FWS Geological & Geo-Environmental Consultants

SIRIUS MINERALS PLC - DISCHARGE OF PLANNING CONDITIONS FOR PLANNING APPLICATION NYM/2014/0676/MEIA, THE YORK POTASH PROJECT

CONDITION	NYMNPA 46
REPORT	HYDROGEOLOGICAL RISK ASSESSMENT
SITE	PHASE 3 WORKS AT WOODSMITH MINE, NORTH YORKSHIRE
DOCUMENT NUMBER	40-FWS-WS-70-WM-RA-0003Rev4

1433DevOR175Rev4/March 2017

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PROJECT NUMBER	1433Dev	
PROJECT TITLE	York Potash Project	
CLIENT	Sirius Minerals Plc 7-10 Manor Court Manor Garth SCARBOROUGH YO11 3TU	
REPORT TITLE	Hydrogeological Risk Assessment For Phase 3 Works At Woodsmith Mine, North Yorkshire	
REPORT REFERENCE	1433DevOR175	
DOCUMENT NUMBER	40-FWS-WS-70-WM-RA-0003	
REVISION	**Date**	**Checked**
Rev0	14/03/2017	RIL
Rev1	27/03/2017	RIL
Rev2	31/03/2017	RIL
Rev3	03/04/2017	RIL
Rev4	04/04/2017	RIL

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HYDROGEOLOGICAL RISK ASSESSMENT FOR THE PHASE 3 WORKS AT WOODSMITH MINE, NORTH YORKSHIRE

1 INTRODUCTION

1.1 General Background

This document has been prepared on behalf of Sirius Minerals Plc and provides the Hydrogeological Risk Assessment for the Phase 3 development condition at Woodsmith Mine following completion of the Phase 2 works. This is required to satisfy Conditions 45 and 46 of the North York Moors National Park Authority (NYMNPA) planning permission NYM/2014/0676/MEIA.

FWS Consultants Ltd (FWS) prepared a revised Hydrogeological Baseline Report (Ref. 1) presenting the geological and hydrogeological conditions determined for the proposed minesite, all of the monitoring data from 2012 to 2016 and identifying the hydrogeological receptors in the vicinity of the site. A Hydrogeological Risk Assessment (HRA) was prepared in January 2017 specifically in relation to the Phase 2 Works only (Ref. 2).

This report presents a summary of the Phase 3 construction elements, including the groundwater management measures incorporated into the design. The report provides a qualitative assessment of the potential effects of these works on groundwater conditions on and adjacent to the site and presents the results of quantitative modelling by ESI (Ref. 3) of changes to groundwater levels and spring flow rates caused by completion of the combined Phase 2 and 3 Works.

West and south of the minesite are two areas of moorland that are designated as part of the North York Moors SAC, namely Ugglebarnby Moor and Sneaton Low Moor (Drawing 1433DevOD215). Within this report they will be referred to as Ugglebarnby Moor SAC and Sneaton Low Moor SAC respectively for clear distinction.

Subsequent revisions of this document will be issued to present the hydrogeological risk assessment and recommendations for all future phases of the development.

1.2 Compliance With Conditions

The tables below set out the wording of Planning Conditions 45 and 46 to Planning Consent Ref No. NYM/2014/0676/MEIA that relates for the Hydrogeological Risk Assessment and details where the relevant material, to comply with this condition, has been provided within this report:-

NYMNP	Compliance with Condition 45
Prior to the commencement of shaft sinking or chamber formation beneath ground at Doves Nest Farm site the following shall be installed, brought into operation and maintained to the satisfaction of the MPA in accordance with the details in the document "York Potash Project: Habitats Regulations Assessment" prepared by Amec Foster Wheeler dated June 2015, with document reference 35190CGos064R:	1. Details of the initial shaft sinking and chamber formation works to be undertaken during the Phase 3 development are presented in Section 3. 2. Details of the Hydrogeological Risk Assessment, Modelling and recommendations on the mitigation measures necessary as part of the initial shaft sinking and chamber formation works to be undertaken during Phase 3 are presented in

I. A grout wall along the western and southern perimeter of the mineshaft platform extending down to the interface between the Moor Grit and Scarborough aquifers. II. A groundwater pressure relief drain to the west of the grout wall; and III. A recharge trench around the western perimeter of PWMF Bund CD to discharge runoff from this structure into the Moor Grit aquifer.	Sections 6 to 9. 3. Confirmation as to whether a grout wall, groundwater pressure relief drain and recharge trench are necessary as part of the Phase 3 works to provide environmental protection to sensitive hydrogeologically supported receptors is presented in Section 9.6.

NYMNP	Compliance with Condition 46
Prior to the Commencement of Development at the Doves Nest Farm Minesite a revised Hydrogeological Risk Assessment based on the most up to date monitoring data shall be undertaken in accordance with the details in the document "York Potash Project: Habitats Regulations Assessment" prepared by Amec Foster Wheeler dated June 2015, with document reference 35190CGos064R and submitted for approval in writing by the MPA in consultation with Natural England and the Environment Agency.	1. Details of the Phase 3 Works development elements are presented in Section 3. 2. Up to date monitoring is presented in FWS Consultants Ltd, 2016. Hydrogeological Baseline Report for the Doves Nest Farm Minesite, North Yorkshire 2012 to 2016 (1975OR01; Ref. 1) 3. Clarification to address the queries raised by Amec Foster Wheeler is presented in Section 5. 4. Details of the Hydrogeological Risk Assessment, Modelling and Recommendations are presented in Sections 6 to 9.

1.3 Objectives

The purpose of this document is to:-

- Provide details of the hydrogeology of the site and adjacent areas,
- Provide details of the completed Phase 2 and 3 Works and the associated groundwater control measures.
- To address the comments raised in the York Potash Project: Habitats Regulations Assessment regarding the qualitative risk assessment and quantitative modelling, as relevant to Phase 3 Work only.
- Provide a qualitative assessment of the magnitude of risks to hydrogeological receptors from the cumulative completed Phase 2 and 3 Works, utilising the criteria for impacts adopted in the original Environmental Impact Assessment submitted as part of the planning application. Where appropriate, quantitative multi-layered hydrogeological modelling has been conducted to analyse the potential magnitude of impact of groundwater levels and spring flows.
- To provide recommendations on construction phase monitoring, to confirm the effectiveness of the groundwater controls to be adopted within the Phase 3 Works.

2 DATA SOURCES

The data considered within this report are from the following sources:-

Hydrogeological Data

- Hydrogeological Baseline Report for the Woodsmith Mine, North Yorkshire 2012 to 2016 (1975OR01; Ref. 1)
- Hydrogeological Risk Assessment Phase 2 Works at Woodsmith Mine, North Yorkshire (1433DevOR27 Rev3 January 2017 Ref. 2)
- Hydrogeological Risk Assessment of the Minesite Development at the Woodsmith Mine, North Yorkshire (1433MineOR024E; Ref. 7)
- ESI Ltd, 2017 - York Potash: Groundwater Model Update and Simulation of the Phase 3 Works, Report No. 61415R6 (Ref. 3; included as Appendix 4)

Ecological Data

- Royal Haskoning / DHV (RHDHV), Hydrogeologically Supported Terrestrial Ecosystems and Ecological Monitoring for the Phase 2 Works at Woodsmith Mine No. RHDHV TN002 (included as Appendix 5).

Development Details of Phase 3 Works

Construction development details provided by Arup, presented in Appendix 2, including:-

- 40-ARI-WS-71-CI-DR-1050 Phase 3 Masterplan
- 40-ARI-WS-71-CI-DR-1051 Phase 3 Vegetation Clearance
- 40-ARI-WS-71-CI-DR-1052 Phase 3 Sections
- 40-ARI-WS-71-CI-DR-1053 Phase 3 Earthworks Strategy
- 40-ARI-WS-71-CI-DR-1054 Phase 3 Earth Works Volumes
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3 DETAILS OF THE PHASE 3 WORKS

3.1 General Description

This report presents the revised hydrogeological risk assessment that relates to the combined completed Phase 2 and 3 Works elements only. The works completed prior to and as part of Phase 3, comprise the following, as shown on Arup Drawing 40-ARI-WS-71-CI-DR-1050:-

Works Completed Prior to Phase 3

- General site clearance and construction of an acoustic fence / environmental barrier and installation of fencing, gates and security;
- Construction of the site road, a site compound to the east of the Welfare Access Road;
- Construction of the two tiered working platform, two temporary soil mounds north and two to the south of the Shaft Platform, and a permanent environmental screening bund (Bund A) along the western boundary, and;
- Construction of surface water drainage, a silt removal facility and an attenuation pond with outfalls to an existing drain.

Works Completed as Part of Phase 3

- General site clearance including demolition of all farm buildings and sheds, and localised tree and scrub clearance, as shown on Arup Drawing 40-ARI-WS-71-CI-DR-1051;
- Excavation and construction of the south western extension of the upper tiered working platform at around 203m AOD, as shown on Arup Drawing 40-ARI-WS-71-CI-DR-1053 with earthworks volumes presented in 40-ARI-WS-71-CI-DR-1054;
- Excavation and construction of the Platform for the Construction Welfare Facility, Parking Area and Concrete Batching Plant, as shown on Arup Drawing 40-ARI-WS-71-CI-DR-1053 with earthworks volumes presented in 40-ARI-WS-71-CI-DR-1054;
- Construction of temporary and permanent soil mounds, including the basal liner for the future non-hazardous non-inert (NHNI) facility in the northeast corner of the site and three topsoil, subsoil and inert material storage bunds in the southwestern area of the site, as shown on Arup Drawing 40-ARI-WS-71-CI-DR-1053 and 40-ARI-WS-71-CI-DR-1055, with earthworks volumes presented in 40-ARI-WS-71-CI-DR-1054;
- Construction of surface water drainage, a temporary surface water attenuation pond and temporary wetland in the southern area and two permanent attenuation ponds and two wetland areas in the north eastern area, as shown on Drawing 40-ARI-WS-71-CI-DR-1050;
- Construction of a spring and groundwater drainage layer in the north eastern area, discharging into a wetland area, as shown in Arup Drawing 40-ARI-WS-71-CI-DR-1080;
- Installation and commissioning of temporary dewatering, as shown in Arup Drawing 40-ARI-WS-71-CI-DR-1058.

- Erection on site of the Concrete Batching Plant as shown in AMC UK Ltd (AMC) Drawing 40-AMC-WS-72- SW-DR-0005, complete with reticulated water supplies and tanks;

- Construction of the drilling platform and temporary saline lagoon area for the groundwater reinjection well as shown in Arup Drawing 40-ARI-WS-71-CI-DR-1057.

- Provision of Construction Welfare and Security Facilities - complete with hook-up of power, communications & water supplies and new waste water collection facilities.

In the following sections are presented details of the design levels and construction methodology for the Phase 3 Works.

3.2 Site Construction

3.2.1 Southern Extension of Upper Tiered Shaft Platform

The southern area to the Upper Tiered Platform will be extended from the Service Shaft platform constructed in Phase 2, as shown in Arup Drawings 40-ARI-WS-71-CI-DR-1050 and 40-ARI-WS-71-CI-DR-1053. These works will entail excavation of the existing glacial soils stockpiled in this area and reducing ground levels to between 202.6m AOD to 202.8m AOD on the southern boundary and between 202.8m AOD and 203m AOD abutting the Service Shaft platform.

Construction of this Shaft Platform extension will entail removal of the made ground and soft to firm glacial clays, to a depth of 0.6m below finished level, followed by placement of a granular working platform, with a finished surface profiled to fall to the edges of the platform to promote surface drainage. As such, formation level to the working platform will be around 202.2m AOD in the north (i.e. around 0.5m to 0.6m above rockhead) and around 202.0m AOD in the south (i.e. between 0.55m to 2.0m above rockhead). To provide protection to groundwater quality in the Moor Grit aquifer from shaft construction activities, a natural or man-made barrier will be maintained beneath the full footprint of the Shaft Platform area. The man-made barrier is to comprise a 1mm low-density polyethylene (LLDPE) geomembrane with top and bottom geotextile protection layer that will be installed in accordance with a Construction Quality Assurance (CQA) Plan with independent CQA verification. The finished surface of the tiered shaft platform will comprise a 0.6m granular unbound pavement construction.

A drainage ditch is to be constructed at the crest of the cut slope in the west and at the toe of the slope along the western and southern platform boundary. The toe ditch is to be 0.5m deep and lined to prevent erosion, enable future maintenance, limit the ingress of construction surface waters into the groundwater table, and to prevent groundwater discharge into the surface water system during periods of high groundwater conditions. The drainage ditch liner is to comprise a concrete canvas liner that will be installed in accordance with a Quality Control Plan with independent CQA verification.

3.2.2 Dewatering In Advance of Future Shaft Sinking

To facilitate the commencement of preparatory works for shaft sinking in future phases, Phase 3 will include installing an array of dewatering wells around the shaft platform, as illustrated in Arup Drawing 40-ARI-WS-71-CI-DR-1058, which will be operated to reduce groundwater levels to 3m below the Shaft Platform Level (bspl) at each of the shaft locations.

3.2.3 Southern Working Platform and Batching Plant Area

To the south of the Upper Tiered Platform extension, an at grade granular surfaced hardstanding area will be constructed, incorporating welfare facility units in the northwest, a parking area in the southwest and a concrete batching plant in the southeast, as shown in Arup Drawing Nos. 40-ARI-WS-71-CI-DR-1050 and 40-ARI-WS-71-CI-DR-1053. These works will entail excavation of the top and subsoil materials to a maximum depth of 0.6m bgl and regrade the surface to provide a fall to the northeast at a gradient to match the existing (approximately 1 in 20). Only minor earthworks are proposed in this area, entailing cut and fill of up to 1m with a finished surface comprising 0.5m of a granular unbound pavement construction, incorporating basal geogrid reinforcement, except around the concrete batching plant area, which will have a concrete slab hardstanding draining to a blind sump. Waste water arisings collected at this sump are to be disposed offsite.

A drainage ditch is to be constructed around the southern and western boundary of the batching plant and car park area, as shown in Arup Drawing 40-ARI-WS-71-CI-DR-1070 This is to be 0.5m deep and lined to prevent erosion, enable future maintenance, limit the ingress of construction surface waters into the groundwater table and to prevent drainage discharge into the surface water system during periods of high groundwater conditions.

3.2.4 Screening Bunds and Stockpiles

As part of the Phase 3 Works, a topsoil and subsoil strip to a depth of up to 0.6 m is to be undertaken within the footprints of the storage facility for NHNI spoil in the northeast corner of the site and topsoil is to be stripped from the temporary topsoil, subsoil and inert material storage bunds in the southwestern area of the site, as shown on Arup Drawing 40-ARI-WS-71-CI-DR-1053.

The future NHNI Extractive Materials Management Facility, to be constructed in the northeastern area as shown in Arup Drawing 40-ARI-WS-71-CI-DR-1053, will have a basal 1 m thick artificially enhanced geological barrier, engineered to achieve a permeability of less than 1×10^{-9} m/s using site won glacial till (clay). During the Phase 3 works, only the basal liner will be constructed and no NHNI material will be deposited. The material that will be contained within this Materials Management Facility during future Phases will comprise pyritic mudstones that have the potential to generate low concentrations of leachate. These spoil materials will be placed as an engineered fill to minimise their porosity and permeability.

The soil volumes and footprints of the permanent and temporary soil stockpiles that will be generated are illustrated in Arup Drawings 40-ARI-WS-71-CI-DR-1053 and 40-ARI-WS-71-CI-DR-1054.

Landscape restoration of the temporary and permanent soil bunds will comprise scrubland and grassland seeding on completion of the earthworks, as shown in (Arup Drawing 40-ARI-WS-71-CI-DR-1051).

3.2.5 Surface Water Drainage

The drainage ditches, to be constructed around the internal edge of the southern platform and the South Shaft Platform extension will be 0.5m deep and lined to prevent erosion, enable future maintenance, limit the ingress of construction surface waters into the groundwater table and to prevent groundwater discharge into the surface water system, during periods of high groundwater conditions.

The finished surface of the Shaft Platform extension and southern platform will be profiled to promote natural surface drainage to the perimeter collector drains. Both of these areas will drain to oil separators in the southeastern corner of the platform prior to discharge to a silt removal facility and then an attenuation pond to the east outflowing to the existing drainage ditch out falling to Sneaton Thorpe Beck in the east (Arup Drawing 40-ARI-WS-71-CI-DR-1070). Two additional attenuation ponds and two new wetland areas are to be constructed in the northeastern corner of the site. In the southern area, southeast of the batching plant working platform, are to be constructed a wetland area and an attenuation pond. To the west of the northern most wetland area, a spring and groundwater drainage system is to be constructed, as shown in Arup Drawings 40-ARI-WS-71-CI-DR-1070 and 40-ARI-WS-71-CI-DR-1080, discharging into this wetland feature.

Swales with check dams and silt fences will be constructed around the temporary and permanent bunds.

3.2.6 Reinjection Well and Saline Water Lagoon

A groundwater reinjection well drill pad and associated saline water lagoon are to be constructed in the southern area of the minesite, as illustrated in Arup Drawings 40-ARI-WS-71-CI-DR-1050 and 40-ARI-WS-71-CI-DR-1057 and detailed in Arup Technical Note on Summary of Deep Saline Injection Well (Ref. YP-P2-Rep-003 January 2015; Appendix 6).

Construction of the drill pad will involve removal of topsoil and subsoil to temporary stockpiles and cut/fill to create a level platform area with a maximum fall of 2% towards the northeast. The platform will be built up with a finished surface comprising a 0.5m thick granular unbound pavement construction with a basal geogrid underlain by either 0.5m of insitu or an artificially enhanced geological clay barrier. Filter drains will be constructed along the southwestern and southeastern sides of the platform discharging to an existing ditch via an oil interceptor.

The saline water lagoon has been designed to provide a temporary storage facility for the saline water that comes from drilling and development of the well, which will then be reinjected into the Sherwood Sandstone as part of the well testing programme. As such, storage of this saline water in the lagoon is currently anticipated to be for a period of around four to eight weeks that will occur during the future phased construction process. The saline water lagoon will be formed by cut/fill within the glacial till and will be constructed with a composite liner comprising a 2mm high density polyethylene geomembrane underlain by 1m of a geological clay barrier.

3.3 Groundwater Management Measures

Groundwater management measures that are incorporated into the design of these works will include the following:-

- Either a natural geological clay barrier or a geomembrane groundwater separation liner over the Moor Grit aquifer underlying the southern extension to the Shaft Platform and, where necessary beneath the reinjection well drill pad.

- A concrete impregnated geosynthetic liner to drainage ditches around the Shaft Platform and Southern Working Platform to prevent ingress of construction surface water into the groundwater table and to prevent drainage discharge into the surface water system during periods of high groundwater conditions.

- Dewatering well operations will be undertaken within the shaft platform area to establish the groundwater levels at a level 3m bspl.

- Construction of a groundwater drainage layer in the northeastern area to control groundwater egress from the Moor Grit and Scarborough spring issues beneath the future formation to the NHNI Extractive Materials Management Facility.

- Construction of 1m thick enhanced geological barrier over the Scarborough and Cloughton aquifers underlying the formation to a future NHNI Extractive Materials Management Facility.

- Construction of a composite lined lagoon, comprising a 2mm smooth / rough HDPE geomembrane underlain by 1m of either insitu or a compacted clay enhanced geological barrier over the Moor Grit aquifer for the temporary containment of saline water generated from the future shaft sinking works prior to reinjection in the discharge well.

<u>Shaft Platform and Drill Pad Barrier Above Moor Grit Aquifer</u>

As part of the Phase 3 Shaft Platform extension and Drill Pad construction, where low permeable glacial clays, forming a natural geological barrier, are less than 0.5m thick, a groundwater protection membrane will be placed at formation level. This artificial barrier will comprise as a 1mm LLDPE geomembrane with top and bottom protection with a 300 g/m^2 geotextile covered by a minimum of 600mm of Type 3 crushed aggregate. This will be installed to provide groundwater protection throughout the future construction works.

The precise extent of placement for this geomembrane will be determined on-site once the formation has been exposed; however, it is estimated that it will be required under the western half of the southern platform extension. An indication of the expected extent of this geomembrane liner, to be installed as part of the Shaft Platform extension, is illustrated in Arup Drawing 40-ARI-WS-71-CI-DR-1053. This geomembrane with top and bottom geotextile protection layers will be installed in accordance with EA Guidance (Refs. 8 & 9), as detailed in Appendix 3 of the Groundwater Management Scheme (Ref. 6) and will be tied into the glacial clay to provide a laterally continuous barrier over the full footprint of the platform and drill pad areas.

The geomembrane will be installed in accordance with a Quality Control Plan with independent Construction Quality Assurance verification, as detailed in the Groundwater Management Scheme (Ref 6).

<u>Liner to the Shaft Platform Surface Water Collection Ditch</u>

Lined ditches will be constructed around the Shaft Platform extension and Working Platform areas to collect surface water runoff. The ditches will be lined with a concrete canvas that will be installed in accordance with a Quality Control Plan with independent Construction Quality Assurance verification, as detailed in the Groundwater Management Scheme (Ref 6).

Temporary Dewatering

To achieve the required temporary reduction in groundwater levels in the Moor Grit aquifer beneath the Shaft Platform to a maximum level of 3m bspl, an array of dewatering wells will be installed within a 2m wide corridor around the perimeter of the upper shaft platform. Provisionally, it is estimated that this array may comprise 31 wells, at a spacing of 20m around the perimeter of the upper tier Production and Service Shaft Platform and six wells around the MTS shaft, as illustrated in Arup Drawing 40-ARI-WS-71-CI-DR-1058. However, the final number, depth and arrangement are dependent upon the detailed design by the dewatering contractor and trial pumping.

Dewatering will be managed utilising construction phase monitoring wells and down hole pumps within this array of abstraction wells to maintain groundwater levels below the target design depths. Groundwater abstracted from this system will be discharged to an existing 300mm pipe that drains the current pilot borehole drill platforms into a tributary to Sneaton Thorpe Beck to the east of the working platform, as shown in Arup Drawing 40-ARI-WS-71-CI-DR-1058.

Spring and Groundwater Control Drainage Blanket

Construction of groundwater and spring issue collector drains along the alignment of the Moor Grit and Scarborough aquifers' interface will be undertaken as shown in Arup Drawing 40-ARI-WS-71-CI-DR-1080. This will discharge into the "Wetland Area" in the northeast of the Shaft Platform, as shown in Arup Drawing 40-ARI-WS-71-CI-DR-1070.

Extractive Materials Management Facility

Beneath the footprint of the future NHNI Extractive Materials Management Facility a 1m thick artificially enhanced geological barrier will be engineered to achieve a clay liner with a maximum permeability of 1×10^{-9}m/s.

During subsequent phases, pyritic mudstone that is characterised in terms of its waste classification as a NHNI material will be stored here.

Placement of the enhanced geological barrier will be undertaken in accordance with a Quality Control Plan with independent Construction Quality Assurance verification, as detailed in the Groundwater Management Scheme (Ref 6).

Saline Water Lagoon at the Reinjection Facility

The saline water lagoon will be constructed with a composite liner, comprising a 2mm high density polyethylene geomembrane underlain by 1m of a geological clay barrier. The geomembrane liner and the enhanced geological clay barrier will be installed in accordance with a Quality Control Plan with independent Construction Quality Assurance verification, as detailed in the Groundwater Management Scheme (Ref 6).

3.4 Programme of Construction

The Phase 3 Works are scheduled to commence in June 2017, following completion of the Phase 2 Works, and be complete by the end of October 2017. Dewatering operations on the Shaft Platform are due to commence in June 2017.

4 MINESITE HYDROGEOLOGICAL CONDITIONS

4.1 Introduction

From the development and construction details for the combined Phase 2 and 3 Works, presented in Section 3, and the baseline hydrogeological conditions determined for the site (Ref. 1), the following sections present an overview of the interaction between aquifer conditions and the construction works within the depths of excavations proposed.

Within this Section, reference is made to specific groundwater monitoring well locations, as shown in Drawing 1433DevOD237. In order to maintain a sequential list of boreholes with no duplication of borehole names, a number of the monitoring wells have been renamed from their original borehole name, as detailed in Table 1 (Appendix 3), and both original and new names have been presented within this report for ease of reference. That table details the groundwater monitoring boreholes that will be utilised during this and future phases of the development including their location, target aquifer and response zone.

