

**Client Name: Global Centre of
Rail Excellence**
Site: GCRE (Onllywyn Washery)
**Project No.
5209796**

Photo No. 88	Date: 7 July 2022	
Lagoons (052 to 054) View of lagoons in east of site. Vegetation too thick to view well. The photograph aspect is west.		

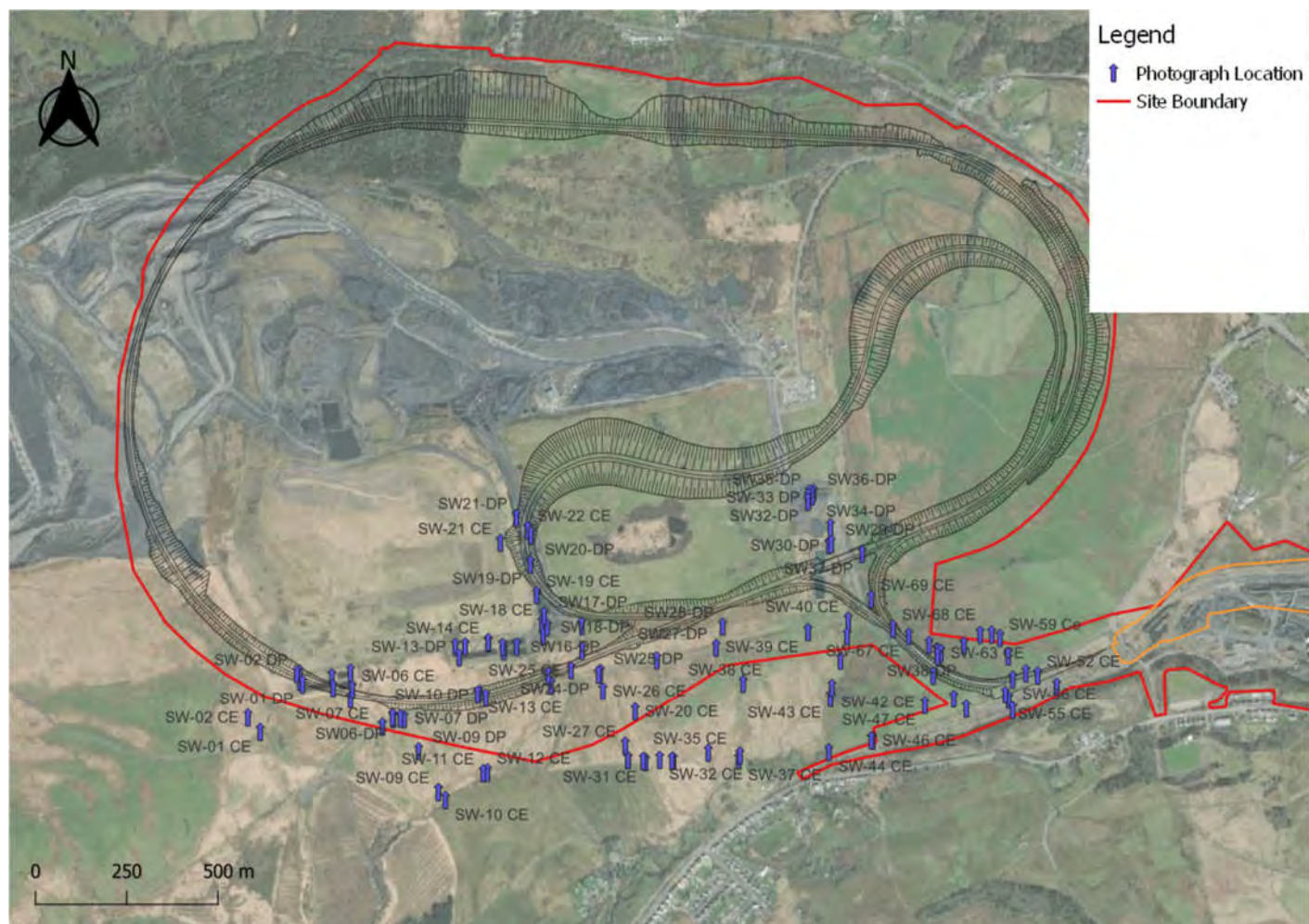
Photo No. 89	Date: 7 July 2022	
Weighbridge (048) View of weighbridge and site office from colliery spoil heap. The photograph aspect is north.		

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Photograph Location Plan



NB: Please refer to walkover drawings for building ID and polygonised land use occurring at location.

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Photo No.	Date:	
SW-01 CE	12 July 2022	
Surface Water Feature SW-01 CE: Surface Water Course (Minor ditch), possibly used as a field drainage/runoff. No water flowing observed at the time. Approximate measurements 1.2m wide, 0.8m depth.		

Photo No.	Date:	
SW-02 CE	12 July 2022	
Surface Water Feature SW-02 CE: Marshy Land, rainfall/runoff. Mildly wet. No water flowing observed at the time. Approximate measurements 10m wide.		

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Photo No. SW-03 CE	Date: 12 July 2022	
Surface Water Feature SW-03 CE: Lagoon, water storage area, probably lined with low permeability material, drainage/runoff from restoration area. No water flowing observed at the time. Approximate measurements 5m wide, 10m length. Measurements DO 103.83%, ORP 137.5 mV, Cond 134.34 ms/cm, pH 7.34, T22.8C		

Photo No. SW-04 CE	Date: 12 July 2022	
Surface Water Feature SW-04 CE: Lagoon, water storage area, probably lined, drainage/runoff from restoration area. No water flowing observed at the time. Approximate measurements 5m wide, 10m length. DO 95.89%, ORP 211.0 mV, Cond 144.6ms/cm, pH 7.61, T21.7		

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Photo No.	Date:	
SW-06 CE	12 July 2022	
Surface Water Feature SW-06 CE: Discharge ditch from lagoon, lined with concrete cast approximately 70cm wide and 40cm depth, drainage/runoff from lagoon. No water flowing observed at the time. Approximate measurements 5m wide, 10m length.		

Photo No.	Date:	
SW-07 CE	12 July 2022	
Surface Water Feature SW-07 CE: Surface Water Course (minor ditch), possibly used as a field drainage/runoff. Not lined. No water flowing observed at the time. Approximate measurements 3m wide, 2m depth.		

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Photo No.	Date:	
SW-10 CE	12 July 2022	
Surface Water Feature SW-10 CE: Surface Water Course (Stream), collecting water from all other discharge drains. Not lined, probably natural. Approximate measurements 0.5m wide, 2.5cm depth. Average speed 0.008m/s, DO 102.5, ORP123.9, Cond 1225.1, pH 8.38, T 19.69.		

Photo No.	Date:	
SW-11 CE	12 July 2022	
Surface Water Feature SW-11 CE: Surface Water Course (minor ditch), possibly used as a field drainage/runoff. Not lined. Ground slightly wet. No water flowing observed at the time. Approximate measurements 2.5m wide, 0.5m depth.		

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Photo No.	Date:	
SW-14 CE	12 July 2022	
Surface Water Feature SW-14 CE: Surface Water Course (Minor ditch), possibly used as to collect restoration area drainage/runoff. Lined. No water flowing observed at the time. Approximate measurements 5m wide, 1m depth.		

Photo No.	Date:	
SW-15 CE	12 July 2022	
Surface Water Feature SW-15 CE: Surface Water Course (Minor ditch), possibly used as to collect restoration area drainage/runoff. Lined. No water flowing observed at the time. Approximate measurements 5m wide, 1m depth.		

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Photo No.	Date:	
SW-16 CE	12 July 2022	
A Surface Water Feature SW-16 CE: Lagoon, water storage area, probably lined, drainage/runoff from restoration area. No water flowing observed at the time in or out. Approximate measurements 10m wide, 20m length. DO 126%, ORP 164.9 mV, Cond 1497ms/cm, pH 7.7, T21.41		

Photo No.	Date:	
SW-17 CE	12 July 2022	
A Surface Water Feature SW-17 CE: Surface Water Course (Minor ditch), possibly used as to collect restoration area drainage/runoff. Lined. No water flowing observed at the time. Approximate measurements 1m wide, 0.5m depth.		

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Photo No.	Date:	
SW-18 CE	12 July 2022	
A Surface Water Feature SW-18 CE: Surface Water Course (Minor ditch), connecting two lagoons. Not lined. No water flowing observed at the time. Approximate measurements 1m wide, 0.5m depth.		

Photo No.	Date:	
SW-19 CE	12 July 2022	
A Surface Water Feature SW-19 CE: Lagoon, quite dry, probably lined but looked silted up, drainage/runoff from restoration area. No water flowing observed at the time in or out. No measurements obtained as mainly dry.		

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Photo No.	Date:	
SW-20 CE	12 July 2022	
A Surface Water Feature SW-20 CE: Lagoon, quite dry, probably not lined but looked silted up, drainage/runoff from restoration or adjacent areas. Minimal water flowing observed at the time in or out, flow 0.335m/s. 5m wide by 20m long. No measurements obtained low water present.		

Photo No.	Date:	
SW-21 CE	12 July 2022	
A Surface Water Feature SW-21 CE: Surface Water Course (Minor ditch), collecting runoff/drainage from restoration area. Not lined. Dry at the time. Approximate measurements 3m wide, 0.5m depth.		

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Photo No. SW-22 CE	Date: 12 July 2022	
A Surface Water Feature SW-22 CE: Lagoon, no flow out, probably not lined but looked but within a low permeability material, possibly water storage area from runoff from adjacent areas. 20m wide by 50m long. No measurements obtained H&S concerns.		

Photo No. SW-23 CE	Date: 12 July 2022	
A Surface Water Feature SW-23 CE: Surface Water Course (Minor ditch), collecting runoff/drainage from pastoral areas. Not likely to be lined. Dry at the time. Approximate measurements 1.5m wide, 0.5m depth.		

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Photo No. SW-24 CE	Date: 12 July 2022	
A Surface Water Feature SW-24 CE: Marshy Land, rainfall/runoff. Soil mostly dry, but occasional signs of moist soil. No water flowing observed at the time. Approximate measurements 2m wide.		

Photo No. SW-25 CE	Date: 12 July 2022	
A Surface Water Feature SW-25 CE: Marshy Land, rainfall/runoff. Soil mostly dry, but occasional signs of moist soil. No water flowing observed at the time. Approximate measurements 2m wide.		

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Photo No.	Date:	
SW-26 CE	12 July 2022	
A Surface Water Feature SW-26 CE: Surface Water (minor ditch), land drainage, no flow at the time, area slightly moist. No water flowing observed at the time. Approximate measurements 2m wide by 0.3m depth.		

Photo No.	Date:	
SW-29 CE	12 July 2022	
A Surface Water Feature SW-29 CE: Surface Water (minor ditch), land drainage from adjacent areas, dry at the time, not likely to be lined. Approximate measurements 2m wide by 0.2 depth.		

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Photo No.	Date:	
SW-30 CE	12 July 2022	
Surface Water Feature SW-30 CE: Surface Water (minor ditch), land drainage from adjacent areas, dry at the time, no likely to be lined. Approximate measurements 2m wide by 0.2 depth.		

Photo No.	Date:	
SW-31 CE	12 July 2022	
Surface Water Feature SW-31 CE: Surface Water (minor ditch), land drainage from adjacent areas, dry at the time, no likely to be lined. Approximate measurements 0.5m wide by 0.2 depth.		

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Photo No.	Date:	
SW-32 CE	12 July 2022	
Surface Water Feature SW-32 CE: Marshy Land, rainfall/runoff. Soil mostly dry, but occasional signs of moist soil. No water flowing observed at the time. Approximate measurements 2m wide.		

Photo No.	Date:	
SW-33 CE	12 July 2022	
Surface Water Feature SW-33 CE: Surface Water (minor ditch), land drainage from adjacent areas, dry at the time, no likely to be lined. Approximate measurements 1m wide by 0.5 depth.		

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Photo No.	Date:	
SW-34 CE	12 July 2022	
Surface Water Feature SW-34 CE: Surface Water (minor ditch), land drainage from adjacent areas, dry at the time, no likely to be lined. Approximate measurements 1m wide by 0.5 depth.		

Photo No.	Date:	
SW-35 CE	12 July 2022	
Surface Water Feature SW-35 CE: Surface Water (minor ditch), land drainage from adjacent areas, no flow but ground slightly moist, no likely to be lined. Approximate measurements 1m wide by 0.5 depth.		

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Photo No.	Date:	
SW-36 CE	12 July 2022	
Surface Water Feature SW-36 CE: Surface Water Course (Stream), collecting water from all other discharge drains, rainfall, runoff. Not lined, probably natural. Approximate measurements 1m wide, 2cm depth. Average speed 0.053m/s, no readings taken		

Photo No.	Date:	
SW-39 CE	12 July 2022	
Surface Water Feature SW-39 CE: Surface Water (minor ditch), land drainage/runoff from adjacent areas, dry/no flow, no likely to be lined.		

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Photo No.	Date:	
SW-41 CE	12 July 2022	
Surface Water Feature SW-41 CE: Surface Water (minor ditch), land drainage/runoff from adjacent areas, dry/no flow, no likely to be lined.		

Photo No.	Date:	
SW-43 CE	12 July 2022	
Surface Water Feature SW-43 CE: Surface Water Course (Stream), collecting water from all other discharge drains, rainfall, runoff. Not lined, probably natural. Approximate measurements 75cm wide, 2cm depth. Average speed 0.013m/s, no readings taken		

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Photo No. SW-46 CE	Date: 12 July 2022	
Surface Water Feature SW-46 CE: Surface Water (minor ditch), land drainage/runoff from adjacent restored and pastoral areas, dry/no flow, no likely to be lined. Approximate measurements 2m wide by 1m depth		

Photo No. SW-47 CE	Date: 12 July 2022	
Surface Water Feature SW-47 CE: Surface Water (minor ditch), land drainage/runoff from adjacent restored and pastoral areas, dry/no flow, no likely to be lined.		

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Photo No.	Date:	
SW-48 CE	12 July 2022	
Surface Water Feature SW-48 CE: Lagoon dry, runoff from ditch, approximate dimensions 17m wide by 25m length.		

Photo No.	Date:	
SW-52 CE	12 July 2022	
Surface Water Feature SW-52 CE: Surface Water (minor ditch), land drainage/runoff from adjacent restored and pastoral areas, no flow, no likely to be lined		

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Photo No.	Date:	
SW-53 CE	12 July 2022	
Surface Water Feature SW-53 CE: Surface Water (minor ditch), land drainage/runoff from adjacent restored and pastoral areas, no apparent flow, no likely to be lined. Parameters not taken due to H&S risks.		

Photo No.	Date:	
SW-54 CE	12 July 2022	
Surface Water Feature SW-54 CE: Surface Water (stream), land drainage/runoff from adjacent restored and pastoral areas and rainfall, flow noted, no likely to be lined. Parameters not taken due to H&S risks.		

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Photo No.	Date:	
SW-55 CE	12 July 2022	
Surface Water Feature SW-55 CE: Surface Water (minor ditch), land drainage/runoff from adjacent restored and pastoral areas, dry, no likely to be lined.		
		

Photo No.	Date:	
SW-56 CE	12 July 2022	
Surface Water Feature SW-56 CE: Surface Water (minor ditch), land drainage/runoff from adjacent restored and pastoral areas, water in the ditch but not apparent flow, no likely to be lined.		
		

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Photo No.	Date:	
SW-58 CE	12 July 2022	
Surface Water Feature SW-58 CE: Marshy Land, rainfall/runoff. Soil mostly dry, but occasional signs of moist soil. No water flowing observed at the time. Approximate measurements 2m wide.		

Photo No.	Date:	
SW-59 CE	12 July 2022	
Surface Water Feature SW-59 CE: Surface Water (minor ditch), land drainage/runoff from adjacent restored and pastoral areas, dry, no likely to be lined.		

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Photo No.	Date:	
SW-60 CE	12 July 2022	
Surface Water Feature SW-60 CE: Surface Water (minor ditch), land drainage/runoff from adjacent restored and pastoral areas, dry, no likely to be lined.		

Photo No.	Date:	
SW-64 CE	12 July 2022	
Surface Water Feature SW-64 CE: Surface Water (minor ditch), land drainage/runoff from adjacent restored and pastoral areas, dry, no likely to be lined.		

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Photo No.	Date:	
SW-66 CE	12 July 2022	
Surface Water Feature SW-66 CE: Surface Water (minor ditch), land drainage/runoff from adjacent restored and pastoral areas, dry, no likely to be lined.		

Photo No.	Date:	
SW-68 CE	12 July 2022	
Surface Water Feature SW-68 CE: Marshy Land, rainfall/runoff. Soil mostly dry, but occasional signs of moist soil. No water flowing observed at the time. Approximate measurements 2m wide.		

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Photo No. SW-01 DP	Date: 12 July 2022	
Offsite View View of northern site and land offsite. The photograph aspect is north.		

Photo No. SW-01 CE	Date: 12 July 2022	
Norther Main Site View restored area of open cast mining in north of site. The photograph aspect is south.		

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Photo No. SW-01 CE	Date: 12 July 2022	
Relict Colliery Structure View of topographic change associated with former colliery use. The photograph aspect is north.		

Photo No. SW-01 CE	Date: 12 July 2022	
Access Road View of asphalt track in north of site. The photograph aspect is west.		

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Photo No.	Date:	
SW-01 CE	12 July 2022	
Lagoons (025) View of residential land off-site to north. The photograph aspect is north.		

Photo No.	Date:	
SW-01 CE	12 July 2022	
Railway Land (023) View former railway embankment running along sites northern boundary. The photograph aspect is west.		

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Photo No. SW-01 CE	Date: 12 July 2022	
Plant Crossing View excavation into bedrock on northern boundary of site. The photograph aspect is south-west.		

Photo No. SW-01 CE	Date: 12 July 2022	
Loading bays (026) View of access track through wood land in north of site. Woods to left and right thick and difficult to navigate in. The photograph aspect is south-west.		

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Photo No.	Date:	
SW-01 DP	12 July 2022	
Surface Water Feature SW-01 DP: Lagoon, water storage area, probably lined with low permeability material, drainage/runoff from restoration area. No water flowing observed at the time. Spillway (SW-02 DP) connected to north-eastern corner via culvert. Approximate measurements 10m wide, 70m length. Measurements DO 150.81%, ORP 178.6 mV, Cond 136.84 ms/cm, pH 8.07, T22.17C The photo aspect is east.		

Photo No.	Date:	
SW-02- DP	12 July 2022	
Surface Water Feature SW-02 DP: Spillway chute orientated north to south from the top of the overburden to the lagoon (SW01-DP). No water flowing observed at the time. Constructed of metal. Joins to concrete culvert before reaching lagoon. Rusty base. Approximate measurements 170m length, 0.4m deep, 1.4m wide. The photo aspect is north.		

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Photo No.	Date:	
SW-03-DP	12 July 2022	
Surface Water Feature SW-03 DP: Overflow ditch connected to spillway chute (SW02-DP) orientated east to west along the entire length of the overburden. No water flowing observed at the time. Vegetated at base along entire length. Approximate measurements 650m length, 1.4m deep, 3.0 m wide. The photo aspect is east		

Photo No.	Date:	
SW-04 DP	12 July 2022	
Surface Water Feature SW-04 DP: Concrete culvert at base of spillway chute (SW-02-DP). Poor condition. No water flowing observed at the time. Approximate measurements 0.5m deep, 4.0 m wide. The photo aspect is east		

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Photo No. SW-05 DP	Date: 12 July 2022	
Surface Water Feature SW-05 DP: Grassy ditch exiting from metal pipe orientated north to south below a grassed bank. Abundant rocks. No water flowing observed at the time. Vegetated at base along entire length. Approximate measurements 650m length, 1.2m deep from the surface, 35.0 m wide. The photo aspect is north		

Photo No. SW-06 DP	Date: 12 July 2022	
Surface Water Feature SW-06 DP: Grassy ditch exiting from the south of the grassed bank and ditch (SW05-DP) . This channel extends east to west along the access track along the south of the site. Stagnant water not observed to be flowing. Slight sheen on water from sheep/agriculture. Approximate measurements 0.25 m deep water. The photo aspect is north. Measurements DO 45.51%, ORP 87.60 mV, Cond 666.01 ms/cm, pH 7.26, T20.132C		

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Photo No. SW-07 DP	Date: 12 July 2022	
Surface Water Feature SW-07 DP: Grassed ditch extending east to west along the northern boundary of the access track in the south of the site. Abundant rocks. Multiple ditches to the north feed into this ditch. No water flowing observed at the time. Vegetated at base along entire length. Stagnant standing water in places. Approximate measurements 1.1km length, 1.0m deep from the surface, 2.0 m wide. The photo aspect is east.		

Photo No. SW-08 DP	Date: 12 July 2022	
Surface Water Feature SW-08 DP: Grassed ditch extending south from the access road. No water flowing observed at the time. Stagnant standing water. Becomes vegetated along ditch. Tributary of Nany Ystalwyn, 250m south Approximate measurements 250m length, 1.0m deep 2.0 m wide. The photo aspect is south.		

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Photo No. SW-09 DP	Date: 12 July 2022	
Surface Water Feature SW-09 DP: Continuation of grassed ditch extending south from SW-08 DP. No water flowing observed at the time. The photo aspect is south.		

Photo No. SW-10 DP	Date: 12 July 2022	
Surface Water Feature SW-10 DP: Grassed ditch orientated north to south joining the east to west ditch along the northern boundary of the access track. No water flowing observed at the time. Stagnant standing water. Vegetated along ditch to the north. The photo aspect is south.		

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Photo No. SW-11 DP	Date: 12 July 2022	
Surface Water Feature SW-11 DP: Stone lined ditch extending south from access track. No water flowing observed at the time. Vegetated at base along entire length. Approximate measurements 70m length, 1.0m 2.0 m wide. The photo aspect is south.		

Photo No. SW-12 DP	Date: 12 July 2022	
Surface Water Feature SW-12 DP: Lagoon, water storage area, probably lined with low permeability material, drainage/runoff from restoration area. No water flowing observed at the time. Approximate measurements 10m wide, 100m length. Not accessible for water parameter measurements. The photo aspect is east.		

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Photo No. SW-13 DP	Date: 12 July 2022	
Surface Water Feature SW-13 DP: Continuation of SW03 ditch. Photo aspect is west.		

Photo No. SW-14 DP	Date: 12 July 2022	
Surface Water Feature SW-14 DP: Continuation of SW14 ditch. Photo aspect is east.		

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Photo No. SW-15 DP	Date: 12 July 2022	
Surface Water Feature SW-15 DP: Smaller lagoon, water storage area, probably lined with low permeability material, drainage/runoff from restoration area. No water flowing observed at the time. Approximate measurements 10m wide, 50m length. Measurements DO 134.57%, ORP 163.8 mV, Cond 1,602.50 ms/cm, pH 7.62, T19.55C The photo aspect is east.		

Photo No. SW-16 DP	Date: 12 July 2022	
Pump SW-16 DP: Pump present on northern boundary of SW16 CE holding lagoon. Pump not on at time of walkover. Connected to SW17 DP via pipes and presumed up to pumping uphill to this lagoon. The photo aspect is east		

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Photo No. SW-17 DP	Date: 12 July 2022	
Surface Water Feature SW-17 DP: Lagoon, water storage area, probably lined with low permeability material, drainage/runoff from restoration area. No water flowing observed at the time. Submersible pump working and pumping water to lagoon to north. Not able to access for water parameter measurements. Approximate measurements 30m wide, 55m length. The photo aspect is east.		

Photo No. SW-18 DP	Date: 12 July 2022	
Surface Water Feature SW-18 DP: Overflow / washout pond. Water observed to be silty. Measurements DO 92.29%, ORP 147.0 mV, Cond 199.29 ms/cm, pH 7.84, T22.79C. Approximate measurements 25m wide, 30m length. The photo aspect is south.		

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Photo No. SW-19 DP	Date: 12 July 2022	
Surface Water Feature SW-19 DP: Lagoon, water storage area, probably lined with low permeability material, drainage/runoff from restoration area. No water flowing observed at the time. Black and silty. Not able to access for water parameter measurements. Approximate measurements 20m wide, 40m length. The photo aspect is north.		

Photo No. SW-20 DP	Date: 12 July 2022	
Surface Water Feature SW-20 DP: Lagoon, water storage area, probably lined with low permeability material, drainage/runoff from restoration area. No water flowing observed at the time. Black and silty. Not able to access for water parameter measurements. Approximate measurements 26m wide, 80m length. The photo aspect is north.		

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Photo No. SW-21 DP	Date: 12 July 2022	
Surface Water Feature SW-21 DP: Lagoon, water storage area, probably lined with low permeability material, drainage/runoff from restoration area. No water flowing observed at the time. Black and silty. Approximate measurements 26m wide, 80m length. Measurements DO 39.87%, ORP 160.5 mV, Cond 680.60 ms/cm, pH 7.71, T20.00C The photo aspect is north.		

Photo No. SW-22 DP	Date: 12 July 2022	
Surface Water Feature SW-22 DP: Grassed ditch extending south from the holding lagoon area. No water flowing observed at the time. Stagnant standing water 25cm deep. Becomes vegetated along ditch. Tributary of Nany Ystalwyn, Approximate measurements 70m length, 1.20m deep 2.0 m wide. The photo aspect is south.		

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Photo No. SW-23 DP	Date: 12 July 2022	
Surface Water Feature SW-23 DP: Continuation of SW22-DP extending south. Rocky ditch No water flowing observed at the time. Standing water 20cm deep. Becomes vegetated along ditch. Labelled as Nany Ystalwyn, Approximate measurements 1.20m deep 2.0 m wide. Measurements DO 96.95%, ORP 164.8 mV, Cond 1,238.6 ms/cm, pH 8.17, T15.5C The photo aspect is south.		

Photo No. SW-24 DP	Date: 12 July 2022	
Surface Water Feature SW-23 DP: Dry grassed ditch No water flowing observed at the time. Extending south from the access track The photo aspect is south.		

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Photo No. SW-25 DP	Date: 12 July 2022	
Surface Water Feature SW-25 DP: Continuation of the east to west ditch to the north of the access track in the south of the site. The photo aspect is west.		

Photo No. SW-26 DP	Date: 12 July 2022	
Surface Water Feature SW-26 DP: Continuation of the east to west ditch to the north of the access track in the south of the site. Drop in elevation from the road, damp at base. The photo aspect is east.		

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Photo No. SW-27 DP	Date: 12 July 2022	
Surface Water Feature SW-27 DP: Rocky gully extending south from the access track. No water flowing observed at the time. Standing water 10cm deep. Becomes vegetated along ditch. Approximate measurements 2.20m deep 1.0 m wide. The photo aspect is south.		

Photo No. SW-28 DP	Date: 12 July 2022	
Surface Water Feature SW-28 DP: Continuation of SW27 DP, located north of the access track. Dry, grassy ditch. The photo aspect is north.		

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Photo No. SW-29 DP	Date: 12 July 2022	
Surface Water Feature SW-29 DP: Concrete lined spillway chute between SW31 and SW30. Approximately 20m long. The photo aspect is north.		

Photo No. SW-30 DP	Date: 12 July 2022	
Surface Water Feature SW-30 DP: One of two holding lagoon, water storage areas, probably lined with low permeability material, drainage/runoff from restoration area. No water flowing observed at the time. Approximate measurements 25m wide, 130m length. No access. The photo aspect is south west.		

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Photo No.	Date:	
SW-31 DP	12 July 2022	
Surface Water Feature SW-31 DP: Holding lagoon, water storage areas, probably lined with low permeability material, drainage/runoff from restoration area. No water flowing observed at the time. Approximate measurements 40m wide, 45m length. No access. Pump not operational during walkover. The photo aspect is north.		

Photo No.	Date:	
SW-32 DP	12 July 2022	
Surface Water Feature SW-32 DP: Holding lagoon, concrete lined drainage/runoff from restoration area. Possible wheel wash area. No water flowing observed at the time. Approximate measurements 10m wide, 5m length. No access. Pump not operational during walkover. The photo aspect is west.		

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Photo No. SW-33 DP	Date: 12 July 2022	
Surface Water Feature SW-33 DP: Black silty pond. Possible overspill from wheel wash area. Approximate measurements 5m wide, 10m length The photo aspect is west.		

Photo No. SW-34 DP	Date: 12 July 2022	
Surface Water Feature SW-34 DP: Overflow ditch, dry Approximate measurements 5m wide, 30m length The photo aspect is east.		

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Photo No. SW-35 DP	Date: 12 July 2022	
Surface Water Feature SW-35 DP: Holding lagoon, water storage area, probably lined with low permeability material, drainage/runoff from restoration area. No water flowing observed at the time. Approximate measurements 25m wide, 20 m length. No access. Not accessible The photo aspect is north.		

Photo No. SW-36 DP	Date: 12 July 2022	
Surface Water Feature SW-36 DP: Holding lagoon, water storage area, probably lined with low permeability material, drainage/runoff from restoration area. No water flowing observed at the time. Approximate measurements 45m wide, 10 m length. No access. Not accessible The photo aspect is north.		

Client Name: Global Centre of Rail Excellence

Site: GCRE (Main Site)

Project No. 5209796

Photo No. SW-37 DP	Date: 12 July 2022	
Surface Water Feature SW-37 DP: Rocky ditch with standing water, orientated east to west under road adjacent to the west. Approximate measurements 1m wide, 145 m length 0.6m deep. Measurements DO 96.25%, ORP 144.7 mV, Cond 344.20 ms/cm, pH 8.31, T16.5C The photo aspect is north.		

Photo No. SW-38 DP	Date: 12 July 2022	
Surface Water Feature SW-38 DP: Possible dry grassed ditch orientated north to south towards access track. The photo aspect is south.		

Client Name: Global Centre of Rail Excellence

Site: GCRE (Main Site)

Project No. 5209796

Photo No.
SW-39 DP

Date:
12 July
2022

Surface Water Feature SW-39 DP:

Steep rock gully, orientated north to south, dry with standing water in paces. Lows south towards River Dulais located 320 m south of photo location.

Measurements DO 95.5%, ORP 155.3 mV, Cond 412.5 ms/cm, pH 8.07, T15.4C
The photo aspect is north



Appendix E. Mining Risk Assessment

Global Centre of Rail Excellence (GCRE)

Coal Mining Risk Review

Walters Group

16/01/2023

GCRE001-AWJV-00-XX-RP-GE-00003



Notice

This document and its contents have been prepared and are intended solely as information for Walters Group and use in relation to GCRE.

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Document history

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Document reference: GCRE001-AWJV-00-XX-RP-GE-00003

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Client signoff

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Project	Global Centre of Rail Excellence (GCRE)
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Client signature/date	

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Executive Summary

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.

The site is divided into two areas; the proposed GCRE track alignment at the 'Land at Nant Helen' and 'The Washery'. The proposed alignment surrounds and overlies the Nant Helen opencast workings (previously operated for extraction of coal by Celtic Energy and now in process of being restored) and covers an area spanning approximately 2.7 km by 1.9 km.

The site is within the influence of historic underground and more recent surface mining activities. Arup has previously completed a Geotechnical and Geoenvironmental Desk Study Report, Detailed Mine Workings Study and Ground Investigation Report to inform mining risks at the site.

Reinstatement of the open cast works and risks associated therein are discussed outside this report.

Arup completed the Desk Study in December 2019 and identified a number of mining risk zones across the proposed scheme area and recommended that a further assessment of the instability risk posed by coal mining was undertaken.

The Mine Workings Study, completed in June 2020, considered abandonment plans obtained from the CA to further refine the instability risk and make recommendations for GI.

A preliminary GI, incorporating positions to investigate mining risk, was completed between November 2021 and January 2022 with a GIR completed in May 2022, summarising the findings of the GI.

This work identified a significant instability risk to the proposed project from legacy coal mining activities within the Middle and Lower Coal Measures.

The risks posed can be summarised as:

- Shallow workings present within under the proposed alignment where rockhead cover is insufficient to prevent migration of voids to surface;
- Shafts with collapse zones that encroach on the proposed alignment;
- Adits and/or roadways present under the proposed alignment where rock head cover is insufficient to prevent migration of voids to surface; and;
- Presence of historical bell pitting.

Through this process Arup identified four Risk Zones (A, B, C and D) defined by the presence of underground workings. Atkins synthesised key information provided by Arup and reviewed this information against available mine abandonment plans from the Coal Authority, open cast completion plans from Celtic Energy and open-access information from both the BGS and the Coal Authority.

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

In addition to the risks highlighted in the MRZs, Atkins considers there to be a high probability of unrecorded mine entries occurring across the entire site, but particularly within and surrounding the extents of recorded mine workings. Atkins also considers there to be high probability of unrecorded mine workings occurring across the site, similar to the apparently unrecorded workings identified in the Washery Area (MRZ 7).

To mitigate the risks it is considered that actions will be necessary to either 'dig out' or undertake drill and grout treatment of shallow mine workings where these are present below the 'earthwork formation' and where these have less than 20m of rock cover.

Further investigations, including a site walkover, are recommended to validate the results of the risk assessment and inform future pricing of the scheme.

Approval from the Coal Authority is required prior to any further intrusive investigation works.

Anecdotal evidence from the Celtic Energy indicates that the groundwater has been artificially depressed by pumping to prevent flooding of the opencast workings. Further anecdotal evidence from Celtic Energy indicates that pumping ceased in 2021 and it is anticipated that the hydrogeological regime is in the process of stabilising.

It is understood from communication with Celtic Energy that rebound has stabilised at between 100-120m AOD. Deep underground workings and adits draining to the River Tawe are believed to be responsible for maintaining the groundwater level at this elevation.

To satisfy regulatory requirements, a hydrogeological risk assessment will be required to show that the recommended stabilisation works will not cause any adverse effects to environmental receptors. It is recommended that further ground investigations and studies be carried out to inform the baseline hydrogeological conditions.

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.

Remediation works will be required to mitigate the mining risk posed to the site. The treatment type will vary depending on the final arrangement and will be subject to the findings of the additional investigation. This will likely comprise either cut and fill for workings near surface or bulk infill stabilisation for deeper workings.

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 having been remediated in the past. Information on the remediation strategy completed should be sought. Additional validation of the remediation may be required.

1. Introduction

1.1. Overview

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.

The GCRE project entails the design and construction of a railway test track at the site of the former Nant Helen Opencast mine. High speed and low speed train tests will be undertaken at the proposed facility on two new test loops.

The site is understood to be within the influence of historic underground and more recent surface mining activities. Arup has previously completed a Geotechnical and Geoenvironmental Desk Study Report [1], Detailed Mine Workings Study [2] and Ground Investigation Report [3] for the site. This work identified a significant instability risk to the proposed project from legacy coal mining activities.

Atkins' commission includes the development of a Ground Investigation Report (GIR) in accordance with the Design Manual for Roads and Bridges (DMRB) CD622 managing Geotechnical Risk (CD622) [4], and the GCRE Employer's Requirements [5].

This document represents the Mining Risk Review (MRR) which will be included as an appendix to Atkins GIR.

1.2. Scope

The GCRE Employers Requirements [5] identify that workings are present in the Middle and Lower Coal Measures and that it will be necessary to either 'dig out' or undertake drill and grout treatment of shallow mine workings where these are present below the 'earthwork formation' and where these have less than 15-20m of rock cover. It is further noted that an intrusive Ground Investigation is required to refine the risk zoning and allow the areas of mineworking's that require treatment to be refined.

In support of these requirements a GIR is being produced for the overall scheme for which this Mine Risk Assessment is being prepared.

The objectives of this report are to:

- Provide a review and synthesis of the available previous reporting pertaining to mining for GCRE;
- Review existing datasets (see Section 1.4) pertaining to mining at the site;
- Provide an assessment of the current level of instability risk posed by mining activities,
- Present the instability risk to the proposed scheme due to previous mining activities with identification risk zones; and
- Recommend next steps, including preliminary recommendations with regards to remediation options.

This MRR does not cover the optioneering and remediation design.

1.3. Site Description

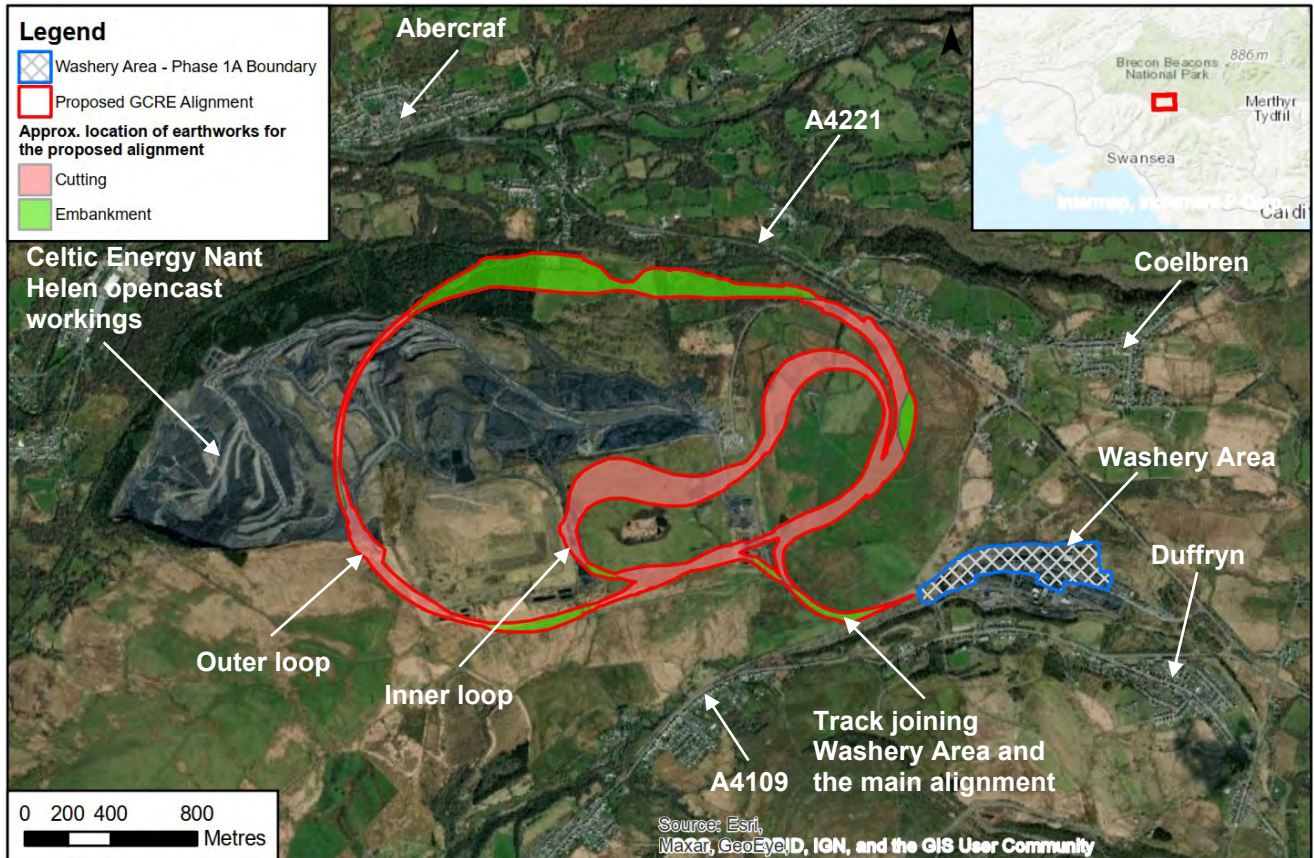
The site is located immediately south of the village of Abercraf, approximately 20 km northeast of Swansea, south Wales, as shown on Figure 1-1. The approximate centre of site is National Grid Reference SN 83290 11091.

The site is divided into two areas; the proposed GCRE track alignment and the Washery Area. The proposed alignment surrounds and overlies the Nant Helen opencast workings (previously operated for extraction of coal by Celtic Energy and now in process of being restored) and covers an area spanning approximately 2.7 km by 1.9 km.

The alignment comprises an inner loop test track and an outer loop test track with respective track lengths of approximate 4.0 km and 6.7 km respectively. The alignment construction will require earthworks in the form of cuttings and embankments as shown in Figure 1-1.

The Washery Area refers to the extension of the site to the southeast incorporating sidings, located between the villages of Coelbryn and Duffryn and immediately north of the A4109. Access to the wider UK rail network is through this area.

An extract of the project visualisation model of the proposed site is shown in Figure 1-2.



1.4. Sources of Information

A combination of open-access resources from the Coal Authority (CA) and the British Geological Survey (BGS), datasets and reports provided by third parties (Arup and Celtic Energy) and purchased data from Groundsure have been used in compiling this review. Table 1-1 identifies the sources of information that were available to Atkins at the time of writing.

Table 1-1 - Sources of information

Owner	Type	Title	Status	Date
British Geological Survey	Online Interactive Map	GeoIndex [6]	Open-Access	N/A
	Geological Map	Merthyr Tydfil, Sheet 231, Solid Edition, 1:50:000 Series [7]	Published	1979
		Merthyr Tydfil, Sheet 231, Drift Edition, 1:50:000 Series [8]	Published	1979
The Coal Authority	Online Interactive Map	Interactive Map Viewer [9]	Open-Access	N/A
	Mine Abandonment Plans and Completion Plans [10]	<u>Abercraf and International Colliery</u>		
		12641_99 9999	Published	1939
		13040_99 9999	Published	1941/1954
		13041_99 9999	Published	1941
		SW203_99 9999_2 OF 2	Published	1953
		SW204_99 9999_2 OF 2	Published	1953
		SWA1077_22 8010	Published	1953
		SWA1077_22 8011	Published	1953
		SWA1077_22 8210	Published	1953
		SWA1077_22 8211	Published	1953
		SWA4053_22 8211	Published	1953
		SW198_99 9999	Published	1954
		SW341_22 8110	Published	1957
		SWR754_99 9999	Published	1967
		<u>Cwmtawe Anthracite Colliery</u>		
		10378_99 9999	Published	1929
		11122_99 9999_1 OF 4	Published	1933
		11122_99 9999_3 OF 4	Published	1933
		11122_99 9999_4 OF 4	Published	1933
		Tyn y Pant Colliery		
		SW2233_99 9999	Published	1901
		<u>Duffryn Anthracite Colliery</u>		
		6638_99 9999	Published	1916
		<u>Dulais Anthracite Colliery</u>		
		6784_99 9999_1 OF 2	Published	1918/1931
		8825_99 9999	Published	1926
		9796_99 9999	Published	1927
		11207_99 9999_1 OF 4	Published	1934
		11207_99 9999_3 OF 4	Published	1934
		11207_99 9999_4 OF 4	Published	1934
		<u>Onllwyn No.1 Colliery</u>		
		SW61_99 9999	Published	1949

Owner	Type	Title	Status	Date
		SW133_99 9999	Published	1951
		SW150_99 9999	Published	1953
		SWR750_99 9999	Published	1964
		<u>Ynyscedwyn Colliery</u>		
		12563_99 9999	Published	1939
		SWA1078_22 8010	Published	1953
Celtic Energy	Opencast Completion Plans [11]	SWA4053_22 8011	Published	1953
		Nan Helen Completion Plans	Issue	N/A
		Nan Helen Extension Completion Plans	Issue	N/A
		<u>Abercraf Gwaunton Opencast</u>		
		SWR2547_99 9999_1 OF 7 to 7 OF 7	Published	1981
		<u>Onllwyn Opencast</u>		
GCRE Co. Ltd	Employers Requirements	SWR2909_99 9999_1 OF 2 and 2 OF 2	Published	1983
		SW164_99 9999	Published	1953
		GCRE Earthworks – Volume 2 (C) GCRE	Issue	12 Sep. 2021
		Employers Requirements Document [5]		
Arup	Desk Study	Land at Nant Helen and Onllwyn Coal Washery - Geotechnical and Geoenvironmental Desk Study [1]	Issue	18 Dec. 2019
	Mining Note	Detailed Mine Workings Study (Ref. 4-70) [2]	Issue	20 Jun. 2020
	GIR	Global Centre of Rail Excellence - Ground Investigation Report (Ref. 4-50) [3]	Draft	31 Mar. 2022
	Shapefiles	Risk Zones used in the Geotechnical and Geoenvironmental Desk Study. Areas of shallow mine workings used in the GIR. Nant Helen Geotechnical Borehole Locations. Location of underground workings. Mine entry location points; including the Easting, Northing, type, azimuth and Coal Authority ID.	N/A	N/A
Quantum Geotech	GI Factual Report	Global Centre of Rail Excellence Ground Investigation: Factual Report (Ref. Q0652/FR_01) [12]	Draft	7 Feb. 2022
	AGS data	Q0652 210222 [13]	Draft	24 Feb 2022
Pauley	3D model	'GCRE Scaled Assets' 3D model [14].	N/A	16 Dec 2021
Groundsure	Report	Groundsure Report (Ref: GSIP-2021-12345-10399) [15]	Issue	2022
	Shapefiles	Standard Groundsure reporting shapefiles, including but not limited to BGS geology, borehole locations and locations of opencast workings.	N/A	N/A

1.5. Assumptions and Report Limitations

This report has been prepared for use solely by GCRE Co. Ltd. Thereafter, this report shall not be relied upon, or transferred to any other parties without the express written consent of Atkins. If an unauthorised third party comes into possession of this report, they rely on its contents at their own risk.

Opinions and recommendations presented in this report are based upon information provided by third party sources. Atkins has not been able to verify independently all third-party information and for the purposes of this assessment has assumed that such information is accurate and complete. Therefore, whilst this report and the opinions contained herein are accurate to the best of Atkins' knowledge and belief, Atkins cannot guarantee the completeness or accuracy of any descriptions or conclusions based on supplied third party information.

The information presented in this report is geotechnical in nature. Any geological, geotechnical risk assessment considerations are based on an exploratory ground investigation and are subject to the inherent limitations of any such study, whereby the nature of the work means that only a small proportion of the sub-surface conditions can be observed/sampled. Ground conditions can vary significantly between exploratory hole locations and groundwater/ground gas conditions vary seasonally. Therefore, unexpected ground conditions could occur between the sampling points and groundwater/ground gas conditions may differ from those encountered during the monitoring periods.

This review has been based on the current scheme at the time of writing, should the scheme proposals change as design develops or new information become available then a further review may be required.

1.5.1. Assumptions

The following assumptions and limitations are relevant throughout this report :

- This report relies on a variety of mine abandonment plans produced by former mine operators at the site (e.g., Celtic Energy). Atkins assumes these third party data are complete and that the details shown on the plans are accurate.
- A Site Walkover has not yet been undertaken to ground truth current conditions.
- The estimates of competent cover above conjectured workings consider the rockhead above seam pavement.
- Due to the limited data on the state of the workings, Atkins has assumed that all workings are open and have not collapsed at some point in the past. This is a conservative approach given that the subsidence above open workings is typically far greater than partially or fully collapsed workings.
- When calculating the potential collapse zones for the shafts, Atkins assumed a circular shaft geometry and an internal angle of shearing resistance of 25°. [19]
- Atkins was not involved in the scoping and supervising of the most recent GI (2021/22) and assumes that the factual data produced from the GI are accurate.
- Mine entry locations were received as a dataset from Arup, it is understood that Arup compiled the dataset based on Coal Authority records and information from Celtic Energy. Atkins assumes that these mine entries have been accurately plotted based on the datasets available to Arup. Atkins has reviewed these mine entry locations against the mine abandonment plans. Atkins notes that the spatial locations of mine entries are often inaccurately reported and therefore, Atkins expects at least some of the mine entry locations presented in this report to differ from the true locations on site.
- The location and extents of underground workings have been assessed from pdf mine abandonment plans. Arup provided some georeferenced mine abandonment plans, these were reviewed by Atkins. However, the remainder were provided in non-georeferenced format and were subsequently georeferenced by Atkins using landmarks and other features visible on the plans and aerial imagery for the site or against historical plans that themselves have been georeferenced. As such there may be some discrepancy between locations on mine entries and workings reported in this report and the actual locations on site.
- Based on correspondence with Celtic Energy, Atkins understands that all groundwater pumping has already ceased on site and that the groundwater has rebounded to the previous natural level of between 100-120m AOD. Atkins has not verified this as part of this report and assumes this information is correct as agreed in conversations with GCRE.
- Mining risk zones have been identified from the available information. Unknown workings may be present on site both within and outside the MRZ's that have not been identified during the desk study, ground investigation or during the due diligence review.
- This MRR does not cover wider hydrogeological or ground gas conditions which are reported in the main Atkins GIR and other reports.

2. Site History

2.1. Overview

This section provides an overview of the site history pertaining to mining, with key historic mining features and potential areas of risks being identified from historical mapping (1876-2019) as well as available aerial imagery (1945-2019), additional information is provided through peer-review of pre-existing technical reports [1] [2] [3].

2.2. Historical Maps

From the earliest maps on record, the site has been subject to extensive industrial activity revolving around the extraction of coal. These activities are initially recorded as a collection of underground workings in the 19th and 20th centuries before becoming an open cast colliery in the latter part of the 20th century.

Coal mining as an industrial activity in the South Wales valleys predates the 1876 maps, as such unidentified underground and surface workings from before this date may exist across the site.

The near 200-year mining history of the areas has created a legacy of potential risks and constraints, these are discussed in further detail throughout this report.

Table 2-1 provides an overview of known mine working both underground and surface working from the earliest known workings to present.

Table 2-1 – Known historical mine workings

Dates	Collieries	Type of mining
1840 - 1968	Hendre Ladis Colliery (located 1.4km to the western boundary)	Underground
1840 - 1964	Onllwyn Colliery	Underground
1864 - 1938	Gwaucnclawdd	Underground
1872 - 1964	Seven Sisters Colliery	Underground
1872 - 1967	Abercraf Colliery (also known as the Abercrave Colliery)	Underground
1893 - 1913	International Colliery	Underground
1905 - 1947	Dulais Colliery	Underground
1914 - 1978	Glynllech Colliery	Underground
Unknown	Cwm Tawe Colliery	Underground
1946 - 1949	Onllwyn	Opencast
1952 - 1953	Cefn Byrle	Opencast
1963 - 1973	Abercraf /Gwaunton 1	Opencast
1972 - 1982	Onllwyn (expansion in the east)	Opencast
1986 -1999	Nant Helen	Opencast
2002 - Present	Nant Helen Extension	Opencast

3. Synthesis of Previous Works

3.1. Overview

This section provides a review and synthesis of previous reporting and open-access data relevant to the project. This includes key information from the Geotechnical and Geoenvironmental Desk Study report [1], the Detailed Mine Workings Study [2], the GIR [3], BGS sources [6] [8] [7] and the Coal Authority [9].

Arup completed the Desk Study [1] in December 2019 to summarise published information, provide an initial conceptual site model, provide a preliminary engineering assessment and quantify expected risks.

The Desk Study [1] identified a number of mining risk zones across the proposed scheme area and recommended that a further assessment of the instability risk posed by coal mining was undertaken.

The Mine Workings Study [2], completed in June 2020, considered abandonment plans obtained from the CA to further refine the instability risk and make recommendations for GI.

A preliminary GI, incorporating positions to investigate mining risk, was completed between November 2021 and January 2022 with a GIR [3] completed in May 2022, summarising the findings of the GI.

Through this process Arup identified four Risk Zones (A, B, C and D) defined by the presence of underground workings, which are summarised and assessed in the following section.

3.2. Geology

A summary of the geology of the area is presented below based on a review of the BGS GeoIndex [6], BGS geological maps [7] [8] for the site and the opencast workings extents from Celtic Energy [11].

3.2.1. Made Ground

Several areas of artificial ground have been identified across the site identified as areas of backfilled opencast workings, as shown on Figure 3-1. The large area in the north of the main site is associated with the backfilling of the Abercraf/Gwaunton opencast coal mine. The area east of site is associated with the backfilling of the Onllwyn opencast coal mine and the area within the western portion of the cutting of the inner loop is associated with the backfilling on Nant Helen opencast coal mine. Made Ground is also shown beneath the Washery, which is likely associated with levelling of this area for the railway sidings and buildings.

3.2.2. Superficial Deposits

The BGS geological maps [7] show Glacial Till along the southern boundary of the outer loop, the western boundary of the inner loop and adjacent to the track leading to the Washery, as shown on Figure 3-2. Peat is also shown on the western edge of the inner loop and within the Washery (Figure 3-2). Most of this peat is likely to have been removed during the opencast workings in the centre of the site and the former construction in the Washery Area.

Glacial till typically comprises a heterogeneous mixture of clay, sand and gravel with large cobble and boulder inclusions of various sizes and shapes (diamicton). Peat typically comprises a partially decomposed mass of vegetation that has been deposited under largely anaerobic conditions, usually found in bogs or swamps.

3.2.3. Bedrock Geology

The bedrock beneath the site is part of the South Wales Middle and Lower Coal Measures. They are reported to comprise rhythmic sequences of mudstones (commonly containing pyrite), siltstones, sandstones, grits, fireclays, seatearths and coals; the coals found in these measures tend to be amongst the thickest and most economically significant in South Wales.

The geological mapping [7] indicates that dip angles for the bedding in the coal measures are typically between 5° and 15° in a west to south-westerly direction. However, there are localised variations to this, with a number of anticlines and synclines shown.

Three named normal faults are shown on the published geological maps [7] crossing the site with a NNW-SSE strike, there are two other parallel unnamed faults which extend into the northern boundary of the site. The three named faults: the Pwllau Bach Fault, the Chapel Fault, and the Glynccorwg Fault (ordered from west to east) divide the bedrock beneath the site into three fault blocks as shown on Figure 3-3. Unidentified faults are also likely to be present within the site boundary.

