until the works are completed and the riverbed is reinstated in, as close as is possible to, natural conditions.

3.3.2. There is a scenario which could result in a discharge of flow into the excavation, which is where a productive fracture is encountered that is holding water under pressure. In this scenario, dewatering of the excavation may be required. The aim would be to stop the inflow using permeation grouting of the fracture to cut-off future or existing flow, with dewatering reducing the groundwater inflow temporarily to allow the (quick-setting) grout to be injected. The excavation will be filled with permeable sand or gravel material which surrounds the pipe (to prevent it from being in direct contact with bedrock). Concrete will be added on top of the gravel material. Alternatively, it may be that the whole excavation is filled with concrete (and the concrete supports the pipe instead of the sand/gravel). The final construction approach is to be confirmed at detailed design by the Construction Contractor.

OPERATIONAL PHASE

3.3.3. The structure once completed is intended to not allow flow to discharge from ground into the Alltami Brook, as it will be sealed through being filled with concrete and any fractures, fissures, joints will be grouted. The risk of washout of grout would be reduced by the use of appropriate grout materials and/or accelerators to ensure rapid gel setting and strength gain. The degradation of the grout within a fissure is an unlikely outcome as the grout will be buried beneath the structure. A specialist contractor would undertake the grouting works to the appropriate British Standards (i.e., BS EN 12715:2020), effectively creating a low permeability plug within the bedrock, eliminating the fissures. A schedule of general inspections and principal inspections of the Alltami Brook crossing will be carried out to determine condition and identify any potential maintenance requirements. Inspections will be undertaken following an intense rainfall event or heatwave to monitor any damage and implement appropriate mitigation as necessary as stated within the DMRB BD 63/17. At decommissioning the pipe at the Alltami Brook crossing will be filled with grout or concrete. Monitoring beyond the lifespan of the DCO Proposed Development is not considered a necessary requirement.

3.3.4. However, in the scenario where there is a failure in the structure’s ability to prevent throughflow, this is not considered to result in a major loss of flow to or from the Alltami Brook. The reason is because the conceptual understanding of the area indicates that there is a groundwater baseflow component to the Alltami Brook resulting from an overall upwards hydraulic pressure/flow gradient from bedrock (where fractures allow). This means that groundwater levels are higher than the river level. In this situation, loss of flow from the river to ground is impossible as the hydraulic gradient doesn’t allow it.

3.3.5. There is a possibility that if a productive fracture is encountered, the crossing would result in a new discharge point for groundwater to be discharged into the Alltami Brook. However, this is not expected to result in a significant change in terms of the overall water balance of the valley, as the Alltami Brook is already considered the primary recipient of groundwater flow reaching ground surface in this area. The potential change would be a local change in terms of the location at which water is discharged from the aquifer into the Brook, but the overall volume in not expected to change from the current water balance.

3.3.6. The laterally discontinuous fracture flow conditions, along with the overall upward hydraulic gradient of the bedrock aquifers, prevents any significant loss of flow from occurring from the Alltami Brook to ground. The Alltami Brook has been observed on walkovers to be widening downstream of the Newbuild Infrastructure Boundary, where the watercourse is flowing the approximate same route as a fault for an approximately 80 m stretch. Due to the presence of the fault this location significant fracturing would be expected to be present, however this seems to be resulting in a gain, rather than a loss of flow from groundwater to the Alltami Brook.

3.3.7. The nearby former coal mine workings are not considered to represent a realistic recipient of flow from the Alltami Brook. The primary reason is because any mine voids are expected to be saturated due to mine water levels having recovered to match surrounding groundwater in the duration since abandonment (thought to be in the late 1940s). Additionally, a direct fracture route allowing sufficient throughflow would be required from the crossing excavation to the mine workings. Due to the laterally discontinuous flow conditions and the distance from the preferred crossing location to the mine workings, such a connection is considered unlikely. It is also not guaranteed that a productive fracture would be exposed by the excavation which is relatively shallow at 4 m deep.

UNCERTAINTIES IN CONCEPTUAL UNDERSTANDING

3.3.8. The exact relationship between surface water in the Alltami Brook and surrounding groundwater, whilst not considered to represent a significant concern in terms of potential water loss (because of the information which is available), is not currently known in detail. Ground investigation (which includes groundwater monitoring) will be undertaken at detailed design stage at the proposed crossing location to verify the relationship between surface water and groundwater and confirm the conceptual understanding.

3.3.9. However seasonal variations in groundwater pressures are possible which could result in a lower groundwater level (e.g., during dryer summer months). Due to the nature of the aquifers present (limited lateral fracture flow), this would not be expected to be significant (e.g., compared to a Chalk fracture flow aquifer). The design also is intended to prevent loss of flow; therefore, this is considered a manageable risk.

