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25 May 2022

Dear Rob

NYMNPA EMAIL DATED 18 MAY 2022 – ANGLO AMERICAN WOODSMITH RESPONSE – NYM/2022/0286/CVC LADYCROSS PHASE 4 CONDITIONS DISCHARGE

This letter sets out the response of Anglo American to a request for clarification from NYMNPA, as referenced above. For each issue, the NYMNPA's request is presented in blue text with the Anglo American response following in black text.

1. Deliveries to Site

The Construction Method Statement (Attachment E) contains a table setting out an indicative programme of works for the Phase 4 stage. The table suggests that cement deliveries (utilising 30t wagons) could take place on a 24 hour/day basis during Activity 3 (the second stage grout campaign). The table also suggest that Activity 6 (ongoing site works) would also take place on a 24 hour/day basis. Please can you confirm whether this is the intention and, if overnight deliveries are required, the estimated number of such movements. It is noted in this regard that the noise and vibration assessment elsewhere in the submission has been produced on the basis that lorry movements are day-time only.

All deliveries are planned for daytime only (7am to 7pm). There will be no deliveries outside these times.

2. Lighting

The Construction Environment Management Plan, Section 3.6, sets out lighting control measures. It would be helpful if this contained a more specific commitment to achieving a zero upward light ratio for all lighting and include reference to use a low colour temperature (less than 3000k) where practicable.

A commitment to achieving a zero upward light ratio for all lighting, and use of low colour temperature (less than 3000k) is not achievable during this construction phase. While we will minimise upward lighting wherever practicable, there are cases where this is unavoidable given the need for a safe working environment. This is particularly the case for the drilling rigs, which will require some illumination on the masts.

Low colour temperature lighting will be utilised in fixed lights around the welfare, workshop and walkway, and elsewhere on site where practicable.

3. Community and Stakeholder Engagement Framework

The Community and Stakeholder Engagement Framework doesn't appear to make any specific reference to the Lady Cross site, although references to Woodsmith Mine and the Lockwood Beck site are included. It would be helpful if a specific reference could be included for the avoidance of doubt.

The Community and Stakeholder Engagement Framework document, appended to the CEMP for information, is currently undergoing revision. Once the document has completed internal review and approval process, a revised copy will be submitted to NYMNPA. Whilst Ladycross is not specifically referenced in the current iteration of the report, we are activity engaging with stakeholders around the Ladycross site and the requirements will be applied in full.

4. Hydrogeological Risk Assessment

Table 6.2 of the Hydrogeological Risk Assessment identifies a number of receptors and their sensitivity. It is noted that a 'Low Sensitivity' rating is attributed to surface water courses that are tributaries of the River Esk. The related Table E1 defines Low Sensitivity as 'tolerant to change and of low or local importance'. This rating is queried taking into account the known sensitivity of the River Esk in ecological terms and it would be useful if either further justification for this rating were provided, or the assessment revised accordingly.

A revised version of the document is included with this response, in which the sensitivity has been amended to the correct rating of 'Moderate-High' rather than Low. As source magnitude (Table 6-1) for all the effects considered ranges from Negligible to Minor, the risk rating for watercourses would be unchanged and remain at Low. The Risk Statement (Table 6-4) remains valid as drafted.

We trust that this response addresses these points of clarification raised by the NYMNPA and that the relevant conditions relating to Ladycross Phase 4 can now be partially discharged. If you have any further questions, however, please contact the undersigned.

Yours sincerely

Robert Staniland
Manager – Environment and Permitting

Project Title / Facility Name:

Woodsmith Project

Document Title:

HYDROGEOLOGICAL RISK ASSESSMENT - PHASE 4 - NYMNPA CONDITION 88 & 90 - LADYCROSS

Document Review Status

- [x] 1. Reviewed – Accepted – Work May Proceed — By: Angela Samuels
- [ ] 2. Reviewed – Accepted As Noted, Work May Proceed, Revise & Resubmit — On: 25 May 2022 14:39
- [ ] 3. Reviewed – Work May Not Proceed, Revise & Resubmit
- [ ] 4. For information only
- [ ] 5. On Hold – Pending Project Restart & Ramp Up

Rev.	Revision Date (dd mmm yyyy)	Reason For Issue	Prepared by	Verified by	Approved by
D	23-May-2022	Planning	PLA			
C	01-Apr-2022	Planning	PLA			
B	23-Mar-2022	Planning	PLA			
A	15-Feb-2022	Planning	PLA			

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40-STS-LC-2100-EN-RA-00002

NORTH YORKSHIRE POLYHALITE PROJECT (788.5030)

HYDROGEOLOGICAL RISK ASSESSMENT - PHASE 4 NYMNPA CONDITION 88 & 90 - LADYCROSS PLANTATION / 40-STS-LC-2100-EN-RA-00002

Revision	Date of issue	Prepared by	Checked by	Approved by	Changes
A (PLA)	15-02-2022	Stephen Foster	Carl Thomas	Paul Howlett	First Draft
B (PLA)	23-03-2022	Stephen Foster	Carl Thomas	Paul Howlett	Review post comments
C (PLA)	01-04-2022	Stephen Foster	Carl Thomas	Paul Howlett	Final Version
D (PLA)	23-05-2022	Stephen Foster	Carl Thomas	Paul Howlett	Update to Risk Statement

TABLE OF CONTENTS

1. INTRODUCTION

1.1. General Background

STRABAG has been commissioned by Anglo American to construct the Mineral Transport System (MTS) tunnel, a part of its wider Woodsmith Project. The tunnel will be used to transport polyhalite from the Woodsmith Mine site to the Material Handling Facility (MHF) at Wilton, Teesside.

In 2014 a planning application (reference NYM/2014/0676/MEIA) was submitted to the North York Moors National Park Authority (NYMNPA) for permission to develop a polyhalite mine and underground Mineral Transport System (MTS). Planning permission was subsequently granted in 2015 subject to conditions, as varied in February 2018 by NYM/2017/0505/MEIA. This permits the construction of intermediate shafts, including at Ladycross Plantation.

Phase 2 of the works at the Ladycross Plantation site comprised the mobilisation of STRABAG to site, topsoil and subsoil stripping, drainage works, and construction of roads. Phase 3 will incorporate additional surface works intended to establish the basis for pre-grouting. Phase 3 works include additional soil stripping and drainage works, development and installation of welfare and operational facilities, cuttings lagoon development and installation of a working pad for pre-grouting and shaft sinking works.

Phase 4 of the works at the Ladycross site comprise utilities installation and two-stage pre-grouting works.

1.2. Phase 4 Scope of Works

The Phase 4 Scope of Works is as follows:

- Installation and use of site utilities, including water supply, electrical supply, substation, and transformer;
- Extension of working pad for grout plant and installation of wedge pit;
- Mobilisation of grouting rig and associated services, including grout plant and compressors; and
- Grouting works;

1.3. Purpose of Document

This Revised Hydrogeological Risk Assessment is required to partially discharge an element of condition NYMNPA-88 as stated in the planning permission ref. no NYM/2017/0505/MEIA. Table 1-1 details where the relevant information has been provided within this report.

1.4. Scope of Document

The scope of this document includes the installation of utilities and the pre-grouting programme. It does not include any previous phases of activity.

This document does not include an assessment of the risks relating to surface works (e.g. establishment of temporary welfare facilities, installation of shaft sinking equipment and shaft platform civils and infrastructure) as the risks from activities of these types have been assessed in submissions supporting previous phases.

