Net Zero Teesside – Environmental Statement

Planning Inspectorate Reference: EN010103

Volume III – Appendices

Appendix 10D: Geotechnical Risk Register

The Infrastructure Planning (Environmental Impact Assessment) Regulations 2017 (as amended)

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10D. Geotechnical Risk Register

10.1.1 This geotechnical risk register lists the primary engineering risks currently identified at the Site of the Proposed Development and assesses the impact these risks may have upon the project. Risk has been assessed with reference to 'probability', 'impact' and 'risk rating'. Risk rating (R) = Probability (P) x Impact (I), see Tables 10D-1 and 10D-2.

Table 10D-1: Geotechnical Risk Assessment Criteria

Likelihood (L)		Severity (S)				Risk (R = L X S)	
Very probable	5	Very High	5	Potential to halt project	Or	Potential for major claim or similar	17 to 25
Probable	4	High	4	Significant delay to overall project		Major impact on cost	13 to 16
Possible	3	Medium	3	Major delay on this task, but significant impact on overall project unlikely		Minor impact on cost	9 to 12
Unlikely	2	Low	2	Minor delay on this task, but significant impact on overall project unlikely		Minor impact on cost	5 to 8
Negligible	1	Very Low	1	No significant impact on task or project		Negligible impact on cost	1 to 4

Table 10D-2: Geotechnical Risk Register

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
PCC Site						
Inadequate bearing resistance – shallow foundations	Thick various types of Made Ground, of variable, (sometimes very loose and loose) density and chemical composition	5	4	20	Collapse - Structural failure of buildings supported on shallow pad or spread foundations.	Development specific GI. Adequate design for the ground conditions proved on site.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
	underlain by low strength, potentially highly compressible Tidal Flat Deposits and Glacio-lacustrine Deposits.				Injury to site workers, development users.	If necessary, adopt piled foundations to transfer structure loads to soils or bedrock of adequate strength.
Excessive total and / or differential ground displacement (settlement and / or heave)	Thick various types of Made Ground, of variable, (sometimes very loose, loose to very dense) density and chemical composition underlain by low strength, potentially highly compressible Tidal Flat Deposits and Glacio-lacustrine Deposits.	3	4	12	Excessive total and / or differential settlement. Structural damage caused by excessive ground displacement. Serviceability problems leading to structural damage / long term maintenance.	Development specific GI. Adequate design for the ground conditions proved on site. If necessary, adopt piled foundations to transfer structure loads to soils or bedrock of adequate strength.
Excessive ground displacement (vertical and / or lateral heave)	Chemical changes of slag-dominant material. [Walkover of SSI1 in the vicinity of the former sinter plant undertaken by Arcadis observed cracking of brickwork, movement / distortion of brick walls and uneven pavements].	3	4	12	Serviceability problems affecting foundations, ground bearing floor slabs, hardstanding areas, service roads and the connections / cross fall of buried utilities.	Development specific GI. Adequate design for the ground conditions proved on site. If necessary, adopt piled foundations to transfer structure loads to soils or bedrock of adequate strength. If necessary, consider use of sleeved piles to accommodate lateral expansion and / or heave.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
Collapse settlement	Infiltration of surface water. Inundation of poorly compacted Made Ground due to a permanent rise in groundwater levels. [Arcadis GRAR indicated there was evidence that 'hydraulic fill' (river dredging) was placed as part of pre-development site reclamation works].	3	4	12	Collapse - Structural failure. Excessive total and / or differential settlement.	Development specific GI. Adequate design for the groundwater and ground conditions proved on site. If necessary, adopt piled foundations to transfer structure loads to soils or bedrock of adequate strength.
Unexploded ordnance (UXO)	UXO dropped during WWII. [Arcadis SCR reports that one anomaly was found in a borehole 11m bgl].	3	5	15	Explosion, injury or fatality (site personnel and / or the public). Damage to on site and third-party infrastructure. Construction delay; increase in cost and possible redesign.	Provision of detailed report for site from specialist UXO data provider. Adequate assessment and design. Specialist UXO clearance surveys undertaken as part of all future below ground works. If necessary, re-route sections to avoid known UXO constraints.
Difficult construction conditions – buried relict infrastructure – General	Obstructions in the Made Ground including gravel, cobble and boulder sized pieces of slag, very dense	5	3	15	Structural damage (cracking / spalling) to driven concrete or steel piles or loss of plan	Development specific GI including geophysics. Adequate design.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
	material, relict buried foundations, walls, ground slabs, tunnels and possibly pile foundations from former infrastructure. [Arcadis SCR reported the presence of a disused tunnel within the former Redcar Stores area (SSI 2A)].				position and verticality tolerances. Unable to construct shallow foundations, ground slabs, road / hardstanding areas for utilities as planned. Possible redesign, construction delay, increase in cost.	Consideration to the viability of undertaking targeted excavation and replacement of obstructions. Advanced probing / clearance works at proposed pile foundation positions.
Difficult foundation construction – potential volume expansion of slag dominant material	Future expansion of slag-dominant material	3	4	12	Unexpected axial tensile actions imposed on buried shallow foundations, slabs and utilities leading to serviceability problems and possibly, structural damage / integrity problems. Unexpected transverse compressive actions imposed on buried pile foundations.	Development specific GI. Identification and treatment of the most expansive types of slag. Adequate design
Difficult foundation construction – pile foundations	Soft, variable, compressible and / or saturated soils [Figure 10.2 Superficial Geology shows that Blown Sand, Tidal Flat Deposits – Sand and Silt are present	4	4	16	Ground squeezing leading to 'necking' of pile shafts formed using continuous flight auger (CFA) techniques	Development specific GI. Adequate design for the ground conditions proved on site. Appropriate techniques selection, which may include balancing of pore water pressures at pile toes

