Prairie Phase 4, Teesworks, Redcar

Phase II Site Assessment

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Appendices

1 Introduction

1.1 Project Background

Prairie Phase 4 is a land parcel located within the Dorman Point Area of the Teesworks redevelopment. The wider site is within the Redcar, Lackenby, Grangetown and South Bank conurbations of the Borough of Redcar & Cleveland, within the industrial area generally known as 'South Tees'.

The site location is shown below and in Appendix A on Figure 1.

Figure 1: Site location plan. Green line: Wider Dorman Point redevelopment area. Red line: Prairie Phase 4 redevelopment area (topic of this report).

The South Tees Regeneration Masterplan has been developed detailing the industrial-led regeneration of the Teesworks site into a world class employment-generating zone and economic growth enabler for the Tees Valley.

The Prairie area has been split into multiple redevelopment phases. At the time writing remedial earthworks are underway within selected plots across the wider Dorman Point area.

1.2 Contract Details

Arcadis (UK) Limited (Arcadis) was appointed by South Tees Development Corporation (STDC) to oversee and manage a ground investigation undertaken by Allied Exploration and Geotechnics Limited (AEG) and to provide consultancy advice on the redevelopment of the site.

The scope of works was defined by Arcadis, on behalf of STDC, as presented in:

- Prairie Phase 4 – Arcadis PM and Technical Support – Fee Proposal_2021. Dated August 2021.

1.3 Project Aims and Objectives

The overarching aim of the works was to deliver a sustainable ground remediation strategy for the contract sites which is compliant with regulatory needs and has their approval in principle. As technical consultant, our specific objectives of this phase of works were to:

- Manage and technically supervise the site works, undertaken by AEG, on behalf of STDC;
- Direct the site works to ensure compliance by the ground investigation contractors with existing site management protocols and procedures;
- Specify the requirements for laboratory analysis;
- Analyse the results of ground investigations;
- Prepare interpretative technical reports,
- Consult with regulators to ensure compliance with all relevant regulatory requirements; and,
- Develop cost-effective, value-engineered outline remediation strategies.

1.4 Previous Information

Arcadis oversaw a historic ground investigation at the site in 2017. Phase 1 reports provided by STDC (and written by 3rd parties) were reviewed and the information incorporated into the Conceptual Site Model. Data was gathered from shallow soils around the outside of the former Torpedo Ladle Repair Shop (TLRS).

The conceptual site model and the relevant 3rd party reports are detailed in:

- Arcadis (2018a) - *The Former SSI Steelworks, Redcar: Priority Areas within SSI Landholdings Contract 3: Site Condition Report,* report reference: *Redcar Steelworks-AUK-XX-XX-RP-GE-0001-02-SSI3_GI_SCR*

Arcadis further assessed the geo-environmental risk within:

- Arcadis (2018b) – *The Former SSI Steelworks, Redcar: Priority Areas within SSI Landholdings Contract 3: Environmental Risk Assessment Report*, report reference: *Redcar Steelworks-AUK-XX-XX-RP-GE-0001-01-SSI3_GI_ERA*
- Arcadis (2018c) - *The Former SSI Steelworks, Redcar: Priority Areas within SSI Landholdings Contract 3: Geotechnical Risk Assessment Report*, report reference: *Redcar Steelworks-AUK-XX-XX-RP-GE-0001-P1-SSI3_GI_GRA*

A Remediation Options Appraisal exists for the site and is detailed in:

- Arcadis (2021) – *The Former SSI Steelworks, Redcar: Priority Areas within SSI Landholdings Contract: Contract 3: Ground Remediation Options Appraisal Report (Prairie Phase 4 / TLRS Area)*, report reference: *Redcar Steelworks-AUK-XX-XX-RP-GE-0001-02-SSI3_GI_ROA*

1.5 Report Aims

The aim of the investigation was to fill data gaps associated with ground conditions underneath the former TLRS building in order to refine the conceptual site model previously developed for the site and undertake a generic quantitative risk assessment considering the 2021 ground investigation performed by AEG in order to assess if conclusions previously drawn remain valid.

1.6 Reliability / Limitations of Information

A complete list of Arcadis Study Limitations is presented in Appendix B.

It should be noted that ground conditions between exploratory holes may vary from those identified during this ground investigation; any design should take this into consideration. It should also be noted that groundwater levels may be subject to diurnal, tidal, seasonal, climatic variations and those recorded in this report are solely dependent on the time the ground investigation was carried out and the weather before and during the investigation.

2 Site Conceptualisation

A detailed analysis of the site conceptualisation can be found in Arcadis 2018a [*Redcar Steelworks-AUK-XX-XX-RP-GE-0001-02-SSI3_GI_SCR*], with key points being placed in the table below:

Table 1: Site Conceptualisation summary

Item	Comment
Site Description	Demolished steelworks. TLRS building was demolished in 2021 leaving reinforced concrete footing behind. Associated disused rail tracks are present to the north and south of the former building footprint, converging in the east before leaving site. 2no. tanks have been noted on site. A solidified steel ingot associated with a torpedo ladle is present on site.
Site Location	OS National Grid: 454792, 521116 (approximate centre of the site) Indicative Post Code: TS6 7BH
Elevation	9 to 13 metres Above Ordnance Datum (m AOD)
Size	7.9 hectares
History	No potentially contaminative land uses identified prior to construction of the steelworks in 1929. Building position and orientation has remained largely the same through the site's operation.
Intended End Use	Commercial / Industrial
Geology	Made Ground (comprising slag and steel working wastes) across the footprint of the site, overlying superficial deposits of laminated clay and silt (Glaciolacustrine Deposits) and slightly gravelly clays (Glacial Till). Bedrock is the Penarth group in the north of site and Redcar Mudstone Formation across the majority of site.
Hydrogeology	The site is not within a Groundwater Source Protection Zone. Groundwater is perched within Made Ground resting on lower permeability natural soils. Groundwater is present within more permeable horizons of the Superficial Deposits. Groundwater flow is affected by structures and presence of permeable horizons within the deposits underlying the site.
Hydrology	No watercourses on site. Nearest water courses are Holme Beck (approximately 100m west) and Knitting Wife Beck (immediately east of site) both of which are culverted to the SLEMS area approximately 850m to the north.

The scope completed by AEG during the 2021 works included:

- 2no. cable percussion / rotary core boreholes drilled by AEG to depths of 16m below ground level with progression of 5m into rock
- 12no. trial pits excavated by a 30 tonne tracked excavator, to a target depth of 4.5m or refusal, or until natural material was encountered;
- Soil sampling for in-field assessment and submission to Derwentside Environmental Testing Services (DETS), AEG in-house Geotechnical Laboratory and Thomas Research Services (TRS) laboratories for chemical and geotechnical testing;
- Installation of 4no. groundwater monitoring wells (2no. twin installations) with subsequent purge development;
- 1no. round of groundwater sampling of all newly installed monitoring wells;

- Groundwater elevation survey of all newly installed monitoring wells and aquifer property testing on selected wells; and
- 5no. rounds of ground gas monitoring.

2.1 Geology

The following table provides an overview of the site-specific geology encountered during the AEG investigation across the site. The geology is consistent with the findings reported within Arcadis 2018a.

The full geology encountered is provided in Appendix C.

It should be noted that data received is still draft and partially incomplete in nature. Conclusions may be subject to change based on finalised AEG report.

