Hamer Quarry Complex: Bleak Hill III

Hydrogeological Risk Assessment for Waste Recovery Permit

B031732

Issued to

Cemex UK Material Limited (CEMEX)

December 2022

Document prepared by Tetra Tech Environmental Planning Transport Limited.

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Document control

Document:	Hydrogeological Risk Assessment
Project:	Hamer Waste Recovery Permit
Client:	Cemex Material UK Material Limited
Job Number:	B031732
File Origin:	

Revision:	001	**Status:**	Final
Date:	December 2022		
Prepared by: Peter Murphy	**Checked by** Adam James	**Approved By:** Conor Lydon	
Description of revision: First Issue			

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1.0 INTRODUCTION

1.1 INSTRUCTION

Tetra Tech Environment Planning Transport ('Tetra Tech') have been commissioned by Cemex UK Materials Limited ('Cemex') to undertake a Hydrogeological Risk Assessment (HRA) to support a Waste Recovery Plan (WRP) at Bleak Hill III (the site).

The location of the site is shown on Figure 1 (Drawing P6/206/2 by CEMEX, dated March 2019).

1.2 BACKGROUND

Hamer Warren Quarry, which is situated to the south of Bleak Hill Quarry, started mineral extraction in the 1930's. The original quarry has been fully worked and restored and is known as 'Hamer Landfill'. In 1988, planning permission (reference 031987) was granted for the extraction of sand and gravel deposits, and restoration of the site to agricultural land use. This area of the site is known as 'Bleak Hill I'. In 1992, planning permission (reference 046239) was granted for an extension to the North of Bleak Hill 1, which is known as 'Bleak Hill II'.

An original HRA was prepared by ESI (now 'Stantec') in c. 2004 to support the Pollution, Prevention and Control (PPC) Permit (now 'Environmental Permit') which was determined in April 2005. In 2010, the HRA was updated to support the application to vary the permit to include the extension of the site (Bleak Hill II) and was determined in August 2011.

In July 2019, a planning application (reference 19/11326) was approved by Hampshire County Council (HCC) for an extension of mineral working with progressive infilling and restoration at the site:

"Planning permission for an extension of mineral working at Hamer Warren Quarry, to extract some 600,000 tonnes of sand and gravel from Bleak Hill III, including works to create an extended haul road and back filling with inert material and progressive restoration to agriculture with increased nature conservation and biodiversity enhancements until 31 December 2025"

CEMEX seeks to gain a bespoke waste recovery permit for the permanent deposit of waste to land at the site to facilitate the restoration scheme outlined in the planning permission. CEMEX propose to import approximately 381,579m^3 (or 725,000 tonnes) of inert waste for the restoration scheme, which intends to restore the site to agricultural land with a small pond in the south east corner and with nature conservation provision and biodiversity enhancements around the boundaries.

1.3 OBJECTIVES

The principal objective of this HRA is to characterise the hydrological and hydrogeological site setting through the development of a robust Conceptual Site Model (CSM) so that the potential impacts of the proposed Deposit for Recovery on controlled waters can be fully assessed.

Further objectives of this HRA are:

- Determine baseline conditions in relation to the water environment at the site and in the wider surrounding area;
- Establish compliance with the Water Framework Directive & Groundwater Daughter Directive (GWDD), Groundwater Regulations (2009) and the Environmental Permitting Regulations (2016) (as amended);
- Develop a hydrogeological conceptual model for the site including source term, pathway receptor relationship and to define groundwater levels and direction beneath the site;
- Identify the likely risk to identified groundwater dependant receptors due to the proposed restoration of the site; and,
- Run a quantitative model using ESI's RAM software modelling tool to quantitatively model the risks associated with the proposed infilling of the eastern quarry void with imported inert waste.

1.4 LEGISLATIVE FRAMEWORK

The Water Framework Directive (WFD) (2000/EC/60) came into force in December 2000. The WFD establishes an integrated approach to the protection, improvement and sustainable use of Europe's surface waters and groundwater. It is implemented in England and Wales through the Water Environment (Water Framework Directive) (England and Wales) Regulations 2003 (as amended), known as the Water Framework Regulations.

The WFD and Groundwater Daughter Directive (GWDD) superseded the former Groundwater Directive (80/68/EEC) in December 2013 with European Union (EU) member states ensuring an equal level of protection to groundwater quality under WFD measures. In January 2021, the UK left the European Union. In the near future there may be changes to environmental law and policy, however, the UK government has committed to maintaining environmental standards and international obligations from 1 January 2021. On exiting the EU, EU environmental laws have continued to operate in UK law.

From 1 January 2021, the UK government will establish a new, independent statutory body - The Office for Environmental Protection (OEP). The OEP will oversee compliance with environmental law and will be able to bring legal proceedings against government and public authorities if necessary. The OEP will also scrutinise and advise government using environmental principles to guide future government policy.

The two main objectives for groundwater in the WFD are 'No deterioration in status' and 'Good quantitative status' of groundwater bodies by 2027 (WFD Cycle 2). Objectives for groundwater quality are subject to a more detailed description and criteria under the GWDD.

The controls to protect groundwater quality formerly dealt with under the transitory Groundwater Regulations 2009 (which superseded the Groundwater Regulations 1998) came within phase 2 of environmental permitting regime via the Environmental Permitting (England & Wales) Regulations (EPR) 2016 (as amended). The EPR regulations implements the requirements for the control of discharges to groundwater imposed by the WFD and GWDD.

This HRA has been completed using following guidance to provide a comprehensive assessment of all hydrogeological risks posed by the development:

- Department of Environment, Food & Rural Affairs, Groundwater risk assessment for your environmental permit, published 1 February 2016, Last updated 03 April 2018 (Link: https://www.gov.uk/guidance/groundwater-risk-assessment-for-your-environmental-permit);
- The Environment Agency's approach to groundwater protection, Published February 2018, Version 1.2 (Link: https://www.gov.uk/government/publications/groundwater-protection-position-statements
- Protect groundwater and prevent groundwater pollution, Published 14 March 2017, (Link: https://www.gov.uk/government/publications/protect-groundwater-and-prevent-groundwater-pollution);
- Groundwater protection technical guidance Published 14 March 2017, (Link: https://www.gov.uk/government/publications/groundwater-protection-technical-guidance);
- Groundwater activity exclusions from environmental permits Published 14 March 2017, (Link: https://www.gov.uk/government/publications/groundwater-activity-exclusions-from-environmental-permits), last updated 11 July 2018.

The EA framework for the regulation, protection and management of groundwater is set out in their *'approach to groundwater protection guidance document'* which replaced *'Groundwater Protection: Policy and Practice (GP3)'* which was withdrawn in March 2017. This guidance documents detail the technical framework to the EA approach to the management and protection of groundwater, the tools used in the assessment of groundwater, and the policy and legislation.

1.5 LIMITATIONS

This report has been prepared in accordance with the scope of works agreed between Tetra Tech and Cemex. It is subject to the Tetra Tech report conditions presented at Appendix A.

The information contained in this report is intended for the use of Cemex. Tetra Tech can take no responsibility for the use of this information by any third party or for uses other than that described in this report.

2.0 SITE SETTING

2.1 INTRODUCTION

This section of the report summarises available information collected during the desk-based study into the geology, hydrology and hydrogeology of the site and surrounding area. Furthermore, data supplied as a result of borehole investigations, subsequent monitoring and previous assessments have been reviewed and outlined herein.

Details about the proposed works and the environmental site setting are based on our review of the following reports:

- Bleak Hill Variation – Hydrogeological Risk Assessment (ESI, 2010)
- Bleak Hill Landfill – Hydrogeological Risk Assessment Review (Stantec, March 2021)

The following resources have also been referred to during the preparation of this report:

- British Geological Survey Geology of Britain Viewer - http://mapapps.bgs.ac.uk/geologyofbritain/home.html [Consulted February 2022];
- British Geology Survey GeoIndex Onshore Viewer - http://www.bgs.ac.uk/data/mapViewers [Consulted February 2022];
- National Library of Scotland Ordnance Survey Maps - Six-inch England and Wales, 1842-1952 - https://maps.nls.uk/os/6inch-england-and-wales/ [Consulted February 2022;
- Environment Agency Nitrate Vulnerable Zones map - https://environment-agency.cloud.esriuk.com/farmers/ [Consulted February 2022];
- Environment Agency Catchment Data Explorer - https://environment.data.gov.uk/catchment-planning/ [Consulted February 2022];
- DEFRA Magic Map Viewer - https://magic.defra.gov.uk/MagicMap.aspx [Consulted February 2022];
- Environment Agency Water Discharges Public Registers - https://environment.data.gov.uk/public-register/view/search-water-discharge-consents [Consulted February 2022];
- Environment Agency Historical Landfill Register - https://data.gov.uk/dataset/17edf94f-6de3-4034-b66b-004ebd0dd010/historic-landfill-sites [Consulted February 2022];
- Environment Agency Landfill Register - https://data.gov.uk/dataset/ad695596-d71d-4cbb-8e32-99108371c0ee/permitted-waste-sites-authorised-landfill-site-boundaries [Consulted February 2022];
- Environment Agency Environmental Pollution Incidents Register - https://data.gov.uk/dataset/c8625e18-c329-4032-b4c7-444b33af6780/environmental-pollution-incidents-category-1-and-2 [Consulted February 2022];
- The physical properties of major aquifers in England and Wales. British Geological Survey in partnership with the Environment Agency. Technical Report WD/97/34. Publication 8.

2.2 SITE LOCATION AND DESCRIPTION

The Site lies just inside the western boundary of Hampshire, approximately 6km north-northeast of Ringwood and 3.5km south-southwest of Fordingbridge.

The site is triangular in shape, and is located to the north of the Bleak Hill II. It covers an area of 10.2 ha and is 530m long along its long (east-west) axis its southern boundary.

The Harbridge Public Footpath 43 runs along the western boundary of the site, which separates the site from an extensive mature plantation woodland. Along its eastern boundary runs Harbridge Drove. The site has an area of approximately 10.7ha. A hedgerow runs east – west along its southern boundary, this currently separates Bleak Hill III from Bleak Hill II to the South.

