

Global Centre of Rail Excellence (GCRE)

Ground Investigation Report

Walters Group

7 February 2023

GCRE001-AWJV-00-XX-RP-GE-00002



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1. Introduction

1.1. Scope and objectives of the report

Atkins Limited (Atkins), part of the SNC-Lavalin Group, has been commissioned by Walters Group as their designer to undertake the detailed design of proposed earthworks for the redevelopment of the Nant Helen site, near Onllwyn, and Onllwyn Washery area as the Global Centre of Rail Excellence (GCRE), a rolling stock and rail infrastructure testing facility.

As part of these works, a Ground Investigation Report (GIR) has been prepared in accordance with CD 622 'Managing Geotechnical Risk' [1], the objectives of which are to:

- Summarise any existing information regarding the site.
- Outline the works associated with the latest Ground Investigation (GI).
- Establish a ground model, conceptual site model (CSM), and geotechnical parameters based on the available information.
- Identify geotechnical and geo-environmental risks.
- Undertake an engineering assessment for the proposed works. Complete generic quantitative risk assessments considering soils, controlled waters and ground gases.

Arup were previously commissioned by GCRE Ltd to produce a GIR detailing interpretation of the ground and groundwater conditions at the site and to support the discharge of planning conditions. The Arup GIR [2] has been referenced in the production of this report, however, additional work was undertaken which includes:

- A detailed site walkover of areas anticipated to be of particular geotechnical risk.
- The development of earthwork zones, with specific ground models developed.
- Derivation of geotechnical parameters for design.
- Completion of a detailed Mining Risk Assessment.
- Revision and development of the sites CSM based on active planning permissions.

1.2. Description of the project

1.2.1. Site Description

The site is located immediately to the south of Abercraf, approximately 20 km northwest of Swansea, south Wales. The site, as indicated in Figure 1-1, comprises of two areas: the 'Land at Nant Helen' and 'The Washery'.

The 'Land at Nant Helen' refers to the central body of the site located at the Celtic Energy Nant Helen opencast site and contains the proposed rail test track, centred on approximate Ordnance Survey (OS) coordinates 282643E, 211288N. The Celtic Energy Nant Helen Extension opencast mine was active until very recently but is now in the process of being restored. Other parts of the proposed 'Land at Nant Helen' have been mined through opencast techniques in the past and have since been restored to their current levels.

The 'washery' refers to the extension of the site to the southeast incorporating the Onllwyn Washery, centred on approximate OS coordinates 284734E, 210533N. The Onllwyn Washery comprises several buildings, conveyer belts and material sorting facilities.

1.2.1. Proposed Scheme

Proposals comprise the development of a rail testing, storage, and maintenance facility at the Nant Helen opencast coal mine currently owned and operated by Celtic Energy.

The proposal for the Washery comprises the development of an earthwork for the GCRE rail depot and storage facility. This development consists of the installation of multiple sidings for train stabling, as well as inspection and maintenance sheds, fuelling roads and carriage wash facilities. In addition to the track elements, the southern area of the colliery wash site is proposed to include several buildings forming an Innovation Hub as well as further industrial/commercial developments.

1.2.2. Planning Status

Celtic Energy is required to restore the Nant Helen site in accordance with regulatory requirements and agreements with Powys County Council (PCC) and Neath Port Talbot Council (NPTC).

The Nant Helen Complementary Earthworks scheme, which includes the creation of 17.5 m wide plateaus on the site, has planning approval with several pre-commencement conditions still to be discharged.

Following Welsh Government (WG) discussions with both PCC and NPTC, the local authorities expressed a desire to develop a GCRE earthworks proposal for the Nant Helen site, in advance of the detailed rail project. This project was known as the Nant Helen Complementary Earthworks Scheme and an application was submitted for this earthworks scheme, seeking consent for the earthworks for two testing tracks, and the earthworks for a link from the existing railway in the south of the site which currently services the Onllwyn Washery to both councils. This earthwork full planning permission was submitted, and approval granted in July 2020. Following on from the Complimentary Earthworks Application a further Application was made for outline permission for the GCRE scheme.

This latter application was for the “Development of a Global Centre of Rail Excellence”, with proposals comprising two rail tracks on sleepers set in a ballast track foundation, associated Overhead Line Equipment (OLE) and all other required supporting infrastructure. The two test tracks of loop configuration are the outer loop (OL), which is an electrified high speed rolling stock test track of 6.9 km in length and the inner loop (IL), which is an electrified low speed infrastructure test track of 4.5 km. A vehicle access track is proposed adjacent to the proposed rail loops.

Planning conditions that relate to assessment of land quality risks, their status and the stakeholder responsible for obtaining information to address them are summarised in Table 1-1 below.

Table 1-1 - Planning Application and Land Quality Condition Summary

Planning Decision:	20/0738/ FUL	Local Planning Authority	Powys County Council (PCC)	Entity Obtaining Information for condition.	Status
Description:	Earthworks Planning Permission: Construction of complementary restoration earthworks to create two looped landform platforms (part in cutting and part on embankment) with associated drainage infrastructure and areas of landscaping and habitat creation to create a flexible and adaptable area of land that could be used for a variety of uses including agriculture, nature conservation, leisure, tourism and industrial, research and development/business uses (potentially including a proposed rail testing, research and development and storage facility).				
Condition and Summary					
15	Condition requires preliminary investigation and assessment of nature and extent of contamination. Requires Desk Study, site reconnaissance, initial conceptual site model (CSM) and preliminary risk assessment (PRA).			Arup in discussion with LPAs	Not discharged
16	Completion of site investigation into nature and extent of contamination, and reporting. To include appraisal of remedial options and identification of appropriate remedial options. Methodology of site investigation to be submitted to and approved in writing by the local planning authority prior to commencement.			Arup in discussion with LPAs	Not discharged
17	Preparation of detailed remediation scheme.			Atkins	Not discharged
18	Implementation of remediation scheme and notification to LPA that it has commenced.			TBC	Not discharged

19	Remediation monitoring and maintenance scheme.			TBC	Not discharged
20	Reporting, investigation and remediation of any unidentified contamination.			TBC	Not discharged
Planning Decision:	21/0559/OUT	Local Planning Authority	PCC	TBC	
Description:	GCRE Planning Permission: Development of a Global Centre of Rail Excellence, comprising of two test tracks of loop configuration being an electrified high speed rolling stock test track of 6.9km in length and an electrified low speed infrastructure test track of 4.5km, with overhead line equipment (OLE) and dual platform station test environment; together with operations and control offices (including staff accommodation and welfare), shunter cabins (2 no.), research and development, education and training, rolling stock storage sidings and maintenance/cleaning/decommissioning facilities; associated, drainage, internal vehicular accesses, branch line rail connection, staff and visitor car parking, lighting, electrical infrastructure (including substations and lineside shore supplies and transformers), fencing (perimeter security, acoustic and stock proof), land reformation and hard and soft landscaping, together with demolition of existing buildings/structures			TBC	Not discharged
Condition and Summary				TBC	Not discharged
21	Requirement to complete preliminary investigation and assessment of the nature and extent of contamination in accordance with agreed phasing plan (Phasing Conditions 7). Requires Desk Study, site reconnaissance, initial conceptual site model (CSM) and preliminary risk assessment (PRA).			TBC	Not discharged
22	Completion of site investigation into nature and extent of contamination, and reporting in accordance with agreed phasing plan (Phasing Conditions 7). To include appraisal of remedial options and identification of appropriate remediation options and mine gas risk assessment. Methodology of site investigation to be submitted to and approved in writing by the local planning authority prior to commencement.			TBC	Not discharged
23	Preparation of detailed remediation scheme.			TBC	Not discharged
35	Implementation of remediation scheme and notification to LPA that it has commenced.			TBC	Not discharged
36	Remediation monitoring and maintenance scheme.			TBC	Not discharged
37	Reporting, investigation and remediation of any unidentified contamination.			TBC	Not discharged
48	No part of development to be brought into beneficial use until declaration by a competent person that			TBC	Not discharged

	remediation/mitigation needed to address risks posed by coal mining activity have been addressed.				
Planning Decision:	P2020/0362	Local Planning Authority	Neath and Port Talbot Council (NPTC)		
Description:	Earthworks Planning Permission: Construction of complementary restoration earthworks to create 2 looped landform platforms (part in cutting and part on embankment) with associated drainage infrastructure and areas of landscaping and habitat creation to create a flexible and adaptable area of land that could be used for a variety of uses including agriculture, nature conservation, leisure, tourism and industrial, research and development/business uses (potentially including a proposed rail testing, research and development and storage facility).				
Condition and Summary					
10	Requires CEMP to be prepared.			Atkins	Not discharged
13	Condition requires preliminary investigation and assessment of nature and extent of contamination. Requires Desk Study, site reconnaissance, initial conceptual site model (CSM) and preliminary risk assessment (PRA).			Arup in discussion with LPAs	Not discharged
14	Completion of site investigation into nature and extent of contamination, and reporting. To include appraisal of remedial options and identification of appropriate remedial options. Methodology of site investigation to be submitted to and approved in writing by the local planning authority prior to commencement.			Arup in discussion with LPAs	Not discharged
15	Preparation of detailed remediation scheme.			Atkins	Not discharged
16	Implementation of remediation scheme and notification to LPA that it has commenced.			TBC	Not discharged
18	Remediation monitoring and maintenance scheme.			TBC	Not discharged
19	Reporting, investigation and remediation of any unidentified contamination.			TBC	Not discharged
24	Requirement to submit any additional remediation requirements arising from unidentified contamination to the LPA.			TBC	Not discharged
Planning Decision:	P2021/0327	Local Planning Authority	NPTC		

Description:	GCRC Planning Permission: Development of a Global Centre of Rail Excellence, comprising of two test tracks of loop configuration being an electrified high speed rolling stock test track of 6.9km in length and an electrified low speed infrastructure test track of 4.5km, with overhead line equipment (OLE) and dual platform station test environment; together with operations and control offices (including staff accommodation and welfare), shunter cabins (2 no.), research and development, education and training, rolling stock storage sidings and maintenance/cleaning/decommissioning facilities; associated, drainage, internal vehicular accesses, branch line rail connection, staff and visitor car parking, lighting, electrical infrastructure (including substations and lineside shore supplies and transformers), fencing (perimeter security, acoustic and stock proof), land reformation and hard and soft landscaping, together with demolition of existing buildings/structures.		
Condition and Summary			
21	Requirement to complete preliminary investigation and assessment of the nature and extent of contamination in accordance with agreed phasing plan (Phasing Conditions 7). Requires Desk Study, site reconnaissance, initial conceptual site model (CSM) and preliminary risk assessment (PRA).	TBC	Not discharged
22	Completion of site investigation into nature and extent of contamination, and reporting in accordance with agreed phasing plan (Phasing Conditions 7). To include appraisal of remedial options and identification of appropriate remediation options and mine gas risk assessment. Methodology of site investigation to be submitted to and approved in writing by the local planning authority prior to commencement.	TBC	Not discharged
23	Preparation of detailed remediation scheme.	TBC	Not discharged
38	Implementation of remediation scheme and notification to LPA that it has commenced.	TBC	Not discharged
39	Remediation monitoring and maintenance scheme.	TBC	Not discharged
40	Reporting, investigation and remediation of any unidentified contamination.	TBC	Not discharged
48	No part of development to be brought into beneficial use until declaration by a competent person that remediation/mitigation needed to address risks posed by coal mining activity have been addressed.	TBC	Not discharged

NB: All conditions require submission to the LPA for approval before development/beneficial use can commence.

1.3. Geotechnical Category

Proposals comprise geotechnical earthworks and activities with no exceptional geotechnical risks. Based on the current scheme proposals and a review of the currently available information, it is determined that the

scheme will fall within Geotechnical Category 3 as defined by Eurocode 7 [3] in accordance with the guidance given in Part 5 of CD622 [1].

1.4. Other relevant information

None.

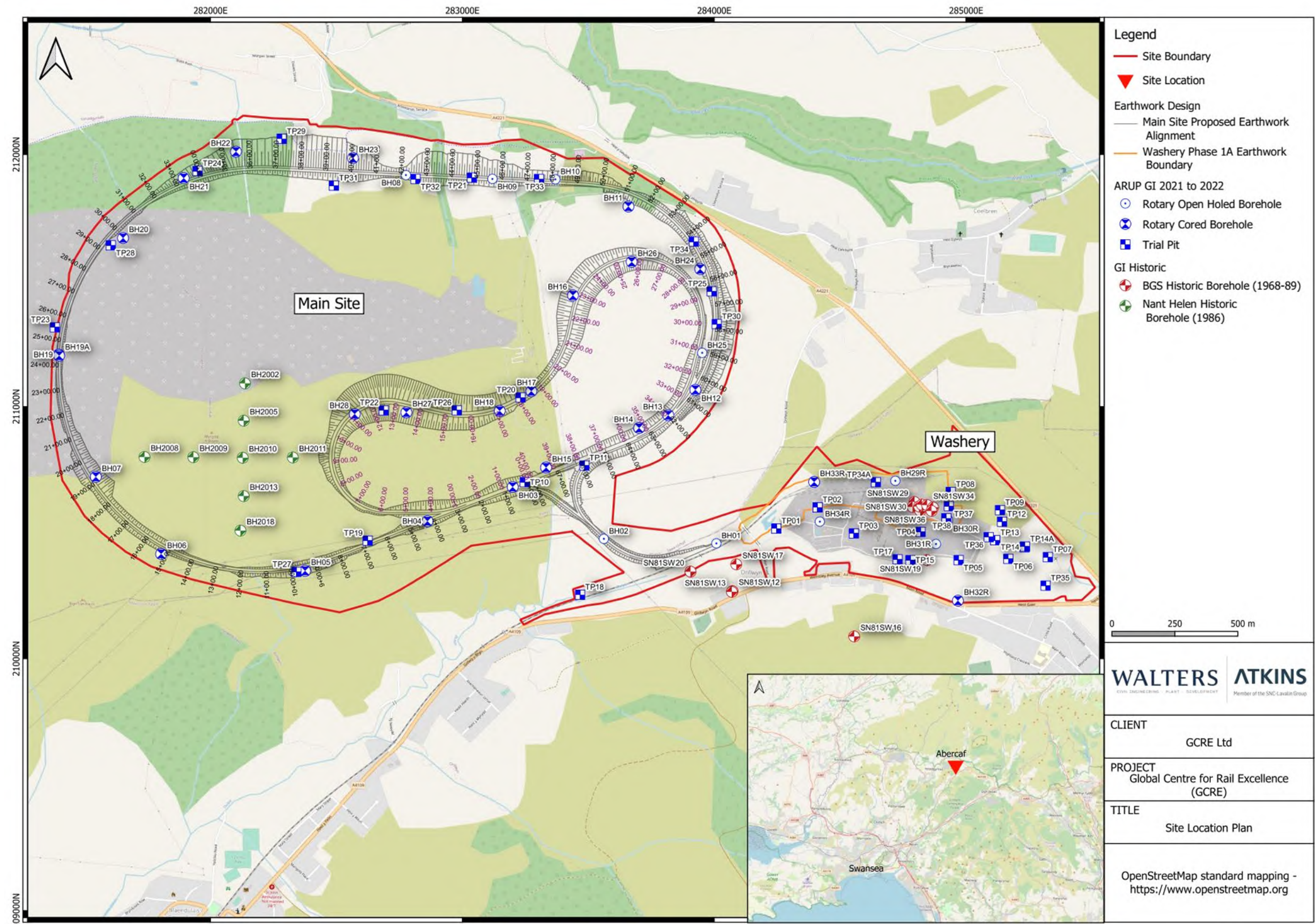


Figure 1-1: Site location plan.

2. Existing Information

2.1. Previous Work

The following sources of information relating to previous work for the project have been reviewed in preparation of this report:

- Land at Nant Helen and Onllwyn Coal Washery, Geotechnical and Geo-environmental Desk Study, Arup, 2018 [4]: A desk study for the proposed site near Onllwyn in Powys, including a summary of the site history and ground conditions, including topography, geology, hydrogeology, hydrology, and coal mining legacy. Included a preliminary Conceptual Site Model, preliminary engineering assessment, summary of the identified geotechnical and geo-environmental risks and opportunities and recommendations for further work.
- Detailed Mine Workings Study, Arup, 2020 [5]: An addendum to the mining section of the desk study presenting a detailed review of the available mine abandonment plans, a more detailed assessment of the subsidence risks across the site and the available information on the extent and depth of opencast backfill. Provided recommendations for targeted intrusive ground investigation for areas identified to be at significant risk of subsidence as a results of mining activity.
- Environmental Statement, Arup, 2020 [6]: An environmental statement document prepared to support the full planning application submitted to Powys County Council (PCC) and Neath Port Talbot County Borough Council (NPTCBC).
- Ground Investigation Specification, Arup, 2021 [7]: Specification for ground investigation works at the site in accordance with UK Specification for Ground Investigation [8]. The specification included works (geophysical, trial pitting and rotary open holes) to target the risk areas identified by the Detailed Mine Workings Study.
- Ground Investigation Factual Report, Quantum Geotechnical Limited, 2022 [9]: Factual report detailing ground investigation fieldwork undertaken across the site between 15 November 2021 and 19 January 2022. Includes an account of the fieldworks undertaken, descriptions of strata encountered and subsequent laboratory test results.
- Ground Investigation Report, Arup, 2022 [2]: Geotechnical and geo-environmental interpretation of the ground and groundwater conditions encountered in the ground investigation undertaken by Quantum Geotechnical Limited and to support the discharge of the project planning conditions. Notably, no characteristic geotechnical parameters are proposed within this report. This report was not written in accordance with CD622 hence the requirement for this Atkins report.

2.2. Topography

The ground level generally rises inwards from the site boundaries towards the centre of the Land at Nant Helen. The highest point is approximately 335 m Above Ordnance Datum (AOD) located at the centre of the 'overburden storage area', in the southwest portion of the Land at Nant Helen. The overburden storage area is understood to be spoil heaps placed above the natural ground level. The maximum height of the spoil material reaches approximately 80 m above the natural ground surface.

The ground level falls most significantly along the northern part of the Land at Nant Helen to a minimum of approximately 200 m AOD. While the ground level falls to approximately 240 to 260 m AOD at the eastern, southern, and western extents of the Land at Nant Helen.

The Washery site is located at a lower elevation of approximately 230 m AOD, with mounds in the north and south that respectively peak at 240 m AOD and 245 m AOD. Changes in topography in the washery area are a result of the colliery spoil being historically deposited on the site. The washery forms an elevated saddle between the hill of the main to the north and hills to the south, the valley formed by these two hillsides then falls away to the east and west of the washery.

2.3. Land Use

2.3.1. Historical Land Use

Historical features and constraints have been identified through a review of historical mapping sets (1876 to 2022) and historical aerial photography (1985 to 2021), purchased from Groundsure [10]. The mapping sets cover a range of scales from 1:1,250 to 1:10,560. This was supplemented through the review of aerial photographs acquired from Groundsure [11] and publicly available online satellite imagery.

The historical land use has been considered based on two distinct zones of historic and proposed land use:

- Onllwyn Coal Washery, referred to as the Washery, is located to the south-east of the Land at Nant Helen and has an area of circa 54 Hectares (Ha)
- Nant Helen opencast mine and surrounding formerly restored opencast workings, referred to as the Land at Nant Helen, is located northwest of the washery and covering an area of circa 420 Ha.

The site history is summarised in Table 2-1.

Table 2-1: Summary of historical development.

Mapping Epoch	On-Site	Off-Site
Onllwyn Coal Washery (Southern portion of wider site)		
1876 to 1877	The Onllwyn Coal Washery shows extensive evidence of ground workings prior to the earliest mapping epoch. These workings are labelled as 'old quarries'. The majority of the Washery is labelled as being marshy. Within the east of the Washery are two features labelled Old Coal Levels. Several ponds, land drains and a spring are shown and the eastern boundary of the Washery is formed by a stream named the Camnant which flows to the north. A branch line from the Neath and Brecon Railway runs through the centre of the Washery (east to west). Coal workings from the off-site Onllwyn Pit coal extend on-site in the south-east. Several tracks cross the Washery and two unlabelled buildings are shown in the east. Onllwyn Station, a post-office and Public House (Hallway House) are located surrounding the railway line. An old coal pit is present north of the railway. A tramway enters the Washery from the west and runs west to east before turning to the south to run parallel to the Washery's eastern boundary.	Most of the north, south and east of the Washery is open countryside consisting of moorland and a number of old quarries, coal, gravel, and clay pits. Land to the north of the Washery is an area of marsh land called Gors Llwyn. Land to the northeast is labelled as Cefy-y-byrle and several residential / farm buildings are present with a railway line running east to west also present, additionally an Old Level (Ironstone) is labelled along with several quarries. To the east of the Washery is a stream named the Camnant and a spring is located south of the Washery. To the south of the Washery is the village of Onllwyn, the Onllwyn Coal Pit and an independent chapel.
1900 to 1905	The Washery is predominantly unchanged. The Onllwyn Colliery has expanded and extends into the south of the Washery. Dyrm Colliery is now present on land to the north of the railway line in an area with several old shafts and building. A new	The majority of the north and east of the Washery remains undeveloped and unchanged. Circa 20m north of the Washery is an old quarry, with a spring, circa 240m north. South of the Washery has undergone some development with two 'Old Coal

Mapping Epoch	On-Site	Off-Site
	section of tramway connects a spoil heap to an off-site feature labelled Old Tramway. The Neath and Brecon railway and the tramway are still present and have expanded to cover a wider corridor with additional lines and tram tracks running in parallel to each other. A spring is labelled to the south of the railway line and this appears to be feeding a stream that flows to the west and is later labelled as the Dulais.	Levels' and an Old Quarries' present. Additionally, a spring is still present south of the Washery.
1914 to 1921	The tramway that was present is now called the Mineral Railway. Onllwyn Colliery continues to expand in the south and east of the Washery. The Dyrn Colliery is now renamed as the Dulais Colliery and the number of buildings associated with it has expanded. Additionally, on-site there are two rises, one in the centre of the Washery and one on the southern boundary.	To the north and east of the Washery, no major changes have occurred. The town of Onllwyn continues to develop / expand and Onllwyn Colliery continues to develop to the south. Further old quarries, levels and old drift are labelled to the south and southwest.
1948	The Onllwyn Colliery is still present. Land that was not previously in use in the eastern half of the Washery is now occupied by several railway sidings which are associated with a brickworks, assumed 'Washery' infrastructure, and localised spoil heaps. Disused shafts, levels and mines are labelled to the north-west. In the north, an area is now labelled as a colliery with an aerial ropeway present.	Expansion of Onllwyn to the south of the Washery continues, with notable new uses including a second chapel, a cemetery and recreation ground.
1964 to 1965	Dulais Colliery buildings and features no longer shown. Further development has occurred within the Washery with demolition and replacement of several structures now labelled as works. The brickworks from 1948 is now marked as a works and a further works is marked north of the railway lines. Large portions of the Washery are now shown as being covered by 'slag heaps' [Sic].	Wembley Avenue now borders the south of the Washery boundary. To the south, the recreation ground has been marked as a football ground. An area of spoil is labelled as a refuse tip approximately 250 m south / southwest of the Washery.
1984/1993	A disused tip is present within the south-eastern quadrant of the site and continues to the south-west beyond the site boundary. Tanks are labelled in the centre of the Washery east of the railway tracks, with three ponds associated with them.	Refuse tip to south / south-west now labelled as disused. To the east of the football ground is now a tennis court. A further tip is now present immediately adjacent to the south-eastern boundary.

Mapping Epoch	On-Site	Off-Site
		Residential land to the north now includes a playground area that immediately adjoins the Washery.
Land at Nant Helen - Nant Helen Coal Mine (northern portion of wider site)		
1876 to 1877	The southern portion of the Land at Nant Helen is undeveloped moorland with an old quarry in the south-west and the Cwm Mawr old coal level entrance in the southeast. The north contains the Aber-craf Colliery which is surrounded by numerous old quarries, old coal levels and active coal levels, and works / spoil heaps associated with the off-site to the north International Anthracite Colliery. In the north of the Land at Nant Helen, a reservoir is present and the Neath and Brecon Railways runs west to east adjacent to the northern boundary. Additionally, eight unnamed streams originate from within the northern portion of the Land at Nant Helen and flow to the north before discharging into the River Tawe. A tramway (extending into the Washery) runs west to east through the south of the Land at Nant Helen.	To the south of the Land at Nant Helen is an area of developed land that includes the Onllwyn Coal pit and the Washery whose history is discussed above. The Washery contains Onllwyn Station and associated train track, a post office and Public House. The tramway and northern section of the Neath and Brecon Railway noted on-site extends off-site to the east. Several old quarries are present to the east. To the west, an old ironstone pit is present. Old coal and clay pits are also present to the east. The Neath and Brecon railway runs east to west adjacent to the northern site boundary. International Anthracite Colliery extends across the northern boundary. Approximately 200 m to the north-west, the Nant Llech (stream) flows east to west, beyond this 500 m to the north flows the River Tawe. The River Dulais originates in the Washery area and flows east from the site.
1900-1903	The Dyrm Colliery is present within the site boundary and is located north of the tramway, which is still present on-site. The collieries in the north develop and expand, including development of buildings labelled the International Purification Works (Sewage and Water) and an engine house. A feature labelled as an Old Tramway connects some previously unidentified Old Levels and an Air Shaft.	To the west, an old mining shaft is noted indicating historical mining in this area. To the south, the tramway off-site running to the east is now noted as 'Old Tramway'. To the east, old levels and tanks associated with the railway are shown.
1914-1921	The Dyrm colliery is now marked as the Dulais Colliery and has expanded with several new structures to the north of the tramway. By 1914, the Glynlllich Colliery is labelled on-site to the north, a previously labelled Old Tramway is no longer shown and has been replaced by a tramway that's runs to the northeast to from the Glynlllich Colliery to the Neath and Brecon Railway. Several rises are present on-site.	Development has occurred in Onllwyn with a reservoir present. Several rises and old levels are labelled to the east of site.

Mapping Epoch	On-Site	Off-Site
	The southern Tramway is labelled as the Old Tramway. A further engine House is present near the International Anthracite Colliery in the north of the site. Further small sections of tramway are shown in relation to coal workings in the north.	
1948	The Dulais Colliery is now labelled as disused and all the coal mining related infrastructure that was previously shown is no longer shown. A 'slag tip' [Sic] is labelled to the east of Abercraf Colliery. Tramways in the north of the site have been removed and are no longer labelled.	Onllwyn town continues to develop in the south. The town of Coelbren is labelled to the east.
1964-1965	The old tramway is marked as the Dismantled tramway. Structures and buildings associated with collieries in the north Abercraf Colliery and Glynlllich) are present, however, surrounding levels are noted as disused. A 'sink' (area of surface water infiltration) is present in the north-west of the site.	Colliery spoil is shown placed approximately 100 m to southwest.
1985-1988	The branch line of the Neath and Brecon railway running through the north of the site is marked as dismantled from 1987 onwards. Virtually all buildings in the north of the site associated with the former collieries have been demolished. Disused workings are shown in the east of the site. Aerial photos from 1985 are of too poor a resolution to show on-site features.	A tip (disused) is labelled adjacent to the northern boundary and the Neath and Brecon railway in the north is now noted as a dismantled railway.
2001-present	Most recent mapping does not show details of the Land at Nant Helen. However, a number of reservoirs and water bodies are labelled across the Land at Nant Helen. Aerial photos from 2006 to 2021 show an area of opencast coal mining in the northwest of the Land at Nant Helen, with stockpiles of coal on the surface. Access tracks connect the opencast area to the wider Land at Nant Helen and Washery to the south. A hard surface area with car parking and three buildings is present in the centre with a further open yard area with plant, sheds and four aboveground storage tanks (ASTs). An additional building is present 1.2 km to the west of the main compound. A series of land	Most recent mapping does not show detail of off-site developments.

Mapping Epoch	On-Site	Off-Site
	drains, lagoons and water management systems extending from the opencast area to the south. The south-western portion of the Land at Nant Helen contains three tiers of bunded overburden.	

2.3.2. Current Land Use

The present-day Washery site consists of a core of industrial land, where the washery is based, concentrated around a network of site access roads and railway land (sidings and train heads) that connects to the Neath and Brecon Line at the western edge of the site. This industrial use is surrounded to the east, north and west by open land that comprises of colliery spoil / slag heaps (slag heaps are labelled in historical mapping but this may be an error on the part of the Ordnance Survey when describing colliery spoil) vegetated with rough grassland, areas of scrub and deciduous woodland. The following clusters of water storage lagoons are present within the Washery:

- Eastern most cluster located adjacent to the site boundary with the A422.
- Central cluster is located adjacent to the washery building.
- Western cluster at the point mineral railway connects to the main railway line.

The central area of the Washery comprises:

- A network of access roads that are linked to the A4221 in the east, where a weighbridge is located, and Onllwyn Road in the west.
- Areas of car parking.
- Waste storage areas.
- Railway land forming a Y shape.
- Series of buildings and overhead conveyor belts associated with the washery for the processing and washing of coal.
- Former tram way embankment.
- Tanks and lagoons storing water used by the Washery.
- Considerable areas of stockpiled coal.
- Storage yards where coal is packaged and transferred for transport by road.
- It has been assumed, but not confirmed that, areas used for the maintenance of vehicles are also present and that on-site fuel storage is occurring.

The Land at Nant Helen consists of the Celtic Energy Nant Helen opencast mine and is an active opencast coal mine. The Nant Helen extension, located in the northwest of the Land at Nant Helen, is the location of the most recent opencast mining. In this Nant Helen Extension, overburden (natural soils / and rock and Made Ground associated with previous colliery and industrial uses) has been removed and coal excavation is occurring at circa 150 m lower than the surrounding ground surface. Land east and north of the Nant Helen Extension has been subject to several earlier phases of opencast mining and backfilled with previously excavated overburden. The southwestern portion of the Land at Nant Helen has not been subject to opencast mining and contains an 'Overburden Storage Area'. The centre of the site holds a depot where ASTs containing diesel are present. The depot is also used for the repair and maintenance of mining plant. Several ponds and surface drains are present along with a network of access roads and haulage tracks. Areas of the site that are not in active use by the opencast mine are vegetated with a mixture of grassland and scrub, with land to the north of the Nant Helen Extension covered by planted forestry.

2.4. Published Geology

The geology beneath the whole site has been interpreted through a review of published geological sources. These sources include the British Geological Survey (BGS) 1:10,560 geological mapping (sheet SN 81 SW) [12], the BGS 1:50,000 geological mapping (Sheet 231) [13] and the BGS GeoIndex online viewer [14].

Additionally, mining records for the opencast sites have been referenced to inform the interpretation of the geological conditions. A Mining Risk Assessment (MRA) has been undertaken, provided in Appendix C.

2.4.1. Made Ground

Made Ground is indicated to be present across a large proportion of the site by Groundsure data [11].

At the Land at Nant Helen, this is associated with areas of backfilled opencast workings, as summarised below and shown in Figure 2-3:

- Abercraf/Gwaunton opencast coal mine backfill area is located to the north of the site; records indicate a maximum excavation (backfill) of approximately 40 m.
- Onllwyn opencast coal mine backfill area is located to the east of the site; records indicate a maximum excavation (backfill) of approximately 82 m.
- Nant Helen Extension opencast coal mine backfill area is located to the west of the site; records indicate a maximum excavation (backfill) of approximately 150 m.
- Nant Helen opencast coal mine backfill area is located to the centre of the site; records indicated a maximum excavation (backfill) of approximately 130 m.
- Colliery spoil and slag generated by the Onllwyn and Dulais Collieries is present below the majority of the Washery.

At the washery, these areas are likely to be associated with levelling this area for the railway sidings and buildings with areas of Made Ground arising from railway land use and the demolition of previous colliery building.

2.4.2. Superficial Deposits

BGS mapping [14] indicates the presence of small areas of superficial deposits across the site, as shown in Figure 2-2.

Peat, described by the BGS as 'partially decomposed mass of semi-carbonized vegetation which has grown under waterlogged, anaerobic conditions, usually in bogs or swamps' [15], is mapped to the centre of the Land at Nant Helen and to the north and west of the washery.

While Glacial Till, described by the BGS as 'heterogenous mixture of clay, sand and gravel with large cobble and boulder inclusions of various sizes and shapes (diamicton)' [15], is mapped to the south and west of the Land at Nant Helen, the east of the washery and along the northern site boundary. Within the areas of open cast workings, it is anticipated that the mapped superficial deposits may have been excavated and no longer present.

2.4.3. Bedrock Geology

BGS mapping [14] indicates that the site is underlain by South Wales Middle and Lower Coal Measure Formations, as shown in Figure 2-3, which are described as 'grey, (productive) coal-bearing mudstones/siltstones, with seatearths and minor sandstones'. The Geological memoir (Sheet Memoir 231) [16], details that nodular masses of pyrite, up to 0.15m thick, are often present within the Middle and Lower Coal Measures Formations.

Due to the similarity of the Middle and Lower Coal Measure Formations and the difficulty of differentiating them in the field they have been treated as one unit for the purposes of this report.

The 1:10,560 geological mapping [12] typically indicates that the bedrock dips in a west south-westerly direction at angles ranging from between 5° and 15°. However, there are localised variations to this, with several anticlines and synclines shown.

Three named faults, Pwllau Bach Fault, Chapel Fault, and Glyncorrwg Fault (ordered from west to east), are shown on the published geological maps crossing the site with a NNW-SSE strike. Two other parallel unnamed faults which protrude into the northern boundary of the site are also shown, and it is likely that there are other unidentified faults within the site boundary.

2.5. Mining

The site is located within the South Wales Coal Field and is designated as a Development High Risk area by the Coal Authority [17] and has a known extensive history of coal mining, including the current opencast mining. In total, 16No. coal seams have been identified across the site, as indicated in Figure 2-3.

For more detailed information relating to the mining history and risk at the site the Mining Risk Assessment (MRA) report should be referred to in Appendix C or the summary in Section 4.5.

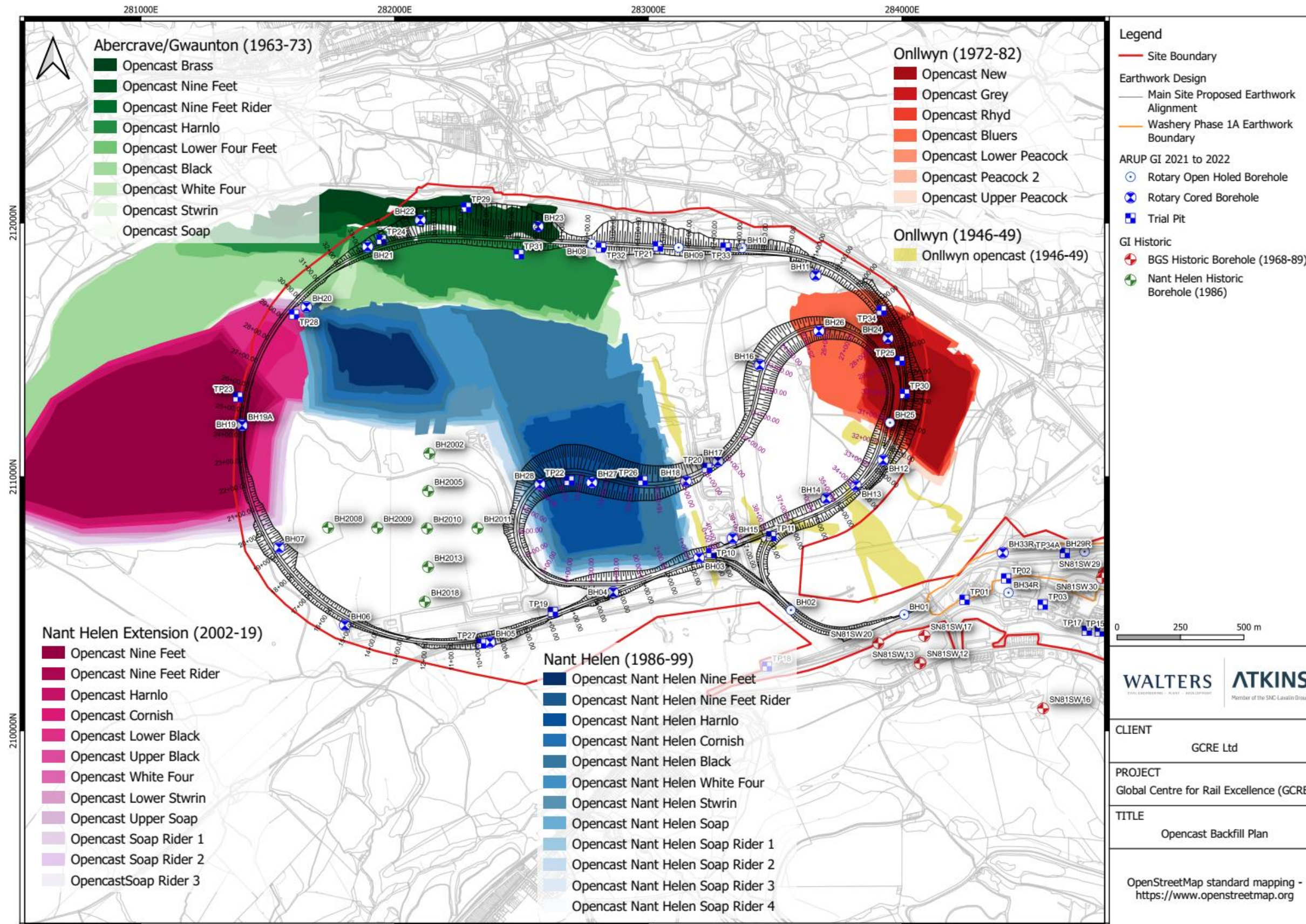


Figure 2-1: Opencast backfill plan.

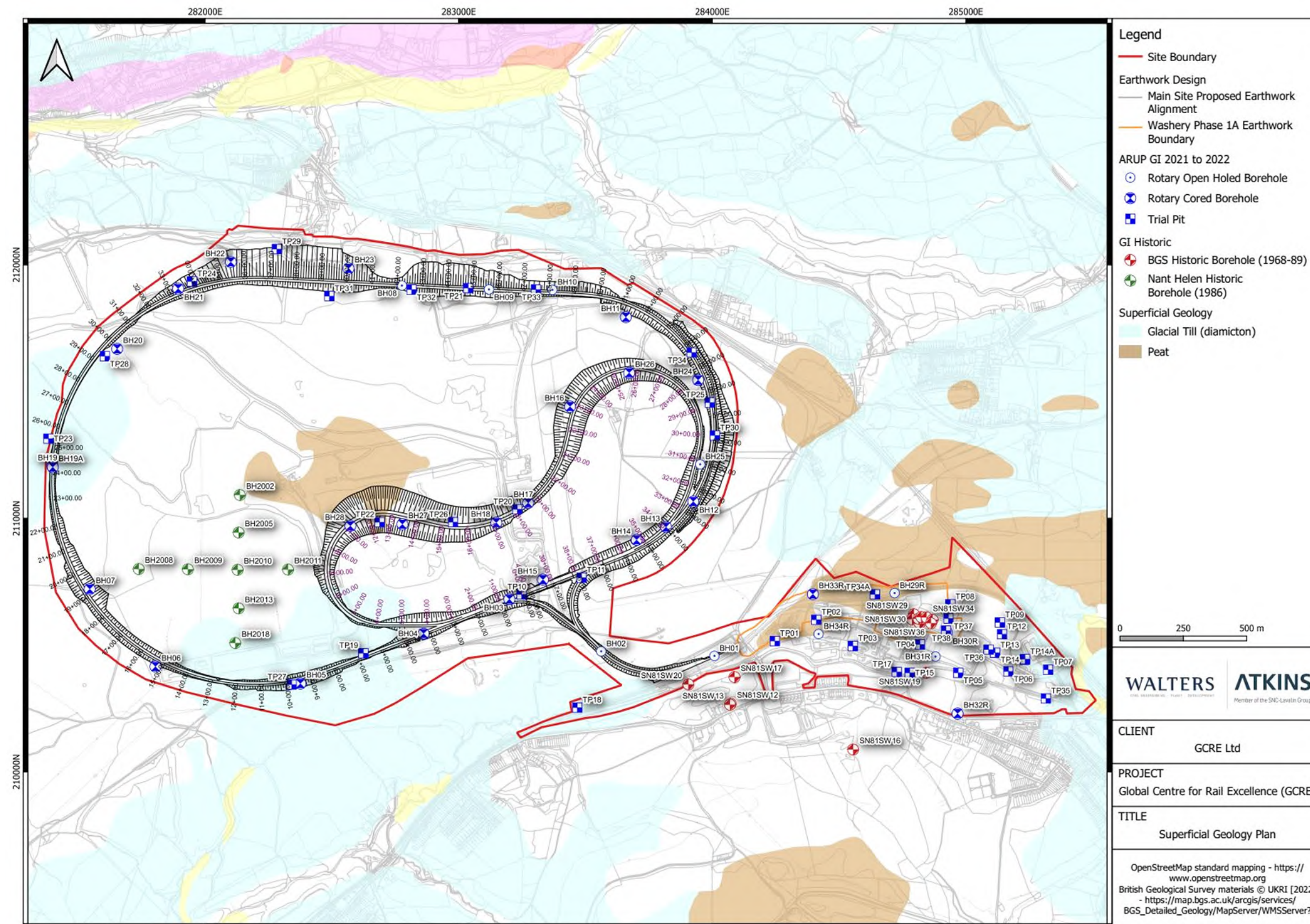


Figure 2-2: Superficial geology plan.

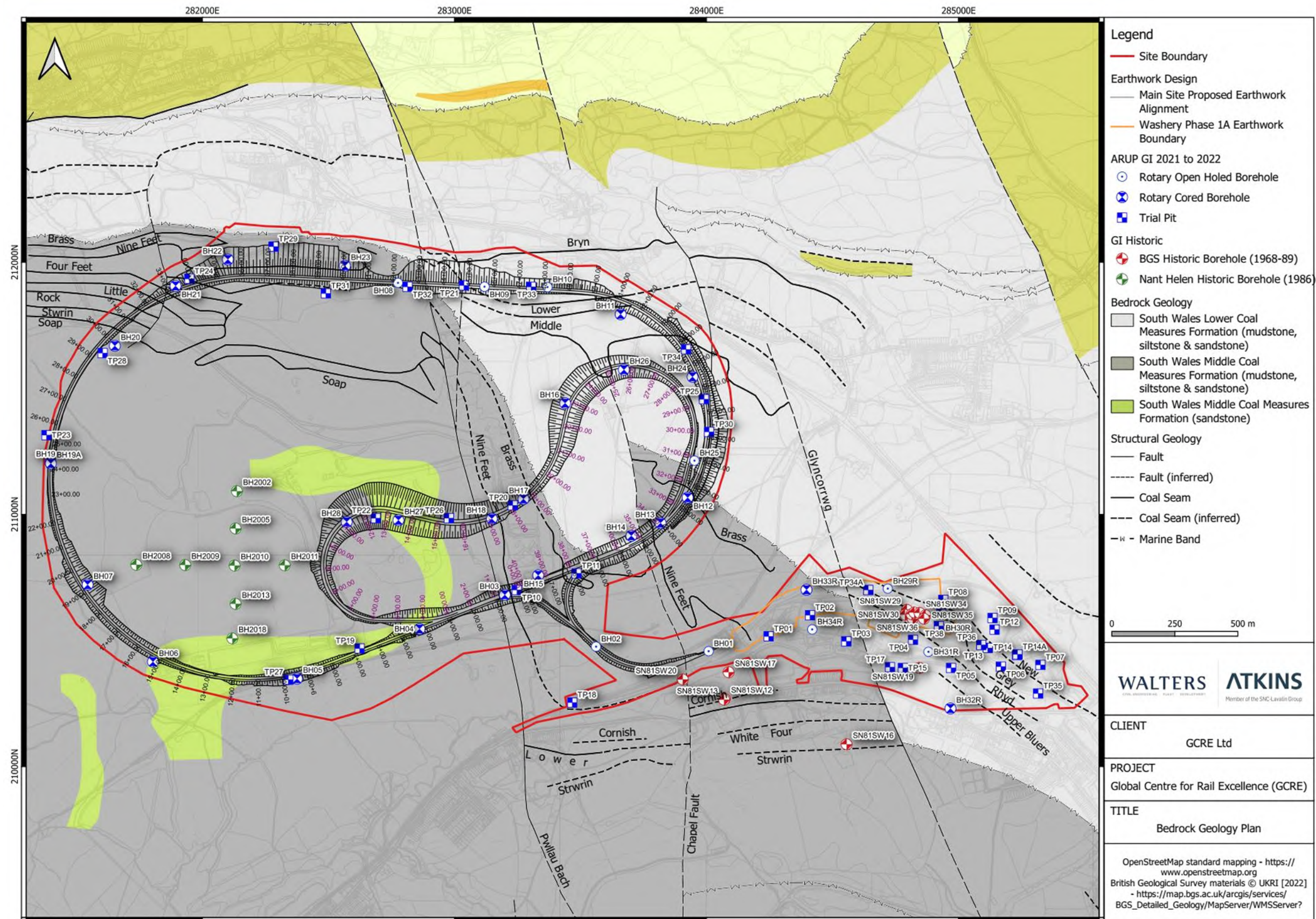


Figure 2-3: Bedrock geology plan.

2.6. Hydrogeology

The following sections present a summary of the hydrogeological regime in the immediate vicinity of the site. Given the limited nature of the GI with respect to the main site, the hydrogeology of the main site is drawn from previous assessments prepared by Arup [4] [2] and Celtic Energy Limited [18].

2.6.1. Aquifer Properties and Classifications

While superficial deposits of alluvium and peat are mapped as being present across the site (Section 2.4), it is considered that the majority of overburden has been removed in proximity to former areas of opencast coal mining, to enable coal extraction.

Glacial Till is classified by the BGS [19] and NRW [20] [21] as a Secondary Undifferentiated aquifer, assigned where it is not possible to attribute either category A or B to a rock type which might previously have been mapped as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.

Glacial Till deposits that remain on-site are understood to comprise predominantly of well graded gravels cobbles and boulders within a low permeability silty clay matrix which limits recharge to, and confines water, with underlying bedrock formations [2]. Where lenses of higher permeability silt and more continuous bands of stratified sand and gravel occur, Atkins agrees with Arup [2] [4] that these may be considered to act as localised perched aquifers but are not considered to alter the role of the strata as a barrier to vertical flow.

The underlying rhythmic sequences of mudstones, siltstones, sandstones, fireclays and coals which make up the South Wales Upper Coal Measures (SWCM) are collectively classified by NRW [20] as a Secondary A aquifer. The permeable siltstones and sandstones are understood to form a multi-layered aquifer system supporting large quantities of water at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers or emerging as springs where basal horizons of subordinate sandstones intersect the ground surface.

2.6.2. Groundwater Vulnerability

The BGS Geoindex [14] indicates there are two groundwater vulnerability designation within the Onllwyn Coal Washery and a further two within 250 m of the site.

The vulnerability classification of these areas are presented in Table 2-2.

Table 2-2: Groundwater Vulnerability Zones.

Geology	Aquifer(s) Type	Vulnerability Classification	Distance from Site	Direction from Site
South Wales Lower Coal Measures Formation – mudstone, siltstone and sandstone	Secondary A Bedrock Aquifer	Medium	On-site	NA
South Wales Lower Coal Measures Formation – mudstone, siltstone and sandstone	Secondary A Bedrock Aquifer	Low	On-site	NA
South Wales Lower Coal Measures Formation – mudstone, siltstone and sandstone	Secondary A Bedrock Aquifer	Medium	180 m	Southwest
South Wales Lower Coal Measures Formation – mudstone, siltstone and sandstone	Secondary A Bedrock Aquifer	Low	180 m	Southwest

2.6.3. Groundwater Source Protection Zones

The Welsh Governments Data Map [22] indicates the site is not within a groundwater source protection zone.

2.6.4. Ground Water Levels

The hydrogeological regime beneath the site is complex, owing to a combination of geological structure, hydraulic properties, historical groundwater control and backfilling of opencast voids.

2.6.4.1. Historical Conditions (Pre-Opencast Mining)

Limited information is available with respect to natural groundwater levels prior to the commencement of operational opencast mining.

It is understood from Arup [2] [4] and Celtic [18] that prior to opencast coal mining, numerous on-site springs and sinks were evident on historical OS mapping within the Land at Nant Helen. Atkins agree with prior assessments [2] [4] [18] that low permeability Glacial Till likely causes perched groundwater at shallow depths. Present day mapping shows numerous artificial ponds but also identifies ponded water within areas of peat and streams issuing from the backfilled colliery spoil.

Groundwater levels within the “Nine Feet” and “Brass” seams during the late 1990’s was previously reported to be between approximately between 100 m AOD (approximately 50 m bgl) west of the Nant Helen Extension opencast site and 126 m AOD (approximately 170 m bgl) between the Nant Helen Extension and the older Nant Helen opencast site [2] [23] [18]. The disparity in reduced levels with respect to groundwater level was explained by Arup [2] as a reflection of the current landform including the Nant Helen Extension void in the west and the overburden storage area to the east.

In the absence of any contemporary discussion of groundwater flow, it is considered likely that natural groundwater flow would likely be toward the south-west, commensurate with the flow directions of the Rivers Tawe and Dulais which likely draw water toward the north and south respectively however no detailed identification of the location of the resulting flow divide can be made. The degree to which the structure of the geology affects (or does not affect) groundwater flow direction is unknown.

2.6.4.2. Current Conditions

Nant Helen Extension

Historical dewatering operations within the Nant Helen Extension opencast site aimed to maintain the groundwater level at approximately 100 m AOD [18]. Recent operations required sump pumping to be undertaken with all water flowing through the site water treatment facility and via the north to the River Tawe. Additional control on groundwater levels is imparted by three drainage adits draining to the River Tawe: Yard Adit (122.5 m AOD), Gwaun Clawdd (106.1 m AOD) and the Cwm Du Adit (93.6 m AOD).

Average discharge rates reported by Celtic [18], from the three adits, are summarised below:

Table 2-3: Average outflow per year (2010).

	Yard Adit	Gwaun Clawdd Adit	Cwm Du Adit
Max (l/sec)	40	135	25
Min (l/sec)	10	0	15
Average (l/sec)	30	40	20
Average Total discharge/year (m ³)	940,000	1,209,000	552,000

The assessment of hydrogeological impacts by Celtic [18] highlighted that there is potential for natural drainage from the site due to the disposition of the Nine Feet contours which are favourably orientated in the North-eastern part of the site. Any natural flow from the site would be via the Gwaun Clawdd adit which intercepts the Nine Feet seam workings.

It is unknown if the in-situ barrier at Nine Feet seam level between the Gwaun Clawdd and Ynyscedwen workings has been removed or not. Celtic considered that removal of this barrier will likely result in an increase in the discharge volume from the Cwm Du adit which is located at a lower elevation than the Gwaun Clawdd adit.

Other Opencast Areas

It is anticipated that groundwater beneath the other opencast workings is likely controlled by a combination of operations in the vicinity of the Nant Helen Extension and under-drainage via numerous existing adits, with groundwater levels dependent on the capacity of the adits to remove water and the secondary permeability of the bedrock.