1.5. STRUCTURE OF DOCUMENT

The structure of this document is as follows:

Section 1 – Introduction - this section,

Section 2 – Geology – provides a summary description of the ground conditions pertinent to the risk assessment,

Section 3 – Hydrology - provides a summary description of the surface water environment pertinent to the risk assessment,

Section 4 – Hydrogeology – provides a summary of the current hydrogeological understanding of the site,

Section 5 – Construction Methodology – describes a summary of the proposed Phase 4 works,

Section 6 – Risk Statement – a statement of water related risks from the Phase 4 works,

Section 7 – Groundwater Management Scheme – describes proposed control measures to be used during the Phase 4 works to mitigate the identified risks, and

Section 8 – Groundwater and Surface Water Monitoring Scheme – describes any monitoring required to confirm the efficacy of the control measures during the Phase 4 activities.

1.6. COMPLIANCE WITH CONDITIONS

This document is required to partially discharge the first part of condition NYMNPA-88 and condition NYMNPA-90. These parts of the planning conditions state that:

Table 1-1 NYNMPA Discharge Condition No 88 – Revised Hydrogeological Risk Assessment

NYMNPA Description	Compliance with Condition NYMNPA 88
Prior to Commencement of Development for the MTS at Lady Cross Plantation and informed by the most up-to-date monitoring, a Revised Hydro-geological Risk Assessment shall be submitted to and approved in writing by the MPA in consultation with the Environment Agency.	Whole text.

Table 1-2 NYNMPA Discharge Condition No 90 – Groundwater Management Scheme

NYMNPA Description	Compliance with Condition NYMNPA 90
Following the approval of the Revised Hydro-Geological Risk Assessment for the MTS, but prior to the Commencement of the Development of the MTS at Lady Cross Plantation, a Groundwater Management Scheme (covering construction, operation, and post-operation phases), shall be submitted to and approved in writing by the MPA. The Scheme shall include technical drawings detailing the conceptualised hydrogeology with the final detail designs of the proposed mitigation measures outlined in the York Potash Environmental Statement (September 2014 as updated by the Supplementary Environmental Statement dated February 2015). Development shall thereafter proceed only in strict accordance with the approved Scheme and a timetable to be included within it.	**Section 7 & 8**

2. GEOLOGY

2.1. REGIONAL GEOLOGY

A geological section of the tunnel at the Ladycross Plantation site is shown in **Attachment A**.

2.2. LOCAL GEOLOGY

The local geological model is reproduced from the Hydrogeological Baseline Report, FWS, Sept 2014 (ref 1433AmtsOR27Rev2).

2.2.1. GEOLOGICAL SEQUENCE

A detailed geological sequence established from on-site and near site boreholes is presented in Table 2-1, below. Locally, the strata dip gently (~2°) to the southwest.

Table 2-1 – Ladycross Plantation geological sequence

Formation Name		Approximate thickness (m)	Geological description
Topsoil		-	Now removed over large parts of the site and stockpiled for reinstatement.
Superficial deposits		2.4 to 4	Glacial till to depths of 2.9 m in the northern part of the site. Fluvioglacial interbedded sands, gravels, and clays to depths of 2.4 m to > 4 m in the southern part.
Scalby Formation (Long Nab Member and Moor Grit Member)	**Ravenscar Group**	9 to 15	Comprises two members: The upper Long Nab Member with yellow-grey sandstones and grey mudstones, siltstones with some heavily fractured zones. Up to ~12 m thick with up to 3 m of the upper surface weathered in places. The Long Nab Member is absent in the south-eastern half of the site. The lower Moor Grit Member which is mainly grey fine-grained sandstones, in places interbedded with siltstones and mudstones. Between ~5 m and ~ 7 m thick.
Scarborough Formation		12 to 16	Sandstone with thin beds of mudstones and siltstones that are often interlaminated and interbedded.
Cloughton Formation		54	Strong thinly laminated to medium bedded light to dark grey fine to medium sandstone with occasional interlaminations of mudstone, siltstones and thin coal laminae.

Formation Name	Approximate thickness (m)	Geological description
Saltwick Formation	32	The upper sandstone unit is a thinly bedded orange brown and medium grained with rare to occasional siltstone and coal/micaceous laminae and discontinuous coals. This is underlain by a sandy siltstone and a thickly bedded orange-brown sandstone basal unit with siltstone and carbonaceous mudstone laminae.
Dogger Formation	3	Thinly to thickly laminated grey to brownish grey argillaceous sandstone with laminae of mudstone and mica.
Whitby Mudstone Formation	60	Strong thinly interlaminated to thinly interbedded dark grey mudstone with pyritic inclusions and highly calcareous fossiliferous material.
Cleveland Ironstone Formation	27	A succession of grey mudstones, siltstones and sandstones with rare to occasional ironstone nodules and thin beds of ironstone. The upper sequence is calcareous with occasional fossils.
Staithes Sandstone Formation	28	Thinly to thickly laminated light to dark grey argillaceous silty fine sandstone. It contains occasional thin beds of shell fossils, ironstone nodules and green pyritic inclusions.
Redcar Mudstone Formation	Full depth not proven on site but expected to be > 190	The Redcar Mudstone Formation comprises grey silty mudstones and clayey siltstones with subordinate thin beds of limestone and sandstone. Bands of ironstone nodules and fossil shells as well as pyrite are present in places. The formation is divided into four main members, from youngest to oldest: • Ironstone Shale Member. Can be further subdivided into an upper ironstone shale and lower banded ironstone shale. Grey silty mudstone or clayey siltstone with occasional sandstone and siltstone laminations or beds and numerous ironstone bands and nodular horizons, as well as fossil shell (bivalve and belemnite) beds and occasional pyrite nodules. • Pyritious Shale Member. Similar to the ironstone shales above and also contains some ironstone

Formation Name	Approximate thickness (m)	Geological description
		bands / nodular horizons, but with a higher pyrite content. • Siliceous Shale Member. Grey silty mudstones and clayey siltstones with interbeds and laminations of calcareous or sandy siltstone and fine-grained sandstone. With rare pyrite and fossil shells. • Calcareous Shale Member. Grey silty mudstones and clayey siltstones with thin beds of shelly clayey limestone. Becoming sandy in places. This is unlikely to be encountered in the shaft.

2.2.2. STRUCTURAL GEOLOGY

No faults are recorded in site investigation boreholes or reported by the BGS within 800 m of the site.

3. HYDROLOGY

The Ladycross Plantation site is situated at an average elevation of approximately 200mAOD close to an east-west trending surface water drainage divide. Land to the south of the divide, including the Ladycross Plantation site, is located within the River Esk catchment, with surface water runoff from the area draining to the river via multiple ordinary watercourses that flow in a south to south-easterly direction. Land to the north of the divide is located within the East Row Beck catchment with surface water draining in a northerly direction via several ordinary watercourses. The location of the Ladycross Plantation site in relation to local hydrology is shown in **Attachment B**.

Prior to Phase 1 of the development, a number of watercourses were identifiable in the vicinity of the site:

- A stream exits from the Lady Cross Caravan Park, via a culvert then flows through the wooded area along the southern boundary of the works area. This was joined by field drainage from the site as it flowed through the wooded area towards a culvert under the Egton Road. On the southern side of Egton Road, the culvert discharges to an ordinary watercourse that flows southeast away from the site to join Cat Scar Beck, a tributary of the River Esk;
- A road ditch runs the length of the Egton Road on the eastern boundary of the site, and
- Water also flows into this watercourse from an area of boggy/flooded ground in the adjacent woodland.

Beyond these, the following surface water features have been identified:

- A wet shallow valley with abundant aquatic vegetation is located 450 m northeast of the site. This is in the lowest area of Egton Low Moor and collects surface water draining from the moorland. The water collects and drains south in an ordinary watercourse that flows via Murk Beck Slack towards Grosmont Farm and the River Esk approximately 2km downstream;
- An area of wet/saturated ground is located 400 m to the northeast. Water from this area feeds an ordinary watercourse that drains south, 200 m east of the site, which collects in a pond/boggy area, by the entrance track to Coopers Farm, before entering a culvert that discharges to an open watercourse east of Watergate Farm;
- Water collects in an ordinary watercourse approximately 800 m east of the works area by Coopers Farm North that flows south in an open channel to join the River Esk at Dorsley Bank Wood approximately 1.5km downstream;
- A small pond is located 500 m north of the site. The pond drains to an open field drainage channel that flows to the south around 500 m west of the site before combining with other

local field drains to become Cold Keld Beck which flows away from the site in a south westerly direction to join the River Esk approximately 4km to the west; and

- There are a number of springs approx. 700 m north of the works area, within the East Row Beck catchment, which form the head of a stream flowing north past Duns Bogs.