Table 2: Summary of geology encountered during 2021 Ground Investigation

Unit	Minimum Basal Elevation (m AOD)	Maximum Thickness (m)	Comment
Made Ground	5.10	4.70* **Where base of MG was proven average thickness was 1.74m*	Site surfacing comprised predominantly of concrete slab. In discrete locations no concrete slab was present with granular Made Ground being exposed at the surface. The Made Ground encountered during the investigation predominantly comprised granular material with a fine-grained component and medium cobble/boulder content which included slag, brick, concrete. Timber, metal, ceramic, plastic and/or glass were frequently noted. Based on visual assessment slag was found to compose between 0 to 50% of the soil matrix at all locations.
Glaciolacustrine Deposits (unproductive strata)	1.70	3.50	Glaciolacustrine Deposits were recorded in both boreholes directly below Made Ground, and in 10 of the 12 trial pits. The deposits were generally described as a firm to stiff thinly laminated dark yellowish-brown clay, often with sand along laminations. Blue grey mottling was frequently noted.
Glacial Till (unproductive strata)	-0.20	3.10	Glacial Till was identified in both boreholes below the Glaciolacustrine Deposits. Glacial Till was described as a stiff red brown slightly sandy slightly gravelly clay, with gravel composed of mixed lithologies, including sandstone and mudstone.
Redcar Mudstone Formation (Secondary Undifferentiated Aquifer)	-5.10* **Base not proven*	5.30* **Base not proven*	Identified in both boreholes underlying the Glacial Till. Initially described as extremely weak light / dark grey mudstone / sandstone / siltstone. This material was noted to increase in strength with increasing depth, with the weaker layers being associated with more weathered zones within the rock profile. Pyrite and calcareous material (fossils) were noted along material recovered from S3_BHA03 and micaceous material was noted along laminations within the unit in S3_BHA04.

Trial pit S3_TPA_TP102 was terminated at 2.5m below ground level due to a concrete obstruction. The trial pit was moved to S3_TPA_TP102A (which encountered a concrete obstruction at 2.2m bgl).

Two types of Made Ground were noted:

- **Slag-rich Made Ground (SRMG) (25-50% slag):** Generally, gravel sized fragments and intermixed with other types of manmade fragments including brick, concrete, plastic, glass, and metal. The slag was noted to be dark grey mostly vesicular. SRMG was found close to the surface of S3_BHA104 and S3_TPA_TP109 only.
- **Granular Made Ground (GMG):** Noted within all intrusive locations described as a slightly clayey slightly sandy gravel with medium cobble and boulder content. Gravel, cobbles and boulders include brick, concrete and other demolition materials, slag was not the dominant constituent although often still present within the soil matrix.

Glaciolacustrine deposits underlying the base of the Made Ground (in all locations where the base of the Made Ground was proven). The thickness of these deposits was identified in boreholes S3_BHA103 and S3_BHA104 to be between 2.5m and 3.5m. The Glacial Till was found to be 1.95m and 3.1m in thickness. The combined thickness of both low permeability clay units was typically around 5m.

Redcar Mudstone Formation was identified underlying the Glacial Till in both boreholes, the base of which was not proven.

2.2 Obstructions

Concrete surfacing covers much of the former building footprint and was identified at 11 of the 14no. intrusive locations. Concrete surfacing was noted to be between 0.20 and 0.50m thick.

Concrete obstructions were noted at depth within the Made Ground at 3no. locations (S3_TPA_TP102, S3_TPA_TP102A & S3_TPA_TP111) at the south-eastern end of the former building footprint.

Obstructions (predominantly concrete) were identified in 12no. intrusive locations during the 2017 investigation (Arcadis 2018a [Redcar Steelworks-AUK-XX-XX-RP-GE-0001-02-SSI3_GI_SCR]).

2.3 Hydrogeology

During the ground investigation groundwater strikes were encountered in the Made Ground and upper layers of the Glaciolacustrine Deposits between 9.50 to 7.30m AOD. Groundwater appears to either be perched within the Made Ground or present within more permeable layers of the underlying (predominantly) cohesive natural soils. This is in line with information reported previously.

A groundwater strike was noted during progression of S3_BHA04 at 2.02m AOD within the Redcar Mudstone Formation. Groundwater levels identified during the monitoring visits are summarised in the table below:

Table 3: Summary of groundwater monitoring results

Borehole	Screened Aquifer	Range in Depth to Groundwater (m bgl)	Range in Depth to Groundwater (m AOD)
Made Ground / Superficial Deposits			
S3_BHA02*	Glaciolacustrine Deposits / Glacial Till	0.83 to 1.58	10.33 to 9.58
S3_BHA03S	Made Ground / Glacio-lacustrine Deposits	4.62 to 5.02	5.28 to 4.88

Borehole	Screened Aquifer	Range in Depth to Groundwater (m bgl)	Range in Depth to Groundwater (m AOD)
S3_BHA04S	Made Ground / Glacio-lacustrine Deposits	0.62 to 1.51	9.40 to 8.51
Bedrock			
S3_BHA03D	Redcar Mudstone Formation	6.22 to 6.36	3.68 to 3.54
S3_BHA04D	Redcar Mudstone Formation	0.60 to 1.53	9.42 to 8.49

**Well installed during 2017 ground investigation, data collected on 3no. monitoring visits.*

Groundwater flow direction for deposits on site cannot be defined from the limited number of data points.

Groundwater is present within the Made Ground and Superficial Deposits, and is conceptualised to be in the more granular horizons which will dictate the preferential flow pathways. Given the nature of the Superficial Deposits, groundwater is likely to be laterally and vertically discontinuous. The Glaciolacustrine and Glacial Till geological units are classified as Unproductive Strata and are not considered a receptor for the site. Groundwater inflow within trial pits was noted as slow or "seepage", suggesting that there may only be small volumes of water within the more permeable horizons.

Groundwater is present within the Redcar Mudstone Formation. Groundwater within S3_BHA03D and S3_BHA04 is resting above the slotted section of the monitoring well indicating that the phreatic surface rests above the mudstone.

2.4 Potential Areas of Concern

As detailed in Arcadis 2018a [*Redcar Steelworks-AUK-XX-XX-RP-GE-0001-02-SSI3_GI_SCR*] the main potential areas of concern (PAOC) within the site are:

- Made Ground,
- Former Torpedo ladle workshop area (now demolished),
- Electricity transformers (now demolished) and;
- Former steelworks infrastructure from the surrounding area.

3 Environmental Site Condition Assessment

Arcadis 2018a [*Redcar Steelworks-AUK-XX-XX-RP-GE-0001-02-SSI3_GI_SCR*] identified potential on-site and off-site contaminant sources and generated a conceptual site model.

The CSM allows a qualitative evaluation of potentially active "pollutant linkages" at the site; these being plausible scenarios whereby a contamination source is connected to a possible receptor by one or more pathways:

- Potential sources of contamination: these include any actual or potentially contaminating materials and activities, located either on or in the vicinity of the site;
- Potential pathways for contamination migration: these comprise the routes or mechanisms by which contaminants may migrate from the source to the receptor including environmental migration pathways and human health exposure pathways; and
- Potential receptors of contamination: these include present and/or future land users, ecological systems, water resources and property.

The potential significance of these source-pathway-receptor linkages will be assessed in Section 4.

3.1 Contamination Sources

A detailed review of potential contamination sources is presented within Arcadis 2018a [*Redcar Steelworks-AUK-XX-XX-RP-GE-0001-02-SSI3_GI_SCR*].

The primary contaminants of concern (CoC) for the site are:

- Metals (including heavy metals), refractory materials, polyaromatic hydrocarbons (PAHs), cyanide, thiocyanate, sulphate, sulphide, carbonates, pH, ammonia, total petroleum hydrocarbons, volatile organic compounds (VOC), semi-volatile organic compounds (SVOC) and asbestos potentially originated from Made Ground or historic industrial land use.
- Polychlorinated biphenyls potentially originating from the substations on site.
- Ground gas potentially originating from organic material within the Made Ground.
- TPH, VOCs, SVOCs, chloride, ammonia, sulphate, pH and potential ground gas originating from a historic (1982 to 1983) inert/commercial landfill located 225m southeast of the site.

3.2 Contamination Sources Assessment

Arcadis 2018a [*Redcar Steelworks-AUK-XX-XX-RP-GE-0001-02-SSI3_GI_SCR*] undertook a detailed contamination sources assessment, reviewing contaminants based on material composition and potential point source. This data has been reviewed and is summarised below in conjunction with the current data set.

Soils

During this phase of investigation Made Ground on site has elevated concentrations of heavy metals, sulphate, PAHs, relatively low levels of free cyanide and alkaline pH. Asbestos fibres have been noted approximately 10% of samples. These findings are in line with Arcadis 2018a.

Arcadis 2018a noted that contaminants present within the Made Ground are also present within leachate samples.

Elevated concentrations of TPH (>1,000mg/kg) were identified in shallow Made Ground soils at S3_TPA_TP111 and S3_BHA03 at the eastern end of the building footprint. The analysis indicates this contamination is predominantly mid-heavy end hydrocarbons. This potentially represents a source area of hydrocarbon contamination, separate from the rail sidings source conceptualised in Arcadis 2018a.

