Castle Hill Quarry
Hydrogeological Risk Assessment for Waste Recovery Permit

784-B043634

Issued to Castle Hill Quarry Co. Limited

Document prepared by Tetra Tech Limited.

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1.0 INTRODUCTION

1.1 INSTRUCTION

Tetra Tech Limited (‘Tetra Tech’) have been commissioned by Land & Mineral Management (‘LMM'), on behalf of Castle Hill Quarry Co. Ltd. (‘CHQ Ltd.’) to undertake a Hydrogeological Risk Assessment (HRA) to support a bespoke waste recovery permit. The permit is to be for the permanent deposit of inert waste to land to facilitate the infilling of the eastern extension area and the Old Golf Course Extension at Castle Hill Quarry.

A site location plan is included at Figure 1.

1.2 BACKGROUND

CHQC Ltd. currently operate a site known as Castle Hill Quarry at Cannington, Bridgewater, TA5 2QF. The current quarry site is centered at approximate National Grid Reference (NGR) ST 24562 40684 and comprises an active limestone quarry site. Limestone is extracted and processed on site to provide aggregates for the construction industry, carboniferous lime for agricultural use and limestone products to the animal feedstuffs industry.

This application relates to two extension areas at the quarry. The first area (known as ‘Eastern Extension’) is located to the southeast of the existing quarry and is centered at approximate NGR ST 24834 40637. The second area (known as ‘Old Golf Course Extension’) is located to the south of the Eastern Extension and is centered at approximate NGR ST 24834 40637. The location of both extension areas is shown on Drawing Number CHQC/B043634/PER/01.

CHQC are seeking to gain a bespoke waste recovery permit for the permanent deposit of inert waste to land to facilitate the infilling and restoration at the Eastern Extension and the Old Golf Course Extension Areas following the extraction of mineral.

This HRA has been prepared to support the environmental permit and to demonstrate that the site will be compliant with the Environmental Permitting Regulations 2016 (as amended) and Groundwater Regulations. These Regulations require that certain substances (Hazardous Substances) are not discharged to groundwater such that they are discernible, and that the discharge of other substances (Non-Hazardous Pollutants) is limited to prevent pollution of the water environment.

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 development on the surrounding controlled waters can be fully assessed.

This HRA builds on earlier hydrogeological work, assessments and interpretative reports undertaken by others at the wider quarry complex (including for Castle Hill Quarry, Cannington Park Quarry and the Eastern Extension).

For this HRA, outputs from previous assessments have been used to inform the HRA presented herein, in addition to contemporary data made available to Tetra Tech.

The scope of work undertaken for this HRA includes:

- Review the 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 site specific hydrogeological conceptual site model for the site including source term, pathway receptor relationship and to define groundwater levels and flow direction beneath the site
- Identify the likely risk to identified groundwater dependent receptors due to the proposed restoration of the site; and,
- Run a quantitative model using RAM software modelling tool to quantitatively model the risks associated with the proposed infilling of the site with imported inert waste.

1.4 REGULATORY CONTEXT

The Water Framework Directive (WFD) (2000/EC/60) came into force in December 2000. The Water Framework Directive establishes an integrated approach to the protection, improvement and sustainable use of Europe's surface waters and groundwater. The WFD and Groundwater Daughter Directive (GWDD) have superseded the former Groundwater Directive (80/68/EEC) in December 2013 with EU member states ensuring an equal level of protection to groundwater quality under the WFD measures. 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 Groundwater Daughter Directive (GWDD).

The Waste Framework Directive (2008/98/EC) requires member states to ensure that waste is recovered or disposed of without endangering human health and without using processes and methods which could harm the environment. One of the key aims of the Directive is to promote the better use of resources by encouraging the use of waste for beneficial purposes. To this end, recovery operations which result in waste being used in place of primary resources are to be encouraged over disposal operations which are intended to simply get rid of the waste safely.

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.

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

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://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/692989/Envirnment-Agency-approach-to-groundwater-protection.pdf)
- 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, Last updated 5 August 2021, (Link: https://www.gov.uk/government/publications/groundwater-activity-exclusions-from-environmental-permits).

2.0 ENVIRONMENTAL SETTING

2.1 INTRODUCTION

This section of the report summarises available information collected during the desk-based study of the geology and hydrogeology of the site and surrounding area. Details on the current scheme, proposed restoration and the environmental setting of the site are set out in the following reports which should be referred to during the review of this HRA.

Details on the current scheme, proposed restoration and the environmental setting of the site are set out in the following reports and resources which should be referred to during the review of this HRA.

- Castle Hill Quarry, Cannington, Somerset, Water Environment Protection Scheme, Version 2, S_CHQC_CHQ_WEPS22_00, BCL Consultant Hydrogeologists Limited, July 2022
- Castle Hill Quarry Golf Course Extension: Hydrogeological Impact Assessment, Report reference: 330201690R1, October 2021, Stantec.
- Castle Hill Quarry Environmental Statement for the Old Golf Course Extension, October 2021, Land and Mineral Management.
- Castle Hill Quarry Extension: Hydrogeological Impact Assessment Report reference: 65158R1, December 2016, ESI Ltd
- Water Management Plan for Castle Hill Quarry, Report reference: 6159 WMP D3, March 2004, ESI Ltd.
- Hydrogeological Assessment of Proposed Dewatering at Castle Hill Quarry, Report reference 6159R1D2, June 2001, ESI Ltd.

Further data sources consulted in the preparation of the HRA include the following.

- British Geological Survey mapping and geological data (BGS, 2023).
- Data provided by the Environment Agency including water quality, rainfall, and abstraction and discharge licenses.
- Details of unlicensed private water supplies from West Somerset Council and Sedgemoor District Council.
- Ordnance Survey mapping and other publicly available environmental data (UK Government, 2021a).

2.2 SITE LOCATION AND DESCRIPTION

The wider Castle Hill Quarry site is located approximately 960m northwest from the village center of Cannington in Bridgwater and is centered at National Grid Reference (NGR) ST 24562 40684.

This application relates to two extension areas at the quarry. The first area (known as ‘Eastern Extension’) is located to the southeast of the existing quarry and is centered at approximate NGR ST 24834 40637. The second area (known as ‘Old Golf Course Extension’) is located to the south of the Eastern Extension and is centered at approximate NGR ST 24834 40637. The location of both extension areas is shown on Drawing Number CHQC/B043634/PER/01.

The immediate surroundings of the site comprise predominantly of woodland and agricultural with commercial properties located to the immediate south of the proposed site.

A Scheduled Monument named 'Cynwit Castle' lies adjacent to the wider Castle Hill Quarry. A further Scheduled Monument named 'Settlement Southeast of Cannington Park' lies adjacent to the Eastern Extension area. The nearest residential properties, 1-2 Lime Kiln Cottages, lie approximately 30m southeast of the Old Golf Course Extension. These properties are in CHQC's ownership and rented to tenants.

The regional topography slopes from ~300 mAOD in the Quantock Hills lying approximately 7 km to the south-west; down to the River Parrett at ~10 mAOD (at its closest approximately 2 km north-east of the Extension). The Quantock Hills are designated as an Area of Outstanding Natural Beauty (AONB) and the River Parrett is part of the Bridgwater Bay Site of Special Scientific Interest (SSSI) and also the Severn Estuary (Special Protection Area (SPA), Special Area of Conservation (SAC) and Ramsar site).

2.3 REGIONAL GEOLOGY

The Castle Hill area's regional bedrock geology has been summarised following a review of supporting reports (BCL Hydro, 2022 and Stantec, 2021) and published geological mapping (British Geological Survey (BGS), 1984; 2021) in Table 1.

Table 1- Regional geological succession

Name	Stratigraphic Age	Thickness (m)	Lithological Description
Blue Lias Formation	Jurassic	0-60m	Thinly interbedded limestone and calcareous mudstones and siltstones
Mercia Mudstone Group (including Blue Anchor Formation)	Permo-Triassic	>300 m	Red mudstones and silty mudstones (Blue anchor Formation comprises pale green-grey mudstones and siltstones)
Helsby Sandstone Formation	Perma-Triassic	30-60m	Red fine to medium grained sandstone
Unconformity			
Rodway siltstone Formation	Upper Carboniferous	> 100m	Micaceous siltstones with thin fine to medium grained sandstones
Carboniferous Limestone Supergroup	Lower Carboniferous	>1,000 m	Fine grained, grey non-oolitic limestone and coarser grey/white oolitic limestone

2.3.1 Superficial Deposits

Superficial deposits (2) predominately comprise River Terrace Deposits and Tidal Flat deposits which tend to be confined to the routes of watercourses. These deposits pass into a wide area of Tidal Flat Deposits associated with the River Parrett c. 1 km to the north-east of the site. An area of Tidal Flat Deposits also widen westwards and passes immediately to the north of the Castle Hill Quarry (c. 600 m to the north of the Extension areas) throughout the route of South Moor Main Brook.

The Tidal Flat Deposits contain a mixture of clays, silts and peats with occasional sand and gravel layers. Alluvium (which will tend to comprise clay, silt, sand or gravels) is present along the route of Cannington Brook c. 1.5 km to the south of the extension.

2.3.2 Solid Geology

Carboniferous Limestone (Figure 3) is anticipated to be present under the entire quarry complex inclusive of the application area, with the overlying Mercia Mudstone outcropping directly to the north-east. Exposures within the quarry complex indicate that the limestone is jointed in places with large sub-vertical faces formed throughout joints which are generally orientated north-south, however some east-west joints are also present.

At Cannington Park Quarry the bedding can be observed to dip slightly to the east. Sedimentary (Red stained Neptunian) dykes are present however other karstic features are uncommon in the exposed faces. Except for a small cave in the workings near the top of Castle Hill Quarry no large voids have been found within the quarried areas.

A BGS borehole (ST24SW1) was drilled at Knapp Farm, located almost 450 m south of the eastern extension, to a depth of 1,153 m. Carboniferous rocks, including grey limestones with chert bands, were proved to a depth of 966 m. Underlying this unit was a further 140 m of Carboniferous shales and mudstones with lower limestone layers. These underlying units were both argillaceous and disturbed, however there was no obvious sign of faulting. This thickness of limestone most likely extends west-north-west and east-south-east beneath the Permo-Triassic strata.

A second BGS borehole (ST24SW11) at Castle Hill Quarry itself penetrated limestone to the borehole completion depth of 80 m. Four boreholes (BH1, BH2, BH3, BH4, Figure 4) were drilled as part of previous investigations at the quarry complex (ESI, 2001). There are no superficial deposits overlying the limestone at the quarry complex other than a layer of topsoil, which varies in thickness from around 0.3 to 3 m. A layer of weathered limestone underlies this which was up to 4.4 m thick, followed by limestone to the base of each borehole (which were progressed up to a 55 m depth). A further three boreholes (Boreholes 5 to 7) were drilled at the quarry complex in 2021; they were positioned at locations to provide additional groundwater monitoring data for the Old Golf Course Extension. All three boreholes were drilled into the Carboniferous Limestone to a depth of 40 m. (Stantec, 2021).

2.4 HYDROGEOLOGY

2.4.1 Aquifer Designations

The aquifer designations of the geology underlying and surrounding the Site are listed in the Table 2.

Table 2- Bedrock Aquifer

Bedrock aquifer		
Carboniferous Limestone	Principal aquifer Layers of rock or drift deposits that have high intergranular and/or fracture permeability, meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale.	Karstic aquifer underlying the Eastern Extension & Old Golf Course Extension.
Blue Lias Formation	Secondary A aquifer Permeable layers capable of supporting water supplies at a local rather than strategic scale and can be an important source of base flow to rivers.	Crops out c. 1 km to the north of the Eastern Extension & Old Golf Course Extension.
Mercia Mudstone Group	Secondary B aquifer Lower permeability layers that may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and/or weathering	Dominant bedrock geology of the region.
Helsby Sandstone Formation	Principal aquifer Layers of rock or drift deposits that have high intergranular and/or fracture permeability, meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale.	Part of the Sherwood Sandstone aquifer. Crops out approximately 400 m south of the Eastern Extension & Old Golf Course Extension.
Rodway Siltstone Formation	Secondary A aquifer Permeable layers capable of supporting water supplies at a local rather than strategic scale and can be an important source of base flow to rivers.	Crops out to the south of the Helsby Sandstone Formation approximately 600 m south of the Eastern Extension & Old Golf Course Extension.

The two main aquifers in the region are the Helsby Sandstone and the Carboniferous Limestone with the principal formation relevant to the application area being the carboniferous formation. The limestone matrix is considered to be of low porosity and permeability, with groundwater flows typically promoted via a network of karstic fractures and conduits. As stated, (Stantec, 2021) significant karstic features have not been observed within the formation following quarrying activity to date. (Section 2.2.2. Stantec, 2021 'A small cave was encountered in the workings near the top of Castle Hill Quarry but otherwise no large voids have been reported within the existing quarried areas.')

Mercia Mudstone Group is a boundary of the extent of the Carboniferous Limestone and Helsby Sandstone aquifers. Thus, flow through the confined part of the aquifer away from the outcrop area is expected to be limited.

2.4.2 Aquifer Properties

Karst rocks are rocks that can dissolve under the influence of water. The aquifer properties of Carboniferous limestones are not easy to predict because karst channels and fissures are unpredictable. The range of the Somerset hydraulic conductivity coefficient for limestone was determined as 0.0007 m/d to 110 m/d. (Allen et al.,1997[1]). Hydraulic tests were carried out in four boreholes drilled in 2000 (ESI, 2001) and the average hydraulic conductivity of the first three boreholes was determined as 0.007 m/d. However, at the fourth borehole the permeability was higher, and hydraulic test could not complete due to the borehole having penetrated a zone of weathered and significantly fractured limestone (Stantec, 2021).

The limestone is not thought to be heavily fissured locally. Stantec, 2021 offered the following reasons to suggest why this may be the case.

- the limestone block is relatively isolated relevant to an active surface water basin, reducing through flow and active development of karstic features.
- Clay-filled features have been detected at depth in some boreholes, which may be due to the slow circulation of the flow at depth.

2.5 HYDROLOGY

2.5.1 Catchment areas

The quarry complex is located within the lower reach of the River Parrett (Figure 5.) which flows north from Chedington in West Dorset, c.40 km to the south-east of the site and reaches the coast c.7 km to the north-east, where it flows into Bridgwater Bay.

Fiddington Brook lies c. 550 m to the north of the main part of the permit application area (eastern extension and old golf course extension); and Cannington Brook lies c. 1 km to the south. The application area lies across an undefined divide between the two catchment areas. Castle Hill Quarry and the northern part of the application area are located within the Fiddington Brook catchment. The southern part of the application area is located in a minor undefined sub-catchment that drains to the River Parrett to the east via various smaller ditches (locally referred to as rhynes).The distance between this undefined area and the Cannington Brook - Lower catchment is c. 350 m. The upper reaches that drain into Cannington Brook are divided into two further catchments known as Currypool Stream and Cannington Brook Upper.

2.5.2 Rainfall

Section 2.3.3 of the Stantec report, (2021) states a standard average annual rainfall (SAAR) value for the area of 749mm (CEH, 2021a[2]). This is based on rainfall data for two rain gauges. One is located at Wembdon on the outskirts of Bridgwater (NGR: ST27793793) which is c. 4 km south-east of the application area and another is located at Rivers House (NGR: ST3012237803) which is c. 6 km south-east of the application area.

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[1] *Allen, D. J., Brewerton, L. J., Coleby, L. M., Gibbs, B. R., Lewis, M. A., MacDonald, A. M., .. Williams, A. T. 1997. The physical properties of major aquifers in England and Wales. British Geological Survey Technical Report WD/97/34*
[2] *Centre of Ecology and Hydrology (CEH), 2021a. Flood Estimation Handbook Website. https://fehweb.ceh.ac.uk/ Last accessed 28 September 2021.*

2.5.3 Surface water abstractions

Stantec report (2021), section 2.3.4 references Environment Agency data which indicates that there are four licensed surface water abstractions near to the application area. An abstraction (16/52/007/S/158) from South Moor Main Brook at Mill Farm which is located c. 3 km to the west of the application area. There is also an abstraction (16/52/007/S/069) from Ashford reservoir (for public water supply) which is c. 2 km to the south-west of the application area; and the final two abstractions are both c. 3.2 km to the south-west of the application area, from Currypool Stream (16/52/007/S/069) (which is also for public water supply and part of the same abstraction from Ashford reservoir) and from another tributary of Cannington Brook (16/52/007/S/136). All of the abstractions were identified to be up-stream from the application area and are therefore considered unlikely to be unaffected by the works proposed.

2.5.4 Groundwater abstractions

Stantec report (2021), section 2.3.4 identified five nearby private water supplies / licenced groundwater abstractions. These were the private water supplies at Keepers Cottage (800 m south-west of the application area), Horn Hill Cottage (1 km west), Edbrook Farm (1.2 km west) and Edbrook (1.3 km west); and also the licenced groundwater abstraction (16/52/007/G/046) at Rodway Farm (700 m east) with is part of Bridgwater College.