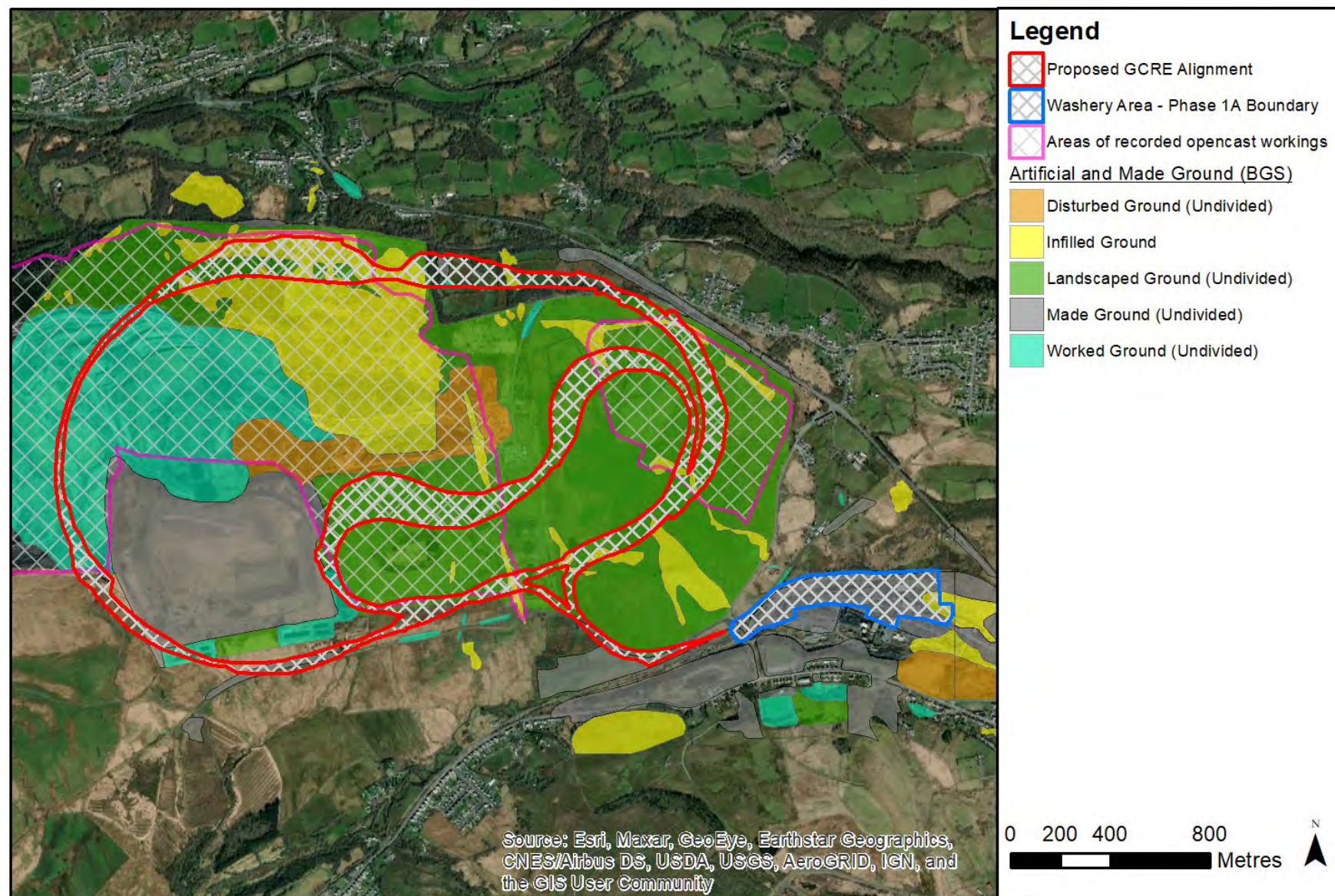


Figure 3-1 - Artificial and Made Ground.

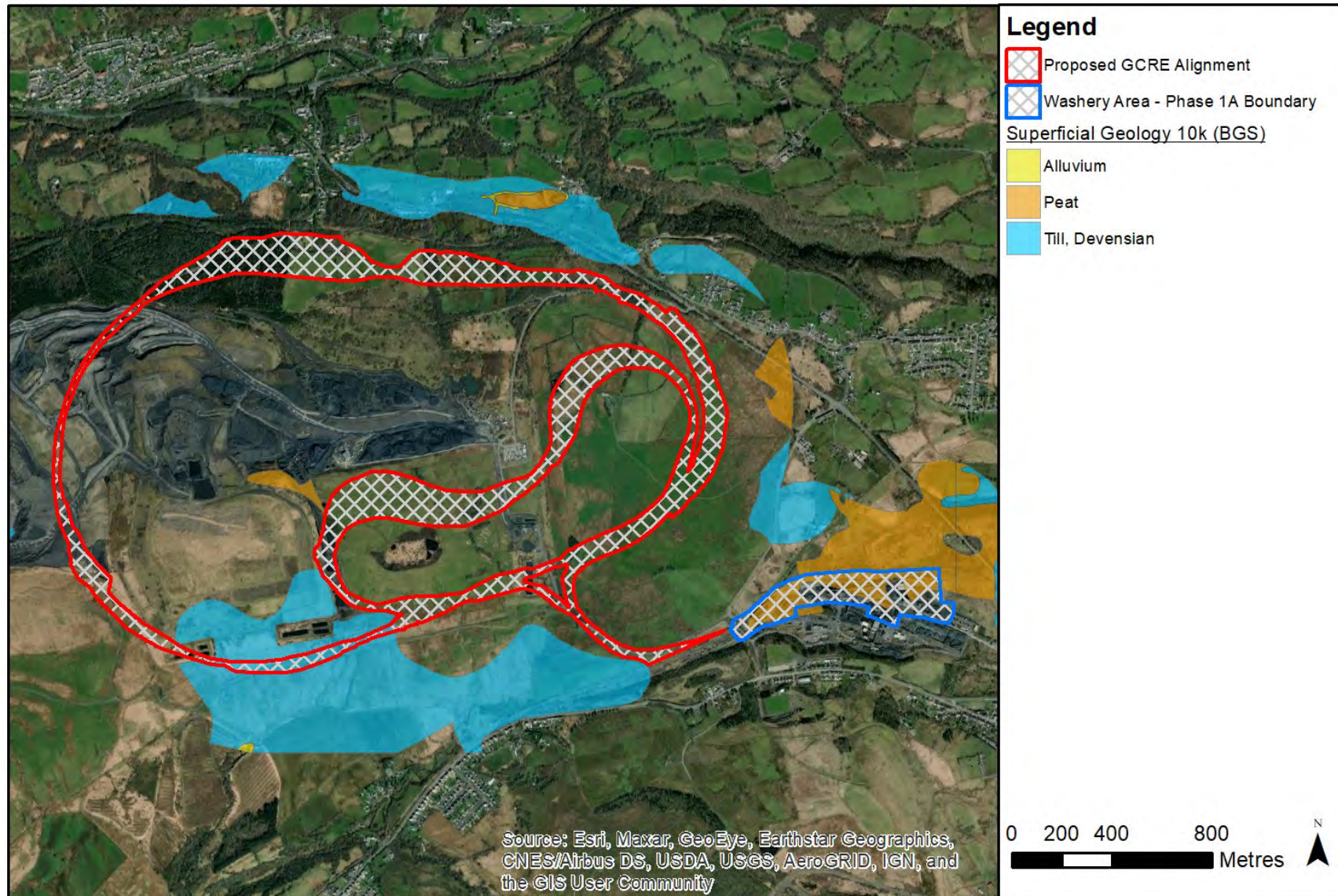


Figure 3-2 - Superficial geology.

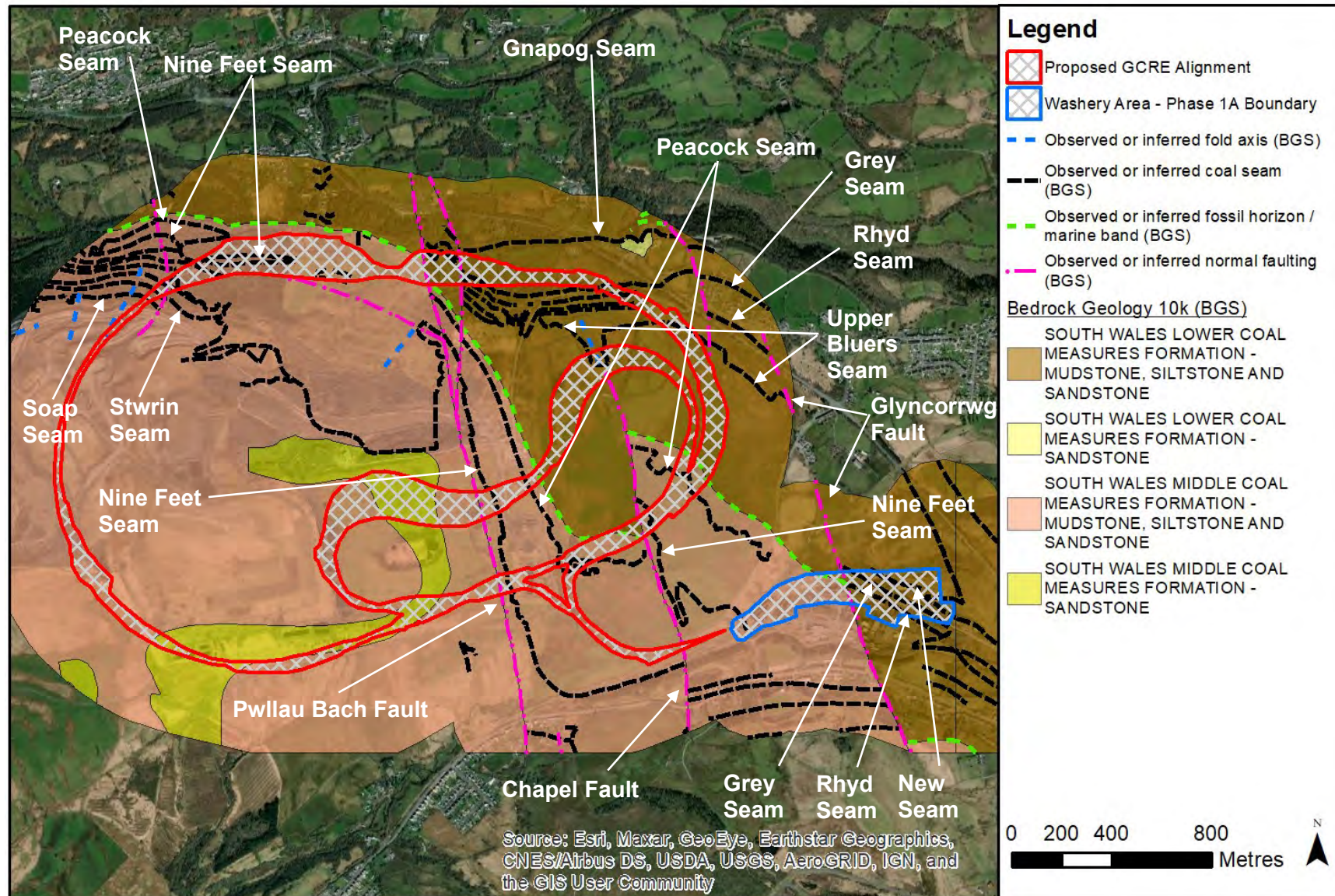


Figure 3-3 - Bedrock, faults and linear features.

3.3. Ground Investigations

A preliminary GI, incorporating positions to investigate mining risk, was completed between November 2021 and January 2022 with the findings captured in Arup's GIR [3]. A full review of this report and the GI findings is provided Atkins GIR.

Information, gained from the GI prevalent to the mining is discussed within this report. As an overview the recently completed GI comprised:

- 35 No. boreholes;
- 40. No trial pits;
- Insitu testing and soakaway tests;
- Geophysical surveys, and;
- Installations and monitoring.

The completed GI locations are shown in Figure 3-4.

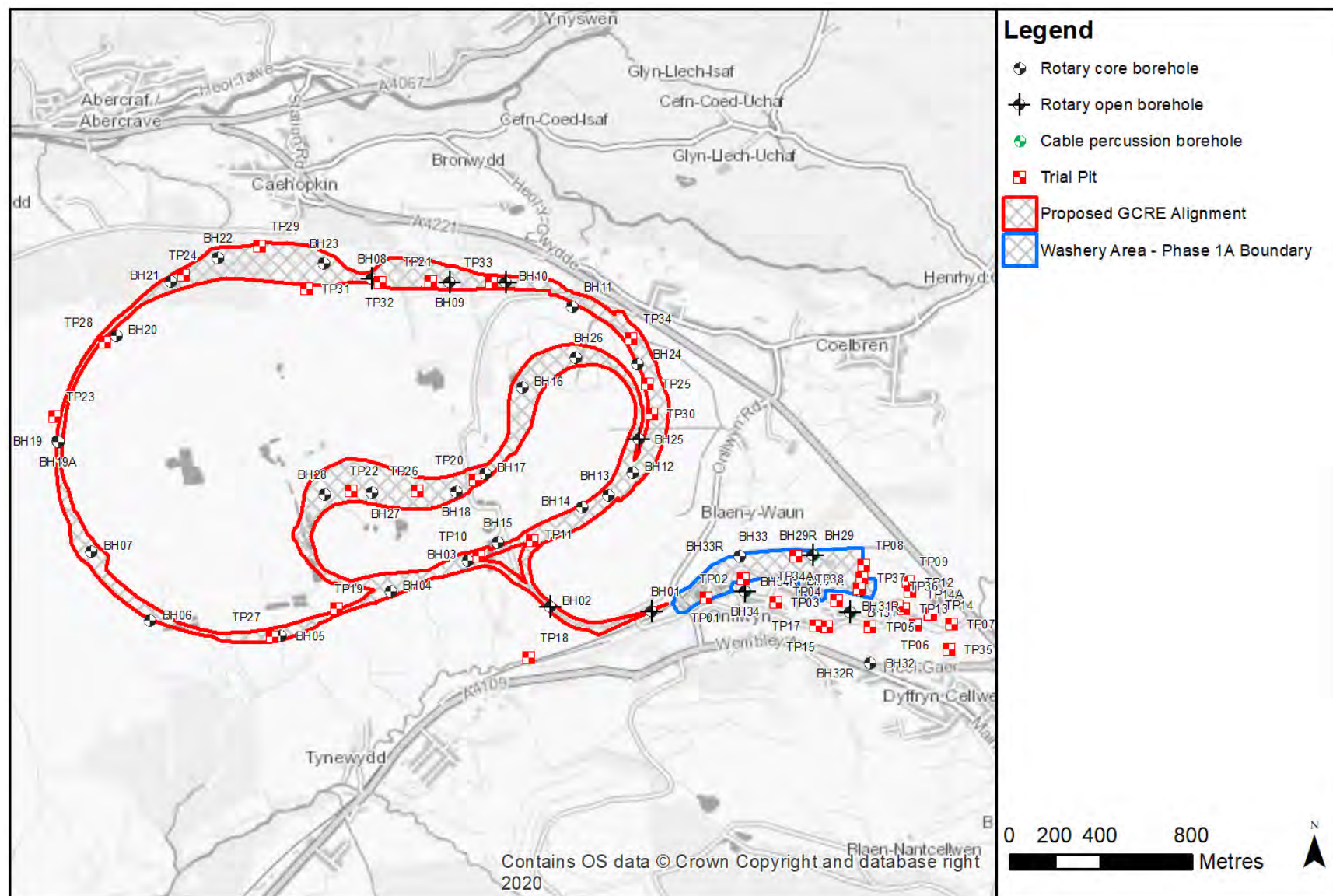


Figure 3-4 - Ground investigation location plan.

3.4. Mine Entries

The Desk Study [1] provided an initial assessment of known mine entries based on a review of the CA online viewer, opencast completion plans and abandonment plans provided by Celtic Energy.

This desk study identified a total of 95 mine entries within the site boundary. Arup identified clusters of mine entries in the northwest, northeast and south-central parts of the main railway alignment, and a cluster of mine entries around the Washery.

Arup suggested that the majority of the mine entries in the northwest of the site are likely to have been excavated during the opencast mining activities associated with the Abercraf/Gwaunton opencast site, and therefore may no longer be in place.

Arup also identified the potential for bell pitting across the north and south of the site based on satellite imagery from 1945 [16] and BGS inferred and observed coal outcrop locations [6] [7] [1] (bell pitting is discussed in detail in Section 334.2.3). A map showing the mine entries identified in the Desk Study is included in Section 3.6 (Figure 3-8).

The Detailed Mine Workings Study [2] refined the Desk Study [1] assessment of the mine entries through review of the available mine abandonment plans. Of the original 95 mine entries identified in the Desk Study [1], Arup identified seven mine entries within the proposed alignment and the Washery posing a risk to the site. This included four adits and two shafts in the south of the site, potentially extending beneath the inner loop, outer loop and access track, and one adit in the north of the site beneath the proposed location of an embankment.

Arup state the mine entries in the south of the site are associated with the Dulais Colliery West and East Slants [2]. The mine entry in the north of the site, called 'Duffryn Level', is associated with Duffryn Colliery, which is located approximately 90 m south of the proposed alignment.

Arup provided a summary of the mine entries identified on the mine abandonment plans, which is provided in Table 3-1.

Table 3-1 - Mine entry summary table from the Detailed Mine Workings Study [2].

Colliery	Entry name	Interpreted location		Arup Risk Zone	Shaft depth noted on abandonment plans
		Easting	Northing		
Dulais Colliery West Slant	"North Level" or "Cwm Mawr Level"	283373	210740	A	n/a
	"New Drift"	283684	210410		n/a
	"Air pit"	283414	210784		12ft (~4m)
Dulais Colliery East Slant	"East Slant"	283846	210410	A	n/a
	"Level to Big Vein"	283904	210436		n/a
	"Pumping Pit to Peacock Vein"	283838	210402		54ft (~17m)
Duffryn Colliery	"Duffryn Level"	282957	211907	B	n/a

The Detailed Mine Workings Study [2] recommended that the locations of mine entries in Table 3-1 should be investigated further in order to positively identify the entries locations and allow any mitigation or treatment measures which may be required to be developed.

3.5. Mine Workings

The entirety of the proposed site is situated within a CA 'Development High-Risk Area'. A Development high-risk area is defined as an "area which contains one or more recorded coal mining related features which have the potential for instability or a degree of risk to the surface from the legacy of coal mining operations" [9].

These "features" typically include mine entries (shafts and adits) and shallow coal workings (recorded and probable).

Table 3-2 sets out an interpretation of the stratigraphic sequences from shallowest to deepest of the known and named coal seams as well as the typical seam thickness. It is noted that within the provided information and literature there are some variations between names.

Table 3-2 - Interpreted coal seam sequence

Seam	Other name	Typical seam section thickness
South Wales Middle Coal Measures		
Soap	Two Feet-nine	-
Stwrin	Two Feet-nine	-
Four feet	Upper Four Feet, Lower Four Feet, White Four Feet, Wite, Stwrin	0.9m
Eight feet	Lower Eight Feet, Six Feet, Black	-
Cornish	Red Vein, Two Feet	0.76m
Harnlo	-	-
Nine feet	Big	2.7 - 3.0m
Brass	Bute, Peacock	0.9 - 1.4m
South Wales Lower Coal Measure		
Yard	Lower Peacock, Lower Brass	-
Bluers	Bluers, upper Bluers, lower, Seven Feet	0.6 - 0.85
Rhyd	Five Feet, Little Brass	0.75m
Grey	Gellideg	0.66m
Middle	Gellideg	0.63m
New	Lower	0.69m
Bryn	Gnaplog	0.5m

3.5.1. Underground Mining

Underground workings are distributed across the site, with more extensive workings located in the west working the thicker Nine Feet and Four Feet seams in the International and Abercraf collieries. These workings extend from north to south increasing in depth to the south due to the southerly dip.

Additional underground workings in the South Wales Middle Coal measures occur in the south of the site, predominantly working the Peacock (Brass) seam from the Dulais colliery. These workings extend from outcrop in the south to the north, these workings are offset by the north-south Chapel faults

Underground workings in the Lower Coal Measures (Cwmtawe Bryn Colliery) occur in the northeast of the site and adjacent to the southern boundary of the site, encroaching into the Washery. Figure 3-5 illustrates the known mineworking's.

Types of workings

It is understood from historic information and abandonment plans that room and pillar mining was used. This method of mining involves extraction of coal from specific areas of the seam (rooms) while leaving untouched

(pillars) to support the roof. A significant proportion of the coal may be left behind in pillars. These workings are commonly set out on a grid pattern and extend along a horizontal or shallowly dipping seam. Latterly, pillars may be 'robbed' to remove additional coal near to the end of life of the underground working to maximise seam yield, this may lead to insufficient coal being left in place to support the roof and cause collapse.

Previous Risk Assessment

Underground workings present on site with less than 20 m of overlaying bedrock were deemed to pose a stability serious risk to the proposed scheme, 20m was used by Arup as the minimum bedrock requirement by Arup to prevent void migration following the '10t rule' after CIRIA C758D [17] and assuming a maximum extraction thickness of 2m.

A number of risk zones related to underground mining were defined, see Section 3.6

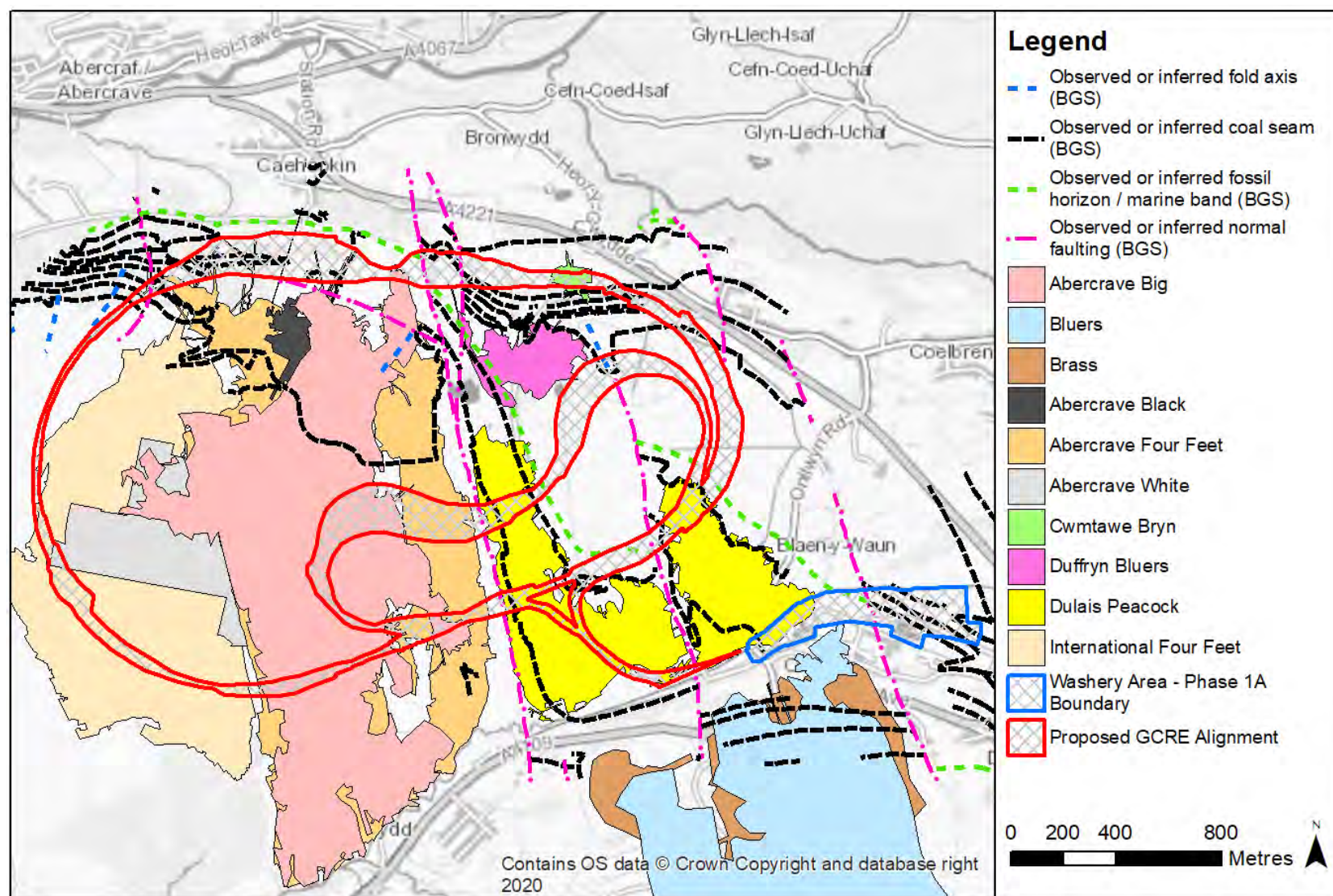


Figure 3-5 – Locations of recorded mine workings based on mine abandonment plans provided by the Coal Authority; data derived by Arup and Atkins, map generated by Atkins [3]

3.5.2. Surface Mining

Opencast mining was undertaken across the site. The most significant opencast workings are the Nant Helen workings located in the centre and north of the site as well as the later Nant Helen Extension to the west, as shown in Figure 3-6. It is understood that all extraction has now ceased with restoration now ongoing in accordance with regulatory requirements and the agreements with Powys County Council.

Aerial imagery [1] indicates that bell pitting was undertaken on site.

Open Cast Mining

Opencast mining is a form of bulk mining involving the removal of large quantities of overburden to access economic deposits (in this case coal) below the surface. This method of mining targets all of the seams in a location, stripping one before lowering the base of the pit to target the next. This method of mining is still economic in areas that have historical room and pillar mining due to the high proportion of resources that are left in situ, for example the Nant Helen and Abercraf opencasts that have reworked seams historically worked via underground mining.

Previous Risk Assessment

Backfill of opencast workings was considered to present a risk to the proposed scheme due to expected large settlements occurring within this material likely to cause subsidence at surface, this is addressed in the main Atkins GIR and not considered further in this report.

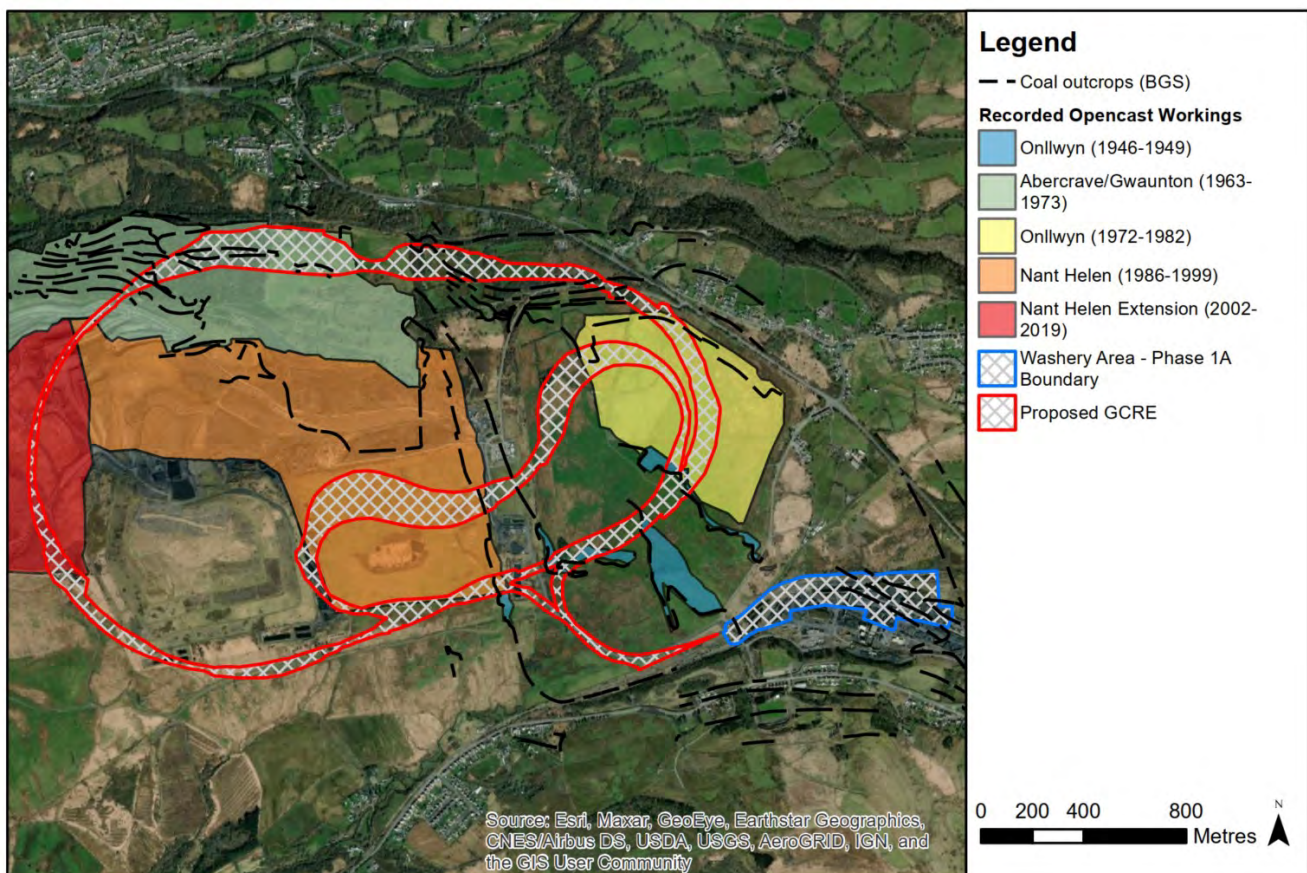


Figure 3-6 - Recorded opencast workings.

Bell Pitting

Bell pitting is a historic method of extracting shallow coal resources from narrow shafts opened into small caverns (bells) once coal is encountered. Coal was extracted by hand to a point the bell became unstable at which point a new, adjacent bell pit could be opened. Bell pit locations are generally unrecorded, poorly backfilled and a common source of mining related instability at surface.

Previous Risk Assessment

Evidence of bell pitting onsite was observed in aerial imagery [1] as open bell pits or crown holes, these occur predominantly in the south of the site (Figure 3-7).

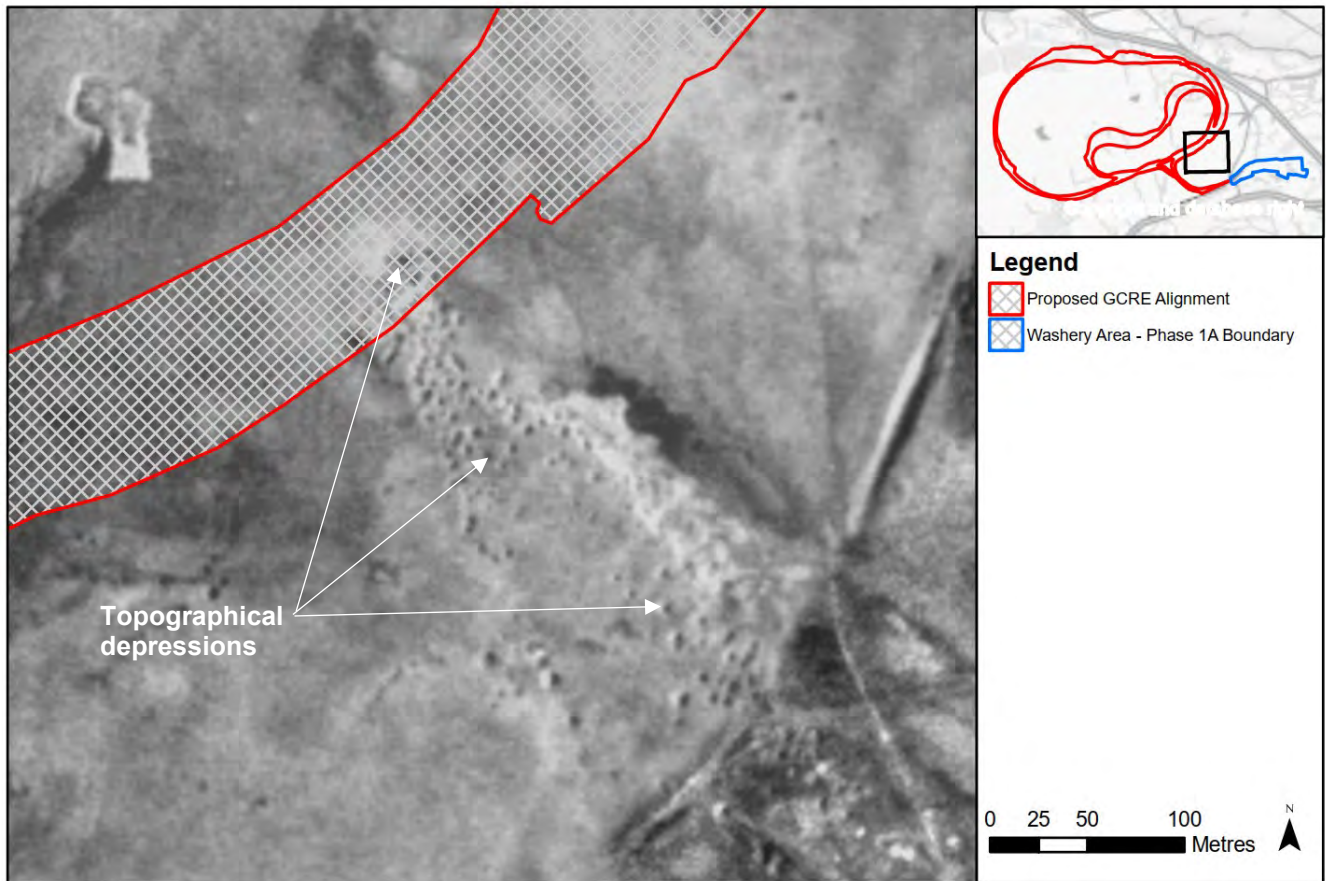


Figure 3-7 - Example of potential evidence for bell pitting in the southeast of the alignment.

3.6. Arup Risk Zones

Taking cognisance of all information, Arup identified four Risk Zones (A, B, C and D) defined by the presence of underground workings, as shown in Figure 3-8. Evidence of known workings beneath the proposed alignment was found within these zones, which therefore have a greater probability of being impacted by mining related instability.

3.6.1. Risk Zone A

Risk Zone A covers the south-eastern section of the outer main rail loop and the central section of the inner loop along with the section of rail that will connect the testing loop to the stabling yard and wider rail network. There was deemed to be a stability risk to the track due to:

- Shallow workings (within 10t of rockhead) in the Peacock (Brass) seam; and
- Shallow workings (within 10t of rockhead) in the Nine Feet seam.

Both being worked from the Dulais colliery. The stratigraphically higher Peacock also shows signs of having been worked from the surface by bell-pitting as evident from the earliest aerial photographs [16].

Deeper workings relating to the working of the Four Foot Seam from the Abercraf Colliery are anticipated to be at depths of approximately 80m bgl and therefore considered to pose a negligible instability risk.

The GI records evidence of suspected workings within the Peacock (Brass) seam from the Dulais Colliery (West and East Slants) were encountered within BH02, BH12, BH15, BH17 and BH18 at <20 m from proposed track level (except in BH12 and BH17).

Arup's GIR [3] provides a further update to the risk zones. Risk Zone A remains largely unchanged following the GI.

3.6.2. Risk Zone B

Risk Zone B covers the northeastern section of the loop. There was deemed to be a stability risk to the track due to:

- A number of shafts and adits in proximity to the track;
- Outcropping Bryn, Lower, Middle and Upper Bluers seams were shown to be present in the area and were assessed to have a high likelihood of containing unknown workings within the 10t limit; and
- Shallow workings within the Bryn seam from the Cwmtawe Colliery, within 10t of rock head.

The seams in this area dip predominantly north to south, the topography rises to the south increasing the relative depth of the seams below ground level and bedrock.

There are workings within the Bluers seam from the Duffryn Colliery, whilst the main workings do not directly interact with the track, an adit has been shown to be located on the north side of the proposed embankment.

Whilst no direct evidence of mine workings had been found during the 2021 ground investigation it is considered that underground workings are present in the area, due to the high concentration of adits and shafts in the vicinity of the proposed rail line.

3.6.3. Risk Zone C

Risk Zone C is located in the southwest of the site between the Nant Helen and Nant Helen Extension open casts. There was deemed to be a stability risk to the track due to:

- Lack of data coverage in the area, workings were identified within the Nine Feet and Brass; and
- Open-access data provided by the Coal Authority indicates that the stratigraphically higher “Four Feet” (Cornish), “Black” and “White” (Four Feet) seams were all worked in the areas, but to an unknown extent and are therefore considered a risk.

Workings within the Nine Feet and Brass Seams were at considerable depth and far greater than the 20 m of bedrock cover required to provide stability. Similarly, workings within the Four Feet and White Seams were found to be at a great depth (~80-115 m bgl) and therefore do not pose a significant risk.

Arup concluded that further ground investigation is required targeted around the location of BH05 to confirm that a zone of ‘core loss’ in BH05 does not represent unrecorded workings within the Soap Rider seams.

3.6.4. Risk Zone D

Risk Zone D covers the southeast section of the site in what will be the stabling yard and Washery. There was deemed to be a stability risk to the track due to:

- Lack of data coverage in the area;
- Shallow workings from the Dulais Colliery East Slant in the Peacock (Brass) seam, cross from Risk Zone A into the footprint of the Washery, within 10t of rockhead.
- Numerous mine entries relating to the Onllwyn Colliery; and
- The inferred presence of the “New”, “Grey”, “Rhyd” and “Upper Bluers” seam outcrops as shown on the Coal Authority Online Viewer [9].

No abandonment plans exist for workings in these inferred seams, but if worked can be expected to be shallow.

The GI encountered voids in this area which are interpreted as unrecorded mine workings potentially related to working of the New/Lower and Grey/Middle seams. Arup's recommendation was to carry out further intrusive investigations in the area to confirm the extent of the interpreted workings.

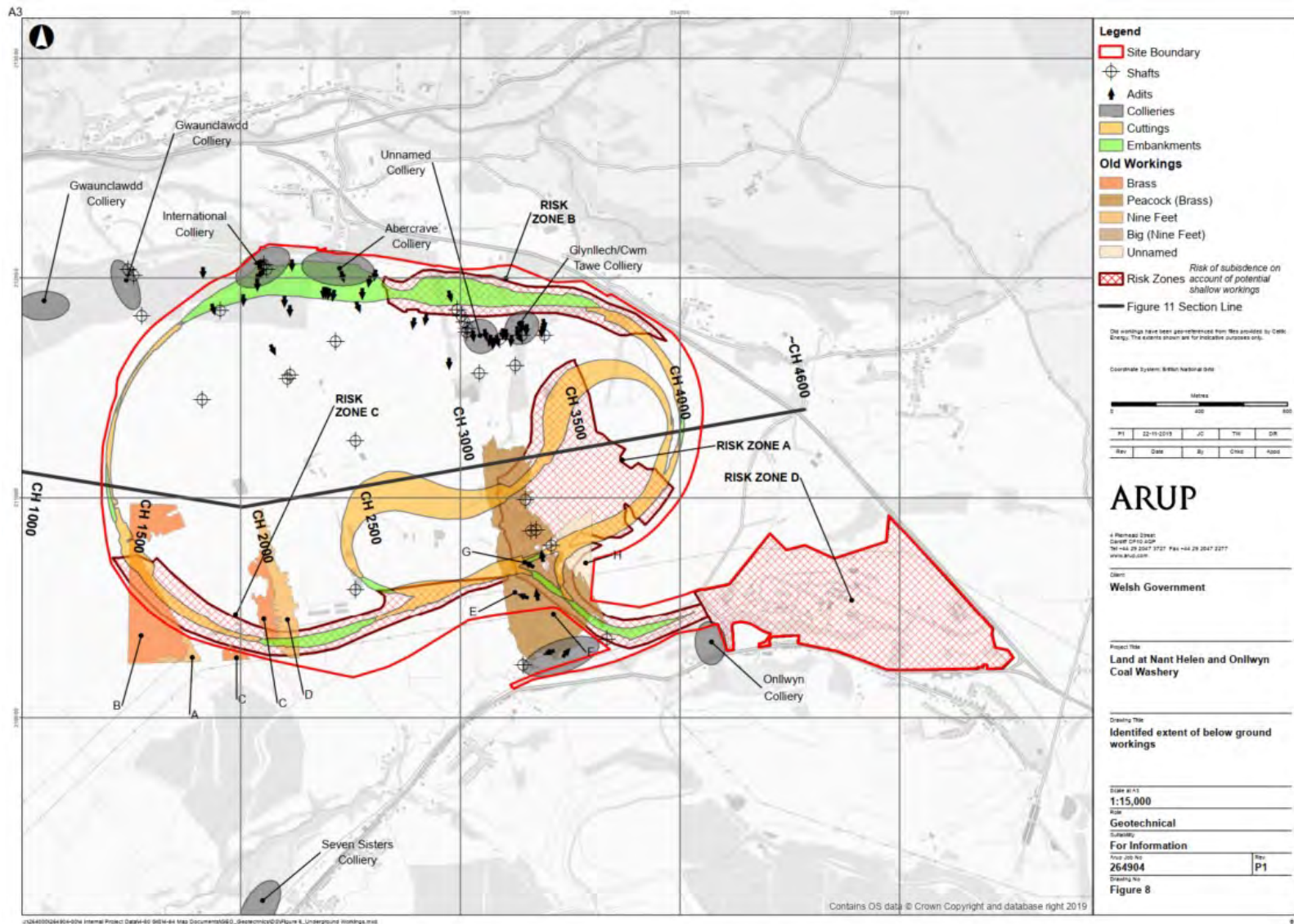


Figure 3-8 - Map of Arup risk zones from the Geotechnical and Geoenvironmental Desk Study by Arup [1].

3.7. Review of Preliminary Ground Investigation

A preliminary GI to investigate mine workings and entries, scoped by Arup was undertaken in between November 2021 and January 2022 by Quantum Geotech. The GI included cable percussive, sonic and rotary boreholes, trial pits and geophysical testing. Full details of the completed works are presented in the Arup GIR [3] and Quantum Factual Report [12] with a review provided in the main Atkins GIR.

3.7.1. Mine Entries Investigation

The GI investigated a select number of mine entries in the Washery and surrounding area, as shown on Figure 3-9. The investigation comprised magnetic, electromagnetic and microgravity geophysical surveying by Terradat, which identified a series of geophysical anomalies.

The works identified two geophysical anomalies (Z1-6 and Z1-9) in close proximity to the recorded locations of an adit (284210-035) and a shaft (284210-029) in the Washery (Figure 3-10). Both geophysical anomalies were subsequently investigated by trial pitting (TP37 and TP38), however, the intrusive investigations did not encounter any evidence of mine entries.

One additional adit is also recorded within the Washery (284210-023), however, this is beyond the extents of the geophysical survey area and has not been investigated by intrusive investigations.

The mine entries in vicinity of the main alignment were not targeted during the 2021/22 GI [12]. Conversations with Arup suggest this was due in part to limitations of proposed geophysical investigation techniques over thick sequences of fill material. Areas of bell pitting were also not investigated.

Further details of the geophysical anomalies encountered in the Washery are provided in the Terradat Geophysical Survey Report, which is included in Appendix IX of the Factual Report [12].

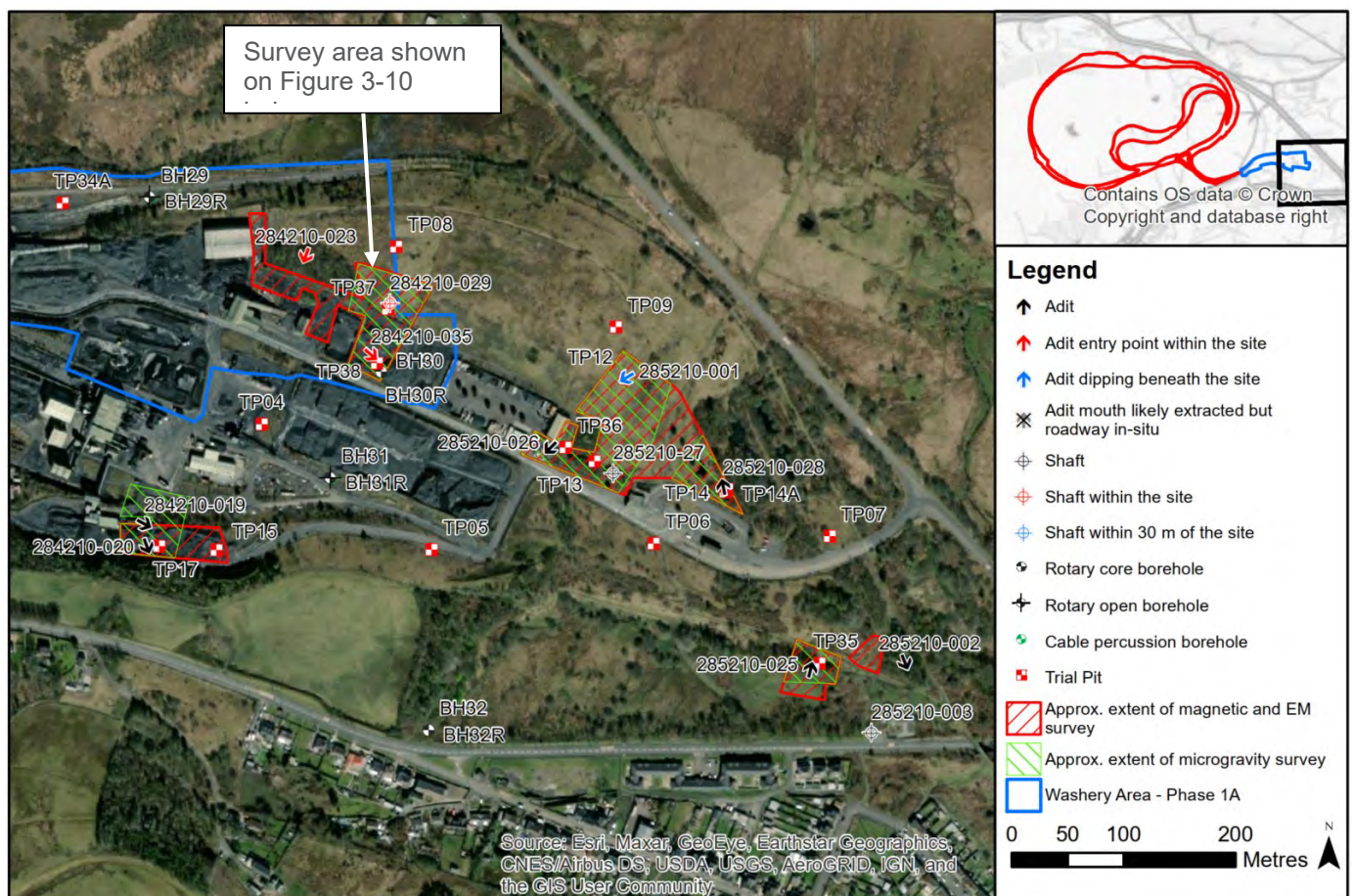


Figure 3-9 - Overview of geophysical survey conducted by Terradat.

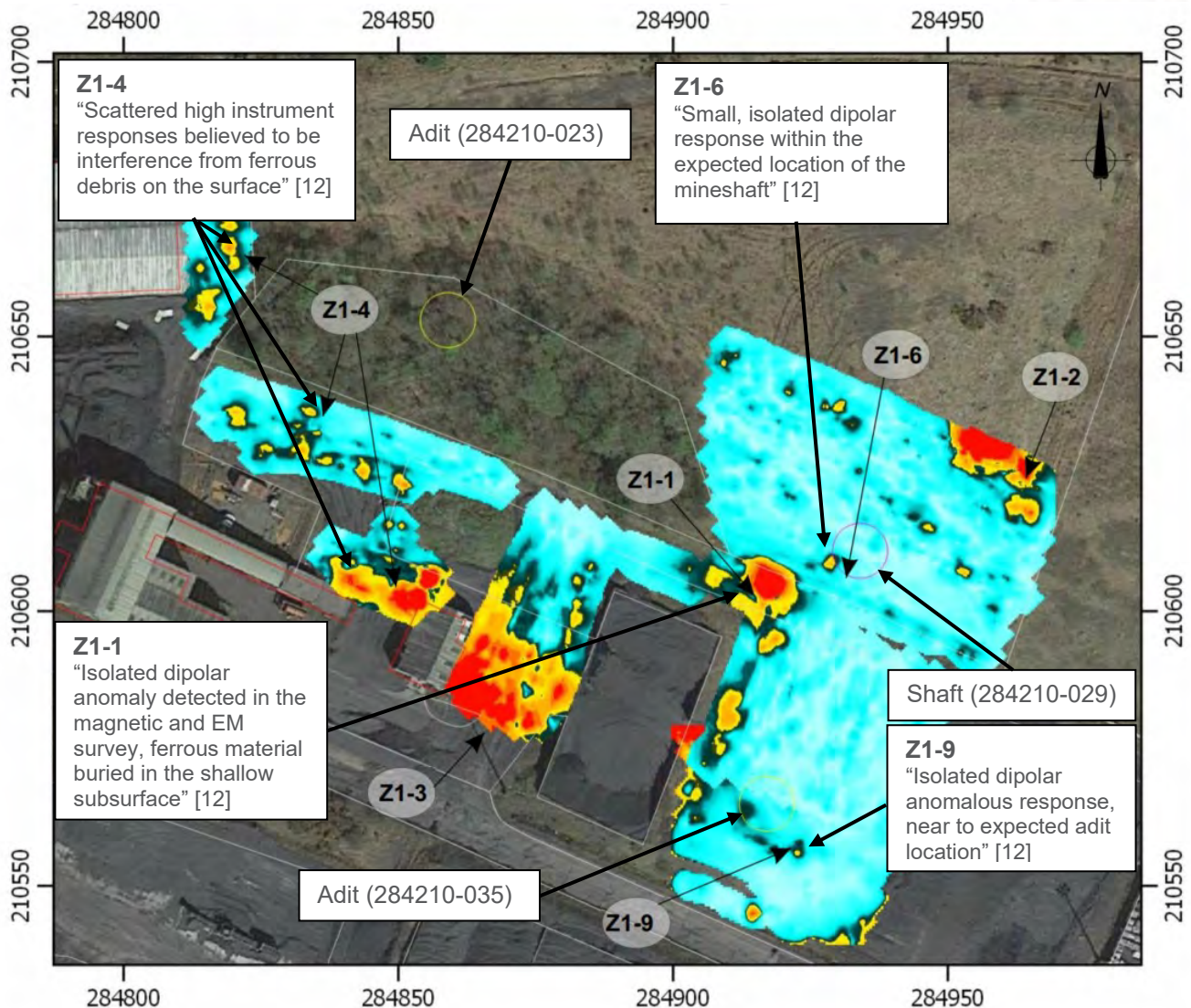


Figure 3-10 - Magnetic analytical signals indicative of significant ferrous metal anomalies, image taken from the Terradat Geophysical Survey Report [12].

3.7.2. Sub-surface Mine Workings

Sub-surface mine workings, as identified in the Desk Study [1] were targeted by the GI to better understand their extents, location and condition.

Table 3-3 and Table 3-4 indicate where coal and voids were encountered in the GI and interpretation of these features. For clarity boreholes where coal/voids are absent are not included in the tables. Borehole locations are shown on Figure 3-4 and in Drawings GCRE001-AWJV-00-XX-DR-GE-00014 to GCRE001-AWJV-00-XX-DR-GE-00018 in Annex A.

A number of boreholes did not reach target depth across the site due to difficult drilling conditions. A number of the borehole logs have limited geological descriptions due to drilling methods employed, there is therefore a reliance on drillers descriptions

The voids found in BH30R within the Washery were interpreted as unrecorded workings and would require further intrusive investigation to define the extent of workings. BH05 contains a “Zone of Actual Core Loss” in an area of the site where no known underground ground workings have occurred. BH18 “Zone of Actual Core Loss” has been attributed to potential mine workings relating to the Brass/Peacock Seam this is also the case for BH02, BH12 and BH17. BH15 has a small 0.3m section of core loss that has been attributed to potential workings within the Peacock (Brass) seam.

The preliminary GI confirms the presence of coal seams and open mine workings underlying the site within 10t of rockhead, thus posing a stability risk to the proposed scheme. It is concluded that further investigation to quantify the risk and define the remediation works are required.