Following the cessation of dewatering, Celtic [18] considers it likely that groundwater will likely re-bound in the backfill, with some outflow via Cwm Du adit. It is not known whether there will be a significant build-up of water level above that of the Cwm Du adit (93.6 m AOD) [18]. Celtic [18] considered it conceivable that water levels could build up, eventually discharging via coal seams in the excavation sequence or permeable sandy horizons within the overlying glacial deposits. However, Celtic [18] concluded it was not possible to predict with certainty. A programme of groundwater monitoring is ongoing around and within the backfill of the Nant Helen Extension.

No significant groundwater is expected to be intercepted in the existing historical backfill deposits. Overburden that has been removed then replaced during restoration is considered to have a considerable range of permeability associated with it and, areas with high clay contents likely support laterally inconsistent bodies of perched water. Generally, it is considered that these perched bodies of groundwater will be present at shallow depths (consistent with trapped meteoric water), but deeper perched units present throughout the backfill, until natural rockhead is encountered a between 75 and 150 m AOD, cannot be discounted. Overall, for the reasons outlined, any groundwater encountered, is likely to be of limited volume and likely occurs in isolated pockets.

Washery

Shallow groundwater (circa 1 m to 5m bgl) was recorded during the most recent GI, completed by Arup [2] between December 2021 to March 2022, over a period when highest seasonal groundwater elevations may typically be expected, no monitoring during summer months (seasonal low period) has been completed.

In contrast, historical exploratory hole logs available from the BGS [14] indicate the groundwater level within the Washery to be, on occasion, between 3.4 m and 7.2 m bgl. Shallower strikes and slight seepages were also noted as shallow as 1.0 m bgl.

No recent monitoring during summer months (seasonal low period) has been completed. Therefore, no detailed discussion on likely seasonal variation is possible and it is not possible to comment on whether shallow mine workings will be permanently flooded (a lower risk scenario) or subject to seasonal inundation (a higher risk scenario).

2.7. Hydrology

2.7.1. Water Catchments

The wider Nant Helen site is located at the intersection of three principal river catchments.

River Tawe

The River Tawe is the largest watercourse within 1 km of the site, flowing towards the west approximately 500 m north of the site boundary.

The catchment extends across the northern portion of the site, encompassing the former opencast mining areas of Abercraf/Gwaunton, the majority of Nant Helen and the Nant Helen Extension.

Nant Lech

A tributary of the River Tawe, Nant Lech flows in a north westerly direction approximately 350 m north-east of the Onllwyn mining area. Nant Lech is classified as a Site of Special Scientific Interest (SSSI) and ultimately feeds into the River Tawe.

The catchment of Nant Lech extends across the eastern portion of the site, encompassing the Onllwyn mining area as well as a number of small unnamed water features to the north-east of the site which drain into Nant Lech.

River Dulais

The River Dulais flows in a west-south-westerly direction through the Washery and along a portion of the south-eastern boundary of the site.

The Dulais catchment extends across the southern part of the Nant Helen mining area and the Washery. The catchment also includes:

- Nant Ystalwyn, a tributary of the Dulais: Nant Ystalwyn is understood [4] to be fed by a selection of former water treatment ponds within the body of the Land at Nant Helen which are in-turn fed by the drainage features present on the southern face of the large overburden storage area.
- Unnamed streams: A collection of other tributary streams which originate within the central portion of the site flow in a southerly direction to their respective convergences with the River Dulais.
- Manmade drainage features: These are understood to pass beneath and along Onllwyn Road before feeding into a collection of ponds within the washery portion of the site.

All catchments include additional unnamed streams and watercourses which have been re-aligned or diverted several times during the earlier operational phases of opencast coal mining at the site.

2.7.2. Discharges to Surface Water

The data from Groundsure [11] indicates that 21 on-site permitted discharge consents have been granted in relation to surface water. Of these only six are still active. A further 19 within 250 m of the site, of which five are still active. No active groundwater discharge consents are recorded.

A summary of the active on-site and off-site (within 250 m) licensed discharges to controlled waters is presented in Table 2-4.

Table 2-4: Surface water discharge consent summary.

Permit Number	Address	Receiving water	Distance from site (m)	Direction from site	Effective date
BM0032103	Outlet C Nant Helen OCCS	River Dulais	On-site	NA	09/01/1998
BA2010001	Onllwyn Washery Neath	Afon Dulais (Tributary of River Nea)	On-site	NA	30/03/1994
BB4027001	Vedmore Sidings Outlet B	Nant Camnant	On-site	NA	20/03/1989
BB4027002	Vedmore Sidings Outlet B	Nant Camnant	On-site	NA	20/03/1989
BM0032107	Storm Outlet B2 Nant Helen OCCS	River Dulais	On-site	NA	12/03/1997
BM0032102	Storm Outlet B2 Nant Helen OCCS	River Dulais	On-site	NA	13/03/1997
BP0135001	Onllwyn SPS, OPP 1 Heol Gaer, Onllwyn, Neath, SA10 9HT	Afon Camnant	14	West	17/12/2019
BP0135001	Onllwyn SPS, OPP 1 Heol Gaer, Onllwyn, Neath, SA10 9HT	Afon Camnant	14	West	17/12/2019
BP0135001	Dyffryn Cellwen, NR 7 Sisters	Afon Camnant to Pyrddin	15	East	20/02/2009

2.7.3. Surface Water Abstraction Licences

The data from Groundsure indicates there are no active or historical licensed surface water abstraction licenses on site or within 250 m.

The nearest groundwater abstraction is an historical abstraction located 650 m north-west of the site.

2.7.4. Flood Risk

The data from Groundsure indicates that the site does not lie within an area of flooding by sea or river. It also indicated that there was a potential for groundwater flooding at surface within 50 m of the study site (Low risk). Table 2-5 presents a summary of the flood risk datasets assessed.

Table 2-5: Summary of flood risk datasets.

Dataset	Summary
Flood Defences	There are no flood defences on-site.
Areas Benefiting from Flood Defences	There are no area benefiting from flood defences within 250 m of the site.
Flood Storage Areas	There are no flood storage areas within 250 m of the site.
Flooding Zone 2	There is one Flood Zone 2 area on-site.
Flooding Zone 3	There is one Flood Zone 3 area on-site.

2.8. Initial Conceptual Site Model

2.8.1. Introduction

This report has been prepared to assist in the identification of potential constraints that contamination might pose to the development site and to provide a preliminary risk assessment to inform the design of the proposed development. The assessment methodology used is similar to that derived for the determination of statutory Contaminated Land, as defined in the Part 2A statutory guidance [24] which is assessed through the identification and assessment of contaminant linkages (Source-Pathway-Receptor relationships). Implicit in the Defra statutory guidance is the application of risk assessment to consider whether potential contaminant linkages may be significant. In accordance with guidance provided in Land Contamination: Risk Management (LC:RM) [25],) and as endorsed by Natural Resources Wales (NRW), human health, buildings and wider environmental receptors and pathways have been identified based on the proposed end-uses.

Primary guidance for assessing and managing land contamination is presented in LC:RM [25]. This provides a technical framework for identifying and remediating contamination through the application of a risk management process. The question of whether risk is unacceptable in any case involves not only scientific and technical assessments, but also appropriate criteria by which to judge the risk and identify what risk would be unacceptable.

Ground gas and mine gas risks have been considered in general accordance with BS8576 Guidance on investigation for ground gas [26] and CL:AIRE's Good Practice for Risk Assessment for Coal Mine Gas Emissions [27].

An initial conceptual site model (CSM) has been developed based on the available information, to enable the assessment of the potential land contamination. An Initial CSM describes the relationship between potential sources of contamination (resulting from both on- and off-site historical and current activities) and receptors to the potential contamination. As part of the Initial CSM development, three elements are identified and assessed:

- Source of contamination and associated contaminants;
- Receptors to that contamination – human beings, controlled waters (surface water/groundwater), ecological systems and property/services; and
- Pathways between the sources and receptors.

Where all three elements are present or are likely to be present, they are described as potential contaminant linkages (PCLs), which can then be subjected to the risk assessment and risk management process.

The preliminary risk categorisations presented are based on an assessment of the potential consequence of each PCL occurring along with the likelihood that each PCL will occur. Potential contaminants that might be present have been identified through knowledge of historical land uses on or adjoining the site.

2.8.2. Initial Conceptual Site Model

Through a review of available historical and published information (e.g., geological, hydrogeological and hydrological information), potential sources of contamination and associated contaminants were identified and/or discounted. Those sources/contaminants that are not discounted are then considered in relation to

potential receptors that may be harmed by the source, and potential pathways that may link the sources to the receptors, i.e., source-pathway-receptor relationship.

Several historical and current land uses have been identified on-site and within 250 m of the site which may have given rise to contamination.

The risk assessment has been undertaken in consideration of the proposed future uses of the site.

2.8.3. Potential Sources

Based on the review of available information, the following key potentially contaminative sources have been identified within the site boundary and near the Land at Nant Helen (Nant Helen) and Washery. Further detail on the history of mining at the site is provided in Section 2.5 and a Mining Risk Assessment that is presented in Appendix C and based on review of Coal Authority mine abandonment records, site walkover to map features and review of Ground Investigation works and mining risk assessment completed by Arup.

Land at Nant Helen

- On-site:
 - Made Ground associated with historic mining and extraction activities;
 - Potentially contaminated surface water/road run-off from Made Ground and mining activities;
 - Historic contamination associated with historic industrial activities including extensive mining activities, purification works, engine houses, old tramway;
 - Underlying mine shafts and workings;
 - Current opencast mining activities (Nant Helen) including exposed coal, colliery materials, AST holding diesel, vehicle maintenance and repair; and
 - Railway land.
- Off-site:
 - Historical landfills and tips within 250 m of the site;
 - Contamination and Made Ground associated with historical and current mining and quarrying activities;
 - Potentially contaminated surface water/run-off from historical and current mining activities;
 - Surrounding historic and current mine shafts and workings; and
 - Railway land.

Potential contaminants associated with the above sources include:

- Inorganics including metals and metalloids, asbestos, cyanide, sulphate, ammonia;
- Organics including phenols, petroleum hydrocarbons, polycyclic aromatic hydrocarbons (PAHs), benzene, toluene, ethylbenzene, and xylenes (BTEX), volatile and semi volatile organic compounds (VOCs/SVOCs); and
- Ground gases:
 - Central site - Low Risk Area – coal mine risks are present at sufficient depth that it poses a low risk to new development depth which are likely to affect new development. Levels and shafts removed by open cast mining activities and restoration of overburden.;
 - Northern Site - High Risk Area – coal mine risks are present at shallow depth which are likely to affect new development. Adits, shafts and mine levels identified as potentially present;
 - Made ground is present – in form of colliery spoil and fill from historic and current uses; and
 - Natural soils with a potential to generate ground gases – Peat.

Washery

- On-site:
 - Made Ground associated with historic and current industrial activities (Coal Washery);
 - Contamination associated with current Coal Washery activities;
 - Potentially contaminated surface water/road run-off from current Mineral Railway and Coal Washery;
 - Localised spillages of hydrocarbons/fuels/lubricants from current Mineral Railway activities;

- Historic contamination associated with historic industrial activities including mining activities, unspecified works and brickworks; and
- Underlying historic mine shafts and workings.
- Off-site:
 - Historical landfills and tips within 250 m of the site;
 - Contamination and Made Ground associated with historical and current mining and quarrying activities;
 - Potentially contaminated surface water/run-off from historical and current mining activities; and
 - Historic mine shafts and workings.

Potential contaminants associated with the above sources include:

- Inorganics including metals and metalloids, asbestos, cyanide, sulphate, ammonia;
- Organics including phenols, petroleum hydrocarbons, PAHs, BTEX, VOCs/SVOCs; and
- Ground gases:
 - High Risk Area – coal mine risks are present at shallow depth (<30m) which are likely to affect new development and presence of shafts identified from historic maps;
 - Made ground is present – in form of colliery spoil and fill from historic and current uses; and
 - Natural soils with a potential to generate ground gas es – Peat.

2.8.4. Potential Receptors

Planning permissions P2020/0362 (Neath and Port Talbot County Council) and 20/0738/FUL (Powys County Council) relate to construction of complementary restoration earthworks. They both, via contaminated land specific planning conditions, require characterisation of contaminated land risks before development can commence. The land use set out within these planning permissions in addition to allowing the creation of two looped landform platforms includes 'areas of landscaping and habitat creation to create a flexible and adaptable area of land that could be used for a variety of uses including agriculture, nature conservation, leisure, tourism and industrial, research and development/business uses (potentially including a proposed rail testing, research and development and storage facility)'. These land uses allow the presence of a more sensitive set of human health, ecological and property receptors than a solely commercial land use.

Land at Nant Helen

The following receptors have been identified at the site based on a public open space end use:

- Human Health:
 - On-site – Maintenance workers, commercial site users, site workers, and adults and children visiting potential nature conservation, leisure and tourism related land uses; and
 - Off-site – Local residents, workers in commercial properties surrounding the site, visitors.
- Controlled Waters:
 - Groundwater – Secondary A superficial aquifer and Secondary Undifferentiated aquifer and Secondary A bedrock aquifer; and
 - Surface Water – River Taw, Dulais and Nant Lech plus unnamed tributary land drains and streams.
- Property and Services:
 - Existing infrastructure associated with current development;
 - Agricultural crops and livestock;
 - Neighbouring residential and commercial properties (northern edge of site); and
 - Proposed new infrastructure (Limited in earthworks phase but may be added during GCRE (Track) construction) .

Washery

The following receptors have been identified at the site based on a commercial end use:

- Human Health:
 - On-site – Future site users (workers), site workers; and
 - Off-site – Local residents, workers in commercial properties surrounding the site.

- Controlled Waters:
 - Groundwater – Secondary A superficial aquifer and Secondary A bedrock aquifer; and
 - Surface Water – Dulais and Nant Lech
- Property and Services:
 - Proposed new infrastructure;
 - Existing infrastructure; and
 - Neighbouring residential and commercial properties.

2.8.5. Potential Pathways

Considering the identified receptors, several pathways are considered plausible based on the information gathered to date.

- Human Health
 - Dermal contact with and ingestion of contaminants in soils, soil-derived dusts and water; and
 - Ingestion / inhalation of soil, soil-derived dust, fibres and gas/vapours.
- Controlled Waters
 - Leaching of contaminants in soil to groundwater in underlying aquifer;
 - Migration of contaminated water through preferential pathways such as underground services, pipes and granular material to groundwater in underlying aquifer;
 - Lateral migration of contaminated groundwater with discharge to surface watercourses as base flow;
 - Discharge of contaminants entrained in surface water run-off followed by overland flow and discharge.
- Property and Services:
 - Direct contact of contaminants in soil and/or groundwater with buried services; and
 - Migration of contaminated groundwater, ground gas and/or vapours along strata and preferential pathways such as service routes or differentially permeable strata.

It should be noted that under current health and safety legislation, construction and maintenance workers are required to carry out appropriate risk assessments and instigate appropriate mitigating measures to protect themselves, other human receptors and the environment from contamination which may be present. Such risks must be adequately mitigated by the measures required under current legislation, specifically the Construction Design Management (CDM) Regulations [28] which requires that potential risks to human health and the environment from construction activities are appropriately identified and all necessary steps taken to eliminate / manage that risk. On this basis, it been assumed that personal protective equipment (PPE) and health and safety best practices will be adopted during the construction works and acute risks to construction workers / site visitors have therefore not been considered as part of this assessment.

At this stage it has not been confirmed if piled foundations will be required. Should piled foundations be required the risk of creation of a preferential pathway should be assessed in a Piling Risk Assessment and the piles designed to mitigate the creation of a pathway for potential contamination.

2.8.6. Qualitative Risk Assessment

Table 2-6 below provides the qualitative risk matrix, based on CIRIA guidance, in which the likelihood or probability of each contaminant linkage being realised is ranked against the severity of the consequences. The result is the relative risk classification, the results of which can inform the due diligence process and allow prioritisation of any further assessments or the implementation of risk management measures.

Table 2-6: Qualitative risk assessment matrix.

		Severity of consequence			
		Severe	Medium	Mild	Minor
Probability of contaminant linkage	High likelihood	Very high risk	High risk	Moderate risk	Moderate/low risk
	Likely	High risk	Moderate risk	Moderate/low risk	Low risk
	Low likelihood	Moderate risk	Moderate/low risk	Low risk	Very low risk
	Unlikely	Moderate/low risk	Low risk	Very low risk	Very low risk

Definitions of the risk, probability and severity of consequence classifications presented in the guidance are given in Table 2-7, Table 2-8 and

Table 2-9.

Table 2-7: Risk classification descriptors.

Risk class	Definition
Very high risk	High probability of severe harm to a designated receptor from an identified source, or there is evidence that severe harm to a designated receptor is currently happening.
High risk	Harm is likely to arise to a designated receptor from an identified source.
Moderate risk	It is possible that harm could arise to a designated receptor from an identified source. However, it is relatively unlikely that any such harm would be severe, or if any harm were to occur it is more likely that the harm would be relatively mild.
Low risk	It is possible that harm could arise to a designated receptor from an identified source, but it is likely that this harm, if realised, would at worst normally be mild.
Very low risk	There is a low possibility that harm could arise to a receptor. In the event of such harm being realised it is not likely to be severe.

Table 2-8: Probability of linkage occurring classifications.

Probability class	Definition
High likelihood	There is a pollution linkage, and an event appears very likely in the short term and almost inevitable over the long term, or there is evidence at the receptor of harm or pollution.
Likely	There is a pollution linkage, and all the elements are present and in the right place, which means it is probable that an event will occur. Circumstances are such that the event is not inevitable, but possible in the short term and likely over the long term.
Low likelihood	There is a pollution linkage and circumstances are possible under which an event could occur. However, it is by no means certain even over a longer period such event would take place and is less likely in the short term.
Unlikely	There is a pollution linkage, but circumstances are such that it is improbable the event would occur even in the long term.

Table 2-9: Hazard classification

Hazard class	Definition
Severe	Short term (acute) risk to human health likely to result in 'significant harm' as defined by the Environment Protection Act 1990, Part 2A. Short-term risk of pollution of sensitive water resources. Catastrophic damage to buildings or property. A short-term risk to a particular ecosystem or organism forming part of that ecosystem. Due to the specific hazards ground gas and asbestos place these will always generate a severe hazard classification where potentially present.
Medium	Chronic damage to human health. Pollution of sensitive water resources. A significant change in a particular ecosystem or organism forming part of that ecosystem
Mild	Pollution of non-sensitive water resources. Significant damage to crops, buildings, structures and services. Damage to sensitive buildings, structures, services or the environment.
Minor	Harm, not necessarily significant harm, which may result in financial loss or expenditure to resolve. Non-permanent health effects to human health (easily prevented by use of personal protective clothing etc). Easily repairable effects of damage to buildings, structures and services.

The individual sources, pathways and receptors identified in previous sections are judged against this risk matrix and professional judgement has been used to estimate the combination of probability of a contaminant linkage being realised and the consequence of the harm that might result in line with CIRIA C552 [29]. Details of the potential contaminant linkages and associated risks are recorded in Table 2-10.

Table 2-10: Land at Nant Helen initial conceptual site model and preliminary risk assessment.

Sources	Pathway	Receptor	Probability	Consequence	Classification of risk
Potential contaminants in soil/groundwater on-site, originating from the following <u>on-site</u> sources: Made Ground associated with historic mining and extraction activities. Underlying mine shafts and workings Potentially contaminated surface water/road run-off from Made Ground and mining activities. Historic contamination associated with historic industrial activities. Current opencast mining activities (Nant Helen). Possible contaminants include: <i>Asbestos</i> <i>Metals</i> <i>Polycyclic aromatic hydrocarbons (PAHs)</i> <i>Petroleum hydrocarbons</i> <i>Volatile organic compounds (VOCs)</i> <i>Ground gases (methane, carbon dioxide, hydrogen sulphide or carbon monoxide)</i>	Inhalation, ingestion, and dermal contact with contaminants in soil and soil derived dust.	<u>Human Health</u> – current and future users of site, construction workers, Maintenance workers, commercial site users, site workers, and adults and children visiting potential nature conservation, leisure and tourism related land uses;	Likely	Medium	Moderate The site has a long history of industrial use with historic coal mining activities occurring in the north, the majority of this material was stripped from the site and mixed in with the overburden that was removed to allow access to underlying coal levels, then stockpiled or stockpiled and used to restore previously opencast mined area. Overburden of natural origin is considered to present a negligible risk, however higher risk material will be 1) entrained as pods of higher risk material, 2) mixed within the overburden therefore reducing the risk or 3) present in intact areas such as former railway land, tramways, coal stockpiles, colliery areas, vehicle repair and fuelling areas or areas that have had a potentially contaminating use after opencast mining has finished. Risks are more elevated due to the combination of leisure, agricultural and commercial land uses. <u>Recommend Actions</u> GI to confirm/refute CSM Trial pitting and soil sampling to confirm the presence of Made Ground and assess the composition of site soils. Drilling of exploratory holes to assess composition of Overburden at depth of cuttings.
	Inhalation of vapours.		Low	Medium	Moderate at AST location / Low remainder of Land at Nant Helen A known potentially viable on-site vapour source is restricted to ASTs identified at the Celtic compound in the centre of the site. Other potential sources are hydrocarbon holding AST and UST that may have historically been present within Colliery areas and leaks / spillages from vehicles associated with Celtics works area. The earthworks proposed at this time do not include development of confined spaces therefore build-up of vapour is not considered plausible. If under passes or tunnels are proposed within the earthworks or future phases of development, as have been discussed to allow access to leisure or agricultural areas, these areas would potentially be at more elevated risk <u>Recommend Actions</u> GI to confirm/refute CSM Trial pitting, headspace sampling and soil sampling to confirm the presence of Made Ground and assess the composition of site soils. Installation of monitoring wells and vapour monitoring at location of AST and vapour monitoring in all ground gas wells.
	Inhalation of ground gas (asphyxiation).	<u>Human Health</u> – current and future users of site, construction workers. <u>Property</u> – neighbouring residential properties, nearby commercial properties.	Unlikely	Medium	Moderate/Low The Coal Measures present beneath the site from extensive mining activities and underlying workings are, if present at shallow depth, potentially a significant source of mine gas generation. Opencast mining has removed the underlying coal measures and placed a considerable thickness of backfill over the majority of the site as shown in Figure 2-3 Opencast Mining Plan. The exception to this are the southwest quadrant (Ground Model Zone 8), southern edge (Ground Model Zones 3 and 11) and a strip that runs north to south through the centre of the site (crossing portions of Ground Model Zones 2, 3, 5 and 6) where no opencast activities have occurred and mine workings are present at shallow depth and mine entries/shafts have been recorded. Groundwater levels within the Main Site are uncertain, however the likelihood is that groundwater sits between 100 and 126 m AOD, with the potential for perched water to sit in areas of restored Overburden or Quaternary Deposits. Overburden will have consisted of Lower and Middle Coal Measures that did not hold coal, Devensian Till and Alluvium (both not considered a viable source of gas) and Peat (potentially a source of ground gas). Infrequent and localised areas of putrescible Made Ground are also likely to be present within the Overburden following mixing with other on-site contamination sources. The earthworks proposed at this time do not include development of confined spaces therefore build-up of gases is not considered viable. If under passes or tunnels are proposed within the earthworks or future phases of development, as have been discussed to allow access to leisure or agricultural areas, these areas would potentially be at risk.

Sources	Pathway	Receptor	Probability	Consequence	Classification of risk
					<u>Recommend Actions</u> GI to confirm/refute CSM. Review of CSM following establishment of groundwater levels, Trial pitting and soil sampling to confirm the presence of Made Ground and assess the composition of site soils. Installation of monitoring wells and ground gas monitoring.
	Direct contact of foundations/services with aggressive soils and or groundwater. Chemical attack to buried structures.	<u>Property and Services</u> – neighbouring residential and commercial properties. Current and future infrastructure.	Low	Mild	Low Current and future below ground infrastructure is assumed to have been/will be constructed to appropriate standards for the site to withstand attack from soil chemistry. <u>Recommended Actions</u> Trial pitting to assess the composition of site soils is recommended in order to allow appropriate design of future services and foundations.
	Leaching or dissolution of contaminants in unsaturated soils and subsequent migration Lateral and vertical migration through Made Ground, superficial deposits and bedrock. Migration via preferential pathways e.g. existing drainage, foul sewer, proposed service pipes/trenches, piled foundations.	<u>Groundwater Controlled Waters</u> Secondary A bedrock aquifer	Likely	Medium	Moderate The works are likely to result in disturbance of soils and changes in water levels during excavation and construction which may result in the release of contaminants in Made Ground/Overburden and disused mine workings with potential migration to groundwater. Groundwater below the site is classified as Secondary A aquifers, the distance to identified abstractions and surface waters is such that groundwater is considered to have a medium sensitivity. Migration to the site from off-site sources is not considered to be plausible. Due to opencast mining superficial aquifers are not considered to be a plausible on-site receptor. <u>Recommended Actions</u> GI to confirm/refute CSM. Trial pitting with soil and leachability sampling to assess the composition of site soils is recommended. Monitoring installations are recommended to be installed with a regime of groundwater monitoring and sampling to establish groundwater levels and contamination to further assess this risk.
	Leaching or dissolution of contaminants in unsaturated soils and subsequent migration Lateral and vertical migration through Made Ground, superficial deposits and bedrock Surface water runoff. Migration of contaminated water in drainage ditches to controlled surface waters.	<u>Surface Water Controlled Waters</u> – Unnamed watercourses, Nant Helen and bodies on-site. Tawe, Dulais (including unnamed tributaries and Nant Ystalwyn) and Nant Llech off-site respectively to the north, north-east and south	Low	Medium	Moderate The works are likely to result in disturbance of soils and changes in water levels during excavation and construction which may result in the release of contaminants in Made Ground/Overburden and disused mine workings with potential migration to surface waters. The site contributes to the catchments of the Tawe, Dulais and Nant Llech with unnamed streams and the Nant Helen arising from the Land at Nant Helen that feed into them. Additionally numerous ponds and lagoon are currently present on-site Migration to the site from off-site sources is not considered to be plausible. Due to opencast mining superficial aquifers are not considered to be a plausible on-site receptor. <u>Recommended Actions</u> Sampling and analysis of surface waters to confirm baseline conditions. Survey of surface waters, springs, and sinks. Installation of monitoring wells and ground water monitoring. GI to collect leachability samples and ground water samples.
Potential contaminants in soil/groundwater on-site, originating from the following <u>off-site</u> sources: Historical landfills and tips within 250 m of the site. Contamination and Made Ground associated with	Inhalation, ingestion and dermal contact with contaminants in soil derived dust.	<u>Human Health</u> – current and future users of site, construction workers.	Unlikely	Medium	Low The majority of the surrounding area is covered with moorland and vegetation. Given the topography of the Land at Nant Helen it is not considered plausible that contaminants migrating onto site within windblown dust pose a viable exposure pathway.
	Leaching of contaminants from soil and migration to groundwater, followed by lateral migration beneath the site.		Unlikely	Medium	Low

Sources	Pathway	Receptor	Probability	Consequence	Classification of risk
historical and current mining and quarrying activities. Potentially contaminated surface water/run-off from historical mining activities and current washery activities. <i>Possible contaminants include:</i> <i>Asbestos</i> <i>Metals</i> <i>PAHs</i> <i>Petroleum hydrocarbons</i> <i>VOCs</i> <i>Ground gases (methane, carbon dioxide, hydrogen sulphide or carbon monoxide)</i>					The majority of the surrounding area is covered with moorland and vegetation. Given the topography of the Land at Nant Helen it is not considered plausible that contaminants migrating onto site within windblown dust pose a viable exposure pathway.
	Migration of gases into confined spaces (excavations) and accumulation (explosion). Inhalation of ground gas (asphyxiation).	<u>Human Health</u> – current and future users of site, construction workers. <u>Property and Services</u> – neighbouring residential and commercial properties.	Unlikely	Medium	Low The Made Ground present beneath the surrounding area from previous development and extensive mining and extraction activities could be a potential source of ground gas. The topography of the site is such that off-site sources are not considered to have a plausible migration pathway.

Table 2-11: Onllwyn Washery initial conceptual site model and preliminary risk assessment.

Sources	Pathway	Receptor	Probability	Consequence	Classification of Risk
Potential contaminants in soil/groundwater on-site, originating from the following <u>on-site</u> sources: Made Ground associated with historic and current industrial activities (Coal Washery, former Colliery, Railway Land, former tramways, spoil heaps). Potentially contaminated surface water/road run-off from current Mineral Railway and Coal Washery. Localised spillages of hydrocarbons/fuels from current Mineral Railway activities. Historic contamination associated with historic industrial activities. <i>Possible contaminants include:</i> <i>Asbestos</i> <i>Metals</i> <i>Polycyclic aromatic hydrocarbons (PAHs)</i> <i>Petroleum hydrocarbons</i>	Inhalation, ingestion and dermal contact with contaminants in soil and soil derived dust.	<u>Human Health</u> – current and future users of site, construction workers.	Likely	Severe	High Risk with respect to asbestos / Medium otherwise Made Ground is present beneath the majority of the Washery site due to historic mining activities, placement of spoil from the former Onllwyn and Dulais Collieries operations and Made Ground originating from their structures, railway land and the current Washery land use. These uses present a high risk to future redevelopment from inhalation of asbestos if present and a medium risk for other potential contamination linkages. The planned development will result in a substantial thickness of engineered fill being placed to deliver the levels required for GCRE's operation this material will break the majority of inhalation, ingestion and dermal contact pathways once construction is complete <u>Recommended Actions</u> GI to confirm/refute CSM. Trial pitting and drilling of boreholes to confirm the presence of Made Ground and assess the composition of site soils. Chemical testing of soils.
	Inhalation of vapours.		Likely	Medium	Moderate Risk Fuel storage tank presence in the Washery area has not been confirmed by Arup during their walkover, however, it is considered likely that UST and AST are present and in conjunction with leaks from vehicles and spillages from railway use these present a potential vapour source that may affect future development. <u>Recommended Actions</u> GI to confirm/refute CSM. Trial pitting and drilling of boreholes and to confirm the presence of Made Ground and assess the composition of site soils. Chemical testing of soils. Monitoring of boreholes for vapour, headspace testing of samples, groundwater sampling to assess presence of LNAPL/dissolved phase.

Sources	Pathway	Receptor	Probability	Consequence	Classification of Risk
<i>Volatile organic compounds (VOCs)</i> <i>Ground gases (methane, carbon dioxide, hydrogen sulphide or carbon monoxide)</i>	Inhalation of ground gas (asphyxiation) and explosion.	<u>Human Health</u> – current and future users of site, construction workers. <u>Property</u> – neighbouring residential properties, nearby commercial properties.	Likely	Medium	Moderate Risk The Made Ground and shallow mine workings present beneath the site are a potential source of ground gas. Mine workings are identified at depths of <30 m and shafts/adits are recorded within the washery area. Groundwater is likely to be shallow based on the levels of adjacent streams/drains, however it is not known whether underlying mine workings are permanently flooded or subject to a seasonal cycle of drying and flooding. The Earthworks do not involve the construction of buildings, but the proposed GCRE works involve the construction of buildings (confined spaces) and so the potential for inhalation of ground gas and explosion is likely. No information has been provided in relation to whether ground gas or vapour mitigation measures were included in the construction of neighbouring buildings. <u>Recommended Actions</u> GI to confirm/refute CSM. Trial pitting and drilling of boreholes to target different sources of gas (natural peat, Made Ground, mine workings) and to confirm the presence of Made Ground and assess the composition of site soils. Monitoring installations and ground gas monitoring is recommended.
	Direct contact of foundations/services with aggressive soils and or groundwater. Chemical attack to buried structures.	<u>Property and Services</u> – neighbouring residential and commercial properties.	Low	Mild	Low Current and future below ground infrastructure is assumed to have been/will be constructed to appropriate standards for the site to withstand attack from soil chemistry. The planned development will result in a substantial thickness of engineered fill being placed to deliver the levels required for GCRE's operation this material will break the exposure pathway once its construction is complete. <u>Recommended Actions</u> Trial pitting to assess the composition of site soils is recommended to allow appropriate design of future services and foundations.
	Leaching or dissolution of contaminants in unsaturated soils and subsequent migration Lateral and vertical migration through Made Ground, superficial deposits and bedrock. Migration via preferential pathways e.g. existing drainage, foul sewer, proposed service pipes/trenches, piled foundations.	<u>Groundwater Controlled Waters</u> – Secondary A superficial aquifer Secondary Undifferentiated Secondary A bedrock aquifer	Likely	Medium	Moderate The works are likely to result in disturbance of soils and colliery spoil during excavation and construction which may result in the release of contaminants with a potential to migrate to groundwater. Groundwater below the site is present at a shallow depth and predominantly classified as Secondary or Secondary Undifferentiated aquifers with limited superficial deposits that are unproductive. The distance to identified abstractions and surface waters is such that groundwater is considered to have a medium sensitivity. Potentially contaminated groundwater may migrate to the site from off-site sources. <u>Recommended Actions</u> Installation of monitoring wells and ground water monitoring. Collection of leachability, surface water and ground water samples. Analysis of leachability, surface, and groundwater samples to confirm baseline conditions.
	Leaching or dissolution of contaminants in unsaturated soils and subsequent migration Lateral and vertical migration through Made Ground, superficial deposits and bedrock Surface water runoff. Migration of contaminated water in drainage ditches to controlled surface waters.	<u>Surface Water Controlled Waters</u> – Camnant (immediately adjacent to east of site) and Dulais (arises in west of site)	Likely	Medium	Moderate The construction works are likely to result in disturbance of shallow unsaturated soils which may result in the release of contaminants in unsaturated Made Ground soils and disused mine workings with potential migration to surface water. Given the distance of the nearest surface water course, the risk of contaminants migrating to affect this receptor is moderate. Potentially contaminated groundwater may migrate to the site from within the Main Site to the north, potentially affecting surface water. <u>Recommended Actions</u> Installation of monitoring wells and ground water monitoring. Collection of leachability, surface water and ground water samples. Analysis of leachability, surface, and groundwater samples to confirm baseline conditions.

Sources	Pathway	Receptor	Probability	Consequence	Classification of Risk
Potential contaminants in soil/groundwater on-site, originating from the following off-site sources: Historical landfills and tips within 250 m of the site; Contamination and Made Ground associated with historical and current mining and quarrying activities; Potentially contaminated surface water/run-off from historical and current mining activities <i>Possible contaminants include:</i> <i>Asbestos</i> <i>Metals</i> <i>PAHs</i> <i>Petroleum hydrocarbons</i> <i>VOCs</i> <i>Ground gases (methane, carbon dioxide, hydrogen sulphide or carbon monoxide)</i>	Inhalation, ingestion and dermal contact with contaminants in soil derived dust.	<u>Human Health</u> – Current and future users of site	Unlikely	Medium	Low Off-site land uses are similar in nature to identified on-site historical contaminating uses with off-site soils typically covered by vegetation and not exposed directly to atmosphere. <u>Recommended Actions</u> None required.
	Leaching of contaminants from soil and migration to groundwater, followed by lateral migration beneath the site.		Unlikely	Medium	Low Based on the presence of commercial land use nearby and extensive historical mine workings and landfilling there is a potential off-site source of contamination, however groundwater is considered to flow away from the site to the west and the east. Off-site sources are therefore considered to be downgradient of the site and to present a low risk. <u>Recommended Actions</u> None
	Migration of gases into confined spaces/buildings and accumulation (explosion). Inhalation of ground gas (asphyxiation).	<u>Human Health</u> – Current and future users of site <u>Property and Services</u> – neighbouring residential and commercial properties	Likely	Medium	Moderate Risk The Made Ground and shallow mine workings present beneath the site extend off-site due to the presence of the former Onllwyn Colliery and are a potential source of ground gas. The proposed Earthworks planning application does includes commercial uses so buildings may potentially be present as part of this land use, additionally the GCRE planning application involves construction of buildings (confined spaces) and so the potential for inhalation of ground gas is likely. No information has been provided in relation to whether ground gas or vapour mitigation measures were included in the construction of neighbouring buildings. <u>Recommended Actions</u> GI to confirm/refute CSM Trial pitting and drilling of boreholes to target different sources of gas (natural peat, Made Ground, mine workings) and to confirm the presence of Made Ground and assess the composition of site soils. Monitoring installations and ground gas monitoring is recommended.

3. Field and Laboratory Studies

3.1. Geomorphological and geological mapping

Geomorphological or geological mapping across the proposed alignment was being undertaken on site at the time of this report. Reporting regarding this work, including mapping method and location, is to be detailed within the Geotechnical Design Reports (GDR).

3.2. Topographic Survey

A partial topographical survey of the scheme area was previously undertaken in October 2020. The data provided was supplemented by the Open Access Lidar data and the mine restoration levels to inform the ground modelling and earthwork design.

Due to the expected variation in ground levels due to the ongoing mine restoration activities, a new topographic survey has been commissioned to inform the detailed earthwork design. This survey had been carried out at the time of writing, but the results not available.

3.3. Walkover surveys

A general sitewide walkover survey was undertaken by Arup on 28 November 2018.

A geomorphological site walkover of the northern slopes was undertaken by Atkins on 14 and 16 June 2022. The results are presented in **Error! Reference source not found..**

3.3.1. Arup November 2018

The Arup walkover comprised a broad overview of the site looking at many areas of the site in limited detail. The following key features were identified:

- A large over burden stockpile just within the southwest edge of the proposed outer loop a pond was also noted on this part of the loop.
- The existing Nant Helen opencast mine was viewed to the immediate west of the proposed rail loop. At the time of the walkover, it was noted to be approximately 150m deep with a small lake visible at the base of the pit. Backfilling was evident on the eastern edge of the pit in the form of engineered soil slopes.
- A haul road was viewed running across the northern part of the site to transport coal from the opencast site to yard / office complex in the centre of the site. The proposed track alignment is expected to run through the forestry land to the north of this haul route. Several stockpiles of material were noted to either side of this haul route.
- Stockpiles of colliery spoil were noted in many locations across the site. The material was noted to be predominantly gravel sized fragments of mudstone and siltstone with larger cobble and boulder sized inclusions. The cobble and boulder sized inclusions were noted to be fractured.
- The eastern part of the site was not examined in significant detail but was noted to rise gently to the north-west.
- The washery area in the southeast corner was also not examined in detail although a large pond was noted adjacent to the washery infrastructure.

3.3.2. Atkins June 2022

Atkins undertook two days of geomorphological mapping in the northern part of the site on 14 and 16 June 2022 to identify features of concern for the proposed embankments to be constructed in this area.

The results of this mapping are presented in **Error! Reference source not found..** Key features identified include the following:

- The hillside which underlies the western part of the slope in (which is almost entirely opencast colliery backfill) is considerably steeper than the eastern part which is mostly natural material with some thinner patches of mining waste.

- There is no evidence of natural hillslope instability with some evidence of minor instability within areas of colliery waste.
- There are several deep stream gullies running from south to north and cutting perpendicularly across the proposed track alignment.
- Cuttings up to around 10m high are present along the course of the former Brecon and Swansea railway which runs along the base of the slope. These appear to be generally stable and involve an element of rock cut at the base.
- On the eastern part of the slope spoil heaps visible on historical aerial photographs are no longer present although there is evidence of colliery spoil at surface across much of the area.
- The natural slope in this area is generally of a relatively slack angle with some steepening where the access track that cuts across from east to west has been constructed.

3.4. Ground Investigation

3.4.1. BGS Exploratory Hole Records

There are 14No. historical exploratory holes in proximity to the site that are available through the BGS online GeolIndex database [14]. These have been used to inform the site ground model.

These historical exploratory holes, which comprised of cable percussion and rotary cored boreholes progressed to a maximum depth of 45.1 m below ground level (bgl), are understood to have been undertaken in two phases:

- 1968 to 1969: SN81SW12, SN81SW13, SN81SW16, SN81SW17, SN81SW19 & SN81SW20
- 1989: SN81SW29, SN81SW30, SN81SW31, SN81SW32, SN81SW33, SN81SW34, SN81SW35 & SN81SW36

3.4.2. 1986 Ground Investigation

A ground investigation was undertaken at the Nant Helen opencast site in 1986. These records, which were provided by Celtic Energy, have been used to inform the site ground model. The investigation comprised 8No. exploratory holes (BH2002, BH2005, BH2008, BH2009, BH2010, BH2011, BH2013 and BH2018) and were progressed to a maximum depth of 7.5 m bgl.

3.4.3. 2021 to 2022 Ground Investigation

3.4.3.1. Exploratory holes

A GI at the site was scoped and specified by Arup (the investigation supervisor) on behalf of GCRE Ltd and undertaken by Quantum Geotechnical Limited between 15th November 2021 and 19th January 2022. The investigation comprised the following intrusive works:

- 35No. boreholes progressed to between 19.2 m and 61.5 m bgl drilled using either cable percussive, open hole rotary, rotary coring, or sonic coring methods. Of these locations, six boreholes were in the Washery and 29 in the Land at Nant Helen.
- The original GI slope specified that 10No. of the exploratory holes were to be completed using sonic drilling within the areas of opencast backfill. However, during the investigations, after three locations were completed, it was found that sonic drilling was less effective (slower progression and depth could not be achieved) than conventional rotary drilling. Therefore, the remaining seven were completed using only rotary methods to the maximum depth that could be achieved with the rigs being used on site at the time.
- 40No. trial pits, 11No. of which were to investigate anomalies identified by the geophysical surveys and 8No. to undertake soakaway testing. Of these locations, 19No. were in the Washery and 21No. within the Land at Nant Helen.

3.4.3.2. In-situ testing

The following in-situ testing was undertaken during the works:

- Standard Penetration Tests (SPT) was undertaken in 30No. boreholes, with 196No. tests being completed in total.
- Hand shear vane tests undertaken within 1No. borehole and 3No. trial pits, with 17No. tests being completed in total.
- 7No. soakaway test pits.
- Particle size grading of material larger than 125 mm using a graticule was undertaken in eight trial pits that were in areas of backfilled opencast working.

Completed GI works did not involve headspace sampling.

3.4.3.3. Instrumentation

The following instrumentation was installed during the works, with the location of each borehole where monitoring wells were installed presented in Figure 7-1.

- 16No. holes were fitted with 50mm standpipes to allow for groundwater level/ground gas monitoring. Two of these holes were also fitted with 19mm standpipes to allow for water monitoring in a deeper stratigraphy. From these locations, six monitoring wells (two consisting of dual shallow and deep installations were in the Washery and ten monitoring wells were installed within the Land at Nant Helen.
- Groundwater and ground gas monitoring has been undertaken fortnightly for 12 weeks from the completion of the site works (between 20/01/22 and 25/04/22).

Taking account of the proposed development and the highly variable and challenging ground conditions present at the site, it is noted that the ground investigation described above, has several limitations, including:

- Exploratory holes are generally widely spaced with up to 400 m between individual exploratory holes in some areas of the site. This is considered as being too widely spaced to take full account of the highly variable geological ground conditions across the site.
- Most of the drilling was undertaken using ODEX or standard open hole techniques meaning that much of the recovered material was recovered as chippings rather than as rock cores. This meant that it was not possible for appropriate engineering rock descriptions to be provided and consequently engineering classification of the rock was not possible. While ODEX drilling may be used to progress through difficult strata, in this investigation it was used to drill through superficial deposits which could have been dynamically sampled. It is therefore considered that it was used to save time, and this has reduced the quality of the ground investigation data.
- A significant proportion of the field geological descriptions were not recorded in accordance with BS 5930 [30] guidance and only drillers descriptions provided.
- The selection of these drilling techniques also meant that the collection of geotechnical samples of an appropriate standard for laboratory testing was not possible in the areas where these drilling techniques were used, and this limited the geotechnical testing and classification that could be undertaken.
- Only 16No. of the boreholes were installed with monitoring standpipes following completion and there is therefore a limited amount of groundwater data available.
- In some locations materials have been given the same description. For example, in BH08 from the ground surface to 12.0 m was described as colliery spoil meaning that much of the detail of these units has been missed which potentially has resulted in an oversimplification of the ground model.
- Significant thicknesses of reworked overburden are anticipated, but in many areas of the site there is the potential for Made Ground horizons derived from reinstated opencast overburden, multiple phases of historic use and associated with modern mining activities (haul roads, yards, former buildings) are potentially in close juxtaposition. Made Ground of differing age and composition will present different risk profiles to construction workers and future users of the site, knowledge of its distribution or definitive absence would allow a more nuanced assessment of risk. In some areas this has led to an overly conservative assessment.
- Completed GI works did not involve headspace sampling and no comments regarding the presence or absence of hydrocarbon odours and visual evidence of contamination other than noting the presence of ash and coal in some Made Ground were reported in the GI.

3.5. Laboratory Investigation

Laboratory testing of soil and rock was scheduled by Arup as part of the GI undertaken between 2021 and 2022. The results of the laboratory testing is presented within the GI Factual report [9].

3.5.1. Geotechnical soil testing

A summary of all laboratory testing undertaken on soil is presented in Table 3-1 below.

Table 3-1: Summary of geotechnical soil laboratory testing

Material	Category	Geotechnical test type	Quantity
Soil	Classification testing	Moisture content of soil	85
		Atterberg Limits tests	30
		Particle size distribution (PSD) tests	57
	Strength testing	Unconsolidated undrained (UU) triaxial compression tests	4
	Consolidation testing	One-dimensional consolidation tests	4
	Earthworks testing	Compaction tests (dry density/moisture content relationship testing)	11
		Moisture condition value/moisture content relationship testing	11

Testing to BRE SD-1 [31] sulphate suites was undertaken to determine the class of concrete required across the site.

3.5.2. Geotechnical rock testing

A summary of all laboratory testing undertaken on rock is presented in Table 3-2 below.

Table 3-2: Summary of geotechnical rock laboratory testing

Material	Category	Geotechnical test type	Quantity
Rock	Strength testing	Point load Index (Rock)	54
		Uniaxial Compressive Strength (UCS – Rock)	2
	Aggregate testing	LA coefficient	6
		Soundness by magnesium sulphate	6
		Slake Durability	6

Testing to BRE SD-1 [31] sulphate suites was undertaken to determine the class of concrete required across the site.

3.5.3. Geo-environmental soil testing

Under the direction of Quantum Geotech, contamination laboratory analysis was undertaken by Eurofins Chemtest, in accordance with the laboratory's quality control system. Eurofins Chemtest are a UKAS and MCERTS approved analytical laboratory.

28No. soil samples were subject to a general suite of analysis based on the desk study and ground conditions encountered, including the following:

- Metals (Arsenic, Boron, Cadmium, Chromium, Copper, Iron, Lead, Manganese, Mercury, Nickel, Selenium, Zinc);
- Polyaromatic Hydrocarbons (PAHs);
- Total Petroleum Hydrocarbons (TPHCWG) inc. BTEX (21 samples) ;
- Total Cyanide, Free Cyanide, Phenols;
- pH, Soil Organic Matter (SOM);

- VOC & SVOC (One sample);
- Hexavalent Chromium (Seven samples);
- Asbestos (26No. samples);

Nine soil derived leachate samples were also obtained and scheduled for analysis outlined below:

- Metals (Arsenic, Boron, Cadmium, Chromium, Copper, Iron, Lead, Manganese, Mercury, Nickel, Selenium, Zinc);
- Cyanide, Phenols;

And one soil leachate analysis completed for:

- Polyaromatic Hydrocarbons (PAHs);

Logs from the Factual Report [9] are in most cases based on drillers descriptions with limited detail on Made Ground composition other than to state it is colliery spoil and to note the presence of coal and ash amongst the clayey GRAVEL that has typically been recovered. No observations on odour, headspace testing, or visual evidence of contamination are provided.

3.5.4. Geo-environmental groundwater testing

Fifteen groundwater samples were also obtained over two rounds of sampling and scheduled for the following analysis:

- Metals (Arsenic, Boron, Cadmium, Chromium, Copper, Iron, Lead, Manganese, Mercury, Nickel, Selenium, Zinc);
- PAHs;
- TPHCWG inc. BTEX; and
- pH, Total Cyanide, Sulphate as SO₄, Dissolved Organic Carbon (DOC), Hardness - Total, Total Phenols.

The Arup GIR [2] indicates that two surface water samples have also been subject to laboratory analysis, however laboratory results are not available at the time of writing.

3.6. Drainage Studies

7No. soakaway tests were undertaken within trial pits as part of the 2021 to 2021 GI (TP01, TP02, TP18, TP19, TP20, TP21, TP34A).

TP01, TP02 and TP34A were carried out in the Washery. Groundwater levels were too high for soakaway tests to be carried out.

TP18 was carried out within granular colliery spoil on the south-west side of the proposed junction (Earthwork Zone 12). The test provided an infiltration rate of 1.9×10^{-5} m/s on the first test but did not drain on the second test and therefore does not comply with BRE365.

TP19 was carried out in Earthwork Zone 11 of the outer loop within Glacial Till. Ground conditions comprised 4m of cohesive Glacial Till. No groundwater was encountered during excavation. Water was added from the base of the hole (4.0m bgl) to a height of 2.8m bgl. The water did not soakaway, hence it was not possible to calculate infiltration rate.

TP20 was carried out in Earthwork Zone 6 of the inner loop. Ground conditions comprised 3.4m of granular Made Ground underlain by cohesive Glacial Till. No groundwater was encountered during excavation. Water was added from the base of the hole (4.0m bgl) to a height of 2.5m bgl. There was insufficient outflow to calculate an infiltration rate.

TP21 was carried out in Earthwork Zone 5 of the outer loop within Made Ground. Ground conditions comprised 2.6m of granular Made Ground underlain by cohesive Glacial Till. No groundwater was encountered during excavation. Water was added from the base of the hole (4.0m bgl) to a height of 2.9m bgl. There was insufficient outflow to calculate an infiltration rate.

3.7. Geophysical Studies

As part of the 2021 to 2022 GI, magnetic, electromagnetic (conductivity) and microgravity geophysical surveys were undertaken by TerraDat (UK) Ltd between 15 November 2021 and 10 December 2021 across four areas within the Onllwyn Coal Washery to investigate the locations of recorded mine entries.

The findings of the geophysical surveys are presented in the TerraDat geophysical survey report which is presented in Appendix IX of the GI factual report [9].

Anomalies identified by the geophysical surveys were investigated with trial pits. None of the trial pits encountered anything to suggest the presence of a mine entry. TP14, TP35 and TP38 proved the base of the Made Ground, where it overlay glacial till, whilst the rest of the holes failed to prove the thickness of Made Ground, meaning that mine entries could still be present at these locations. TP16 was not undertaken due to the proximity of utilities at this location, which also could be the reason for the anomaly. The results and implications of the geophysical survey are discussed in further detail within the Mining Risk Assessment provided in Appendix C.

3.8. Other Fieldwork

As part of the 2021 to 2022 GI, ground level monitoring points were set out at 28 No. locations across the areas of the site with backfilled opencast workings, to assess the rate of settlement. These points had been monitored between 28th October 2020 and 7th April 2021.

The settlement points were installed and then subsequently monitored by John Vincent Land Survey (JVS) at a fortnightly frequency for the first 3 months and then monthly over the last 3 months (i.e., 9 discreet monitoring visits). The monitoring obtained levels with respect to Ordnance Datum (Newlyn) for each of the 28 survey points.

4. Ground Summary

4.1. General

This section of the report provides an interpretation of the ground investigations and studies that have been carried out to date. Interpreted ground models and geotechnical models are presented for recognisably different parts of the site (referred to hereafter as 'Earthwork Zones').

4.2. Earthwork Zones

The site has been split into eleven earthworks zones based on the following criteria:

- Topography;
- Site history;
- Anticipated geology;
- Type of earthwork;
- Proximity to adjacent structures.