During Phase 1 and 2 of the development, surface water drainage works were undertaken at the site as follows:

- A swale was installed alongside the site road. It also discharges to the culvert beneath Egton Road, and into the southerly flowing ordinary watercourse. The drainage from the road junction built in Phase 1, including drainage from a significant length of Egton Road, also enters this watercourse;
- Site perimeter drainage ditches have been installed around the entire perimeter of the site to intercept notionally clean surface water runoff from surrounding land and shallow field drainage. The interceptor drainage system is intended to minimise overland flow across the site and hence minimise risk of silt entrainment in surface water runoff. The site interceptor drainage system discharges to the existing culvert beneath Egton Road;
- Field drainage pipes that previously entered the site from higher ground to the north east and north west have been intercepted by the peripheral site drainage system to reduce shallow soil water flow onto the site with associated reduction in risk of site waterlogging;
- The pipe which collected field drains before discharging into the stream in the wooded area to the south of the site has been isolated in order to prevent silt laden runoff from discharging directly into the stream; and
- A temporary site surface water drainage system has been installed within the works area to control surface water falling directly onto the area and any groundwater arising during the preparatory soil stripping activities. A temporary attenuation pond has been constructed to provide additional storage of site surface water. The system comprises a network of temporary ditches and sumps that drain to the temporary attenuation pond. Accumulated site surface water is passed through a silt removal system prior to off-site discharge of clean water via a shallow swale with outfall to the culvert beneath Egton Road.

During Phase 3 the provisional surface water drainage works installed during Phases 1 and 2 will be expanded and upgraded in accordance with the Phase 3 Surface Water Management Plan (40-STS-LC-2100-PA-PL-20102). The Phase 3 surface water drainage scheme is designed to manage surface water from all areas of the site including areas of hardstanding within the site, the internal site access road and temporary earthworks storage bunds. The drainage system has two functions as follows:

- To provide stormwater attenuation capacity to restrict off-site discharge to the pre-development QBar greenfield rate; and

- To manage surface water quality within the site to mitigate risk to the receiving watercourse and downstream sections of Cat Scar Beck.

As detailed in the Phase 3 Surface Water Management Plan, stormwater attenuation capacity is to be provided through installation of an attenuation lagoon, swale systems and flow control structures in the peripheral interceptor drains. On-site silt management systems, including swales, filter drains, silt fences and a surface water treatment facility are designed to prevent off-site discharge of silt to the receiving watercourse. An oil separator will be installed at the downstream end of drainage components serving operational areas of the site.

The Phase 3 surface water drainage system will remain in-place and operational throughout Phase 4 and subsequent phases of development.

4. HYDROGEOLOGY

Regionally, the formations of the Ravenscar Group have potential as aquifers although flow is restricted by numerous interbedded, thin mudstone aquitards (BGS, 2000). Of particular note, the thick sequence of the Whitby Mudstone Formation is a regionally significant aquiclude. Beneath the Whitby Mudstone Formation, the Staithes Sandstone Formation and Cleveland Ironstone Formation are generally found to be in close hydraulic continuity, although hydraulic conductivity is expected to be low. Whilst where the Redcar Mudstone Formation subcrops at the MTS portal site in Wilton, flow is dominated by bedding parallel fractures, it is anticipated that at the proposed tunnel depths at Ladycross Plantation, any bedding parallel fractures will be geomechanically tight and the conductivity will be low.

4.1. LOCAL HYDROGEOLOGY

Characterisation of the local hydrogeological flow regime has been provisionally undertaken on the basis of site-specific investigation, testing and monitoring information derived from existing monitoring boreholes and the on-going ground investigation programme. The investigation has provided information to define local geological conditions, site-specific groundwater levels, aquifer hydraulic properties and provisional evaluation of local groundwater - surface water linkages. Hydrogeological characterisation provides a robust basis for evaluation of potential Phase 4 development risk to local surface water and groundwater resources. A summary of local hydrogeological conditions is presented below.

Recent ground investigation works have included the installation of an additional 5 new groundwater monitoring boreholes, downhole permeability testing, continued groundwater level and quality monitoring and targeted tracer testing to investigate groundwater flow pathways.

The 5 new boreholes have been drilled within the site boundary to depths of between 40.10mbgl to 130.70mbgl, extending into geological strata of the Scalby Formation, Scarborough Formation, Cloughton Formation, Saltwick Formation and Dogger Formation, with the deepest boreholes terminating in the underlying Whitby Mudstone Formation. In general, recently drilled boreholes reconfirm the geological succession defined by previous drilling at the site. However, it should be noted that the formations above the Whitby Mudstone Formation are thinner than is typically found in surrounding areas and some aquifer units may be less significant or absent, and so the assessment of risks particularly involving the Scalby, Scarborough and Cloughton Formations may be overestimated.

Summary details related to average permeability values and rest water levels have been updated on the basis of data derived from the recent ground investigation. Permeability values have been established in two of the recent boreholes (BH03 and BH05) by packer testing at defined intervals in each borehole. The results are summarised in Table 4-1.

Table 4-1 Summary of Hydrogeological Conditions

Stratigraphic Unit		Base level of unit (m AOD)	Inferred groundwater surface (m AOD)	Mean permeability** ($m \cdot s^{-1}$)	Water quality
Superficials – glacial tills / sands, gravels and clays		198.98	-	Clays- 3.3×10^{-10} to 2.9×10^{-11} Sands and Gravels– 1×10^{-5}	Good
Scalby Formation	**Long Nab Member**	193.88	195	1.2×10^{-5} to 5.6×10^{-6} With discreet zones of higher permeability	Good
	Moor Grit Member	186.7			
Scarborough Formation		171.92	174	2.8×10^{-5} to 6.8×10^{-6}	
Cloughton Formation		133.61	174	6.10×10^{-6} to 7.20×10^{-8} With discreet zones of higher permeability	
Saltwick Formation		101.99	173	5.21×10^{-6} With discreet zones of higher permeability	
Dogger Formation		98.69	146	5.5×10^{-8} With discreet zones of higher permeability	
Whitby Mudstone Formation		20.93	88	-	-
Cleveland Ironstone Formation		-6.07	-	2.36×10^{-6}	Probably poor
Staithes Sandstone Formation		-39.02	-	2.5×10^{-6}	Probably good
Redcar Mudstone Formation	**Banded Ironstone and Pyritious Shale**	-136.17	-	1.43×10^{-8}	If present probably poor
	Siliceous Shale	< -153.69	165	1.40×10^{-8}	

** Measured, estimated or design

Packer testing in recent boreholes BH03 and BH05, located within the site boundary, was unsuccessful at several depths as formation permeability was found to be too high to maintain an adequate hydraulic head for testing. Further investigation and analysis is being undertaken to try and quantify permeabilities and potential flow rates in these discrete high permeability zones.

Groundwater levels in eight monitoring boreholes located around the periphery of the site are recorded on a weekly basis since November 2020. The majority of boreholes contain multiple monitoring installations that collectively allow discrete monitoring of groundwater levels in the superficial deposits, Scalby Formation, Scarborough Formation and the Cloughton Formation, respectively. During the monitoring period, groundwater levels in the superficial deposits have varied within a range of approximately 2m with a hydraulic gradient to the south, consistent with local topographic variation. Groundwater levels in the underlying Scalby Formation are consistent with levels recorded in the superficial deposits indicating full hydraulic continuity between the two formations.