4.2 Geology

A geological map (Drawing 1433DevOD265) showing the Phase 3 Works is included in Appendix 1. Schematic geological cross-sections of the minesite, illustrating the principal stratigraphic units across the development area and extending to the land to the north and east of the site and towards the Ugglebarnby Moor and Sneaton Low Moor areas to the west and south of the site, are presented in Drawings 1433DevOD234, 235, 244 and 266 Appendix 1.

4.2.1 Superficial Deposits

The superficial deposits across the minesite and the moorland areas of the SAC consist of sandy gravelly clay (Glacial Till) to depths between 1.4m to 4.7m bgl, generally thinning towards the southeast of the minesite, and containing frequent sand lenses at the base of this unit. Within the SAC, the soils consist of topsoil and peat, while on the minesite there is a thin covering of topsoil.

4.2.2 Long Nab Member

The Long Nab Member underlies the south of the minesite and Sneaton Low Moor. It comprises weathered grey or orange/yellow fine to medium grained sandstone over a thin (0.2m to 0.45m thick) layer of dark grey mudstone.

4.2.3 Moor Grit Member

The Moor Grit Member un-conformably overlies the Scarborough Formation and comprises a grey, iron-stained fine to medium grained cross bedded sandstone with occasional medium to coarse gravel to pebble beds, discontinuous argillaceous beds and thin coal laminations within the mid-section of this unit. The upper part of this sandstone unit is distinctly weathered to destructured, whilst the lower part of the sandstone unit is only partially weathered. This sandstone unit ranged in thickness from 2.3m to 13.2m and the discontinuous argillaceous units within the mid-section ranged from 1m to 4m in thickness. The base of the Moor Grit has a maximum dip of approximately 2° to the east beneath the SAC moorland and Woodsmith Mine, forming a shallow basin-like structure.

4.2.4 Scarborough Formation

The Scarborough Formation comprises three horizontal to sub-horizontal bedded weak to very weak, partially to distinctly weathered units including an upper moderately to highly fractured mudstone or siltstone, a grey-green sandstone/siltstone mid-section unit and a basal mudstone unit. To the west of the site, in the northern part of Ugglebarnby Moor (HG106A/GW121B), the lower argillaceous unit is a light to dark grey sandy argillaceous limestone with shell fragments.

The upper mudstone/siltstone unit ranges in thickness from 0.08m to 5.0m (averaging around 2m). The middle sandstone unit ranges in thickness from 0.3m to 5.7m and the lower mudstone ranges in thickness from 0.05 to 9m (averaging around 3m). The upper mudstone unit is discontinuous, especially towards the northern boundary of the Woodsmith Mine. The base of the Scarborough Formation dips at a relatively shallow angle of around 1° to the east beneath the SAC and Woodsmith Mine, forming a basin-like structure.

4.2.5 Cloughton Formation

The Cloughton Formation comprises a series of interbedded sandstones and mudstones with occasional siltstones of between 23.5m to 52m thick. Beneath Ugglebarnby Moor, the Cloughton dips at a relatively shallow angle (1 to 5°) to the east, becoming roughly horizontal beneath, and to the east of, the Woodsmith Mine.

The upper part of the Cloughton Formation comprises a weak to extremely weak weathered mudstone of between 1 to 5m thick, which thickens to the south. This overlies a medium strong to strong, partially to distinctly weathered, fine to medium grained sandstone, containing interbedded mudstone and occasional coaly and carbonaceous beds, particularly towards the base. The total thickness of this sandstone-dominated Formation ranges from 11.2 to 33.1m. The Formation becomes more sandy and thicker towards the south, with fewer mudstone beds. In the central part of the minesite, the sandstone sequence contains a higher proportion of mudstone/siltstone beds. The base of the Cloughton is dominated by an interbedded mudstone/siltstone sequence, of between 20 to 25m thick.

4.2.6 Eller Beck Formation

The Eller Beck Formation comprises 4 to 7 m of fine to medium sandstone, with a basal shale and ironstone unit (Ref. 30).

Mud losses recorded during drilling of SM14 between 954 and 23,850 litres/hr indicate a significant fracture zone in the Eller Beck Formation from 141 to 152 m AOD (Ref. 3).

4.2.7 Saltwick Formation

The Saltwick Formation was between 37 to 40 m thick and comprises a series of interbedded sandstones, mudstones and siltstones, with some thin coals, with an upper argillaceous unit, a middle arenaceous unit and then a basal argillaceous unit.

The upper argillaceous unit comprises a weak to strong grey, fresh to moderately weathered mudstones with thin sandstone interbeds. This argillaceous unit is less fractured than the mudstones at the base of the Cloughton Formation, and contains numerous, interbedded, thin sandstone/siltstone horizons.

The arenaceous unit comprises medium strong, fresh to moderately weathered, fine to medium grained occasionally silty sandstones of between 31 to 34 m thickness.

The basal argillaceous unit comprises 7 m of interbedded mudstones, siltstone and fine sandstones and then a 3 to 5 m thick conglomerate, taken to indicate the unconformable contact with the underlying Whitby Mudstone Formation, and may form part of the Dogger Formation.

Mud losses recorded during drilling in this Formation ranged from 477 litres/hr to total losses at an elevation of between 119 and 124 m AOD and also deeper in this sequence at between 165 and 187 m AOD (Ref. 23).

4.3 Phase 2 Tiered Shaft Platform and Phase 3 Southern Extension

4.3.1 Existing Ground Conditions

The Phase 3 Southern Platform Extension is to be located where topsoil and subsoil from the SM11 and SM14 drill pad construction has been stockpiled, to a maximum elevation of 210.5m AOD. Beneath this stockpile superficial deposits consist of thin topsoil overlying 4 m of sandy clay to an elevation of 200.4 to 202.4m AOD and directly onto the Moor Grit.

4.3.2 Construction Considerations

As detailed in Section 3, a tiered Shaft Platform has been constructed during Phase 2 in the northern area of Woodsmith Mine with a finished surface level for the western upper level grading 202.8 to 204.1m AOD from southeast to northwest and an eastern lower level grading from around 201.4m AOD in the west to 200.16m in the east (Arup's Drawing 40-ARI-WS-71-CI-DR-1050Appendix 2). The Phase 3 Southern Platform Extension is to be constructed with a finished surface level of 202.8m AOD in the southwest and 202.6mAOD in the southeast.

A groundwater separation layer will have been provided by tying in a geomembrane liner to the natural clay geological barrier, thereby maintaining a low permeable layer across the full surface area of the final two tiered platform, including the Southern Platform Extension. The surface to the platform will have been constructed of a free draining material, and profiled to collect all runoff into two interceptors along the eastern and southeastern edges of the platform Arup Drawing 40-ARI-WS-71-CI-DR-1070.

4.3.3 Aquifer Conditions

From the results of the ground investigation and the baseline groundwater monitoring a summary is provided overleaf of; the aquifer units, the interpreted groundwater surface, design permeability characteristics and water quality conditions that characterise the hydrogeological conditions associated with the completed tiered Shaft Platform location. From this assessment, it is anticipated that within the Shaft Platform construction depth the groundwater levels encountered in the Moor Grit sandstone (as illustrated in Drawing 1433DevOD244), the earthworks excavations, to be undertaken in the southwest of the Southern Extension, may encounter groundwater in the sandstone bedrock at formation level, during seasonal high groundwater conditions. The chemical quality of the groundwaters to be encountered in the Moor Grit aquifer may be characterised as freshwater of good quality.

Tiered Shaft Platform and Southern Extension Construction Considerations

	Area of Shaft Platform		Northwest Corner Upper Tier	Southwest Corner Upper Tier	Northeast Corner Upper Tier	Southeast Corner Upper Tier	Northwest Corner Lower Tier	Southwest Corner Lower Tier	Northeast Corner Lower Tier	Southeast Corner Lower Tier	Southern Extension Southwest Corner	Southern Extension Southeast Corner
	Platform Level	m AOD	204.1	203.00	203.5	202.95	201.4	200.9	200.16	200.3	202.8	202.6
Superficials	Current Ground Level	m AOD	204.1 to <203.5 Shaft Platform construction incorporating geomembrane	203.1 to <202.5 Shaft Platform construction incorporating geomembrane	203.5 Shaft Platform construction Clay to 202.2 202.2 to 201.8 sand	202.8 to <202.2 Shaft Platform construction incorporating geomembrane. Clay to 201.2 201.2 to 200.4 sand	201.4 to <200.8 Shaft Platform Construction incorporating geomembrane	201.3 to <200.7 Shaft Platform Construction incorporating geomembrane	200.2 Shaft Platform construction Clay to 199.5 199.5 to 199.2 sand	200.5 Shaft Platform construction (possibly incorporating geomembrane	(BH 3A) 206.8 to 206.6 topsoil 206.6 to 202.4 clay	(GCBH9) 204.8 to 204.4 topsoil 204.4 to 200.4 clay
Superficials	Groundwater Conditions	m AOD	none	water seepages at 200.8 and 200.0	water seepage at 202.0	none	water seepage at 202.0	none	none	NIA	none	none
Moor Grit	Top & Base Level of Aquifer	m AOD	(GCBH10) ~203.4 to 196.2	(GCBH04) ~201.8 to 193.5	(GCBH07) ~202.0 to 193.0	~200.4 to 193.0	(GCBH07) ~200.8 to 193.0	~200.7 to 193.0	~199.0 to 194.5	~200.0 to 195	(BH3A) ~202.4 to 194.8	(GCBH9) ~200.4 to 192.0
Moor Grit	Inferred Groundwater Surface (Winter, Summer & Mean levels)	m AOD	Winter 201.4 to 206.4, average 205.2 Summer 200.8 to 206.4, Mean 203.5 (HG115)	Winter 198.2 to 203.4, average 201.9 Summer 198.0 to 202.9, Mean 201.0 (HG3)	Winter 198.6 to 203.0, average 201.7 Summer 198.3 to 202.9, Mean 200.4 (HG115 & HG116)	Winter 196.0 to 198.7, average 197.6 Summer 196.8 to 198.2, Mean 196.8 (HG127)	Winter 198.6 to 203.0, average 201.7 Summer 198.3 to 202.9, Mean 200.4 (HG115 & HG116)	Winter 196.0 to 198.7, average 197.6 Summer 196.8 to 198.2, Mean 196.8 (HG127)	Winter 195.8 to 199.6, average 198.2 Summer 195.7 to 199.4, Mean 197.3 (HG116)	Winter 195.8 to 199.4, average 198.5 Summer 195.7 to 198.4, Mean 197.3 (HG117)	Winter ~202 Summer ~201	Winter ~200 Summer ~198
Moor Grit	Aquifer Design Permeability	m/s	Most Likely 1.3 x10^{-5} m/s									
Moor Grit	Water Quality		Good									
Scarborough Formation	Top and Base Level of Upper Aquitard Unit	m AOD	~196.5 to 193.1	~193.5 to 192.5	~193 to 191.5	~194.5 to 190.0	~193.0 to 191.5	~194.5 to 190.0	~194.5 to 192.0	~193.0 to 192.0	~194.8 to 193.3	~192.0-191.5
Scarborough Formation	Upper Aquitard Design Permeability	m/s	Most Likely 4.0 x 10^{-6} m/s									
Scarborough Formation	Elevation of Mid-Section Permeable Aquifer	m AOD	~193.1 to 191.3	~192.5 to 189.5	~191.5 to 188.0	~190.0 to 188.0	~191.5 to 188.0	~190.0 to 188.0	~192.0 to 188.0	~192.0 to 188.0	~193.3 to 191.8	~191.5 to 188.3
Scarborough Formation	Inferred Groundwater Surface	m AOD	Variable between 195.8 to 197.1 (GW101A)	Variable between 191.1 to 193.1 (HG128)	NIA	Variable between 191.1 to 193.1 (HG128)	NIA	Variable between 191.1 to 193.1 (HG128)	Variable between 197.7 to 190.9 (GW105)	Variable between 191.1 to 193.1 (HG128)	~198 to 195	~195
Scarborough Formation	Aquifer Design Permeability	m/s	Most Likely 1.3 x 10^{-5} m/s (Fractures 5.2 x 10^{-4} m/s)									
Scarborough Formation	Water Quality		Good									
Scarborough Formation	Elevation of lower Aquitard Unit	m AOD	~191.3 to 188.3	~189.5 to 186.0	~188.0 to 184.0	~188.0 to 184.5	~188.0 to 184.0	~188.0 to 184.5	~188.0 to 186.0	~188.0 to 185.0	~191.8 to 186.6	~188.3 to 184.5
Scarborough Formation	Lower Aquitard Design Permeability	m/s	Most Likely K_h 2 x 10^{-6} m/s, K_v 1 x 10^{-8} m/s									

NIA = No Information Available

4.4 Dewatering in Advance of Shaft Sinking

4.4.1 Existing Ground Conditions

The shaft platforms, where dewatering wells are to be installed to maintain groundwater levels to 3m bspl in advance of shaft sinking, are underlain by engineered fill overlying either a geomembrane liner or a natural clay barrier of glacial till above the Moor Grit sandstone and then the Scarborough aquifer. A summary of the ground levels, aquifer properties and groundwater levels at each shaft location is presented below.

Aquifer Conditions Influencing Dewatering in Advance of Shaft Sinking

			Service Shaft	Production Shaft	MTS Shaft
	Platform Level	mAOD	203.17	203.66	200.66
	Maximum Water Level (3m bspl)	mAOD	200.17	200.66	197.66
Superficials	**Current Ground Level**	mAOD	203.17 to <202.57 Shaft Platform construction incorporating geomembrane. Clay to 201.2 201.2 to 200.4 sand	203.66 Shaft Platform construction Clay to ~202 202 to 201.8 sand	200.8 Shaft Platform construction Clay to 199.5 199.5 to 199.2 sand
Superficials	**Groundwater Conditions**	mAOD	water seepages in sand	water seepage in sand	water seepage in sand
Moor Grit	**Top Level of Aquifer (Rockhead)**	mAOD	~200.4	~202.0	~199.0
Moor Grit	**Base Level of Aquifer**	mAOD	~193.0	~193.0	~190.9
Moor Grit	**Inferred Groundwater Surface (Winter, Summer & Mean levels)**	mAOD	Winter 196.0 to 198.7, average 197.6 Summer 196.8 to 198.2, Mean 196.8 (HG127)	Winter 197.5 to 200.6, average 198.9 (BHs 505 & 507)	Winter 195 to 196.8, average 195.9 (BH515)
Moor Grit	**Aquifer Design Permeability**	**m/s**	Most Likely 1.3 x10^{-5} m/s		
Moor Grit	**Water Quality**		Good		
Scarborough Formation	**Top and Base Level of Upper Aquitard Unit**	mAOD	~194.5 to 190.0	193.0 to 192.1	190.9 to 189.9
Scarborough Formation	**Upper Aquitard Design Permeability**		Most Likely 4.0 x 10^{-6} m/s		
Scarborough Formation	**Elevation of Mid-Section Permeable Aquifer**		~190.0 to 188.0	192.1 to 189.5	189.9 to 187.9
Scarborough Formation	**Inferred Groundwater Surface**	mAOD	Variable between 191.1 to 193.1 (HG128)	190.9 to 193.6 (BHs 505 & 507)	190.2 to 193.6 (BH515)
Scarborough Formation	**Aquifer Design Permeability**	**m/s**	Most Likely 1.3 x 10^{-5} m/s (Fractures 5.2 x 10^{-4} m/s)		
Scarborough Formation	**Water Quality**				
Scarborough Formation	**Elevation of lower Aquitard Unit**	mAOD	~188.0 to 184.5	192.1 to ~185.5	187.9 to ~186
Scarborough Formation	**Lower Aquitard Design Permeability**		Most Likely K_h 2 x 10^{-6} m/s, K_v 1 x 10^{-8} m/s		

4.4.2 Construction Considerations

Throughout the duration of the subsequent shaft sinking operations, it is a requirement that the groundwater table is maintained 3m below the shaft platform level. The water levels in the Moor Grit aquifer, within the depth where dewatering is necessary, are subject to significant seasonal variation of between 1m to 3m.

4.4.3 Aquifer Conditions

A summary is provided above of; the aquifer units, the interpreted groundwater surface, design permeability characteristics and water quality conditions that characterise the hydrogeological conditions anticipated within the depth profile of the proposed dewatering in advance of future shaft sinking operations. From this assessment, only groundwaters in the Moor Grit aquifer will require local lowering to maintain groundwater levels at 3m bspl to facilitate future shaft sinking works.

The chemical quality of the groundwaters to be encountered in the Moor Grit aquifer is characterised as freshwater of good quality.

4.5 Southern Working Platform and Batching Plant Area

4.5.1 Existing Ground Conditions

The ground conditions beneath the southern working platform and batching plant consist of 0.2 to 0.3 m of topsoil underlain by over 2m of cohesive Glacial Till at an elevation of between 204.05 and 201.3m AOD, with a gravel band between 203.15 and 202.05 in the southeastern part. The superficial deposits in this area are underlain by Moor Grit sandstone of between 5.6 and 6.4 m thick, to a depth of 197.63 to 194.87m AOD.

4.5.2 Construction Considerations

Construction of the southern working platform and batching plant will entail an initial strip of topsoil and subsoil materials to a depth of 0.6m to regrade the surface to provide a fall to the northeast. Only minor earthworks are proposed in this area, entailing cut and fill of up to 1m with a finished surface comprising a granular unbound pavement construction except around the concrete batching plant area, which will have a concrete slab hardstanding.

4.5.3 Aquifer Conditions

A summary is provided below of; the aquifer units, the interpreted groundwater surface, design permeability characteristics and water quality conditions that characterise the hydrogeological conditions associated with the completed Working Platform and Batching Plant location. From the groundwater levels encountered in the Moor Grit sandstone, this construction will be above the seasonal high groundwater levels recorded in the Moor Grit aquifer, with the exception of the northwestern corner, however the groundwater in this area will be confined below 1.9m of clay.

The chemical quality of the groundwaters to be encountered in the Moor Grit aquifer may be characterised as freshwater of good quality.

Aquifer Conditions Beneath the Southern Working Platform and Batching Plant Area

Area of Southern Working Platform and Batching Plant Area			Northwest	Southwest	Northeast	Southeast
Platform Level		m AOD	205.70	210.30	202.60	205.85
Superficials	Current Ground Level	m AOD	206.8 to 206.6 topsoil 206.6 to 203.8 clay	209.05 to 208.81 topsoil 208.81 to 204.05 clay	205.15 to 204.85 topsoil 204.85 to 201.45 clay	206.55 to 206.35 topsoil 206.35 to 203.15 clay 203.15 to 202.05 gravel 202.05 to 201.30 clay
	Groundwater Conditions	m AOD	NIA	NIA	NIA	NIA
Moor Grit	Top & Base Level of Aquifer	m AOD	203.8 to 197.38	204.05 to 197.63	201.45 to 195.85	201.30 to 194.87
	Inferred Groundwater Surface (Winter, Summer & Mean levels)	m AOD	~197.98 to 206.13	204.14 to 208.35	~195.72 to 199.42	200.79 to 205.66
	Aquifer Design Permeability	m/s	Most Likely 1.3 x10^{-5} m/s			
	Water Quality		Good			

4.6 Screening Bunds and Stockpiles

4.6.1 Existing Ground Conditions

The ground conditions beneath the footprint of the NHNI Extractive Materials Management Facility and the Groundwater Drainage Layer will comprise 0.3m to 0.4m thick of topsoil underlain by 3.2 m to 5.3 m of cohesive Glacial Till to an elevation of between 192 and 184 m AOD. Bedrock in the west of the area consists of Scarborough Formation lower mudstone at rockhead, underlain by the Cloughton Formation, while in the east of the area rockhead consists of the Cloughton Formation interbedded sandstone and mudstone.

4.6.2 Construction Considerations

During Phase 3 the construction of the NHNI Extractive Materials Management Facility basal layer is to entail an initial strip of topsoil and subsoil materials to a depth of 0.6m followed by construction of a basal 1 m thick artificially enhanced geological barrier, engineered to achieve a maximum permeability of less than 1 x 10^{-9} m/s using site won glacial till (clay).

The Groundwater Drainage Blanket will be constructed of a 0.5m thick groundwater collection layer with a network of 225mm Ø HDPE carrier pipes over a permeable geotextile separator. During future phases, the drainage blanket will ultimately be overlain by either inert spoil or a 1 m thick compacted clay enhanced geological barrier overlain by capped NHNI waste. The piped Groundwater Drainage Blanket collecting spring discharges from the Scarborough Formation will discharge to the wetland area to the east.

4.6.3 Aquifer Conditions

Based on the results of the ground investigation and the baseline groundwater monitoring undertaken, the NHNI Extractive Materials Management Facility will be constructed above the superficial deposits (3.2 m to 5.3 m thick) overlying the Scarborough and Cloughton Formations.

From the baseline monitoring, groundwater levels beneath the NHNI Extractive Materials Management Facility and the Groundwater Drainage Blanket within the Cloughton Formation occur at a depth of 5.0 to 6.5 m bgl. Groundwaters collected within the Drainage Blanket are inferred to be from the sandstone unit in the Scarborough Formation upslope of this location that are discharging at the interface with the basal mudstone unit above the Cloughton Formation.

4.7 Surface Water Drainage

4.7.1 Existing Ground Conditions

The ground conditions in the location of the two additional northern Attenuation Ponds and Wetland consist of approximately 0.3 m topsoil overlying sandy gravelly clay to a depth of between 3.0 and 5.5 m (182.3 to 170.8 m AOD) where sand is encountered. Rockhead, consisting of the Cloughton Formation, is anticipated at an elevation of around 178 to 170 m AOD sloping down to the east.

The ground conditions at the location of the wetland to the east of the groundwater drainage layer consist of approximately 0.4m of topsoil overlying sandy gravelly clay, with rockhead (Cloughton Formation) at 183.1 m AOD.

The ground conditions in the location of the southern Attenuation Pond are expected to comprise 0.4 m topsoil overlying sandy gravelly clay to a depth of 2.7 m, with sandstone (Moor Grit) rockhead at around 202.7 m AOD.

The ground conditions in the location of the southern Wetland are expected to comprise 0.25 m topsoil overlying 0.95 m of very clayey sand, and 1.2 m of sandy gravelly clay to a depth of 2.4m, with sandstone (Scarborough Formation) rockhead at around 192.0 m AOD.

4.7.2 Construction Considerations

The attenuation ponds and wetland area are expected to be excavated to depths of between 1.0 to 2.0m bgl into the underlying glacial till predominantly comprising low permeable clay interbedded with sand lenses.

4.7.3 Aquifer Conditions

Surface Water Drainage Feature	Ground Level	Rockhead	Groundwater Level
Northern Attenuation Ponds (Two) and Wetland	185.3 m AOD	182.3 m AOD (West) to 170.8 m AOD (East) 3.0 m bgl (West) to 5.8 m bgl (East) (weathered Cloughton Fm.)	183 to 185.3 mAOD (West) to 174 to 176 m AOD (East) (GW07&108 - Cloughton Fm.)
Wetland East Of The Groundwater Drainage Layer	186 m AOD	183 m AOD 3 m bgl (weathered Cloughton Fm.)	180.7 to 186.3 m AOD (MB5 – Superficial Deposits) 183.5 to 185.2 m AOD (GW106 Cloughton Fm.)
Southern Attenuation Pond	205.4 m AOD	202.7 m AOD 2.7 m bgl (Moor Grit) HG114	199.0 to 204.3 m AOD (HG114 – Moor Grit)
Southern Wetland	194.4 m AOD	192.0 m AOD 2.4 m bgl (Scarborough Fm.) HG120	190.8 to 193.4 m AOD (HG120 – Scarborough Fm.)

From the above summary of construction levels, aquifer strata and groundwater levels recorded, the northern two attenuation ponds and wetland area, and the wetland area east of the groundwater drainage layer are expected to be underlain by low permeable glacial clays of over 1m thick that will isolate these surface water features from the underlying Cloughton rock aquifers.

Depending on the final depth of the southern Attenuation Pond and Southern Wetland, they may be underlain by <1 m of low permeable clay. Maximum groundwater levels recorded may be above the base depth of these features. As such, the depth of these ponds will need to be reviewed on site during construction to maintain an adequate separation between the surface waters and the underlying groundwaters.

4.8 Reinjection Well and Saline Water Lagoon

4.8.1 Existing Ground Conditions

The ground conditions beneath the footprint of the Reinjection Well Drill Pad and Saline Water Lagoon are expected to comprise topsoil underlain by 2-3 m thick of cohesive Glacial Till to rockhead at 207 m AOD. Bedrock consists of Long Nab and Moor Grit sandstone.