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
	below the Artificial Ground].					during construction if required. Consider adopting cased rotary bored piled foundations. Use of trained and experienced rig operators.
Difficult foundation construction – pile foundations	Natural obstructions within the glacial drift soils present below the Site. [Arcadis GRAR reported the presence of Glacial Till (Diamicton) below the PCC. Although cobbles and boulders were not recorded on the borehole logs, this may in part be due to the diameter of the drilling equipment used in the Advanced GI Works undertaken on STSC SSI1 & SSI2A land holdings]. Obstructions are expected to be present.	3	2	6	If piling required, unable to achieve pile design toe levels. Construction results in damage to piles if required, or piles which do meet specified out of plan and / or verticality tolerances. Construction delay; increase in cost and possible redesign.	GI. Adequate design for the ground conditions proved on site. Appropriate pile technique selection if required. Carry out advanced magnetometer probing at any required pile positions if necessary. Consider use of cased rotary bored or ODEX piling techniques as alternative to contiguous flight auger (cfa) or driven precast concrete segmental piles if necessary.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
Difficult foundation construction – pile foundations if required.	Presence of strong bands of limestone and / or ironstone within solid succession. [Figure 10.3 Bedrock Geology indicates Penarth Group and Redcar Mudstone Formation underlies the centre and east of the PCC Site].	3	3	9	Unable to achieve design pile toe levels. Damage to piling equipment (e.g. augers). Slow progress during construction. Construction delay, increase in cost, possible redesign.	Development specific GI. Adequate design for the ground conditions proved on site. Appropriate technique selection, including consideration of unconfined compressive strength of bedrock and rig torque capacity. Consider use of rotary or ODEX piling techniques as alternative to contiguous flight auger (cfa) or driven precast concrete segmental piles if piling necessary.
Difficult construction conditions – buried utilities	Disused redundant and / or live buried services associated with past land use. New construction causes damage to existing buried infrastructure / services.	4	3	12	Severing / damaging utility. Settlement of utility / services. Restricted maintenance access to utility provider. Litigation resulting from damage caused to third party infrastructure.	Adequate service survey / drawings to confirm status of utility. Non-intrusive geophysical survey and / or intrusive trial excavations to confirm presence and status of utilities. Use best practice for diversion of utilities if required.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
Aggressive ground conditions	Aggressive elevated concentrations of sulphate and chloride and acidic or alkaline pH in soil or groundwater. [Arcadis GRAR reports Design Sulfate Class DS-5 and corresponding ACEC class AC-5].	5	3	15	Corrosion of buried steel leading to a loss in strength and / or excessive structural deflection. Sulphate attack on buried concrete resulting in a reduction in concrete strength. Serviceability problems leading to long term maintenance liability. Corrosion of polyethylene (PE) and polyvinyl chloride (PVC) plastic pipes.	Development specific GI. Adequate design. Consideration to the provision of permanent sleeving to protect any piles installed through the most aggressive material (Slag dominant material). Consideration to the provision of Additional Protective Measures (APM) to provide additional protection against sulfate attack. Utilities to be installed within clean inert pipe bedding material. Consider the use of wrapped steel, wrapped ductile iron, copper and polyethylene (PE) barrier pipe with an aluminium barrier layer (PE-Al-PE) for services and water supplies in contaminated soils.
Contamination of controlled waters – groundwater	Piled foundations may create source – pathway – receptor between contaminated groundwater	3	5	15	Release of leachable contaminants into underlying aquifers:	GI and groundwater quality testing and monitoring.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
	and the underlying superficial and bedrock aquifers.				Superficial – Secondary 'A' Aquifers (Blown Sand, Tidal Flat Deposits (sand and silt). Bedrock - Secondary 'B' Aquifer (Mercia Mudstone Group & Penarth Group) and the Secondary Aquifer (undifferentiated) Redcar Mudstone Formation. Construction delays; increase in cost. Fines and / or enforcement action from Regulator. Reputational damage.	Adequate design for the ground conditions proved on site. Consultation with the EA and Redcar and Cleveland Borough Council. Preparation of a Foundation Works Risk Assessment. If piling required, consider adopting cased rotary bored piled foundations to remove potential pathway between Made Ground and underlying aquifers.
Material re-use – unacceptable excavated soils	Material excavated to form development platforms not suitable for re-use as bulk earthwork fill. Soft spots or areas exposed at development platform sub-formations. Material excavated during bulk earthworks undertaken on site is contaminated.	5	3	15	Disposal off site or in landscape / development screening mounds. Excavate soft spots / soft areas with well compacted acceptable material.	Development specific GI. Adequate design. Assessment of earthworks volumes required / minimise surplus and create earthwork balance. Cost / risk allowance for waste disposal of contaminated soils including non-hazardous and hazardous waste to be