4. SUMMARY OF FINDINGS

4.1.1. The findings of this report are as follows:

- The conceptual understanding of the hydrogeology, based on all the available information presented (including site observations), indicates that there is an overall upwards hydraulic gradient from the bedrock aquifers to the Alltami Brook watercourse. This is likely to be providing a groundwater baseflow component to the overall flow in the watercourse (where sufficient fracturing facilitates it).
- The laterally discontinuous nature of the bedrock aquifer reduces the likelihood of the aquifer representing a likely receptor for a significant flow of water from the Alltami Brook. This is evidenced in part by observations made on site, as the watercourse follows a fault line as it flows downstream of the preferred crossing location.
- The presence of nearby historic mines is not considered a significant risk in relation to the open cut crossing option because of the following:
  - Mine water levels have likely recovered since abandonment.
  - The geophysical surveys undertaken did not detect any presence of open mine voids in the area.
  - It is unlikely that shallow mining would have been undertaken directly beneath a river (due to the associated flood risk), and the available information on where the mine was situated, the seams worked and the historical information (e.g., the abandonment plans) indicates that mining was not undertaken near to the preferred crossing location.
  - The scenario where a productive fracture within the excavation which is directly connected to unsaturated mine voids allowing significant throughflow from the built crossing structure (which itself is designed to prevent loss of flow) is considered extremely unlikely.
- There is not considered to be a mechanism present which would allow a discernible loss of flow from the Alltami Brook to the underlying bedrock aquifer.

4.1.2. For all the above reasons the DCO Proposed Development is not considered to be a risk to impacting the WFD status of the Wepre Brook surface water body.

4.2. NEXT STEPS

4.2.1. A ground investigation which is sufficiently scoped to address the uncertainties in the current conceptual understanding could be undertaken to inform the detailed design. This would be informed through consultation with NRW and the design team, including specialist geotechnical contractors with an expertise in dewatering and geotechnical grouting.

5. REFERENCES

- **Ref 1 -** Hydrogeology of Wales technical report, BGS, 2015
- **Ref 2 -** White Rock Geo-Environmental Ltd. (2020) Parrys Quarry Landfill Hydrogeological Risk Assessment
- **Ref 3 -** Environment Agency (2017) Groundwater protection – guidance. Available at: https://www.gov.uk/government/collections/groundwater-protection (Accessed: 15th May 2023). Robins, N.S., Davies, J. (2015) Hydrogeology of Wales. British Geological Survey. NERC, Keyworth, Nottingham.
- **Ref 4 -** British Geological Survey (1990) Geological Survey of England and Wales 1:10,000 geological map series, New Series – sheet number SJ26NE. Solid Edition. [online] Available at:[redacted] (Accessed: 15th May 2023).
- **Ref 5 -** British Geological Survey (1999) Geological Survey of England and Wales 1:63,360/1:50,000 geological map series, New Series – sheet number 108 (Flint). Solid Edition. [online] Available at: [redacted] (Accessed: 21st April 2023).
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- **Ref 8 -** Davies, J.R., Wilson, D., Williamson, I.T. (2004) Geology of the country around Flint. Memoir for 1:50000 Geological Sheet 108 (England and Wales). [online] Available at: [redacted]Accessed: 21st April 2023).
- **Ref 9 -** UK Centre of Ecology & Hydrology (2023) Flood estimation handbook web service. [online] Available [redacted] (Accessed: 21st April 2023).
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- **Ref 11 -** Wrexham History (2022) North Wales Coalfield Sites. Available at: [redacted]Accessed: 15th May 2023).
- **Ref 12 -** Jones, H K, Morris, B L,Cheney, C S, Brewerton, L J, Merrin, P D, Lewis, M A, MacDonald, A M, Coleby, L M, Talbot, J C, McKenzie, A A, Bird, M J, Cunningham, J, and Robinson, V K. 2000. The physical properties of minor aquifers in England and Wales. British Geological Survey Technical Report, WD/00/4. 234pp. Environment Agency R&D Publication 68.

Appendices

Appendix A

MARCH 2023 SITE WALKOVER PHOTOGRAPHS

MARCH 2023 SITE WALKOVER PHOTOGRAPHS

Seepage through made ground creating small waterfall

Seepage from made ground discharging into Alltami Brook

Saturated made ground/seepage

Saturated made ground/seepage

Additional Notes and Photographs from March 2023 site walkover

Alltami Brook site photos 14 March 2023

	
View looking upstream of the minor road bridge. Spate flow following heavy overnight rain on saturated ground. Deep v-shaped channel in otherwise flat landscape. A minor tributary of land drainage is discharging into the Alltami Brook on the right bank.	Outlet of the A55 culvert. Large pipe culvert discharging onto a concrete slab perched above bed level. Banks are lined with gabion baskets. Fast-flowing water and high step from concrete ledge to natural bed (height difficult to estimate due to elevated flows but possibly 0.3-0.3m). Bedrock channel with boulders and gravel deposits downstream of the step along with trash (tyre observed in the middle of the channel).
	