Directly to the south of the site is Bleak Hill II, which in turn lies directly to the north of Bleak Hill I, and is separated from the existing site by a bridleway that runs east west between the two areas. The Bleak Hill II footprint covers an area of 15.1 ha and also occupies an approximately rectangular piece of land, 580m in length along its east-west axis, and a maximum of 290 m wide (north-south).

The Bleak Hill I site is roughly rectangular in shape, 580 m long along its long (east-west) axis and a maximum of 320 m wide (north-south). The currently permitted extraction area at Bleak Hill I is approximately 16.5 ha.

2.3 CURRENT SITE SETTING

The Site is currently in agricultural use as pastoral grassland and is classified as Agricultural Grade 3 land. It is divided into three fields by three existing low level 1.5m hedgerows crossing the site on a west to east axis. The western and eastern boundaries bounding the footpath and highway respectively are also marked by similar height low level hedgerows.

There are a number of isolated farm buildings within a 2 km radius of the site. The nearest village to the site is Alderholt, the centre of which lies 1.9 km north-northwest of the northern boundary of Bleak Hill 1. There are a number of public footpaths in the immediate vicinity of the site, a golf course is located approximately 2.6 km to the south of the site and a designated water park about 2.1 km to the east on the eastern bank of the River Avon.

The site is relatively flat, as shown in Figure 2 (Drawing P6/206/3 by CEMEX, dated March 2019). In addition, the land surrounding the site is generally a level plateau area with levels in the immediate vicinity at around 49.0-50.0m AOD. The land falls away to the east to the River Avon valley, and to the west to the afforested valley of the Sleep Brook, flowing into the Hamer Brook stream. The location of relevant surface water features is shown on Figure 8.

2.4 PROPOSED DEVELOPMENT

Th extension area at Bleak Hill III was proposed to allow mineral working at Hamer Warren Quarry, to extract some 600,000 tonnes of sand and gravel, including works to create an extended haul road and back filling with recovery material and progressive restoration to agriculture with increased nature conservation and biodiversity enhancements until 31 December 2025.

The proposed Bleak Hill III extension area would be worked in five phases (Phases 15-19) as a continuation of mineral extraction operations at Bleak Hill I and II, as shown in Figure 3 (Drawing P6/206/5 by CEMEX, dated July 2019). Extraction will progress in a clockwise direction around the site, with Phase 19 being the last to be worked. Restoration utilising inert materials mplaced as a Deposit for Recovery will follow on progressively behind.

Any mineral extracted from Bleak Hill III would be processed in the processing plant in Bleak Hill I. All existing operational areas including the quarry site office, weighbridge, silt lagoon, freshwater lagoons, aggregate recycling area, stockpiles would be retained and operated as existing.

The overall aim is to reinstate the site to Grade 3 agricultural land, to the same level and quality involving use of indigenous materials and the minimum amount of recovered restoration materials from local construction projects. The restoration scheme also includes nature conservation and biodiversity enhancements for the application site including a waterbody in the southeast of the site. The full restoration plan is shown on Figure 4 (Drawing P6/206/7 by CEMEX, dated November 2018).

2.5 SITE HISTORY

There are a number of existing and historic quarries in the vicinity of the site, with quarrying taking place to the south of Bleak Hill I since at least the early 1930's. Plummley Quarry lies some 600m to the southwest of the Site and beyond that further to the southwest lies Blue Haze Landfill. Ellingham, Blashford Lakes quarry lies some 3000m to the southeast of Hamer Warren. Prior to the appearance of these quarries, historical mapping shows that the site was used predominantly for agricultural purposes.

2.6 SURROUNDING LAND USE

The local area surrounding the site is predominantly rural, utilised for agricultural purposes. There are a number of settlements in the area, the closest of which are Harbridge Green (920 m east), Alderholt (1 km north-west), and Midgham (1.4 km north-east). A number of scattered farms are present around the site. Bleak Hill Farm and the properties known as Braemoor, and Lindens all lie immediately to the east of Bleak Hill II and Bleak Hill III. The northern boundaries of the properties of Braemoor and Lindens are approximately 25m and 65m respectively from the southern boundary of the extension site at Bleak Hill III. On the eastern side of Harbridge Drove lie a complex of properties known as Warren Park Farm and associated holiday cottages to the west.

Further to the south of Bleak Hill I lie a number of older landfills which generally accepted a wider range of wastes than Bleak Hill I or II.

2.7 REGIONAL GEOLOGY

2.7.1 Made ground

There are no Made Ground deposits shown on site on published BGS mapping.

2.7.2 Superficial Deposits

Superficial deposits are shown to be present across the site. The River Terrace Deposits are the mineral resource that has predominately been worked from within Bleak Hill I and II, where they have been found to be present up to a thickness of between 4 and 10 m.

Within Bleak Hill III, the River Terrace Deposits are approximately 5 m thick; apart from the south-eastern corner where a thickness 7 m was locally observed. Generally, the unit is described as a sequence of slightly clayey sands and flint gravels.

2.7.3 Solid Geology

Current published geological mapping (BGS, 2022) indicates that the Site is underlain by bedrock of the Parkstone Sand Member. Locally, the Parkstone Clay Member outcrops to the north-east. A wider outcrop of the Broadstone Clay Member, which underlies the Parkstone Sand Member, is also present to the east and northeast. All of these units are assigned to the Poole Formation. The Poole Formation (part of the Bracklesham Group) is underlain progressively by the London Clay Formation (Thames Group); the Reading Formation (Lambeth Group) and the Chalk Group which are present at outcrop approximately 2.5km to the north of the Site. These strata dip to the south-east with a regional dip of around 2° to 2.5°.

According to earlier geological mapping (BGS, 2004); the Parkstone Sand Member comprises fine to medium grained sand and is between 15 and 20 m thick; the Parkstone Clay Member comprises a grey clay and is up to 5 m thick; and the Broadstone Clay Member is a carbonaceous clay which is between 5 and 15 m thick. The London Clay Formation is a sandy clay with some fine-grained sand layers and is between 85 and 115 m thick. The geological mapping differentiates sandy beds within the London Clay towards its base. The Reading Formation is dominated by clays but also includes sands and is between 10 and 45 m thick. The Chalk Group is typically around 500 m thick in the Hampshire area.

2.8 SITE GEOLOGY

Cemex has historically undertaken various phases of site investigation and borehole drilling for the purposes of mineral exploration at the Site, as well as groundwater and ground gas monitoring. The information from these boreholes has allowed a detailed understanding of the geology at the Site to be developed.

The River Terrace Deposits are the mineral resource that has predominately been worked from within Bleak Hill, where they have been found to be present up to a thickness of between 4 and 10 m.

Within Bleak Hill III, which is the northernmost area, the River Terrace Deposits tend to be around 5m thick; apart from the south-eastern corner where a thickness of 7m was locally observed. Generally, the unit is described as a sequence of slightly clayey sands and flint gravels.

A stiff sandy clay, sometimes with laminations, tends to be observed beneath the River Terrace Deposits, although a clayey sand overlying the sandy clay can also locally be present. The sand is distinct and is differentiated from the River Terrace Deposits by its clay content and lack of gravel. The sandy clay and clayey sand are the upper units of the Poole Formation (i.e. what was formerly known as the Bagshot Beds). It is assumed that the clayey sand found locally at the base of the River Terrace Deposits belongs to the Parkstone Sand Member; with the underlying sandy clay belonging to the Parkstone Clay Member.

The base of the Poole Formation has only been confirmed in three boreholes along the southern boundary of Bleak Hill III and to the north of Phase 14 of Bleak Hill II. These boreholes show that the sandy clay usually identified at the base of the River Terrace Deposits is in the order of 2 m thick. The full thickness of the Poole Formation ranges in thickness from c. 2 m in the west to over 7 m in the east of the Site.

The boreholes that have penetrated the entire Poole Formation sequence indicate that it comprises a series of inter-bedded sandy clays and clayey sands. Individual beds are generally between 0.5 m and 2 m in thickness. This suggests that locally the sequence may be more variable than is suggested by the published geological mapping.

The London Clay is encountered beneath the Poole Formation; as described above it is present at a shallower depth (around 6 m or 44 m AOD) in the east of the Site than in the west (around 12 m or 38 m AOD). The London Clay is described as a stiff dark grey sandy clay with some fissuring and some sandy layers.

2.9 HYDROGEOLOGY

2.9.1 Aquifer Designations

The superficial River Terrace Deposits and the Parkstone Sand Member bedrock present within the Site are classified by the Environment Agency as Secondary A Aquifers (i.e. permeable strata supporting local water supplies). The Parkstone Clay Member and the Broadstone Clay Member are classified as unproductive strata.

In the wider area, sandy units of the London Clay are classified as a Secondary A Aquifer; the non-sand units of the London Clay are classified as unproductive strata; and the Chalk Group is classified as a Principal Aquifer as it provides a major water source at a regional scale.

2.9.2 Aquifer Properties

There is little regional information available regarding the hydrogeological properties of the Secondary A aquifers in this area (BGS, 2000). However, water is thought to migrate through the more permeable units of the Poole Formation and discharge to rivers and springs at the contact with the underlying low permeability London Clay (and possibly the Parkstone and Broadstone Clay Members). A regional transmissivity value of 20 m^2/d and a storage coefficient of 1% are reported by BGS (2000).

Values of hydraulic conductivity were calculated from variable head tests performed on a number of boreholes across the wider Site during site investigations carried out in 1990 (Aspinwall & Company, 1990). These tests gave values of hydraulic conductivity for the Poole Formation, ranging between 0.05 and 9.7 m/d, with an average of 3 m/d.

2.9.3 Groundwater Source Protection Zones

The site does not lie within a groundwater Source Protection Zone (SPZ). The closest SPZ is located approximately 2 km to the south. It is assumed that this abstraction takes water from the Chalk aquifer (i.e., beneath the London Clay). Given its distance from the site, and the thickness of the London Clay confining the Chalk there is unlikely to be a hydraulic connection.

2.9.4 Groundwater Levels

Groundwater level data across Bleak Hill I and II is summarised in the most recent Hydrogeological Risk Assessment Review Report, produced by Stantec in March 2021.