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						allowed for in the Construction Risk Register. Development of a Remediation Design Strategy and implementation of Materials Management Plan, Construction Environmental Mitigation Plan, Asbestos Management Plan and Verification Report on completion of the works.
CO_2 Export Pipeline						
Unexploded ordnance	UXO dropped during WWII.	3	5	15	Explosion, injury or fatality (site personnel and / or the public). Damage to on site and third-party infrastructure. Construction delay; increase in cost and possible redesign.	Provision of detailed report for site from specialist UXO data provider. Adequate assessment and design. Specialist UXO clearance surveys undertaken as part of all future below ground works. If necessary, re-route sections to avoid known UXO constraints.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
Difficult construction conditions – relict buried infrastructure	Obstructions in the Made Ground including gravel, cobble and boulder sized pieces of slag, relict buried foundations, walls, ground slabs, tunnels and possibly pile foundations associated with demolished former buildings.	5	3	15	Not possible to construct in-ground sections to depth or vertical alignment as planned. Construction delay; increase in cost and possible redesign.	Development specific GI targeted at suspected relict buried foundations, walls, slabs and tunnels etc (identified from historical land use review) including non-intrusive geophysical surveys along proposed in-ground services corridor. Adequate design, including identification of in-ground constraints from the review of historical land use carried out as part of the PSSR. Assess feasibility of re-routing sections to avoid problems. If re-routing is not practical, carry out advanced works ahead of main construction including probing and / or limited earthworks to remove identified relict buried structures by undertaking targeted excavation and replacement of obstructions. Include cost / risk allowance for impeded construction progress in the Construction Risk Register.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
Difficult construction conditions – tidal groundwater control	Shallow groundwater inflows [from wet, coarse soils].	4	3	12	Groundwater inflows into excavations, side slope instability, slumping or ravelling of slopes dug below ground, liquefaction or pumping of silts and / or sands under loading from earth moving plant. Construction delay; increase in cost and possible redesign.	Development specific GI. Adequate design for ground and groundwater conditions proved on site. Temporary groundwater control measures could be required, such as sump pumping, well pointing, vacuum extraction systems, and provision of temporary sheet pile cut off. Include cost / risk allowance for slow construction progress in the Construction Risk Register.
Dewatering	Prolonged pumping of groundwater induces ground settlement and damages adjacent third-party infrastructure.	3	3	9	Construction delay; increase in cost and possible redesign. Litigation resulting from damage caused to third party infrastructure. Adverse effect on nationally protected habitats and wildlife within the SPA, Ramsar & SSSI sites (dune habitat and migratory birds).	GI. Adequate design for the ground and groundwater conditions proved on site. If dewatering is required, assess feasibility of relocating pumping to avoid settlement sensitive infrastructure.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						Design / implement a programme of geotechnical monitoring during construction if necessary with appropriate controls / actions. Liaison with third party infrastructure owner (and technical advisors) during design and construction if required.
Difficult construction conditions – sensitive environmental location	Due to sensitive environmental designations [SPA Ramsar & SSSI].	5	3	15	Special environmental / ecological requirements. Potential loss of sand habitat (Blown Sand and Tidal Flat deposits (sand and silt). Construction delay; increase in cost and possible redesign. Adverse effect on nationally protected habitats and wildlife within the SPA, Ramsar & SSSI sites (dune habitat and migratory birds)	GI. Adequate design for the ground and groundwater conditions proved on site. Maximise re-instatement of excavated sands in construction to minimise temporary loss of dune habitat. Habitat Regulations Assessment. Baseline ecological assessment, Development of Ecological Risk Assessment and Mitigation Strategy and implementation in Construction Environmental Mitigation Plan.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
Contamination of controlled waters	Surface water runoff into controlled waters. Contaminated groundwater generated / released during construction.	3	2	6	Adverse impact on water quality, with resultant impact on wildlife. Construction delay; increase in cost and possible redesign. Fines and / or enforcement action from Regulator. Regulatory damage.	GI and groundwater quality testing and monitoring. Development and adherence to CEMP. Obtain appropriate discharge permit to allow discharge to existing NWL sewerage network if practical. Alternatively tanker off site or collect, store and treat on site.
Difficult construction conditions – buried utilities	Disused redundant and / or live buried services associated with past land use. New construction causes damage to existing buried infrastructure / services.	4	3	12	Severing / damaging utility. Settlement of utility / services. Restricted maintenance access to utility provider. Litigation resulting from damage caused to third party infrastructure.	Adequate service survey / drawings to confirm status of utility. Non-intrusive geophysical survey and / or intrusive trial excavations to confirm presence and status of utilities. Use best practice for diversion of utilities if required. Use of existing above / below ground service conduits where possible.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
Aggressive ground conditions	Aggressive elevated concentrations of sulphate and chloride and acidic or alkaline pH in soil or groundwater.	3	3	9	Corrosion of buried steel leading to a loss in strength and / or excessive structural deflection. Sulphate attack on buried concrete resulting in a reduction in concrete strength. Serviceability problems leading to long term maintenance liability. Corrosion of polyethylene (PE) and polyvinyl chloride (PVC) plastic pipes.	Development specific GI. Adequate design. Consideration to the provision of APM to provide additional protection against sulfate attack if BRE SD1 assessment indicates Design Sulfate Class DS-5 conditions are present. Utilities to be installed within clean inert pipe bedding material. Consider the use of wrapped steel, wrapped ductile iron, copper and PE barrier pipe with an aluminium barrier layer (PE-Al-PE) for services and water supplies in contaminated soils.
Material re-use	Material excavated may be contaminated and / or unacceptable for re-use as bulk backfill above buried service utilities.	4	2	8	Disposal offsite.	Soils are unlikely to be acceptable for re-use. GI. Contamination assessment of all chemical data. Cost / risk allowance for waste disposal of

