ARCADIS Design & Consultancy for natural and built assets

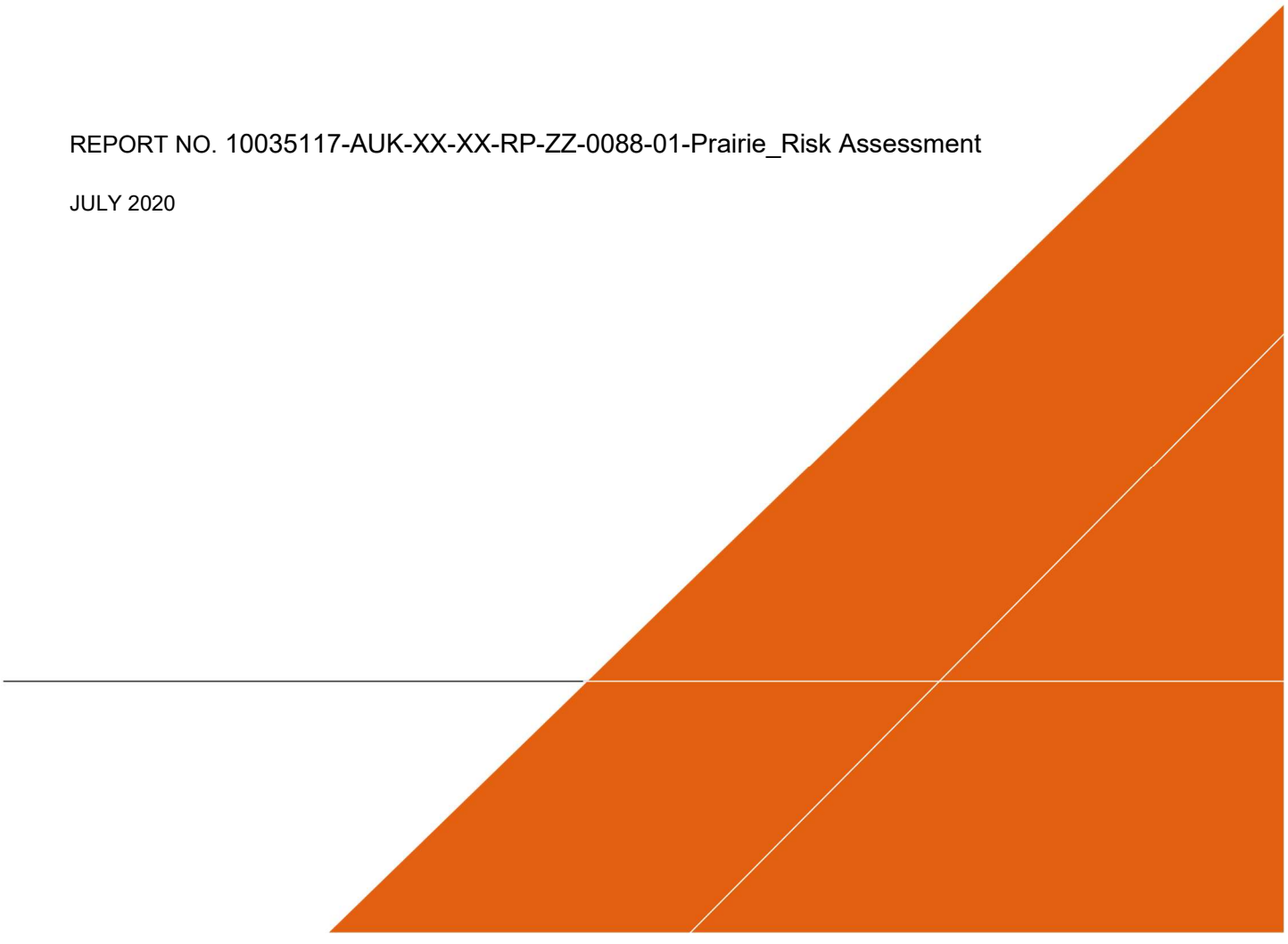
# GRANGETOWN PRAIRIE AREA, FORMER STEELWORKS, REDCAR

## Detailed Conceptual Site Model Review and Risk Assessment

South Tees Development Corporation

REPORT NO. 10035117-AUK-XX-XX-RP-ZZ-0088-01-Prairie_Risk Assessment

JULY 2020



# CONTACTS


**NEIL THURSTON**
**Project Manager**

dd 01132 845300
m 07870 572824
e Neil.Thurston@arcadis.com

Arcadis.
1 Whitehall Riverside
Leeds
LS1 4BN

**Grangetown Prairie Area, Former Steelworks Redcar, Detailed Conceptual Site Model Review and Risk Assessment**

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|---|---|
| Author | Rachel Barratt |
| Checker | Laura Garland |
| Approver | Paul Wrigley |
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# CONTENTS

# FIGURES



# APPENDICES

# 1 Introduction

Arcadis (UK) Limited (Arcadis) was appointed by South Tees Development Corporation (STDC) to undertake further risk assessment of the Grangetown Prairie (Prairie) Area (the site) located on the Former Redcar Steelworks within the Redcar, Lackenby, Grangetown and South Bank conurbations of the Borough of Redcar & Cleveland, within the industrial area generally known as 'South Tees' (indicative postcode TS10 5QW).

With the exception of a small relic Oxygen Plant and a former Loco Repair Shop, the site has been demolished to slab level, with concrete foundations, roadways and crushed aggregate, including steelmaking wastes, forming the bulk of the site surfacing. Industrial activity had been ongoing at the site since at least 1857 when an iron works was present in the north west of the site, with later development comprising a steelworks and associated industry including coke ovens, a biproducts plant, a power station and railway infrastructure. The majority of the site was demolished by 2010.

The South Tees Regeneration Masterplan has been developed detailing the industrial-led regeneration of the Former Redcar Steelworks into a world class employment-generating zone and economic growth enabler for the Tees Valley. The Masterplan has identified the Prairie Area (also known as Cleveland South) as being located within the Southern Industrial Zone. The site is a priority development area and Arcadis understands this report will be used to support a detailed planning application which was submitted in June 2020.

Arcadis understands that the proposed end use of the site is commercial/industrial with a mixture of landscaping and hardstanding and the development of highways to access the commercial/industrial plots.

A plan showing the Site location and environmental setting is presented as Figure 1.

The work was conducted with reference to English legislation and regulatory guidance pertinent at the time of reporting.

## 1.1 Background Information

| Item | Comment |
|---|---|
| Site status | Demolished steelworks |
| Intended end use | Commercial / Industrial |
| OS National Grid Coordinates | 454675, 521389 (approximate centre of the site) |
| Elevation | 5 to 15 metres Above Ordnance Datum (m AOD) |
| Size | 54 hectares |
| Previous Reports by Arcadis | • Arcadis 2020a. Phase II Environmental Site Assessment, Grangetown Prairie Area, Former Steelworks, Redcar, prepared by Arcadis for STDC, Ref 10035117-AUK-XX-XX-RP-ZZ-0062-01-Prairie_ESA dated June 2020<br>• Arcadis 2020b. Remediation Options Appraisal, Enabling Earthworks and Remediation Strategy Report, Grangetown Prairie Area, Former Steelworks, Redcar, prepared by Arcadis for STDC, Ref 10035117-AUK-XX-XX-RP-ZZ-0066-01-Prairie ROA and Strategy dated June 2020<br>• Arcadis 2020c. Phase II Environmental Site Assessment – Addendum, Grangetown Prairie Area, Former Steelworks, Redcar, prepared by Arcadis for STDC, Ref 10035117-AUK-XX-XX-RP-ZZ-0117-01-Prairie_ESA_Addendum (*in press*) |
| Previous Known Third Party Reports | • Enviros 2004*. Soil and Groundwater Baseline Characterisation Study, Teesside Works, prepared by Enviros for Corus UK Ltd, Comprising: |

| Item | Comment |
|---|---|
| | – Volume 1 – Factual Report, Ref. Rlp250604corusteessidefactual.Doc dated 25th June 2004 and marked Final;<br>– Volume 2 – Interpretive Report Ref. Mwicorusdraftinterpretivemmdv#2.Doc dated 25th June 2004 and marked Final; and,<br>– Volume 3 – Summary Report dated June 2004<br>• Enviros 2007. Corus Cleveland Prairie Teesside Site Phase I Environmental Review, prepared by Enviros Consulting Ltd. for Graphite Resources, Ref. GR1280001 dated August 2007<br>• Enviros 2008. Phase II Geo-environmental Assessment at Corus Cleveland Prairie Teesside Site, prepared by Enviros Consulting Ltd. for Graphite Resources, Ref. GR1280001 dated March 2008<br>• Shadbolt 2011. Prairie Site, Off Clay lane – Ground Investigation Factual Report, Prepared for One North East by Shadbolt Environmental dated July 2011<br>• MD2 2011. Former Corus Cleveland Prairie Site: Land off Clay Lane – Ground Investigation Interpretative Report, prepared by MD2 for One North East, Ref MD2_113 dated 25th July 2011<br>• CH2M 2017*. TS3 Grangetown Prairie – Phase 1 Geo-Environmental Desk Study, prepared by CH2M Hill for the Homes and Communities Agency, report ref. 678079_TS3_001 dated August 2017 and marked Final |

* Includes the site and wider area

This assessment has been undertaken following on from the findings of the previous phases of works. As such, this report should be read in conjunction with the previous environmental reports as the information presented provides the basis for the conceptual understanding of the Site. A large number of reports have been produced for the Site; the reports most pertinent to this assessment are detailed in Section 2.

## 1.2 Aims & Objectives

The overall aim of the works is to determine if concentrations of Contaminants of Concern (CoC) encountered in the subsurface as a result of historical iron-making, steel-making and related activities at the site present a potentially significant risk to identified human health and water resource receptors.

The assessment has been undertaken with the following objectives:

- To further characterise pollutant linkages at the site using site-specific information, where available; and
- To evaluate the potential significance of the identified CoC beneath the site within the existing legislative framework.

## 1.3 Scope of Work

The scope of work was developed with reference to the Department of the Environment Food and Rural Affairs (DEFRA) and the EA's 2004 Contaminated Land Report 11 (CLR 11) and additionally Land Contamination: Risk Management, May 2020 (LC:RM).

The scope of works has been defined as follows:

- Review of previous phases of work;
- Refinement of site conceptualisation based on-site specific data (geological and hydrogeological parameters);
- Identification of potential source area(s);
- Chemical & toxicological parameter review, where required;
- Modelling of contaminant fate and transport, where required; and,
  Risk estimation and evaluation.

## 1.4 Reliance

This report is only valid when read in its entirety. Any information or advice included in this report should not be relied on unless considered in the context of the whole report. Reference should be made to the notes on study limitations included in Appendix A of this report.

There are neither third party rights nor benefits conferred under this report. Use of this report is strictly limited to STDC and its direct and indirect subsidiaries, which are the sole parties to whom Arcadis intends to confer any rights. Any reliance on the contents of this report by any other party is the sole responsibility of that party.

## 1.5 Limitations

The following scenarios are not considered in this assessment:

- Risks to Construction Workers – any redevelopment and construction work should be conducted in full recognition of HS(G)66.
- Nuisance health effects – the Statutory Nuisance Act considers olfactory impacts from odours and allows comparison of enclosed space air concentrations with odour threshold concentrations.

Arcadis' liability, pursuant to the terms of the appointment of Arcadis by STDC, is strictly limited to the work undertaken and the matters contained and specifically referred to in this report.

A copy of Arcadis' study limitations are included in Appendix A.

# 2 Summary of Pertinent Information

## 2.1 Summary of Previous Reports

### 2.1.1 Overview

A number of previous environmental investigations have been undertaken at the site by different companies with the earliest available report dated 2004. Ground investigation works undertaken at the site by third parties have included trial pitting, borehole drilling, soil and groundwater monitoring and analytical testing (Enviros 2004, Enviros 2008 and Shadbolt 2011). Arcadis 2020a included a review of available third party reports undertaken prior to 2020, and as such, the information contained within these reports has not been summarised or reproduced here.

The most recent ground investigation at the site was undertaken by AEG. Data from this investigation was included and interpreted by Arcadis in an Environmental Site Assessment (ESA) report dated June 2020 (Arcadis 2020a). Additional groundwater and surface water monitoring has since been undertaken by AEG and represents the most recent water quality data available for the site (Arcadis 2020c). Groundwater and surface water data presented in Arcadis 2020c forms a key part of this assessment, representing current conditions. At this time, the Arcadis 2020c report is *in press*, and as such, the findings have not been discussed in detail, although information from this report has been used to support this assessment, where applicable.

### 2.1.2 Planning

A number of environmental reports have been submitted in support of planning in relation to the former Redcar Steelworks site. In 2019, STDC submitted a planning application for 'Land at former South Bank Works; Grangetown prairie; British Steel and Warrenby Area' (ref. R/2019/0427/FFM). Wood were commissioned to prepare an outline contaminated land remediation strategy for land held by STDC which included 'Grangetown Prairie'. This report was submitted as part of the 2019 planning application for the '*demolition of structures and engineering operations associated with ground preparation and temporary storage of soils and its final use in the remediation and preparation of land for regeneration and development*'.