The local authority (Sedegmoor District Council) confirmed the presence of three other private water supplies in the area, located c. 1.4km, 1.5 and 2km from the application area. The Environment Agency were consulted (Stantec, 2021) with regard to licensed abstractions in the area. Other groundwater abstractions within 2 km of the main part of the application area are located in / close to Cannington c. 1.1 km south-east (16/52/007/G/043) and 1.4 km to the south (16/52/007/G/081). Five other licenced groundwater abstractions are located between 2 and 4 km to the north and west of the Extension.

2.5.5 Groundwater Source Protection Zones

Stantec report (2021), Section 2.3.5 identified no groundwater Source Protection Zones (SPZ) mapped within a 3 km radius of the application area. The closest SPZ is located c. 5 km to the west.

2.11. ENVIRONMENTAL DESIGNATIONS

The Stantec report provides a summary of environmental designations for the area, replicated at Table 3 below.

Table 3 - Summary of Environmental Designated Sites (Stantec, 2021)

Name	Designation	Reason for designation	Distance
Bridgwater Bay	SSSI	Aggregations of non-breeding birds; fen, marsh and swamp;	2 km north-east

Name	Designation	Reason for designation	Distance
		littoral sediment; standing open water and canals; other invertebrates; and vascular plants	
Severn Estuary	SAC/Ramsar/SPA	Aggregations of non-breeding birds; fen, marsh and swamp; littoral sediment; standing open water and canals; other invertebrates; and vascular plants.	2 km north-east
Putnell Moor	CWS	Marshy grassland and species-rich rhyne system with nationally scarce vascular plant species	300 m north

Somerset Levels and Moors Ramsar site is located c. 13 km to the east of the quarry complex. In 2020, Natural England notified Local Authorities in the area in relation to developments that may affect the Ramsar site. Natural England advised that due to current phosphate levels within the hydrological catchment that includes the Ramsar site, habitat assessments would be required to support proposed developments to avoid any adverse effect. The application area lies outside the hydrological catchment area for the Somerset Levels and Moors Ramsar site.

3.0 RESTORATION ENGINEERING

The restoration of the Eastern Extension and Old Golf Course Extension (application area) will be via importation and placement of imported inert infill material, forming a single continuous landform principally graded northward. A post restoration layout is presented at Figure 6. Restoration works will be progressive and will proceed southwards. The restoration volume of materials is estimated at 669,000m^3 based on the extraction void following working. The proposed basal depth is detailed with the Environmental Site Setting and Design Report, estimated at 6 mAOD.

As presented in the BCL Report (July 2022), dewatering is not anticipated to be required during much of the extraction phases. However, there is the potential for some dewatering during Phase 3 to maintain dry working conditions to 6 mAOD. Should groundwater be encountered during the extraction process, groundwater control measures will be put in place to control the ingress of groundwater into the site

3.1 SITE ENGINEERING

3.1.1 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. An artificial attenuation layer will be installed on top of the Limestone Formation across the base of the site. The barrier will be constructed using suitable imported materials which will either be 1m in thickness with a permeability no greater than $1x10^{-7}$m/s or its EA approved equivalent of 0.5m with a permeability of no greater than $5x10^{-8}$m/s.

In situ testing and sampling will be undertaken to ensure that the imported material is suitable for this purpose. The method and testing of the material will be pre-agreed with the Environment Agency and subsequently demonstrated to ensure that the quality of installation is to the required standards.

An engineered side wall barrier is to be constructed along the sidewall of the quarry and is to have a thickness of 1m and a permeability of no greater than $1x10^{-7}$m/s or its EA approved equivalent.

The proposed construction of the attenuation layer would be to the specification detailed in the Construction Quality Assurance (CQA) Plan that will be produced for the site. The method and testing of the material will be pre-agreed with the Environment Agency and subsequently demonstrated to ensure that the quality of installation is to the required standards (i.e. no greater than $1x10^{-7}$m/s or as agreed).

3.1.2 Capping Layer

In accordance with the requirements of the Landfill Directive, an engineered cap (clay or plastic) is not required. However, on completion of filling to final levels, the site will be restored with 1m of previously stripped low permeability subsoils and soils comprising not less than 0.3m of topsoil. High moisture content materials will be avoided to minimise the risk of consolidation.

3.1.3 Restoration

It is proposed that the quarry void created in the application area will also be restored with inert material to pre-development ground levels and be returned to pasture and woodland vegetation. Permitted wastes accepted at the site will be strictly inert as classified under the Landfill Directive (1999/31/EC) and Council Decision (2003/33/EC) of 19th December 2002 'establishing criteria and procedures for the acceptance of waste landfill. Waste types permitted and corresponding waste catalogue codes are included at Appendix B.

3.1.4 Leachate Management and Monitoring.

An engineered leachate drainage / collection system will not be installed. The quality of the 'leachate' generated by the inert material is expected to pose a negligible risk to the receiving environment. Therefore, no management of leachate levels will be necessary.

Strict adherence to Waste Acceptance Criteria (WAC) under the Environmental Permitting Regime will ensure that the material inputs remain within the inert classification, mitigating risk to groundwater. Details on recommended surveillance monitoring during the restoration works is provided at the conclusion of this risk assessment.

Given the inert nature of the materials and reference to EA guidance 'Standards and Measures for the Deposit of Inert Waste on Land', it is not necessary to manage and monitor leachate at sites which comprise the recovery or disposal of inert waste. The site will fall outside the scope of the EPR 2016 (as amended) and therefore, no leachate management and monitoring is proposed for the site.

4.0 CONCEPTUAL SITE MODEL AND RISK SCREENING

4.1 INTRODUCTION

This section sets out a Conceptual Site Model (CSM) (Figure 7), which qualitatively describes the potential contaminant sources / ground conditions of the proposed restoration, receptors upon which contaminants could potentially have an impact and also pathways that may exist to allow contaminants to impact upon the identified receptors.

The Conceptual Site Model development has focused on characterising the hydrogeological model for groundwater beneath and around the site, anticipated post restoration based on current characterisation. A conceptual understanding of the hydrogeological regime in the vicinity of Castle Hill Quarry and the proposed restoration has been derived following an assessment of published and site-specific information.

To assess the potential impact of any contamination identified at the site on groundwater receptors, this risk assessment has been progressed. In order for any risk to be present at the site three components must exist:

- Contaminant(s) must be present at concentrations capable of causing adverse effects on groundwater (Source);
- A groundwater/surface water dependent receptor must be present, (Receptor); and
- There must be an exposure migration pathway by which the receptor comes into contact with the contaminant (Pollutant Linkage).

The source-pathway-receptor scenario act as the cornerstones when developing a conceptual model, which can then be used to identify critical pathways and inform the decision whether a more detailed quantitative analysis of risk is required. The first stage of the process is to determine the presence or absence of any contaminant(s) of concern (source) at the site, followed by the most likely pathways that these contaminants would take in the environment and finally the potential receptors of concern.

A geological site conceptual and cross section model has been prepared for the site, and can be viewed in Figure 7

4.2 SOURCE TERM CHARACTERISTICS

4.2.1 Waste Type

In order to achieve the restoration profiles, approximately 669,000m^3 of material will be required. Materials will be designated as inert waste as described by the Landfill Directive. Proposed waste types are listed at Appendix B and where applicable should be tested to ensure they meet the inert WAC as defined within the Directive.

4.2.2 Leachate Contaminants of Concern

Inert waste is defined by the Landfill Directive (article 2(e)) as “waste that does not undergo any significant physical, chemical or biological transformations. Inert wastes do not dissolve burn or otherwise physically or chemically react, biodegrade or adversely affect other matter with which it comes into contact in a way likely to give rise to environmental pollution or harm human health."

The standard WAC threshold values for inert landfills and the equivalent leachate quantity are summarised in Table 4.

Table 4 - Inert WAC Limit Leachate Quality

Pollutant	WAC Inert Limit (mg/kg to 10 l/kg)*	Equivalent Leachability (µg/l)	EQS (µg/l)	UKDWS (µg/l)
Arsenic	0.5	50	50	10
Barium	20	**2,000**	-	700
Cadmium	0.04	**4**	0.15	50
Chromium	0.5	**50**	4.7	-
Copper	2	**200**	1	2,000
Mercury	0.01	**1**	0.07	1
Molybdenum	0.5	50	-	70
Nickel	0.4	**40**	4	20
Lead	0.5	**50**	1.2	10
Antimony	0.06	**6**	-	5
Selenium	0.1	10	-	10
Zinc	4	**400**	14***	-
Chloride	800	80,000	-	250,000
Fluoride	10	1,000	-	1,500
Sulphate	1000	100,000	-	250,000
Phenol	1	**100**	7.7	-

*Limit values (mg/kg) for compliance leachate testing using BS EN 12457-3 at L/S 10 l/kg
**Equivalent leachability calculated as limit value as outlined in Appendix C.
***Zinc 10.9µg/l + 3.1µg/l in accordance with 2015 Environmental Quality Standards (EQS) Guidance.
Text in bold **blue** text highlights an exceedance of the UKDWS
Text in bold **orange** text highlights an exceedance of the EQS

The Environment Agency (2013) report on waste sampling and testing for disposal to landfill (page 27), which states *'for most wastes destined for disposal in landfill sites government consider that a single step leaching test at a Liquid to Solis (L:S) ratio of 10:1 l/kg is adequate for establishing and monitoring the cumulative mass leached and general leaching behaviour'*.

Equivalent leachability concentrations for the Inert WAC values have been calculated using the methodology presented in Appendix C and screened against EQS/UKDWS.

Please note that the inert WAC limit values represent the maximum values (worst case scenario) and the majority of imported waste is expected to be significantly below these levels. It is therefore considered that a risk assessment based upon a source term set at the inert WAC limits will be highly conservative.

4.2.3 Leachate Generation and Source Term Decline

Due to the inert nature of the proposed waste material, we consider it unlikely that water coming into contact with the material at the site will result in the generation of highly concentrated leachate / pollutants. To ensure that this remains the case, the operator can restrict source of waste materials allowed on to the site through the implementation of waste acceptance protocols.

The decline in leachate concentrations is controlled by water inputs to the fill material at the site. Both during filling and following the completion of restoration, the site will be open to rainfall infiltration to the waste which will either run-off over the waste and be subject to evapotranspiration or, infiltrate through waste mass as effective rainfall.

During rainfall events, rainwater will fall onto the restoration soils, where a proportion will infiltrate through the top of the restoration soils and the balance will run off. The remaining water will seep into the underlying restoration soils where it will be subject to evaporation and use by plants (transpiration). These two processes are known as evapotranspiration.

The Standard Average Annual Rainfall (SAAR) for the area is 749 mm (CEH, 2021a) (Stantec, 2021). UK Centre for Ecology and Hydrology (CEH) CHESS data indicates that the site annual average for evapotranspiration between 2008 to 2012 is 541mm/year[3]; subtracting this from the standard annual average rainfall for the site of 749mm/yr, the effective infiltration is expected to be c. 208mm/year.

The final restoration profile will see an increased elevation in the south with a gradual reduction to the north (refer to Figure 6). This restoration soil profile will promote surface water run-off and limit effective rainfall infiltration and leachate migration. However, to produce a conservative HRA, no reduction in effective rainfall has been assumed for the modelling of the final restored profile of the site.

Effective rainwater which does infiltrate through the surface of the restoration profile will migrate vertically through the inert waste materials. 'Leachate' generated will be subject to attenuation and retardation processes as it migrates through the unsaturated zone, where present, beneath the inert infill.

Given the inert nature of the materials and reference to EA guidance 'Standards and Measures for the Deposit of Inert Waste on Land', it is not necessary to manage and monitor leachate at sites which comprise the recovery or disposal of inert waste. The site will fall outside the scope of the EPR 2016 (as amended) and therefore, no leachate management and monitoring is proposed for the site.

4.3 PATHWAYS

A conceptual understanding of hydrogeological regime in the vicinity of the site and proposed restoration has been derived from an assessment of both published and site-specific information.

The generation of leachate and its resultant concentration is controlled by the level of water contact with the restoration material on site. The primary water inputs are expected to be effective rainfall (infiltration), and groundwater flowing through the very basal part of the restoration material.

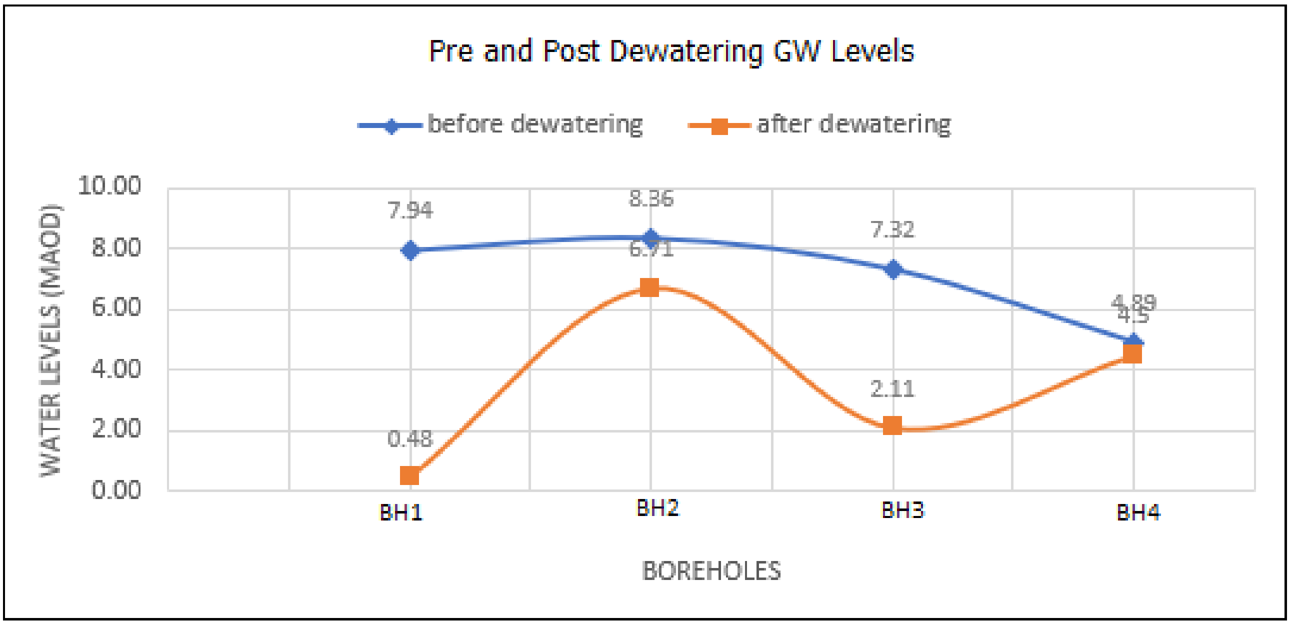
4.3.1 Groundwater Levels and Flow

To characterise anticipated future hydrogeological conditions or post restoration conditions available groundwater monitoring data applicable to the application area has been reviewed. As part of the requirements

[3] *https://eip.ceh.ac.uk/apps/chess/ (Accessed 18/01/2023).*

of existing Water Management Plans (WMPs), groundwater levels have been measured monthly by CHQC from 4 monitoring wells (BH1, BH2, BH3, BH4) since 2000. Three new boreholes (BH5, BH6, BH7) have been drilled near the eastern extension in 2021. The locations of these boreholes are shown in the Figure 4.

Pre and levels measured post dewatering commencement are presented below for monitoring wells BH1-BH4. The pre-dewatering anticipated dominant groundwater flow direction is shown in Figure 8. Post dewatering water contours and flow directions are shown in Figure 9 which is inclusive of monitoring data from the more recently installed boreholes BH5, 6 and 7. Average groundwater levels were calculated for both periods and are presented below.



Graph 1: Pre and post dewatering groundwater levels.

More recent groundwater level monitoring data is considered in the BCL report (July 2022) assessment following the cessation of dewatering Cannington Park Quarry in September 2020. Existing piezometer data has been reviewed and adjusted to best reflect anticipated groundwater levels post restoration across the application area. Table 5 of the BCL report (July 2022) presents a minimum (7.5 mAOD) and maximum (12.3 mAOD) post restoration groundwater level with an average of 8.9 mAOD.

The site will be worked for the extraction of limestone deposits to a basal level of 6 mAOD. A conservative assumed groundwater level post restoration is 12.3 mAOD (maximum groundwater level post restoration, BCL, 2022) based on the latest available monitoring data applicable to the application area has been adopted in the model. Adopting the anticipated post restoration groundwater levels will see a saturated zone of c. 6.3 m at the base of the imported restoration material assuming a basal level of extraction 6 mAOD.