4.8.2 Construction Considerations

The Reinjection Well Drill Pad will be constructed with a finished surface elevation of 209.7 to 208 m AOD, with a 2% fall to the northeast, requiring a cut of approximately 1 m. The granular working platform will include a geogrid reinforcement. If the thickness of the natural geological barrier of low permeable cohesive glacial till is less than 0.5 m, a Linear Low Density Polyethylene (LLDPE) liner will be installed to tie into the natural geological barrier.

The Saline Lagoon is to be lined with a composite High Density Polyethylene (HDPE) liner underlain by a minimum of either 1m of a natural geological barrier of low permeable cohesive glacial till, or by an enhanced geological barrier of 1m thick of Class 2A material.

4.8.3 Aquifer Conditions

From the baseline monitoring, piezometric groundwater levels within the Moor Grit are expected at approximately 207 mAOD (1 to 2 m bgl).

5 CLARIFICATION TO ADDRESS MATTERS RAISED IN THE HABITATS REGULATIONS ASSESSMENT

A Hydrogeological Risk Assessment Report for the minesite development was submitted as part of the planning application in 2014 (Ref. 7) and a Hydrogeological Assessment of Changes to the York Potash Planning Submission for the Mine Surface Development Site and Mineral Transport System (Ref 20). On behalf of the Minerals Planning Authority (MPA), Amec Foster Wheeler (AFW) provided comment on the Hydrogeological Risk Assessment within its Habitats Regulations Assessment (Ref. 11). To satisfy Planning Condition 46, the MPA has requested that the revised hydrogeological risk assessment addresses the matters raised by AFW in the Habitats Regulations Assessment.

This Section of the report addresses the matters raised by AFW on the Qualitative Risk Assessment and the Groundwater Modelling in respect to the Phase 2 Works aspects of the Hydrogeological Risk Assessment. It should be noted that this report presents the hydrogeological risk for the combined Phase 2 and 3 Works only. Therefore, the scope of construction works assessed is significantly reduced compared to the planning application stage Hydrogeological Risk Assessment (Ref. 7) reviewed by AFW. All future phases of the development works will include a phase specific hydrogeological risk assessment and will address the comments included in AFWs Habitats Regulations Assessment in relation to the phase reported on.

5.1 Clarification on Baseline Data

At the time of the planning application, AFW advised that the data presented in the Hydrogeological Baseline Report (Ref. 10) and utilised within the initial Hydrogeological Risk Assessment (Ref. 7) was only “a relatively short dataset” (Ref. 11).

To address the size of the dataset, hydrogeological baseline monitoring has continued on site since the issue of those reports, and this Risk Assessment takes due consideration of that full dataset from 2012 to 2016, as presented in the revised Hydrogeological Baseline Report (Ref. 1).

5.2 Clarifications on Qualitative Risk Assessment

Based on AFW’s interpretation of the study area and receptor sensitivity, AFW considered that Little Beck Stream should be included as a potential receptor in future hydrogeological risk assessments.

Within this HRA report Little Beck has been included as a potential receptor and considered as being of medium sensitivity, as required by AFW.

AFW advised that the groundwater modelling was undertaken only on those receptors assessed being potentially vulnerable to “significant” effects as part of qualitative risk assessment. As the Hydrogeological Risk Assessment (Ref. 7) did not contain the matrix to combine connectivity and proximity, AFW was unable to audit this approach.

To address this issue, the assumptions in respect of the connectivity and proximity assessment for each receptor have been addressed in the text and included in Tables 2 and 3 (Appendix 3) of this report respectively .

5.3 Clarifications on Groundwater Modelling

Presented below is a summary of the principal queries raised on the groundwater modelling in the Habitats Regulations Assessment and how these matters have been addressed within this revised Hydrogeological Risk Assessment:-

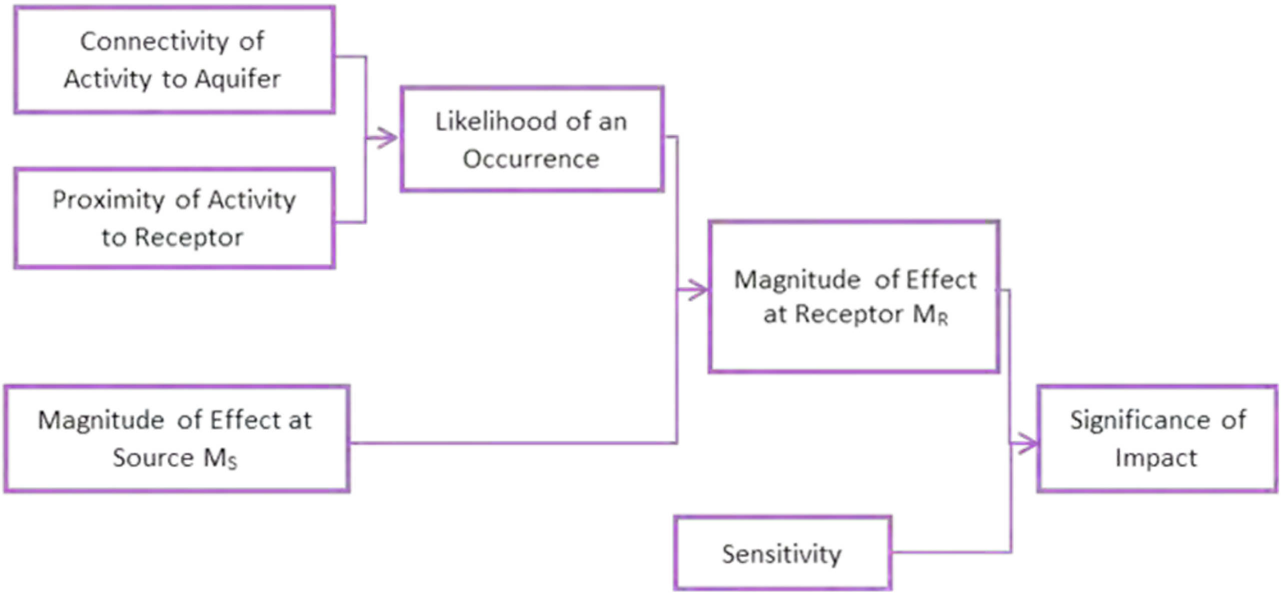
Summary of Queries Raised by AFW in the Habitats Regulations Assessment	**Confirmation of how this matter has been addressed in this report**
The model does not incorporate the superficial deposits.	The superficial deposits are considered via the recharge estimates. There is a small amount of additional storage represented by the more porous superficials than is allowed for in the model and this makes the model more conservative with respect to drawdown.
Assumptions have been made regarding the model hydraulic parameters to achieve model calibration that go beyond the findings of the limited field investigations.	Additional field data has been obtained within the extended monitoring period that has been presented in the revised baseline report (Ref. 1) and has been utilised within this report. The field data is used in forming the conceptual model and determining hydraulic parameters. It is acknowledged that they may not be representative of the full range of variation in parameter values that may be present at the site. There is a disparity between the local scale at which the field testing samples the formations and the larger scale appropriate to the groundwater model. This is not uncommon in groundwater modelling in which parameters are more appropriately constrained by calibration to observed heads and flows than by direct input of field based property data.
Transient model calibration is of variable quality, and restricted by groundwater level record.	Additional field data has been obtained within the extended monitoring period and utilised within this report.
Grouting has not been able to be represented as a horizontal flow barrier during construction, or no-flow barrier on completion for minehead structures which would not fully penetrate a model layer.	No grouting is to be to be undertaken during the Phase 2 or 3 Works.
The predictive modelling has not looked at individual components of the proposed development in isolation, and therefore the results cannot be used to inform the impact assessment relating to individual activities, as anticipated in the FWSC and RHDHV assessment tables. It appears from the assessment tables that the combined physical effects of all the minehead construction activities have been assessed as if they relate solely to the alteration of groundwater levels due to the tiered Shaft Platform.	The modelling presented in this report considers the development components to be constructed as part of the Phase 2 and 3 Works.
Initial model results not included in detail.	As above
Include some additional assessment points within the model, located further away from the minehead	Additional assessment points have been added in to the review process for the Phase 3 Works model and the results are presented in this report.
The transient construction and post-construction predictive groundwater levels suggest that the main residual effects without a pressure relief drain are groundwater level rises as a result of easterly groundwater flow mounding up behind the grout barrier. The steady state post-constriction indicates a water level decline in the lee of the barrier to the east.	The modelling presented in this report considers the development components to be constructed as part of the combined Phase 2 and 3 Works.

A reduction in the PWMF runoff diversion to the recharge trench and inclusion of the pressure relief drain appears to reduce the steady state water level beneath Ugglebarnby Moor SAC. However a fuller understanding of the residual water levels and flows is prevented by the absence of any reporting of the results of a transient version of this full suite of mitigation measures. Furthermore the suggested "monitor and mitigate" approach would be challenging to model in a transient manner and to implement in reality	
Predicted maximum dewatering rates for the tiered Shaft Platform are understood to be higher than the design volumes, and there is no discussion or modelling of the discharge of this volume.	The tiered Shaft Platform has been redesigned to predominantly take it above mean groundwater levels within the Moor Grit aquifer. Temporary dewatering is to be undertaken to facilitate the subsequent shaft sinking. This is addressed within the model and simulated discharge rates are provided accordingly.

6 RISK ASSESSMENT METHODOLOGY

The revised qualitative hydrogeological risk assessment presented in this report evaluates the "Significance of Impact" of the Phase 2 and 3 Works on hydrogeologically sensitive receptors, and follows a source-pathway-receptor approach to meet regulatory requirements.

In order to evaluate the physical and chemical hydrogeological impacts, the following criteria, and the linkages between them, have been considered:-



Two criteria have been used to assess the "Likelihood" of an effect propagating through the hydrogeological system to a receptor. These are the Connectivity and Proximity of an activity to a receptor. Therefore, the closer and more directly connected an activity is to a receptor, the more likely it is that a pathway will exist between an activity and that receptor.

The Magnitude of Effect at Source (MS) has been considered in terms of the worst-case physical and chemical changes to baseline conditions that might occur.

Combining the Likelihood of an Occurrence with the Magnitude of Effect at Source provides a qualitative evaluation for the Magnitude of Effect at Receptor (MR), which is the effect that a particular activity will have on a specific receptor.

The Magnitude of Effect at Receptor is then combined with the Sensitivity of the Receptor to provide an estimate of the Significance of Impact.

Five categories are used to describe the Connectivity, the Proximity, the Likelihood of an Occurrence, the Magnitude of Effect at Source (MS), the Magnitude of Effect at Receptor (MR); and the Sensitivity of a Receptor:-

- Very High
- High
- Medium
- Low
- Very Low

Four categories are then used to describe the overall "Significance of Impact":-

- Major
- Moderate
- Minor
- Negligible

The results of the revised qualitative assessment are given in risk matrices presented in Appendix 3 that identify which of the five categories above apply to specific activities and receptors during the Phase 3 Works and, from this, it has been assessed which of the four categories of "Significance of Impact" they belong.

The following sections provide descriptions and definitions for each of these categories as they apply to each of the components of the qualitative risk assessment.

6.1 Likelihood of Occurrence

The Likelihood of Occurrence of a physical or chemical effect is evaluated by combining Connectivity and Proximity of an activity to a receptor, as detailed below.

Likelihood	**Connectivity between Activity and Receptor**					
		Very Low	**Low**	**Medium**	**High**	**Very High**
Receptor Proximity to Activity	**Very Low**	Very Low	Low	Low	Medium	Medium
	Low	Low	Low	Medium	Medium	High
	Medium	Low	Medium	Medium	High	High
	High	Medium	Medium	High	High	Very High
	Very High	Medium	High	High	Very High	Very High

6.1.1 Connectivity

Very High Connectivity	Activity and receptor occur in the same aquifer unit, with a direct or known pathway between them. For chemical impacts, the receptor is also down hydraulic gradient from the activity and on the same flow path (determined as being a line of flow between the source and the receptor that is perpendicular to groundwater contours).
High Connectivity	Activity and receptor occur in the same aquifer unit but the pathway is indirect as a result of the presence of a very thin (<1 m) or discontinuous aquitard. For chemical impacts, the receptor is down hydraulic gradient from the activity and is slightly oblique to the flow path.
Medium Connectivity	Activity and receptor occur in adjacent aquifer units that are in hydraulic continuity but are separated by a thin (>1 m), fractured or leaky aquitard. For chemical impacts the receptor is down hydraulic gradient from the activity and is strongly oblique to a flow path.
Low Connectivity	Activity and receptor are in adjacent aquifer units with no or very limited hydraulic continuity between them due to the presence of a natural or man-made aquitard. For chemical impacts the receptor is down hydraulic gradient from the activity and is on a different flow path.
Very Low Connectivity	There is no hydraulic continuity between the activity and the receptor due to the presence of a laterally and vertically continuous, or multiple thin (>1 m) aquitard units, an aquiclude unit or an engineered barrier unit. For chemical impacts, the receptor is up hydraulic gradient from the activity.

6.1.2 Proximity

In accordance with Environment Agency guidance on groundwater protection (Ref. 12), the minimum permitted distance for the proximity of a potentially polluting activity to a water abstraction is 50 m (equivalent to Source Protection Zone I). As such, for the purpose of this qualitative risk assessment a distance of <50 m has been used to define the condition of Very High Proximity. By consideration of Environment Agency guidance for the minimum distance of 250 m to a Source Protection Zone II this distance has been used to define the condition of High Proximity. Moderate and a Low Proximity limits have been set equally spaced from the 250 m zone, at 500 and 750 m respectively, and a Very Low Proximity has been defined as >750 m. The following absolute values have, therefore, been used to evaluate the Proximity of an activity to a receptor.

Very high proximity	< 50 m
High proximity	51 – 250 m
Medium proximity	251 – 500 m
Low proximity	501 – 750 m
Very low proximity	>750 m

A multi-layered aquifer system also requires consideration of vertical proximity. In order to take this into account, the proximity between aquifers moving down vertically through a sequence is reduced by one category for each aquifer to be consistent with the concept of connectivity.

6.2 Magnitude of Effect at Source (M_S)

The Magnitude of Effect at Source of a physical or chemical impact is categorised, as detailed below:-

Very High Magnitude of Effect at Source	A very high degree of physical change is a change in groundwater level that is >150% of the regional natural annual groundwater level variation for an aquifer, or >150% of the natural variation in flowrate from a spring. A very high degree of chemical change is a change of >150% of the natural baseline chemical quality variation that could cause a risk of harm or give rise to a pollution risk.
High Magnitude of Effect at Source	A high degree of physical change is a change in groundwater level that is between 100 and 150% of the regional natural annual groundwater level variation for an aquifer, or between 100 and 150% of the natural variation in flowrate from a spring. A high degree of chemical change is a change of between 100 and 150% of the natural baseline chemical quality variation that could cause a risk of harm or give rise to a pollution risk.
Medium Magnitude of Effect at Source	A moderate degree of physical change is a change in groundwater level that is between 50 and 100% of the local natural annual groundwater level variation for an aquifer, or between 50 and 100% of the natural variation in flowrate from a spring. A high degree of chemical change is a local change of between 50 and 100% of the natural baseline chemical quality variation that could cause a risk of harm or give rise to a pollution risk.
Low Magnitude of Effect at Source	A low degree of physical change is a change in groundwater level that is between 20 and 50% of the local natural annual groundwater level variation for an aquifer, or between 20 and 50% of the natural variation in flowrate from a spring. A low degree of chemical change is a local change of between 20 and 50% of the natural baseline chemical quality variation.
Very Low Magnitude of Effect at Source.	A very low degree of physical change is a change in groundwater level that is <20% of the local natural annual groundwater level variation for an aquifer, or <20% of the flow from a spring. A very low degree of chemical change is a local change of <20% of the local natural baseline chemical variation.

6.3 Magnitude of Effect at Receptor (MR)

The Magnitude of Effect at any Receptor is estimated by combining the Magnitude of Effect at Source and the Likelihood of a hydrogeological "effect" occurring, as detailed in the matrix below:-

Magnitude of Effect at the Receptor		Likelihood				
		Very Low	Low	Medium	High	Very High
Magnitude of Effect at Source	Very Low	Very Low	Very Low	Very Low	Very Low	Very Low
	Low	Very Low	Very Low	Low	Low	Low
	Medium	Very Low	Low	Low	Medium	Medium
	High	Very Low	Low	Medium	High	High
	Very High	Very Low	Low	Medium	High	Very High

A description of the five categories of hydrogeological "Magnitude of Effect at the Receptor" that have been used in this report are presented below:-

Magnitude of Effect at Receptor	Description
Very High	Loss of resource and/or integrity of the resource; severe damage to key characteristics or features and permanent/ irreplaceable change is certain to occur.
High	Loss of resource, but not affecting the overall integrity of the resource; partial loss of or damage to key characteristics or features and permanent/irreplaceable change is likely to occur.
Medium	Minor loss of, or alteration to, key characteristics of a resource; measurable change in attributes, quality or vulnerability. Long term, though reversible change, is likely to occur.
Low	Very minor loss of, or alteration to, key characteristics of a resource; noticeable change in attributes, quality or vulnerability. Short to medium term, though reversible, change could possibly occur.
Very Low	Temporary or intermittent very minor loss of, or alteration to, key characteristics of a resource; noticeable change in attributes, quality or vulnerability. Short to medium term change is unlikely to occur, and when does is likely to be intermittent and reversible.

6.4 Receptor Sensitivity

The sensitivity of groundwater receptors in the qualitative risk assessment has been assessed in terms of their ability to accommodate physical or chemical change and on the impact any change may have on a regional or local ecological or other environmental system. By adopting this approach to the qualitative assessment, the most sensitive receptors are determined to be those with very limited or no capacity to accommodate physical and/or chemical change that are of very high importance as a groundwater resource. Conversely very low sensitivity receptors are those that can generally tolerate physical and/or chemical changes and are of low importance as a groundwater resource. Groundwater receptor characteristics and receptor examples are detailed in the table overleaf:-

Sensitivity	Groundwater Receptor Characteristics	Receptor Examples
Very High	• has very limited or no capacity to accommodate physical or chemical changes • supports internationally important ecological, amenity or landscape features	• licensed public water supply or major industrial abstractions (e.g. SPZ 1/2) • licensed/unlicensed abstractions and springs providing potable water supply, for which there is no alternative source (e.g. mains water) • designated SAC, SPA, or Ramsar site with fauna or flora that are hydrogeologically supported from groundwaters within rock aquifers • surface water bodies supporting the above
High	• has limited capacity to accommodate physical or chemical changes • supports nationally important ecological amenity or landscape features	• designated 'Principal Aquifer' • licensed/unlicensed abstractions and springs providing potable water supply, for which an alternative source (e.g. mains water) is available • SSSI, NNR with fauna or flora that are hydrogeologically supported from groundwaters within rock aquifers • surface water bodies supporting the above
Medium	• has limited capacity to accommodate physical or chemical changes • supports regionally important ecological, amenity or landscape features	• designated 'Secondary A (or Undifferentiated) Aquifer' • regionally important wildlife sites with fauna or flora that are hydrogeologically supported from groundwaters within rock aquifers • non-potable licensed abstractions • surface water bodies supporting the above or classified as Good under Water Framework Directive.
Low	• has moderate capacity to accommodate physical or chemical changes • supports locally important ecological, amenity or landscape features	• non-potable unlicensed abstractions • local wildlife sites (LNR, SNCI, RIGS), country parks with flora hydrogeologically supported from groundwaters within rock aquifers • designated SAC, SPA, or Ramsar site with fauna or flora that are not hydrogeologically supported from groundwaters within rock aquifers • surface water bodies supporting the above or classified as Moderate under Water Framework Directive.
Very Low	• generally tolerant of and can accommodate physical or chemical changes • supports no features of significant ecological, amenity or landscape value	• designated 'Secondary B Aquifer' or 'Unproductive Strata' • surface waters with no important, dependent receptors • SSSI, NNR with fauna or flora that are not hydrogeologically supported from groundwaters within rock aquifers

6.5 Significance of Impact

The significance of the impact that changes will have on a hydrogeological receptor is assessed by comparing the Magnitude of Effect at Receptor with the receptor Sensitivity. This is assessed using the following matrix.

Receptor Sensitivity	Magnitude Of Effect At Receptor				
	Very Low	**Low**	**Medium**	**High**	**Very High**
Very Low	Negligible	Negligible	Negligible	Negligible	Minor
Low	Negligible	Negligible	Minor	Minor	Minor
Medium	Negligible	Minor	Minor	Moderate	Moderate
High	Negligible	Minor	Moderate	Moderate	Major
Very High	Negligible	Minor	Moderate	Major	Major

The four categories assigned to the Significance of Impact above relate to a Major, Moderate, Minor or negligible (as identified below) against which the necessity to implement mitigation measures is evaluated.

Significance of Impact	Description	Necessity Of Mitigation Measures
Major	Major risk of unacceptable change to a sensitive hydrogeological receptor.	Mitigation measures required.
Moderate	Moderate risk with measurable change to a sensitive hydrogeological receptor.	Mitigation measures required.
Minor	Minor risk with local minor change to a sensitive hydrogeological receptor.	Mitigation measures may be required.
Negligible	No risk and no discernible change to a sensitive hydrogeological receptor.	No mitigation measures required.

7 RECEPTORS

All groundwater level, spring flow and water quality data referred to in this report is presented in detail in the revised Hydrogeological Baseline Report (Ref. 1).

From the Hydrogeological Baseline Report (Ref. 1), five types of groundwater receptors have been identified in the vicinity of the Woodsmith Mine that could be impacted on by the Phase 3 Works. These are streams, springs, private water supplies, the Special Areas of Conservation containing potentially groundwater-supported terrestrial ecosystems, and controlled waters in sensitive aquifers comprising the Secondary A Aquifers (Moor Grit, Scarborough, Cloughton and Saltwick Formations).

The site is designated by the Environment Agency as having a Low Groundwater Vulnerability (Ref. 1). There are no groundwater Source Protection Zones (SPZs) recorded by the Environment Agency within 2.5 km of the site (Ref. 1).

7.1 Sensitive Aquifers

Presented below is a summary of the key physical and chemical characteristics of the groundwater aquifer receptors that may be impacted on by the Phase 3 Works.

7.1.1 Moor Grit Member

Aquifer classification	Secondary A.
Geometry and physical properties	This formation principally comprises sandstone units of between 6 to 10 m thick and is underlain by a low permeability argillaceous unit, with dips of between 1 to 5°. The most likely values of hydraulic conductivity have been determined of 1.3 x 10^{-5}m/s (Ref. 1).
Groundwater levels	Observed seasonal variation of the groundwater table within the winter "wet" period (November to June) is between 2.1 m and 5.2 m on the minesite (Drawing 1433DevOD228 and 229), 3.2 m to 4.8 m on Ugglebarnby Moor SAC (Drawing 1433DevOD230) and around 0.7 m on Sneaton Low Moor. Observed seasonal variation within the summer "dry" period (June to November) is between 1.0 m and 5.3 on the minesite, 3.5 m to 4.7 m on Ugglebarnby Moor SAC (Drawing 1433DevOD230) and around 1.9 m on Sneaton Low Moor. Groundwater variation is highest along the western side of the site adjacent to the hydrological divide.
Groundwater quality	Freshwater and of good (chemical) quality.
Sensitivity	**Medium** – The Moor Grit aquifer beneath Woodsmith Mine is classified as a Secondary A Aquifer. It supports single dwelling drinking water supplies via spring discharges (Moorside Farm Spring MF2 located over 500 m from the shaft platform), and provides a limited contribution of base flow to a Sneaton Thorpe Beck. This aquifer has a limited capacity to accommodate physical or chemical changes and influences. Note-Although the Moor Grit supports unlicensed abstractions and springs providing potable water supply that are classified as a High Sensitivity, these abstractions and springs are assessed in their own right in Section 7.3, and the classification of the Moor Grit Aquifer beneath the Phase 3 Works has been made based on its Secondary A Aquifer status.