Groundwater levels in the underlying Scarborough Formation in the southern part of the site have averaged 184mAOD during the monitoring period with no significant seasonal variation. During more recent monitoring, following the current ground investigation, groundwater levels in some boreholes fell by several metres, potentially due to increased connection with more transmissive zones in underlying formations. Following the grouting of deep borehole 34_BH01, groundwater levels in the affected boreholes have begun to rise and it is expected that levels will progressively return to pre-investigation average levels. The rest water level in the Scarborough Formation is currently established at approximately 174mAOD. Groundwater levels in the Scarborough Formation are up to 20m below groundwater level in the overlying Scalby Formation and superficial deposits. Comparable groundwater levels were recorded in the underlying Cloughton Formation. Groundwater levels in the Scarborough and Cloughton Formations indicate a hydraulic gradient to the south and southwest.

Through a combination of the analysis of borehole core logs and downhole geophysical surveying it has been demonstrated that the majority of competent bedrock formations beneath the site contain multiple discontinuities consisting of bedding planes, faults and fractures. Groundwater storage and transmission is therefore likely to be dominated by flow through discontinuity systems. As indicated in Table 4-1, downhole permeability testing in on-site boreholes resulted in hydraulic conductivity values in the range 2.8×10^{-5} m/s to 1.4×10^{-8} m/s with a tendency to lower hydraulic conductivity with depth, consistent with increasing discontinuity closure with depth. Pumping tests undertaken in the Cloughton Formation at the Doves Nest South Shaft, 8km from the Ladycross site, resulted in the determination of higher hydraulic conductivity values within the range 2×10^{-4} m/s to 8×10^{-4} m/s.

Provisional groundwater level observations in the recently constructed boreholes suggest the potential presence of a thin, highly transmissive, groundwater drainage horizon at an elevation of approximately 85mAOD, within the weathered upper few metres of the Whitby Mudstone Formation. Six Vibrating Wire Piezometers (VWP's) have been installed in Borehole 34_BH01 which was constructed to a depth of 380mbgl and located in close proximity to the shaft centre. VWP depths and target formation are summarised in Table 4-2.

Table 4-2 VWP installations in 34_BH01

VWP ID	Depth of install (mbgl)	Geology
34_BH01_1	12	Scarborough Formation
34_BH01_2	37	Cloughton Formation
34_BH01_3	53	Cloughton Formation
34_BH01_4	76	Cloughton / Saltwick Formation
34_BH01_5	111.5	Saltwick Formation
34_BH01_6	118.5	Saltwick Formation

A conceptual interpretation of local hydrogeological conditions at the site is shown on a drawing prepared by Geo-Design and included for reference at **Attachment C**. The drawing shows probable local groundwater flowpaths and measured groundwater heads in respective aquifer units.

Groundwater quality monitoring in superficial deposits and bedrock formations above the Whitby Mudstone Formation has been undertaken on a monthly basis since January 2021. In general, the quality of groundwater is relatively good but there is consistent evidence of high background concentrations of iron and manganese together with elevated concentrations of other heavy metals. Groundwater quality is consistent with presence of groundwater flow through iron-rich sedimentary formations which form the bedrock beneath the site.

The ground investigation and hydrogeological monitoring programme has demonstrated that groundwater is present in both superficial deposits and bedrock formations beneath the site and that groundwater flow to the south and southwest is likely to be dominated by flow through secondary porosity fracture flow systems. Groundwater in the superficial deposits, and hence the Scalby Formation, is likely to be in hydraulic continuity with the surface water drainage system in the vicinity of the site. Monitoring evidence indicates that deeper groundwater in the underlying strata may be draining to the surface water system via fracture flow systems in the Cloughton and Saltwick Formations and a drainage horizon at the top of the Whitby Mudstone Formation.

Current understanding of local hydrogeological conditions, based on site-specific investigation, testing and monitoring, provides a robust basis for evaluation of potential hydrological and hydrogeological risk and the development of effective risk management strategies.

5. CONSTRUCTION METHODOLOGY

5.1. PRE GROUT WORKS

A detailed Construction Method Statement has been provided to accompany the submissions for the proposed Phase 4 works (40-STS-LC-2100-CN-MS-00004).

The Phase 4 Scope of Works is as follows:

- Installation and use of site utilities, including water supply, electrical supply, substation and transformer;
- Extension of working pad for grout plant and installation of wedge pit;
- Mobilisation of grouting rig and associated services, including grout plant and compressors; and
- Grouting works;

To facilitate future shaft sinking via the blind bore methodology, there is a requirement to stabilise the ground conditions in the vicinity of the shaft, and reduce the permeability, with a pre-excavation grouting programme. At Ladycross, the pre-excavation grouting will consist of a two-stage process.

- **Stage 1** – installation of a 'grout curtain' using a low bleed colloidal silica grout with associated additives around the proposed shaft area to act as an external barrier and reduce hydraulic connectivity with the surrounding strata, and:
- **Stage 2** - a standard pre grouting programme to create a stable rock mass which holds ground water.

6. RISK STATEMENT

The consideration of the risks from the Phase 4 activities is based on source-pathway-receptor linkages. The following sections describe the sources, pathways and receptors which have been considered here. An assessment of the risks relating to surface works (e.g. establishment of temporary welfare facilities, installation of shaft sinking equipment and shaft platform civils and infrastructure) has not been undertaken as the risks from activities of these types have been assessed in submissions supporting previous phases, and appropriate mitigation agreed.

6.1. SOURCES

The sources of impact which have been considered are detailed in Table 6-1.

Table 6-1 - Sources

Source	Discussion	Potential Magnitude
Physical effects		
Raised groundwater level/pore pressure	During drilling of boreholes, grouting, groundwater level or pore pressure local to the shaft will be elevated.	**Minor**
Lowered groundwater level/pore pressure	Although no dewatering of groundwater is proposed, during drilling of boreholes, linkage between water bearing strata may result in a slight lowering of groundwater levels in the upper aquifer units.	**Minor**
Changes to groundwater flow paths	Grouting of rock discontinuities around the shaft may result in local alteration of groundwater flow paths through upper aquifer units.	**Minor**
Quality effects		
Drilling fluid	Drilling fluid will be water based but will also contain cuttings fines and may contain amendments such as bentonite. There is potential for localised migration of drilling fluid into shaft wall discontinuities during shaft construction.	**Minor**
Grout	Colloidal silica grouts will be used in the grout curtain containing suspended silica and saline solution, the mix is mineral grout and no chemical reaction is required. There is potential for highly localised migration of grout to upper aquifer groundwater during installation of the grout curtain.	**Minor**

Source	Discussion	Potential Magnitude
	Cementitious grout will be used in the Ravenscar Group aquifers. There is potential for localised migration of grout to upper formation aquifer groundwater during the grouting process. Grout migration potential is likely to be significantly restricted by the presence of the grout curtain.	
Reactivated sediment	Sediment held within subsurface conduits has the potential to be mobilised.	**Negligible**
Unconsolidated drift and soils	Soil, subsoil and glacial till have the potential to be mobilised.	**Negligible**

6.2. RECEPTORS

The receptors which have been considered are detailed in Table 6-2. The water quality in the Staithes Sandstone Formation, Cleveland Ironstone Formation and Redcar Mudstone Formation is likely to be poor and of limited resource value. Strata beneath the Whitby Mudstone Formation have not been considered as receptors in this assessment. The location of defined receptors is shown on Drawing 1433AmtsOD27Rev1 which is included at Attachment D.

The groundwater within the Ravenscar Group is of generally good quality and has water resource value. Strata within the group are defined as Secondary A aquifers with low-medium groundwater vulnerability at surface.