Table 3-3 - Coal seams encountered in ground investigation

Borehole ID	Depth (m bgl)	Depth below rockhead (m bgl)	Thickness (m)	Log Description	Seam Interpretation
BH01	13.2	8.2	1.7	Weak coal (drillers description)	Nine Feet
BH04	17.0	13.1	0.2	Weak black coal, highly weathered to fine to medium gravel	Soap Rider
BH05	20.1	9.1	0.6	Weak to medium black coal with one discontinuity set	Soap Rider
BH06	27.0	25.0	0.8	Coal (drillers description)	Soap Rider
BH07	22.0	17.8	1.5	Coal (drillers description)	Soap Rider
BH10	24.0	23.3	1.2	Coal (drillers description)	Bryn/Gnapiog
BH11	10.7	5.3	0.6	Weak black coal	Grey/Middle
BH12	15.0	12.3	1.3	Coal (drillers description)	Peacock (Brass)
BH13	24.2	19.0	0.3	Weak black coal, highly weathered to fine to coarse angular gravel and cobbles	Peacock (Brass)
BH16	12.1	8.1	0.6	Weak black coal, highly weathered to fine to coarse angular gravel	Bluers
BH16	14.0	10.0	0.3	Weak to medium strong black coal	Bluers
BH26	36.2	1.0	1.0	Weak black coal	Rhyd
BH30R	13.7	7.1	0.6	Weak to medium strong black coal	Unnamed inferior seam
BH31R	16.0	5.6	1.1	Coal (drillers description)	Grey/Middle
BH31R	25.5	15.1	1.0	Coal (drillers description)	New/Lower
BH32R	11.8	7.5	3.2	Weak black coal, highly weathered to fine to coarse angular gravel and cobbles	Bluers
BH33R	28.1	23.2	0.8	Coal (drillers description)	Peacock (Brass)
BH34R	22.1	12.2	1.9	Weak coal (drillers description)	Peacock (Brass)

Table 3-4 - Summary of Evidence of Encountered in Ground Investigation

Borehole ID	Depth (m bgl)	Depth below rockhead (m bgl)	Thickness (m)	Log description	Seam/Working interpretation
BH02	19.7	15.8	0.7	Cavity (Drillers Description)	Brass/Peacock Dulais Colliery
BH02	20.4	16.5	9.6	Hard Drill - Loss of Returns (Drillers Description)	n/a
BH05	24.1	13.1	0.6	Actual Zone of Core Loss	n/a
BH12	5.7	3	1	Actual Zone of Core Loss - No recovery between 5.7 and 6.7mbgl. SPT sample grey gravelly Clay. Gravel is fine angular weak Mudstone	Brass/Peacock Dulais Colliery
BH12	7.9	5.2	0.3	Actual Zone of Core Loss	n/a
BH15	3.9	1.2	0.3	Actual Zone of Core Loss	Possible Brass
BH17	12.9	6.5	0.4	No Recovery	Brass/Peacock Dulais Colliery
BH18	30.7	6.7	1.2	Actual Zone of Core Loss - Recorded between 30.7 and 31.9mbgl very soft, no recovery, loss of returns	Brass/Peacock Dulais Colliery
BH18	35.4	11.4	2.9	Hard Drill - Drillers Description, No returns	n/a
BH18	38.3	14.3	0.7	Soft Drill - Drillers Description, No returns	n/a
BH18	39	15	2.3	Hard Drill - Drillers Description, No returns	n/a
BH18	41.3	17.3	1.1	Soft Drill - Drillers Description, No returns	n/a
BH18	42.4	18.4	2.8	Hard Drill - Drillers Description, No returns	n/a
BH30R	9.7	3.2	2	VOID	Grey/Middle [SWLCM]
BH30R	20.1	13.6	1	VOID	New/Lower [SWLCM]
BH30R	21.1	14.6	0.9	Soft Drill (Drillers Description)	n/a
BH30R	22.0	15.5	5.8	Hard Drill (Drillers Description)	n/a

3.7.3. Surface Mining

The GI targeted areas of known surface mining to assess the nature and competency of the backfill and inform the settlement risk. The information collected from these boreholes and the assessment is detailed within the main Atkins GIR.

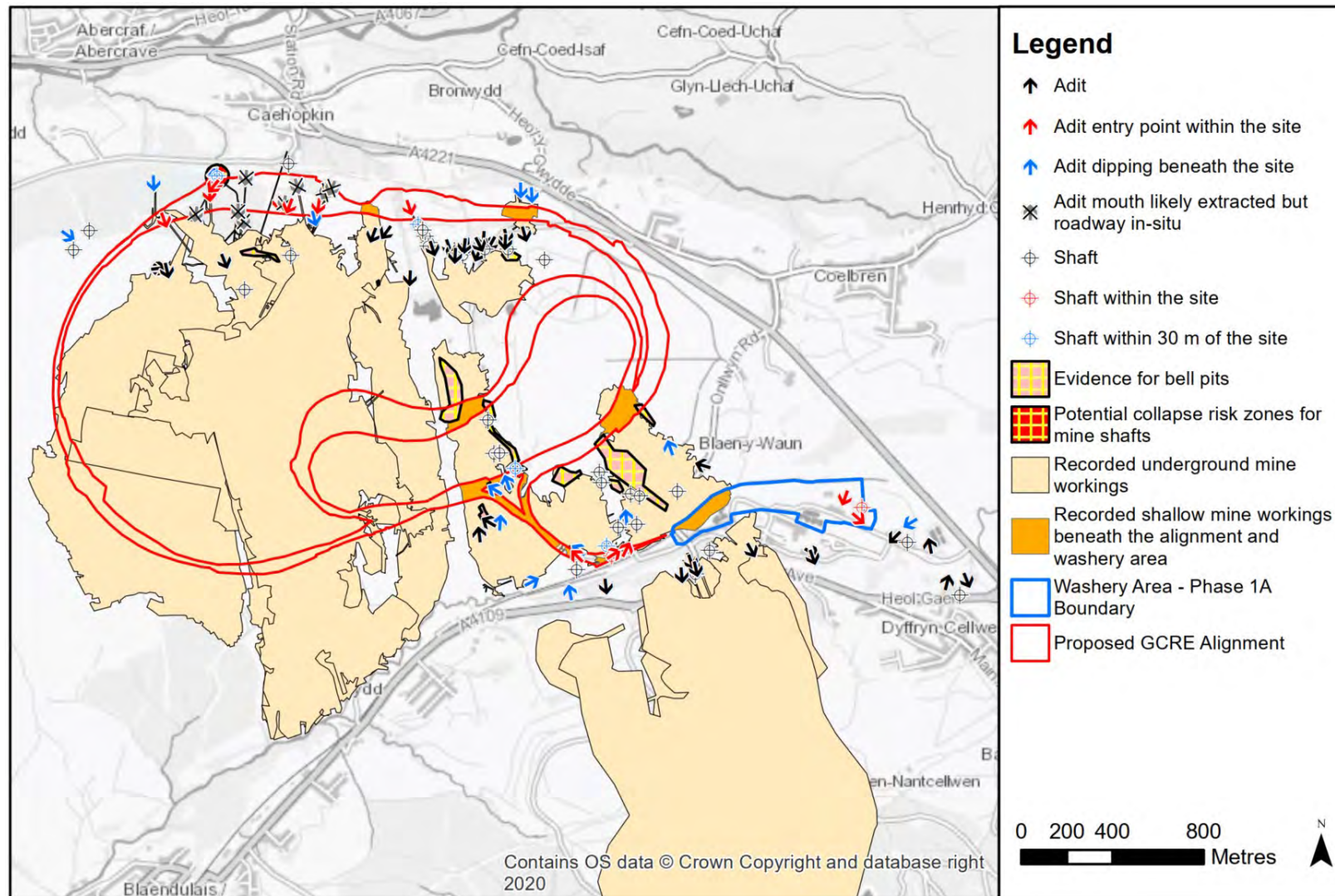
4. Assessment of Current Mining Risk

4.1. Overview

Drawing upon the information made available this section outlines Atkins' current understanding of the mining risks across the site at the time of writing and methodology for assessing the mining-related risks on site.

This information is then utilised to update and refine the Risk Zones identified by Arup to provide Atkins' 'Mining Risk Zones' (MRZ), with nine MRZs identified across the alignment and a further MRZ covering the Washery.

Drawings showing the mine entries and conjectured shallow workings across the site are included in Annex A and are discussed in detail throughout this Section (Drawings GCRE001-AWJV-00-XX-DR-GE-00014 to GCRE001-AWJV-00-XX-DR-GE-00018). A simplified hazard map (Figure 4-1) is included for reference.



* Refer to Drawings 5209796-MRR-DWG001-005 in Annex A for a more detailed illustration of the mining risks.

Figure 4-1 - Simplified overview map of the key mining risks.

4.2. Methodology used for Assessing Mining Risks

4.2.1. Assumed Height (Extraction Thickness) of Mine Workings

In line with the GCRE Employers Requirements [5] an assumed maximum extraction thickness of 2 m within workings (roadway height) is assumed. The required bedrock cover above all recorded workings and roadways to prevent void migration to surface is assumed to be 20 m based upon a cover equal to ten times worked seam thickness (10t rule) to prevent void migration after CIRIA C758D [17].

This assumption does not apply to the Nine Feet Seam, which is estimated to have a maximum extraction thickness of 3 m and therefore requires at least 30 m of bedrock cover under the 10t rule.

The design seam thickness shall be reviewed further as part of the remediation design process

4.2.2. Site Walkover

Atkins have prepared a proposed walkover plan to investigate surface features expected to be evidence of mining related instability and locate mine entries. At the time of writing this walkover has not yet been completed. The works will be completed as part of the remediation design process.

4.2.3. Mine Entries

The risk from mine entries was assessed using the following datasets.

- Purchased data from Groundsure [15]; key information including but not limited to historical borehole locations, historical OS maps and surface ground working extents
- Data provided by Arup; including mine entry locations in shapefile format, mine abandonment plans originally from the Coal Authority [12] and completion plans originally from Celtic Energy [13].
- Open-access data; including the Coal Authority interactive map [7], BGS GeoIndex [4], BGS historical maps [6] [5] and historical imagery [10], to corroborate the data and findings provided by Groundsure and Arup.
- GI data from the 2021/2022 investigation.

Shafts

Initially, all known or suspected shafts within 30m of the GCRE alignment or Washery were considered on the basis that their collapse zones may interact with the proposed permanent works. This was then expanded to include any additional locations to review all shafts.

The potential collapse zone for the shafts of interest was then assessed using guidance from CIRIA C758D [17] comprising the following equation:

$$C = z \tan(90 - \phi) + S + D$$

C = Potential collapse zone

ϕ = Internal angle of friction of overlying superficial deposits

z = Thickness of overlying superficial deposits

S = Shaft radius

D = Departure (location uncertainty)

A visual representation of a potential collapse zone for a shaft is shown in Figure 4-2. A summary of the parameters that were used to assess the potential collapse zone, and the rationale and assumptions for the chosen values, is included in Table 4-1.

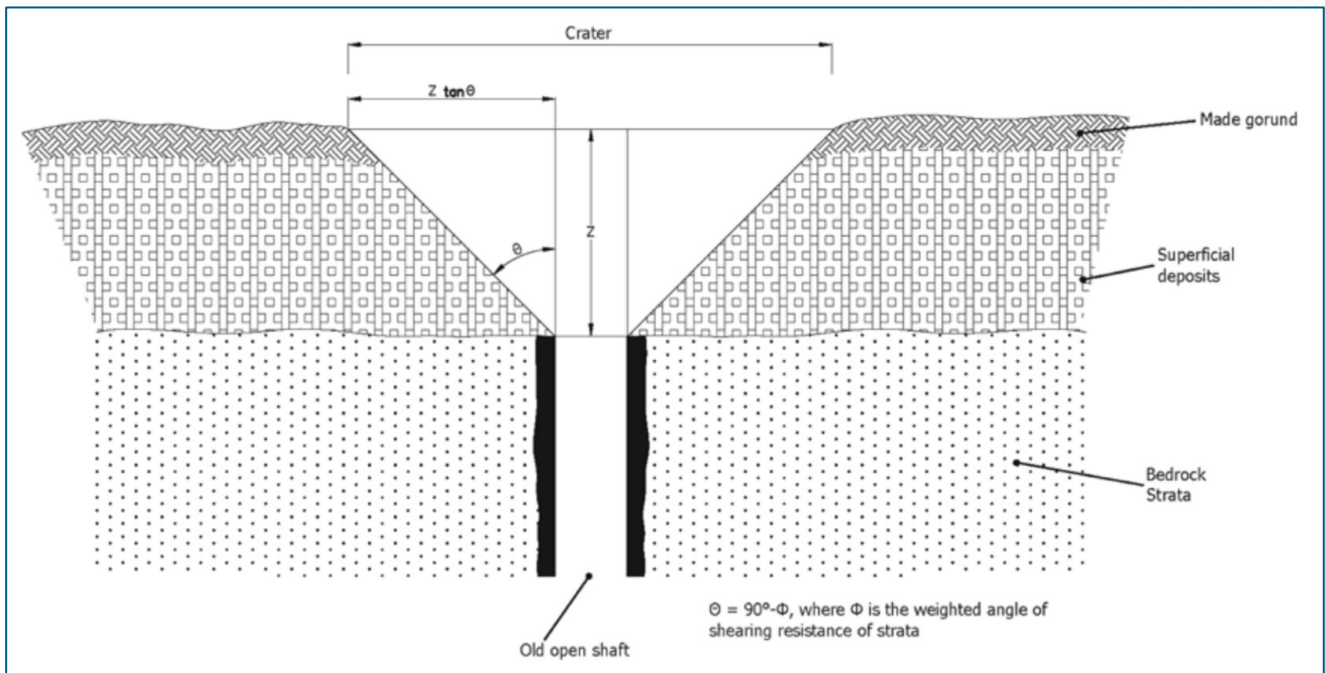


Figure 4-2 - Possible diameter of a crater due to shaft collapse (after Bell, 1978) [17].

Table 4-1 - Summary of parameters used in assessing the potential zone of collapse for shafts.

Parameter	Value(s)	Rationale and assumptions
Angle of shearing resistance (ϕ')	25 °	No strength testing was conducted as part of the GI by Quantum Geotech [13]. Atkins conservatively assumed a characteristic phi value of 25° this is less than that has been assumed in the main Atkins GIR (30° for cohesive Made Ground and 34° for granular). The value has been selected to reflect the unknown location of shafts.
Thickness of superficial deposits	2.60 – 34.00 m	The thickness of superficial deposits was assessed individually for each suspected shaft location based on the GI data from Quantum Geotech [13] and records of backfilling across the site [11]. Greater thicknesses of superficial deposits were typically associated with backfill material in the northwest of the site.
Shaft diameter	2.50 – 4.00 m	Atkins used the 'Assumed Shaft Diameter' and 'Actual Shaft Diameter' values from the Coal Authority Interactive Map to estimate the diameter of each shaft.
Shaft shape	Circular	No available information on the shape of the shafts on site was available, therefore, Atkins assumed a circular shaft shape for all shafts.
Departure	0 – 10 m	Atkins used the 'Departure' values from the Coal Authority Interactive Map to estimate the uncertainty in the location of the mine shafts. The values provided by the Coal Authority typically vary depending on the data source used to derive the mine entry locations; ranging from definitive positioning (0 m) to 1/2500 OS plans (5 m), mine abandonment plans (8 m) and geological plans (10 m).

Adits

Initially, all known or suspected adits within 30m of the GCRE alignment or Washery were considered. Adits represent a risk in the event of collapse of the adit portal, but also in the event of the collapse of the underground portion, or roadway, of the adit.

This assessment was expanded to include a review of all adits that are beyond the alignment but dip towards the alignment. Although located away from the alignment, roadways emanating from these adits are likely to extend beneath the alignment and therefore present an instability risk.

Atkins estimated the risk from these adits based on an assessment of the anticipated bedrock cover above the roadways at the point they pass under the alignment using available mine abandonment plans and GI data [12]. Finally, Atkins assessed the likelihood of the adits having been excavated and removed during past open cast mining activities. This assessment was based on a review of the opencast completion plans for the site and a comparison of this data against the levels for the adits shown on the available mine abandonment plans.

Bell Pits

Atkins assessed the risk from bell pitting by returning to the 1945 historical satellite imagery [16] as, included in the Desk Study (Figure 4-3) [1].

Atkins re-mapped the satellite imagery that showed evidence for bell pitting and then compared it against coal outcrops mapped by the BGS [6]. It was found that bell pits occurred where outcrops were mapped suggesting a correlation between this basic historical coal mining method and shallow coal seams.

This relationship was then used to infer additional locations where historical bell pitting may have occurred based on the presence of mapped outcrops. Using an approximate seam dip of 8 degrees SW [7] and an assumed maximum depth for bell pits of 12 m from CIRIA C758D [17]. The estimated distance down-dip of the coal seams in the south of the site where bell pitting could have occurred was then derived.

Collated information was then reviewed against the recorded opencast workings across the site to anticipate whether the bell pits have been extracted or remain in situ.

As shown in Figure 4-3, many of the bell pits overlap with the areas of opencast workings and expected to have been removed, however, some bell pits likely remain in situ, particularly in the northern part of the inner loop.

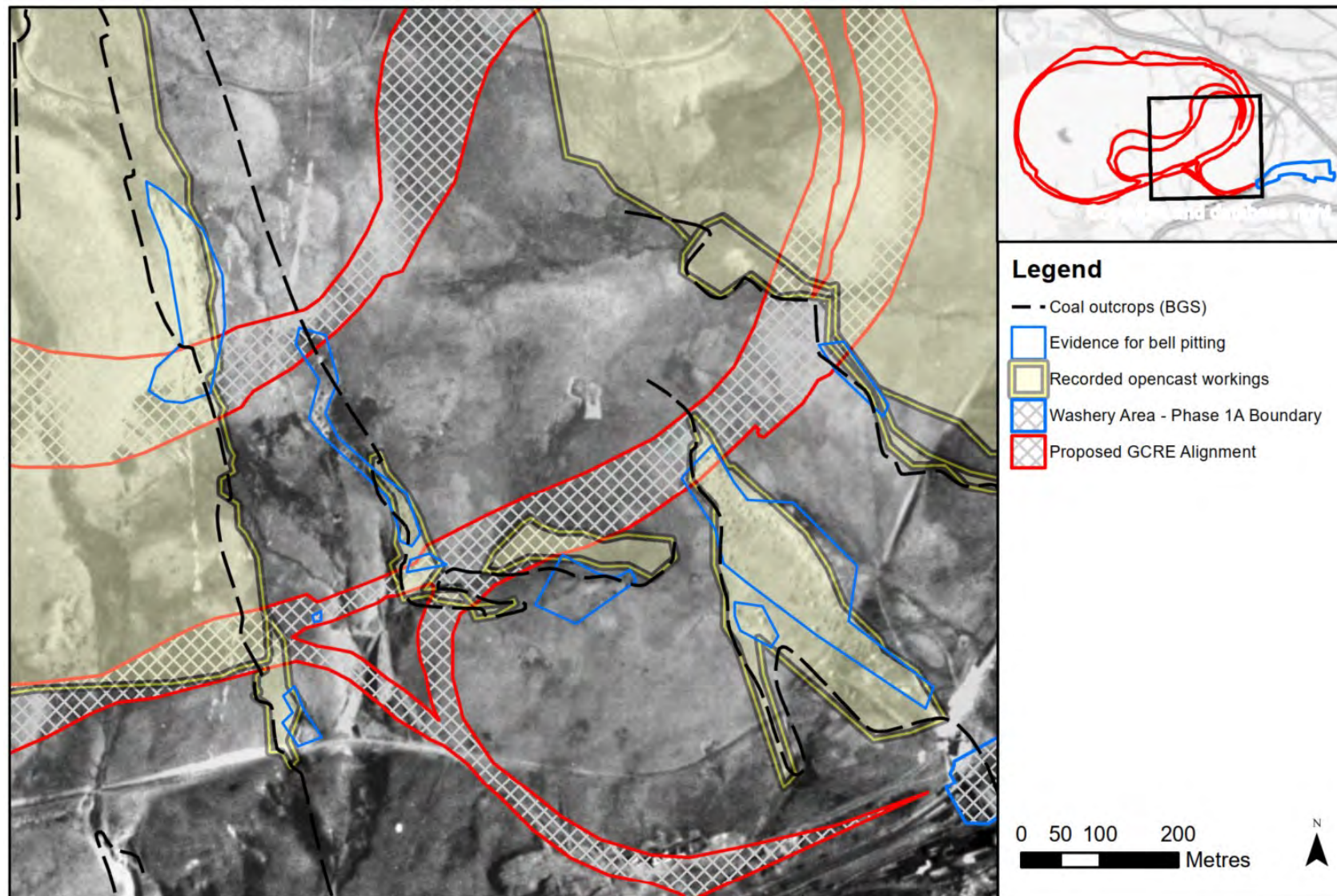


Figure 4-3 – Areas of potential evidence for bell pits shown on the 1945 historical satellite imagery compared against BGS coal outcrops and areas of recorded opencast workings.

4.2.4. Sub-surface Mine Workings

Assessment of risk posed by mine workings was completed by reviewing abandonment plans from underground workings and opencast working completion plans on site and in close proximity to the site. The topographic information from the abandonment plans were cross referenced to assess if and how the different methods of mining interacted, in order to determine to what degree underground workings have been removed due to opencast extraction. Where underground workings remain, there remains a risk of collapse causing subsidence at surface.

Atkins has also considered the likelihood of unknown workings occurring across the site, focusing on areas of known adits with no attached abandonment plans as well as evidence of voids, actual core loss and interpreted mine working from the GI.

Risk attached to the backfilling of the opencast workings on site will be covered in the main GIR.

4.3. Mining Risk

4.3.1. Mine Entries

The mine entries on site are generally clustered around the northern embankments of the outer loop, the junction in the southeast, the track leading to the Washery, and the Washery itself. Within these areas, Atkins has identified a total of four shafts with potential collapse zones that interact with the site and 29 adits that either lie within the proposed alignment or Washery (14 No.) or adits with roadways dipping beneath the proposed alignment or Washery (15 No.). Some of these mine entries can be observed from satellite imagery [18]

Of the 29 adits, Atkins identified six adits that are likely to have been removed during the operation of the Abercraf Opencast Colliery in the northwest. However, the underground adit roadways associated with these adits are likely to remain in place with insufficient bedrock cover. A summary table of shafts calculated to pose a stability risk to site is provided in Table 4-2, a full table of all shafts assessed is included in Annex B. A summary table of adits assessed to pose a stability risk to the site is provided in Table 4-3, a full table of all adits assessed is included in Annex B. A series of drawings showing the risk from shafts and adits across the site are provided in Annex A (Drawing 5209796-MRR-DWG001-005).

4.3.2. Underground Mine Workings

Abandonment plans indicate that the site was extensively worked from the 19th century until the early to mid 20th century with the majority of the underground workings being located to the south-west, south and south-east and smaller workings located in the northeast. A total of eight underground collieries are recorded on site working a number of coal seams, the most extensively worked are the Four Feet, Nine Feet and the Peacock (Brass) seams. A summary of these workings is included in Table 4-4.

An assessment of where opencast workings have removed sufficient bedrock to bring deep underground workings within 20-30 m of the base of the opencast and as such pose a risk of potential collapse and void migration following the 10t rule was also undertaken. This assumes that voids would migrate through the overlying backfill in the restored opencast without bridging or other wise stopping before reaching surface.

A series of drawings showing the risk from underground workings across the site are provided in Drawings 5209796-MRR-DWG001-005 in Annex A. Four east-west trending geological cross-sections through the recorded mine workings are provided in Drawing 5209796-MRR-DWG006 in Annex A.

4.3.3. Opencast Mine Workings

Opencast working of coal has been undertaken via the Abercraf, Onllwyn and Nant Helen pits across the site. Backfill placed in reclaimed opencasts is likely to experience settlement, as already recorded on site and documented in the Arup GIR [3]. Settlement of backfill in opencasts is considered in the main Atkins GIR, therefore it is not assessed here. Although it is noted that differential settlement is likely across the transition between unexcavated natural ground and backfill.

CIRIA C758D [17] states that instability of the opencast excavation highwall due to loosening of natural deposits during excavation and over steepening of faces may lead to later failure in the area of the former highwall. It is expected that further GI will be recommended in the main Atkins GIR where the alignment crosses the transition from natural ground to backfill.

4.3.4. Mine Gas

Ground gas monitoring was undertaken over a three-month period from January to April 2022, following the completion of the most recent GI [12]. This comprised monitoring 13 locations, including seven locations along the inner/outer loop and six locations within and around the washery area.

The ground gas assessment in the GIR by Arup [3] generally considered gas from Made Ground, peat and combusting strata and did not focus on the risks from mine gasses. As such the presence, or absence, and composition of mine gases is currently undefined.

Mine gas may migrate through underground mine workings towards surface. Where cuttings proposed as part of the scheme expose or nearly expose mine workings there is a risk of any mine gas present migrating into these cuttings. This should be assessed during any further investigation and/or remediation works. Mitigation measures should be followed to reduce the risk from mine gas migration in accordance with Coal Authority guidance and industry standards.

4.3.5. Minewater

To allow for opencast mining, the groundwater has been artificially depressed by pumping to prevent flooding of the opencast workings. On completion of the workings, it is understood that the pumps were switched off allowing the groundwater to naturally stabilise.

It is understood from communication with Celtic Energy that rebound has stabilised at between 100-120m AOD. Deep underground workings and adits draining to the River Tawe are believed to be responsible for maintaining the groundwater level at this elevation.

No boreholes were advanced deep enough to measure groundwater during the GI, therefore it has been assumed in agreement with the client, that groundwater will remain at this level (100-120m AOD).

Further review of hydrogeological data is to be included as part of the main Atkins GIR, a more detailed assessment of the risk due to minewater is required during remediation design.

Table 4-2 - Summary of mine shafts calculated to pose instability risk to the site.

Mine Entry ID	Easting (m)	Northing (m)	Distance from alignment/ washery area (m)	Estimated thickness of superficial deposits (m)	Phi (°)	Shaft diameter (m)	Departure (m)	Estimated potential collapse radius (m)	Does the estimated potential collapse zone overlap with the proposed development?	Treatment Records
282212-009	282108	212066	7	34	25	1.25	8	82	Yes	Treated, no further details.
283210-005	283838	210401	0 (below)	5	25	2	0	13	Yes	Treated 09/03/1987, no further details.
283210-029	283414	210785	5	2.7	25	1.25	8	15	Yes	Treated, no further details.
284210-029*	284934	210611	0 (below)	10	25	1.25	10	33	Yes	No records of treatment.

* Noted that geophysical anomalies in proximity to this mine entry were investigated by intrusive ground investigation, the location could not be confirmed

Table 4-3 - Summary of adits expected to pose instability risk to the site, ordered by location from northwest to southeast.

Mine Entry Ref.	Easting	Northing	Azimuth	Approximately distance from alignment (m)	Direction relative to alignment / Washery Area	Adit Portal Level (mAOD)	Adit Level below alignment/ washery area (mAOD)	Track Level Above Adit (mAOD)	Anticipated Status of Adit Mouth	Risk Comments
281211-008	281453	211804	126	185	Towards alignment	N/A	N/A		Unknown	Directed towards the alignment. May intersect the Nant Helen extension area of opencast. No mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the alignment.
281212-009	281829	212034	178	118	Towards alignment	N/A	N/A	235*	Unknown	Directed towards the alignment. Mine plans shown that is located within an opencast area, but no levels are indicated for this adit on the mine plan. Risk of subsidence / void migration below the alignment.
281211-061	281875	211872	160	Below	N/A	226.00		240*	In situ	Located below the alignment. Opencast working plans suggest the adit has not been extracted. Risk of subsidence / void migration below the alignment.
282211-009	282014	211899	188	Below	N/A	219.14		236*	Extracted	Located below the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Risk of subsidence / void migration below the alignment.
282211-001	282075	211987	175	Below	N/A	208.25		208*	In situ	Located below the alignment and beyond known opencast working areas. Risk of subsidence / void migration below the alignment.
282212-012	282090	212020	219	Below	N/A	200.48		205*	In situ	Located below the alignment. Opencast working plans suggest that the mouth of the adit is likely to have been excavated by the roadways likely remain in place. Risk of subsidence / void migration below the alignment.
282212-001	282101	212035	219	Below	N/A	N/A		207*	Unknown	Located below the alignment. No mine plans are available to inform location/level/extent of this adit. The adit is within the Nant Helen opencast area. Risk of subsidence / void migration below the alignment.
282212-006	282097	212073	266	15	Parallel to alignment	N/A	Not dipping below the alignment	N/A	Unknown	Orientated parallel to the alignment approximately 15m from the alignment. Adit located in an opencast working area but no levels are available on plans to inform if the adit has been extracted. Risk of subsidence / void migration below the alignment due to uncertainty of the area of influence of the adit / accuracy of mine plan.
282212-002	282233	212059	186	Below	N/A	199.59		203*	Extracted	Located below the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Risk of subsidence / void migration below the alignment.
282211-004	282379	211948	180	Below	N/A	N/A	N/A	230*	Unknown	Located below the alignment. No mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the alignment.
282211-005	282403	211946	187	Below	N/A	217.10		229*	Extracted	Located below the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Risk of subsidence / void migration below the alignment.
282211-006	282422	211934	201	Below	N/A	N/A		229*	Unknown	Located below the alignment. No mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the alignment.
282212-003	282459	212023	165	Below	N/A	185.93		195*	Extracted	Located below the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Risk of subsidence / void migration below the alignment.

Mine Entry Ref.	Easting	Northing	Azimuth	Approximately distance from alignment (m)	Direction relative to alignment / Washery Area	Adit Portal Level (mAOD)	Adit Level below alignment/ washery area (mAOD)	Track Level Above Adit (mAOD)	Anticipated Status of Adit Mouth	Risk Comments
282211-008	282550	211934	188	Below	N/A	217.10		227*	In situ	Located below the alignment. Opencast working plans suggest the adit has not been extracted. Risk of subsidence / void migration below the alignment.
282211-010	282582	211994	210	Below	N/A	201.17		208*	Extracted	Located below the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Risk of subsidence / void migration below the alignment.
282212-004	282609	212014	204	Below	N/A	207.31		208*	Extracted	Located below the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Risk of subsidence / void migration below the alignment.
282211-016	282951	211927	162	Below	N/A	222.70		231.71*	Unknown	Located below the alignment. No opencast working plans are available for this area to assess if this adit was extracted or remains in-situ. Risk of subsidence / void migration below the alignment.
283211-017	283252	211738	129	137	Towards alignment	254.81	252.07	261	Unknown	Directed towards the alignment. Abandonment plan shows the roadway intersecting with the site. If adit extends into base of cutting then expected <10m of bedrock cover below the alignment which posing a risk of subsidence / void migration.
283211-043	283257	211765	153	109	Towards alignment	N/A	N/A	261	Unknown	Directed towards the alignment. No mine plans to inform location/level/extent of this adit are available. Risk of subsidence / void migration below the alignment if running parallel to adit 283211-043.
283211-037	283376	211800	165	75	Towards alignment	N/A	N/A	261	Unknown	Directed towards the alignment. No mine plans to inform location/level/extent of this adit are available. Risk of subsidence / void migration below the alignment.
283211-040	283487	211981	177	45	Towards alignment	216.21	204.78	230*	Unknown	Directed towards the alignment. Abandonment plan shows that intersects at the end with the alignment. Potential for <20m of bedrock cover below the alignment which may pose a risk of subsidence / void migration.
283210-026	283325	210691	302	19.5	Towards alignment	243.84	243.84	249	In situ	Directed towards the alignment. Shown on mine abandonment plan, but no indication of depth beneath alignment is available. Expected <20m of bedrock cover below the alignment which may pose a risk of subsidence / void migration.
283210-013	283379	210725	341	7.9	Towards alignment	241.84	241.84	249	In situ	Directed towards the alignment. Expected <20m of bedrock cover below the alignment which may pose a risk of subsidence / void migration.
283210-012	283348	210547	4	70	Towards alignment	N/A	N/A	247	In situ	Directed towards the alignment. No mine plans to inform location/level/extent of this adit are available. Located out of opencast working areas of Onllwyn opencast. Risk of subsidence / void migration below the alignment.
283210-032	283686	210400	315	Below	N/A	234.31		239	In situ	Located below the alignment. Located outside of working areas of Onllwyn opencast.
283210-015	283691	210426	307	6/ Below	N/A	232.64		239	In situ	Shown below the alignment on the mine abandonment plans. Located outside the working area of Onllwyn opencast. Risk of subsidence / void migration below the alignment.
283210-033	283488	210287	62	178	Towards alignment	N/A	N/A	234	In situ	Mine abandonment plan shows the roadway dipping beneath the alignment. Located beyond the opencast working areas of Onllwyn opencast. Risk of subsidence / void migration below the alignment.
283210-036	283654	210242	349	145	Towards alignment	N/A	N/A	236	In situ	Directed towards the alignment. No available mine plans to inform location/level/extent of this adit are available. Located out of opencast

Mine Entry Ref.	Easting	Northing	Azimuth	Approximately distance from alignment (m)	Direction relative to alignment / Washery Area	Adit Portal Level (mAOD)	Adit Level below alignment/ washery area (mAOD)	Track Level Above Adit (mAOD)	Anticipated Status of Adit Mouth	Risk Comments
										working areas of Onllwyn opencast. Risk of subsidence / void migration below the alignment.
283210-022	283846	210408	56	Below	N/A	228.73		228*	In situ	Located below the alignment. Located out of opencast working areas of Onllwyn opencast. Risk of subsidence / void migration below the alignment.
283210-023	283902	210428	26	Below	N/A	194.26		227*	In situ	Located below the alignment. Located out of opencast working areas of Onllwyn opencast. Potential for <20m of bedrock cover below the alignment which may pose a risk of subsidence / void migration, risk of subsidence / void migration below the alignment.
283210-003	283900	210571	355	128.3	Towards alignment	N/A	N/A	250	Unknown	Directed towards the alignment. Onllwyn completion plans shows that the adit may dip towards opencast working areas, but no mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the alignment, although possible that adit ends before reaching alignment.
284210-031	284093	210877	341	220	Towards alignment	N/A	N/A	253	Unknown	Directed towards the alignment. Onllwyn completion plans shows that the adit may dip towards opencast working areas, but no mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the alignment.
284210-023	284859	210653	200	Below	N/A	N/A	N/A	Assume current ground level	Unknown	Located below washery area. No mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the washery area.
284210-035	284917	210565	131	Below	N/A	N/A	N/A	Assume current ground level	Unknown	Located below the washery area. No mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the washery area. Noted that geophysical anomalies in proximity to this mine entry were investigated by intrusive ground investigation, the location could not be confirmed
285210-001	285145	210544	239	155	Towards washery area	N/A	N/A	Assume current ground level	Unknown	Directed away from the washery area but potential for adit roadway to pass beneath washery area. No mine plans are available to inform location/level/extent of this adit. May pass to south of The Washery area.

*Elevation at base of embankment at nearest point

Table 4-4 – Summary of Mine Workings Below Track

Colliery	Workings	Atkins Mining Risk Zone Number	Assumed Extraction Thickness (m)	Approximate level of workings below track from abandonment plans (m AOD)	Rockhead level	Approximate track level above mine workings (m AOD)	Required bedrock thickness [10t] (m)	Expected Bedrock Thickness	Workings occur within 10t of bedrock	Opencasting	Risk comment
Abercraf	Four Feet (Old Workings)	MRZ1	2	Unknown, nearest level is 197 (estimated)	Not proven, log of BH21 suggests 195 m AOD (base of opencast backfill)	236 (base of embankment)	20	~0	Possible	Opencasting taken place to 217m AOD	Potential risk from Four Feet Old Workings where these underlie the track. Discrepancy in level information across mining plans however possible that these old workings remain in place just below rock head level.
	Four Feet	N/A	2	217	N/A	N/A	20	N/A	N/A	Opencasting has likely removed these workings which occur in the centre of the site	Main workings are located outside of the alignment footprint. Adits used to access these workings do pose risk, covered in Table 4-3
	Cornish			190							
	Nine feet			192							
	Brass			Unknown							
	Nine Feet	MRZ2	3	206	214m AOD (proven in BH08)	232 - 237	30	8	Yes	None undertaken	Nine Feet workings underly track, recorded levels on mine plans indicate that there is risk of void migration to surface due to mine workings being within the 10t zone. BH08 did not encounter coal or workings to 194m AOD.
	Nine Feet	MRZ5	3	Between 120 - 135	Not proven by GI, fill proven to 220m AOD. Rockhead assumed to be at base of opencast (159m - 190 AOD)	260	30	29 - 55	Yes	Opencasting undertaken to between 159 – 190 m AOD (Nant Helen Main)	Opencasting to extract the Harnlow seam has pushed rock head down to within 10t of Nine Feet seam, potential for void migration to occur. Due to variability in elevation of worked Harnlow and Nine Feet seams this may not occur across the entirety of the seam. 10t limit increased to 30m for this seam as extraction thickness recorded to be 3m in seam. Assume void migration through >100 of overlying fill occurs.
International	Four Feet	N/A	2	Unknown	Not proven by GI, BH21 indicates that workings extend down to a depth of 195m AOD	235 - 241	20	N/A	N/A	Opencasting appears to have removed workings	No perceived risk based on reviewed information
	Nine Feet		2	Unknown	Unknown	235 - 237	20	N/A	Unknown	N/A	Limited information available, no GI coverage or abandonment plans covering this area.
	Brass										
Duffryn	Bluers	MRZ3b	2	240	238m AOD proven in nearby BH26 (~125m away)	280 (top of cutting)	20	~0	Yes	None	Workings recorded occur at or coincident with rock head level, therefore within 10t limit. BH26 indicates coal immediately below rock head.

Colliery	Workings	Atkins Mining Risk Zone Number	Assumed Extraction Thickness (m)	Approximate level of workings below track from abandonment plans (m AOD)	Rockhead level	Approximate track level above mine workings (m AOD)	Required bedrock thickness [10t] (m)	Expected Bedrock Thickness	Workings occur within 10t of bedrock	Opencasting	Risk comment
Cwmtawe	Bryn	MRZ4	2	200 - 204	236m AOD proven in BH10	233 (base of embankment)	20	32 - 36	Potential	None	Although depths of workings and rockhead indicate sufficient rock head cover coal was encountered at 213m AOD in BH10 very close to 10t, this area should be further investigated.
Dulais West Slant	Brass/Peacock	MRZ6a	2	244 (west side of workings) 268 (east side of workings)	Proven at 251m AOD in BH18 (west) Proven at 270m AOD in BH17 (east)	262 – 264 west to east (base of cutting)	20	6 - 7	Yes	None	Abandonment plan records indicate that workings likely to be exposed in cutting in the east and within 10t limit in the west. Zone of core loss recorded in BH18 at 244m AOD (coincident with recorded working depth in the west), between 229-239m AOD no recovery was possible. BH17 encountered zone of no recovery between 263.5-264m AOD.
	Brass/Peacock	MRZ6c	2	Levels vary from 224 to 234. Large number of old workings recorded without levels.	Proven at 247m AOD in BH15 (north) Proven at 234m AOD in BH02 (south) Proven at 223m AOD in BH01 (east)	226 – 255 (base of embankment)	20	~0 - 23	Yes	None	Workings recorded to occur within 10t limit – risk of void subsidence. BH15 – actual zone of core loss at 246m AOD BH02 – cavity at 218m AOD, no recovery down to 208m AOD BH01 – coal recorded at 215m AOD
Dulais East Slant	Brass /Peacock	MRZ6b	2	236 (west side of workings) 257 (east side of workings)	Proven at 254m AOD in BH14 (west) Proven at 254m AOD in BH13 (centre) Proven at 246m AOD in BH12 (east)	251 – 253 west to east (base of cutting)	20	~0 - 18	Yes	None	Abandonment plan records indicate that workings likely to be exposed in cutting in the east and within 10t limit in the west. Noted that levels of workings from plans in east exceed current bedrock level. Coal encountered at 243m AOD in BH12 Coal encountered at 235m AOD in BH13
		MRZ7	2	204 (west side of workings) 226 (east side of workings)	Proven at 226m AOD in BH33R (west) Proven at 223m AOD in BH34R (south), 25m south of area Proven at 232m AOD in BH30R (east) Proven at 226m AOD in BH29R (east)	230	20	~0 – 22m	Yes	None	Workings recorded to occur within 10t limit – risk of void subsidence. No GI undertaken within these workings BH33R encountered coal at 202m AOD BH34R encountered coal at 210m AOD
Unknown Workings	New / Lower		2	No plans available – unknown workings			20				No records of workings on plans, potential conjectured from outcrop. BH30R encountered coal at 225m AOD and void at 220m AOD Potential for voiding within 10t limit

4.4. Revised Mining Risk Zones (MRZs)

This section outlines the updated MRZs based on Atkins' understanding of the key mining risks across the site at the time of writing this report.

Atkins identifies a total of nine MRZs across the track alignment and one MRZ covering underlying the Washery. Some of the MRZs detailed in this section are similar to the 'Risk Zones' outlined in the previous reporting by Arup [1] [3].

Table 4-5 - Comparison of mining risk zones

Atkins MRZ	Arup Risk Zone	Comment
MRZ 1	N/A	Assessed that mine workings and entries have not been removed by opencasting
MRZ 2	Risk Zone B	Refinement of Risk Zone B
MRZ 3a	Risk Zone B	Refinement of Risk Zone B, for the adit called 'Duffryn's Level' in the north of the outer loop
MRZ 3b	Risk Zone A	Refinement of Risk Zone A, along the northern extent of the inner loop to highlight risks of shallow workings in the Duffryn Colliery.
MRZ 4	Risk Zone B	Refinement of Risk Zone B
MRZ 5	N/A	Assessed that opencast workings has pushed rockhead level to within 10t of expected workings, along the west of the inner loop to highlight risks from deep workings of the Abercraf Nine Feet Seam, which were raised relative to rockhead during opencast workings of the Harlow Seam
MRZ 6a	Risk Zone A	Refinement of Risk Zone A
MRZ 6b	Risk Zone A	Refinement of Risk Zone A
MRZ 6c	Risk Zone A	Refinement of Risk Zone A
MRZ 7	Risk Zone D	Refinement of Risk Zone D

The MRZs for the project are presented in Table 4-6. Drawings 5209796-MRR-DWG001-005 in Annex A illustrates the Mining Risk Zones across the site. Geological cross-sections through the mine workings are provided in Drawing 5209796-MRR-DWG006 in Annex A.

Table 4-6 - Mining Risk Zones.

Mining Risk Zone (MRZ)		Description of Extents and Overview of Risks	Details on Mine Workings	Details on Mine Entries
1		MRZ 1 is located in the northwest of the outer loop and extends for approximately 1 km along the track, from the potential interaction with Mine Entry 281211-008 in the west to the Mine Entry 282212-004 in the east. There is a stability risk posed by adits, shafts and shallow mine workings.	Older workings of the Four Feet Seam from Abercraf Colliery with limited level information recorded as underlying this risk zone. Opencast working may have removed Four Feet workings based on the depth of backfill encountered in BH21 Nearest level indicator for old workings is 197m AOD, base of backfill is 195m AOD suggesting that workings may have been removed but could also be present at or around rockhead level, therefore within 10t limit and present risk of void migration.	Total of 14No. adits within 30 m. 6 No. adits are believed to have been removed by opencast workings and 8 No. adits are believed to be in-situ. Numerous adit roadways lie beneath the site, some of which were likely not removed during the open cast workings and therefore may remain in-situ. The elevations of these roadways are not shown on the mine abandonment plans and may have < 20 m of bedrock cover beneath the alignment. An additional 2 No. adits located 118 m and 185 m northwest of the alignment have recorded dips towards the alignment but have no associated mine abandonment plans. As such it has not been possible to determine if these extend under the alignment but there is potential for this. One shaft is within 30 m. This shaft’s potential collapse zone is estimated to have an 80 m overlap with the embankment in the north of the site. This shaft was treated at some point in the past but there is no available information on the date of treatment [7].
2		MRZ 2 is located in the north of the outer loop and extends for approximately 75 m along the track and is defined by the extents of the shallow workings of the Abercraf Colliery. There is a stability risk posed by shallow mine workings.	Underground workings are expected to be present in this location relating to the working of the Nine Feet seam from the Abercraf Colliery Records indicate mine workings at 206m AOD within 10t limit of rock head at 214m AOD presenting risk of void migration. Noted that BH08 drilled in this area did not encounter coal or evidence workings to 194m AOD.	No mine entries are recorded within 30 m of MRZ 2.
3	a	MRZ 3a is located in the north of the outer loop and extends for approximately 45 m along the track. This risk zone includes one SE-dipping mine entry, which is associated with the Duffryn Colliery 90 m southeast. There is a stability risk posed by adits and underground roadways with <20 m of bedrock cover.	No underground workings are expected to be present at this location	1 No. adit (annotated as ‘Duffryn level’) beneath the alignment and dips southeast towards the Duffryn Colliery, which lies approximately 90 m south of the alignment boundary in this area. The elevations of the roadway associated with this adit are not shown on the mine abandonment plans and are likely to have < 20 m of bedrock cover beneath the alignment based on the location of the adit mouth. 1No. shaft is recorded approximately 22 m south of the site boundary but is not estimated to have a potential collapse zone that overlaps with the embankment in this region. This shaft has no records of treatment.
	b	MRZ 3b is 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. There is a stability risk posed by shallow mine workings.	Underground workings are expected to be present in this location relating to the working of the Bluers seam from the Duffryn Colliery. Workings are recorded at 240m AOD coincident with rockhead at 238m AOD and therefore within 10t limit, BH26 encountered coal immediately below rockhead	No mine entries are recorded within 30 m of MRZ 3b.
4		MRZ 4 is located in the northeast of the outer loop and extends for approximately 150 m along the track. This risk zone is defined by the extents of the shallow workings of the Cwmtawe Colliery. There is a stability risk posed by adits and shallow mine workings.	Underground workings are expected to be present in this location relating to the working of the Bryn seam from the Cwmtawe Colliery Recorded levels of workings (220-204m AOD) and rockhead encountered in BH10 (236m AOD) would indicate sufficient bedrock cover to prevent void migration. BH10 encountered coal at 213m AOD – edge of 10t limit. BH10 is the only borehole drilled in location and is located at the edge of risk zone.	2No. adits are recorded approximately 70 m and 50 m north of the embankment and dip beneath the rail loop embankment. Roadways associated with this adit are expected to be at 205 m AOD when they pass under the alignment with a level of 230 m AOD (base of embankment) with rockhead at 225 m AOD. Applying the 10t rule, there is a comparatively low risk of void migration from the workings to track level. No shafts are recorded within 30 m of MRZ 4.
5		MRZ 5 is 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 Harlow Seam. There is a stability risk posed by deep workings.	The Abercraf colliery worked the Nine Feet seam from underground workings below the later Nant Helen opencast, in this are the opencast did not work the Nine Feet seam, opencast workings extended down to the overlying Harnlow seam. Open cast workings have brought the base of the pit within 20-30 m of the Nine Feet seam, resulting in insufficient bedrock cover.	No mine entries are recorded within 30 m of MRZ 3b.

Mining Risk Zone (MRZ)		Description of Extents and Overview of Risks	Details on Mine Workings	Details on Mine Entries
			Nine Feet seam recorded as being extracted to a thickness of 3m, increasing 10t from 20m to 30m. Rockhead assumed to be at base of opencast (159-190m AOD), not proven by GI, Nine Feet seam recorded at 120-135m AOD within 10t limit and presenting risk of void migration. Approximately 100 m of backfill has been place above the lowest workings to formation level, assume that a void migrates through the full thickness of this back fill	
6	a	MRZ 6a is located in the north of the inner loop and extends for approximately 150 m along the track. This zone is defined by the extents of the Nant Helen opencast and the bell pit workings. Much of this risk zone is also underlain by the shallow workings of the Dulais Colliery (Peacock Seam). There is a stability risk posed by shallow mine workings and bell pitting.	Shallow underground workings are expected to be present in this location relating to the working of the Peacock seam from the west slant of Dyffryn Colliery. The shallowest workings in the east at 268m AOD are likely to be exposed during construction of the proposed cutting to 264m AOD. Following the 10t rule, there is a risk of void migration from workings likely to occur very near surface beneath the track in west. Workings recorded at 244m AOD, proposed cutting depth of 262m AOD. Noted that the above cutting will be partially into rock (below current rockhead of 270m AOD in east Zone of core loss recorded in BH18	No mine entries are recorded within 30 m of MRZ 6a. 1945 satellite imagery indicates that bell pitting has been undertaken within MRZ 6a.
	b	MRZ 6b is located in the southeast of both the inner loop and outer loop and extends for approximately 350 m along the track. This risk zone is defined by the extent of possible bell pitting in the west and shallow workings of the Dulais Colliery (Peacock Seam) and evidence for bell pitting in the east. There is a stability risk posed by shallow mine workings, potential underground roadways with <20 m of bedrock cover and bell pitting.	Shallow underground workings are expected to be present in this location relating to the working of the Peacock seam from the east slant of Dyffryn Colliery. Evidence of suspected shallow underground workings was encountered in BH12 (actual zone of core loss), coal was encountered in BH12 and BH14 thought to be the Peacock seam. Coal and core loss are within 20m of rockhead. The levels of the workings are expected to be between 219 and 241 mAOD, track formation level is 249 m AOD with rock head at 255 m AOD (cutting in rock). Hence, following the 10t rule, there is a risk of void migration from the workings to track level.	No mine entries are recorded within 30 m of MRZ 6b. However, 2No. adits are located approximately 140 m and 220 m southeast of the alignment. The roadways associated with these adits are not shown on the mine abandonment plans, therefore, there is a risk these may pass beneath the alignment with < 20 m of bedrock cover. 1945 satellite imagery indicates that bell pitting has been undertaken within MRZ 6b.
	c	MRZ 6c is located in the south of both the inner loop and outer loop and extends for approximately 180 m along the main track and an additional 1 km along the track leading to the washery area. This risk zone is defined by extent of the Nant Helen opencast in the west and the extent of shallow workings of the Dulais Colliery (Peacock Seam) and evidence for bell pitting in the east. There is a stability risk posed by shafts, adits, shallow mine workings with <20 m of bedrock cover and bell pitting.	Shallow underground workings are expected to be present in this location relating to the working of the Peacock seam from the west slant of Dyffryn Colliery. Recorded workings expected between 224m AOD 234m AOD in this area Proven rockhead level varies form 223m AOD to 247m AOD, proposed track level between 226m AOD and 255m AOD Workings can be expected at or just below rock head, within 10t limit and therefore presenting a void migration risk. Evidence of the suspected shallow underground workings was encountered in BH02 and BH15 (void and zone of core loss), within 10t limit	Total of 2 No. adits are recorded within 30 m of the alignment, of which 4 No. lie directly under the alignment and 2 No. are adjacent to the alignment. Of 2 No. adjacent to the alignment: 1 No. roadway is expected to be at 242 m AOD when it passes under the alignment with a level of 250 m AOD with rockhead at 250 m AOD. Hence, following the 10t rule, there is a risk of void migration from the workings to track level. 1 No. roadway does not have any details on the mine abandonment plan to indicate the depth beneath the alignment. However, this adit is close to the other adit, and therefore there is a risk that this adit may also pass beneath the alignment with < 20 m of bedrock cover. The three adits underlying the alignment are expected to be near/at surface. A further 3 No. adits have roadways that dip beneath the alignment with <20 m of bedrock cover. The elevations of these roadways are not shown on the mine abandonment plans and may have < 20 m of bedrock cover beneath the alignment. A total of 3 No. shafts are within 30 m, comprising: 1No. shaft is within the site and was treated in March 1987. 1No. shafts potential collapse zone is estimated to have an approximately 8 m overlap with the earthworks in the north of MRZ 6c. This shaft was treated at some point in the past but there is no available information on the date of treatment [9]. 1No. shaft is located approximately 20 m north of the site. This potential zone of collapse for this shaft is estimated to not overlap with the alignment and this shaft was treated in August 1973.

Mining Risk Zone (MRZ)	Description of Extents and Overview of Risks	Details on Mine Workings	Details on Mine Entries
7	MRZ 7 includes all of the land within the Washery Area Phase 1A Boundary. There is a stability risk posed by shafts, adits and shallow mine workings.	Shallow underground workings are expected to be present in this location relating to the working of the Bluers seam and the brass seam from the Dulais East Slant and Onllwyn Colliery. Bedrock is proven by GI between 223m AOD and 232m AOD, workings are recorded between 204m AOD and 226m AOD within 10t limit and therefore presenting a risk of void migration. A 1 m void found in BH30R at a depth of 220m AOD has been interpreted as unrecorded mine workings, possibly of the New and Grey seams. Further evidence of void migration risk.	1945 satellite imagery suggests bell pitting within MRZ 6c. A total of two adits are within 30 m. Both adits underlie the alignment. The GI findings suggest that the two adits underlying the alignment may be buried with 4-10 m of Made Ground. 1No. mine shaft is located within the site and has an estimated potential collapse radius of 33 m, there are no historical records of treatment [7]. One adit and the shaft were investigated during the most recent geophysical survey by Terradat. Geophysical anomalies were identified in the vicinity of both mine entries, but the trial pitting at these locations found no evidence for mine entries There is a risk that these mine entries are present in other locations within the Washery. The second adit was not investigated and remains a risk.

5. Conclusions and Recommendations

5.1. Summary

Atkins Limited (Atkins) has been commissioned by GCRE Co. Ltd to complete the design of the earthworks (cuttings and embankments) for the Global Centre of Rail Excellence (GCRE) Project in South Wales. The project entails the design and construction of a railway test track at the site of the former Nant Helen Opencast mine. High speed and low speed train tests will be undertaken at the proposed facility on two new test loops.

The site is divided into two areas; the proposed GCRE track alignment and the Washery Area. The proposed alignment surrounds and overlies the Nant Helen opencast workings (previously operated for extraction of coal by Celtic Energy and now in process of being restored) and covers an area spanning approximately 2.7 km by 1.9 km.

The site is within the influence of historic underground and more recent surface mining activities. Arup has previously completed a Geotechnical and Geoenvironmental Desk Study Report [1], Detailed Mine Workings Study [2] and Ground Investigation Report [3] to inform mining risks at the site.

This work identified a significant instability risk to the proposed project from legacy coal mining activities within the Middle and Lower Coal Measures in the following:

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

5.2. Identification of Mining Risks

The risks posed to the scheme emanate from the following:

- Shallow workings present within under the proposed alignment where rockhead cover is insufficient to prevent migration of voids to surface;
- Shafts with collapse zones that encroach on the proposed alignment;
- Adits and/or roadways present under the proposed alignment where rock head cover is insufficient to prevent migration of voids to surface; and;
- Presence of historical bell pitting.

To mitigate the risks, it is considered that actions will be necessary to either 'dig out' or undertake drill and grout treatment of shallow mine workings where these are present below the 'earthwork formation' and where these have less than 20m of rock cover. Arup's assessment separated designated the risks into four discrete Mining Risk Zones (A – D). These risk zones have been further refined by Atkins

Atkins synthesised key information provided by Arup and reviewed this information against available mine abandonment plans from the Coal Authority, open cast completion plans from Celtic Energy and open-access information from both the BGS and the Coal Authority.