Typically, concentrations of CoC within the Glaciolacustrine Deposits were lower than in the Made Ground.

Elevated concentrations of VOC, SVOC, PCBs or phenolics were not measured in any of the soil samples.

Surface Contamination

During the site investigation hydrocarbon staining (Plate 1 below) was noted on the ground at the former substation, a sample (PRA-BK-34-S1) was collected with the location displayed on Figure 2 in Appendix A. This contamination was characterised by elevated TPH. Concentrations of heavy metals and PAHs were typically lower than those found in the Made Ground. PCB concentrations were measured below the laboratory MDL and asbestos fibres were not detected within the sample.

Plate 1: Hydrocarbon staining on surface at location of a former substation on site.

Source Assessment

Including the sources conceptualised in Arcadis 2018a, four main sources of contamination are conceptualised for the site:

- Asbestos, metals, inorganic compounds and PAHs are present within the Made Ground, their wide-spread distribution indicates that Made Ground is a potential source for these contaminants;
- TPH contamination, based on contaminant distribution a point source at the eastern end of the building footprint is conceptualised; and,
- TPH contamination, based on the visual impacts observed and the contaminant distribution a point source at the former substation is conceptualised.
- TPH contamination associated with rail sidings, based on contaminant distribution outside the footprint of the building (Arcadis 2018a).

3.2.1 Groundwater

Samples were collected from three wells and screened across the following strata:

- 1no. well cross-screening Made Ground and Glaciolacustrine Deposits
- 2no. wells screening the Redcar Mudstone Formation

Metals and Inorganics

Metals and inorganics were identified within all monitoring wells within the same order of magnitude. The pH of groundwater was neutral, ranging between 7.2 and 8.4.

Organics

TPH, VOC, SVOC, phenolics were rarely detected above the laboratory method detection limit (MDL). Chloroform was identified marginally in exceedance of the MDL at all locations.

PAHs were identified in all locations marginally in excess of the MDL.

3.3 Ground Gas

Arcadis 2018b [*Redcar Steelworks-AUK-XX-XX-RP-GE-0001-01-SSI3_GI_ERA*] undertook a ground gas risk assessment based on the available data set. While elevated concentrations of ground gas were not identified the report notes limitations to the data set.

The main potential source of ground gases identified for the site is the Made Ground (degradation of organic material and hydrocarbon contamination). In line with guidance set out in BS8576:2013 '*Guidance on investigations for ground gas – Permanent gases and Volatile Organic Compounds (VOCs)*' and considering the outline CSM for sources of ground gas, the site is considered to be at a very low to low risk from ground gases. For low-risk sites, 2 months of monitoring may be required.

Five no. monitoring visits (over a two-month period) were undertaken for the newly install wells (S3_BHA03 & S3_BHA04) and three no. monitoring visits were undertaken for the historic well. This data is included in Appendix C.

3.3.1 Review of GI Ground Gas Monitoring Data

Organic Material in Soils

The ground investigation identified limited amounts of organic material to be present (predominantly wood inclusions within the Made Ground). Samples analysed for organic matter composed 0.5 to 4.7%. Typically, those samples reporting the greatest organic matter content also reported elevated TPH.

Ground Gas Data

Review of the gas monitoring rounds has been undertaken and the following were noted:

- Data from S3_BHA01 could not be collected;
- Depth to the base of the well or the steady flow rates were not obtained by AEG;
- In four (of 5no.) wells, resting groundwater was above the well screening (indicated in Appendix D).

Resting groundwater was identified above the well screening of the monitoring wells due to shallow perched groundwater within the Made Ground, as such the data will be used as part of the high-level review. However, conclusions should be reviewed (and additional data gathered) once any earthworks / dewatering operations have taken place and should also account for proposed building layouts.

3.4 Pathways

Arcadis 2018b [*Redcar Steelworks-AUK-XX-XX-RP-GE-0001-01-SSI3_GI_ERA*] reviewed contaminant data and refined the active pathways thought to be present at the site. Pathways considered to need further consideration given the expanded data set are discussed below in the context of the proposed commercial / industrial end use.

3.4.1 Airborne Migration Pathways

- Particulate inhalation due to dust generation is a potentially active pathway in areas not covered in hard standing;
- Vapour inhalation pathways in relation to contaminants in soil and groundwater are potentially active, both for an exposure scenario in outdoor or indoor air space;
- Migration and accumulation of permanent ground gases originating from the Made Ground on site in confined spaces leading to asphyxiation and/or explosion is considered potentially active.
- During potential re-development works, sub-surface soils could be exposed at the surface due to trenching and or re-profiling requirements and therefore dust has the potential to be generated. It is anticipated that the Construction Phase Environmental Management Plan will be developed by the relevant contractor to address this pathway. Therefore, this pathway is not considered further in this document.

3.4.2 Direct Contact Exposure Pathways

- The proposed site surfacing under any potential re-development scenario is unknown, should a significant portion of the site area be covered in some form soft landscaping direct contact pathways and ingestion in relation to soil would be considered active.
- Shallow groundwater has been identified within the Made Ground, this is conceptualised to be perched within the Made Ground and following earthworks it is anticipated that groundwater will not be present at a shallow depth. Therefore, considering the anticipated works, the pathway between shallow groundwater and future site users is not thought to be active.
- Direct contact pathways would be active throughout a potential redevelopment; typical mitigation measures such as personal protective equipment (PPE; overalls, gloves etc.) would be used to mitigate this risk. If significant levels of contamination (such as NAPL) are present additional PPE may be required as mitigation.

3.4.3 Aqueous Migration Pathways

- Groundwater identified within the Made Ground is thought to represent pockets of perched water, rather than a consistent groundwater body. As such vertical or lateral migration of the groundwater within the Made Ground is likely to be limited.
- Leaching of contaminants in the shallow soils to groundwater within the Superficial Deposits is considered potentially active.
- The low permeability superficial deposits (Glaciolacustrine Deposits and Glacial Till) which combined are anticipated to be at least 5m thick, and the conceptualised upward head of water are thought to limit potential for migration of contaminants into the underlying bedrock aquifer. However, potential for vertical contaminant migration cannot be ruled out.
- Given the granular nature and thickness of the identified Made Ground, lateral migration of off-site impacts onto the site from nearby PAOC is considered potentially active. The most likely sources would be the former Cleveland Steelworks and Mill to the north.
- Lateral migration through the Superficial Deposits off-site is likely limited by the groundwater being limited to granular lenses through the low permeability clay. These granular lenses are thought to be laterally and vertically discontinuous. However, contaminant migration within these strata cannot be discounted at this stage.
- The surface water courses near to site are culverted, limiting hydraulic connection between contaminants in the groundwater and surface water. As the quality of the culvert is not known this pathway is considered potentially active however, it is noted that any culverts are likely to be diverted/improved during development works.

- Migration of contaminants of concern in surface water runoff from the Made Ground is considered potentially active.

3.5 Receptors

The potential receptors to be considered for this site can be summarised as follows:

3.5.1 Human Health

For the purposes of this assessment it is assumed that the proposed development will comprise a commercial or industrial end use, and as such commercial and industrial workers are the primary receptor of concern for any contamination risk. The risk would be influenced by the duration and location of the staff work regimes.

During any re-development works, workers may be exposed to contamination risk. This risk will need to be assessed and controlled for during the re-development works. This report does not consider risk to construction workers.

Particulate inhalation of dust has been identified as a potentially active pathway, users of the adjacent buildings could also be at risk. The nearest neighbouring residents are situated over 200m from the site, for exposure to occur an active cross-boundary migration pathway is required. The pathway is thought to be potentially active during the construction phase, however it is expected that dust will be managed under the Construction Phase Environmental Management Plan.

3.5.2 Property (buildings, etc)

The proposed development will include new structures and associated infrastructure, which could be subject to potential sulphate attack in relation to buried concrete and contaminant attack (hydrocarbons, solvents, PAHs etc.) on buried water pipes. Given the presence of slag deposits within the Made Ground the potential for expansive slag to impact structures is considered active.

Ground gas risk from Made Ground is considered potentially active.