7.1.2 Scarborough Formation

Aquifer classification	Secondary A.
Geometry and physical properties	This formation principally comprises an upper 0.6 m to 5 m thick low permeability mudstone, a middle 2 m to 5 m thick sandstone and a lower 2 m to 7 m thick low permeability mudstone with dips of between 1 to 5°. The most likely values of hydraulic conductivities for this unit are:- • Upper Mudstone $K_h = 3 \times 10^{-6}$ m/s, $K_v = 1 \times 10^{-6}$ m/s, • Middle Sandstone $K_h = 35.2 \times 10^{-4}$ m/s (fracture), $K_h = 1.3 \times 10^{-5}$ m/s (Intergranular), • Lower Mudstone $K_h = 2 \times 10^{-6}$ m/s, $K_v = 1 \times 10^{-8}$ m/s,
Groundwater levels	Observed annual seasonal variation are between 1.9 m to 5.63 m on the minesite, 4.3 m on Ugglebarnby Moor SAC and 1.1 m on Sneaton Low Moor SAC.
Groundwater quality	Freshwater, good (chemical) quality.
Sensitivity	**Medium** - This aquifer locally supports non-continuous and continuous spring flows used locally for single dwelling drinking water supplies (Soulsgrave Farm Spring SF2), and may provide base flow to a number of surface water bodies including Knaggy House Farm ponds and Sneaton Thorpe Beck. This aquifer has a limited capacity to accommodate physical or chemical changes and influences.

7.1.3 Cloughton Formation

Aquifer classification	Secondary A.
Geometry and physical properties	This formation principally comprises an interbedded mudstone, siltstone and sandstone unit of between 32 and 43 m thick, with horizontal to sub-horizontal dips. The most likely hydraulic conductivity values determined for this unit is 2×10^{-4} m/s (fracture) (Ref. 1).
Groundwater levels	Observed annual seasonal variation from January 2014 to December 2015 are between 1.96 to 6.64 m.
Groundwater quality	Freshwater and of good (chemical) quality, although can contain elevated levels of iron.
Sensitivity	**Medium** - locally used for a borehole drinking water supply is capable of generating a high yield, and contributes via spring discharge to surface water flows to surface water bodies, such as Little Beck. This aquifer has a limited capacity to accommodate physical or chemical changes and influences.

7.1.4 Saltwick Formation

Aquifer classification	Secondary A
Geometry and physical properties	This formation principally comprises an interbedded mudstone, siltstone and sandstone unit around 50 m thick with horizontal to sub-horizontal dips. The most likely hydraulic conductivity values determined for this unit is 2 x 10-5 m/s (fracture) (Ref. 1)
Groundwater levels	Observed variation from April 2013 to May 2014 of between 1.21 and 2.27 m bgl
Groundwater quality	Freshwater and of good (chemical) quality, although can contain elevated levels of iron.
Sensitivity	**Medium** - contributes via spring discharge to surface water flows to surface water bodies, such as Little Beck. This aquifer has a limited capacity to accommodate physical or chemical changes and influences.

7.2 Base Flow Springs

From the results of the ground investigations and the baseline groundwater and spring monitoring undertaken (Ref. 1), the following sections summarise hydrogeological baseline conditions, conceptual models and spring sources determined at each of the spring discharges identified on and adjacent to the minesite. The location of these springs (DNS1, SP01 to 04 and KHF), is shown on Drawing 1433DevOD260.

7.2.1 Doves Nest Farm Spring (DNS1)

Geometry and physical properties	Located in the central eastern area of the minesite and discharges from a piped overflow at an elevation of 200 m AOD, from a buried tank into a drainage channel that ultimately outflows to Sneaton Thorpe Beck. The ground conditions are likely to comprise 5 m of soft to firm sandy gravelly clay (base at 200.2 m AOD) overlying 6.5 m of Moor Grit comprising a fine to coarse partially weathered sandstone with some iron staining (to 193.7 m AOD) beneath which is 1.4 m of heavily weathered grey/mottled orange-brown siltstone forming the upper part of the Scarborough Formation.
Spring Flows	DNS1(A) shows a maximum manually recorded flow rate of 0.20 l/sec and repeated prolonged periods of no recorded flow. From the manual flow rates recorded, it is evident that this spring does not provide a continuous flow of groundwater to Sneaton Thorpe Beck, and is usually dry.
Groundwater quality	Freshwater, good (chemical) quality. Similar chemical signature as groundwater in the Moor Grit aquifer
Source of Spring	Moor Grit
Sensitivity	**Very Low** - located at the headwaters of Sneaton Thorpe Beck and provides a limited and non-continuous discharge to this surface watercourse. It has, therefore, a moderate capacity to accommodate chemical change. As the groundwater source is the Moor Grit aquifer that has been determined locally to exhibit high seasonal variation in groundwater levels of between 1.8 and 5.6 m, this spring is also considered to have a moderate to high capacity to accommodate physical change in water levels and can often dry up completely.

7.2.2 Ugglebarnby Moor Spring (SP01)

Geometry and physical properties	This spring is located in the southern part of Ugglebarnby Moor SAC. It comprises a discharge to surface through moorland peat into a narrow channel that discharges into Little Beck. The ground level at SP01 is 207.3 m AOD. From the BGS geological map this spring is shown to be located close to the top of the Scarborough Formation, with around 1.5 m of very sandy clay overlying the Scarborough Formation that is likely to comprise an upper and lower silty mudstone aquitard unit approximately 0.9 and 9 m thick respectively, with an intervening interlayered sandstone/mudstone aquifer unit between 5 to 6 m thick.
Spring Flows	A maximum manual flow rate of 0.8 l/sec was recorded, with no flows recorded during dry periods. From the flow rates recorded since February 2014, it is evident that this spring does not provide a continuous flow of groundwater to Little Beck to the west. Drawing 1433DevOD239 illustrates that the spring flow is moderately affect by rainfall conditions.
Groundwater quality	Freshwater, good (chemical) quality.
Source of Spring	It is interpreted that the groundwater discharge at SP01 is from a mixture of Moor Grit aquifer groundwater and groundwater from the superficial deposit on Ugglebarnby Moor SAC. In order to reach the surface, the groundwater discharging from the Moor Grit will need to flow through around 2 to 3 m of superficial deposits. This may explain the location of the discharge at the top of the Scarborough Formation on the geological map, as the water has travelled down gradient through the superficial deposits until it has reached the ground surface. As the groundwater flows through the superficial deposits, it will undergo water:rock interaction and acquire the mixed geochemical characteristics of groundwater from the Moor Grit and the superficial deposits.
Sensitivity	**Very Low** - This groundwater spring located 600 m to the east of Little Beck provides a limited and non-continuous indirect discharge to this surface watercourse and has, therefore, a moderate capacity to accommodate chemical change. As the groundwater source is from the Moor Grit aquifer that has been determined locally to exhibit seasonal variation in groundwater levels in the order of 4.4 m to 5.4 m, this spring is also considered to have a moderate capacity to accommodate physical change in water levels and can sometimes dry up completely.

7.2.3 Springs Northwest of Ugglebarnby Moor (SP02, SP03)

Geometry and physical properties	SP02 is located to the northwest of Ugglebarnby Moor SAC. It comprises a discharge from an ornamental Lions Head (public access drinking fountain) located on the roadside. The ground level at SP02 is 145 m AOD and it is inferred that there is between 2 to 4 m of superficial gravelly clays, overlying the Secondary A Aquifer sandstones of the Cloughton Formation. Spring SP03 is located approximately 100 m north of SP02, to the northwest of Ugglebarnby Moor SAC. The ground level at SP03 is 162.4 m AOD and it is inferred that there is around 2 to 4 m of superficial gravelly clays, overlying the Secondary A Aquifer sandstones of the Cloughton Formation.
Spring Flows	A maximum flow rate for SP02 of 0.8 l/sec and a minimum of no flow was recorded. It should be noted that discharge will be artificially limited by its discharge from the ornamental Lions Head, and that at low flow rates discharge may be controlled solely by impounded flow. Based on the flow rates recorded since February 2014, it is evident that this spring provides a continual annual discharge of groundwater, only running dry for a short period late in the year. This monitoring has determined that seasonal flows fluctuate between 0.05 to 0.8 l/sec during the winter and spring months and no flow to 0.7 l/sec during the summer and autumn months. A maximum flow rate for SP03 of 26.9 l/sec was recorded during a high heavy rainfall event, and a minimum flow rate of 2.5 l/sec. Based on the flow rates recorded since February 2014, it is evident that this spring does provide a continual annual flow of groundwater. This monitoring has determined that flows of between 2.5 to 11.6 l/sec would be expected during the winter months, 2.5 to 14.0 l/sec during the spring months, 3.4 to 7.5 l/sec during the summer months, and 2.9 to 7.6 l/sec during the autumn months.
Groundwater quality	Freshwater, good (chemical) quality.
Source of Spring	Based on geological, topographical and water geochemical data, the source of SP02 and SP03 is the Cloughton Formation beneath Ugglebarnby Moor SAC.
Sensitivity	**Very Low** - These groundwater springs located 800 to 950 m east of Little Beck (SP02 and SP03) respectively, potentially provide indirect discharge to this surface watercourse and has, therefore, a moderate capacity to accommodate chemical change. As the groundwater source for SP02 and 03 is the Cloughton Formation aquifer that has been determined locally to exhibit high seasonal variation in groundwater levels of between 2.0 to 6.6 m, these two springs are also considered to have a moderate capacity to accommodate physical change in water levels.

7.2.4 Springs North of Woodsmith Mine (SP04)

Geometry and physical properties	SP04 is located to the north of the Woodsmith Mine. The ground level at SP04 is 195.6 m AOD. Based on borehole HG9, it is inferred that there is approximately 2 m of superficial deposits comprising a sandy gravelly clay, overlying the weathered Secondary A Aquifer sandstones of the Moor Grit Formation.
Spring Flows	It is not possible to measure the flow rate from SP04. As SP04 discharges from the same aquifer unit, it may be expected to show values similar to DNS1(A) (see section above), and be dry during summer/autumn, and relatively low flows up to 0.2 l/s during winter.
Groundwater quality	Freshwater, good (chemical) quality.
Source of Spring	Based on geological and topographical data, the source of SP04 is expected to be the Moor Grit beneath the Woodsmith Mine.
Sensitivity	**Very Low** - This groundwater spring located 550 m south of Buskey Beck provides a limited, potentially indirect discharge to this surface watercourse and has, therefore, a moderate capacity to accommodate chemical change. As the groundwater source for SP04 is the Moor Grit, it has been determined to locally exhibit seasonal variations in groundwater levels of between 1.8 and 5.6 m. This spring is considered to have a moderate capacity to accommodate physical change in water levels.

7.2.5 Springs North of Woodsmith Mine (KHF)

Geometry and physical properties	The Knaggy House Farm (KHF) spring is located approximately 30 m east of SP04 The ground level at KHF spring is 185.0 m AOD. Based on borehole HG9 it is inferred that there will be approximately 2 m of superficial deposits comprising sandy gravelly clay overlying mudstone and sandstone/siltstone of the Scarborough Formation.
Spring Flows	It is not possible to measure the flow rate from KHF. As the groundwater at KHF is considered to be from the Scarborough Formation, the discharge from this spring, if present, is likely to be similar to that of other discharges SF2, and be dry during summer/autumn and show a maximum flow rate of around 1 l/sec.
Groundwater quality	Freshwater, good (chemical) quality.
Source of Spring	Based on geological and topographical data, the source of KHF is the Scarborough Formation beneath the Woodsmith Mine.
Sensitivity	**Very Low** - This groundwater spring located 50 m west of the surface water ponds at Knaggy House Farm (KHF) provide a limited, potentially indirect discharge to this surface watercourse and has, therefore, a moderate capacity to accommodate chemical change. The groundwater at KHF is inferred to be from the Scarborough Formation that has been measured to show a variation in groundwater levels of between 1.9 to 5.6 m. It is considered to have a moderate to high capacity to accommodate physical change in water levels.

7.3 Spring Water Supplies

From the results of the ground investigations and the baseline groundwater and spring monitoring undertaken (Ref. 1), the following sections summarise hydrogeological baseline conditions, conceptual models and spring sources determined at each of the spring discharges identified on and adjacent to the minesite. The location of these springs (MF2, SF2 and NHF1) is shown on Drawing 1466DevOD231.

7.3.1 Moorside Farm Spring (MF2)

Licenced Abstraction	No
Geometry and physical properties	MF2 discharges from an elevation of 210.0 m AOD and feeds a domestic water storage tank with an overflow from the tank at an elevation of 202.6 m AOD. A proportion of the flow from the spring at MF2 provides the spring water that feeds this storage tank whilst the remaining (and larger) proportion forms the Spring Flush area within Ugglebarnby Moor SAC. The geological sequences in the vicinity of Spring MF2 comprises between 1.5 and 3.5 m of sandy gravelly clay overlying around 8 m of Moor Grit sandstone to an elevation of between 203 and 204 m AOD. This in turn overlies the Scarborough Formation sequence comprising upper and lower mudstone aquitard units, with an intervening sandstone/siltstone aquifer unit.
Spring Flows	Due to the nature of the groundwater discharge, no flow rate can be monitored at the groundwater discharge point MF2 (Drawing 1466DevOD232). Manually measured flow rate data for the overflow tank at MF1 report a maximum flow rate for MF1 of 0.25 l/sec was 23 May 2014 (during a period of heavy sustained rainfall), and a minimum flow rate of no flow on 28 July 2014, 25 September to 20 October 2014 and 5 to 10 November 2014 (Drawing 1466DevOD232). Seasonal flows typically have been determined to range between 0.15 l/s during the winter spring months (with an average of 0.06 l/sec) to 0.03 l/s during the summer and autumn months. Based on the flow rates recorded for the tank discharge, it is evident that Spring MF2 does not provide a continuous flow of groundwater to the storage tank at MF1. However, as MF1 is a storage tank for drinking water, a zero flow from MF1 does not directly represent a zero flow of groundwater from the Spring MF2 as it may represent heavy usage of the drinking water by the properties from the tank in excess of the MF2 recharge into the tank. It is considered likely that repeated no flow values from MF1 over a period of weeks may reflect no, or very limited,

	flow from Spring MF2 providing groundwater to the storage tank at MF1.
Groundwater quality	Freshwater, good (chemical) quality.
Source of Spring	From the ground conditions determined at MF2 and the groundwater levels monitored separately in the superficial deposits and in the Moor Grit strata (Drawing 1466DevOD23), it is determined that during the winter months the source of the spring to the domestic water supply at MF1 is from both the Moor Grit and superficial soils. In the later spring and summer months, the superficial deposits appear to become dry (e.g. 28 July to 10 October 2014), and the water levels fall in the Moor Grit strata, such that only low groundwater flows from the Moor Grit provide the sole contributing source to the domestic water supply at MF1. Periods of sustained rainfall, for example from mid-May 2014 onwards, replenish the groundwater within the superficial deposits. It is determined that when groundwater levels in the Moor Grit fall below a level of approximately 210 m AOD (at HG111A), only very limited bedrock groundwater flows will occur from the spring at MF2 to recharge the domestic water supply at MF1. HG111A monitoring the Moor Grit immediately up hydraulic gradient of this spring exhibits high seasonal variation in groundwater levels from 213.1 to <211.18 m AOD in the superficial deposits and from 212.9 to 209.2 m AOD in the Moor Grit, with a range in the winter months (November to June) of 3.2 m and a range in the summer months (July to October) of 2.8 m (Drawing 1466DevOD23). The influence of rainfall events on the flow rate at MF1, and the relatively short lag period of 12 hours between a rainfall event and an increase in flow rate at MF1, indicates that during winter and spring conditions there is a significant surface water contribution to the tank recharge at MF1.
Sensitivity	**High** - This groundwater spring (MF2) recharges a high quality drinking water supply at MF1 for two domestic properties. It has, therefore, a very limited potential to accommodate chemical change. It does not provide continuous flow throughout the year, with very low or no flow observed during the summer months. The groundwater source to this spring is from the superficial glacial deposits and the Moor Grit sandstone aquifer. As the source to this spring has been determined locally to exhibit high seasonal variation in groundwater levels from 213.1 to <211.18 m AOD in the superficial deposits and from 212.9 to 209.2 m AOD in the Moor Grit, this spring is considered to have a moderate capacity to accommodate physical change in water levels and can sometimes dry up completely.

7.3.2 Soulsgrave Farm Spring (SF2)

Licenced Abstraction	No
Geometry and physical properties	SF2 is a spring discharge associated with Soulsgrave Farm to the east of the Woodsmith Mine at an elevation of 196.8 m AOD. The storage chamber used to collect spring water for Soulsgrave Farm is referred to in this study as SF1 at an elevation of 198.0 m AOD. There are no visible inflow or outflow pipes associated with this storage tank and so no estimated or measurable spring flow rate was possible from this location. There are a number of spring discharges present in this area, marked by distinctive rush-dominated vegetation. Ground conditions in the vicinity of Soulsgrave Farm are expected to comprise 1 to 3 m of gravelly clay (superficial deposits), overlying the Scarborough Formation comprising an upper and lower mudstone aquitard unit and an intervening sandstone aquifer unit.
Spring Flows	A maximum manual flow rate value of 1.0 l/sec was recorded on 03 December 2014, and a minimum value of no flow was recorded on 30 August 2013, between 15 September to 16 October 2014, 30 October to 5 November 2014 and 1 July 2015 to 4 November 2015. Based on the flow rates recorded since February 2014, it is evident that this spring does not provide a continuous flow. During periods of no flow from the spring anecdotal evidence suggests that storage in the tank at SF1 is sufficient to provide the drinking water requirements for Soulsgrave Farm.

	Monitoring has determined that seasonal flows vary between 0.1 and 1.0 l/sec during the winter months, 0.02 and 0.7 l/sec during the spring months, no flow to 0.6 l/sec during the summer months, and no flow to 0.53 l/s during the autumn months.
Groundwater quality	Freshwater, good (chemical) quality.
Source of Spring	A Scarborough Formation source is supported by the geological evidence of the topographic levels and geographical location of the spring. It is likely, therefore, that the recharge zone for this spring is in fairly close proximity to the discharge zone, most likely within the northern part of Sneaton Low Moor.
Sensitivity	**High** - This high quality groundwater spring is used for drinking water purposes to this individual property and has, therefore, a very limited potential to accommodate chemical change. It does not provide continuous flow throughout the year, with no flow observed during the summer months. The groundwater source is from the Scarborough Formation sandstone aquifer, which has been determined locally to exhibit seasonal variations in groundwater levels of between 0.7 and 1.4 m. This spring is considered to have a moderate capacity to accommodate physical change in water levels and can sometimes dry up completely.

7.3.3 Newton House Farm Spring (NHF1)

Licenced Abstraction	Yes - The Newton House Farm groundwater is abstracted from a spring located beneath a stone monument for both general farming and domestic use under licence 2/27/29/149, which has a daily abstraction limit of 10 m^3 and an annual limit of 1950 m^3.
Geometry and physical properties	As groundwater enters a storage chamber beneath the stone monument and as overflow from the chamber is allowed to discharge into the subsurface, it is not possible to determine spring flow rates at this location. Based on ground level and geology of this location it is determined that this spring is sourced from the Cloughton Formation. Based on groundwater level monitoring in the Cloughton on the minesite area, seasonal groundwater level fluctuations of 2 m may impact on spring flows from this aquifer at this location.
Spring Flows	It is not possible to measure the flow rate from Newton House Farm Spring, however based on anecdotal evidence there is reported to be a continuous annual flow from this spring
Groundwater quality	Freshwater, good (chemical) quality.
Source of Spring	Based on ground level and geology of this location it is determined that this spring is sourced from the Cloughton Formation.
Sensitivity	**High** - This high quality groundwater spring is used for drinking water purposes and has, therefore, a very limited potential to accommodate chemical change. As the groundwater source is from the Cloughton Formation aquifer, which has been determined locally to exhibit high seasonal variation in groundwater levels of between 1.7 to 4.5 m, this spring is considered to have a moderate capacity to accommodate physical change in water levels.

7.4 Groundwater Abstractions

From the results of the ground investigations and the baseline groundwater monitoring, summarised below are the hydrogeological baseline conditions and conceptual model determined for the groundwater borehole abstraction at Sneaton Low Moor Caravan Park situated to the south of the minesite, as illustrated in Drawing 1433DevOD260.

Licenced Abstraction	Yes
Geometry and physical properties	The groundwater abstraction receptor nearest the site is at Sneaton Low Moor Caravan Park located approximately 1.1 km from the minesite. Groundwater is reported to be abstracted from a “shale and sandstone unit”. Based on geological data, it is inferred that the groundwater at this location is abstracted from the base of the Cloughton Formation. From the groundwater levels monitored in the Cloughton Formation in the

	minesite as part of this investigation, it would be expected that water levels at the abstraction well location would normally be between 190 and 200 m AOD, if no abstraction was occurring, and would be subject to seasonal groundwater level fluctuations in the order of 2 m.
Groundwater quality	Freshwater, good (chemical) quality.
Source of Abstraction	Cloughton Formation.
Sensitivity	**High** - This groundwater abstraction well is used for drinking water purposes and has, therefore, a very limited potential to accommodate chemical change. As the response zone to the well is in the Cloughton Formation, which is likely to exhibit moderate seasonal variation in groundwater levels of between 1.7 m to 4.5 m around a reported rest water level of 170 m AOD, this well is considered to have a moderate capacity to accommodate physical change in water levels.

7.5 Ecological Receptors

There are two principal areas of sensitive ecological receptors in close proximity to the site; Ugglebarnby Moor and Sneaton Low Moor, which are designated as Special Areas of Conservation (SACs), Special Protection Areas (SPA) and Sites of Special Scientific Interest (SSSI).

From the ecological survey (Ref. 13), and a review by Royal Haskoning DHV (Ref. 14), the following sensitive habitats have been identified in the Ugglebarnby Moor and Sneaton Low Moor areas of the North York Moors SAC (Drawing 1433DevOD270 and 1433DevOD260):-

- An area of Dry Heath in the north of Ugglebarnby Moor SAC.
- An area of Wet Heath in the central area of Ugglebarnby Moor SAC.
- An area of Dry Heath in the south of Ugglebarnby Moor SAC.
- An area of Spring Flush in the south of Ugglebarnby Moor SAC.
- An area of Dry Heath in Sneaton Low Moor SAC.

From the results of the ground investigations and the baseline groundwater and spring monitoring undertaken (Ref. 1), the following sections summarise the hydrogeological baseline conditions, conceptual models and evidence of whether the terrestrial ecosystems within these SAC areas have been determined to be hydrogeologically supported.