A summary of the earthworks zones is provided below in Table 4-1 and shown on a site plan provided in Figure 4-1.

Table 4-1: Summary of Earthwork Zones.

Zone No.	Name of Earthwork	Chainage Extents
1	Phase 1A (Washery)	-
2	East merged loops	OL Ch 6150 to Ch 6700 IL Ch 3350 to Ch 3900
3	West merged loops	OL Ch 0 to Ch 600 & Ch 6700 to Ch 6800 IL Ch 0 to Ch 600 & Ch 3900 to Ch 4000
4	West embankment	OL Ch 3250 to Ch 4150
5	East embankment	OL Ch 4150 to 5100
6	West inner loop cutting	IL Ch 600 to 2000
7	East inner loop cutting	IL Ch 2000 to 3350
8	West outer loop cutting	OL Ch 1250 to Ch 2000
9	East outer loop cutting	OL Ch 5100 to Ch 6150
10	Nant Helen Extension	OL Ch 2000 to Ch 3250
11	Southern embankments	OL Ch 600 to Ch 1250
12	Junction	-

Notes:

OL – Outer Loop, IL – Inner Loop

Phase 1A (Washery) and Junction outside Land at Nant Helen earthworks chainage extents

Ground models have been produced for each of the earthwork zones. In addition, a 3D ground model has been developed in Leapfrog Works for the whole site.

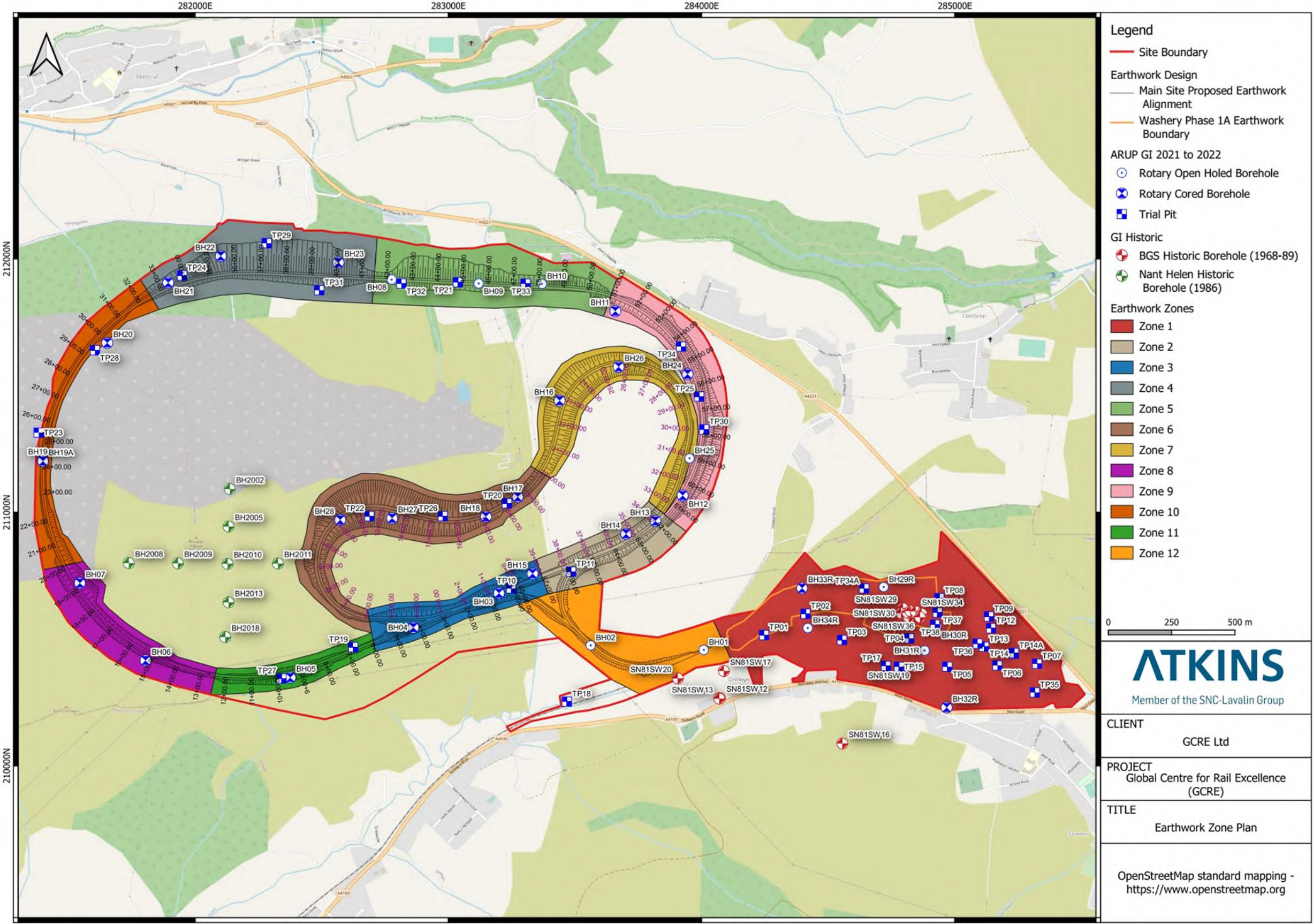


Figure 4-1: Earthwork Zone plan.

4.3. Ground Modelling

4.3.1. 2D Ground Modelling

2D ground modelling was initially carried out to enable the development of the design. Ground models for the various earthwork zones have been developed from the following information:

- Site characterisation Information from the Arup Desk Study and Arup GIR.
- Site walkover observations from the Arup walkover (described in Section 3.1 of the Arup Desk Study) and Atkins walkover.
- Historical and recent intrusive and non-intrusive ground investigations.
- Published geological information presented within the Arup Desk Study and Arup GIR
- Detailed stratigraphical information presented within Celtic Energy mine completion plans.
- Selected cross sections and long sections that present the current understanding of the ground models for each earthwork zone are presented in Appendix B.

4.3.2. 3D ground modelling

3D ground modelling was undertaken concurrent to the development of the design. The 3D ground model was developed in Leapfrog Works and is work in progress. It will be updated as more ground investigation information becomes available.

4.4. Earthwork Zone Ground Models

4.4.1. Earthwork Zone 1

Earthwork Zone 1 is located to the southeast of the proposed track loops (see Figure 4-1) and was historically used as a coal washery for the Onllwyn colliery.

29No. exploratory holes, comprising 21No. trial pits and 8No. boreholes progressed to depths of between 2.0 and 35.0 m bgl (195.5 to 243.6 m AOD), have been used to interpret the ground conditions.

The zone has been split into two ground model zones as shown in Figure 4-2. The strata levels and thicknesses for the zones are tabulated in Table 4-2 and Table 4-3. In the west of Earthwork Zone 1, the Made Ground is underlain by peat and then bedrock (Ground Model 1A). In the east of the zone, peat is absent and glacial till is present between the Made Ground and bedrock (Ground Model 1B).

The Made Ground was encountered in all exploratory holes within Earthwork Zone 1 and is representative of colliery spoil that had been used to raise ground levels across the washery area at some point during the course of mining operations.

The thickness of the Made Ground is predominantly based on borehole observations, as most trial pits did not penetrate the base of the unit. This stratum was generally encountered as a granular material, however cohesive Made Ground was encountered in two locations: TP09 from ground level to 2.0m bgl where it was described as a soft black to dark grey slightly sandy slightly gravelly silty CLAY with medium cobble content and BH34 from 3.3 to 8.0m bgl where it was generally described as a soft silty locally gravelly CLAY with a thick band of soft fibrous PEAT from 5.0 to 6.9m bgl. This anomalously thick observation of Made Ground in BH34 corresponds to the location of a pond or lagoon that has subsequently been backfilled. The peat is interpreted to be reworked material.

Geophysical investigations (magnetic, electromagnetic and microgravity) were undertaken at locations within the washery area where mine entries are recorded on Coal Authority records and trial pits then excavated where these anomalies were noted. These trial pits were as follows: TP12, TP13, TP14, TP15, TP16, TP17, TP35, TP36, TP37 and TP38. None of these trial pits encountered any mining voids suggesting that the mine entries have been at least partially filled.

A geological long section taken along through the proposed earthwork for Earthwork Zone 1 is presented in drawing GCRE001-AWJV-00-XX-DR-GE-00002 in Appendix B, the 3D model [32] should be referenced for more detailed ground modelling conditions.

Table 4-2: Earthwork Zone 1 – Ground Model 1A.

Strata	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground*	0.0	230.5 to 236.5	2.0 to 6.0	0.0	> 3.0	Generally encountered as a loose black sandy silty clayey GRAVEL locally with cobbles and boulders. Gravel is generally angular to subangular of mudstone and coal with ash. Cobbles and boulders are of mudstone and coal locally with other constituents such as concrete, timber, metal fragments, glass, clinker, bricks, bones and concrete. Reworked PEAT and silty gravelly CLAY was encountered from 3.0 to 8.0m bgl in TP34. This is considered to be representative of a backfilled pond / lagoon. These may be present in other parts of the site.
Peat	2.0 to 3.4	227.4 to 228.5	1.1 to 2.0	3.0	1.5	Generally described as a soft brown to dark brown fibrous PEAT.
Weathered South Wales Coal Measures	4.0 to 4.5	226.3 to 226.5	0.4 to 0.9	4.5	0.5	Generally described as a medium dense to dense dark grey silty sandy GRAVEL. Gravel is angular to subangular fine to coarse of mudstone. The weathered material generally comprised the uppermost 0.5m of the South Wales Coal Measures directly underlying the superficial deposits.
South Wales Coal Measures	4.9 to 9.9	222.8 to 225.9	Base of strata not encountered	5.0	Base of strata not encountered	Generally recovered as weak to medium strong MUDSTONE with one discontinuity set and locally as weak to strong SILTSTONE. Medium strong to strong grey mudstone CONGLOMERATE was noted in one location 15.0 to 16.2m bgl in BH32. Coal seams up to 1.9 m thick were noted in 7Noo. locations. Refer to separate Coal Mining Risk Assessment

* Cohesive Made Ground parameters should be considered

Table 4-3: Earthwork Zone 1 – Ground Model 1B.

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0.0	232.5 to 239.1	1.5 to 6.7	0.0	4.0	Generally encountered as a loose black sandy silty clayey GRAVEL locally with cobbles and boulders. Gravel is generally angular to subangular of mudstone and coal with ash. Cobbles and boulders are of mudstone and coal locally with other constituents such as concrete, timber, metal fragments, glass, clinker, bricks, bones and concrete.
Glacial Till	1.5 to 7.8	228.8 to 235.6	1.7 to 2.6	4.0	2.0	Generally encountered as a firm locally soft locally stiff sandy gravelly silty CLAY with low to medium cobble and boulder content. Gravel is rounded to subrounded fine to coarse of siltstone and sandstone and cobbles are rounded to subrounded of sandstone.
Weathered South Wales Coal Measures	3.5 to 9.5	229.1 to 235.5	0.9 to 1.1	6.0	1.0	Generally described as a medium dense to dense dark grey silty sandy GRAVEL. Gravel is angular to subangular fine to coarse of mudstone. The weathered material generally comprised the uppermost 0.5 to 1.0m of the South Wales Coal Measures directly underlying the superficial deposits.
South Wales Coal Measures	6.7 to 10.6	228.0 to 231.6	Base of strata not encountered	7.0	Base of strata not encountered	Generally recovered as weak to medium strong MUDSTONE with one discontinuity set and locally as weak to strong SILTSTONE. Voids up to 2m thick, likely representing abandoned mine workings were noted in two locations; BH30 9.7 – 11.7m bgl and 20.1 – 21.1m bgl. A coal seam was noted in BH30 from 13.6 to 14.2m bgl.

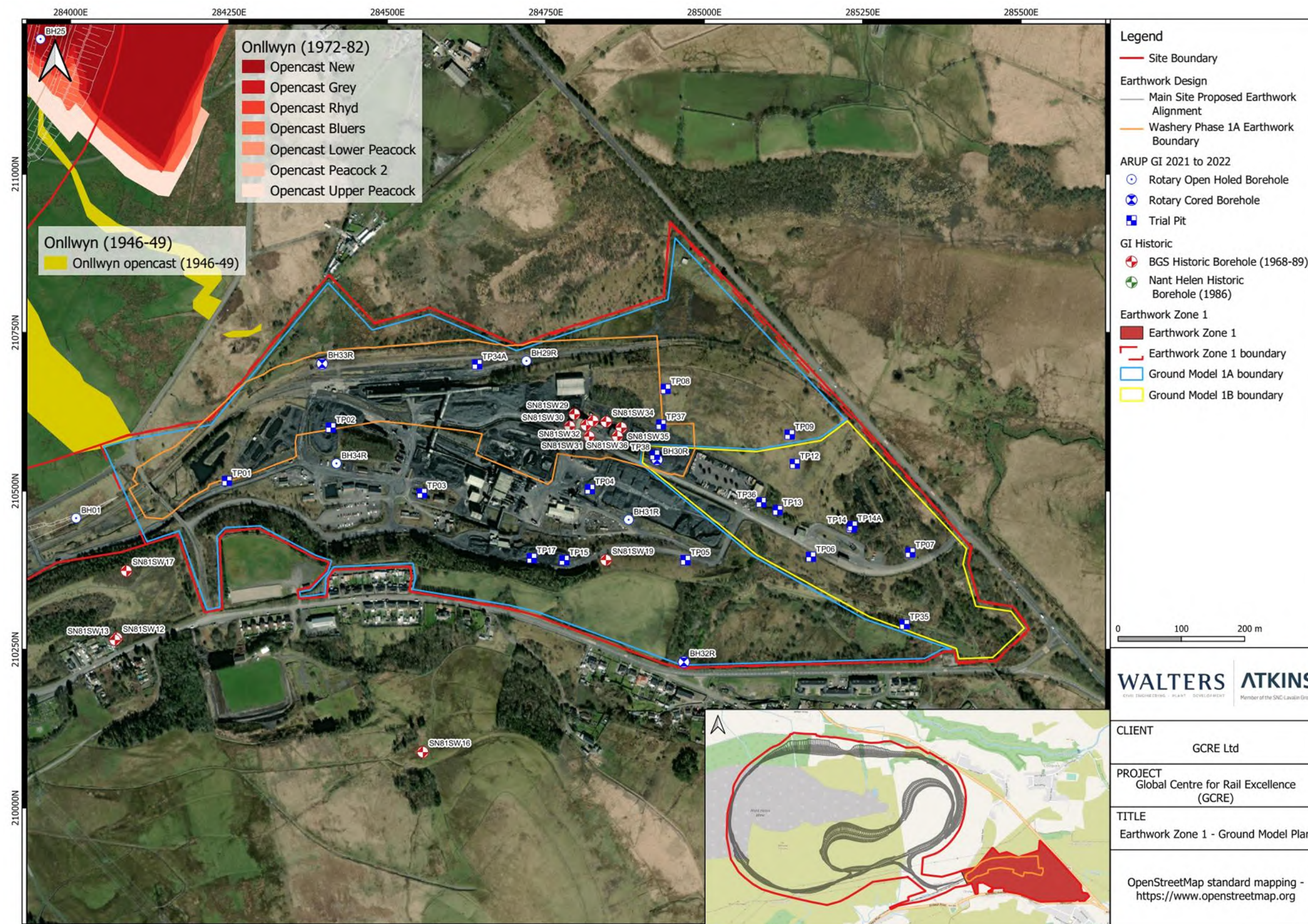


Figure 4-2: Earthwork Zone 1 – Ground model plan.

4.4.2. Earthwork Zone 2

Earthwork Zone 2 is located to the south-east of the outer loop (OL Ch 6150 to Ch 6700 and IL Ch 3350 to Ch 3900), at the point where the outer and inner loops are proposed to merge. The design alignment within this zone is anticipated to be predominantly within a cutting with a maximum height of 11.5 m.

Five exploratory holes, progressed to depths of between 2.7 and 49.2 m bgl (234.8 to 257.7 m AOD), were undertaken in proximity to Earthwork Zone 2 (BH15, TP11, BH14, BH13 and BH12) and have been used to develop the ground model.

Onllwyn (1946-49) backfilled opencast areas are mapped to underlie sections of the zone, as indicated in Figure 4-3. Subsequently, the ground conditions were found to vary across the zone with Made Ground encountered in the historically mined areas while Glacial Till was encountered across the zone within the natural ground.

As such, two ground models are proposed for Earthwork Zone 2 – Ground Model 2A and Ground Model 2B. The extents of these ground models are presented within Table 4-6.

Table 4-4: Extents of Earthwork Zone 2 ground models.

Ground model	Loop	Chainage extents
Ground Model 2A	Outer Loop	Ch 6150 to 6225 Ch 6300 to 6525
	Inner Loop	Ch 3350 to Ch 3400 Ch 3525 to Ch 3700
Ground Model 2B	Outer Loop	Ch 6225 to 6300
	Inner Loop	Ch 3400 to 3550 Ch 3700 to 3900

The interpreted ground models are described in Table 4-5 and Table 4-6 below.

Ground Model 2A represents the predominantly natural ground conditions. Ground Model 2B represents the part of alignment which falls within the footprint of the restored Nant Helen opencast coal mine.

There is some uncertainty regarding the ground model and the change in ground conditions as BH14 and BH15 are spaced a significant distance apart (approximately 400 m, indicated in Figure 4-3) with the only other investigation point (TP11) terminated at shallow depths within the Made Ground.

Possible drainage pathways, structures, or channels adjacent to the north of Earthwork Zone 2 are noted from the satellite mapping, as indicated in Figure 4-3. It is currently unclear if these pathways are a part of a localised engineering solution, as a result of (unmapped) placed fill or used to mitigate localised ground movement from the Onllwyn (1972-82) backfilled opencast site (located to the north-east, as shown in Figure 4-3). This risk should be considered during design, particularly as the earthworks comprise cuttings where excavation into the existing ground will be required.

A geological long section taken along the rail alignment for Earthwork Zone 2 is presented in drawing is presented in drawing GCRE001-AWJV-00-XX-DR-GE-00003 in Appendix B, the 3D model [32] should be referenced for more detailed ground modelling conditions.

Table 4-5: Earthwork Zone 2 – Ground Model 2A.

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0.1 to 0.5	258.8 to 259.9	0.5 to 1.1	GS	>0.8	Grey gravelly CLAY with medium cobble content. Gravel is fine to coarse angular mudstone. Cobbles are sub-angular mudstone.
Glacial Till	0.5 to 1.2	257.7 to 258.8	0.7 to 4.2	1.0	4.2	Firm brown and grey slightly gravelly silty CLAY. Gravel is fine to medium sub-rounded mudstone.
Weathered South Wales Coal Measures	5.2 to 5.4	254.1 to 254.6	0.3 to 0.5	5.2	0.5	Firm dark grey Clay with medium to coarse sub-angular to angular Gravel and Cobbles.
South Wales Coal Measures	5.6 to 5.7	255.5 to 253.6	Base of strata not encountered	5.7	Base of strata not encountered	Weak to medium strong grey MUDSTONE with discontinuity sets. Bands of sandstone and coal noted.

Table 4-6: Earthwork Zone 2 – Ground Model 2B.

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0 to 0.1	234.8 to 260.0	1.1 to 2.6	GS	1.8	Dark grey slightly silty slightly sandy GRAVEL. Gravel is angular to sub angular fine to coarse siltstone. Plastic and timber noted - possible colliery spoil.
Glacial Till	1.2 to 2.6	258.8 to 247.9	1.0 to 4.2	2.0	1.0	Firm slightly gravelly CLAY. Gravel is fine to medium sub-rounded to angular mudstone.

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Weathered South Wales Coal Measures	-	-	-	-	-	-
South Wales Coal Measures	2.7	246.9	Base of strata not encountered	2.7	Base of strata not encountered	Medium strong grey MUDSTONE with discontinuity sets. Bands of sandstone and coal noted.

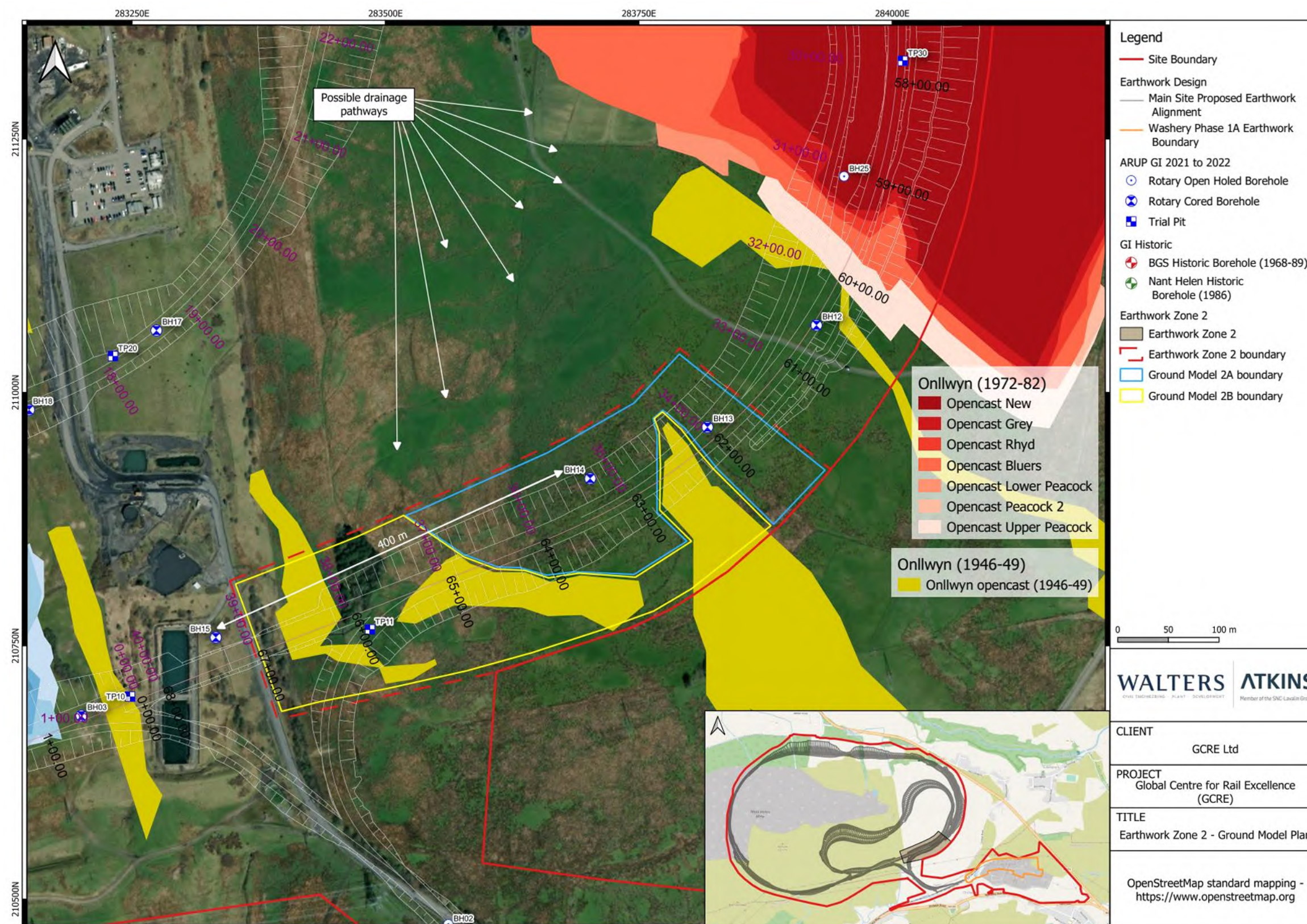


Figure 4-3: Earthwork Zone 2 – Ground Model Plan.

4.4.3. Earthwork Zone 3

Earthwork Zone 3 is located at the western merge of the inner and outer loop (OL Ch 0 to Ch 600 & Ch 6700 to Ch 6800, IL Ch 0 to Ch 600 & Ch 3900 to Ch 4000). The design alignment within this zone is anticipated to be predominantly within a cutting with a maximum height of 19.0 m.

Five exploratory holes, progressed to depths of between 2.6 and 32.7 m bgl (219.6 to 255.2 m AOD), were undertaken in proximity to Earthwork Zone 3 (BH03, BH04, BH15, TP10 and TP19) have been used to develop the ground model.

The north of the zone is located within the Nant Helen (1986-99) opencast backfilled area, as shown in Figure 4-4. Whilst the remainder of the zone is anticipated to be within natural ground. Subsequently, the ground conditions were found to vary across the zone with Made Ground encountered in the historically mined areas while Glacial Till was encountered across the zone within the natural ground.

As such, two ground models are proposed for Earthwork Zone 3 – Ground Model 3A and Ground Model 3B. The extents of these ground models are presented within Table 4-7.

Table 4-7: Extents of Earthwork Zone 3 ground models.

Ground model	Loop	Chainage extents
Ground Model 3A	Outer Loop	Ch 0 to Ch 350 Ch 6700 to Ch 6823
	Inner Loop	Ch 0 to Ch 600 Ch 3900 to Ch 4015
Ground Model 3B	Outer Loop	Ch 350 to Ch 600

The interpreted ground models are described in Table 4-8 and Table 4-9.

Ground Model 3A represents the part of alignment which falls within the footprint of the restored Nant Helen opencast coal mine. Ground Model 3B represents the predominantly natural ground conditions. Ground Model 3B is also affected by the presence of peat.

A geological long section taken along the rail alignment for Earthwork Zone 3 is presented in drawing GCRE001-AWJV-00-XX-DR-GE-00004 in Appendix B, the 3D model [32] should be referenced for more detailed ground modelling conditions.

Table 4-8: Earthwork Zone 3 – Ground Model 3A.

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0.0 to 0.2	258.3 to 249.6	2.5 to 21.8	0	13.0 ⁽¹⁾	Generally described as clayey slightly sandy GRAVEL with low cobble content of siltstone. Gravel is angular to sub angular fine to coarse mudstone and siltstone.
Glacial Till	1.8	247.9	1.0	13.0	1.0	Described as firm slightly gravelly CLAY. Gravel is fine to medium sub-rounded to angular mudstone.
South Wales Coal Measures	2.7 to 21.8	246.9 to 236.5	>27.3 base not proven.	14.0	>27.3 base not proven.	The bedrock of the South Wales Coal Measures was generally recovered as weak to medium strong MUDSTONE with two discontinuity sets. Broken mudstone and sandstone was noted in BH15 from 12.7 to 13.75m bgl and mudstone with sandstone bands from 13.75 to 30.0m bgl. Zone of core loss observed from 3.9 to 4.2m bgl in BH15.

Notes:

- (1) Characteristic thickness of Made Ground may vary depending on the location. The thickness of this unit shall be referred from Nant Helen completion plans. This data is contained with the Leapfrog 3D model.

Table 4-9: Earthwork Zone 3 – Ground Model 3B.

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0	257.7	1.6	0	1.6	Soft to firm grey gravelly CLAY. Gravel is fine to coarse angular mudstone. Slightly gravelly organic SILT for the top 0.5m.
Peat	1.6	256.1	0.4	1.6	0.4	Dark brown PEAT.
Glacial Till	0.2 to 3.9	247.2 to 243.4	1.9 to 3.8	2.0	2.9	Firm dark grey slightly sandy gravelly CLAY with low cobble content of sandstone. Gravel is angular to sub rounded fine to coarse sandstone, angular to sub angular fine to coarse siltstone. Clay and Boulders in BH04
Weathered South Wales Coal Measures	3.9	253.8	1.3	4.9	1.3	Light grey slightly clayey slightly silty slightly sandy GRAVEL. Gravel is fine to coarse angular to sub-angular mudstone.
South Wales Coal Measures	5.2	252.5	>24.8 base not proven	6.2	>24.8 base not proven	The bedrock of the South Wales Coal Measures was generally weak to medium strong MUDSTONE with one or two discontinuity sets and locally as weak SILTSTONE. Coal seams described as Weak black COAL, highly weathered to fine to medium angular Gravel noted in BH04 from 17.0 - 17.15m bgl.

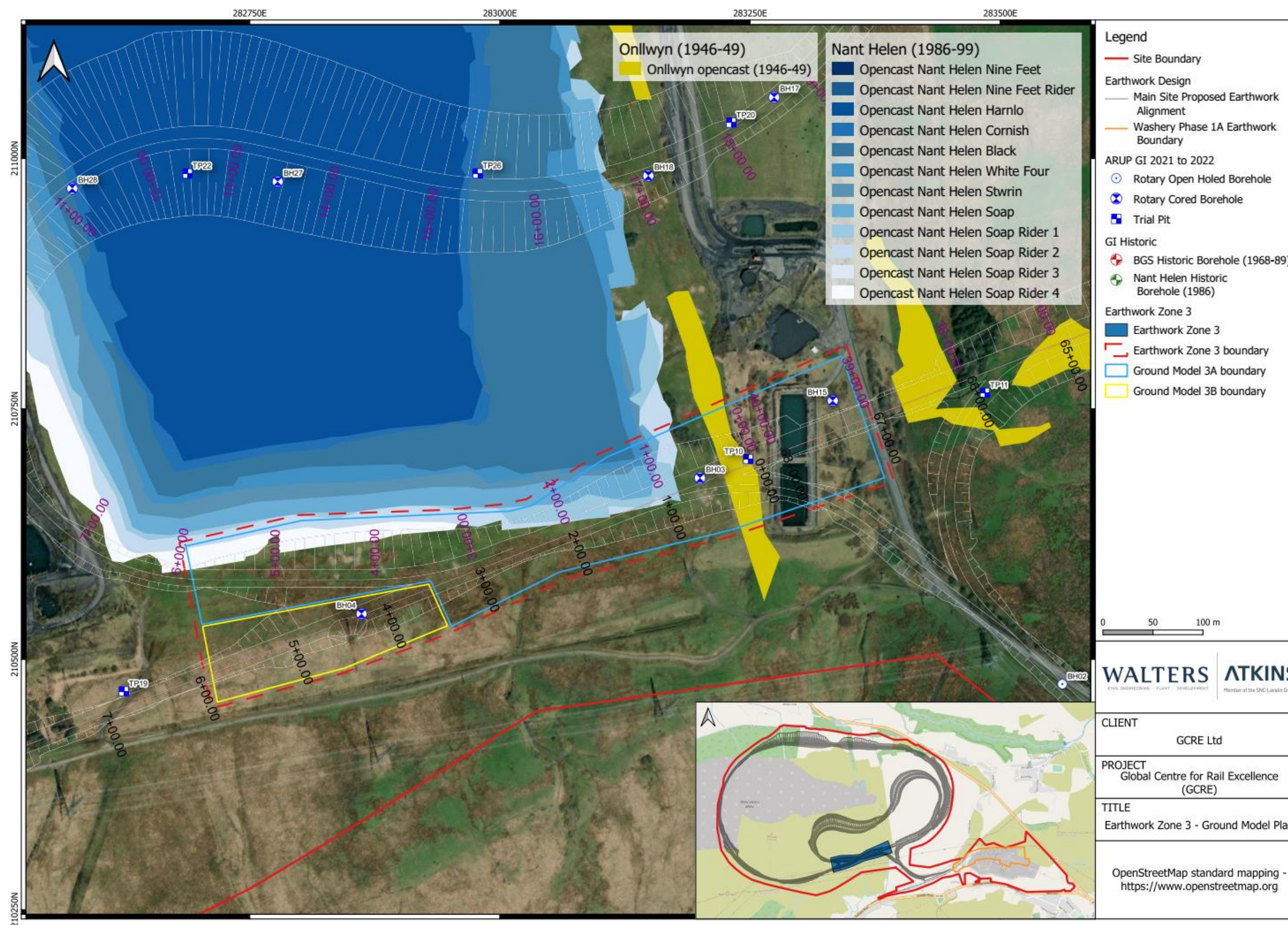


Figure 4-4: Earthwork Zone 3 – Ground Model Plan.

4.4.4. Earthwork Zone 4

Earthwork Zone 4 is in the north-west of the outer loop (OL Ch 3250 to 4150). This zone will comprise an embankment on side long ground with a maximum height of 20 m although this increases to around 40m if the northern toe of the proposed embankment (which is a significant distance downslope) is taken as the low point.

Six exploratory holes (BH21, BH22, BH23, TP24, TP29, TP31) to depths of between 4.5 and 33 m bgl, as presented within Figure 4-5, have been used to interpret ground conditions.

A single ground model has been proposed for Earthwork Zone 4. The interpreted ground model is described in Table 4-10.

Ground Model 4 represents the part of alignment which falls within the footprint of the restored Abercraf/Gwaunton opencast coal mine.

A geological long section taken along through the proposed earthwork for Earthwork Zone 4 is presented in drawing GCRE001-AWJV-00-XX-DR-GE-00005 in Appendix B, the 3D model [32] should be referenced for more detailed ground modelling conditions.

Table 4-10: Earthwork Zone 4 – Ground Model 4.

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground*	0.0 to 0.1	232.4 to 228.2	0 to 3.9	0.0	3.2	Soft to firm grey slightly sandy gravelly silty CLAY with low to medium cobble content. Gravel is fine to coarse angular siltstone, mudstone and occasional coal. Cobbles are angular siltstone.
Made Ground	0.0 to 3.2	230.7 to 199.8	4.5 to 31.5	3.2	27.6	Grey slightly clayey slightly silty slightly sandy GRAVEL with low cobble and low boulder content of siltstone. Gravel is angular to sub angular fine to coarse siltstone and rare fine to medium coal.
South Wales Coal Measures	21.4 to 31.5	181.5 to 178.4	>2.2 base not proven	30.8	>2.2 base not proven	Grey weathered or Strong grey MUDSTONE/SILTSTONE. Driller's description in BH22.

* Cohesive Made Ground parameters should be considered

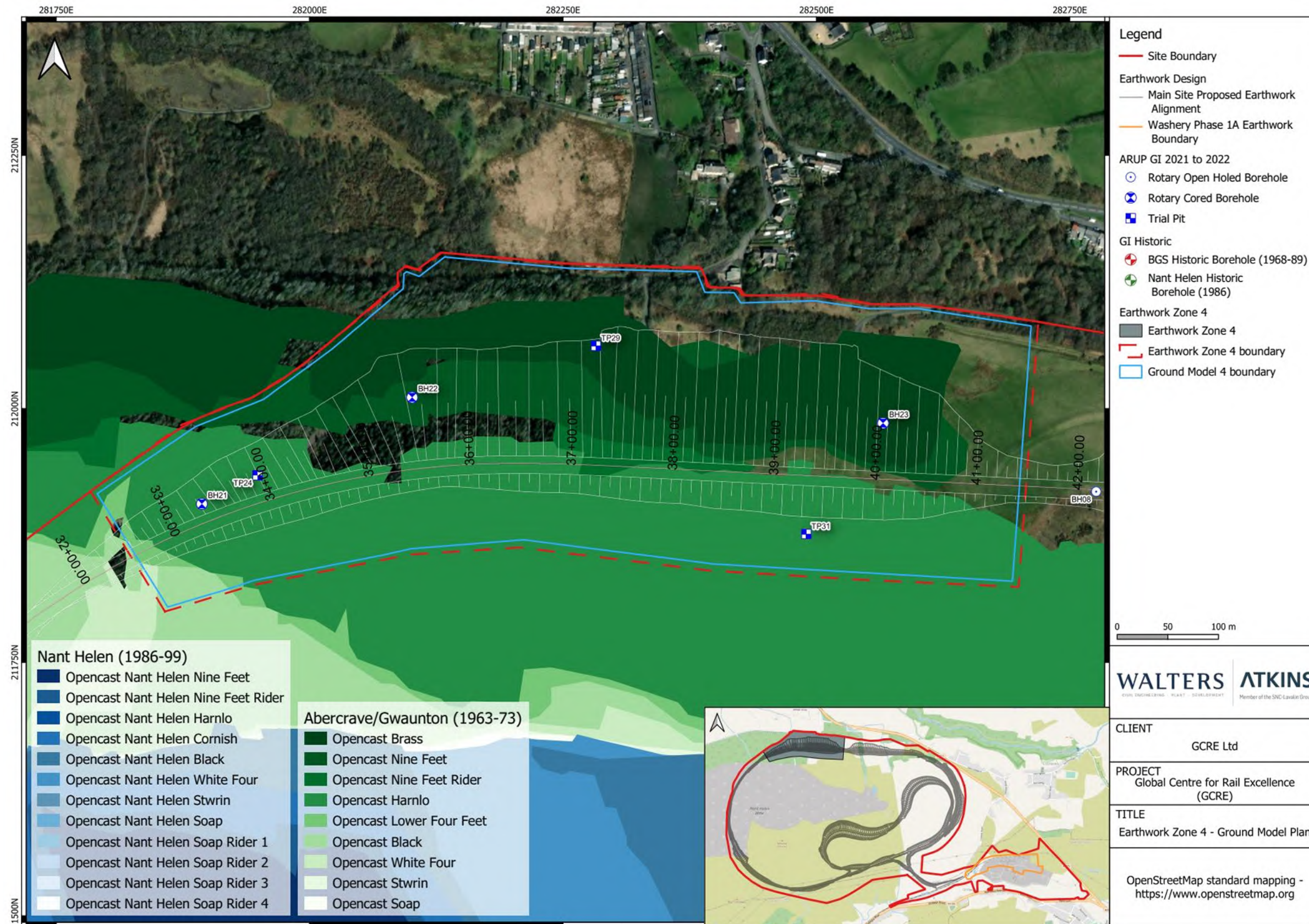


Figure 4-5: Earthwork Zone 4 – Ground Model Plan.

4.4.5. Earthwork Zone 5

Earthwork Zone 5 is in the north-east of the outer loop (OL Ch 4150 to 5100). This zone will comprise an embankment on side long ground with a maximum height of 20m although this increases to around 35 m if the northern toe of the proposed embankment (which is a significant distance downslope) is taken as the low point. Six exploratory holes (BH08, TP32, TP21, BH09, TP33 and BH10) to depths of between 4.5 and 42 m bgl, as presented within Figure 4-6, have been used to interpret ground conditions. Two ground models are proposed for Earthwork Zone 5 – Ground Model 5A and Ground Model 5B. The extents of these ground models are presented within Table 4-11 and Figure 4-6.

The transition between these two ground model zones is based upon the distribution of mining spoil heaps with significant amounts of mining spoil present in Ground Model Zone 5A and a much lesser amount present in Ground Model Zone 5B although the division between these zones is very approximate due to a relative lack of data.

Table 4-11: Extents of Earthwork Zone 5 ground models.

Ground model	Loop	Chainage extents
Ground Model 5A	Outer Loop	Ch 4150 to 4500
Ground Model 5B	Outer Loop	Ch 4500 to 5100

The interpreted ground models are described in Table 4-12 and Table 4-13.

Note that the boreholes in this area were advanced using ODEX or standard open hole techniques which means that the recovered material is not representative of the in-situ material and sample descriptions are based on the material recovered from trial pits.

A geological long section taken along through the proposed earthwork for Earthwork Zone 5 is presented in drawing GCRE001-AWJV-00-XX-DR-GE-00006 in Appendix B, the 3D model [32] should be referenced for more detailed ground modelling conditions.

Table 4-12: Earthwork Zone 5 – Ground Model 5A

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0.0	235.7 to 236.3	12.0	0.0	12.0	Made ground was generally described as a dark grey clayey sandy GRAVEL with a low cobble and boulder content. Cobbles and boulders are of siltstone. Gravel is angular to subangular fine to coarse siltstone and sandstone with rare fine to medium coal and brick. As the Made Ground is made up of mining spoil heaps it's distribution and thickness is expected to be very variable.
Glacial Till	12.0	224.3	10.0	12.0	10.0	Glacial till was generally described as a firm brownish grey sandy silty gravelly CLAY locally with low content of sandstone cobbles.
South Wales Coal Measures	22.0	214.3	Base not proven	22.0	Not proven	Driller's descriptions identified mudstone, mudstone with sandstone bands, siltstone and sandstone.

Table 4-13: Earthwork Zone 5 – Ground Model 5B

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0.0	230.4 to 236.3	2.4 to 5.7	0.0	2.5	Made ground was generally described as a dark grey clayey sandy GRAVEL with a low cobble and boulder content. Cobbles and boulders are of siltstone. Gravel is angular to subangular fine to coarse siltstone and sandstone with rare fine to medium coal and brick. As with Zone 5A the Made Ground is made

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
						up of mining spoil heaps and is expected to be very variable in terms of its distribution and thickness.
Glacial Till	2.40	233.9	>2.10 (base not proven)	2.5	3.0	Glacial till was generally described as a firm brownish grey sandy silty gravelly CLAY locally with low content of sandstone cobbles.
South Wales Coal Measures	0.0 to 5.7	225.2 to 237.0	Base not proven	3.0	Not proven	Driller's descriptions identified mudstone, mudstone with sandstone bands, siltstone and sandstone. A coal seam was noted from 24.0 to 25.2m bgl in BH10.

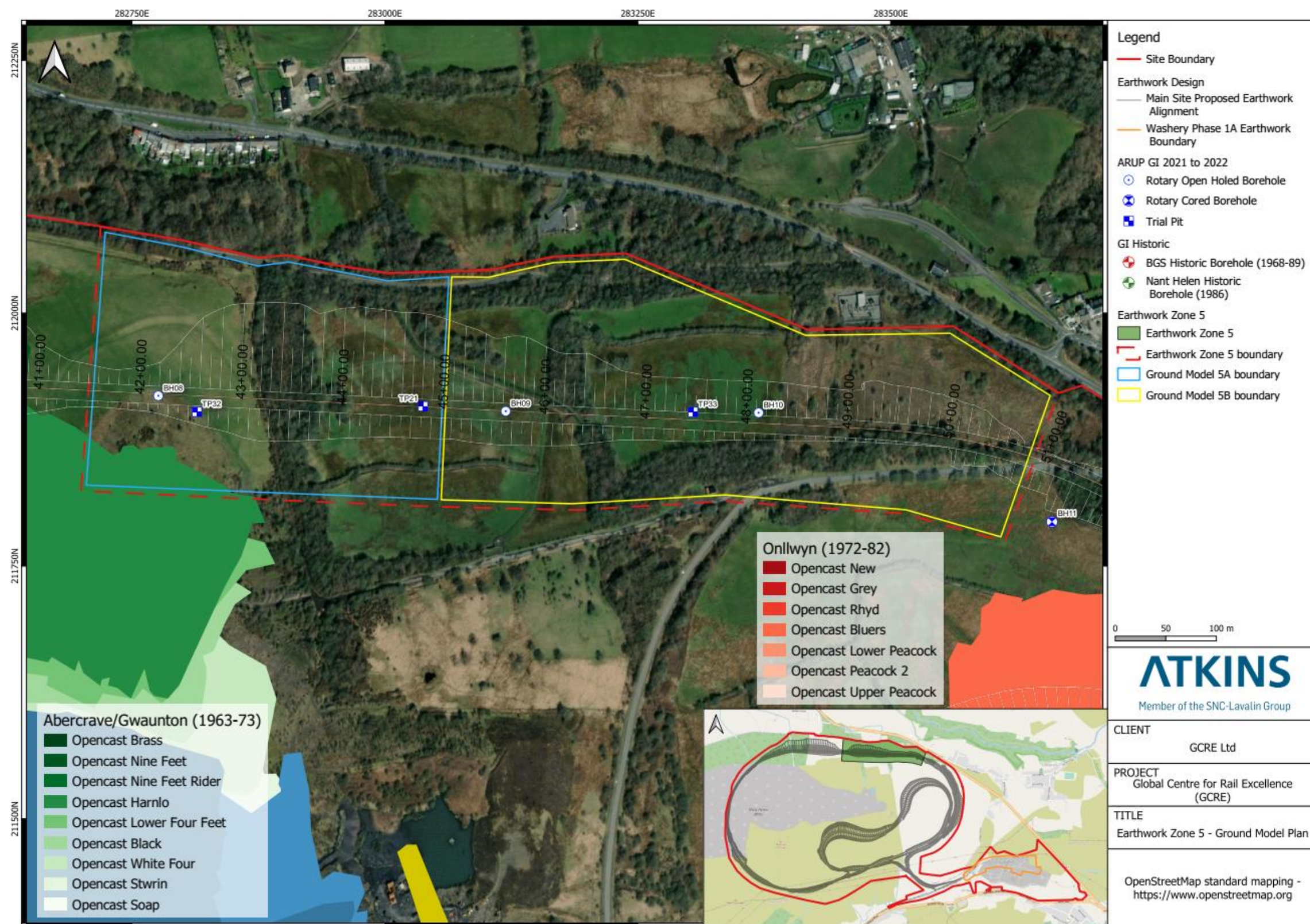


Figure 4-6: Earthwork Zone 5 – Ground model plan.

4.4.6. Earthwork Zone 6

Earthwork Zone 6 is located within the west side of the inner loop cutting (OL Ch 600 to 1900) and comprises a cutting up to 30m in depth.

7 no. exploratory holes (BH28, TP22, BH27, TP26, BH18, TP20 and BH17) advanced to depths of between 4.0 and 61.5m bgl, as presented within Figure 4-7, have been used to interpret ground conditions. Two ground models are proposed for Earthwork Zone 6 – Ground Model 6A and Ground Model 6B. The extents of these ground models are presented within Table 4-14.

Table 4-14: Extents of Earthwork Zone 6 ground models

Ground model	Loop	Chainage extents
Ground Model 6A	Inner Loop	Ch 1050 to 1650
Ground Model 6B	Inner Loop	Ch 600 to 1050 and 1650 to 1900

The interpreted ground models are described in Table 4-15 and Table 4-16.

Note that the boreholes in this area were advanced using ODEX or standard open hole techniques which means that the recovered material is not representative of the in-situ material and sample descriptions are based on the material recovered from trial pits.

The proposed earthwork within this zone extends across the footprint of the restored Nant Helen open cast coal mine. Ground Model 6A represents the model within the backfill, whereas Ground Model 6B represents the conditions outside the footprint of the workings.

A geological long section taken along through the proposed earthwork for Earthwork Zone 6 is presented in drawing GCRE001-AWJV-00-XX-DR-GE-00007 in Appendix B, the 3D model [32] should be referenced for more detailed ground modelling conditions.

Table 4-15: Earthwork Zone 6 – Ground Model 6A

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0.0	275.0 to 286.1	18.0 to >100.0	0	Variable – 3D model to be consulted [32]	Generally described as a dark grey slightly clayey slightly sandy GRAVEL with a low cobble and boulder content. Cobbles and boulders are of siltstone. Gravel is angular to subangular fine to coarse siltstone and sandstone with rare fine to medium coal. The base of the Made Ground has been estimated from mine completion plans. Which have been incorporated into the 3D model.
South Wales Coal Measures	18.0 to > 100.0	251.1 to < 175.0	Base not proven	Variable – 3D model to be consulted [32]	Not proven	Generally encountered as a medium strong to strong grey SILTSTONE with one discontinuity set. A 30cm thick band of strong grey SANDSTONE was encountered at a depth of 33.4 m bgl (elevation 241.6m AOD).

Table 4-16: Earthwork Zone 6 – Ground Model 6B

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0	275.0 to 276.9	2.7 to 3.4	0.0	3.0	Generally described as a dark grey slightly clayey slightly sandy GRAVEL with a low cobble and boulder content. Cobbles and boulders are of siltstone. Gravel is angular to subangular fine to coarse siltstone and sandstone with rare fine to medium coal.

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Glacial Till	2.7 to 3.4	275.0 to 276.9	3.7	3.0	3.7	Generally described as a firm brown slightly sandy gravelly silty CLAY. Gravel is subangular to subrounded fine to coarse of sandstone.
Weathered South Wales Coal Measures	6.4	270.5	0.8	6.4	0.8	This was encountered in only one of the holes and was drilled using ODEX techniques meaning that no meaningful description is available.
South Wales Coal Measures	7.2	269.7	Base not proven	7.2	Not proven	Generally encountered as a medium strong dark grey MUDSTONE with one discontinuity set. A 1.75m thick band of strong grey sandstone CONGLOMERATE with mudstone nodules was encountered at a depth of 11.05m bgl (elevation 265.8 m AOD). Immediately beneath this conglomerate band it was described as a black clayey subrounded to subangular mudstone and conglomerate GRAVEL possibly representative of backfilled mine workings.

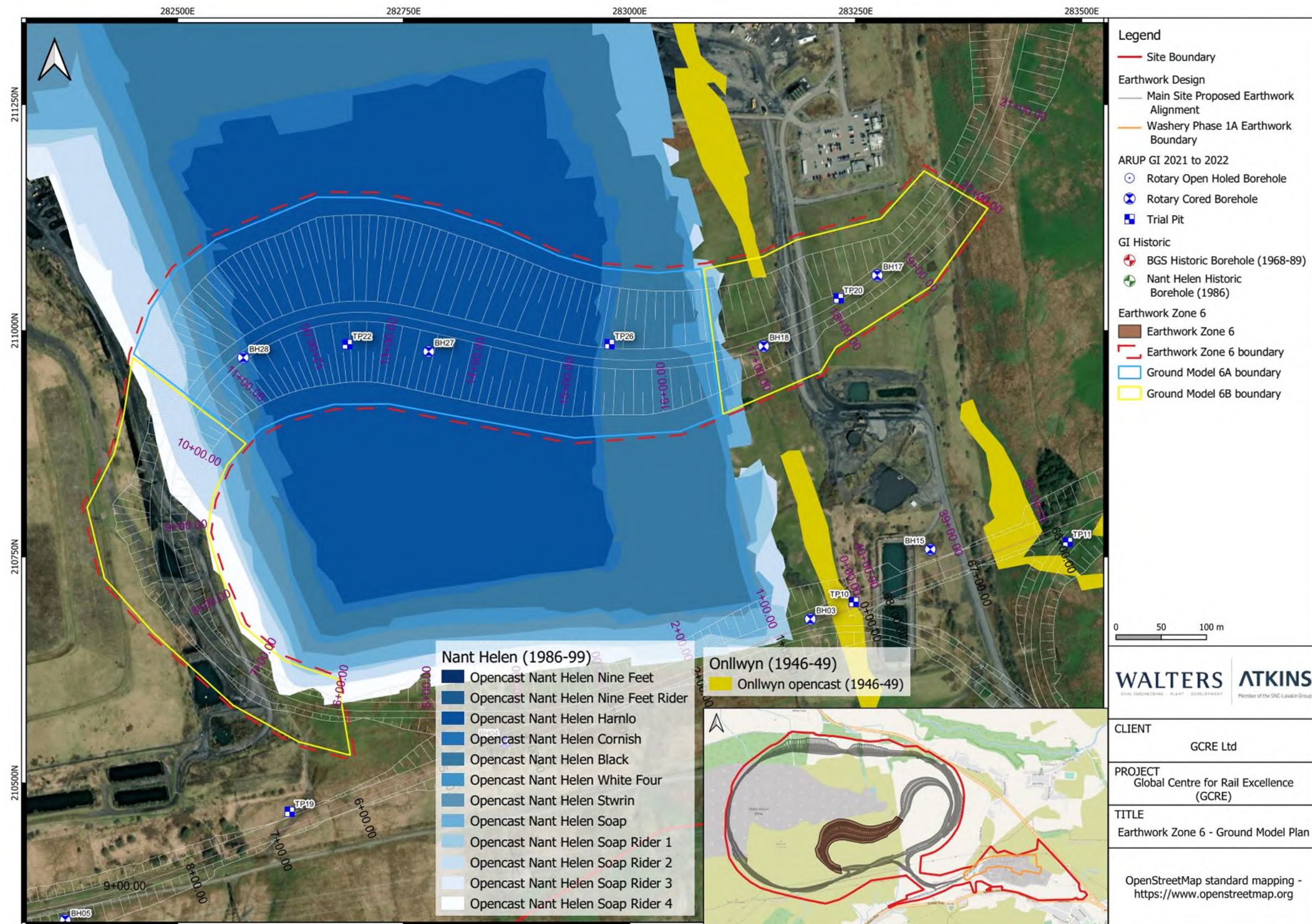


Figure 4-7: Earthwork Zone 6 – Ground Model Plan.