Following a review of the environmental context of Grangetown Prairie, which included a review of third party intrusive investigation data, Wood 2019 produced a preliminary risk assessment. Based on the information available at the time, Wood 2019 concluded that the risk to human health (future site users) from contaminants in the Made Ground was considered to be moderate to high, with a high risk posed by asbestos. Following a detailed review of the environmental site context and third party site investigation data, Wood 2019 concluded that the risk to controlled waters (both groundwater and surface waters) was moderate / low and commented that the groundwater within the area is recognised by the Environment Agency as being non-viable. The focus of the subsequent remediation options appraisal was on therefore the risk to human health.

Planning permission was granted on 2nd July 2019 following review by multiple consultees, including the Environment Agency and the Local Authority.

It is noted that the Arcadis 2020a and Arcadis 2020b reports have since been submitted to the Local Authority in support of a planning application for the construction of a development platform, engineering works and remediation and reclamation of the Site (Application reference R/2020/0318/FFM).

## 2.2 Arcadis Reports

A summary of the reports containing the most recent environmental site assessments undertaken is presented below for context.

### 2.2.1 Arcadis, 2020a

Following a ground investigation undertaken by AEG and overseen by Arcadis, Arcadis produced a Phase II ESA. The aim of the ESA was to use available information to develop a Conceptual Site Model (CSM) for the site and assess the significance of any identified source-pathway-receptor linkages. This included a Generic Quantitative Risk Assessment (GQRA) to assess the potential risk posed by concentrations of CoC measured in soil and groundwater to the identified human health and controlled waters receptors.

Review of historical mapping indicated that Prairie has been the site of metal works since the first available mapping in 1857 when the site was predominantly agricultural land with railways bordering the northern and western boundaries and a small iron works was located in the north west of the site. During this period, the Tees Estuary is shown immediately beyond the railway running along the northern boundary of the site. Later, reclamation of land increases the distance of the site to the Tees estuary. A steel works has been present on the site since at least 1893 and continued to expand and change up until 2010 when much of the site was demolished. Industrial activity at the site has included coke ovens, railways, storage tanks, workshops, laboratories, a power station, substation and biproducts plants. Made Ground and an infilled reservoir were also identified as Potential Areas of Concern (PAOC) at the site. The PAOC were considered potential sources and CoC determined based on these. The CoC considered were as follows: metals, refractory materials, Total Petroleum Hydrocarbons (TPH), Polycyclic Aromatic Hydrocarbons (PAHs), cyanide, thiocyanate, sulphate, pH, ammonia, asbestos, chloride, Volatile Organic Compounds (VOCs), Semi Volatile Organic Compounds (SVOCs) and Polychlorinated Biphenyls (PCBs). Ground gas was also considered.

The ground investigation undertaken by AEG in April 2020 comprised the excavation of 110no. trial pits, advancement of 10no. boreholes to a maximum depth of 20.8m below ground level (bgl) and the installation of 12no. groundwater monitoring wells including 2no. twin installations which screened different strata underlying the site. The first round of groundwater monitoring using the newly installed monitoring wells was undertaken in May 2020.

The geology recorded during the ground investigation largely confirmed the regional geology shown on geological maps. The site is underlain by up to 5m of Made Ground which predominantly comprises granular material with a fine-grained component and a medium to high cobble content including slag, brick, concrete, clinker, coke, coal and metal. Superficial deposits encountered beneath the Made Ground included approximately 1.5m of Tidal Flat Deposits comprising soft to firm sandy silty clays or sandy clayey silts, Glaciolacustrine Deposits which consisted of soft to firm laminated clay and Glacial Till which was described as firm to stiff slightly sandy slightly gravelly clay. Neither the Tidal Flat Deposits or the Glaciolacustrine Deposits were found to be continuous across the site, however in every borehole that was progressed to bedrock, Glacial Till was identified. Three types of bedrock were shown on geological mapping of the site: Mercia Mudstone in the northern half of the site, the Penarth Group in a north-east to south-west stripe across the central part of the site and the Redcar Mudstone Formation in the southern most part of the site. Each of these rock units was identified during the intrusive investigation.

Of the superficial deposits underlying the site, the Environment Agency has classified only the Tidal Flat Deposits as an aquifer (Secondary (A) Aquifer). Of the bedrock units, the Redcar Mudstone Formation and Penarth Group are classified as Secondary (Undifferentiated) Aquifers and the Mercia Mudstone is classified as a Secondary B Aquifer. The site is not located within a Source Protection Zone (SPZ) and there are no SPZ within 1 km of the site. Based on the groundwater elevation data collected from the monitoring wells in May 2020, the groundwater flow direction within both the superficial deposits and the bedrock is towards the north to north-east. Water was also encountered in Made Ground in half of the trial pits excavated during the ground investigation. Water levels in the Made Grounded showed considerable variation between adjacent trial pits and the water was considered to be perched within more granular horizons of the Made Ground and not laterally continuous.

In addition to water pooling on the surface of the site, two flowing surface water features were identified on the site: Holme Beck which runs along the western edge of the site and Knitting Wife Beck which runs along the eastern boundary of the site. Both features were noted to be culverted and flow towards the north and ultimately the River Tees. Additionally, a section of the River Tees and foreshore noted to be part of the Teesmouth and Cleveland Coast Site of Special Scientific Interest (SSSI) which is also designated as a Special Protection Area (SPA) and Ramsar site, is located approximately 750m to the north of the site with the River Tees itself approximately 1km to the north of the site.

Given the presence of aquifers underlying the site and the becks, albeit culverted, in the eastern and western parts of the site, both groundwater and surface water were considered potential controlled waters receptors associated with the site. The proposed end use for the site is a commercial/industrial development and as such the primary human health receptors were considered to be commercial workers. Consideration was given to neighbouring residents located approximately 70m to the south-west of the site, however given that they were located hydraulically upgradient, there was not considered to be a significant risk. The ESA also

considered built receptors noting that significant contamination can pose a risk to subsurface structures and that based on the concentrations of CoC measured in soil, further consideration would need to be given to the type of water supply pipes or the long-term protection of water supply as part of the redevelopment.

Following the results of the site investigation, a GQRA was undertaken. Four exposure pathways in relation to human health (future commercial workers) were assessed for a generic commercial redevelopment:

- Vapour inhalation of indoor and outdoor air from volatile contaminants in soils
- Vapour inhalation of indoor and outdoor air from volatile contaminants in groundwater
- Dermal contact/ingestion of soil
- Dust inhalation

The pathways considered to be potentially active for controlled waters were as follows:

- Leaching of CoC from Made Ground to groundwater in the Tidal Flat Deposits (Secondary (A) Aquifer
- Vertical migration of CoC to Redcar Mudstone Formation, Penarth Group or Mercia Mudstone
- Horizontal migration of contaminated groundwater to the on-site watercourses
- Migration of CoC in groundwater onto site from off-site sources
- Migration of CoC in groundwater off-site

During the site investigation, Non-Aqueous Phase Liquid (NAPL) was observed associated with tar and underground structures in the Made Ground.

Concentrations of CoC measured in soil were compared to the relevant Generic Assessment Criteria (GAC) for human health. Concentrations of arsenic, total cyanide and PAHs were measured above their respective GAC which were driven by the dermal contact and dust inhalation exposure pathways. Concentrations of naphthalene and free cyanide were also measured above the relevant GAC and, as both are volatile, were considered to represent a potential risk via the vapour inhalation pathways. A potential risk was also identified based on the presence of NAPL, with asbestos additionally recorded in a third of the Made ground samples from the site, representing a risk through the inhalation pathways (including within dust). It was suggested that a clean cover system or the presence of hardstanding would mitigate the risks posed by asbestos fibres in shallow soils.

A risk to human health from concentrations of CoC measured in groundwater was not identified as part of the GQRA.

Multiple CoC including metals, total cyanide, ammoniacal nitrogen, TPH, PAH, phenol, xylene and 1,2-dichloroethane were measured in leachate and/or groundwater in excess of Drinking Water Standards (DWS) and Environmental Quality Standards (EQS) protective of coastal waters and estuaries. The report concluded that further assessment of the risk to controlled waters was required from measured concentrations of CoC in leachate and groundwater and additionally the presence of NAPL and tar.

### 2.2.2 Arcadis, 2020b

The following remediation objectives were defined as part of the Remediation Options Appraisal (ROA):

- Manage the contamination in excess of screening levels identified in the ESA and that are likely to be present following competition of further assessment, including NAPL containing soils
- Manage the identified pollutant linkage identified between asbestos in shallow Made Ground such that that exposure pathway for on-site commercial workers are inactive
- Maximise the reuse of excavated soils by making them suitable for use under DoWCoP
- To develop an unexpected contamination strategy in order to mitigate the risks presented in the preparation of historical brownfield land.

A review of remediation technologies suitable for meeting these objectives resulted in the following technologies potentially being suitable for remediation, considering technical, operational and commercial feasibility:

- Capping in-situ
- Ex-situ bioremediation
- Stabilisation/solidification
- Smouldering combustion or Thermopiles
- Excavation and disposal

As part of the remediation, a clean cover system (capping in-situ) is planned to break the direct contact pathways. Ex-situ bioremediation, stabilisation/solidification, smouldering combustion/thermopiles or excavation and disposal were suggested to address NAPL impacted materials and soil which poses a risk to human health via vapour pathways. Arcadis 2020b was written prior to this assessment, and as such, the remediation technology and approach will be confirmed on completion and issue of this report.

### 2.2.3 Arcadis, 2020c

Additional monitoring of the groundwater and the surface water was undertaken by AEG at the site following the issue of the Arcadis 2020a report and has been interpreted by Arcadis in Arcadis 2020c (*in press* at the time of writing).

The additional monitoring comprised two mobilisations to site, one in June 2020 and one in July 2020. The following was undertaken over the course of the June and July 2020 monitoring visits:

- Measurement of groundwater elevation on 15th June and 30th June
- Sampling of groundwater on 15th June and 1st and 2nd July 2020 with subsequent laboratory analysis
- Tidal monitoring of BH101D, BH103 and BH108D between 11th May and 16th June 2020
- Variable Head Test in BH101D on 3rd July 2020
- Slug Test in BH103 on 16th June 2020, BH103 on 24th June and in BH101S, BH103, BH108S and BH110 on 3rd July.
- Sampling of surface water in the Holme Beck with subsequent laboratory analysis on 15th June 2020.

Since Arcadis 2020a was issued, further ground investigation has also been undertaken at the site by Atkins, in the western part of the site. The findings of this ground investigation are provided in Arcadis 2020c.

This data and the interpretation of it is presented in full in Arcadis 2020c.

## 2.3 Requirement for Further Assessment

### 2.3.1 Human Health

The risk to future commercial workers from concentrations of contaminants via the direct contact and dust inhalation pathways is to be mitigated using a clean cover system in areas which are to be used for landscaping and by encapsulating material below new infrastructure constructed as part of the development such as additional building roads or car parks (Arcadis 2020b). Concentrations of volatile compounds (naphthalene and free cyanide) which were measured at concentrations above the GAC, or for which no applicable GAC was available, will be further considered as part of this assessment prior to confirmation of the remediation strategy.

### 2.3.2 Water Resources

Concentrations of CoC measured in soil leachate and groundwater were identified in excess of DWS and EQS screening criteria in the GQRA undertaken in Arcadis 2020b. As such, the risk to water resources requires further consideration.

# 3 Assessment Methodology

Prior to undertaking further detailed assessment, review and refinement of the existing CSM will be undertaken following the collection of additional site data (Arcadis 2020c). A review of the receptors, sources and pathways associated with the site in the context of additional data will be presented in the following sections:

- Receptors – Section 4
- Sources – Section 5
- Pathways – Section 6

If review of site-specific details in relation to part of the Source-Pathway-Receptor (S-P-R) linkage suggests no significant risk, then further consideration may not be warranted and additional risk assessment will not be required. Where a potentially active S-P-R linkage is identified, further risk assessment will be undertaken to assess the significance of the risk.

# 4 Receptors

## 4.1 Human Health

The Masterplan for the STDC area indicates that the site will be redeveloped for an industrial/commercial end use with mixed hardstanding and landscaping. As such the human health receptors associated with the site are considered to be future commercial workers. Neighbouring residents were discounted as a potential receptor in Arcadis 2020a.