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						contaminated soils to be allowed for in the Construction Risk Register. Waste may be contaminated with Hazardous materials. Development of a Remediation Design Strategy and implementation of Materials Management Plan, Asbestos Management Plan, Construction Environmental Mitigation Plan and Verification Report on completion of the works.
Water Connections Corridor						
Unexploded ordnance	UXO dropped during WWII.	3	5	15	Explosion, injury or fatality (site personnel and / or the public). Damage to on site and third-party infrastructure. Construction delay; increase in cost and possible redesign.	Provision of detailed report for site from specialist UXO data provider. Adequate assessment and design. Specialist UXO clearance surveys undertaken as part of all future below ground works.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						If necessary, re-route sections to avoid known UXO constraints.
Difficult construction conditions – relict buried infrastructure	Obstructions in the Made Ground including gravel, cobble and boulder sized pieces of slag, relict buried foundations, walls, ground slabs, tunnels and possibly pile foundations associated with demolished former buildings.	5	3	15	Not possible to construct in-ground sections to depth or vertical alignment as planned. Construction delay; increase in cost and possible redesign.	Development specific GI targeted at suspected relict buried foundations, walls, slabs and tunnels etc (identified from historical land use review) including non-intrusive geophysical surveys along proposed in-ground services corridor. Adequate design, including identification of in-ground constraints from the review of historical land use carried out as part of the PSSR. Assess feasibility of re-routing sections to avoid problems. If re-routing is not practical, carry out advanced works ahead of main construction including probing and / or limited earthworks to remove identified relict buried structures by undertaking targeted excavation and