4.4.7. Earthwork Zone 7

Earthwork Zone 7 is located to the centre of the Land at Nant Helen, (IL Ch 2000 to Ch 3350), forming the eastern part of the inner loop. The design alignment within this zone is within a cutting with a maximum depth of 19 m.

A total of 9 No. exploratory holes, progressed to depths of between 4.5 and 50.7 m bgl (208.0 to 251.1 m AOD), were undertaken in proximity to the Zone 7 earthworks (BH12, BH13, BH14, BH16, BH17, BH24, BH26, TP25 & TP30) have been used to develop a ground model.

The central section of this zone is located within the Onllwyn opencast backfilled areas (1946-49 and 1972-82), as shown in Figure 4-8. Whilst the remainder of the zone is anticipated to be within natural ground. Subsequently, the ground conditions were found to vary across the zone with Made Ground encountered in the historically mined areas while Glacial Till was encountered across the zone within the natural ground.

As such, two ground models are proposed for Earthwork Zone 7 – Ground Model 7A and Ground Model 7B. The extents of these ground models are presented within Table 4-17.

Table 4-17: Extents of Earthwork Zone 7 ground models.

Ground model	Loop	Chainage extents
Ground Model 7A	Inner Loop	Ch 2000 to Ch 2525 Ch 3225 to Ch 3350
Ground Model 7B	Inner Loop	Ch 2525 to Ch 3225,

The interpreted ground models are described in Table 4-18 and Table 4-19.

Exploratory holes located within the Onllwyn backfill did not prove the full thickness of the backfill, however, mining records indicate that the maximum depth of the backfill was 82 m bgl. 3D restoration plans for the backfilled areas have been provided and used to inform the 3D ground model. Due to the significant variation in the ground model within the Onllwyn backfill, the 3D model [32] should be referenced directly.

The extent of the weathering within this region is not clear. BH26, located to the edge of the Onllwyn backfill, recorded approximately 0.5 m of weathered bedrock, whilst BH12 recorded a thickness of 1.5 m.

An indicative geological long section taken along the rail alignment for Zone 7 is presented in drawing GCRE001-AWJV-00-XX-DR-GE-00008 in Appendix B, the 3D model [32] should be referenced for more detailed ground modelling conditions.

Table 4-18: Earthwork Zone 7A – Ground Model

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0 to 0.5	258.8 to 276.8	0.5 to 2.7	GS	0.5	Clayey GRAVEL, of fine angular Mudstone
Glacial Till	0 to 2.7	257.7 to 280.7	0.7 to 4.2	0.5	4.0	Firm brown and grey slightly gravelly silty CLAY. Gravel is fine to medium sub-rounded mudstone
Weathered South Wales Coal Measures	1.2 to 6.4	254.1 to 270.4	0.2 to 1.5	4.5	0.5	Fine to coarse sub-angular to angular GRAVEL and Cobbles
South Wales Coal Measures*	2.7 to 7.2	253.6 to 276.5	Base of strata not encountered	5.0	Base of strata not encountered	Weak to medium strong grey MUDSTONE with one discontinuity set with bands of sandstone and coal

*Two zones of no recovery recorded in BH12

Table 4-19: Zone 7B – Ground Model

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0 to 0.9	252.6 to 273.1	35.2 – base of strata not encountered (max 82 m based on mining records)	GS	Variable – 3D model to be consulted [32]	Colliery Spoil – variable description Predominantly Grey clayey slightly sandy GRAVEL with low cobble content of siltstone. Gravel is angular to sub angular fine to coarse mudstone and siltstone and rare coal

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Weathered South Wales Coal Measures*	35.2	237.9	0.5	Variable – 3D model to be consulted [32]	0.5 – 1.5	Grey weathered MUDSTONE

South Wales Coal Measures

*Only encountered by BH26, bedrock level variable due to mining activity

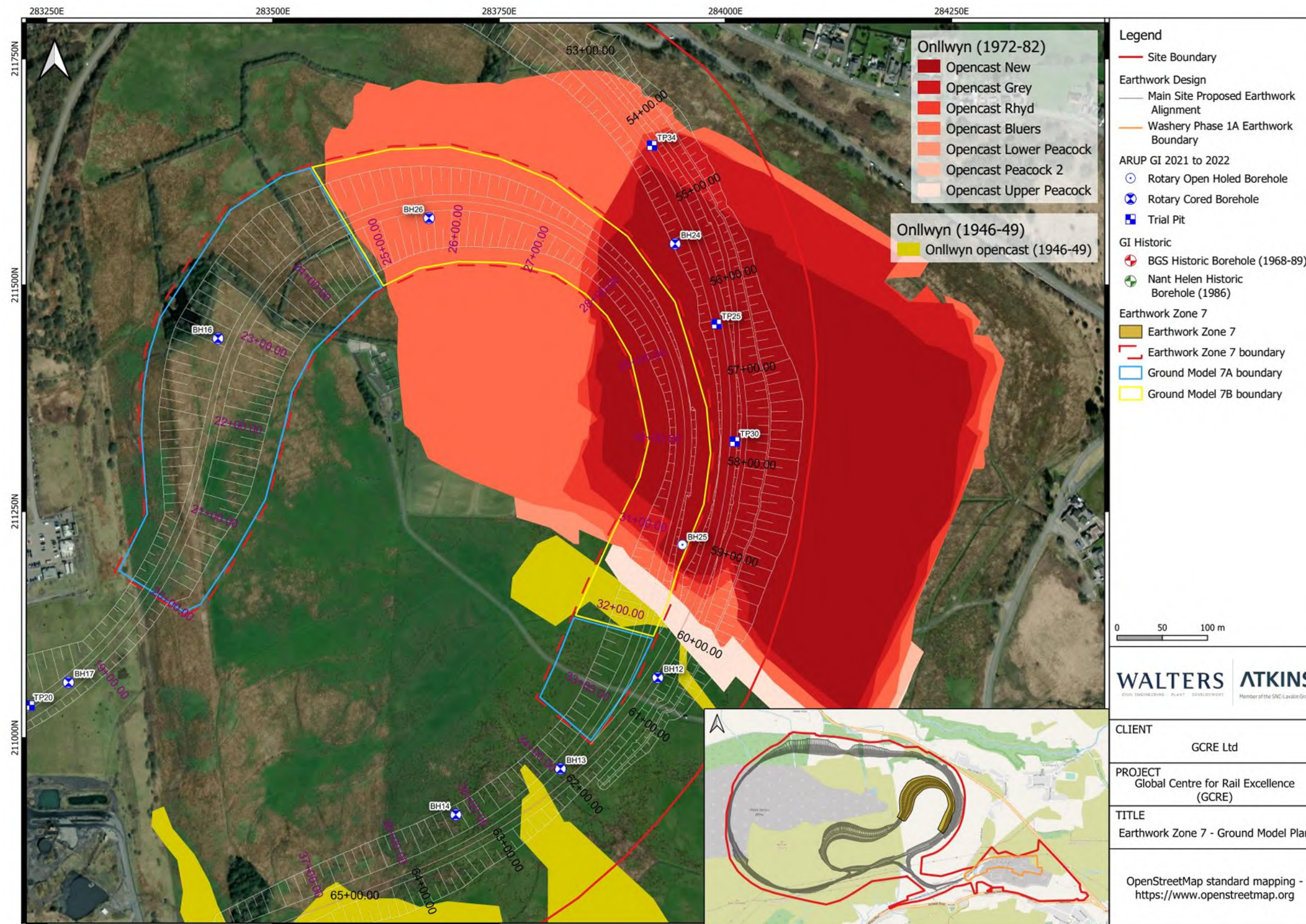


Figure 4-8: Earthwork Zone 7 – Ground Model Plan.

4.4.8. Earthwork Zone 8

Earthwork Zone 8 comprises the west outer loop cutting is located on the south-west edge of the outer loop between Ch 1250 and 2000 and comprises a cutting up to 20m in depth around the southwest edge of the overburden storage area.

Two exploratory holes (BH06 and BH07) advanced to depths of between 30.0 and 35.0m bgl, as presented within Figure 4-10, have been used to interpret ground conditions. Two ground models are proposed for Earthwork Zone 8 – Ground Model 8A and Ground Model 8B. The extents of these ground models are presented within Table 4-20.

Table 4-20: Extents of Earthwork Zone 8 ground models.

Ground model	Loop	Chainage extents
Ground Model 8A	Outer Loop	Ch 1250 to 1350 and 1600 to 2000
Ground Model 8B	Outer Loop	Ch 1350 to 1600

The interpreted ground models are described in Table 4-21 and Table 4-22. ODEX techniques were used to advance through the Glacial Till meaning that the material descriptions are not necessarily representative of the in-situ material. The description given below is based upon the material recovered from the SPT sampler although this will not have captured any coarse element of the material.

The proposed earthwork within this zone extends across the toe of the overburden storage area. Ground Model 8A represents the model outside of the area of the overburden storage area, whereas Ground Model 8B represents the conditions within the area of the overburden storage area.

No data is available for the Made Ground of the overburden storage area and the interpretation of the stockpile as being comprised of cohesive Made Ground is an assumption based upon the purpose of the stockpile.

Evidence of peat was noted in the vicinity of the earthwork zone during the Atkins site walkover. However, due to the limited number of investigations the material was not encountered by either of the exploratory holes. The peat is anticipated to be a localised deposit, however, due to the limited ground investigation no additional information is known about the thickness or composition of the material.

A geological long section taken along through the proposed earthwork for Earthwork Zone 8 is presented in drawing GCRE001-AWJV-00-XX-DR-GE-00009 in Appendix B, the 3D model [32] should be referenced for more detailed ground modelling conditions.

Table 4-21: Earthwork Zone 8 – Ground Model 8A

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Glacial Till	0 – 0.3	263.1 - 271	2.0 – 3.9	0	3	Generally described as a soft grey and light brown slightly gravelly CLAY. Gravel is sub-rounded to angular fine to coarse mudstone.
SWCM	2.0 – 3.9	261.7 - 267.1	Base not proven	3	Not proven	Generally described as a medium strong dark grey MUDSTONE with one discontinuity set. It was described as a weak to medium strong grey SILTSTONE with one discontinuity set in the uppermost 1.5m from 267.1 to 265.6 m AOD. There is a band of highly to completely weathered material between 5.7 and 5.95 m bgl. Coal was encountered from 249.3m AOD to 247.8m.

Table 4-22 - Earthwork Zone 8 – Ground Model 8B

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0	250.7 – 274.5*	0 – 10*	GS	0 – 10.0* Variable thickness, increasing towards centre of overburden storage area	Anticipated to comprise reworked local cohesive superficial deposits
Glacial Till	0.3 – 10.0	263.1 - 271	2.0 – 3.9	0 – 10.0*	4.0	Generally described as a soft grey and light brown slightly gravelly CLAY. Gravel is sub-rounded to angular fine to coarse mudstone.
SWCM	2.0 – 3.9	261.7 - 267.1	Base not proven	4.0 - 14*	Not proven	In BH07 bedrock of the South Wales Coal Measures was generally described as a medium strong dark grey MUDSTONE with one discontinuity set. It was described as a weak to medium strong grey SILTSTONE with one discontinuity set in the uppermost 1.5m from 267.1 to 265.6 m AOD. There is a band of highly to completely weathered material between 5.7 and 5.95 m bgl. In BH06 was described as a medium strong grey MUDSTONE with two discontinuity sets. Between 3.7 and 4.3m bgl it was described as completely weathered and recovered as a fine to coarse angular GRAVEL. Coal was encountered from 249.3m AOD to 247.8m AOD in BH07 and from 236.1m AOD to 235.3m AOD in BH06. Given the general dip of South Wales Coal Measures to the south it is likely that these are representative of the same seam although this cannot be proven with certainty based upon this data set.

* estimated values based on topography due to no ground investigation information within the overburden storage area



Figure 4-9: Earthwork Zone 8 – Ground Model Plan.

4.4.9. Earthwork Zone 9

Earthwork Zone 9 is located at the east of the outer loop (OL Ch 5100 to 6150). The design alignment within this zone is anticipated to be predominantly within a cutting with a maximum height of 9.5 m.

Six ground investigation points, progressed to depths of between 4.5 and 50.7 m bgl (208.0 to 251.1 m AOD), (BH11, BH12, BH24, TP25, TP30 and TP34) have been used to develop the ground model.

Sections of the zone are located within the Onllwyn opencast backfilled areas (1946-49 and 1972-82), as shown in Figure 4-10, whilst the remainder of the zone is anticipated to be within predominantly natural ground. Subsequently, the ground conditions were found to vary across the zone with Made Ground encountered in the historically mined areas while Glacial Till was encountered across the zone within the natural ground.

As such, two ground models are proposed for Earthwork Zone 9 – Ground Model 9A and Ground Model 9B. The extents of these ground models are presented within Table 4-23.

Table 4-23: Extents of Earthwork Zone 9 ground models.

Ground Model	Loop	Chainage
Ground Model 9A	Outer Loop	Ch 5100 to 5300 Ch 6050 to Ch 6150
Ground Model 9B	Outer Loop	Ch 5300 to Ch 6050

The interpreted ground models are described in Table 4-24 and Table 4-25.

Ground Model 9A represents the predominantly natural ground conditions. Ground Model 9B represents the part of alignment which falls within the footprint of the restored Onllwyn opencast coal mines.

The thickness of backfill was not proven during ground investigations, however, mining records indicate that the maximum depth of the backfill was 82 m bgl. 3D restoration plans for the backfilled areas have been provided and used to inform the 3D ground model. Due to the significant variation in the ground model within the Onllwyn backfill, the 3D model [32] should be referenced directly.

Additionally, as the boreholes were terminated within the Made Ground material, the quality of the bedrock was not proven, and the extent of weathering was not confirmed.

A geological long section taken along the rail alignment for Earthwork Zone 9 is presented in drawing GCRE001-AWJV-00-XX-DR-GE-00010 in Appendix B, the 3D model [32] should be referenced for more detailed ground modelling conditions.

Table 4-24: Earthwork Zone 9 – Ground Model 9A.

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground ^{1*}	0	258.8	5.4	0	5.4	Grass over brown, grey Sandstone boulders with clay bands (Drillers Description)
Glacial Till ²	0	257.7	0.7	0	0.7	Brown Clay
Weathered South Wales Coal Measures	5.4	253.4	0.3	5.4	0.3	Grey weathered MUDSTONE (Drillers Description)
South Wales Coal Measures	5.7	253.1	>24.3 base not proven	5.7	>24.3 base not proven	Weak to strong dark grey MUDSTONE with one discontinuity set with bands of siltstone. 0.55m thick Weak black COAL observed from 10.65m bgl to 11.2 m bgl.

(1) North of zone (BH11)

(2) South of zone (BH12)

* Cohesive Made Ground parameters should be considered

Table 4-25: Earthwork Zone 9 – Ground Model 9B.

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0 to 0.9	257.8 to 252.6	> 4.3 - base of strata not encountered (max 82 m based on mining records)	GS	Variable – 3D model to be consulted [32]	clayey slightly sandy GRAVEL with low cobble content of siltstone. Gravel is angular to sub angular fine to coarse siltstone and rare coal, sub angular to sub rounded fine to coarse sandstone.
South Wales Coal Measures ¹	-	-	-	-	-	-

(1) Not encountered during investigation as exploratory holes not progressed through Made Ground strata

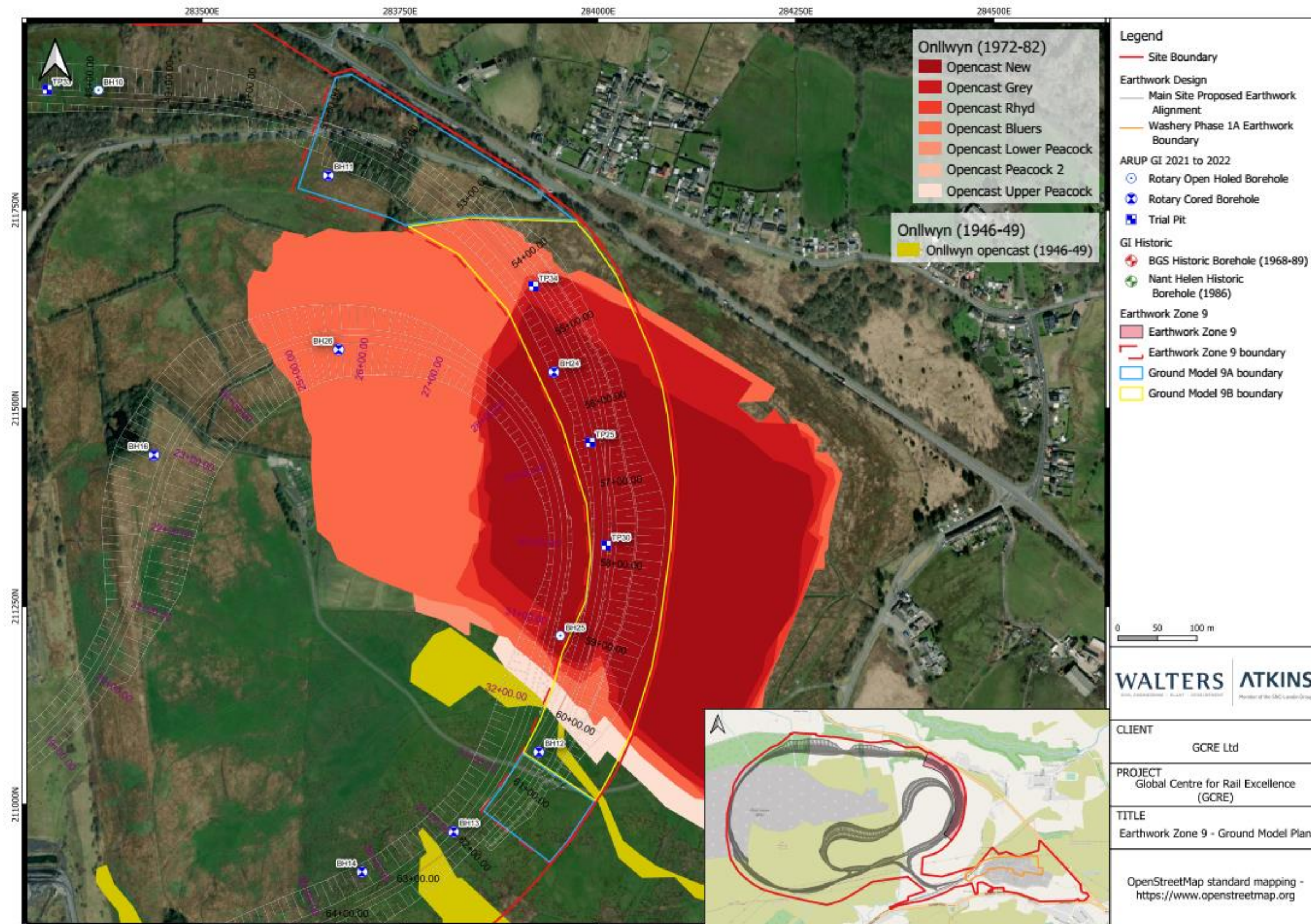


Figure 4-10: Earthwork Zone 9 – Ground Model Plan.

4.4.10. Earthwork Zone 10

Earthwork Zone 10 the westernmost section of the outer loop (OL Ch 2000 to 3250). This zone runs through the backfilled Nant Helen extension and is mostly at grade with limited earthworks likely to be required.

Five exploratory holes (BH19, BH19A, TP23, TP28 and BH20) to depths of between 4.0 and 40.2m bgl, as presented within Figure 4-11, have been used to interpret ground conditions.

None of the exploratory holes proved the base of the Made Ground. All the boreholes were advanced using ODEX techniques and therefore the arisings recovered are not considered to be representative of the in-situ material and the Made Ground descriptions have been based on the trial pit arisings.

A single ground model has been proposed for Earthwork Zone 10. The interpreted ground model is described in Table 4-26.

A geological long section taken along through the proposed earthwork for Earthwork Zone 10 is presented in drawing GCRE001-AWJV-00-XX-DR-GE-00011 in Appendix B, the 3D model [32] should be referenced for more detailed ground modelling conditions.

Table 4-26: Earthwork Zone 10 – Ground Model.

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	0.0	248.1 – 255.3	>40.2 base not proven	0	>40.2 base not proven	Generally described as a dense black to dark grey slightly sandy silty angular to subangular fine to coarse mudstone GRAVEL with high cobble and boulder content. Cobbles and boulders are subangular to subrounded mudstone and siltstone.

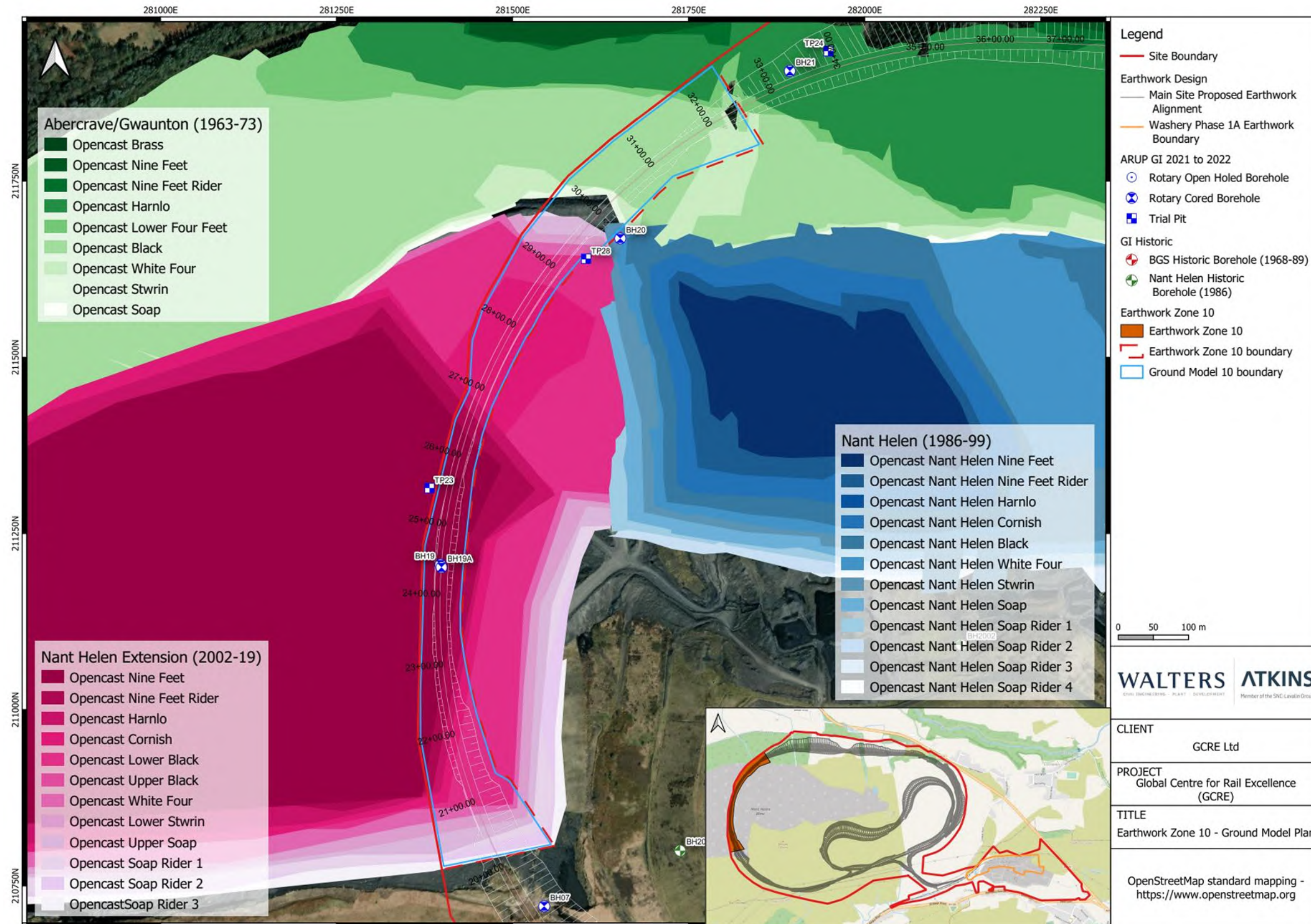


Figure 4-11: Earthwork Zone 10 – Ground Model Plan.

4.4.11. Earthwork Zone 11

Earthwork Zone 11 is located at the southwest of the outer loop (OL Ch 600 to Ch 1250). The design alignment within this zone is anticipated to be predominantly within an embankment with a maximum height of 8.3 m.

Three ground investigation points, progressed to depths of between 4.0 and 30.7 m bgl (210.0 to 246.3 m AOD), (BH05, TP19, TP27), as presented in Figure 4-12, have been used to have been used to develop the ground model.

The zone is anticipated to be within predominantly natural ground, with no significant changes in ground conditions. As such, one ground model is proposed for Earthwork Zone 11 – Ground Model 11, as shown in Figure 4-12.

The interpreted ground model is described in Table 4-27.

Ground Model 9A represents the predominantly natural ground conditions. Ground Model 9B represents the part of alignment which falls within the footprint of the restored Onllwyn opencast coal mines.

A geological long section taken along the rail alignment for Earthwork Zone 11 is presented in drawing GCRE001-AWJV-00-XX-DR-GE-00012 in Appendix B, the 3D model [32] should be referenced for more detailed ground modelling conditions.

Table 4-27: Earthwork Zone 11 – Ground Model

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground (Cohesive)	0.0-0.2	239.5	0.6	0.0	0.6	Brown gravelly sandy slightly organic CLAY
Peat	0.8	238.9	0.2	0.6	0.2	Dark brown very fibrous PEAT.
Glacial Till (Cohesive)	0.0 – 0.9	239.4	11.0	0.8	11.0	Very soft to Firm to stiff grey very gravelly CLAY with low cobble content. Gravel is fine to coarse sub-rounded to angular mudstone, occasional coal and sandstone. Cobbles are sub-rounded sandstone and mudstone.
South Wales Coal Measures	11.0	228.4	>19.7 base not proven.	11.8	>19.7 base not proven.	Medium strong to strong grey thinly to thickly interlaminated MUDSTONE and SANDSTONE with one discontinuity set.

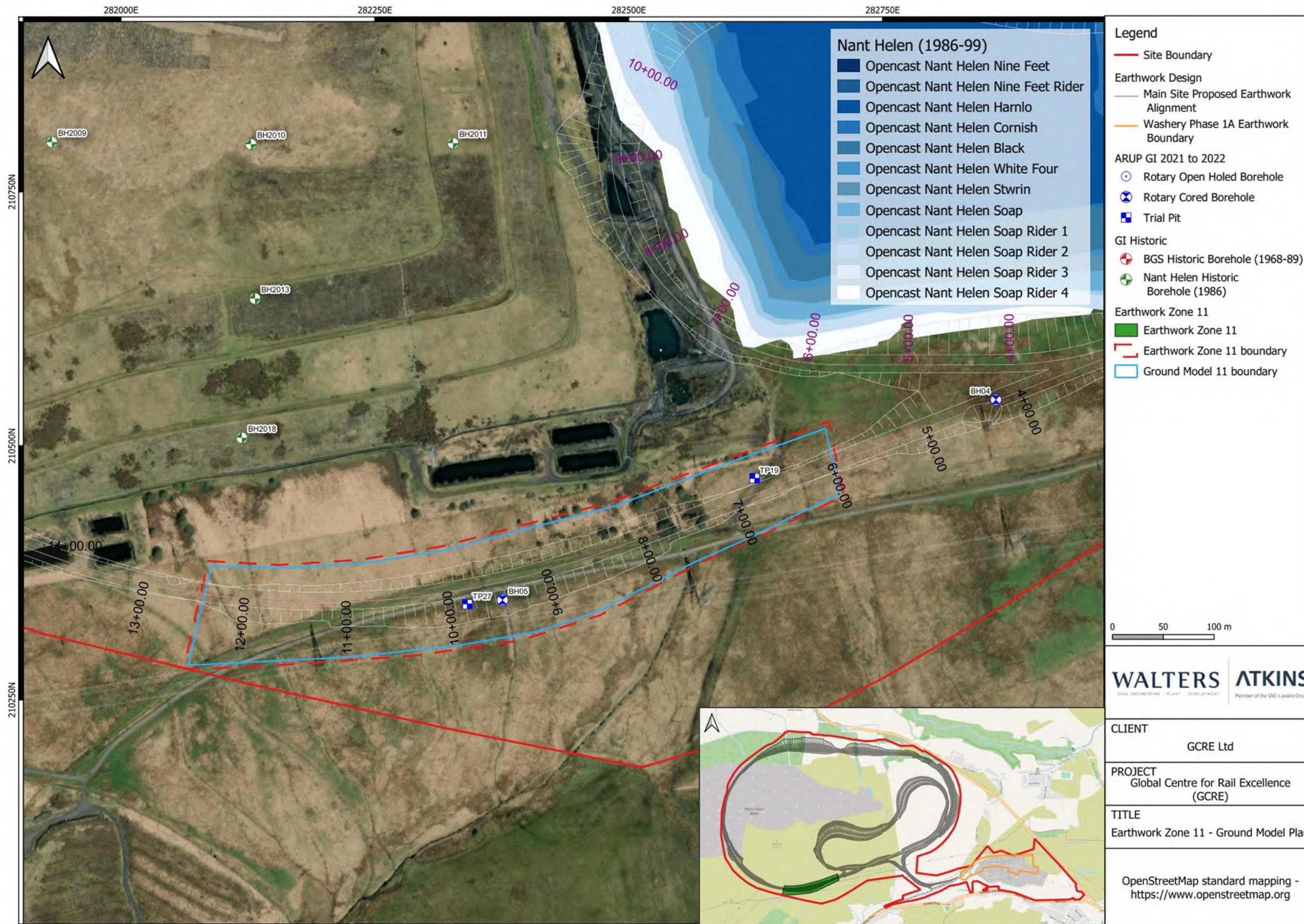


Figure 4-12: Earthwork Zone 11 – Ground Model Plan.

4.4.12. Earthwork Zone 12

Earthwork Zone 12 is the junction between the Land at Nant Helen and the washery and will comprise embankments of maximum height 5.5 m which transition into cuttings of maximum height 10.2 m.

Seven exploratory holes, progressed to depths of between 2.6 and 32.7 m bgl (219.6 to 255.2 m AOD), (BH01, BH02, TP18, SN81SW17 and SN81SW20), as presented within Figure 4-13, have been used to have been used to develop the ground model.

A single ground model has been proposed for Earthwork Zone 12. The interpreted ground model is described in Table 4-28.

The zone is comprised of multiple engineered features (Nant Helen access roads, public roads & the Neath and Brecon railway line) with Made Ground encountered across the area. However, the available ground investigation was predominantly undertaken along the centreline of the proposed earthworks, which in this area broadly align with the man-made features. Therefore, there may be variation in the ground model across the cross-section of the earthwork where the Made Ground transitions into natural ground (where glacial till may be present). This risk should be considered during detailed design.

Additionally, there is some uncertainty regarding the ground model as BH02 is spaced a significant distance apart (approximately 500 m) from other exploratory holes.

A geological long section taken along the rail alignment for Earthwork Zone 12 is presented in drawing GCRE001-AWJV-00-XX-DR-GE-00013 in Appendix B, the 3D model [32] should be referenced for more detailed ground modelling conditions.

Table 4-28: Earthwork Zone 12 – Ground Model.

Stratum	Top of stratum (m bgl)	Top of stratum (m AOD)	Thickness range (m)	FOR USE IN DESIGN		Strata description
				Characteristic stratum top (m bgl)	Characteristic thickness (m)	
Made Ground	GS to 0.1	238.0 to 225.8	1.2 to 5.9	GS	5.0	Brown CLAY with colliery spoil/tip material
Glacial Till ¹	1.2	236.8	2.7	1.2	2.7	Brown CLAY and boulders.
Weathered South Wales Coal Measures	5.0 to 3.9	223.3 to 234.1	1.8 to 2.2	5.0	1.8	Weathered MUDSTONE
South Wales Coal Measures	5.7 to 7.2	255.5 to 253.6	Base of strata not encountered	6.8	Base of strata not encountered	Grey silty MUDSTONE Bands of sandstone, siltstone and coal noted.

(1) Encountered by BH02 only

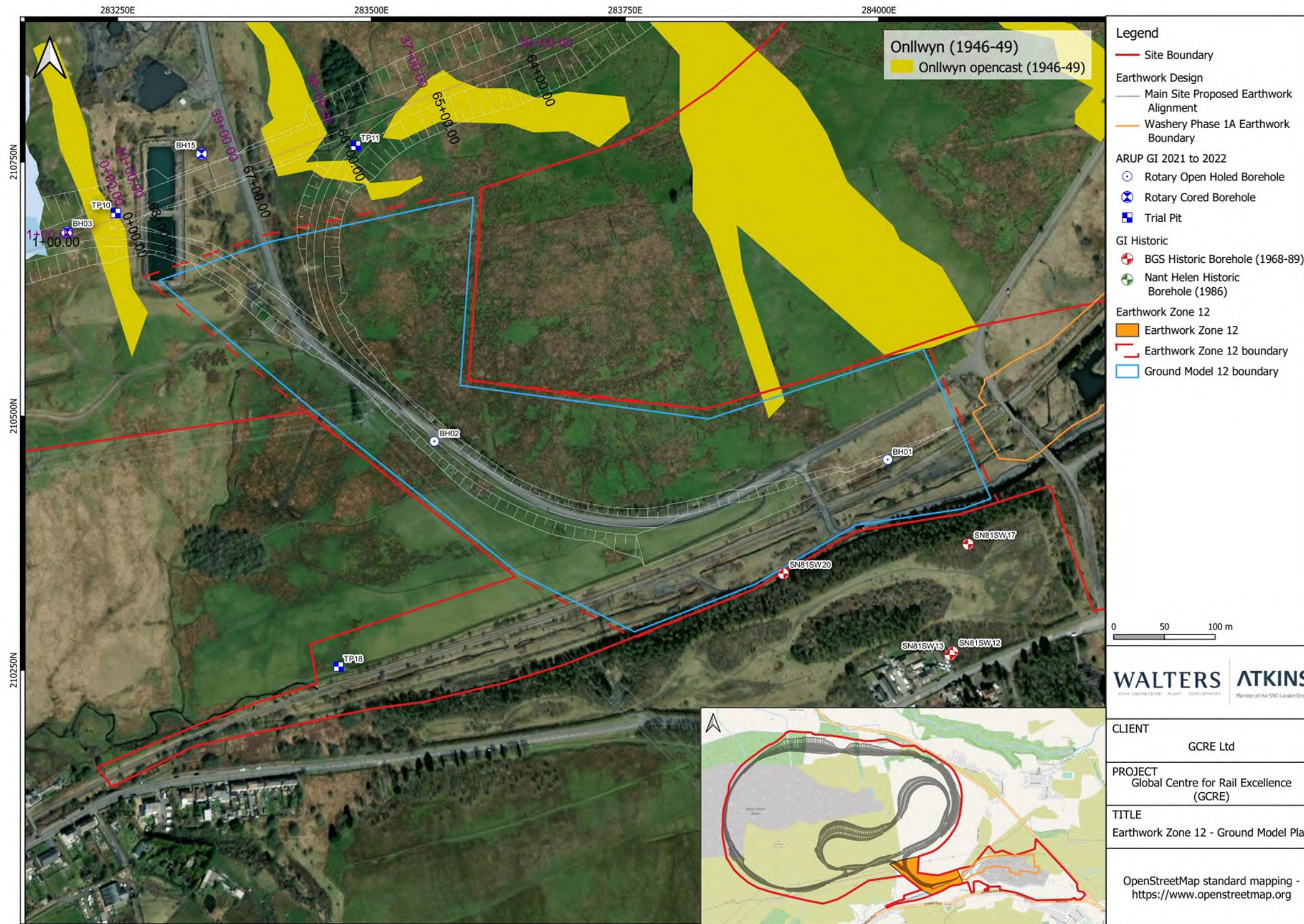


Figure 4-13: Earthwork Zone 12 – Ground Model Plan.

4.5. Coal Mining

4.5.1. Previous work

The proposed scheme is within the influence of historical underground and surface coal mining activities. Arup previously completed a Geotechnical and Geo-environmental Desk Study Report [4], Detailed Mine Workings Study [5] and Ground Investigation Report [2] to inform the assessment of coal mining risks at the site.

The Arup Desk Study [4] identified mining risk zones across the proposed scheme area and recommended further assessment be carried out to inform the assessment of risk.

The Arup Mine Workings Study [5] reported on the study of abandonment plans obtained from the Coal Authority, with the aim of further refining the risk assessment and to inform ground investigation proposals.

A preliminary ground investigation, which included exploratory holes in investigate mining, was carried out between November 2021 and January 2022. The Arup Ground Investigation Report [2] was completed in May 2022. The report summarised the findings of the ground investigation. The findings were used to inform further refinement of the coal mining risk assessment.

4.5.2. Detailed risk assessment summary

A detailed coal mining risk assessment was carried out using risk assessment information previously carried out by Arup; available mine abandonment plans from the Coal Authority; opencast completion plans from Celtic Energy; and open-access information from both the BGS and the Coal Authority.

The findings of the detailed coal mining risk assessment are provided within Appendix C and summarised here.

A significant risk of instability was identified associated with legacy coal mining activities within the Middle and Lower Coal Measures in the following seams:

- Brass,
- Peacock (Brass),
- Nine Feet
- Big Seams and
- Unrecorded workings

The key hazards include:

- Shallow underground workings influencing the footprint of the proposed scheme alignment where rockhead cover is insufficient to prevent migration of voids to surface.
- Shafts with collapse zones that encroach to within the footprint of the proposed alignment.
- Adits and/or roadways with collapse zones that encroach to within the footprint of the proposed alignment and where rockhead cover is insufficient to prevent migration of voids to surface.
- Bell pits with collapse zones that encroach to within the footprint of the proposed alignment.

The results of this review generally agree with the four mining risk zones (MRZ) previously identified by Arup, with the zones sub-divided to ten mining risk zones (MRZ). Nine MRZs are within the proposed track alignment and one MRZ in the Washery Area. The MRZs are shown on Drawings GCRE001-AWJV-00-XX-DR-GE-00014 to GCRE001-AWJV-00-XX-DR-GE-00018 within Appendix C.

- MRZ 1: located in the north-west of the outer loop and extends for approximately 1 km along the track. This zone includes 17 adits and one shaft not entirely removed by open cast mining as well as shallow mine workings where bedrock cover is unlikely to be sufficient to prevent void migration. There is currently a limited coverage of deeper ground investigation within MRZ 1 and none of the mine entries identified in this MRZ were previously investigated.
- MRZ 2: located in the north of the outer loop and extends for approximately 75 m along the track. This zone includes shallow mine workings in the Nine Feet Seam of the Abercraf Colliery with a recorded extraction thickness of 2.7 m to 3.0 m and bedrock cover unlikely to be sufficient to prevent void migration.
- MRZ 3a: located in the north of the outer loop and extends for approximately 45 m along the track. This risk zone includes one shallow south-east dipping mine entry. Both the adit mouth and the associated underground roadway pose a risk to the embankment in this area.

- MRZ 3b: located in the north of the inner loop and extends for approximately 110 m along the outside cutting of the bend. This risk zone includes the edge of the shallow workings of the Duffryn Colliery with a bedrock cover unlikely to be sufficient to prevent void migration.
- MRZ 4: located in the north-east of the outer loop and extends for approximately 150 m along the track. This risk zone is defined by the extent of the shallow workings of the Cwmtawe Colliery with bedrock cover unlikely to be sufficient to prevent void migration. Two adits are recorded approximately 70 m and 50 m north of the embankment in this area, and likely dip beneath the embankment at shallow depth.
- MRZ 5: located in the west of the inner loop and extends for approximately 300 m along the track. It is defined by the extent of the workings of the Abercraf Nine Feet Seam beneath the opencast workings of the Harnlo Seam. Post opencast extraction, the bedrock cover above the Nine Feet Seam is unlikely to be sufficient to prevent void migration. This assumes that a void would propagate through 100 m of opencast backfill material and reach the surface.
- MRZ 6a: located in the north of the inner loop and extends for approximately 250 m along the track.
- MRZ 6b: located in the south-east of both the inner loop and outer loop and extends for approximately 350 m along the track.
- MRZ 6c: located in the south of both the inner loop and outer loop and extends for approximately 360 m along the main track and an additional 1 km along the track leading to the washery area.
- All three risk zones are underlain by the shallow workings of the Dulais Colliery (Peacock Seam) where bedrock cover is unlikely to be sufficient to prevent void migration. Historical satellite imagery from 1945 also suggests that bell pitting may have occurred within all three MRZs. The cuttings within these areas may also interact with the mine workings and/or coal seams during construction, exposing these at ground level. Additionally, two adits are located approximately 140 m and 220 m southeast of MRZ 6b and there is a risk that these roadways dip beneath the site with bedrock cover unlikely to be sufficient to prevent void migration. A total of nine adits and two shafts also represent a risk to the proposed scheme in MRZ 6c.
- MRZ 7: comprises all of the land within the Washery Area Phase 1A Boundary and includes two recorded adits and one recorded mine shaft. There are no recorded mine workings underlying this part of the site. However, the recent ground investigation encountered a 2.0 m thick void at 3.2 m below rockhead and a 1.0 m thick void at 13.6 m below rockhead in one borehole (BH30R). Coal was also encountered in three boreholes (BH30R, BH32R and BH33R). These boreholes suggest that there are unrecorded mine workings with bedrock cover unlikely to be sufficient to prevent void migration beneath MRZ 7.
- In addition to the risks highlighted in the MRZs, there is a high likelihood of unrecorded mine entries occurring across the entire site, but particularly within and surrounding the extents of recorded mine workings. There is also a high likelihood of unrecorded mine workings occurring across the site, like the apparently unrecorded workings identified in the Washery Area (MRZ 7).

4.5.3. Mine Gas

Ground gas monitoring has to date been targeted at the Made Ground and peat. As such the presence, or absence, and composition of mine gases is currently undefined. Further investigation and monitoring is required.

4.6. Material Parameters – Soil

4.6.1. Rationale for Geotechnical Parameter Derivation

Wherever possible, direct testing results have been used to provide characteristic geotechnical parameters. However, where direct testing was not available or the number of available direct tests was insufficient, published empirical correlations have been used to inform the derivation of the required characteristic parameters.

The parameter derivation methodology is outlined below. Where several methods have been proposed, the results of each will be considered to establish characteristic values to be used for design purposes.

4.6.1.1. Unit Weight (γ , kN/m³)

Unit weight values were obtained by converting density (ρ) values ($\gamma = 9.81\rho$) recorded during direct laboratory testing (triaxial and consolidation). In addition, values have been established from BS 8004:2015 [33] based on sample description (granular soils) or estimated undrained shear strength (cohesive soils).

4.6.1.2. Cohesion, (c' , kPa)

Generally, cohesion values can be derived from direct laboratory shear box or triaxial testing. However, the currently available GCRE GI data is limited for this parameter, with only 4No. unconsolidated-undrained (UU) triaxial tests undertaken on samples of predominantly the same soil type.

4.6.1.3. Angle of Shearing Resistance (ϕ' , °)

Generally, angle of shearing resistance values can be derived from effective stress triaxial or shear box testing. However, none of these tests were undertaken as part of the GCRE GI. Therefore, the following empirical correlations were used.

Granular soils

Critical angle of shearing resistance (ϕ'_{cv}) values for coarse grained soils have been estimated from SPT N-value using the empirical chart presented within Figure 2.13 of Tomlinson [34] and using the correlation given in BS 8002:2015 [35]:

$$\phi'_{cv} = 30^\circ + \phi'_{ang} + \phi'_{PSD}$$

Where:

ϕ'_{ang} is the contribution from the angularity of the particles

ϕ'_{PSD} is the contribution from the soils particle size distribution

The peak angle of shearing resistance (ϕ'_{pk}) has also been estimated using the correlation given in BS 8002:2015 [35]:

$$\phi'_{pk} = \phi'_{cv} + \phi'_{dil}$$

Where:

ϕ'_{dil} is the contribution from soil dilatancy

Values for ϕ'_{ang} , ϕ'_{PSD} and ϕ'_{dil} were estimated using BS 8002:2015 Table 1 [35].

Cohesive soils

Critical angle of shearing resistance values for fine grained soils have been estimated using the correlation given in BS 8002:2015 [35]:

$$\phi'_{cv} = 42^\circ - 12.5 \log_{10} I_p \quad \text{for} \quad 5\% \leq I_p \leq 100\%$$

Where:

I_p is plasticity index expressed as a percentage.

The peak angle of shearing resistance has also been estimated using the correlation given in BS 8002:2015 [35]:

$$\phi'_{pk} = \phi'_{cv} + \phi'_{dil}$$

Where:

ϕ'_{dil} is the contribution from soil dilatancy, specified by BS 8002:2015 [35] as typically in the range 0 to 4°

Glacial Till

Peak angle of shearing resistance for glacial soils has also been estimated from CIRIA 504 [36] which provides a chart based on case study data.

4.6.1.4. Undrained Shear Strength (c_u , kPa)

Undrained shear strength values have been obtained from direct laboratory triaxial testing and in-situ hand shear vane testing. However, the currently available GCRE GI laboratory testing is limited for this parameter, with only 4No. unconsolidated-undrained (UU) triaxial tests undertaken on samples of predominantly the same soil type.

Where the in-situ and direct laboratory information is insufficient, empirical correlations, as discussed below, were used.

SPT N-value

Undrained shear strength values were estimated from SPT N-value using guidance for over-consolidated clays presented within CIRIA 143 [37]:

$$c_u = f_1 N_{60}$$

Where:

f_1 is a coefficient dependent on the plasticity of the soil, estimated using I_p

Description

Undrained shear strength values were estimated from soil stiffness description using tables presented within BS 5930:2015+A1:2020 [30].

4.6.1.5. Undrained Young's Modulus (E_u , MPa)

Undrained Young's Modulus values were estimated from SPT N-value using Butler's equation presented within CIRIA 143 [7]:

$$\frac{E_u}{N_{60}} = 1 \text{ MPa}$$

4.6.1.6. Drained Young's Modulus (E' , MPa)

Granular soils

Drained Young's Modulus values for granular soils were estimated from SPT N-value using the equation provided by CIRIA 143 [7]:

$$\frac{E'}{N_{60}} = 1 \text{ MPa}$$

Cohesive soils

Drained Young's Modulus for cohesive soils were calculated from undrained Young's Modulus using the equation presented within Muir Wood [38]:

$$E' = \frac{2E_u(1 + \nu')}{3}$$

4.6.1.7. Coefficient of Volume Compressibility (m_v , m²/MN)

Coefficient of volume compressibility values were estimated from SPT N-value using Stroud and Butler's correlation presented within CIRIA 143 [37]:

$$m_v = \frac{1}{f_2 N_{60}}$$

Where:

f_2 is a coefficient dependent on the plasticity of the soil, estimated using I_p

Additionally, m_v was also estimated using drained Young's Modulus and Poisson's Ratio, as set out in the ICE Manual of Geotechnical Engineering Volume 1 [39]:

$$m_v = \frac{1 - \frac{2\nu'^2}{1 - \nu'}}{E'}$$

4.6.1.8. Poisson's Ratio

Poisson's Ratio values were specified using the table of typical values provided within CIRIA 103 [40].

4.6.1.9. Moisture Condition Value (MCV, %)

Values were obtained from direct testing.

4.6.1.10. Optimum Moisture Content (OMC, %)

Values were obtained from direct testing.

4.6.1.11. Maximum Dry Density (MDD, Mg/m³)

Values were obtained from direct testing.

4.6.1.12. California Bearing Ratio (CBR, %)

Values were obtained from direct CBR or Plate Load Testing. CBR values can be estimated from Plate Load Testing using guidance set out in IAN 73/06 [41].

4.6.1.13. BRE Sulphate Classification

Sulphate Classification (design sulphate (DS) class & aggressive chemical environment for concrete classification (ACEC)) were assessed using direct laboratory testing following the procedures outlined by the BRE Special Digest 1 [42].

4.6.2. Made Ground

Made Ground was encountered across the site, predominantly within the areas known to have been historically mined, by 73No. exploratory holes from the 2021 to 2022 GI and by 2No. of the historical exploratory holes. The available information provided by these investigations is summarised:

- 124No. field based geological descriptions, 32 (or 26%) of which were drillers descriptions;
- 136No. SPTs, 8 (or 6%) of which refused at 50 blows most likely on cobbles or boulders;
- Particle size grading of material larger than 125 mm using a graticule was undertaken in eight trial pits;
- 57No. PSD tests;
- 12No. Atterberg tests;
- 45No. MCV tests; and
- 38No. moisture content tests.

Characterisation

As shown in Figure A.3, only 7No. of the PSD tests yielded fines content above 35%, defined by BS 6031:2009 [35]. 4No. of these are located within the Washery area (earthwork zone 1), 2No. are located in proximity to the west embankment (earthwork zone 4) and one is located to the east of the site (earthwork zone 9).

In addition to the laboratory PSD tests, the GI contractor used a graticule to do a field assessment of the proportion of material between 125 mm and 300 mm and of the material greater than 300 mm excavated from 8No. trial pits. Typically, the fill comprised of approximately 10% of grains between 125 mm and 300 mm and approximately 5% of grains greater than 300 mm.

12No. Atterberg tests undertaken on cohesive samples yielded Plasticity Index (PI) values between 5 and 26% (average 15%) ranging from a low to intermediate plasticity clay, as shown in Figure A.4. A characteristic PI of 15% was used for the purposes of geotechnical parameter derivation.

On the basis of this discussion, this stratum is predominantly granular and therefore granular parameters should be used for design across the whole site. This assumption is subject to the review of any additional ground investigation data.

Geotechnical parameters proposed for the granular Made Ground are summarised in Table 4-29.

Table 4-29: Summary of site wide Made Ground (granular) parameters.

Parameter		Range (No. of results)	Proposed characteristics value	Figure
Typical description: clayey slightly silty slightly sandy GRAVEL with low cobble content of siltstone. Gravel is angular to sub angular fine to coarse mudstone and siltstone.				
Unit Weight, γ' (kN/m ³)		-	20	-
Effective stress parameters	Cohesion, c' (kPa)	-	0	-
	Angle of shearing resistance, ϕ' (°)	BS8004: 29 to 40 (46 SPTs)	34	
Undrained shear strength, c_u (kPa)		-	-	-
Young's Modulus	Drained, E' (MPa)	C143: 5 to 49	23	Figure A.2
	Undrained, E_u (MPa)	-	-	-
Poisson's Ratio	Drained, ν'	0.1 to 0.3	0.2	-
	Undrained, ν_u	-	-	
Coefficient of volume compressibility, m_v (m ² /MN)		-		
Moisture Condition Value (%)			No available testing	
Optimum Moisture Content (%)		11 to 18 (4)	13.3	-
Maximum Dry Density (Mg/m ³)		1.19 to 2.06 (4)		
California Bearing Ratio (%)			No available testing	
BRE Classification	Design Sulphate Class	DS-5		
	ACEC Class	AC-4s		

4.6.3. Glacial Till

Glacial Till was encountered across the site, within the areas known not to have been historically mined, by 31No. exploratory holes from the 2021 to 2022 GI and by 9No. of the historical exploratory holes. The available information provided by these investigations is summarised:

- 60No. field based geological descriptions, 23 (or 38%) of which were drillers descriptions;
- 34No. SPTs, 13 (or 38%) of which refused at 50 blows most likely on cobbles or boulders;
- 17No. in-situ hand shear vane tests;
- 10No. PSD tests;
- 12No. Atterberg tests;
- 5No. MCV tests; and
- 16No. moisture content tests.