Immediately downstream of the A55 culvert outlet. Concrete wingwalls and gabion mattress bank reinforcement on both banks. Concrete slab at the culvert outlet and high step down to the natural channel. It is likely that this culvert structure arrangement is not passable to fish.	View looking upstream towards the A55 culvert outlet showing the transition from the modified reach with gabion basket bank reinforcement to natural banks. Bedrock was observed on the left bank face downstream of the culvert where the bank renaturalised.

	
Made ground on the right bank. Very high and steep engineered bank with a composite bank profile due to creep.	The made ground was saturated with extensive surface water puddling.
	
Made ground bank profile with surface water puddling due to saturation of the earth.	View looking down to the Alltami Brook from the top of the made ground on the right bank. View looking downstream. The left bank is also steep and high but possibly a more natural landscape feature. Approximate crossing location for the pipeline.
	
Seepage observed from bedrock on the left bank face immediately upstream of SJ 27726 67182.	Land drainage pipe discharging water into the brook on the right bank face. Small volume of water seeping from the pipe. SJ 27726 67182. Bedrock and boulder channel

	bed. Chute and broken standing wave flow types observed.
	
SJ 27786 67196 surface water flow paths on the right bank draining into the Alltami Brook.	SJ 27786 67196 small waterfall on the right bank discharging into the Alltami Brook.
	
Surface water flow draining the right bank hillside into the Alltami Brook at SJ 27793 67229.	Surface water flow draining the right bank hillside into the Alltami Brook at SJ 27793 67229.

Appendix B

GEOLOGICAL SECTIONS

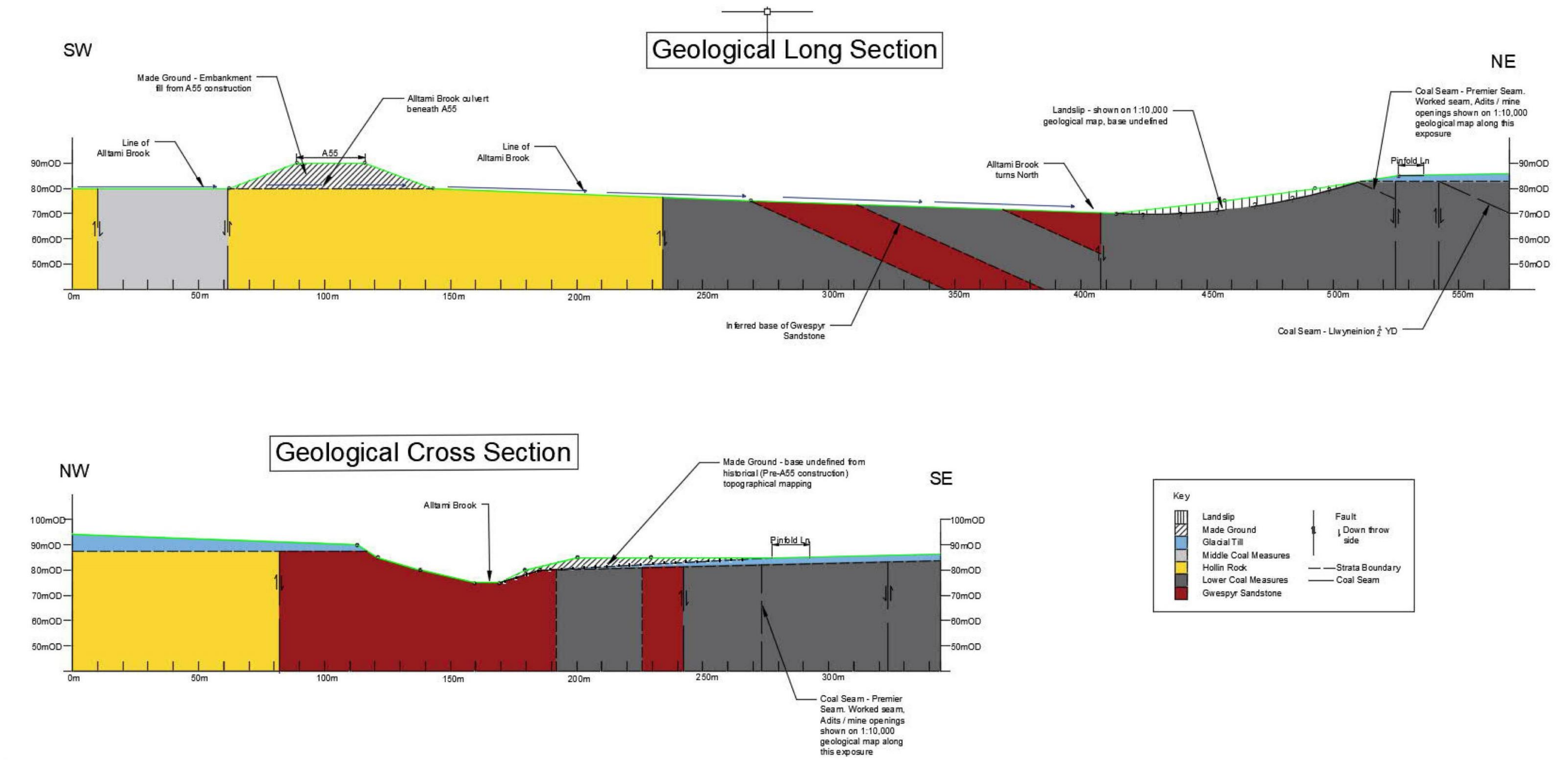
Alltami Brook
Location Plan

Figure 1
(NTS)