Principal groundwater flow direction post-restoration is anticipated to be towards a series of drainage features or rhynes located c.450m to the north. Groundwater flow mapping (refer to Figure 8) has been developed to simulate anticipated post restoration hydraulic head based on pre dewatering monitoring data for the period 2000-2010 (Stantec, 2021).

No significant superficial deposits are anticipated immediately surrounding the primary area of extraction with the primary aquifer considered be within the limestone deposits.

On the basis of pre dewatering hydraulic head measurements, a hydraulic gradient of 0.0081 has been calculated based upon anticipated post restoration groundwater levels. Groundwater flow within the deposits is anticipated to be via intergranular flow (primary porosity).

The hydraulic conductivity and porosity values for the limestone aquifer have been estimated from literature sources, 3.5 x 10^{-6}m/s (Allen et al. (1997) cite a range of hydraulic conductivity between 0.0007 m/d and 110 m/d, with a geometric mean of 0.3 m/d, from tests carried out in the Mendips (Somerset)) and 0.275 for porosity (ConSIM). Hydraulic testing was undertaken in the four boreholes drilled in 2000 (ESI, 2001) and the average hydraulic conductivity at three of the boreholes was 0.007 m/d, which is towards the lower end of the range stated in the regional data. This value was increased by circa two orders of magnitude to reflect sensitivity of the principal aquifer. There was no evidence of significant fissure/voids in existing quarried areas (Section 2.2.2. Stantec HIS, 2021).

An artificial attenuation layer is to be installed on top of the Limestone Formation across the base of the site which will provide further attenuation and retardation to any leachable contaminants generated. The barrier will be constructed using suitable imported materials consisting of non-waste materials which will either be 1m in thickness with a permeability no greater than 1x10^{-7}m/s or its EA approved equivalent of 0.5m with a permeability of no greater than 5x10^{-8}m/s. Initial model iterations are not assuming retardation resultant from barrier construction which will increase the conservatism of modelling outcomes.

4.3.2 Groundwater & Surface Water Quality

CHQ Limited have provided contemporary ground and surface water monitoring data from 8th February to 19th October 2022 for groundwater monitoring locations BH5-BH6-BH7 and surface water locations SWS1 and SWS2 (refer to Figure 4). Analytical testing suites are expansive and include heavy metals and inorganic compounds. Average determinand concentrations for the monitoring period are presented at Table 5 below.

Table 5- Average Water Quality Date (2022)

Average Water Quality Data(ug/l)	BH5	BH6	BH7	SWS1	SWS2
Antimony as Sb	<0.001	<0.001	<0.001	<0.001	<0.001
Arsenic as As	0.009438	0.0035	0.021375	0.0064	0.009200
Cadmium as Cd	6E-05	3.57E-05	4.73E-05	0.00004	0.000038
Copper as Cu	0.005438	0.003125	0.017625	0.005	0.002286
Lead as Pb	<0.001	<0.001	<0.001	<0.001	<0.001
Mercury as Hg	<0.00003	<0.00003	<0.00003	<0.00003	<0.00003
Molybdenum as Mo	0.002938	0.0025	0.008938	0.002667	0.001357
Nickel as Ni	0.0013	0.001	0.0026	0.002444	0.001500
Selenium as Se	0.001	0.001	0.001	0.001	0.001000
Total Chromium as Cr	0.002	0.001	0.001	0.001	0.001000
Zinc as Zn	0.022	0.023688	0.0215	0.014643	0.010538
Barium as Ba	0.4325	0.211875	0.279333	0.178667	0.215333
Calcium as Ca	130	114.5	96.13333	127.4667	165.533333
Sodium as Na	44.25	184.375	25.26667	165	257.400000

Average Water Quality Data(ug/l)	BH5	BH6	BH7	SWS1	SWS2
Total Sulphur as SO4	27.8125	70.25	18.13333	86.93333	107.933333
Fluoride as F	0.18125	0.1375	0.116667	0.133333	0.109091
Ammoniacal Nitrogen as N	0.0975	0.063333	0.079	0.258333	0.197692
Chloride as Cl	81.125	290.625	41.6875	252.5333	401.266667
Orthophosphate as P	0.975	0.131429	1.642	0.304286	0.077143
Total Oxidised Nitrogen	8.14375	3.8625	6.3625	3.96	5.535714
Acenaphthene	<0.01	<0.01	<0.01	<0.01	<0.01
Acenaphthylene	<0.01	<0.01	<0.01	<0.01	<0.01
Anthracene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo[a]anthracene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo[a]pyrene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo[b]fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo[g,h,i]perylene	<0.01	<0.01	<0.01	<0.01	<0.01
Benzo[k]fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01
Chrysene	<0.01	<0.01	<0.01	<0.01	<0.01
Dibenzo[a,h]anthracene	<0.01	<0.01	<0.01	<0.01	<0.01
Fluoranthene	<0.01	<0.01	<0.01	<0.01	<0.01
Fluorene	<0.01	<0.01	<0.01	<0.01	<0.01
Indeno[1,2,3-cd]pyrene	<0.01	<0.01	<0.01	<0.01	<0.01
Naphthalene	<0.01	<0.01	<0.01	<0.01	<0.01
Phenanthrene	<0.01	<0.01	<0.01	<0.01	<0.01
Pyrene	<0.01	<0.01	<0.01	<0.01	<0.01
Total PAH 16	0.21	0.2	0.272	0.18	0.18
PCB 101	<0.01	<0.01	<0.01	<0.01	<0.01
PCB 118	<0.01	<0.01	<0.01	<0.01	<0.01
PCB 138	<0.01	<0.01	<0.01	<0.01	<0.01
PCB 153	<0.01	<0.01	<0.01	<0.01	<0.01
PCB 180	<0.01	<0.01	<0.01	<0.01	<0.01
PCB 28	<0.01	<0.01	<0.01	<0.01	<0.01
PCB 52	<0.01	<0.01	<0.01	<0.01	<0.01
Dimethylphenols	<0.05	<0.05	<0.05	<0.05	<0.05
Methylphenols	<0.05	<0.05	<0.05	<0.05	<0.05
Phenol	<0.05	<0.05	<0.05	<0.05	<0.05
Total Phenols	<0.20	<0.20	<0.20	<0.20	<0.20
Trimethylphenols	<0.05	<0.05	<0.05	<0.05	<0.05
Total TPH >C8-C40	0.028571	0.033333	0.033333	0.025556	0.024
Dissolved Organic Carbon	2.265625	1.878125	6.599375	8.142	4.49
Total Organic Carbon	2.40625	1.938125	16.05813	8.861333	4.57
TDS as mg/L	503.6875	867.125	420.375	1018.867	1411.53

Section 2.3.5 of the Stantec 2021 presents data on surface water quality applicable to the application area. The ecological classification for the Lower catchment of the Cannington Brook was reported as moderate. Industrial discharges, sewage discharges and poor rural land management are reasons for not achieving good status or reasons for deterioration.

Surface water quality data is held by the Environment Agency for Fiddington Brook (South Moor Main Brook) at Fiddington (NGR: 321654 140564) which is located c. 2.6 km to the west and upstream of the quarry complex;

and at Bolham House (NGR: 325479 141773) which is located downstream c. 1.2 km to the north-east of the quarry complex near Combwich.

Data is available for samples collected every few months in both locations between 2000 and 2017. Surface water quality data is also available for Cannington Brook at Blackmoor Farm (NGR: 324486 138801) which is located c. 1.5 km to the south-west and up-stream of the quarry complex; and from the A39 road bridge in Cannington (NGR: 325839 139390) which is located down-stream c. 1.3 km to the south-west of the quarry complex.

4.4 WATER BALANCE

4.4.1 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.

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

4.4.2 Flux out of site sides

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;

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

4.4.3 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 limestone. Conservatively, this dilution has not been incorporated in the model.

Dilution by groundwater flowing within the aquifer has been applied. 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;

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

Where;

L = length of source edge perpendicular to pathway
D = Distance from source to receptor
ER = Effective rainfall

4.4.4 Transport Mechanisms

The following transport mechanisms are considered within the quantitative assessment:

- **Advection** - The principal mechanism by which contaminations move through the aquifer is advection, which means that the contaminants move with the average velocity of the groundwater. The average velocity of the groundwater flow is the average velocity of the mobile water molecules
- **Dispersion** - The spreading of the advancing solute front as a result of tortuous flow paths within porous media. This is assumed to occur in the direction of groundwater flow (longitudinal dispersion), and also perpendicular to the flow path (lateral /transverse dispersion) whereby contaminants moved around the grains of the rock or soil
- **Dilution** – Leachate generated from the inert waste materials which migrate vertically through the base of the restoration area will be subject to dilution beneath the site area.
- **Adsorption and Desorption** - The process of adsorption of contaminant molecules to soil particles, retarding the movement of the advecting solute front. Retardation processes are likely to occur primarily within the unsaturated zone. Retardation is also expected to occur as contaminants migrate through the saturated aquifer pathway. Contaminants will be subject to sorption processes such as adsorption, chemisorption, absorption and cation exchange
- **Biodegradation** - Biodegradation has not been included within the modelling. No degradation (denitrification) of ammonium (NH_4) is considered in the quantitative assessment.

4.5 RECEPTORS

The following are considered to represent potential receptors for leachate influenced groundwater following the proposed site restoration works.

Surface water features

Rhyne and Wild Moor Middle Rhyne and associated smaller drainage ditches.

A series of drainage ditches or rhynes are located to the north of the proposed development and are considered the critical surface water receptors based on their proximity (c.450m).

Groundwater features

The Carboniferous Limestone underlying the Extension is a Principal Aquifer; which the Environment Agency classify as having the potential to support public water supply on a strategic scale and has been considered a critical receptor for the purposes of this assessment.

As per Table 2.8 of the Stantec 2021 report a number of local groundwater abstractions are present in the area. These are not considered as critical receptors based on distance and location relevant to the proposed development based on anticipated groundwater flow direction post restoration (refer to pre dewatering groundwater flow, Figure 8). However, the assessment of risk to the Principal Aquifer and immediately adjacent to the site also effectively considers risk to those receptors. Determination Of Environmental Assessment Limits (EALS)

The setting of Environmental Assessment Levels (EALs) is necessary to ensure the protection of controlled water receptors that exist beyond the site boundary, such as groundwater and the surface water features located to the north/north west (Rhynes, 450m).

The priority contaminants to be modelled are based on the inert Waste Acceptance Criteria (WAC) limits.

The adopted EAL's are based upon The UK Drinking Water Standards (UKDWS), and Freshwater EQS – whichever is the lower of the two values have been adopted as the EAL. The exception to this has been where the maximum background concentrations already exceeds the relevant standards. In this case, the EAL has been calculated using the maximum background groundwater concentration up-hydraulic gradient and adding an additional 25%.

The rationale for adopting the UKDWS is that whilst the primary receptors are considered to be groundwater underlying the application site and the surface water features to the north of site. Given the distance to the surface water receptors (approx. 450m) and to account for the potential future use of the groundwater, we consider that the UKDWS are the most appropriate standards to ensure protection of the groundwater resource located immediately down-gradient of the site, in line with the requirements of the Water Framework Directive.

The selected EALs for the hazardous and non-hazardous contaminants are summarised in Table 6.

Table 6 – Environmental Assessment Levels

Determinand	Maximum Concentration in Background Quality (µg/l)	EQS	UKDWS	EAL
Arsenic	11.4	50	10	14.25
Barium	307.9	-	700	700
Cadmium	0.02	0.15	50	0.15
Chromium	1.3	4.7	-	4.7
Copper	8.7	1	2,000	10.87
Mercury	<0.3	0.07	1	0.07
Molybdenum	4.7	-	70	70
Nickel	1.6	4	20	4
Lead	1	1.2	10	1.2
Antimony	1	-	5	5

Determinand	Maximum Concentration in Background Quality (µg/l)	EQS	UKDWS	EAL
Selenium	1	-	10	10
Zinc	22.3	14	-	27.85
Chloride	137,812	-	250,000	250,000
Fluoride	145.1	-	1,500	1,500
Sulphate	38,731.9	-	250,000	250,000
Phenol	<0.05	7.7	-	7.7

5.0 HYDROGEOLOGICAL RISK ASSESSMENT

5.1 NUMERICAL MODELLING

5.1.1 Justification for Modelling Approach

The hydrogeological risk assessment has been carried out using conservative assumptions regarding the source, pathways and receptors. Site specific data have been used wherever possible to parameterise the risk assessment.

As stated previously, the quarry void will be restored using inert material. Based on the defined characteristics of inert waste the site should not produce any leachate that could result in any significant discharge of hazardous substances or non-hazardous pollutants throughout the lifecycle of the site.

However, notwithstanding this, a risk assessment is required for an inert landfill where the receiving environment is particularly sensitive, for example where waste is located below the water table or a direct pathway exists to a sensitive surface water receptor.

5.1.2 The Priority Contaminants to be Modelled

The priority contaminants which are to be modelled are the determinands presented in Table 6 which are based on the Waste Acceptance Criteria (WAC) for inert landfills. Total concentration limits are also stipulated for organic parameters, including PAHs, PCBs, BTEX and mineral oils. It is therefore prudent to consider the potential for such contaminants to be present as part of a rogue load entering the site. For the purpose of this modelling (and assessment), phenol is considered in the model as the hazardous organic contaminant.

The representative contaminants that are modelled in the assessment are as follows:

- Non-hazardous inorganic contaminants: **arsenic, chloride, chromium, copper, nickel, lead, selenium, zinc, barium, molybdenum, antimony, fluoride** and **sulphate**
- Hazardous inorganic contaminants: **cadmium and mercury**; and,
- Hazardous organic contaminants: **Phenol**

5.1.3 Modelling Approach

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 groundwater 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 this instance, RAM is used to address pathways of potential contaminant migration from the restoration material, laterally through the limestone deposits to adjacent groundwater and surface water receptors. The UK DWS and freshwater EQS were used as a basis for deriving EAL's for the groundwater and surface water compliance points respectively. 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. No dilution has been accounted for within any surface water stream receptor, as a conservative measure.

5.1.4 Proposed Assessment Scenarios

The following assessment (models) scenarios have been carried out using the modelling approach outlined above:

- **Model 1 – Inert WAC Limits Model:** The source term applied in the model are the inert WAC limits. These input concentrations represent the maximum values (worst case scenario) and the majority of imported material is expected to be significantly below these levels; and,
- **Model 2 – Rogue Load Assessment Model:** Inert WAC limits are increased by 10% to model the potential for a rogue load to be accidentally incorporated within the waste stream. Rogue loads would be expected to marginally exceed inert WAC thresholds for one or two determinands, resulting in a classification of non-hazardous material.

5.2 MODEL PARAMETERISATION

The model parameterisation is presented in the following tables, with justification provided for each of the parameters based upon the site conceptual model.

Table 7 - Site Geometry

Description	Value	Data Source
Surface Area	38 000 m^2	Client supplied area of excavation
Basal Area	38 000 m^2	Assume equal to surface area
Basal Depth	6 mAOD	Client supplied data
Average Thickness of Restoration Soils	17.6 m	Calculated based on the Client supplied excavation area and volume restoration materials

Description	Value	Data Source
Saturated thickness in restoration materials	63 m	Calculated based on estimated maximum hydraulic head post restoration (BCL, 2022) and basal depth (6 mOAD)
Width perpendicular to groundwater flow	152 m	From survey plans
Void to be filled	669,000 m^3	Client supplied data
Maximum leachate head before overtopping occurs	25 mAOD	Estimated mean elevation of post completion ground level at site

Infiltrating precipitation percolating through the waste, together with groundwater flowing laterally through the base of the infill will leach potential contaminants from the waste. The source term concentrations used are presented in Table 8.

Table 8 - Source Term Values

CoC	Value (mg/L)	Justification
Arsenic	0.05	See section 4.2.2 – based on inert WAC limits.
Barium	2	
Cadmium	0.004	
Chromium	0.05	
Copper	0.2	
Mercury	0.001	
Molybdenum	0.05	
Nickel	0.04	
Lead	0.05	
Antimony	0.006	
Selenium	0.01	
Zinc	0.4	
Chloride	80	
Fluoride	1	
Sulphate	100	
Phenol	0.1	

For the saturated pathways the parameters given in Table 9 are used for modelling.

Table 9 - Aquifer pathway definition

Description	Value	Units	Data Source
Maximum Groundwater Head	12.3	mOAD	Estimated maximum hydraulic head post restoration (BCL, 2022)

Description	Value	Units	Data Source
Hydraulic gradient	0.014	-	BCL, 2022 estimated gradient under maximum baseline conditions
Fraction Organic Carbon	0.0011	-	Environment Agency Science Report SC030110/SR, 2012) Jurassic formation
Porosity	0.275	-	Mean value (ConSim suggested values)
Hydraulic conductivity	0.3 (Note1)	m/d	Geo-metric mean (Allen et al. (1997)).
Dry bulk density	2,265	kg/m3	Mean value (ConSim Help Files)

Note 1 - site measured (ESI, 2001) 0.007 m/d. Increased by c. two orders of magnitude to reflect sensitivity of principal aquifer. No evidence of significant fissure/voids in existing quarried areas (Section 2.2.2. Stantec HIS, 2021)

Retardation parameters have been selected from ConSim suggested values provided within the ConSim help files.