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

- **MRZ 1:** located in the northwest of the outer loop and extends for approximately 1 km along the track. This zone includes seventeen adits and one shaft not entirely removed by open casting 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 deep GI 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 – 3 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 SE-dipping mine entry is likely to be present on site according to satellite imagery. 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:** is located in the northeast 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:** is 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 open cast 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:** is located in the north of the inner loop and extends for approximately 250 m along the track.
- **MRZ 6b:** is located in the southeast of both the inner loop and outer loop and extends for approximately 350 m along the track.
- **MRZ 6c:** is 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 GI encountered a 2 m wide void at 3.20 m below rockhead and a 1 m wide void at 13.60 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, Atkins considers there to be a high probability of unrecorded mine entries occurring across the entire site, but particularly within and surrounding the extents of recorded mine workings. Atkins also considers there to be high probability of unrecorded mine workings occurring across the site, similar to the apparently unrecorded workings identified in the Washery Area (MRZ 7).

5.3. Recommendations and Further Works

Ground Investigation

Ground Investigations have confirmed the presence of legacy mining activities across the site. Further investigation will be required to confirm the extents of treatment required. The scope of investigation will vary but is expected to comprise:

- Rotary core boreholes to categorise geological conditions
- Rotary probe drilling to delineate underground mine workings
- Geophysical surveys to locate entries
- Rotary probe drilling to delineate mine entries
- Trenching to delineate mine entries
- Inspection and mapping of adits

Approval from the Coal Authority is required prior to any further intrusive investigation works.

A site walkover is recommended to locate and map mine entries and identify areas of existing subsidence due to collapse of underground workings or bell pits. This should be undertaken before the design phase is completed.

Hydrogeological Conditions

To allow for opencast mining, the groundwater has been artificially depressed by pumping to prevent flooding of the opencast workings. On completion of the workings, it is understood that the pumps were switched off allowing the groundwater to naturally stabilise.

It is understood from communication with Celtic Energy that rebound has stabilised at between 100-120m AOD. Deep underground workings and adits draining to the River Tawe are believed to be responsible for maintaining the groundwater level at this elevation.

No boreholes were advanced deep enough to measure groundwater during the GI, therefore it has been assumed in agreement with the client, that groundwater will remain at this level (100-120m AOD).

A detailed assessment of the risk due to minewater is required to inform remediation design strategy and the impacts from any such works. Further investigation and monitoring is likely to be required.

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.

Remediation Strategy

Remediation works will be required to mitigate the mining risk posed to the site. The treatment type will vary depending on the final arrangement and will be subject to the findings of the additional investigation. This will likely comprise either cut and fill for workings near surface or bulk infill stabilisation for deeper workings. The type of remediation will vary subject to the performance tolerances, e.g., at structure locations the use of high strength grout may be necessary.

The risk summary has been developed on the basis of a general work seam thickness of 2m, increased to 3m for the Nine Feet Seam. Application of the '10t rule' after CIRIA C758D [17] is proposed to mitigate risk posed by upward migration from collapsing voids.

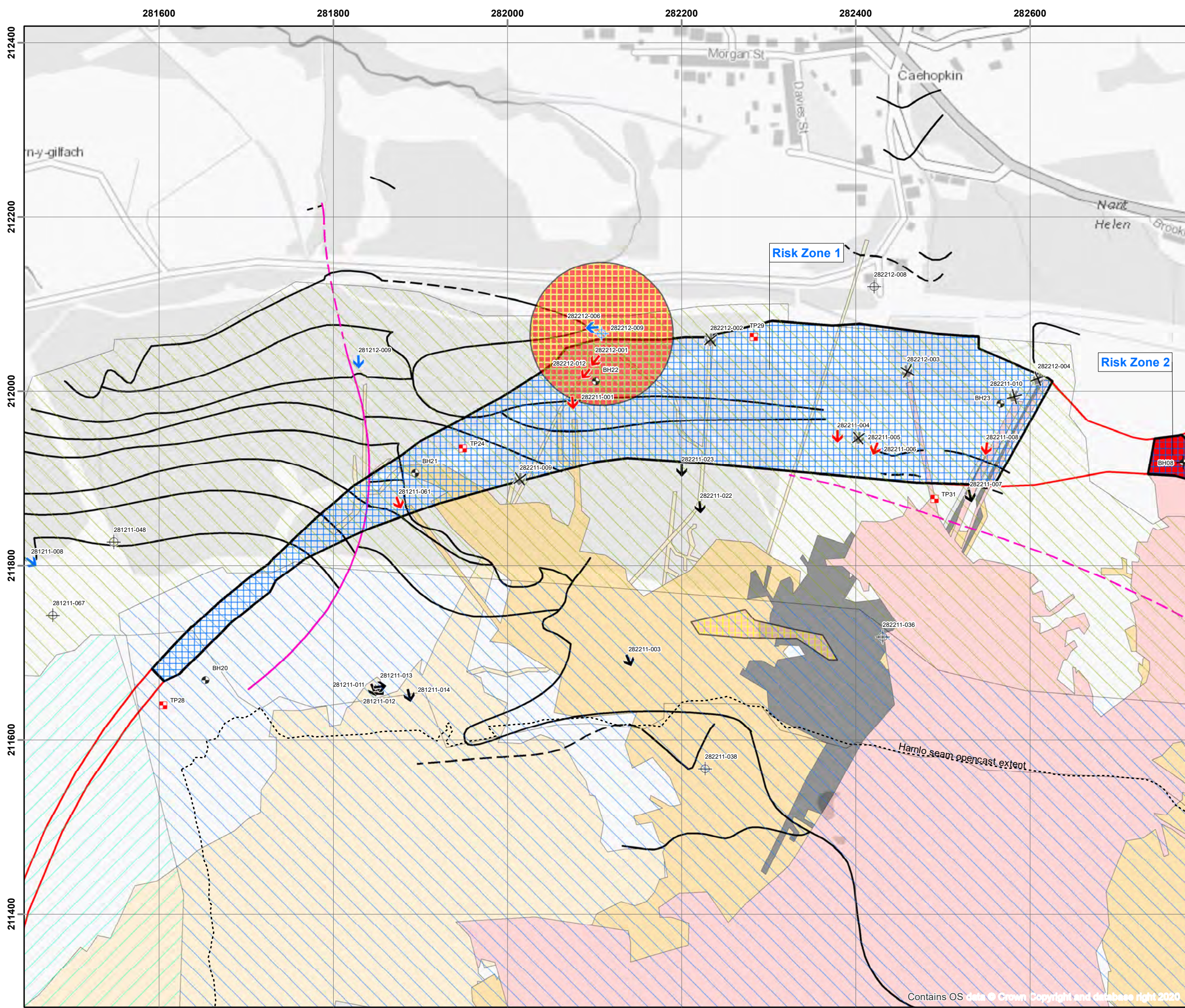
Remediation of mine entries is expected to comprise either bulk infill or concrete cap at surface. This will be reviewed once the entry arrangements and conditions have been confirmed. It is noted that a selection of entries are reported as being remediated. Information on the remediation strategy completed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

6. References

- [1] Arup, "Land at Nant Helen and Onllwyn Coal Washery - Geotechnical and Geoenvironmental Desk Study, Job number 264904-00, Issue," 18 December 2019.
- [2] Arup, "Detailed Mine Workings Study, Job Number 264904, File Reference 4-70," 10 June 2020.
- [3] Arup, "Global Centre of Rail Excellence - Ground Investigation Report, Job number 284523, File reference 4-50, Draft 1," 31 March 2022.
- [4] Welsh Government, "Design Manual for Roads and Bridges CD 622 Managing geotechnical risk, Revision 0, (formerly HD 22/08, BD 10/97, HA 120/08)," August 2019.
- [5] GCRE Co. Ltd, "GCRE Earthworks – Volume 2 (C) GCRE Employers Requirements Document, REF GER01".
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- [8] British Geological Survey, "Geological Survey of England and Wales 1:63,360/1:50,000 geological map series, New Series, Merthyr Tydfil, Sheet 231, 1:50,000 Scale, Drift edition, 2nd colour edition.," 1979.
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- [16] Lle, "<https://lle.gov.wales/home>," lle.gov.wales, [Online]. Available: WMTS Server: <http://lle.gov.wales/services/tiles/apu/wmts>. [Accessed 4 May 2022].
- [17] CIRIA, "Abandoned mine workings manual, C758D," London, 2019.
- [18] Google Earth, Google, [Online]. Available: <https://earth.google.com/web/@0,0,0a,22251752.77375655d,35y,0h,0t,0r>. [Accessed 2022].
- [19] T. W. Lambe and R. V. Whitman, "Soil Mechanics, SI version," Wiley, New York, 1979.
- [20] Highways England, "DMRB Volume 1 Section 3 Part 14 (BD 10/97) Highway structures: Approval procedures and general design. General design. Design of highway structures in areas of mining subsidence (Withdrawn)," 1997.

Annexes

Annex A. Drawings



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Legend

Mining Risk Zones (MRZs)

Recorded adit

Recorded adit entry point within the site

Recorded adit dipping beneath the site

Recorded adit mouth likely extracted but roadway in-situ

Recorded shaft

Recorded shaft within the site

Recorded shaft within 30 m of the site

Rotary core borehole

Rotary open borehole

Cable percussion borehole

Trial pit

Potential collapse risk zones for mine shafts

Coal seam, inferred (BGS)

Coal seam, observed (BGS)

Normal fault, inferred (BGS)

Normal fault, observed (BGS)

Washery Area - Phase 1A Boundary (Arup, 2022)

Proposed GCRC Alignment

Evidence for bell pits

Recorded shallow mine workings beneath the proposed alignment and Washery Area

Abercrave Big underground working

Onlywn Bluers underground working

Onlywn Brass underground working

Abercrave Black underground working

Abercrave Four Feet underground working

Abercrave White underground working

Cwmatawe Bryn underground working

Duffryn Bluers underground working

Dulais Peacock underground working

International Four Feet underground working

Onilwyn - Peacock opencast (1946-1949)

Onilwyn - Nine Feet opencast (1946-1949)

Abercrave/Gwaunton opencast (1963-1973)

Onilwyn opencast (1972-1982)

Nant Helen opencast (1986-1999)

Nant Helen Extension opencast (2002-2019)

NOTES

- Do not scale from this drawing.
- This drawing is not intended for design.
- The 'Washery Phase 1A Boundary' was derived from the Phase 1A Boundary shown on the 'Phase 1A Proposed Finished Levels' drawing by Arup (Drawing No. CG3500).

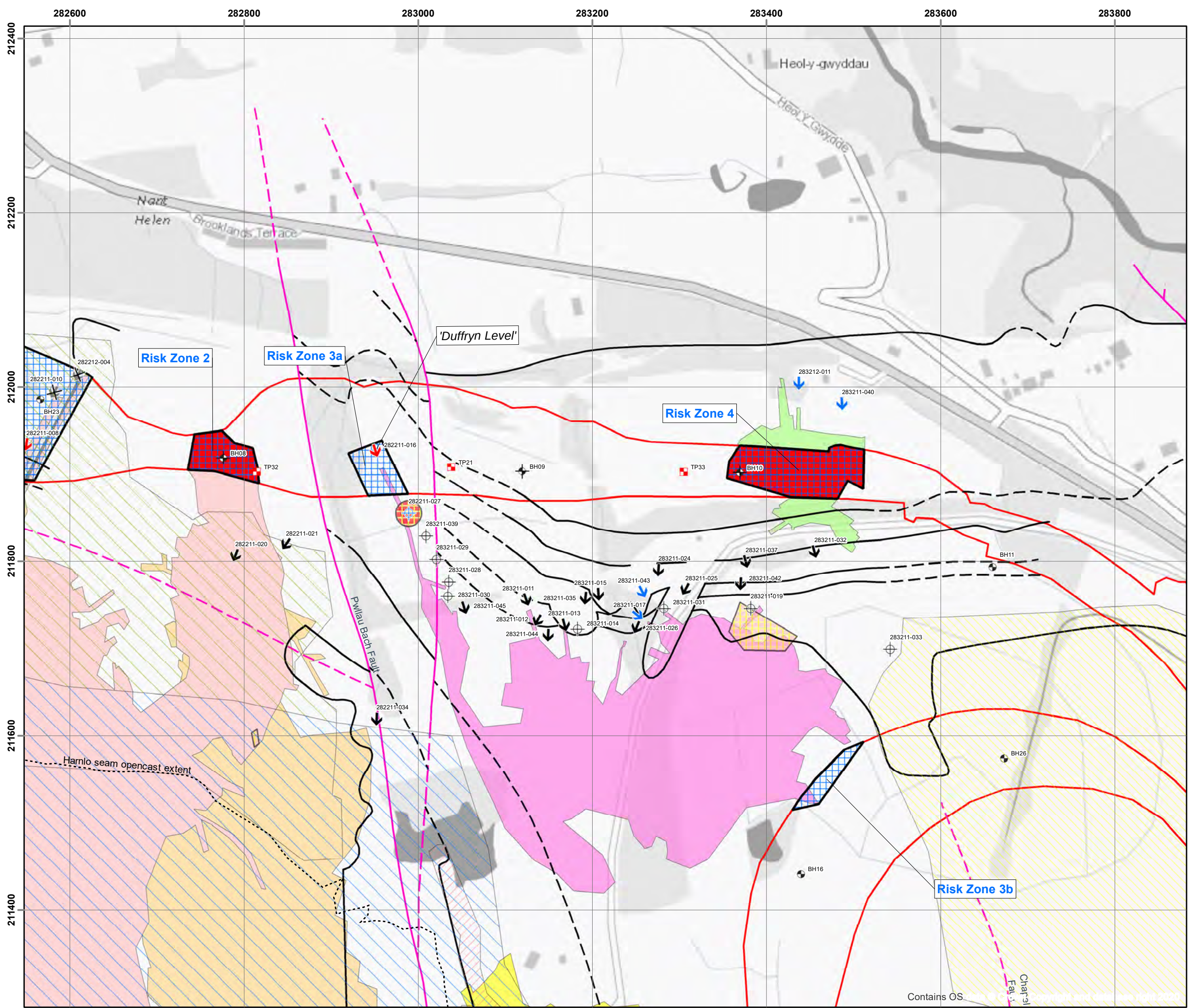
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PROJECT: Global Centre for Rail Excellence						
TITLE: Overview of Mining Hazards (MRZ 1)						
SCALE: 1:4,000	ORIGINATOR: HW	CHECKED: PA	REVIEWED: KP	AUTHORISED: -		
SIZE: A3	DATE: 09/06/2022	DATE: 16/06/2022	DATE: 16/06/2022	DATE: -		
STATUS: DRAFT	DRAWING NO: GCRC001-AWJV-00-XX-DR-GE-00014					VER: 1

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Legend

- Mining Risk Zones (MRZs)
- Recorded adit
- Recorded adit entry point within the site
- Recorded adit dipping beneath the site
- Recorded adit mouth likely extracted but roadway in-situ
- Recorded shaft
- Recorded shaft within the site
- Recorded shaft within 30 m of the site
- Rotary core borehole
- Rotary open borehole
- Cable percussion borehole
- Trial pit
- Potential collapse risk zones for mine shafts
- Coal seam, inferred (BGS)
- Coal seam, observed (BGS)
- Normal fault, inferred (BGS)
- Normal fault, observed (BGS)
- Washery Area - Phase 1A Boundary (Arup, 2022)
- Proposed GCRE Alignment
- Evidence for bell pits
- Recorded shallow mine workings beneath the proposed alignment and Washery Area
- Abercrave Big underground working
- Onllywn Bluers underground working
- Onllywn Brass underground working
- Abercrave Black underground working
- Abercrave Four Feet underground working
- Abercrave White underground working
- Cwmtawe Bryn underground working
- Duffryn Bluers underground working
- Dulais Peacock underground working
- International Four Feet underground working
- Onllywn - Peacock opencast (1946-1949)
- Onllywn - Nine Feet opencast (1946-1949)
- Abercrave/Gwaunton opencast (1963-1973)
- Onllywn opencast (1972-1982)
- Nant Helen opencast (1986-1999)
- Nant Helen Extension opencast (2002-2019)

NOTES

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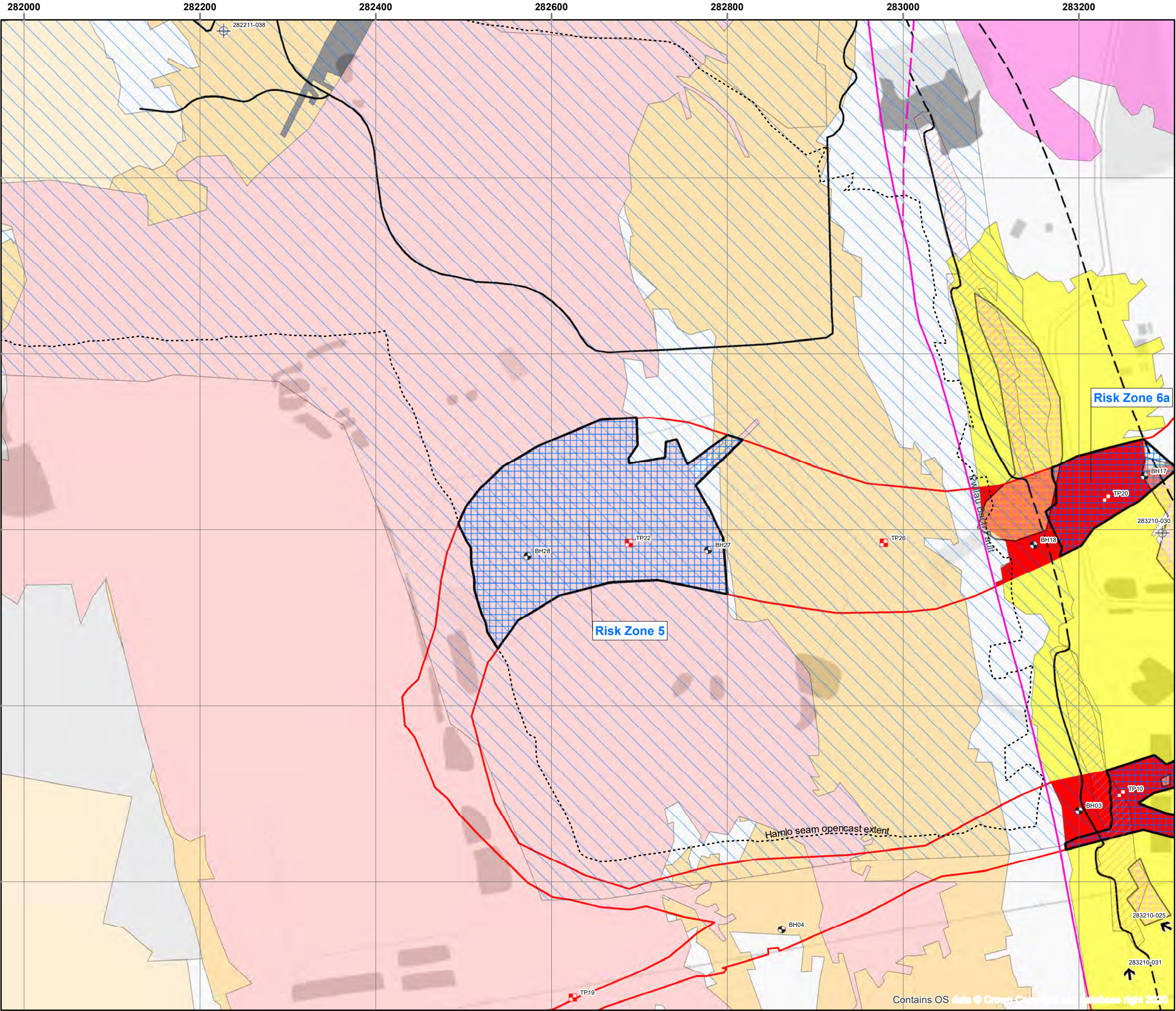
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GCRE Co Ltd

PROJECT:
Global Centre for Rail Excellence

TITLE:
Overview of Mining Hazards (MRZ 2, 3a, 3b and 4)

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DRAWING NO: GCRE001-AWJV-00-XX-DR-GE-00015
VER: 1



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Legend

Mining Risk Zones (MRZs)

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Recorded adit mouth likely extracted but roadway in-situ

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Recorded shaft within the site

Recorded shaft within 30 m of the site

Rotary core borehole

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Evidence for bell pits

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Onlylwn Bluers underground working

Onlylwn Brass underground working

Abercra Black underground working

Abercra Four Feet underground working

Abercra White underground working

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Onilwyn opencast (1972-1982)

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Nant Helen Extension opencast (2002-2019)

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1. Do not scale from this drawing.

2. This drawing is not intended for design.

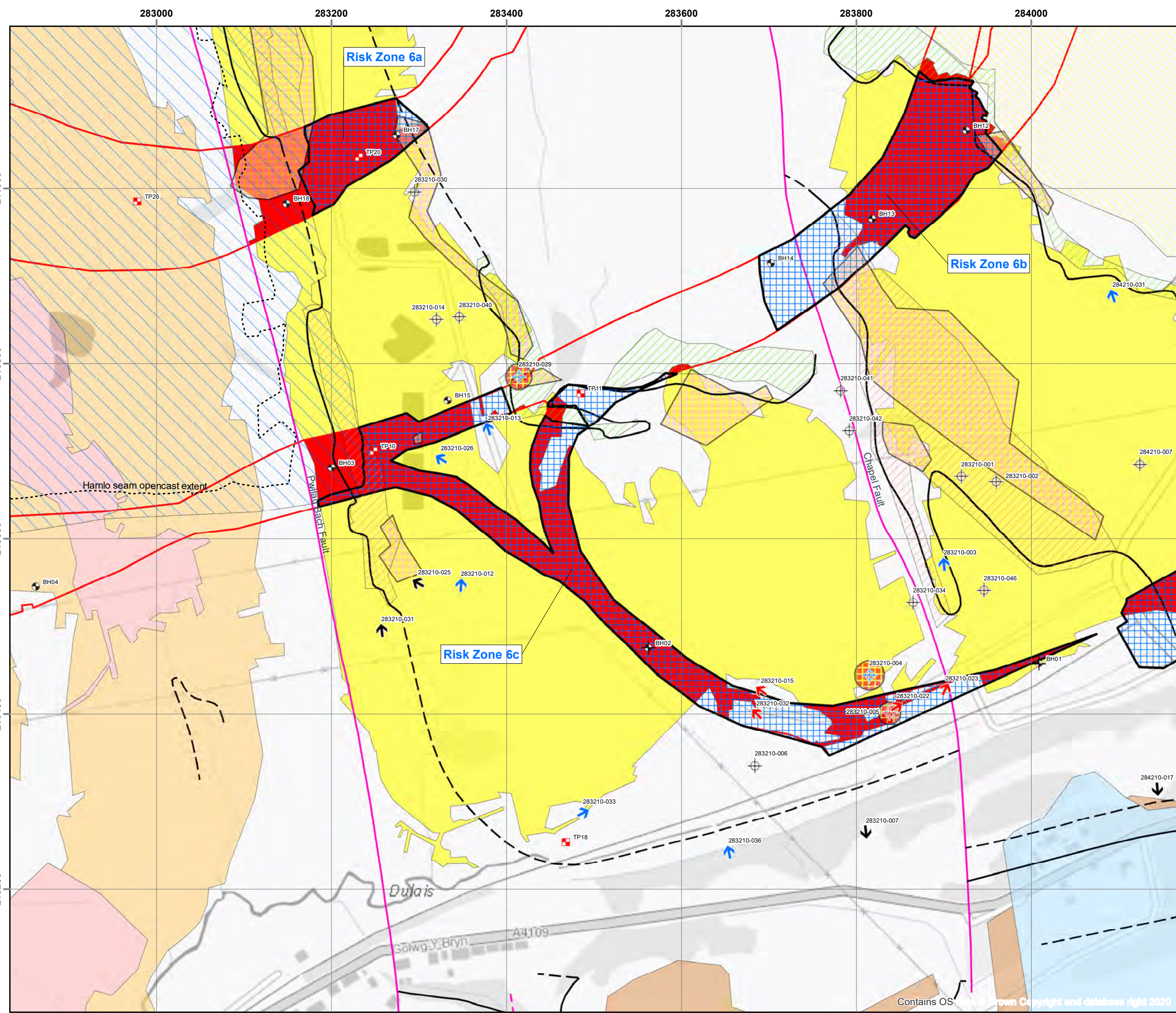
3. The 'Washery Phase 1A Boundary' was derived from the Phase 1A Boundary shown on the 'Phase 1A Proposed Finished Levels' drawing by Arup (Drawing No. CG3500).

02550100

Metres

N

1	DRAFT FOR ISSUE	HW	09/06/2022	PA	KP	-
VER	DESCRIPTION	BY	DATE	CHK'D	REVW	AUTH
CLIENT: GCRE Co Ltd						
PROJECT: Global Centre for Rail Excellence						
TITLE: Overview of Mining Hazards (MRZ 5)						
SCALE: 1:4,000	ORIGINATOR: HW	CHECKED: PA	REVIEWED: KP	AUTHORISED: -		
SIZE: A3	DATE: 09/06/2022	DATE: 16/06/2022	DATE: 16/06/2022	DATE: -		
STATUS: DRAFT	DRAWING NO: GCRE001-AWJV-00-XX-DR-GE-00016					VER: 1



ATKINS

Member of the SNC-Lavalin Group

Legend

Mining Risk Zones (MRZs)

Recorded adit

Recorded adit entry point within the site

Recorded adit dipping beneath the site

Recorded adit mouth likely extracted but roadway in-situ

Recorded shaft

Recorded shaft within the site

Recorded shaft within 30 m of the site

Rotary core borehole

Rotary open borehole

Cable percussion borehole

Trial pit

Potential collapse risk zones for mine shafts

Coal seam, inferred (BGS)

Coal seam, observed (BGS)

Normal fault, inferred (BGS)

Normal fault, observed (BGS)

Washery Area - Phase 1A Boundary (Arup, 2022)

Proposed GCRE Alignment

Evidence for bell pits

Recorded shallow mine workings beneath the proposed alignment and Washery Area

Abercra Big underground working

Onlylwn Bluers underground working

Onlylwn Brass underground working

Abercra Black underground working

Abercra Four Feet underground working

Abercra White underground working

Cwmawe Bryn underground working

Duffryn Bluers underground working

Dulais Peacock underground working

International Four Feet underground working

Onilwyn - Peacock opencast (1946-1949)

Onilwyn - Nine Feet opencast (1946-1949)

Abercra/Gwaunton opencast (1963-1973)

Onilwyn opencast (1972-1982)

Nant Helen opencast (1986-1999)

Nant Helen Extension opencast (2002-2019)

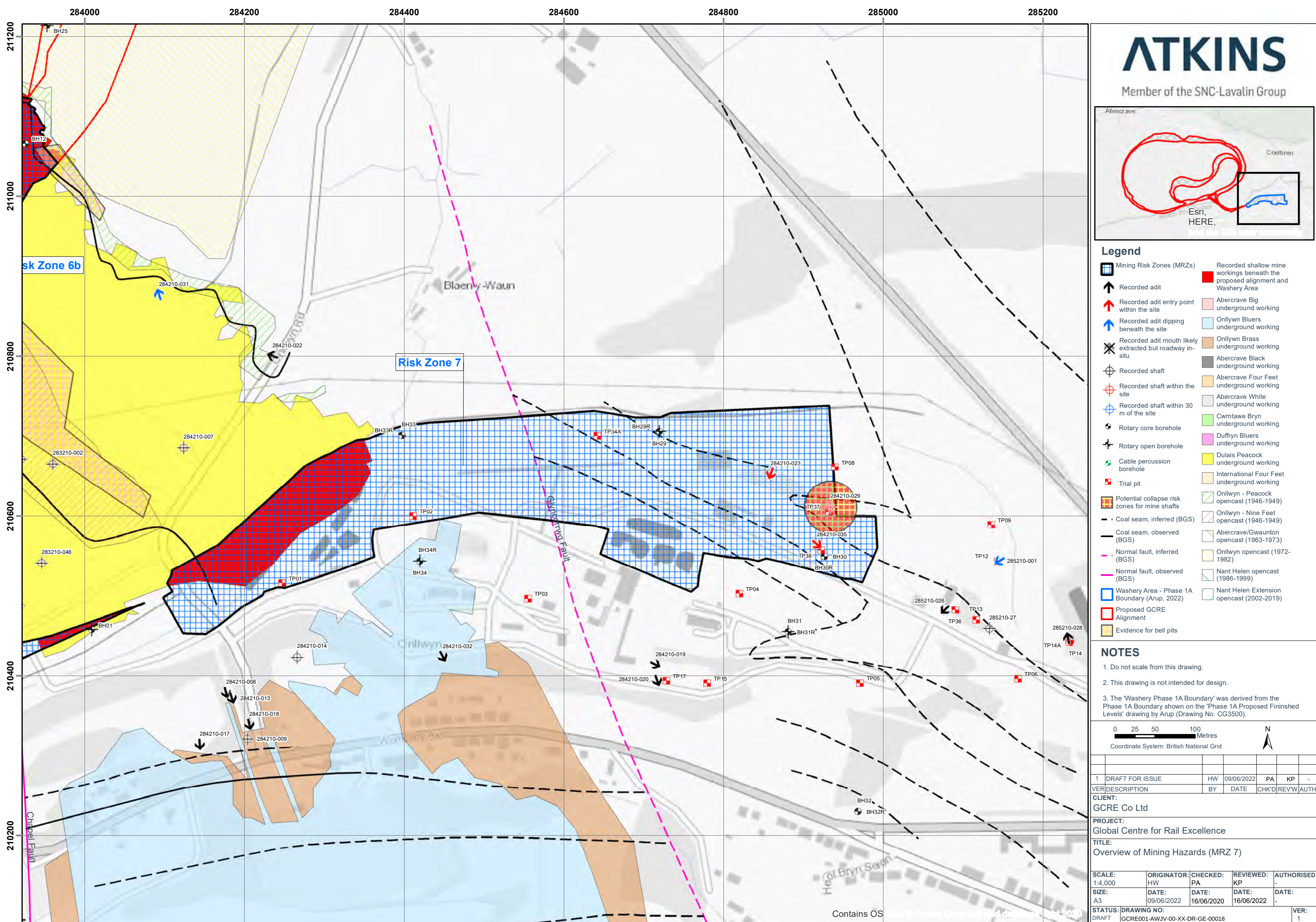
NOTES

- Do not scale from this drawing.
- This drawing is not intended for design.
- The 'Washery Phase 1A Boundary' was derived from the Phase 1A Boundary shown on the 'Phase 1A Proposed Finished Levels' drawing by Arup (Drawing No. CG3500).

02550100

Metres

1	DRAFT FOR ISSUE	HW	09/06/2022	PA	KP
VER	DESCRIPTION	BY	DATE	CHK'D	REVW/AUTH
CLIENT: GCRE Co Ltd					
PROJECT: Global Centre for Rail Excellence					
TITLE: Overview of Mining Hazards (MRZ 6a, 6b and 6c)					
SCALE: 1:4,000	ORIGINATOR: HW	CHECKED: PA	REVIEWED: KP	AUTHORISED: -	
SIZE: A3	DATE: 09/06/2022	DATE: 16/06/2022	DATE: 16/06/2022	DATE: -	
STATUS: DRAFT	DRAWING NO: GCRE001-AWJV-00-XX-DR-GE-00017				VER: 1



KEY

Plan View

- Mining Risk Zones (MRZs)
- Washery Area - Phase 1A
- Boundary (Arup, 2022)
- Proposed GCRE Alignment

Recorded opencast Workings

- Onllwyn - Peacock opencast (1946-1949)
- Onllwyn - Nine Feet opencast (1946-1949)
- Abercrave/Gwaunton opencast (1963-1973)
- Onllwyn opencast (1972-1982)
- Nant Helen opencast (1986-1999)
- Nant Helen Extension opencast (2002-2019)

Recorded Mine Entries

- Adit
- Adit entry point within the site
- Adit dipping beneath the site
- Adit mouth likely extracted but roadway in-situ
- Shaft
- Shaft within the site
- Shaft within 30 m of the site

Exploratory Holes

- Rotary cored
- Rotary open
- Cable percussion
- Trial pit

Cross Section

Colours

- Mining Risk Zones (MRZs)
- Recorded opencast fill
- Superficial cover (artificial and natural)
- Interpreted bedrock
- Peat
- Made Ground
- Glacial Till
- Bedrock
- Coal
- Void
- Recorded mine working

Faults and Linear Features

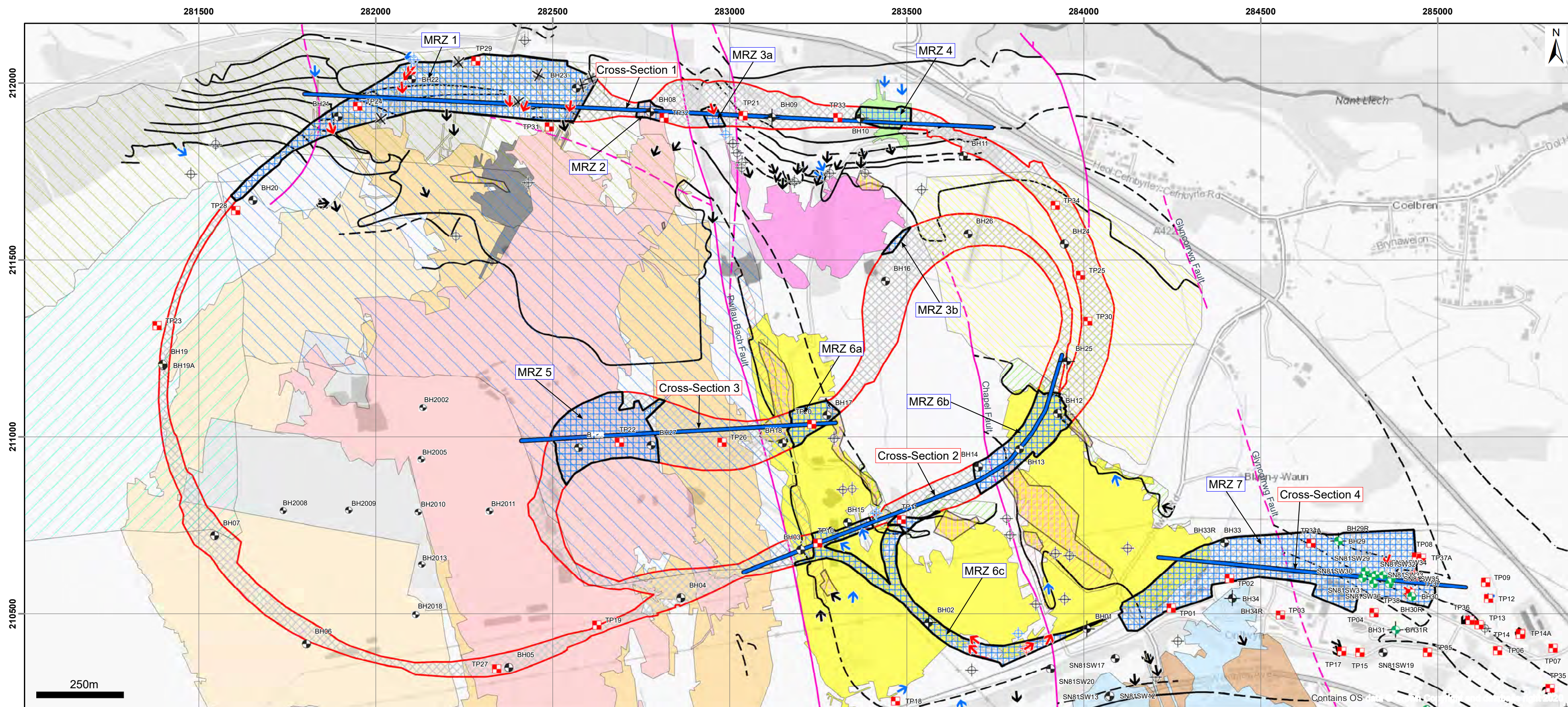
- 10k (BGS)
- Coal seam, inferred
- Coal seam, observed
- Normal fault, inferred
- Normal fault, observed
- Evidence for bell pitting
- Recorded Underground Workings
- Abercrave Big
- Onllwyn Bluers
- Onllwyn Brass
- Abercrave Black
- Abercrave Four Feet
- Abercrave White
- Cwmtawe Bryn
- Duffryn Bluers
- Dulais Peacock
- International Four Feet

Symbols

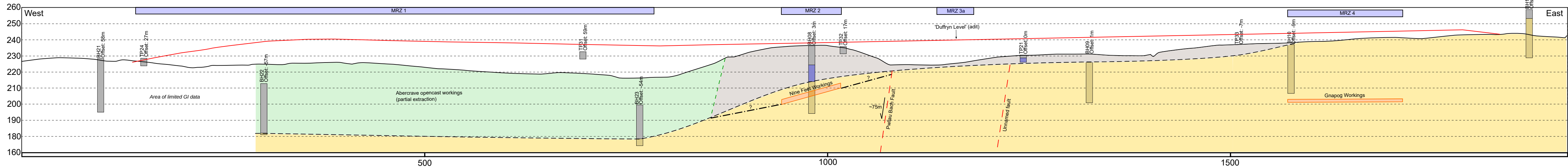
- Existing ground surface
- Proposed ground surface
- Interpreted rockhead
- Interpreted boundary of opencast area
- Interpreted coal seam
- Recorded fault
- Recorded mine working
- Fault displacement

NOTES

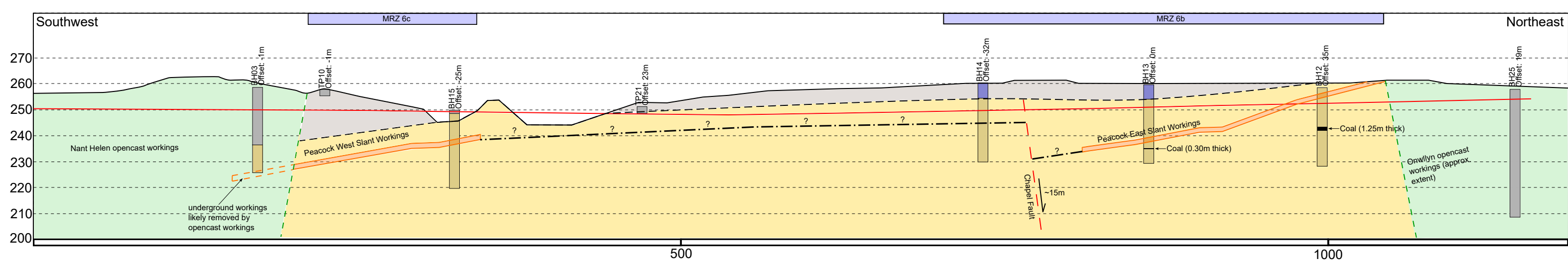
- This drawing and its contents have been prepared and are intended solely as information for GCRE Co. Ltd and use in relation to the Atkins GIR for the earthworks design and associated Mining Risk Review Document. Atkins Limited assumes no responsibility to any other party in respect of or arising out of or in connection with this drawing and/or its contents.
- Do not scale from this drawing.
- This drawing is not intended for design.
- This drawing and the cross-sections included therein represent an interpretation of the ground conditions on site from a limited ground investigation dataset. The true ground conditions may vary from those shown in this drawing.
- The levels of the recorded mine workings were approximated based on the mine abandonment plans available to Atkins at the time of origination. Atkins conservatively assumed that the levels shown on the mine abandonment plans represent the base of the mine workings.
- The ground investigation (GI) data includes the GI by Quantum Geotech (2021/22) and relevant holes provided by Celtic Energy and made available through the BGS Geotindex.
- The interpreted coal seam levels and interpreted rockhead levels are indicative only. The true levels of coal seams are likely to vary across the site in accordance with the variable dip of the bedrock.
- Mine entries were omitted from the cross-sections for clarity.



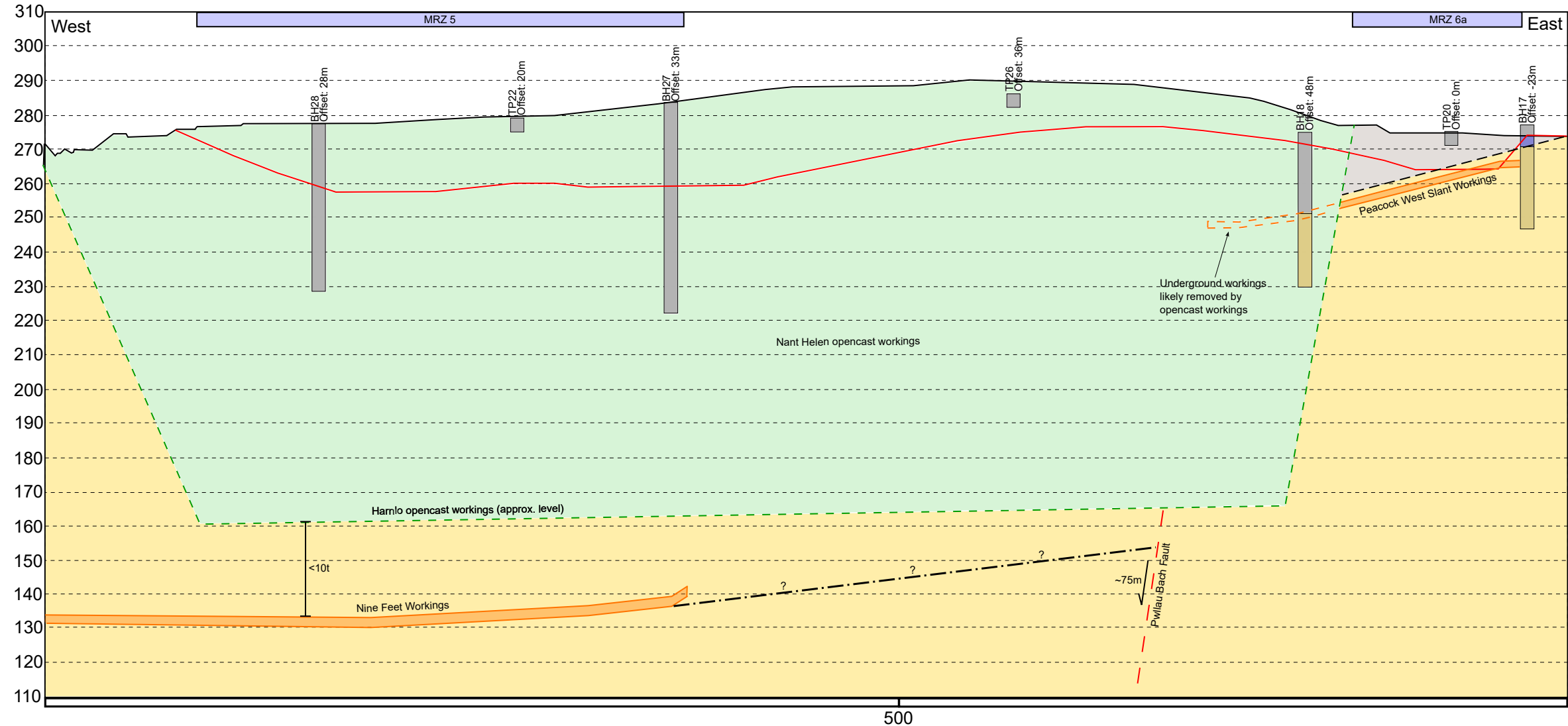
CROSS-SECTION 1



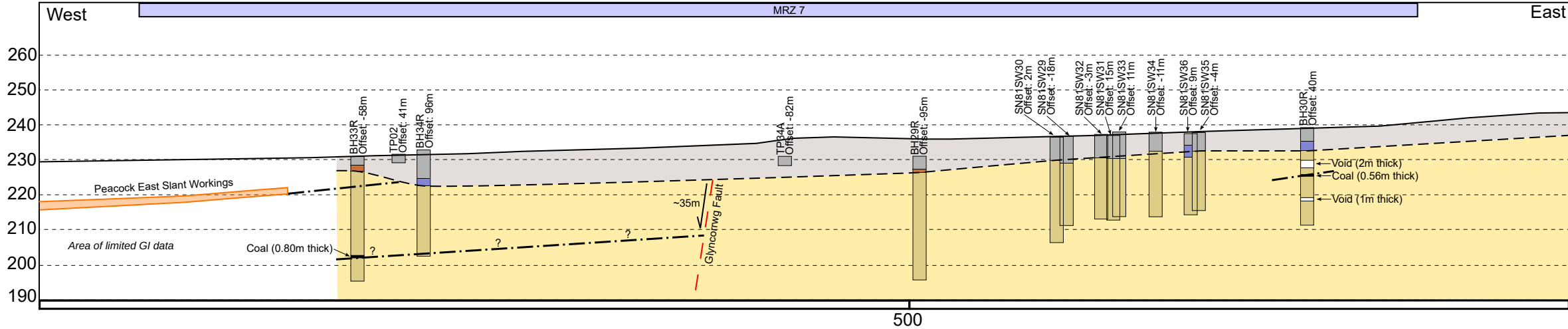
CROSS-SECTION 2



CROSS-SECTION 3



CROSS-SECTION 4



1	DRAFT FOR ISSUE	HW	16/06/2022	PA	KP	
VER	DESCRIPTION	BY	DATE	CHK'D	REV'D	AUTH
CLIENT:						
GCRC Co Ltd						
PROJECT:						
Global Centre of Rail Excellence						
TITLE:						
Mine Workings Cross Sections						
SCALE:	ORIGINATOR:	CHECKED:	REVIEWED:	AUTHORISED:		
N/A	HW	PA	KP			
SIZE:	DATE:	DATE:	DATE:	DATE:		
A1	16/06/2022	16/06/2022	16/06/2022			
STATUS:	DRAWING NO.:					VER:
DRAFT	GCRC001-AWJV-00-XX-DR-GE-00019					2

Annex B. Full Mining Risk Assessment Tables

Table B-1: Full table of assessed mine shafts across the site

Mine Entry ID	Easting (m)	Northing (m)	Distance from alignment/ washery area (m)	Estimated thickness of superficial deposits (m)	Phi (°)	Shaft diameter (m)	Departure (m) [9]	Estimated potential collapse radius (m)	Does the estimated potential collapse zone overlap with the proposed development?	Treatment Records
282211-027	282989	211855	22	2.6	25	1.25	8	15	No	No records of treatment.
282212-009	282108	212066	7	34	25	1.25	8	82	Yes	Treated, no further details.
283210-004	283815	210444	26	5	25	1.25	5	17	No	Treated 01/08/1973, no further details.
283210-005	283838	210401	0 (below)	5	25	2	0	13	Yes	Treated 09/03/1987, no further details.
283210-029	283414	210785	5	2.7	25	1.25	8	15	Yes	Treated, no further details.
284210-029**	284934	210611	0 (below)	10	25	1.25	10	33	Yes	No records of treatment.
281211-048	281548	211827	132	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
281211-067	281478	211743	126	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
282211-036	282431	211718	180	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
282211-038	282227	211567	349	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
282212-008	282421	212120	44	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283210-001	283920	210671	221	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283210-002	283960	210665	200	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283210-006	283684	210341	42	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283210-014	283320	210850	101	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283210-030	283295	210996	45	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283210-034	283865	210527	96	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283210-040	283346	210853	94	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283210-041	283782	210769	97	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283210-042	283792	210723	141	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283210-046	283946	210541	90	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283211-014	283183	211722	148	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283211-019	283382	211746	128	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283211-028	283035	211776	100	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283211-029	283021	211802	75	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283211-030	283034	211760	116	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283211-031	283282	211746	128	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
283211-033	283542	211699	88	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A

Mine Entry ID	Easting (m)	Northing (m)	Distance from alignment/ washery area (m)	Estimated thickness of superficial deposits (m)	Phi (°)	Shaft diameter (m)	Departure (m) [9]	Estimated potential collapse radius (m)	Does the estimated potential collapse zone overlap with the proposed development?	Treatment Records
283211-039	283009	211829	48	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
284210-007	284124	210685	119	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
284210-009	284204	210321	141	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
284210-014	284266	210423	88	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
285210-003	285363	210228	485	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A
285210-027	285133	210459	169	N/A *	N/A *	N/A *	N/A *	N/A *	No	N/A

*Mine shafts beyond area of concern (30 m), have been reviewed and established that collapse does not pose a risk to the alignment.

** Noted that geophysical anomalies in proximity to this mine entry were investigated by intrusive ground investigation, the location could not be confirmed.

Table B-2 - Full table of adits assessed across the site, ordered by location from northwest to southeast

Mine Entry Ref.	Easting	Northing	Azimuth	Approximately distance from alignment (m)	Direction relative to alignment / Washery Area	Adit Portal Level (mAOD)	Adit Level below alignment/ washery area (mAOD)	Track Level Above Adit (mAOD)	Anticipated Status of Adit Mouth	Risk Comments
281211-008	281453	211804	126	185	Towards alignment	N/A	N/A		Unknown	Directed towards the alignment. May intersect the Nan Helen extension area of opencast. No mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the alignment.
281211-011	281846	211657	158	160	Away from alignment	N/A	-	N/A	Unknown	Directed away from the alignment. No mine plans are available to inform location/level/extent of this adit. The adit is within the Nan Helen opencast area. Low risk of subsidence / void migration below the alignment.
281211-012	281853	211657	135	160	Away from alignment	N/A	-	N/A	Unknown	Directed away from the alignment. No mine plans are available to inform location/level/extent of this adit. The adit is within the Nan Helen opencast area. Low risk of subsidence / void migration below the alignment.
281211-013	281854	211661	83	160	Away from alignment	N/A	-	N/A	Unknown	Directed away from the alignment. No mine plans are available to inform location/level/extent of this adit. The adit is within the Nan Helen opencast area. Low risk of subsidence / void migration below the alignment.
281211-014	281887	211651	167	190	Away from alignment	N/A	-	N/A	Unknown	Directed away from the alignment. No mine plans are available to inform location/level/extent of this adit. The adit is within the Nan Helen opencast area. Low risk of subsidence / void migration below the alignment.
281212-009	281829	212034	178	118	Towards alignment	N/A	N/A	235*	Unknown	Directed towards the alignment. Mine plans shown that is located within an opencast area, but no levels are indicated for this adit on the mine plan. Risk of subsidence / void migration below the alignment.
281211-061	281875	211872	160	Below	N/A	226.00		240*	In situ	Located below the alignment. Opencast working plans suggest the adit has not been extracted. Risk of subsidence / void migration below the alignment.
282211-009	282014	211899	188	Below	N/A	219.14		236*	Extracted	Located below the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Risk of subsidence / void migration below the alignment.
282211-001	282075	211987	175	Below	N/A	208.25		208*	In situ	Located below the alignment and beyond known opencast working areas. Risk of subsidence / void migration below the alignment.
282212-012	282090	212020	219	Below	N/A	200.48		205*	In situ	Located below the alignment. Opencast working plans suggest that the mouth of the adit is likely to have been excavated by the roadways likely remain in place. Risk of subsidence / void migration below the alignment.
282212-001	282101	212035	219	Below	N/A	N/A		207*	Unknown	Located below the alignment. No mine plans are available to inform location/level/extent of this adit. The adit is within the Nan Helen opencast area. Risk of subsidence / void migration below the alignment.
282212-006	282097	212073	266	15	Parallel to alignment	N/A	Not dipping below the alignment	N/A	Unknown	Orientated parallel to the alignment approximately 15m from the alignment. Adit located in an opencast working area but no levels are available on plans to inform if the adit has been extracted. Risk of subsidence / void migration below the alignment due to uncertainty of the area of influence of the adit / accuracy of mine plan.
282212-002	282233	212059	186	Below	N/A	199.59		203*	Extracted	Located below the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Risk of subsidence / void migration below the alignment.
282211-004	282379	211948	180	Below	N/A	N/A	N/A	230*	Unknown	Located below the alignment. No mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the alignment.

Mine Entry Ref.	Easting	Northing	Azimuth	Approximately distance from alignment (m)	Direction relative to alignment / Washery Area	Adit Portal Level (mAOD)	Adit Level below alignment/ washery area (mAOD)	Track Level Above Adit (mAOD)	Anticipated Status of Adit Mouth	Risk Comments
282211-023	282200	211909	180	11	Away from alignment	221.70	Not dipping below the alignment	N/A	Extracted	Directed away from the alignment, although located approx. 11m from the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Low risk of subsidence / void migration below the alignment.
282211-022	282221	211867	175	48	Away from alignment	221.82	N/A	N/A	Extracted	Directed away from the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Low risk of subsidence / void migration below the alignment.
282211-003	282139	211691	158	225	Away from alignment	N/A	N/A	N/A	Unknown	Directed away from the alignment and towards the Nan Helen opencast area and at significant distance from the alignment. No mine plans are available to inform location/level/extent of this adit. Low risk of subsidence / void migration below the alignment.
282211-005	282403	211946	187	Below	N/A	217.10		229*	Extracted	Located below the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Risk of subsidence / void migration below the alignment.
282211-006	282422	211934	201	Below	N/A	N/A		229*	Unknown	Located below the alignment. No mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the alignment.
282212-003	282459	212023	165	Below	N/A	185.93		195*	Extracted	Located below the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Risk of subsidence / void migration below the alignment.
282211-007	282531	211880	167	12	Away from alignment	182.88	N/A	N/A	In situ	Directed away from the alignment, dipping at close distance. Opencast working plans suggest surface extraction to above the elevation of the adit, suggesting the adit remains in-situ. Low risk of subsidence / void migration below the alignment.
282211-008	282550	211934	188	Below	N/A	217.10		227*	In situ	Located below the alignment. Opencast working plans suggest the adit has not been extracted. Risk of subsidence / void migration below the alignment.
282211-010	282582	211994	210	Below	N/A	201.17		208*	Extracted	Located below the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Risk of subsidence / void migration below the alignment.
282212-004	282609	212014	204	Below	N/A	207.31		208*	Extracted	Located below the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Risk of subsidence / void migration below the alignment.
282211-020	282790	211807	201	84	Away from alignment	N/A	N/A	N/A	In situ	Directed away from the alignment. The abandonment plan shows that the adit does not intersect with the alignment and ends at a distance from it. Low risk of subsidence / void migration below the alignment.
282211-021	282848	211820	216	61	Away from alignment	N/A	N/A	N/A	In situ	Directed away from the alignment. The abandonment plan shows that the adit does not intersect with the alignment and ends at a distance from it. Low risk of subsidence / void migration below the alignment.
282211-016	282951	211927	162	Below	N/A	222.70		231.71*	Unknown	Located below the alignment. No opencast working plans are available for this area to assess if this adit was extracted or remains in-situ. Risk of subsidence / void migration below the alignment.