Generally, groundwater levels across Bleak Hill I and II vary from approximately 32 mAOD in the south to 48 mAOD in the north. The data also show long-term seasonal variations, with a clear indication that the maximum groundwater levels achieved on the Site were in the spring of 2014, after the extremely wet winters of 2013 and 2014. Most years show a slight seasonal variation, with water levels higher in the spring than in the autumn. Some boreholes show more seasonal variability than others. There have been no significant long-term trends noted in groundwater levels across the previously conducted HRA Reviews, and there have not been any significant changes since excavations commenced in Bleak Hill II in 2009. (Prior to this dewatering of the mineral excavations in Bleakhill I caused localised falls in groundwater levels and created depressions in the water table that changed local groundwater flow directions.)

The Site lies on a groundwater divide with groundwater on the western side flowing towards the Hamer Brook and Whitefield Bottom and groundwater on the eastern side towards the Lomer Stream and the River Avon beyond. This groundwater divide reflects the original topography of the Bleak Hill site, and is controlled by the local watercourses.

Additional groundwater plots have been created from the most recent groundwater monitoring data from 2021, including dips taken from the monitoring boreholes WOB1, WOB2 and WOB3, installed to the west, north and east of the Bleak Hill III site, respectively. These plots demonstrate the groundwater flow direction and gradient across the Bleak Hill III site (and Bleak Hill I and II) for January, March, June and December 2021. The plots can be viewed in Figure 5.

Groundwater levels seasonally vary across the Bleak Hill III site. In March 2021, the levels ranged from 48.67mAOD at WOB2 in the north, down to around 45.00 to 45.87 m AOD in the boreholes located along the southern boundary of the extension area (W204P1, W203P2, W202).

In September 2021, groundwater levels ranged from 47.29 m AOD at WOB2 in the north, down to around 44.58 to 43.2 m AOD in the boreholes located along the southern boundary of the extension area. Overall, it appears that there is a seasonal variation of groundwater levels in the order of around 1.5m across the Bleak Hill III site.

Groundwater flow direction across the extension area is generally from north to south, with some component of east and westwards flow in the eastern and western margins of the extension, similar to the groundwater divide observed across Bleak Hill I and II, but less pronounced.

The groundwater contours produced using the 2021 monitoring data are consistent with the contours produced for previous assessments and HRA reviews for Bleak Hill I and II; thus demonstrating the pronounced groundwater divide reflecting the local topography and influence of local watercourses.

2.9.5 Groundwater Quality

Groundwater quality is monitored on a quarterly basis in 22 boreholes located around the Site as part of the environmental monitoring programme. Of these monitoring boreholes, six are located around the perimeter of the Bleak Hill III site: WOB1, WOB2, WOB3, W202, W203 and W204). The boreholes monitored include those that are down-hydraulic gradient of Bleak Hill III; and boreholes that are down-hydraulic gradient of the previously worked and now restored areas of Bleak Hill I and II. A number of other boreholes are located down-gradient of other previously works and restored areas within the Hamer Warren quarry complex. Water Quality is also monitored from the groundwater abstraction point, which is moved from phase to phase according to operational requirements.

Groundwater quality at the site is described in detail in the annual reports, and also within the most recent Hydrogeological Risk Assessment Review Report (Stantec, 2021) The report compares surface water and groundwater monitoring data from the current reporting period (December 2014 – February 2021) with the previous reporting period (September 2008 - November 2014).

A summary of the groundwater quality data review is presented below. Full table and graphs of key parameters can be viewed in the HRA Review, attached as Appendix B.

Field parameters

Mean electrical conductivity (EC) is generally low at the Site but is slightly higher at BL2DIS compared to the groundwater boreholes. However, the 95th percentiles are more similar at around 750 µS/cm for field readings and 600-650 µS/cm for laboratory results. Conductivity readings are similar between field and laboratory methods. M04 continues to record the highest conductivities at 600 – 1000 µS/cm compared to most other locations recording below 400 µS/cm.

Mean pH is greater in groundwater than at BL2DIS with an average pH of 6.3-6.8 compared to 3.6-4.1. pH values are similar between field and laboratory methods. Groundwater pH is slightly acidic, which is typical of groundwater within the Bagshot Beds.

Mean temperature is also typical for groundwater but is slightly higher in groundwater than BL2DIS which is affected by surface temperatures.

Major Ions

Major ion concentrations in groundwater are generally low, with no results being above the UK Drinking Water Standards (DWS) for any of these determinands. ESI (2014) noted that the sole sample from BL2DIS for alkalinity gave a result that was below the detection limit whereas the mean value for the groundwater monitoring wells was 51.4 mg/l. During the current reporting period alkalinity has only been analysed on two further occasions at BL2DIS and was not detected on either occasion.

Figure 2.11 shows time series chloride concentrations in groundwater. Chloride concentrations generally remain low and stable during the current reporting period. The average chloride concentration for the current reporting period was 24.2 mg/l compared to a historic mean of 22.4 mg/l showing concentrations are comparable to historic concentrations. Concentrations at M04 have stabilised at around 30 mg/l since 2014 compared to the decline in concentrations during the previous reporting period. Concentrations at 301P1 and W501P1 have declined compared to the elevated concentrations between early 2010 and late 2013 at 301P1 and 2014 and 2015 at W501P1

Figure 2.12 shows time series calcium concentrations in groundwater. As with other determinands, concentrations are highest at M04. Location 301P1 shows more stable concentrations at around 60 mg/l excluding the decline in December 2020. Calcium concentrations are generally consistent with previous data with a mean value of 37.5 mg/l for the current reporting period compared to a historic mean of 36 mg/l (1995 – 2014).

Figure 2.13 shows time series potassium concentrations in groundwater. As with other determinands concentrations are highest at M04 excluding elevated concentrations at 402P1 in December 2019 and March 2020. There are also single elevated concentrations at M09 and 301P1, but the times do not coincide. Average potassium concentrations during the current reporting value are at 2.2 mg/l compared to a historic average of 2.63 mg/l showing similar concentrations are still recorded.

Site Parameters

Mean ammoniacal nitrogen concentration for groundwater is 0.67 mg/l as N, which is above the UK Drinking Water Standard (DWS) concentration of 0.39 mg/l. The 95th percentile maximum concentration is 5.11 mg/l and the maximum concentration is 15.2 mg/l indicating that there is a significant proportion of higher ammoniacal nitrogen results in the dataset. However, this is a slight decline compared to a historic average of 0.77 mg/l as N, 95th percentile of 6.9 mg/l and maximum concentration of 18.3 mg/l.

Figure 2.14 shows time series concentrations for ammoniacal nitrogen in groundwater. This shows that almost all of the elevated ammoniacal nitrogen records have occurred at M04, due to the impact of Hamer Warren Landfill. However, concentrations at this borehole have decreased during the current reporting period to between 4 and 6 mg/l. M09 recorded its highest concentration in June 2020 at 15.2 mg/l but this reduced to 1.14 mg/l in the following monitoring round. A slight increase in concentrations have been observed at 301P1 since 2012.

Ammoniacal nitrogen concentrations at BL2DIS have all been at or below the limit of detection.

Chemical Oxygen Demand (COD) is generally low, and the maximum value of 275 mg/l is likely to be an outlier as the 95th percentile concentration is 43.9 mg/l.

Suspended solids in the Bleak Hill 2 discharge are low.

Total Organic Carbon (TOC) concentrations are generally low. The elevated maximum concentration in groundwater (56 mg/l with a 95th percentile concentration of 12.8 mg/l) is attributed to higher concentrations at M04 which is impacted by Hamer Warren Landfill to the south and 402P1 which recorded elevated peaks in December 2019 and March 2020 to 56 mg/l. The current dataset is comparable to historic concentrations which had a 95th percentile of 12.4 mg/l.

Minor Ions

Minor ion concentrations are generally low in groundwater, although iron and manganese are elevated. These determinands are known to be found naturally at elevated concentrations in Bagshot Beds groundwater. 1% of lead detections and 1.6% of nickel detections were recorded above the UK DWS.

Figure 2.15 shows time series iron concentrations in groundwater. As with other determinands, iron is highest at M04 and all other locations show low and stable concentrations. A decrease in 95th percentile concentrations is recorded during the current reporting period (4 mg/l) compared to historical data (11.5 mg/l).

Figure 2.16 shows time series zinc concentrations in groundwater. Concentrations remain low and stable and there are few concentrations above 0.1 mg/l. W201P1 recorded the greatest variation in concentrations which is consistent with historic data. The average and 95th percentile zinc concentrations have slightly declined during the current reporting period (0.016 mg/l and 0.05 mg/l respectively) in comparison with historical data (0.028 mg/l and 0.1 mg/l respectively).

There were no or very few detections of antimony, cadmium, chromium, lead and zinc during the current reporting period. There have been no chromium detections since 2017.

The most frequently detected metals were manganese and nickel, which were detected in 97% and 62% of analysed samples respectively. Of these, manganese was reported as being above its respective UK DWS value in 67% of samples, although this may be naturally elevated in background groundwater in the shallow sand and gravel aquifer, as evidenced by the fact that concentrations have been recorded above the UK DWS both up-gradient (W203P2) and down-gradient (W112) of the landfill.

Organic compounds

Hydrocarbon compounds have been analysed for in groundwater for 27 samples. C21-C40 was recorded in groundwater samples above the limit of detection on eight occasions between W103 and W501P1 in 2016 – 2019. Two detections of C21-C40 were recorded in BL2DIS in 2015/2016. However, these were very low concentrations. One detection of C6-C8 was recorded in groundwater samples at W103 in September 2020.

Comparison of key groundwater quality parameters with compliance limits generated in previous HRAs produced for Bleak Hill I and II demonstrate few exceedances of the limits, with mean and 95th percentile concentrations remaining well below the limits (Table 2-1).