3.5.3 Controlled Water

Groundwater is a Controlled Water; therefore, the groundwater beneath the site requires consideration and protection. At this site, the Redcar Mudstone Formation is classified as a Secondary (undifferentiated) Aquifer and is considered as a groundwater receptor. The Glacial Till and Glaciolacustrine Deposits which underly the Made Ground and overlie the bedrock are not classed as aquifers by the Environment Agency, and as such are not considered as a significant receptor.

Surface water courses are also considered Controlled Water receptors with Knitting Wife Beck or Holme Beck (which discharge into the River Tees ~2000m north of the site) being considered the primary receptor for contaminants from site.

3.5.4 Ecological

The Teesmouth and Cleveland Coast SSSI which includes a section of the River Tees is located approximately 2km north of the Site. The Teesmouth and Cleveland Coast is also designated as an SPA and RAMSAR.

Based on the distance from the site the risk to ecological receptors is considered low. In addition, potential discharges from the site to the Teesmouth and Cleveland Coast SPA and RAMSAR via the River Tees are likely to be limited by tidal exchange and the large volume of the River Tees receiving water. This is in line with the findings of Wood 2019 [*41825-wood-XX-XX-RP-OC-0001_S0_P01*].

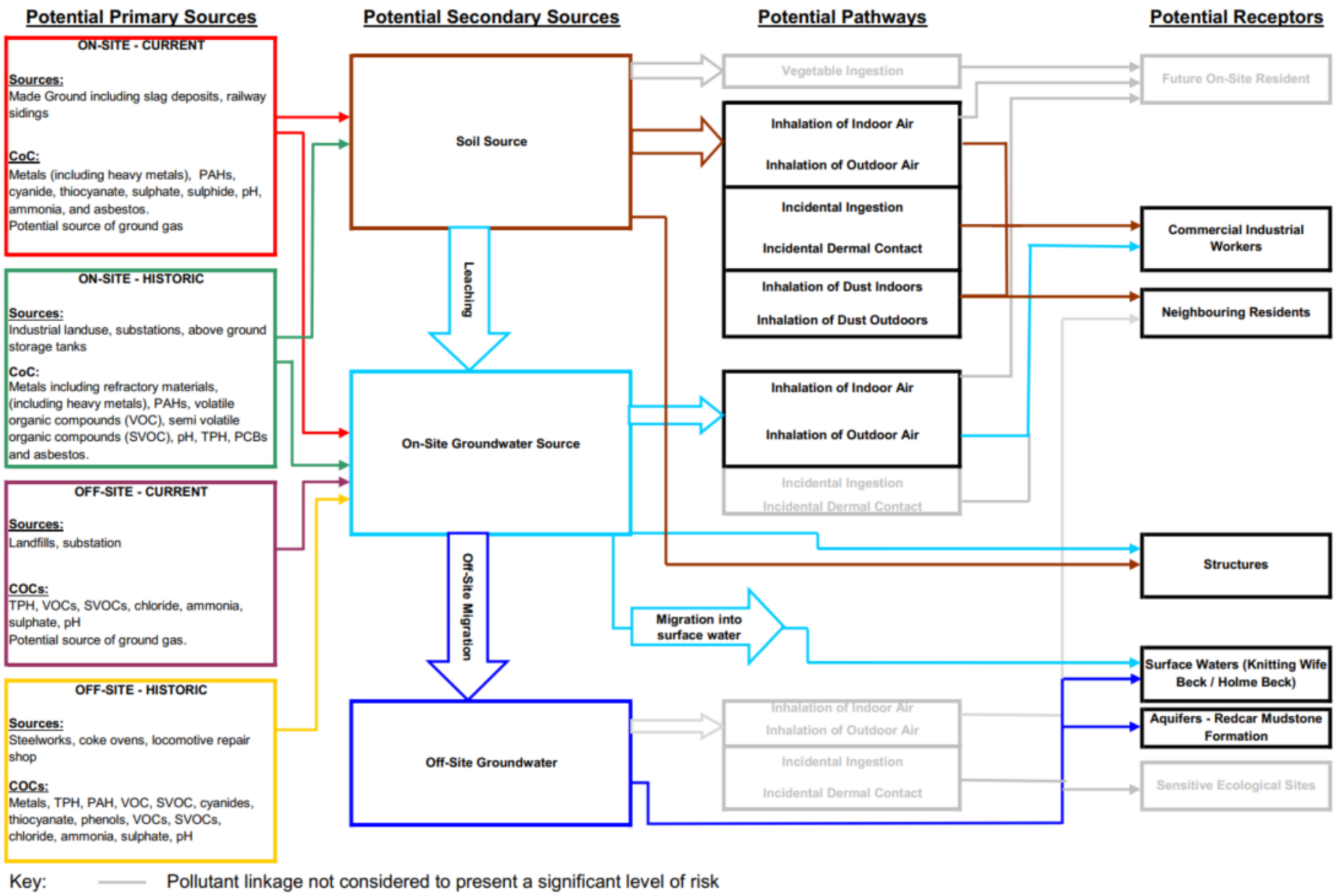
3.6 Obstructions

Obstructions (predominantly concrete) have been noted within the Made Ground across the Prairie Phase 4 plot. There is the possibility of further obstructions in areas not investigated.

3.7 Conceptual Site Model

The above data has been used to produce an initial CSM for the site, this is presented below and in Appendix A as Figure 3.

Figure 3
Outline Conceptual Site Model - Commercial Industrial End Use



4 Generic Quantitative Risk Assessment

4.1 Tiered Approach

The purpose of this assessment is to quantify potential risks to the identified human health, controlled waters, and built receptors identified in the CSM in relation to the redevelopment of the site for a continued commercial/industrial use.

The following scenarios are not considered in this section:

- Risks to Construction Workers – any redevelopment and construction work should be conducted in full recognition of HS(G)66 (no longer current but has not been updated and is cited in The Building Regulations, 2010) and with reference to CIRIA Report 132 *A Guide for Safe Working on Contaminated sites (CIRIA 1996)*. This will be considered within the contractor risk assessments and pre-works planning.
- Nuisance health effects – the Statutory Nuisance Act considered olfactory impacts from odours and allows comparison of enclosed space air concentrations with odour threshold concentrations.

Assessment of risks associated with contamination measured in soil, groundwater and soil gas have been considered in accordance with the framework presented in Land Contamination: Risk Management (LC:RM) (EA, 2020). This sets out a tiered approach to risk assessment comprising:

- Generic Quantitative Risk Assessment (GQRA) - Comparison of site contaminant levels against generic standards and compliance criteria including an assessment of risk using a source-pathway-receptor model.
- Detailed Quantitative Risk Assessment (DQRA) - Derivation of site-specific risk assessment criteria and calculation of site-specific clean-up goals.

In this section, a GQRA has been carried out. The potential identified pollutant linkages identified in the preliminary CSM for human health and controlled water receptors have been assessed by comparison against relevant generic assessment criteria (GAC). These have been derived using conservative assumptions to enable potential pollutant pathways that do not pose unacceptable risks to be identified and discounted. Exceedance of a GAC does not imply that an unacceptable risk is necessarily present, rather that further assessment may be required to verify the potential risk.

It is assumed that the site will be redeveloped as a typical commercial industrial development including, hardstanding and some areas of soft landscaping. The site has not been zoned at this stage and all data has been considered on an individual sample basis.

4.2 Human Health Risks

4.2.1 Selection of Soil GAC

Potentially active pollutant linkages and contaminants of concern (CoC) in relation to human health risks have been identified in the initial CSM as:

A. Vapour inhalation of indoor and outdoor air from volatile contaminants in soils, (potential CoC include volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs))
B. Vapour inhalation of indoor and outdoor air from volatile contaminants in shallow groundwater, (potential CoC include VOCs and SVOCs)
C. Dermal contact/ingestion of soil (potential CoC include heavy metals, organic/inorganic compounds)

D. Dust inhalation (potential CoC include asbestos, volatiles, and heavy metals)

For the purposes of this assessment, it is assumed that future re-development will comprise a commercial or industrial end use, thus commercial and industrial workers are the primary receptor of concern for any contamination risk. The risk would be influenced by the duration and location of the staff work regimes. For the basis of this assessment, it is assumed that site workers will be on-site for a “standard” 8-hour working day. This is considered suitable protective of neighbouring residents given the end use of the site is likely to be covered with hardstanding or landscaping.