Alltami Brook

1:10,000 Geological Map Extract

Figure 2
(NTS)



wsp

Alltami Brook

Geological Sections

Figure 3

(NTS)

Appendix C

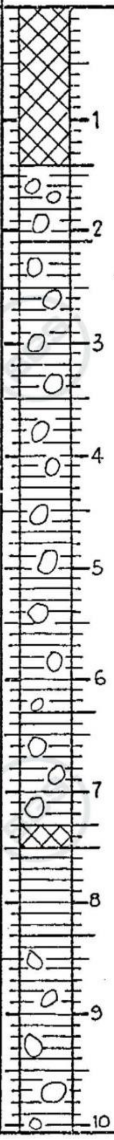
HISTORIC BOREHOLE LOGS

SJ26NE726

CONTRACTOR		BOREHOLE Nº
Exploration Associates.	10 – 11/4/75	Shell.Rotary core: Water flush.	15

GROUND LEVEL	ORIENTATION	CO-ORDINATES	SITE	PAGE 1 OF 2
89.0m.A.O.D.	-90°	E 274 830 N 670 870	S726NE/726 Hawarden By-pass.	

TOTAL CORE RECOV.% & SIZE	R.Q.D.	DESCRIPTION OF STRATA	SOLID CORE RECOV. %	FRACTURE LOG
		FILL, ashes.	Driller's report: shell.	
		BOULDER CLAY, firm, red, brown, sandy with ash content.		
		BOULDER CLAY, red brown silty, soft to firm.		
		BOULDER CLAY, grey, brown,green, silty, firm.		
		TOPSOIL, silty.		
		CLAY, light grey, silty, firm.		
		BOULDER CLAY, brown grey, firm.		



KEY

REMARKS
Drill H casing to 15.0m.
Lost water returns at 13.5m.
Cased through this- then full returns.
Overall core recovery 87%

LOGGED BY	SCALE
K.F.	1/50 METRES

K. WARDELL & PTNRS.

CLIENT	JOB Nº
Welsh Office.	5619/1

SJ26NE 726

Sampling Depth	Type	Properties Strength kN/m²	w %	SPT N	Strata Description	Depth	Level	Legend
						G.L	89.0	
0.3	D		21					
0.5–1.0	D.S.		52	12	Made Ground:- Loose ash, clinker etc.			
1.4	D		21			1.4	87.6	
1.5–2.0	U(75)		20		Soft-firm grey brown silty sandy CLAY with ash, coal fragments. (Made Ground)			
2.1	D		22			2.1	86.9	
2.5–3.0	U(60)		20		Soft firm light red brown becoming grey brown silty CLAY with rock fragments and gravel. (Made Ground).			
3.2	D		25					
3.5–4.0	U(65)	25 38	21 19					
4.2	D		21					
4.5–5.0	U(60)		21					
5.2	D		18					
5.5–6.0	U(60)		28					
6.3	D		22					
7.0–7.5	U(85)		24			7.3	81.7	
7.4	D		25		Soft grey brown very silty CLAY.	7.5	81.5	
7.6	D		5		Soft-firm brown grey silty slightly sandy CLAY with occasional fine gravel.			
8.0–8.5	U(80)	75	18 17			8.3	80.7	
8.5	D		18		Stiff grey brown silty sandy CLAY with rock fragments and gravel of coal, mudstone, sandstone.			
9.0	D		15					
9.5–10.0	U(100)	220	14 15					
					Cont. over from 10.0.	10.0	79.0	

Drilling

Type	From	To	Size	Fluid
Shell and Auger	G.L.	10.0	0.15	

Ground Water

Struck	Behaviour	Sealed	Date	Hole	Cased	Water
			9.4.75	-	-	-
			9.4.75	11.2	1.5	Nil

Remarks

Borehole Record

exploration associates

Project Clwyd County Council
Hawarden By-Pass
Section No. 1. Chainage 2090

Contract S1118

Borehole 15
Sheet 1 of 3

SJ26NE 726

Sampling / Properties

Depth	Type	Strength kN/m²	w %	SPT N
0.3	D		21	
0.5-1.0	D.S.		52	12
1.4	D		21	
1.5-2.0	U(75)		20	
2.1	D		22	
2.5-3.0	U(60)		20	
3.2	D		25	
3.5-4.0	U(65)	25 38	21 19	
4.2	D		21	
4.5-5.0	U(60)		21	
5.2	D		18	
5.5-6.0	U(60)		28	
6.3	D		22	
7.0-7.5	U(85)		24	
7.4	D		25	
7.6	D		5	
8.0-8.5	U(80)	75	18 17	
8.5	D		18	
9.0	D		15	
9.5-10.0	U(100)	220	14 15	