Table 2-1 - Groundwater quality compared to Compliance Limits (Dec 2014 to Feb 2021), from the Stantec 2021 HRA Review

Determinand	Location	Unit	Compliance Limit	Count	Min	Max	Mean	95th Percentile
Ammoniacal Nitrogen	W501P1, W103,M09, M02	mg/L	5	86	<0.06	15.2	0.547	2.06
Chloride		mg/L	100	85	11.9	181	30.6	49.9
Zinc		mg/L	1	85	<0.018	0.08	n.d.	n.d.
Ammoniacal Nitrogen	BL2DIS	mg/L	5	6	<0.06	0.06	0.035	0.0525
Chloride		mg/L	100	6	11.5	14.3	12.5	14.2
Zinc		mg/L	1	2	0.235	0.311	0.273	0.307

There have only been three breaches since the previous HRA review (Stantec 2021), once of the ammoniacal nitrogen limit (M09 on 16/06/2020 at 20 mg/l) and twice of the chloride limit (W501P1 on 16/12/2014 and 20/01/2015 at 181 mg/l and 111 mg/l respectively). The compliance limits are consistent with background groundwater quality at the Site which has not significantly changed since the previous HRA review.

2.10 HYDROLOGY

Information on the hydrology and topography for Bleak Hill was presented in detail in the original HRA's produced for Bleak Hill I and II. Updated information relevant to the Bleak Hill III extension is presented below, and up to date water quality data is also presented.

2.10.1 River Avon

The Site lies on the interfluve between the River Avon (c 1.5 km to the east) and its tributary Hamer Brook (to the west). The Avon valley includes a broad flood plain (about 500 m wide) with numerous drainage ditches flowing into the River Avon. A tributary of Hamer Brook called Whitefield Brook flows along the western side of the Site with the spring source located 60 m to the west of Bleak Hill III. It joins Hamer Brook c. 500 m to the south-west of the Site.

The surface water quality of the River Avon is monitored by the Environment Agency in the reach from Woodgreen (NGR 417000, 117600) to the confluence with Ashford Water approximately 3.5 km northeast of the site. In 2019 the physio-chemical of quality of this reach was classified as "good".

2.10.2 Hamer Brook and Whitefield Brook

Hamer Brook flows from north to south to the south-west of Bleak Hill II and III and then along the boundary of the Site to the south. Hamer Brook then joins Turmer Brook c. 1.5 km south of the Site which discharges into the River Avon about 2.2 km south-east. The main tributary of Hamer Brook is Sleep Brook, which becomes the Hamer Brook at the confluence with Whitefield Brook.

Whitefield Brook has a catchment area of 2.06 km^2 to its confluence with Hamer Brook. Hamer Brook has a catchment area of 7.24 km^2 to its confluence with the Turmer Brook.

Another smaller tributary of Turmer Brook, known locally as Lomer stream, is located on the eastern side of the Site. It rises from springs within Lomer Copse and flows eastwards towards Harbridge Green. It then flows southwards and discharges into Turmer Brook a few hundred metres downstream of its confluence with Hamer Brook. It passes c. 210 m from Bleak Hill III at its closest point in the south-eastern corner.

The location of relevant surface water features is shown on Figure 8.

2.10.3 Surface Water Quality

At Bleak Hill surface water quality has been monitored regularly at seven locations around the site. Four of these are required by the existing landfill permit (HB1, HB2, Lake 1 and HAMBL1DIS) and the remaining are undertaken voluntarily to obtain additional background data for the site (location no's 5 to 7). Monitoring has been undertaken on a quarterly and annual basis, in line with the site permit.

Surface water is monitored at the following locations:

- Two locations, HB1 and HB2, in the Hamer Brook stream to the west of the Site;
- LAKE1 – the restored lake in the Hamer Warren part of the Site;
- WB1 – a location on the stream known as Whitefield Bottom to the north-west of Bleak Hill; this stream is a tributary to the Hamer Brook and is up-stream of HB1;
- At three locations, S1, S2 and S3, in the small stream to the east of the Site, known locally as the Lomer Stream;
- HAMBL1DIS – the surface water discharge from the dewatering of the sand excavation into LAKE1; and
- BL2DIS – abstraction point for Bleak Hill 2; water discharged may be to either on-site lagoons in Bleak Hill 1 or into LAKE1.
- WB1 and S1 are the upstream locations for the Bleak Hill 2 landfill on these two surface water systems.

Water level data is sampled at the surface water monitoring reports on a quarterly basis. Reference should be made to the most recent *Hydrogeological Risk Assessment Review Report*, produced by Stantec in March 2021, which compares recent trends in surface water quality with past data. A summary of surface water quality taken from the most recent HRA review follows:

Results have been compared to the Environmental Quality Standards for Fresh Waters (EQS FW). These data show a good quality surface water. Electrical conductivity is moderate, and pH is neutral which is consistent *with historical data. LAKE1 has recorded an increase in conductivity from 2014 to 2018 reaching a maximum value of 403 µS/cm at this location, followed by a decline during 2019 and the start of 2020. Major ions are present at modest concentrations.*

The mean ammoniacal nitrogen concentration is low at 0.067 mg/l. HB1 has mostly recorded the highest concentrations in recent years at up to 0.68 mg/l which is reflected in the 95th percentile concentration which is 0.24 mg/l. These values are similar to those historically recorded.

Chloride concentrations are generally low. Concentrations were on average 22.1 mg/l, with a maximum concentration of 43.9 mg/l. These are considered to be normal for local surface waters, and the data are very similar to that from previous years with a historic mean of 22.3 mg/l and maximum of 114 mg/l.

BOD, COD and TOC are all present at low concentrations.

Metal concentrations are generally low. Lead, cadmium, chromium and antimony have not been detected since December 2014 and the present day. Copper, iron and zinc were recorded above the EQS but on less than 10% of occasions. Manganese and nickel recorded concentrations above the EQS on 11% and 29% of occasions respectively. All the higher manganese concentrations were recorded at WB1 which recorded the maximum concentration of 1.79 mg/l in September 2019 and similarly the higher nickel concentrations were predominantly recorded at HB1 and WB1.

In comparison to surface water quality statistics calculated in the last HRA review, major ion concentrations have remained similar or have slightly declined except for sulphate. This is due to the increasing trend at LAKE1 recorded from 2014 to 2018 as shown on Figure 2.17. The Bleak Hill Landfill: Hydrogeological Risk Assessment Review Page 32 Report Reference: 330201712R1 Report Status: Final Report increase of sulphate at LAKE1 is likely to be due to the pumping of the dewatering water from the excavation at Bleak Hill 2 into the lake which has previously been in contact with the Bagshot Clays. Sulphate follows the same trend as electrical conductivity at LAKE1. Concentrations have since declined throughout 2019 and the start of 2020 but a sharp increase was observed from June to August 2020 from 75.5 mg/l to 94.1 mg/l. However, this still shows a decrease in concentrations compared to 2017, 2018 and 2019. The highest concentration of sulphate to date on Site was 189 mg/l in HAMBL1DIS in December 2015.

2.10.4 Rainfall

The original HRAs for Bleak Hill I and Bleak Hill II used data from Meteorological Office Rainfall and Evapotranspiration Calculation System (MORECS) Square 181. MORECS data for the period 1961 to 1990 were used and these data are considered to remain appropriate for use in this HRA.

The mean annual effective rainfall for the area is 348.5 mm, and this represents a maximum value for the amount of recharge to groundwater via rainfall.

2.11. ECOLOGICAL DESIGNATIONS

The Avon valley (containing the River Avon) located c. 1.5 km to the east of the Site is a designated Ramsar site; Site of Special Scientific Interest (SSSI) and Special Protection Area (SPA). The river itself is a designated Special Area of Conservation (SAC).

Several areas of heathland c. 2 km to the west of the Site are a designated Ramsar site, SPA and SAC known as Dorset Heathland. Cranbourne SSSI also covers similar areas.

The New Forest National Park is also located c. 3 km to the east of the Site beyond the River Avon. Much of the National Park in this area is designated as Ramsar sites, SSSI, SPA and SAC.

3.0 CONCEPTUAL SITE MODEL AND RISK SCREENING

3.1 INTRODUCTION

Geological sections of the Bleak Hill III site have been produced, based upon monitoring and mineral proving borehole logs and are shown in Figure 6. The hydrogeological conceptual model for the site follows the approach previously used in the HRAs for Bleak Hill I and II, and is shown in Figure 7.

On completion of deposition of the restoration material, a 900mm thick restoration layer will be placed over the inert soils in order to restore it to agriculture. This will comprise 300mm topsoil and 600mm subsoil, original stockpiled from the site strip, or suitable material from the on-site soil recycling process.

The Bleak Hill I and II sites are currently permitted to accept inert waste and the same waste streams will be accepted into Bleak Hill III. As such hazardous substances will not be accepted at the site. According to Environment Agency (2010a), an HRA for a restoration site is only required if the site is in a sensitive location, in which case an assessment of the risk of accidentally accepting small quantities of listed substances is required.

The EA's locational requirements for landfill sites (Environment Agency, 2008) are presented in Table 3-1 and discussed below.

Table 3-1 – Additional Criteria for determining the required level of risk

Criteria	Bleak Hill 3	Comments
Aquifer Status	Secondary A Aquifer	No major abstractions nearby
Location with respect to Source Protection Zones	Not within any SPZ	-
Location of water table with respect to the site	Site is below water table	See discussion below
Presence of surface water receptors	River Avon, Hamer Brook, Whitefield Brook, Lomer Stream and Hamer Warren Lake.	See discussion below

Similar to Bleak Hill I and II, it is anticipated that the infilled areas of the site will be partly below the water table on a seasonal basis. Groundwater contour plots constructed for the site indicate that the site is located on a groundwater divide, with both topography and surface watercourses influencing the groundwater flow direction beneath the sites. Therefore, the contribution from groundwater to baseflow in Hamer Warren Lake, Hamer Brook, Whitefield Brook, Lomer Stream and the River Avon are considered.

3.2 WATER BALANCE

Building on the hydrogeological risk assessments previously produced for Bleak Hill I and II areas of the site, the hydrogeological conceptual model for Bleak Hill III is based on a steady-state local water balance for each of the three quarried areas that is designed to represent the long term post-closure hydrogeological system at the site following restoration.