7.5.1 Ugglebarnby Moor Northern Dry Heath Area

Geometry and physical properties	The area of Dry Heath in the north of the SAC (Drawing 1433DevOD270) borders the northwestern boundary of the minesite development. Ground levels in this area slope from 210 m AOD in the east down to between 180 to 190 m AOD in the west. Natural England (Refs. 15 & 16) and the ecological survey of this section of Ugglebarnby Moor SAC (Ref. 13) have identified this area as a Dry Heath ecology and, it is therefore, not a hydrologically supported ecological system. The superficial deposits of between 2.4 m to 4.5 m thick comprise clay with occasional sand lenses. Beneath the superficial deposits, the Moor Grit aquifer comprises 4 to 8.7 m of sandstone overlying the Scarborough Formation aquifer and then the Cloughton Formation aquifer, which dip to the east at around 5°. The Scarborough aquifer comprises an upper low permeable interbedded siltstone and mudstone aquitard unit of between 1.5 m to 4.7 m thick, underlain by a limestone and sandstone aquifer of around 2 m thick and then a further basal mudstone aquitard around 3.4 m thick. Beneath the basal Scarborough aquitard is the aquifer unit of the Cloughton Formation, which is around 27 m of interbedded sandstones and mudstones. Due to the predominantly low permeable nature of the superficial deposits and the absence of laterally continuous granular lenses, the measured groundwater levels in the northern Dry Heath area are considered to represent a laterally discontinuous perched water table through these superficial strata. This is substantiated by the groundwater levels in the bedrock formations underlying the superficial deposits in this area. From the groundwater levels determined, there is a permanent unsaturated zone of at least 8 m at the top of the Cloughton Formation, and an unsaturated zone of between 1 to 3.5 m at the top of the Scarborough and Moor Grit Formations during the summer periods. Therefore, as there is a recurrent unsaturated zone present at the top of the bedrock formations, there is no sustained connectivity throughout the year between the groundwaters in the bedrock and those in the superficial deposits. Consequently, the groundwaters in the superficial deposits are considered to be predominantly derived from surface water (rainfall) infiltration. It has been shown in the Moor Grit and Scarborough Formations that there is the potential for a periodic rise of groundwater from the bedrock into the overlying superficial deposits. However, the superficial deposits are of a sufficiently low permeability to prevent the groundwater rising up, even when it is under pressure as observed in the winter months (Drawing 1433DevOD240). As such, due to the thick low permeable barrier created by the superficial deposits that separates the bedrock aquifer from the surface ecology (Drawing 1433DevOD240), change in the groundwater levels within the Moor Grit and Scarborough Formation does not appear to result in a significant impact on the overlying Dry Heath ecology.
Hydrogeologically Supported Ecosystem	No – This area of the SAC is reported to contain no flora that is sensitive to hydrogeological variations within the shallow rock aquifer.
Sensitivity	**Low**

7.5.2 Ugglebarnby Moor Central Wet Heath Area

Geometry and physical properties	The central Wet Heath area of Ugglebarnby Moor SAC comprises a strip of mixed woodland along the flat upland area bordering the eastern boundary; a broad linear belt of Wet Heath across the steeper sloping section where ground levels grade between 210 m in the east down to 200 m in the west; and then Mire vegetation in the lowland shallow slope to the west where ground levels grade between 200 m AOD to 195 m AOD. The woodland area is underlain by 2 to 3 m of sandy gravelly clay and then by 1 to 5 m of Moor Grit sandstone dipping (~5°) to the east, beneath which are mudstones of the Scarborough Formation. The Wet Heath vegetation forming the broad linear belt is underlain by 0.1 to 0.3 m of peat and then 3 to 4 m of sandy gravelly clay with thin discontinuous sand lenses. This in turn is underlain by up to 1 m of Moor Grit sandstone, 4 to 5 m of Scarborough mudstone and then 3 m of Scarborough sandstone. Due to the sloping topography, the superficial deposits are underlain by the Moor Grit in the east of this area and by the Scarborough Formation in the west of this area (Drawing 1433DevOD234). The Mire vegetation at the toe of the slope is underlain by 2.5 to 4 m of sandy gravelly clay and then over 10 m of interbedded sandstone, siltstone and mudstone of the Cloughton Formation (Drawings 1433DevOD234). From the ground and groundwater conditions determined in the central Wet Heath area, it has been demonstrated that the eastern woodland and Wet Heath vegetation strip has groundwater levels at a depth of 1.0 to 1.8 m bgl within the full thickness of the cohesive superficial deposits. These groundwaters are of low chemical maturity and comprise a significant component of coastal rainwater. Soil moisture conditions at depths of between 1 to 2 m bgl in this area are likely to be contributed to by high groundwater levels (i.e. during the winter "wet" periods) in the Moor Grit and Scarborough aquifers. Terrestrial ecosystems in this area are rooted in the upper 0.1 to 0.3 m thick layer of the more permeable peat soil overlying the glacial clays. During the wet period, the shallow (<1 m deep) soils/sub-soils are fully saturated however during the summer "dry period" groundwater levels drop to 0.69 m to >1 m bgl. This indicates that the soil moisture conditions in the peat and sub-soil primarily receive recharge from seasonal rainfall but may receive a small component by capillary rise through the underlying cohesive superficial deposits during the dry periods. Due to the cohesive nature of the superficial deposits in this area, and the thickness of these soils (3 to 4 m), groundwater in the bedrock aquifer is not considered to contribute significantly to soil moisture conditions within the upper 1 m of the soil profile across the Wet Heath vegetated area. Therefore this Wet Heath terrestrial ecosystem is considered to receive only a limited contribution of groundwater from the bedrock aquifer. In the western Mire area of the central Ugglebarnby Moor SAC area a significant unsaturated zone exists beneath the superficial deposits and the water table in the Cloughton bedrock throughout the year. It is, therefore, confirmed that the terrestrial ecosystems in the Mire area are not hydrogeologically supported by groundwaters in the Cloughton bedrock aquifer. The groundwater level in these superficial deposits increases due to gravitational groundwater flow accumulating at the toe of the central Ugglebarnby Moor slope.
Hydrogeologically Supported Ecosystem	No – This area of the SAC is reported to contain no flora that is sensitive to hydrogeological variations within the shallow rock aquifer.
Sensitivity	**Low**

7.5.3 Ugglebarnby Moor Southern Dry Heath Area

Geometry and physical properties	The area of Dry Heath in the southern part of Ugglebarnby Moor SAC lies to the southwest of the Woodsmith Mine (Drawing 1433DevOD270). Ground levels in this area of the SAC slope from 210 m AOD in the east down to between 180 to 190 m AOD in the west. The superficial deposits in this area are between 1.5 to 2.7 m in thickness and comprise 0.2 to 0.5 m of peaty topsoil underlain by 1.1 to 2.3 m of sandy gravelly clay. As this southern area is designated as Dry Heath ecology (Refs. 13, 15 and 16) it is not hydrogeologically supported and the superficial deposits are of sufficiently low permeability to prevent groundwater rising up from the bedrock. Due to the predominantly low permeable nature of these deposits, and the absence of laterally continuous granular lenses, the measured groundwater levels within these deposits are considered to represent a laterally discontinuous perched water table through the superficial strata. From monitoring of wells installed in GW133 (HG111)/GW133A (HG111A), it has been shown that that the superficial deposits are of sufficiently low permeability to prevent groundwater from the Moor Grit rising up into the superficial deposits during the wet period when the piezometric surface of the Moor Grit lies within the superficial deposits. At HG113/HG113A, the monitoring has demonstrated that there is a permanent unsaturated zone of around 12.5 m thick at the top of the Cloughton Formation over the whole monitoring period (Drawing 1433DevOD270). As such, from the ground and groundwater conditions determined for the southern Dry Heath area of Ugglebarnby Moor SAC, it is considered that the terrestrial ecosystems in this Dry Heath area of the SAC are not hydrogeologically supported throughout the year by groundwater in the bedrock aquifers.
Hydrogeologically Supported Ecosystem	No – This area of the SAC is reported to contain no flora that is sensitive to hydrogeological variations within the shallow rock aquifer.
Sensitivity	**Low**

7.5.4 Ugglebarnby Moor Southern Spring Flush

Geometry and physical properties	The area of Spring Flush in the southern part of Ugglebarnby Moor SAC lies to the southwest of the Woodsmith Mine (Drawing 1433DevOD270). Ground levels in this area of the SAC slope from around 210 m AOD in the east down to around 197 m AOD in the west. Groundwater discharge from Spring MF2 marks the top of the Spring Flush area, although the typical Spring Flush vegetation is only visible around 50 m further downslope to the west (Ref. 13). The superficial deposits within the Spring Flush (boreholes GW133/HG111 and GW112/HG112) are between 1.5 to 3.5 m thick and comprise 0.2 to 0.5 m of peat/pseudofibrous peat underlain by 1.1 to 2.3 m of sandy gravelly clay (Drawing 1433DevOD270). Beneath the superficial deposits along the line of the Spring Flush this ecosystem is underlain at depth by the Moor Grit, Scarborough Formation and Cloughton Formation aquifers (Drawing 1433DevOD235). The Scarborough Formation comprises an upper and lower mudstone aquitard unit and a central sandstone aquifer unit. The geological sequence within this area dips to the east at <1°. From the ground and groundwater conditions monitored to date, it is determined that the Spring Flush terrestrial ecosystem is supported by a combination of surface runoff and shallow groundwater in the superficial deposits, and by groundwater discharge from the Moor Grit aquifer at Spring MF2. The contribution of bedrock groundwater flow from the Moor Grit aquifer at MF2 is most significant during the winter/spring period and then during the summer/autumn period groundwater flow from the Moor Grit reduces to provide only intermittent flow. GW133A/HG111A monitoring the Moor Grit immediately up hydraulic gradient of Spring MF2 (Drawing 1433DevOD270) exhibits high seasonal variation in groundwater levels from 212.9 to 209.2 m AOD in the Moor Grit, with a range in the winter months (November to June) of 3.2 m and a range in the summer months of 2.8 m (Drawing 1433DevOD232). In view of the large unsaturated zone beneath the base of the superficial deposits and the groundwater table in the Cloughton Formation in borehole HG112A, groundwater from the Cloughton Formation does not contribute to the soil moisture conditions in the Spring Flush area.
Hydrogeologically Supported Ecosystem	Yes – This Spring Flush area of the SAC is reported to contain flora that is dependent on soil moisture conditions sustained by the spring flows and, as such, is sensitive to hydrogeological variations within the shallow rock aquifer.
Sensitivity	**Very High**

7.5.5 Sneaton Low Moor Dry Heath Area

Geometry and physical properties	The Dry Heath of Sneaton Low Moor SAC lies to the south of the Woodsmith Mine. Ground levels in this area slope from a high of 231 m AOD in the centre of the SAC, and decrease to between 212 and 214 m AOD along the B1416 to the north. The superficial deposits are between 1.5 and 2.5 m thick and comprise around 0.2 m of peat overlying 1.3 to 2.3 m of sandy gravelly clay or mottled clay. Beneath the superficial deposits the Long Nab comprises 1.3 m of sandstone and 3.6 m of mudstone, overlying the Moor Grit aquifer which comprises 2.9 m of sandstone and then the Scarborough aquifer. The Scarborough aquifer comprises an upper low permeability interbedded siltstone and mudstone aquitard unit 0.9 m thick, underlain by a sandstone aquifer of around 5.7 m thick and then a further basal mudstone aquitard of around 9 m thick. From the groundwater levels recorded, it is evident that the water table in the Long Nab Formation is above rockhead, rising into the overlying superficial deposits, and can fluctuate by 1.64 m. From the water levels recorded over this part of the SAC, it has been demonstrated that there is no unsaturated zone at the top of the Long Nab aquifer and the recorded piezometric groundwater levels indicate the Long Nab aquifer is confined by the superficial deposits. Based on the cohesive low permeable nature of the superficial deposits and the piezometric levels recorded in the Long Nab in this location, it is likely that the principal recharge area for this aquifer unit is to the south of HG118, either within Sneaton Low Moor or further to the south. The ecology of Sneaton Low Moor is Dry Heath and is, therefore, not hydrologically supported (Refs. 13, 15 & 16). The high and sustained piezometric groundwater level in the Long Nab Member indicates that the superficial deposits act as an effective aquiclude that inhibits the bedrock groundwater from rising up through the superficial deposits (Drawing 1433DevOD240). Consequently any change to the groundwater level in the Long Nab aquifer will have no impact on the overlying ecology due to the presence of the low permeability superficial deposits providing an effective barrier between the bedrock aquifer and the Dry Heath ecology of Sneaton Low Moor.
Hydrogeologically Supported Ecosystem	No – This area of the SAC is reported to contain no flora that is sensitive to hydrogeological variations within the shallow rock aquifer.
Sensitivity	**Low**

7.6 Surface Waters

7.6.1 Sneaton Thorpe Beck

Geometry and physical properties	The Sneaton Thorpe Beck is located to the east of Woodsmith Mine and its headwaters are located in Haxby Plantation in the southeast of the site. The Woodsmith Mine lies within the catchment area of the Sneaton Thorpe Beck. The headwaters of the Sneaton Thorpe Beck are located within the Moor Grit and Scarborough Formation, whilst the main channel of the beck is within the Cloughton Formation. Numerous drains, issues, and un-named streams discharge into Sneaton Thorpe Beck.
Surface water quality	Freshwater, good (chemical) quality.
Surface Water Flows	The flow rate within the Sneaton Thorpe Beck shows a response to heavy rainfall events generally rising rapidly and then decreasing rapidly as the rainfall decreases. As expected, flow rates within the Sneaton Thorpe Beck increase as the distance downstream increases (FM01 to FM03). It is also noted that during periods of low rainfall, flow rates within the upper reaches of the Sneaton Thorpe Beck (FM01 and FM02) reduce to very small flows (<2 l/s). This indicates that rainfall rapidly flows into the Sneaton Thorpe Beck as surface runoff.
Groundwater Sources	It is expected that minor and discontinuous groundwater flow to the beck is provided by the spring discharge DNS(1) and other unnamed springs and dispersed seepages along the outcrop of the Moor Grit and/or Scarborough Formation. However, as noted in Section 7.2.1 DNS1(A) spring has only intermittent flow and is dry for large periods of time (i.e. 5 June 2014 to 27 April 2015). As such this spring will not provide continual flow to the Sneaton Thorpe Beck.
Sensitivity	**Low** – Classified as Moderate under Water Framework Directive.

7.6.2 Little Beck

Geometry and physical properties	Little Beck is located approximately 1.2 km west of the Woodsmith Mine and is a tributary of the River Esk. Its headwaters are located around 4 km southwest of Dove's Nest at an elevation of 200 to 250 m AOD. The Ugglebarnby Moor part of the SAC lies within the catchment area of the Little Beck. Where the alignment of the Little Beck is closest to the Woodsmith Mine it flows over an area underlain by Glacial Till and the Whitby Mudstone Formation
Surface water quality	No water chemistry data are available for the Little Beck.
Surface Water Flows	No flow monitoring data are available for the Little Beck.
Groundwater Sources	Numerous drains, issues, collects and un-named streams within the Ugglebarnby SAC discharge into Little Beck that are sourced in part from groundwaters within the Moor Grit, Scarborough and Cloughton Formations and include the Springs SP01, MF1, SP02 and SP03. The springs SP01, SP02 and MF1 do not provide continual flow to the Little Beck throughout the year as they become dry in the summer months. SP03 is a collection of diffuse groundwater discharges from a former quarry within the Cloughton Formation and monitoring has determined flow from this spring has ranged from 0.1 to 26 l/sec throughout the year.
Sensitivity	**Medium** – Classified as Good under Water Framework Directive.

8 QUALITIVATIVE HYDROGEOLOGICAL RISK ASSESSMENT

8.1 Conceptual Model

The Phase 3 Works comprise earthworks that will locally penetrate the superficial deposits interacting with the groundwater system in the Moor Grit, Scarborough and Cloughton strata and will construct a non-permeable area of hardstanding and permanent and temporary soil stockpiles that will locally reduce infiltration to the Moor Grit aquifer at Woodsmith Mine.

Temporary dewatering is to be undertaken from an array of dewatering wells installed in to the Moor Grit strata to maintain the groundwater levels 3m below the shaft platform level at the future shaft construction locations.

A reinjection well drill pad and saline lagoon will be constructed in the south of the site.

Presented below is a summary of the conceptual model, in terms of the principal works affecting the groundwater system, the hydrogeological regime specific to this site and the hydrogeological receptors that may be impacted on by the completed Phase 2 and 3 Works.

The earthworks elements, interacting with the groundwater system will include:-

- Tiered Shaft Platform and southern platform extension, incorporating a geomembrane or natural geological barrier, with a lined surface water collection system.
- A Working Platform and Batching Plant Area underlain by a natural geological barrier.
- Temporary dewatering to reduce groundwater levels to a maximum of 3m bspl at the future shaft locations.
- Permanent Landscaping Bund (Bund A) and temporary topsoil, subsoil and clay stockpiles constructed of Inert material.
- Installation of the basal layer enhanced geological barrier to NHNI Extractive Materials Management Facility.
- Groundwater Drainage Layer beneath a future area of the NHNI Extractive Materials Management Facility.
- Reinjection well drill pad underlain by a natural geological barrier or a geomembrane barrier.
- A saline lagoon with a composite geomembrane and clay liner.
- Site roads and temporary construction compound.
- Attenuation Ponds, Silt Removal Facility and Wetlands.

The principal hydrogeological units underlying the minesite and surrounding area include thin cohesive and locally granular superficial glacial deposits, designated as non-aquifer strata, underlain by a sequence of Secondary A aquifers of local importance (Moor Grit, Scarborough, Cloughton and Saltwick) to depths of around 100 m. Discontinuous groundwater bodies exist in the superficial deposits beneath which, four individual freshwater groundwater bodies of high quality are present in the Moor Grit, Scarborough, Cloughton and Saltwick Formation aquifers. Due to the presence of leaky argillaceous aquitard units between these aquifers, there is limited vertical connectivity between the aquifers. Groundwater levels in all of the four Secondary A Aquifers have been determined to show seasonal variability. Groundwater levels in the Moor Grit and Scarborough aquifers however, exhibit a significant magnitude of seasonal groundwater level variation and a short time response to major rainfall events.

In general, the direction of groundwater flow in these aquifers occurs to the north/northeast, with a significant westerly and easterly flow from the hydrogeological divide that is approximately aligned along the B1416 to the west of the Woodsmith Mine.

Beneath the Secondary A Aquifers is a major aquiclude of unproductive strata (the Whitby Mudstone Formation) that restricts groundwater interaction between the freshwater groundwaters in the Ravenscar Formation.

Onsite, within the minesite area, there are no hydrogeologically-supported terrestrial ecosystems and there are no groundwater abstractions. There is one spring discharge (Doves Nest Farm Spring) that contributes a very low volume of intermittent base flow to Sneaton Thorpe Beck. The shallow Secondary A Aquifers beneath the minesite area are determined as of local importance to base flow to surface waters.

Offsite, bordering and within close proximity to the minesite, there is a hydrogeologically supported terrestrial ecosystem within the flora of the Spring Flush habitat in the southern areas to Ugglebarnby Moor (Drawing 1433DevOD270). The dry heath ecosystems in the northern and southern areas of Ugglebarnby Moor, and on Sneaton Low Moor and the wet heath ecosystems in the central area of Ugglebarnby Moor, are reported not to be hydrogeologically supported and, as such, are not reliant of the presence of shallow groundwaters in the bedrock aquifers (Ref. 147). There are four groundwater abstractions in close proximity to the minesite (Drawing 1433DevOD260); one from a well drilled into the Cloughton Formation at Sneaton Low Moor Caravan Park, and three from spring issues; one associated with Thornhill Farm (and the adjacent property) Moorside Farm Spring (MF2), Soulsgrave Farm Spring (SF2) and Newton House Farm Spring (NHF1). There are three spring discharges that have been determined to contribute low and intermittent volumes to surface water flows to the west of Ugglebarnby Moor (SP01, SP02 and SP03), and two to the north of the Woodsmith Mine (SP04 and KHF), as shown on Drawing 1433DevOD260.

8.2 Groundwater Hazards

The potential groundwater hazards, in terms of the physical and chemical effects that may arise due to the Completed Phase 2 and 3 Works, both during the construction period and longer term, are as follows:-

8.2.1 Physical Effects

Effect	Discussion	Magnitude of Effect at Source
Alteration of groundwater flow paths and levels in the Moor Grit and Scarborough Secondary A Aquifers may arise due to the introduction of permanent and temporary inert soil bunds and storage mounds, tiered Shaft Platform area, platform extension, a Working Platform and Batching Plant area and access roads that will limit infiltration promoting aquifer recharge.	This will have an effect of locally reducing recharge into the Moor Grit and Scarborough Formations particularly in the areas of the soil bunds, tiered Shaft Platform, Working Platform and Batching Plant areas. These works could locally cause a small reduction in groundwater levels in the Moor Grit and Scarborough Formation.	Medium Magnitude of Effect at Source
Alteration of groundwater flow paths and levels in the Moor Grit Secondary A Aquifer may arise due to dewatering around the future Shaft Sinking Operations to maintain groundwater levels a minimum of 3 m bspl.	This will have an effect of locally drawing down the groundwater levels into the Moor Grit in the Shaft Platform Area. These works could locally cause a small reduction in groundwater levels in the Scarborough Formation.	Medium Magnitude of Effect at Source
Groundwater drainage layer	Groundwater issues are currently occurring from the spring line where the drainage layer is to be located. These works will locally remove the superficial soils to collect and control groundwater issue to surface waters from this spring line. This drainage layer will locally increase groundwater drainage to the surface where the clay soils are removed.	Very Low Magnitude of Effect at Source

8.2.2 Chemical Effects

Effect	Discussion	Magnitude of Effect at Source
Construction related pollution, mobilised within surface water runoff on the Shaft Platform area and Working Platform / Batching Plant area could infiltrate into the Moor Grit and Scarborough aquifers.	Engineering measures have been incorporated into the design of the tiered Shaft Platform area to include a geomembrane to supplement the natural protection provided by the glacial clay layer overlying the Moor Grit aquifer, where the clay layer is <0.5m thick. This geomembrane liner will be installed under a CQA system and will be tied into the glacial clay to provide a laterally continuous natural clay barrier over the full footprint of the platform area. The thickness of the natural clay geological barrier will be proved by inspection pits. It is very unlikely that surface runoff, which may be contaminated by surface activities, could affect the chemical quality of groundwaters in this Secondary A Aquifer. If such conditions arise, it would affect those groundwaters down hydraulic gradient from the facility to the north and northeast of the platform area. Dewatering operations will concentrate groundwater flow into the shaft platform area and away from the receptors up hydraulic gradient, therefore further reducing the risk of pollution impact offsite. Potential Contaminants of Concern from these works include hydrocarbons and salts, as detailed in Table 4.	Very Low Magnitude of Effect at Source
Polluted surface water runoff from the Phase 3 Site Compound Area to be temporarily constructed to the east of the Welfare access road (Arup Drawing 40-ARI-WS-71-CI-DR-1050) could infiltrate into the Moor Grit and Scarborough aquifers.	The Site Compound and Vehicle Maintenance area is to be managed to minimise environmental impact in accordance with the Construction Environmental Management Plan. As such, it is very unlikely that surface runoff from the compound, which may be contaminated by surface activities, could affect the chemical quality of groundwaters in the underlying Secondary A Aquifers. Should such pollution arise, it could affect the groundwaters down hydraulic gradient from this facility to the east. Dewatering operations will concentrate groundwater flow into the shaft platform area and away from the receptors up hydraulic gradient, therefore further reducing the risk of pollution impact offsite. Potential Contaminants of Concern from these works include hydrocarbons and salts, as detailed in Table 4.	Very Low Magnitude of Effect at Source

Reinjection Well Drill Pad (Note the reinjection well is not to be drilled in this phase of works)	Engineering measures have been incorporated into the design of the Drill Pad to include a geomembrane to supplement the natural protection provided by the glacial clay layer overlying the Moor Grit aquifer, where the clay layer is <0.5m thick. This geomembrane liner will be installed under a CQA system and will be tied into the glacial clay to provide a laterally continuous natural clay barrier over the full footprint of the Drill Pad area. The thickness of the natural clay geological barrier will be proved by inspection pits. It is very unlikely that surface runoff, which may be contaminated by drilling activities, could affect the chemical quality of groundwaters in this Secondary A Aquifer. If such conditions arise, it would affect those groundwaters down hydraulic gradient from the facility to the north and northeast of the Drill Pad area. Potential Contaminants of Concern from these works include hydrocarbons and salts, as detailed in Table 4.	Very Low Magnitude of Effect at Source
Reinjection Well Saline Lagoon (Note the reinjection well is not to be drilled in this phase of works and, as such, the saline lagoon will not be utilised in this phase)	Engineering measures have been incorporated into the design of the saline lagoon to include a 2mm high density polyethylene geomembrane underlain by 1m of a geological clay barrier overlying the Moor Grit aquifer. This geomembrane liner will be installed under a CQA system to provide a laterally continuous barrier over the full footprint of the lagoon area. It is very unlikely that the saline brines to be stored in this lagoon for between 4 – 8 weeks during the future reinjection well test period, could affect the chemical quality of groundwaters in this Secondary A Aquifer. If such conditions arise, it would affect those groundwaters down hydraulic gradient from the facility to the north and northeast of the lagoon. Potential Contaminants of Concern from these works include salts, as detailed in Table 4.	Very Low Magnitude of Effect at Source

8.3 Hydrogeological Risk Assessment

A qualitative hydrogeological risk assessment has been carried out in accordance with the methodology presented in Section 6 to evaluate the potential physical and chemical impacts of the completed Phase 2 and 3 Works on the site specific hydrogeological receptors detailed in Section 7.

Evaluation of the Likelihood of Occurrence of an impact has been undertaken by consideration of the Proximity and Connectivity between an activity and the receptor. Table 2, Appendix 3, evaluates the proximity of each activity to each receptor taking account of both horizontal and vertical proximity. To determine the Likelihood of Occurrence of an impact on a receptor, the physical and chemical impacts have been evaluated by consideration of the activity with the worst case proximity (i.e. highest values detailed in Table 2) to each receptor in conjunction with the worst case connectivity (between an activity and the receptor), in accordance with the methodology detailed in Section 6. The magnitude of the worst case proximity adopted for each receptor and the Likelihood of Occurrence determined are presented in Table 3, Appendix 3.

The Magnitude of Effect at the Receptor has been evaluated by consideration of the qualitative assessment of the Magnitude of Effect at Source, as presented in Section 8.2 and the Likelihood of Occurrence as presented in Table 3, Appendix 3.