Strata

Description	Depth	Level
	G.L	89.0
Made Ground:- Loose ash, clinker etc.	1.4	87.6
Soft-firm grey brown silty sandy CLAY with ash, coal fragments. (Made Ground)	2.1	86.9
Soft firm light red brown becoming grey brown silty CLAY with rock fragments and gravel. (Made Ground).	7.3	81.7
Soft grey brown very silty CLAY.	7.5	81.5
Soft-firm brown grey silty slightly sandy CLAY with occasional fine gravel.	8.3	80.7
Stiff grey brown silty sandy CLAY with rock fragments and gravel of coal, mudstone, sandstone.	10.0	79.0

Cont. over from 10.0.

Drilling

Type	From	To	Size	Fluid
Shell and Auger	G.L.	10.0	0.15	

Ground Water

Struck	Behaviour	Sealed	Date	Hole	Cased	Water
			9.4.75	-	-	-
			9.4.75	11.2	1.5	Nil

Remarks

Borehole Record

exploration associates

Project Clwyd County Council
Hawarden By-Pass

Section No.1. Chainage 2090

Contract S1118

Borehole 15
Sheet 1 of 3

SJ 26NE/726

Sampling Depth	Type	Strength kN/m²	w %	SPT N	Strata Description	Depth	Level
					Continued from 10.0.	10.0	79.0
10.3	D		15			10.3	78.7
10.5-10.9	U(140)		16		Stiff light grey shaly CLAY.		
11.0	D					11.0	78.0
11.2	D						

Drill Run	Fluid Return	Core Recovery	F.I.	R.Q.D	Description	Depth	Level
11.2–12.7	100%	60%	-	-	Faintly weathered grey medium hard MUDSTONE with ironstone nodules. Clayey zones noted.		
12.7–14.0	100% / Nil	54%	-	40%		14.0	75.0
14.0–15.5	100%	100%	6	20%	Faintly weathered grey medium hard becoming hard fine SILTSTONE. Occasional sandy zones and thin layers of grey hard - very hard silty fine sandstone.		
15.5–17.0	100%	100%	15	30%			
17.0–18.5	100%	100%	5	40%		17.7	71.3
18.5–20.0	100%	100%	10	40%	Faintly weathered grey hard - very hard fine-medium SANDSTONE.		
20.0					Continued from 20.0.	20.0	69.0

Drilling

Type	From	To	Size	Fluid
Shell and Auger	10.0	11.2	0.15	-
Rotary Core	11.2	20.0	0.07	Water

Ground Water

Struck	Behaviour	Sealed	Date	Hole	Cased	Water
			10.4.75	11.2	1.5	Nil
			11.4.75	18.5	15.0	6.9
			11.4.75	21.3	15.0	G.L.

Remarks Rock chisel used from 11.0-11.2 (0.5 hours)

Rotary Borehole Record based on interpretation by K. Wardell and Partners.

Borehole Record

exploration associates

Project Clwyd County Council Hawarden By-Pass

Section No.1.

Contract S1118

Borehole 15

Sheet 2 of 3

HyNet Carbon Dioxide Pipeline DCO

Hydrogeological Impact Appraisal of Open Cut Crossing, Alltami Brook

SJ26NE/726

Sampling		Properties			Strata			
Drill Run	Fluid Return	Core Recovery	FI	RQD	Description	Depth	Level	Legend
20.0					Continued from 20.0	20.0	69.0	
	100%	100%	4	75%	As above.			
21.3						21.3	67.7	
					End of Borehole.			

Drilling

Type	From	To	Size	Fluid
Rotary Core	10.0	21.3	0.07	Water

Ground Water

Struck	Behaviour	Sealed	Date	Hole	Cased	Water

Remarks

Borehole Record

exploration associates

Project Clwyd County Council
Hawarden By-Pass

Section No. 1.

Contract S1118

Borehole 15

Sheet 3 of 3

SJ26NE727

CONTRACTOR	DATE OF DRILLING	DRILLING METHOD	BOREHOLE No
Exploration Associates.	11-14/4/75	Shell. Rotary core: Water flush.	16

GROUND LEVEL	ORIENTATION	CO-ORDINATES	SITE	PAGE 1 OF 2
79.5m.A.O.D.	-90°	E 275 260 N 670 640	SJ26NE/727 Hawarden By-pass.	