## 4.2 Controlled Waters (Aquifers)

In order to assess the applicability of aquifers as a controlled water receptor associated with the site, and additionally the resource potential of the aquifers underlying the site, the following information has been reviewed in this section:

- Review of the viability of aquifers for groundwater abstraction in the context of additional permeability data, additional groundwater elevation data and detailed review of the results of the ground investigation
- Potential for saline intrusion following the collection of additional salinity data and tidal monitoring

### 4.2.1 Hydrogeological Setting

Following the collection of additional site data (Arcadis 2020c) and in the context of the findings of 2020 ground investigation (Arcadis 2020b), a review of the aquifers underlying the site has been undertaken.

| Geology | Aquifer Designation | Comment |
|---|---|---|
| Made Ground | None – generally encountered as perched water | Water held within the Made Ground is considered to be perched and not part of a continuous water body. While a limited degree of lateral or vertical movement (downwards) may be plausible, water held within the Made Ground is not considered to be a groundwater receptor. |
| Tidal Flat Deposits | Secondary (A) Aquifer | A Secondary (A) Aquifer is defined by the EA as having permeable layers capable of supporting water supplies at a local level and are sometimes an important source of base flow to rivers. Tidal Flat Deposits have been identified at the Prairie site, generally in the west. Where the full thickness was proven, their extent was found to be limited and generally less than 1.5m. Given that the Tidal Flat deposits are not laterally continuous across the site and the limited thickness of the deposits, the Tidal Flat Deposits are considered to be of limited resource potential and are not considered to be a significant water resource receptor associated with the site. |
| Glaciolacustrine Deposits | Unproductive strata | Unproductive strata are defined by the EA as having low permeability that have negligible significance for water supply or river base flow. Based on the impermeable nature of this geology and the aquifer designation, groundwater within the Glacial Lacustrine and the Glacial Till deposits is not considered to be a significant water resource receptor. |
| Glacial Till | | |
| Mercia Mudstone | Secondary (B) Aquifer | A Secondary (B) Aquifer is defined by the EA as comprising predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features. Mercia Mudstone was encountered in boreholes drilled in the northern part of the site where Mercia Mudstone was proven to a depth of 20.8m bgl and recovered as a partially weathered mudstone with numerous gypsum veins and inclusions.<br>Whilst Secondary (B) Aquifers may be abstracted for a limited amount of water and are considered to be water resource receptors in their own right, given the industrial nature of the site and surrounding land, it is |

| Geology | Aquifer Designation | Comment |
|---|---|---|
| | | unlikely to be abstracted, especially for drinking water. This is consistent with findings of the Wood 2019 report which additionally stated that the groundwater in the area is recognised by the Environmental Agency as being non-viable. |
| Penarth Group | Secondary Undifferentiated Aquifer | A Secondary Undifferentiated Aquifer is defined by the EA as having variable characteristics and being previously defined as both a minor aquifer and a non-aquifer. The likely yield from such an aquifer is low and as such it is unlikely that an aquifer of this type would be used for abstraction now or in the future.<br>Similarly to the discussion in relation to the Mercia Mudstone, the industrial nature of the site and surrounding land, mean it is unlikely to be abstracted, especially for drinking water. This is consistent with findings of the Wood 2019 report which stated that the groundwater in the area is recognised by the Environmental Agency as being non-viable. As such, the Secondary Undifferentiated Aquifers underlying the site are not considered to represent significant receptors of concern. |
| Redcar Mudstone Formation | | |
| Sherwood Sandstone | Principal Aquifer | The Sherwood Sandstone is a Principal Aquifer and as such is important for water supply and/or base river flow on a strategic scale. At Prairie, the Sherwood Sandstone is understood to be at depth and overlain by a significant thickness of Mercia Mudstone (approximately 200m). As such, this aquifer is likely to have limited connectivity with groundwater encountered in the superficial and bedrock deposits identified as part of the site investigation. In line with Wood 2019, the Sherwood Sandstone underlying the site is considered to be of limited hydrogeological concern. |

In the superficial deposits, the aquifer classification which suggests the most potential for future abstraction is that in the Tidal Flat Deposits. However the Tidal Flat Deposits are not laterally continuous across the site and are of limited thickness (generally less than 1.5m), on this basis the Secondary (A) Aquifer in the Tidal Flat Deposits is not considered to have a significant potential for future groundwater abstraction.

The Sherwood Sandstone is a Principal Aquifer and as such, most likely to be abstracted for groundwater. However, given the depth of the Sherwood Sandstone below the site and the presence of approximately 200m of Mercia Mudstone above it, this aquifer is considered to be of limited hydrogeological concern.

Groundwater within the remaining aquifers are classified as Secondary B Aquifers, Secondary Undifferentiated Aquifers or Unproductive Strata and as such are less likely to support sufficient groundwater yields to be abstracted on a significant scale. The industrial nature of the site and surrounding land suggest that the aquifers underlying the site are unlikely to be abstracted, especially for drinking water. This is consistent with findings of the Wood 2019 report which stated that the groundwater in the area is recognised by the Environmental Agency as being non-viable.

### 4.2.2 Aquifer Permeability

Permeability testing of the aquifer was undertaken in four monitoring well locations in June and July 2020:

- BH101D – screening Glacial Till Deposits
- BH103 – screening Glaciolacustrine Deposits
- BH108D – screening Mercia Mudstone
- BH110 - screening Mercia Mudstone

The results of the testing undertaken in BH103 were disregarded as recharge into the well was rapid during the test and not representative of the cohesive geology screened.

The aquifer permeability calculated by Arcadis from testing completed at BH101D was 0.007 to 0.025 m/day with an average of 0.015 m/day calculated across the four tests undertaken. These values are broadly in line with literature values for a clay such as the US EPA 1988 who suggest 0.014m/day, Morris and Johnson 1967, who suggest 0.0002m/day and ConSim 2000, where a range in hydraulic conductivity of 8.6 x $10^{-7}$ to 0.00041 m/day is presented for a clay. The permeabilities calculated are considered to be representative of the geology encountered and the low permeability values indicate that the clayey superficial deposits would be unlikely support significant groundwater flow (or abstraction).

Both BH108D and BH110 screen the Mercia Mudstone and as such will be considered together. A total of 12 tests were undertaken across both the monitoring wells with calculated permeabilities ranging from 0.3 to 0.61 m/day and an average of 0.5 m/day. In comparison to literature values for a mudstone, these permeabilities are more rapid than expected. For example, ConSim 2000 suggests between 8.64 x $10^{-9}$ to 0.00017 m/day for a shale, with similar values reported by Tindal 1998. The literature values presented are at least 3 orders of magnitude below the calculated permeabilities. The higher than expected permeabilities may be the result of drilling induced fracturing of the mudstone in the close proximity of the well, where mudstone is described in some sections of the well screen as extremely weak and moderately weak. Generally, while the calculated permeabilities are considered high for the geology, the permeabilities remain relatively low and would be unlikely to support significant groundwater flow (or the yields likely required for a viable abstraction).

### 4.2.3 Aquifer Protection

The site is not located in, or within 1km of an SPZ or a Drinking Water Safeguard Zone for groundwater.

### 4.2.4 Salinity and Tidal Influence

The site is located approximately 1km to the south of the River Tees (at its closest point) and approximately 5km from the east coast of England and the North Sea. Prior to the reclamation of land, the tidal River Tees estuary was present immediately beyond the railway line which borders the north of the site. Given the current and historical location of the site, an assessment of the salinity of the groundwater and monitoring for tidal influence at the site was undertaken to determine the natural quality of the groundwater underlying the site. Laboratory analysis of the groundwater and the results of the tidal monitoring are presented in Arcadis 2020c.

#### 4.2.4.1 Salinity

Sodium chloride (NaCl) is the most abundant salt in marine waters and as such concentrations of NaCl measured in groundwater underlying the site were calculated to indicate whether the groundwater was fresh, brackish or saline. Of the 12 groundwater samples collected in May 2020 (including groundwater from the Made Ground, Glaciolacustrine Deposits, Glacial Till, Mercia Mudstone and Redcar Mudstone Formation / Penarth Group), concentrations of NaCl in all 12 were less than 500 mg/l indicating that the groundwater in these units is fresh water. When groundwater collected in June 2020 and again in July 2020 was tested, concentrations of NaCl in 10 of the 12 samples were less than 500 mg/l indicating fresh water. However, concentrations of NaCl in groundwater sampled from the remaining two samples (BH109 and BH110) were 2798 mg/l and 1068 mg/l respectively in June and 890 mg/l and 1235 mg/l respectively in July 2020, suggesting that the groundwater to the west of the site, in the bedrock may be brackish.

A laboratory test for %salinity was also completed for the same groundwater samples. A comparison of the salinity in the groundwater to the salinity of seawater suggested that the majority of the groundwater samples were brackish. However, it is noted that the salinity analysis was undertaken using conductivity which can be impacted by compounds which aren't associated with marine salt water. As such, the measure of NaCl is considered to be better representative of groundwater conditions.

Overall, concentrations of NaCl measured in the groundwater suggest that much of groundwater underlying the site is likely to be fresh water. However, pockets of brackish water may be present within the bedrock which may indicate periodic saline intrusion.

#### 4.2.4.2 Tidal Influence

Tidal monitoring was undertaken by AEG in BH101D (located in the northwest of the site and screening the Glacial Till), BH103 (located in the north-east of the site and screening the Glaciolacustrine Deposits) and

BH108D (located in the south-west of the site and screening the Mercia Mudstone) over a period of 36 days between 11th May and 16th June 2020.

Regular cyclical changes in the groundwater level were recorded in the monitoring wells however the peaks and troughs of the cycles were not in line with the approximately 6-hourly fluctuations expected in tidally influenced groundwater. The peaks and troughs were generally 8 hours apart and the change in water level was generally less than 4cm. While the cycles were regular in BH101D and BH103, the cycles observed in BH108D were interrupted by larger variations in groundwater elevation (in the order of 15cm and over a period of several days).

Whilst it is possible that the regular cycles measured during the tidal monitoring reflect changes in the tides, there is insufficient evidence to conclusively state that the groundwater is tidally influenced.

### 4.2.5 Summary

Groundwater underlying the site was largely found to be fresh based on calculated concentrations of NaCl measured in groundwater samples with the exception of groundwater in BH109 and BH110 during monitoring in June and July 2020. Both BH109 and BH110 screen bedrock in the west of the site and groundwater sampled from these locations in June and July 2020 was identified as brackish. The presence of brackish water may indicate sporadic saline intrusion into the groundwater in the bedrock underlying the site.

The overall suitability of the groundwater for abstraction, now or in the future, is considered to be low. The aquifers located within the top 20m are generally classified as low yielding with the much deeper Sherwood Sandstone Aquifer, which is a Principal Aquifer, protected from the shallow groundwater by a significant thickness of Mercia Mudstone. The permeability of the aquifers (in the superficial deposits and the Mercia Mudstone) underlying the site calculated from on-site testing, indicated that they are unlikely to yield sufficient water to support a future abstraction. Additionally, the industrial setting of the site, that the site is not located with 1km of an SPZ and the potential for saline intrusion makes it unlikely that abstraction of the identified aquifers, especially for drinking water, would be desirable.

On this basis, groundwater underlying the site is considered to be of low resource potential and has not been considered as a receptor of concern. On this basis, further consideration of groundwater within the underlying aquifers has not been undertaken.

## 4.3 Controlled Waters (Surface Water) and Ecological Receptors

### 4.3.1 Hydrological Setting

| Watercourse | Current Condition | Proposed Condition |
|---|---|---|
| Holme Beck | Holme Beck runs along the western boundary of the site, to the east of Eston Road.<br>The watercourse enters the Prairie site in the southwestern corner and flows north above ground in an open slab lined channel for approximately 125m before entering a 1.2m diameter concrete culvert for the remainder of the course until it leaves site at the Holme Beck underpass and turns east to join the Cleveland Channel. | As part of the Eston Road Development, it is proposed for the Holme Beck to be 'daylighted' so that it forms an open water course for approximately 2/3 of its route through the site. At this time, Arcadis is not aware of any development plan for the northern part of the beck which is currently culverted. |
| Knitting Wife Beck | Knitting Wife Beck runs along the eastern part of the site and is understood to be culverted along the entirety of its route through the site. Like Holme Beck, the flow direction in the culvert is to the north and the beck flows into the Cleveland Channel. | No changes to Knitting Wife Beck have been proposed as part of the development however an investigation of the culvert is planned. |

| Watercourse | Current Condition | Proposed Condition |
|---|---|---|
| Cross Connector | The Cross Connector periodically crosses into the southernmost part of the site. It is understood to be culverted along the entirety of its route on the site. The flow direction is understood to be towards Knitting Wife Beck. | No changes to the Cross Connector have been proposed as part of the development. |
| River Tees | The River Tees is approximately 1 km to the north of the site and represents the ultimate destination of both the Holme Beck and Knitting Wife Beck. Approximately 750m to the north of the site is the Teesmouth and Cleveland Coast SSSI, SPA and RAMSAR site which includes the River Tees and part of the foreshore. Due to the size of the river/estuary, the River Tees is likely to influence the regional groundwater system. The groundwater flow direction in both superficial and bedrock deposits on the site ranges from north, north-east to east, broadly towards the River Tees and the North Sea. | |

The location of the surface water features on the Prairie site are shown on Figure 2. Two approximate routes for the Knitting Wife Beck are shown on the plan. It is understood that work is being undertaken to confirm the route of the beck.

### 4.3.2 Interaction with Groundwater

Groundwater has been identified in both the superficial deposits and bedrock underlying the site. Water has also been encountered in the Made Ground, however it is considered to be perched. Unlike the continuous groundwater bodies in the superficial deposits and bedrock which show a coherent groundwater flow direction, the perched water is likely to have localised flow. As such, perched water may interact with surface waters periodically at a local scale although it is not possible to assess this interaction further.