Table 10 10 - Selected retardation and decay parameters

Parameter	Decay (days)	Kd (L/kg)	Justification
Arsenic	No Decay	25	ConSim Suggested Values
Barium	No Decay	1.4	ConSim Suggested Values
Cadmium	No Decay	240	ConSim Suggested Values
Chromium	No Decay	67	ConSim Suggested Values
Copper	No Decay	295	ConSim Suggested Values
Mercury	No Decay	450	ConSim Suggested Values
Molybdenum	No Decay	110	ConSim Suggested Values
Nickel	No Decay	400	ConSim Suggested Values
Lead	No Decay	270	ConSim Suggested Values
Antimony	No Decay	400	ConSim Suggested Values
Selenium	No Decay	9.5	ConSim Suggested Values
Zinc	No Decay	200	ConSim Suggested Values
Chloride	No Decay	0	ConSim Suggested Values
Fluoride	No Decay	0.8	ConSim Suggested Values

Parameter	Decay (days)	Kd (L/kg)	Justification
Sulphate	No Decay	0.23	ConSim Suggested Values
Phenol	100	0.22	ConSim Suggested Values Decay – high end of aerobic half life.

Table 11 11 - Distance to receptors applied in model

Description	Value	Justification
Compliance point borehole	50m	Default protective of principal aquifer
Downgradient watercourse	450m	Rhynes (Putnell and Wild Moor)

5.3 HYDROLOGY

Hydrological parameters are presented in Table 12. Effective rainfall is assumed to apply to the source and to the area between the source and the receptors.

Table 12 - Rainfall applied in model

Parameter	Value	Units	Justification
Effective Rainfall	208	mm/a	The Standard Average Annual Rainfall (SAAR) for the area is 749 mm (CEH, 2021a). HIA Stantec, October 2021. Losses due to evapotranspiration 541mm (UK centre for Ecology & Hydrology, mean value 2008-2012)

5.4 EMISSIONS TO GROUNDWATER & SURFACE WATERS

The source term applied to the model assumes that the concentrations of the material to be imported to site are at the limits for inert material for all modelled contaminants. This is a highly conservative assessment as the input source term represents the maximum values for all contaminants (worst case scenario) to be applied across the entire waste stream.

Predicted concentrations at the receptors for each of the modelled contaminants are outlined in Table 13 and Table 14.

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

Table 1313 - Predicted concentrations (mg/l), 50m compliance point receptor – Model 1

Time (Years)	Arsenic	Chloride	Chromium	Copper	Nickel	Lead	Selenium	Zinc
5	0.000E+00	7.458E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	3.433E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.228E-35	0.000E+00
50	0.000E+00	1.115E+01	1.160E-40	0.000E+00	0.000E+00	0.000E+00	6.328E-17	0.000E+00
100	1.304E-19	1.553E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.287E-09	0.000E+00
500	1.860E-05	7.534E-08	7.587E-12	2.341E-26	1.990E-31	0.000E+00	2.767E-04	0.000E+00
1000	4.077E-04	0.000E+00	6.612E-07	3.917E-21	0.000E+00	1.894E-20	1.030E-04	3.209E-16
5000	6.055E-06	0.000E+00	1.567E-04	2.424E-06	1.455E-08	1.361E-06	2.146E-11	3.209E-16
10000	3.438E-09	1.126E-09	1.422E-05	1.021E-04	4.828E-06	3.446E-05	2.146E-11	5.390E-04
EAL (mg/l)	1.425E-02	2.500E+02	4.700E-03	1.087E-02	4.000E-03	1.200E-03	1.000E-02	2.780E-02

Table 1414 - Predicted concentrations (mg/l), 50m compliance point receptor – Model 2

Time (Years)	Barium	Cadmium	Mercury	Molybdenum	Antimony	Fluoride	Sulphate	Phenol
5	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.912E-14	3.033E-03	2.080E-10
10	2.025E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.671E-07	1.526E+00	2.899E-10
50	5.484E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.541E-01	2.603E+01	5.993E-11
100	2.956E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.569E-01	4.175E+00	8.354E-12
500	7.815E-05	1.164E-25	1.087E-34	5.699E-08	1.147E-04	1.875E-07	5.796E-07	1.153E-19
1000	6.555E-10	0.000E+00	3.233E-26	5.699E-08	0.000E+00	2.115E-11	0.000E+00	0.000E+00
5000	0.000E+00	2.818E-07	3.233E-26	1.147E-04	2.183E-09	0.000E+00	0.000E+00	0.000E+00
10000	0.000E+00	3.815E-06	5.699E-08	1.147E-04	7.244E-07	0.000E+00	0.000E+00	1.174E-20
EAL (mg/l)	7.000E-01	1.500E-04	7.000E-04	7.000E-02	5.000E-03	1.500E+00	2.500E+02	7.700E-03

Table 1515- Predicted Concentrations 450m Watercourse receptors (Rhynes) – Model 1

Time (Years)	Arsenic	Chloride	Chromium	Copper	Nickel	Lead	Selenium	Zinc
5	0.000E+00	3.547E-15	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	2.006E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
50	0.000E+00	7.934E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
100	0.000E+00	1.359E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.091E-32	0.000E+00
500	4.821E-24	8.957E-05	5.251E-39	0.000E+00	0.000E+00	0.000E+00	1.380E-15	0.000E+00
1000	3.314E-19	9.373E-09	2.365E-27	0.000E+00	0.000E+00	0.000E+00	4.660E-09	0.000E+00
5000	5.439E-06	0.000E+00	1.576E-11	0.000E+00	0.000E+00	1.463E-25	3.125E-05	4.292E-22
10000	5.455E-05	0.000E+00	2.470E-07	3.108E-21	2.090E-23	0.000E+00	7.217E-06	1.931E-15
EAL (mg/l)	1.425E-02	2.500E+02	4.700E-03	1.087E-02	4.000E-03	1.200E-03	1.000E-02	2.780E-02

Table 1616 - Predicted Concentrations 450m Watercourse receptors (Rhynes) – Model 2

Time (Years)	Barium	Cadmium	Mercury	Molybdenum	Antimony	Fluoride	Sulphate	Phenol
5	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.488E-10	0.000E+00
10	1.532E-39	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.357E-30	0.000E+00	2.901E-34
50	5.352E-19	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.925E-13	9.522E-03	2.431E-32
100	5.352E-19	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.504E-06	1.825E+00	3.389E-33
500	2.345E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.243E-02	6.016E-01	3.263E-40
1000	3.267E-02	0.000E+00	0.000E+00	1.412E-35	0.000E+00	6.996E-03	6.016E-01	0.000E+00
5000	8.903E-07	0.000E+00	3.391E-20	1.802E-17	0.000E+00	1.488E-10	0.000E+00	0.000E+00
10000	2.224E-11	3.391E-20	0.000E+00	3.582E-10	3.136E-24	0.000E+00	0.000E+00	0.000E+00
EAL (mg/l)	7.000E-01	1.500E-04	7.000E-04	7.000E-02	5.000E-03	1.500E+00	2.500E+02	7.700E-03

RAM modelling output files are presented at Appendix D.

No exceedances of the EAL are noted at either the 50m compliance point, or the compliance point adopted to be protective of the watercourses to the north of the site.

Assigning the concentrations of the source term at the Inert WAC Limit and applied across the site is considered a highly conservative approach. Importation of restoration materials will be completed in phased or gradual manner, and it is considered highly improbable that the leachable concentrations of the whole waste mass will be present at the upper inert WAC limits.

5.5 SENSITIVITY ANALYSIS

5.5.1 Model 2 – Rogue Load Assessment

The HRA is required to demonstrate that the proposed restoration materials will be compliant with the Environmental Permitting Regulations 2016 (as amended) including the Landfills for inert waste Guidance (2020). These regulations & guidance documents require that certain substances (Hazardous Substances) are not discharged to groundwater such that they are discernible, and that the discharge of other substances (Non-Hazardous Pollutants) is limited to prevent pollution of the water environment.

For a rogue load to be deposited at the Site, a series of failures would need to occur in the Waste Acceptance Procedures such that non-permitted wastes bypass the stringent procedures and checks in the site's management system and are accidentally deposited at the Site without being detected.

For the purpose of this assessment, rogue loads would be expected to marginally exceed inert WAC thresholds of one or two determinants, resulting in a classification of non-hazardous. Inert WAC limits have been increased by 10% and applied to the source term, to model the potential for a rogue load to be accidentally incorporated within the waste stream. Predicted concentrations at the receptors for each of the modelled contaminants are outlined in the table below for the 50m compliance point.

Table 1717 - Predicted concentrations (mg/l), 50m compliance point receptor – Model 1, rogue load assessment

Time (Years)	Arsenic	Chloride	Chromium	Copper	Nickel	Lead	Selenium	Zinc
5	0.000E+00	8.197E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	3.780E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.845E-35	0.000E+00
50	0.000E+00	1.263E+01	1.275E-40	0.000E+00	0.000E+00	0.000E+00	6.958E-17	0.000E+00
100	1.439E-19	1.828E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.520E-09	0.000E+00
500	2.071E-05	1.913E-07	8.406E-12	2.628E-26	2.229E-31	0.000E+00	2.520E-09	0.000E+00
1000	4.561E-04	0.000E+00	7.373E-07	4.160E-21	0.000E+00	2.134E-20	1.156E-04	3.561E-16

Time (Years)	Arsenic	Chloride	Chromium	Copper	Nickel	Lead	Selenium	Zinc
5000	6.786E-06	0.000E+00	7.373E-07	2.712E-06	1.628E-08	1.523E-06	2.408E-11	1.066E-04
10000	3.853E-09	1.169E-09	1.593E-05	1.143E-04	5.406E-06	3.859E-05	0.000E+00	6.037E-04
EAL (mg/l)	1.425E-02	2.500E+02	4.700E-03	1.087E-02	4.000E-03	1.200E-03	1.000E-02	2.780E-02

Table 1818 - Predicted concentrations (mg/l), 50m compliance point receptor – Model 2

Time (Years)	Barium	Cadmium	Mercury	Molybdenum	Antimony	Fluoride	Sulphate	Phenol
5	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.203E-14	3.336E-03	5.721E-12
10	2.227E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.238E-07	3.336E-03	7.972E-12
50	6.033E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.695E-01	2.863E+01	1.648E-12
100	3.251E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.726E-01	4.593E+00	2.297E-13
500	8.597E-05	1.281E-25	1.196E-34	1.500E-18	3.284E-32	2.063E-07	6.375E-07	3.171E-21
1000	7.209E-10	0.000E+00	3.556E-26	4.151E-10	0.000E+00	2.322E-11	0.000E+00	0.000E+00
5000	0.000E+00	3.100E-07	7.254E-11	1.262E-04	2.402E-09	0.000E+00	0.000E+00	0.000E+00
10000	0.000E+00	4.197E-06	6.269E-08	6.853E-05	7.968E-07	0.000E+00	0.000E+00	3.226E-22
EAL (mg/l)	7.000E-01	1.500E-04	7.000E-04	7.000E-02	5.000E-03	1.500E+00	2.500E+02	7.700E-03

No exceedances of the EAL are noted at the 50m compliance point, when increasing the contaminant loading for the proposed rogue load scenario. No failures at the 50m compliance point assumes protection of offsite surface water receptors at 450m. Again, stringent waste acceptance protocol should be in place to ensure only materials which meet the inert WAC or are designated as inert are accepted for restoration purposes.

6.0 REQUISITE SURVEILLANCE

6.1 INTRODUCTION

Requisite surveillance for groundwater and surface water that is considered necessary and appropriate for the site is presented in the following sections.

Monitoring infrastructure is currently in place downgradient of the site, such that no additional monitoring boreholes are required.

Monitoring borehole, BH07 is present on the up-gradient side of the proposed permit application area and it is assumed can be retained during mineral extraction.

Details of the proposed groundwater monitoring locations for the site are shown in Table 19 below.

Table 1919 - Proposed groundwater monitoring infrastructure

Monitoring Location	Parameter	Frequency
Upgradient BH07 Replacement borehole to be installed if removed.	Water Level, Electrical Conductivity, Chloride, Phenol, pH, Nickel, Sulphate, Lead	Quarterly
Downgradient BH01, BH05, BH06 and BH04	Water Level, Electrical Conductivity, Chloride, Phenol, pH, Nickel, Sulphate, Lead	Quarterly
BH01, BH05, BH06, BH04 and BH07	Base of monitoring point (mAOD)	Annually

Table 20 presents the compliance levels and trigger levels that are proposed for the site, based upon background groundwater quality and the assessment EALs.

Representative contaminants of concern have been selected for monitoring - Phenol, Chloride, Sulphate, Nickel, and Lead, representing one organic compound, two major anions and two heavy metal species.

Compliance levels are set at the background groundwater quality, plus 25% based on monitoring date from boreholes BH5, BH6 and BH7 (February to October 2022). Where no determinants have been detected over the laboratory limit of detection (lead and phenol), the compliance level is set at the LOD.

Table 2020 - Proposed Compliance Limits

Compliance Location	Parameter	Compliance Limit (mg/L)
BH01, BH04, BH05, BH06 and BH07	Chloride	250
	Sulphate	250
	Nickel	0.004
	Lead	0.0012
	Phenol	0.0077

7.0 CONCLUSIONS

The modelling has demonstrated that based on the proposed restoration scheme, and the importation of materials compliant with inert WAC, there will be no significant release of hazardous substances or non-hazardous pollutants to the water environment. Therefore, the installation should not result in any discernible discharge of hazardous substances to groundwater or result in groundwater or surface water pollution by non-hazardous pollutants.

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 restoration site.

Source term characterisation has assumed that materials that meet the defined WAC for acceptance at inert landfill will be used for site restoration.

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

Compliance of the extension to Castle Hill Quarry with the relevant parts of the Environmental Permitting Regulations 2016 (as amended) is discussed in the following sections.

7.1.1 Accidents and their consequences

A rogue load analysis has been undertaken, demonstrating that if the inert waste acceptance criteria thresholds were exceeded, there would be no exceedance of the EALs at the downgradient receptors.

7.1.2 Acceptance of Simulated Contaminants

It is conceivable that the waste may unintentionally contain substances not acceptable by the restoration site, 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.

7.1.3 Compliance Limits

Assessment and compliance of the site will be quantified against the proposed groundwater compliance and trigger levels.

Groundwater control and trigger levels are proposed within Table 20 of this report and are based on observed groundwater quality data for the site, and the outcomes of the assessment.

Comprehensive surface water monitoring is also undertaken at the site, details of which are also provided within the Environmental Management and Monitoring Plan.

7.1.4 Groundwater Quality

The risk assessment model shows that the proposed restoration of the extension to the Castle Hill Quarry is unlikely to impact upon the groundwater quality or the quality of the groundwater or surface water receptors.

The maximum concentrations that may result from the site are based on a theoretical source term, set at the Inert WAC limits. Given that the actual source term concentrations in the site are likely to be much lower than simulated here, as strict adherence to the Waste Acceptance Criteria and Procedures will be applied, the actual predicted concentrations at the assigned compliance points 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.

8.0 REFERENCES

Allen, D. J., Brewerton, L. J., Coleby, L. M., Gibbs, B. R., Lewis, M. A., MacDonald, A. M., .. Williams, A. T. 1997. The physical properties of major aquifers in England and Wales. British Geological Survey Technical Report WD/97/34.

British Geological Survey (BGS), 1984. Taunton: Sheet 295. Solid and Drift Edition, 1:50,000.

British Geological Survey (BGS), 2021. Geology of Britain Viewer. http://mapapps.bgs.ac.uk/geologyofbritain/home.html Last accessed 28 September 2021.

Centre of Ecology and Hydrology (CEH), 2021a. Flood Estimation Handbook Website. https://fehweb.ceh.ac.uk/ Last accessed 28 September 2021.

Centre for Ecology and Hydrology (CEH) 2021b. National River Flow Archive: https://nrfa.ceh.ac.uk/data/station/meanflow/52016 Last accessed 28 September 2021.

Environment Agency, 2018. The Environment Agency's approach to groundwater protection. https://www.gov.uk/government/publications/groundwater-protection-position-statements Last accessed 28 September 2021.

NRFA Station Data for 52016 - Currypool Stream at Currypool Farm (ceh.ac.uk),2023. https://nrfa.ceh.ac.uk/data/station/spatial/52016.