Separate water balances are required for Bleak Hill I, II and III. Bleak Hill I was not excavated entirely to the base of the London Clay, and as such flux out of the base of the site may occur. Bleak Hill II was excavated to the base of the Parkstone Sand Member and has previously been modelled with no basal flux due to the presence of the clay rich Broadstone Clay Member and London Clay at the base of the restored area.

It is understood that Bleak Hill III will be excavated to the base of the 6th River Terrace deposits, leaving the Parkstone Sand Member of the Pool Formation in place. In Bleak Hill II, the Parkstone Sand member was excavated for the production of building sand; however, it was found to be variable in thickness, and the Parkstone Sand member will not be targeted in Bleak Hill III:

Previously within Bleak Hill II the basal Parkstone Sand member has been used for a building sand, however this unit has not been proven in viable thicknesses to warrant any further investigation, with the Broadstone Clay member being present in the majority of the boreholes.

- Geological Assessment Report, Cemex, December 2018

Whilst the mineral exploration boreholes do prove the presence of the clay rich Broadstone Member in many of the boreholes across Bleak Hill III, it is assumed that some basal flux will occur through the remaining Parkstone Sand Member and more permeable sections of the Broadstone Clay Member.

Following completion and restoration of the site, dewatering will cease entirely and surface water discharge to Hamer Warren Lake will no longer occur. The water level within the restored site is therefore expected to rise following the cessation of dewatering. Under this situation, the various fluxes into and out of the restoration soils will be estimated in the model using a water balance approach, as detailed below.

3.2.1 Infiltration

The infiltration flux for each phase is calculated from the recharge rate (effective rainfall (ER)) multiplied by the surface area of the phase. Recharge is assumed to be 100% of the effective precipitation.

$$\mathbf{Q_{inf} = ER \times Area}$$

3.2.2 Flux out of site sides

For the up and down hydraulic gradient edges of each of the phases, the combined flux out of the two faces is calculated as follows;

$$Q_{up/down} = [(h_l - h_{gw} / (W/2)) \times K_{waste} \times L \times SatThick] \times 2$$

And, for the remaining sides of each of the phases, the combined flux out of the two faces is calculated as follows;

$$Q_{side} = [(hl - h_{gw} / (L/2)) \times K_{waste} \times W \times SatThick] \times 2$$

Where;

h_l = leachate head in phase

h_{gw} = groundwater head outside phase

K_{waste} = hydraulic conductivity of waste

L = Length of site (perpendicular to groundwater flow)

W = width of site (parallel to groundwater flow)

SatThick = saturated thickness of Poole Formation (Bagshot Beds)

For Bleak Hill II, which will extract all of the Poole Formation down to the low permeability London Clay, the flux out of the base is assumed to be zero. A Basal Flux is calculated for Bleak Hill I and III.

The flux in the pathway (Q_{path}) is equal to the sum of the fluxes out of the sides and base of the site. Or, if this value exceeds the infiltration flux, then Q_{path} is limited to the infiltration. This is included in the model using the following logic;

$$Q_{path} = \min(Q_{inf}, (Q_{up/down} + Q_{side} + Q_{base}))$$

3.2.3 Dilution

If the conditions are such that the permeability of the strata around the restored site leads to more water entering the source by infiltration, than is able to leave via the sides or base, this will result in surface runoff. This is calculated as follows;

$$Qrunoff = Qinf - Qpath$$

This runoff will contribute to dilution between the source and receptors, re-entering the aquifer through the permeable River Terrace Deposits. Conservatively, this dilution has not been incorporated in the model.

Dilution by groundwater flowing within the aquifer has been applied to the flux leaving Bleak Hill I and III, as some of the Poole Formation material remains in place beneath the site. This dilution flux is calculated as follows;

$$Q_{dilute\_aquifer} = K_{aq} \times I_{aq} \times M_w \times M_d$$

Where;

K_{aq} = Hydraulic conductivity of aquifer

I_{aq} = Hydraulic gradient in aquifer

M_w = Mixing width of aquifer perpendicular to groundwater flow

M_d = Mixing depth of aquifer

Dilution due to rainfall recharge to the aquifer, between the source and the receptors is incorporated in the model and is calculated as follows;

$$Q_{rainfall\_recharge} = L \times D \times ER$$

Where;

L = length of source edge perpendicular to pathway

D = Distance from source to receptor

ER = Effective rainfall

This dilution flux is approximately divided into three, so that 33% is applied to the flux from each of the Bleak Hill phases.

For the Whitefield Brook receptor (i.e. the water course itself), dilution within the water course is incorporated. A flow rate in the brook of 0.04 m^3/s is assumed (ESI, 2004). As a conservative measure, it is considered that only 50% of this baseflow is available to dilute contamination associated with Bleak Hill to allow for the fact that Whitefield Brook is upstream of the location at which the flow estimate was made and that some baseflow will be required to dilute contamination from other sources.

The remaining 50% is split between diluting the flux from three Bleak Hill Phases (i.e. only $1/6^{th}$ of the flow in the brook is applied as dilution in each of these pathways).

3.2.4 Combining the results

The model calculates separately the concentrations of the contaminants resulting from the three phases at each of the receptors. This allows the impact of each individual phase to be assessed. The fluxes are then combined, to show the cumulative impact of all three phases. This is undertaken in the model using the following equation;

$$C_{total} = (C1 \times Q1) + (C2 \times Q2) + (C3 \times Q3) / (Q1 + Q2 + Q3)$$

Where;

C_{total} = the total concentration at the receptor

C1 = concentration at the receptor resulting from Bleak Hill 1

Q1 = the flux from Bleak Hill 1 along the pathway

C2 = concentration at the receptor resulting from Bleak Hill 2

Q2 = the flux from Bleak Hill 2 along the pathway

C3 = concentration at the receptor resulting from Bleak Hill 3

Q3 = the flux from Bleak Hill 3 along the pathway

3.3 SOURCE DEFINITION

The volume of restoration soils within the site at the time of completion is expected to equal the quarried void space of approximately 476,000 m^3 in Bleak Hill I, 944,000 m^3 in Bleak Hill II, and 381,579 m^3 in Bleak Hill III.

Landfill Directive compliant inert material is currently accepted at the Bleak Hill I and II sites and the same material streams are to be accepted at Bleak Hill III. With inert material, by definition, the pollutant content of the material and any resultant leachate must be insignificant and not endanger the quality of groundwater. The same source term has been used in this HRA as was used in the HRAs submitted with the original permit applications for Bleak Hill I and II as this is considered to remain applicable.

A small recycling facility operates at the site, accepting demolition and construction waste. There is not considered to be any contamination associated with this activity and it has, therefore, not been included in the HRA, as was the case in the original application HRA for Bleak Hill I and II.

3.4 POTENTIAL RECEPTORS

Surface water receptors are considered to be the most sensitive in the context of this risk assessment. The receptors that have been considered are as follows.

- **Groundwater adjacent to Whitefield Brook.** With the proposed Bleak Hill III site, Whitefield Brook (tributary to Hamer Brook) remains the water course closest to the site. The watercourse is located cross gradient to Bleak Hill III based on groundwater contour plots, but could potentially receive some westerly flow from Bleak Hill II after having passed through Bleak Hill III. Therefore, the risk to groundwater adjacent to Whitefield Brook where it passes closest to the site is assessed.
- **Whitefield Brook.** Whitefield Brook is considered the most sensitive receptor due to its proximity to the site. The risk to surface water is therefore assessed within the water course itself.
- **Groundwater adjacent to Hamer Brook.** Hamer Brook is the water course closest to Bleak Hill I area. This could potentially receive westerly flow from Bleak Hill I. Therefore, the risk to groundwater adjacent to Hamer Brook where it passes closest to the site is assessed.
- **Hamer Brook.** Hamer Brook itself is considered a sensitive receptor due to its proximity to the Bleak Hill site. The risk to surface water is therefore assessed within the water course itself.
- **Hamer Warren Lake.** This receptor lies within Hamer Warren landfill and on occasion discharges to Hamer Brook. It is therefore considered an appropriate receptor for consideration in the risk assessment.
- **Groundwater adjacent to the Lomer Stream.** Groundwater flowing south eastwards under the Bleak Hill site is likely to discharge into the drainage ditches that are present and into the Lomer Stream.
- **Groundwater adjacent to the River Avon drainage ditch.** Groundwater flowing south eastwards under the Bleak Hill site is likely to discharge into the drainage ditches that are present and into Lomer Steam and thence into the River Avon.

- **Groundwater at the southern limit of the 20 m stand off between the Bleak Hill I phase and the adjacent old waste of the Hamer Warren site.** This receptor has been chosen as it provides an assessment of potential impacts immediately down hydraulic gradient of the site prior to the influence of the adjacent Hamer Warren site.
- **Private water supply boreholes.** Two private water supplies are located to the east and north east of the site at distances of approximately 40 m and 180 m from the installation boundary. It is understood that these are no longer used for drinking water supply but have been selected in order to give confidence that these will not be impacted by the current and proposed development, should they be required for use in the future.

3.5 PATHWAYS

There are a number of potential pathways from the source to the receptors identified above. These are discussed below. Where a source, pathway, receptor linkage is considered insignificant, or duplicate, this is highlighted and the linkage is not taken forward in the risk assessment.

3.5.1 Bagshot Beds: Whitefield Brook / Hamer Brook (groundwater and surface water receptors)

A proportion of the source term in Bleak Hill will be intercepted by groundwater flowing through the site towards Whitefield and Hamer Brooks. It is estimated that the western third of Bleak Hill lies within the groundwater catchment of these water courses. However, following the restoration of Bleak Hill with low permeability restoration material and the resultant rise in water level in the site, this proportion may increase, and it is assumed that half of the source lies within the groundwater catchment of the brooks.

For the purpose of this risk assessment the shortest route to the water course is considered (i.e. to Whitefield Brook). In reality this is clearly not the case as some discharge will instead occur to Hamer Brook further downstream.

Potential contamination migrating out of Bleak Hill will pass through the Poole Formation (Bagshot Beds). Along this pathway segment, dilution due to recharge will occur. Although there is a small part of the River Terrace Deposits saturated in the west of the site, it is conservatively assumed that all groundwater flow occurs in the Bagshot Beds. This assumption is conservative as the River Terrace Deposits have a higher permeability compared to the Bagshot Beds, affording more dilution.