Characterisation

As shown in Figure A.9, 6No. of the PSD tests yielded fines content above 35%, defined by BS 6031:2009 [43] as likely to behave as a cohesive soil. Of the 4No. that yielded fines content below 35%, 3No. (TP27, TP19 and BH05) are in proximity to each other (to the southwest of the site within Earthwork Zone 11), based on exploratory hole log descriptions these tests may be a result of granular layers within a predominantly cohesive material and should be considered on a location specific basis. The remaining test (BH34) was located within the Washery area (earthwork zone 1).

12No. Atterberg tests yielded Plasticity Index (PI) values between 14 and 50% (average 27%) ranging from a low to high plasticity clay, as shown in Figure A.10. A characteristic PI of 24% was used for the purposes of geotechnical parameter derivation. One test (TP21, earthwork zone 5) yielded significantly higher PI (50%), this could potentially be an erroneous test or a localised area of organic material.

A number of SPTs refused at 50 blows, which may indicate a more significant granular element within the material which is not represented within the exploratory hole logs and laboratory testing. However, based on the available information, the Glacial Till is conservatively assumed to behave as a cohesive material, with derivation methodology and geotechnical parameters applied accordingly, as described in Section 4.6.1. The presence of granular layers within the Glacial Till material should be considered as a risk during detailed design, as they may contain perched water or create permeable pathways for groundwater leading to softening of the surrounding material.

Geotechnical parameters proposed for the Glacial Till are summarised in Table 4-30.

The proposed values have been verified based on Atkins design and construction experience of Glacial Till within South Wales. The currently available testing indicates a higher than typical Plasticity Index and moisture content at the GCRE site, which has resulted in conservatively lower parameters. However, due to the limited currently available test results this should be confirmed prior to construction.

The proposed characteristic undrained shear strength values have been based on an assessment of the limited available site wide data. However, investigations within two particular zones (BH31 & BH31R earthwork zone 1, BH05 earthwork zone 11) encountered softer material at depth and should be considered on a site-specific basis.

Table 4-30: Summary of Glacial Till geotechnical parameter summary.

Parameter		Range (No. of results)	Proposed characteristics value	Figure
Typical description: firm brown and grey slightly gravelly silty CLAY. Gravel is fine to medium sub-rounded mudstone				
Bulk Unit Weight, γ' (kN/m ³)		Description: 15 to 22	19	-
Effective stress parameters	Cohesion, c' (kPa)	-	0	-
	Angle of shearing resistance, ϕ' (°)	PI BS8002: 25 PI C504: 22 to 35	25	
Undrained shear strength, c_u (kPa)		PI C143: 31.5 to 284 Shear Vane: 10 to 140 Description: 20 to 150	<2.5 m bgl: 40 2.5 to 8.0 m bgl: 20z-10 >8.0 m bgl: 150	Figure A.11
Young's Modulus	Drained, E' (MPa)	C143: 7 - 63 Muir Wood: 23 Cu: 16	<2 m bgl: 12 2 to 8 m bgl: 7.16z-2.32 >8 m bgl: 55	Figure A.12
	Undrained, E_u (MPa)	C143: 7 to 63	<2 m bgl: 10 2 to 8 m bgl: 5.97z-1.94 >8 m bgl: 45.8	Figure A.13
Poisson's Ratio	Drained, ν'	0.1 to 0.3	0.25	-
	Undrained, ν_u	-	0.5	
Coefficient of volume compressibility, m_v (m ² /MN)		PI C143: 0.03 to 0.3 ICE Manual: 0.01 to 0.12		
Moisture Condition Value (%)		4.1 to 12.1 (5)		
Optimum Moisture Content (%)		11 (1)		
Maximum Dry Density (Mg/m ³)		2.05 (1)		
California Bearing Ratio (%)		No available testing		
BRE Classification	Design Sulphate Class	DS-1		
	ACEC Class	AC-1s		

4.7. Material Parameters – Rock

The following section presents the parameters that have been derived based on limited information, with their use in design discussed in detail within the GDR.

Kinematic analysis of the rock mass as a whole has not been undertaken, with only a wider scale knowledge of the kinematics of the South Wales Coal Measures known at this stage. Full time supervision of the construction of the cuttings will be undertaken by a Geotechnical Engineer or Engineering Geologist to ensure that the kinematic regime of the rock mass is accounted for in the design. This will be discussed further in the GDR.

4.7.1. Rationale for Geotechnical Parameter Derivation

4.7.1.1. Unit Weight (γ , kN/m³)

No direct testing for unit weight of rock was currently available.

The density (ρ) of the lithologies was estimated from published values provided in Tomlinson [44].

4.7.1.2. Uniaxial Compressive Strength (UCS, MPa)

UCS values were obtained from direct UCS or Point Load Testing (PLT). UCS values were estimated from PLT testing using the below equation [45]:

$$\sigma_c = k_{50} I_{s50}$$

Where:

I_{s50} is the point load strength index, provided by direct testing.

k_{50} is a factor provided by published literature.

4.7.1.3. Geological Strength Index (GSI)

GSI values were estimated from rock mass description presented in the exploratory hole logs using tables presented within the Rock Slope Engineering Textbook [46].

4.7.1.4. m_i

m_i is a material constant for intact rock which was estimated for rock groups using tables presented within the Rock Slope Engineering Textbook [46].

4.7.1.5. Disturbance Factor (D)

Disturbance factor values were estimated from rock mass description using tables presented within the Rock Slope Engineering Textbook [46].

4.7.1.6. Rock Quality Designation (RQD, %)

RQD values were obtained from exploratory hole logs.

4.7.1.7. BRE Sulphate Classification

Sulphate Classification (DS class & ACEC) were assessed using direct laboratory testing following the procedures outlined by the BRE Special Digest 1 [42].

4.7.2. Weathered Mudstone

Large areas of mudstone will be directly exposed to weathering in the proposed cut slopes. Due to the degradation associated with excavation and subsequent weathering, separate geotechnical parameters have been derived for the weathered mudstone.

Note that the majority of exploratory hole logs do not identify a distinction between weathered and unweathered mudstone and therefore the parameters provided in Table 4-31 have used the same lab testing data as those derived for the unweathered mudstone with engineering judgement used to assess the differences in the geotechnical parameters for the two.

Table 4-31: Summary of Weathered mudstone parameters.

Parameter	Range (No. of results)	Proposed characteristics value	Figure
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Typical description: weak to strong dark grey MUDSTONE

Unit Weight, γ' (kN/m ³)	-	22	-
Uniaxial Compressive Strength, UCS (MPa)	2 – 136 (43)	2.5	Figure A.15
Geological Strength Index, GSI	-	15	-
mi	-	6	-
Disturbance factor, D	-	0.7	-
Rock Quality Designation, RQD (%)	0 – 88 (131)	20	
BRE Classification	Design Sulphate Class	DS-3	
	ACEC Class	AC-3	

4.7.3. Mudstone

Parameters for mudstone that is outside of the likely zone of weathering and excavation disturbance are provided in Table 4-32. Note that most of the South Wales Coal Measures at the site that were classified with a full engineering description were described as mudstone and this should therefore be considered the dominant element of the bedrock.

Table 4-32: Summary of unweathered mudstone parameters.

Parameter	Range (No. of results)	Proposed characteristics value	Figure
Typical description: weak to strong dark grey MUDSTONE			
Unit Weight, γ' (kN/m ³)	-	22	-
Uniaxial Compressive Strength, UCS (MPa)	2 – 136 (43)	5	Figure A.15
Geological Strength Index, GSI	-	30	-
mi	-	6	-
Disturbance factor, D	-	0	-
Rock Quality Designation, RQD (%)	0 – 88 (131)	20	
BRE Classification	Design Sulphate Class	DS-3	
	ACEC Class	AC-3	

4.7.4. Siltstone

Geotechnical parameters for siltstone are provided in Table 4-33. Note that these parameters are for unweathered and undisturbed material.

Table 4-33: Summary of siltstone parameters.

Parameter	Range (No. of results)	Proposed characteristics value	Figure
Typical description: weak to strong dark grey SILTSTONE			
Unit Weight, γ' (kN/m ³)	-	22	-
Uniaxial Compressive Strength, UCS (MPa)	4 – 84 (7)	5	Figure A.17

Geological Strength Index, GSI	-	40	-
mi	-	8	-
Disturbance factor, D	-	0	-
Rock Quality Designation, RQD (%)	0 - 92 (27)	30	
BRE Classification	Design Sulphate Class	DS-3	
	ACEC Class	AC-3	

4.7.5. Sandstone

Geotechnical parameters for sandstone are provided in Table 4-34. Note that these parameters are based upon unweathered and undisturbed material. As sandstone is a minor element of the bedrock at the site these parameters are based on a limited data set.

Table 4-34: Summary of sandstone parameters.

Parameter	Range (No. of results)	Proposed characteristics value	Figure
Typical description: Strong grey SANDSTONE			
Unit Weight, γ' (kN/m ³)	-	24	-
Uniaxial Compressive Strength, UCS (MPa)	54 (1)	50	Figure A.19
Geological Strength Index, GSI	-	50	-
mi	-	17	-
Disturbance factor, D	-	0.7	-
Rock Quality Designation, RQD (%)	0 – 78 (4)	30	
BRE Classification	Design Sulphate Class	DS-3	
	ACEC Class	AC-3	

5. Geotechnical risk register

5.1. Geotechnical risk matrix

Geotechnical risk is defined as the possibility of an adverse consequence arising from a ground hazard or circumstance. The Geotechnical Risk Register considers the identified geotechnical constraints, along with additional project details to ensure that all significant geotechnical risks are identified, recorded, analysed, and controlled. The geotechnical risks are discussed in terms of likelihood, severity, and risk, as defined below:

- Likelihood (L): The perceived likelihood of the identified geotechnical hazard occurring.
- Severity (S): The perceived severity, in terms of safety, financial, temporal, legal, or operational consequence, of the occurrence of the identified geotechnical hazard on the identified receptor(s)
- Risk (R): The perceived level of concern which should be assigned to the identified hazard, based on the likelihood of occurrence, and taking into due account the perceived severity of the impact.

The risk uses the following equation:

$$\text{Degree of Risk (R)} = \text{Likelihood (L)} \times \text{Severity (S)}$$

The geotechnical risk assessment descriptors for likelihood and severity are detailed in Table 5-1 and Table 5-2 respectively, with the risk matrix presented in Table 5-3 and the perceived degree of risk in Table 5-4.

Table 5-1: Geotechnical risk assessment criteria for likelihood.

Likelihood score	Descriptor	Probability
1	Remote	<5%
2	Unlikely	5 to 19%
3	Possible	20 to 49%
4	Likely	50 to 74%
5	Very likely	75 to 100%

Table 5-2: Geotechnical risk assessment criteria for severity.

Severity score	Descriptor	Criteria			
		Programme delay	Cost (£)	Health and Safety	Environmental
1	Very low	<1 month	<£100k	Injuries requiring first aid treatment or occupational ill health condition with no lost time	Minimal environmental impact.
2	Low	1 to 2 months	£100k to £1m	Lost time injury (<7 days lost time) or multiple minor injuries or occupational health condition (< 7 days lost time).	Local impact requiring management response, but from which there is natural recovery.
3	Medium	2 to 4 months	£1m to 2.5m	RIDDOR reportable injury (≥ 7 days lost time) or occupational health condition (≥ 7 days lost time).	Unanticipated adverse transient environmental effect or effect on local community requiring remedy or intervention and reportable to regulatory authorities.

Severity score	Descriptor	Criteria			
		Programme delay	Cost (£)	Health and Safety	Environmental
4	High	4 to 6 months	£2.5m to £10m	Single non-life changing injury, occupational health, RIDDOR Reportable Disease	Significant new, recurring, or additional transient adverse environmental effect or effect on local community requiring remedy or intervention and/or remedy or intervention by external authorities.
5	Very high	>6 months	>£10m	One or more fatalities or major injuries or occupational health conditions resulting in life changing disability.	Significant new or additional permanent adverse environmental effect on the natural or historic environment or local community requiring remedy or intervention or management by relevant authorities

Table 5-3: Geotechnical risk assessment matrix.

Likelihood	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
Severity						

Table 5-4: Perceived degree of risk.

Risk Number	Risk Ranking	Comments
20 - 25	Unacceptable	Which cannot be justified except in extraordinary circumstances, where resources and finance are provided to control the risk irrespective of cost.
15 - 19	Substantial	Tolerable only if risk reduction is impracticable or if its cost is disproportionate to improvement.
7 - 12	Moderate Risk	Tolerable if cost of reduction would exceed the improvement gained in reducing the risk further.
0 - 6	Low	Tolerable

5.2. Geotechnical risks

The Geotechnical Risk Register comprises an initial assessment of the risks identified, prior to the application of risk mitigation measures, and shows how the risks can be reduced by the application of certain measures.

Table 5-5: Geotechnical risk register.

PART A -RISK IDENTIFICATION															PART B-RISK ELIMINATION/REDUCTION			
Hazard ID	Location	Chainage	Risk Owner-Lead Discipline	Risk Owner	Hazard Summary	Hazard Description (the cause of a potentially unfavourable event)	Hazard Consequences (description of the consequences)	Construction	Operational & Maintenance	Decommission	CSM- Risk	Likelihood	Severity	Risk	Design measures considered and taken to Eliminate or Reduce Risk	Likelihood	Severity	Residual Risk
GCRE-ERW-HAZ-001	Site wide	Site wide	RH/LT	Geotech	Greater than anticipated extent of peat/compressible soils.	Lack of site characterisation information, resulting in the extent of peat/compressible soils being greater than anticipated.	Additional cost and programme extension due to dealing with a greater extent of peat/compressible soils during construction.	Y				4	3	12	Site characterisation to identify potential risk zones that can be targeted with additional GI. The presence of peat/compressible soils shall be considered during design. If encountered during excavations or within formations, it shall be excavated and replaced with competent material.	2	3	6
GCRE-ERW-HAZ-002	Site wide	Site wide	RH/LT	Geotech	Poorer than anticipated ground conditions.	Lack of site characterisation information, resulting in the extent of poorer than anticipated ground conditions.	Construction in poorer than anticipated ground conditions resulting in re-design, increased costs and/or programme extension.	Y				5	3	15	Gaps in ground investigation shall be identified to characterise ground conditions. Conservative assumptions shall be made while carrying out the designs. Presence of an appropriately trained ground engineering specialist on site during construction. Allowance for modifying design during construction.	3	3	9
GCRE-ERW-HAZ-003	Site wide	Site wide	RH/LT	Geotech	Unable to identify extent and location of areas susceptible to inundation settlement.	Lack of site characterisation information, resulting in the inability to identify the extent and location of areas susceptible to inundation settlement.	Excessive settlement and serviceability limit state failure of earthworks due to unpredictability of inundation settlement, resulting in remediation, increased costs and/or programme extension.	Y	Y			3	3	9	Ground investigation shall be carried out to characterise the hydrogeological regime correctly. Monitor groundwater and undertake detailed hydrogeological risk assessment to understand potential changes in the hydrogeology and potential for future inundation settlement. Adequate under-drainage to be included within the design of earthworks.	2	2	4
GCRE-ERW-HAZ-004	Site wide	Cuttings within former opencast workings	RH/LT	Geotech	Boundaries of opencast workings different to anticipated.	Lack of site characterisation information, resulting in the boundaries of restored former opencast workings being different to anticipated.	Cuttings in different to anticipated materials resulting in re-design, increased costs and/or programme extension.	Y				4	3	12	Gaps in ground investigation shall be identified to confirm opencast boundaries. Conservative assumptions shall be made while carrying out the designs. Presence of an appropriately trained ground engineering specialist	3	2	6

PART A -RISK IDENTIFICATION															PART B-RISK ELIMINATION/REDUCTION			
Hazard ID	Location	Chainage	Risk Owner-Lead Discipline	Risk Owner	Hazard Summary	Hazard Description (the cause of a potentially unfavourable event)	Hazard Consequences (description of the consequences)	Construction	Operational & Maintenance	Decommission	CSM- Risk Assessment	Likelihood	Severity	Risk	Design measures considered and taken to Eliminate or Reduce Risk	Likelihood	Severity	Residual Risk
															on site during construction. Allowance for modifying design during construction.			
GCRE-ERW-HAZ-005	Site wide	All rock cuttings	PA	Geotech	Greater than anticipated extent of coal seams encountered within cuttings.	Lack of site characterisation information, resulting in greater than anticipated extent of potentially flammable coal seams encountered within cuttings.	Increased costs and/or programme to implement mitigation required to prevent coal seams igniting during construction and operation.	Y	Y	Y		3	3	9	Ground investigation to validate the stratigraphy and disposition of coal seams. 3D modelling to accurately predict where coal seams may be encountered in cuttings. Mitigation measures implemented by contractor to prevent coal seams igniting, including no smoking policy, drill rigs with water flush and construction works to minimise the exposure of coal to the air. Implementation of a fire safety plan in the event of a coal seam igniting.	2	3	6
GCRE-ERW-HAZ-006	Site wide	All rock cuttings	RH/LT	Geotech	Rock mass characteristics poorer than anticipated.	Lack of rock mass characterisation data resulting in a higher likelihood of incorrectly characterising the rock mass.	Increased requirement for stabilisation measures resulting in re-design, increased costs and/or programme extension.	Y	Y			3	3	9	Ground investigation, including characterisation of the rock mass to inform a detailed estimate of areas of potential instability. Design of support and reinforcement measures where required. Presence of an appropriately trained ground engineering specialist on site during construction. Allowance for modifying design during construction.	2	2	4

PART A -RISK IDENTIFICATION																PART B-RISK ELIMINATION/REDUCTION			
Hazard ID	Location	Chainage	Risk Owner-Lead Discipline	Risk Owner	Hazard Summary	Hazard Description (the cause of a potentially unfavourable event)	Hazard Consequences (description of the consequences)	Construction	Operational & Maintenance	Decommission	CSM- Risk Assessment	Likelihood	Severity	Risk	Design measures considered and taken to Eliminate or Reduce Risk	Likelihood	Severity	Residual Risk	
GCRE-ERW-HAZ-007	Mining Risk Zones (where grouting required)	Mining Risk Zones (where grouting required)	DW/PA	Contam/ Hydrogel	Hydrogeological regime more onerous than anticipated in drill and grout zones.	Lack of site characterisation information, resulting misunderstanding the hydrogeological regime in drill and grout zones.	Increased costs and/or programme to deal with unexpected impacts on the hydrogeological regime from drill and grout operations.	Y	Y	Y		4	4	16	Ground investigation to collect information on the hydrogeological regime to be used to assess the potential impacts of any drill and grout operations on the hydrogeological regime. Drill and grout design shall implement suitable measures to avoid impacting the flow of groundwater. Discussions will be held with NRW and Coal Authority during permit application.	2	4	8	
GCRE-ERW-HAZ-008	Site wide	Location of faults	PA/LT	Geotech	Potential for fault reactivation greater to anticipated.	Lack of information on the potential for fault reactivation, resulting in incorrect assessment.	Increased costs and/or programme due to dealing with impacts of fault reactivation and the time taken for faults to stabilise.	Y	Y	Y		2	4	8	Ground investigation to collect information on the nature of mine workings and faults, informing an assessment of the potential for fault reactivation. Mine workings to be stabilised by drill and grout operations and longer-term ground movement monitoring to be carried out within the vicinity of faults.	1	4	4	
GCRE-ERW-HAZ-009	Mining Risk Zones	Mining Risk Zones	PA	Geotech	Condition and depth of recorded below ground mine workings more onerous than anticipated.	Lack of information on the condition and depth of recorded workings resulting in a greater level of uncertainty associated with coal mining risk assessment.	Increased requirement for stabilisation measures (i.e. drill and grout) resulting in re-design, increased costs and/or programme extension.	Y	Y	Y		5	4	20	Further ground investigation of recorded coal mine workings to verify the depth and condition of workings. Presence of an appropriately trained ground engineering specialist on site during construction. Allowance for modifying design during construction.	3	4	12	
GCRE-ERW-HAZ-010	Site wide	Site wide	PA	Geotech	Extent of unrecorded mine workings greater than anticipated.	Lack of information on the potential for unrecorded workings resulting in a greater level of uncertainty associated with coal mining risk assessment.	Increased requirement for stabilisation measures (i.e. drill and grout) resulting in re-design, increased costs and/or programme extension.	Y	Y	Y		4	4	16	Further ground investigation of zones potentially impacted by unrecorded workings. Presence of an appropriately trained ground engineering specialist on site during construction. Allowance for modifying design during construction.	3	4	12	

PART A -RISK IDENTIFICATION															PART B-RISK ELIMINATION/REDUCTION			
Hazard ID	Location	Chainage	Risk Owner-Lead Discipline	Risk Owner	Hazard Summary	Hazard Description (the cause of a potentially unfavourable event)	Hazard Consequences (description of the consequences)	Construction	Operational & Maintenance	Decommission	CSM- Risk	Likelihood	Severity	Risk	Design measures considered and taken to Eliminate or Reduce Risk	Likelihood	Severity	Residual Risk
GCRE-ERW-HAZ-011	Mining Risk Zones	Mining Risk Zones	PA	Geotech	Condition of recorded mine entries more onerous than anticipated.	Lack of information on the condition of recorded mine entries resulting in a greater level of uncertainty associated with coal mining risk assessment.	Increased requirement for stabilisation measures (i.e. drill and grout) resulting in re-design, increased costs and/or programme extension.	Y	Y	Y		5	4	20	Further ground investigation of recorded coal mine entries to verify the condition. Presence of an appropriately trained ground engineering specialist on site during construction. Allowance for modifying design during construction.	3	4	12
GCRE-ERW-HAZ-012	Site wide	Site wide	PA	Geotech	Presence of unrecorded mine entries greater than anticipated.	Lack of information on the potential for unrecorded entries resulting in a greater level of uncertainty associated with coal mining risk assessment.	Increased requirement for stabilisation measures resulting in re-design, increased costs and/or programme extension.	Y	Y	Y		4	4	16	Further ground investigation of zones potentially impacted by unrecorded mine entries. Presence of an appropriately trained ground engineering specialist on site during construction. Allowance for modifying design during construction.	3	4	12
GCRE-ERW-HAZ-013	Mining Risk Zones	Mining Risk Zones	PA/JW	Geo-Env	Mine gas migration	Mine gas migration - including but not limited to mine gas migration caused by consolidation of mine workings.	Mine gas is a danger to human health and can cause death.	Y	Y	Y		4	5	20	a) Ground gas monitoring. b) The structural barrier of the floor slab. c) Ventilation measures. d) Gas resistant membrane. Coal Authority Guidelines shall be followed at all times. Gas risk classified as CS2 based on data that has significant data limitations. 1) Additional GI and monitoring required to increase confidence in level of risk; 2) Further risk assessment 3) Review of intended land use and associated risks as landscaping and intended uses become better defined/understood. 4) Installation of gas protection within enclosed spaces and areas where explosion risk and risk of asphyxiation are present.	3	5	15
GCRE-ERW-HAZ-015	Mining Risk Zones	Mining Risk Zones	PA	Geotech	Drilling induced collapse	Drilling-induced collapse - Drilling activities, including but not limited to GI works, have the potential to drain mine water and relieve confining pressure of the mine, leading to collapse.	Potential subsidence at the surface and damage to structures and harm or death to humans.					3	5	15	a) Awareness for drilling operators. b) Capping and backfilling of exploratory holes if significant artesian water conditions are encountered.	2	5	10

PART A -RISK IDENTIFICATION															PART B-RISK ELIMINATION/REDUCTION			
Hazard ID	Location	Chainage	Risk Owner-Lead Discipline	Risk Owner	Hazard Summary	Hazard Description (the cause of a potentially unfavourable event)	Hazard Consequences (description of the consequences)	Construction	Operational & Maintenance	Decommission	CSM- Risk Assessment	Likelihood	Severity	Risk	Design measures considered and taken to Eliminate or Reduce Risk	Likelihood	Severity	Residual Risk
						Alternatively, drilling could open new pathway between mine workings, allowing an overlying flooded mine to drain into an underlying dry mine, leading to collapse of both mine workings. Collapse of mine workings and/or entries can induce upward propagating voids, which can lead to subsidence or collapse at the surface.												
GCRE-ERW-HAZ-016	Mining Risk Zones	Mining Risk Zones	PA	Geotech	Water table re-establishment	Water table re-establishment - Previously dry mine entries and/or workings may collapse when the water table re-establishes and groundwater percolates into the mines. Collapse of mine workings and/or entries can induce upward propagating voids, which can lead to subsidence or collapse at the surface.	Potential subsidence at the surface and damage to structures and harm or death to humans.					3	5	15	a) Assessment of hydrogeological regime. b) Detailed mining investigation to determine the condition and characteristics of mine workings.	2	5	10
GCRE-ERW-HAZ-018	Site wide	Site wide	JW	Geo-Env	Breaking Ground - contaminated soils and ground waters	Breaking Ground - contaminated soils and ground waters	Significant harm to construction workers, future operations staff, property, controlled waters, ecological receptors and public					3	5	15	a) PRA and GQRA/DQRA to assess risks b) Additional GI to fill in information gaps c) Design and implementation of mitigation and remediation (RMS and Verification Reporting) . d) Use of appropriate PPE/RPE, hygiene and controls such as damping down of soils, segregation of materials and appropriate materials handling. Classification of works under Control of Asbestos Regulations 2012	3	3	9

PART A -RISK IDENTIFICATION															PART B-RISK ELIMINATION/REDUCTION			
Hazard ID	Location	Chainage	Risk Owner-Lead Discipline	Risk Owner	Hazard Summary	Hazard Description (the cause of a potentially unfavourable event)	Hazard Consequences (description of the consequences)	Construction	Operational & Maintenance	Decommission	CSM- Risk Assessment	Likelihood	Severity	Risk	Design measures considered and taken to Eliminate or Reduce Risk	Likelihood	Severity	Residual Risk
GCRE-ERW-HAZ-019	Site wide	Site wide	JW	Geo-Env	Water table re-establishment - Contamination	Water table re-establishment - dewatering activities ceasing and new loading associated with development earthworks/restoration will change groundwater regime and potentially cause previously dry mine workings to flood introducing new Source-Pathway-Receptor linkages.	Harm to adjacent surface waters and aquifers due to existing or new contaminant sources migrating off-site and impacting controlled waters					4	4	16	a) GI and monitoring and sampling programme to investigate controlled waters b) Assessment of hydrogeological regime. c) Design and implementation of mitigation and remediation measures if necessary, and as appropriate.	3	3	9
GCRE-ERW-HAZ-020	Site wide	Site wide	JW	Geo-Env	Materials Management	Materials Management - Inappropriate treatment/classification and reuse of waste due to 1) limited data and 2) interplay of Mining Waste Directive and DoW CoP	Prosecution and fines from NRW/HMRC, delays to project works, reputational loss, additional GI and risk assessment costs, additional construction costs.					4	5	20	a) assessment of whether DoWCOP/MWD applies and route to controlling materials reuse. b) GI and assessment of materials to demonstrate suitability for use. c) MMP and/or WMP to control reuse of materials on-site.	3	3	9
GCRE-ERW-HAZ-021	Site wide	Site wide	JW	Geo-Env	Contamination - Additional data requirements	Contamination - Additional data requirements. GI data provided does not provide sufficient coverage of site to allow risks to be managed and planning conditions to be discharged.	Delays to project delivery and associated increase in costs.					4	5	20	a) PRA and GQRA/DGRA to assess risks b) Additional GI to fill in information gaps. c) Design and implementation of mitigation and remediation (RMS and Verification Reporting) . d) Early and ongoing engagement with stakeholders such as LPA, EHO, NRW	2	4	8

PART A -RISK IDENTIFICATION															PART B-RISK ELIMINATION/REDUCTION			
Hazard ID	Location	Chainage	Risk Owner-Lead Discipline	Risk Owner	Hazard Summary	Hazard Description (the cause of a potentially unfavourable event)	Hazard Consequences (description of the consequences)	Construction	Operational & Maintenance	Decommission	CSM- Risk Assessment	Likelihood	Severity	Risk	Design measures considered and taken to Eliminate or Reduce Risk	Likelihood	Severity	Residual Risk
GCRE-ERW-HAZ-022	Site wide	Site wide	JW	Geo-Env	Contamination - Data Quality	Contamination - Data Quality. Logs are not all BS5930 compliant, UKAS deviations in analytical data approx. 1/3 of TPH banding, TPH CWG, BTEX, TOC, boron, cyanide, headspace readings and monitoring data not complete.	Regulators data requirements not met and delay/refusal to discharge planning conditions					3	4	12	a) Revision of data by contractor/Arup to address issues. b) Additional GI to address data gaps. c) Engagement with regulator and provision of argument/risk assessment to demonstrate impact is acceptable.	3	3	9
GCRE-ERW-HAZ-029	Site wide	Site wide	JW	Geo-Env	Asbestos in Made Ground	Asbestos in Made Ground	Risks to construction workers and users of site Regulatory compliance during construction works					3	5	15	-Refurbishment and demo survey of washery buildings before demolition. - Removal of asbestos and ACM from structures with verification of this work in accordance with CAR 2012. - Additional GI works targeting made ground below and adjacent to colliery and washery structures. - Compliance with CAR 2012s PPE/PRE, notification and risk assessment/management requirements	1	5	5

6. Engineering Assessment

6.1. General

This section presents an engineering assessment for the proposed scheme based on the findings and recommendations of this GIR. The engineering assessment is based on the preliminary analyses undertaken by Atkins as part of the initial earthworks design development. The findings and recommendations presented herein shall be reviewed and updated as part of the detailed design.

6.2. Earthworks

6.2.1. Concept Design

The proposed GCRE scheme requires extensive earthworks to provide a 17.5m wide track corridor along the alignment of the test tracks and to facilitate construction of sidings in the Washery area. The size and extent of the earthworks is dependant of the proposed track level and the existing site topography.

The concept design for the proposed earthworks is detailed in the Employers Requirements [47] which specifies the following slope angles for the earthworks:

- Embankments: side slopes of 1V:3H;
- Cuttings in soil/backfill: side slopes of 1V:2.5H; and
- Cuttings in rock: side slopes of 1V:1H.

The Employers Requirements also stipulate the following key requirements in relation to the earthworks design:

- The upper 2m of all embankments is to be formed using material limited to Class 1A and 1B granular material.
- CBR >5% is required for the surface of constructed embankments and formation level of cuttings.
- A 0.5m thick starter layer / drainage blanket is required at the base of the embankments.
- Benching in for embankment construction is required where the existing slope is steeper than 1V:5H.
- The footprint of the earthwork area shall be stripped of any vegetation and topsoil.

As described within the Arup GIR [2], the proposed slope profiles described above were estimated based on an initial assessment of the ground conditions. As part of the ongoing detailed design for the earthworks, Atkins has undertaken detailed stability analyses to explore opportunities to optimise the earthworks design.

6.2.2. Embankments

The highest embankments are found along the northern boundary of the outer loop and are up to 42m in height. The north-eastern embankment shall be constructed over opencast backfill material, whereas the north-western embankment shall be partially constructed over natural ground comprising Glacial Till underlain by the South Wales Coal Measures. The stability analyses for the embankments should consider variations in the underlying ground and groundwater conditions which may impact the design.

As described in the Initial Design Options Report [48], as part of the preliminary earthworks design, Atkins has undertaken stability analyses to explore opportunities to optimise the concept design and increase the embankment side slope profiles.

Stability analyses undertaken for the critical northern embankments suggests that there is scope for some improvement on the side slope gradient proposed in the concept design, summarised as follows:

- Side slopes of 1V:2.5H.
- 2m (min.) wide benches every 10m in elevation below the embankment crest.
- Benching in where the existing slope gradient exceeds 1V:5H.

Since the proposed works are envisaged to generate a surplus of excavated material, it is likely that the geometry of the embankments may be modified to optimise the balance of earthwork material volumes.

Given that the embankments will be constructed using free draining, predominantly granular material, there is considered to be no need for a distinct drainage blanket with geotextile separating layers. Therefore, it is recommended that the requirement for a 0.5m thick drainage blanket, as specified in the Employers Requirements [47], is reviewed as part of the detailed design.

The Employers Requirements [47] also specify that the upper 2m of all embankments is to be formed using material limited to Class 1A and 1B granular material. It is recommended that the required thickness of this capping layer is reviewed following review of the results of the trial embankment. It is proposed to use the trial embankment to demonstrate that the performance requirements for the track formation (i.e., CBR>5%) can be achieved using reworked site-won material. This will ensure that the material is still workable when installing services and avoiding any hard / soft spots in the track formation. The proposed process will also avoid importing additional material into the site and help control surplus material.

6.2.3. Cuttings

Most of the proposed track alignment shall be constructed within cuttings, which include soil and rock cuttings. The deepest cuttings, up to 32m in depth, are encountered on the inner loop. The design of the earthwork cuttings will depend on the level of the rockhead which shall be determined from GI records and from the extents of the historical mining works (Figure 2-1). Given the spacing of exploratory holes and lack of certainty regarding the extents of the mine working, it is envisaged that the transitions between cuttings in rock and cuttings in backfill material (soil) will need largely be determined on site.

Stability analyses undertaken for critical cutting sections suggest that there is scope for some improvement on the side slope gradients proposed in the concept design, summarised as follows:

- Side slopes of 1V:2.2H for cuttings in soil.
- Side slopes of 1V:0.6H for cuttings in rock.
- 2m (min.) wide benches every 10m in elevation above cutting formation level.
- 3m (min.) wide berm at the boundary between the rock and the superficial deposits.
- Consideration of rockfall protection measures on rock cutting slopes.

Detailed analysis of the steepening of the cut slopes is provided in the GDR. Given the sparsity of data, some assumptions have been made for determining the maximum angle of the rock cuttings. The assumptions will be validated on site during construction by an Engineering Geologist or Geotechnical Engineer, and the design adjusted to suit the as-dug ground conditions as required.

6.3. Material Reuse

It is proposed to construct the embankments using site won material from within the backfilled opencast areas. Given the volume of earthwork embankments required for the GCRE scheme, it is recommended that the as-dug site won material is used for the embankment construction. This will avoid the need for extensive processing and compaction of materials on site. However, since the as-dug, site won material comprises oversized particles including large boulders, embankment trails should be carried out to demonstrate that a satisfactory degree of compaction can be achieved by tracking in with conventional earth moving machinery, including large dozers used with and without a roller.

The trial embankment will be used to assess the following:

- The relative effectiveness of compaction of the materials at the site using different methods proposed, and the associated risks of ongoing movements of the placed fill during the operational lifetime of the earthworks.
- Establishing an appropriate upper particle size limit for the placed fill, and the ease with which oversized particles can be separated from the fill during placement.
- Establishing the effectiveness of different testing and assessment methods to determine that the necessary degree of compaction has been achieved.

A series of trial embankments will be constructed at varying layer thicknesses, ranging from 0.5m to 2.0m. Some will be constructed using a dozer only and others will be constructed using a dozer and roller.

Settlement monitoring installation in the form of rod and plate will be installed to assess the settlement of the embankments.

6.4. Settlement

6.4.1. Creep Settlement

The potential impact of creep settlement within backfilled opencast areas and newly constructed earthwork embankments should be considered as part of the detailed design for the earthworks. Although no settlement criteria have been specified in the Employers Requirements [47], the design of the earthworks should consider the maintenance implications for the proposed rail infrastructure due to excessive settlement over the serviceable life of the asset.

The settlement monitoring of the backfilled opencast areas undertaken between October 2020 and April 2021 demonstrated that creep settlements are ongoing at each of the four backfilled opencast sites. The magnitude of the creep settlement observed was found to be dependent on the age, thickness and composition of the backfilled opencast areas. From the period of monitoring, it is estimated that within the Abercraf, Onllwyn and Nant Helen opencast sites, maximum rates of surface settlements are currently approximately 20 to 30mm/year. However, for the more recently backfilled Nant Helen Extension site, the current rate of surface settlement was as high as 100mm/year.

Given that the earthwork embankments are likely to be constructed with little or no systematic compaction and using opencast backfill material, long term creep movements should also be expected within the constructed embankments. Different types of compaction plants will be trialled during the construction of the trial embankment and the results will be reviewed to identify a suitable compaction method, but this might not align with systematic compaction method as required by standards such as SHW series 600 or similar as the material used is unconventional and therefore, the compaction method will be reviewed outside the bounds of guidelines if required.

Estimations of the magnitude of the anticipated creep movements should be based on the extrapolation of the surface monitoring data gathered from the four opencast sites. To inform the detailed design of the earthworks, it is recommended that regular surveying of the existing monitoring points is carried out.

6.4.2. Differential Settlement

There is potential for significant differential settlement along the proposed test track alignments due to variations in the ground conditions. As discussed in Section 6.4.1, backfilled opencast areas will continue to settle over the serviceable life of the asset, whereas earthworks formed within the rock are unlikely to settle.

As discussed in Section 6.4.1, the rate of the creep settlement will depend upon the age, thickness and composition of the backfilled opencast areas, therefore, significant variations in the rates of movement should be expected across the site. The highest rates of settlement should be expected in the most recently backfilled areas and within newly constructed embankments.

Although it will be difficult to control long term settlement at the site, measures can be implemented to accelerate short term movements, such as sequencing the earthworks construction such that the large embankments are constructed early in the programme to maximise the amount of settlement occurring prior to construction of the track.

6.4.3. Heave

Heave can occur at the base of cuttings due to the removal of the overburden. However, for cuttings formed in opencast backfill material, this is anticipated to be offset by the ongoing creep settlement. Based on the initial review of cuttings, little or no heave is expected in areas where cuttings are to be introduced in backfilled materials as the backfill material is granular and heave in granular material is generally not present or insignificant.

Heave may also occur because of seasonal shrink-swell cycles within near surface cohesive strata. The risk and potential impact of heave should be considered as part of the earthworks detailed design. The initial review of cuttings identified that the formation levels to be either on granular fill material or rock. Therefore heave is not anticipated to be significant in comparison to creep settlement.

6.5. Peat

Four of the deep exploratory holes advanced within the Washery area identified a layer of Peat, approximately 1 to 2m thick. The elevation of the surface of the Peat layer increases from north to south. Based on the available GI information, it is anticipated that the level of the Peat is between 3.5m and 5.5m below the finished

formation level at the north of the Washery but may be a little as 1m and 2m in the south the Washery. The potential for consolidation within the Peat layer should be addressed as part of the earthworks detailed design. It is recommended that supplementary GI is undertaken within the Washery area to improve mapping of the level of the Peat and determine the requirements for settlement mitigation.

6.6. Mining

Remedial works will be required to mitigate the mining risk posed to the proposed earthworks. The type of remediation will vary depending on the final arrangement and will be subject to the findings of additional ground investigations. This will likely comprise either cut and fill for workings near surface or bulk infill stabilisation for deeper workings.

The risk summary has been developed based on a general work seam thickness of 2m, increased to 3m for the Nine Feet Seam. Application of the '10t rule' after CIRIA C758D [49] is proposed to mitigate risk posed by upward migration from collapsing voids.

Remediation of mine entries is expected to comprise either bulk infill or concrete cap at surface. This will be reviewed once the entry arrangements and conditions have been confirmed. It is noted that a selection of entries are reported as being remediated. Information on the remediation strategy completed should be sought. Additional validation of the remediation may be required.

7. Land Contamination Assessment

This contamination assessment uses site-specific soil, leachate, ground gas, groundwater and surface water data collected during the GI designed by Arup and undertaken by Quantum Geotech in late 2021/early 2022 to determine the level of risk to human health and Controlled Waters receptors associated with the proposed development. This data can be found in Appendix E of the associated Quantum Geotech Ltd Factual Report [9], included within Appendix C of this report.

7.1. Previous Investigation

No previous geo-environmental reports relevant to the site have been made available following the completion of the Arup desk study [4] and GIR [2], however, the BGS holds exploratory hole records from several previous investigations of the Land at Nant Helen and Washery. The assessments below have been completed using data supplied by Quantum and Arup from their GI works.

Figure 7-1 details the location of monitoring wells installed during these works while Figure 2-2 presents the sites geology and the location of the trial holes that were excavated. Figure 4-1



Figure 7-1: Installed Monitoring Well Plan.

7.2. Preliminary Conceptual Site Model

A preliminary CSM was completed and is detailed in Section 2.8 of this report, additionally Arup present a preliminary conceptual site model in their Geotechnical and Geo-environmental Desk Study [4].

7.3. Human Health

7.3.1. Assessment Methodology

To support the evaluation of potential risks to human health from site soils via direct contact exposure (inhalation of dust, accidental ingestion, and dermal contact), soil data have been screened against Environment Agency Soil Guideline Values (SGVs), Category 4 Screening Levels (C4SLs) and Atkins' soil screening values (SSVs, based on the Contaminated Land Exposure Assessment (CLEA) model [50]¹), collectively termed generic assessment criteria (GAC).

Planning permissions P2020/0362 and 20/0738/FUL allow for leisure and commercial use. Buildings that will be used as offices, accommodation, train depots and research will be present in the Washery with a series of train tracks and sidings also present, the general public are not considered to be able to access this area under the future GCRE occupation. The Land at Nant Helen (Nant Helen) will contain two test track loops and is the portion of the site that is most likely to support leisure, conservation or agricultural activities in addition to commercial land use. Therefore, public open space (parks) (POS) GACs, where available, and commercial land use GACs are considered protective of human receptors and have been deemed pertinent for use in this Generic Quantitative Risk Assessment (GQRA). As discussed previously, the potential risk to site maintenance workers through breaking ground has been excluded as it is assumed that they will adopt industry best practice procedures under their own risk assessment process.

The 2022 Arup / Quantum Geotech investigation included geo-environmental analysis on 28No. soil samples from the Washery, with no geo-environmental analysis undertaken on the Land at Nant Helen. Atkins has therefore screened the soil data against GACs for a public open space (parks) and commercial settings with a 1% soil organic matter (SOM) content, as this is considered to be the most conservative criteria.

7.3.2. Results

Asbestos was not detected in the 28No. soil samples from the Washery scheduled for microscopic analysis. The full screening results for the 28No. soil samples tested is presented in Appendix D.

7.3.2.1. Washery - Commercial Land Use

No exceedances of the selected GACs, protective of human health in a commercial land use scenario were recorded in the soil samples.

7.3.2.2. Washery - Public Open Space (Parks)

No exceedances of the selected GACs, protective of human health in a public open space (parks) land use scenario were recorded in the soil samples.

7.3.2.3. Land at Nant Helen

No geo-environmental testing data available to be screened.

7.3.3. Discussion

7.3.3.1. Washery

Results of the soil screening process record no exceedances of public open space (parks) or commercial land use GACs. While no exceedances were identified there remains the potential for unencountered contamination between the exploratory locations in areas not investigated. This is because GI locations were not targeted on potentially contaminating land uses or deployed in a grid to ensure a robust coverage of the Washery and Land at Nant Helen that could be subject to statistical analysis.

Within the Washery, exploratory holes were located at points of opportunity that did not conflict with site operations. The six exploratory holes and 19No. trial pits located in the 54 Ha Washery equate to approximately one investigation location per 2.84 Ha or 28,400 m² with a nominal 170 m by 170 m area characterised by

¹ For further information, please refer to www.atrisksoil.co.uk

each location. As such considerable uncertainty remains regarding ground conditions between the investigation locations with the majority of areas identified as railway land, coal stockpiles, waste storage and washery buildings not subject to detailed investigation. If contamination is encountered during works, it should be reported and persons with suitable knowledge and qualifications should be consulted.

Asbestos was not visually observed during the ground works or detected in the 28No. soil samples scheduled for laboratory analysis. However, there is a potential risk that asbestos could be found in Made Ground, especially around areas of former buildings, and its mitigation, if found, should be considered as part of the construction works design.

It should be noted that seven out of the 28No. soil samples (25%) have been noted as deviating by the laboratory due to no sampling date being provided. This lowers confidence in the affected analysis results, especially volatile organic compounds, petroleum hydrocarbon analysis and other organics such as phenols which are more mobile and susceptible to extended holding times affecting the recorded analysis results.

7.3.3.2. Land at Nant Helen

No geo-environmental soil data is available for the Land at Nant Helen. The CSM indicates that the majority of the geology / soils in this area are natural in origin and likely to be low risk while field observation do not note evidence of contamination, however there are identified potentially contaminating activities such as fuel storage, depot areas, former collieries, tramways and railway land in various parts of the Land at Nant Helen and a significant number of former colliery including associated buildings, spoil heaps, waste areas, fuel storage etc have been removed as part of the overburden strip. Material from these land uses and activities is likely to be entrained within the stockpiled / restored overburden. Soil data, from this material and the locations of potentially contaminating activities associated with Opencast activity that have not been targeted by GI works, is needed to adequately assess the risk to human health associated with development in this portion of the site and to classify material for reuse or disposal as waste.

7.3.3.3. Recommendations

It is recommended that a further phase of site investigation, one that targets identified potentially contaminating site uses and extends investigation coverage to include the entirety of the Washery's planning footprint, is completed prior to earthworks commencing. Materials reuse will be under either the Definition of Waste: Code of Practice (DoWCoP) or Mining Waste Directive (MWD). These both require collection of verification data demonstrating that their requirements have been complied with during construction works to avoid regulatory action. Additionally, during earthworks a watching brief should be undertaken with screening of soils proposed for reuse in areas of landscaping where exposure of future site staff to contaminants could occur.

Within the Land at Nant Helen, geo-environmental sampling is required to allow risk assessment of identified potential sources of contamination and to allow characterisation of materials for reuse under the DoWCoP or MWD. This should consist of further investigation by trial pitting with soil sampling and analysis. Following this and during earthworks, a watching brief should be undertaken with screening of soils proposed for reuse in areas of landscaping or embankment cut or fill where exposure or migration of contaminants could occur.

It should be noted that material reuse will need to either comply with the DoWCoP (where soils/geology are natural or contain anthropogenic material that is not classified as mining waste) or the MWD (where soil/overburden consists of spoil from mining activities). The DoWCoP would require a Material Management Plan (MMP) to be prepared then declared by a Qualified Person (QP), with verification activities undertaken during construction works, then submission of a MMP Verification Report to CLAIRE. The MWD requires that a Waste Management Plan (WMP) is prepared if mining waste is not classified as inert waste. Within the Land at Nant Helen geo-environmental sampling and analysis is needed to allow either approach to be followed. Non-compliance with the waste regime exposes a developer or contractor to prosecution by the regulator and substantial fines, additional Her Majesty Revenue and Customs (HMRC) can require that landfill tax is paid on materials/wastes that they deem to have an incorrect waste classification or have been illegally landfilled.

7.4. Controlled Waters

7.4.1. Assessment Methodology

The potential risks to identified receptors has been assessed by comparison of soil-derived leachate, groundwater and surface water analytical results against screening criteria determined based on the nature of the identified relevant receptors.

There are a number of water bodies (including reservoirs), rivers, streams and drains located on-site, including the Nant Helen (Land at Nant Helen), Dulais (Washery) and Nant Ystalwyn Watercourses (Land at Nant

Helen). Off-site, the River Camnant (37 m northeast of the Washery) is the nearest named surface water receptor, with both the Tawe (340 m north) and Nant Llech (280 m northeast) the nearest offsite surface water receptors for the Land at Nant Helen.

The Environmental Quality Standards (EQS), as per the EU Water Framework Directive as implemented by the Water Framework Directive (England and Wales) 2017 [51] (where available), have been selected as appropriate water quality standards (WQSs) in order to protect identified surface water receptors.

The site is underlain by Superficial Secondary A and Secondary Undifferentiated aquifers in parts of the Washery and a Secondary A aquifer in limited areas of the Land at Nant Helen. The underlying bedrock is classed also as a Secondary A aquifer. Overall, it is considered that groundwater likely contributes baseflow discharge to identified surface water courses however, the potential for local private water supplies and offsite migration to other aquifer units downstream of the site cannot be discounted. From review of the 2020 Arup Environmental Statement [6] there are no active groundwater abstraction licenses that pertain to boreholes located within 1km of the site. However, dewatering operations of the current Nant Helen Extension opencast site is known to be being undertaken.

Therefore, the UK Drinking Water Standards (DWS), as set out in “The Water Supply (Water Quality) Regulations (England and Wales) 2018 [52], have been chosen as WQS considered protective of Secondary A aquifers present beneath and downstream of the site.

Bioavailable determinands have not been assessed against Predicted No Effect Concentrations (PNECs) (which is the concentration at which a chemical will likely have no toxic affect to the identified receptors) using the Water Framework Directive UK Technical Advisory Group metal bioavailability assessment tool (M-BAT) [14] as no receptor specific parameters for hardness, pH and Dissolved Oxygen Concentration (DOC) have been measured. The key output of the M BAT tool is to estimate the bioavailable concentration of a metal under the surface water conditions found at a site, which can then be compared to the EQS bioavailable to assess compliance using a derived PNEC.

Where results are reported as below the Limit of Detection (LOD) it has been assumed they below the LOD rather than equal to it.

7.4.2. Leachate Test Results

Nine soil samples were scheduled for soil-derived leachate analysis (BH29, BH30, BH32, BH33, BH34, TP01, TP02, TP06 and TP09), in the Washery, but none in the Land at Nant Helen.

The concentrations from the analysis of three leachate samples and six WAC completed from soils taken in the Washery were combined and screened against freshwater EQS. It should be noted that the 10:1 results have been used in the absence of 2:1 results. The full screening assessment is provided in Appendix D. Table 7-1 provides a summary of the EQS exceedances and Table 7-2 summarises exceedances of DWS.

Table 7-1: Summary of Leachate Exceedances of EQS – Washery.