There are a number of abstractions in the proximity of the site which take water from boreholes in the aquifer units within the Ravenscar Group, or from springs fed from the same aquifers. These are provided in Table 6-2.

Table 6-2 Receptors

Receptor	Discussion	Sensitivity
1) Duns Bog Farm	Used for general farming and domestic purposes, from springs issuing from the Cloughton Formation upgradient of the site.	**Moderate**
2) Newbiggin Hall	Used for general farming and domestic purposes, from springs issuing from the Cloughton Formation or Saltwick Formation upgradient of the site.	**Moderate**

Receptor	Discussion	Sensitivity
3) Lamplands Farm	Used for general farming and domestic purposes, from springs issuing from the superficials downgradient of the site. It is possible that the source is actually the underlying Cloughton Formation.	**Moderate**
4) Topstone Farm	A private water undertaking and general farming and domestic purposes, from springs issuing from the Cloughton Formation upgradient of the site. Source Protection Zone (SPZ) II	**High**
5) Ladycross Plantation Caravan Park	Used for general domestic purposes from a borehole which abstracts from the Cloughton Formation up- or cross-gradient of the site	**Moderate**
1) Church Cliff	Confluence of springs providing base flows to Cat Scar Beck. No known abstractions, medium base flow rates observed from multiple springs.	**Moderate-High**
2) Newstead Farm	Spring head providing base flow to Cat Scar Beck and water for cattle.	**Moderate**
3) Priory Farm	Confluence of springs providing base flows to Cat Scar Beck. Situated close to Haggs Farm mine drift. High base flow rates observed from multiple springs. Close to the Esk and likely influence from ironstone mines.	**Moderate**
4) Egton Bridge	Confluence of springs providing base flows to unnamed tributary of the River Esk. High base flow rates observed from multiple springs. No abstractions and close to the Esk.	**Moderate-High**
5) Grosmont Farm	Confluence of springs providing base flows to Murk Beck Slack. High base flow rates observed from multiple springs. No abstractions and close to the Esk.	**Moderate-High**

Receptor	Discussion	Sensitivity
All watercourses	Surface watercourses in the area can be defined as those that combine to form Cold Keld Beck, Cat Scar Beck and the un-named system that flows through Grosmont Farm. All are tributaries of the River Esk. All watercourses which flow in the proximity of the site have been considered together. They collectively have: 1) high ecological value (the River Esk and its tributaries support populations of salmonids and protected populations of Freshwater Pearl Mussels) 2) value as a water resource, and 3) high visual amenity value due to the location within the North York Moors National Park.	**Moderate-High**

6.3. PATHWAYS/MECHANISMS

The pathways/mechanisms which have been considered are detailed in Table 6-3.

Table 6-3 Pathways

Mechanism			
Key	**Source**	**Receptor**	**Pathway**
1	Raised/Lowered groundwater level	Ravenscar Group aquifers	Variation in groundwater level during the drilling of pre-grouting boreholes, resulting in change in the local groundwater regime and impacting the resource value of the aquifers.
2	Raised/Lowered groundwater level	Surface watercourses	Connectivity between the Ravenscar Group aquifers and surface watercourses via direct discharge spring flows or baseflow contribution.
3	Changes to groundwater flow paths	Ravenscar Group aquifers	Grouting of discontinuities in the Ravenscar Group aquifers resulting in localised alteration of groundwater flow paths in the vicinity of the shaft
4	Changes to groundwater flow paths	Surface watercourses	Grouting of discontinuities in the Ravenscar Group aquifers resulting in variation in flow to springs and surface watercourses
5	Drilling fluid	Ravenscar Group aquifers	Direct discharge of drilling fluid into the aquifer during borehole installation and reaming.

Mechanism			
Key	**Source**	**Receptor**	**Pathway**
6	Drilling fluid	Surface watercourses	Indirect discharge of drilling fluid into surface watercourses as a consequence of migration through strata of the Ravenscar Group aquifers.
7	Drilling fluid	Surface watercourses	Loss of containment in the cuttings lagoon leading to overtopping and overland flow into the site interceptor drainage system or the boundary watercourse. If storage tanks are used in place of lagoon, loss of containment from storage tanks or burst hose.
8	Grout	Ravenscar Group aquifers	Migration of grout into Ravenscar Group aquifers via high permeability flow horizons.
9	Grout	Surface watercourses	Indirect discharge of grout into surface watercourses as a consequence of migration through strata of the Ravenscar Group aquifers.
10	Reactivated sediment	Surface watercourses	Changes to groundwater level or pore pressure mobilise sediment in the subsurface leading to discharge of sediment laden groundwater into local watercourses.

6.4 Risk Assessment

Assessment of hydrological and hydrogeological risk has been undertaken by consideration of receptor sensitivity, the potential magnitude of any impacts and the potential significance of any consequent effect. The risk assessment methodology is summarised at **Attachment E**. The conclusion of the risk assessment process is summarised in the Risk Statement which is included as Table 6-4.

Table 6-4 Risk Statement

Key	Mechanism	Discussion	Impact Significance
1.	Variation in groundwater levels during pre-grouting boreholes impacting groundwater resources in Ravenscar Group aquifers.	Any potential lowering of groundwater levels would take place during drilling of the Stage 1 grout curtain boreholes as a result of hydraulic continuity between aquifer units. No active dewatering will take place.-Provisional analysis indicates that any lowering of ground water level would be localised and of short duration. Following the completion of Stage 1 grout curtain installation the potential for groundwater level lowering during Stage 2 grouting works is expected to be significantly reduced.	**Low**
2.	Variation in groundwater levels during the sinking of pre-grouting boreholes impacting surface water flow or quality in local watercourses.	Any potential lowering of groundwater levels would take place during drilling of the Stage 1 grout curtain boreholes as a result of hydraulic continuity between aquifer units. No active dewatering will take place.-Provisional analysis indicates that any lowering of ground water level would be localised and of short duration. Following the completion of Stage 1 grout curtain installation the potential for groundwater level lowering during Stage 2 grouting works is expected to be significantly reduced. Temporary groundwater level variations are expected to be too localised and transitory to have an effect on surface water systems.	**Low**
3.	Grouting of discontinuities in the Ravenscar Group aquifers resulting in localised alteration of groundwater flow paths in the vicinity of the shaft	Ground investigation and long-term groundwater monitoring has demonstrated that there is good lateral hydraulic continuity within aquifer units. Reduction in groundwater flow capacity within a few metres radius of the shaft, due to Stage 1 and Stage 2 grouting works is unlikely to affect groundwater levels or flow rates through the wider area.	**Low**

Key	Mechanism	Discussion	Impact Significance
4.	Grouting of discontinuities in the Ravenscar Group aquifers resulting in variation in flow to springs and surface watercourses	Ground investigation and long-term groundwater monitoring has demonstrated that there is good lateral hydraulic continuity within aquifer units. Reduction in groundwater flow capacity within a few metres radius of the shaft, due to Stage 1 and Stage 2 grouting works is unlikely to affect groundwater levels or flow rates through the wider area. As a consequence, risk of variation in flow to springs and surface watercourses is expected to be low.	**Low**
5.	Direct discharge of drilling fluid into the aquifer during borehole installation.	Pre-grouting works are intended to reduce hydraulic connectivity. Whilst not intended as a complete seal, the pre-grouting will have the effect of reducing the interaction with groundwater, therefore any loss of drilling fluid to aquifers should be localised and limited, reducing risk of migration to surface watercourses.	**Low**
6.	Indirect discharge of drilling fluid to surface watercourses via groundwater migration.	Pre-grouting works are intended to reduce hydraulic connectivity. Whilst not intended as a complete seal, the pre-grouting will have the effect of reducing the interaction with groundwater, therefore any loss of drilling fluid to aquifers should be localised and limited, reducing risk of migration to surface watercourses.	**Low**