The groundwater flow direction in the superficial deposits inferred from site groundwater elevation data is generally towards the north and north-east. As such, Holme Beck is considered to be hydraulically upgradient or cross gradient of the groundwater flow direction and the risk to Holme Beck is therefore considered to be low.

Knitting Wife Beck is considered hydraulically downgradient and is currently culverted. Arcadis are not aware of plans to ‘daylight’ the culvert as part of the redevelopment. On this basis, provided that the culvert can be proven to be in good condition and that shallow groundwater is not in continuity with the water in the culvert, the risk to Knitting Wife Beck from concentrations of CoC measured in groundwater is considered to be low.

The Cross Connector is hydraulically upgradient from the majority of the site and is understood to be culverted. Arcadis are not aware of plans to ‘daylight’ the water course as part of the redevelopment. Like Knitting Wife Beck, provided that the culvert can be proven to be in good condition and that shallow groundwater is not in continuity with the water in the culvert, the risk to the Cross Connector from concentrations of CoC measured in shallow groundwater is considered to be low.

It should be noted that the inferred flow directions within the superficial deposits are based on elevations from a limited number of monitoring wells given the size of the site, given the River Tees is located to the north of the site and runs eastwards towards the North Sea, the inferred groundwater flow direction is considered to be in line with regional hydrogeology. Groundwater Elevation is presented on Figure 3a for monitoring wells screening the bedrock and Figure 3b for those screening the superficial deposits.

### 4.3.3 Surface Water Monitoring

Surface water sampling was undertaken in June 2020 from two locations: an upstream location (SW1) as the Holme Beck enters the site, and a downstream location (SW2) from the northern side of the railway bridge as the Holme Beck leaves the site. The Knitting Wife Beck and Cross Connector are culverted and could not be accessed. As such no surface water sampling was undertaken for the eastern or southern water course. The results of the June 2020 surface water monitoring are presented in full in Arcadis 2020c.

Concentrations of TPH, phenol, cyanide, hexavalent chromium, mercury and SVOC were measured below the laboratory Method Detection Limit (MDL) in the surface water sampled. With the exception of toluene, which was measured at 1µg/l (the same as the MDL), no VOC were measured in the surface water samples collected. Where concentrations of CoC were measured above the MDL they did not vary significantly between the upstream and the downstream sample (were typically in the same order of magnitude).

When compared to EQS (estuaries and coastal) concentrations measured in both the upstream and downstream samples were below the EQS with the exception of fluoranthene and benzo(g,h,i)pyrene which were measured at the same concentration as the MDL (0.01µg/l) in the upstream sample and below the MDL in the downstream sample.

Generally, where concentrations measured in the surface water samples were marginally higher in the downstream sample (albeit remaining within the same order of magnitude as the upstream sample), the CoC are likely to be associated with slag in the Made Ground. This is not unexpected given the former use of the site and of surrounding sites (including that to the west). Perched water has been encountered in a number of locations in the Made Ground and in the vicinity of Holme Beck there may be localised flow in the Made Ground toward the surface water. The localised and discontinuous nature of perched water in the Made Ground indicates that the risk to the surface water is generally low.

The surface water monitoring indicates that the quality of the surface water has not altered significantly as it passes through the site. On this basis, concentrations of CoC measured in soil and groundwater do not appear to be significantly impacting the quality if the Holme Beck.

The results of the surface water sampling are broadly in line with surface water monitoring undertaken in January 2008 (Enviros 2008). Enviros 2008 found that the majority of contaminants were below the relevant EQS or DWS and that in some cases, concentrations of contaminants were greater in the upstream sample, than in the downstream sample taken from Holme Beck.

### 4.3.4 Consideration of the River Tees

The River Tees is located approximately 1km to the north of the site at its closest point. The river flows east to the North Sea.

Given the distance to the River Tees, there is considerable time for contaminants to undergo attenuation, dispersion and dilution as the groundwater migrates. The risk to the River Tees from concentrations of CoC measured in groundwater is considered to be low.

### 4.3.5 Summary

An assessment of the surface water quality as the Holme Beck flows through the site indicates that it does not alter significantly between entering and leaving the site. Additionally, concentrations of CoC measured in Holme Beck were generally less than the applicable EQS with the exception of two PAH compounds which were measured at MDL as the surface water entered the site, and below MDL as the water left the site. Based on this and that the bulk of the groundwater flow direction on the site is to the north, north-east and east, making Holme Beck hydraulically upgradient of the majority of the site, the risk to Holme Beck is considered to be low.

The other surface water features on the site are Knitting Wife Beck and the Cross Connector. Knitting Wife Beck and the Cross Connector are currently culverted and Arcadis are not aware of plans to ‘daylight’ the culverts as part of the redevelopment. On this basis, provided that the culverts can be proven to be in good condition and that groundwater is not in continuity with the water in the culvert, the risk to Knitting Wife Beck and the Cross Connector from concentrations of CoC measured in groundwater is considered to be low.

Based on the above, the surface water receptors located on-site are not considered to be water resource receptors associated with the site.

# 5 Sources

Following the findings of the previous phases of work, free cyanide and naphthalene have been identified as CoC associated with the site which may represent a risk to human health via the vapour inhalation pathway. The risks posed by those compounds representing a direct contact risk are considered to be addressed by the installation of a cover system on-site in landscaped areas. The risk to controlled waters and ecological receptors is not considered to require further assessment based on the findings of Section 4.

Cyanide at steel works sites is a contaminant generally associated with coke making and iron making. Coke ovens were located in the south-western part of the site and before the steel works, an iron works was present in the north-west of the site. Concentrations of free cyanide were measured below the human health GAC in soil, albeit the GAC was based solely on the direct contact pathways. As such, further assessment of the vapour pathways in relation to both soil and groundwater sampled from the site is required due to the potential for free cyanide to volatilise as hydrogen cyanide.

Naphthalene has been measured in soil at concentrations greater than the GAC (Arcadis 2020a), and like cyanide, is likely to be associated with coke making, a process that took place in the south-western part of the site. Naphthalene was not measured above the human health GAC in groundwater.

## 5.1 Contaminant Distribution

### 5.1.1 Free Cyanide

The distribution of free cyanide measured in soil sampled from the site (inclusive of Enviros 2008, Shadbolt 2011 and Arcadis 2020a) are presented on Figure 4.

During the most recent ground investigation undertaken at the site in 2020 (Arcadis 2020a), concentrations of free cyanide were identified above the MDL in 24 of 117 soil samples collected from the site. Free cyanide was detected in soil sampled between ground level and 3.6 m bgl with the majority measured between 0.8 and 1.5 m bgl in granular Made Ground. There was a single concentration of free cyanide measured above MDL at 0.9 m bgl in natural deposits (Tidal Flat Deposits) however given the remaining 23 detections (out of 117 samples) were in Made Ground, the detection in the Tidal Flat Deposits appears to be an outlier.

The highest concentration of free cyanide measured over the four ground investigations undertaken at the site (Enviros 2008, Shadbolt 2011 and Arcadis 2020a) was identified in soil sampled from TP04 at 0.1 m bgl in the Shadbolt 2011 investigation. Free cyanide was measured in the north-west of the site at a concentration of 16.2 mg/kg. Concentrations of free cyanide above MDL were generally measured in soil sampled from the western part of the site with sporadic detections of free cyanide in the central and north-eastern part of the site.

The highest concentration of free cyanide measured in groundwater during the May 2020 and June 2020 monitoring visits was measured in BH110 (screening the Mercia Mudstone) in June 2020 at a concentration of 240 µg/l. Concentrations above MDL were also measured above MDL in BH101S, BH101D and BH103, screening the Glaciolacustrine Deposits, Glacial Till and Glaciolacustrine Deposits respectively. BH101S, BH101D and BH103 are located in the northern part of the site and concentrations of free cyanide measured in the groundwater were an order of magnitude lower than those observed in monitoring well BH110.

### 5.1.2 Naphthalene

The distribution of naphthalene measured in soil sampled from the site (inclusive of Enviros 2008, Shadbolt 2011 and Arcadis 2020a) are presented on Figure 5.

Concentrations of naphthalene measured in soils in the south-west of the site were generally highest with the exception of soil sampled from TP114 which is located in the north of the site and recorded the highest concentration of naphthalene (37,000 mg/kg). Concentrations in the central and eastern areas were generally less than 1 mg/kg.

Of 117 soil samples collected in Arcadis 2020a, concentrations of naphthalene were measured above the GAC in two soil samples. The highest concentration of naphthalene (37,000 mg/kg) was measured in soil sampled from TP114 at 0.9 m bgl in the central northern part of the site. Review of the trial pit log indicates that at 0.9m bgl a clay pipe of 12-inch diameter was identified. At the same depth a black tar with a ‘hydrocarbon’ odour

was noted. The second highest concentration of 3500 mg/kg was measured in TP182 at 0.9 m bgl in the south-western part of the site. A strong hydrocarbon/creosote odour was noted between 0.8 and 1.0m bgl in this trial pit and Arcadis 2020a noted NAPL at the base of the Made Ground associated with a relic slab/railway structure adjacent to the coke oven slab.

Where concentrations of naphthalene were measured over 100 mg/kg in soil samples collected (Arcadis 2020a), the soils were generally observed to have a sheen or impacted with NAPL or tar.

## 5.2 Consideration of NAPL

As part of the GQRA undertaken in Arcadis 2020a, only two measured concentrations of naphthalene (TP114 and TP182) were in excess of the human health GAC. Review of these detections (as presented in Section 5.1.2 above) indicates that they are both associated with NAPL.

Under the remediation strategy (Arcadis 2020b), soils encountered in both TP114 and TP182 would be subject to remediation due to the presence NAPL and tar: '*Materials impacted with NAPL and tar should not be reinstated due to being a primary source of contamination. The impacted material will be required to be consigned to a treatment process to remove the NAPL element or disposed of at an appropriate waste facility under duty of care'.* As such it is anticipated that these soils would be removed/treated, removing the source of naphthalene exceedances. As such, further consideration of naphthalene is not required.

# 6 Pathways

On the basis of works planned as part of the remedial strategy, and following a review of the receptors and sources associated with the site in Sections 4 and 5, one potential source-pathway-receptor linkage remains active: the potential risk of concentrations of free cyanide in measured soil and groundwater to future commercial workers. The fate and transport and exposure pathways for this potentially active linkage are presented below.

## 6.1 Fate and Transport

The environmental fate and transport pathways considered potentially active are presented below:

- Partitioning of soil and groundwater impacts into soil gas and vertical migration (upwards) towards ground surface (and human health receptors); and,
- Dilution in an overlying air space.

## 6.2 Exposure Pathways

The exposure pathways considered active in relation to human health are presented below:

- Inhalation of indoor air impacted by a soil or groundwater source; and,
- Inhalation of outdoor air impacted by a soil or groundwater source.

The remaining pathways including dermal, oral and dust inhalation are considered to have been addressed as part of the remediation strategy for the site (Arcadis 2020b).

# 7 Refined Conceptual Site Model

Following the detailed CSM review undertaken in Sections 4, 5 and 6 a refined CSM has been produced.

Future commercial workers have been retained as human health receptors associated with the site. Review of controlled waters comprising aquifers underlying the site and surface water associated with the site has indicated that they do not represent significant receptors of concern. Ecological receptors associated with the site are intrinsically linked to the surface water at the site as they focus on the River Tees estuary, and following the conclusion that surface water at the site does not represent a significant receptor of concern, it follows that the ecological receptors are also not a significant receptor of concern.

The sources of contamination at the site remain unchanged following Arcadis 2020a. Compounds including heavy metals, inorganic compounds and PAHs have been identified in the subsurface at concentrations which may represent a risk to future users of the site via the direct contact and dust inhalation pathways. To break these pathways, the implementation of a clean cover system has been proposed as part of the remedial strategy for the site (Arcadis 2020c).

NAPL and tar have also been identified at the site and represent a source of concentrations of contaminants such as PAHs, including naphthalene. A number of options for the remediation of this gross contamination have been presented in Arcadis 2020b and it is understood that as part of the redevelopment areas of identified NAPL and tar will be treated.

Made Ground at the site remains a potential source of free cyanide and a potential pathway existing between this and future users of the site. Free cyanide is an ion which will bind to elements or compounds it comes into contact with and in some cases can form a volatile compound. As such, it remains a potential risk via vapour inhalation in indoor and outdoor air. This S-P-R linkage warrants further assessment which will be undertaken in Section 8.

No other S-P-R linkage in relation to human health has been identified as part of this report.

A Conceptual Site Model and a site-specific cross-section are presented on Figure 6.

# 8 Free Cyanide Risk Assessment

A potentially active S-P-R linkage has been identified as part of the detailed CSM review. Concentrations of free cyanide measured in soil and groundwater potentially pose a risk to future commercial workers at the site via the volatilisation pathway and subsequent exposure through the inhalation of indoor and outdoor air.