TOTAL CORE RECOV% & SIZE	R.Q.D.	DESCRIPTION OF STRATA	SOLID CORE RECOV. %	FRACTURE LOG
		MUDSTONE, grey, brown.	Driller's report: Shell.	
H 60%	-	SILTSTONE, light grey, laminated, slightly weathered, firm-hard.	Core 17%	most broken
83%	46%	MUDSTONE, grey, laminated, fresh, micaceous, firm-hard. COAL, "cubes" set in grey clay matrix, clarain, bright, hard. MUDSTONE, as above, plant remains, patches of iron enrichment.	75%	APPROX 5 bedding
90%	-	COAL, fragments in grey clay matrix caved from above? MUDSTONE, (clay) as above, soft-firm. Black shaly carbonaceous band, friable.	50%	APPROX. 4 bedding
73%	64%	MUDSTONE, (seatearth) light-dark grey, fresh, soft, (clay) firm-hard, sandy patches, iron enriched patches, sometimes pseudo-brecciated appearance some friable plant remains (rootlets) occasional silty band.	73%	4 bedding
70%	60%		60%	4 bedding
100%	27%	SILTSTONE, grey, laminated, fresh, hard, plant remains, (rootlets) Alternating MUDSTONE, SILTSTONE, and fine grained, silty SANDSTONE laminae, slightly weathered on joints, "striped beds" currents bedding, ripple drift lamination.	90%	1 85°

Depth scale (metres): 1, 2, 3, 4, 5, 6, 7, 8, 9, 10

KEY

REMARKS
Drilled H casing to 9.0m.
Lost some returns at 4.5m.
Artesian "Water" fast ingress at 14.3m.
Overall core recovery 88%

LOGGED BY	SCALE
K.F.	1/50 METRES

K. WARDELL & PTNRS.

CLIENT	JOB No
Welsh Office.	3169/1

SITE	PAGE 2 OF 2	BOREHOLE No
Hawarden By-pass.	SJ 26 NE/727	16

TOTAL CORE RECOV.% & SIZE	R.Q.D.	SOLID CORE RECOV. %	FRACTURE LOG
100%	13%	80%	2@ 85° 1@ 70° 3 beds
100%	70%	93%	2 70°
100%	100%	100%	2 bedding
100%	50%	100%	4 bedding

DESCRIPTION OF STRATA

SANDSTONE BAND, weathered in joint.

Alternating laminae ("striped beds") as above. (11)

Dip 5°

SANDSTONE, grey, fine-medium grained, medium-thickly bedded, slightly weathered, (on open bedding plane), dark micaceous laminae, hard-very hard, some more or less silty. (12)

END (15)

Depth scale (m): 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22

K. WARDELL & PTNRS.	CLIENT: Welsh Office.	JOB No 3619/1

SJ26NE 727

Sampling Depth	Type	Strength kN/m²	w %	SPT N	Strata Description	Depth	Level
					Turf over TOPSOIL.	G.L	79.5
0.3	D		23			0.3	79.2
0.5-1.0	U(40)	11	24 25		Soft red-brown silty slightly sandy CLAY with occasional fine gravel.		
1.3	D		7			1.4	78.1
1.4	D		11				
1.8	D		7		Faintly weathered light grey medium hard SANDSTONE.		

Drill Run	Fluid Return	Core Recovery	F.I.	R.Q.D	Strata Description	Depth	Level
1.8-3.3	100%	63%	-	-		3.0	76.5
3.3-4.5	100% *	83%	5	55%	Fresh grey medium hard MUDSTONE with zones of coal fragments. Occasional thin siltstone and sandstone bands.		
4.5-5.5	100%	90%	4	-			
5.5-7.0	100%	83%	4	65%			
7.0-8.0	100%	80%	4	85%			
8.0-9.5	100%	100%	1	25%			
9.5-10.0	100%	100%	2	15%	Cont. over from 10.0.	10.0	69.5

Drilling

Type	From	To	Size	Fluid
Shell and Auger	G.L.	1.8	0.15	
Rotary Core	1.8	10.0	0.07	Water

Ground Water

Struck	Behaviour	Sealed	Date	Hole	Cased	Water
			11.4.75	-	-	-
			11.4.75	1.8	1.5	Nil
			14.4.75	4.5	3.0	2.7

Remarks Rock chisel used from 1.4-1.8 (0.75 hours)
* Slight loss at 4.5
Rotary Borehole Record Based on interpretation by K. Wardell and Partners.

Borehole Record
exploration associates

Project Clwyd County Council
Hawarden By-Pass
Section No.1. Chainage 2140

Contract S1118

Borehole 16
Sheet 1 of 2

HyNet Carbon Dioxide Pipeline DCO

Hydrogeological Impact Appraisal of Open Cut Crossing, Alltami Brook

SJ26NE/727

Sampling: Drill Run	Fluid Return	Properties: Core Recovery	FI	RQD	Strata: Description	Depth	Level	Legend
	100%	100%	2	15%	Continued from 10.0 As before.	10.0	69.5	
11.0	100%	100%	2	70%				
12.5	100%	100%	2	100%	Faintly weathered grey hard-very hard fine-medium SANDSTONE.	11.6	67.9	
14.0	100%	100%	4	60%				
15.1					End of Borehole.	15.1	64.4	

Drilling

Type	From	To	Size	Fluid
Rotary Core	10.0	15.1		

Ground Water

Struck	Behaviour	Sealed	Date	Hole	Cased	Water
14.3	Rose to 0.3 above G.L.		14.4.75	15.1	9.0	+0.3

Remarks Rotary Borehole Record based on interpretation by K. Wardell & Partners.