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						replacement of obstructions. Examine potential for utilising the existing intake and associated abstraction licence from the former SSI Redcar Steelworks to supply water to the Proposed Development. Include cost / risk allowance for slow construction progress in the Construction Risk Register.
Difficult construction conditions – groundwater control	Shallow groundwater inflows [from wet, coarse soils].	4	3	12	Groundwater inflows into excavations, side slope instability, slumping or ravelling of slopes dug below ground, liquefaction or pumping of silts and / or sands under loading from earth moving plant. Construction delay; increase in cost and possible redesign.	Development specific GI. Adequate design for ground conditions proved on site. Temporary groundwater control measures could be required, such as sump pumping, well pointing, vacuum extraction systems, and provision of temporary sheet pile cut off. Include cost / risk allowance for slow construction progress in the Construction Risk Register.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
Dewatering	Prolonged pumping of groundwater induces settlement and damages adjacent third-party infrastructure.	3	3	9	Construction delay; increase in cost and possible redesign. Litigation resulting from damage caused to third party infrastructure.	GI. Adequate design for the ground conditions proved on site. If dewatering is required, assess feasibility of relocating pumping to avoid settlement sensitive infrastructure. Design / implement a programme of geotechnical monitoring during construction if necessary, with appropriate controls / actions. Liaison with third party infrastructure owner (and technical advisors) during design and construction if required.
Contamination of controlled waters	Surface water runoff into controlled waters. Contaminated groundwater generated / released during construction.	3	2	6	Adverse impact on water quality, with resultant impact on wildlife. Construction delay; increase in cost and possible redesign. Fines and / or enforcement action from Regulator. Regulatory damage.	GI and groundwater quality testing and monitoring. Development and adherence to CEMP. Obtain appropriate discharge permit to allow discharge to existing NWL sewerage network if practical.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						Alternatively tanker off site or collect, store and treat on site.
Buried utilities	Disused redundant and / or live buried services associated with past land use. New construction causes damage to existing buried infrastructure / services.	4	3	12	Severing / damaging utility. Settlement of utility / services. Restricted maintenance access to utility provider. Litigation resulting from damage caused to third party infrastructure.	Adequate service survey / drawings to confirm status of utility. Non-intrusive geophysical survey and / or intrusive trial excavations to confirm presence and status of utilities. Use best practice for diversion of utilities if required.
Aggressive ground conditions	Aggressive elevated concentrations of sulphate and chloride and acidic or alkaline pH in soil or groundwater.	3	3	9	Corrosion of buried steel leading to a loss in strength and / or excessive structural deflection. Sulphate attack on buried concrete resulting in a reduction in concrete strength. Serviceability problems leading to long term maintenance liability.	Development specific GI. Adequate design. Consideration to the provision of APM to provide additional protection against sulfate attack if BRE SD1 assessment indicates Design Sulfate Class DS-5 conditions are present.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
					Corrosion of polyethylene (PE) and polyvinyl chloride (PVC) plastic pipes.	Utilities to be installed within clean inert pipe bedding material. Consider the use of wrapped steel, wrapped ductile iron, copper and PE barrier pipe with an aluminium barrier layer (PE-Al-PE) for services and water supplies in contaminated soils.
Material re-use	Material excavated may be contaminated and unacceptable for re-use as bulk backfill above buried service utilities.	4	2	8	Disposal offsite.	Soils are unlikely to be acceptable for re-use. GI. Contamination assessment of all chemical data. Cost / risk allowance for waste disposal of contaminated soils to be allowed for in the Construction Risk Register. Waste may be contaminated with Hazardous materials. Development of a Remediation Design Strategy and implementation of Materials Management Plan,