No appropriate GAC which considers both direct contact and vapour pathways has been identified following review of available screening criteria (Arcadis 2020a). The US EPA provide a GAC for free cyanide however it is based on the direct contact pathways only. As such detailed modelling of the risk to human health has been undertaken, to incorporate both the direct contact and vapour pathways and generate a suitable assessment criteria for use in screening both soil and groundwater at the site.

As an initial step, literature review of the physical, toxicological and fate and transport properties of free cyanide was undertaken. While cyanide is not an uncommon compound, this risk assessment is concerned with free cyanide (CN-) and specifically the potential formation of hydrogen cyanide (HCN) gas. As such, the available properties of both cyanide and HCN were reviewed.

Following literature review, modelling of the risk to human health from both soil and groundwater was undertaken using two modelling tools: the Contaminated Land Exposure Assessment (CLEA) tool (produced by the EA) and the Risk Based Corrective Action (RBCA) tool) which has been adapted to incorporate EA guidance. Assessment criteria were then calculated from the outputs of these models.

The assessment criteria have been derived for free cyanide for a generic commercial end-use incorporating soil parameters, in line with the derivation of the GAC adopted in Arcadis 2020a. A full account of the methodology and detailed findings of the assessment and derivation are presented in Appendix B.

It is anticipated that free cyanide will be identified in parts of the wider Redcar Steel Works development area. As such, the assessment criteria derived for free cyanide can be used to screen in other areas of the wider site.

## 8.1 Result of the Risk Assessment

The maximum measured concentrations of free cyanide in soil and groundwater during previous phases of work (Enviros 2008, Shadbolt 2011 and Arcadis 2020a), have been compared to the human health assessment criteria derived as part of this report in Table 2, presented in Appendix B. Concentrations of free cyanide in soil and groundwater were not measured in excess of the GAC derived.

Based on the results of the modelling, the risk to commercial workers from measured concentrations of free cyanide in soil and groundwater beneath the site is not significant.

# 9 Summary and Conclusions

Following on from the most recent ground investigation undertaken earlier this year (Arcadis 2020a), the findings of the remediation options appraisal (Arcadis 2020b) and the collection of additional groundwater and surface water data (Arcadis 2020c) a detailed review of the CSM at the Prairie site and an assessment of the risk to identified receptors has been undertaken.

## 9.1 Human Health

The risk to future commercial workers from concentrations of contaminants via the direct contact and dust inhalation pathways is to be mitigated using a clean cover system (Arcadis 2020b). Following the findings of Arcadis 2020a, concentrations of volatile compounds (naphthalene and free cyanide) have been further considered as part of this assessment, to provide confirmation of the remediation strategy.

Further review of the concentrations of naphthalene measured in soil above the GAC in Arcadis 2020a, indicates that the concentrations are associated with tar or NAPL. Under the remediation strategy (Arcadis 2020b) '*Materials impacted with NAPL and tar should not be reinstated due to being a primary source of contamination. The impacted material will be required to be consigned to a treatment process to remove the NAPL element or disposed of at an appropriate waste facility under duty of care'.* As such it is anticipated that these soils would be removed/treated, removing the source and reducing the concentrations of naphthalene to acceptable levels, below the GAC.

No applicable GAC was identified for free cyanide as part of Arcadis 2020a to assess both the direct contact and vapour pathways, with only a GAC (based on international criteria) available for the direct contact pathways. As such, an assessment was derived for free cyanide as part of this report, incorporating both the direct contact and vapour pathways. The concentrations of free cyanide measured in soil and groundwater at the site were not in excess of the assessment criteria derived for a generic commercial development. As such, the risk to human health from measured concentrations of free cyanide is not considered to be significant. It is anticipated that the assessment criteria in this report derived may be used on other parts of the wider former Redcar Steelworks.

## 9.2 Water Resources

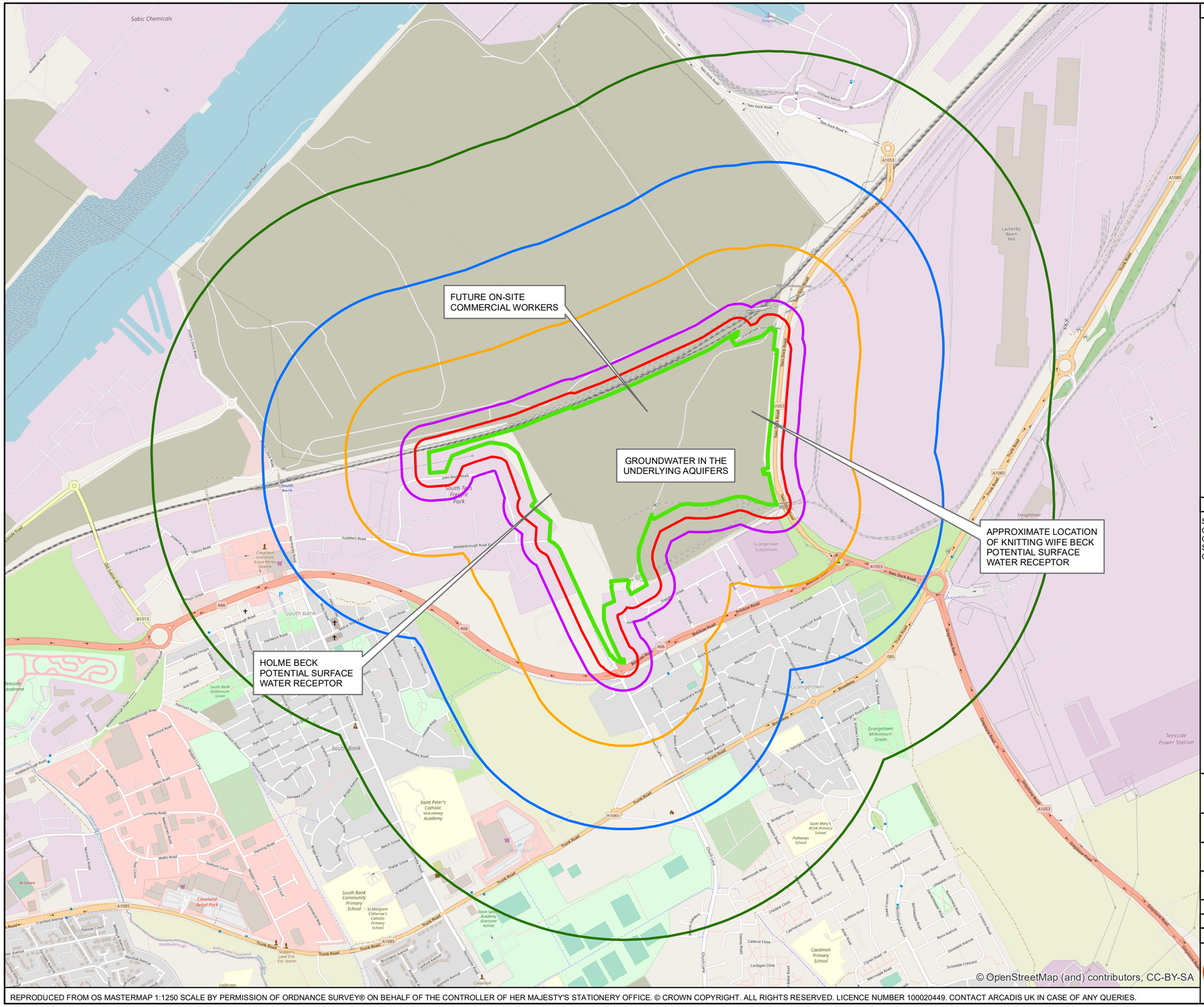
Further assessment of the applicability of water resources associated with the site (groundwater in the underlying aquifers and surface water features) as receptors of concern has been undertaken using the additional site-specific data collected.

With regard to groundwater, whilst the majority of groundwater underlying the site was indicative of freshwater, concentrations of NaCl calculated in the groundwater samples collected in June 2020 and July 2020 indicated groundwater in the bedrock in the west of the site was brackish. This suggests there may be periodic saline intrusion into the bedrock and should pumping of the groundwater be undertaken, further saline intrusion may result. The aquifers located within 20m of the ground level are generally classified as low yielding with the much deeper Sherwood Sandstone Aquifer, which is a Principal Aquifer, protected from the shallow groundwater by a significant thickness of Mercia Mudstone. The permeabilities of the underlying superficial and bedrock deposits have been tested on-site and were generally low, indicating that the aquifers would be unlikely to yield sufficient water to support a future abstraction. Additionally, the industrial setting of the site, that the site is not located with 1km of an SPZ and the potential for saline intrusion makes it unlikely that abstraction of the identified aquifers, especially for drinking water, would be desirable. On this basis, groundwater underlying the site was considered to be of low resource potential and has not been considered as a receptor of concern.

With consideration of surface water and ecological receptors, an assessment of the surface water quality as the Holme Beck flows through the site indicates that it does not vary significantly. Concentrations of CoC measured in Holme Beck were generally less than the applicable EQS with the exception of two PAH compounds which were measured at the MDL entering the site, and below MDL leaving the site. Based on this and that the bulk of the groundwater flow direction on the site is to the north, north-east and east making Holme Beck hydraulically upgradient of the majority of the site, the risk to Holme Beck is considered to be low.

The other surface water features on the site are Knitting Wife Beck and the Cross Connector. Knitting Wife Beck and the Cross Connector are currently culverted and Arcadis are not aware of plans to 'daylight' the culverts as part of the redevelopment. On this basis, provided that the culverts can be proven to be in good condition and that groundwater is not in continuity with the water in the culvert, the risk to Knitting Wife Beck and the Cross Connector from concentrations of CoC measured in groundwater is considered to be low.

# FIGURES




## LEGEND

- SITE BOUNDARY
- 50m
- 100m
- 300m
- 600m
- 1000m

## NOTES

SYMBOLS FOR BOREHOLES, TRIAL PITS AND OTHER SPECIFIC FEATURES ARE REPRESENTATIONS OF LOCATION ONLY AND UNLESS OTHERWISE SPECIFIED, DO NOT REPRESENT THE TRUE SIZE OF THE FEATURE.

0 50 100 200 300 400 500 Metres

N

TITLE:
**SITE LOCATION AND ENVIRONMENTAL SETTINGS**

SITE : **FORMER REDCAR STEELWORKS, REDCAR**

CLIENT : **SOUTH TEES DEVELOPMENT CORPORATION**

| | |
|---|---|
| PROJECT : **10035117** | **FIGURE 1** |
| DATE : 27/07/20 | DRAWN BY : BNB |
| DRG No. : 10035117-AUK-XX-XX-DR-ZZ-0113-P1 | |
| SCALE : **1 : 13,000** | PRINT : **A3** |

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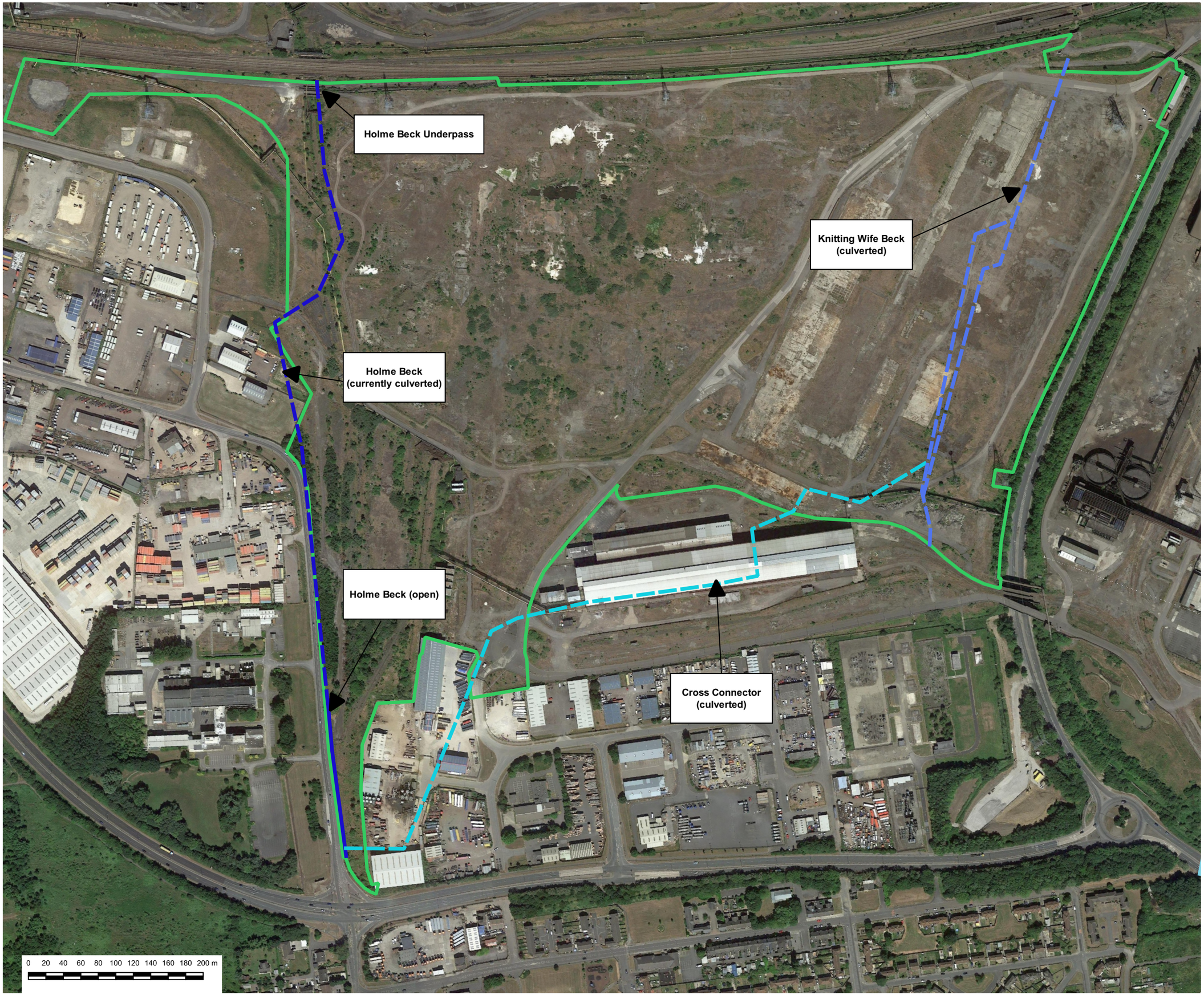


## Legend

Boundary Line

Prairie

Surface Water Features

Holme Beck

Cross Connector

Knitting Wife Beck

Notes:

The accuracy of non-Arcadis data has not been verified.