Mine Entry Ref.	Easting	Northing	Azimuth	Approximately distance from alignment (m)	Direction relative to alignment / Washery Area	Adit Portal Level (mAOD)	Adit Level below alignment/ washery area (mAOD)	Track Level Above Adit (mAOD)	Anticipated Status of Adit Mouth	Risk Comments
282211-034	282952	211619	183	257	Towards alignment	N/A	N/A	N/A	Unknown	Directed towards the alignment. No mine plans to inform location/level/extent of this adit are available. Consider low risk as occurs at centre of site at a distance from alignment and The Washery areas
283211-045	283053	211747	162	129	Towards alignment	N/A	N/A	N/A	Unknown	Directed towards the alignment. The abandonment plan shows the adit roadway terminating away from the alignment. Low risk of subsidence / void migration below the alignment.
283211-011	283124	211756	160	113	Towards alignment	N/A	N/A	N/A	Unknown	Directed towards the alignment. The abandonment plan shows the adit roadway terminating away from the alignment. Low risk of subsidence / void migration below the alignment.
283211-012	283137	211732	208	136	Towards alignment	N/A	N/A	N/A	Unknown	Directed towards the alignment. The abandonment plan shows the adit roadway terminating away from the alignment. Low risk of subsidence / void migration below the alignment.
283211-044	283149	211715	183	153	Towards alignment	N/A	N/A	N/A	Unknown	Directed towards the alignment. The abandonment plan shows the adit roadway terminating away from the alignment. Low risk of subsidence / void migration below the alignment.
283211-013	283168	211727	165	141	Towards alignment	N/A	N/A	N/A	Unknown	Directed towards the alignment. The abandonment plan shows the adit roadway terminating away from the alignment. Low risk of subsidence / void migration below the alignment.
283211-035	283192	211758	186	111	Towards alignment	N/A	N/A	N/A	Unknown	Directed towards the alignment. No mine plans to inform location/level/extent of this adit are available. However, considered low risk given location relative to alignment and The Washery and expected adit orientation.
283211-015	283207	211762	176	108	Towards alignment	N/A	N/A	N/A	Unknown	Directed towards the alignment. The abandonment plan shows the adit roadway terminating away from the alignment. Low risk of subsidence / void migration below the alignment.
283211-026	283251	211724	203	149	Towards alignment	N/A	N/A	N/A	Unknown	Directed towards the alignment. The abandonment plan shows the adit roadway terminating away from the alignment. Low risk of subsidence / void migration below the alignment.
283211-017	283252	211738	129	137	Towards alignment	254.81	252.07	261	Unknown	Directed towards the alignment. Abandonment plan shows the roadway intersecting with the site. If adit extends into base of cutting then expected <10m of bedrock cover below the alignment which posing a risk of subsidence / void migration.
283211-043	283257	211765	153	109	Towards alignment	N/A	N/A	261	Unknown	Directed towards the alignment. No mine plans to inform location/level/extent of this adit are available. Risk of subsidence / void migration below the alignment if running parallel to adit 283211-043.
283211-024	283276	211790	184	83	Towards alignment	251.84	N/A	N/A	Unknown	Directed towards the alignment. The abandonment plan shows the adit roadway terminating away from the alignment. Low risk of subsidence / void migration below the alignment.
283211-025	283307	211768	209	104	Towards alignment	251.84	N/A	N/A	Unknown	Directed towards the alignment. The abandonment plan shows the adit roadway terminating away from the alignment. Low risk of subsidence / void migration below the alignment.
283211-042	283370	211774	183	100	Towards alignment	N/A	N/A	N/A	Unknown	Directed towards the alignment. No mine plans to inform location/level/extent of this adit are available. However, given alignment and location in relation to alignment and The Washery considered low risk
283211-037	283376	211800	165	75	Towards alignment	N/A	N/A	261	Unknown	Directed towards the alignment. No mine plans to inform location/level/extent of this adit are available. Risk of subsidence / void migration below the alignment.

Mine Entry Ref.	Easting	Northing	Azimuth	Approximately distance from alignment (m)	Direction relative to alignment / Washery Area	Adit Portal Level (mAOD)	Adit Level below alignment/ washery area (mAOD)	Track Level Above Adit (mAOD)	Anticipated Status of Adit Mouth	Risk Comments
283211-032	283455	211811	164	61	Towards alignment	N/A	N/A	N/A	Unknown	Directed towards the alignment. The abandonment plan shows the adit roadway terminating away from the alignment. Low risk of subsidence / void migration below the alignment.
283212-011	283437	212004	180	76	Towards alignment	215.1	N/A	N/A	Unknown	Directed towards the alignment. Abandonment plan shows the adit roadway terminating at approximately <10m from the alignment and becoming mine workings, although adit is not a risk associated mine workings are – risk captured elsewhere in this report.
283211-040	283487	211981	177	45	Towards alignment	216.21	204.78	230*	Unknown	Directed towards the alignment. Abandonment plan shows that intersects at the end with the alignment. Potential for <20m of bedrock cover below the alignment which may pose a risk of subsidence / void migration.
283210-026	283325	210691	302	19.5	Towards alignment	243.84	243.84	249	In situ	Directed towards the alignment. Shown on mine abandonment plan, but no indication of depth beneath alignment is available. Expected <20m of bedrock cover below the alignment which may pose a risk of subsidence / void migration.
283210-013	283379	210725	341	7.9	Towards alignment	241.84	241.84	249	In situ	Directed towards the alignment. Expected <20m of bedrock cover below the alignment which may pose a risk of subsidence / void migration.
283210-025	283299	210549	300	130	Towards alignment	N/A	N/A		In situ	Directed towards the alignment, but mine abandonment plans show the roadway terminating >30 m from the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Low risk of subsidence / void migration below the alignment.
283210-031	283257	210495	353	154	Towards alignment	N/A	N/A		In situ	Directed towards the alignment but mine abandonment plans show the roadway terminating >30 m from the alignment. Opencast working plans suggest surface extraction to below the elevation of the mouth of the adit, suggesting the adit mouth has been extracted but the adit roadway may remain in-situ. Low risk of subsidence / void migration below the alignment.
283210-012	283348	210547	4	70	Towards alignment	N/A	N/A	247	In situ	Directed towards the alignment. No mine plans to inform location/level/extent of this adit are available. Located out of opencast working areas of Onllwyn opencast. Risk of subsidence / void migration below the alignment.
283210-032	283686	210400	315	Below	N/A	234.31		239	In situ	Located below the alignment. Located outside of working areas of Onllwyn opencast.
283210-015	283691	210426	307	6/ Below	N/A	232.64		239	In situ	Shown below the alignment on the mine abandonment plans. Located outside the working area of Onllwyn opencast. Risk of subsidence / void migration below the alignment.
283210-033	283488	210287	62	178	Towards alignment	N/A	N/A	234	In situ	Mine abandonment plan shows the roadway dipping beneath the alignment. Located beyond the opencast working areas of Onllwyn opencast. Risk of subsidence / void migration below the alignment.
283210-036	283654	210242	349	145	Towards alignment	N/A	N/A	236	In situ	Directed towards the alignment. No available mine plans to inform location/level/extent of this adit are available. Located out of opencast working areas of Onllwyn opencast. Risk of subsidence / void migration below the alignment.
283210-022	283846	210408	56	Below	N/A	228.73		228*	In situ	Located below the alignment. Located out of opencast working areas of Onllwyn opencast. Risk of subsidence / void migration below the alignment.
283210-023	283902	210428	26	Below	N/A	194.26		227*	In situ	Located below the alignment. Located out of opencast working areas of Onllwyn opencast. Potential for <20m of bedrock cover below the alignment which may pose a risk of subsidence / void migration, risk of subsidence / void migration below the alignment.

Mine Entry Ref.	Easting	Northing	Azimuth	Approximately distance from alignment (m)	Direction relative to alignment / Washery Area	Adit Portal Level (mAOD)	Adit Level below alignment/ washery area (mAOD)	Track Level Above Adit (mAOD)	Anticipated Status of Adit Mouth	Risk Comments
283210-007	283811	210265	174	97	Away from alignment	N/A	N/A	N/A	In situ	Directed away from the alignment. Located out of opencast working areas of Onllwyn opencast. Low risk of subsidence / void migration below the alignment.
283210-003	283900	210571	355	128.3	Towards alignment	N/A	N/A	250	Unknown	Directed towards the alignment. Onllwyn completion plans shows that the adit may dip towards opencast working areas, but no mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the alignment, although possible that adit ends before reaching alignment.
284210-031	284093	210877	341	220	Towards alignment	N/A	N/A	253	Unknown	Directed towards the alignment. Onllwyn completion plans shows that the adit may dip towards opencast working areas, but no mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the alignment.
284210-022	284235	210800	287	138	Towards alignment	N/A	N/A	N/A	Unknown	Directed towards the alignment, but mine plans show the roadway terminating at great distance from the alignment. Onllwyn completion plans shows that the adit may dip towards opencast working areas, but no levels are available for this adit on the mine plan. Low risk of subsidence / void migration below the alignment.
284210-017	284144	210314	175	135	Away from alignment / washery area	236.51	N/A	N/A	In situ	Directed away from the alignment / washery area. Located beyond opencast working areas of Onllwyn opencast. Low risk of subsidence / void migration below the alignment/washery area.
284210-008	284177	210379	165	75	Away from alignment / washery area	229.38	N/A	N/A	In situ	Directed away from the alignment / washery area. Located beyond opencast working areas of Onllwyn opencast. Low risk of subsidence / void migration below the alignment/washery area.
284210-013	284184	210372	161	85	Away from alignment / washery area	N/A	N/A	N/A	In situ	Directed away from the alignment / washery area. Located beyond opencast working areas of Onllwyn opencast. Low risk of subsidence / void migration below the alignment/washery area.
284210-018	284206	210339	167	120	Away from alignment / washery area	213.36	N/A	N/A	Unknown	Directed away from the alignment / washery area. Located beyond opencast working areas of Onllwyn opencast. Low risk of subsidence / void migration below the alignment/washery area.
284210-032	284448	210424	151	150	Away from alignment / washery area	N/A	N/A	N/A	Unknown	Directed away from the alignment / washery area. No mine plans are available to inform location/level/extent of this adit. Low risk of subsidence / void migration below the alignment/washery area.
284210-020	284717	210394	160	125	Away from washery area	238.42	N/A	N/A	Unknown	Directed away from the washery area. No mine plans are available to inform location/level/extent of this adit. Low risk of subsidence / void migration below the washery area.
284210-019	284715	210414	118	105	Away from washery area	N/A	N/A	N/A	Unknown	Directed away from the washery area. No mine plans are available to inform location/level/extent of this adit. Low risk of subsidence / void migration below the washery area.
284210-023	284859	210653	200	Below	N/A	N/A	N/A	Assume current ground level	Unknown	Located below washery area. No mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the washery area.
284210-035	284917	210565	131	Below	N/A	N/A	N/A	Assume current ground level	Unknown	Located below the washery area. No mine plans are available to inform location/level/extent of this adit. Risk of subsidence / void migration below the washery area. Noted that geophysical anomalies in proximity to this mine entry were investigated by intrusive ground investigation, the location could not be confirmed
285210-026	285077	210482	225	105	Away from washery area	N/A	N/A	N/A	Unknown	Directed away from the washery area. No mine plans are available to inform location/level/extent of this adit. Low risk of subsidence / void migration below the washery area.

Mine Entry Ref.	Easting	Northing	Azimuth	Approximately distance from alignment (m)	Direction relative to alignment / Washery Area	Adit Portal Level (mAOD)	Adit Level below alignment/ washery area (mAOD)	Track Level Above Adit (mAOD)	Anticipated Status of Adit Mouth	Risk Comments
285210-001	285145	210544	239	155	Towards washery area	N/A	N/A	Assume current ground level	Unknown	Directed away from the washery area but potential for adit roadway to pass beneath washery area. No mine plans are available to inform location/level/extent of this adit. May pass to south of The Washery area.
285210-028	285231	210447	349	160	Away from washery area	N/A	N/A	N/A	Unknown	Directed away from the washery area. No mine plans are available to inform location/level/extent of this adit. Low risk of subsidence / void migration below the washery area.
285210-025	285309	210284	14	410	Away from washery area	N/A	N/A	N/A	Unknown	Directed away from the washery area. No mine plans are available to inform location/level/extent of this adit. Low risk of subsidence / void migration below the washery area.
285210-002	285393	210290	158	470	Away from washery area	N/A	N/A	N/A	Unknown	Directed away from the washery area. No mine plans are available to inform location/level/extent of this adit. Low risk of subsidence / void migration below the washery area.

*Elevation at base of embankment at nearest point

Harry Wild
Atkins Limited
Woodcote Grove
Ashley Road
Epsom
KT18 5BW

Harry.Wild@atkinsglobal.com

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Appendix F. Factual Report Arup Ground Investigation 2021/2022



Global Centre of Rail Excellence Ltd

Global Centre of Rail Excellence

Ground Investigation Report

Reference: CG3600

I03 | 17 October 2022

This report takes into account the particular instructions and requirements of our client. It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 284523

Ove Arup & Partners Limited

4 Pierhead Street
Capital Waterside
Cardiff
CF10 4QP
United Kingdom
arup.com

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Appendix E – Mining Sections, Plans and the Detailed Mine Risk Study

1. Introduction

1.1 Background

Celtic Energy's Nant Helen site and Onllwyn Washery are to be developed by Global Centre of Rail Excellence Ltd. (GCRE Ltd.) as a rolling stock and rail infrastructure testing facility. The site is currently an operational opencast coal mine and coal washery. The proposed development would allow the site to be re-purposed once the opencast mining activities have ceased and the site has been restored.

1.2 Scope of report

Arup have been commissioned by GCRE Ltd. to produce a geotechnical and geoenvironmental interpretation of the ground and groundwater conditions encountered by a ground investigation undertaken by Quantum Geotechnical Limited and to support the discharge of the following planning conditions:

- Nant Helen Earthworks Conditions 16 (Powys) and 14 (NPT)

No development shall take place until a site investigation of the nature and extent of contamination has been carried out, by a suitably qualified competent person, in accordance with a methodology which has previously been submitted to and approved in writing by the local planning authority. A written report of the findings of the site investigation shall be made available to the local planning authority before any development begins. The written report should include an appraisal of remedial options and identification of the most appropriate remediation option(s) for each relevant pollutant linkage. The report is subject to the written approval of the local planning authority.

- GCRE Condition 22 (Powys & NPT)

No development shall take place in each phase of development as identified in condition 7 (including demolition, ground works, site, or vegetation clearance) until a site investigation of the nature and extent of contamination has been carried out, by a suitably qualified competent person, in accordance with a methodology which has previously been submitted to and approved in writing by the local planning authority. A written report of the findings of the site investigation shall be made available to the local planning authority before any development begins. A mine gas risk assessment should form part of the overall assessment.

The written report should include an appraisal of remedial options and identification of the most appropriate remediation option(s) for each relevant pollutant linkage. The report is subject to the written approval of the local planning authority.

It should be noted that the following conditions have already been informed by the desk study [1] and Environmental Statements for the main Nant Helen Complementary Restoration works [2] and GCRE [3]: Nant Helen Earthworks Conditions 15 (Powys) and 13 (NPT)

No development shall commence until a preliminary investigation and assessment of the nature and extent of contamination affecting the application site area has been submitted to and approved in writing by the local planning authority. This investigation and assessment must be carried out by or under the direction of a suitably qualified competent person, in accordance with extant guidance and best practice, and shall assess any contamination on the site, whether or not it originates on the site.

The report of the findings shall include:

- *A desk study*
- *A non-intrusive site reconnaissance*
- *Formulation of an initial conceptual model*
- *A preliminary risk assessment*

If the preliminary risk assessment identifies there are potentially unacceptable risks a detailed scope of works for an intrusive investigation, including details of the risk assessment methodologies, must be prepared by a suitably qualified competent person. The contents of the scheme and scope of works are subject to the approval in writing of the local planning authority.

- **GCRE Condition 21 (Powys & NPT)**

Notwithstanding those works already permitted and approved in accordance with planning approval 20/0738/FUL, no development shall take place in each phase of development as identified in condition 7 (including demolition, ground works, site, or vegetation clearance) until a preliminary investigation and assessment of the nature and extent of contamination affecting the application site area has been submitted to and approved in writing by the local planning authority. This investigation and assessment must be carried out by or under the direction of a suitably qualified competent person, in accordance with current guidance and best practice, and shall assess any contamination on the site, whether or not it originates on the site.

The report of the findings shall include:

- o A desk study*
- o A non-intrusive site reconnaissance*
- o Formulation of an initial conceptual model*
- o A preliminary risk assessment*

If the preliminary risk assessment identifies there are potentially unacceptable risks a detailed scope of works for an intrusive investigation, including details of the risk assessment methodologies, must be prepared by a suitably qualified competent person. The contents of the scheme and scope of works are subject to the approval in writing of the local planning authority.

All work and submissions carried out for the purposes of this condition must be conducted in accordance with DEFRA and the Environment Agency's 'Land Contamination Risk Management' and the WLGA document 'Development of Land Affected by Contamination: A Guide for Developers' (2012).

2. Existing Information

2.1 Location and topography

The Celtic Energy Nant Helen site is located approximately 20km north-west of Swansea, immediately south of Abercraf (refer to Drawing 1). The site boundary and track proposals are shown on the illustrative masterplan Drawing 003A. For ease of identification, throughout the report the site (as a whole) has been split into the “main site” and the “washery” portions. The main portion refers to the area that has been largely subject to opencast activity and is proposed to contain the rail test tracks, whereas, the “washery” portion refers to the extension of the site to the southeast incorporating the Onllwyn Washery.

The site is located on a hill with the highest point located roughly in the centre of the main site (~335m AOD) and with ground levels falling away in all directions from this point. The ground levels fall more substantially towards the north; down to about 200m AOD, whereas the eastern, southern, and western extents of the main site fall to around 240 – 260m AOD. Immediately to the west of the site boundary is part of the opencast workings that is currently active. Its lowest point is at approximately 90m AOD (approximately 150m below surrounding natural ground level) The Washery portion of the site is sat at a lower elevation of approximately 230m AOD.

2.2 History

A detailed review of the site’s history based on historical maps dating back to 1867 is provided in the desk study [1]. In summary, several collieries were located along the northern and southern boundaries of the site between 1876 and 1977. Where the coal seams are known to be relatively shallow, in the north and the south of the site, they may have been worked by bell pitting (near surface shafts of typically less than 10m depth). Depressions which may be the result of bell pitting can be observed in Figure 12 of the desk study which shows an aerial image from 1945. Onllwyn Colliery was the last shown to be active on the 1977 aerial photography.

From review of mine abandonment plans and aerial images opencast working is understood to have started in 1946 in the Onllwyn excavation. The subsequent aerial photographs show evidence for the working of the second Onllwyn, the Abercraf/Gwaunton, the Nant Helen and the Nant Helen Extension opencast sites. With the exception of the Nant Helen Extension, the rest of the opencast workings have now been backfilled.

Since the map dated 1876, various rail tracks and tramways are shown to have crossed through and run along the boundaries of the site. The washery portion of the site has contained rail tracks/sidings and tramways since the earliest historical mapping and towards the end of the 20th century the extent of coal mining washery infrastructure and stockpile/spoil heaps increased.

2.3 Geology

The geology beneath the 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) [4], the BGS 1:50,000 geological mapping (Sheet 231) [5] and the BGS GeoIndex online viewer [6]. Refer to Drawing 2 and Drawing 3 throughout, which show BGS’s 1:50,000 geological mapping.

2.3.1 Made ground

Several areas of artificial ground are shown on Drawing 2. In the main site, these are associated with areas of backfilled opencast workings. The large area in the north of the main site is associated with the backfilling of the Abercraf/Gwaunton opencast coal mine. Made ground is also shown

beneath the washery, which is likely associated with levelling this area for the railway sidings and buildings.

2.3.2 Natural superficial deposits

The geological maps show that the site, for the most part, is devoid of superficial deposits. The exceptions being: an area of peat in the centre of the main site and in the north and west of the washery; glacial till, in the south and west of the main site and along the eastern boundary of the washery. The peat in the centre of the main site and the glacial till in the west of the main site are on areas of opencast working, so are unlikely to be present.

Glacial till typically comprises a heterogenous mixture of clay, sand and gravel with large cobble and boulder inclusions of various sizes and shapes (diamicton). Peat typically comprises a partially decomposed mass of vegetation that has been deposited under largely anaerobic conditions, usually found in bogs or swamps.

2.3.3 Bedrock

The bedrock beneath the site is part of the South Wales Middle and Lower Coal Measures. They typically comprise rhythmic sequences of mudstones (commonly containing pyrite), siltstones, sandstones, grits, fireclays, seatearths and coals; the coals found in these measures tend to be amongst the thickest and most economically significant in South Wales. According to the geological memoir (Sheet Memoir 231) from 1988, nodular masses of pyrite, up to 0.15m thick, are often present within the Middle and Lower Coal Measures formations [7].

Dip angles for the bedrock bedding shown on the 1:10,560 geological mapping typically dip in a west south-westerly direction at angles ranging from between 5° and 15° [4]. However, there are localised variations to this, with a number of anticlines and synclines shown.

Three named faults are shown on the published geological maps crossing the site with a NNW-SSE strike, as well as two other parallel unnamed faults which protrude into the northern boundary of the site. The three major faults the Pwllau Bach Fault, the Chapel Fault, and the Glyncorrwg Fault (ordered from west to east) divide the bedrock beneath the site into three fault blocks as shown on Drawing 3. The throw of the faults shown on Figure 11 of the desk study is based on values reported in the geological memoir for sheet 231 from 1904 [7]. As well as the two unnamed faults that extend into the northern part of the site, it is likely that there are other unidentified faults within the site boundary.

2.4 Hydrology

The site covers three principal river catchments: the River Tawe to the north; the Nant Llech, to the northeast and the Dulais, to the south. There are many tributaries; some of which are associated with ponds or adits on the site, which feed these streams. Figure 7 of the desk study [1] shows many of the watercourses, including a culverted watercourse in the washery.

2.5 Hydrogeology

Section 8 of the desk study provides a review of published hydrogeological maps, the aquifer designations of the materials beneath the site, abstraction licences close to the site and considers the potential groundwater levels beneath the site.

Based on logs available from the BGS, the groundwater level within the washery portion of the site is anticipated to be between 3.4m and 7.2m below ground level. Shallower strikes and slight seepages were also noted as shallow as 1.0m bgl.

It is understood that dewatering operations within the Nant Helen Extension opencast site aim to maintain the water level at approximately 100m AOD. As highlighted in the Environmental Statement for the Nant Helen Extension opencast, the lowest projected level of excavation within the Nine Feet seam could be as low as 76m AOD. As dewatering would be required to reach this depth, it is likely that the groundwater level would be locally reduced to a similar level.

Post completion of opencast excavation in the area it is possible that the groundwater levels will rebound to a similar level that was encountered within the boreholes progressed during the British Coal ground investigation in the 1990s (between ~100m AOD and ~120m AOD) [8].

Based on the levels of the adits shown on mine abandonment plans and the monitored rates of discharge, the Environmental Statement [8] states that the level of the groundwater in mine workings to the west of the Pwllau Bach Fault is controlled by the discharge from three main adits: the Yard Adit, which discharges to the River Tawe at approximately 122m AOD; the Gwaun Clawdd Adit, which discharges to the River Tawe at approximately 106m AOD and the Cwm Du adit, which discharges to the River Tawe at 93.6m AOD.

2.6 Mining

Section 9 of the desk study [1] reviews published geological maps and the Coal Authority Online viewer to inform on the location of coal seam outcrops and their sequence beneath the site. In all, 16no. seams were identified. It then discusses the location of collieries and mine entries across the site and the extent of underground workings, based on mine abandonment plans provided by Celtic Energy. The extent of opencast mine workings is assessed based on opencast completion plans and aerial images. Risk zones were drawn up on Figures 8 and 9 of the desk study, which are areas where there was considered to be the potential for subsidence as a result of collapsing shallow mine workings.

3. Proposed development

Global Centre of Rail Excellence Limited (GCRE Ltd), propose to construct a rail testing, storage, and maintenance facility. The proposed infrastructure is to be located on the site of the former Nant Helen open cast coal mine and colliery wash area, currently owned and operated by Celtic Energy.

Celtic Energy are required to restore the Nant Helen site in accordance with regulatory requirements and agreements with Powys County Council (PCC). The Nant Helen Complementary Earthworks scheme which includes the creation of 17.5m wide plateaus on the site has been approved through the Planning process.

The proposed GCRE rail test track is composed of two rail tracks on sleepers set in a ballast track foundation, associated Overhead Line Equipment (OLE) to support electric trains and all other required supporting infrastructure. The tracks are proposed to be located on the plateaus provided by the Complementary Earthworks scheme. The tracks include a larger outer loop as well as a smaller inner loop (Drawing 2). A vehicle access track is proposed adjacent to the proposed rail loops.

The GCRE rail depot and storage facility is proposed to be located on the site of the current colliery washery. 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 a number of buildings forming an Innovation Hub as well as further Industrial/Commercial developments.

4. Field and laboratory studies

4.1 Previous ground investigations

The desk study reviews the materials encountered in the boreholes of the 1986 Nant Helen Geotechnical ground investigation and eight borehole scans that are available through the BGS web viewer [6]. The positions of these exploratory holes are shown on Drawing 2 to 5.

4.2 Global Centre of Rail Excellence – Initial ground investigation

The site works for the initial ground investigation for the Global Centre of Rail Excellence was undertaken between 15th November 2021 and 19th January 2022. The completed scope of works is summarised in Table 1 below.

Table 1: Scope of initial ground investigation for GCRE

Fieldwork component	Description
Exploratory holes	35no boreholes between 19.2m and 61.5m depth drilled using either cable percussive, open hole rotary, rotary coring, or sonic coring methods. In the original scope ten of the holes were to be completed using sonic drilling within the areas of open cast backfill. After three holes it was found that sonic drilling was less effective (slower and could achieve less depth) than conventional rotary drilling, so the remaining holes scheduled to be undertaken with sonic drilling were undertaken using rotary methods to the maximum depth that could be achieved with these rigs.
	40no trial pits. 11no of which were to investigate anomalies identified by the geophysical surveys and eight to undertake soakaway testing.
In-situ testing	Standard Penetration Tests (SPT).
	Hand shear vane tests in trial pits when cohesive deposits were encountered.
	7no. soakaway test pits.
	Particle size grading of material larger than 125mm using a graticule was undertaken in eight trial pits that were in areas of backfilled opencast working.
Geophysical surveys	Magnetic, electromagnetic and microgravity surveys undertaken across 4 areas within the Washery area of the site to investigate the locations of recorded mine entries.
Installations and monitoring	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. Groundwater and ground gas monitoring has been undertaken fortnightly for 12 weeks from the completion of the site works.

Locations of the exploratory holes for the GCRE initial ground investigation are presented on Drawing 2 to 5. The factual report and AGS data for this ground investigation is available as a separate document [9].

The results from the ground gas monitoring are summarised in Appendix C-3. The results from the groundwater monitoring are summarised in Appendix C-5.

4.2.1 Objectives of ground investigation (BS10175)

The ground investigation was carried out in accordance with BS10175 (2011) [10] as an initial exploratory investigation in order to:

- test the conceptual model(s) of contamination and site characteristics;
- obtain further information in relation to potential sources of contamination, likely pathways and features of immediate concern;
- obtain further information on the geology, geochemistry, soil and hydrogeology of the site;
- provide further information to aid the design of the detailed investigation, including health and safety aspects; and
- provide data for a review of the conceptual model and to update the risk assessment.

4.2.2 Installations and monitoring plan

The installations and monitoring plan as part of the initial GI was to construct installations within both the Nant Helen and washery sites based on preliminary investigation data and the initial conceptual model [1], to enable the measurement of water levels and preliminary water quality analysis. The monitoring wells were installed within the bedrock (Nant Helen and washery sites), colliery spoil (Nant Helen site) and made ground (Washery site).

With respect to ground gas, the monitoring plan was the construction of installations within all potential sources of ground gas identified as part of the initial conceptual site model including made ground in the washery, colliery spoil and backfill in the Nant Helen site and bedrock underlying both sites in order to confirm potential for ground gas generation from the coal measures strata and mine gas in relation to the undergoing workings within the coal measures.

4.2.3 Spacing between sampling locations

Exploratory hole locations for contamination sampling from the boreholes and trial pits within the washery were targeted at potential sources of contamination and where access was available spaced on a grid of approximately 50m centres. The spacing was determined taking into account the conceptual site model, acceptable levels of uncertainty as part of this initial GI and the requirements for preliminary risk assessments. The Nant Helen site was not targeted for sampling for contamination, as the backfill from the opencast workings was not expected to contain any man-made inclusions (any material that is showing sign of contamination would be sampled and tested) and its potential for contamination is low. This material would be targeted as part of the detailed ground investigation to confirm this.

4.2.4 Frequency of sampling locations

The frequency of contamination sampling from the boreholes and trial pits within the washery and from any material that is showing sign of contamination (e.g. olfactory or visual) is summarised below:

- 1m intervals and at each change in strata up to 5m bgl in made ground;
- 3m intervals and at each change in strata between 5m bgl and 20m bgl in made ground;
- One sample is required from natural ground that underlies made ground (at depths of less than 20m bgl);
- Where natural ground is not overlain by made ground no samples are required.

4.2.5 Geotechnical laboratory testing

Soil and rock samples were taken from the ground investigation exploratory holes and selected samples subject to geotechnical and geoenvironmental laboratory testing. Table 2 below details the geotechnical laboratory tests that were undertaken on the collected samples.

Table 2: Summary of geotechnical laboratory testing

Material	Category	Geotechnical test type
Soil	Classification tests	Moisture content of soil
		Atterberg Limits tests
		Particle size distribution (PSD) tests
	Strength tests	Unconsolidated undrained (UU) triaxial compression tests
	Consolidation tests	One-dimensional consolidation tests
	Earthworks tests	Compaction tests (dry density/moisture content relationship testing)
		Moisture condition value/moisture content relationship testing
Soil and rock	Chemical tests	Mass loss on ignition
		Organic matter content
		BRE SD1 Suite B concrete aggressivity tests
		BRE SD1 Suite D concrete aggressivity tests
Rock		Point load Index (Rock)
		Unconfined Compressive Strength (UCS – Rock)
		LA coefficient
		Freeze Thaw
		Soundness by magnesium sulphate
		Slake Durability

4.2.6 Geoenvironmental laboratory testing

The following geoenvironmental laboratory tests were undertaken as informed by the potential sources of contamination identified as part of the desk study [1]:

Soils samples:

- General suite (metals, cyanide phenol, TOC, pH)
- Asbestos identification (no asbestos quantification testing carried out as none of the samples tested identified asbestos)
- Speciated TPH (CWG)
- Speciated PAH (USEPA16) & BTEX
- VOC & SVOC
- Hexavalent Chromium
- Loss on Ignition
- Waste Acceptance Total Solids
- Waste Acceptance Leachability

Groundwater samples:

- General suite (metals, cyanide phenol, DOC, pH)
- Speciated TPH (CWG)
- Speciated PAH (USEPA16) & BTEX
- PCBs

Leachate samples:

- Soil Leachability general suite (metals, cyanide, phenol, pH)
- Soil Leachability PAH

The results of the geoenvironmental laboratory testing on soil, leachate and groundwater samples obtained from the exploratory holes are summarised in the table presented in Appendices C-1 and C-2 respectively.

4.3 Settlement monitoring

Ground level monitoring points had been set out at 28No. locations across the areas 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 in terms of Ordnance Datum (Newlyn) for each of the 28 survey points.

The settlement points were specified as part of the wider topographical survey of the site the points themselves were constructed based on the standard detail set out in Figure 1 below.

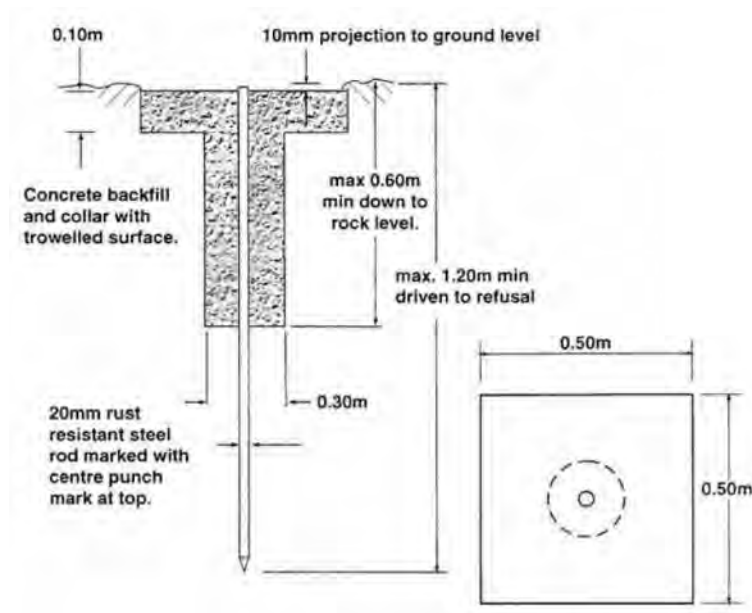


Figure 1 Settlement monitoring point standard detail

5. Ground conditions

The ground conditions described in the following sub sections have been deduced from the available site investigation data, that includes reference to both the Initial GCRE Ground Investigation and the boreholes for the Nant Helen opencast workings.

5.1 Topsoil

Topsoil was encountered in 21no. of the 75no. completed holes with thicknesses ranging between 0.05m and 0.9m. It was not recorded in any of the Washery holes but was found in TP18 (south of the main site, near the railway) and in holes typically on the eastern side of the main site.

It is typically described as a *Brown clayey sandy gravel* or a *Brown sandy gravelly clay*.

5.2 Made ground

5.2.1 Description and site coverage

Made ground was encountered in all but one of the holes in the Washery (BH32). The opencast backfill within the main site is considered separately in Section 5.3 below, on the grounds that this is purely reworked natural material.

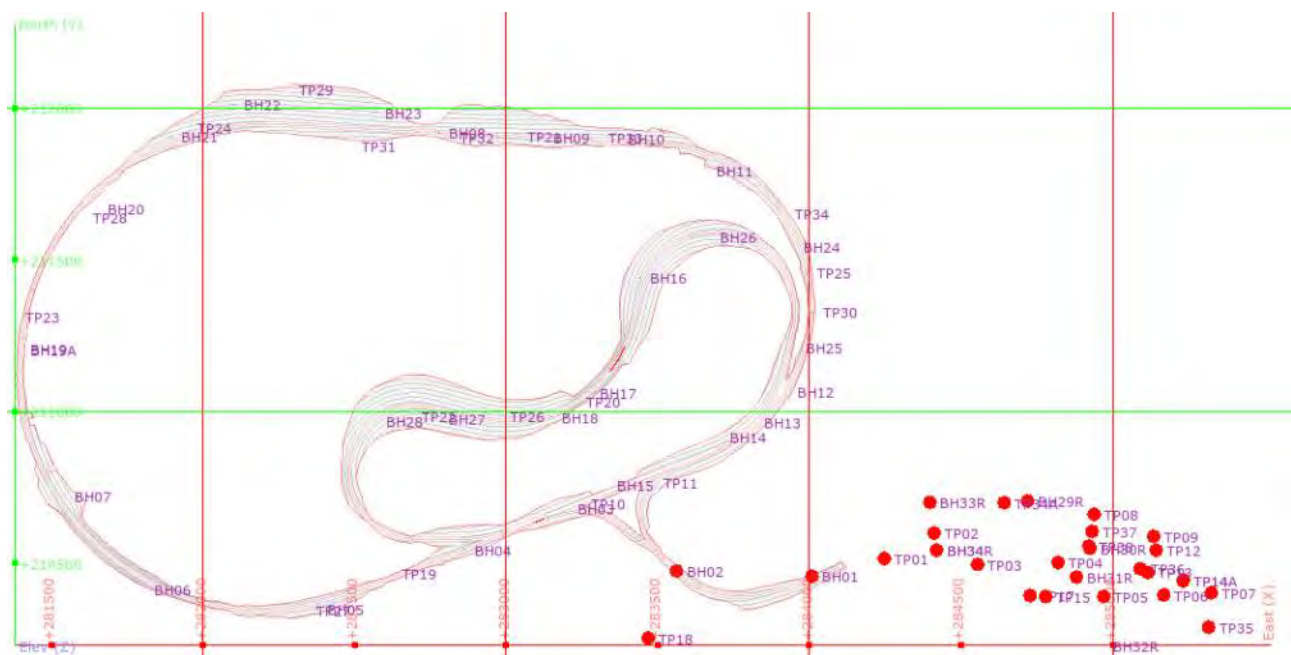


Figure 2: Holes that encountered made ground

The proven thickness of made ground ranged between 1.2m and 8m, with the greater thicknesses typically recorded in the centre of the washery and the lesser thicknesses on the periphery of the Washery.

The made ground was typically described as a *loose black or dark grey slightly clayey slightly sandy gravel*. The gravel component typically comprised coarse angular to sub-angular mudstone and the material sometimes includes coal, ash, concrete, clinker, bricks, timber, plastic, and metal. Other man-made items that were encountered include: cable, steel rope, metal sheeting and plastic bags in TP13; railway sleepers in TP34A and TP08 and rubber in TP07 and TP36.

Soft clay or silt was found in BH34 and TP09. In BH34, the soft clay was recorded from 3.3m bgl to 4.95m bgl and from 6.9m bgl to 8m bgl. In TP09, slightly sandy gravelly silt was recorded from 0 to 2m bgl.

Peat was also recorded within the made ground of BH34 from 5m bgl to 6.9m bgl.

5.2.2 Engineering properties

A summary of the classification test results on samples from the made ground are presented below in Table 3. The associated plots are presented in Appendix B (B01 to B04).

Table 3: Made ground classification test results summary

Property	Result range	Mean	Number of tests
Moisture content %	2 - 30	14	28
Plastic limit %	14 - 26	19	3
Liquid limit %	42 - 70	52	3
Plasticity index %	19 – 56	34	3
Bulk unit weight (kN/m ³)	22.5	22.5	1

Atterberg Limits testing was undertaken on cohesive samples of the made ground (note that the made ground is primarily granular). The plasticity index results indicate that two of the samples were of intermediate plasticity and one (BH34 at 6.2m bgl) was between high and very high plasticity. (The high plasticity sample is a sample of peat).

Particle size distribution tests were undertaken on 17no. samples of made ground. They show that the material is primarily a clayey silty sandy gravel, but there is a range of results up to a material comprised predominantly (77%) clay/silt.

The SPT-N values in the made ground range from 8 to 18.

An undrained unconsolidated triaxial test was undertaken on one sample of made ground from BH34 at 6.2m bgl. It recorded an undrained shear strength of 48kPa at a cell pressure of 120kPa.

5.3 Backfill from opencast workings

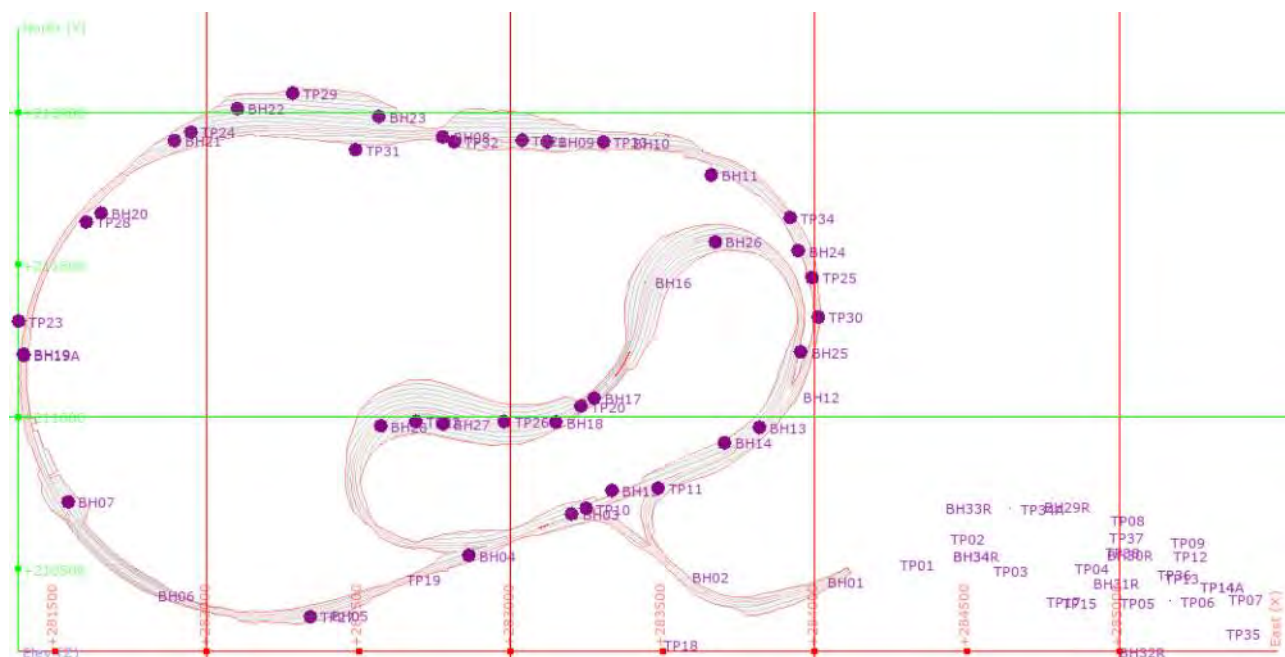
5.3.1 Description and site coverage

Areas of opencast backfill had been identified from mine completion plans during the desk study as shown on Drawings 2 and 3. The completion plans also provided details on the depth of each former opencast working (refer to Table 4). The ground investigation proposed to prove the base of each worked area using sonic drilling rigs. However, having attempted the first three holes, it became evident that the rigs would not be able to achieve these depths and that a conventional drilling rig would likely achieve a similar depth to what was possible with the sonic rig, but in less time. The remaining holes were completed using rotary drilling to either the scheduled depth or the maximum depth that the rig could achieve. The depths achieved by these holes is provided in Table 4 below.

Table 4: Opencast workings summary table

Name	Maximum excavation depth from completion plans	Depth achieved in the ground investigation
Nant Helen	~130m	BH27: 61.5m bgl base unproven BH28: 49.2 m bgl base unproven
Nant Helen Extension	~150m	BH19: 28.2m bgl base unproven BH20: 40.2m bgl base unproven
Abercraf/Gwaunton	~40m	BH21: 33m unproven BH22: base proved at 31.5m bgl BH23: base proved at 21.4m bgl
Onllwyn	~82m	BH24: 49.8m bgl base unproven BH25: 49.2m bgl base unproven BH26: base proved 35.2m bgl

Backfill from the opencast workings was found in the majority of holes on the main site, including areas outside the extents of the former excavations. Thickness of the backfill encountered in the ground investigation ranged from 0.3m to greater than 61.5m bgl but is anticipated to be up to 150m thick in the Nant Helen Extension.

**Figure 3: Holes that encountered opencast backfill**

The backfill is typically described as a *dark grey/black slightly sandy clayey gravel with medium cobble content*. Boulders were also commonly encountered in the trial pits. In some holes it is described as a *soft to firm grey slightly sandy gravelly clay*, which is generally at shallow depths (less than 4.5m), with the exception of BH21 where it is 33m thick.

Thicknesses of colliery spoil were encountered outside of the known areas of opencast working. This is presumably associated with the movement and stockpiling of the material around the site.

5.3.2 Engineering properties

A summary of the classification test results on samples from the opencast backfill are presented below in Table 5. The associated plots are presented in Appendix B (B05 to B10)

Table 5: Backfill classification test results summary

Property	Result range	Mean	Number of tests
Moisture content %	14 - 27	19	11
Plastic limit %	13 - 19	17	11
Liquid limit %	20 - 45	31	11
Plasticity index %	5 – 26	15	11

The Atterberg Limits tests were undertaken on cohesive samples of the backfill (note that the backfill is primarily granular). The plasticity index results show that the sampled cohesive material of the backfill is of low to intermediate plasticity.

Particle size distribution tests were undertaken on 26no. samples of backfill. They show that the material is primarily a slightly clayey slightly silty slightly sandy gravel. In addition to the laboratory particle size distribution tests, the contractor used a graticule to do a field assessment of the proportion of material between 125mm and 300mm and of the material greater than 300mm excavated from trial pits. Typically, the fill comprised approximately 10% grains of between 125mm and 300mm, and 5% grains of greater than 300mm.

The SPT-N values in the fill have a broad scatter, ranging from 5 to an extrapolated values of 3400. The scatter in the SPT-N values is likely reflective of the random sorting and variable grain size of the material i.e., the high values likely being when the test was undertaken on a boulder.

Seven 5-point compaction tests were undertaken on samples of opencast backfill. Note that these tests were undertaken on samples of backfill that will have been sieved to remove the coarse fraction of material. There was one outlier, TP23, which had an optimum moisture content of 6.7%. The others had optimum moisture contents of between 10% and 12%.

Moisture condition value (MCV) – moisture content relationships were undertaken on seven samples of the backfill, at moisture contents ranging between 2.4% and 18%, which resulted in MCVs ranging between 3.9 and 14.5.

With the backfill having been worked, placed, and moved at different times it may be necessary to do a more detailed assessment, where by the areas of backfill are zoned into areas of similar geotechnical properties.

5.4 Glacial till

5.4.1 Description and site coverage

Glacial till was encountered in 28no. of the exploratory holes. The areas where it was encountered include:

- the southern edge of the main loop (between chainages 0 – 1100m and 5100 – 7000m of the main loop section in Appendix A);
- the north-south transect between the Onllwyn and the Nant Helen excavations;
- within approximately half of the exploratory hole locations in the washery, primarily the ones towards the southeast.

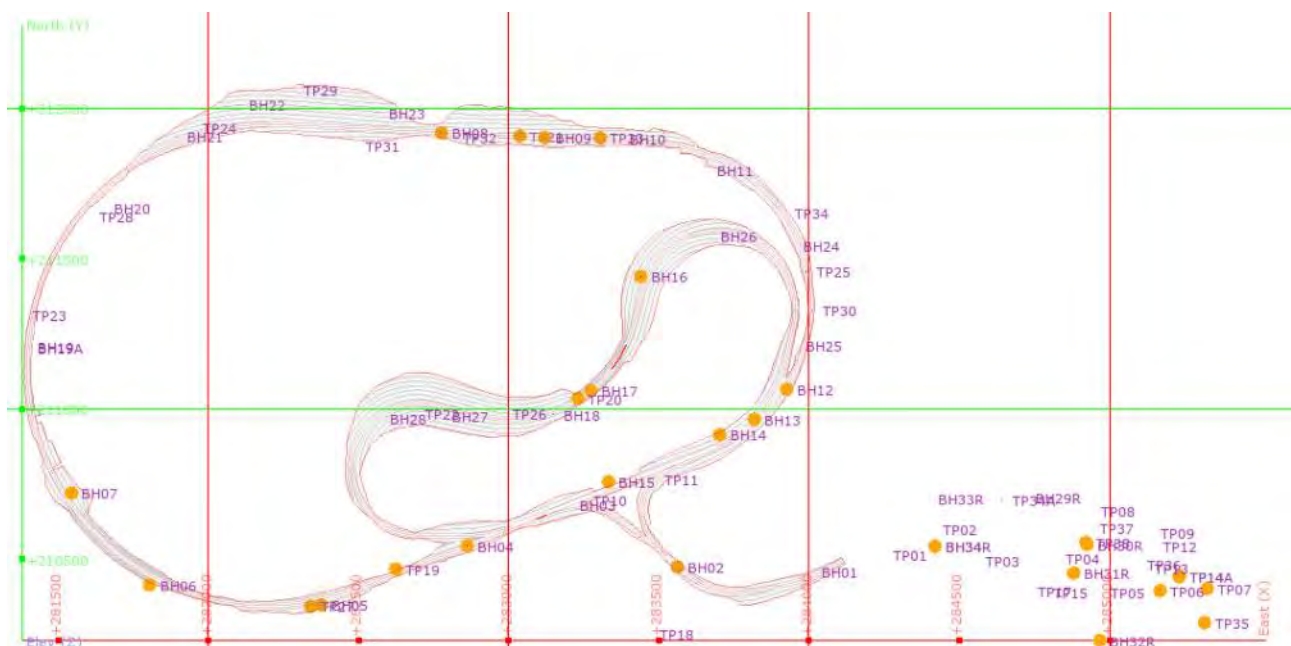


Figure 4: Holes that encountered glacial till

The glacial till was encountered across the (except areas where it is assumed to have been excavated i.e., opencast working) and typically was between 0.7 and 4.4m thick but was recorded to be 10m thick in BH08 and 11m thick in BH05. In BH08, the glacial till underlies the backfill associated with the Gwaunton/Abercraf excavation, and in BH15 the glacial till was encountered from surface and is within the area indicated by the BGS mapping [6] to be covered by glacial till.

It is typically described as a *firm brown sandy gravelly clay with medium cobble and boulder content. Gravel is fine to coarse sub-angular to sub-rounded mudstone, siltstone, and sandstone. Cobbles are rounded to sub-rounded sandstone.*

5.4.2 Engineering properties

A summary of the classification test results on samples from the glacial till are presented below in Table 6. The associated plots are presented in Appendix B (B11 to B18).

Table 6: Glacial till classification test results summary

Property	Result range	Mean	Number of tests
Moisture content %	11 - 39	21	14
Plastic limit %	11 - 28	17	12
Liquid limit %	29 - 62	44	12
Plasticity index %	14 - 50	27	12

The plasticity index results show that the clay ranges between low and high plasticity.

Particle size distribution tests were undertaken on 10no. samples of glacial till. They show that there is wide variety in grain size from predominantly cobbles and boulders in TP27 to predominantly clay in BH31.

Three organic matter content tests were undertaken on samples of glacial till. The samples from BH30 and TP19 had 3.8 and 3.6% organic matter, whilst the sample from BH32 at 2m bgl had an organic matter content of 43%. The material in BH32 is described as *soft to firm brown sandy gravelly silty CLAY with medium cobble content. Gravel is fine to coarse sub-angular to sub-rounded Mudstone, Siltstone and Sandstone. Cobbles are rounded to sub-rounded Sandstone.*

The SPT-N values in the glacial till also have a wide range of results from 5 to an extrapolated value of 1020. (The high SPT N values are anticipated to be due to the tests hitting a cobble or boulder). Excluding high results that may be attributed to hitting boulders during the test, the results typically ranged between 10 and 50.

Hand shear vane tests were undertaken in four holes. The peak undrained shear strength results ranged between 10kPa and 140kPa and were typically between 30kPa and 75kPa. The residual undrained shear strength test results ranged between 2kPa and 44kPa and were typically between 14kPa and 24kPa. The very low hand vane strength values (<5kPa residual) were all in TP27 in material described as *Very soft yellow brown slightly silty slightly sandy slightly gravelly CLAY*, which was 0.4m thick and underlay a band of peat. The next trial pit to the east of TP27 encountered *Soft to firm yellowish brown grey sandy gravelly CLAY with low cobble content of sandstone. Gravel is sub angular to sub rounded fine to coarse sandstone*, which recorded peak handvane strengths of between 32kPa and 40kPa. BH05, also in the area of TP27 and TP19, recorded peak hand vane test results of between 40kPa and 140kPa, which is typical of a firm to stiff clay. The SPT N values in the same material from BH05 are 23, 40 and 36, which is typical of a stiff to very stiff clay. The variability of these results may be due to the glacial till being gravelly and containing cobbles.

One compaction test was undertaken on a sample of the glacial till, from TP19 at 1.5m bgl, which had an optimum moisture content of 11%. The sample is from material described as *Firm dark grey slightly sandy gravelly CLAY with low cobble content of sandstone*, which is considered to be fairly representative of the glacial till at the site. Note that for the compaction test to be undertaken the coarse fraction (gravel, cobbles, and boulders), will have been removed from the material. Moisture content – moisture condition value (MCV) relationship testing was undertaken on the same sample of glacial till at moisture contents between 4% and 16%. The MCV's ranged between 12 and 4 and was 8.5 at 11% moisture content.

5.5 Peat

5.5.1 Description and site coverage

Peat was encountered in five holes across two areas of the site; the Washery and the southern part of the main loop.