Constituent	LOD (mg/l)	GAC (mg/l)	No. of Samples	Min. Value (mg/l)	Max. Value (mg/l)	No. of Exceedances	Locations of Exceedances
Copper (Dissolved)	<0.0005	0.001	9	0.0001	0.0091	7	BBH32, 0.2m, GT-GLYGV; BH33, 0.2m, MGR-FILL; BH29, 0.2m, MGR-FILL; BH34, 1m, MGR-FILL; TP01, 1m, MGR-FILL; TP02, 1m, MGR-FILL; TP09, 1m, MGR-FILL
Lead (Dissolved)	<0.0005	0.0012	9	0.0005	0.0056	1	BH32, 0.2m, GT-GLYGV
Nickel (Dissolved)	<0.0005	0.004	9	<0.0005	2.2	1	BH33, 0.2m, MGR-FILL
Zinc (Dissolved)	<0.0025	0.0123	9	<0.00025	0.013	1	BH32, 0.2m, GT-GLYGV

Constituent	LOD (mg/l)	GAC (mg/l)	No. of Samples	Min. Value (mg/l)	Max. Value (mg/l)	No. of Exceedances	Locations of Exceedances
Phenol (aq)	<0.03	0.0077	9	<0.03	0.35	1	TP02, 1m, MGR-FILL
Fluoranthene	<0.00001	0.0000063	9	<0.00001	0.0054	1	BH33, 0.2m, MGR-FILL
Anthracene	<0.00001	0.0001	9	<0.00001	0.0014	1	BH33, 0.2m, MGR-FILL
Benzo[a]-pyrene	<0.00001	0.00000017	9	<0.00001	0.0018	1	BH33, 0.2m, MGR-FILL

Table 7-2: Summary of Leachate Exceedances of DWS - Washery

Constituent	LOD	GAC (mg/l)	No. of Samples	Min. Value	Max. Value	No. of Exceedances	Locations of Exceedances
Arsenic (Dissolved)	<0.0002	0.01	9	<0.0002	0.015	1	BH32, BH32, 0.2m, GT-GLYGV
Nickel (Dissolved)	<0.0005	0.02	9	<0.0005	2.2	1	BH33, BH33, 0.2m, MGR-FILL
Phenol (aq)	<0.03	0.05	9	<0.03	0.35	1	TP02, TP02, 1m, MGR-FILL
Total PAH(16)	<0.0002	0.0001	9	<0.0002	0.028	1	BH33, BH33, 0.2m, MGR-FILL
Benzo[a]-pyrene	<0.00001	0.00001	9	<0.00001	0.0018	1	BH33, BH33, 0.2m, MGR-FILL

7.4.3. Groundwater Test Results

Fifteen groundwater samples were scheduled for analysis, Figure 7-1 shows monitoring well installations within the Land at Nant Helen and Washery and Table 7-3 summarises the location of each monitoring well relative to Earthworks zones, response zones and the number of monitoring rounds completed. Three samples were in the Land at Nant Helen from BH15, BH16 and BH25, which are respectively located in earthworks zones three, seven and nine and in locations that are likely to be within the catchment of the Dulais. Six locations (BH29, BH30, BH31, BH32, BH33 and BH34) are in the Washery with two sampling rounds completed.

Table 7-3: Monitoring well location summary.

Exploratory Location	Response zone	Earthwork zone	Monitoring Rounds Completed
Washery			
BH29	SWCM	Washery	2
BH30	SWCM		2
BH31	SWCM		2
BH32	Alluvium/ SWCM		2
BH33	SWCM		2
BH34	SWCM		2

Land at Nant Helen

Exploratory Location	Response zone	Earthwork zone	Monitoring Rounds Completed
BH15	Backfill/ Glacial Till/ SWCM	Zone 3	1
BH16	SWCM	Zone 7	1
BH25	Backfill	Zone 9	1

Three samples were in the Land at Nant Helen from BH15, BH16 and BH25, which are respectively located in earthworks zones three, seven and nine and in locations that are likely to be within the catchment of the Dulais. Six locations (BH29, BH30, BH31, BH32, BH33 and BH34) are located in the Washery with two sampling rounds completed

Groundwater analysis was screened against freshwater EQS and UK DWS. The full screening assessment is presented in Appendix G. Table 7-4 and Table 7-5 respectively summarises exceedances of EQS by samples from the Washery and the Land at Nant Helen.

Table 7-4: Groundwater exceedances of EQS - Washery

Constituent	LOD (mg/l)	GAC (mg/l)	No. of Samples	Max. Value (mg/l)	No. of Exceedances	Locations of Exceedances
Chromium (Dissolved)	<0.5	0.0034	12	0.0089	2	BH30, Coal Measures; BH32, Alluvium/Coal Measure;
Copper (Dissolved)	<0.5	0.001	12	0.0033	5	BH30, Coal Measures; BH30, Coal Measures; BH31, Coal Measures; BH32, Alluvium/Coal Measure; BH33, Coal Measures
Nickel (Dissolved)	<0.5	0.004	12	0.0047	2	BH30, Coal Measures; BH31, Coal Measures
Zinc (Dissolved)	<2.5	0.0123	12	0.034	6	BH29, Coal Measures; BH30, Coal Measures; BH31, Coal Measures; BH32, Alluvium/Coal Measure; BH33, Coal Measures; BH34, Coal Measures

Table 7-5: Groundwater exceedances of EQS – Land at Nant Helen

Constituent	LOD (mg/l)	GAC (mg/l)	No. of Samples	Max. Value (mg/l)	No. of Exceedances	Locations of Exceedances
Arsenic (Dissolved)	<0.2	0.05	3	0.44	2	BH15; BH25
Chromium (Dissolved)	<0.5	0.0034	3	14	3	BH15; BH16; BH25
Copper (Dissolved)	<0.5	0.001	3	2.1	3	BH15; BH16; BH25
Nickel (Dissolved)	<0.5	0.004	3	23	3	BH15; BH16; BH25
Zinc (Dissolved)	<2.5	0.0123	3	54	3	BH15; BH16; BH25

Table 7-6: Ground Water exceedances of DWS - Washery

Constituent	LOD	GAC (mg/l)	No. of Samples	Max. Value (mg/l)	No. of Exceedances	Locations of Exceedances
Sulphate	<1	250	12	330	2	BH30, Coal Measures; BH31, Coal Measures

Table 7-7: Ground Water exceedances of DWS – Land at Nant Helen

Constituent	LOD	GAC (mg/l)	No. of Samples	Max. Value (mg/l)	No. of Exceedances	Locations of Exceedances
Arsenic (Dissolved)	0.2	0.01	3	0.44	2	BH15 , 0.4m; BH25 , 5m
Chromium (Dissolved)	0.5	0.05	3	14	3	BH15 , 0.4m; BH16 , 4.52m; BH25 , 5m
Copper (Dissolved)	0.5	2	3	2.1	1	BH25 , 5m
Nickel (Dissolved)	0.5	0.02	3	23	3	BH15 , 0.4m; BH16 , 4.52m; BH25 , 5m
Zinc (Dissolved)	2.5	3	3	54	3	BH15 , 0.4m; BH16 , 4.52m; BH25 , 5m

7.4.4. Surface Water Testing Results

The Arup GIR [2] states that surface water samples were taken from the Lower Reservoir. Official laboratory results from this analysis have not been received at the time of writing. Therefore, surface water results have not been screened against the EQS.

It should be noted that the Lower Reservoir is not likely to be in continuity with site Ground Water and samples analysed from this water body are not likely to be representative of conditions in the Tawe, Dulais and Nant Lech or other unnamed streams that originate on-site.

Further assessment of surface water receptors (streams, rivers and surface ponds in continuity with groundwaters) and chemical testing is recommended.

7.4.5. Discussion & Recommendations

7.4.5.1. Washery

Two exceedances of the EQS for chromium were recorded in the Washery area. It is noted that the other ten samples were compliant with the chromium EQS however the size of the dataset is insufficient to justify discounting the potential risk to controlled waters from these exceedances.

Exceedances of metals (including bioavailable metals) were recorded in soil-leachate and groundwater analysis in comparison to EQS and DWS criteria. Organic compounds were also recorded in excess of the EQS in soil-leachate analysis.

It should be noted that soil leachate tests can be overly aggressive, resulting in values that are not representative of actual hydro chemical conditions. There is no apparent adverse correlation between soil leachate exceedances and groundwater exceedances recorded.

All exceedances in soil derived leachate are associated with shallow Made Ground, to a maximum depth of 0.2 m bgl. All groundwater samples analysed are considered to be representative of the Secondary A multi-layered SWCM aquifer.

A single soil-leachate exceedance of the EQS for arsenic was recorded in the Washery area. It is noted that both of the other two samples for arsenic were compliant with the EQS. The absence of any exceedance of arsenic in groundwater likely indicates that should there be migration of groundwater towards either of the surface watercourses, that there will be a factor of dilution of groundwater contaminant concentrations recorded by mixing and the exceedance in soil-leachate is not considered to represent a significant risk with respect to the surface water receptors.

Exceedances of bioavailable metals were also recorded in both soil-leachate and groundwater. Copper was recorded in excess of the EQS in five soil-leachate samples, nickel in two and zinc in six soil-leachate samples were also recorded. For all bioavailable metals, maximum concentrations in groundwater within the SWCM were far lower than in soil-leachate and are considered to be more representative of the background groundwater regime.

It is not possible to discount or robustly conclude the potential significance of these exceedances in lieu of any data on the quality of receiving water. Application of the metals bioavailable assessment tool on receipt of surface water analysis is necessary to generate predicted no effect (PNEC) concentrations against which an appropriate assessment can be made.

Exceedances of the EQS for phenol, fluoranthene, benzo[a]pyrene and anthracene in soil-leachate are likely a reflection of coal and ash inclusions within the backfilled material but the aggressive nature of leachate extraction method has likely overestimated the leachability of organic determinants in soil. Further sampling of groundwater and analysis of organic determinants is required.

7.4.5.2. Land at Nant Helen

Within the Land at Nant Helen water sampling has been restricted to a single round with data collected from three exploratory holes. It is considered these samples are representative of the background quality of deeper groundwater within the SWCM however the size and spatial distribution of the quality dataset with respect to the Land at Nant Helen is not considered sufficiently robust enough on which to make any conclusion as to the significance of any risk to controlled waters,

It should be noted that all groundwater samples are flagged by the laboratory as deviating due to no sampling date being supplied.

The lack of surface water sampling data from receptor streams/rivers prevents PNECs being calculated for copper, nickel and zinc which make up a significant portion of the other exceedances.

To allow robust conclusions to be drawn the following further work is recommended:

- Installation of additional monitoring wells with a greater coverage of the site.
- Further groundwater sampling and monitoring.
- Surface water monitoring and sampling.

7.5. Mine / Ground Gas Assessment

7.5.1. Introduction

Six rounds of gas monitoring have been undertaken as part of the post ground investigation from standpipes installed across the site. The monitored gases include methane (CH₄), carbon dioxide (CO₂), oxygen (O₂) and hydrogen sulphide (H₂S).

The full set of results are presented in Quantum's Factual Report [9], located in Appendix C and summarised in Section 7.5.2 below.

The following sections detail the generic ground gas risk assessment.

7.5.2. Methodology

The results of the ground gas monitoring have been assessed using the classification system contained within BS8485:2015+A1:2019 [53] and CIRIA C665 [54]. The classification system uses gas concentrations and recorded flow rates for methane (CH₄) and carbon dioxide (CO₂) to determine an exploratory hole hazardous gas flow rate (Q_{hg}). Q_{hg} is used to assign a Characteristic Situation (CS) for each exploratory hole, based on Table 2 in BS8485:2015+A1:2019 [53].

Additionally, mine gas risks have been considered in accordance with CL:AIREs Good practice for Risk Assessment for Coal Mine Gas Emissions [27].

The exploratory hole hazardous gas flow rate (Q_{hg}) has been calculated using the equation below, in accordance with BS8485:2015+A1:2019 [53].

$$Q_{hg} = q \left(\frac{C_{hg}}{100} \right)$$

where:

q is the measured flow rate of combined gases from the monitoring standpipe (l/hr)

C_{hg} is the measured hazardous gas concentration (% v/v)

The Gas Screening Value (GSV) is the flow rate of a specific hazardous gas considered to be representative of a site, following assessment of all exploratory hole concentrations and gas flow rates, whilst taking account of other influencing factors. Such factors being, for example, whether a response zone was completely flooded (which can compromise gas data), the temporal/spatial nature of the data set and the acute one-off nature of the risk.

7.5.2.1. Results

A summary of the gas monitoring results with details of the stratum for each monitoring location is presented in Table 7-8 and Table 7-9. The full results of the gas monitoring are presented in the Factual Report [9] presented in Appendix C.

Table 7-8: Summary of gas monitoring results - Land at Nant Helen (Nant Helen)

Hole ID	Screened stratum	Max flow (l/h)	Max CH ₄ (% vol)	Max CO ₂ (% vol)	Min O ₂ (% vol)	Max H ₂ S (ppm)	Max CO (ppm)	Comment
BH7	MDST ² (SWMCM ³)	0.1	0.50	3.50	8.70	0	0	
BH15	MDST (SWMCM)	0.1	0.10	2.10	19.10	0	0	Flooded during all rounds
BH16	MDST (SWMCM)	0	0.10	2.50	18.90	0	0	Flooded during all rounds
BH19A	Colliery Spoil	0	0	1.30	19.90	0	0	
BH22	SLTST ⁴ (SWMCM)	0	0.10	2.70	13.20	0	0	
BH25	Colliery Spoil	0.1	0.10	12.30	8.40	0	0	Flooded during all rounds
BH28	Colliery Spoil	0.1	0.10	4.10	15.90	0	0	

Table 7-9: Summary of gas monitoring results - Washery

Hole ID	Screened stratum	Max flow (l/h)	Max CH ₄ (% vol)	Max CO ₂ (% vol)	Min O ₂ (% vol)	Max H ₂ S (ppm)	Max CO (ppm)	Comment
BH29	MDST (SWMCM)	0	0.70	2.90	20.10	0	0	Flooded during all rounds
BH30	MG-FILL ⁵	0.4	0.80	5.20	3.20	0	0	Flooded during two rounds

² MDST - Mudstone

³ SWMCM - South Wales Middle Coal Measures

⁴ SLTST - Silt Stone

⁵ MG-FILL - Made Ground / Fill

Hole ID	Screened stratum	Max flow (l/h)	Max CH ₄ (% vol)	Max CO ₂ (% vol)	Min O ₂ (% vol)	Max H ₂ S (ppm)	Max CO (ppm)	Comment
BH31 (Shallow)	MG-FILL	0.05	0.10	4.80	16.10	0	0	
BH31 (Deep)	MDST (SWMCM)	0.05	0.10	2.10	18.60	0	0	Flooded during all rounds
BH32	MDST (SWMCM)	25.2	2.30	3.90	16.40	0	0	Flooded during all rounds
BH33	MDST (SWMCM)	0.3	0.10	2.80	17.30	0	0	Flooded during all rounds
BH34 (Shallow)	MG-FILL (with peat)	0.1	0.60	5.40	17.90	0	0	
BH34 (deep)	SLTST (SWMCM)	0	60.30	2.80	4.90	0	0	Flooded during all rounds

Table 7-10 presented below, details changes in barometric pressure recorded at a private weather station in Neath accessed via Weather Underground [55]. This shows pressure trends from 1800 the day before each monitoring event to midday of the event. The barometric pressure recorded on-site during the monitoring event is also reported.

Table 7-10: Monitoring Visit Pressure Trend Summary

Date of Monitoring Event	Barometric Pressures Record Prior to Monitoring Visit (mB)					Trend	Modified Zone 4 (Y/N)
	Preceding Day 18:00	Day of Visit 00:00	Day of Visit 06:00	Site Reading 08.30-12:00	Day of Visit 12:00		
31/01/2022	1018.8	1013.9	1015.9	1018	1019.9	Rising Fast	N
22/02/2022	1011.9	1012	1007.6	1020	1008.4	Rising slightly	N
09/03/2022	1012.1	1015.4	1001.5	1015	1000.44	Gradual Fall	N
23/03/2022	1015.9	1018.1	1018.7	1001	1018.8	Steady	N
06/04/2022	999.2	996	990.7	967	986.8	Sharp Fall	Y
25/04/2022	1000.8	1004.5	1005.2	989	1006.4	Rising slightly	N

Table 7-10 shows that falling pressure coincided with monitoring events on two occasions. Slightly falling pressure occurred during the 22 February 2022 event and a sharp fall in pressure occurred on the 6 April 2022. Only the event of the 6 April 2022 is considered to represent worst case pressure conditions. It should be noted that the highest methane, carbon dioxide and flow values from the six monitoring rounds coincided with the most significant fall in pressure of the monitoring period. This suggests that gas concentrations and flows on-site are controlled by falling pressure and higher risk conditions than those encountered could potentially occur during greater falls in barometric pressure.

Carbon monoxide (CO) and hydrogen sulphide (H₂S) were not detected during any of the monitoring events. Many of the monitoring installations were flooded during all monitoring rounds, the results from these locations have been excluded from further assessment as they are not considered representative of sub-surface flow or

gas conditions. A summary of maximum Qhg, implied CS and site GSV determined from the gas monitoring are presented in Table 7-11.

Table 7-11: Summary of maximum hazardous gas flow rates.

Area/Exploratory hole						
Land at Nant Helen						
Location	Max. Flow (l/hr)	Max. CH ₄ (% v/v)	Max. CO ₂ (% v/v)	CH ₄ Qhg (l/hr)	CO ₂ Qhg (l/hr)	CS
BH7	0.1	0.50	3.50	5E-04	3.5E-04	1
BH19A	0	0	1.30	0	0	1
BH22	0	0.10	2.70	0	0	1
BH28						
Washery						
Location	Max. Flow (l/hr)	Max. CH ₄ (% v/v)	Max. CO ₂ (% v/v)	CH ₄ Qhg (l/hr)	CO ₂ Qhg (l/hr)	CS
BH30	0.4	0.80	5.20	3.2E-03	0.0208	2*
BH31 (shallow)	0.05	0.10	2.10	5E-05	1.05E-03	1
BH34 (Shallow)	0.1	0.60	5.40	6E-04	5.4E-03	2*

* CS increased from CS1 to CS2 due to CO₂ concentration exceeding 5% threshold.

The worst-case non-location or time linked gas monitoring data is summarised below. This shows an absolute worst case GSV and Characterisation Situation for the site based on the site wide data set. Results in brackets utilise the highest site wide flows after results that are potentially an artefact of monitoring well design and water levels are excluded.

Table 7-12: Summary of the worst-case non-location or time linked gas monitoring data.

	Max. CO ₂ (% v/v)	Max. CH ₄ (% v/v)	Max. CO ₂ (% v/v)	Max. Steady Flow (l/hr)	CH ₄ Qhg (l/hr)	CO ₂ Qhg (l/hr)	CS
Location	BH31 (Deep)	BH34 (Deep)	BH25	BH32 (BH30)	-	-	-
Date	06/04/2022	06/04/2022	06/04/2022	06/04/2022	-	-	-
Maximum Recorded Values	21.7	60.3	12.3	25.2 (0.4)	15.2 (0.24)	3.1 (0.049)	CS5 (CS2)

7.5.3. Discussion

Overall and in accordance with the assessment methodology detailed in BS8485:2015+A1:2019 [53] and CIRIA C665 [53], the calculated GSV (based on the worst case data for each monitoring location) indicates the maximum Characteristic Situation with respect to both carbon dioxide and methane was CS2 (Low risk).

BS8485 requires that an assessment of data quality is completed and the level of conservatism in a gas risk assessment should reflect the robustness of the monitoring data. Gas monitoring locations within the Main Site (Nant Helen), where no enclosed spaces are currently planned, have a significant distance between them and are targeted on the embankment structures footprint. The Washery where structures with enclosed spaces are planned (offices, research buildings, on-site accommodation, train depot) has six monitoring locations installed (two with dual shallow and deep monitoring wells). This results in three monitoring wells (BH30, BH31 shallow and BH32) screened in Made Ground, one (BH34 shallow) in peat, and three monitoring wells (BH31 Deep, BH33 and BH34) installed in the underlying Coal Measures over a 54 Ha area. This represents a small data set

from each of the sources of ground gas identified within the Washery with the potential for considerable variation in ground conditions between each monitoring well.

A site worst case GSV should be calculated and the recorded GSVs compared to this value. In the case of the Washery the maximum methane concentration recorded was 60.3 % v/v in monitoring well BH34 (shallow) with a maximum flow of 0.4 l/hr recorded in monitoring well BH30 during the same monitoring round. These values when combined equate to a GSV of 0.24 l/hr and Characterisation Situation 2 (Low Risk). If an elevated flow of 25.2 l/hr from BH32 (assessed as being an artefact of well design) is utilised the maximum calculated GSV is 15.1 l/hr and Characterisation Situation 5 (High Risk).

BS8485 also requires that ground gas monitoring datasets should include two readings from what are considered to be worst case conditions. These are conditions where pressure is falling rapidly and meets the requirements set out in TB17 [56]. The Washery and Land at Nant Helen datasets have one monitoring event that coincides with worse case conditions.

It should also be noted that across the monitoring area three out of six exploratory holes located within the Washery were flooded and three out of seven installations within the Land at Nant Helen were flooded during all rounds. The data from these wells has been discounted as unrepresentative of sub-surface ground gas conditions as the screened horizon has been flooded, thus potentially limiting ground gas entry and causing flow rates that are an artefact of the screened level and water levels. Overall, across the site, data from six wells (40%) is considered appropriate for inclusion in the ground gas assessment indicating only limited information on the ground gas conditions under the site.

CIRIA C665 [54] outlines in Table 4.2 the necessary spacing of gas monitoring wells for development sites dependent on the sensitivity of end use. CL:AIRE's Good practice for the risk assessment of coal mine gas emissions [27] document in Figure 13.1 provides a decision support tool for mine gas risk assessment. The Washery is considered to demonstrate a moderate gas hazard due to extensive Made Ground and underlying disused mine workings that are present at a shallow depth. Made Ground within the Land at Nant Helen may locally present a gas risk but the majority of the backfilled Overburden is reworked natural Quaternary deposits or South Wales Coal Measures that have a limited potential to generate ground gases, additionally opencast mining has removed underground coal workings from beneath the majority of the Land at Nant Helen.

The Land at Nant Helen is considered to have a low end of use sensitivity and the Washery is considered to have a low to moderate end use sensitivity. Therefore, wells should ideally be spaced 25-75 m apart (Land at Nant Helen) and 25-50 m apart (Washery). It is considered that current monitoring installations do not meet these requirements to provide a detailed assessment of ground gas conditions. It is recommended that either a conservative assessment of risk is adopted with the contingent additional costs associated with installing a level of gas protection into buildings that may not be required to reflect the available data or that additional monitoring exploratory holes are installed and additional monitoring completed to meet the requirements set out in CIRIA C665 [54]. Further ground gas monitoring is recommended to provide more data for to assess ground gas risk further.

With respect to Mine Gas risks specifically a key uncertainty in the Washery area is how ground water levels change over the hydrogeological cycle and whether shallow mine workings identified in Section 4.4 and the MRA in Appendix C will be flooded under all circumstances. Data collected to date shows shallow ground water (circa 1m to 5m bgl) between December 2021 to March 2022 when groundwater levels are most likely to be elevated, but does not establish how ground water levels vary with respect to seasonality and whether shallow mine workings will be permanently flooded (a lower risk scenario) or subject to seasonal inundation (a higher risk scenario).

Reduced oxygen levels (<18%) are noted in BH7, BH22, BH25, BH28, BH29, BH30, BH31 (shallow), BH32, BH33, BH34 (shallow) and BH34 (deep).

Appropriate health and safety measures should be implemented during any on-site works and a safe system of work must always be implemented to address risks of asphyxiation from elevated methane, carbon dioxide or reduced oxygen concentrations if entry to a confined space is required and unavoidable. Guidance issued by the HSE for working in confined spaces should be followed [57].

7.6. Refined Conceptual Site Model (CSM)

Risks to human health and environmental receptors from land contamination are assessed through the development of a CSM and the identification of Potential Contaminant Linkages (PCLs). A PCL exists when a plausible pathway exists between a potential source of contamination and a receptor.

In accordance with Land Contamination: Risk Management (LC:RM) report [58], the initial CSM has been updated based on the human health, controlled waters GQRAs and gas risk assessment presented in Sections

6.3, 6.4 and 6.5 respectively. CSMs have been provided for the Land at Nant Helen and the Washery separately.

In addition, the following details of the proposed development work and mitigation measures have been considered when updating the CSM:

- The proposed development works affect open spaces and the planning permission for Earthworks Restoration will allow agricultural, leisure and commercial uses.
- Enclosed spaces are anticipated in the Washery.

The likelihood and severity of a PCL being realised have been classified in accordance with CIRIA C552 [29]. Comparison of the consequence and probability has been undertaken to derive a risk category. A summary of the risk categories is presented in Table-7-13.

Table-7-13: Description of risk categories and likely action required (as per CIRIA C552).

Risk Category	Description	Action Required
Very high risk	High probability that severe harm could happen to an identified receptor and would result in substantial liability.	Urgent investigation and remediation are likely required.
High risk	Harm is likely to happen to an identified receptor and would present a substantial liability.	Urgent investigation is required, and remediation is likely to be required in the longer term.
Moderate risk	Harm could happen to an identified receptor, but it may not present a substantial liability.	Investigation is normally required to clarify the risk and whether remediation is required.
Low risk	Harm could happen to an identified receptor but is unlikely to present a substantial liability.	Investigation may be required.
Very low risk	It is unlikely that harm could happen to a receptor and even if it is unlikely to present a substantial liability.	None.

Table-7-14: Refined Conceptual Site Model - Land at Nant Helen (Nant Helen).

Sources	Receptors	Potential pathway	Classification of risk (Consequence/Likelihood)
Potential contaminants in soil/groundwater on-site originating from the following on-site sources: Made ground associated with historic mining and extraction activities. Underlying mine shafts and workings. Historic contamination associated with historic industrial activities. Current opencast mining activities (Nant Helen). Potential contaminants of concern: Leachable contaminants, contaminants within soils including asbestos, contaminants within groundwater and surface water, vapours and ground gas	On-site future site users and workers, and off site users (human health).	Inhalation, ingestion and dermal contact with contaminants in soil and soil derived dust/fibres in groundwater.	Moderate Risk (Medium/Low) Extensive old mining workings and infilled ground including colliery spoil are recorded in the vicinity and on-site. Made Ground was present within all borehole and trial pit locations. No chemical analysis of soils or leachate has been carried out in this area to assess this risk quantitatively. <u>Recommend Actions</u> GI to confirm/refute CSM Trial pitting and soil sampling to confirm the composition of overburden, assess the composition of site soils and to inform MMP suitability of use assessments. Targeted drilling boreholes to assess composition of overburden at depth of cuttings or sampling in conjunction with watching brief during construction earthworks. Targeted trial pitting and drilling of areas of elevated risk (Celtic compounds, fuel storage AST, areas where evidence from walkover identifies evidence of contamination)
		Migration and inhalation of vapours from contaminants at the site.	Moderate at AST location / Low remainder of Main Site A known potentially viable on-site vapour source is restricted to ASTs identified at the Celtic compound in the centre of the site. Other potential sources are hydrocarbon holding AST and UST that may have historically been present within Colliery areas and leaks / spillages from vehicles associated with Celtics works area. Completed GI works did not involve headspace sampling and no reports of hydrocarbon odours or visual evidence were reported in the GI. The earthworks proposed at this time do not include development of confined spaces therefore build-up of vapour is not considered plausible. If underpasses or tunnels are proposed within the earthworks or future phases of development, as have been discussed to allow access to leisure or agricultural areas, these areas would potentially be at risk. <u>Recommend Actions</u> GI to confirm/refute CSM Trial pitting, headspace sampling and soil sampling to confirm the presence of Made Ground and assess the composition of site soils. Installation of monitoring wells and vapour monitoring at location of AST and vapour monitoring in all ground gas wells.

Sources	Receptors	Potential pathway	Classification of risk (Consequence/Likelihood)
		Migration and inhalation of ground gas and risk to property from explosion.	Moderate/Low The Coal Measures present beneath the Main Site are associated with extensive mining activities. Areas of opencast mining and then backfilling/restoration with overburden are shown in Figure 2-1. In these areas Coal Measures and historic workings/shafts and adits that fall within the opencast have been sterilised to depths of circa 74 to 100 m AOD with 100 to 150 m of overburden placed as restoration. While coal workings are known to underly areas of opencast their depths and the absence of confined spaces within the Main Site footprint are such that Mine Gas risk is low in these areas of the site. Data from boreholes within these portions of the site when plotted on a ternary plot do not indicate a thermogenic methane source. Workings are, if present at shallow depth, potentially a significant source of mine gas that presents a risk of asphyxiation from methane and carbon dioxide, depleted oxygen and risk to human health and property from explosion. While Opencast mining has removed the underlying coal measures and placed a considerable thickness of backfill over the majority of the site as shown in Figure 2-1, the exception to this are the south-west quadrant (Earthwork Zone 8), southern edge (Earthwork Zones 3 and 11) and a strip that runs north to south through the centre of the site (crossing portions of Earth Work Zones 2, 3,5 and 6) where no opencast activities have occurred. In these areas past shallow coal mining has been identified by the MRA and historical adits and shafts have been identified from CA records. Ground gas monitoring data from these areas is limited to data from BH22 where methane, carbon dioxide and balance gas concentrations are such that if subject to ternary plotting, they do not indicate a thermogenic methane source. These areas of the site present a more significant gas source however, again no enclosed spaces where mine gas may build up are planned. Overburden will have consisted of Lower and Middle Coal Measures that did not hold coal, Devensian Till and Alluvium (both not considered a viable source of gas) and Peat (potentially a source of ground gas). Infrequent and localised areas of putrescible Made Ground are also likely to be present within the overburden following the stripping of overlying material to allow coal extraction. The earthworks proposed at this time do not include development of confined spaces therefore build-up of gases is not considered viable. If underpasses or tunnels are proposed within the earthworks or future phases of development, as have been discussed to allow access to leisure or agricultural areas, these areas would potentially be at risk. <u>Recommend Actions</u>

Sources	Receptors	Potential pathway	Classification of risk (Consequence/Likelihood)
			GI to confirm/refute CSM Trial pitting and limited suite of soil sampling analysis to confirm the presence of Made Ground and assess the composition of site soils. Installation of additional monitoring wells and ground gas monitoring if development plans change to include confined spaces / buildings within the Main Site.
	Property and Services – neighbouring residential and commercial properties. Current and future infrastructure.	Direct contact of foundations/services with aggressive soils and or groundwater. Chemical attack to buried structures.	Low Current and future below ground infrastructure is assumed to have been/will be constructed to appropriate standards for the site to withstand attack from soil chemistry. <u>Recommended Actions</u> Trial pitting to assess the composition of site soils is recommended in order to allow appropriate design of future services and foundations.
	Secondary A aquifer / Secondary Undifferentiated aquifer	Leaching from unsaturated soils to shallow groundwater, then migration of dissolved or separated non-aqueous phase contamination within groundwater.	Moderate The works are likely to result in disturbance of soils and changes in water levels during excavation and construction which may result in the release of contaminants in Made Ground/overburden and disused mine workings with potential migration to groundwater. Groundwater below the site is classified as Secondary A aquifers, the distance to identified abstractions and surface waters is such that groundwater is considered to have a medium sensitivity. Migration to the site from off-site sources is not considered to be plausible. Due to opencast mining, superficial aquifers are not considered to be a plausible on-site receptor. GI works have identified significant exceedances of chromium within the Main Site and lower-level exceedances of bioavailable metals. Groundwater monitoring is restricted to the southeast quarter and insufficient information is available to define this risk. <u>Recommended Actions</u> GI to confirm/refute CSM. Trial pitting with soil and leachability sampling to assess the composition of site soils is recommended.

Sources	Receptors	Potential pathway	Classification of risk (Consequence/Likelihood)
			Monitoring installations are recommended to be installed with a regime of groundwater monitoring and sampling to establish groundwater levels, flow patterns and contamination levels to further assess this risk.
	Surface waters (on-site and off-site)	Groundwater migration and subsequent migration or via surface water runoff.	Moderate The works are likely to result in disturbance of soils and changes in water levels during excavation and construction which may result in the release of contaminants in Made Ground/overburden and disused mine workings with potential migration to surface waters. The site contributes to the catchments of the Tawe, Dulais and Nant Llech with unnamed streams and the Nant Helen arising from the Main Site that feed into them. Additionally numerous ponds and lagoon are currently present on-site. Migration to the site from off-site sources is not considered to be plausible. Due to opencast mining superficial aquifers are not considered to be a plausible on-site receptor. <u>Recommended Actions</u> Sampling and analysis of surface waters to confirm baseline conditions. Survey of surface waters, springs and sinks. Installation of monitoring wells and groundwater monitoring. GI to collect leachability samples and groundwater samples.

Table-7-15: Revised conceptual model for the Washery area

Sources	Receptors	Potential Pathway	Classification of Risk (Consequence/Likelihood)
Potential contaminants in soil/groundwater on-site originating from the following on-site sources:	On-site future site users (future workers) and off site users	Inhalation, ingestion and dermal contact with contaminants in soil and soil derived dust/fibres in groundwater.	Low Risk (Medium/unlikely) Made Ground is present beneath the majority of the Washery site due to historic mining activities, placement of spoil from the former Onllwyn and Dulais Collieries operation, railway land and the current Washery land use. The planned development will result in an substantial thickness of engineered fill being placed to deliver the levels required for GCRE's operation breaking the majority of inhalation, ingestion and dermal contact pathways once construction is complete.

Made Ground associated with historic and current industrial activities (Coal Washery, Mineral Railway, former tramway, former colliery, spoil heaps). Contamination associated with current Coal Washery activities. Localised spillages of hydrocarbons/fuels from current Mineral Railway activities. Historic contamination associated with historic industrial activities. Potential contaminants of concern: <i>Asbestos</i> <i>Metals</i> <i>Polycyclic aromatic hydrocarbons (PAHs)</i>	(human health).		<u>Recommended Actions</u> Additional trial pitting, soil sampling and soil analysis to assess potential sources that have not been subject to investigation and to increase confidence in conclusions.
		Inhalation of dust	Moderate/low Risk (Unlikely / Severe) GI to date has not identified the presence of asbestos. Many buildings and Made Ground present on-site predate 1999 when asbestos was banned and its presence in un-investigated parts of the Washery could be anticipated. However, post-construction it is considered that any plausible pathway between potential asbestos-containing soils and future end users will be broken by the placement of clean cover and new hardstanding. <u>Recommended Actions</u> Further soil sampling to better characterise asbestos risk. Refurbishment and demolition survey of site buildings before demolition and removal and verification of ACM before demolition.
		Migration and inhalation of ground gas and/or vapours from contaminants at the site.	Moderate Risk (Medium/Low) Sources of ground gas are confirmed as present; The Made Ground, shallow mine workings (<30m depth) and adits/shafts identified as present beneath the Washery are a potential source of ground gas and mine gas. A key uncertainty with respect to Mine Gas risk is whether shallow mine working below the site are flooded throughout the year or subject to a seasonal cycle of drying and inundation as ground water levels change. Water level data collected to date is on from December to March and showed a consistent water level of between 1m to 5m depth, however monitoring over periods time when the hydrogeological cycle may lead to a decrease in water levels has not occurred. Risk to earthworks is considered to be low, however, the proposed works associated with the GCRE planning decision involve construction of buildings (confined spaces) and so vulnerable receptors will be present once earthworks are completed. A mining risk assessment has also been completed and it is anticipated that grouting of identified shallow mine workings will occur and change the mine gas regime when it occurs. Ground gas data collected indicates a potential CS2 level of risk. However, additional data and risk assessment is required to demonstrate that higher levels of risk are not present in areas of the site that do not have extensive monitoring coverage. <u>Recommended Actions</u> GI to confirm/refute CSM. Installation of additional monitoring wells to target different sources of gas (natural peat, Made Ground, mine workings) and to assess the composition of site soils.

<i>Petroleum hydrocarbons</i> <i>Volatile organic compounds (VOCs)</i> <i>Ground gases (methane, carbon dioxide, hydrogen sulphide or carbon monoxide)</i>			Additional ground gas monitoring to increase the number of monitoring rounds that meet the worst-case gas generation criteria is recommended and to provide more information on groundwater levels across the hydrogeological cycle.
	Secondary A aquifer	Leaching from unsaturated soils to shallow groundwater, then migration of dissolved or separated non-aqueous phase contamination within groundwater.	Moderate Risk (Medium/Low) The works are likely to result in disturbance of soils and colliery spoil during excavation and construction which may result in the release of contaminants with a potential to migrate to groundwater. Groundwater below the site is present at a shallow depth and predominantly classified as Secondary A or Secondary Undifferentiated aquifers with limited superficial deposits that are unproductive. The distance to identified abstractions and surface waters is such that groundwater is considered to have a medium sensitivity. Sampling to date indicates a low-level exceedances of EQS for copper, nickel and zinc that is anticipated likely to not present an unacceptable risk if PNECs using parameters from adjacent watercourses were utilised. <u>Recommended Actions</u> Installation of additional monitoring wells and completion of further groundwater monitoring to strengthen dataset. Collection of leachability, surface water and groundwater samples. Analysis of leachability, surface and groundwater samples to confirm baseline conditions.
	Surface waters	Groundwater migration and subsequent migration or via surface water runoff.	Low/Moderate Risk (Medium/Low) Potential for leachable metals has been identified with limited exceedances of EQS in groundwater samples and it is recommended that any reuse of soils within areas of surface waters are verified and assessed for suitability. <u>Recommended Actions</u> Installation of additional monitoring wells and further groundwater monitoring. Collection of leachability, surface water and groundwater samples. Analysis of leachability, surface and groundwater samples to confirm baseline conditions.

7.7. Geo-environmental Conclusions

7.7.1. Risks from Soils

No exceedances of the commercial or public open space (parks) GAC have been identified in soils within the Washery, therefore there is no demonstrated unacceptable risk to receptors from soils in this area of the site. Sampling locations, primarily where access was possible, are typically not targeted on identified potential contamination sources. Additionally, the number / frequency of investigation locations relative to the Washery's size is low, there is therefore a high potential for ground conditions to vary significantly between the investigation positions and contaminants concentrations to be present that may pose an unacceptable risk. Additional investigation, sampling and analysis is recommended to increase the level of confidence in the soils risk assessments conclusions.

No asbestos has been identified in soils analysed, however there is potential for asbestos to be present within the Made Ground on-site in the Washery and areas of Made Ground dating from before 1999 in the Land at Nant Helen. Should any unexpected visual or olfactory evidence of potential contamination, including asbestos, or potential sources of ground gas be encountered during construction works, that part of the works should be halted. A contaminated land / asbestos specialist should be consulted immediately so that additional assessment can be undertaken, and appropriate mitigation measures are put in place.

The Washery will have its levels raised by several meters in order to deliver a level platform for GCREs use, this increase in level will place a considerable quantity of fill over the Washery and the presence of this material (if demonstrated to be clean) will break the ingestion, dust inhalation and dermal exposure pathways that users of the developed site would be exposed to.

No testing of soils has been undertaken in the Land at Nant Helen (Nant Helen), therefore risk to receptors from contaminants in soils cannot be discounted or quantitatively assessed. It is acknowledged that the majority of material in the Land at Nant Helen is natural in origin, but the historic presence of railway land, collieries, tram ways and mining activities means that potentially contaminated material will have been entrained within the overburden that has been striped and then replaced as restoration material. It is recommended that a further investigation is carried out to further assess this risk.

7.7.2. Ground Gas / Mine Gas and Vapour Risks

Based on site historical information, the ground conditions encountered, from the data and limited monitoring currently undertaken it is considered that harmful ground gases pose a moderate risk to the human health and property receptors identified in the Washery. It is considered that ground gas risk is likely to be CS2 (Low Risk) but that there is insufficient information to provide a robust conclusion to be made regarding the ground gas regime on-site.

Further monitoring installations are recommended to be installed at smaller intervals on site with further monitoring rounds also recommended.

Additionally following a decision regarding treatment (grouting/additional GI/excavation) of shallow mining risks the Mine Gas portion of the risk assessment will require revision.

7.7.3. Risks to Controlled Waters

The results of the groundwater and leachate testing suggest that the site poses a risk to the identified Controlled Waters receptors including waterbodies / watercourses on-site and off-site and the Secondary 'A' Aquifers beneath the site. However, chemical testing of groundwater is considered limited and surface water laboratory results have not been received at the time of writing. Further groundwater and surface water testing is recommended to further assess the risks.

7.7.4. Materials Management

The absence of geo-environmental testing from the Land at Nant Helen means that Waste Classification has not occurred and cannot occur in this portion of the site. Additionally, the absence of this information means that the appropriate route for materials management cannot be selected until information to demonstrate suitability of use is available.

Waste characterisation would be needed in the event of earth removal during future construction works. Any material to be removed off-site for disposal must be appropriately classified and agreed with the chosen landfill operator. It is the responsibility of the waste producer to classify, treat, manage and dispose of waste appropriately, and to ensure the chosen landfill is licensed to accept such material. Furthermore, the permits for

individual landfill sites may contain soil and soil-derived leachate limits for waste acceptance. It should also be noted that colliery spoil's reuse falls under the Mining Waste Directive (MWD) rather than the conventional waste regime and that compliance with the MWD requires preparation of a Waste Management Plan. Works that involve reuse / disposal of natural soils or Made Ground that is not formed of mining waste such as railway land or deriving from other works present within the Washery will need to comply with the UK Waste Regime's requirements.

Should any natural or non-mining waste materials be proposed to be made available for re-use, the earthworks should be undertaken in accordance with the CL:AIRE Definition of Waste: Code of Practice (DoW:CoP) [52] through preparation of a Materials Management Plan. Verification of the Materials Management Plan will be reported in a Materials Management Verification report in accordance with the DoW:CoP [52].

7.7.5. Construction Risks

Under current health and safety legislation, employers (i.e., the Contractor) are required to carry out their own appropriate health and safety risk assessments and mitigation actions to protect themselves and their employees, other human receptors and the environment from potential contamination. Such risks must be adequately mitigated by law, specifically The Construction (Design and Management) Regulations, 2015 (CDM) (Health and Safety Executive, 2015) which require that potential risks to Human Health and the environment from construction activities are appropriately identified and all necessary steps taken to eliminate / manage those risks.

The adoption of appropriate best practice environmental management during construction to mitigate potential risks to environmental receptors (e.g., minimisation of dust generation and migration, and controlled surface water run-off) should be incorporated in future site works.

7.8. Geo-environmental Recommendations

Atkins has provided the following recommendations:

- If groundwater is encountered and evidence of contamination is noted, an environmental specialist should be consulted to ensure the appropriate handling and disposal of any contaminated waters. If encountered, further work would require reassessment that may alter risk of leaching materials into groundwater.
- The adoption of appropriate best practice environmental management during construction to mitigate potential risks to environmental receptors (e.g. minimisation of dust generation and migration, and controlled surface water run-off) should be incorporated in future site works.
- Although not detected in the soil samples, due to the land use there is the potential for asbestos to be present on-site specifically in the Washery and areas where former Colliery Structures are still present. Groundworkers and sub-surface maintenance workers should be made aware of the possibility of encountering contaminated soils through toolbox talks and in particular the potential presence of asbestos. Appropriate risk assessments to mitigate exposure of the workforce and general public during development of the site will be required. The contractor will need to prepare a risk assessment which identifies a safe system of work to handle any Made Ground material including that which contains localised asbestos.
- Due to the inherent variability which can be expected, there is a possibility that previously unidentified contamination may be encountered. It is recommended that this uncertainty is considered within health and safety risk assessments and a watching brief is provided during all excavation works in order to identify any unexpected, potentially contaminated ground conditions.
- Further ground investigation is recommended to be carried out; this should include:
 - Trial pitting in the Land at Nant Helen (to assess risks to human health, controlled waters and support materials management activities) and Washery (to increase confidence in the completed risk assessment);
 - Targeted drilling of exploratory holes and installation of monitoring wells in the Land at Nant Helen to characterise risks from identified AST, intact colliery structures, former railway land and Celtic depot/works areas;
 - Installation of additional ground gas monitoring wells in the Washery to increase confidence in the ground gas risk assessment;
 - Geochemical testing of soils to further assess the risks posed to receptors from contamination for the Land at Nant Helen (Nant Helen) with additional testing of soils in the Washery completed in order to increase the confidence that can be placed in the current risk assessment.

- Installation of additional groundwater monitoring wells across the Land at Nant Helen to allow groundwater levels, flow directions and groundwater quality in the north and south of the Land at Nant Helen to be assessed;
- Further surface water testing is recommended to be carried out to assess the background concentrations of contaminants upstream and downstream of the site and to allow suitable GACs to be developed.
- Further groundwater sampling is recommended to assess the risk to groundwater and surface water receptors.
- Further ground gas installations and monitoring is recommended to comply with BS8485 [59], CIRIA C665 [54] and CL:AIREs Good Practice for Risk Assessment for Mine Gas Emissions [60], in order to allow further assessment on the risks from ground gas.