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						Asbestos Management Plan, Construction Environmental Mitigation Plan and Verification Report on completion of the works.
CO_2 Gathering Network & Gas Connection Corridors						
Unexploded ordnance	UXO dropped during WWII.	3	5	15	Explosion, injury or fatality (site personnel and / or the public).	Provision of detailed report for site from specialist UXO data provider.
					Damage to on site and third-party infrastructure.	Adequate assessment and design.
					Construction delay; increase in cost and possible redesign.	Specialist UXO clearance surveys undertaken as part of all future below ground works.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						If necessary, re-route sections to avoid known UXO constraints.
Difficult construction conditions – relict buried infrastructure	Obstructions in the Made Ground including gravel, cobble and boulder sized pieces of slag, relict buried foundations, walls, ground slabs, tunnels and possibly pile foundations associated with demolished former buildings.	5	3	15	Not possible to construct in-ground sections to depth or vertical alignment as planned. Construction delay; increase in cost and possible redesign.	Development specific GI targeted at suspected relict buried foundations, walls, slabs and tunnels etc (identified from historical land use review) including non-intrusive geophysical surveys along proposed in-ground services corridor. Adequate design, including identification of in-ground constraints from the review of historical land use carried out as part of the PSSR. Assess feasibility of re-routing sections to avoid problems. If re-routing is not practical, carry out advanced works ahead of main construction including probing and / or limited earthworks to remove identified relict buried structures by undertaking targeted excavation and

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						replacement of obstructions. Use of existing above / below ground service conduits where possible. Include cost / risk allowance for slow construction progress in the Construction Risk Register.
Difficult construction conditions – peat	Presence of peat locally in or below utilities excavations. [Figure 10.2 Superficial Geology shows an elongate area of peat present across the route south east of Reservoirs near Saltholme].	3	2	6	Compressible formation susceptible to ground displacements (heave / settlement) during and after construction. Construction delay; increase in cost and possible redesign.	Development specific GI. Adequate design for the ground conditions proved on site. Removal of soft spots and replacement with suitable compacted engineered fill material. Include cost / risk allowance for slow construction progress in the Construction Risk Register.
Difficult construction – buried utilities	Disused redundant and / or live buried services associated with past land use.	4	3	12	Severing / damaging utility. Settlement of utility / services. Restricted maintenance access to utility provider.	Adequate service survey / drawings to confirm status of utility. Non-intrusive geophysical survey and / or intrusive trial excavations to confirm