Key	Mechanism	Discussion	Impact Significance
7.	Loss of containment in the cuttings lagoon leading to overtopping and overland flow to surface watercourses. If storage tanks are used in place of lagoon, loss of containment from storage tanks or burst hose.	The cuttings lagoon is designed to accommodate a significant freeboard in excess of the volume of storage required to accommodate borehole cuttings.	**Very Low**
8	Migration of grout into Ravenscar group aquifers	Prior to drilling the main shaft, a two-stage pre-grouting programme will be implemented. Holes will be bored from the surface to produce a grouted zone to stabilise the ground by controlling the level of groundwater interaction with the shaft during construction. The programme is carried out in advance of pilot hole drilling and fore-shaft construction. It is based on existing geotechnical data and will be reviewed periodically and adapted based on results. It is anticipated that pre-grouting works will be undertaken in the following separate stages: Stage 1 - installation of a 'grout curtain' using a low bleed colloidal silica grout with associated additives, around the proposed shaft area to act as an external barrier and reduce hydraulic connectivity with the surrounding strata, and: Stage 2 - a standard pre grouting programme to create a stable rock mass which holds ground water.	**Low**
9.	Transport of grout into surface watercourses via migration in groundwater .		**Low**

Key	Mechanism	Discussion	Impact Significance
10.	Changes to groundwater level or pore pressure mobilise sediment in the subsurface leading to discharge of sediment laden groundwater into surface watercourses	During pre-grouting borehole construction and grouting works, it is intended that unconsolidated drift and soils will be cased to maintain borehole stability. The potential for change to groundwater levels or pressures within such superficial deposits would therefore be negligible.	**Very Low**

7. GROUNDWATER MANAGEMENT SCHEME

To demonstrate the effectiveness of the groundwater management measures adopted during the Phase 4 works, the Groundwater and Surface Water Monitoring Scheme (see Section 8, below) and the Remedial Action Plan (40-STS-LC-2100-EN-PL-00017) will be implemented.

7.1. PRE-SHAFT CONSTRUCTION

7.1.1. PRE-GROUTING

Pre-grouting would be undertaken in two stages. Stage 1 would comprise installation of a perimeter grout 'curtain' around the shaft to reduce the permeability of the more transmissive zones within the Ravenscar Group aquifers and reduce groundwater flow rates through the shaft site in advance of Stage 2 works. The use of two-part rapid gelling grout materials would mitigate risk of grout migration into the aquifer. During Stage 2 a series of pre-grouting boreholes will be installed inside the perimeter curtain and around the proposed shaft location. It is anticipated that between eight and sixteen will be required, with eight extending into the Whitby Mudstone Formation. The number extending to tunnel depth will be subject to the response during grouting of the first holes, although at least two are anticipated.

The proposed Stage 1 grout hole pattern is illustrated in **Attachment C** and can be summarised as follows:

- Pre-excavation grouting works will be carried out from surface down to 20m below the top of the Whitby Mudstone;
- Primary (inner) grout row = 11m from centre, spacing 3.14m (approximately 22 holes),
- Secondary (outer) grout row = 14m from centre, spacing 4m (approximately 22 holes),
- Lugeon test row = 12.5m from centre, spacing 8m (approximately 10 holes), second round split at 8m spacing (approximately 10 holes);
- Drill hole diameter 150mm;
- Maximum deviation at 100m = 1m. Deviation may be measured in selected holes to assess deviation;
- Holes will be incrementally stabilised based upon geological permeability;
- Drilling fluid circulation system will filter colloidal silica fragments; and
- Stop criteria will vary with hydrogeological unit.

The above summary is indicative, and the number of grout holes installed and tests caried out will be open to interpretation and will be confirmed by the final design methodology.

All Stage 2 pre-grouting boreholes will be subject to packer pressure testing to help characterise the ground and specify the grout. The grout is anticipated to be cementitious only. Grouting will be placed at intervals using packers. The grout design will stipulate max pressure to be applied within different strata during the Stage 2 grout works. The Phase 4 Construction Method Statement (CMS) provides further design methodology and controls.

The purpose of the grouting programme is to reduce groundwater interaction with the shaft and to help stabilise the surrounding rock mass.

Daily drilling shift reports will be produced and will summarise control measures implemented including volumes of material pumped, depths of grout holes and validation testing results.

7.2. Groundwater Abstraction and Water Discharge

7.2.1. Groundwater Abstraction

The only potential requirement for abstraction of groundwater would be during the drilling of grout boreholes. It is anticipated based upon the results from the Ground Investigation (GI) works less than 20m3/day of groundwater will be abstracted for short durations during the Phase 4 pre-grout works. All abstracted water would be discharged to the on-site cuttings lagoon.

7.2.2. Water Discharge

All water discharged from the Ladycross Plantation site will discharge to the existing drainage culvert beneath Egton Road. Surface water discharged from the site will comprise:

- clean surface water and field drainage water collected by the site interceptor drainage system;
- treated site surface water that is subject to primary settlement in the attenuation pond, followed by active silt removal and flow via an oil interceptor;
- water will be discharged under an Environment Agency Permit, currently in process.

7.3. Construction Environmental Management Plan

The Phase 4 works will be operated in accordance with the Ladycross Plantation Phase 4 Construction Environmental Management Plan (CEMP) (40-STS-LC-2100-EN-PL-00016).

8. GROUNDWATER AND SURFACE WATER MONITORING SCHEME

Phase 4 works will be operated in accordance with the Ladycross Plantation Phase 4 Groundwater and Surface Water Monitoring Scheme (40-STS-LC-2100-EN-PL-00020). The scheme comprises the following:

- Details of the monitoring locations
- The frequency of monitoring
- Determinants to be analysed for
- Control and Compliance Trigger Values
- Reporting procedures