Alluvium is not present at Whitefield Brook, however, at Hamer Brook, groundwater flowing in the Bagshot beds may discharge into Alluvium or Head Deposits before discharging into the Brook. Alternatively, if the permeability of the Alluvium/Head is locally low, it may discharge to the surface at the contact and flow as overland flow to Hamer Brook. However, given the uncertainty with regard to flow processes in the superficial deposits, the short travel distance and the fact that superficial deposits are not shown to be present at Whitefield Brook, which is the closest receptor, this pathway segment is conservatively ignored in the risk assessment model.

Concentrations in groundwater are assessed adjacent to Whitefield Brook. Following discharge into the Brook, any potential contamination will be diluted in the surface water as described in Section 3.2.3 above.

3.5.2 Bagshot Beds: Hamer Warren old inert waste: Bagshot Beds: Alluvium: Hamer Brook (groundwater and surface water receptors)

These pathway segments are the same as those described in Section 6.5.1. However, the total pathway length is longer, even after allowing for no pathway processes in the inert waste comprising Hamer Warren. The shorter pathway described in Section 3.5.1 has therefore been used, conservatively, in the risk assessment model and this longer pathway has been excluded.

3.5.3 Bagshot Beds: Hamer Warren old waste: Bagshot Beds: Alluvium: groundwater adjacent to River Avon drains

These pathway segment properties are similar to those described in Section 3.5.1. As described in Section 3.5.1, it is assumed that half of the flux from Bleak Hill 1, 2 and 3 migrates towards the River Avon drains.

3.5.4 Bagshot Beds: Hamer Warren old inert waste: Hamer Warren Lake

When dewatering is taking place at Bleak Hill groundwater locally flows approximately radially into the quarry void and is intermittently discharged via a surface water discharge to the lake. Data presented in a review of surface water quality conducted in the most recent HRA Review show that there is no significant issue with water quality in this discharge. Once Bleak Hill is restored, dewatering will no longer occur. Under these conditions groundwater will flow through and / or around Bleak Hill and Hamer Warren depending on the permeability contrast between the restoration soils and the Bagshot Beds. Some of this groundwater will flow within the Whitefield Brook / Hamer Brook catchment, some within the River Avon catchment and some within the lake catchment. Given the size of the lake and its position, down hydraulic gradient of Bleak Hill within lower permeability restoration material (effectively within a hydraulic shadow of the landfill sites), it is likely that the contribution of potentially contaminated water to the lake by groundwater discharge will be smaller than is currently the case due to surface water discharge.

It is, therefore, considered that the long term post closure risk to the lake will be reduced compared to the current risk during the operational phase of the site and it is not necessary to consider the impact on the lake in the risk assessment model described in Section 4.0.

It is noted that as the source term in Hamer Warren declines, so the impact on the Hamer Warren Lake due to Hamer Warren will be reduced. The phase of restoration in which the Hamer Warren Lake is situated was completed in 2000. Both the Hamer Warren and Bleak Hill sites will be uncapped and the source terms will decline relatively quickly. The groundwater contribution to the lake, derived from Hamer Warren, is considerably greater than from Bleak Hill and it is considered that Bleak Hill will not cause the lake water quality to be significantly poorer than it would have otherwise.

3.5.5 Bagshot Beds: Limit of 20 m stand off

A proportion of the source term in Bleak Hill will be intercepted by groundwater flowing in a southerly direction through the site. Potential contamination migrating out of Bleak Hill will pass through the strip of Bagshot Sands that form the stand off between Bleak Hill I and Hamer Warren. Along this pathway segment, dilution due to recharge will also occur. The minimum width of the strip of 20m has been used in the model as a conservative measure.

3.5.6 London Clay: River Avon / Chalk

A small quantity of leakage will occur through the base of the site and migrate downwards into more permeable horizons within the London Clay. It is considered that groundwater flow within the London Clay is most likely to be towards the River Avon or downwards towards the Chalk. However, the London Clay is considered to act as a groundwater barrier, when compared to the more permeable preferential pathways within the Poole Formation and River Terrace Deposits. It is considered that this does not form a significant transport pathway and this source, pathway, receptor linkage is not considered further.

3.5.7 Bagshot Beds: Private water supply boreholes

These pathway segments, are the same as those described in 3.5.5 above except that the distance to the receptors is greater. This pathway has not been considered further in the risk assessment as compliance at the limit of the 20 m stand off will also address these receptors.

3.5.8 Bagshot Beds: Lomer Stream (groundwater and surface water receptors)

These pathway segment properties are similar to those described in Section 3.5.1. As described in Section 3.5.1, it is assumed that half of the flux from Bleak Hill I, II and III migrates towards the Lomer Stream. However the total pathway length is longer. This pathway has not been considered further in the risk assessment as compliance at the limit of groundwater and surface water in Whitefield Brook will also address these receptors.

3.6 ATTENUATION LAYER

The Environmental Permitting Regulations (England and Wales) 2016 (as amended) specify that an attenuation layer to prevent leachate migration must be present at the base and sides of sites which accept inert materials for deposition. The default specification for the layer is 1 m with a permeability of 1 x 10^{-7} m/s.

At Bleak Hill I and Bleak Hill III, any downward flux from the phase will enter shallow groundwater flowing beneath the site and is accounted for in the risk assessment model. No artificially enhanced or engineered side wall or basal attenuation layer is incorporated in the risk assessment model which shows that no reliance need be placed on this aspect of engineering for Bleak Hill II and III.

An attenuation layer is required to be constructed along the base and sides of Bleak Hill II (one metre thick with a maximum permeability of 1x10-7 m/s). Construction of the AEGB is detailed in the Arup report *Bleak Hill 2 Landfill CQA Validation Report for Phase 12 (north east) Basal Geological Barrier* (August 2020) for the most recent phase.

3.7 ENVIRONMENTAL ASSESSMENT LIMITS (EALS)

The EALs used in modelling are summarised in Table 3-2.

Table 3-2 - EAL's applied in model

Receptor	EAL	Justification
Groundwater adjacent to Hamer Brook and its tributary Whitefield Brook.	UK DWS	Assessed in groundwater adjacent to the Brook.
Whitefield Brook / Hamer Brook / River Avon Dr	Fresh water EQS	Most sensitive receptor due to its proximity to Bleak Hill, therefore also assessed in the surface water course.
River Avon Drainage Ditch	Fresh water EQS	Feeds major watercourse.
Groundwater at the southern limit of the 20 m stand off.	UK DWS	In order to remain protective of groundwater.

It is noted that the Freshwater EQS for ammonium (2.66 mg/l) has been converted from the Freshwater EQS for ammonia (0.015 mg/l) using the following formula, and a pH of 7 (by reference to surface water quality data for Hamer Brook);

$$[NH_3] = \frac{10^{-9.25}}{10^{-pH}}[NH_4]$$

3.7.1 Essential and technical precautions

It is worth noting that as a conservative modelling measure, no side or basal attenuation layer has been modelled within the Hydrogeological Risk Assessment for Bleak Hill I and III.

Leachate would be generated by rainfall infiltrating through areas of open inert restoration materials and through capped and restored areas. Due to the inert nature of the proposed restoration material, there will be no polluting leachate generated at the site and therefore no leachate management or monitoring is needed.

4.0 HYDROGEOLOGICAL RISK ASSESSMENT

4.1 PROPOSED ASSESSMENT SCENARIO

One assessment scenario is necessary for the site, namely the closure of the site following the completion of the Deposit for Recovery activities at Bleak Hill. The modelling for the site considered the impact for all three phases of Bleak Hill (I, II, and III) in conjunction.

4.2 RISK ASSESSMENT MODEL

The site conceptual model has been developed based on quantifying contaminant migration from a source along each possible pathway identified. This follows the Agency's recommended approach to landfill risk assessment (Environment Agency, 2010b). This approach has been implemented in a site specific spreadsheet model based on Stantec's (formerly ESI's) commercial software package RAM3 (Risk Assessment Model v3). This software uses a spreadsheet model to solve a water balance for the site, considering as many distinct regions as required. The source of contaminant is then defined in terms of a contaminant inventory and the release of contaminants from the inventory has been quantified in a contaminant mass balance, leading to a declining source term. An advantage of the RAM software is that this contaminant mass balance can address several distinct pathways to receptors.

ESI benchmarked a number of groundwater risk assessment tools for the Agency and used a similar approach to benchmark RAM (ESI, 2001). Additionally, the equations used in RAM have been verified by comparison between direct evaluation of an analytical solution and the semi-analytic transform approach applied for more complex pathways, and by comparison with published solutions used for verification as part of the nuclear waste industry code comparison exercise INTRACOIN (Robinson and Hodgkinson, 1996).

In the case of Bleak Hill, RAM is used to address pathways of potential contaminant migration laterally through the Poole Formation to adjacent surface water and groundwater bodies. The UK DWS and freshwater EQS were used as EAL's for the groundwater and surface water compliance points respectively, as described in Section 3.7. The simple risk assessment model constructed is based on a Level 3 risk assessment (Environment Agency, 2006), which accounts for dilution in groundwater and for attenuation, dispersion, decay and retardation.

4.3 MODEL PARAMETERISATION

The current and restoration soils at the Bleak Hill site represents the contaminant source to be considered in the risk assessment. Table 4-1 presents the site geometry.