Sedgemoor District Council, 2021. Phosphate Update - Somerset Levels and Moors SPA Surface Water Catchment Map https://www.sedgemoor.gov.uk/media/9644/Somerset-Levels-and-Moors-SPA-Surface-Water-Catchment-Map/pdf/Somerset_Levels_and_Moors_SPA_Surface_Water_Catchment.pdf Last accessed 22 September 2021.

UK Government, 2021a. MAGIC website https://magic.defra.gov.uk/ Last accessed 28 September 2021.

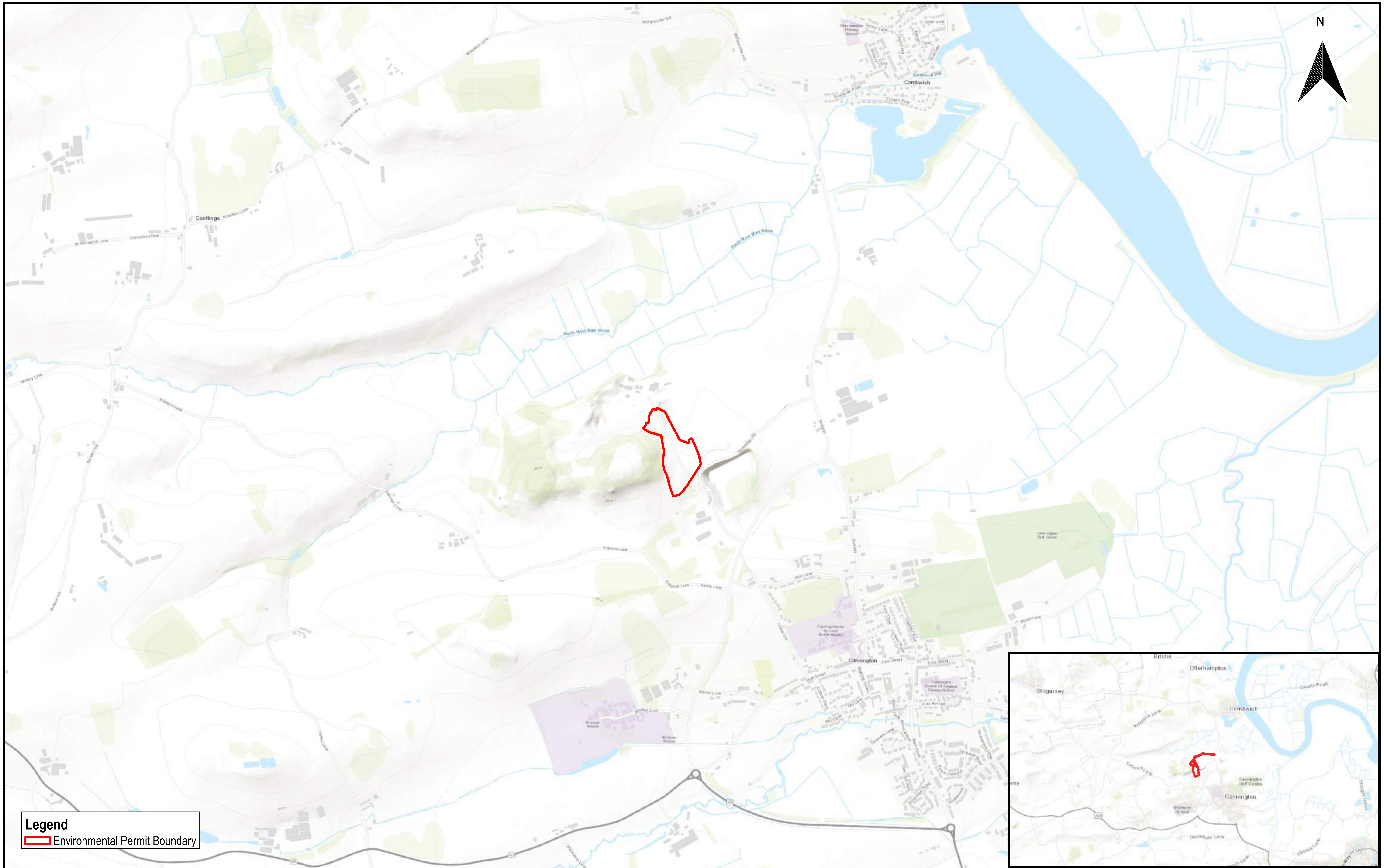
UK Government, 2021b. Catchment Data Explorer. https://environment.data.gov.uk/catchment-planning Last accessed 28 September 2021.

UK Government, 2021c. Water Quality Archive. https://environment.data.gov.uk/water-quality/view/explore Last accessed 28 September 2021.

WFD Classification Status Cycle 2, 2021. https://www.data.gov.uk/dataset/41cb73a1-91b7-4a36-80f4-b4c6e102651a/wfd-classification-status-cycle-2 last updated 28 January 2021.

Figures

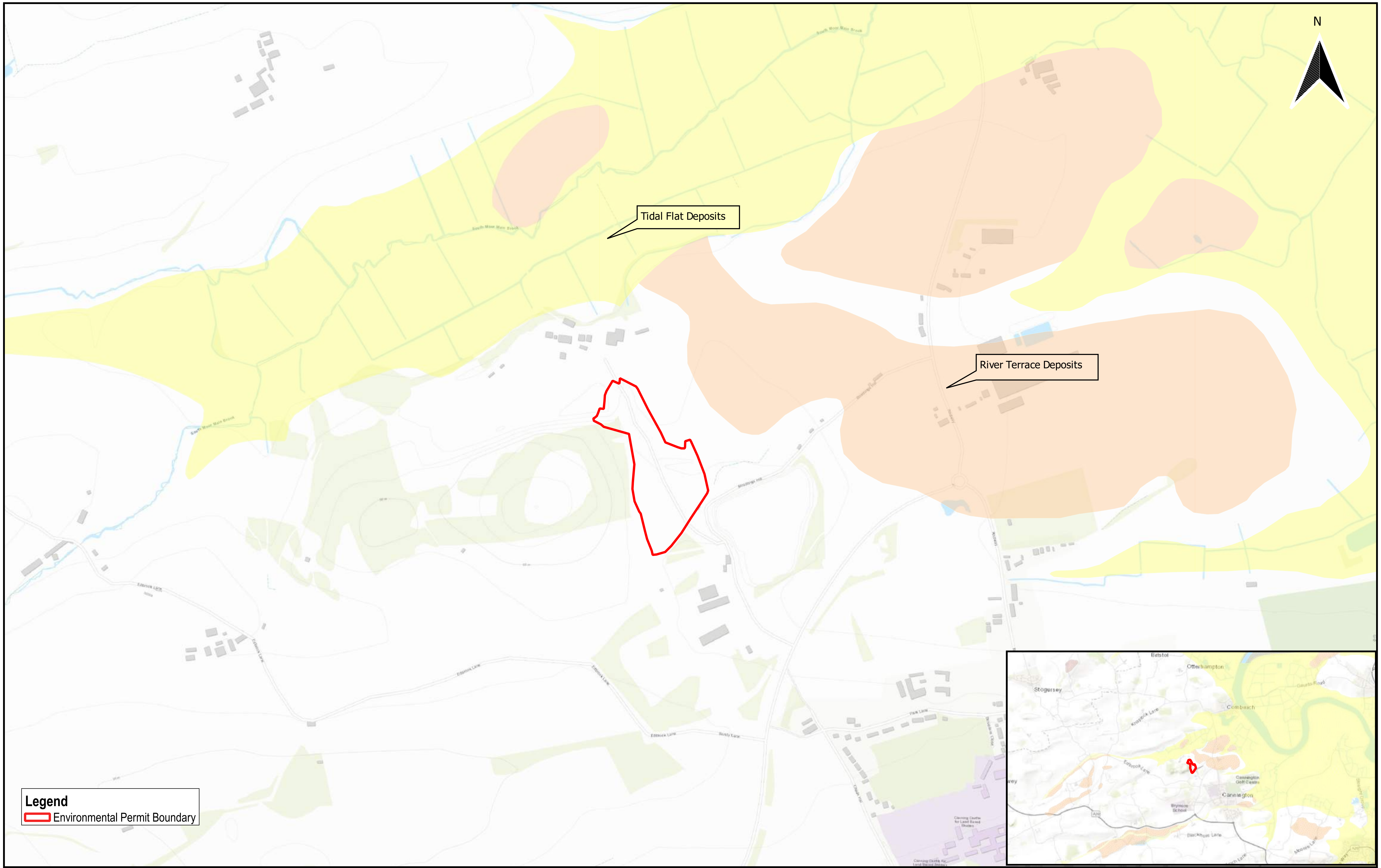
Figure 1 Site Location Plan



0 0.25 0.5 km Scale (at A3): 1:15,000 Datum: OSGB36 / British National Grid	Notes:	TETRA TECH	**Site Location Plan**

PROJECT: Castle Hill Quarry	FIGURE#: 1
CLIENT: Castle Hill Quarry Co. Limited	PROJECT NUMBER: B043634
DRAWN: TH / CHECKED: AJ	DATE: 13/04/2023

Figure 2 Superficial Deposits



0 0.25 0.5 km

Scale (at A3): 1:7,500

Datum: OSGB36 / British National Grid

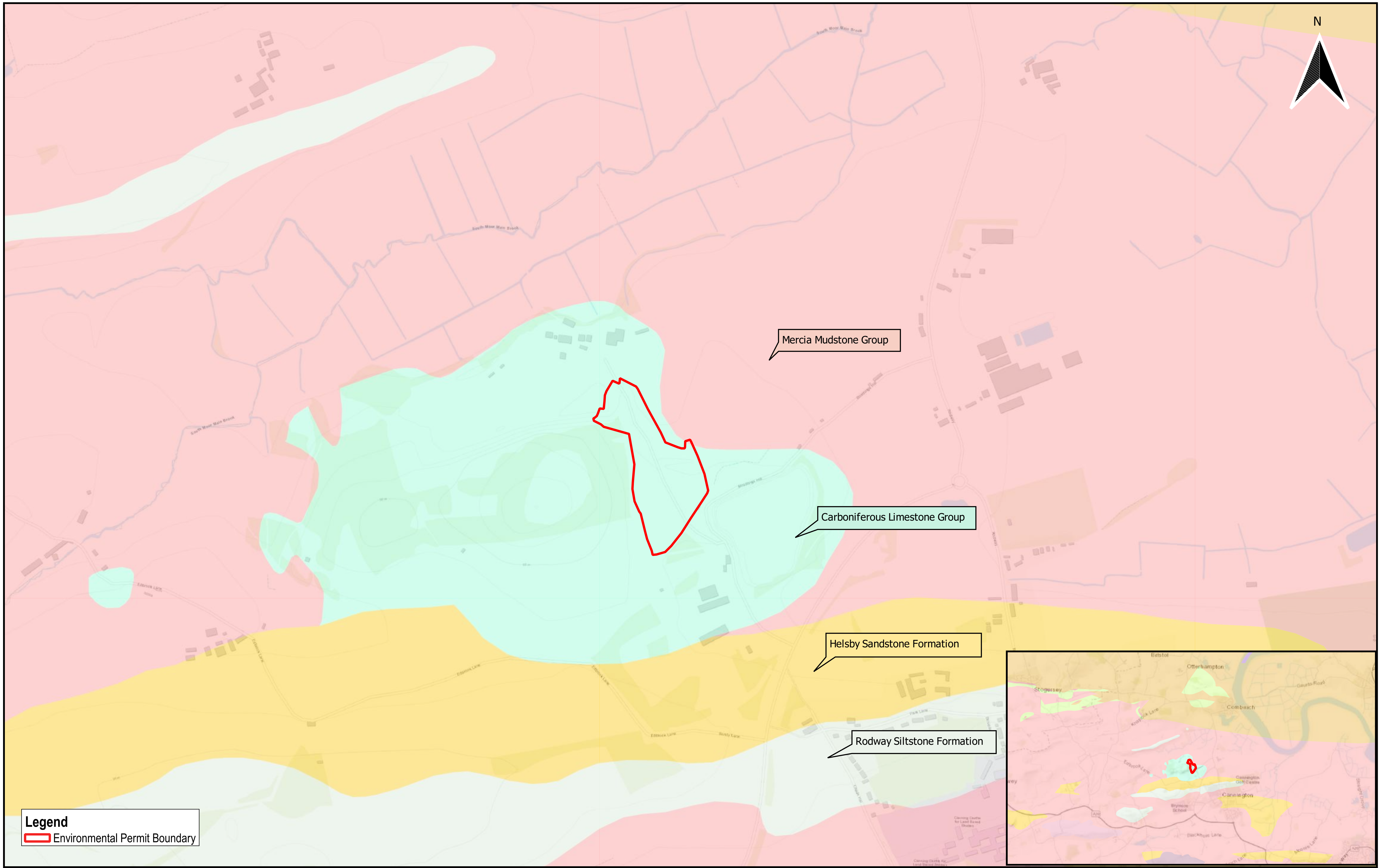
Notes:

TETRA TECH

Superficial Geology Map

PROJECT: Castle Hill Quarry	FIGURE#: 2
CLIENT: Castle Hill Quarry Co. Limited	PROJECT NUMBER: B043634
DRAWN: TH / CHECKED: AJ	DATE: 13/04/2023

Figure 3 Solid Geology



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Scale (at A3): 1:7,500

Datum: OSGB36 / British National Grid

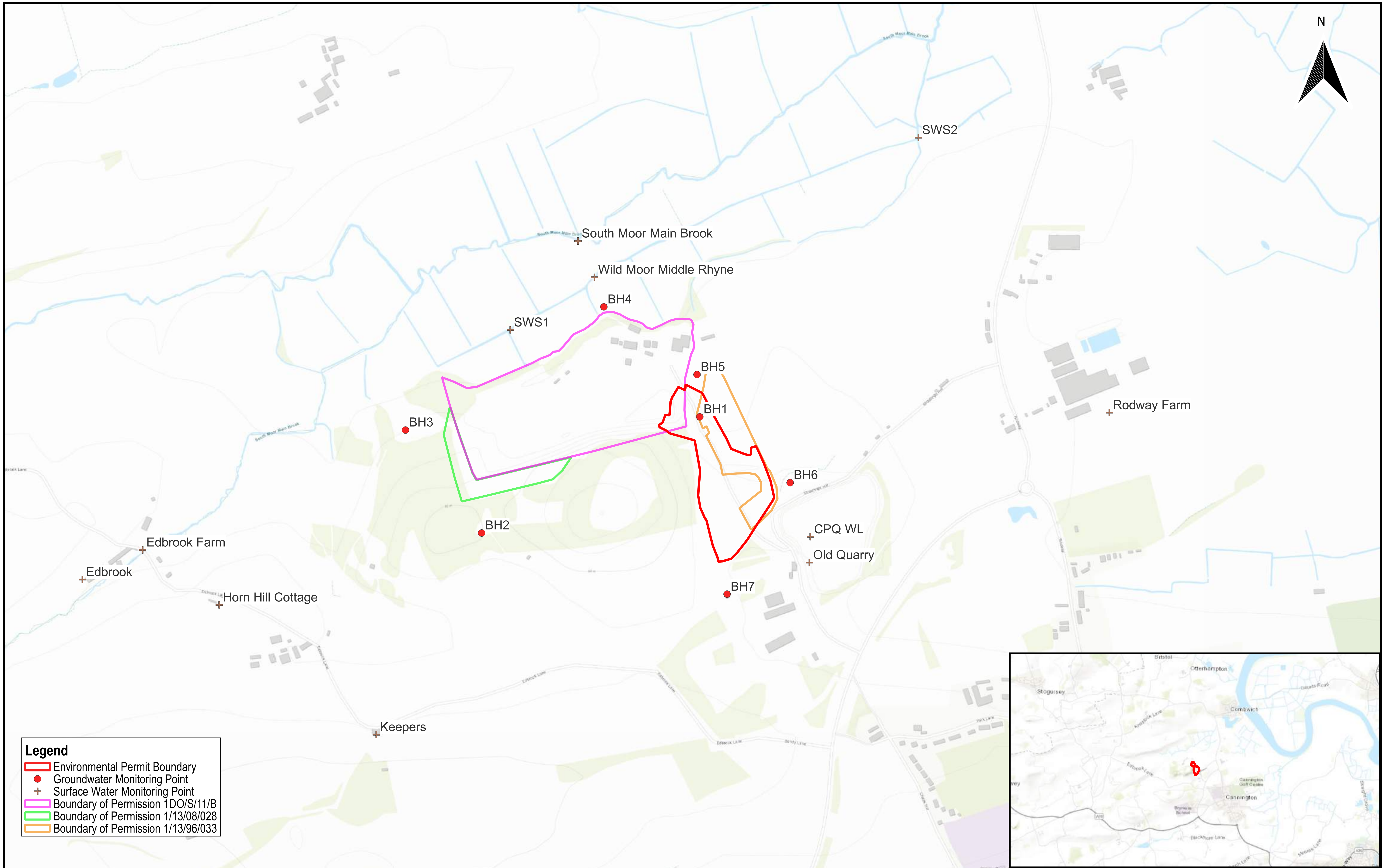
Notes:

TETRA TECH

Solid Geology Map

PROJECT: Castle Hill Quarry	FIGURE#: 3
CLIENT: Castle Hill Quarry Co. Limited	PROJECT NUMBER: B043634
DRAWN: TH CHECKED: AJ	DATE: 13/04/2023

Figure 4 Groundwater and surface water monitoring points



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Scale (at A3): 1:7,500

Datum: OSGB36 / British National Grid

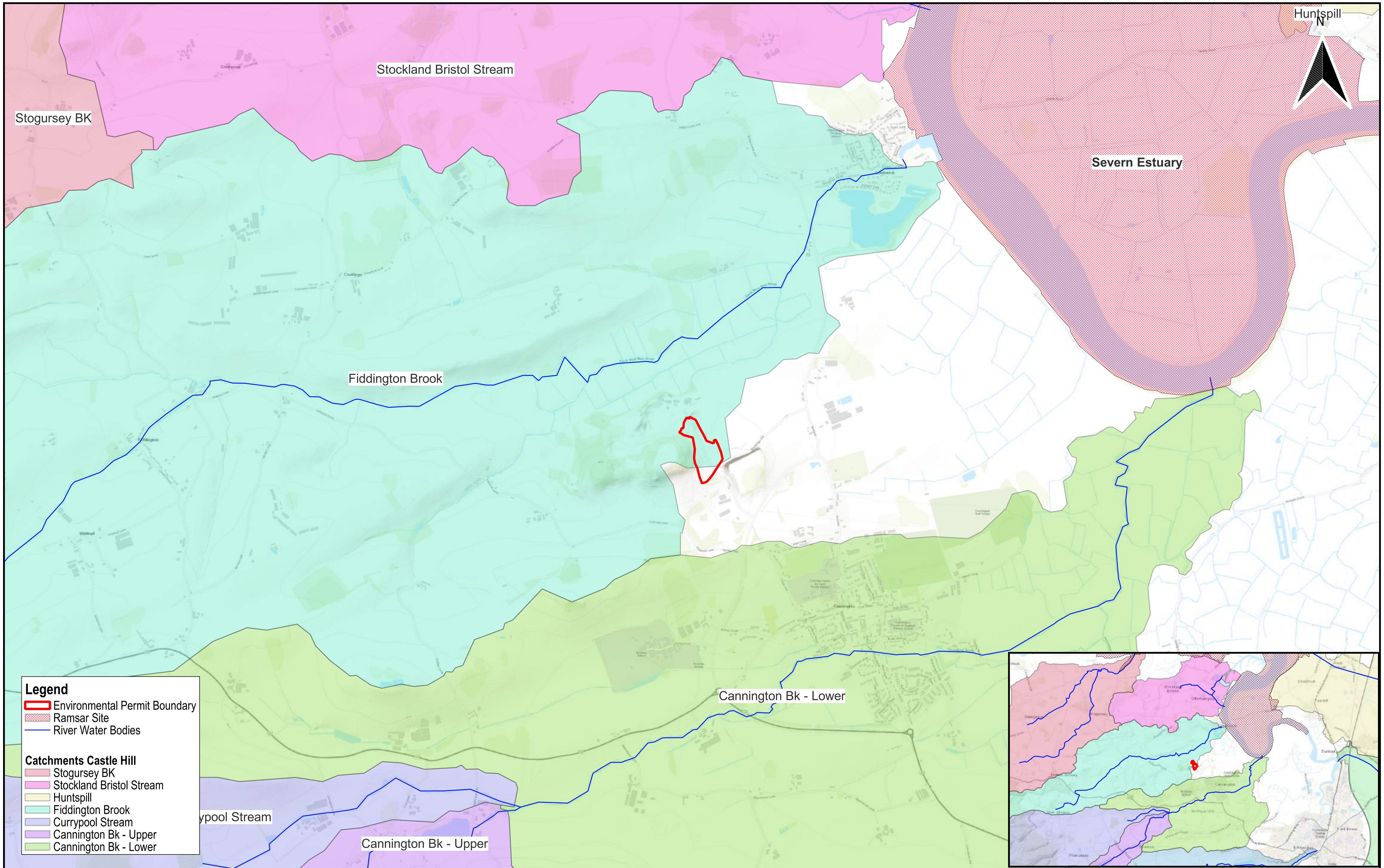
Notes:

TETRA TECH

Groundwater and Surface Water Monitoring Points

PROJECT: Castle Hill Quarry	FIGURE#: 4
CLIENT: Castle Hill Quarry Co. Limited	PROJECT NUMBER: B043634
DRAWN: TH CHECKED: AJ	DATE: 13/04/2023

Figure 5 Catchment Area



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Scale (at A3): 1:20,000
Datum: OSGB36 / British National Grid

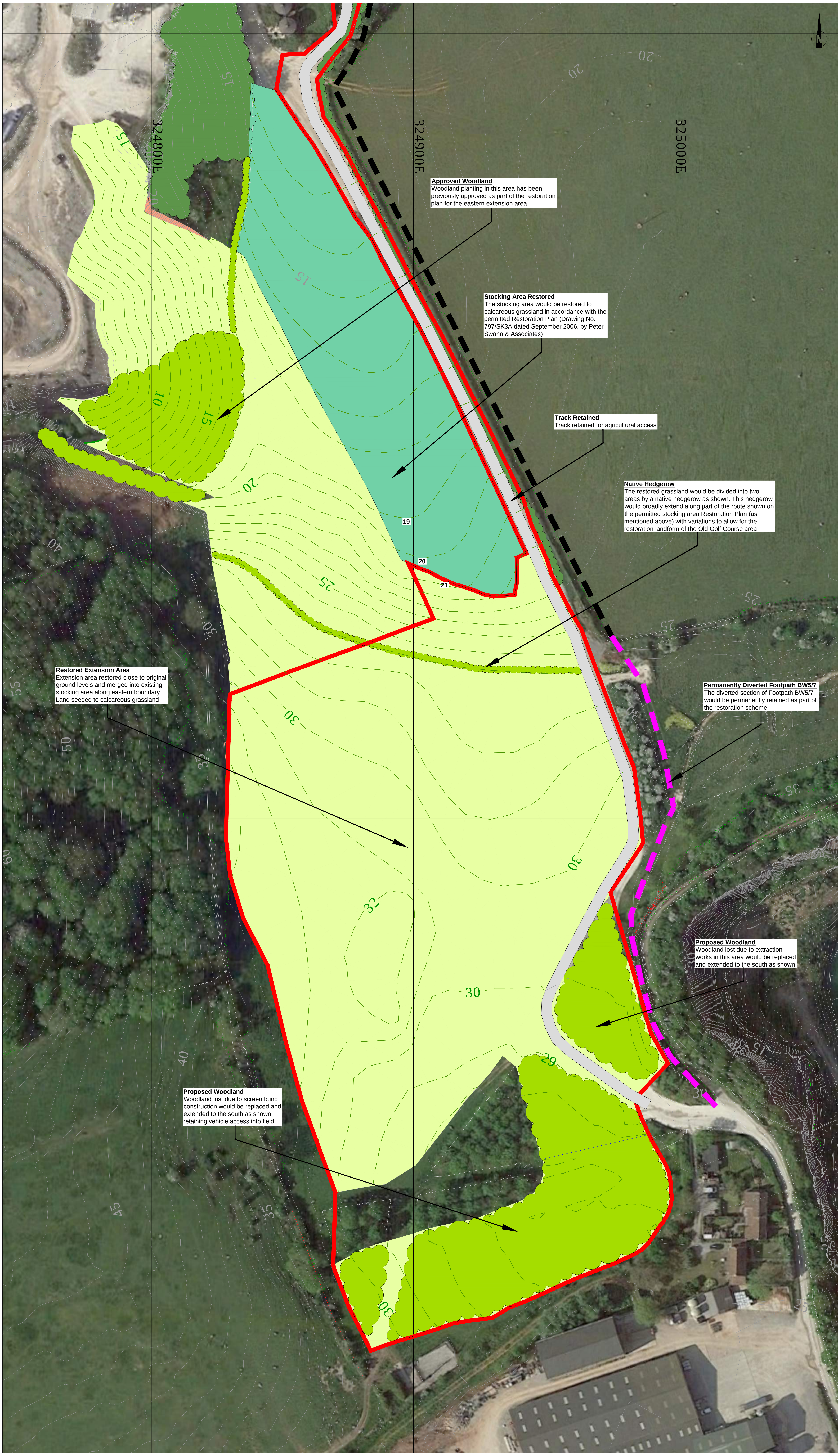
Notes:

TETRA TECH

Catchment Map

PROJECT: Castle Hill Quarry	FIGURE#: 5
CLIENT: Castle Hill Quarry Co. Limited	PROJECT NUMBER: B043634
DRAWN: TH / CHECKED: AJ	DATE: 13/04/2023

Figure 6 Restoration Plan



KEY

- APPLICATION BOUNDARY
- RESTORATION CONTOURS (@ 1m intervals)
- EXISTING FOOTPATH BW 5/7
- PERMANENT DIVERSION TO FOOTPATH BW 5/7
- STOCKING AREA RESTORED TO CALCAREOUS GRASSLAND IN ACCORDANCE WITH PERMITTED RESTORATION PLAN
- LAND INFILLED TO ORIGINAL GROUND LEVELS AND RESTORED TO CALCAREOUS GRASSLAND
- EXISTING WOODLAND/HEDGEROWS (NOT SHOWN ON AERIAL BACKGROUND IMAGE)
- PROPOSED WOODLAND AND HEDGROWS

0 10 20 30 40 50 METRES

SCALE 1:1000

Client	CASTLE HILL QUARRY CO. LTD.
Site	CASTLE HILL QUARRY
Project	PROPOSED OLD GOLF COURSE EXTENSION
Drawing Title	FINAL RESTORATION PLAN
Date	SEPTEMBER 2021
Drawing No.	6
Scale	1:1000 @ A2
Ref.	2109_006.012_CHILL025_OGC Rest Plan
Revision	0

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www.dblc.co.uk

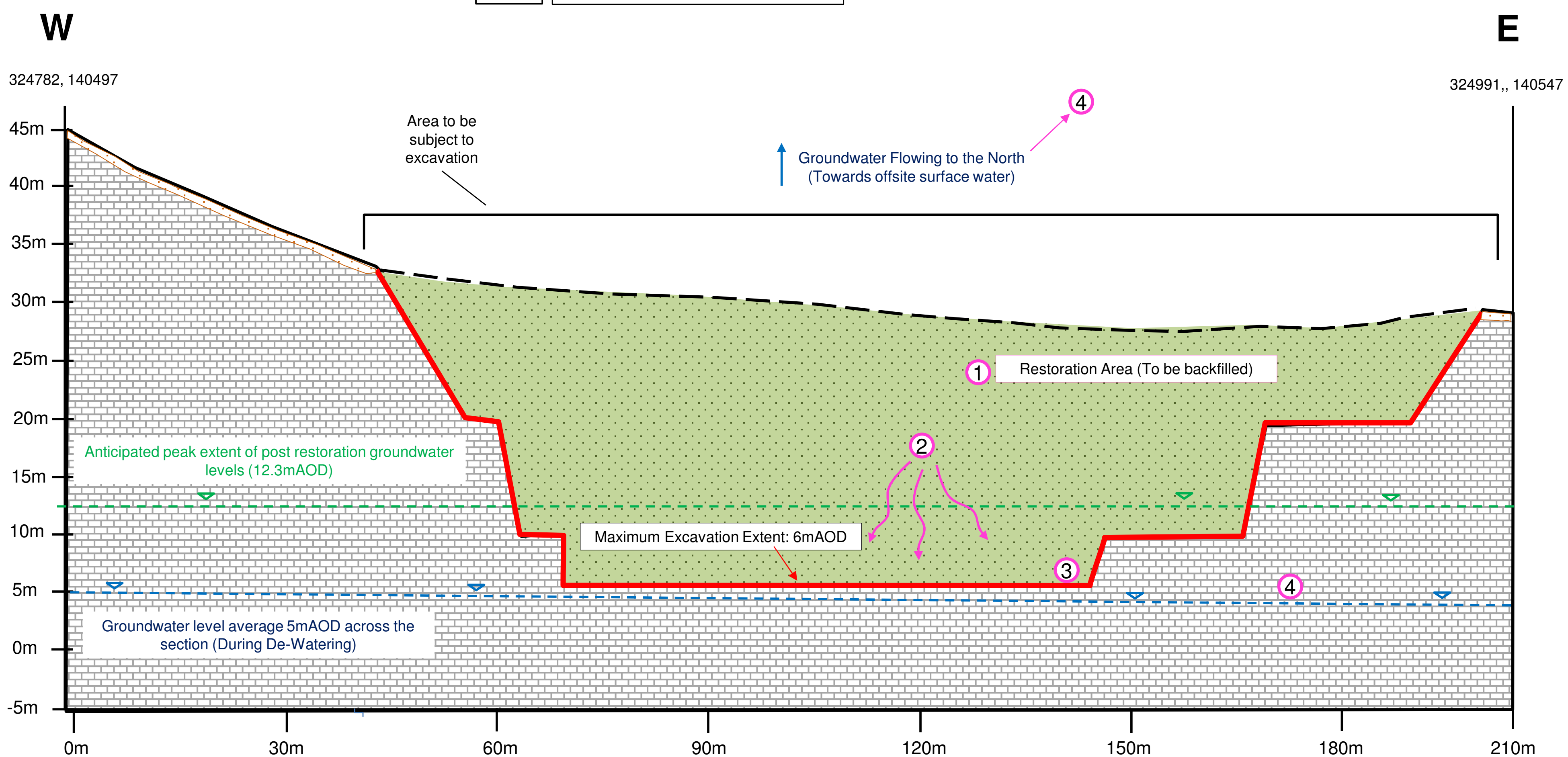
Figure 7 Conceptual Site Model

Legend

	Limestone.		Topsoil
	Current and post restoration ground level		Groundwater flow direction
	Proposed maximum extent of excavations		Groundwater level (During dewatering)
	Lands to be infilled to original ground levels and restored to calcareous grassland		Anticipated peak extent of post restoration groundwater levels
			Pollutant Linkage

Source, Pathways and Receptors:

1. Source – Leaching of contaminants from restoration soils and inert material.
2. Pathway – vertical migration through unsaturated backfill
3. Receptor – Groundwater
4. Pathway – Lateral migration with groundwater flow towards offsite surface water to the North
5. Receptor – Offsite surface water



Hydrogeological Conceptual Model: West to East Section (A – A')

Client: Castle Hill Quarry

Project: B043634

Date: January 2023 Checked: AJ

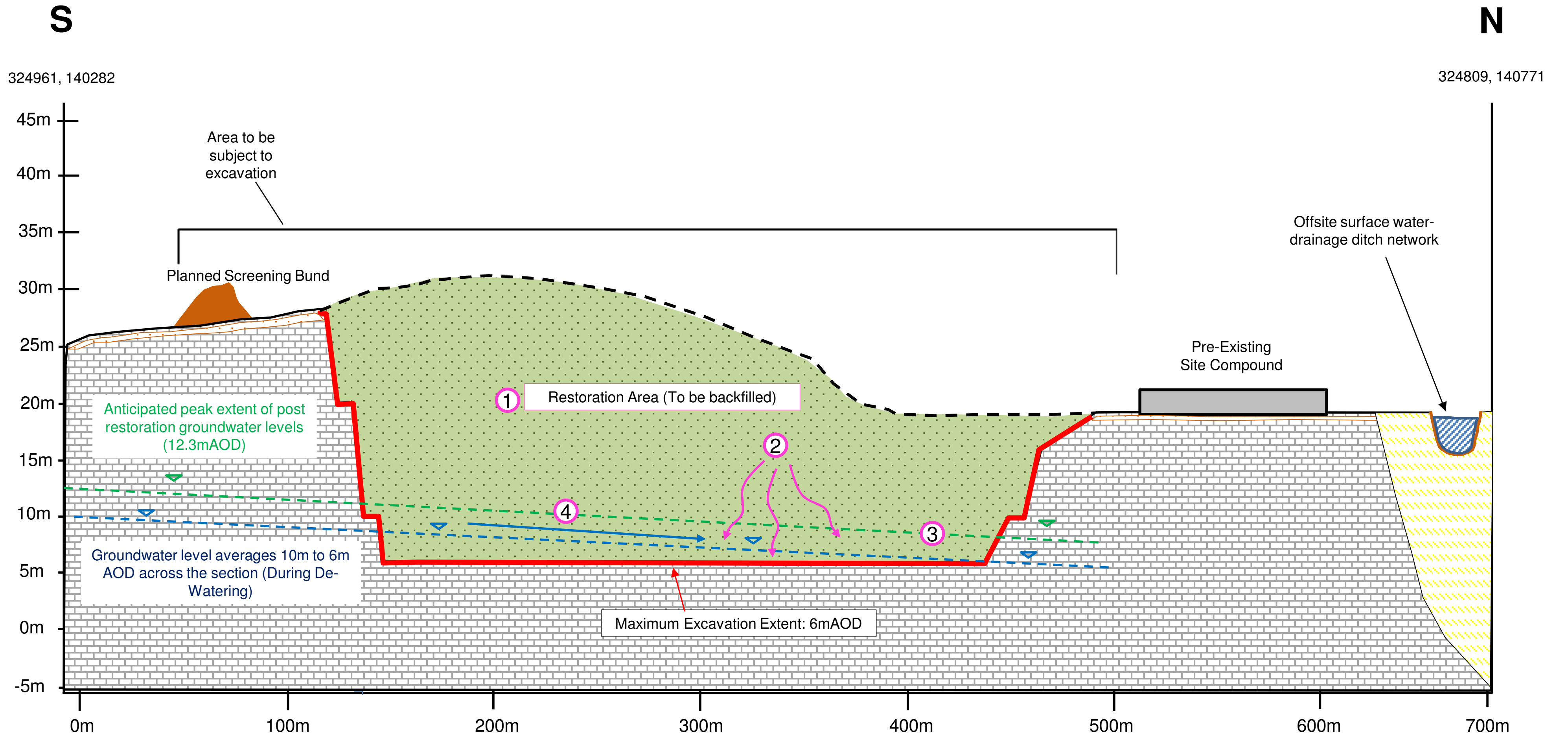
TETRA TECH

Legend

(limestone hatch)	Limestone.	(topsoil hatch)	Topsoil
(yellow hatch)	Tidal Flat Deposits	(blue arrow)	Groundwater flow direction
(black dashed line)	Current and post restoration ground level	(blue dashed line)	Groundwater level (During dewatering)
(red line)	Proposed maximum extent of excavations	(green dashed line)	Anticipated peak extent of post restoration groundwater levels
(green dotted fill)	Lands to be infilled to original ground levels and restored to calcareous grassland	(pink arrow)	Pollutant Linkage