Commercial end use assumes a pre-1970s commercial property is present at the site with some open areas uncovered by hardstanding and is therefore regarded as conservative for a redevelopment scenario as new structures are assumed to be constructed to current standards.

To assess potential linkages A, C and D above, GAC have been chosen, based on an assumed industrial/commercial end use. Criteria published by authoritative industry bodies and commonly accepted by regulators for use under the planning regime for development sites have been used first. For contaminants for which no published values are available, Arcadis derived criteria (developed following the CLEA framework (v1.07)) or foreign national criteria have been used.

The GAC comprise (in order of priority):

- LQM/CIEH Suitable for Use Levels (S4UL) (LQM / CIEH, 2015),
- Department of Environment Food and Rural Affairs (DEFRA) Category 4 Screening Levels (C4SL) (DEFRA, 2012),
- Wood GAC for naphthalene and benzo(a)pyrene [Wood 2019],
- Arcadis site specific assessment criteria for free cyanide derived in 10035117-AUK-XX-XX-RP-ZZ-0088-01-Prairie_Risk Assessment,
- Arcadis derived generic assessment criteria based on CLEA v1.07,
- United States Environmental Protection Agency (U.S. EPA) Regional Screening Levels (RSLs) (USEPA, 2018)

Soil organic matter (SOM) recorded in 20 soil samples obtained from site ranged from 0.5 to 4.7% SOM, however some elevated SOM values are considered to be influenced by contamination within the sample. As such, the S4UL selected as the GAC are those for a commercial end use assuming 1% SOM.

The selected human health GAC for soil are presented in Appendix E.

4.2.2 Soil Quality Screening

Contaminant concentrations in soil samples have been compared to the GAC presented in Appendix E. Contaminants which measured in excess of the GAC are summarised below. Contaminants that have not been identified in excess of their respective GAC are not considered to represent a significant risk to identified human health receptors and as such do not require further assessment in relation to the redevelopment of the site unless the above assumptions are not valid.

The following samples were analysed:

- 14no. samples of granular made ground (GMG);
- 7no. samples of glaciolacustrine deposits (GD);
- 1no. sample of visually impacted surface material (SS) – a localised area associated with the old substation.

Table 4: Exceedances of Human Health GAC

Contaminant	Unit	No. Samples Exceeding	GAC Exceeded		Sample (Geology)	Concentration (mg/kg)
TPH (Aromatic C16-C21)	mg/kg	1 / 22	S4UL	28,000	PRA-BK-34-S1 (SS)	29,000
TPH (Aromatic C21-C35)	mg/kg	1 / 22	S4UL	32,000	PRA-BK-34-S1 (SS)	32,000

Contaminants for which no screening criteria were available have been reviewed. Most contaminants with no screening criteria were recorded below the MDL in soil samples.

Contaminants measured in soil at concentrations above MDL, for which no screening criteria were available were: aluminium, iron, magnesium, manganese, cyanide total, ammoniacal nitrogen, sulphate, sulphur, p-cresol, 2,6-dichlorophenol, p-isopropyltoluene, and carbazole. Potential human health risks from these are qualitatively assessed in Section 4.2.4.

4.2.3 Asbestos in Soil

A total of 21 soil samples were screened by polarised light microscopy in accordance with HSG248 for the presence of asbestos (HSE, 2005). In 2 no. samples asbestos was detected as chrysotile fibres.

Quantification of the asbestos was carried out on the 2no. samples by gravimetric methods, the samples recorded asbestos mass between 0.022% to 0.032%.

The presence of quantifiable levels of asbestos in soil warrants further consideration. Asbestos in shallow soils in areas without buildings or hardstanding has the potential to become airborne and available for inhalation, particularly during construction, posing chronic risks to human health.

4.2.4 Qualitative Risk Assessment for Substances in Soil without GACs

As discussed in Section 4.2.2 above and presented in Appendix E several contaminants without screening criteria were measured in soil at concentrations above MDL.

These contaminants are: aluminium, iron, magnesium, manganese, cyanide total, ammoniacal nitrogen, sulphate, sulphur, p-cresol, 2,6-dichlorophenol, p-isopropyltoluene, and carbazole.

Of these aluminium, iron, magnesium, manganese, sulphate and sulphur are present naturally in soil and some are biologically required nutrients. They may be elevated above natural levels where slag and other steelmaking wastes are incorporated into soil due to the site's former use, particularly manganese and iron. However, regardless of these elevations, their typically low toxicity is likely to mean these occurrences present a low risk of adverse harm following development, particularly if the ground is covered by buildings, hardstanding or permanent landscaping.

It is considered appropriate to assess cyanide using the Arcadis free cyanide concentrations rather than total cyanide concentrations as free cyanide is considered a higher toxicity compound. Although total cyanide was measured above the MDL, the levels of free cyanide in these samples were well below the GAC and therefore the risks from the concentrations are not considered significant.

Ammoniacal nitrogen is present in low concentrations in all samples assessed. Due to the low concentrations and given that ammoniacal nitrogen is typically considered more of a risk for controlled waters (and will be discussed in section 4.3) the risk to human health is considered low.

P-cresol, 2,6-dichlorophenol, p-isopropyltoluene, and carbazole were all infrequently identified at concentrations marginally in excess of the MDL, as such the risk to human health from these compounds is thought to be low.

It is noted that substances analysed as part of this investigation without GACs are typically considered to be those with low known toxicity, or incomplete toxicity information. In the absence of suitable toxicity information, the applicable regulators have not defined screening values. As such, further action with regards to these substances is unlikely to be mandated by the local authority.

4.2.5 Selection of Groundwater GAC

To assess the potential risk to human health via pollutant linkage B above (inhalation of volatile contaminants in groundwater), inhalation GAC have been derived by Arcadis for volatile contaminants in groundwater.

These have been derived by Arcadis using the CLEA process and industry standard vapour transport modelling (Johnson & Ettinger model). The same assumptions relating to a commercial end use of the site have been included in the model and an on-site commercial worker has been considered as the receptor.

The inhalation GAC are listed in Appendix F.

4.2.6 Human Health Risk Assessment for Contaminants in Groundwater

Concentrations of volatile contaminants in 3no. groundwater samples were screened against the inhalation GAC described above (where GAC have been derived).

The vapour inhalation GAC are designed to determine whether there is a significant risk of harm to human health from inhaling volatile contaminants emanating from groundwater beneath the site (potential pollutant linkage B in the preliminary CSM).

None of the concentrations of volatile contaminants measured in groundwater were in excess of the inhalation GAC for on-site commercial workers or off-site neighbouring residents. As such, the risk to human health from measured concentrations of CoC in groundwater is not considered to be significant.

Volatile contaminants for which no GAC are readily available were not identified in the 3no. groundwater samples analysed.

4.2.7 Discussion on Potential Risks to Human Health

Of the 22no. samples taken, 1no soil sample showed exceedance of the GAC protective of human health for heavy and mid-range hydrocarbons via pollutant linkages A and C. This sample was collected from visible hydrocarbon contamination present at the surface. This contamination is thought to represent a minor spillage associated with the demolition of the former substation, it is recommended that the contamination is removed.

Asbestos fibres were identified in 2no. soil samples. Asbestos is potentially hazardous when inhaled therefore pollutant linkage D (inhalation of dust) is considered potentially active as surface soils may become airborne during construction or if incorporated into soft landscaping without any cover.

Acute risks to construction workers arising from short-term contact with contaminated soils during demolition and redevelopment of the site are not assessed by the chronic risk assessment methods in this report. During construction works, site workers should remain vigilant to the possible risk of encountering isolated areas of contaminated material. Should potentially contaminated material be encountered, further testing may be required to assess the risk to health and safety of the site workers and the environment. All persons engaged in site construction works should be made aware of the findings of the intrusive investigation and the hazards associated with handling potentially contaminated materials. It is recommended that all works are conducted in accordance with the Health and Safety Executive publication entitled “Protection of Workers and the General Public during the Development of Contaminated Land” (HSE, 1991).