8. References

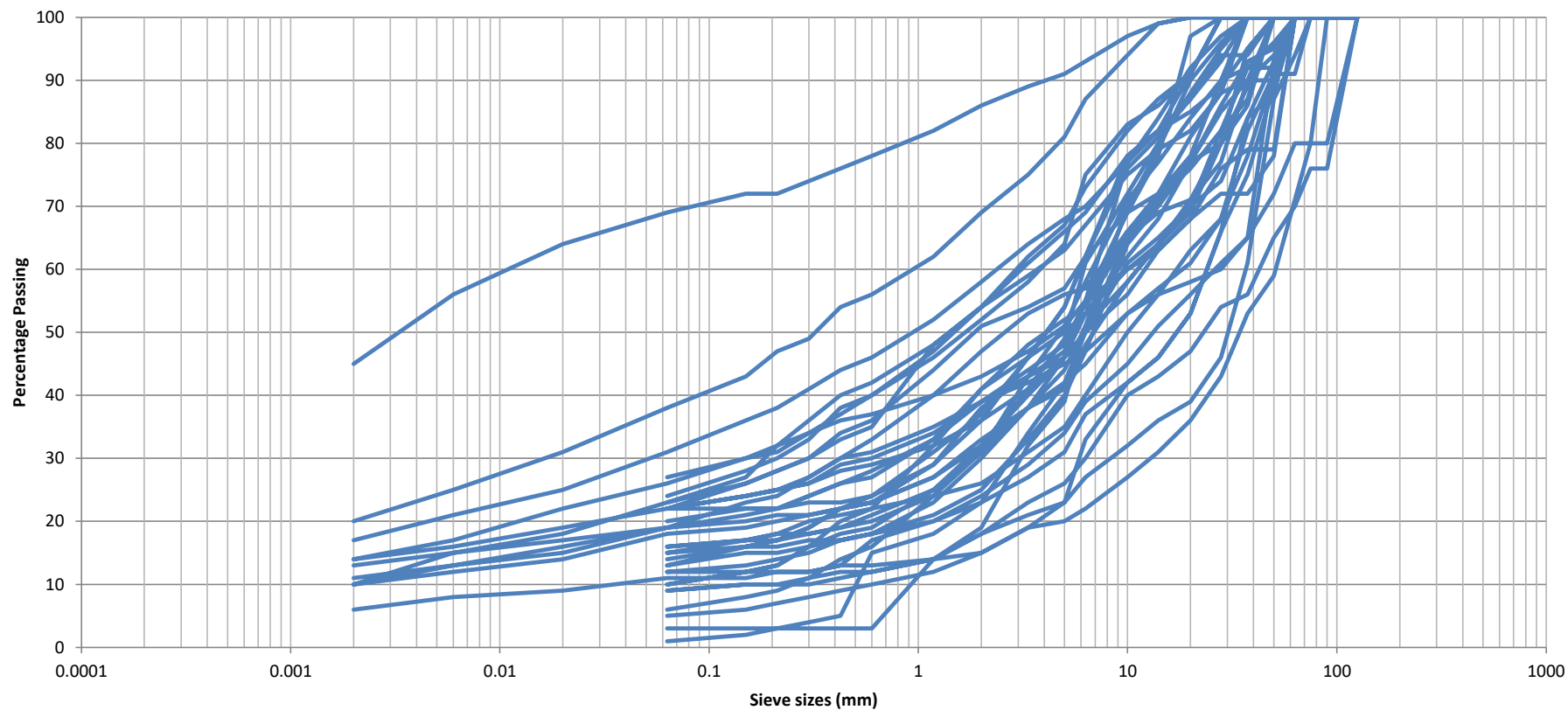
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Appendix A. Geotechnical Parameter Plots

- A.1. Made Ground (Granular) – Particle Size Distribution
- A.2. Made Ground (Granular) – Drained Young's Modulus vs Depth
- A.3. Made Ground (Cohesive) - Particle Size Distribution
- A.4. Made Ground (Cohesive) – A line
- A.5. Made Ground (Cohesive) – Undrained Shear Strength vs Depth
- A.6. Made Ground (Cohesive) – Drained Young's Modulus vs Depth
- A.7. Made Ground (Cohesive) – Undrained Young's Modulus vs Depth
- A.8. Made Ground (Cohesive) - Coefficient of Volume Compressibility vs Depth
- A.9. Glacial Till - Particle Size Distribution
- A.10. Glacial Till – A line
- A.11. Glacial Till – Undrained Shear Strength vs Depth
- A.12. Glacial Till – Drained Young's Modulus vs Depth
- A.13. Glacial Till – Undrained Young's Modulus vs Depth
- A.14. Glacial Till - Coefficient of Volume Compressibility vs Depth
- A.15. South Wales Coal Measures (Mudstone) – Uniaxial Compressive Strength vs Depth
- A.16. South Wales Coal Measures (Mudstone) – Rock Quality
- A.17. South Wales Coal Measures (Siltstone) – Uniaxial Compressive Strength vs Depth
- A.18. South Wales Coal Measures (Siltstone) – Rock Quality
- A.19. South Wales Coal Measures (Sandstone) – Uniaxial Compressive Strength vs Depth
- A.20. South Wales Coal Measures (Sandstone) – Rock Quality

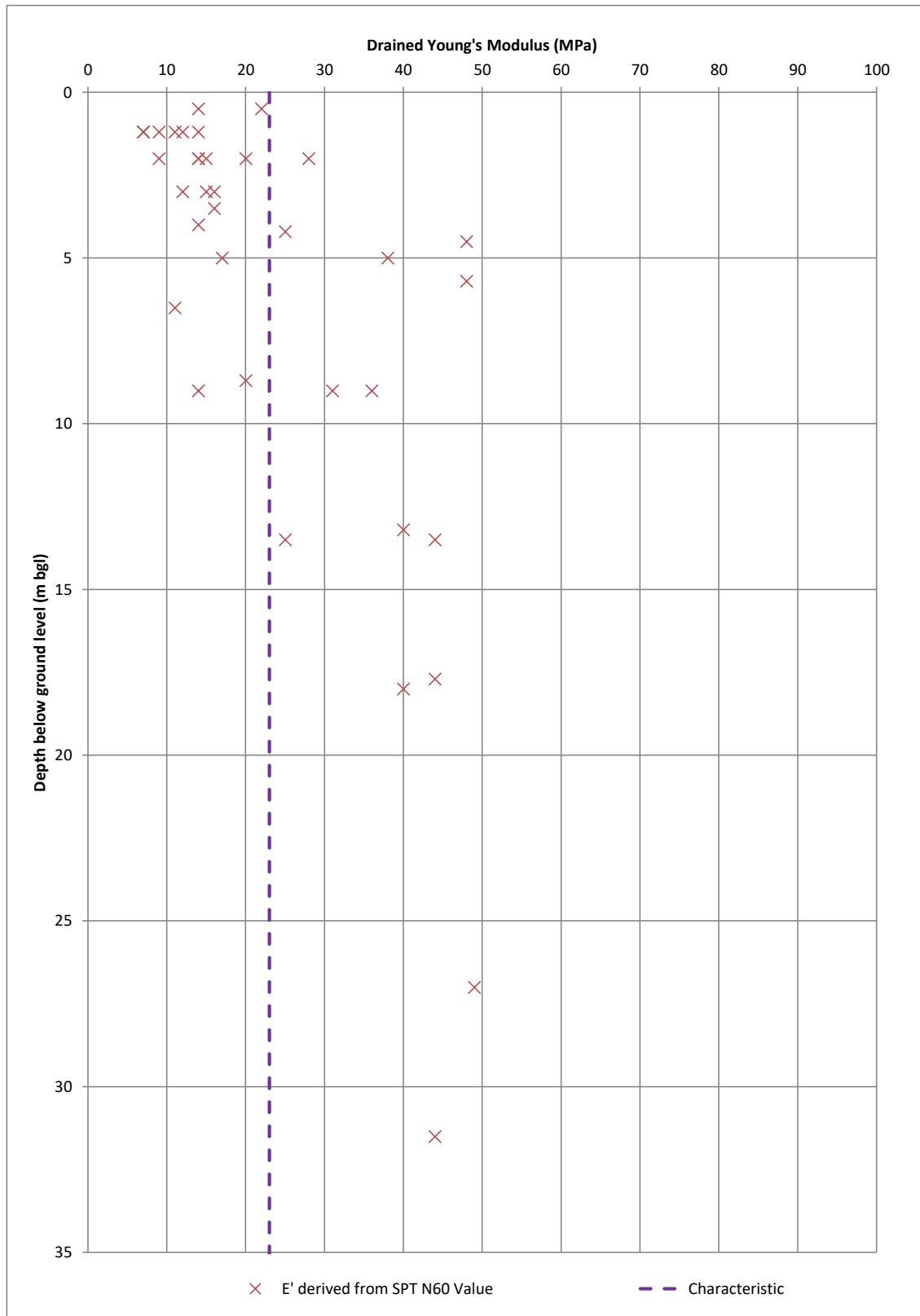


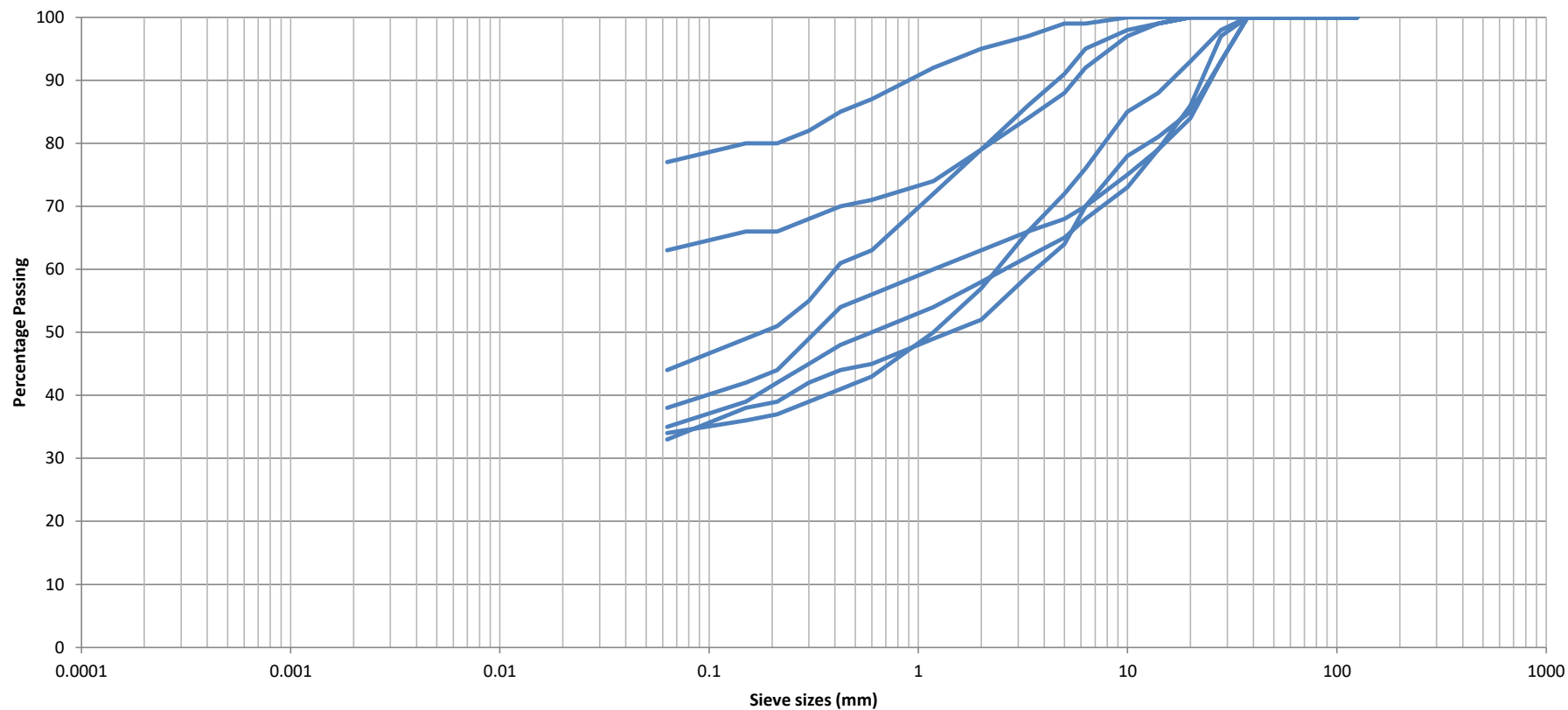
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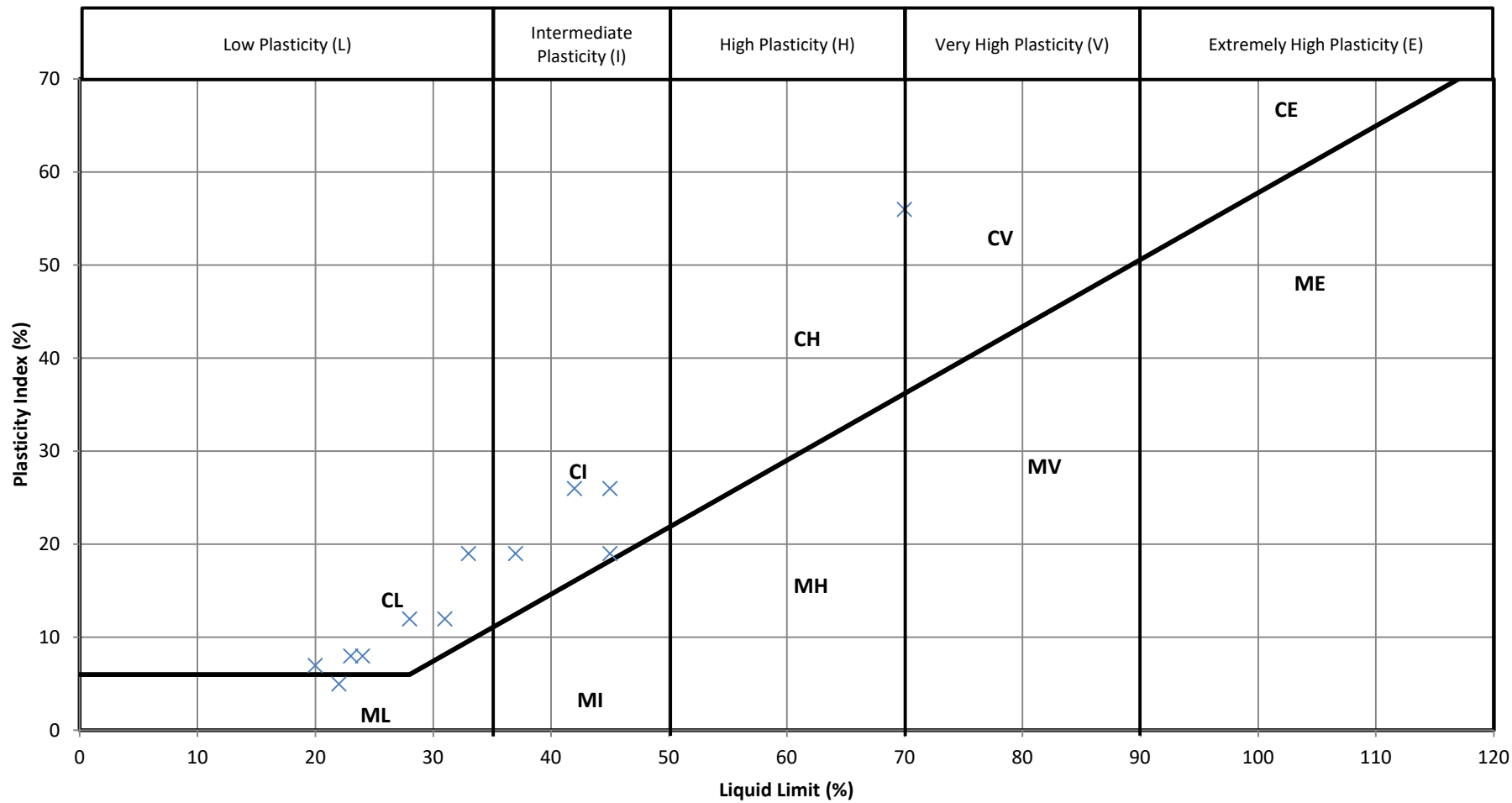
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Member of the SNC-Lavalin Group

Project
Global Centre for Rail Excellence
Figure Number
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Title
Made Ground (Granular) - Particle Size Distribution

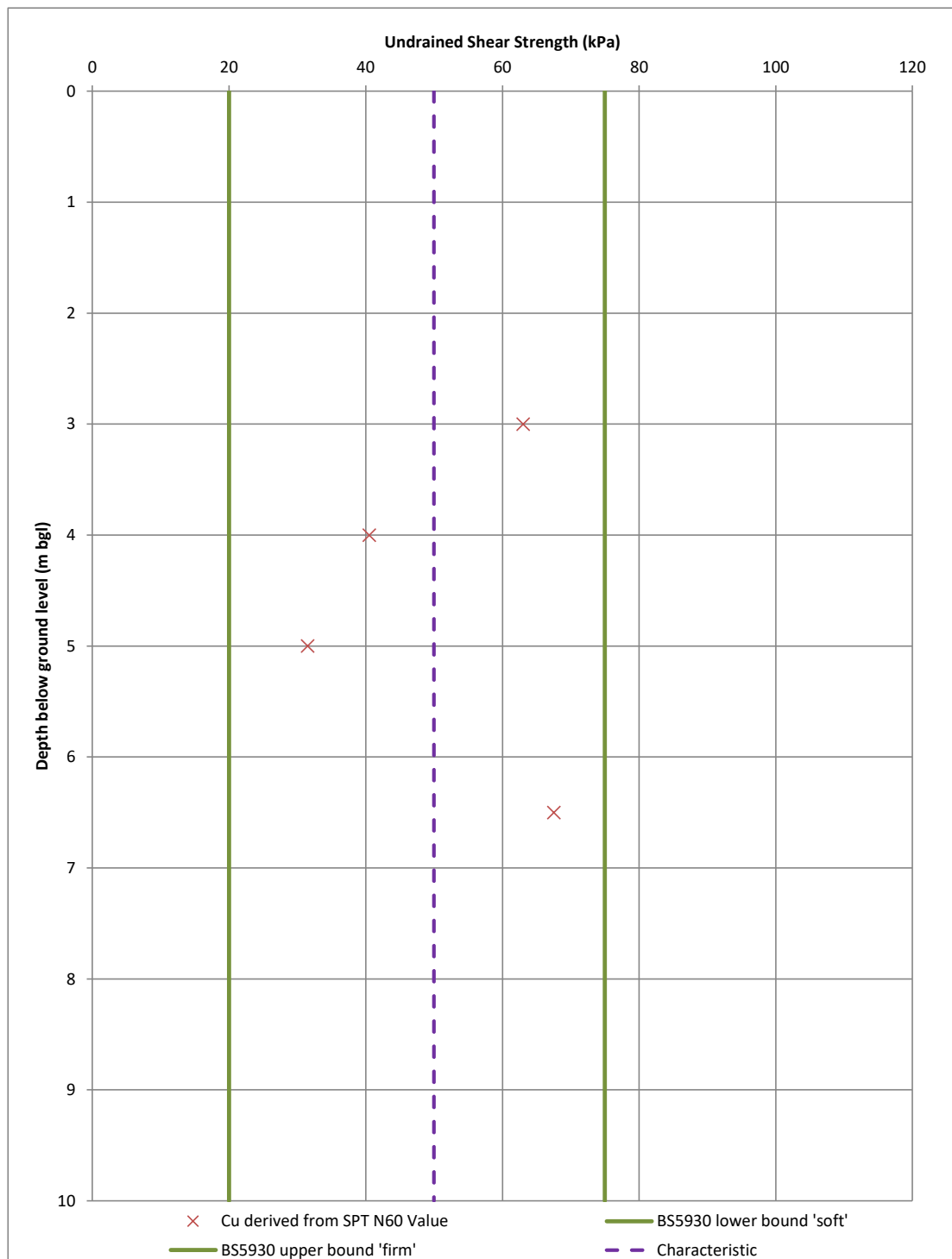




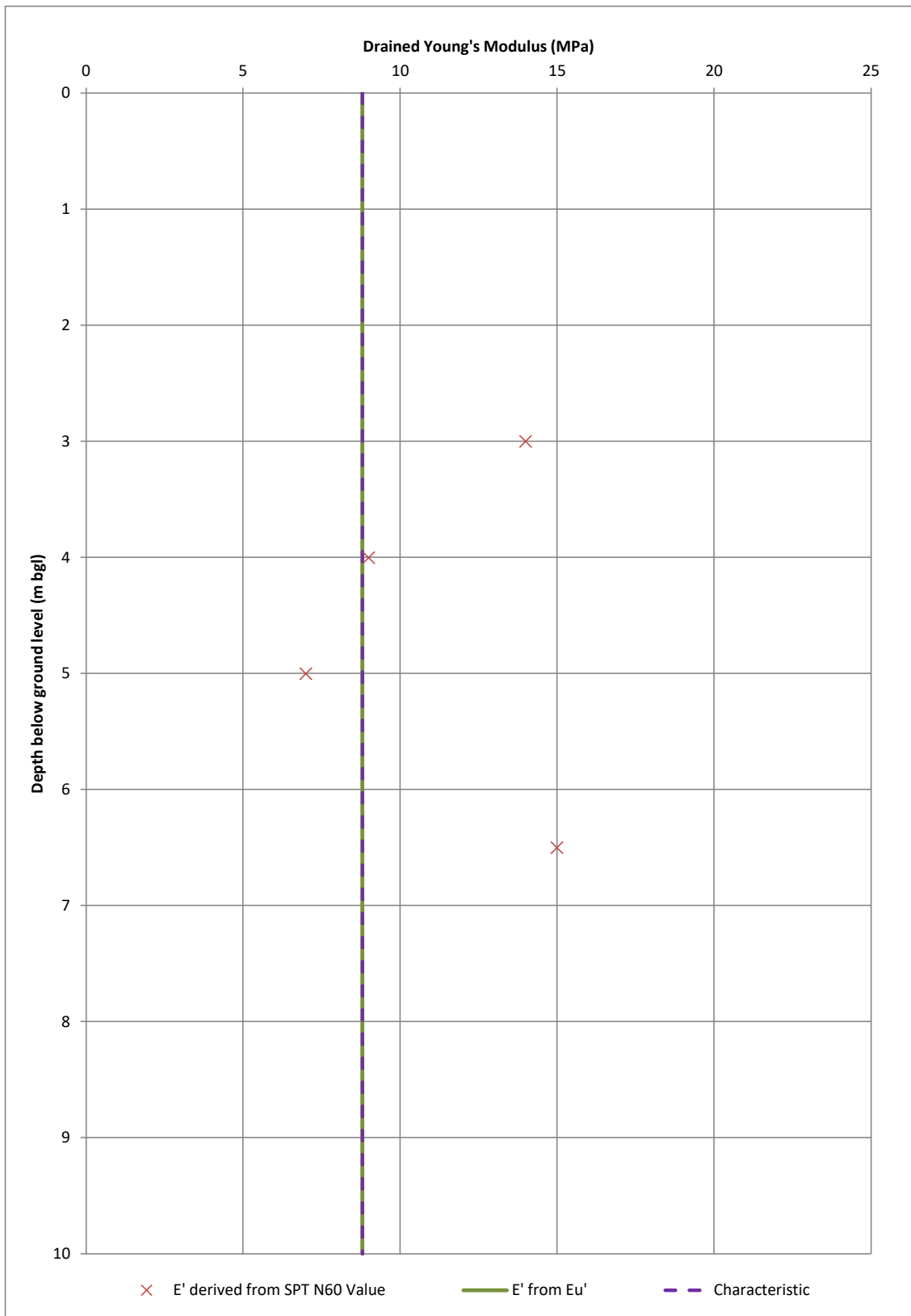


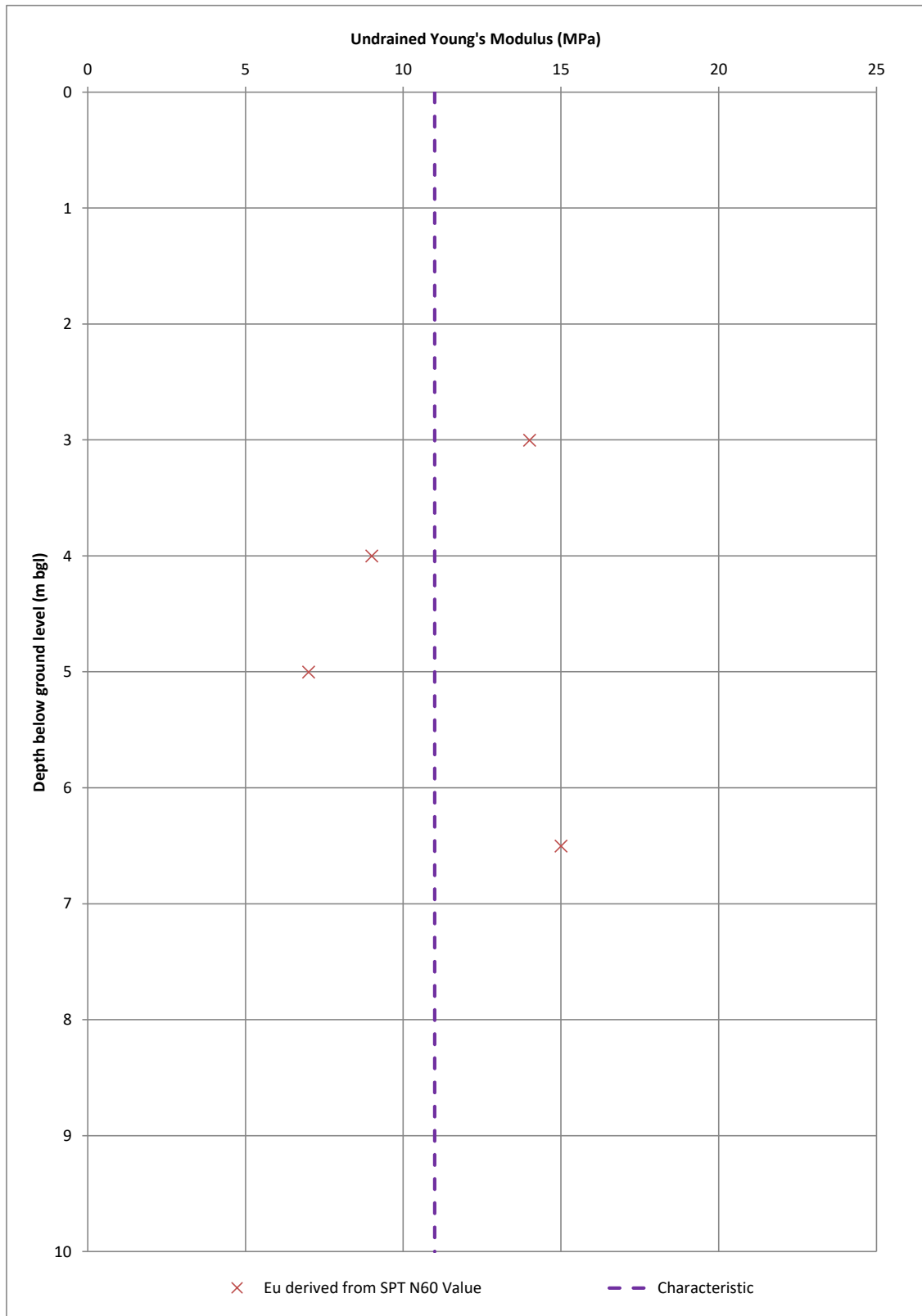
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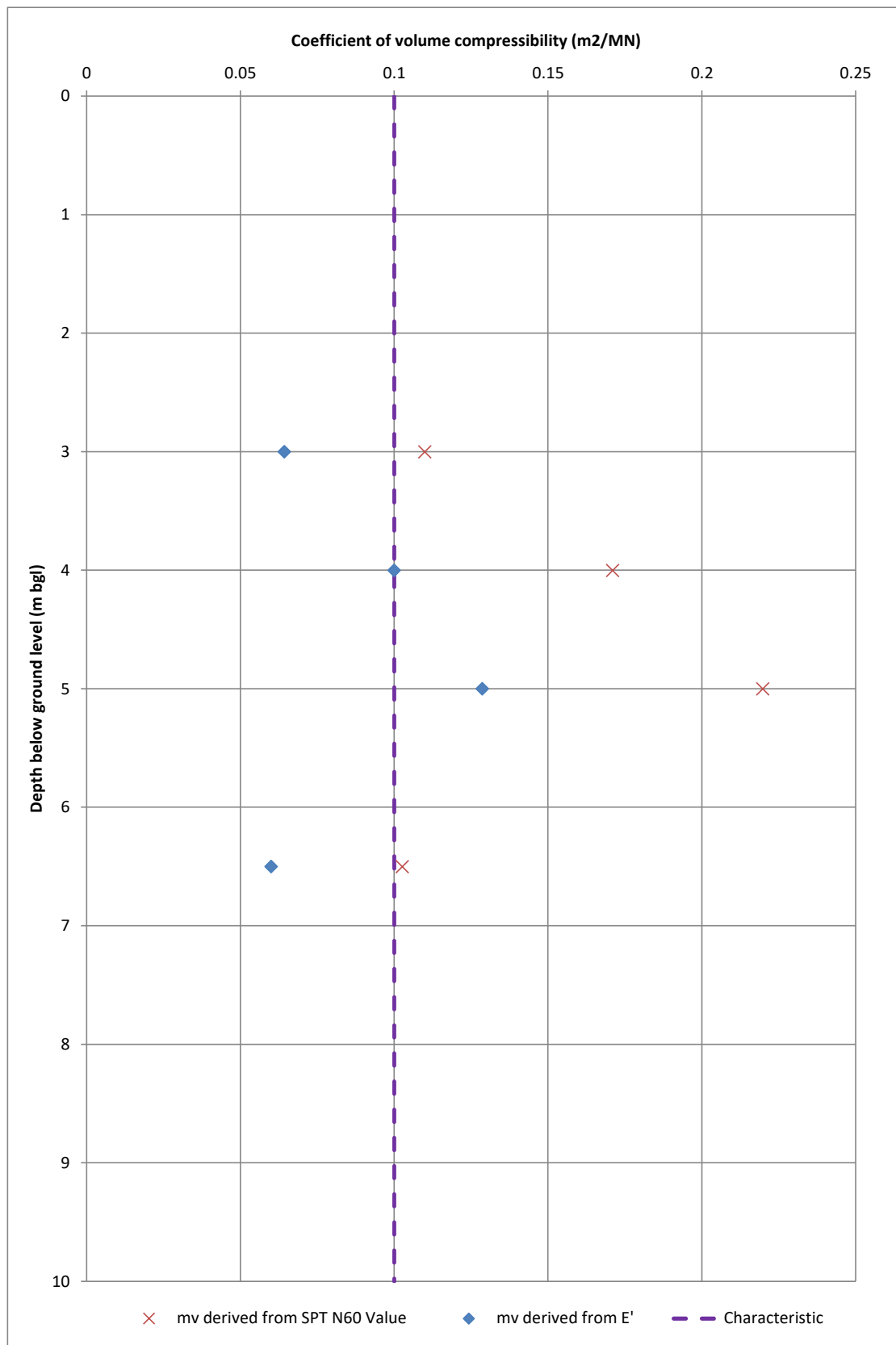
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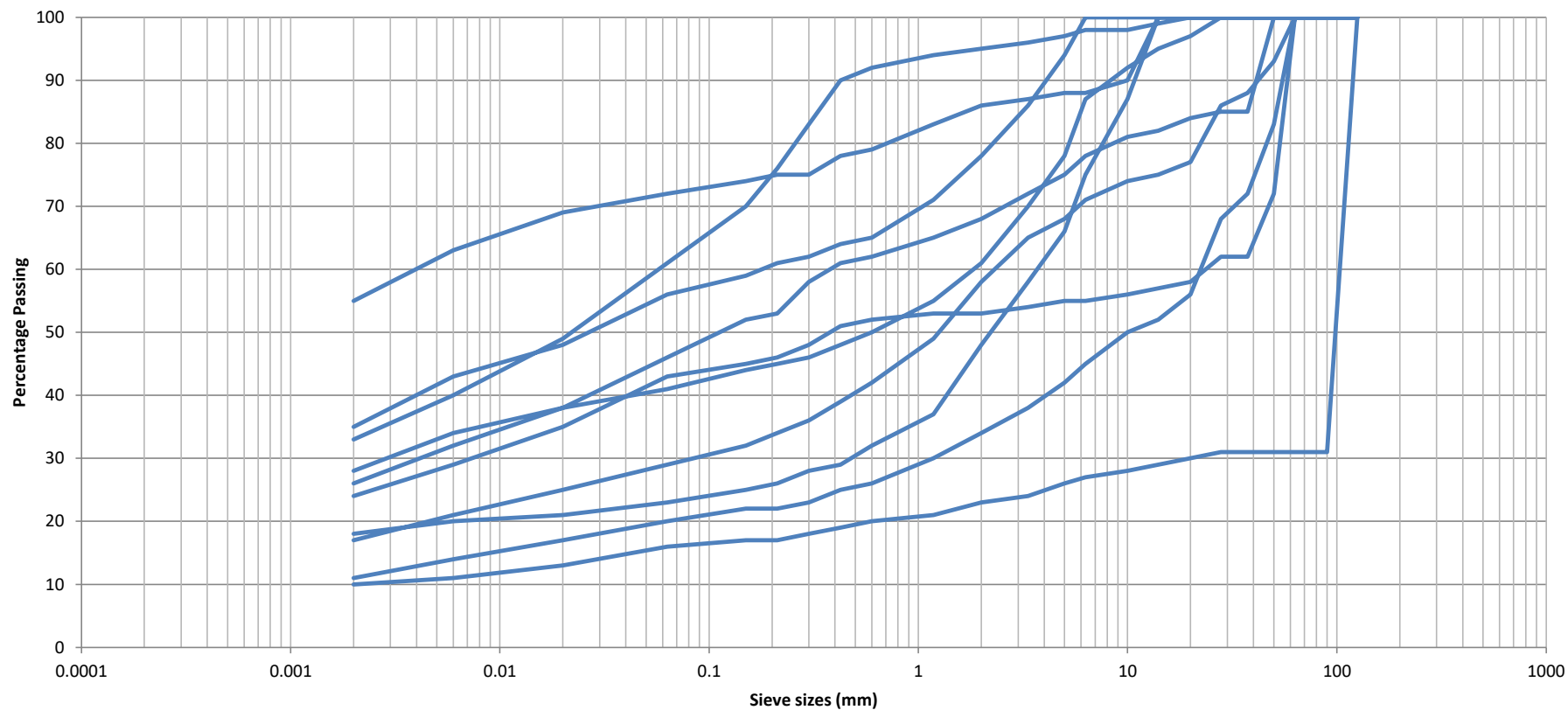


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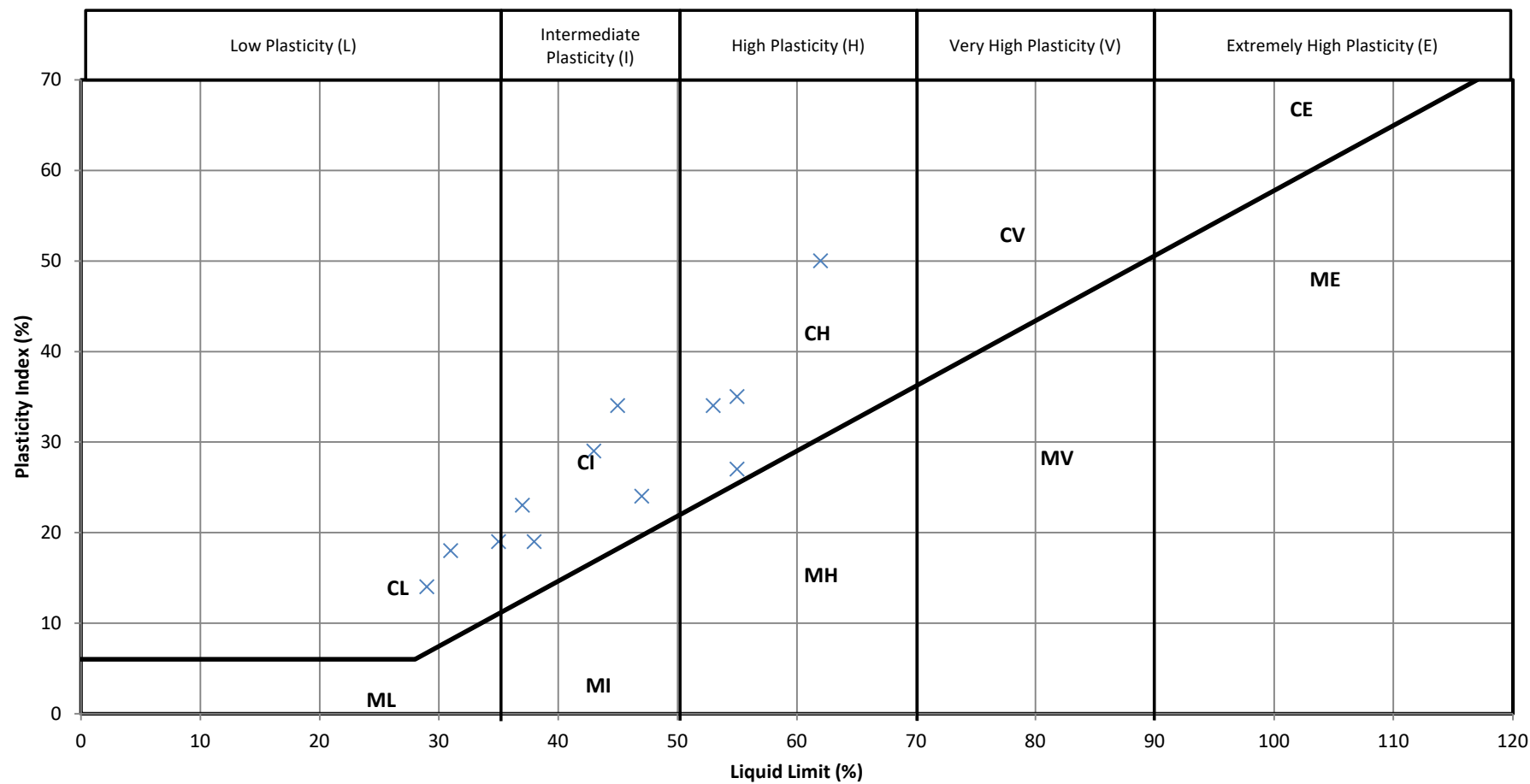






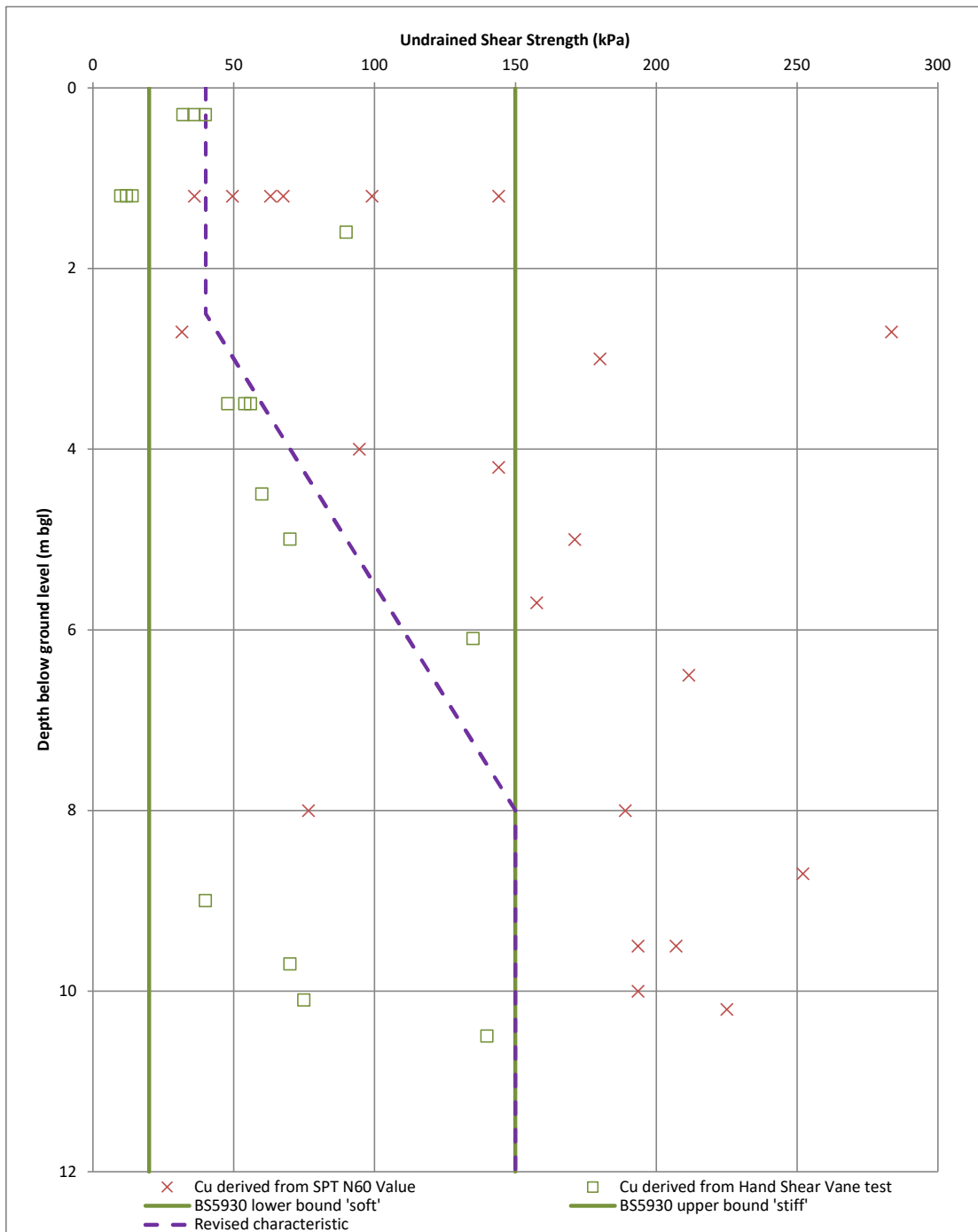


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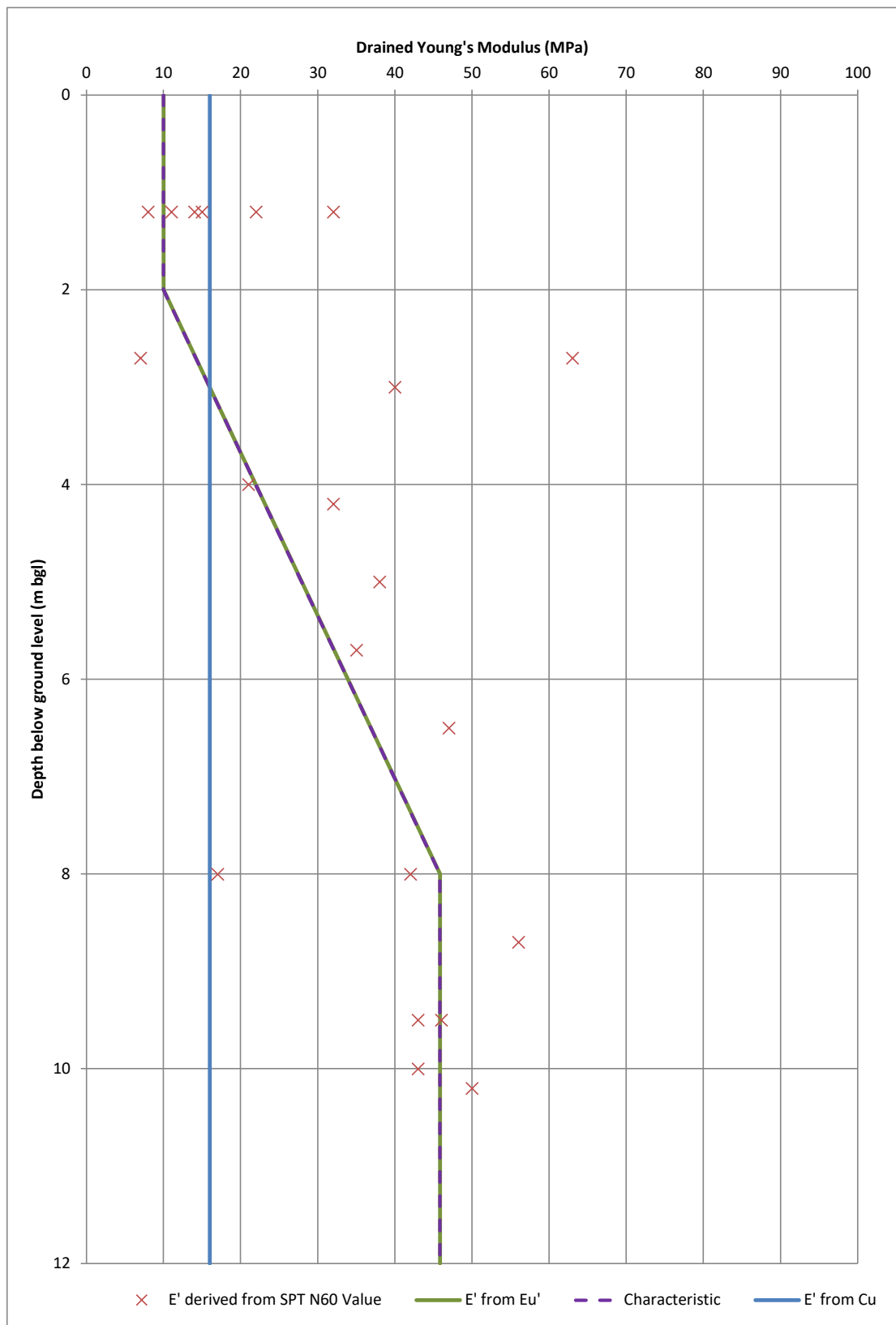


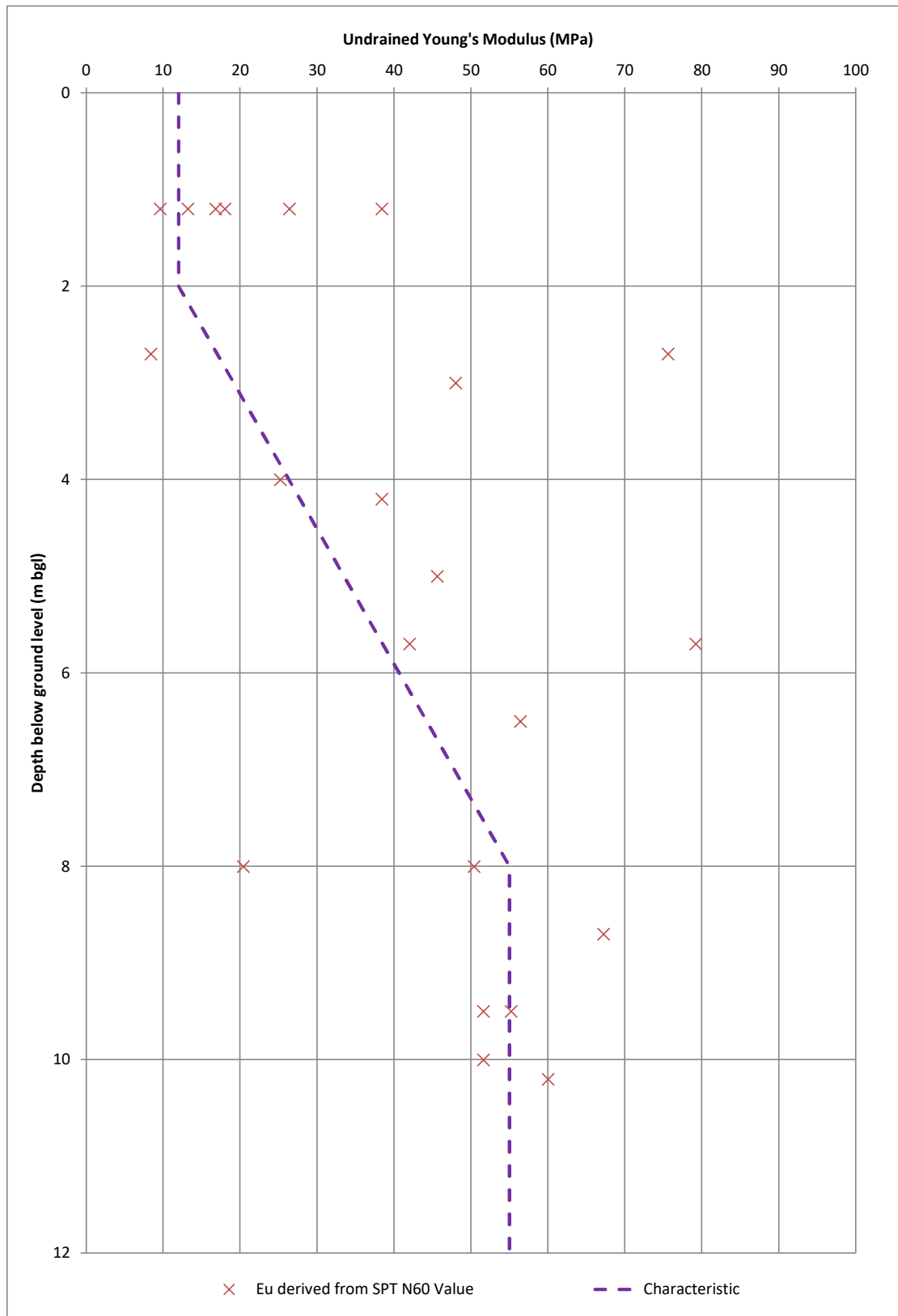
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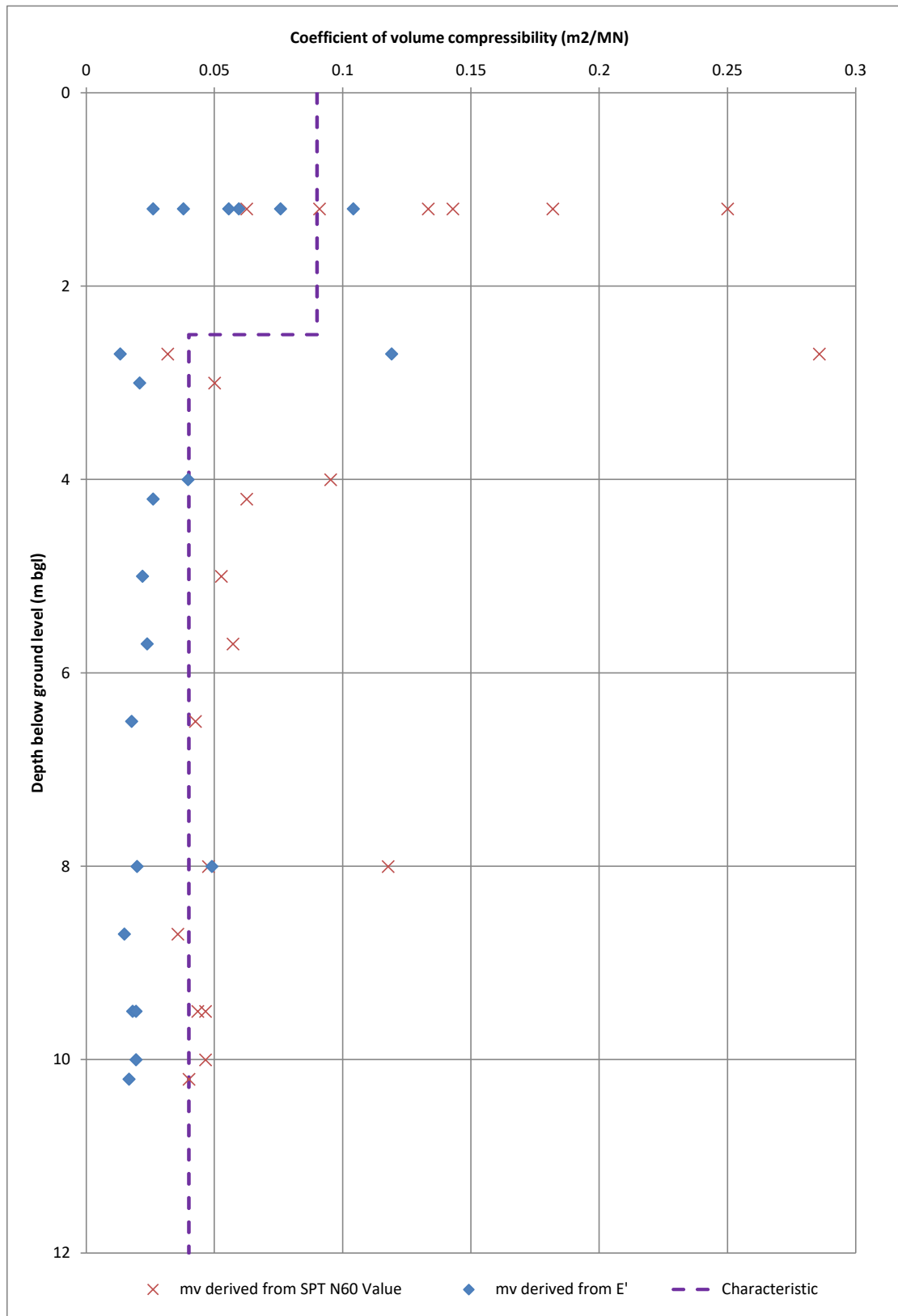
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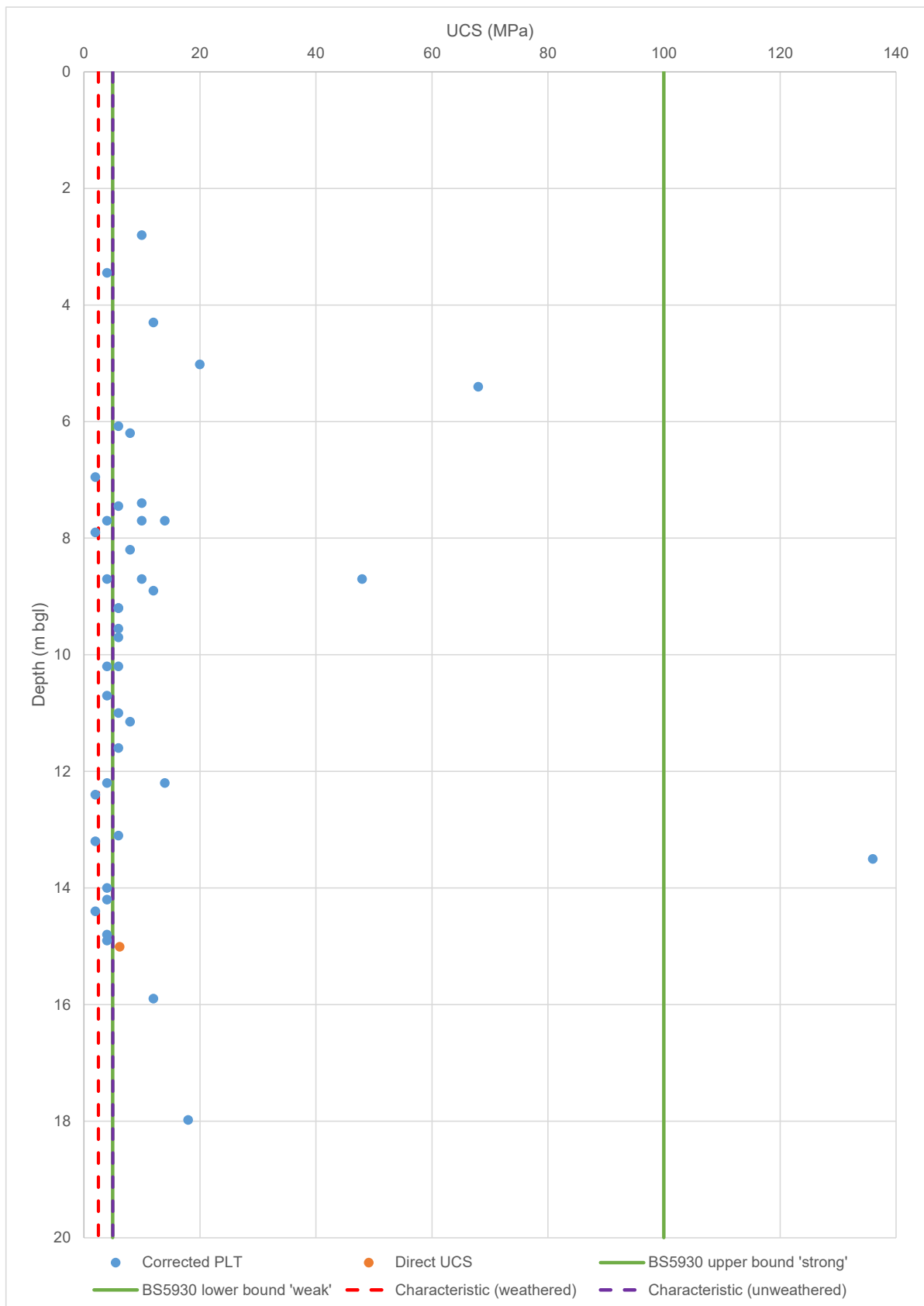