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
	New construction causes damage to existing buried infrastructure / services.				Litigation resulting from damage caused to third party infrastructure.	presence and status of utilities. Use best practice for diversion of utilities if required.
Difficult construction conditions – groundwater control	Shallow groundwater inflows [from wet, coarse soils].	4	3	12	Groundwater inflows into excavations, side slope instability, slumping or ravelling of slopes dug below ground, liquefaction or pumping of silts and / or sands under loading from earth moving plant. Construction delay; increase in cost and possible redesign.	Development specific GI. Adequate design for ground conditions proved on site. Temporary groundwater control measures could be required, such as sump pumping, well pointing, vacuum extraction systems, and provision of temporary sheet pile cut off. Include cost / risk allowance for slow construction progress in the Construction Risk Register.
Dewatering	Prolonged pumping of groundwater indicates settlement and damages adjacent third-party infrastructure.	3	3	9	Construction delay; increase in cost and possible redesign. Litigation resulting from damage caused to third party infrastructure.	GI. Adequate design for the ground conditions proved on site. If dewatering is required, assess feasibility of relocating pumping to avoid

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						settlement sensitive infrastructure. Design / implement a programme of geotechnical monitoring during construction if necessary, with appropriate controls / actions. Liaison with third party infrastructure owner (and technical advisors) during design and construction if required.
Contamination of controlled waters	Surface water runoff into controlled waters. Contaminated groundwater generated / released during construction.	3	2	6	Adverse impact on water quality, with resultant impact on wildlife. Construction delay; increase in cost and possible redesign. Fines and / or enforcement action from Regulator. Regulatory damage.	GI and groundwater quality testing and monitoring. Development and adherence to CEMP. Obtain appropriate discharge permit to allow discharge to existing NWL sewerage network if practical. Alternatively tanker off site or collect, store and treat on site.
Aggressive ground conditions	Aggressive elevated concentrations of sulphate and chloride and acidic or	3	3	9	Corrosion of buried steel leading to a loss in strength and / or excessive structural deflection.	Development specific GI. Adequate design. Consideration to the provision of APM to provide

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
	alkaline pH in soil or groundwater.				Sulphate attack on buried concrete resulting in a reduction in concrete strength. Serviceability problems leading to long term maintenance liability. Corrosion of polyethylene (PE) and polyvinyl chloride (PVC) plastic pipes.	additional protection against sulfate attack if BRE SD1 assessment indicates Design Sulfate Class DS-5 conditions are present. Utilities to be installed within clean inert pipe bedding material. Consider the use of wrapped steel, wrapped ductile iron, copper and PE barrier pipe with an aluminium barrier layer (PE-Al-PE) for services and water supplies in contaminated soils.
Material re-use	Material excavated may be contaminated and unacceptable for re-use as bulk backfill above buried service utilities.	4	2	8	Disposal offsite.	Soils are unlikely to be suitable for re-use. GI. Contamination assessment of all chemical data. Cost / risk allowance for waste disposal of contaminated soils to be allowed for in the Construction Risk Register. Waste may be

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						contaminated with Hazardous materials. Development of a Remediation Design Strategy and implementation of Materials Management Plan, Asbestos Management Plan, Construction Environmental Mitigation Plan and Verification Report on completion of the works.
Electrical Connection Corridor						
Unexploded ordnance	UXO dropped during WWII	3	5	15	Explosion, injury or fatality (site personnel and / or the public). Damage to on site and third-party infrastructure. Construction delay; increase in cost and possible redesign.	Provision of detailed report for site from specialist UXO data provider. Adequate assessment and design. Specialist UXO clearance surveys undertaken as part of all future below ground works. If necessary, re-route sections to avoid known UXO constraints.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
Difficult construction conditions – relict buried infrastructure	Obstructions in the Made Ground including gravel, cobble and boulder sized pieces of slag, relict buried foundations, walls, ground slabs, tunnels and possibly pile foundations associated with demolished former buildings.	5	3	15	Not possible to construct in-ground sections to depth or vertical alignment as planned. Construction delay; increase in cost and possible redesign.	Development specific GI targeted at suspected relict buried foundations, walls, slabs and tunnels etc (identified from historical land use review) including non-intrusive geophysical surveys along proposed in-ground services corridor. Adequate design, including identification of in-ground constraints from the review of historical land use carried out as part of the PSSR. Assess feasibility of re-routing sections to avoid problems. If re-routing is not practical, carry out advanced works ahead of main construction including probing and / or limited earthworks to remove identified relict buried structures by undertaking targeted excavation and replacement of obstructions. Use of existing overhead lines and below ground