Source, Pathways and Receptors:

1. Source – Leaching of contaminants from restoration soils and inert material.
2. Pathway – vertical migration through unsaturated backfill
3. Receptor – Groundwater
4. Pathway – Lateral migration with groundwater flow towards offsite surface water to the North
5. Receptor – Offsite surface water



Hydrogeological Conceptual Model: South to North Section (B-B')

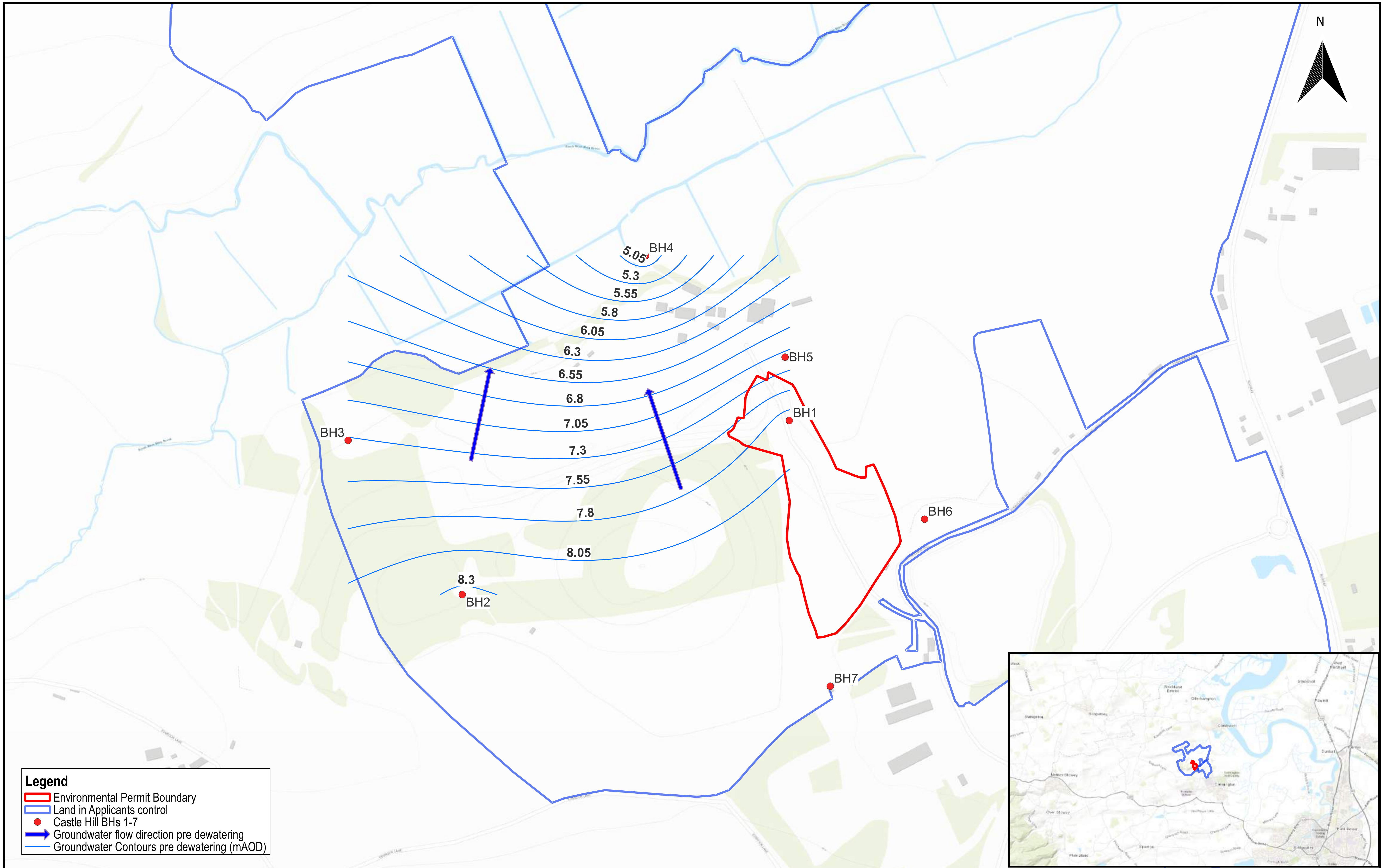
Client: Castle Hill Quarry

Project: B043634

Date: January 2023 Checked: AJ

TETRA TECH

Figure 8 Groundwater flow direction pre dewatering



0 0.25 0.5 km

Scale (at A3): 1:5,000

Datum: OSGB36 / British National Grid

Notes:

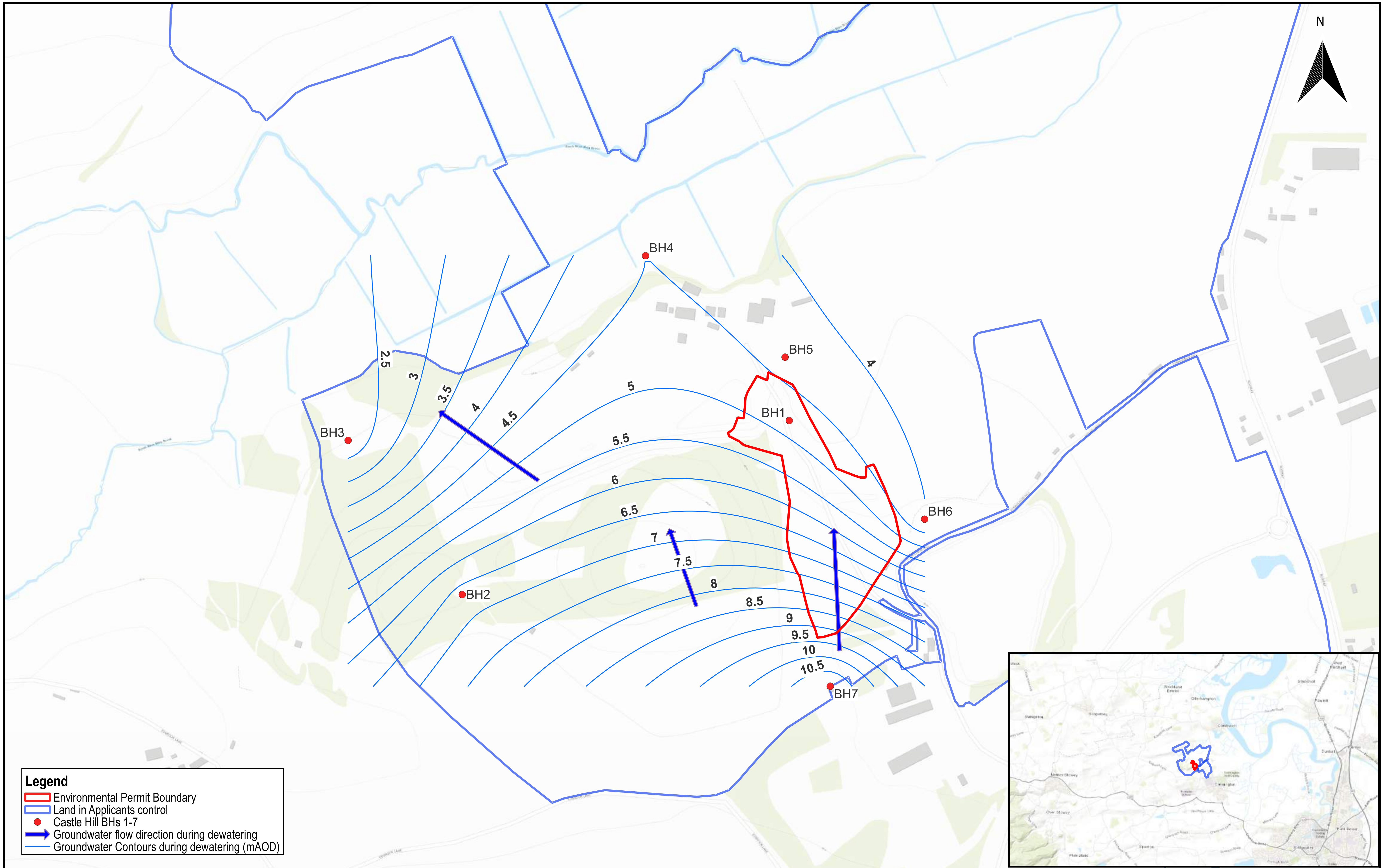
TETRA TECH

Groundwater Flow Direction pre de-watering

PROJECT: Castle Hill Quarry	FIGURE#: 8
CLIENT: Castle Hill Quarry Co. Limited	PROJECT NUMBER: B043634
DRAWN: TH / CHECKED: AJ	DATE: 13/04/2023

Figure 9 Groundwater flow direction post dewatering

1



0 0.25 0.5 km

Scale (at A3): 1:5,000

Datum: OSGB36 / British National Grid

Notes:

Groundwater Levels based on average data collected at BHs 2,3,4,5,6 and 7 since 2021.

BH1 data has been omitted from the dataset as this borehole was noted to have been blocked.

TETRA TECH

Groundwater Flow Direction during de-watering

PROJECT: Castle Hill Quarry	FIGURE#: 9
CLIENT: Castle Hill Quarry Co. Limited	PROJECT NUMBER: B043634
DRAWN: TH / CHECKED: AJ	DATE: 13/04/2023

2
Appendices

Appendix A: Standard Terms & Conditions

APPENDIX A - REPORT CONDITIONS

This report is produced solely for the benefit of Castle Hill Quarry Co. Limited and no liability is accepted for any reliance placed on it by any other party unless specifically agreed in writing otherwise.

This report refers, within the limitations stated, to the condition of the site at the time of the inspections. No warranty is given as to the possibility of future changes in the condition of the site.

This report is based on a visual site inspection, reference to accessible referenced historical records, information supplied by those parties referenced in the text and preliminary discussions with local and Statutory Authorities. Some of the opinions are based on unconfirmed data and information and are presented as the best that can be obtained without further extensive research. Where ground contamination is suspected but no physical site test results are available to confirm this, the report must be regarded as initial advice only, and further assessment should be undertaken prior to activities related to the site. Where test results undertaken by others have been made available these can only be regarded as a limited sample. The possibility of the presence of contaminants, perhaps in higher concentrations, elsewhere on the site cannot be discounted.

Whilst confident in the findings detailed within this report because there are no exact UK definitions of these matters, being subject to risk analysis, we are unable to give categoric assurances that they will be accepted by Authorities or Funds etc. without question as such bodies often have unpublished, more stringent objectives. This report is prepared for the proposed uses stated in the report and should not be used in a different context without reference to Tetra Tech. In time improved practices or amended legislation may necessitate a re-assessment.

The assessment of ground conditions within this report is based upon the findings of the study undertaken. We have interpreted the ground conditions in between locations on the assumption that conditions do not vary significantly. However, no investigation can inspect each and every part of the site and therefore changes or variances in the physical and chemical site conditions as described in this report cannot be discounted.

The report is limited to those aspects of land contamination specifically reported on and is necessarily restricted and no liability is accepted for any other aspect especially concerning gradual or sudden pollution incidents. The opinions expressed cannot be absolute due to the limitations of time and resources imposed by the agreed brief and the possibility of unrecorded previous use and abuse of the site and adjacent sites. The report concentrates on the site as defined in the report and provides an opinion on surrounding sites. If migrating pollution or contamination (past or present) exists further extensive research will be required before the effects can be better determined.

Appendix B - Waste Types Permitted

EWC Code	Description	Restriction
01	**WASTE RESULTING FROM EXPLORATION, MINING, QUARRYING AND PHYSICAL AND CHEMICAL TREATMENT OF MINERALS**	
01 01	**Wastes from mineral excavation**	
01 01 02	Waste glass-based fibrous materials	Restricted to waste overburden and interburden only
01 04	**Wastes from physical and chemical processing of non-metafillerous minerals**	
01 04 08	Waste gravel and crushed rocks other than those mentioned in 04 04 06	
01 04 09	Waste sand and clay	
02	**WASTES FROM AGRICULTURE, HORTICULTURE, AQUACULTURE, FORESTRY, HUNTING AND FISHING, FOOD PREPARATION AND PROCESSING**	
02 04	**wastes from the preparation and processing of meat, fish and other foods of animal origin**	
02 04 01	Soil from cleaning and washing beet	
10	**WASTES FROM THERMAL PROCESSES**	
10 12	**Wastes from manufacture of ceramic goods, bricks, tiles and construction products**	
10 12 08	Waste ceramics, brick, tiles and construction products (after thermal processing)	
10 13	**Wastes from manufacture of cement, lime and plaster and articles and products made from them**	
10 13 14	Waste concrete	
17	**CONSTRUCTION AND DEMOLITION WASTES (INCLUDING EXCAVATED SOIL FROM CONTAMINATED SITES)**	
17 01	**Concrete, bricks, tiles and ceramics**	
17 01 01	Concrete	
17 01 02	Bricks	
17 01 03	Tiles and ceramics	
17 01 07	Mixtures of concrete, bricks, tiles and ceramics other than those mentioned in 17 01 06	Metal from reinforced concrete must have been removed.
17 05	**Soil (including excavated soil from contaminated sites), stones and dredging spoil**	
17 05 04	Soil and stones other than those mentioned in 17 05 03	Excluding topsoil, peat; excluding soil and stones from contaminated sites
19	**WASTES FROM WASTE MANAGEMENT FACILITIES, OFF-SITE WASTE WATER TREATMENT PLANTS AND THE PREPARATION OF WATER INTENDED FOR HUMAN CONSUMPTION AND WATER FOR INDUSTRIAL USE**	
19 12	**Wastes from the mechanical treatment of waste (for example sorting, crushing, compacting, pelletising) not otherwise specified**	
19 12 09	Minerals only	Wastes from the treatment of waste aggregates that are otherwise naturally occurring minerals. Does

		not include fines from treatment of any non-hazardous waste or gypsum from recovered plasterboard.
19 12 12	Other wastes from mechanical treatment of wastes other than those mentioned in 19 12 12	Restricted to crushed bricks, tiles, concrete and ceramics only. Metal from reinforced concrete must be removed. Does not include fines from treatment of any non-hazardous waste or gypsum from recovered plasterboard.
20	**MUNICIPAL WASTES (HOUSEHOLD WASTE AND SIMILAR COMMERCIAL, INDUSTRIAL AND INSITUTIONAL WASTES) INCLUDING SEPARATELY COLLECTED FRACTIONS**	
20 02	**Garden and park wastes (including cemetery waste)**	
20 02 02	Soil and stones	Only from garden and parks waste; excluding topsoil, peat.