Assessment of the Significance of Impact of the physical and chemical effects on the specific hydrogeological receptors have been evaluated by consideration of the Magnitude of Effect at Receptor and the Receptor Sensitivity, as presented in Section 7, and the results are presented in Table 3 Appendix 3 and evaluated in Section 8.4 below.

8.4 Results of the Qualitative Hydrogeological Risk Assessment

This qualitative risk assessment (Table 3 Appendix 3) has determined that the construction of the tiered Shaft Platform, platform extension, working platform and batching plant, access roads and bunds and stockpiles, and the dewatering for the future shaft sinking operations have the potential to cause a Moderate Significance of Physical Impact on groundwater levels in the Spring Flush and to Moorside Farm Spring (MF2). These two activities also have the potential to cause a Minor Significance of Physical Impact on the Moor Grit, Scarborough, Cloughton and Saltwick Aquifers, and impact of Sneaton Thorpe Beck and the drinking water spring supplies at Soulsgrave Farm and Newton House Farm.

A Negligible Significance of Physical Impact has been determined from the construction works proposed at the tiered Shaft Platform, platform extension, working platform and batching plant, access roads and bunds and stockpiles, and the dewatering for the future shaft sinking operations on all other hydrogeological receptors.

A Negligible Significance of Physical Impact has been determined from the Groundwater Drainage Layer.

A Negligible Significance of Chemical Impact on all hydrogeological receptors has been determined from all elements of the proposed construction works including; at the tiered Shaft Platform, Platform Extension, Working Platform, Batching Plant, Site Compound, the dewatering for future shaft sinking operations, the Reinjection Well and the Saline Lagoon.

8.5 Consideration of Mitigation Measures

On the basis of this Qualitative Hydrogeological Risk Assessment, undertaken specifically in relation to the combined Phase 2 and 3 Works, the only significant adverse impact from these works identified relates to a potential Moderate Significance of Physical Impact on groundwater levels in the area of the Spring Flush and Moorside Farm Spring (MF2). This potential Moderate adverse impact is anticipated to arise from a combination of the reduced infiltration into the Moor Grit aquifer, caused by construction of the Shaft Platform, Platform Extension, Working Platform and Batching Plant and the inert soil bunds and mounds, in conjunction with the temporary dewatering operations that are required to facilitate future shaft sinking operations. The sensitive hydrogeological receptors that are identified as being affected by this potential Moderate adverse impact include the wetland ecology within the Spring Flush and the drinking water supply for Moorside Farm that are both fed from Moorside Farm Spring.

Due to the high sensitivity to variations in groundwater level changes in the Moor Grit aquifer of the Spring Flush hydrogeologically supported ecosystem and of the domestic water supply sourced from Moorside Farm Spring, quantitative modelling has been undertaken to further evaluate the likely magnitude of cumulative groundwater drawdown caused by the combined Phase 2 and 3 works and its effects on spring flows. The purpose of this modelling, detailed in Section 9, has been to confirm whether or not additional mitigation measures are necessary to maintain the current condition of the Spring Flush ecosystem and domestic water supplies from Moorside Farm Spring.

9 QUANTITATIVE HYDROGEOLOGICAL MODELLING TO ASSESS THE IMPACTS OF THE COMBUNED PHASE 2 And 3 DEVELOPMENT ON GROUNDWATER DRAWDOWN AND FLOWS FROM MOORSIDE FARM SPRING

As detailed in Section 8, sensitive hydrogeological receptors exist in close proximity to the minesite that could be impacted upon by the combined Phase 2 and 3 Works. From the qualitative hydrogeological risk assessment presented above, two potential Moderate adverse physical hydrogeological impacts (i.e. to the hydrogeologically supported terrestrial ecosystems in the Spring Flush area and to Moorside farm Spring (MF2)) have been identified from these development works.

To evaluate the magnitude of these potential Moderate adverse impacts, quantitative Transient and Steady State Modelling of a multi-layered hydrogeological system has been carried out by ESI Ltd (ESI) in two principal stages:-

- Stage 1 - Calibration of baseline conditions.
- Stage 2 - Evaluation of the combined Phase 2 and 3 development hydrogeological physical effects to highlight potentially unacceptable adverse impacts on the key sensitive receptors and to determine whether additional mitigation measures are warranted.

In the following sections, details are provided on the conceptual models developed to evaluate the impact of the combined Phase 2 and 3 Works, the groundwater modelling approach adopted, the calibration achieved and the model runs undertaken. The results of the multi-layered quantitative analysis of the simulated physical changes in groundwater levels in the Moor Grit and Scarborough aquifers beneath the Ugglebarnby Moor part of the SAC and the spring flowrates at Moorside Farm, are presented in ESI's report that has been included as Appendix 4 and are summarised Section 9 of this report.

9.1 Conceptual Models

The construction elements of the Phase 2 and 3 Works that have been considered within the model are as presented in Section 3 and 4 of this report. Key groundwater receptors, identified in the Hydrogeological Baseline Report (Ref. 1), are described in Section 7 of this report. For the multi-layered quantitative model, full details of the conceptual hydrogeological model characteristics are given in Section 3 of the ESI report (Appendix 4) including geological cross-sections of the site showing the aquifer units affected by the proposed development.

9.1.1 Pre-Construction Baseline Conditions

The model area is shown in Figure 3.1 (Appendix 4) and the baseline/pre-construction cross-section of the model geometry is shown in Figure 3.2 (Appendix 4), which is based on data presented in the Hydrogeological Baseline Report (Ref. 1). The model has an active area of approximately 3.7 km east-west, 6.2 km north-south. Model grid cells are 20 x 20 m in size. A refined grid area, where the model cells are 2 x 2 m in size, is also shown which includes the dewatering in conjunction with the reduced recharge into the Moor Grit created by the tiered Shaft Platform, the Working Platform and Batching Plant surfaced areas, and the soil bunds the eastern part of the Ugglebarnby Moor SAC and the area to the east of the tiered Shaft Platform including the NHNI Extractive Material Management Facility and the spring line groundwater drainage area.

The superficial deposits have been determined to be primarily cohesive and of a low permeability. These deposits are considered as non-aquifer units, which cannot therefore be modelled. As such, the model does not apply to the superficial deposits present on both the minesite and the SAC, and the simulated changes in groundwater levels are representative of those occurring in bedrock aquifers only.

The external model boundaries for the four main aquifer units are shown in Figure 3.3 (Appendix 4). The Moor Grit and Scarborough have drain cells to the west, north and east, with a recharge boundary to the south. The Cloughton and Saltwick have drain cells to the west and north, and a recharge boundary to the south. The drain cells are used to simulate both spring discharges and discharge from the aquifer outcrop edges (which include transfers from an upper to a lower aquifer unit). ESI has determined that as there is reduced vertical hydraulic conductivity between the four main aquifer units in the Ravenscar Formation, the hydrogeological regime should be modelled as a multi-layered system. However, based on the borehole records and calibration of the model, it has been determined that the low permeability unit between the Moor Grit and Scarborough Formation is too thin in places to act as a complete vertical barrier to flow between the aquifer units. In the groundwater model developed, these aquitards have been modelled as leaky units with major flows occurring horizontally through a multi-layered aquifer.

The multi-layer model is divided into seven layers; three layers of low vertical hydraulic conductivity layers (aquitards) are present between the four modelled aquifer units (Table 3.1, Appendix 4). Based on the groundwater level monitoring and pumping tests undertaken on the minesite and surrounding area there is an observed degree of hydraulic separation between the aquifer units (Ref. 17). Generally the groundwater level in the underlying aquifer is below the base of the overlying one (Ref. 1). There is a shallow hydraulic gradient from south to north and a hydrological divide, identified on the groundwater contours plots shown in the baseline report (Ref. 1), which trends north/south and lies within the minesite area to the east of the north/south section of the B1416 road.

Recharge occurs through the superficial deposits. Variability in annual recharge is dealt with through ESI's uncertainty analysis. It was not considered to be feasible to realistically model variable recharge across the minesite as a result of differences in the thickness or hydrogeological properties of the superficial deposits. Groundwater moves vertically downwards through the aquifer and aquitard units to provide recharge to the groundwater system as a whole.

As determined from the Hydrogeological Baseline Report (Ref. 1), there are a number of discrete but generally small springs represented in the model as drain cells. These have low and highly variable flowrates, some springs drying out during the summer whist others, in particular those associated with the Cloughton Formation, flowing throughout the year. The SM11 and 14 Drilling Platform, constructed of dolomitic limestone hard core of high permeability, has been represented as a drain cell to a stage level of 201.7 m AOD.

9.1.2 Construction Conditions

The Phase 3 Works design is shown on the Arup Phase 3 Masterplan (Drawing no. 40-ARI-WS-71-CI-DR-1050). The following construction elements that are expected to impact on groundwater levels and spring flows have been simulated in the model:

1. Extension to South Shaft Platform to a minimum of 202.6 m AOD, including a lined perimeter drain that will not drain groundwater.
2. Construction of a Working Platform laydown and batching plant area.
3. Construction of a re-infiltration well Drill Pad and lagoon in the southern area.
4. Construction of soil mounds around the shaft platform.
5. Construction of lined attenuation ponds to the east.
6. Installation of dewatering wells around the Service, Production and MTS shafts with abstraction sufficient to reduce groundwater levels to 3 m below platform levels. Target groundwater levels are 200.5 m AOD at the Production Shaft, 200 m AOD at the Service Shaft and 197.5 m AOD at the MTS shaft.
7. Construction of a spring and groundwater drainage collection system in the north-east to a depth of 0.5 m below existing ground level.

Areas covered by features described in 1 to 5 above have been simulated in the groundwater flow model as no recharge zones. Over these areas, no recharge to groundwater is permitted. These zones are shown in Figure 5.1 and 5.2 (Appendix 4) for the Moor Grit and Scarborough formations respectively.

Thirty seven dewatering wells have been incorporated into the model as drain boundary conditions. These wells have been positioned around the Production Shaft, Service Shaft and MTS Shaft as is shown in Figure 5.1 (Appendix 4) Around the Production and Service shafts, a drain level of 196 m AOD has been set (within the Moor Grit Formation in Layer one). Around the MTS Shaft, the drain stage is set to be approximately at the base of the modelled Moor Grit Formation in this area (195 – 196 m AOD). These levels were chosen so that the required dewatering levels listed in point 6 (above) could be reached quickly.

The drain boundary cells cause groundwater levels to the lowered to the drain stage. This is analogous to pumping to the drain stage level. Drain conductance was set sufficiently high to ensure that there was no additional resistance to flow out of the model. This makes the hydraulic conductivity of the Moor Grit the limiting factor to outflow, as would be the case with dewatering in the field. The model calculates the rate of flow from the model through these drain cells, which is equivalent to the pumping rate required to achieve the levels calculated by the model.

Drain boundary cells were placed at a stage of 0.5 m below ground level to represent the groundwater drainage collection system (described in point 7). Due to the outcrop pattern, these cells are variably placed in the Scarborough and Cloughton formations where these outcrop at the surface.

9.2 Modelling Approach

The groundwater modelling has been undertaken using the USGS numerical finite difference groundwater model code MODFLOW-2005, using the Groundwater Vistas 6 (GV6) interface. A modified version of MODFLOW-2005 (MODFLOW-USG) called MODFLOW-USG (Ref. 18), has also been used which allows for the use of unstructured grids. Two baseline groundwater models were developed, a Steady State Model and a Transient Model.

Full details of the model construction, parameter setting, input parameters and model calibration are presented in their report (Appendix 4).

The Steady State model, in general, was used as a pre-cursor to the Transient Model to assess average groundwater levels in the Spring Flush area of Ugglebarnby Moor SAC and at Moorside Farm Spring (MF2) and flow conditions from the springs. It used an average recharge value of 200 mm/a, which is the average recharge value over which the Steady State model was calibrated.

The Transient Model adopts seasonal recharge conditions and is considered to be the more robust model, in respect to its representation of seasonal groundwater level variations and of the intermittent spring flows. The Transient Multi-Layered Model created for the period between January 2013 and September 2015, used historical daily climatic data and was calibrated against weekly manual dips from the site boreholes and measured spring flowrates. This was used to generate a best estimate Transient Model to represent current baseline predevelopment conditions over an arbitrary 33 month period that reflects long term average groundwater recharge.

9.3 Model Calibration

The objectives of the modelling calibration were to confirm that the simulated average and seasonal groundwater levels and flow directions, determined by the Steady State and Transient Models, display a reasonable degree of correlation with observed groundwater conditions determined from the baseline monitoring. In addition, the modelling calibration was used to confirm that the simulated average and seasonal spring flowrates determined by the Steady State and Transient Models displayed a reasonable correlation with observed flow conditions determined from the baseline monitoring.

9.3.1 Groundwater Level Calibration

The Steady State model was calibrated based on the average recorded groundwater levels for the period June 2013 to March 2016 at 72 observation wells. The report states that the Steady State model calibration successfully simulates the hydraulic separation between the aquifer units and that average groundwater contours simulated for the Moor Grit and Scarborough aquifers exhibit a reasonable overall correlation to observed head and groundwater flow directions.

The Transient Model calibration reflects seasonal variation in simulated heads and compares the simulated model groundwater level with the FWS weekly manual dip data for the period February 2013 to September 2015. Model calibration is achieved through changes to specific yield (in unconfined aquifers) or specific storage (in confined aquifers). The observed and simulated groundwater level trends and range of variation are reported to be well matched, particularly for the Moor Grit and Scarborough aquifers.

9.3.2 Water Balance Calibration

The hydraulic separation between aquifer layers in the model is achieved by carefully balancing recharge and vertical flux between the intervening aquitard layers. Thus for a given amount of recharge, vertical flux needed to be high enough to permit sufficient water to enter a lower aquifer layer, but low enough to prevent drying out of the upper aquifer layers. Based on this calibration, it is reported that approximately 44% of water flowing into the Moor Grit (via recharge) is released through the base and flows vertically through the intervening aquitard layer, or by more diffuse downward seepage around the edge of the outcrop, to the underlying Scarborough Formation. Of the remaining 56%, the majority is discharged via spring flow or diffuse seepage. The lower Cloughton and Saltwick aquifers are both fed by vertical flux from upper layers and general recharge inflow in this area. As with the Moor Grit, this is released via vertical flow into the lower layers or diffuse flow around the outcrop boundary.

9.3.3 Spring Flow Calibration

The modelling demonstrated that although in general the Steady State condition broadly simulated the right amount of average flow at the various springs, because baseline monitoring determined that the springs are intermittent and have been dry or exhibited significantly reduced flow between 2013/16 average conditions, the Transient Model provides a better approximation to the seasonal intermittent spring flows observed onsite.

9.4 Transient Conditions Modelled

Environmental Objectives

The principal environmental design objectives of the modelling were to determine impacts on groundwater levels in the Moor Grit aquifer at Moorside Farm Spring and in the Scarborough formation, over the Phase 3 (June to October 2017) dewatering and construction period and the associated impacts on spring flows at these locations.

As the dewatering operations in preparation for shaft sinking are only a temporary construction condition (i.e for a period of months and less than 1 year) they will not influence the long term average groundwater level conditions at the Woodsmith minesite. For the purpose of simulating the combined effects of the Phase 2 and 3 construction works over the Phase 3 construction period and as this temporary dewatering is likely to continue into the early part of Phase 4 (i.e. June to December 2017) the duration of Transient State modelling has been undertaken over a conservatively extended period of 12 months.

In order to simulate the effect of the Phase 3 Works on the Moorside Farm Spring and Spring Flush area of Ugglebarnby Moor SAC and on Soulsgrave Farm Spring, one conservative Transient model run was undertaken, which adopted calibrated steady state recharge over summer and autumn and a high recharge in winter. As the summer and autumn recharge modelled much higher than would typically be expected the run conservatively determines maximum changes in groundwater levels within the construction period modelled as 12 months. In reality, recharge over the summer months (June to September 2017) is likely to be close to zero, but the winter recharge could be similar to the profile used in the model. Due to the conservative nature of this model, the results determined should be treated as conservative upper bound simulations.

The base case steady state heads were taken as the initial conditions at the start of the model runs. For the post Phase 3 development model run, it is conservatively assumed that all of the Phase 3 Works were implemented instantaneously on 1st June 2017 (the start of the model run).

To enable evaluation of the magnitude of physical impacts at the key sensitive groundwater receptors described above, the following existing monitoring locations and dummy points were considered in the simulations, as shown in Figure 6.1 and 6.2 (Appendix 4) for the Moor Grit and Scarborough aquifers respectively:-

- Spring Flush Receptor: the impacts on groundwater level changes in the Moor Grit strata were considered by simulated changes at Assessment Points SAC 6, 7 and 8 (at well GW133A/HG11A) and at existing wells GW130 and 131.
- Moorside Farm Spring Receptor: the impacts on groundwater level changes in the Moor Grit strata were considered by simulated changes at Assessment Points SAC 6, 7 and 8 (at well GW133A/HG11A) and at existing wells GW130 and 131.
- Soulsgrave Farm Spring Receptor: the impacts on groundwater level changes in the Scarborough strata were considered at the intermediate well position GW112 from the simulated impacts on spring flows at SF2.

Construction Objectives

The construction design objectives of the modelling, where to determine the duration of dewatering to achieve the designed lowering in groundwater levels (i.e. to 3m bspl) and the pumping rates that will be discharged from this system.

9.5 Model Results

9.5.1 Environmental Impacts

Impacts on Ground Water Levels

From the groundwater modelling described above, the following sections present the Transient State results and an assessment of the potential impacts of the combined Phase 2 and 3 development on the principal sensitive hydrogeological receptors, including the Spring Flush area to Ugglebarnby Moor SAC, and spring flows at Moorside Farm Spring (MF2) and Soulsgrave Farm (SF2).

As illustrated in Figure 6.7 (Appendix 4) and demonstrated from the baseline hydrogeological monitoring (Drawing 1433DevOD232 Appendix 1), commencement of the Phase 3 works is during a period of sustained but lower spring / summer / autumn recharge, where recharge rates are modelled at around 20 mm / month. At the end of the Phase 3 dewatering period higher recharge rates of up to 60mm / month are modelled characteristic of the December to March winter period. The groundwater level changes simulated by the model, detailed below, should be considered in relation to their impacts on the seasonal changes in groundwater level, as demonstrated for the Moor Grit strata and Moorside Farm Spring in Drawing 1433DevOD232 Appendix 1.

The results of the Transient State modelling have been compared with the baseline conditions for the Moor Grit and Scarborough Formations. The results simulate a declining impact on groundwater levels with distance from the dewatering wells over the June to October dewatering and construction period.

In the Moor Grit aquifer, which sustains the Moorside Farm Spring and the Spring Flush terrestrial ecosystem, the following drop in ground water levels are simulated to occur over the June to October 2017 period:-

- 0.3m at SAC 6 - 200m from Moorside Farm Spring.
- 0.15m at SAC 7 - 115m from Moorside Farm Spring.
- <0.05m at SAC 8 - 125m from Moorside Farm Spring.
- <0.05m at Moorside Farm Spring.

As illustrated by the baseline data (Drawing 1433DevOD232 Appendix 1), during this summer to autumn period groundwater levels in the Moor Grit at Moorside Farm Spring (GW133A / HG111A) typically fluctuate by around 1.5m, Consequently the magnitude of groundwater level change simulated at SAC 8 (GW133A / HG111A) represents a change of <5% in comparison with the monitored seasonal variation during this period.

Simulated groundwater level changes over the full 12 month modelling period in the Moor Grit aquifer at SAC 8 (GW133A / HG111A) at the Moorside Farm Spring, also demonstrate a low degree of impact of <0.1m. When compared with the annual seasonal groundwater level fluctuation monitored at this location, as illustrated in Drawing 1433DevOD232 (Appendix 1), this magnitude of potential impact also represents a change of <5%.

In the Scarborough aquifer, the simulated groundwater level changes over the full 12 month modelling period at both GW112/HG119, 600m from the spring, and at the Soulsgrave Farm Spring also demonstrate a very low degree of impact of <0.01m. When compared with the annual seasonal groundwater level fluctuation monitored in the Scarborough in HG119 and GW 115 of 1.3m and 1.5m respectively (Ref. 1), this magnitude of potential impact also represents a change of <5%.

The results of this modelling have demonstrated that the combined Phase 2 and 3 construction works over the June to October period of 2017 will have a very low impact on groundwater levels in the Moor Grit and Scarborough aquifers that support the sensitive hydrogeological receptors including Moorside and Soulsgrave Farm springs and the terrestrial ecosystem at the Ugglebarnby Moor Spring Flush area. As the magnitude of groundwater level impacts simulated are less than 5% of the seasonal range in groundwater levels monitored in these aquifers, it is determined that these works will present a negligible physical impact on groundwater levels supporting these receptors.

Impacts on Spring Flow Rates

As illustrated in Figure 6.9 (Appendix 4) and demonstrated from the baseline hydrogeological monitoring (Drawing 1433DevOD232 Appendix 1), commencement of the Phase 3 works is during a period of sustained but lower spring / summer / autumn recharge, where recharge rates are modelled at around 20 mm / month. At the end of the Phase 3 dewatering period higher recharge rates of up to 60mm / month are modelled characteristic of the December to March winter period. The spring flow rate changes simulated by the model, detailed below, should be considered in relation to their impacts on the seasonal changes in flow conditions, as demonstrated for the Moor Grit strata and Moorside Farm Spring in Drawing 1433DevOD232 Appendix 1.

Simulated reductions in spring flow rate changes at Moorside Farm Spring, over the June to October period, caused by the Phase 3 works, are <1.2 x 10^{-6} l/s (0.1 m^3/day). As illustrated in Drawing 1433DevOD232, during this summer to autumn period of lower recharge baseline monitoring has typically recorded spring flow rate discharges at this location of around 0.03 l/s, although varying between no flow and peak of 0.06 l/s, which is less than 1% of the measured seasonal range in flow rates. Such changes would be beyond the resolution of measurement in the field, and would therefore not be noticeable**.**

Simulated reductions in spring flow rate changes at Soulsgrave Farm Spring, over the June to October period, caused by the Phase 3 works, are <1.2 x 10^{-6} l/s (0.1 m^3/day). Baseline monitoring has determined that seasonal flows vary between 0.1 and 1.0 l/sec during the winter months, 0.02 and 0.7 l/sec during the spring months, no flow to 0.6 l/sec during the summer months, and no flow to 0.53 l/s during the autumn months. As such, the simulated changes in spring flows at this location, caused by the proposed construction works is less than 1% of the measured seasonal range in flow rates. Such changes would be beyond the resolution of measurement in the field, and would therefore not be noticeable.

Over the full 12 month modelling period the simulated spring flow rate changes at Moorside Farm Spring and Soulsgrave Farm Spring are 3 x 10^{-6} l/s (0.25 m3/day) and <1.2 x 10^{-7} l/s (0.01 m^3/day) respectively, which are also less than 1% of their measured seasonal range in flow rates.

Conclusion

This modelling has demonstrated that the combined Phase 2 and 3 construction works over the June to October period of 2017 will have a very low impact on groundwater levels spring flow rates at Moorside and Soulsgrave Farm springs and on groundwater levels and spring flows that sustain the Spring Flush terrestrial ecosystem. As the magnitude of groundwater level impacts simulated are less than 5% of the seasonal range in groundwater levels recorded in the Moor Grit and Scarborough aquifers at these locations and less that 1% of the seasonal range in spring flow rates monitored at these locations, it is determined that these works will present a negligible physical impact on these springs and to the Spring Flush terrestrial ecosystem.

9.5.2 Construction Considerations

The results of the modelling have determined for this arrangement of dewatering wells will achieve lowering of the groundwater table to 3 m bspl at all three future shaft sinking locations within a period of 7 days. As illustrated in Figure 6.10 Appendix 4, the dewatering rate from all 37 wells is simulated to initially discharge > 1,200 m^3/day (13.9 l/s) which then rapidly reduces to < 500 m^3/day (5.8 l/s) after a week and to < 90 m3/day (1 l/s) after 12 months. Pumping rates will increase in response to the greater recharge over the winter months.

As such, although high peak discharge rates should be allowed for at the commencement of dewatering (i.e. around 20 l/s) these are expected to reduce significantly within the first week (<10 l/s) and then stabilising out at <2 l/s over the future months.