Inhalation risk of contaminants present within groundwater has been assessed against GAC protective of commercial workers, no contaminants have been identified to present a risk to human health based on a future commercial use of the site.

4.3 Risks to Controlled Waters and Ecological Receptors

4.3.1 Selection of GAC

Potentially active pollutant linkages in relation to Controlled Waters and ecological receptors have been identified in the initial CSM as:

1. Leaching of CoC from Made Ground to groundwater in Superficial Deposits
2. Vertical migration of CoC to the bedrock aquifer
3. Migration of CoC in groundwater into surface water features
4. Migration of CoC in groundwater onto site from off-site sources (adjacent STDC land parcels)
5. Migration of CoC in groundwater off site.

The Water Quality Standards (WQS) used are UK Drinking Water Standards (DWS) protective of aquifer resources, and Environmental Quality Standards (EQS) are considered protective of surface waterbody quality. The EQS adopted are for fresh water, protective of the surface waters that have been identified near to the site.

The Superficial Deposits underlying site are classified as Unproductive Strata meaning that screening against DWS is regarded as a very conservative approach but will provide context for the assessment. The WQS are listed in Appendix F.

4.3.2 Groundwater

3no. groundwater samples were obtained from monitoring wells and analysed for a range of contaminants. The monitoring wells installed in the boreholes screen subsurface geology as shown in the table below:

Table 5: Summary of monitoring wells and screened aquifer for groundwater samples collected

Borehole	Aquifer
S3_BHA03D	Redcar Mudstone Formation
S3_BHA04S	Made Ground / Glaciolacustrine Deposits
S3_BHA04D	Redcar Mudstone Formation

Contaminant concentrations in groundwater were compared to the WQS in Appendix F and exceedances are summarised in the table below. Concentrations of heavy metals, ammoniacal nitrogen, chloride, sulphate, and select PAHs were measured in excess of WQS, these contaminants will be assessed further.

Table 6: Summary of contaminants of concern measured above the WQS within samples of groundwater

Contaminant	Unit	No. Samples Exceeding	WQS Exceeded		Sample (aquifer)	Concentration
Boron	µg/l	1 / 3	DWS	1,000	S3_BHA03D (RMF)	1,400
Copper	µg/l	2 / 3	EQS	1	S3_BHA03D (RMF)	1.7

Contaminant	Unit	No. Samples Exceeding	WQS Exceeded		Sample (aquifer)	Concentration
					S3_BHA04D (RMF)	2.3
Iron	µg/l	1 / 3	DWS	200	S3_BHA03D (RMF)	240
Lead	µg/l	1 / 3	EWS	1.2	S3_BHA03D (RMF)	5
Manganese	µg/l	3 / 3	EQS DWS	123 50	S3_BHA03D (RMF) S3_BHA04S (MG/GL) S3_BHA04D (RMF)	550 580 130
Mercury	µg/l	3 / 3	EQS	0.07	S3_BHA03D (RMF) S3_BHA04S (MG/GL) S3_BHA04D (RMF)	0.07 0.08 0.1
Nickel	µg/l	1 / 3	EQS	4	S3_BHA04S (MG/GL)	5.1
Zinc	µg/l	1 / 3	EQS	10.9	S3_BHA03D (RMF)	14
Ammoniacal Nitrogen	µg/l	3 / 3	EQS	0.6	S3_BHA03D (RMF) S3_BHA04S (MG/GL) S3_BHA04D (RMF)	0.80 0.85 0.74
Chloride	µg/l	1 / 3	EQS DWS	250 250	S3_BHA03D (RMF)	260
Sulphate (as SO_4)	µg/l	3 / 3	EQS DWS	400 250	S3_BHA03D (RMF) S3_BHA04S (MG/GL) S3_BHA04D (RMF)	1,200 410 480
Fluoranthene	µg/l	3 / 3	EQS	0.0063	S3_BHA03D (RMF) S3_BHA04S (MG/GL) S3_BHA04D (RMF)	0.02 0.03 0.04
Benzo(b)fluoranthene	µg/l	3 / 3	EQS	0.0000425	S3_BHA03D (RMF) S3_BHA04S (MG/GL) S3_BHA04D (RMF)	0.01 0.02 0.02
Benzo(g,h,i)perylene	µg/l	1 / 3	EQS	0.0000425	S3_BHA04D (RMF)	0.01

4.3.3 Qualitative Risk Assessment for Substances in Groundwater without WQS

As shown in Appendix F several contaminants (including some metals, PAHs, and VOCs) do not have a readily available WQS for comparison. Where concentrations have been measured below MDL in the groundwater samples, these contaminants are not considered to represent a risk to water resources.

The following compounds did not have a readily available WQS and were recorded at concentrations in excess of their MDL: magnesium, thiocyanate, silicate, and selected PAHs.

Magnesium and silicate are present naturally in groundwater and, considering the relatively low concentrations, are not considered to pose a significant risk to water resources and will not be assessed further.

No statutory UK EQS for thiocyanate exists, the absence of an EQS may indicate that a substance is less well characterised or of lower environmental concern. There is, however, a Predicted No Effects Concentration (PNEC) for thiocyanate in freshwater (95µg/l). No concentrations of thiocyanate identified in groundwater samples exceed the PNEC. This is considered to be sufficiently protective of water resources.

Given a number of PAHs do not have readily available WQS, assessment of the risk to water resources will be made using PAHs in groundwater that have available WQS. This is considered to be sufficiently protective of water resources.

4.3.4 Discussion

Arcadis 2018b [*Redcar Steelworks-AUK-XX-XX-RP-GE-0001-01-SSI3_GI_ERA*] assessed 10no. leachate samples against appropriate WQS, various heavy metals, ammoniacal nitrogen and various PAHs were identified in leachate effluent indicating that CoC present within the Made Ground on site could leach into underlying groundwater (pollutant linkage 1).

This leaching may be limited into groundwater within the bedrock given the thickness of the low permeability Superficial Deposits (anticipated to be at least 5.0m thick) and conceptualised upward head of pressure which will act to limit movement of contaminants into the bedrock aquifer. However, based on contaminant concentrations within groundwater samples from the bedrock, it is possible that contamination is leaching from overlying materials and pollutant linkage 2 is considered to be active.

Contaminants of concern have been identified in excess of the WQS within groundwater, including heavy metals, ammoniacal nitrogen, chloride, sulphate and selected PAHs. This section will discuss these exceedances in the context of the site.

Bioavailability (copper, lead, manganese, nickel, zinc)

The WQS for copper, lead, manganese, nickel, and zinc is based on the bioavailable fraction of the element. This can be assessed using the Metal Bioavailability Assessment Tool (M-BAT) recognised by the UK Water Framework Directive and allows for scientific assessment of the bioavailable fraction of select metals, thus supporting accurate risk assessment.

The M-BAT tool requires the pH, dissolved oxygen concentration and calcium concentration of the receiving waterbody to be assessed. For the Prairie Phase 4 site, the primary receptor is the culverted Knitting Wife Beck, this watercourse is culverted until it is exposed to the surface as the Cleveland Channel. 3no. surface water samples have been collected (reported as SLEMS-SW01 in Arcadis 2022 [*10035117-AUK-XX-XX-RP-ZZ-0139-01-SLEMS_ESA*]) from the Cleveland Channel at the point it is exposed to the surface and the averaged reported values for pH (7.83), DOC (5.53%), and Calcium (133.3mg/l) have been used in a high-level assessment of the likely bioavailability of copper, lead, manganese, nickel and zinc within the M-BAT tool.

Table 7: Summary of Metal Bioavailability Assessment Tool outputs.

Contaminant	Site Specific PNEC calculated by M-BAT (µg/l)	Exceedances
Copper	20.71	No exceedances. Risk to surface water receptor is considered to be low.
Zinc	30.39	No exceedances. Risk to surface water receptor is considered to be low.

Contaminant	Site Specific PNEC calculated by M-BAT (µg/l)	Exceedances
Manganese	303.15	Bioavailable fraction of manganese in S3_BHA03D (550µg/l) and S3_BHA04S (580µg/l) exceeds the statutory EQS and DWS. Bioavailable concentrations do exceed the PNEC calculated by M-BAT. There is a potential risk to surface waters.
Nickel	13.16	No exceedances. Risk to surface water receptor is considered to be low.
Lead	6.64	No exceedances. Risk to surface water receptor is considered to be low.