9. RELATED DOCUMENTS AND REFERENCES

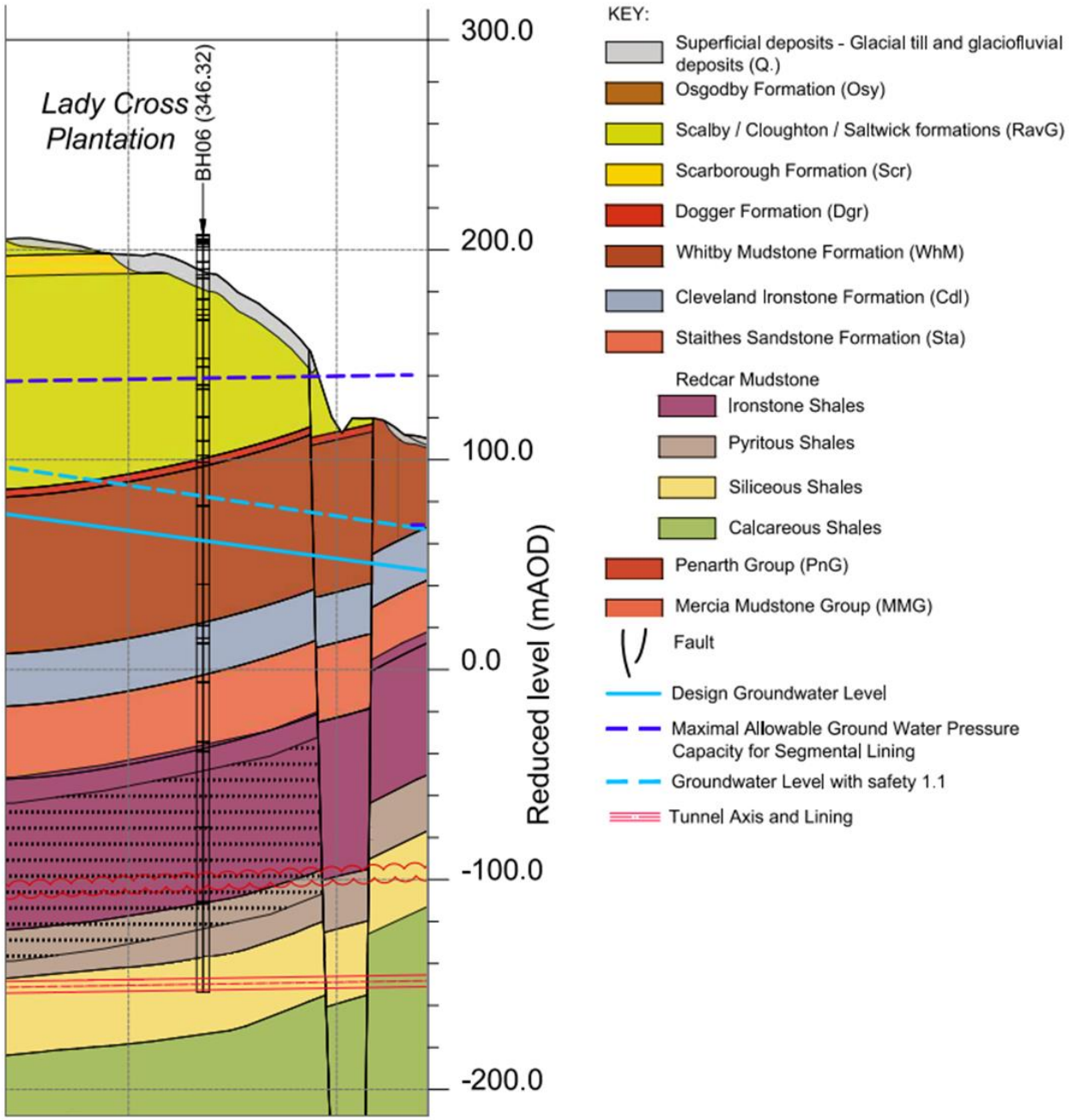
BGS, 2000	Jones, H K, Morris, B L, Cheney, C S, Brewerton, L J, Merrin, P D, Lewis, M A, MacDonald, A M, Coleby, L M, Talbot, J C, McKenzie, A, Bird, M J, Cunningham, J, and Robinson, V K. 2000. The physical properties of minor aquifers in England and Wales. British Geological Survey Technical Report, WD/00/4. 234pp. Environment Agency R&D Publication 68.
40-STS-LC-2100-CN-MS-00004	CONSTRUCTION METHOD STATEMENT - PHASE 4 -NYMNPA CONDITION 94 - LADYCROSS
40-STS-LC-2100-EN-PL-00016	CONSTRUCTION ENVIRONMENTAL MANAGEMENT PLAN - PHASE 4 - NYMNPA CONDITION 93 - LADYCROSS
40-STS-LC-2100-EN-PL-00017	REMEDIAL ACTION PLAN - PHASE 4 – NYMNPA CONDITION 89 - LADYCROSS
40-STS-LC-2100-EN-PL-00020	CONSTRUCTION & OPERATION GROUNDWATER & SURFACE WATER MONITORING SCHEME - PHASE 4 - NYMNPA CONDITION 88 - LADYCROSS

10. DEFINITIONS AND ABBREVIATIONS

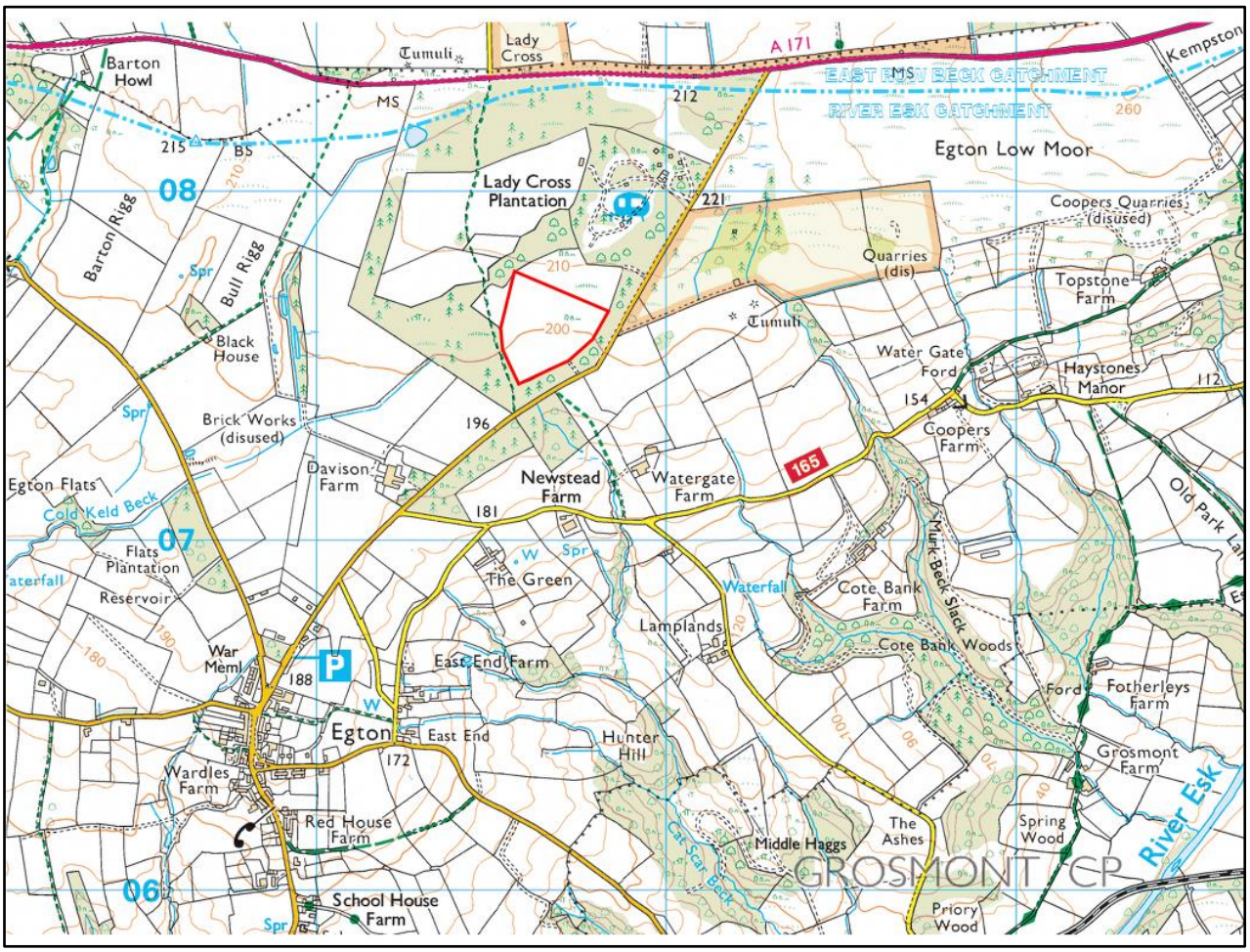
BGS	British Geological Survey
BH	Borehole
HRA	Hydrogeological Risk Assessment
mAOD	Metres Above Ordnance Datum
m bgl	Metres below ground level
MHF	Material Handling Facility
MTS	Mineral Transport System
NYMNPA	North York Moors National Park Authority
RCBC	Redcar and Cleveland Borough Council
TBM	Tunnel Boring Machine