9.6 Consideration of Mitigation Measures

As part of this assessment, consideration has been given as to whether the grout wall, the relief drain and the recharge trench referred to in the HRA for the approved scheme are necessary mitigation measures as part of the Phase 3 works including the preparatory advanced temporary dewatering at commencement of shaft sinking for the Production, Service and MTS shafts. As determined from this quantitative risk assessment, including the multi-layered modelling of construction phase impacts of below ground structures and temporary dewatering, it has been demonstrated that there is no requirement to implement the grout wall, the relief drain and the recharge trench measures at this phase of the construction process. As such, in relation to Condition 45 of the Planning Consent, although preparatory works, entailing temporary dewatering in advance of shaft sinking, are to be undertaken as part of the Phase 3 construction these works present no adverse risk to the environment and no additional groundwater mitigation measures are warranted at this phase of construction.

9.7 Conclusions

The results of the multi-layered Transient State modelling undertaken by ESI has determined that there is no significant physical change in the groundwater levels in the Moor Grit or Scarborough Formations underlying the hydrogeologically supported Spring Flush ecosystem and no significant physical change in the groundwater levels or spring flow rates at the spring water supply at Moorside Farm Spring or to Soulsgrave Farm Spring. On the basis of this modelling, it has been confirmed that there is no requirement for any additional groundwater control measures to be implemented as part of the Phase 3 Works to mitigate physical impacts on groundwater levels or spring flow rates on sensitive receptors.

C BELL
ASSOCIATE DIRECTOR

R IZATT-LOWRY
DIRECTOR

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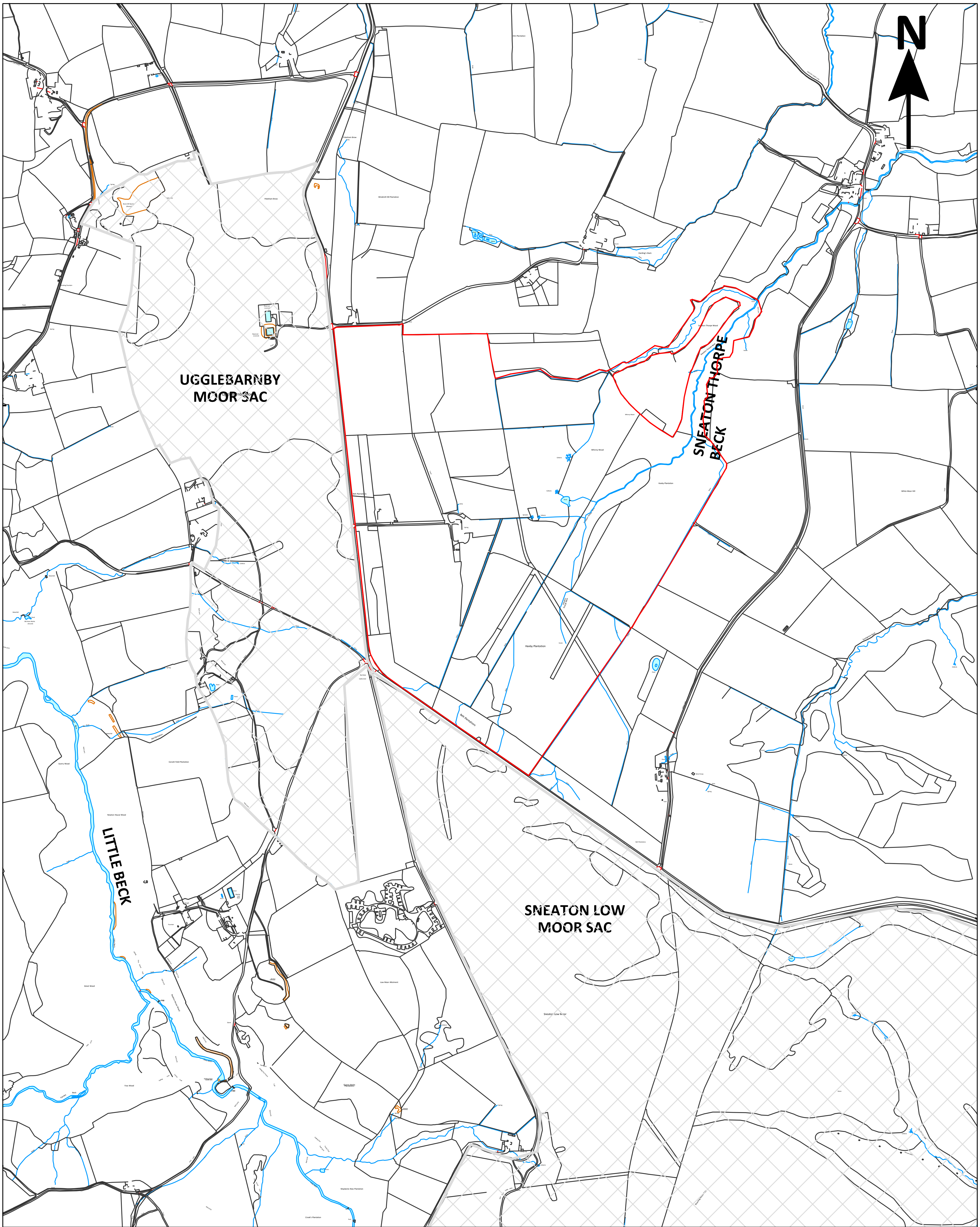
APPENDIX 1

DRAWINGS



NOTES / KEY	DRAWING TITLE	CLIENT	
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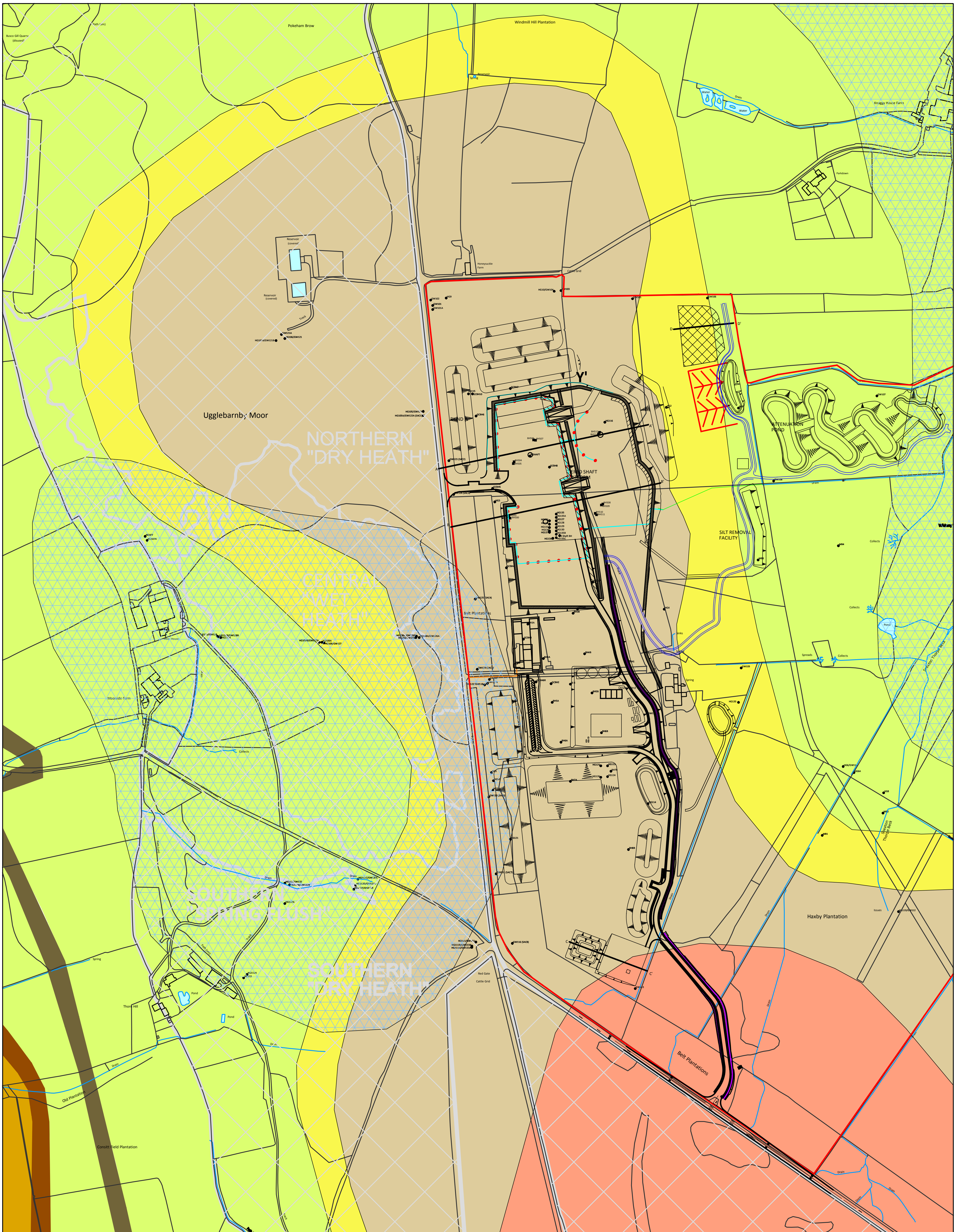
NYM SAC		STATUS: FINAL	PROJECT NUMBER: 1433
SURFACE WATER	PROJECT TITLE: YORK POTASH PROJECT	DRAWN BY: CB	DATE: March 2017
		SCALE: 1:10,000 @ A3	DRG. No.: 1433DevOD215Rev2

Merrington House
Merrington Lane Industrial Estate
Spennymoor
County Durham
DL16 7UT



NOTES / KEY

SITE OWNERSHIP BOUNDARY
NYM SAC
SURFACE WATER
BOREHOLES GCBH01
HYDROGEOLOGICAL RECPTORS MF2
LINE OF CROSS SECTION
CROSS SECTION A-A' and B-B' DRAWING 1433DevOD244
CROSS SECTION A-A' DIAPHRAGM WALL DRAWING1433DevOD268
CROSS SECTION C-C' DRAWING 1433DevOD266
CROSS SECTION D-D' DRAWING 1433DevOD267

GEOLOGY
GLACIAL TILL
LONG NAB
MOOR GRIT
SCARBOROUGH FORMATION
CLOUGHTON & SALTWICK FORMATION
ELLER BECK FORMATION
DOGGER FORMATION
WHITBY MUDSTONE

DRAWING TITLE	GEOLOGICAL MAP AND LINE OF CROSS SECTIONS
PROJECT TITLE	YORK POTASH PROJECT
CLIENT	SIRIUS MINERALS PLC
STATUS	FINAL
PROJECT NUMBER	1433Dev
DRAWN BY	CB
DATE	March 2017
SCALE	1:5,000@A3/1:2,500@A1
DRG. No.	1433DevOD265Rev1

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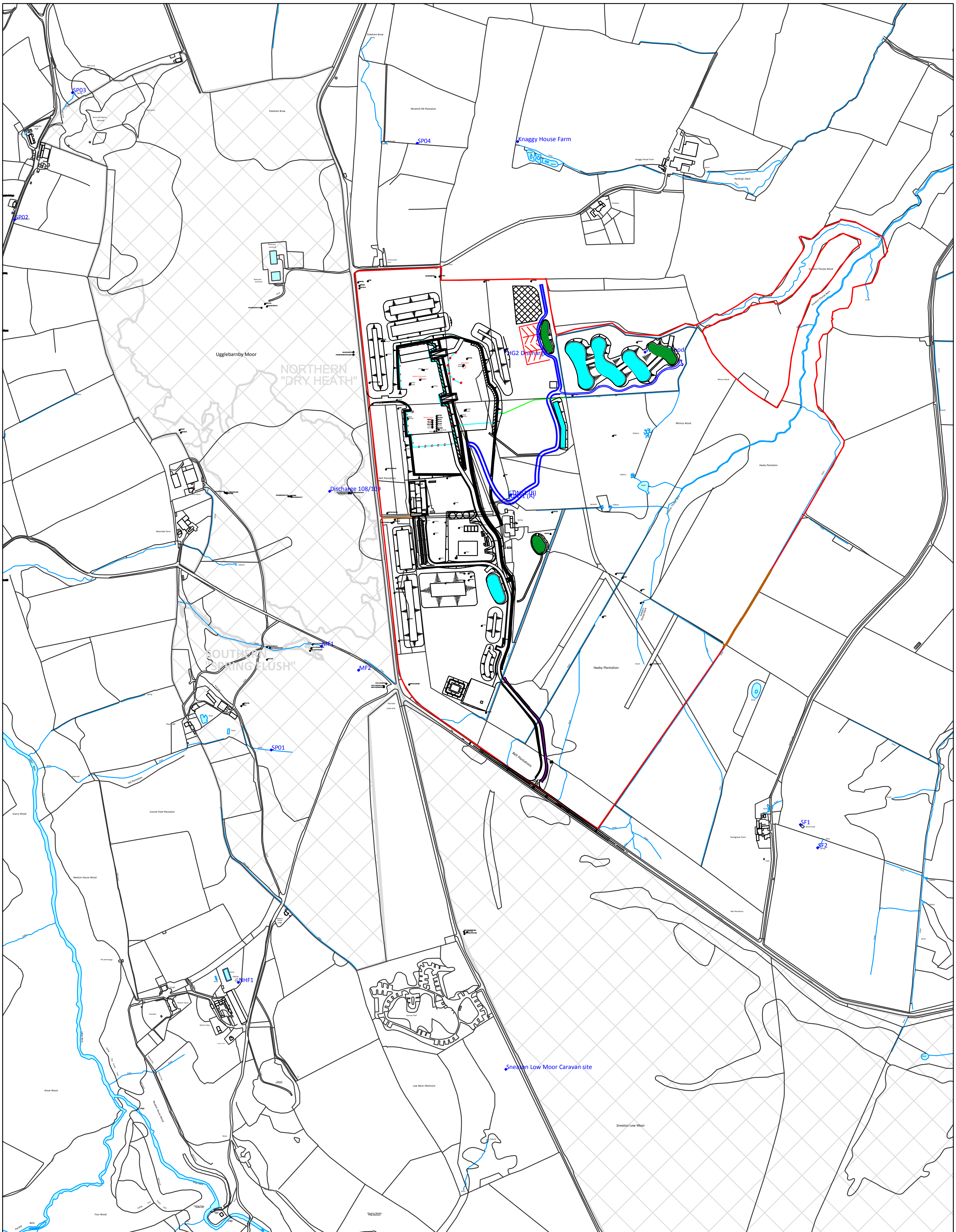

NOTES / KEY

SITE OWNERSHIP BOUNDARY

NYM SAC

SURFACE WATER

BOREHOLES GCBH01

HYDROGEOLOGICAL RECEPTORS MF2

DRAWING TITLE

HYDROGEOLOGICAL RECEPTORS - PHASE 3

PROJECT TITLE

YORK POTASH PROJECT

CLIENT SIRIUS MINERALS PLC	
STATUS FINAL	PROJECT NUMBER 1433Dev
DRAWN BY CB	DATE March 2017
SCALE 1:8,000@A3/1:4,000@A1	DRG. No. 1433DevOD260Rev1

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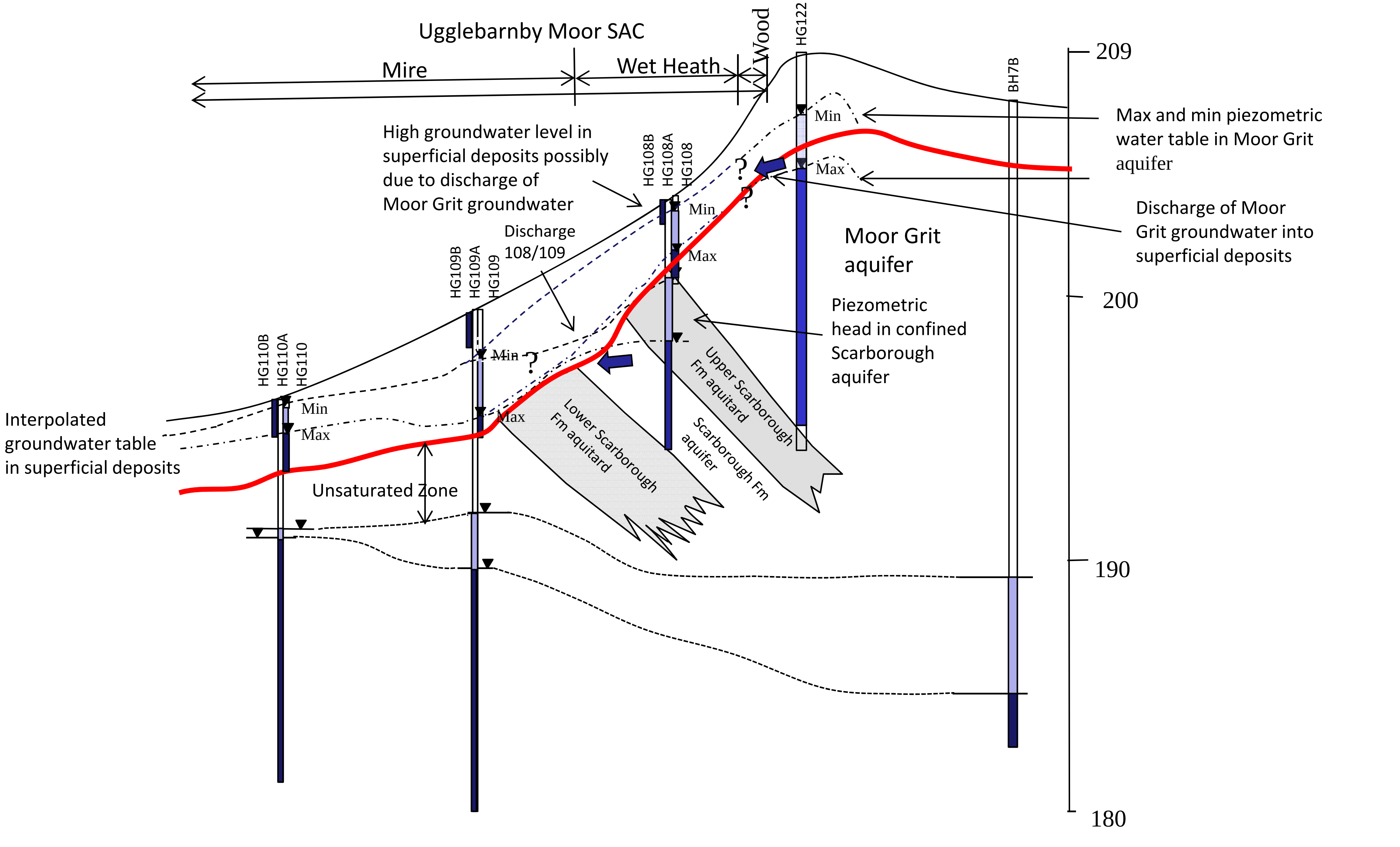

NOTES / KEY

DRAWING TITLE
SCHEMATIC GEOLOGICAL CROSS-SECTION AND HYDROGEOLOGICAL INTERPRETATION OF THE WET HEATH/MIRE ON UGGLEBARNBY MOOR SAC

PROJECT TITLE
YORK POTASH PROJECT

CLIENT: Sirius Minerals plc.	
STATUS: FINAL	PROJECT NUMBER: 1433Dev
DRAWN BY: KW	DATE: December 2015
SCALE: NOT TO SCALE	DRG. No.: 1433DevOD234

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NOTES / KEY

DRAWING TITLE

PHOTOGRAPHS SHOWING DIFFUSED NATURE OF MOORSIDE FARM SPRING (MF2)

PROJECT TITLE

York Potash Project

CLIENT

Sirius Minerals plc.

STATUS	PROJECT NUMBER
FINAL	1433Dev
DRAWN BY	DATE
CB	December 2016
SCALE	DRG. No.
NOT TO SCALE	1433DevOD233

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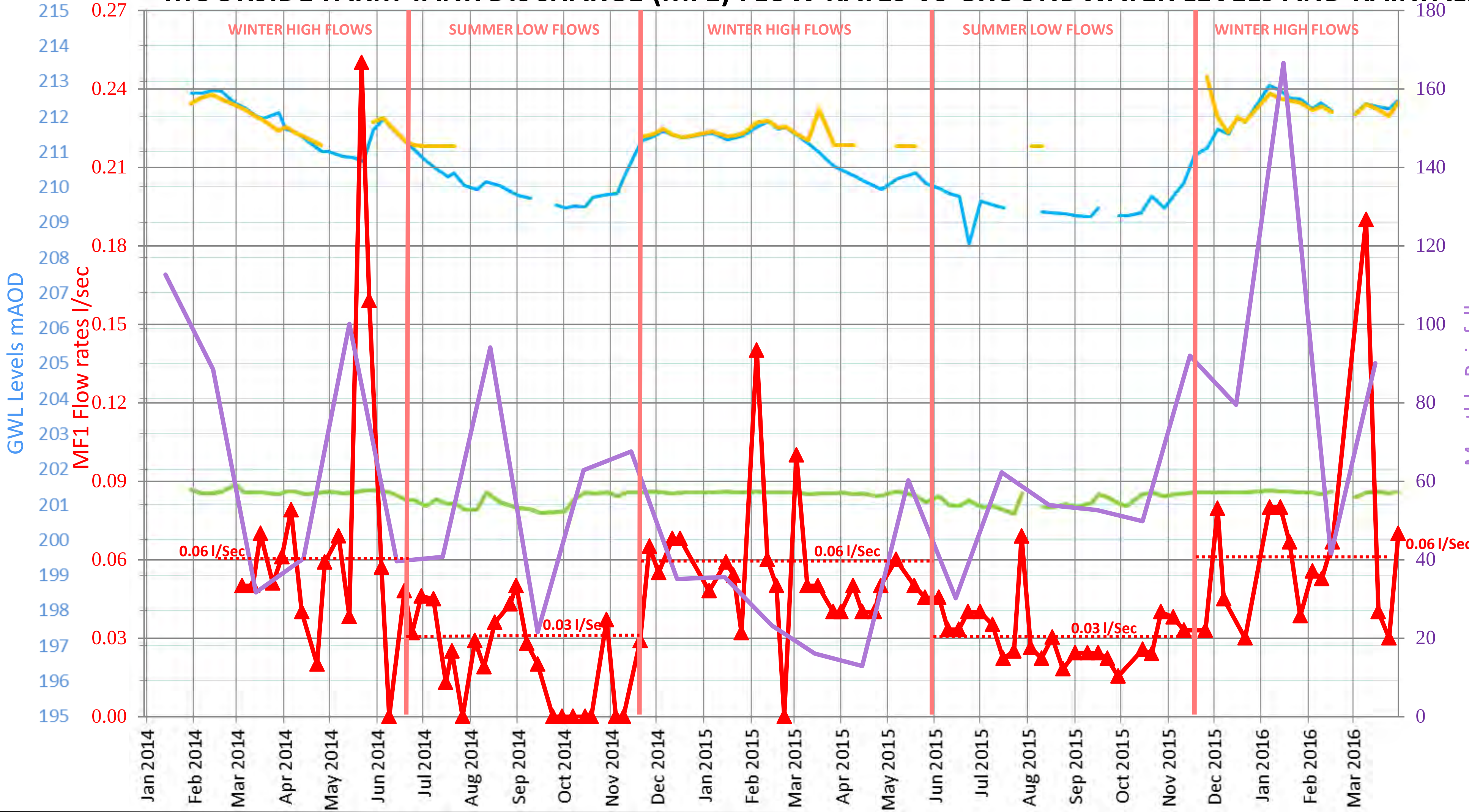
MOORSIDE FARM TANK DISCHARGE (MF1) FLOW RATES VS GROUNDWATER LEVELS AND RAINFALL



NOTES / KEY

DISCHARGE FLOW RATES FROM SPRING FED TANK OVERFLOW (MF1)

SEASONAL AVERAGE FLOW RATES AT MF1

GROUNDWATER LEVEL IN MOOR GRIT UP HYDRAULIC GRADIENT OF MF2 (HG111A)

GROUNDWATER LEVEL IN SUPERFICIAL DEPOSITS UP HYDRAULIC GRADIENT OF MF2 (HG111)

GROUNDWATER LEVEL IN SUPERFICIAL DEPOSITS DOWN HYDRAULIC GRADIENT OF MF2 (HG112C)

MONTHY RAINFALL (WHITBY METEOROLOGICAL DATA

DRAWING TITLE

Moorside Farm Tank Discharge (MF1) Proxy for Moorside Farm Spring (MF2) Flow Rates VS Groundwater Levels and Rainfall

PROJECT TITLE

York Potash Project

CLIENT

Sirius Minerals plc.