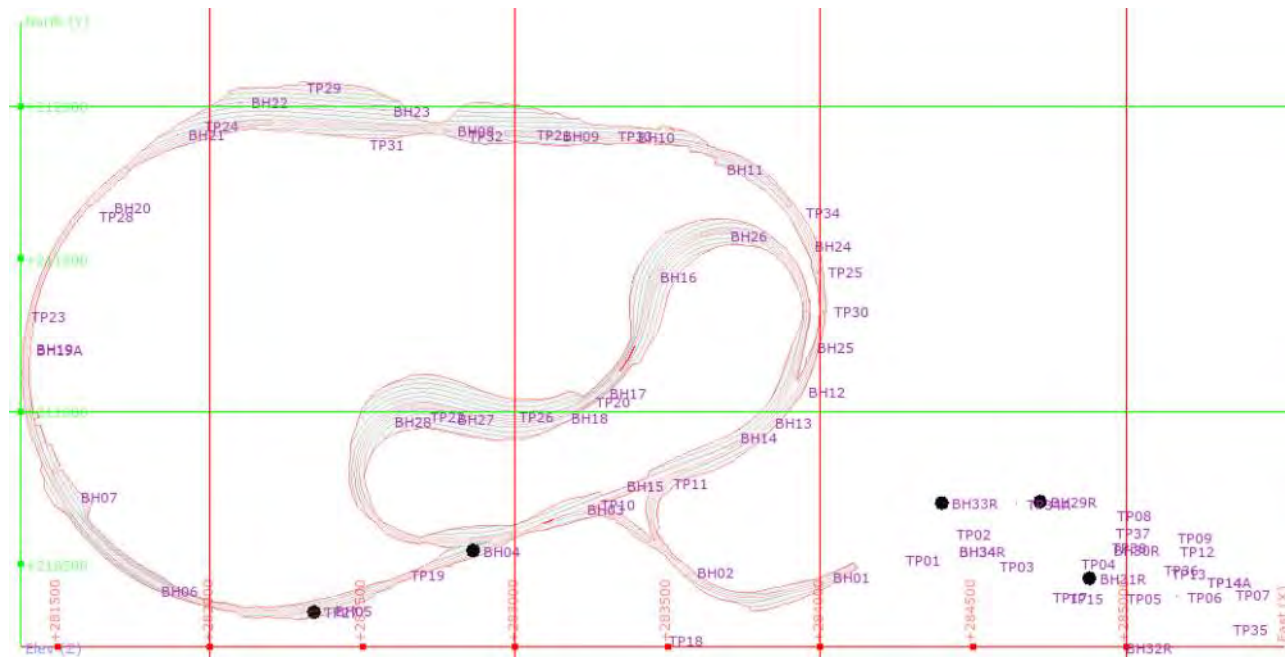


Figure 5: Holes that encountered peat

In the Washery it was encountered in BH33, BH31 and BH29, and was between 1m and 2m thick, at depths ranging from 2m bgl to 7.8m bgl. In each of the boreholes it was described as ‘*Soft brown fibrous peat*’.

It was also found in BH34 in the Washery in the made ground between 4.8 and 6.9m bgl. This was categorised as made ground as the underlying clay contained ash. There is chance that this ash could have been dragged down from material above.

In the southern part of the main site, in the region shown on the BGS geological maps [5] to be covered by glacial till, peat was found in BH04 and TP27. It was 0.4m thick (1.6 – 2.0m bgl) in BH04 and 0.2m thick (0.7 – 0.9m bgl) in TP27. It was described as ‘*dark brown peat*’ and ‘*dark brown fibrous peat*’ in these holes.

5.5.2 Engineering properties

A summary of the classification test results on samples from the peat are presented below in Table 6. The associated plots are presented in Appendix B (B19 to B26)

Table 7: Peat classification test results summary

Property	Result range	Mean	Number of tests
Moisture content %	16 - 174	70	3
Plastic limit %	16 - 99	44	3
Liquid limit %	41 - 230	104	3
Plasticity index %	24 - 131	60.3	3
Bulk unit weight kN/m ³	17.8 – 21.6	19.1	2

The plasticity index results show that the peat ranges between intermediate plasticity (two results) and extremely high plasticity (one results).

Particle size distribution tests were undertaken on three samples of peat. Two samples show that the peat primarily comprises clayey silty sandy gravel, whilst the other, BH31 at 6.8m bgl, primarily comprises silty sandy clay.

Two organic matter tests were undertaken on samples of peat. One in BH31, which had an organic matter content of 46% and one in BH33, which had an organic matter content of 3.9%.

Four SPT-N values were undertaken in the peat ranging between 8 and 11.

Four one dimensional consolidation tests were undertaken on samples of peat. All of which deformed as normally consolidated material. The sample from BH31 at 6.7m bgl recorded much higher void ratios of between 4.1 and 6.3 than the other three samples which had void ratios of between 0.28 and 0.57. Similarly, the sample from BH31 shows much higher coefficient of compressibility (mv) compared to the other three samples. The coefficient of consolidation (Cv) values are highly variable between the sample locations and at different pressure increments.

5.6 South Wales Coal Measures

5.6.1 Description and site coverage

The South Wales Coal Measures underlie the whole site. Where encountered it is typically a *weak to medium strong mudstone/siltstone*. To a lesser extent it does have beds of sandstone, coal, and conglomerate.

The sandstone is described as a *strong grey sandstone* and was encountered in BH01, BH02, BH10, BH14, BH16 and BH18, which are all on the main site to the east of the Pwllau Bach Fault. The sandstone varies in thickness from 0.3 – 7.5m thick and has an upper surface depth of between 4.2m bgl and 33.4m bgl. It is within the proposed cuts at the locations of BH14 and BH16.

The conglomerate was encountered in BH17 (within a proposed cutting on the main site) and BH32 (to the south of the Washery). In BH17 it is described as a '*Strong grey sandstone conglomerate with mudstone nodules*' and is 1.8m thick. It is directly above the proposed cut depth at this location with an elevation of 264 – 265.8mAOD.

Coal seams were encountered in ten of the holes on the main site. These are outside the areas of backfill, in the south and east of the main site. The coal encountered ranged in thickness from 0.2m

to 1.7m and ranged in depth from 10.7 to 36.2m bgl. It is typically described as *weak black coal*. It occurs within the proposed cut depths in BH07 and BH16.

In the Washery, a coal seam was encountered in each of the boreholes except BH29. It ranged in thickness from 0.6m to 3.2m and ranged in depth from 11.8 to 28.1m bgl. It is typically described as *weak black coal*.

Voids, assumed to be a result of historical underground coal mining, were recorded in BH02, BH17 and BH30. These are considered in Section 7.

5.6.2 Engineering properties

Plots to inform on the engineering properties of the underlying bedrock, the South Wales Coal Measures, are included in Appendix B (B27-B34).

Standard penetration tests were undertaken on proving the surface of the bedrock and when soft rock was encountered. They were all undertaken within the top 2m of the bedrock, which may be representative of the depth that the rock's weathered profile extends to. The SPT N range between 11 and an extrapolated value of 1700.

Two unconfined compressive strength test was undertaken on samples taken from the core, which recorded UCS's of 6.2Mpa (mudstone) and 13.2Mpa (siltstone). For UCS tests to be undertaken a sample of intact core of 2.5x the core diameter is required. Due to the rock comprising predominantly weak mudstone, this was rarely achievable at shallow depths and that the results of the two completed UCS tests are likely to be stronger than a truly representative result. The size corrected point load index results range between 0 and 6.8Mpa. Based on the logs descriptions and the core recovery, a correlation of $UCS = 14 \cdot Is_{50}$ was used as recommended [11] for soft rocks. The correlated UCS values therefore range from 0MPa to 95MPa, but typically range between 1 and 10MPa.

Fracture spacing on the main site in the South Wales Coal Measures typically ranged between 50mm and 150mm, with values of less than 50mm more common in the top 10m of the rock. Rock quality designation (RQD) from core collected on the main site ranged between 0% and 92%, averaging 26%.

Fracture spacing on the Washery site in the South Wales Coal Measures typically ranged between 40mm and 110mm. Several higher values, of up to around 250mm, were recorded in the cores from more than 10m below the top of rock. Rock quality designation from core collected on the Washery site ranged between 0% and 67%, averaging 26%. The RQD's were particularly low in the upper 7m of the rock, but below which higher values were commonly recorded. This may be associated with the material below 7m predominantly being logged as siltstone rather than mudstone.

Aggregate testing including slake durability, soundness by magnesium sulphate, Los Angeles coefficient and resistance to freezing and thawing have been undertaken on six samples (five mudstone and one siltstone). The results are summarised in Table 8 below.

Table 8: Summary of aggregate testing results

Test	Results summary
Slake durability	Slake durability index tests were undertaken on six samples. The results of the first cycles ranged between 84.9% and 97.9%. The second cycle of results ranged between 73.8% and 96.2%.
Soundness by magnesium sulphate	One result of 38% and five results between 69 and 90%. The 90% value pertaining to the sample of siltstone, the others are all of mudstone.
Los Angeles coefficient	One result of 22% and five results between 35% and 41%. The 41% values pertaining to the sample of siltstone, whilst the others are sample of mudstone.
Resistance to freezing and thawing	Five results ranging between 18.9% and 25.3%

5.7 Groundwater

5.7.1 Groundwater levels

Groundwater monitoring has been undertaken fortnightly for a period of 12 weeks from 15no. groundwater installations. The results are summarised in Table 9 below and in the graphs in Appendix C-5.

The groundwater in the Washery is typically less than 5m bgl and less than 1m bgl (typically between 230mAOD and 235mAOD) where ground level is lower in the north of the Washery (BH31 and BH33).

The installations in the backfill of the former opencast Nant Helen, Nant Helen Extension and Abercraf/Gwaunton workings have predominantly been dry. This is not surprising as the installations have a minimum elevation of 171m AOD and it is anticipated that the surface of the groundwater is likely less than 120mAOD (refer to Section 2.5). BH07 is also dry (to 10m bgl/261.3m AOD) but is located within 50m of the Nant Helen Extension which is drawing the water level down to around 100m AOD.

BH25, in the backfill of the Onllwyn excavation is the only borehole within the backfilled open cast workings to record groundwater within the installation. It has recorded groundwater levels between 4.9m bgl and 15.1m bgl (242.6 - 252.8m AOD), which is up to approximately 1m below the proposed track level. This suggests that the groundwater in the Onllwyn backfilled opencast workings is not in hydraulic continuity with the Nant Helen opencast working and that the rate of drainage through fractures and/or adits from within the opencast working is relatively low compared to the backfilled excavations to the east.

BH15 and BH16 located on the main site outside of the backfilled opencast areas, have recorded shallow groundwater. BH15 is located on the southern side of the main site in a relatively low-lying area (250m AOD), with ground level rising to the east and west (to around 260m AOD). BH01, between the Washery and the main site encountered artesian groundwater during drilling, recording two strikes: one at 5m bgl (when bedrock was hit) and one at 13m bgl (when a coal seam was hit), both of which rose to 0.5m above ground level (228.8m AOD). The artesian groundwater is assumed to be present here due to the fall in ground level to the south (ground level of 228m AOD at BH01), which is lower than the water level recorded in the bedrock of the boreholes to the north (BH15 – 249m AOD and BH25 – 253m AOD) and due to the cohesive nature of the overlying

superficial deposits which confine the flow of water. It is assumed that the flow of water encountered during drilling is facilitated through fractures, coal seams and sandstone bands.

BH16, located in the area of natural ground between the Onllwyn and the Nant Helen excavations, has recorded relatively shallow groundwater in the monitoring, with the head rising to 3.8m bgl (276mAOD). During drilling groundwater was struck (“medium groundwater inflow”) at 4.2m bgl upon encountering a band of sandstone. As the proposed cutting in this location is to approximately 20m bgl, groundwater inflow during excavation is likely. The rate of inflow will primarily be low as the bedrock predominantly comprises mudstone, but where sandstone beds, coal seams and fractures are encountered higher rates of inflow are likely. As the cutting here is through the highest part of the hill the groundwater catchment that will feed the inflows is anticipated to be small, meaning that it is likely that the rate of inflow will likely diminish as the groundwater table lowers due to the presence of the cutting.

Table 9: Groundwater monitoring results

Borehole	Response zone depth m bgl	Response zone stratigraphy	Water level range mbgl (mAOD)
Washery			
BH30	3 - 4	Made ground	3 - 3.6 (235.5 - 236.2)
BH31	1 - 5	Made ground	4.1 - 4.6 (234 - 234.5)
BH34	1 - 3.3	Made ground	2.6 - 2.9 (229.7 - 230)
BH29	12 - 15	South Wales Coal Measures	0.3 - 1 (229.7 - 230.4)
BH31	16 - 21	South Wales Coal Measures	4.3 - 4.9 (233.7 - 234.3)
BH32	12.5 - 17.5	South Wales Coal Measures	4.5 - 5.8 (226.8 - 228.2)
BH33	15 - 20	South Wales Coal Measures	2.9 - 4.8 (240 - 241.8)
BH34	11 - 13	South Wales Coal Measures	0.1 - 1.1 (229.4 - 230.4)
Main site			
BH15	1 - 5	Fill/glacial till/SWCM	0.4 - 1 (248.6 - 249.3)
BH07	8 - 10	South Wales Coal Measures	Dry (to base of installation at 261.3)
BH16	8 - 10	South Wales Coal Measures	3.8 - 4.8 (276 - 276.9)
BH19A	25.2 - 28.2	Backfill	Dry (to base of installation at 227.1)
BH22	29 - 34	Backfill	32.8 - 33 (180 - 180.3) (dry on four occasions)
BH25	39.2 - 49.2	Backfill	4.9 - 15.1 (242.6 - 252.8)
BH28	39.2 - 49.2	Backfill	Dry (to base of installation at 228.2)

5.7.2 Soakaway testing

Soakaway testing (soil infiltration) was proposed in seven trial pits. For each test there was insufficient infiltration in each of the tests to calculate a soil infiltration rate. This is assumed to primarily be due to shallow groundwater and/or cohesive superficial deposits. The findings are summarised in Table 10.

Table 10: Summary of soakaway test results

Hole	Material description of tested depth range	Test result summary
TP01	0 – 0.6: MADE GROUND- Grass over brown clayey sandy silty GRAVEL with high cobble and boulder content. 0.6 – 2.8: MADE GROUND - Loose black to dark grey slightly silty sandy GRAVEL.	Failed to soakaway. Filled to 0.8m bgl and did not drain at all after one hour.
TP02	0 - 0.3: MADE GROUND - Black COAL 0.3 - 0.4: MADE GROUND - Red slightly sandy GRAVEL. Gravel is fine to coarse angular to sub-angular Clinker and Slag with ash 0.4 - 2.3: MADE GROUND - Loose black to dark grey slightly silty sandy GRAVEL. Gravel is fine to coarse angular to sub-angular Mudstone with coal and ash	Failed to soakaway. Filled to 0.8m bgl and did not drain at all after one hour.
TP18	1.5 – 3.0: MADE GROUND - Dark grey gravelly CLAY with low cobble content.	First test: $f=1.8830E^{-5}$ m/sec. Failed to soakaway on second test. Per BRE365 the infiltration rate should be calculated from the lowest rate of three tests.
TP19	2.8 – 4.0: Firm dark grey slightly sandy gravelly CLAY with low cobble content of sandstone.	Insufficient outflow to calculate permeability.
TP20	2.5 – 3.4: MADE GROUND: Dark grey clayey slightly sandy GRAVEL with low cobble content and low boulder content of siltstone. Gravel is angular to sub angular fine to coarse siltstone and sandstone. 3.4 – 4.0: Firm brown slightly sandy gravelly silty CLAY. Gravel is sub angular to sub rounded fine to coarse sandstone.	Insufficient outflow to calculate permeability. Drained to a level of 3.2m bgl. May be successful with a shallower test only within the made ground.
TP21	2.95 – 4.0: Firm orange brown with grey mottling slightly sandy very gravelly silty CLAY with low cobble content of sandstone.	Failed to soakaway. May be successful if the test was undertaken in the made ground (0.2 – 2.6m bgl).

Hole	Material description of tested depth range	Test result summary
TP34A	0 - 0.2: TOPSOIL: Brown clayey slightly sandy GRAVEL with many rootlets. Gravel is angular to sub angular fine to coarse siltstone. 0.2 - 0.95: MADE GROUND: Brown slightly clayey slightly sandy GRAVEL. Gravel is angular to sub angular fine to coarse siltstone. 0.95 - 4.5: MADE GROUND: Grey 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.	Failed to soakaway. Filled to 0.8m bgl and did not drain at all after one hour.

5.8 Concrete classification

Test results to inform the Design Sulphate (DS) and Aggressive Chemical Environment for Concrete (ACEC) classes have been assessed in accordance with BRE Special Digest 1 [12]. The pH and sulphate test results and derived characteristic values are summarised in Table 11.

The worst-case concrete classification is of DS-5 AC-5 due to samples of glacial till having a characteristic total potential sulphate of 2.7%. The classification for total potential sulphate applies if the material is “to be disturbed to the extent that contained pyrite may oxidise and the resultant sulphate ions reach the concrete”. If the glacial till is not to be disturbed to this extent the next highest classification of DS-4 AC-4 in the washery and DS-3 AC-3 on the main site could be considered.

Table 11: Summary of pH and sulphate test results and characteristic values

Material	Water Soluble Sulphate (SO ₄) mg/l		pH		Total potential sulphate %		Design class
	No. of tests	Characteristic value	No. of tests	Characteristic value	No. of tests	Characteristic value	
Made ground	10	200	10	6	9	1.7	DS-4 AC-4
Backfill	9	100	9	6.4	9	0.6	DS-2 AC-2
Glacial till	9	200	9	5.8	9	2.7	DS-1 AC-1 / DS-5 AC-5 ¹
Peat	1	300	1	7.1	Assumed not to be disturbed to the extent that pyrite would oxidise		DS-1 AC-1
SWCM	10	50	10	7.0	10	0.7	DS-3 AC-3 ²
Groundwater – Fill (BH25)	1	100	1	7.4	-	-	DS-1 AC-1
Groundwater - MG	3	300	3	6.8	-	-	DS-1 AC-1

Material	Water Soluble Sulphate (SO ₄) mg/l		pH		Total potential sulphate %		Design class
	No. of tests	Characteristic value	No. of tests	Characteristic value	No. of tests	Characteristic value	
Groundwater – SWCM	17	200	17	7.2	-	-	DS-1 AC-1

Note¹: The classification of DS-5 AC-5 based on the total potential sulphate applies if the material is “to be disturbed to the extent that contained pyrite may oxidise and the resultant sulphate ions reach the concrete”.

Note²: Pyrite was not recorded on any of the samples tested. Note a band of *iron pyrite conglomerate* was recorded in BH26 at 38.3m bgl, which if tested may require a higher design class.

5.9 Contamination observations

In general, the made ground encountered in the Washery was observed to contain inclusions such as bricks, concrete, timber, ash, coal, clinker, plastic, and metal. Bricks, concrete and timber are potentially indicative of demolition materials and thus a potential source of asbestos. Coal, ash, and clinker are a potential source of metals and PAHs. Plastic is also a potential source of hydrocarbons. Other man-made items that were encountered included cable, steel rope, metal sheeting and plastic bags, railway sleepers and rubber. No other visual or olfactory evidence of hydrocarbon or asbestos contamination was identified during the ground investigation.

The backfill from the opencast workings which was found on the main site was not observed to contain any man-made inclusions. Recorded materials were limited to reworked natural materials (colliery spoil) and no visual or olfactory evidence of hydrocarbon or asbestos contamination was identified during the ground investigation.

6. Geoenvironmental Assessment

6.1 Human Health Tier 2 Generic Quantitative Risk Assessment (GQRA)

6.1.1 Introduction

A preliminary Conceptual Site Model (CSM) and Preliminary Risk Assessment were developed as part of the desk study [1] and Environmental Statements for the main Nant Helen Complementary Restoration works [2] and GCRE [3]. The following potential contamination sources have been identified (Table 12).

Table 12: Potential contamination sources

Potential source of contamination	Location / Contaminants
Made ground	<u>Majority of the proposed track route:</u> Colliery spoil - the non-coal bearing rock arisings used to backfill the areas of opencast working; Leachable metals and sulphates may be present within possibly acidic leachates generated from the colliery spoil fill materials.
	<u>Washery area:</u> Mixture of varied granular backfill material within a cohesive clay matrix (various gravel inclusions - mudstone, sandstone, coal, clinker, and wood); Coal and clinker are potential sources of contamination with metals and PAHs.
	Potential to encounter localised pockets of contamination as a result of fuel spillages and arising from demolition of mining infrastructure.
Coal mining	Potential to encounter contaminants associated with coal mining activities within the backfill in these locations; typical contaminants may include various metals, metalloids, sulphates, PAHs, TPHs and asbestos.
Settlement ponds/lagoons	<u>Washery area:</u> The sediments in water treatment areas comprising ponds and settlement lagoons may be impacted by contaminants such as metals, metalloids, sulphates, PAHs and TPHs.
Rail/tram lines	The Neath and Brecon Railway (main and junction lines) have been identified to have run adjacent to the northern (junction line) and southern (main line) site boundaries. In addition, three tramways (including the Brecon Forest Tramroad) have been identified to have run adjacent to the northern (junction line) and southern (main line) site boundaries. Potential contaminants associated with rail/tram lines typically include various metals, TPHs, PCBs, PAHs, herbicides, ferrous residues, metal fines, ash, sulphates, and asbestos. Given the age of the historical features, the levels of residual contamination are unlikely to be significant.
Fuel tanks	A group of four large cylindrical tanks are currently present close to the site compound and offices centrally located within the site. The tanks are above ground however, there is the potential that spillages and leakages may have occurred and as a result the soils and groundwater present in this location could potentially be impacted by hydrocarbon contamination.
Pollution incidents	As reported in the desk study [1], four pollution incidents have been recorded by NRW within the site or <5m away from the site boundary. All were located within or within the direct vicinity of the washery portion of the site. These pollution incidents are anticipated to have had a localised impact on the soils and groundwater beneath the washery portion of the site. However, given the categorisation of these incidents the level of contamination is anticipated to be minor.

6.1.2 Plausible Pollution Linkages

The following Plausible Pollution Linkages (PPLs) with respect to human health have been identified as part of the desk study [1] and Environmental Statements for the main Nant Helen Complementary Restoration works [2] and the GCRE [3], and were assessed through a GQRA:

During the Nant Helen Earthworks and construction of the GCRE

- **PPL 1:** Construction workers have the potential to be directly exposed to soils and dust from exposed made ground materials and should removal of the ponds and settlement lagoons be required, to water and sediments. Providing that health and safety measures are in place in accordance with current legislation and good practice, is unlikely to pose a risk to construction workers. There is however an increased risk due to encountering unexpected contamination, particularly in the area of the washery site.
- **PPL 2:** The proposed development will result in potentially increased dust generation rate primarily as a result of site clearance and excavation works allowing for the construction of the maintenance facilities and infrastructure, which may migrate towards the residents of nearby settlements. This would be a temporary impact. However, the nearest residential properties in Onllwyn are located at higher ground and are separated from the proposed development by a green belt of woodland, which is likely to significantly reduce the amount of dust migrating off-site.

During operation of the GCRE

- **PPL 3:** End users of the development such as railway testing facilities workers and visitors of the testing facility based both on site and in the offices, are unlikely to be exposed to dust from soils via inhalation and to a lesser extent via dermal contact or ingestion of soil due to the site being covered in hardstanding and buildings. There is still a risk from migration of volatile hydrocarbon vapours into confined spaces or structures. Maintenance workers (e.g., where vegetation maintenance is required or intrusive repair works to tracks) may still come to dermal contact with soils, this will however be likely to be infrequent, short-term, and temporary.

6.1.3 Contamination potential

The ground investigation encountered made ground in all but one of the holes in the Washery (BH32). The opencast backfill within the main site encountered colliery spoil (refer to Section 5).

As already mentioned, the made ground encountered in the Washery site was observed man-made inclusions which are potential sources of asbestos, metals, and PAHs. No other visual or olfactory evidence of hydrocarbon or asbestos contamination was identified during the ground investigation. The backfill from the opencast workings which was found on the main site was not observed to contain any man-made inclusions and no visual or olfactory evidence of hydrocarbon or asbestos contamination was identified during the ground investigation. Therefore, the ground investigation comprised sampling and testing of the soils from the Washery site only for contamination and there was no testing of the colliery spoil in the main site.

A human health risk assessment has been carried out in order to inform on the risk related to the PPLs mentioned above (PPL 1 - 3). The materials encountered within the Washery as part of the ground investigation have been assessed for suitability for their end use and risk to site operatives.

The results of the chemical analyses undertaken on soil samples obtained from across the site have been reviewed and compiled in a table included within Appendix C-1 of this report.

The Generic Quantitative Risk Assessment (GQRA) in relation to risks posed to human health is presented below.

6.1.4 Assessment methodology

Risk to construction workers & site neighbours during construction (PPL 1, PPL 2)

To simplify the assessment of ground contamination risks, UK statutory guidance suggests that generic soil quality guideline values derived using the CLEA software [13] may be useful for initial screening of soil contamination testing results, provided that such guideline values are available and are appropriate to the site circumstances and the potential pollutant linkages in question. If the results from an adequate ground investigation are below such scientific and appropriate guidelines, then the site can be regarded as suitable for use. If the results exceed the screening guidelines, then more detailed investigation and/or site-specific risk assessment may be required to determine whether or not there is a need for remediation.

The assessment of risk to human health is undertaken in line with regulatory guidance (Environment Agency [14]) in the context of the preliminary conceptual site model and the PPLs identified.

Site construction workers involved in the development may be exposed to potentially contaminated soils including dust generated during earthworks (and so may neighbouring site users). It is considered that the risks presented to the above identified receptors will be acute, rather than chronic, as these receptors will only be exposed to potentially contaminated soils for a short period of time.

In order to give an indication of potential risks posed to these short-term receptors and to help inform the Contractor who will undertake the works on any health and safety requirements, the chemical analyses results have been screened against more conservative guideline values (C4SLs [15], S4ULs [16] and Arup Generic Assessment Criteria (GAC) where relevant), for a residential without plant uptake land use scenario, which allows for direct dermal, ingestion and inhalation pathways (considered relevant to these receptors).

Risk to end users and maintenance workers during operation (PPL 3)

Post development, there is a risk to end users (railway testing facilities workers and visitors of the testing facility) from migration of volatile hydrocarbon vapours into confined spaces or structures. In order to assess the risk present to end users, the chemical analysis results for made ground and natural ground samples tested, have been screened against the guideline values (C4SLs [15], S4ULs [16] and Arup GACs where relevant) for a commercial end use. This end use scenario is considered to be the most representative of the proposed GCRE.

Maintenance workers involved in excavations may also be exposed to potentially contaminated soils. It is considered that the risks presented to these receptors will also be acute, as these receptors will only be exposed to potentially contaminated soils for a short period of time. In order to give an indication of potential risks posed to these short-term receptors, the chemical analyses results have also been screened against guideline values (C4SLs [15], S4ULs [16] and Arup GACs where relevant), for a residential without plant uptake land use scenario, which allows for direct dermal, ingestion and inhalation pathways (considered relevant to these receptors).

6.1.5 Averaging areas

Based on the historic land use of the site as a washery (where soil samples were taken from as part of the GI), a single averaging area has been considered for the soils.

The following averaging areas are considered based on different material types:

- Made ground (fill) – Washery site;
- Natural ground (superficial deposits).

6.1.6 Soil quality assessment

The following samples have been analysed for a range of chemical determinands as detailed in section 4.2.

- Made ground (Washery): 24no. samples
- Natural ground (superficial deposits): 3no. samples

A summary of the soil analyses results together with the applied assessment criteria is presented in Appendix C-1 and summarised below with respect to the considered receptors.

6.1.7 Asbestos

All samples obtained from made ground and one sample from natural ground were screened for the presence of asbestos. No asbestos was detected.

6.1.8 Made ground (Washery) analyses results

Construction workers and site neighbours (construction phase) & maintenance workers (operational phase) - PPL 1 to PPL3:

- Aliphatic TPH >C8-C10 (170mg/kg) and Aliphatic TPH >C10-C12 (510mg/kg) above the assessment criteria of 27mg/kg and 132mg/kg respectively, were recorded in one sample taken from BH34 at 1m bgl. The sample was described as “*Made Ground – grass over black dark grey slightly silty clayey sandy GRAVEL. Gravel is fine to coarse angular to sub-angular Mudstone with coal*”.
- Aromatic TPH >C21-C35 (2500mg/kg) above the assessment criterion of 1930mg/kg, were recorded in one sample taken from TP02 at 1m bgl. The sample was described as “*Made Ground – loose black to dark grey slightly silty sandy GRAVEL. Gravel is fine to coarse angular to sub-angular Mudstone with coal and ash*”.
- PAHs above the assessment criteria were recorded in the following samples:
 - Dibenz(a,h)Anthracene (0.35mg/kg – 4.8mg/kg) recorded in BH30 (4m bgl), BH33 (0.2m bgl), BH34 (1m bgl) and TP01 (0.2m bgl) above the assessment criterion of 0.31mg/kg.
 - Naphthalene (8.1mg/kg) recorded in TP09 (1m bgl) above the assessment criterion of 2.3mg/kg.
 - Benzo(a)Anthracene (25mg/kg) recorded in BH34 (1m bgl) above the assessment criterion of 11mg/kg.
 - Benzo(a)pyrene (6.6mg/kg – 21mg/kg) recorded in BH30 (4m bgl), BH33 (0.2m bgl) and BH34 (1m bgl) above the assessment criterion of 3.2mg/kg.
 - Benzo(b)fluoranthene (7.5mg/kg – 34mg/kg) recorded in BH30 (4m bgl), BH33 (0.2m bgl) and BH34 (1m bgl) above the assessment criterion of 3.9mg/kg.
- All other inorganic and organic contaminants have been recorded at low and less than detectable concentrations and there were no exceedances of the applied assessment criteria.

Site end users (operational phase) – PPL3:

- Dibenz(a)Anthracene (4.8mg/kg) recorded in BH34 (1m bgl) above the above the assessment criterion of 3.5mg/kg. The sample was described as “*Made Ground – grass over black dark grey slightly silty clayey sandy GRAVEL. Gravel is fine to coarse angular to sub-angular Mudstone with coal*”. However, the Upper Confidence Limit (95%) value for the sample population (made ground in the Washery site) was 0.86mg/kg, which is lower than the assessment criteria value of 3.5mg/kg (refer to Appendix C-1 for details on the statistical analysis).
- All other inorganic and organic contaminants have been recorded below the applied assessment criteria.

6.1.9 Natural ground (superficial deposits) analysis results**Construction workers and site neighbours (construction phase) & maintenance workers (operational phase) - PPL 1 to PPL3:**

- Dibenz(a,h)Anthracene (0.4mg/kg) recorded in TP06 (2m bgl) slightly above the assessment criterion of 0.31mg/kg. The sample was described as “*Firm grey brown mottled slightly sandy very gravelly CLAY with medium cobble and boulder content. Gravel is fine to coarse sub-angular to sub-rounded Mudstone and Siltstone. Cobbles and boulders are rounded to sub-rounded Sandstone*”.
- All other inorganic and organic contaminants have been recorded at low and less than detectable concentrations and there were no exceedances of the applied assessment criteria.

Site end users (operational phase) – PPL3:

- All inorganic and organic contaminants have been recorded below the applied assessment criteria.

6.1.10 Potential contaminants of concern

The made ground in the Washery site recorded elevated TPHs and PAHs with respect to the applied assessment criteria relevant to construction and maintenance workers. A review of the descriptions of the samples where the elevated concentrations were recorded indicated that the material were generally described as black to dark grey gravel of mudstone, coal, and ash. The recorded concentrations are likely to be related to the coal and ash inclusions. Based on the locations where the elevated concentrations were recorded, these appear to be spread within the Washery site.

The natural ground which directly underlies the made ground in the Washery site was also found to contain elevated PAHs above the applied assessment criteria relevant to construction and maintenance workers in one location (TP06). It is likely that the natural soils that directly underly the made ground may also be impacted by contaminants.

The made ground in the Washery site also recorded elevated Dibenz(a,h)Anthracene on one sample tested with respect to the applied assessment criteria relevant to site end users. However, the data interrogation using statistical analysis suggests that the true mean concentration of Dibenz(a,h)Anthracene for the sample population, which is the made ground within the Washery site, is likely to be below the applied screening criteria and therefore the risk to site end users in relation the made ground within the Washery site is low. Refer to Appendix C-1 for details on the statistical analysis including a histogram showing the spread of data and the GAC as well as a box plot in accordance with the 2020 CL:AIRE guidance on statistical analysis [17].

Three samples from the made ground in the Washery site recorded some TPHs which exceeded the saturation value; this could sometimes indicate that free phase contamination might be present. However, there was no such evidence as part of the ground investigation (no visual or olfactory evidence of hydrocarbons in any of the exploratory holes or groundwater samples taken). Therefore, it is unlikely that free phase contamination is present. The TPHs were all below the applied assessment criteria.

No asbestos was detected in any of the samples tested as part of the ground investigation. However, the possibility that the presence of asbestos and asbestos containing materials within the subsurface are encountered elsewhere within the site cannot be discounted. Risks posed from asbestos will require consideration with respect to site construction workers and site neighbours who may be exposed to airborne dust during construction.

6.1.11 Human health conclusions and recommendations

Elevated TPH and PAH concentrations above the applied assessment criteria were recorded in the soils within the Washery site. This may present a risk to site operatives (construction workers during construction and maintenance workers involved in excavations during operation should these materials be left in place) (PPL 1, PPL 3). However, it is considered that the application of appropriate health and safety including PPE will mitigate the risk adequately. The contractor should undertake their own assessment to confirm the appropriate level of health and safety measures.

With respect to the site neighbours (PPL 2), application of appropriate health & safety measures (use of appropriate dust suppression measures implemented during construction works) will mitigate the risk to those receptors.

The risk from migration of volatile hydrocarbon vapours into confined spaces or structures during operation of the GCRE (PPL 3) is low, as the recorded PAHs would be classified as semi-volatile and as such their potential to generate vapours is considered to be low. The human health risk assessment has indicated that the site is suitable for its end use and no remediation is considered to be required as part of the proposed development.

There was no testing carried out in the Nant Helen main site. The ground investigation carried out in that location did not record any visual or olfactory evidence of contamination. The backfill from the opencast workings was not observed to contain any man-made inclusions (colliery spoil). However, there still remains a risk of encountering contaminated soils within that area (albeit low) and it is recommended that should made ground or visual/olfactory evidence of contamination be encountered during any future ground investigations or construction works in the area, chemical testing on geo-environmental samples is undertaken to determine the type and degree of contamination if present.

A group of four large cylindrical tanks are currently present close to the site compound and offices centrally located within the main Nant Helen site. The tanks are raised above ground and they are mounted on concrete surface. Therefore, any leakages or spillages from the operation of the tanks would be contained and significant hydrocarbon contamination would be unlikely. Post-demolition, verification of the ground in the area of the tanks is recommended to confirm any contamination present. Decommissioning of the tanks should be undertaken by a specialist contractor.

A method statement should be prepared by the contractor to set out procedures on how to deal with unexpected contamination and required health and safety measures. Information regarding the elevated TPH and PAH should be included within the health and safety file for the development.

6.2 Controlled Waters GQRA

6.2.1 Introduction

The following controlled water receptors have been identified:

- Surface watercourses present on site; some of which are associated with ponds or adits on the site, which feed into River Tawe to the north; the Nant Llech, to the northeast and the Dulais, to the south (including a culverted watercourse in the Washery site).
- A collection of pond features present in the area of ‘restored land’ above a portion of the Nant Helen opencast workings. It is understood that these ponds are to renaturalise and create an ecological habitat post backfilling and are possibly lined with low permeability/cohesive materials.
- Groundwater within the superficial (glacial till) deposits (Secondary Aquifer) and the South Wales Coal Measures Formations (Secondary A Aquifer).

6.2.2 Plausible Pollution Linkages

The following PPLs with respect to controlled waters have been identified as part of the desk study [1] and Environmental Statements for the main Nant Helen Complementary Restoration works [2] and the GCRE [3], and were assessed through a GQRA:

During the Nant Helen Earthworks and construction of the GCRE

- PPL 4: Breaking the ground, moving materials within the study area, temporary storage, may result in contaminant mobilisation due to increased exposure to rainfall and consequent increased rate of contaminants leaching into the underlying groundwater or surface run-off into watercourses. Encountering unexpected contamination during the works may also pose a risk to controlled water receptors as a result of mobilisation of contamination due to disturbance or exposure to rainfall.
- PPL 5: Decommissioning of the ponds/lagoons will require draining of the water. If removed water would be discharged to the wider site drainage or ground, this could potentially impact the receiving controlled water receptors. It is assumed that such discharge would only be permissible if there is no detrimental impact on the receiving water quality and where required, treatment would be undertaken.
- PPL 6: The proposed development is located within a sensitive setting with respect to controlled waters. There is a risk from potential mobilisation of contaminants contained within the fill materials during general earthworks and also as a result of disturbing areas of significant unexpected contamination.

During operation of the GCRE

- PPL 7: Piles may be required to provide a suitable founding solution for some of the proposed structures with large loads or sensitive to ground movement. Subject to a selected piling technique, piles may create preferential flow paths allowing for vertical migration of contamination towards the underlying groundwater.

6.2.3 Assessment methodology

A screening assessment of leachate test results has been undertaken to help assess the potential risks posed by contamination to controlled waters. Leachate testing was carried out on 8no. samples of made ground and 1no. sample of natural ground within the Washery site (3no. leachability test results and 6no. WAC test results) to enable assessment of the mobility of soil contaminants.

Groundwater monitoring has been undertaken fortnightly for a period of 12 weeks from 15no. groundwater installations. Six rounds of groundwater level monitoring and three rounds of groundwater sampling and testing have been completed (refer to section 5.7).

A screening assessment of the groundwater test results to date has also been undertaken to help assess the potential risks posed to controlled waters. Groundwater testing was carried out on 3no. samples taken from the main Nant Helen site over one round (response zones within the bedrock in two locations and colliery spoil in one location) and 6no. samples taken from the Washery site over three rounds (18no. tests in total, response zones within the bedrock in five locations and made ground-backfill in one location).

In order to assess the identified contamination risks to controlled waters (PPLs 4 – 7), the results of the chemical analyses undertaken on soil leachate samples and groundwater samples have been reviewed and compiled in tables included within Appendix C-2 of this report. The assessment in relation to risks posed to controlled waters is presented below.

Based on the identified controlled water receptors, the leachate results have been screened, by means of a Tier 2 risk assessment against published Freshwater Environmental quality standards (FEQS).

It is noted that the applied freshwater EQSs for lead, copper, nickel, and zinc pertain to bioavailable concentrations of the substances. The calculation of the bioavailable concentrations was undertaken using the Metal Bioavailability Assessment Tool (M-BAT) produced by UKTAG, which requires the analysis of pH, DOC, and calcium in the receiving water receptor. These tests were carried out on groundwater samples taken as part of the monitoring.

For cadmium and its compounds, the EQS values vary depending on the hardness of the water. Based on the results for hardness for the groundwater samples taken (average of 195mg CaCO₃/l for the groundwater within the bedrock), the area falls under Class 4: 100 to <200mg CaCO₃/l. Therefore, this class was used to derive the criterion for cadmium (0.15µg/l in accordance with the WFD, 2015 [18]).

The EQS for the bioavailable fraction of zinc is 10.9µg/l plus an ambient background concentration, which is 1.4µg/l according to the WFD (2015) [18]. Therefore, a concentration of 12.3µg/l was derived as the criterion for zinc.

6.2.4 Soil leachate quality assessment

The results of the soil leachate testing on 9no. samples (8no. made ground samples, 1no. ground sample) have been compared against the screening criteria discussed above, and these are included in Appendix C-2. It should be noted that the 10:1 results have been used in the absence of 2:1 results.

6.2.5 Made ground (Washery) analyses results

All results were below the applied assessment criteria except for the following:

- One sample taken from BH33 (Washery site) at 0.2m bgl recorded:
 - total cyanide at a concentration of 140µg/l above the FEQS of 1µg/l
 - fluoranthene at a concentration of 5.4µg/l above the FEQS of 0.006µg/l
 - anthracene at a concentration of 1.4µg/l above the FEQS of 0.1µg/l
 - benzo(a)pyrene at a concentration of 1.8µg/l above the FEQS of 1µg/l above the FEQS of 0.00017µg/l

The sample was described as: “*MADE GROUND - black dark grey slightly silty slightly clayey sandy GRAVEL. Gravel is fine to coarse angular to sub-angular Mudstone with coal*”.

- One sample taken from TP02 (Washery site) at 1m bgl recorded total phenol at a concentration of 350µg/l above the FEQS of 7.7µg/l. The sample was described as: “*MADE GROUND – loose black to dark grey silty slightly clayey sandy GRAVEL. Gravel is fine to coarse angular to sub-angular Mudstone with coal and ash*”.

6.2.6 Natural ground (superficial deposits) analysis results

The results of the soil leachate testing on one sample taken from natural soils indicate that there are no exceedances of the applied assessment criteria.

6.2.7 Groundwater quality assessment

The results of the groundwater testing on 21no. samples have been compared against the FEQS, and these are included in Appendix C-2.

6.2.8 Shallow groundwater within Made Ground-Fill (Washery Site)

All results were below the applied assessment criteria except for the following:

- One sample taken from BH30 (1st monitoring round only) recorded chromium at a concentration of 8.9µg/l above the FEQS of 4.7µg/l.

6.2.9 Shallow groundwater within colliery spoil-Opencast Backfill (Nant Helen Main Site)

All results were below the applied assessment criteria except for the following:

- One sample taken from BH15 recorded total cyanide at a concentration of 50µg/l above the FEQS of 1µg/l
- Two samples taken from BH15 and BH25 recorded chromium at concentrations of 14µg/l and 9.6µg/l respectively above the FEQS of 4.7µg/l

6.2.10 Deep groundwater within South Wales Medium Coal Measures (Nant Helen Main Site)

All results were below the applied assessment criteria except for the following:

- One sample taken from BH16 recorded chromium at a concentration of 9µg/l above the FEQS of 4.7µg/l.

6.2.11 Deep groundwater within South Wales Medium Coal Measures (Washery Site)

All results were below the applied assessment criteria except for the following:

- One sample taken from BH32 (1st monitoring round only) recorded chromium at a concentration of 8.8µg/l above the FEQS of 4.7µg/l.

6.2.12 Potential contaminants of concern

Washery site:

The soil leachate assessment has indicated elevated leachable cyanide and PAHs (fluoranthene, anthracene, benzo(a)pyrene) within one sample taken from made ground (BH33 at 0.2m bgl). The same sample also recorded elevated PAHs as part of the dry weight analysis. The recorded concentrations are likely to be related to the coal and ash inclusions within the materials as

described elsewhere within the Washery site. Elevated leachable phenol has also been recorded in one made ground sample (TP02 at 1m bgl). Based on the log description, the material is similar to other exploratory hole locations within the Washery site. The source of the recorded phenol is likely associated with the coal inclusions within the made ground.

The groundwater assessment has indicated that the recorded potentially leachable chemicals above were not recorded within the shallow (made ground/fill) or deep groundwater (bedrock). Elevated chromium above the FEQS was recorded on one occasion (first round only out of the three monitoring rounds) within the shallow groundwater in the made ground/fill (BH30; only one borehole was installed within the made ground). Based on the groundwater monitoring data from the Washery site, the deep groundwater flow appears to be towards the north-west. However, the recorded chromium within the groundwater was not reflected in the leachate results from the made ground which recorded concentrations below the assessment criteria. Elevated chromium above the FEQS was also recorded on one occasion (first round only out of the three monitoring rounds) within the deep groundwater in the bedrock (BH32). The recorded chromium concentrations are likely representative of background conditions.

Nant Helen main site:

The groundwater assessment has indicated that the shallow groundwater within the made ground/reworked natural fill in the area located on the main site outside of the backfilled opencast areas (BH15) in a relatively low-lying area (250m AOD), with ground level rising to the east and west (to around 260m AOD) recorded chromium and total cyanide above the assessment criteria. The shallow groundwater within the colliery spoil in the backfilled open cast workings area (BH25) recorded elevated chromium. BH25, in the backfill of the Onllwyn excavation is the only borehole within the backfilled open cast workings to record groundwater within the installation. It has recorded groundwater levels at approximately 5m bgl (253m AOD), approximately 1m below the proposed track level dropping to approximately 15m bgl (243m AOD) in the last two monitoring rounds. The groundwater in the Onllwyn backfilled opencast workings is not likely to be in hydraulic continuity with the Nant Helen opencast working and the rate of drainage through fractures and/or adits from within the opencast working is relatively low compared to the backfilled excavations to the east (refer to section 5.7).

The groundwater assessment has also indicated chromium above the FEQS within the deep groundwater in the SWMCM. The recorded chromium concentrations are likely representative of background conditions.

6.2.13 Controlled waters conclusions and recommendations

Washery site:

Leachate analysis has indicated that PAHs, cyanide, and phenol have the potential to be mobilised from the made ground soils. However, no exceedances of these contaminants were recorded in the groundwater samples taken under the Washery site. It is anticipated that the proposed development will improve the conditions on site, as the surface where buildings and sheds are proposed as part of the GCRE will be on hardstanding. The only open areas will be where landscaping is proposed on the fringes of the proposed development and where the rail sidings will be covered by ballast (underdrained to prevent the track from flooding).

The shallow and deep groundwater has recorded chromium concentrations above the applied assessment criteria on one occasion (first monitoring round only out of the three undertaken). However, this has not been reflected in the leachate results from the made ground. The recorded concentrations are likely representative of background conditions.

It is considered unlikely that the leachable contaminants identified in the above analysis are to cause a significant risk to controlled waters. The underlying glacial till is of low permeability and any risk to groundwater from leaching and migration of contaminants related to the made ground is currently low. Buildings and vegetation introduced in landscaped areas on the fringes of the proposed development would reduce rainwater effective infiltration and leachate generation and migration towards the controlled water receptors. However, there is a risk that the proposed piling may compromise the protective layer formed by the glacial till. Therefore, there is a risk during operation of the GCRE from vertical migration of contamination towards groundwater through piling as part of the foundations for the proposed buildings (PPL 7). A Foundation Works Risk Assessment should be undertaken to inform the risk.

During construction, excavated made ground should be stored in such a manner so as to minimize run-off (PPL 4). Pollution control systems should also be in place during construction to manage any contaminated groundwater (PPL 6). It is considered that application of surface water and groundwater management as part of Construction Environmental Management Plan (CEMP) will mitigate the above risks posed to controlled waters.

Based on the ground investigation carried out, shallow groundwater may be encountered during excavations. There will be a requirement for any encountered groundwater to be discharged. The same applies to decommissioning of the ponds/lagoons in the Washery site (PPL 5). The GI has indicated that the groundwater contains elevated cyanides and chromium. If this is discharged directly to a watercourse it has a potential to impact the surface water quality and therefore treatment prior to discharge would be required. The contractor should acknowledge the presence of contaminated groundwater and adopt appropriate mitigation measures. Discharge of removed water into watercourses or ground is likely to require a permit. Applications for suitable discharge permits/consents or equivalent should be commenced in advance of construction to allow constraints to be identified.

Nant Helen main site:

Cyanide has been recorded locally within the shallow/perched groundwater within the made ground/reworked natural fill in the area located on the main site outside of the backfilled opencast areas and within the colliery spoil in the backfilled open cast workings area. Leachable cyanide was also recorded within the made ground in the Washery site. The groundwater flow under the Washery site is towards the north west (main Nant Helen site). However, no distinctive sources of contamination were identified on the Washery site based on the assessment carried out. The recorded concentrations are considered to be low and it is unlikely that the Washery site has had a detrimental impact on the deep groundwater under the Nant Helen site.

The shallow (colliery spoil) and deep (bedrock) groundwater within the Nant Helen site has recorded chromium concentrations above the applied assessment criteria. The assessment has indicated that the recorded concentrations are likely representative of background conditions.

6.3 Ground Gas Risk Assessment

6.3.1 Introduction

The desk study [1] and Environmental Statements for the main Nant Helen Complementary Restoration works [2] and the GCRE [3] have identified the potential for ground gases to be present under the site area. These are:

- Ground gas generated from the made ground under the Washery site (methane, carbon dioxide);
- Ground gas generated from the peat present under the central area of the main Nant Helen site and also under the Washery site (as indicated by the ground investigation) (methane, carbon dioxide);
- Ground gas generated from coal waste in colliery spoil tips (carbon dioxide, carbon monoxide, hydrogen sulphide); and
- Ground gas generated from combusting coal measure strata (South Wales Lower Coal Measures) (carbon dioxide, carbon monoxide, hydrogen sulphide);
- Ground gas desorbed into the recorded mine workings within the SWCM.

The following PPLs with respect to ground gas have been identified as part of, and were assessed through a GQRA:

- PPL 8: Made ground and peat are potential sources of ground gas, which may migrate into the buildings proposed in the Washery site through their foundations (shallow or deep) and accumulate within confined spaces or poorly ventilated areas. This may pose a risk of asphyxiation.
- PPL 9: Piles may be required to provide a suitable founding solution for some of the proposed structures with large loads or sensitive to ground movement (Washery site). Subject to a selected piling technique, piles may create preferential flow paths allowing for vertical migration of ground gas (including mine gas under the Washery site) into confined spaces within the structures/buildings.
- PPL 10: Mine gas from worked Coal Measures strata may migrate towards the surface through permeable strata (superficial deposits under the site are limited and discontinuous and granular made ground is anticipated) into the proposed buildings (Washery site).
- PPL 11: Mine gas from worked Coal Measures strata may migrate upwards through adits /shafts (due to change in barometric pressure, rising groundwater or thermal gradient change) into the proposed buildings (Washery site).
- PPL 12: Mine gas from worked Coal Measures strata may be displaced due to grouting of the shallow mine workings causing gas emissions to increase elsewhere off-site (Washery site: housing development 60m south off-site; Nant Helen site: development 250m west off-site)

In order to confirm the PPLs related to mine gas, a preliminary mine gas risk assessment has been carried out in accordance with the 2021 CL:AIRE guidance [19]. This is presented in Appendix F.

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

Six rounds of post works ground gas spot monitoring have been undertaken within the main Nant Helen site and the Washery site to date as part of the ground investigation. A ground gas risk

assessment has been carried out based on the monitoring data. The holes monitored are summarised in Appendix C-3.

6.3.2 Methodology

The potential risk to the proposed development from the ground gas has been assessed in accordance with CIRIA C665 [20] and BS 8485:2015 [21].

The proposed development comprises the GCRE rail depot and storage facility which is proposed to be located on the site of the current Washery site. The 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 a number of buildings forming an Innovation Hub as well as further Industrial/Commercial developments. The development falls in building Type C of the BS 8485:2015 guidance. This type refers to commercial buildings with central building management control of any alterations to the building or its uses and central building management control of the maintenance of the building, small to large size rooms with active ventilation or good passive ventilation of all rooms and other internal spaces throughout ground floor and basement areas.

The assessment method uses both gas concentrations and borehole flow rates to define Characteristic Situation (CS) for a site based on the Gas Screening Value (GSV) for carbon dioxide and methane.

In line with guidance given in CIRIA C665 [17], the ground gas monitoring data are to be reviewed with respect to the PPLs in order to determine the best fitting CS for the site taking into account the development proposals, method of migration, gas production, and potential receptors. The higher the classification of CS, the greater risk posed by the presence of gas and the greater protective measures are required.

Following determination of the CS, the construction and use of the building together with the control of future structural changes and maintenance is assessed in line with guidance provided in BS8485:2015. The building type determines the minimum level of gas protection (gas protection score) required to mitigate the risk from ground gas.

Three averaging areas have been considered as part of the ground gas risk assessment (as reflected on the different response zones within the gas monitoring wells):

- Made ground/fill under the Washery site;
- Colliery spoil under the Nant Helen main site;
- South Wales Lower Coal Measures under both the Washery and Nant Helen sites.

There were no monitoring installations within the peat underlying the site. However, based on the ground investigation carried out, peat was only encountered locally in the Washery site (BH33, BH31 and BH29, thickness of 1- 2m) described as 'Soft brown fibrous peat'. It was also found in BH34 in the Washery site in the made ground between 4.8 and 6.9m bgl. This was categorised as made ground as the underlying clay contained ash. As discussed in section 5.5.1, there is chance that this ash could have been dragged down from material above. In the southern part of the main site peat was found in BH04 and TP27. It was 0.2-0.4m thick and it was described as 'dark brown peat' and 'dark brown fibrous peat' in these holes. Based on the geographical distribution and the encountered thickness of the peat (maximum 2m) the potential source is likely to be scattered and localised and therefore the anticipated volume of potential ground gas produced from the peat is likely to be low and limited. In addition, based on current guidance [22], peat has low gas generation potential due to the gas having had been generated and is trapped in the localised body

of the peat pockets. This is due to limited transport (at low diffusion rates) through materials of low permeability but this does not indicate high rates of production. It is considered that there is no, or very little, current gas generation. The potential ground gas risk from peat is therefore low and it is not considered further in the assessment.

6.3.3 Gas monitoring results

The gas monitoring results are summarised in Table 13, with the full set of results provided within Appendix C-3.

The values within the table comprise the maximum recorded peak values over the six monitoring events, with the exception of O₂ where the lowest concentration is provided. Data from flooded wells was not taken into account as these are not representative of the ground gas regime under the site.

Table 13: Maximum recorded gas concentrations

Hole ID	Location	Response Zone	Peak CH ₄ (% v/v)	Peak CO ₂ (% v/v)	Minimum O ₂ (% v/v)	Peak CO (ppm)	Peak H ₂ S (ppm)	Peak Flow (L/hr)
BH19A	Nant Helen main site	Colliery Spoil	0	1.30	19.90	0	0	0
BH28	Nant Helen main site	Colliery Spoil	0.10	4.10	15.90	0	0	0.10
BH07	Nant Helen main site	MDST (SWMCM)	0.50	3.50	8.70	0	0	0.10
BH22	Nant Helen main site	SLTST (SWMCM)	0.10	2.70	13.20	0	0	0
BH30	Washery site	MG-FILL	0.80	5.20	3.20	0	0	0.40
BH31 (shallow)	Washery site	MG-FILL	0.10	4.80	16.10	0	0	0.40
BH34 (shallow)	Washery site	MG-FILL	0.60	5.40	10.40	0	0	0.10

6.3.4 Gas screening value

Based on the maximum concentrations recorded and peak flow, GSV and the resulting Characteristic Situation have been calculated for methane and carbon dioxide at each monitoring location and is shown in the table below.