Two routes for Knitting Wife Beck are shown due to the variation in the route on different plans.



CONTACT ARCADIS IN CASE OF ANY QUERIES.

N

**Title:**
**Figure 2 - Prairie - Site Layout with Surface Water Features**

**Site: Redcar Steelworks - Prairie**

**Client:**
**South Tees Developement Company**

**Project:**
**10035117**

**Date: 22/07/2020**
**Drawn By: REB**
**DRG No: 10035117-AUK-XX-XX-DR-ZZ-0100-01-Prairie_SW**

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PRAIRIE_AUK_BH104
6 May: 2.3 m AOD
15 June: 4.64 m AOD
30 June: 2.49 m AOD

PRAIRIE_AUK_BH105
6 May: 3.66 m AOD
15 June: 3.77 m AOD
30 June: 3.75 m AOD

PRAIRIE_AUK_BH110
6 May: 3.8 m AOD
15 June: 3.96 m AOD
30 June: 3.93 m AOD

PRAIRIE_AUK_BH108D
6 May: 3.86 m AOD
15 June: 3.95 m AOD
30 June: 4.05 m AOD

PRAIRIE_AUK_BH109
6 May: 6.65 m AOD
15 June: 6.12 m AOD
30 June: 5.37 m AOD

0 20 40 60 80 100 120 140 160 180 200 m

## Legend

### Boundary Line
Prairie

### Monitoring Well Location
Monitoring Well Location

Notes:

Groundwater elevation data collected by AEG in May and June 2020.



CONTACT ARCADIS IN CASE OF ANY QUERIES.

N

**Title:**
**Figure 3a - Groundwater Elevation Plot - Monitoring Wells Screening the Bedrock**

**Site:**
**Redcar Steelworks - Prairie**

**Client:**
**South Tees Developement Company**

**Project:**
**10035117**

**Date: 27/07/2020**
**Drawn By: REB**
**DRG No: 10035117-AUK-XX-XX-DR-ZZ-0116-P1**

ARCADIS Design & Consultancy for natural and built assets

PRAIRIE_AUK_BH103
Screening Glacial Lacustrine
6 May: 5.43 m AOD
15 June: 5.97 m AOD
30 June: 5.76 m AOD

PRAIRIE_AUK_BH101D
Screening Glacial Till
6 May: 5.64 m AOD
15 June: 6.86 m AOD
30 June: 7.00 m AOD

PRAIRE_AUK_BH101S
(shallow well at same location)
Screening Glacial Lacustrine
6 May: 6.64 m AOD
15 June: 6.87 m AOD
30 June: 6.95 m AOD

PRAIRIE_AUK_BH106
Screening Glacial Till
6 May: 4.77 m AOD
15 June: 5.98 m AOD
30 June: 5.43 m AOD

PRAIRIE_AUK_BH108S
Screening Glacial Lacustrine
6 May: 6.66 m AOD
15 June: 7.72 m AOD
30 June: 8.51 m AOD

PRAIRIE_AUK_BH107
Screening Glacial Till
6 May: 7.00 m AOD
15 June: 6.95 m AOD
30 June: 7.04 m AOD

0 20 40 60 80 100 120 140 160 180 200 m

## Legend

### Boundary Line
Prairie

### Monitoring Well Location
Monitoring Well Location

Notes:

Groundwater elevation data collected by AEG in May and June 2020.



CONTACT ARCADIS IN CASE OF ANY QUERIES.

N

**Title:**
**Figure 3b - Groundwater Elevation Plot - Monitoring Wells Screening the Superficial**

**Site:**
**Redcar Steelworks - Prairie**

**Client:**
**South Tees Developement Company**

**Project:**
**10035117**

**Date: 27/07/2020**
**Drawn By: REB**
**DRG No: 10035117-AUK-XX-XX-DR-ZZ-0116-P1**

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## Legend

### Boundary Line

Prairie Boundary

### Naphthalene in Soil

- > 20 mg/kg
- 10 to 20 mg/kg
- 1 to 9 mg/kg
- 0.1 to 0.9 mg/kg
- <MDL

Notes:
Data presented is from Enviros 2008, Shadbolt 2011 and Arcadis 2020a. The accuracy of non-Arcadis data has not been verified.

Where multiple samples have been tested from the same locations or locations close together the coloured dots are linked by a grey ring.



CONTACT ARCADIS IN CASE OF ANY QUERIES.

N

**Title:**
**Figure 5 - Prairie - Distribution of Naphthalene in Soil (mg/kg)**

**Site: Redcar Steelworks - Prairie**

**Client:**
**South Tees Developement Company**

**Project:**
**10035117**

**Date: 22/07/2020**
**Drawn By: REB**
**DRG No: 10035117-AUK-XX-XX-DR-ZZ-0102-01-Prairie_Naphthalene in Soil**

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## Legend

### Boundary Line

- Prairie Boundary

### Naphthalene in Soil

- 1,900 to 37,000 mg/kg
- 1,000 to <1,900 mg/kg
- 100 to <999mg/kg
- 10 to 99 mg/kg
- 1 to 10 mg/kg
- 0.03 to 1.0mg/kg
- <MDL

Notes:

Data presented is from Enviros 2008, Shadbolt 2011 and Arcadis 2020a. The accuracy of non-Arcadis data has not been verified.

Where multiple samples have been tested from teh same location or locations close together, the coloured dots are linked by a grey ring.



CONTACT ARCADIS IN CASE OF ANY QUERIES.

N

**Title:**
**Figure 5 - Prairie - Distribution of Naphthalene in Soil (mg/kg)**

**Site: Redcar Steelworks - Prairie**

**Client:**
**South Tees Developement Company**

**Project:**
**10035117**

**Date: 15/07/2020**
**Drawn By: REB**
**DRG No: 10035117-AUK-XX-XX-DR-ZZ-0102-01-Prairie_Naphthalene in Soil**

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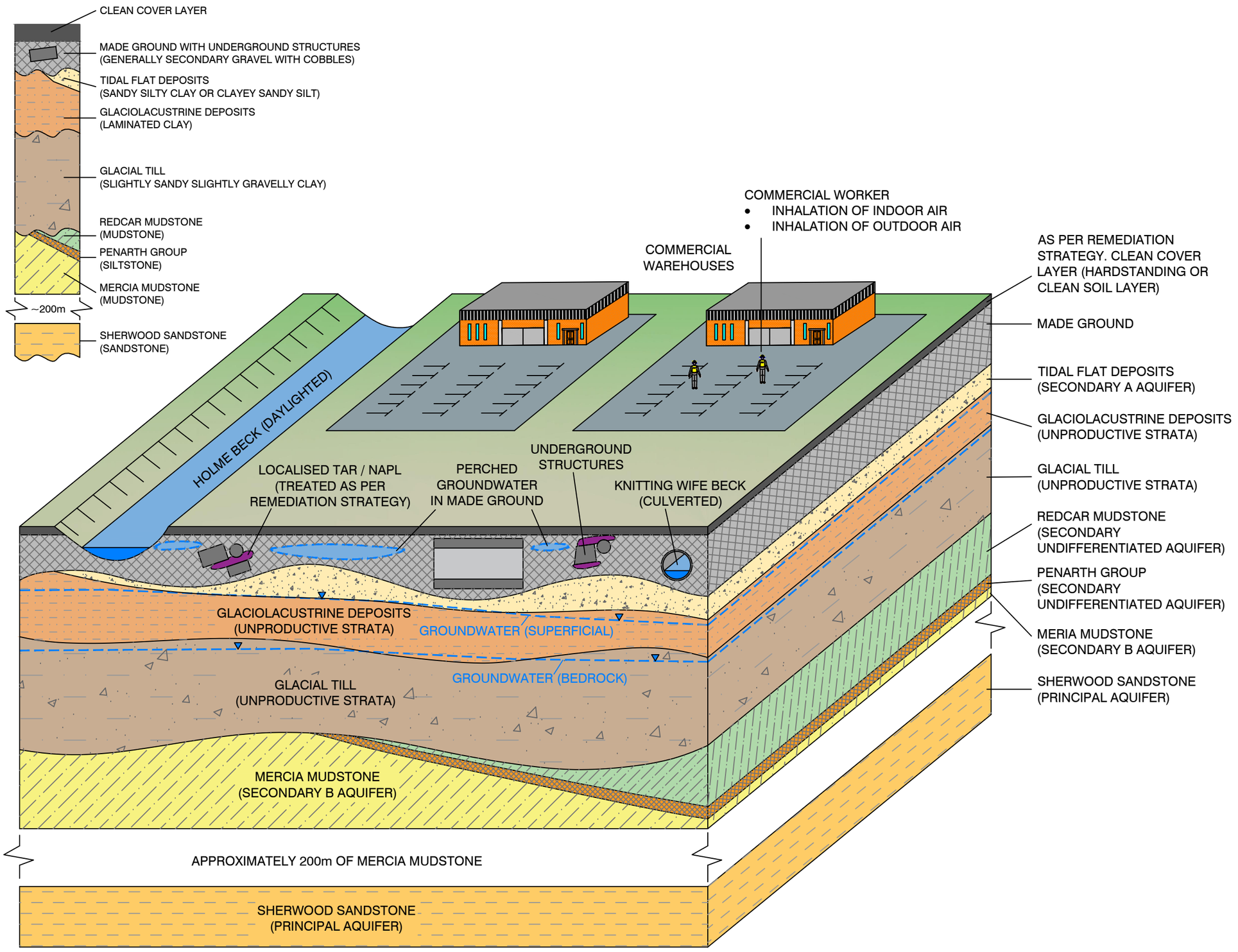
## CROSS SECTION




### KEY

### NOTES

INDICATIVE ONLY - NOT TO SCALE

THE DIRECT CONTACT PATHWAYS ARE NOT CONSIDERED TO BE ACTIVE BASED ON THE PROPOSED INSTALLATION OF A CLEAN COVER SYSTEM

| REV | DATE | COMMENT | CAD |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

TITLE: CONCEPTUAL SITE MODEL

SITE: FORMER REDCAR STEELWORKS, REDCAR

CLIENT: SOUTH TEES DEVELOPMENT CORPORATION

PROJECT: 10035117 | FIGURE 6

DATE: 17/07/20 | DRAWN: BNB | PRINT: A3

DRG.No.: 10035117-AUK-XX-XX-DR-ZZ-0115-P1

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# APPENDICES

# APPENDIX A

## Arcadis' Study Limitations

**IMPORTANT**. This section should be read before reliance is placed on any of the information, opinions, advice, recommendations or conclusions contained in this report.

1 This report has been prepared by Arcadis (UK) Limited ('Arcadis'), with all reasonable skill, care and diligence within the terms of the Appointment and with the resources and manpower agreed with South Tees Development Corporation (the 'Client'). Arcadis does not accept responsibility for any matters outside the agreed scope.

2 This report has been prepared for the sole benefit of the Client unless agreed otherwise in writing. otherwise in writing. The contents of this report may not be used or relied upon by any person other than this party without the express written consent and authorisation of Arcadis.

3 Unless stated otherwise, no consultations with authorities or funders or other interested third parties have been carried out. Arcadis is unable to give categorical assurance that the findings will be accepted by these third parties as such bodies may have unpublished, more stringent objectives. Further work may be required by these parties.

4 All work carried out in preparing this report has used, and is based on, Arcadis' professional knowledge and understanding of current relevant legislation. Changes in legislation or regulatory guidance may cause the opinion or advice contained in this report to become inappropriate or incorrect. In giving opinions and advice, pending changes in legislation, of which Arcadis is aware, have been considered. Following delivery of the report, Arcadis has no obligation to advise the Client or any other party of such changes or their repercussions.

5 This report is only valid when used in its entirety. Any information or advice included in the report should not be relied upon until considered in the context of the whole report.