STATUS	PROJECT NUMBER
FINAL	1433Dev
DRAWN BY	DATE
CB	December 2016
SCALE	DRG. NO.
NOT TO SCALE	1433DevOD232Rev1

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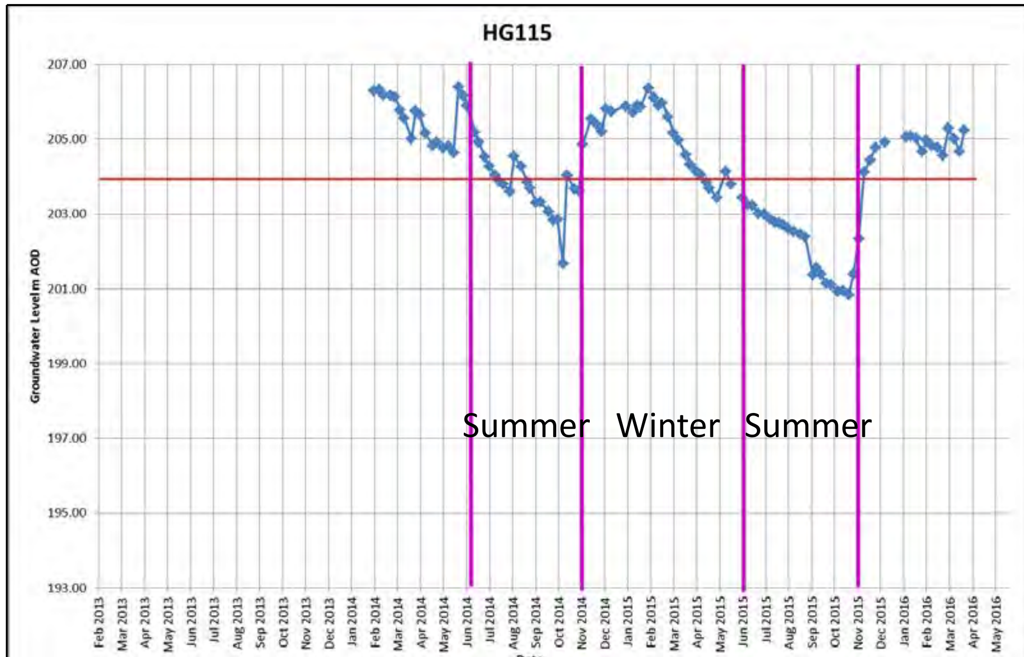

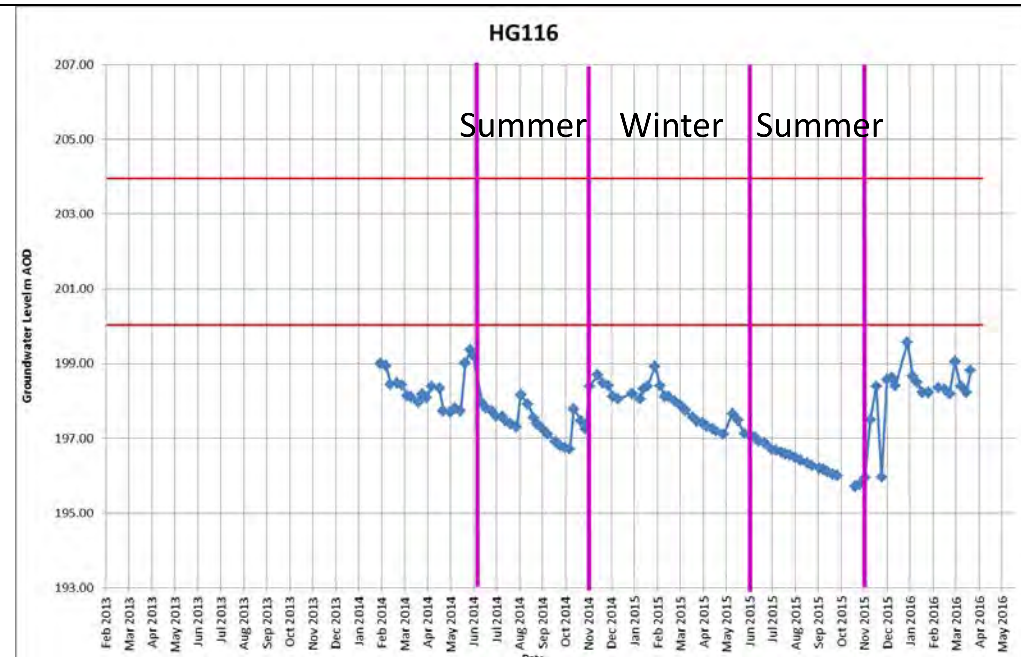

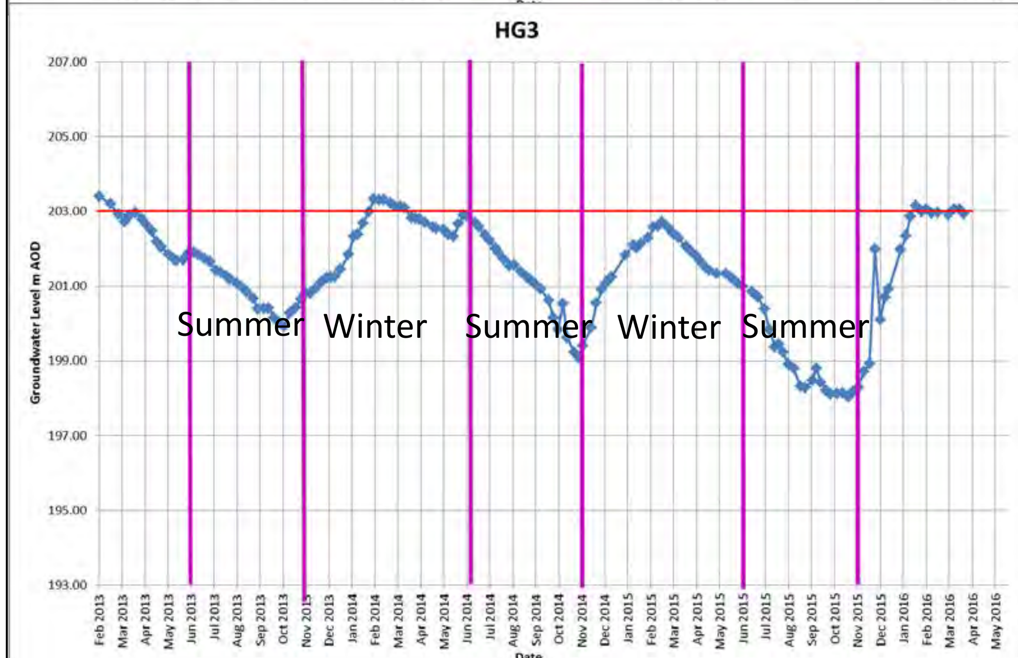

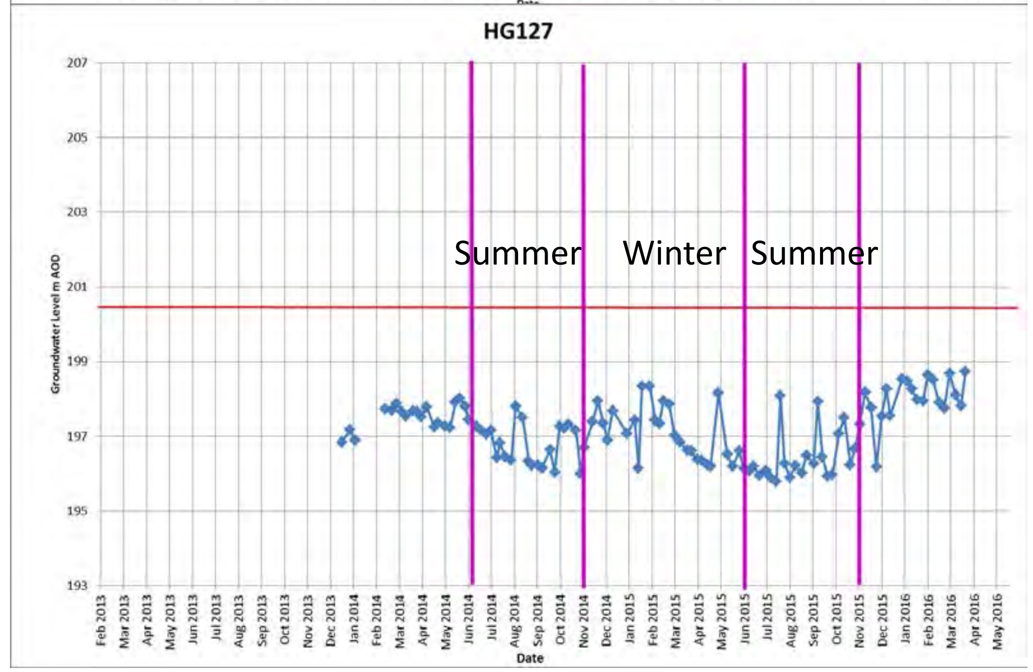

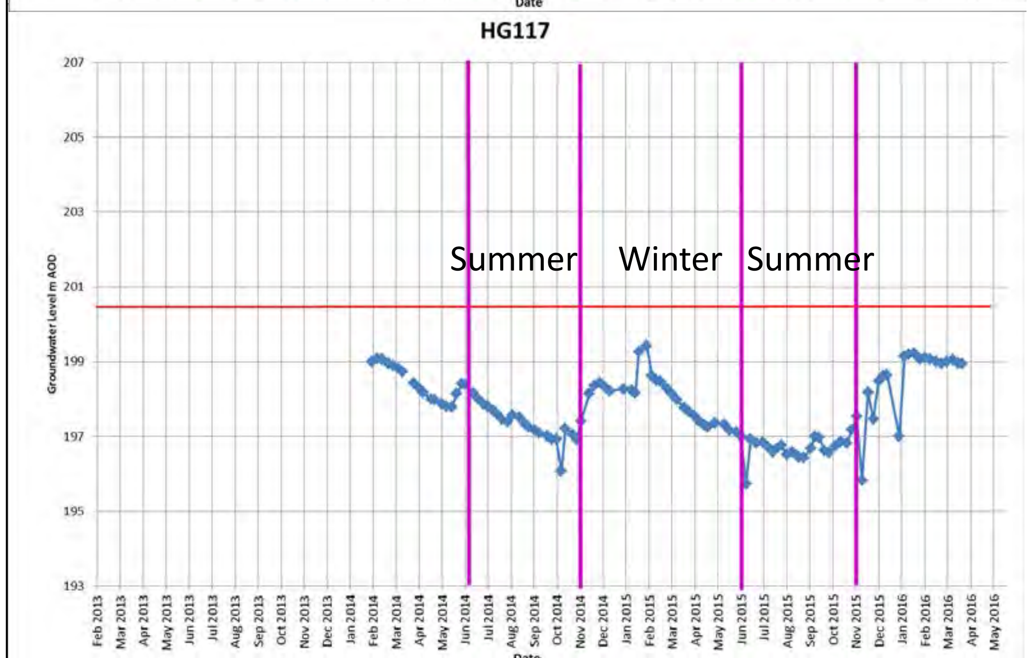

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NOTES / KEY

PLATFORM LEVEL
SEASONS

BOREHOLE LOCATIONS SHOWN ON DRAWING1433DevOD231

CLIENT

SIRIUS MINERALS PLC

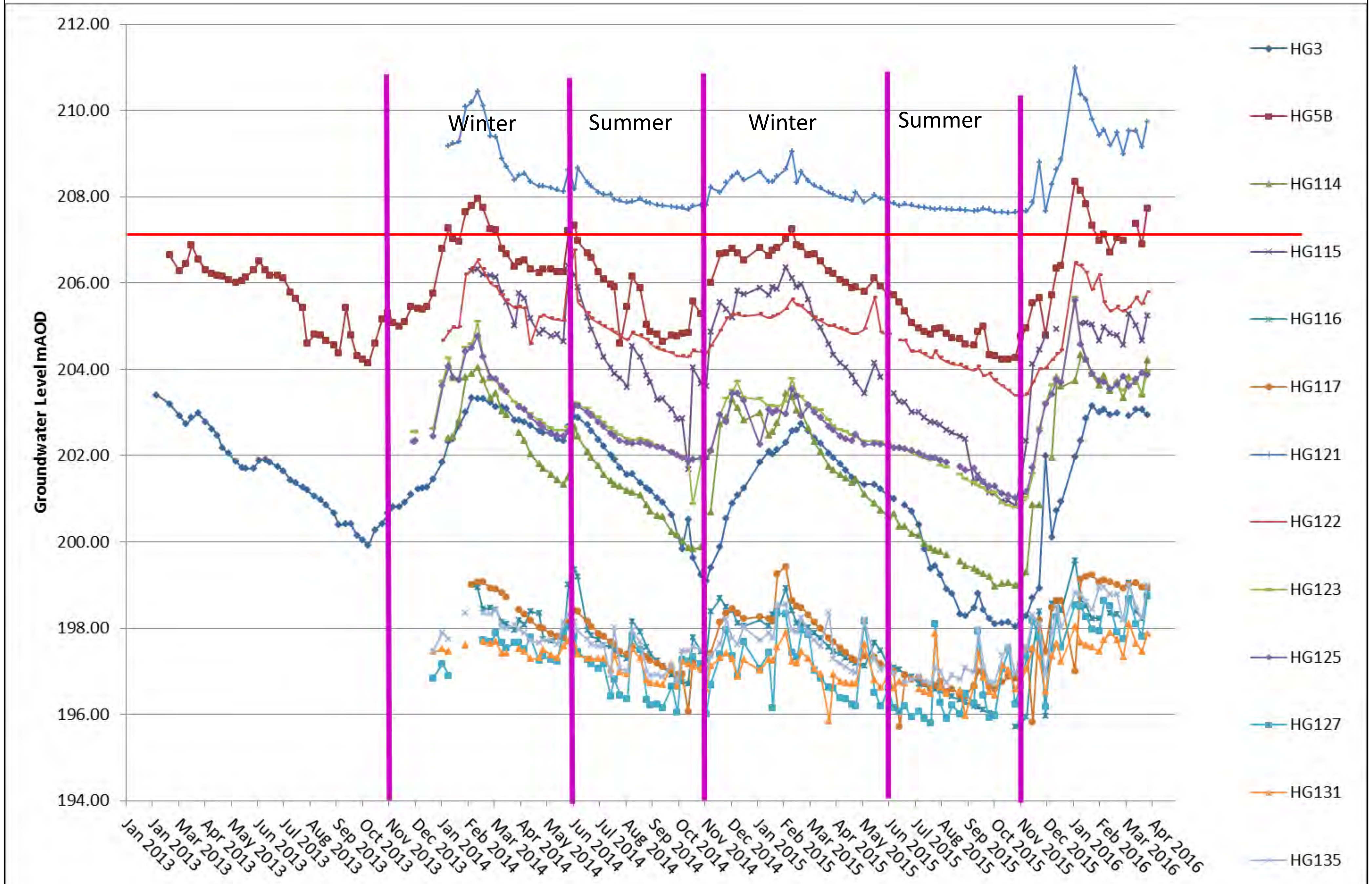
DRAWING TITLE

Groundwater Levels Within the Moor Grit Around Tiered Shaft Platform on Woodsmith Mine

PROJECT TITLE

York Potash Project

STATUS	PROJECT NUMBER
FINAL	1433
DRAWN BY	DATE
CB	December 2016
SCALE	DRG. No.
NOT TO SCALE	1433DevOD228Rev1



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NOTES / KEY

SEASONS

CLIENT

York Potash Ltd

DRAWING TITLE

Groundwater Levels Within the Moor Grit on Woodsmith Minesite

PROJECT TITLE

York Potash Project

STATUS	PROJECT NUMBER
FINAL	1433
DRAWN BY	DATE
CB	December 2016
SCALE	DRG. No.
NOT TO SCALE	1433DevOD229Rev1

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NOTES / KEY

SEASONS

CLIENT

York Potash Ltd

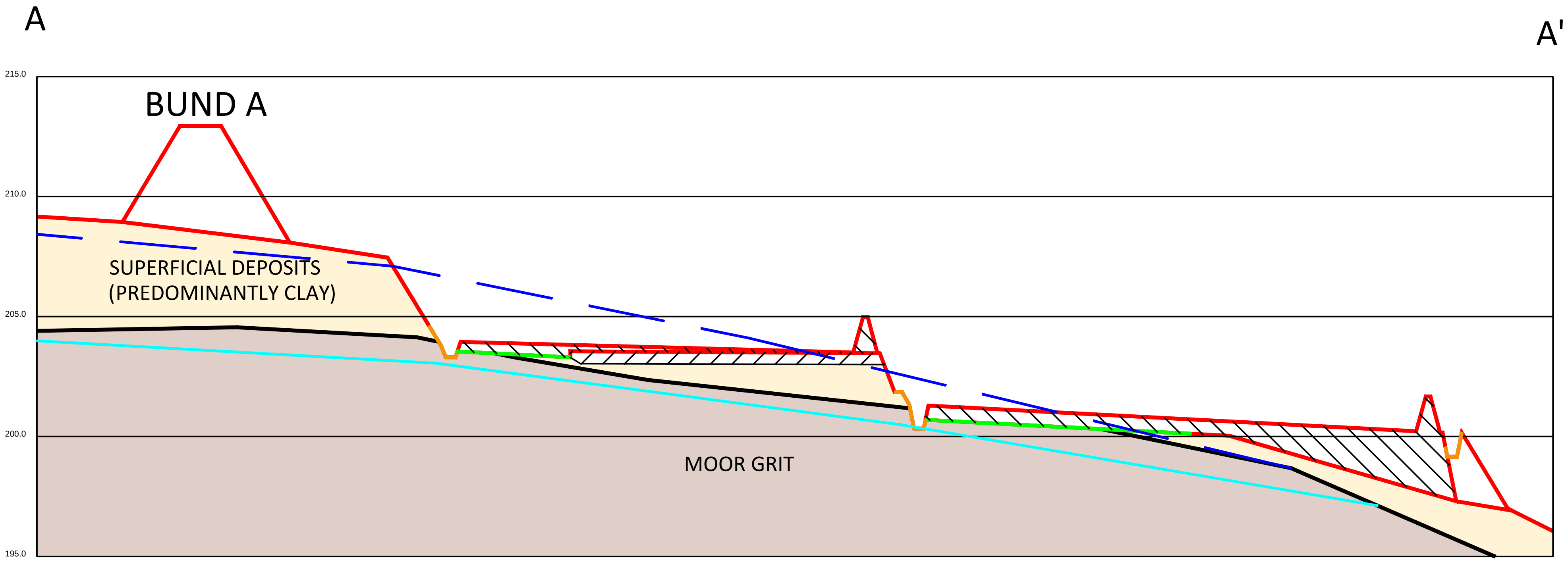
DRAWING TITLE

Groundwater Levels Within the Moor Grit on Ugglebarnby Moor SAC

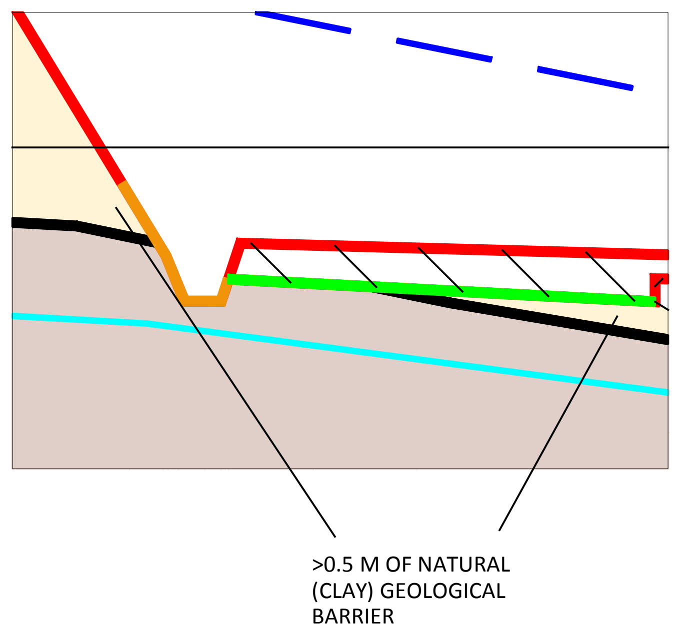
PROJECT TITLE

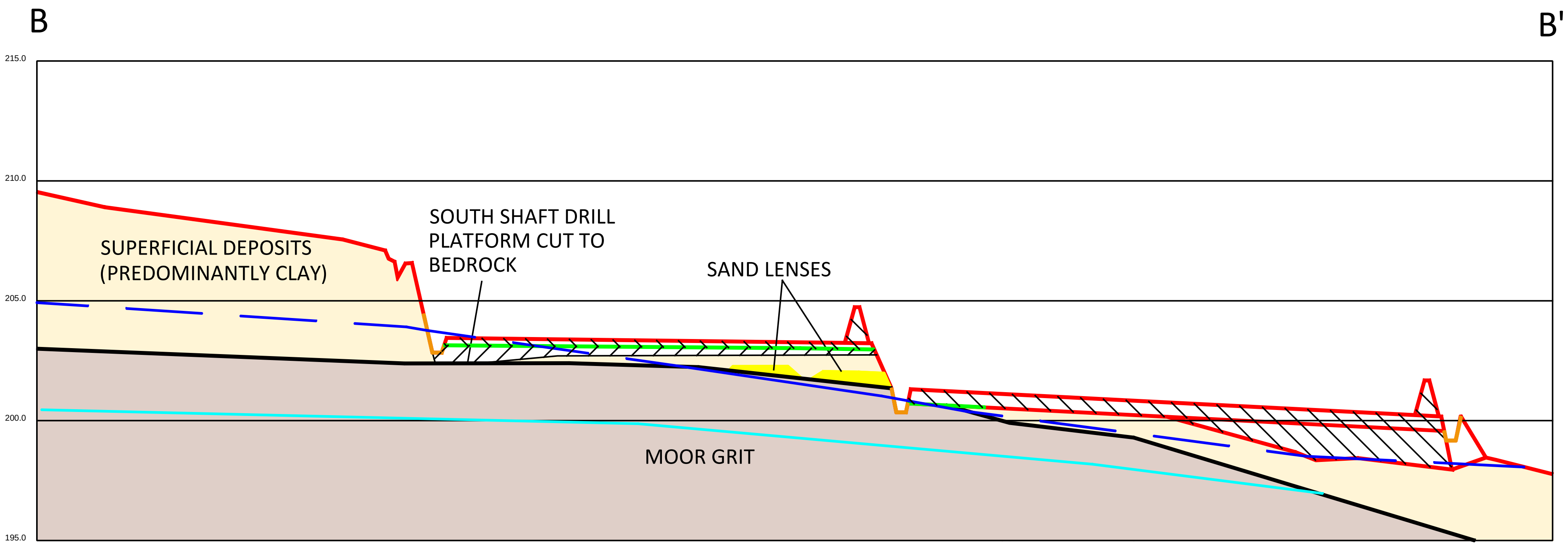
York Potash Project

STATUS	PROJECT NUMBER
FINAL	1433
DRAWN BY	**DATE**
CB	December 2016
SCALE	**DRG. No.**
NOT TO SCALE	1433DevOD230



INSET SHOWING DRAINAGE AND GEOMEMBRANE ARRANGEMENT





NOTES / KEY

GEOLOGY
- COHESIVE SUPERFICIAL DEPOSITS
- MOOR GRIT
- EXISTING GRANULAR PLATFORM CONSTRUCTION
- NEW GRANULAR PLATFORM CONSTRUCTION

GROUNDWATER LEVEL
- MOOR GRIT SEASONAL HIGH GROUNDWATER LEVEL
- MOOR GRIT SEASONAL LOW GROUNDWATER LEVEL

DASHED LINE REPRESENT CONFINED PIEZOMETRIC HEAD WITHIN THE MOOR GRIT AQUIFER

- PHASE 2 WORKS SURFACE CONSTUCTION LEVELS
- GEOMEMBRANE WITH GEOTEXTILE PROTECTION
- LINED DRAINAGE DITCH

DRAWING TITLE	SCHEMATIC HYDROGEOLOGICAL SECTION THROUGH TIERED SHAFT PLATFORM SHOWING GROUNDWATER MANAGEMENT MEASURES
PROJECT TITLE	YORK POTASH PROJECT
CLIENT	SIRIUS MINERALS PLC
STATUS	FINAL
PROJECT NUMBER	1433
DRAWN BY	CB
DATE	DECEMBER 2016
SCALE	AS SHOWN
DRG. No.	1433DevOD244Rev1

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