Table 14: Summary of GSV and Characteristic Situation

Hole ID	Location	Response Zone	GSV (L/h)		Characteristic Situation (CS) (Type C development)
			Methane	Carbon dioxide	
BH19A	Nant Helen main site	Colliery Spoil	0	0	CS1 – Very Low
BH28	Nant Helen main site	Colliery Spoil	0	0	CS1 – Very low
BH07	Nant Helen main site	MDST (SWMCM)	0	0	CS1 – Very Low
BH22	Nant Helen main site	SLTST (SWMCM)	0	0	CS1 – Very Low

Hole ID	Location	Response Zone	GSV (L/h)		Characteristic Situation (CS) (Type C development)
			Methane	Carbon dioxide	
BH30	Washery site	MG-FILL	0.0032	0.0208	CS1 – Very Low (see section 6.3.5)
BH31 (shallow)	Washery site	MG-FILL	0.0002	0.0184	CS1 – Very Low
BH34 (shallow)	Washery site	MG-FILL	0.0003	0.0054	CS1 – Very Low (see section 6.3.5)

6.3.5 Ground gas conclusions and recommendations

Made ground/fill under the Washery site:

In accordance with BS 8485:2015 [21], based on the calculated GSV, the hazard potential for the Washery site with respect to made ground/fill is considered to be very low (CS1). However, two monitoring wells recorded CO₂ concentrations which were higher than 5% (BH30 at 5.2% and BH34 at 5.4 %) during low atmospheric conditions (992mB). In accordance with BS8485, consideration should be given in increasing the Characteristic Situation to CS2 should CO₂ be recorded at concentrations >5%. The recorded CO₂ concentrations are related to the coal which was recorded within the made ground. Although the made ground includes organic materials giving high Total Organic Carbon results (up to 82% recorded) these are not degradable (ash and coal) so these cannot produce methane or carbon dioxide [22]. The ground gas monitoring data indicated that there is ground gas being generated by the made ground during low atmospheric pressure conditions (PPL8). However, an increase to CS2 with respect to made ground is not considered to be applicable for the site under assessment, due to the following main reasons:

- Very low gas flow rates were recorded within the made ground (max of 0.4L/h) as part of the gas monitoring;
- Even during worst atmospheric pressure conditions (992mB) the recorded CO₂ concentrations were marginally above 5% (maximum of 5.4% recorded);
- The nature of the made ground is such that it does not contain any degradable materials (non-gas producing ash and coal recorded within the made ground).

Based on the above, the hazard potential for the Washery site with respect to made ground/fill is considered to be very low (CS1) and no gas protection measures are considered necessary for the new buildings.

Colliery spoil under the Nant Helen main site:

Based on the calculated GSV, the hazard potential for the Nant Helen main site with respect to colliery spoil is considered to be very low (CS1). Based on the current proposals there are no buildings/enclosed spaces proposed within that area. During construction, the risk from ground gas generated from the colliery to workers involved in excavations is considered to be low.

South Wales Lower Coal Measures under both the Washery and Nant Helens sites:

Elevated methane was recorded on two occasions in one monitoring well within the SWLCM during low atmospheric pressure conditions (BH34R 60.30% and 42.80%). However, the well was flooded in all monitoring rounds, therefore these concentrations are not representative of the ground gas regime under the site. The ground within the Washery site is saturated and any ground gas generated from the coal will be in the dissolved phase. In addition, the overlying made ground

where the installs were partially flooded did not record any elevated methane. The resulting calculated GSV is lower than 0.07L/h and the ground gas risk is considered to be very low (CS1). The same applies for carbon dioxide.

Although the monitoring wells were flooded, the readings still indicate that there is ground gas (methane) generated from the bedrock and there is still a risk from creation of preferential gas flow paths should there be piling through the low permeability glacial till (depending on the piling method), allowing for vertical migration of ground gas into confined spaces within the structures/buildings (PPL 9). A Foundation Works Risk Assessment will be required and consideration should be given to increasing the characteristic situation to CS2 subject to the findings of the assessment.

Mine gas (SWCM)

An initial mine gas risk assessment has been completed and is presented in Appendix F. This confirmed the presence of plausible source-pathway-receptor linkages related to mine gas mainly within both the main part of the site as well as the washery. The linkages relate to potential mine gas migration and accumulation in site infrastructure and buildings and gas displacement as a result of the mineworkings treatment. Initial mine gas risk classification indicates the site to be a moderate risk zone from mine gas due to gas generation potential considered to be very low. In accordance with the CL:AIRE guidance [19], this requires a detailed mine risk assessment to proceed with a risk based mitigation design.

The proposed development design is currently being developed and may render the identified plausible pollution linkages as no longer viable. In addition, there is currently insufficient data on groundwater levels in areas of the flooded mineworkings to give greater level of certainty with respect to low risk from flooded mineworkings and this requires further investigations. The completed investigations in the Washery area also identified areas where further investigations are needed to confirm the presence of shallow mineworkings or confirm the presence of recorded mine entries. In addition, data collection to confirm the gas emissions within the unflooded shallow mineworkings should be considered. Therefore, on confirmation of the design and with additional data, the preliminary risk assessment will require review to confirm if the identified PPLs are indeed plausible and review the risk classification of the site.

Radon:

With regard to radon, based on information presented in the Geotechnical Desk Study [1], the current Washery site where buildings are proposed as part of the GCRE, is within a Radon Affected Area as defined by the Health Protection Agency (HPA), where between 1 and 3% of the properties are above the Action Level (200 Bq/m³). In accordance with publication BR211 by the Building Research Establishment, no radon protective measures are necessary for the new buildings.

6.4 Material re-use

Based on current proposals, it is understood that materials arising from the excavation works are to be used within the proposed development. The management of materials during construction would be undertaken in accordance with a materials management plan.

Only materials that do not pose a significant risk to end site users or controlled water receptors are considered suitable for re-use.

The chemical analysis results for made ground and natural ground samples tested, have been screened against the guideline values (C4SLs [15], S4ULs [16] and Arup GACs where relevant) for

a commercial end use, to assess the suitability for re-use of any soils excavated as part of the proposed works. This end use scenario is considered to be the most representative of the proposed GCRE. Further information on the applied assessment criteria is given in Appendix C-1.

All inorganic and organic contaminants have been recorded below the applied assessment criteria with the exception of one sample (BH34 at 1m bgl) which recorded marginally elevated Dibenz(a)Anthracene (4.8mg/kg) above the assessment criterion of 3.5mg/kg. However, the data interrogation using statistical analysis suggests that the true mean concentration of Dibenz(a,h)Anthracene is likely to be below the applied screening criteria.

Based on the findings of the assessments, the made ground materials encountered in the Washery site, are considered to be chemically suitable for re-use with respect to human health following appropriate verification process.

With respect to controlled waters, the risks associated with vertical migration of contamination towards groundwater in open areas of soft landscaping are considered to be low, in areas where the low permeability glacial till underlying the site will remain in place. There is still a risk in areas where cuttings in the underlying South Wales Coal Measure Formation are proposed (cuttings of 10-15m are proposed in some areas of the main Nant Helen site). Should any made ground from the Washery site be re-used in those areas of cutting it should be placed under a cover layer to reduce rainwater infiltration and leachate generation. It is anticipated that any risk from migration of contamination towards surface water receptors will be mitigated by attenuation features installed as part of the drainage design to collect surface water run-off, restricted to discharge at greenfield run off rate or to a lower discharge rate as specified for the restoration scheme; and by maintaining vegetation adjacent to the streams within the redline boundary. Buildings and vegetation introduced in landscaped areas on the fringes of the proposed development would reduce rainwater. Therefore, the made ground from the Washery site is suitable for re-use within that area, subject to verification testing and site specific risk assessment.

Any materials displaying visual or olfactory evidence of contamination are unlikely to be suitable for re-use and further assessment would be required if such materials are encountered.

The natural soils are deemed to be suitable for re-use with respect to human health and controlled waters based on available data.

The colliery spoil in the Nant Helen main site has not been tested as part of the ground investigation. Based on the material descriptions, no visual or olfactory evidence of contamination were recorded as part of the GI. Their reuse will be governed by the wider restoration scheme.

6.5 Waste disposal options

It is understood that it is intended to re-use site won materials where possible. Any surplus or unsuitable materials would require off-site disposal. Disposal options include landfill disposal, soil recycling centres or soil treatment hubs. In order to inform initial assessment of disposal options, a preliminary waste classification has been undertaken. This is presented in Appendix C-4.

In summary, the made ground encountered within the Washery site is likely to be classed as non-hazardous. However, at its current state it is not deemed to be suitable for inert waste disposal due to the Total Organic Carbon (TOC) which was recorded in all samples to be higher than 3%, so the made ground would be suitable for non-hazardous disposal. In accordance with the landfill regulations, if the 3% value of TOC is not achieved, a higher limit value may be permitted by the agency if a value of 500mg/kg is met for DOC (for inert disposal). Given that DOC was recorded in

the samples tested as <50 to 53mg/kg, it may be accepted by the regulator that can be disposed at an inert waste facility without pre-treatment.

The made ground located near the settlement ponds in the eastern part of the Washery site (BH34 at 1m bgl, TP01 at 0.2m bgl, TP02 at 1m bgl) are classified as hazardous (HP 7: Carcinogenic and HP11: Mutagenic on account of TPH). The 6% value of TOC for hazardous waste disposal is unlikely to be achieved (TOC concentrations between 7.2 and 44% recorded); however, a higher limit value may be permitted by the agency if a value of 1000mg/kg is met for DOC (for hazardous disposal). Given that DOC was recorded in the sample tested as <50mg/kg, it may be accepted by the regulator that can be disposed at a hazardous waste facility without pre-treatment.

The natural ground encountered in the Washery site is likely to be classed as non-hazardous based on log descriptions and dry weight analysis results and it may be suitable for inert disposal (depending on the TOC/DOC concentrations). These soils were not subject to WAC testing.

Based on the log descriptions of the locations within the Nant Helen main site, the colliery spoil is likely to be classed as non-hazardous and these may be suitable for inert disposal (depending on their TOC/DOC concentrations). It should be noted that these soils were not subject to dry weight analysis or WAC testing. At this stage this is a high level classification only and a full classification would be required to confirm disposal requirements if removal from site and disposal is necessary.

6.6 Geoenvironmental conclusions

The geoenvironmental assessments carried out have concluded the following:

Human health:

- Elevated TPH and PAH concentrations above the applied assessment criteria were recorded in the made ground soils within the Washery site. This may present a risk to construction workers and site neighbours during construction and maintenance workers involved in excavations during operation should these materials be left in place. The application of appropriate health and safety measures including PPE and the use of appropriate dust suppression measures implemented during construction works will mitigate the risk adequately. The contractor should undertake their own assessment to confirm the appropriate level of health and safety measures.
- The human health risk assessment has indicated that the site is suitable for its end use and no remediation is considered to be required as part of the proposed development.
- There was no testing carried out in the main Nant Helen site. There is a risk of encountering localised areas of contamination within that area (albeit low). It is recommended that should made ground or visual/olfactory evidence of contamination be encountered during any future ground investigations or construction works in the area, chemical testing on geoenvironmental samples is undertaken to determine the type and degree of contamination if present.
- Four large cylindrical tanks are currently present close to the site compound and offices centrally located within the main Nant Helen site. The tanks are raised above ground and they are mounted on concrete surface; any leakages or spillages from the operation of the tanks would be contained and significant hydrocarbon contamination would be unlikely. Post-demolition, verification of the ground in the area of the tanks is recommended to confirm any contamination present. Decommissioning of the tanks should be undertaken by a specialist contractor.
- A detailed ground investigation is recommended as part of the next stage, once detailed development proposals become available, in order to confirm the level of risk in relation to

human health based on the identified plausible pollutant linkages. The detailed GI would include a higher frequency and lower spacing of sampling locations and testing for the identified potential contaminants in the Washery site. It would also include sampling and testing of soils in the location of the identified tanks and sampling and testing of the backfill material in the Nant Helen site.

Controlled waters:

- Leachate analysis has indicated that PAHs, cyanide, and phenol have the potential to be mobilised from the made ground within the Washery site. However, no exceedances of these contaminants were recorded in the groundwater samples taken under the Washery site (only on one shallow groundwater sample within the Nant Helen site). No distinctive sources of contamination were identified on the Washery site based on the assessment carried out. The recorded concentrations are considered to be low and it is unlikely that the Washery site has had a detrimental impact on the deep groundwater under the Nant Helen site.
- The groundwater quality assessment generally indicated chromium above the assessment criteria in the shallow and deep groundwater within the Washery and Nant Helen site. However, this has not been reflected in the leachate results from the made ground. The assessment has indicated that the recorded concentrations are likely representative of background conditions.
- Shallow groundwater containing elevated cyanides and chromium is likely to be encountered during excavations. If this is discharged directly to a watercourse treatment will be required. Discharge of removed water into watercourses or ground is likely to require a permit. Applications for suitable discharge permits/consents or equivalent should be commenced in advance of construction to allow constraints to be identified.
- There is a risk during operation of the GCRE from vertical migration of contamination towards groundwater via piling through the low permeability glacial till (depending on the piling method) as part of the foundations for the proposed buildings, should the piles penetrate the low permeability glacial till. A Foundation Works Risk Assessment should be undertaken to inform the risk.
- A detailed ground investigation is recommended as part of the next stage, once detailed development proposals become available, in order to confirm the level of risk in relation to controlled waters based on the identified plausible pollutant linkages. The detailed GI would include groundwater monitoring installations and sampling and testing for contamination.

Ground gas risk:

- The hazard potential for the Nant Helens and Washery site with respect to ground gas is very low (CS1). During construction, the risk from ground gas generated from the made ground to workers involved in excavations is considered to be low.
- There is a risk from creation of preferential vertical flow paths for ground gas generated from the coal bearing strata under the site (SWLCM) into confined spaces within the structures/buildings should there be piling through the low permeability glacial till. A Foundation Works Risk Assessment will be required to inform the risk. Depending on the selected piling method and the findings of the assessment, consideration may need to be given to increase the characteristic situation to CS2.
- With regard to radon, the current Washery site where buildings are proposed as part of the GCRE, is within a Radon Affected Area, where between 1 and 3% of the properties are above the Action Level. No radon protective measures are necessary for the new buildings

Mine gas risk:

- The initial mine gas risk assessment confirmed the presence of plausible source-pathway-receptor linkages related to mine gas and rated the site (both the Washery and the Nant Helen site) as a moderate risk zone. This will require a detailed mine risk assessment to proceed with a risk based mitigation design.
- The initial mine gas risk assessment identified a number of data gaps. This includes:
 - insufficient data on groundwater levels in areas of the flooded mineworkings to give greater level of certainty with respect to low risk from flooded mineworkings;
 - unknown extent of shallow unrecorded mineworkings and potential for mineworkings entries presence in the Washery site;
 - unknown gas emissions rate from unflooded shallow mineworkings.
- Buildings are proposed as part of the development within the washery site. These require further location specific investigation to determine if gas protection measures are required. The ground investigation should include ground gas monitoring installations within the mine workings. In order to efficiently target investigation in the Washery site, it is recommended that these areas are investigated once the project proposals in the Washery site have been developed further. A review of the mine gas risk assessment will be required once the development design is finalised.
- The treatment of mineworkings may pose a risk to the site neighbours from displacement of mine gas due to grouting of the shallow mine workings causing gas emissions to increase off-site. The risk assessment will need to be undertaken once the grouting plan is finalised.
- It is recommended that areas around interpreted mine entry location should be investigated further in order to positively identify the entries that are currently anticipated to be present beneath the proposed earthworks and to allow any mitigation or treatment measures which may be required to be developed.

Material re-use:

- The made ground materials encountered in the Washery site, are considered to be chemically suitable for re-use with respect to human health and controlled waters following appropriate verification process and site specific risk assessments (with respect to controlled waters if re-used in landscaped areas).
- There is a risk with respect to controlled waters should any made ground from the Washery site be re-used in areas where cuttings in the underlying South Wales Lower Coal Measure Formation are proposed (cover layer will be required over any made ground from the Washery site placed in that area).
- Any materials displaying visual or olfactory evidence of contamination are unlikely to be suitable for re-use and further assessment would be required if such materials are encountered.
- The natural soils are deemed to be suitable for re-use with respect to human health and controlled waters based on available data.
- Further ground investigation is recommended as part of the next stage, in order to confirm the suitability of the materials for reuse within the Nant Helena and Washery sites. The detailed GI would include higher frequency of sampling and testing mainly in the Washery site in order to confirm the suitability of the excavated soils for reuse within the development.

Waste disposal:

- The made ground encountered within the Washery site is likely to be classed as non-hazardous. However, at its current state it is not deemed to be suitable for inert waste disposal due to TOC, so the made ground would be suitable for non-hazardous disposal. Given that DOC was recorded in the samples tested as below 500mg/kg, it may be accepted by the regulator that it can be disposed at an inert waste facility without pre-treatment.
- The made ground located near the settlement ponds in the eastern part of the Washery site are classified as hazardous. At its current state it is not deemed to be suitable for hazardous waste disposal due to TOC. Given that DOC was recorded in the sample tested below 1000mg/kg, it may be accepted by the regulator that it can be disposed at a hazardous waste facility without pre-treatment.
- The natural ground encountered in the Washery site is likely to be classed as non-hazardous and it may be suitable for inert disposal (depending on the TOC/DOC concentrations). These soils were not subject to WAC testing.
- Based on the log descriptions of the locations within the Nant Helen main site, the colliery spoil is likely to be classed as non-hazardous and these may be suitable for inert disposal (depending on their TOC/DOC concentrations).
- A detailed ground investigation is recommended as part of the next stage, once detailed development proposals become available, to include higher frequency of sampling and testing mainly in the Washery site in order to confirm the waste disposal options.

7. Settlement monitoring

This section of the GIR presents the findings of the settlement monitoring that was undertaken for each of the four main backfilled opencast sites. For reference to figures with a 'D' prefix within this section, refer to Appendix D.

7.1 Background

As set out in section 4.3, during a topographical survey of the wider site in October 2020, four arrays of settlement monitoring points were installed across the four major backfilled areas identified within the site. The settlement points were set out in an array along representative sections which were selected to allow an assessment to be made of the rate of ongoing creep settlement within the various areas of backfilled opencast.

The opencast backfill areas which were subjected to monitoring, listed in order of backfill date, are presented below:

- Abercraf/Gwaunton – Completion of opencast working, October 1973
- Onllwyn – Completion of opencast working, May 1982
- Nant Helen – Completion of opencast working, March 1999
- Nant Helen Extension – Completion of backfilling, October 2014

The dates above, for all but the Nant Helen Extension, were determined through review of opencast mining completion plans and so the actual date of completion of backfilling is likely to be marginally more recent than the dates stated. For the Nant Helen Extension site, the completion of backfilling was determined through direct consultation with Celtic Energy concerning the placement of fill in the direct vicinity of the monitoring points; as such, there is a greater degree of confidence with this date.

The current proposed track layout crosses each of the four sites as indicated on Figure 6 below.

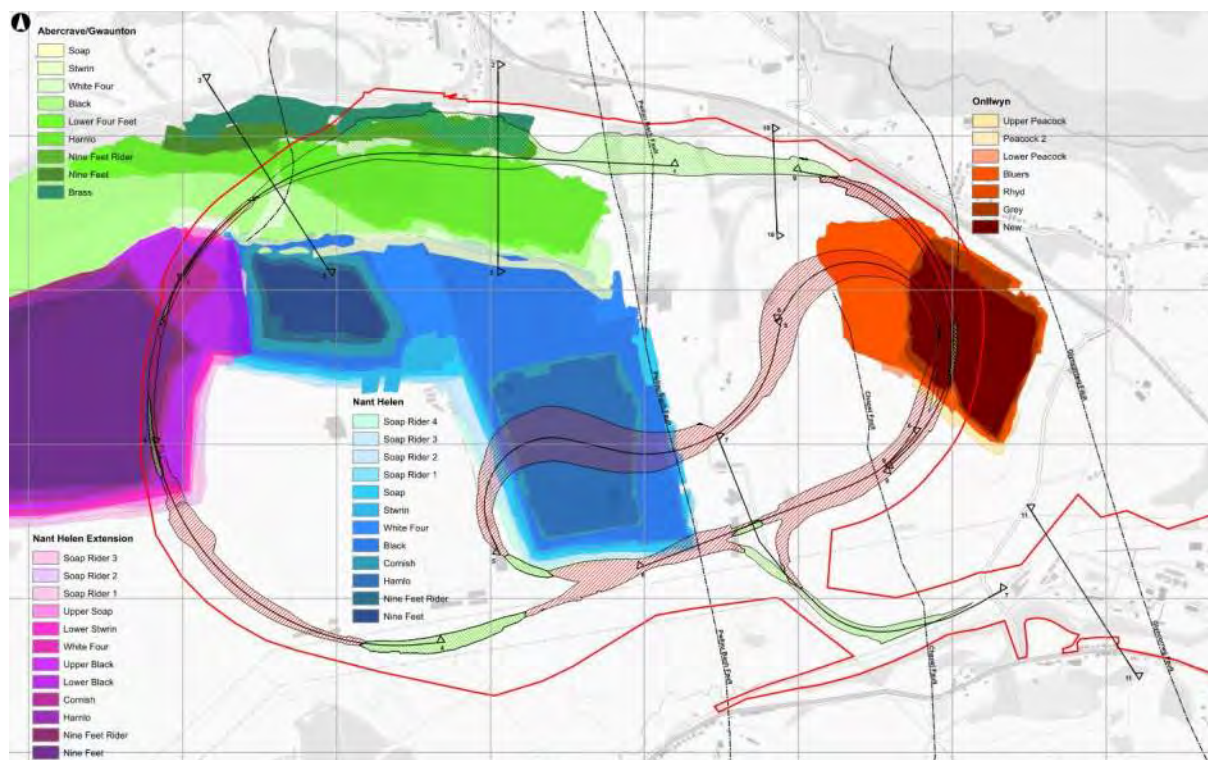


Figure 6 Opencast sites

Each of the four arrays started at a known point where no opencast mining had been undertaken. These points were installed as a control from which movements of the backfilled opencast sites could be assessed against.

The next five settlement points of each array were then installed at approximately 50m intervals following the alignment of the proposed track route into the areas of opencast backfill. The last point in each array was constructed at a larger spacing to target the locations of anticipated greatest thickness of backfill (based on the opencast completion plans) on the proposed track route, refer to Figure 7 below.

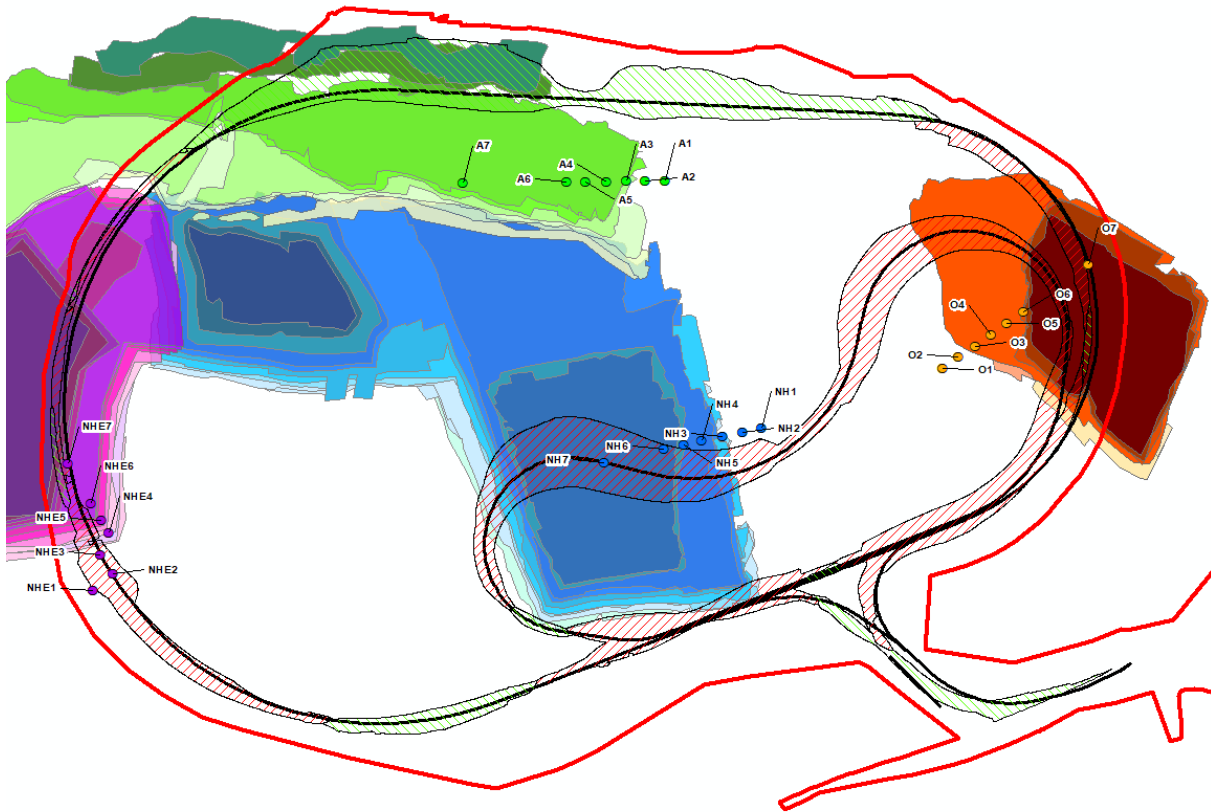


Figure 7 Settlement monitoring points ("as-built")

Once installed, levels at the seven monitoring points on each of the four arrays were periodically surveyed over a period of 161 days between October 2020 and April 2021 (approximately 6 months) with nine discreet monitoring visits undertaken.

With regards to the Nant Helen Extension monitoring points, it should be noted that the settlement monitoring points differed significantly from those specified. This was primarily due to obstructions (i.e., large ponds and overly sloped ground) encountered during the installation of the monitoring points. Another point of note is that the monitoring points do not necessarily reflect the deepest portion of fill in each opencast site.

7.1.1 Creep

The main outcome of the settlement monitoring was to assess the magnitude of the potential ongoing creep settlements associated with the opencast backfill within each of the four main opencast sites.

Creep settlement was initially raised as a potential issue for the site within the Geotechnical desk study [1]. As set out within the desk study, the majority of settlement of placed fill (particularly when the fill is predominantly granular) should occur instantaneously as load is applied from the addition of more fill.

However, further movement will then occur over a prolonged period of time, and this is referred to as creep. The magnitude of creep has been found to decrease over time in a logarithmic fashion. As originally investigated by Sowers et al [23], and then also presented in BRE building on fill guidance [24], the rate of creep for rockfills can be quantified by the logarithmic creep compression factor, ' α '.

Within the BRE building on fill guidance [24], it is suggested that sandstone/mudstone rockfills, with no systematic compaction during filling, will typically display creep movements within an α range of between 0.9% and 1.5%. Within the desk study [1] the potential magnitude of creep settlements rates (mm/year) was demonstrated for the typical range of α values stated in the BRE building on fill guidance taking the Nant Helen opencast site as an example.

7.2 Results

The settlement monitoring was undertaken by John Vincent Land Survey (JVS) at a fortnightly frequency for the first 3 months and then monthly over the last 3 months. The monitoring obtained levels (in Ordnance Datum (Newlyn)) for each of the 28 survey points. JVS were instructed to propose, and then follow, a methodology that would allow for a ± 3 mm degree of accuracy.

7.2.1 Vertical movements

The data gathered from the survey, depicted in terms of relative movement from initial level, is presented across Figures D1 to D4 in Appendix D.

As depicted across Figures D1 to D4, varying degrees of movement were recorded across the four main opencast sites. Refer to Table 15 below for the range in total movements, relative to the initial level measurement, for each point along each of the four arrays.

Table 15 Maximum recorded settlements at each monitoring point

Opencast site	Maximum recorded movement at each survey point [mm]						
	1 (Control)	2	3	4	5	6	7
Abercraf	-1	2	5	5	10	7	4
Onllwyn	-2	5	8	4	6	3	13
Nant Helen	3	7	4	7	7	5	8
Nant Helen Extension	1	3	4	10	6	35	54

The control points (i.e., A1, O1, etc) all experienced negligible movement and all within the error margin (i.e., ± 3 mm). This is to be expected as each of these points were set out in areas where no opencast mining has previously taken place.

As shown in Table 15 above, the majority of movements experienced at each survey point were minimal with 15 of the points experiencing ≤ 5 mm in total movement over the duration of the monitoring period.

As the anticipated depth of fill increases beneath any given monitoring point, the magnitude of settlement also tends to increase. This is particularly well demonstrated on Figure D4 for the Nant Helen Extension site. This location is also where the greatest magnitude of settlement (54 mm) was experienced at NHE7. This is also as expected due to the large depth of fill in this location (~88m) and the recent nature of the backfilling; i.e., given that fill was only placed in the Nant Helen Extension site along this settlement array ~7 years before the survey was undertaken.

The general trend between depth of backfill and settlement was not always consistent across the settlement points with a number of potential anomalies identified. These potential anomalies are clearly visible in Figure D1, point A7, and Figure D4, point NHE5. These two monitoring points contradict the general trend and also the local trends when observing the movements along each array. The possible reason for these anomalies is likely to be due to local variations in the fill material (i.e., concerning particle size for example).

7.2.2 Lateral movements

In addition to vertical movements, the eastings and northings of each survey point, for each phase of the monitoring, were reviewed against the first measurement taken at each point.

At NHE6 and NHE7, where the largest vertical movements were experienced, a noticeable trend in the lateral movement was also identified, see Figure 8 and Figure 9 overleaf.

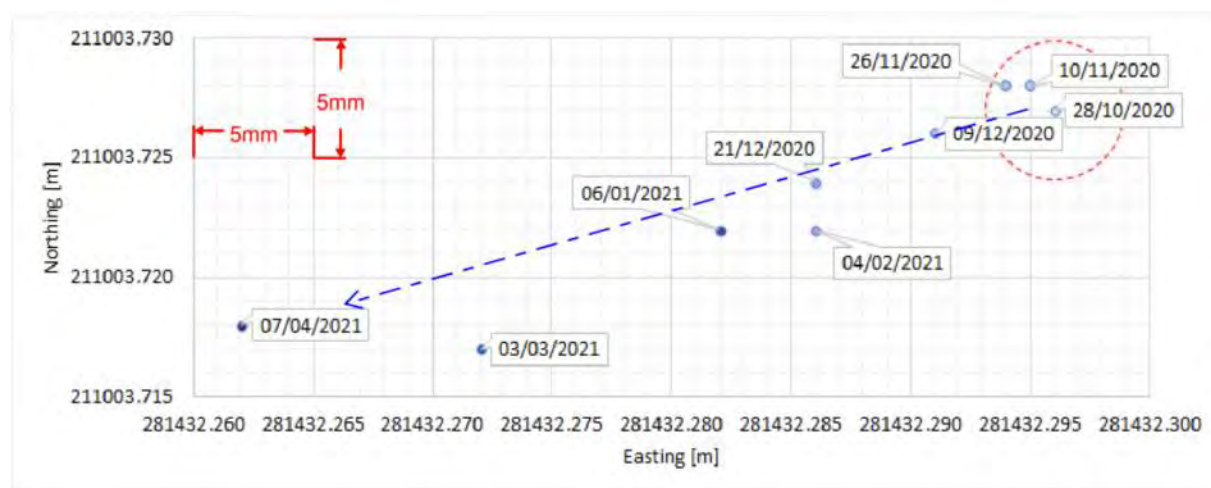


Figure 8 Surveyed location of NHE7 over the duration of the monitoring period

As presented in Figure 8 above, there is a clear trend (indicated by the blue dashed line) in the change of position for the survey point at NHE7 over time. The survey point appears to be moving in an WSW direction with the exception of a few monitoring dates. For example, between 06/01/2021 and 04/02/2021 where the survey point appears to move easterly; however, it should be noted that this particular movement is only 4mm in magnitude which is close to the error margin of all measurements taken (both position and level, $\pm 3\text{mm}$).

A similar trend occurs at NHE6, see Figure 9 below.

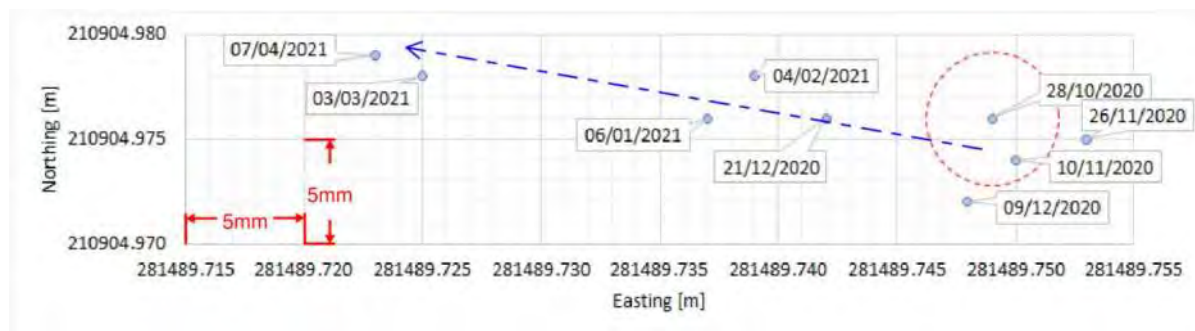


Figure 9 Surveyed location of NHE6 over the duration of the monitoring period

When we look at NHE5, where the vertical movements were found to be considerably less (6mm), we can see that there is a much greater consistency in lateral position of the monitoring point, see Figure 10 below. Many sit within, or just outside of the $\pm 3\text{mm}$ boundary of the originally taken point (see red dashed line).

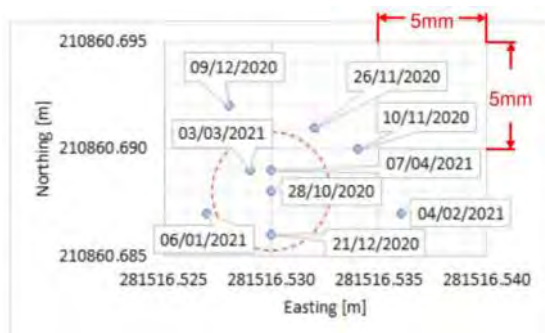


Figure 10 Surveyed location of NHE5 over the duration of the monitoring period

When reviewing these movements against the context of the monitoring point locations, it becomes apparent that whilst the magnitude of apparent lateral movement is very small, the lateral movements may be influenced by the presence of excavations and sloping ground adjacent to the monitoring locations, see Figure 11.



Figure 11 Initial positions of NHE5-NHE7 plotted against aerial imagery

As depicted above, NHE7 is located at the toe of a slope which also falls to in a WSW direction (the fall has been confirmed through review of topographical data). This slope appears to be artificial and is believed to be part of the gradual program of restoration of the Nant Helen Extension void.

Both NHE6 and NHE5 also sit on sloping ground. When cross examining NHE6 and NHE7 against NHE5, where large vertical movements are occurring, there are accompanying lateral movements of similar magnitude. This suggests that a component of the recorded movements may be due to creep movements linked with slope processes in addition to the vertical creep movements anticipated as a result of the settlement of placed backfill.

7.3 Creep analysis

7.3.1 Opencast site-specific creep rates

Using the data gathered during the survey, and the creep formula set out in BRE building on fill guidance [24], logarithmic creep compression factors (i.e., ‘ α ’ values) were determined for each settlement point across each of the settlement arrays.

These values were determined using the formula set out below:

$$\alpha = \Delta s / [H \log (t_2/t_1)]$$

Where;

α – Logarithmic creep compression factor;

t_0 – Date of backfill;

t_1 – Start of survey relative to date backfilled (t_0);

t_2 – End of survey relative to date backfilled (t_0);

Δs – Settlement between t_2 and t_1 ;

H – Depth of fill beneath any given settlement point at t_1 .

For each settlement point determined to be sat above backfill, the Δs was taken as the total settlement between the start of the survey (28/10/2020) and the end of the survey (07/04/2021).

The depth of fill beneath each point was determined through review of the opencast completion plans against the surface levels taken on the first monitoring visit (i.e., t_1). This depth of fill was taken as H in order to determine the ‘ α ’ value.

A summary of the input parameters for each calculation is provided in Table 16 below.

Table 16 Logarithmic creep compression input parameters

Point ID	H, @ t ₁ [m]	Δs [mm]	t ₀	t ₁	t ₂
Abercraf/Gwaunton					
A3	16.9	4	01/10/1973	28/10/2020	07/04/2021
A4	56.3	4			
A5	59.9	9			
A6	56.8	7			
A7	82.0	3			
Onllwyn					
O3	63.3	7	01/05/1982	28/10/2020	07/04/2021
O4	63.4	3			
O5	54.4	5			
O6	63.4	2			
O7	49.1	13			
Nant Helen					
NH4	74.7	7	01/03/1999	28/10/2020	07/04/2021
NH5	91.5	7			
NH6	108.8	4			
NH7	113.5	8			
Nant Helen Extension					
NHE3	32.3	4	01/10/2014	28/10/2020	07/04/2021
NHE4	38.5	10			
NHE5	66.0	5			
NHE6	67.0	35			
NHE7	88.1	54			

Using the input parameters set out above, the following logarithmic creep compression factor, 'α', values were determined for each settlement point, refer to Table 17 overleaf. Alongside each 'α' value, the currently yearly rate of movement and an estimated total movement between t₂ and 2060 (chosen as an arbitrary date to reflect potential movements ~40 years into the future) are presented. It should be noted that both of these values are for indicative purposes only and are based purely on the 'α' value determined at each point between t₁ and t₂.

Please refer to the relevant plots within Appendix D referenced against each settlement point ID (i.e., A3, refer to Figure D5).

Table 17 Logarithmic creep compression factor values and estimated settlement rates/magnitudes

Point ID	H, @ t ₁ [m]	α [%]	Current yearly rate of settlement [mm/year]	Potential total settlement between t ₂ and 2060 [mm]	Appendix D Figure ID
Abercraf/Gwaunton					
A3	16.9	5.86	9	250	Figure D5
A4	56.3	1.76	9	250	Figure D6
A5	59.9	3.71	20	560	Figure D7
A6	56.8	3.04	15	440	Figure D8
A7	82.0	0.90	7	190	Figure D9
Onllwyn					
O3	63.3	2.24	16	420	Figure D10
O4	63.4	0.96	7	180	Figure D11
O5	54.4	1.86	11	300	Figure D12
O6	63.4	0.64	4	120	Figure D13
O7	49.1	5.35	30	800	Figure D14
Nant Helen					
NH4	74.7	1.07	15	350	Figure D15
NH5	91.5	0.87	15	350	Figure D16
NH6	108.8	0.42	9	200	Figure D17
NH7	113.5	0.81	18	400	Figure D18
Nant Helen Extension					
NHE3	32.3	0.78	8	100	Figure D19
NHE4	38.5	1.63	19	250	Figure D20
NHE5	66.0	0.48	10	130	Figure D21
NHE6	67.0	3.28	67	900	Figure D22
NHE7	88.1	2.01	103	1350	Figure D23

7.4 Inundation settlement

Another key settlement phenomena that can occur in areas of extensive backfill is inundation settlement. This risk was initially discussed in the desk study for the site [1] as significant dewatering measures were in place for the Nant Helen Extension opencast site.

Inundation settlement occurs relatively rapidly following inundation of susceptible fill materials by groundwater or surface water. Once dewatering is ceased in the Nant Helen Extension void, the

groundwater levels in this region of the site will likely rebound to a higher level. This rebound has the potential to inundate large portions of placed fill material.

As the Nant Helen Extension, Nant Helen and Abercrave/Gwaunton sites are all somewhat interlinked when considering the worked levels of seams, it is possible that the dewatering measures being undertaken within the Nant Helen Extension void may also be impacting the groundwater levels within the Nant Helen backfilled opencast void.

As part of the ground investigation an attempt to install deep piezometers was made in order to assess the groundwater levels in each of the four main backfilled opencast sites. Refer to Table 9 for a summary of the installed boreholes and the depths of the piezometer installations.

The particular boreholes of relevance are listed below:

- BH22 – Abercrave/Gwaunton opencast site
- BH25 – Onllwyn opencast site
- BH28 – Nant Helen opencast site
- BH19A – Nant Helen Extension opencast site

As presented in Table 9, BH22, BH28 and BH19A were all reported to be dry during the groundwater monitoring. Further interrogation of the installation details reveals that all three of the boreholes have response zones above the level of the deepest workings within the Nant Helen Extension opencast site. Therefore, the fact that all three of these installations are dry suggest that the dewatering within the Nant Helen Extension site may also be having an impact on the groundwater levels within the Nant Helen and Abercrave/Gwaunton opencast sites.

In all three of these opencast sites (i.e., Nant Helen Extension, Nant Helen and Abercrave/Gwaunton) the potential for inundation settlement remains a possibility.

In contrast, BH25 recorded a piezometric surface approximately 5m below surface level within the backfilled Onllwyn opencast site. Based on this level it would suggest that the majority of the backfill within the Onllwyn site has already been inundated and therefore any inundation elated settlement will have already occurred in this region.

7.5 Discussion

From review of the data gathered during the settlement monitoring, it has been established that all four backfilled opencast sites are demonstrating various rates of ongoing creep settlement.

With regards to both the Abercraf/Gwaunton site and Onllwyn site, both exhibit a large range in calculated ' α ' values. With a maximum ' α ' value of 5.86% being determined for point A3 and of 5.35% for O7; these values are far in excess of what was suggested within BRE building on fill guidance (i.e., 0.9-1.5%) [24]. This could suggest that these backfill sites were subject to no systematic compaction during backfilling, hence the large degree of creep movements being experienced 50 to 40 years post backfilling. However, upon closer examination of the raw data, the actual measured movements over the monitoring period are small for the majority of the Abercraf/Gwaunton and Onllwyn sites. The smaller magnitudes of movement are affected to a greater degree by the potential measurement error; this could explain in part the very high ' α ' values determined.

Moving on to focus on Nant Helen, the ' α ' values determined show a greater degree of consistency and all sit around the lower bound ' α ' value as suggested in the BRE building on fill guidance [24].

Despite these values sitting around the lower bound (i.e., 0.9%), all were still demonstrating high levels of creep settlement (~15mm/year) and due to the recent placement of the backfill (compared to Abercraf/Gwaunton and Onllwyn), and the overall depth of fill, a significant magnitude of settlement is likely to occur over the next ~40 years.

At the Nant Helen Extension site, the largest magnitude of ongoing creep settlement across the survey area was determined. This is occurring at NHE7. Over the monitoring period 54mm in total vertical settlement was measured, when taken through into the creep rate analysis this reflected an 'α' value of ~2%. Nant Helen Extension is the "youngest" of the backfilled opencast sites and as such we would expect to see the highest magnitudes in ongoing creep movement. Further analysis of the data would suggest that the points where the largest vertical movements occur, also coincide with where the largest lateral movements are occurring. In the case of the Nant Helen Extension site, it would appear that the larger movements may also be influenced by the sloping nature of the backfill in this region.

Ultimately, the settlement monitoring has confirmed that ongoing creep movements are occurring across all four sites. The rates of these movements do vary, and some may also be being influenced by other factors such as slope creep (i.e., NHE). This variation in rate likely reflects the variability in material composition placed within in these sites, both between distinct backfill areas (e.g., Abercraf/Gwaunton vs Nant Helen), and within different regions of the same backfill area. The variation in 'α' value ranges also likely reflects the varying degree of compactive effort that may have been applied during the filling of each area, with the older backfill sites (likely to have had less control of backfill) showing a greater degree in variability.

The potential impact of ongoing creep settlements and variations in these across the site will be an important consideration for the proposal design development, particularly given the tight movement tolerances that are typically specified for rail infrastructure. Consideration will need to include potential variations in potential long term ground movements due to variations in thickness, age, composition, and topography of the backfilled areas.

8. Mining

This section presents a review of the GI findings considering all aspects of mining related risk items that had been previously identified across the site. For references to figures with a ‘E’ prefix within this section, refer to Appendix E.

8.1 Background

After the desk study for the site was issued in December 2019 [1], it was recommended that a further detailed mining study was undertaken (refer to Appendix E). This detailed review involved the acquisition and thorough review of 30+ abandonment plans for underground working and ~10 opencast completion plans for the various opencast sites across the site.

Through review, the pertinent mining risks were highlighted and visually presented across a set of cross section drawings and plans. The plans highlighted the particular “risk zones” of the site; the four risk zones are outlined below. The risk zones are summarised in Table 18 below.

The “Detailed Mine Workings Study” is contained within Appendix E.

Table 18 Mining study risk zone summary

Risk zone	Description	Risk summary	Detailed Mine Workings Study Figure Ref
A	Southern section of the outer loop, central portion of the inner loop and the rail link to the existing network.	Evidence of shallow underground workings of the Brass/Peacock Seam from the Dulais Colliery. Historical “bell-pitting” evidence from historical site aerial imagery.	Figure 2
B	Northern section of the outer loop and the eastern section of the inner loop.	Evidence of shallow underground working within the Nine Feet/Big seam from the Abercraf Colliery and evidence of shall underground workings of the Bryn Seam from the Cwmtawe Colliery. Potential for shallow underground workings within the Bluers Seam from the Duffryn Colliery.	Figure 3
C	Southwestern section of outer loop.	Significant underground workings but all at great depth. Limited potential for shallow working.	Figure 4
D	Onllwyn Coal Washery	Evidence of shallow underground workings of the Brass/Peacock seam from the Dulais and Onllwyn Collieries. Potential for shallow underground workings associated with the New, Grey, Rhyd and Bluers seams due to the cluster of mine entries mapped in the area.	Figure 5

For this GIR, the findings of the ground investigation have been reviewed against the cross-sections produced for the mining study (i.e., Sections 1-11 within Appendix E). The updated versions of Sections 1-11 should be referred to when reading the corresponding sub sections within Section 8.4.

In addition to Sections 1-11, a further four section lines were cut through the Onllwyn Coal Washery section of the site; these additional sections were produced to assess Risk Zone D.

8.2 Encountered Coal Seams

The summary table below lists the encountered coal seams encountered during the ground investigation undertaken across the main site and the Onllwyn Coal Washery. The table sets out the depth of seam encountered, the corresponding depth below rock head as well as an interpretation of seam identification.

Table 19 Summary of encountered coal seams

BH ID	Depth [m]	Depth below rockhead [m]	Thickness [m]	Log description	Seam interpretation
BH01	13.2	8.2	1.7	Weak Coal (Drillers Description)	Nine Feet/Big [SWMCM]
BH10	24	23.3	1.2	Coal (Drillers Description)	Bryn/Gnapiog [SWLCM]
BH31R	16	5.6	1.1	Coal (Drillers Description)	Grey/Middle [SWLCM]
BH31R	25.5	15.1	1.0	Coal (Drillers Description)	New/Lower [SWLCM]
BH34R	22.1	12.2	1.9	Weak Coal (Drillers Description)	Brass/Peacock [SWMCM]
BH04	17	13.1	0.15	Weak black COAL. Highly weathered to fine to medium angular Gravel. (SOUTH WALES MIDDLE COAL MEASURES)	Soap Rider [SWMCM]
BH05	20.1	9.1	0.6	Weak to medium strong black COAL with one discontinuity set. (SOUTH WALES LOWER COAL MEASURES)	Soap Rider [SWMCM]
BH06	27	25	0.75	Coal (Drillers Description)	Soap Rider [SWMCM]
BH07	22	17.8	1.5	Coal (Drillers Description)	Soap Rider [SWMCM]
BH11	10.65	5.25	0.55	Weak black COAL (SOUTH WALES MIDDLE COAL MEASURES)	Grey/Middle [SWLCM]
BH12	15	12.3	1.25	Coal (Drillers Description)	Upper Peacock/Lower Peacock [SWLCM]

BH ID	Depth [m]	Depth below rockhead [m]	Thickness [m]	Log description	Seam interpretation
BH13	24.2	19	0.3	Weak black COAL. Highly weathered to fine to coarse angular Gravel and Cobbles (SOUTH WALES MIDDLE COAL MEASURES)	Brass/Peacock [SWMCM]
BH16	12.1	8.1	0.6	Weak black COAL. Highly weathered to fine to coarse angular Gravel. (SOUTH WALES MIDDLE COAL MEASURES)	Bluers [SWLCM]
BH16	14	10	0.28	Weak to medium strong black COAL. (SOUTH WALES MIDDLE COAL MEASURES)	Bluers [SWLCM]
BH26	36.2	1	1	Weak black COAL (SOUTH WALES MIDDLE COAL MEASURES)	Rhyd [SWLCM]
BH30R	13.64	7.14	0.56	Weak to medium strong black COAL. (SOUTH WALES MIDDLE COAL MEASURES)	Refer to 8.3
BH32R	11.8	7.5	3.2	Weak black COAL. Highly weathered to fine to coarse angular Gravel and cobbles. (SOUTH WALES MIDDLE COAL MEASURES)	Bluers [SWLCM]
BH33R	28.1	23.2	0.8	Coal (Drillers Description)	Brass/Peacock [SWMCM]

8.3 Voiding Summary

The table below sets out a summary of all encountered voiding and/or core loss during the scope of ground investigation works completed. These voids/zones of core loss have been interrogated against the sections prepared for the site to assess which working/seam they are associated with and/or if the core loss is unlikely to be associated with a void.

The particular findings of note are then discussed after the table.

Table 20 Summary of encountered voiding

BH ID	Depth [m]	Depth below rockhead [m]	Thickness [m]	Log description	Seam/Working interpretation
BH02	19.7	15.8	0.7	Cavity (Drillers Description)	Brass/Peacock Dulais Colliery
BH02	20.4	16.5	9.6	Hard Drill - Loss of Returns (Drillers Description)	n/a
BH05	24.06	13.06	0.64	Actual Zone of Core Loss	n/a
BH12	5.7	3	1	Actual Zone of Core Loss - No recovery between 5.7 and 6.7mbgl. SPT sample grey gravelly Clay. Gravel is fine angular weak Mudstone	Brass/Peacock Dulais Colliery
BH12	7.9	5.2	0.3	Actual Zone of Core Loss	n/a

BH ID	Depth [m]	Depth below rockhead [m]	Thickness [m]	Log description	Seam/Working interpretation
BH15	3.9	1.2	0.3	Actual Zone of Core Loss	<i>Possible Brass</i>
BH17	12.9	6.5	0.35	No Recovery	Brass/Peacock Dulais Colliery
BH18	30.7	6.7	1.2	Actual Zone of Core Loss - Recorded between 30.7 and 31.9mbgl very soft, no recovery, loss of returns	Brass/Peacock Dulais Colliery
BH18	35.4	11.4	2.9	Hard Drill - Drillers Description, No returns	n/a
BH18	38.3	14.3	0.7	Soft Drill - Drillers Description, No returns	n/a
BH18	39	15	2.3	Hard Drill - Drillers Description, No returns	n/a
BH18	41.3	17.3	1.1	Soft Drill - Drillers Description, No returns	n/a
BH18	42.4	18.4	2.8	Hard Drill - Drillers Description, No returns	n/a
BH30R	9.7	3.2	2	VOID	Grey/Middle [SWLCM]
BH30R	20.1	13.6	1	VOID	New/Lower [SWLCM]
BH30R	21.1	14.6	0.9	Soft Drill (Drillers Description)	n/a
BH30R	22	15.5	5.8	Hard Drill (Drillers Description)	n/a

The table above has also listed zones of no recovery during the progression of each borehole. These zones have been reviewed against interpreted seam levels and some have been identified as potential voids; even if not explicitly identified by the GI Contractor. It should be noted that these zones of no recovery have only been considered as potential mine working voids if they appear to coincide with workings that have been georeferenced and when the zones of no recovery are discrete (i.e., overlain and underlain by zones with good core recovery).

Voids which appear to be workings of the Brass/Peacock seam were encountered across four of the boreholes progressed across the site (BH02, BH12, BH17 and BH18). These voids tended to be around 1m in thickness and were interpreted to be related to the Dulais Colliery workings of the Brass/Peacock seam from review of the levels against the mining sections. Each of these voids have proven the presence of underground workings being present in this area and have confirmed that they are within 10t (i.e., 20m) of rockhead assuming a 2m void.

At BH15 the zone of core loss has been interpreted to be a potential indication of the Brass workings. However, this void was considerably thinner and, based on the position of BH15, the mapped workings are not shown to overlap. Regardless, the voids in BH02, BH12, BH17 and BH18 prove that shallow workings are present in the area of BH15.

The only other borehole that presented evidence of definitive workings was BH30R, which was progressed within the Onllwyn Coal Washery area of the site. Within this borehole, two distinct

voids were encountered at discrete depths. The first, 2m in thickness was present 9.7m bgl (3.2m below rockhead) and has been interpreted to represent working of the Grey/Middle seam. The second void in BH30R was encountered 20.1m bgl (13.6m below rockhead) and has been interpreted to represent working of the New/Lower seam. Both of these seams lie within the South Wales Lower Coal Measures Formation and the voiding indicates the presence of workings within these seams which are previously unrecorded.

As referenced to in Table 5, there was a coal seam encountered between these two voids. Based on the thickness of the seam and the review of the geological sequence presented on the 1:50,000 geological mapping of the site, its anticipated that this is an inferior seam and not one of the named seams within the South Wales Lower Coal Measures formation.