Borehole Record

exploration associates

Project Clwyd County Council
Hawarden By-Pass

Section No. 1

Contract S1118

Borehole 16

Sheet 2 of 2

SJ26NE723

CONTRACTOR	DATE OF DRILLING	DRILLING METHOD	BOREHOLE Nº
Exploration Associates.	7/4/75	Shell. Rotary core: water flush.	5

GROUND LEVEL	ORIENTATION	CO-ORDINATES	SITE	PAGE 1 OF 2
90.5m.A.O.D	-90°	E 276 340 N 670 000	SJ 26NE/723 Hawarden By-pass.	

TOTAL CORE RECOV.% & SIZE	R.Q.D.	DEPTH (m)	DESCRIPTION OF STRATA	SOLID CORE RECOV. %	FRACTURE LOG
		0–1	BOULDER CLAY, grey, brown, firm, silty.	Driller's report: Shell.	
		2	BOULDER CLAY, as above, red brown, sandy, silty.		
		5	BOULDER CLAY, dark brown, firm, slightly silty.		
		6	SILT, firm, grey, brown, clayey.		
		6–7	LIMESTONE, boulders with silty grey clay.		
		7–9	GRAVEL, clayey, small and large with silty clay.		
		9	MUDSTONE, grey.		
H 100%	37%	9–10	SILTSTONE, grey, laminated, moderately widely spaced joints, slightly weathered, firm/hard.	core. 73%	3 85° 60°

KEY

REMARKS
H casing to 12.0m.
Full water returns.
Overall core recovery 91%

LOGGED BY K.F.

SCALE 1/50 METRES

K. WARDELL & PTNRS.

CLIENT Hawarden By-pass.

JOB Nº 3619/1

SITE: Hawarden By-pass.

PAGE 2 OF 2 SJ 26 NE/723

BOREHOLE No 5

TOTAL CORE RECOV.% & SIZE	R.Q.D.	DESCRIPTION OF STRATA	SOLID CORE RECOV. %	FRACTURE LOG
		Ironstone nodules.		
93%	27%	SANDSTONE, silty, grey, fine grained, laminated, moderately weathered, jointed. Dip 20° SANDSTONE, as above.	60%	5 80°
		SILTSTONE, as above, slightly weathered, hard. SANDY BAND. IRONSTONE BAND.		
90%	20%	MUDSTONE, grey, laminated, slightly weathered, firm-hard.	27%	2 80°
71%	29%	Ironstone nodules.	29%	1 80°
		END		

Depth scale: 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22

K. WARDELL & PTNRS. | CLIENT: Welsh Office. | JOB No 3619/1

HyNet Carbon Dioxide Pipeline DCO

Hydrogeological Impact Appraisal of Open Cut Crossing, Alltami Brook

SJ26NE | 723

Sampling Depth	Type	Strength kN/m²	w %	SPT N	Strata Description	Depth	Level	Legend
					Turf over TOPSOIL.	G.L	90.5	
0.3	D		27			0.3	90.2	
0.5-1.0	U(80)	120 R 60	21 17		Firm grey brown becoming light grey mottled light brown silty CLAY.			
1.2	D		20					
1.5-2.0	(U100)	80	13 15			1.5	89.0	
2.2	D		13		Firm-stiff fissured red brown silty sandy CLAY with rock fragments and gravel.			
2.5-3.0	(U130)	65	5 13					
3.2 3.3	D D		13 13			3.3	87.2	
3.5-4.0	(U140)		13					
4.2	D		14		Firm-stiff dark grey brown silty sandy CLAY with rock fragments and gravel.			
4.5-5.0	U(100)	45	19 14					
5.3	D		20					
5.5-6.0	U(93)	35	13 17 17			5.7	84.8	
5.8	D				Dark grey brown SILT.	5.9	84.6	
6.0-6.5	C.B		49	136				
6.7	D							
7.0-7.5	C.B			34	Very dense grey green, brown, red, well rounded and angular silty sandy GRAVEL of sandstone, mudstone, quartzite etc.			
8.0	D							
8.5-9.0	C.B			40				
9.0-9.3	S.T.D.D		10	200+		8.9	81.6	
Drill Run	Fluid Return	Core Recovery	F.I.	R.Q.D.	See Over.			
9.3	100%	100%			Continued from 10.0m	10.0	80.5	

Drilling

Type	From	To	Size	Fluid
Shell and Auger	G.L.	9.3	0.15	-
Rotary Core	9.3	10.0	0.07	Water

Ground Water

Struck	Behaviour	Sealed	Date	Hole	Cased	Water
NIL			4.4.75	-	-	-
			7.4.75	8.0	8.0	NIL
			7.4.75	9.3	9.0	NIL