6 Whilst this report and the opinions made are correct to the best of Arcadis' belief, Arcadis cannot guarantee the accuracy or completeness of any information provided by third parties. provided by third parties. Arcadis has taken reasonable steps to ensure that the information sources used for this assessment provided accurate information, and has therefore assumed this to be the case.

7 This report has been prepared based on the information reasonably available during the project programme. All information relevant to the scope may not have been received.

8 This report refers, within the limitations stated, to the condition of the Site at the time of the inspection. No warranty is given as to the possibility of changes in the condition of the Site since the time of the investigation.

9 The content of this report represents the professional opinion of experienced environmental consultants. Arcadis does not provide specialist legal or other professional advice. The advice of other professionals may be required.

10 Where intrusive investigation techniques have been employed they have been designed to provide a reasonable level of assurance on the conditions. Given the discrete nature of sampling, no investigation technique is capable of identifying all conditions present in all areas. In some cases the investigation is further limited by Site operations, underground obstructions and above ground structures. Unless otherwise stated, areas beyond the boundary of the Site have not been investigated.

11 If below ground intrusive investigations have been conducted as part of the scope, safe location of exploratory holes has been carried out with reference to the Arcadis ground disturbances procedure. No guarantee can be given that all services have been identified. Additional services, structures or other below ground obstructions, not indicated on the drawing, may be present on Site.

12 Unless otherwise stated the report provides no comment on the nature of building materials, operational integrity of the facility or on any regulatory compliance issues.

13 Unless otherwise stated, an inspection of the Site has not been undertaken and there may be conditions present at the Site which have not been identified within the scope of this assessment.

14 Unless otherwise stated, samples from the Site (soil, groundwater, building fabric or other samples) have not been obtained.

15 Arcadis has relied upon the accuracy of documents, oral information and other material and information provided by the Client and others, and Arcadis assumes no liability for the accuracy of such data, although in the event of apparent conflicts in information, Arcadis would highlight this and seek to resolve.

16 Unless otherwise stated, the scope of works has not included an environmental compliance review, health and safety compliance review, hazardous building materials assessment, interviews or contacting Local Authority, requests for information to the petroleum officer, sampling or analyses of soil, ground water, surface water, air or hazardous building materials or a chain of title review.

17 Unless otherwise stated, this assessment has considered the ongoing use of the Site and has not been prepared for the purposes of redevelopment which may act as a trigger for Site investigation and remediation works not needed for ongoing use.

# APPENDIX B

## Free Cyanide Human Health Risk Assessment

# Human Health Risk Assessment and Evaluation

## A. Model Selection

There are a number of modelling tools that have been developed to help quantify the potential risk posed to human health receptors. These can be adapted to incorporate the guidance presented by the EA on assessing potential chronic health effects from land contamination. The modelling tools include:

| | |
|---|---|
| CLEA v.1.07 | CLEA v.1.07 is an excel-based modelling tool implementing the guidance within the Contaminated Land Exposure Assessment (CLEA) methodology released by the EA. It enables quantification of levels and calculation of SSAC for CoC present in soils beneath a site. The model can also estimate the risk from measured concentrations from additional source media, including soil gas, but not from groundwater. The model is deterministic. |
| SNIFFER v.1.02 | This excel-based modelling tool was developed by the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) in 2003, and implements the guidance presented within the "Method for Deriving Site Specific Human Health Assessment Criteria for Contaminants in Soil" (SNIFFER, 2003). Since the Environment Agency of England and Wales released the updated guidance as part of the CLEA methodology in January 2009, the assumptions inherent within the SNIFFER model mean that it is less easy to adapt to the UK methodology for assessing land contamination. However, SNIFFER does not model vapour intrusion and vapour emission using appropriate sub-models – which are pathways of concern. |
| RISC v.5 | Risk Integrated Software for Clean-ups (RISC - version 5) is a proprietary modelling tool. Although originally based on the Risk Based Corrective Action (RBCA) methodology (ASTM International (ASTM) Designation E1739-95 and E2081-00), its flexibility allows it, in part, to be adapted to implement the guidance published by the Environment Agency.<br>The tool can be used to model on-site exposure to a range of source media, including groundwater. The vapour migration pathway to indoor air is assessed via the Johnson and Ettinger sub-model, as recommended by the CLEA methodology. |
| RBCA 2.6 | Risk Based Corrective Action Toolkit for Chemical Releases (RBCA – version 2.6) is a second proprietary modelling tool that incorporates the Risk Based Corrective Action (RBCA) methodology. It can be adapted to an extent to implement the guidance published by the Environment Agency, and the vapour migration pathway to indoor air is assessed via the Johnson and Ettinger sub-model, as recommended by the CLEA methodology. However the model compares the predicted air concentration to a defined acceptable air concentration, rather than calculating a dose and comparing to a tolerable daily soil intake for inhalation pathways. This requires alteration of the exposure duration within the model to ensure that the assumptions inherent in the CLEA methodology are incorporated into the assessment of the vapour migration pathways. |

**Assessment of Soil**

For the purpose of deriving a GAC for soil for free cyanide, the CLEA (v1.07) model has been used in conjunction with the RBCA (v2.6) model. CLEA has been used to assess exposure from the direct contact pathways (direct soil and dust ingestion, dermal contact and dust inhalation) while RBCA has been used to assess the vapour pathways. While CLEA has the functionality to assess exposure from both the direct contact and vapour pathways, it is only able to do so in relation to compounds incorporating an organic carbon partition coefficient [Koc]). No appropriate Koc value has been identified in relation to free cyanide, with only a partition coefficient (Kd) value identified. RBCA has the ability to assess exposure from the vapour pathways with either a Kd or Koc value, and as such, RBCA has been selected to assess the vapour pathways in relation to soil.

**Assessment of Groundwater**

While CLEA has the functionality to assess the risk to human health from soil, it does not consider the risk to human health from groundwater, as such RBCA (v2.6) has been selected to assess the vapour pathway in relation to groundwater. Additionally, RBCA has the ability to assess exposure from the vapour pathways with either a Kd or Koc value, making it appropriate for assessing the risk to human health from free cyanide.

# B. Methodology

## Modelling Approach

In order to derive evaluation criteria, or GAC, for on-site commercial workers, an assessment of the level of human exposure to the CoC is undertaken. In CLEA, this is undertaken by predicting a daily average intake for each exposure pathway assessed, with the predicted average daily intake compared to an acceptable daily intake, or a health criteria value. In RBCA, a concentration in air is predicted (for both the indoor and outdoor vapour inhalation pathways), which is then compared to a defined acceptable air concentration.

The ratio of exposure to toxicity is defined as a Hazard Index (CLEA) or Hazard Quotient (RBCA) model, and for an individual chemical and exposure pathway is calculated as follows:

HQij = TTEij / TDSIij (Threshold compounds)

HQij Hazard quotient / index for chemical i, exposure pathway j.

TTEij Total toxicant exposure / Average daily intake for chemical i, exposure pathway j.

TDSI Reference dose / concentration for chemical i, exposure pathway j.

Hazard quotient / indices above 1.0 indicate the potential for adverse health effects and suggest the need to undertake a further level of investigation or action. The human health GAC are defined using a hazard index of 1.0 at the point of exposure and back-calculating, using fate and transport models where necessary, to determine the contaminant level which is acceptable beneath the site in soils and /or groundwater.

The GAC derived for the individual exposure pathways are then combined following the approach outlined in Science Report 3 (Environment Agency, 2009b), to give an additive GAC which results in a sum hazard quotient of 1.0 across all modelled pathways for an environmental medium.

## Selection of Physical and Building Parameters

It is anticipated that free cyanide will be identified in parts of the wider Redcar Steel Works development area. The assessment criteria derived for free cyanide have been modelled using generic characteristics so that they can be used as screening criteria in other areas of the site.

Whilst a redevelopment plan for the site and the wider development has not been confirmed, it is assumed that the site will be redeveloped for a commercial/industrial end use. The risk assessment has assumed a generic pre-1970s commercial office as defined by CLEA (EA 2009) in the modelling of the risk to human health. This is consistent with the derivation of Soil Guideline Values, and is additionally consistent with the building type used in the Land Quality Management (LQM) Suitable for Use Level (S4UL) derivation (which have been adopted as screening criteria for this site – Arcadis 2020a). The soil characteristics have been adopted from that of a sandy loam, which are again consistent with those presented for the derivation of SGV by the EA and the LQM S4UL.

The physical and building parameters used in the modelling are presented in Appendix B.1 for completeness.

## Selection of Exposure Parameters

In line with the active pathways identified in Section 6 of the Detailed CSM Review, the following exposure pathways were considered in the risk assessment:

- Inhalation of indoor air impacted by a soil or groundwater source*; and,
- Inhalation of outdoor air impacted by a soil or groundwater source*.

* Modelled using RBCA.

The direct contact pathways for free cyanide were not considered to represent a risk based on screening criteria presented by the US EPA (as presented in Arcadis 2020a), and additionally due to the planned remedial strategy (where a cover system will be implemented, breaking the pathway). However, to provide a consistent and robust approach in the derivation of GAC, the following exposure pathways have been modelled in line with the UK CLEA methodology:

- Inhalation of indoor dust impacted by a soil source*;
- Inhalation of outdoor dust impacted by a soil source*;
- Direct contact exposure with soils*

* Modelled using CLEA

The pathways were modelled in relation to a 16-65 year old female representing a typical commercial worker.

The exposure parameters used in the modelling are presented in Appendix B.2.

### Selection of Chemical and Toxicological Parameters

The human health risk assessment has been undertaken for free cyanide. While cyanide is not an uncommon compound, this risk assessment is concerned with free cyanide (CN-) and specifically the potential formation of hydrogen cyanide (HCN) gas. A literature review has been undertaken to select appropriate parameters for the fate and transport of HCN; the majority of the chemical characteristics were obtained from the National Center for Biotechnology Information accessed via PubChem.

The chemical and toxicological parameters used in the model are presented in Appendix B.3 along with the sources of this information. Where data on HCN gas was not available, parameters for cyanide were used.

## C. Development of Human Health SSAC

The soil and groundwater SSAC defined for the protection of human health are presented in the Appendix B Table 1.

The CLEA output for commercial worker (direct contact pathways) is presented as Appendix B.4, with an example RBCA output for on-site commercial workers and indoor air also presented in Appendix B.4.

## D. Human Health Risk Estimation and Evaluation

The maximum measured concentrations of CoC in soil and groundwater during previous phases of work (Enviros 2008, Shadbolt 2011 and Arcadis 2020a), have been compared to the human health SSAC in the Table 2 presented in Appendix B.4. Concentrations of free cyanide in soil and groundwater not measured in excess of the SSAC derived.

Based on the results of the modelling, the risk to commercial workers from measured concentrations of free cyanide in soil and groundwater beneath the site is not significant.

## E. Assumptions, Limitations and Data Gaps

The risk assessment defined to offer protection to the identified receptors is based on current best practice and is defined using the site investigation data available at the present time. Modifications to the conceptual model, such as the collection of additional site data or confirmation of the redevelopment plan for the site may result in changes to the risk assessment defined here.

## F. References

Department for Environment, Food and Rural Affairs (DEFRA) & Environment Agency, 2002. Contaminants in Soil: Collation of toxicological data and intake values for humans. Inorganic cyanide. Environment Agency.

DEFRA & Environment Agency (EA), 2004. Model Procedures for the Management of Land Contamination (R&D Publication CLR 11).

DEFRA, 2012. Environmental Protection Act 1990: Part 2A Contaminated Land Statutory Guidance.

DEFRA & Environment Agency (EA), 2019. Land Contamination: Risk Management which came into force in June 2019.

Environment Agency, 2009a. Human health toxicological assessment of contaminants in soil. Science Report – SC050021/SR2.

Environment Agency, 2009b. Updated technical background to the CLEA model. Science Report – SC050021/SR3.

Health Canada, 2007. Federal contaminated site risk assessment in Canada. Part I: Guidance on human health preliminary quantitative risk assessment (PQRA).

US EPA, 2010. Toxicological Review of Hydrogen Cyanide and Cyanide Salts (CAS No. various), In Support of Summary Information on the Integrated Risk Information System (IRIS) (No. EPA/635/R-08/016F). US Environmental Protection Agency (Washington DC).