Appendix C - Methodology for leachability concentration calculations

APPENDIX B

According to BS EN 12457, the leachable contaminant concentrations (mg/kg) are calculated from the concentration of contaminant in the eluate (mg/L) by the following equation:

$A = C [(L/Md) + (MC/100)]$

Where:

A = is the leachable contaminant concentration within the soil sample [mg/kg]
C = is the contaminant concentration within the eluate [mg/L]
L = is the volume of leachate used during the test [L]
Md = is the dry mass of the soil sample [kg]
MC = is the moisture content* of the soil sample [%]

* Note: moisture content is 100 * (Mw – Md)/Md, where:

Mw = is the undried mass of soilsample
L = is calculated by the laboratory from the following equation:
[10 – (MC/100)]
Md

Thus, substituting L into the equation above, it can be seen that

$A = 10C$

The equivalent leachabilities were calculated by re-arranging the formula to:

$C = A/10$

This is then multiplied by 1,000 to allow for the conversion of mg/l to µg/l.

Appendix D - RAM Modelling Outputs

BREAKTHROUGH RESULTS

Site Name: "Extension - Castle Hill"

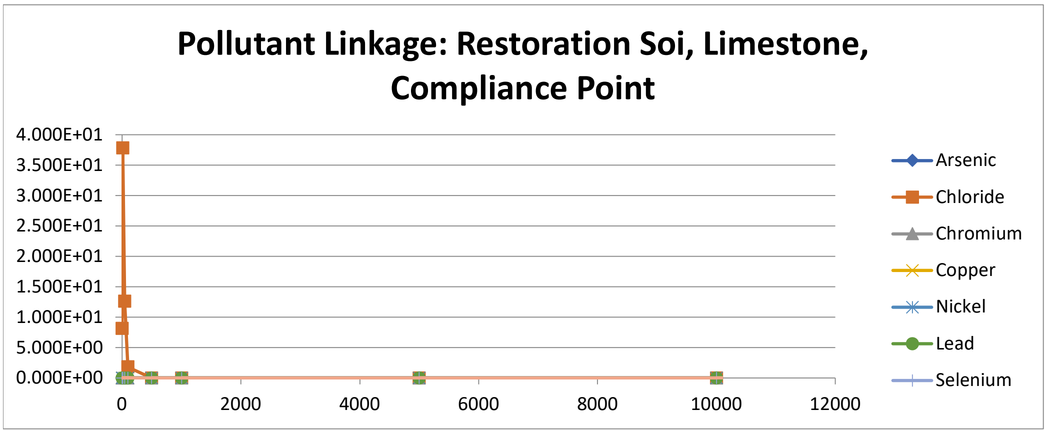
Advanced

Pollutant Linkage: Restoration Soi, Limestone, Compliance Point

Concentrations in mg/L in Compliance Point

Compared with EAL target concentration in mg/L

Time(years)	Species1 **Arsenic**	Species2 **Chloride**	Species3 **Chromium**	Species4 **Copper**	Species5 **Nickel**	Species6 **Lead**	Species7 **Selenium**	Species8 **Zinc**
EAL target	1.425E-02	2.500E+02	4.700E-03	1.087E-02	4.000E-03	1.200E-03	1.000E-02	2.780E-02
5	0.000E+00	8.197E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	3.780E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.845E-35	0.000E+00
50	0.000E+00	1.263E+01	1.275E-40	0.000E+00	0.000E+00	0.000E+00	6.958E-17	0.000E+00
100	1.439E-19	1.828E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.520E-09	0.000E+00
500	2.071E-05	1.913E-07	8.406E-12	2.628E-26	2.229E-31	0.000E+00	3.097E-04	0.000E+00
1000	4.561E-04	0.000E+00	7.373E-07	4.160E-21	0.000E+00	2.134E-20	1.156E-04	3.561E-16
5000	6.786E-06	0.000E+00	1.755E-04	2.712E-06	1.628E-08	1.523E-06	2.408E-11	1.066E-04
10000	3.853E-09	1.169E-09	1.593E-05	1.143E-04	5.406E-06	3.859E-05	0.000E+00	6.037E-04



BREAKTHROUGH RESULTS

Site Name: "Extension - Castle Hill"

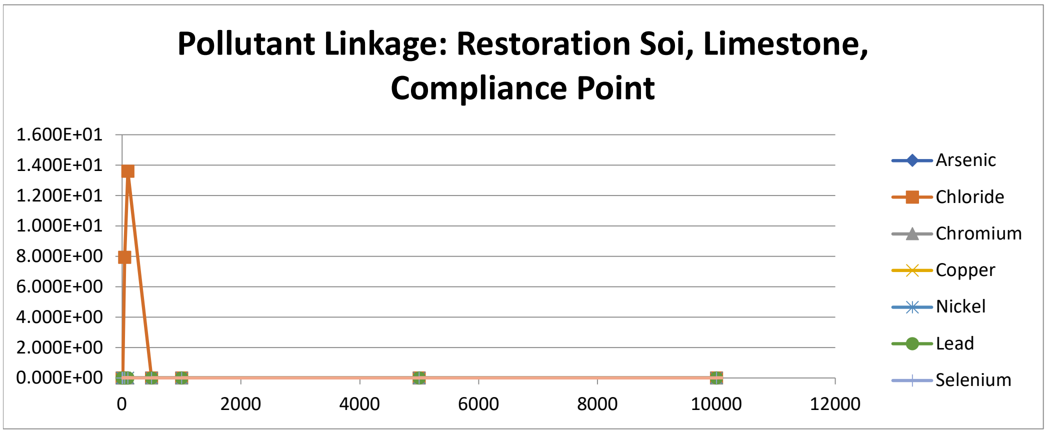
Advanced

Pollutant Linkage: Restoration Soi, Limestone, Compliance Point

Concentrations in mg/L in Compliance Point

Compared with EAL target concentration in mg/L

Time(years)	Species1 Arsenic	Species2 Chloride	Species3 Chromium	Species4 Copper	Species5 Nickel	Species6 Lead	Species7 Selenium	Species8 Zinc
EAL target	1.425E-02	2.500E+02	4.700E-03	1.087E-02	4.000E-03	1.200E-03	1.000E-02	2.780E-02
5	0.000E+00	3.547E-15	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	2.006E-06	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
50	0.000E+00	7.934E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
100	0.000E+00	1.359E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.091E-32	0.000E+00
500	4.821E-24	8.957E-05	5.251E-39	0.000E+00	0.000E+00	0.000E+00	1.380E-15	0.000E+00
1000	3.314E-19	9.373E-09	2.365E-27	0.000E+00	0.000E+00	0.000E+00	4.660E-09	0.000E+00
5000	5.439E-06	0.000E+00	1.576E-11	0.000E+00	0.000E+00	1.463E-25	3.125E-05	4.292E-22
10000	5.455E-05	0.000E+00	2.470E-07	3.108E-21	2.090E-23	0.000E+00	7.217E-06	1.931E-15



BREAKTHROUGH RESULTS

Site Name: "Extension - Castle Hill"

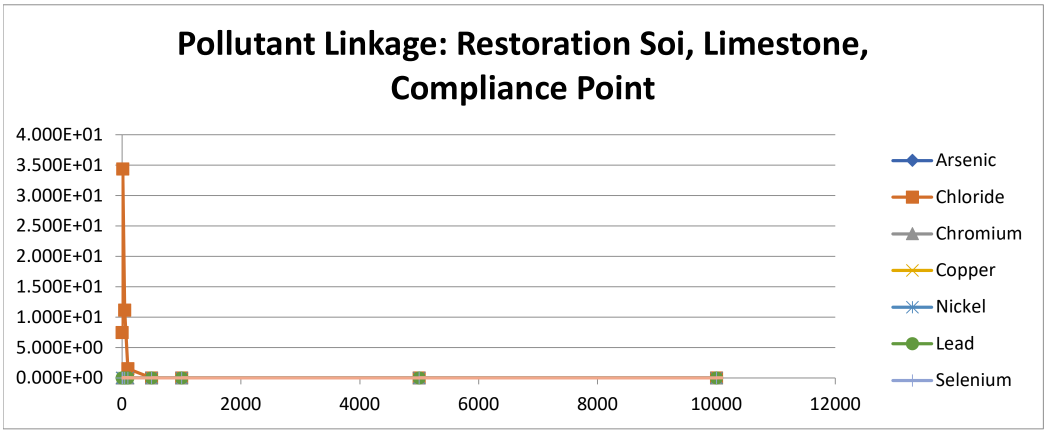
Advanced

Pollutant Linkage: Restoration Soi, Limestone, Compliance Point

Concentrations in mg/L in Compliance Point

Compared with EAL target concentration in mg/L

Time(years)	Species1 Arsenic	Species2 Chloride	Species3 Chromium	Species4 Copper	Species5 Nickel	Species6 Lead	Species7 Selenium	Species8 Zinc
	1.425E-02	2.500E+02	4.700E-03	1.087E-02	4.000E-03	1.200E-03	1.000E-02	2.780E-02
5	0.000E+00	7.458E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
10	0.000E+00	3.433E+01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.228E-35	0.000E+00
50	0.000E+00	1.115E+01	1.160E-40	0.000E+00	0.000E+00	0.000E+00	6.328E-17	0.000E+00
100	1.304E-19	1.553E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.287E-09	0.000E+00
500	1.860E-05	7.534E-08	7.587E-12	2.341E-26	1.990E-31	0.000E+00	2.767E-04	0.000E+00
1000	4.077E-04	0.000E+00	6.612E-07	3.917E-21	0.000E+00	1.894E-20	1.030E-04	3.209E-16
5000	6.055E-06	0.000E+00	1.567E-04	2.424E-06	1.455E-08	1.361E-06	2.146E-11	9.520E-05
10000	3.438E-09	1.126E-09	1.422E-05	1.021E-04	4.828E-06	3.446E-05	0.000E+00	5.390E-04



BREAKTHROUGH RESULTS

Site Name: "Extension - Castle Hill"

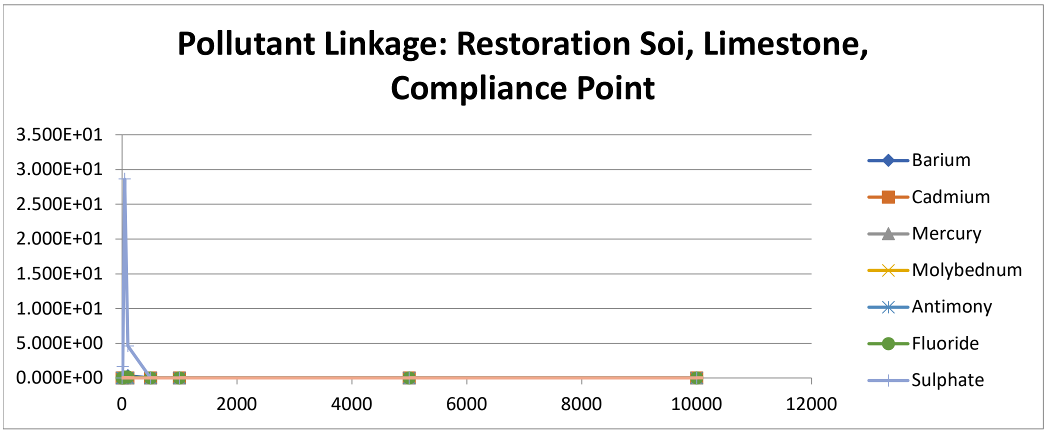
Advanced

Pollutant Linkage: Restoration Soi, Limestone, Compliance Point

Concentrations in mg/L in Compliance Point

Compared with EAL target concentration in mg/L

Time(years)	Species1 Barium	Species2 Cadmium	Species3 Mercury	Species4 Molybednum	Species5 Antimony	Species6 Fluoride	Species7 Sulphate	Species8 Phenol
EAL target	7.000E-01	1.500E-04	7.000E-04	7.000E-02	5.000E-03	1.500E+00	2.500E+02	7.700E-03
5	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.203E-14	3.336E-03	5.721E-12
10	2.227E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.238E-07	1.678E+00	7.972E-12
50	6.033E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.695E-01	2.863E+01	1.648E-12
100	3.251E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.726E-01	4.593E+00	2.297E-13
500	8.597E-05	1.281E-25	1.196E-34	1.500E-18	3.284E-32	2.063E-07	6.375E-07	3.171E-21
1000	7.209E-10	0.000E+00	3.556E-26	4.151E-10	0.000E+00	2.322E-11	0.000E+00	0.000E+00
5000	0.000E+00	3.100E-07	7.254E-11	1.262E-04	2.402E-09	0.000E+00	0.000E+00	0.000E+00
10000	0.000E+00	4.197E-06	6.269E-08	6.853E-05	7.968E-07	0.000E+00	0.000E+00	3.226E-22



BREAKTHROUGH RESULTS

Site Name: "Extension - Castle Hill"

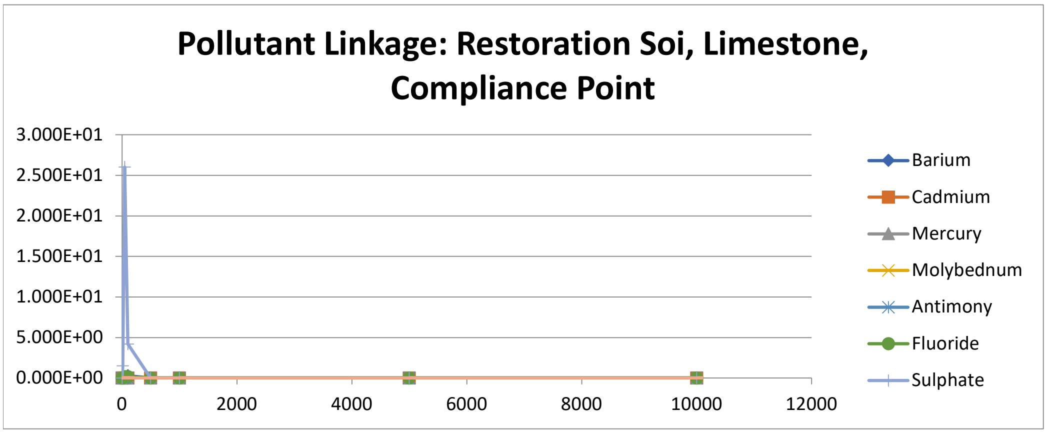
Advanced

Pollutant Linkage: Restoration Soi, Limestone, Compliance Point

Concentrations in mg/L in Compliance Point

Compared with EAL target concentration in mg/L

Time(years)	Species1 Barium	Species2 Cadmium	Species3 Mercury	Species4 Molybednum	Species5 Antimony	Species6 Fluoride	Species7 Sulphate	Species8 Phenol
	7.000E-01	1.500E-04	7.000E-04	7.000E-02	5.000E-03	1.500E+00	2.500E+02	7.700E-03
5	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.912E-14	3.033E-03	2.080E-10
10	2.025E-11	0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.671E-07	1.526E+00	2.899E-10
50	5.484E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.541E-01	2.603E+01	5.993E-11
100	2.956E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.569E-01	4.175E+00	8.354E-12
500	7.815E-05	1.164E-25	1.087E-34	1.363E-18	2.986E-32	1.875E-07	5.796E-07	1.153E-19
1000	6.555E-10	0.000E+00	3.233E-26	3.773E-10	0.000E+00	2.115E-11	0.000E+00	0.000E+00
5000	0.000E+00	2.818E-07	6.594E-11	1.147E-04	2.183E-09	0.000E+00	0.000E+00	0.000E+00
10000	0.000E+00	3.815E-06	5.699E-08	6.230E-05	7.244E-07	0.000E+00	0.000E+00	1.174E-20



BREAKTHROUGH RESULTS

Site Name: "Extension - Castle Hill"

Advanced

Pollutant Linkage: Restoration Soi, Limestone, Compliance Point

Concentrations in mg/L in Compliance Point

Compared with EAL target concentration in mg/L

	7.000E-01	1.500E-04	7.000E-04	7.000E-02	5.000E-03	1.500E+00	2.500E+02	7.700E-03
Time(years)	Species1	Species2	Species3	Species4	Species5	Species6	Species7	Species8
	Barium	**Cadmium**	**Mercury**	**Molybednum**	**Antimony**	**Fluoride**	**Sulphate**	**Phenol**
5	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.041E-24	0.000E+00
10	1.532E-39	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.357E-30	0.000E+00	2.901E-34
50	5.352E-19	0.000E+00	0.000E+00	0.000E+00	0.000E+00	7.925E-13	9.522E-03	2.431E-32
100	2.868E-10	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.504E-06	1.825E+00	3.389E-33
500	2.345E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.243E-02	6.016E-01	3.263E-40
1000	3.267E-02	0.000E+00	0.000E+00	1.412E-35	0.000E+00	6.996E-03	1.608E-03	0.000E+00
5000	8.903E-07	0.000E+00	3.956E-34	1.802E-17	0.000E+00	1.488E-10	0.000E+00	0.000E+00
10000	2.224E-11	3.391E-20	0.000E+00	3.582E-10	3.136E-24	0.000E+00	0.000E+00	0.000E+00