Remarks Rock chisel used from 5.9 - 7.0 (2.25 hours), and 8.9 - 9.3 (1 hour)
Water added to Borehole G.L. - 8.0

Borehole Record

exploration associates

Project Clwyd County Council
Hawarden By-Pass

Section No.1 Chainage 2265

Contract S1118

Borehole 5
Sheet 1 of 2

SJ 26 NE/723

Sampling: Drill Run	Fluid Return	Properties: Core Recovery	FI	RQD	Strata: Description	Depth	Level	Legend
					Continued from 10.0m	10.0	80.5	
10.8	100%	100%			Faintly weathered grey medium hard - hard SILTSTONE. Occasional thin bands of moderately weathered grey fine sandstone.			
12.3	100%	100%						
13.8	100%	100%			Faintly weathered grey medium hard MUDSTONE.	12.9	77.6	
14.5	100%	71%				14.5	76.0	
					End of Borehole			

Drilling

Type	From	To	Size	Fluid
Rotary Core	10.0	14.5	0.07	Water

Ground Water

Struck	Behaviour	Sealed	Date	Hole	Cased	Water
			7.4.75	14.5	12.0	G.L.

Remarks

Borehole Record

exploration associates

Project Clwyd County Council
Hawarden By-Pass

Section No.1

Contract S1118

Borehole 5
Sheet 2 of 2

SJ26NE30

SJ 26 NE 30 2795 6753 Near Ewloe Wood 1" no. 108 Block C

Surface level +84 m
Water not encountered
Shell and Auger, 203 mm diameter
October 1979

Overburden 0.5 m
Mineral 4.3 m
Waste 9.3 m
Bedrock 0.4 m+

LOG

Geological classification	Lithology	Thickness m	Depth m
	Soil, clayey, stony	0.5	0.5
Glacial Sand and Gravel	'Clayey' to 'very clayey' gravel Gravel: coarse and fine, mainly subrounded sandstone and quartzite Sand: medium	4.3	4.8
Till	Clay, grey, stony	9.3	14.1
Coal Measures	Sandstone, buff	0.4+	14.5

GRADING

Mean for deposit percentages: Fines	Sand	Gravel	Depth below surface (m)	percentages: Fines	Sand			Gravel		
				-1/16	+1/16 -1/4	+1/4 -1	+1 -4	+4 -16	+16 -64	+64 mm
18	37	45	0.5-1.5	19	12	17	4	19	26	3
			1.5-2.5	13	4	28	7	19	23	6
			2.5-3.5	12	3	26	8	17	22	12
			3.5-4.5	27	11	22	9	16	13	2
			4.5-4.8	No grading data available						
			Mean	**18**	**8**	**22**	**7**	**18**	**21**	**6**

COMPOSITION

Depth below surface (m)	percentages by weight in +8 mm fraction: Quartz	Quartzite	Greywacke	Sandstone	Limestone	Siltstone	Mudstone	Igneous	Chert, Flint, etc.
2.5-4.5	1	27	trace	29	8	11	2	22	trace

Institute of Geological Sciences

Industrial Minerals Assessment Unit

BOREHOLE RECORD SHEET

Registration Number

6 in. quarter sheet: SJ26NE 6 — Accn. no.: 30 10 — Suffix: 14

Temp. No. 8

Borehole diam. 203 mm

Water struc[redacted]

Remarks: NGR 2795 6753

Classification	Thickness (m)	Lithology
OVERBURDEN	0·3	SOIL
MINERAL	4·5	CLAYEY SANDY GRAVEL
WASTE	9·3	PEBBLY CLAY
BEDROCK	0·4	SANDSTONE

Lithostrat. Code	Description	Thick^{n} (m)	Depth to base (m)	Sample No.
SOIL	Soil: Medium brown clayey, slightly sandy soil, with some pebbles of qtz, qtzite and sandstone, large proportion of qtz	0·3	0·3	
	Clayey Sandy Gravel: Red brown, Pebbles of SR sandstones, SR greywacke qtzites, trace volcanics and qtz. Sand: red brown medium/fine Gravel: medium to fine.		W/A 0·5 B 1·5	MO 213
			W/A 1·5 B 2·5	MO 214
			W/A 2·5 B 3·5	MO 215
			W/A 3·5 B 4·5	MO 216
		4·5	4·8	
	Pebbly clay: grey, stiff with SR/SA fragments of shale, carbonaceous material and siltstones, clay is calcareous	2·2	7·0	

Lithostrat. Code	Description	Thick^n (m)	Depth to base (m)	Sample No.
			7.0	
	Pebbly clay: similar to above but brown coloured. very calcareous, with SR/SA pebbles of siltstones, qtzites, lst and volcanics, buff qtzites sandstones. Very varied lithologies.	7.1	14.1	
	Sandstone: (bedrock) Buff sandstone carboniferous.	0.4	14.5	

IGS 2104 (2008) 3000 12/77