Exceedance of DWS (iron, boron, sulphate, manganese, chloride)

The DWS are protective of water quality at the consumers tap (not accounting for attenuation or dilution along the pathway) and are therefore considered to be conservative assessment of the risk within the groundwater body.

Groundwater within the Made Ground is considered to be perched water. The Glaciolacustrine Deposits are classified as Unproductive Strata. The Redcar Mudstone Formation is a Secondary Undifferentiated Aquifer. Thus yield from each of these groundwater bodies is likely to be low. Therefore, considering the likely yield and the industrial site setting it is unlikely that these resources would be used for abstraction now or in the future.

Based on this conceptualisation, the risk posed from the exceedances of DWS for iron, boron, sulphate, and manganese and chloride is considered to be low.

Exceedance of EQS (manganese, mercury, chloride, ammoniacal nitrogen, sulphate, selected PAHs)

The EQS is protective of the freshwater surface water bodies near to site. Holme Beck and Knitting Wife Beck are culverted and thus interaction between surface water and groundwater will be limited and dependent on the condition of the culvert. A potential pathway for groundwater to impact the surface water feature does exist but is likely to be minor.

Bedrock has been identified at a minimum of 7m below the surface level of site it is thought that groundwater within the bedrock will not interact with surface water, as such exceedances of the EQS within the bedrock aquifer are not considered to pose a significant risk to the surface water features.

Manganese, mercury, ammoniacal nitrogen, sulphate and select PAHs exceed the EQS within the well screening Made Ground / Glaciolacustrine Deposits. The concentrations of these contaminants are marginally in excess of the EQS (either same order of magnitude to the EQS or laboratory MDL) and there is likely to be some attenuation and dilution along the pathway. The receptors are also culverted watercourses underneath an industrial area so are thought to be of low ecological value. Given this reasoning the exceedances of the EQS are not thought to pose a significant risk to the identified surface water receptors.

Summary

While potential pathways exist, concentrations of CoC measured within the groundwater beneath the site are not thought to pose a significant risk to the identified Controlled Water receptors (bedrock and surface water). As such, no further work is recommended.

However, should unexpected contamination be identified during redevelopment (e.g. NAPL) this conclusion will need to be revisited.

4.4 Built Receptors

Significant contamination can pose a risk to subsurface structures and services, where these are in direct contact with soil and/or groundwater. Substances such as dissolved metals, cations, phenols and hydrocarbons in high concentrations can adversely affect in-ground materials such as concrete, metal and plastics.

The most sensitive built receptor is generally plastic water supply pipes, which can be affected by permeation of hydrocarbons and organic solvents into the pipe. The available chemical data for soil samples has been reviewed against the UK Water Industry Research (UKWIR) criteria to provide an indication of the potential acceptability of polyethylene (PE) pipes in brownfield land (Water UK, 2014), although an exact comparison is not possible due to differences in the determinand suites tested.

Concentrations of mid and heavy end petroleum hydrocarbons in 2no. of the soil samples (not including PRA-BK-34-S1 as this is representative of surface contamination) may be above the criteria for unprotected PE water pipes. This is in line with the findings presented within Arcadis 2018b [*Redcar Steelworks-AUK-XX-XX-RP-GE-0001-01-SSI3_GI_ERA*].

Therefore, additional testing should be carried along the route of any proposed new water supply pipe, or barrier pipe or similar could be used.

Elevated concentrations of sulphate within groundwater have been identified within groundwater samples (from both the 2017 and 2021 ground investigations). Therefore, an assessment of the total potential oxidisable sulphate has been undertaken as outlined within BRE Special Digest 1.

The results of the assessment considering the pH and mobility of groundwater are presented within the table below:

Table 8: Summary of ACEC classifications

Geological Unit	Design Sulphate Class (DS)	Aggressive Chemical Environment for Concrete (ACEC) classification
Superficial Deposits	DS-2	AC-2
Redcar Mudstone Formation	DS-3	AC-3

Given the reported ACEC class appropriate mitigation measures in line with BRE SD1 should be incorporated at the detailed design stage.

5 Ground Gas Assessment

The potential sources for ground gas identified on the site are the degradation organic inclusions (i.e. wood) and hydrocarbon contamination within the Made Ground. These are likely to generate methane and carbon dioxide, which present an explosion and asphyxiation risk.

The current guidelines for assessing permanent ground gas are set out in BS8485:2015+A1:2019 '*Code of practice for the design of protective measures for methane and carbon dioxide ground gases for new buildings*'. The code of practice uses the concept of a borehole hazardous gas flow rate (Q_{hg}) which is calculated from individual borehole measurements of total gas flow emission and the concentration of the specific hazardous gas. A Gas Screening Value (GSV) is then determined for the site or zone which is derived from assessment of the borehole concentrations and flow rate measurements which take into account influencing factors (such as atmospheric pressure and weather conditions) and the conceptual site model. This then allows a characteristic gas situation (CS) to be determined which is defined as the ground gas regime assumed for design of gas protective measures from the refined model after an adequate site investigation.

Given the minimal flow rates recorded, and the recorded volumes of ground gas reported, it is unlikely that bulk ground gases are being generated in significant volumes.

The maximum recorded Q_{hg} for the data obtained to date for both methane and carbon dioxide is <0.01 l/hr. As a check against a "worst case" scenario, the highest flow rate / concentrations from across site still produce a Q_{hg} of <0.01 l/hr. As shown on the summary tables provided in Appendix D.

A review of the site history, ground conditions and recent AEG monitoring data indicate that the site can be classified as a whole and that the GSV can use the maximum recorded Q_{hg} (<0.01 l/hr).

A high-level assessment has indicated that significant bulk gas concentrations or volumes are unlikely to be present within the site, as such, the overall risks of bulk ground gas to a given commercial development are considered to be low. The data indicates that the site is likely to be categorised as CS1.

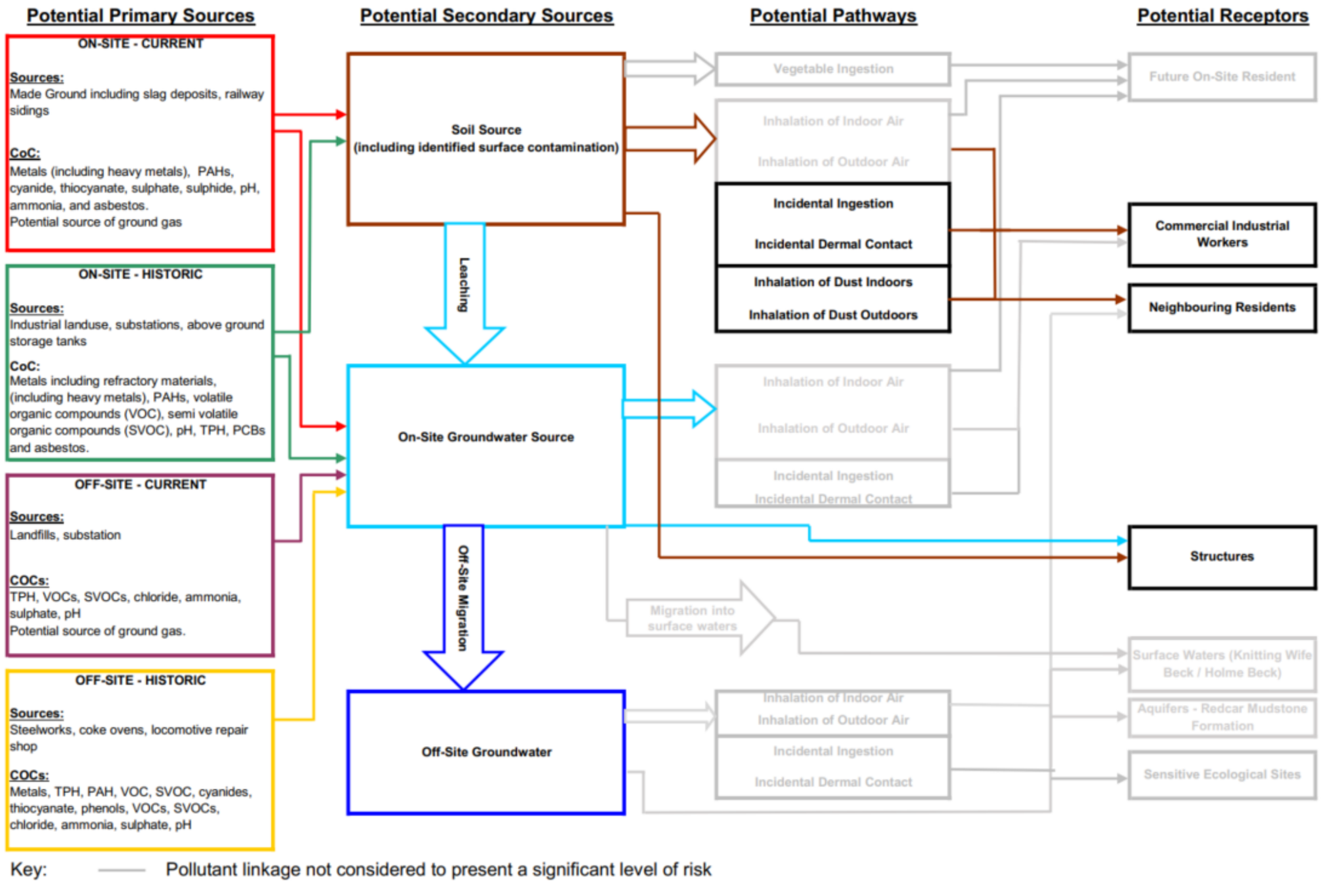
However, it is noted that the majority of the data is collected from wells where groundwater is resting above the screened section (due to shallow perched groundwater within the Made Ground) and thus reduces the validity of the data gathered.