# TABLES



# APPENDIX

| Table 1 | | | | |
|---|---|---|---|---|
| **Generic Assessment Criteria (GAC) for Free Cyanide** | | | | |
| Contaminant of Concern | Human Health GAC for Soil | | | Human Health GAC for Groundwater |
| | Future Commercial Worker | | | Future Commercial Worker |
| | Vapour Inhalation | Direct Contact | Combined | Vapour Inhalation |
| | mg/kg | mg/kg | mg/kg | µg/l |
| Free Cyanide | 78 | 444 | 66 | 18,000 |

**Notes:**

GAC Generic Assessment Criteria

**Table 2**

**Comparison of Maximum Concentration of Free Cyanide Measured in Different Phases of Work with GAC**

## Soil

| Phase of Work | Human Health GAC (mg/kg) | Arcadis 2020a | Shadbolt 2011 | Enviros 2008 |
|---|---|---|---|---|
| Sample Identity | | PRAIRIE_AUK_TP182_SO_0090 | Shadbolt11_TP04_0.1 | Enviros07_TP30_0.5 |
| Sample Date | Future Commercial Worker - Combined | 09/04/2020 | 05/07/2011 | 11/12/2007 |
| Sample Depth | | 0.9 m bgl | 0.1 m bgl | 0.5 m bgl |
| Free Cyanide | 66 | 4.5 | 16.2 | 6 |

## Groundwater

| Phase of Work | Human Health GAC (µg/l) | Arcadis 2020c | Arcadis 2020a | Enviros 2008 |
|---|---|---|---|---|
| Sample Identity | Future Commercial Worker - Vapour Inhalation | PRAIRIE_AUK_BH110_GW_190620 | PRAIRIE_AUK_BH103_GW_050520 | WS7 |
| Sample Date | | 19/06/2020 | 05/05/2020 | 18/01/2008 |
| Free Cyanide | 18,000 | 240 | 86 | 130 |

**Notes:**

| | |
|---|---|
| GAC | Generic Assessment Criteria |
| m bgl | meters below ground level |
| | Concentrations not in excess of the GAC |

| Appendix B.1 | | |
|---|---|---|
| **Physical and Building Input Parameters** | | |
| **Parameter** | **Value** | **Source** |
| **Soil Parameters - Unsaturated Zone** | | |
| Lithology | Sandy Loam | CLEA sandy loam selected (EA, 2009b)[1] - in line with the LQM S4UL derivation |
| Distance to ground surface / building foundation from soil source (m) | 0.65 / 0.50 | In line with LQM S4UL derivation |
| Distance to ground surface / building foundation from groundwater (m) | 1 / 0.95 | Adopted from Arcadis in-house GAC (generic assumption around depth to groundwater) in the absence of a LQM appropriate value |
| Vapour permeability ($m^2$) | $3.05 \times 10^{-12}$ | CLEA Sandy loam (EA, 2009b)[1] - in line with the derivation of the LQM S4UL |
| Air content in capillary fringe | 0.01 | RISC-HUMAN for a sandy loam, 1998[2] |
| Thickness of capillary fringe (cm) | 10 | |
| **Soil Parameters - Source** | | |
| Lithology | Sandy Loam | CLEA sandy loam selected (EA, 2009b)[1] - in line with the LQM S4UL derivation |
| Total porosity ($cm^3/cm^3$) | 0.53 | |
| Water content ($cm^3/cm^3$) | 0.33 | |
| Air-filled porosity ($cm^3/cm^3$) | 0.20 | |
| Bulk Density ($g/cm^3$) | 1.21 | |
| Residual soil water content (cm3/cm3) | 0.12 | |
| **Outdoor Air Model Dimensions** | | |
| Mean annual wind speed at 10m (m/s) | 5 | EA, 2009b [1] |
| Air dispersion factor at 1.6m (g/cm2s per kg/m3) | 120 | Calculated based on data for 2ha source area near Newcastle (EA, 2009b)[1] - in line with the LQM S4UL derivation |
| Fraction of site cover ($m^2/m^2$) | 0.8 | EA, 2009b [1] - commercial development |
| **On-site Outdoor Air Box Model Dimensions - Commercial Worker** | | |
| Box Height - Air Mixing Zone Height (m) | 1.6 | The height of 16-65 year old female (EA, 2009b) [1] |
| Wind speed (m/s) | 3.01 | Wind speed calculated at 1.6m above ground level based on method presented in RISC-HUMAN methodology.[2] |
| **Future Commerical Building - Generic Pre 1970's Office [1]** | | |
| Cross sectional area of building ($m^2$) | 424 | Pre-1970 Office Building (EA, 2009b)[1] - in line with the derivation of the LQM S4UL and the derivation of Soil Guideline Values |
| Foundation Perimeter (m) | 82 | |
| Living space height (above ground) (m) | 9.6 | |
| Living space height (below ground) (m)* | 0 | |
| Pressure difference (soil to enclosed space) (Pa) | 4.4 | |
| Foundation Depth (m) | 0.15 | Commercial building (EA, 2009b)[1] - in line with the derivation of the LQM S4UL |
| Living space air exchange rate ($hr^{-1}$) | 1 | |
| Floor crack area ($cm^2$) | 1,647 | Pre-1970 Office Building (EA, 2009b)[1] - in line with the derivation of the LQM S4UL |
| Porosity in foundation cracks | 0.53 | Unsaturated zone material (Sandy loam - EA, 2009b)[1] |
| Water content in foundation cracks | 0.33 | |

Notes:

[1] Environment Agency, 2009b. Updated technical background to the CLEA model. Science Report – SC050021/SR3.

[2] Van Hall Instituut, 1998, RISC-HUMAN version 3.0.

| Appendix B.2<br>Human Health Exposure Input Parameters | | |
|---|---|---|
| **Exposure Parameter*** | **Units** | **Commercial Worker** |
| Body Weight | kg | 70 |
| Average Height | m | 1.6 |
| Exposure Duration | years | 49 |
| Exposure Frequency for Soil and Dust Ingestion | events/year | 230 |
| Exposure Frequency for Indoor Air Skin Contact | events/year | 230 |
| Exposure Frequency for Outdoor Skin Contact | events/year | 170 |
| Exposure Frequency for Inhalation of Indoor Dust and Vapour | events/year | 230 |
| Exposure Frequency for Inhalation of Outdoor Dust and Vapour | events/year | 170 |
| Occupancy Period (Indoor) | hr/day | 8.3 |
| Occupancy Period (Outdoor) | hr/day | 0.7 |
| Soil to Skin Adherence Factor Indoor | $mg/cm^2/day$ | 0.14 |
| Soil to Skin Adherence Factor Outdoor | $mg/cm^2/day$ | 0.14 |
| Soil and Dust Ingestion Rate | g/day | 0.05 |
| Inhalation Rate | $m^3/hour$ | 0.654 |

**Notes:**
Exposure parameter values presented for:
● A 16-65 year old female representing typical Commercial Worker (UK EA, 2009b).

* Where available, exposure parameters adopted from Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination (CL:AIRE 2014) and for appropriate age class, and averaged where applicable, in line with the derviation of the Land Quality Management Suitable for Use Levels

RBCA Exposure Factors – adjusted to account for difficulty with using toxicity data as an acceptable air concentration as opposed to a dose:
Indoor Air – On Site Commercial Worker Exposure Frequency = 29.9 days/year
Outdoor Air – On Site Commercial Worker Exposure Frequency = 1.87 days/year

## Appendix B3
### Chemical and Toxicological Input Parameter Values

| Contaminant | Molecular Mass | Aqeuous Solubility | Henry's Law Constant | Vapour Pressure | Soil - Water Partition Coefficient | Diffusion Coefficient in Air | Diffusion Coefficient in Water |
|---|---|---|---|---|---|---|---|
| Symbol | M | - | H | - | kD | - | - |
| Units | g/mol | mg/l | Dimensionless | mm / Hg | Log(L/Kg) | $cm^2/s$ | $cm^2/s$ |
| Free Cyanide | 27.025* | 1000000 | 0.00544* | 630* | 0.699 | 0.5214656 | 0.0000228 |

| Contaminant | Toxicological Data[1] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Data | Inhalation HCV | Data Source | Oral HCV | Data Source | Inhalation MDI | Data Source | Oral MDI | Data Source |
| Units | µg/kg-day | | µg/kg-day | | µg -day | | µg -day | |
| Free Cyanide | 0.24 | USEPA | 0.6 | USEPA | 0.06 | UK EA | 300 | UK EA |

**Notes**

[1] A comprehensive review of existing toxicity data has been undertaken, including UK, US, WHO, European and other sources, such as the IRIS database. UK data has been adopted where available, unless more recent research has identified a more appropriate value.

* Data is for hydrogen cyanide, considered to be the primary risk driver in the risk to humam health via the vapour inhalation pathway

USEPA Data taken from Toxicological Review of Hydrogen Cyanide and Cyanide Salts (CAS No. various), In Support of Summary Information on the Integrated Risk Information System (IRIS) (No. EPA/635/R-08/016F). US Environmental Protection Agency (Washington DC)

UK EA Data taken from UK Environment Agency TOX reports (EA 2002)

## STEP 5: RESULTS

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| | | Ratio of ADE to relevant Health Criteria Value | | | Soil Assessment Criteria | | | SAC Flag |
|---|---|---|---|---|---|---|---|---|
| | | oral HCV | inhal HCV | Combined | oral HCV | inhal HCV | Combined | Current SAC used for determining pathway contributions |
| Number | Chemical | (dimensionless) | (dimensionless) | (dimensionless) | mg $kg^{-1}$ | mg $kg^{-1}$ | mg $kg^{-1}$ | (unitless) |
| 1 | Cyanide (free) | 0.99 | 0.01 | 1.00 | **4.46E+02** | **7.84E+04** | **4.44E+02** | Combined |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
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| 22 | | | | | | | | |
| 23 | | | | | | | | |
| 24 | | | | | | | | |
| 25 | | | | | | | | |

| Soil Saturation Limit | Pathway Contributions (%) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | direct soil ingestion | sum of consumption of homegrown produce and attached | dermal contact (indoor) | dermal contact (outdoor) | inhalation of dust (indoor) | inhalation of dust (outdoor) | inhalation of vapour (indoor) | inhalation of vapour (outdoor) | oral background | inhalation background | Total |
| mg $kg^{-1}$ | % | % | % | % | % | % | % | % | % | % | % |
| NR | 33.31 | 0.00 | 6.66 | 9.84 | 0.22 | 0.00 | 0.00 | 0.00 | 49.82 | 0.14 | 100.00 |

## RBCA SITE ASSESSMENT

Site Name: Prairie, Redcar | Completed By: Rachel Barratt | Job ID: 10035117

Site Location: Redcar | Date Completed: 7-Jul-20 | *1 OF 1*

### SUBSURFACE SOIL (1 - 3.6 m) SSTL VALUES

Target Risk (Class A & B) 1.0E-5

Target Hazard Quotient 1.0E+0

Groundwater DAF Option:

**SSTL Results For Complete Exposure Pathways (Checked if Pathway is Complete)**

| CONSTITUENTS OF CONCERN | | Representative Concentration | ☐ Soil Leaching to Groundwater Ingestion / Discharge to Surface Water | | | ☐ Soil Leaching to Groundwater/ Groundwater Volatilization to Indoor Air | | | ■ Soil Vol. to Indoor Air | ☐ Soil Volatilization to Outdoor Air | | | Applicable SSTL | SSTL Exceeded ? | Required CRF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | On-site (0 m) | Off-site 1 (0 m) | Off-site 2 (0 m) | On-site (0 m) | Off-site 1 (0 m) | Off-site 2 (0 m) | On-site (0 m) | On-site (0 m) | Off-site 1 (0 m) | Off-site 2 (0 m) | | | Only if "yes" |
| **CAS No.** | **Name** | (mg/kg) | None | None | None | None | None | None | Commercial | None | None | None | (mg/kg) | "■" if yes | left |
| 74-90-8 | Cyanide (Free) | 1.0E+0 | | | | | | | 8.0E+1 | | | | 8.0E+1 | ☐ | <1 |

* = Chemical with user-specified data

">" indicates risk-based target concentration greater than constituent residual saturation value. NA = Not applicable. NC = Not calculated.

## RBCA SITE ASSESSMENT

Site Name: Prairie, Redcar
Site Location: Redcar

Completed By: Rachel Barratt
Date Completed: 7-Jul-20

Job ID: 10035117



## GROUNDWATER SSTL VALUES

Target Risk (Class A & B) 1.0E-5
Target Hazard Quotient 1.0E+0

Groundwater DAF Option:

**SSTL Results For Complete Exposure Pathways (Checked if Pathway is Complete)**

| CONSTITUENTS OF CONCERN | | Representative Concentration | ☐ Groundwater Ingestion / Discharge to Surface Water | | | ■ Groundwater Volatilization to Indoor Air | | | ☐ Groundwater Volatilization to Outdoor Air | | | Applicable SSTL | SSTL Exceeded ? | Required CRF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | On-site (0 m) | Off-site 1 (0 m) | Off-site 2 (0 m) | On-site (0 m) | Off-site 1 (0 m) | Off-site 2 (0 m) | On-site (0 m) | Off-site 1 (0 m) | Off-site 2 (0 m) | | | Only if "yes" |
| **CAS No.** | **Name** | (mg/L) | None | None | None | Commercial | None | None | None | None | None | (mg/L) | "■" if yes | left |
| 74-90-8 | Cyanide (Free) * | 1.0E+0 | | | | 1.8E+1 | | | | | | 1.8E+1 | ☐ | <1 |

* = Chemical with user-specified data

">" indicates risk-based target concentration greater than constituent solubility value. NA = Not applicable. NC = Not calculated.

Arcadis (UK) Limited

1 Whitehall Riverside
Leeds
LS1 4BN
United Kingdom

T: +44 (0)113 284 5300

**arcadis.com**