Table 4-1 – Site Geometry

Description	Bleak Hill 1 Value	Bleak Hill 2 Value	Bleak Hill 3 Value	Data Source
Surface Area	165 000 m^2	151 000 m^2	102 290m^2	From surveyed plans
Basal Area	165 000 m^2	151 000 m^2	102 290m^2	Assume equal to surface area
Typical thickness in Poole Formation and Superficial Deposits	9 m	8.5m	6m	Calculated from base of mineral and restoration contours, and site sections
Width perpendicular to groundwater flow	580 m	580m	530m	From survey plans
Void to be filled	0.476 Mm^3	0.944 Mm^3	0.409 Mm^3	CEMEX UK Ltd
Proportion of leachate that would freely drain from the soil source	30%	30%	30%	From Beavan, 1996; Robinson 1996.
Hydraulic conductivity of restoration soils	$1x10^{-7}$ m/s	$1x10^{-7}$ m/s	$1x10^{-7}$ m/s	Assumed value for inert material
Average elevation of base of site	38 m aOD	40 m aOD	43.5 m aOD	Bleak Hill 1: and 2 From site surveys showing excavation to this level. Bleak Hill 3: Estimated from proposal plans provided.
Maximum leachate head before overtopping occurs	47 m aOD	48.5 m aOD	49.5 m aOD	Estimated elevation of post completion ground level

Infiltrating precipitation percolating through the restoration soils, together with groundwater will leach potential contaminants from the source. Typical leachate concentrations in inert landfills are used for the assessment, based on the data from a literature review, discussed in the original application. These values are as previously used and accepted in the HRA for Bleak Hill I and Bleak Hill II. The source term concentrations used are presented in Table 4-2.

Table 4-2 – Source Term Values

Parameter	Value	Units	Justification
Concentration of ammonium	1	mg/l	Appropriate value for inert source term, as used in original HRAs
Concentration of chloride	100	mg/l	Appropriate value for inert source term, as used in original HRAs
Concentration of potassium	25	mg/l	Appropriate value for inert source term, as used in original HRAs
Concentration of calcium	340	mg/l	Appropriate value for inert source term, as used in original HRAs
Concentration of iron	10	mg/l	Appropriate value for inert source term, as used in original HRAs
Concentration of zinc	1	mg/l	Appropriate value for inert source term, as used in original HRAs

4.4 HYDROLOGY

Hydrological parameters are presented in Table 4-3. Effective rainfall is assumed to apply to the source and to the area between the source and the receptors.

Table 4-3 - Rainfall applied in model

Parameter	Value	Units	Justification
Effective Rainfall	348.5	mm/a	Average effective rainfall from MORECS data - See Section 2.10.4

4.4.1 Whitefield Brook

Once the leachate reaches Whitefield Brook it will undergo further dilution.

Table 4-4 - Summary of the flow-rate and baseflow index used for Whitefield Brook

Parameter	Value	Justification
Calculated flow rate	0.04 m^3 /s	ESI (2004)
Baseflow Index	0.5	Conservative estimate
Fraction of baseflow available for dilution from Bleak Hilll I & Bleak Hill II separately	0.5	Conservative estimate

4.5 PATHWAY DEFINITION

For the saturated pathways the parameters given in Table 4-5 are used for modelling.

Table 4-5 - Aquifer Parameters

Description	Bleak Hill 1 Value	Bleak Hill 2 Value	Bleak Hill 3 Value	Units	Data Source
Mean Groundwater Head	43.25	45		m aOD	Site monitoring data March 2021
Hydraulic gradient	0.010	0.010	0.0117	-	Site monitoring data March 2021
Bagshot Beds porosity		0.4		-	Mid of range for sand (LandSim 2.5 help files)
Bagshot Beds hydraulic conductivity		3		m/d	Mean of site data (Aspinwall & Company, 1990)
Tortuosity		5		-	Mid of range for sands and clays (Marsily, 1986)
Dry bulk density		1600		kg/m^3	Mid of range for gravelly sand (ConSim help files)

4.6 RETARDATION

Retardation parameters remain unchanged from those previously used for Bleak Hill 1 and 2.

Table 4-6 - Selected retardation parameters

Parameter	Decay (years)	Kd (L/kg)	Justification
Ammonium	3	0.4	Mid range for sand and gravels in Buss et al (2003)
Chloride	No decay	0	Conservative
Potassium	No decay	0	Conservative
Calcium	No decay	0	Conservative
Iron	No decay	100	Low end of range given in LandSim 2.5 suggested values
Zinc	No decay	50	Low end of range given in LandSim 2.5 suggested values

4.7 RECEPTOR DEFINITION

The parameters in Table 4-7 were used to model the receptors. As Bleak Hill III is located hydraulically up gradient of the Bleak Hill I and II, and the closest receptors, these values have remained unchanged.

Table 4-7 - Parameters for receptors applied in the model

Description	Value
Distance from edge of site to the edge of the 20 m stand off	20m
Distance from edge of site to Whitefield Brook	140m
Distance from edge of site to River Avon drainage ditch	1,300m

4.8 MODEL RESULTS

The model was run deterministically using the input parameters defined in previous sections. An electronic copy of the model is included in Appendix C. Full Model results are also appended as Appendix D.

The results of the risk assessment model for the surface water receptor at Whitefield Brook and the groundwater receptor immediately adjacent to Whitefield Brook are presented in Table 4-8 and Table 4-9 respectively, whilst the results for the River Avon drainage ditch and at the southern limit of the 20 m stand off are presented in Table 4-10 and Table 4-11.

These tables present the predicted combined concentration at the receptor at 1, 10, 100, 1000 and 10,000 years, and the applicable EAL.

Table 4-8 - Resultant concentrations at Whitefield Brook (mg/l)

Time (Years)	Ammonium	Chloride	Potassium	Calcium	Iron	Zinc
1	1.123E-13	6.197E-04	1.549E-04	2.107E-03	0.000E+00	0.000E+00
10	9.954E-04	5.361E-01	1.340E-01	1.823E+00	0.000E+00	0.000E+00
100	4.013E-07	4.698E-04	1.175E-04	1.597E-03	2.629E-21	4.204E-11
1000	1.400E-07	1.639E-04	4.098E-05	5.573E-04	4.496E-04	7.175E-05
10000	3.775E-12	4.413E-09	1.103E-09	1.501E-08	1.788E-08	1.760E-10
FW EQS	**2.660E+00**	**2.500E+02**	**1.200E+01**	**2.500E+02**	**1.000E+00**	**8.000E-03**

Table 4-9 -Resultant concentrations in groundwater adjacent to Whitefield Brook (mg/l)

Time (Years)	Ammonium	Chloride	Potassium	Calcium	Iron	Zinc
1	8.055E-13	4.425E-03	1.106E-03	1.504E-02	0.000E+00	0.000E+00
10	7.012E-03	3.752E+00	9.379E-01	1.276E+01	0.000E+00	0.000E+00
100	4.013E-07	4.698E-04	1.175E-04	1.597E-03	2.629E-21	3.015E-10
1000	1.400E-07	1.639E-04	4.098E-05	5.573E-04	3.161E-03	4.889E-04
10000	3.997E-12	4.632E-09	1.158E-09	1.575E-08	2.964E-08	1.760E-10
UKDWS	**5.000E-01**	**2.500E+02**	**1.200E+01**	**2.500E+02**	**2.000E-01**	**8.000E+00**

Table 4-10 - Resultant concentrations in River Avon Drainage Ditch (mg/l)

Time (Years)	Ammonium	Chloride	Potassium	Calcium	Iron	Zinc
1	0.000E+00	6.710E-24	1.677E-24	2.281E-23	0.000E+00	0.000E+00
10	3.345E-13	3.447E-03	8.618E-04	1.172E-02	0.000E+00	0.000E+00
100	1.728E-11	2.275E-02	5.687E-03	7.734E-02	0.000E+00	0.000E+00
1000	5.641E-12	1.723E-04	4.307E-05	5.858E-04	2.397E-18	9.658E-11
10000	1.519E-16	4.601E-09	1.150E-09	1.564E-08	1.658E-04	1.970E-05
FW EQS	**2.660E+00**	**2.500E+02**	**1.200E+01**	**2.500E+02**	**1.000E+00**	**8.000E-03**

Table 4-11 -Resultant concentrations in groundwater at the edge of the 20 m stand-off (mg/l)

Time (Years)	Ammonium	Chloride	Potassium	Calcium	Iron	Zinc
1	1.414E-04	1.292E-01	3.229E-02	4.392E-01	0.000E+00	0.000E+00
10	4.733E-05	1.561E+00	3.902E-01	5.306E+00	0.000E+00	2.253E-18
100	8.163E-08	1.013E-03	2.532E-04	3.444E-03	2.557E-05	3.319E-05
1000	2.848E-08	3.304E-04	8.259E-05	1.123E-03	3.405E-07	9.076E-06
10000	7.764E-13	8.988E-09	2.247E-09	3.056E-08	4.402E-04	2.688E-06
UKDWS	**5.000E-01**	**2.500E+02**	**1.200E+01**	**2.500E+02**	**2.000E-01**	**8.000E+00**

The individual concentrations resulting from Bleak Hill I, Bleak Hill II and Bleak Hill III in the groundwater at the 20m stand-off (closest receptor) are also presented Table 9.5 and Table 9.6 (respectively).

The concentration of Potassium contributed by Phase 1 marginally exceeds the EAL at the year 1 timeslice, with a predicted concentration of 12.09 mg/l vs an EAL of 12.00 mg/l. In the HRA completed for Bleak Hill II, this corresponding predicted concentration was 12.00mg/L, which equalled the EAL. However, with the contribution of more dilute fluxes from Bleak Hill II and Bleak Hill III, the combined predicted concentration is 3.22E-02, two orders of magnitude below the EAL.

Additionally, the predicted concentration of potassium at the receptor derived from Phase 1 is predicted to decline quickly from 12.09mg/l at year 1 to 0.412 mg/l by the year 10 timeslice. This shows that the within a very short timeframe, concentrations resulting from each phase remain below the relevant EALs, and no reliance on fluxes leaving adjacent areas are relied upon for dilution of contaminant concentrations.