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						service infrastructure where possible. Include cost / risk allowance for slow construction progress in the Construction Risk Register.
Difficult construction conditions – groundwater control	Shallow groundwater inflows [from wet, coarse soils].	4	3	12	Groundwater inflows into excavations, side slope instability, slumping or ravelling of slopes dug below ground, liquefaction or pumping of silts and / or sands under loading from earth moving plant. Construction delay; increase in cost and possible redesign.	Development specific GI. Adequate design for ground conditions proved on site. Temporary groundwater control measures could be required, such as sump pumping, well pointing, vacuum extraction systems, and provision of temporary sheet pile cut off. Include cost / risk allowance for slow construction progress in the Construction Risk Register.
Dewatering	Prolonged pumping of groundwater induces settlement and damages adjacent third-party infrastructure.	3	3	9	Construction delay; increase in cost and possible redesign. Litigation resulting from damage caused to third party infrastructure.	GI. Adequate design for the ground conditions proved on site. If dewatering is required, assess feasibility of relocating pumping to avoid

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						settlement sensitive infrastructure. Design / implement a programme of geotechnical monitoring during construction if necessary, with appropriate controls / actions. Liaison with third party infrastructure owner (and technical advisors) during design and construction if required.
Contamination of controlled waters	Surface water runoff into controlled waters. Contaminated groundwater generated / released during construction.	3	2	6	Adverse impact on water quality, with resultant impact on wildlife. Construction delay; increase in cost and possible redesign. Fines and / or enforcement action from Regulator. Regulatory damage.	GI and groundwater quality testing and monitoring. Development and adherence to CEMP. Obtain appropriate discharge permit to allow discharge to existing NWL sewerage network if practical. Alternatively tanker off site or collect, store and treat on site.
Difficult construction conditions – buried utilities	Disused redundant and / or live buried services associated with past land use.	4	3	12	Severing / damaging utility. Settlement of utility / services.	Adequate service survey / drawings to confirm status of utility.

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
	New construction causes damage to existing buried infrastructure / services.				Restricted maintenance access to utility provider. Litigation resulting from damage caused to third party infrastructure.	Non-intrusive geophysical survey and / or intrusive trial excavations to confirm presence and status of utilities. Use of existing overhead lines and below ground service infrastructure where possible. Use best practice for diversion of utilities if required.
Aggressive ground conditions	Aggressive elevated concentrations of sulphate and chloride and acidic or alkaline pH in soil or groundwater.	3	3	9	Corrosion of buried steel leading to a loss in strength and / or excessive structural deflection. Sulphate attack on buried concrete resulting in a reduction in concrete strength. Serviceability problems leading to long term maintenance liability. Corrosion of polyethylene (PE) and polyvinyl chloride (PVC) plastic pipes.	Development specific GI. Adequate design. Consideration to the provision of APM to provide additional protection against sulfate attack if BRE SD1 assessment indicates Design Sulfate Class DS-5 conditions are present. Utilities to be installed within clean inert pipe bedding material. Consider the use of wrapped steel, wrapped ductile iron, copper and PE barrier pipe with an

Identified Geotechnical Hazard / Risk	Cause	Risk before Control			Consequence	Mitigation Measures
		L	S	R (L*S)		
						aluminium barrier layer (PE-Al-PE) for services and water supplies in contaminated soils.
Material re-use	Material excavated may be contaminated and unacceptable for re-use as bulk backfill above buried service utilities.	4	2	8	Disposal offsite.	Soils are unlikely to be suitable for re-use. GI. Contamination assessment of all chemical data. Cost / risk allowance for waste disposal of contaminated soils to be allowed for in the Construction Risk Register. Waste may be contaminated with Hazardous materials. Development of a Remediation Design Strategy and implementation of Materials Management Plan, Asbestos Management Plan, Construction Environmental Mitigation Plan and Verification Report on completion of the works.