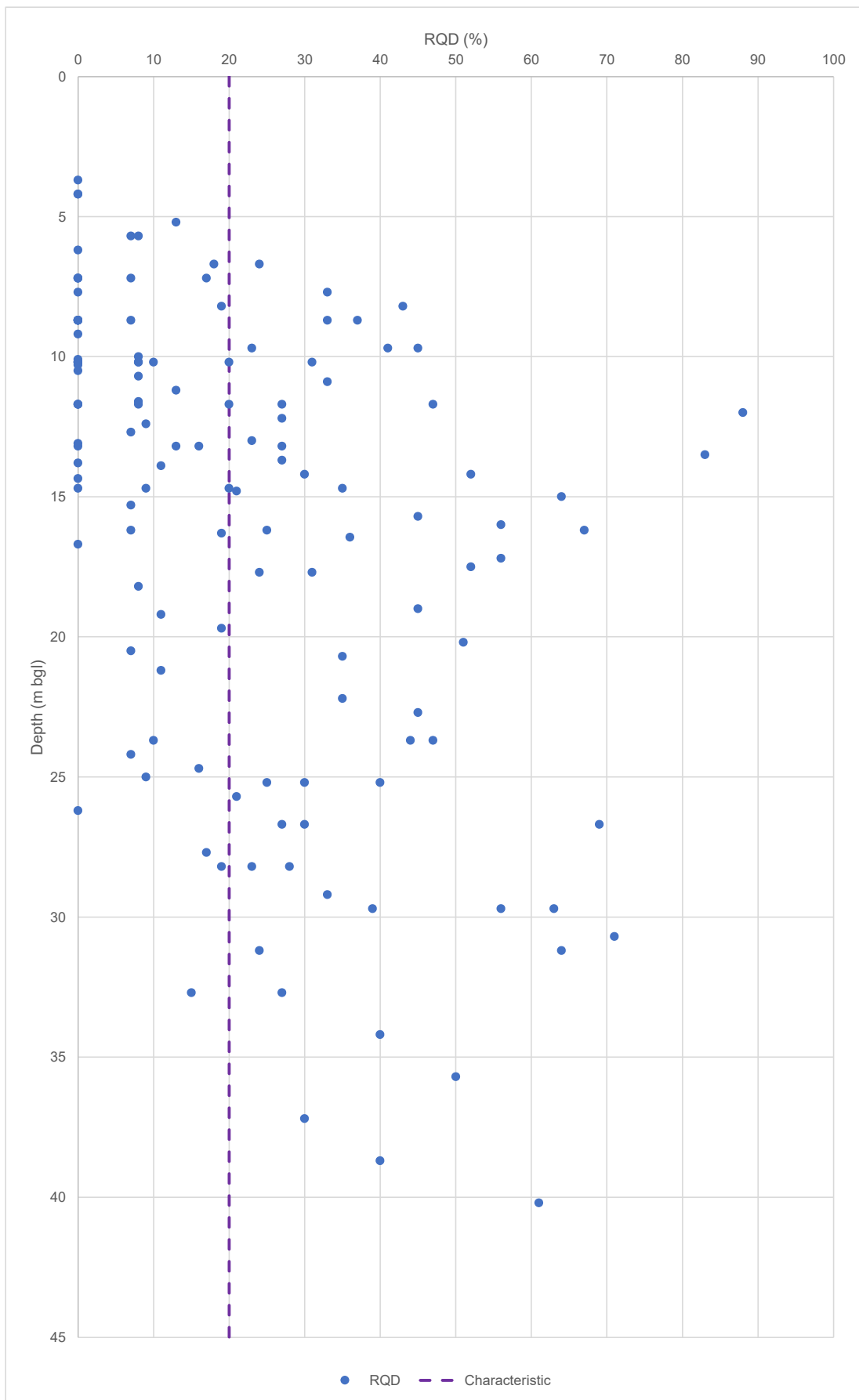
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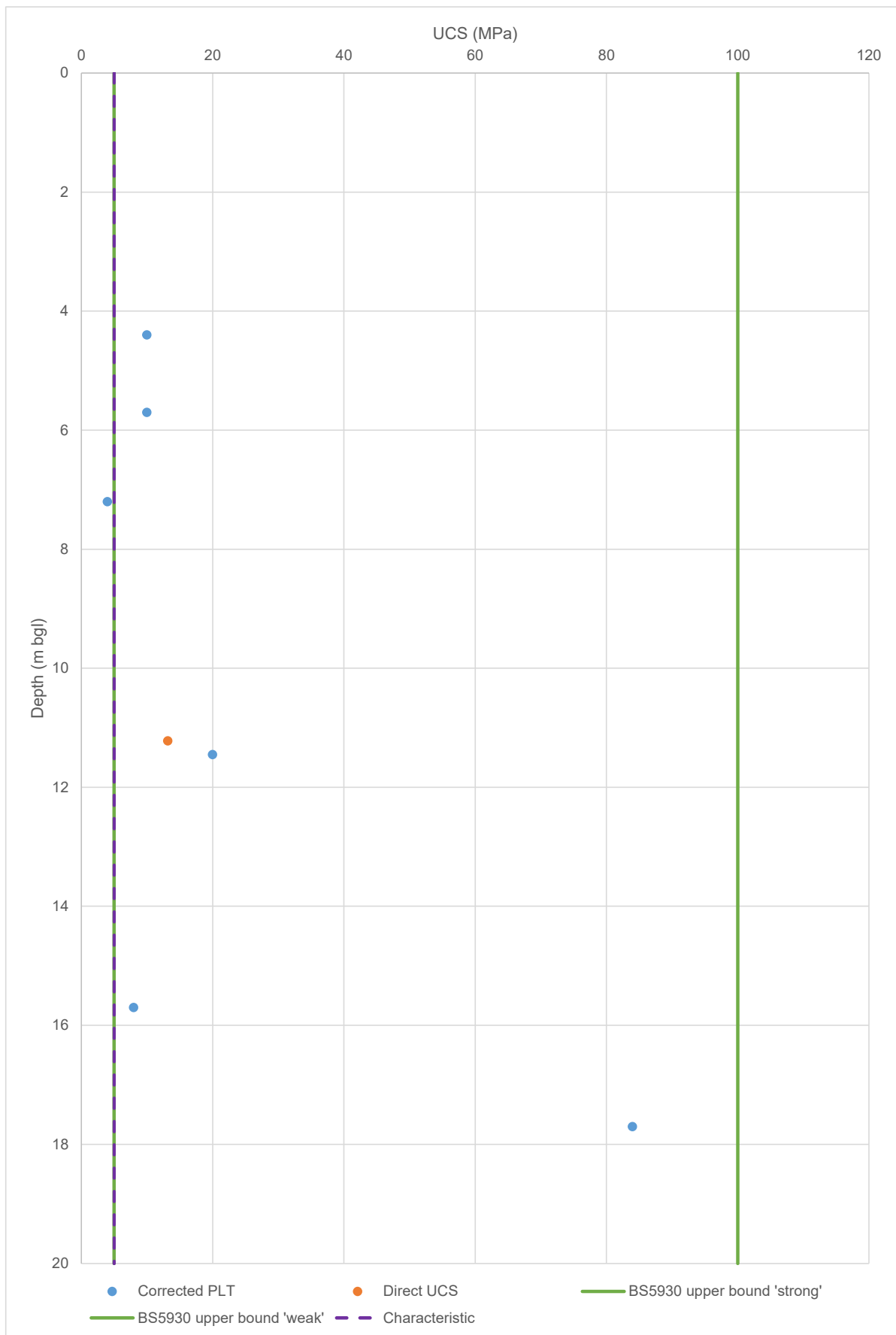


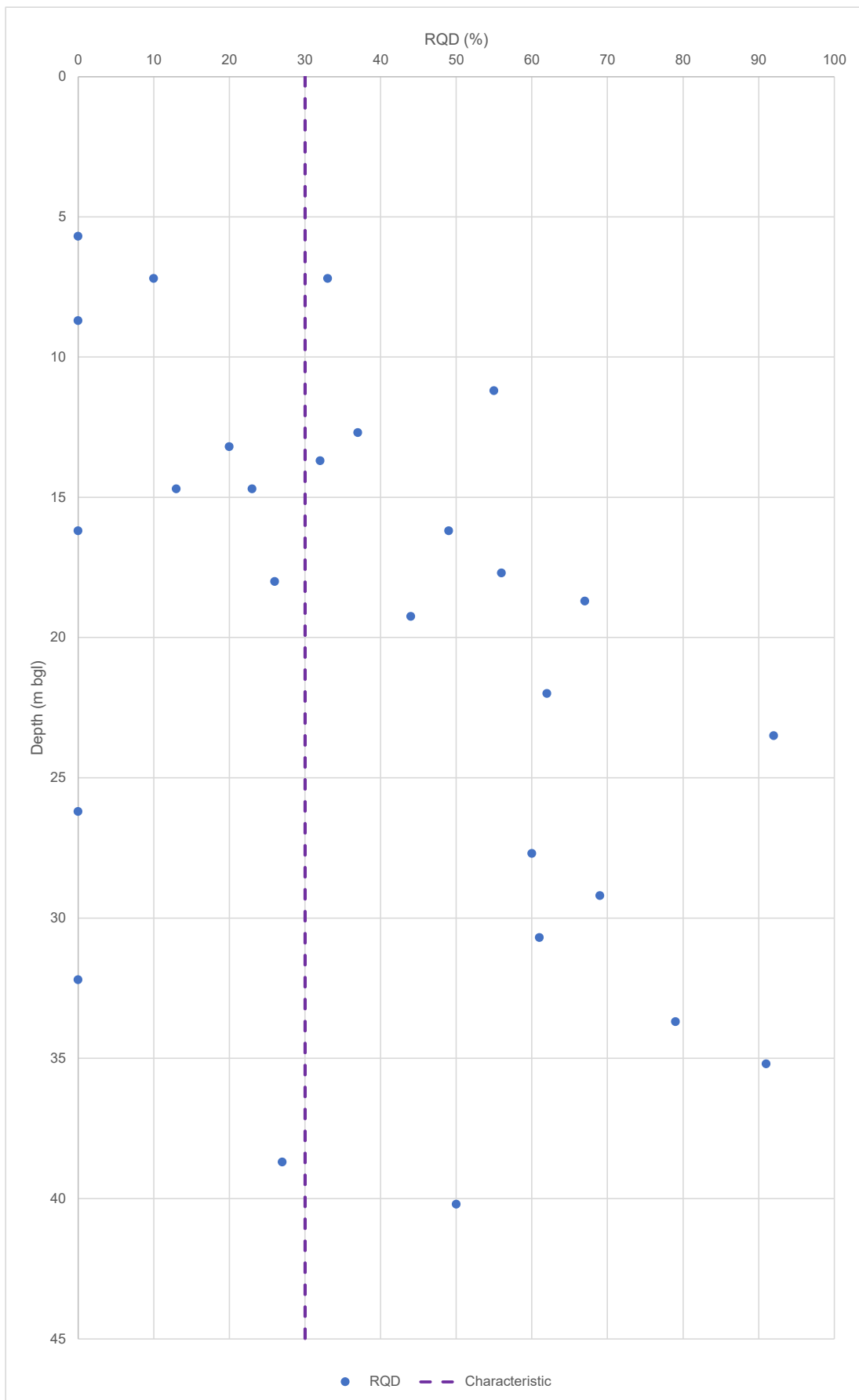


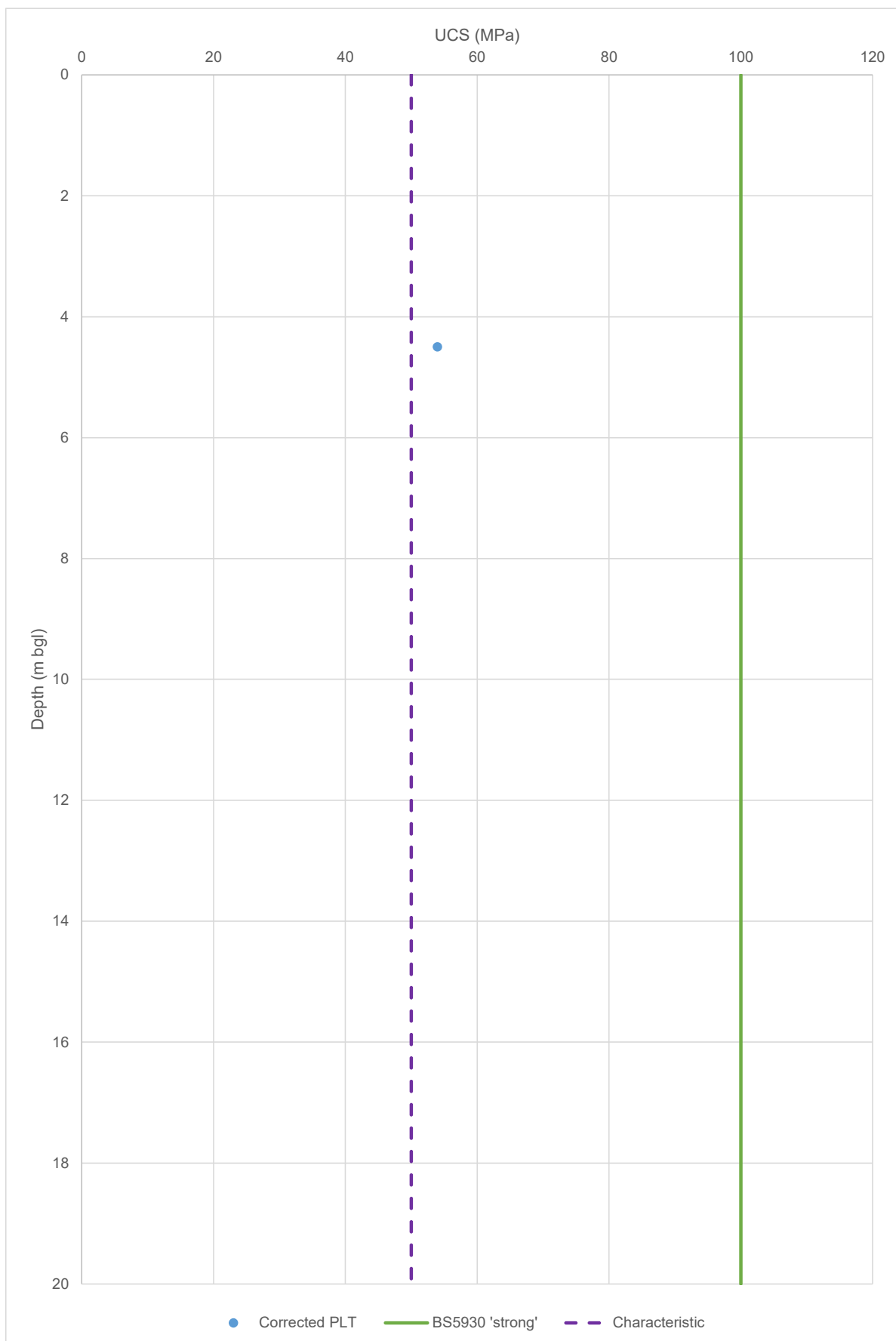


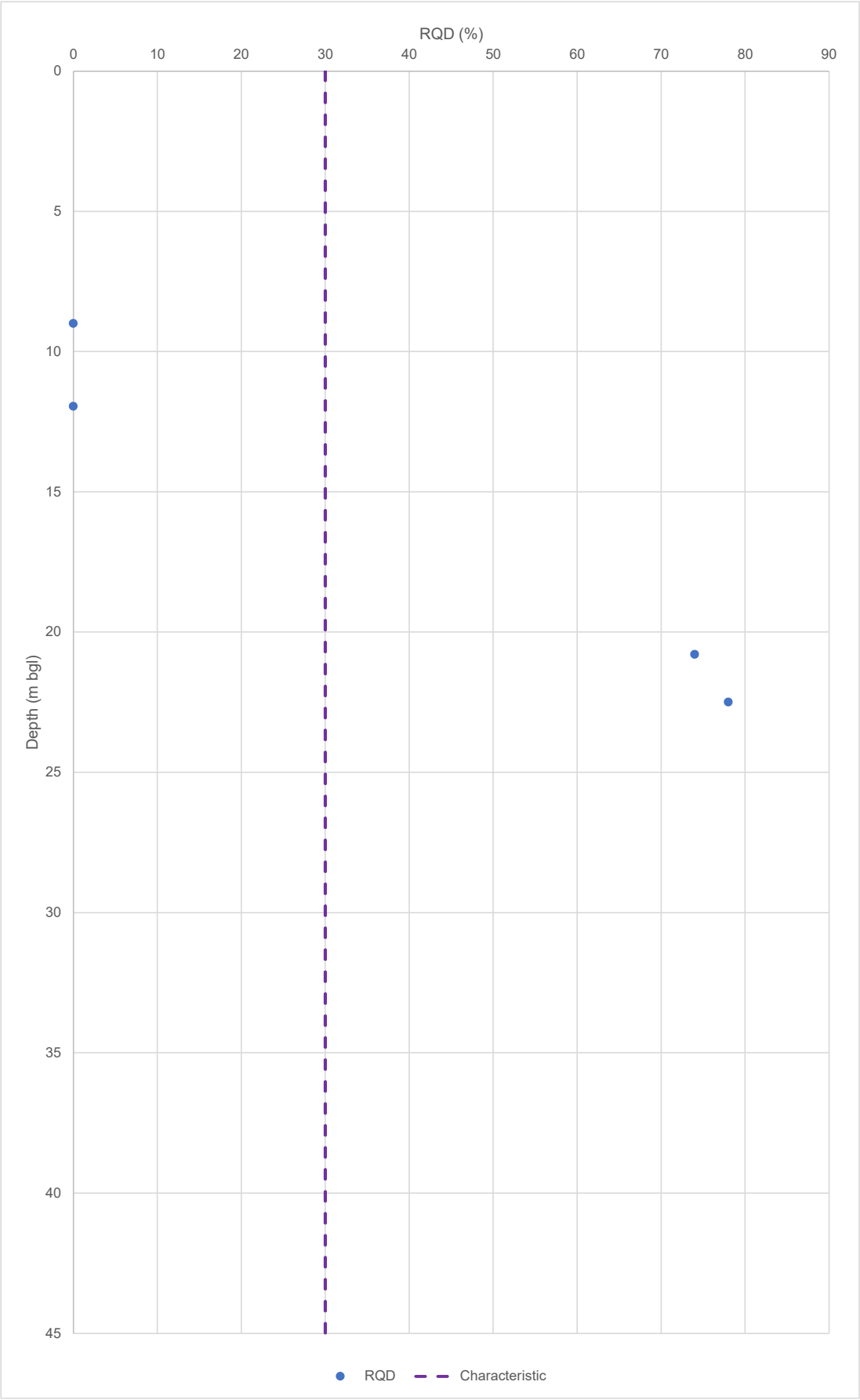






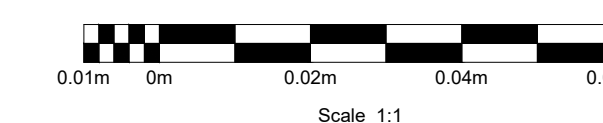
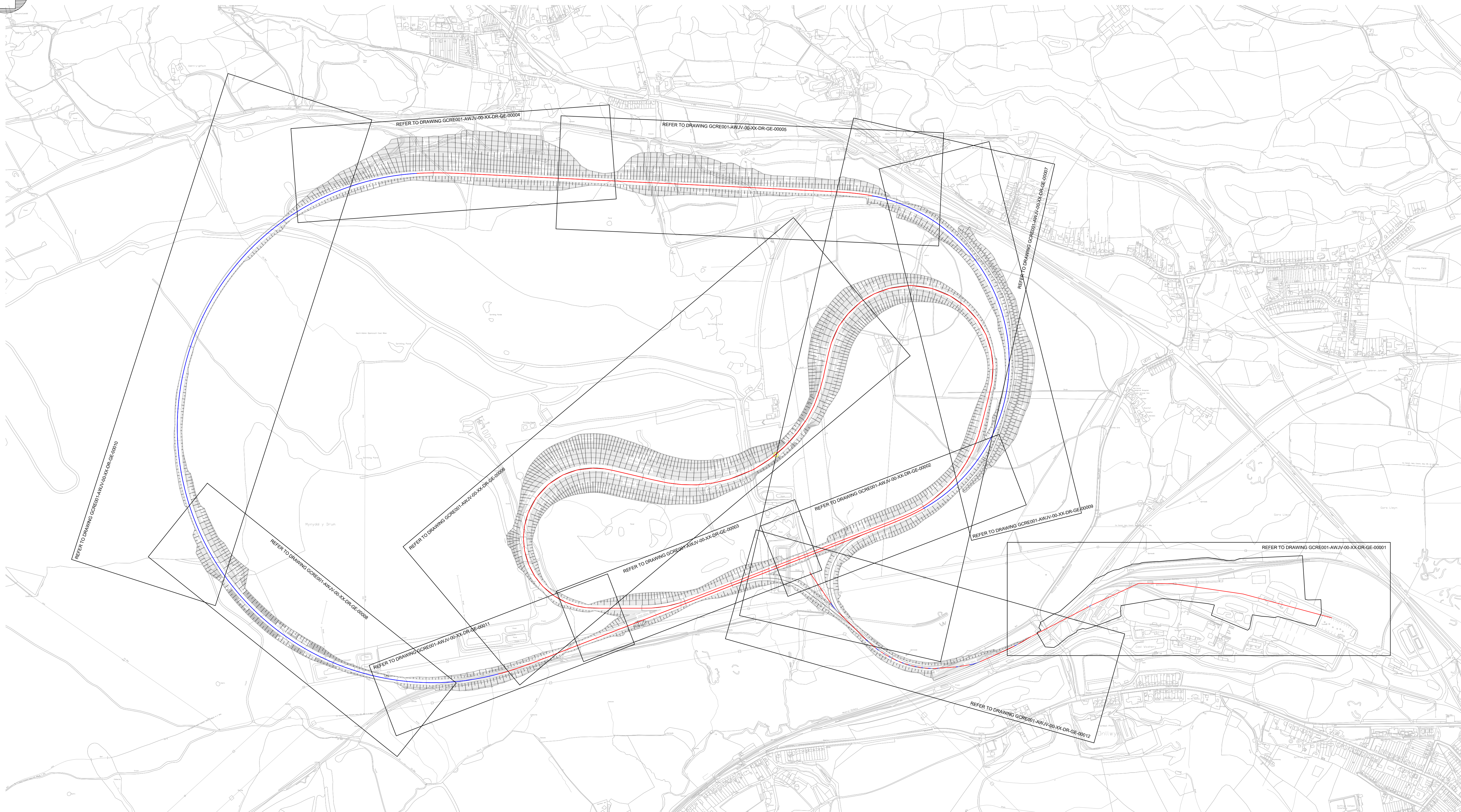
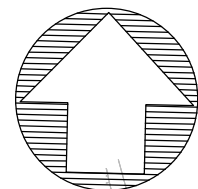






Appendix B. Geological Long Section Drawings

GCRE001-AWJV-00-XX-DR-GE-00001 – Geological Long Section Earthwork Zone Plan
GCRE001-AWJV-00-XX-DR-GE-00002 – Geological Long Section Earthwork Zone 1
GCRE001-AWJV-00-XX-DR-GE-00003 – Geological Long Section Earthwork Zone 2
GCRE001-AWJV-00-XX-DR-GE-00004 – Geological Long Section Earthwork Zone 3
GCRE001-AWJV-00-XX-DR-GE-00005 – Geological Long Section Earthwork Zone 4
GCRE001-AWJV-00-XX-DR-GE-00006 – Geological Long Section Earthwork Zone 5
GCRE001-AWJV-00-XX-DR-GE-00007 – Geological Long Section Earthwork Zone 6
GCRE001-AWJV-00-XX-DR-GE-00008 – Geological Long Section Earthwork Zone 7
GCRE001-AWJV-00-XX-DR-GE-00009 – Geological Long Section Earthwork Zone 8
GCRE001-AWJV-00-XX-DR-GE-00010 – Geological Long Section Earthwork Zone 9
GCRE001-AWJV-00-XX-DR-GE-00011 – Geological Long Section Earthwork Zone 10
GCRE001-AWJV-00-XX-DR-GE-00012 – Geological Long Section Earthwork Zone 11
GCRE001-AWJV-00-XX-DR-GE-00013 – Geological Long Section Earthwork Zone 12



SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

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MAINTENANCE/CLEANING

	N/A
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DECOMMISSIONING/DEMOLITION

	N/A
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It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement

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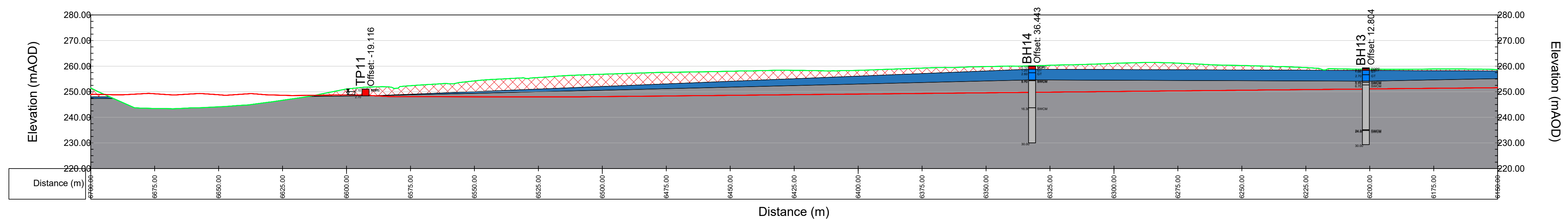
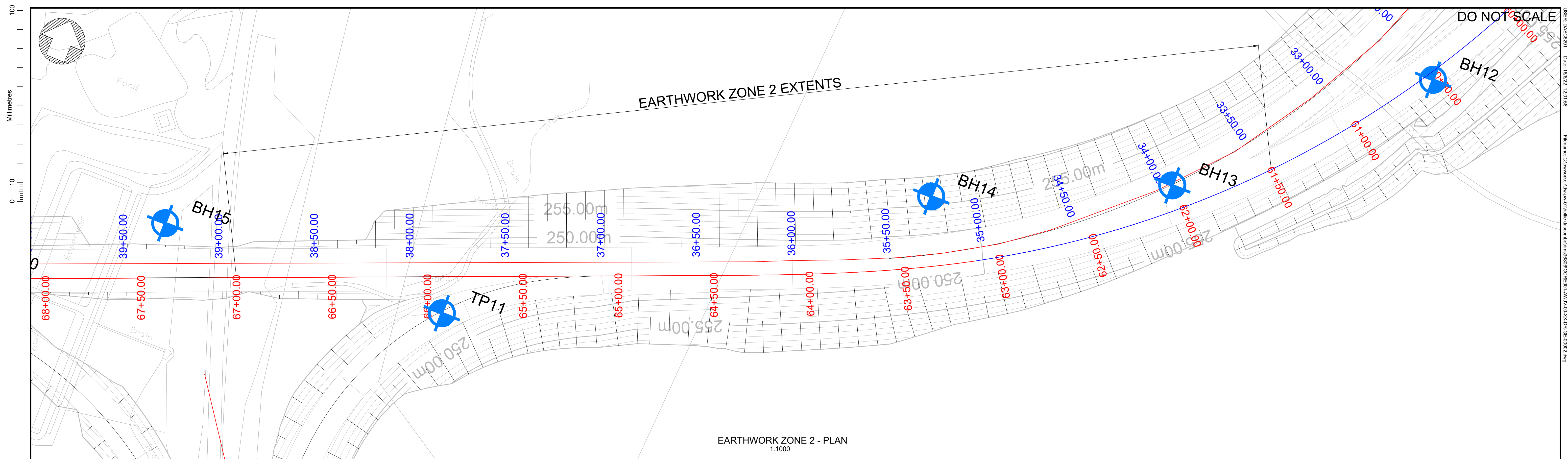
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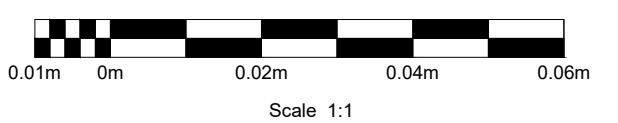
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EARTHWORK ZONE 2 - GEOLOGICAL LONG SECTION
1:1000
1H:1V



NOTES:
(1) GEOLOGICAL SECTION INDICATIVE ONLY, 3D MODEL SHOULD BE REFERENCED FOR DETAILED DESIGN

Geology Code Legend		
	GT	Glacial Till
	MGR	Made Ground
	NOCO	No Core Recovered
	PEAT	Peat
	SWCM	South Wales Coal Measures

LEGEND

-  BOREHOLE
 TRIAL PIT
 EXISTING GROUND SURFACE
 PROPOSED GROUND SURFACE

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following:

CONSTRUCTION

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MAINTENANCE/CLEANING

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DECOMMISSIONING/DEMOLITION

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It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement

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EARTHWORK ZONE 2

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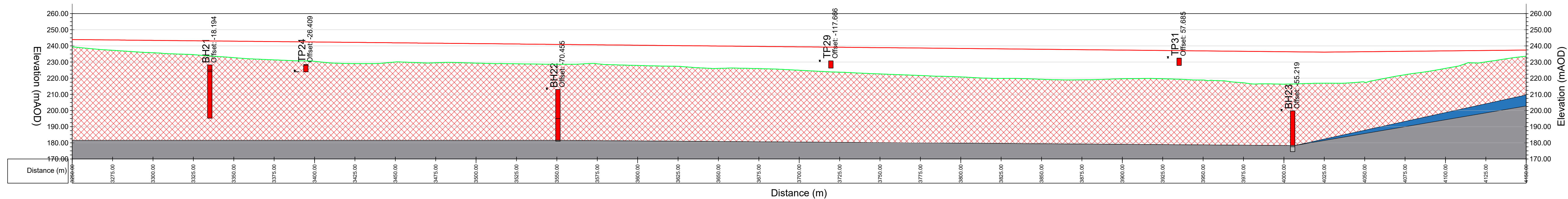
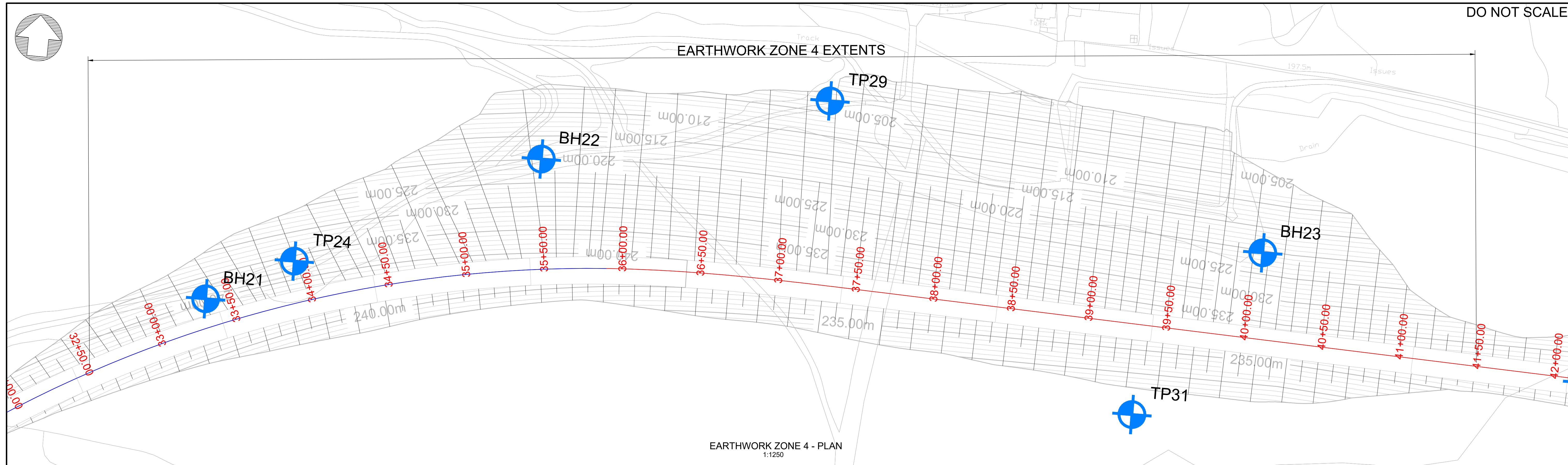
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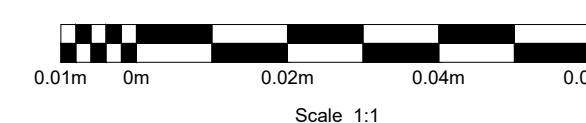
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Revision	D01
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EARTHWORK ZONE 4 - GEOLOGICAL LONG SECTION
1:1250
1H:1V



NOTES:
(1) GEOLOGICAL SECTION INDICATIVE ONLY, 3D MODEL SHOULD BE REFERENCED FOR DETAILED DESIGN

Geology Code Legend		
	GT	Glacial Till
	MGR	Made Ground
	NOCO	No Core Recovered
	PEAT	Peat
	SWCM	South Wales Coal Measures

LEGEND

-  BOREHOLE
 TRIAL PIT
 EXISTING GROUND SURFACE
 PROPOSED GROUND SURFACE

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following:

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MAINTENANCE/CLEANING

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DECOMMISSIONING/DEMOLITION	
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It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement

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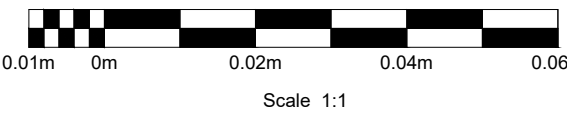
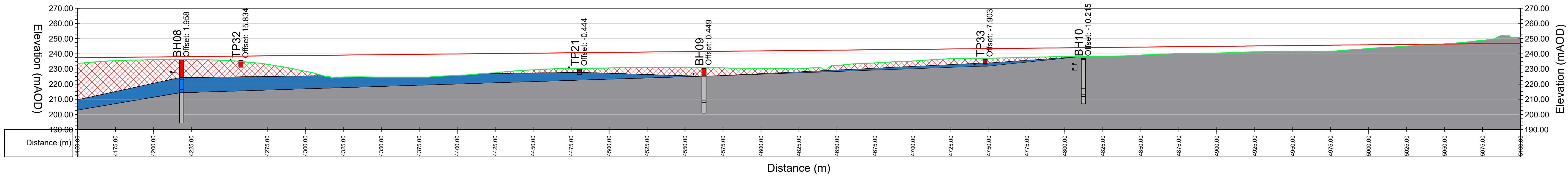
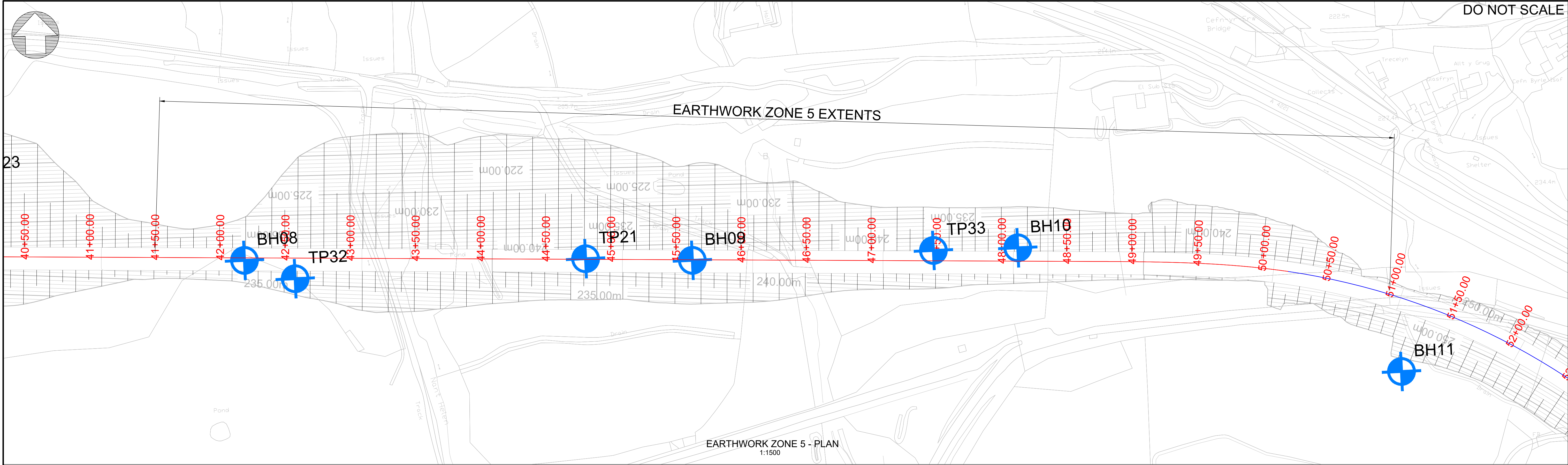
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Drawing Number

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	Revision
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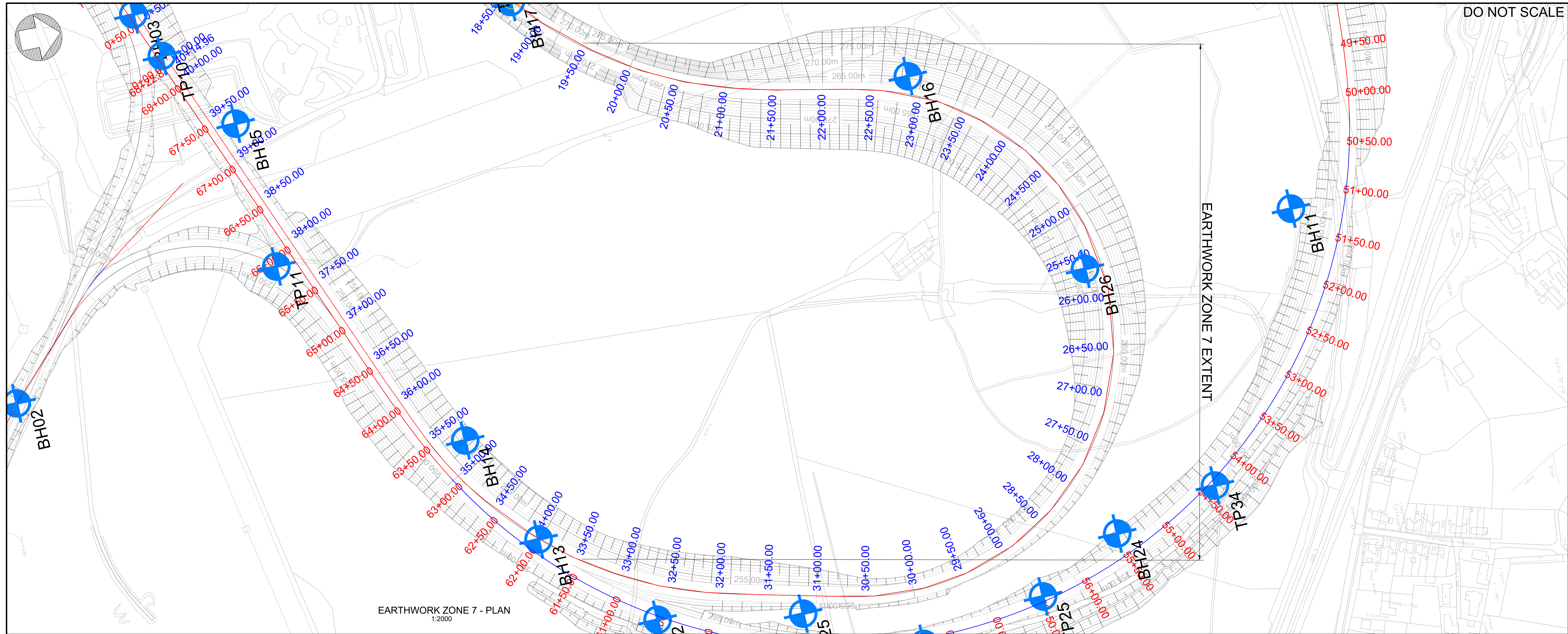
GCRE LTD



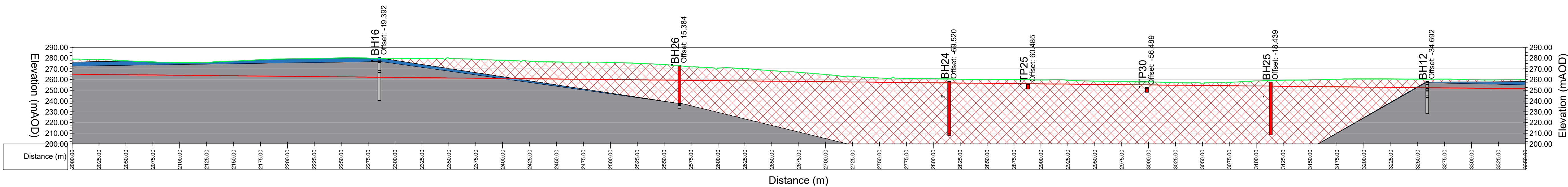
NOTES:
(1) GEOLOGICAL SECTION INDICATIVE ONLY, 3D MODEL SHOULD BE REFERENCED FOR DETAILED DESIGN

Geology Code Legend <table><tr><td></td><td>GT</td><td>Glacial Till</td></tr><tr><td></td><td>MGR</td><td>Made Ground</td></tr><tr><td></td><td>NOCO</td><td>No Core Recovered</td></tr><tr><td></td><td>PEAT</td><td>Peat</td></tr><tr><td></td><td>SWCM</td><td>South Wales Coal Measures</td></tr></table>				GT	Glacial Till		MGR	Made Ground		NOCO	No Core Recovered		PEAT	Peat		SWCM	South Wales Coal Measures	SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following: CONSTRUCTION N/A MAINTENANCE/CLEANING N/A DECOMMISSIONING/DEMOLITION N/A It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																										
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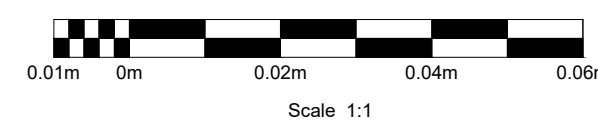
0 10 100
Millimetres



EARTHWORK ZONE 7 - PLAN
1:2000



EARTHWORK ZONE 7 - GEOLOGICAL LONG SECTION
1:2000
1H:1V



NOTES:
(1) GEOLOGICAL SECTION INDICATIVE ONLY, 3D MODEL SHOULD BE REFERENCED FOR DETAILED DESIGN

Geology Code Legend	
GT	Glacial Till
MGR	Made Ground
NOCO	No Core Recovered
PEAT	Peat
SWCM	South Wales Coal Measures

LEGEND

- BOREHOLE
- TRIAL PIT
- EXISTING GROUND SURFACE
- PROPOSED GROUND SURFACE

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following:

CONSTRUCTION

N/A

MAINTENANCE/CLEANING

N/A

DECOMMISSIONING/DEMOLITION

N/A

It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement

Rev.	Date	Description	By	Chkd	App'd
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Drawing Status

WORK IN PROGRESS

Suitability

SO

Project Title
GCRE

Drawing Title

GIR GEOLOGICAL LONG SECTION
EARTHWORK ZONE 7

Client

GCRE LTD

Scale

AS SHOWN

Original Size
A1

Drawing Number

GCRE001-AWJV-00-XX-DR-GE-00008

Designed

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Date

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Drawn

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Date

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Checked

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Date

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Authorised

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Date

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Revision

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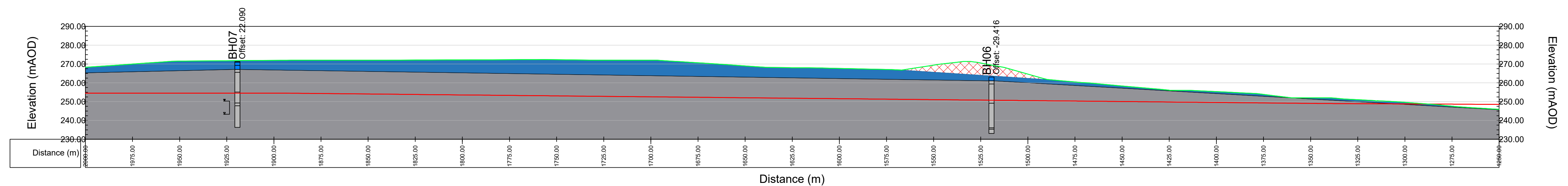
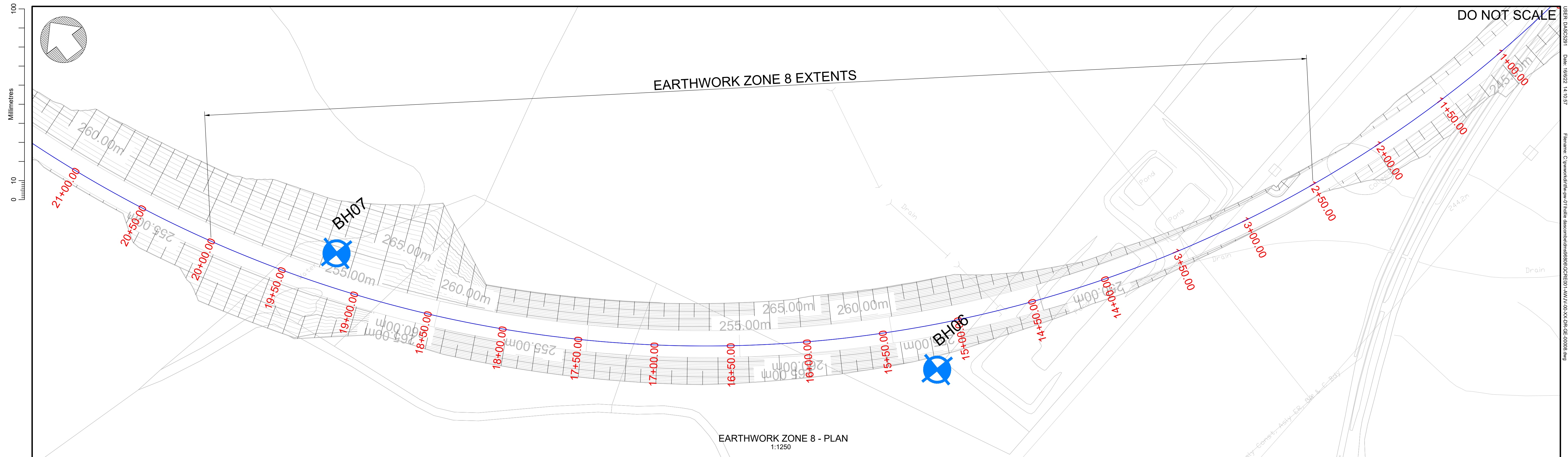
Date

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Revision

P01

DO NOT SCALE



EARTHWORK ZONE 8 - GEOLOGICAL LONG SECTION
1:1250
1H:1V



NOTES:
(1) GEOLOGICAL SECTION INDICATIVE ONLY, 3D MODEL SHOULD BE REFERENCED FOR DETAILED DESIGN

Geology Code Legend		
	GT	Glacial Till
	MGR	Made Ground
	NOCO	No Core Recovered
	PEAT	Peat
	SWCM	South Wales Coal Measures

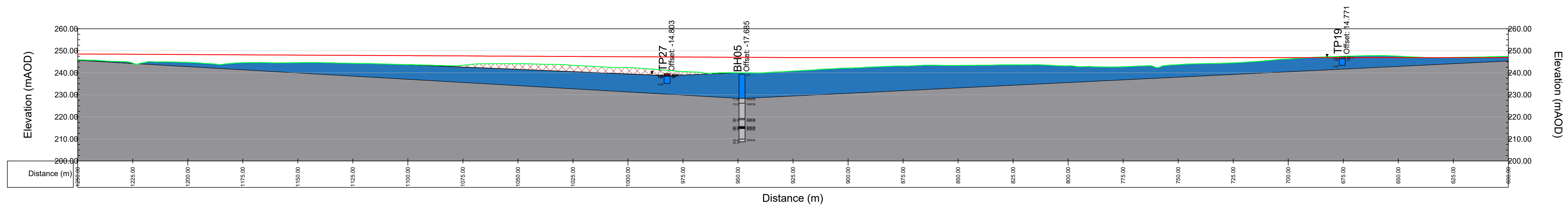
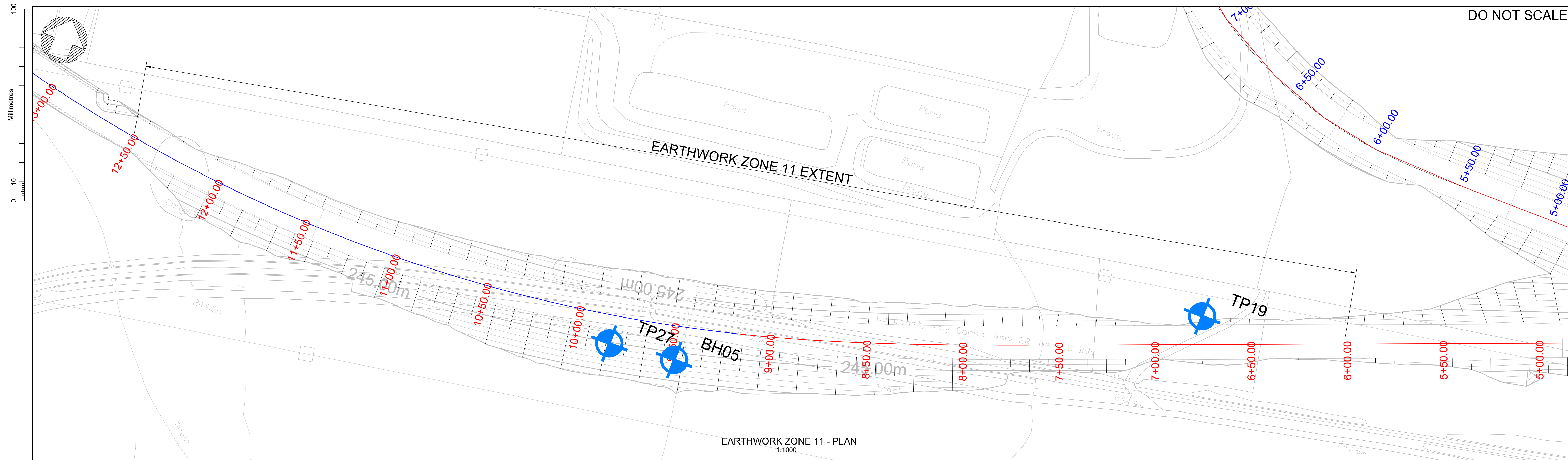
LEGEND

-  BOREHOLE
-  TRIAL PIT
-  EXISTING GROUND SURFACE
-  PROPOSED GROUND SURFACE

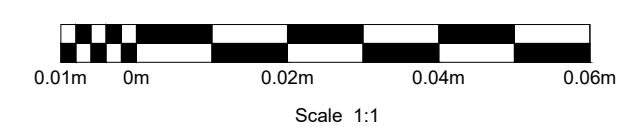
SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION
In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following:
CONSTRUCTION
N/A
MAINTENANCE/CLEANING
N/A
DECOMMISSIONING/DEMOLITION
N/A
It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement

[illegible]

Drawing Status		Suitability		Project Title					
WORK IN PROGRESS		SO		GCRE					
WALTERS ATKINS				Drawing Title					
				GIR GEOLOGICAL LONG SECTION EARTHWORK ZONE 8					
Client GCRE LTD				Scale	Designed	Drawn	Checked	Authorised	
				AS SHOWN		--	--	--	--
				Original Size	Date	Date	Date	Date	
				A1	--/--/--	--/--/--	--/--/--	--/--/--	
				Drawing Number		Revision			
GCRE001-AWJV-00-XX-DR-GE-00009		P01							



EARTHWORK ZONE 11 - GEOLOGICAL LONG SECTION
1:1000
1H:1V



NOTES:
(1) GEOLOGICAL SECTION INDICATIVE ONLY, 3D MODEL SHOULD BE REFERENCED FOR DETAILED DESIGN

Geology Code Legend		
	GT	Glacial Till
	MGR	Made Ground
	NOCO	No Core Recovered
	PEAT	Peat
	SWCM	South Wales Coal Measures

LEGEND

-  BOREHOLE
 TRIAL PIT
 EXISTING GROUND SURFACE
 PROPOSED GROUND SURFACE

SAFETY, HEALTH AND ENVIRONMENTAL INFORMATION

In addition to the hazards/risks normally associated with the types of work detailed on this drawing, note the following:

CONSTRUCTION

N/A

MAINTENANCE/CLEANING

	N/A
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DECOMMISSIONING/DEMOLITION	
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	N/A
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It is assumed that all works will be carried out by a competent contractor working, where appropriate, to an approved method statement.

[illegible]

Drawing Status	
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Status **WORK IN PROGRESS**

	Suitability
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Suitability
SO

Project Title

GCRE

Drawing Title

GIR GEOLOGICAL LONG SECTION
EARTHWORK ZONE 11

Client	
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Scale	
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	Designed
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Drawn

	C
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checked

Authorised

GCRE LTD

Original Size	Date	Date	Date
A1	--/--	--/--	--/--

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