Table 4-12 - Resultant concentrations in groundwater at the edge of the 20m stand-off as a result of Bleak Hill 1

Time (Years)	Ammonium	Chloride	Potassium	Calcium	Iron	Zinc
1	5.298E-02	4.838E+01	1.209E+01	1.645E+02	0.000E+00	0.000E+00
10	1.704E-02	1.648E+00	4.120E-01	5.603E+00	0.000E+00	8.439E-16
100	0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.578E-03	1.243E-02
1000	0.000E+00	1.779E-09	4.448E-10	6.048E-09	1.170E-04	2.502E-09
10000	5.273E-12	8.291E-10	2.073E-10	2.819E-09	0.000E+00	0.000E+00
UKDWS	**5.000E-01**	**2.500E+02**	**1.200E+01**	**2.500E+02**	**2.000E-01**	**8.000E+00**

Table 4-13 - Resultant concentrations in groundwater at the edge of the 20m stand-off as a result of Bleak Hill 2

Time (Years)	Ammonium	Chloride	Potassium	Calcium	Iron	Zinc
1	0.000E+00	5.114E-11	1.278E-11	1.739E-10	0.000E+00	0.000E+00
10	1.789E-04	8.808E+00	2.202E+00	2.995E+01	0.000E+00	0.000E+00
100	1.547E-03	1.794E+01	4.486E+00	6.101E+01	0.000E+00	1.442E-20
1000	5.396E-04	6.260E+00	1.565E+00	2.128E+01	2.155E-04	6.148E-03
10000	1.441E-08	1.672E-04	4.179E-05	5.684E-04	4.231E-02	1.257E-04
UKDWS	**5.000E-01**	**2.500E+02**	**1.200E+01**	**2.500E+02**	**2.000E-01**	**8.000E+00**

Table 4-14 - Resultant concentrations in groundwater at the edge of the 20m stand-off as a result of Bleak Hill 3

Time (Years)	Ammonium	Chloride	Potassium	Calcium	Iron	Zinc
1	0.000E+00	1.512E-16	3.779E-17	5.140E-16	0.000E+00	0.000E+00
10	3.654E-06	3.137E+00	7.843E-01	1.067E+01	0.000E+00	0.000E+00
100	2.987E-12	1.329E-04	3.323E-05	4.519E-04	7.612E-34	0.000E+00
1000	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.403E-08	1.764E-05
10000	3.729E-15	3.300E-10	8.251E-11	1.122E-09	8.831E-04	5.406E-06
UKDWS	**5.000E-01**	**2.500E+02**	**1.200E+01**	**2.500E+02**	**2.000E-01**	**8.000E+00**

4.9 SENSITIVITY ANALYSIS

A sensitivity analysis run was undertaken in which the amount of dilution, resulting from recharge between the source and each receptor, was halved. The combined results remained below the specified EALs, giving confidence that there is no significant risk to groundwater or surface water receptors. Results are presented in Appendix C.

5.0 REQUISITE SURVEILLANCE

The requisite surveillance for groundwater and surface water that is considered necessary and appropriate for the site is presented in the following sections. A comprehensive monitoring infrastructure is currently in place such that no additional monitoring boreholes are required.

5.1 GROUNDWATER MONITORING

The monitoring boreholes WOB1, WOB2 and WOB3 are present on the upgradient side of the Bleak Hill III extension, and boreholes W202, W203 and W204 are located on the downgradient side such that appropriate monitoring can be undertaken.

The proposed routine groundwater monitoring as required by the current permit is presented in Table 5-1 below.

Table 5-1 - Routine groundwater monitoring

Monitoring Location	Parameter	Frequency
Downgradient Boreholes: **W202**, **W203P1, W203P2,** and **W204P1 and W204P2** Upgradient boreholes: **WOB1**, **WOB2** and **WOB3**	Groundwater level (maOD) Ammoniacal Nitrogen, Chloride, Zinc. pH, electrical conductivity, alkalinity, calcium, ionic balance, iron, magnesium, manganese, TON, potassium, sodium, sulphate, TOC	Quarterly
Downgradient Boreholes: **W202**, **W203P1, W203P2,** and **W204P1 and W204P2** Upgradient boreholes: **WOB1**, **WOB2** and **WOB3**	Ammoniacal nitrogen, chloride, zinc, alkalinity, antimony, arsenic, cadmium, calcium, chromium, COD, electrical conductivity, copper, dissolved oxygen, ionic balance, iron, lead, magnesium, manganese, nickel, TON, pH, potassium, selenium, sodium, sulphate, TOC	Annually

5.2 SURFACE WATER MONITORING

The proposed surface water monitoring locations and analysis schedule for the Deposit for Recovery is summarised in Table 5-2 below.

WB1 is located to the west of Bleak Hill III at Whitefield brook. S1 is located to the east, within the upper reach of the Lomer Stream. BL2DIS is a dewatering groundwater abstraction located at the base of Bleak Hill II. All of these locations are expected to receive a component of flow from groundwater flowing through Bleak Hill III, based upon groundwater flow directions. The suites are the same as those already being used for these locations with respect to the landfill permit for Bleak Hill I and II.

Table 5-2 – Routine surface water monitoring

Monitoring Location	Parameter	Frequency
BL2DIS	Ammoniacal nitrogen, chloride, pH, electrical conductivity, iron, suspended solids	Monthly
WB1 S1	Ammoniacal nitrogen, chloride, BOD, pH, electrical conductivity, iron, suspended solids	Monthly
BL2DIS	Ammoniacal nitrogen, chloride, pH, electrical conductivity, iron, suspended solids, alkalinity, arsenic, BOD, COD, dissolved oxygen, TON, sulphate, TOC	Quarterly
WB1 S1	Ammoniacal nitrogen, chloride, BOD, pH, electrical conductivity, iron, suspended solids, alkalinity, antimony, arsenic, cadmium, calcium, chromium, COD, copper, dissolved oxygen, ionic balance, lead, magnesium, manganese, nickel, TON, potassium, selenium, sodium, sulphate, TOC, zinc	Quarterly
BL2DIS	Ammoniacal nitrogen, chloride, pH, electrical conductivity, iron, suspended solids, alkalinity, antimony, arsenic, cadmium, calcium, chromium, COD, copper, dissolved oxygen, ionic balance, lead, magnesium, manganese, nickel, TON, potassium, selenium, sodium, sulphate, TOC, zinc	Annual

5.3 CONTROL AND COMPLIANCE LIMITS

Compliance Limits (formerly 'Trigger' Limits) for groundwater have been specified in previous site permits and HRA's and are shown in Table 5-3, along with the control levels that are also applied.

Table 5-3 - Groundwater control and trigger levels

Compliance Location	Parameter	Control Level (mg/L)	Compliance Limit (mg/L)
Downgradient Boreholes: **W202**,	Ammoniacal nitrogen	1	5
	Chloride	45	100

W203P1, W203P2, W204P1, W204P2	Zinc	0.3	1

These compliance limits have been reviewed in the HRA review (Stantec, March 2021), and following the results of the latest modelling are considered to remain appropriate; no changes to the control or Compliance Limits are therefore proposed.

No surface water Control and Compliance Limits have previously been specified in the site permits for Bleak Hill I and II. This is considered to remain appropriate. Surface water quality is monitored regularly as described above and reviewed thoroughly on an annual basis. The methodology used to assess the site data against control and trigger levels is presented in the Site Operating Plan.

6.0 CONCLUSIONS

This report presents an assessment of the hydrogeological regime at Bleak Hill as the basis of a risk assessment. The assessment uses an accurate model of the relevant flow mechanisms and contaminant transport theory and is based on detailed knowledge of the hydrogeology and hydrology of the area surrounding the proposed Deposit for Recovery site.

A conceptual model of Bleak Hill I was developed for the original permit application through the interpretation of data in the vicinity of the site to provide descriptions of the geology, hydrogeology and hydrology. The original conceptual model was been reviewed and extended to take account of the proposed extension (Bleak Hill II). This report further extends the conceptual model and modelling for the third phase of the site, Bleak Hill III, for which a Waste Recovery Plan has been submitted.

A number of possible source, pathway, receptor linkages have been identified, and those considered insignificant via risk screening have been excluded.

The risk assessment approach is presented, along with data input parameters. A simple Risk Assessment model was constructed. The model considers the fate of the leachate determinands derived in the source along the transport pathway and the effects of attenuation, decay, retardation, dispersion and dilution.

6.1 COMPLIANCE WITH THE ENVIRONMENTAL PERMITTING REGULATIONS (ENGLAND AND WALES) 2016

Compliance of the Bleak Hill site with the relevant parts of the Environmental Permitting Regulations 2016 (as amended) is discussed in the following sections.

6.1.1 Accidents and their consequences

In the event of the site contributing unacceptable contamination to the groundwater the source should be capped to reduce rainwater infiltration. However, given the quantities of listed substances expected to be placed at the site, this is considered an unlikely requirement.

6.1.2 Acceptance of Simulated Contaminants

It is conceivable that the recovery materials may unintentionally contain substances not acceptable by sites classed as inert, in spite of strict waste acceptance criteria being adhered to. The HRA shows that, even if small quantities of non-hazardous substances were tipped at the site, all simulated contaminants are predicted to be present at low concentrations at environmental receptors.

Therefore the risk assessment model predicts that non-hazardous substances from the Site will not impact on the wider groundwater or surface water environment.

6.1.3 Control and Compliance Limits

Assessment and compliance of the contaminant system is quantified against the groundwater control and trigger levels.

Groundwater control and trigger levels are stipulated in the previous permits granted for Bleak Hill I and II, and are based on observed groundwater quality data for the site. These have been reviewed in light of recent data and are considered to remain applicable to the site and the proposed extension.

6.1.4 Groundwater quality

The risk assessment model shows that the Bleak Hill III recovery site is unlikely to impact upon the groundwater quality or the quality of the surface water in the Whitefield Brook, Hamer Warren Lake or the River Avon.

The maximum concentrations that may result from Bleak Hill are based on a theoretical source term. Given that the actual source term concentrations in the site are likely to be much smaller than simulated here, as strict adherence to the Waste Acceptance Criteria and Procedures will be applied, the actual resultant concentrations are likely to be much lower. It is considered extremely unlikely that a breach of the EP Regulations will occur.

This risk assessment has been completed without considering the impact of capping or lining the site, and has conclusively illustrated that the site does not pose any significant risk to groundwater or surface waters.

Figures

Figure 1: Site Location Plan

Figure 2: Site Topographic Survey

Figure 3: Phasing Plan

Figure 4: Restoration Plan

Figure 5: Groundwater Contour Plots

Figure 6: Geological Sections

Figure 7: Hydrogeological Conceptual Model

Figure 8: Surface Water Features

Appendices

Appendix A: Report Conditions

Appendix B: HRA Review (2021)

Appendix C (Digital): Model Copy

Appendix D (Digital): Model Results