8.4 Geophysical findings

Magnetic, electromagnetic (conductivity) and microgravity geophysical surveys were undertaken by Terradat (UK) Ltd. in the Onllwyn Coal Washery around the locations where Coal Authority mine abandonment plans record mine entries. The findings of the geophysical surveys are presented in Terradat's report which is presented in Appendix IX of the ground investigation factual report [9].

Anomalies identified by the geophysical surveys were investigated with trial pits. Table 21 presents a summary of the anomalies detected and the corresponding 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 close proximity of utilities at this location, which also could be the reason for the anomaly.

Table 21: Trial pits for investigating anomalies identified in the geophysical surveys

Hole	
TP12	Z2-4: Circular zone of raised conductivity values in proximity to the expected adit location indicating localised change in made-ground composition - increase in clay and moisture content in the subsurface, potentially related to adit. Z2-5: Circular, high magnetic instrument response in proximity to the expected adit location, indicating localised concentration of ferrous material buried in the subsurface, potentially related to adit. Z2-6: Number of dipolar anomalous instrument responses in close proximity to the expected adit location; may be related to adit. Z2-17: Distinct circular area of low gravity values, indicating lower density ground material. Due to its proximity to the expected adit location and correlation with magnetic and EM anomalous features, it is recommended to ground-truth this area.
TP13	Z2-14: Circular zone of low gravity values, in proximity of expected mineshaft location, recommended for intrusive investigation.
TP14	Z2-18: Linear zone of low gravity values coinciding with EM anomaly (Z2-12), in close proximity to expected adit location, recommended for intrusive investigation. Z2-12: Linear zone of increased conductivity values, indicating change in made ground composition - clay and moisture rich material.
TP15	Z3-2: Increase in magnetic response adjoining access road; may be linked to road construction, service or similar. Due to the relative proximity to the expected adit location, this feature may warrant further investigation.

Hole	
TP16	Z3-6: Relatively broad zone of low gravity values associated with the sloped bank, indicating less dense material than would be expected on uncompacted, loose slip material. May warrant further investigation at closest proximity to proposed mine adit location.
TP17	Z3-7: Subtle localised decrease in ground density in proximity to proposed mine adit location that may warrant further investigation
TP35	Z4-1: Zone of large dipolar instrument responses in close proximity to expected adit location
TP36	Z2-15: Linear zone of low gravity values, in close proximity to the expected adit location, recommended for intrusive investigation.
TP37	Z1-6: Small, isolated dipolar response within the expected location of the mineshaft.
TP38	Z1-9: Isolated dipolar anomalous response, in close proximity to expected adit location

8.5 Section Updates

This section of the report puts the mining related findings regarding seams and voids presented in sections 8.2 and 8.3 above, into the context of the broader scheme proposals by presenting the ground conditions against the 11 sections originally prepared for the detailed mine risk study.

When reading each sub-section, make reference to the accompanying section contained within Appendix E.

It should be noted that wherever reference to the 10t thickness is made, when considering the thickness of rock above encountered voids, “t” has been universally taken as 2m (i.e., 10t = 20m) to reflect the presence of potential roadways workings within each of the targeted seams.

8.5.1 Section 1

Relevant boreholes: BH20, BH21, BH08

Refer to Figure E1.

Section 1 covers the northern limb of the outer track loop running from the edge of the Nant Helen Extension opencast in the west to the Pwllau Bach Fault.

BH20 and BH21 were both progressed within areas of backfill from both the Nant Helen Extension and Abercraf/Gwaunton opencast sites. Both boreholes were terminated due to an inability to progress sections of casing.

At BH21, the log states that the inability to progress the casing at 33m bgl was an indication of “possible bedrock”. Although on the log for BH20 it does not state a reason for the inability to progress the casing, it is assumed that this also represents the base of the opencast backfill.

BH08 was specified to prove the presence of shallow mine workings of the Nine Feet/Big seam from the Abercraf Colliery. From the Detailed Mine Workings Study these workings were interpreted to be deeper than 20m below rockhead (i.e., beyond the risk zone for upward migration of voids assuming a 2m void) and the borehole was to be progressed to prove this interpretation. BH08 did not encounter any evidence of coal or any voiding and was progressed 20m below rock head.

Although no coal or voiding was encountered this borehole, this does not prove that there are no workings in this area. Furthermore, a far greater thickness of opencast backfill and superficial material was encountered at BH08 (22m). This has the knock-on implication of pushing the 10t risk zone (assuming a 2m void) deeper to which ultimately leaves the mapped extent of the Nine Feet/Big workings from the Abercraf Colliery within this zone.

8.5.2 Section 2

Relevant boreholes: BH23

Refer to Figure E1

BH23 was specified to prove the depth and composition of backfill within the Abercraf/Gwaunton backfilled opencast site. This borehole provided that there was 22.2m of backfill in this region of the site by definitively recovering rock core samples to a depth of 3m below the backfill material.

8.5.3 Section 3

There was no investigation within 50m of Section line 3.

Given the findings from BH20, BH21 and BH23, there is now a high level of confidence concerning the interpreted depths of backfill in these regions.

8.5.4 Section 4

Relevant boreholes: BH06, BH07

Refer to Figure E1.

Both BH06 and BH07 were progressed to gather rock core from the section of track that was to be situated within a cutting and to check for coal/voiding within the 10t assuming a 2m void rock cover to inform the risk of crown holing type failure.

Both of these boreholes were progressed within Risk Zone C. Workings at great depth are present in this region, refer to Section 4, and the boreholes were progressed in part to check for unrecorded workings of the shallower seams.

BH06 and BH07 both encountered coal seams with no evidence of working (i.e., voiding) encountered. The seams encountered are both interpreted to be one of the Soap Rider seams (likely to be Soap Rider 3 or Soap Rider 4). Both seams were relatively significant in thickness (0.7-1.5m) but appear to have been un-worked.

Although not covered by Section 4, BH05 also encountered coal interpreted to represent a Soap Rider seam. Contrary to BH06 and BH07, potential evidence of voiding was encountered in BH05, however. This evidence was an “Actual Zone of Core Loss” at 24m bgl (13m below rock head). This zone was not identified as evidence of working by the GI contractor, but further investigation in this area may be necessary to prove that there is no voiding within 10t of rockhead assuming a 2m void.

8.5.5 Section 5

Relevant boreholes: BH28, BH27, BH18, BH17

Refer to Figure E2.

BH28 and BH27 were scheduled to be some of the deepest boreholes as part of this investigation, both with specified depths in excess of 100m. These were both specified to prove the depth of backfill of the Nant Helen opencast, and in the case of BH27 install deep groundwater monitoring to assess the groundwater levels within the area of backfill.

As shown on Section 5, both had to be terminated short of their target depths. Neither were able to confirm the depth of backfill in the Nant Helen site and ultimately had to be terminated due to an inability to progress at 61.5m bgl (BH27) and 49.2m bgl (BH28). The groundwater monitoring standpipe was ultimately installed within BH28 rather than BH27, but not at the base of the backfill as originally proposed.

BH18 and BH17 both encountered voids (“Actual Zone of Core Loss” and “No recovery” respectively) which corroborate with the anticipated depth of workings within the Brass/ Peacock seam from the Dulais Colliery (West Slant). At BH18 24m of backfill was encountered above bedrock. Both of these boreholes prove the presence of working beneath this portion of the inner loop of track. In the case of BH17 the zone of no recovery and “possible backfilled mine workings” is located only ~1m below the proposed base of cutting in this region.

8.5.6 Section 6

Relevant boreholes: BH13, BH14, BH15, BH03

Refer to Figure E2.

The encountered void (“Actual Zone of Core Loss”) within BH15 has been interpreted to be from the Brass/Peacock workings from the Dulais Colliery (West Slant), as referred to earlier in this section.

BH14, to the west of the Pwllau Bach Fault did not encounter any coal or voiding. This is to be expected as the shallowest seam in the South Wales Lower Coal Measures Formation (the Bluers or Lower Peacock) will likely be at significant depth as identified in the Detailed Mine Workings Study.

To the east of the Pwllau Bach Fault, BH13 encountered coal at 24m bgl which is shown to be consistent with the workings of the Brass/Peacock seam from the Dulais Colliery (East Slant). However, BH13 encountered no evidence of working which suggests that the borehole may have been progressed through an area that was left unworked.

BH03 indicates that the extent of backfill from the Nant Helen opencast site stretches further to the south than previously indicated. Consequently, the depth of fill present in this location pushes the 10t thickness of virgin rock deeper to cover the entirety of the Peacock/Brass workings from the Dulais Colliery (West Slant). The depth of fill present in BH03 means that the 10t thickness of rock cannot be proven in this location.

8.5.7 Section 7

Relevant boreholes: BH15, BH02, BH01

Refer to Figure E2.

Section 7 covers the section of proposed track that would link the test loops to the existing rail network.

As outlined in section 8.3, BH15 encountered potential evidence of voiding at level consistent of that of the Brass/Peacock workings from the Dulais Colliery (West Slant).

Voiding/evidence of working was also encountered in BH02 at ~17m below rock head. These workings again corroborate with the level of Brass/Peacock workings from the abandonment plans.

Both of these boreholes are considered to have proven shallow workings beneath this region of the proposed track and this area remains at risk of shallow mine working collapse.

No evidence of working was encountered within BH01, however a band of coal (1.7m thick) was encountered 8.2m below rockhead. Based on the stratigraphic sequence, and the mapped presence of the Brass/Peacock workings some ~20m deeper, this seam has been identified to be the Nine Feet/Big seam. Based on abandonment plans, there is no evidence that this seam has been working in this region of the site, but given the significant thickness, and the near surface location, the possibility for unrecorded workings still remains.

8.5.8 Section 8

Relevant boreholes: BH26, BH24, BH25, BH12

Refer to Figure E2.

BH26 has proven the depth of backfill in the region of the Onllwyn opencast sits and suggests that the depth of backfill is greater than that suggested by the Detailed Mine Workings Study.

BH24 and B25 were terminated at 50.7 and 49.2m bgl respectively. Both were terminated due to an inability to progress the casing. Both appear to be significantly short of the mapped depth of backfill as indicated on Section 8.

As set out in Table 20, an “Actual Zone of Core Loss” occurred at 8m bgl. This zone appears to match well with the plotted zone of Brass/Peacock workings from the Dulais Colliery (East Slant). This zone of core loss has been interpreted to be evidence of workings in this location. From review of the levels, it would suggest that these workings will lie ~1-2m below the proposed cut level in this region.

8.5.9 Section 9

Relevant boreholes: BH11, BH24, BH25, BH12

Refer to Figure E2.

Reviewed in the context of Section 9, it is possible that the refusal that occurred at BH24 did in fact represent the full depth of backfill. However, rock could not be proven below this.

BH11 encountered a coal seam approximately 0.5 thick at 10.65m bgl (~248m OD). Based on the interpretation of the stratigraphy in this region this seam is anticipated to be the Bluers seam. Based on the proposed track level of the outer loop through this section (250m OD) it is likely that this coal seam will lie near the surface of the proposed cut.

As with Section 8, BH12 proves the presences of shallow workings within the Brass/Peacock Seam from the Dulais Colliery (East Slant).

8.5.10 Section 10

Relevant boreholes: BH10

Refer to Figure E3.

BH10 encountered coal of the Bryn seam at 24m bgl. As presented on Section 10 this puts the coal seam below the 10t thickness of rockhead (assuming a 2m thick roadway). BH10 also confirms that the workings within the Bryn seam from the Cwmtawe colliery did not spread further westwards than as was mapped on the abandonment plans.

8.5.11 Section 11

Relevant boreholes: BH33R, BH34R

Refer to Figure E3.

BH34R appears to have picked up an un-worked section of the Brass/Peacock seam as indicated on the updated version of Section 11. The depth of the seam corroborates well with the dip angles of the Brass/Peacock workings from the Dulais Colliery (East Slant) and that on the interpreted levels of the Brass/Peacock workings from the Onllwyn Colliery.

8.5.12 Onllwyn Coal Washery

Relevant boreholes: BH29R, BH30R, BH31R, BH32R, BH33R, BH34R

As explained earlier in this section, as the Onllwyn Coal Washery was not covered by the sections produced by for the Detailed Mine Workings Study, additional sections were cut to illustrate the GI findings in this location.

These sections are listed below, and are also contained within Appendix E (Figure E3):

- Washery NE-SW 1
- Washery NE-SW 2
- Washery NW-SE

As shown on the Washery NE-SW 1 section, both BH01 and BH33R have picked up coal seams. Based on the relative position of the Glyncoirwg Fault both of these seams have been interpreted to be within the South Wales Middle Coal measures. Based on their relative depths the seams have been interpreted to be the Brass/Peacock (BH33R) and the Nine Feet/Big (BH01). Neither presented direct evidence of working within the boreholes progressed. Significant voiding in BH30R was encountered. These voids have been interpreted to be previously unrecorded workings of the Grey/Middle and New/Lower seams based on the coal outcrop mapping. Within BH31R it again appears as though both the Grey and New seams have been encountered, but within this borehole they did not present any evidence of working.

The final section presented on Figure E3 shows a NW-SE long section through the Onllwyn Washery site. This section illustrated the potential for workings of both the Grey and New seams to be present well within the 10t risk zone throughout large portions of the site.

8.6 Risk Zone Updates

8.6.1 Risk Zone A

From review of the ground investigation information, the risk profile within Risk Zone A is broadly unchanged. Workings within Brass/Peacock seam from the Dulais Colliery (West and East Slants) have been confirmed across BH02, BH12, BH15, BH17 and BH18. With the exception of BH12 and BH17, the workings identified lie well within the 10t risk zone when considering the proposed track level and would likely require some form of deep intrusive treatment.

When considering BH12 and BH17 (refer to Sections 5, 8 and 9) treatment options are more open in scope due to the relative depth of working compared to the final cut level (1-2m). As indicated on the sections, the workings of the Brass/Peacock Seam from the Dulais Colliery (East and West Slants) rise as the inner and outer loops moves eastwards to a point where the workings will likely be uncovered during the cutting activities. This brings in the potential option to dig and replace where the voiding is likely to be near cut level.

8.6.2 Risk Zone B

Although not picked up on Section 8 or Section 5, BH16 was progressed to investigate the potential presence for shallow workings beneath the inner loop of the track within the Bluers seam which was worked from the Duffryn Colliery, refer to Figure 3 of the Detailed Mine Workings Study.

BH16 encountered no evidence of working but encountered evidence of a seam between 12 and 14m bgl. This seam is interpreted to be the Bluers seam and appeared to be un-worked in this location (270-268m OD). The proposed level of the cutting in this location, ~260m OD suggests that the coal within the Bluers seam, and any potential unrecorded workings would be dug out during the formation of the cutting. BH16 encountered no further coal or voiding to a level of 240m OD, therefore proving a 10t thickness of bedrock (assuming a 2m void) beneath the proposed cut level.

Along the outer loop, a significant thickness of fill/superficial was encountered at BH08 (as indicated on Section 1 (See Figure E1). This increased thickness places the Nine Feet/Big workings from Abercraf Colliery back within the 10t risk zone (assuming a 2m void), although it should be noted that no coal or workings were encountered withing BH08. Further investigation would be required in this region.

As shown on Section 10, although BH10 has not directly proven the workings from the Cwmtawe Colliery, it has proven that the Bryn seam is present. BH10 cannot definitively prove that workings are present in this area, but the borehole does show that the Bryn seam is below the 10t thickness of rock cover as very little superficial material is present in the locale of BH10.

8.6.3 Risk Zone C

From review of the ground investigation undertaken within Risk Zone C, the risk profile has remained unchanged. This region was previously believed to have been free from shallow underground working and, on the most part, the boreholes progressed prove this.

The only area of potential risk would be around the location of BH05 where a 0.64m “Actual Zone of Core Loss” was reported within the 10t thickness from rockhead. Given the depth, should this core loss represent voiding related to underground workings, then these workings would be within one of the Soap Rider seams. There are no reported underground workings of these Soap Rider seams from any of the collieries that were situated around the site and given the depth at which the

core loss occurred (~24m) it is highly unlikely that this seam would've been accessible from rudimentary surface workings (i.e., early bell-pitting etc).

On the whole, the risk in Risk Zone C is considered low. The only potential target for future investigation would be in the vicinity of BH05 in order to check that the “Actual Zone of Core Loss” does not represent unrecorded working of Soap Ride seams. Although it should be noted that this is considered highly unlikely.

8.6.4 Risk Zone D

One of the more pertinent outcomes of this ground investigation is the discovery of voids, within the 10t zone of influence, in the Onllwyn Coal Washery portion of the site. From the Detailed Mine Workings Review there was no direct indication of working in this area, however the high density of mine entries shown on Coal Authority records indicated the possibility that there could be, and this appears to be supported by the GI evidence.

Previously unrecorded workings were identified in BH30R. Both the New and Grey seams encountered voiding (2m and 1m thick respectively). As illustrated on Washery NE-SW 2 and Washery NW-SE sections these voids are shown to be comfortably within the 10t thickness of rock cover from rockhead, and as such would be considered to be a potential hazard with regards to the upward migration of voiding (i.e., crown-hole collapse).

BH30R was the only borehole where voids were encountered within the Onllwyn Washery site. It is recommended that further deep investigation is progressed around this borehole to better define the extents of working within these seams.

9. Engineering considerations

9.1 Settlement

9.1.1 Creep settlement

The potential impact of ongoing creep settlements of the opencast backfills and variations in these across the site will be an important consideration for the proposal design development, particularly given the tight movement tolerances that are typically specified for rail infrastructure. Consideration will need to include potential variations in potential long term ground movements due to variations in thickness, age, composition, and topography of the backfilled areas.

With regards to the settlement monitoring survey that was conducted across the site, it was proven that creep settlements are ongoing across all four of the backfilled opencast sites. Based on the data gathered, in places the Abercraf, Onllwyn and Nant Helen opencast sites are moving around 20-30mm/year with predicted total vertical movements over the next 40 years of between 500-800mm anticipated.

For the more recently backfilled Nant Helen Extension opencast site, greater vertical ground movements were recorded of up to 100mm/year. The larger ground movements recorded in this region of the site also had accompanying lateral components of movement. This may be a result of slope creep movements in this part of the site due to the sloping ground profile and presence of deep nearby excavations.

The magnitude of creep settlements, (and hence the risks that these movements present to the proposed development) will be greatest within the areas that have been most recently backfilled. This risk particularly pertains to the Nant Helen Extension site beneath the western boundary of the site where the opencast void is yet to be backfilled.

The detailed design of remediation works, and foundation solutions will need to consider the effects of specific features such as spoil mounds, sloping sides of excavation, potential “hard spots” at edge of excavation and hydrological/ hydraulic features in the proposed development.

In order to further refine the ongoing creep movements for each of the four main backfilled opencast sites, it is recommended that the continuation of monitoring at each of the 28 installed monitoring points be undertaken. A larger dataset over a prolonged period of time would minimise the effect of measurement error on conclusions, particularly within the older areas of backfill for which the magnitudes of ongoing movement are smaller and it is therefore more difficult to accurately assess movements over a short monitoring period.

9.1.2 Inundation settlement of fill following the rebound of the groundwater level

The effects of inundation settlement may impact the western part of the site in particular, where dewatering activities have recently been undertaken to allow for the excavations within the Nant Helen Extension opencast site. Once dewatering activities cease, the groundwater levels in this region will rebound to a higher level.

Within the currently installed piezometers in both the Nant Helen, Nant Helen Extension and Abercraf/Gwaunton sites, the water levels appear to be below the response zones with all installations currently being report as dry. It is recommended that when the dewatering measures within the Nant Helen Extension site are ceased, the piezometers are checked regularly along with measurements of the nearest settlement point, to assess any inundation settlement that may occur.

However, with the Onllwyn opencast site, the reported groundwater levels in this area of backfill would suggest that any potential inundations settlement in this region will have already occurred with the piezometric surface sitting 5m below ground level.

During the recent ground investigations, it was not possible to install deep groundwater standpipes below the current water table that would have been used to monitor the rebound of groundwater post completion of opencast working. Installations were installed to the maximum depth achievable (typically about 50m bgl) with the available rigs in the opencast backfill. Depending on the extent to which the groundwater rebounds it may be possible to use these installations to monitor the rising groundwater. Alternatively, consideration should be given to attempting to install deep groundwater monitoring installations using another drilling method (the Ground Investigation Contractor suggested a duplex drilling system may be more successful).

As inundation settlement can be mitigated somewhat through control of air voids within the fill material, opportunities to minimise this risk during the filling of the current opencast mine workings located to the west of the site should be fully explored if possible.

9.1.3 Heave

Elastic heave movements can occur when cuttings are formed through fill material or on removal of surcharge mounds. Heave can also result from the swelling of near surface deposits caused by water ingress and seasonal moisture content changes.

The risk of heave should be considered in any areas where removal of material from the large overburden storage areas is proposed or any areas where extensive cuttings are proposed.

9.1.4 Potential differential settlement

There is the potential for differential settlements to occur along the proposed track route. This is due to the fact that the areas of backfill will continue to settle (both through creep and potentially inundation settlement) whereas the areas that have not been subject to opencast working are unlikely to settle.

There is likely to be a degree of differential settlement within the areas of backfill themselves. This is due to the fact that total settlement is dependent on the thickness of fill; as the thickness is not constant, the areas with greater thicknesses of fill will settle more than those with a shallower thickness.

In order to mitigate against differential settlements at the surface, improvement of near surface materials could be considered. It should be noted however that this would not eliminate the risk of differential settlements resulting from ongoing creep movements where the thickness of the backfill is significant. Improvement of near surface materials could however serve to regulate against differential movements due to any additional loading of the ground, and could be achieved by:

1. Excavating and recompacting
2. High Energy Impact Compactions (HEIC) (likely to improve the upper ~3m)
3. Dynamic Compaction (likely to improve the upper ~10m)
4. Surcharge
5. Grouting

As settlement is likely to occur at the highest rate within the areas that have most recently been backfilled, altering the proposed alignment to avoid the most recent areas of opencast mining could help minimise the risk of differential movements. Ideally the alignment should be altered to avoid the areas of recently backfilled material where possible.

Given that it will be very difficult to control ground movements at the site, particularly those associated with the creep settlements within the areas of former opencast backfill, the design approach will need to consider how the ground movements can be accommodated whilst maintaining serviceability. This may require consideration of significant ongoing maintenance adjustment options, such as track ballast tamping for rail infrastructure. The interfaces between rail, electrification, overhead line electrification equipment, station platform interfaces, etc will need particular consideration.

9.2 Mining

The review of the ground investigation data has proven that there are sections of both the inner and outer loops of track that are impacted by shallow underground workings. This has confirmed the findings of the Detailed Mine Workings Study and also identified other areas that were not shown to have shallow underground workings (i.e., the Onllwyn Coal Washery).

In the areas where shallow mine workings have been identified (within a 10t thickness of rock cover from rockhead/cut level) consideration must be given to the various treatment options that could be employed, as well as the consideration as to whether treatment is necessary. With the voids that are a significant depth below surface/cut level, it is likely that these voids will need treatment through drilling and grouting. Alternatively, this investigation has also proven that there are voids present that are near the proposed cut level in some locations (i.e., BH12 and BH17); in these regions alternative methodologies, that may be more cost effective (i.e., dig and replace), should also be considered.

Going forwards it is recommended that the following areas are subject to further investigation, refer to Table 22.

Note, this does not represent the sole basis for scope of future investigation. Any future investigation shall take into account the development of scheme proposals and any pertinent data gaps identified by the relevant stakeholders.

Table 22 Particular recommendations for future ground investigation

Area	Borehole of interest	Justification
Northern limb of outer loop Risk Zone B	BH08	A significant thickness of superficial material was encountered in BH08 which gives rise to the possibility that working of the Nine Feet/Big seam from the Abercraf Colliery may lie within the 10t zone of influence. Although no coal or voiding was encountered in BH08, a 10t thickness of undisturbed rock was not proven. It is recommended that more boreholes are progressed in this region to investigate the possibility of voiding related to the workings from the Abercraf Colliery.
Southwestern sector of the outer loop Risk Zone C	BH05	A zone of “Actual Zone of Core Loss” was reported withing BH05 at a depth which roughly corroborates with the Soap Rider seams. These have been proven to be free from working in BH06 and BH07, but it is recommended that a selection of other boreholes is progressed in this region to prove that workings are not present in this region.
Onllwyn Coal Washery Risk Zone D	BH30R	Significant voiding of both the New and Grey seams have been identified beneath the Onllwyn Coal Washery. These voids were only encountered within one of the boreholes progressed in this region, but both lie within the 10t zone of influence for potential crown hole migration. Further investigation in this area is strongly recommended to better define the extent of workings beneath the Onllwyn Coal Washery; noting that this area of the site is where some of the larger structures are currently proposed.

It should be reiterated that the scope of investigation covered in this GIR reflects a preliminary investigation to the site and should not be taken as the main set of ground investigation information for any future design development.

9.3 Earthworks

The extent and size of cuttings and embankments required is dependent on the proposed track level. The slope angles of the cuttings and embankments are dependent on material. Based on the anticipated nature of the material used for the embankments and cuttings, and the anticipated groundwater regime across the site, the following slope gradients were estimated to ensure stability with adequate factors of safety:

- Embankments – 1:3
- Cuttings (coal measures) – 1:1
- Cutting (backfill) – 1:2.5

The ground investigations have encountered greater thicknesses of opencast arisings in some areas that are outside of the historical opencast excavations. Due to this the cutting side slopes in these areas may need to be slackened.

It should be noted that the slope angles for the cuttings and embankments proposed here are indicative only and should be verified following design using the ground investigation.

9.4 Material reuse

The scheme requires construction of earthwork embankments that perform adequately to support the proposed rail test track. If the earthworks do not achieve a satisfactory degree of compaction, the magnitude of ongoing settlement may prevent the rail track being used or require excessive amounts of maintenance.

Given the volume of earthworks required for the scheme, the use of as dug material from within backfilled opencast workings without processing would be advantageous. Based on the particle size distribution curves, the majority of the material has suitable grain size for use as Class 2C – stoney cohesive material (5no. of the 26no. tests contain too little material of less than 0.63mm). As mentioned in Section 5.3, the fill typically comprised approximately 10% grains between 125mm and 300mm and 5% grains coarser than 300mm, which would not have been included in the PSD tests. As this exceeds the maximum size permitted for a Class 2C material (and the majority of other classes) further consideration should be given to its suitability for reuse. For example, compaction trials could be considered to assess the feasibility of using the as dug material to form the proposed embankments without further processing.

Key objectives of the trials would be to assess the ability to achieve acceptable earthworks quality control using the proposed methods and understanding how the earthworks for the proposed scheme could be best specified and how the specified requirements could be effectively verified and controlled during the works; specific issues would include 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 understanding the ease with which oversized particles could be separated from the fill during placement;
- establishing the effectiveness of different testing and assessment methods to determine that the necessary degree of compaction can be achieved.

9.5 Groundwater

Groundwater monitoring records that the piezometric surface is shallow in the eastern part of the main site. As shown on cross section A6 of Appendix A, the monitored groundwater level in BH16 is some 14m above the proposed track level. It is also shallow in the Washery, typically about 1m bgl in the north of the Washery. The majority of holes in the Washery recorded groundwater inflow, many of which recorded high rates of flow (refer to cross section A8).

9.6 Soft ground and peat

Soft clay and peat were encountered in three exploratory holes in the Washery area. The potential effects of settlement due to additional loading of the ground from structure foundation loads or due to embankment loading would need to be assessed as part of the design considerations.

9.7 Buildings and structures

Various buildings and structures are proposed on the site including a platform environment, facilities for rail storage, train decommissioning areas, bridges, and culverts.

In the main portion of the site outside any areas of historical opencast activity it may be feasible to found buildings on pad or raft foundations within the glacial till or on top of the relatively shallow bedrock.

The layout of the development should consider the risks presented by ongoing settlement of the backfill.

It may be feasible to found buildings within the areas of previous opencast activity on pad and raft foundations. This would however be subject to careful consideration of the potential magnitude of ground movements; in-particular, the differential movements that may occur within the area of the backfilled opencast workings. Understanding the location of the historical workings, and the variations in the thickness of the backfill present will be important for assessment of potential variations in ground movement across the site.

Regardless of ongoing ground movements, any heavily loaded buildings in these areas may require the use of piled foundations or some form of ground improvement to limit potential settlements under loading to acceptable limits.

Artificial material (made ground) overlying natural superficial material (predominantly glacial till and locally peat) has been encountered within the washery portion of the site.

Based on the anticipated ground conditions in the washery portion of the site, it is possible that piled foundations may be required, depending on the magnitude of loading of the proposed structures. For smaller structures with lower loading pad or raft foundations may be suitable.

The potential subsidence risks associated with shallow mine workings will need to be considered. Mine workings treatment or mitigation is likely to be required within identified risk zones.

The extent of any potential ground treatment, any mining related subsidence risk mitigation measures required, and foundation proposals will need to be reviewed once more detailed ground investigations have been undertaken.

10. Geotechnical risk register

Table 23: Geotechnical Risk Register

Hazard		Consequence	Mitigation Measures
1.	Differential settlement between areas of undisturbed ground and infilled ground.	Potential for structural damage and serviceability issues with the test track and associated structures and infrastructure.	Use the ground investigation and testing findings to better understand the make-up of infill – determine geotechnical design parameters for undisturbed and infilled ground. Undertake additional monitoring of ground movements in order to test theoretical information regarding ongoing ground movements in areas of backfilled opencast workings. Monitor groundwater and undertake detailed hydrogeological risk assessment to understand potential changes in the hydrogeology and potential for future inundation settlement.
2.	Continuing total and differential settlement of infilled areas (associated with backfilled former opencast works).		Develop masterplan and detailed design taking account of areas of higher risk and avoiding these where possible.
3.	Inundation settlement of the infilled areas due to groundwater rebound once dewatering stopped as a result of changes in groundwater regime due to installation of new drainage/soakaways.		Ensure that foundation solutions for structures make sufficient allowance of potential ground movements during design life.
4.	Inundation settlement of the infilled areas due to creation of new drainage paths e.g., installation of drainage across the site.		Design for ground movements e.g., ensure flexible joints in any drainage pipes, incorporate suitable gradients for drainage runs to minimise risks of drainage backing up in the event of differential ground movements occurring.
5.	Potential for significant ground heave in areas of deep cuttings.		Design for regular maintenance, e.g., tamping of track as part of overall development strategy.

Hazard		Consequence	Mitigation Measures
6.	Shallow underground coal workings and associated mine entries, including shafts and adits have been identified to be present beneath sections of the proposed cuttings and embankments	Potential subsidence as a result of subsidence of underground workings or mine entry collapse leading to failure of track and potential train derailment in the permanent case. Risk of encountering underground workings or intact coal seams in the areas of proposed cut. This will need to be considered both in terms of developing safe construction methodologies and permanent works to ensure stability and safety of the final earthwork.	Comprehensive review of all available mine abandonment plans pertaining to workings that are closest to the surface of rockhead and potentially susceptible to crown-holing type subsidence failures (i.e. ~within an influencing depth below rockhead given workings/roadways dimensions and depth of workings). An initial ground investigation comprising a mixture of intrusive and non-intrusive (e.g., non-intrusive gravity surveys) works has been undertaken to locate potential shallow mine workings. If shallow mine workings are identified, mitigatory measures such as grouting of voids may be required to mitigate/negate the risk of subsidence beneath the proposed track route or structures.
6.	Oversteep slope angles in proposed cuttings and earthworks	Failure of earthworks: Cutting – material on the tracks causing derailment Embankment – failure of embankment and track causing derailment.	Use the ground investigation and laboratory testing results and any field scale trials undertaken for derivation of geotechnical parameters and slope stability calculations.
7.	Encountering potentially contaminated soils in relation to the four large cylindrical tanks currently present close to the site compound and offices centrally located within the main Nant Helen site.	Risk of encountering contaminated soils which are potentially hazardous to human health and controlled waters.	The tanks are raised above ground and they are mounted on concrete surface. Therefore any leakages or spillages from the operation of the tanks would be contained; therefore significant hydrocarbon contamination would be unlikely. Post-demolition, verification of the ground in the area of the tanks is recommended to confirm any contamination present. Decommissioning of the tanks should be undertaken by a specialist contractor.

Hazard		Consequence	Mitigation Measures
8.	Encountering unexpected contamination.	Risk of encountering contaminated materials that may not be suitable for re-use, may require hazardous off-site disposal and/or localised remediation.	Due to the historical use of the site there is potential to encounter areas of contamination that have not been identified through the completed investigations. Initial waste assessment completed for the washery site identified materials classified as hazardous waste near the settlement ponds in the eastern part of the Washery site. Other hazardous materials may be encountered during construction works. Any contaminated materials encountered during construction will require assessment to confirm risks to construction workers, controlled waters and suitability for re-use or disposal options.
9.	Potential for instability within rock cuttings or beneath embankments as a result of failure along discontinuities and weak bedding layers within the coal measures (such as coal seat earths).	Large scale instability of rock cuttings.	Design cut slopes to be stable based on literature and ground investigation findings, and/or conditions encountered during excavation of cuttings - and if necessary incorporate stabilisation measures such as rock anchors.
10.	Pyrite is known to be present within the Coal Measures bedrock.	Pyrite containing bedrock can present aggressive conditions to concrete foundations.	Initial concrete assessment completed. Undertake additional testing of materials that are going to be in contact with the proposed concrete in accordance with BRE SD1 and use the concrete classes determined through this process.
11	As dug opencast backfill material not suitable for use in earthworks	Processing of materials required to meet specification requirements	Construct trial embankment to test suitability of as dug materials
12	Mine gas from the shallow workings within the SWCM	Risk to human health from mine gas migration and accumulation into buildings	Further location specific investigation once the project proposals in the Washery site have been developed further to determine if gas protection measures are required. Ground investigation to include ground gas monitoring installations within the mine workings. Review of mine gas risk assessment once the development design is finalised.

11. Further investigations

Additional geotechnical investigation requirements are based on the following considerations:

1. Information required to further delineate the ground conditions across the site, building on the preliminary investigations.
2. The initial ground investigations confirmed the presence of coal seams and in some locations mine workings beneath the site. Further investigations are required to assess the risk posed by shallow mine workings and mine entries that may impact the proposed development.
3. Develop the understanding of long-term ground movements / settlement with further monitoring.
4. The suitability of as dug material on site for reuse in earthworks requires confirmation. The construct of a trial embankment would help assess the suitability of as dug materials.

Additional land quality investigation requirements are based on the following considerations:

1. Information required immediately within the Main Site to allow development of materials handling / reuse documentation (MMP / MWD considerations) and to address information gaps in the main site where no environmental soils or soil-leachate data is available. Works will involve trial pitting, logging of soils and collection of soil/soil-leachate samples to characterise ground condition and allow suitability of reuse to be demonstrated. This information would generate evidence that would allow the LPA/NRW to support the use of a watching brief with detailed exploration strategy for ensuring other materials are suitable for use.
2. Characterisation of Main Site hydrogeology where lines of evidence outside of the CSM are limited with respect to water levels, controlled waters risks, assessment of risk of mine gas emissions from shallow flooded underground mines arising from groundwater seasonal fluctuations (both the Main site and the Washery) and geohazards arising from ground water. Works would involve the drilling of boreholes to allow groundwater monitoring and sampling. Following on monitoring would occur until construction works commence.
3. Investigation of the Washery and Main Site contamination sources identified during walkover activities. Investigation of these sources will involve a mixture of trial pits and targeted boreholes, collecting data on soils, controlled waters and ground gas/vapour risks. At many of these locations demolition is required to enable access.
4. To collect information on the character and distribution of shallow mineworkings and mine entries to inform the boundary conditions of the detailed mine gas risk assessments, where required within both the Washery and Main Site.

It should be noted that environmental investigation will also occur at GI locations intended to assess geotechnical and mining risk. Environmental investigation locations are a mixture of targeted (focused on identified contamination sources) and untargeted (intended to allow statistical analysis and provide robust coverage of the site).

Geoenvironmental testing:

- Environmental soils suite for waste characterisation;
- Soil-leachate testing to inform controlled waters risks/suitability for use.
- Groundwater analysis for controlled waters risk assessment.
- Analysis suites will vary depending on CoC associated with each location. Analysis is likely to include metals, PAHS, SOM, pH, phenols, CN, asbestos ID/quant, with PCBs, TPH CWG, BTEX, VOCs and SVOCs.

The in-situ testing is proposed to comprise:

- Falling / rising head tests;
- Headspace testing; and
- Gas monitoring;

The instrumentation and monitoring are proposed to comprise:

- Dual installation of 50mm plain/slotted HDPE;
- Groundwater monitoring;
- Ground/mine gas monitoring.

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Drawing 1 Site location

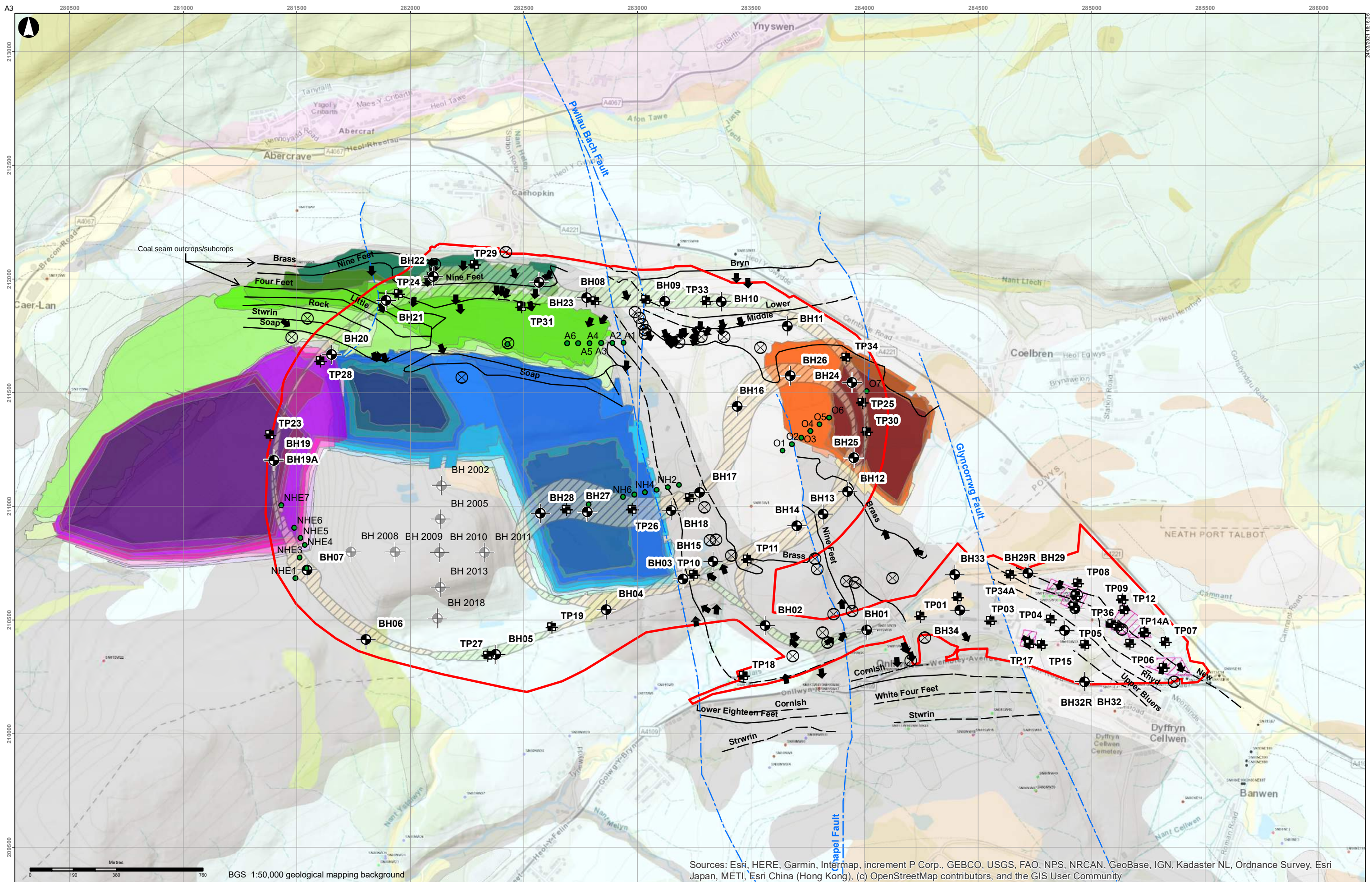
Drawing 2 Superficial deposits and completed ground investigation

Drawing 3 Bedrock geology and completed ground investigation

Drawing 4 Ground investigation plan, main site

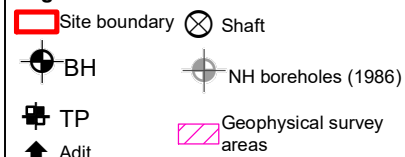
Drawing 5 Ground investigation plan, Washery

Drawing 003A Illustrative Masterplan

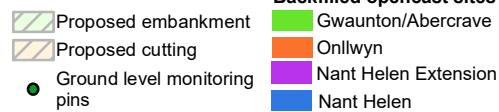


Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

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Backfilled opencast sites



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Rev	Date	By	Chkd	Appd

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Client
Welsh Government

Project Title

Global Centre of Rail Excellence

Drawing Title

Drawing 2 - Superficial cover, bedrock and ground investigation locations

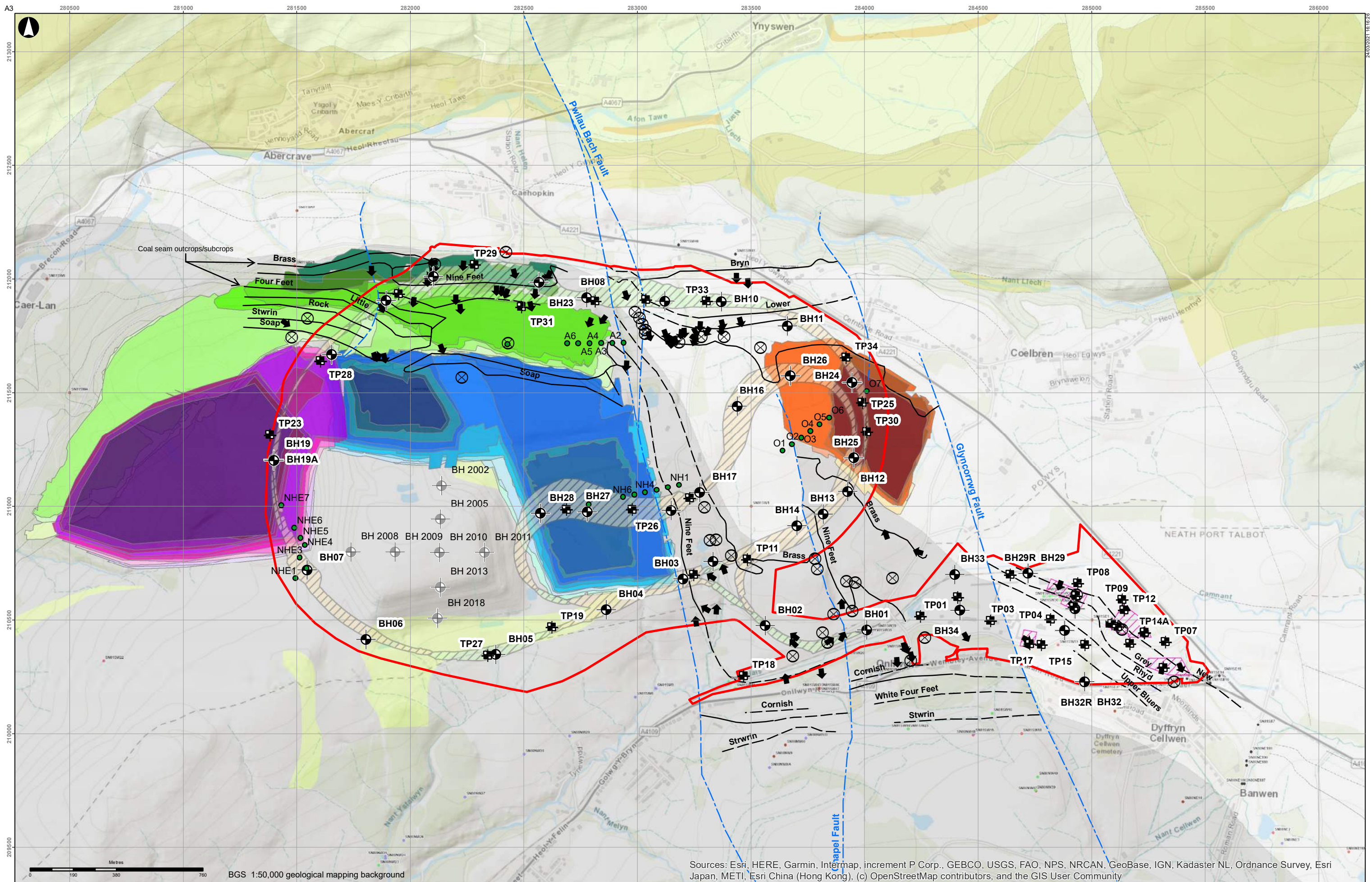
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Role
Geotechnical

Sustainability For Issue

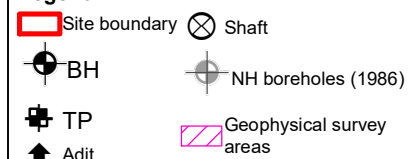
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Drawing Title

Drawing 3 - Bedrock geology and completed ground investigation

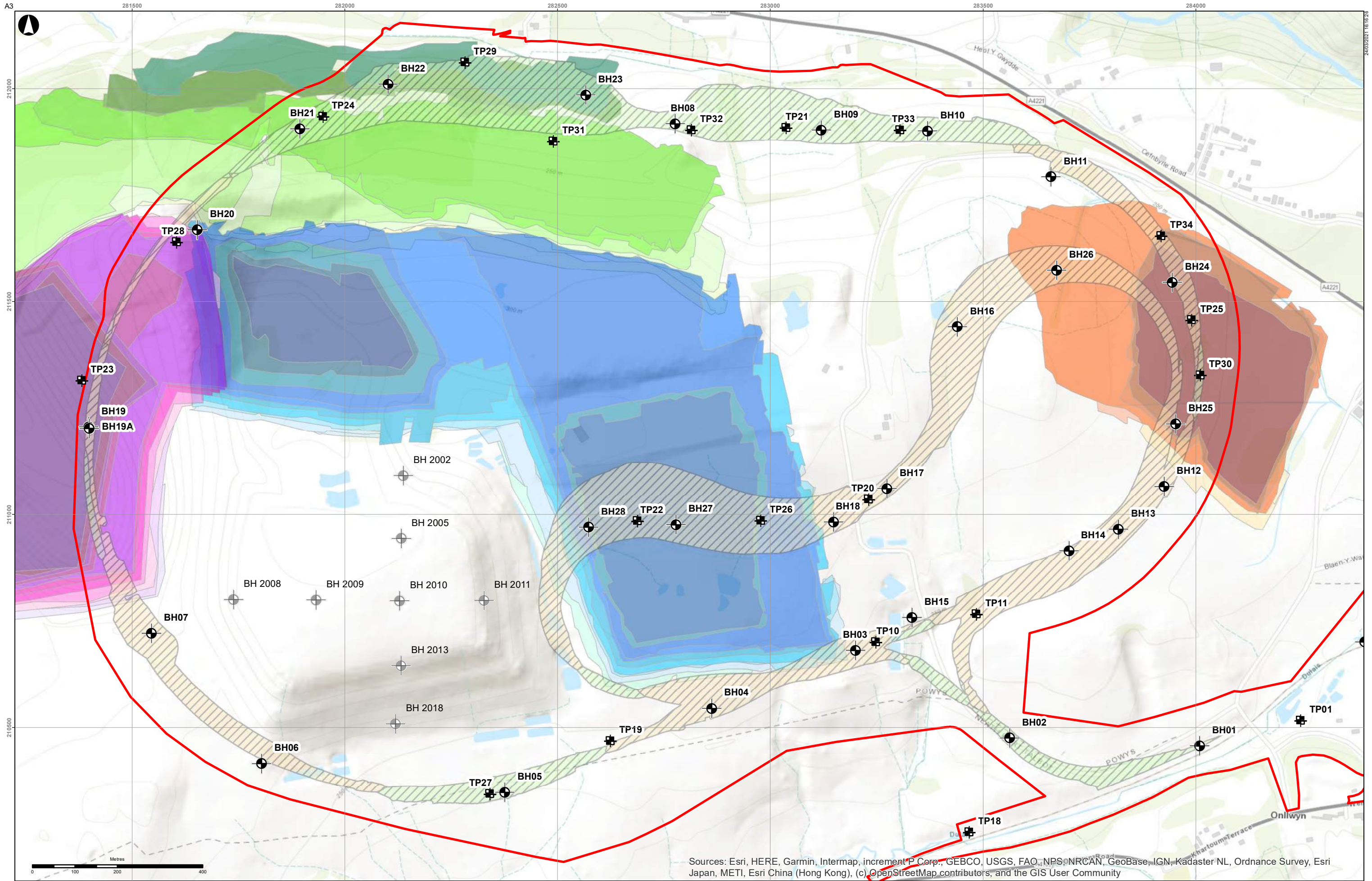
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Role
Geotechnical

Suitability For Issue

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Legend

Site boundary

BH

TP

NH boreholes (1986)

Proposed embankment

Proposed cutting

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Project Title

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Drawing Title

Drawing 4 - Ground investigation locations, main site

Scale at A1

1:8,000

Role

Geotechnical

Suitability

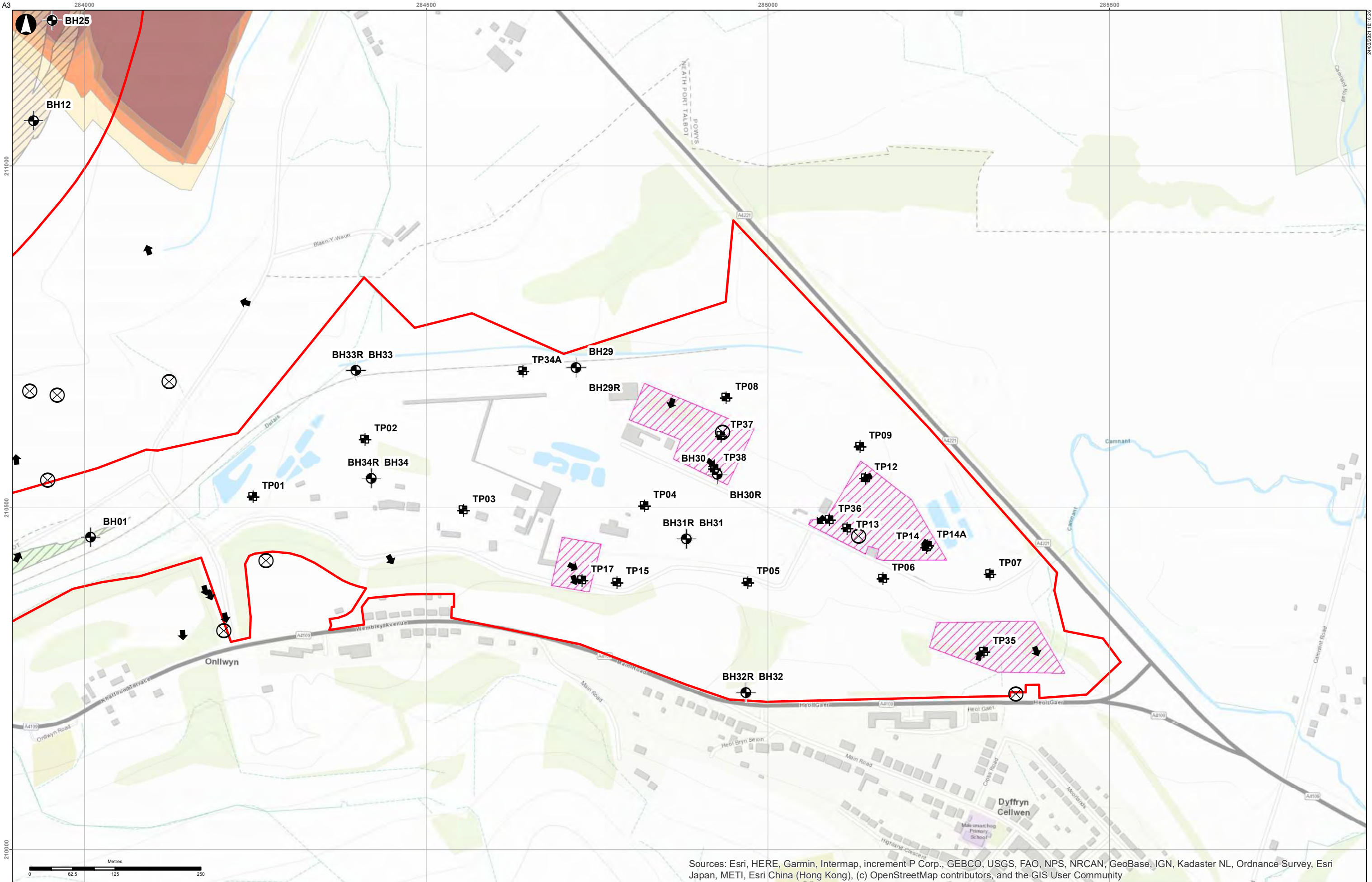
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Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

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Type

Adit

Shaft

Site boundaryBHProposed embankment

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Welsh Government

Project Title
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Drawing Title
Drawing 5 - Ground investigation locations, Washery

Scale at A1 1:5,000	
Role Geotechnical	
Suitability For Issue	
Arup Job No 264904	Rev F1