Thus, following earthworks and for each development scenario, a site-specific ground gas assessment will need to be undertaken to confirm the characteristic gas situation (CS) and further site-specific data should be gathered.

6 Refined Conceptual Site Model

An updated CSM has been developed using the findings of the above assessment and is presented below and in Appendix A as Figure 4. Pollutant linkages that have been shown to be inactive or not a significant risk have been removed.

Figure 4
Refined Conceptual Site Model - Commercial Industrial End Use



7 Geotechnical Constraints

Arcadis 2018c [*Redcar Steelworks-AUK-XX-XX-RP-GE-0001-P1-SSI3_GI_GRA*] reviewed the following geotechnical risk drivers:

- Inadequate bearing capacity of Made Ground to support proposed structures;
- Variations in depth/thickness of Made Ground
- Anticipated total and differential settlement/heave in excess of the tolerable limits;
- Potential collapse compression as a result of surface water infiltration and groundwater movement;
- Potential heave as a result of chemical changes causing expansion of the ferrous slag;
- Sulphate attack of concrete (from Made ground and Bedrock); and,
- Obstructions within the Made Ground (boulder size fragments of slag and buried underground structures) and natural ground (boulders in glacial till).

Following a review of the data generated from this supplementary ground investigation, the assumptions and conclusions of Arcadis 2018c are thought to remain valid and the reader is directed to that report for a detailed discussion on the outlined geotechnical risks.

8 Conclusions

Previous investigations at the site were unable to fully characterise the site due to the presence of structures resulting in a notable data gap. This report has used information from the AEG 2021 ground investigation to address the data gap (i.e. the building footprint) identified within Arcadis 2018a / Arcadis 2018b / Arcadis 2018c.

This report reviewed the potential contamination risk to human health and Controlled Waters posed by the material underlying the former building footprint and considered if conclusions around geotechnical risk presented within Arcadis 2018c remained valid.

8.1 Human Health Risk

Samples taken from subsurface soils were screened against GAC protective of a future commercial / industrial end use (considered protective of off-site residents). All contaminants tested within subsurface soils were recorded below the relevant GAC, indicating that the risk posed to human health from subsurface soils via ingestion, direct contact or vapour inhalation is low. Review of contaminants in groundwater compared to the relevant inhalation GAC indicated that the risk posed to human health from volatile contamination within groundwater is low.

One surface sample, collected from visible hydrocarbon staining near to a former substation, reported concentrations of hydrocarbons in excess of the GAC protective of human health. This is thought to represent an isolated hotspot and material should be removed.

Asbestos fibres were identified within the shallow Made Ground, therefore a potential dust inhalation pathway is considered active. It may be that a clean cover system in areas of soft landscaping can be utilised to mitigate the risk to site occupiers and neighbouring land users. During redevelopment, good construction practice such as minimising handling of asbestos-contaminated soils, damping down and appropriate Personal Protective Equipment (PPE) may be sufficient to mitigate the risk to construction workers. An appropriate occupational risk assessment would be required to determine this.

Although soil containing more than 0.1% m/m asbestos has not been identified on site, if such materials were to be identified and disposed of off-site, they may be classified as hazardous waste and attract significantly higher disposal costs. Additional testing would be required to confirm the quantity of asbestos and delineate any areas above the threshold.

8.2 Controlled Waters

The aquifers underlying the site are considered to have low resource value (given the site setting, and low probability they will be abstracted). The surface water features near to site have been culverted, however since the condition of these culverts is not known a potential pathway could exist. As such, Knitting Wife Beck and Holme Beck were considered the principal surface water receptors for the site.

Contaminants of concern have been measured in excess of the WQS, however risk to Knitting Wife Beck and Holme Beck is thought to be low. This based on bioavailability (for select CoC), low contaminant concentrations, conceptualised attenuation, and dilution along the pathway, and the likely limited interaction between the waterbodies.

No further work is thought to be required with respect to Controlled Waters risk based on the findings of this investigation and historic investigation works.

Should unexpected contamination (e.g. NAPL) be identified these conclusions will need to be revisited.

8.3 Built Structures

Elevated concentrations of hydrocarbon compounds in excess of UK WIR have been identified within soil, this risk should be addressed at the design stage.

Elevated concentrations of sulphate have been identified within the groundwater on site and, given the reported ACEC class (AC-2 for Superficial Deposits, AC-3 for bedrock), appropriate mitigation measures in line with BRE SD1 should be incorporated at the detailed design stage.

8.4 Ground Gas

The overall risks of permanent bulk ground gas to a given commercial development are considered to be low within the site. The data indicates that the site is likely to be categorised as CS1. However, for each development scenario, a site-specific ground gas assessment will need to be undertaken to confirm this.

8.5 Geotechnical Constraints

Data gathered during this ground investigation helped to close a data gap on site related to the former building. Review of the data indicates that the conclusions of Arcadis 2018c [*Redcar Steelworks-AUK-XX-XX-RP-GE-0001-P1-SSI3_GI_GRA*] remain valid and the reader is directed to that report to understand relevant geotechnical constraints present on site.

8.6 Recommendations

1. A Remediation Options Appraisal for the site has been reviewed incorporating the above data (Arcadis 2021 [*Redcar Steelworks-AUK-XX-XX-RP-GE-0001-02-SSI3_GI_ROA*]) and concluded that remedial capping would be the best risk management solution.
2. Depending on the redevelopment scenario further ground investigation including ground gas monitoring of shallow soils should be carried out prior to redevelopment to quantify ground gas risk on the site in the context of the proposed layout and design.
3. If new foundations penetrating the Glacial Till are proposed, a foundation works risk assessment should be carried out to enable appropriate mitigation measures to be designed that will prevent contaminant migration *via* a preferential pathway down into the underlying bedrock aquifers.
4. Barrier pipe should be considered for any proposed new water supply pipes laid in Made Ground, or additional data collection completed to verify if soil can be managed sufficiently to avoid the need for such pipe materials.

9 References

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Appendix A

Figures

Legend

Redline

- Wider Prairie Redevelopment Area
- Prairie Phase 4 (previously SSI3A)

0 10 20 30 40 50 60 70 80 90 100 m

N

Notes:

CONTACT ARCADIS IN CASE OF ANY QUERIES.

Title: Prairie Phase 4 - Site Location Plan

Site:
Teesworks - Prairie Phase 4

Client:
South Tees Development Corporation

Project:
10035117

Figure 1

Date: 14/02/2022
Drawn By: DW
DRG No: 10035117-AUK-XX-XX-DR-ZZ-0478-01-P4_Site_Loc

ARCADIS Design & Consultancy for natural and built assets