11. ATTACHMENTS

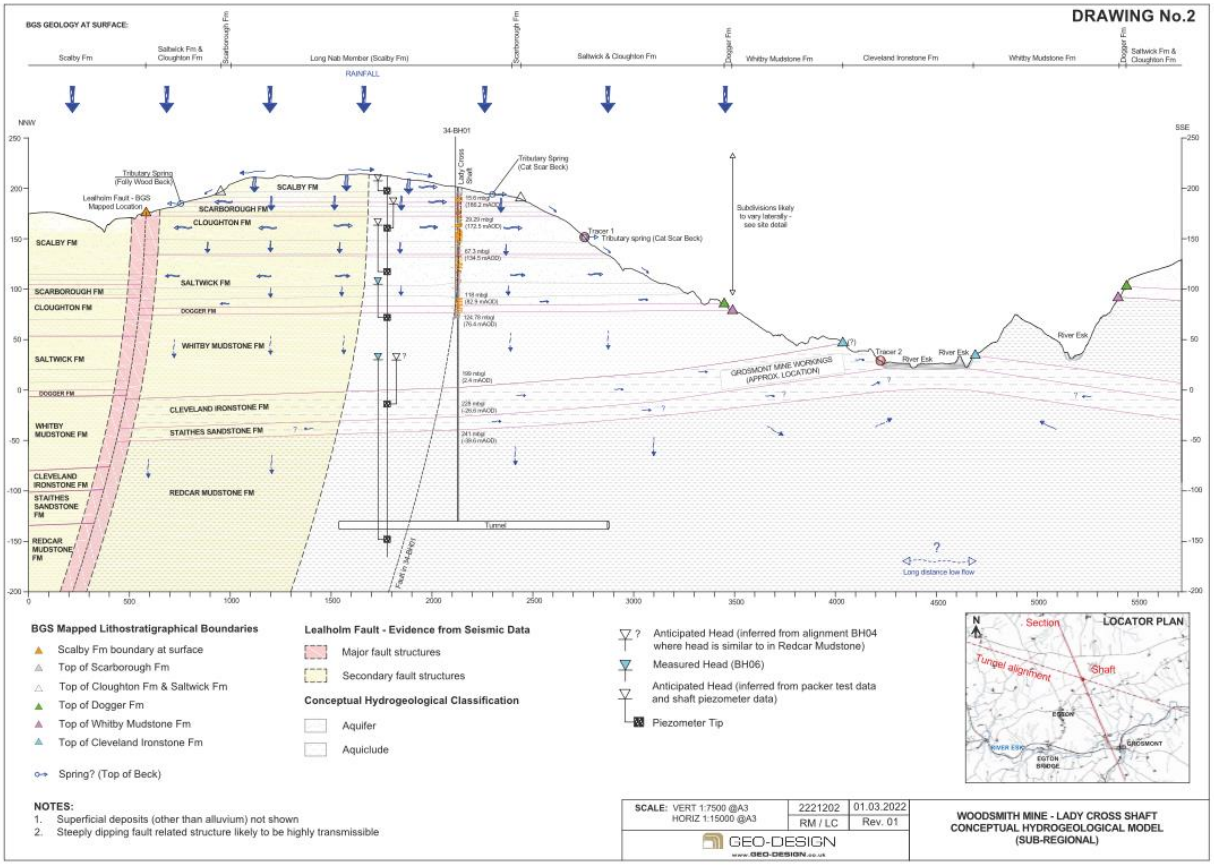
11.1. ATTACHMENT A – GEOLOGICAL SECTION



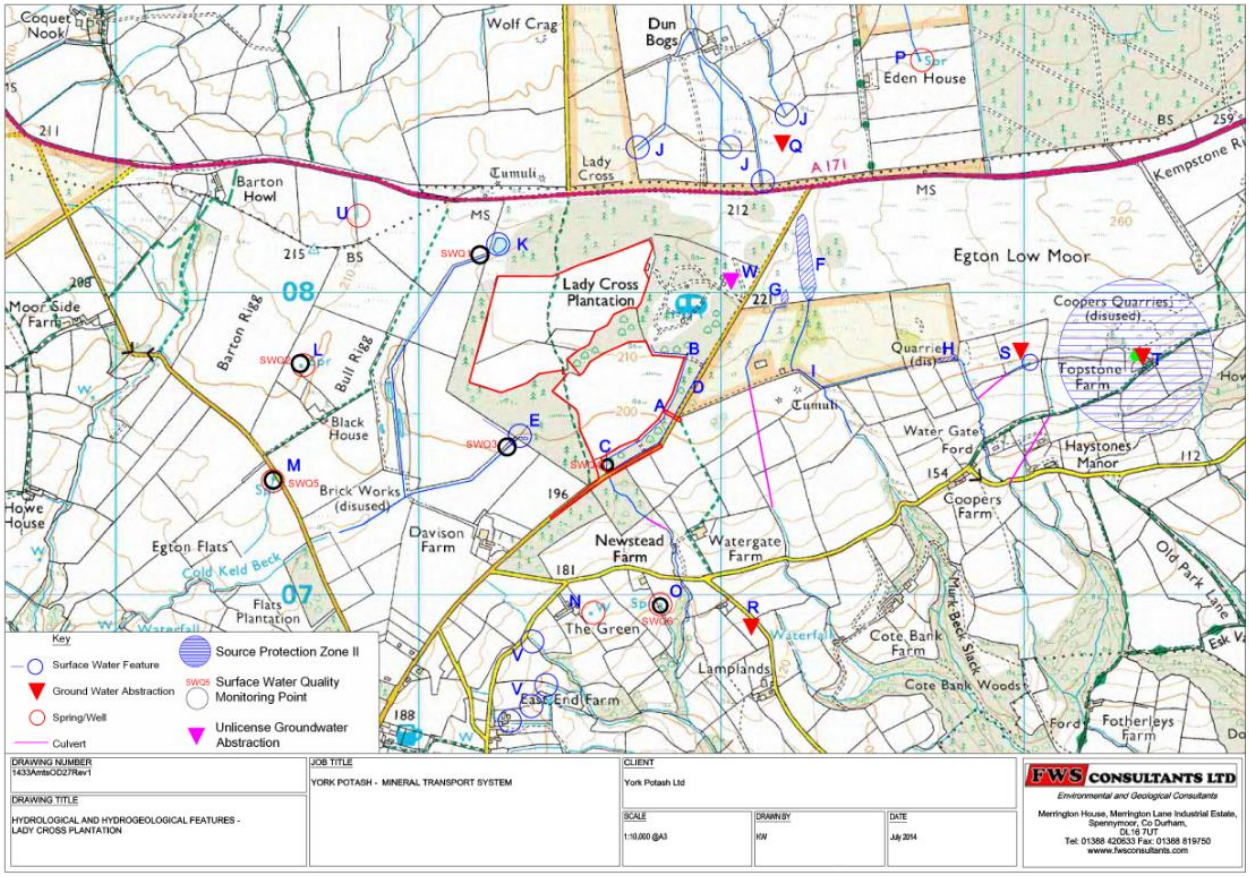
11.2. ATTACHMENT B – LOCAL HYDROLOGY



11.3. ATTACHMENT C – CONCEPTUAL HYDROGEOLOGICAL MODEL



11.4. ATTACHMENT D – POTENTIAL RECEPTORS




York Moors National Park
North York Moors National Park
Location 6_BH401C_onsite borehole
Location 1_Newstead farm
Location 5_Church Cliff
Egton Cemetery
Egton Lane
High Street
North York Moors
North York Moors
Location 3_Grosmont Farm
North York Moors
Location 2_Priory Farm
Location 4_Egton Bridge
River Esk
Old Park Lane
Esk Dale Side

11.5. ATTACHMENT E – RISK ASSESSMENT METHODOLOGY

Assessment of potential development impacts on local hydrology and hydrogeology has been undertaken through a combination of desk-based analysis, site survey work, qualitative and quantitative impact assessment, and consideration of potential impact mitigation requirements. The criteria for determining the significance of effects is based upon the following method:

(i) Assessment of potential receptor sensitivity
(ii) Assessment of potential effect magnitude.
(iii) Determination of potential effect significance

Effect magnitude is considered in relation to the potential impact on the receptor with magnitude defined in a range from negligible to major. The receptor sensitivity is defined as low, medium, or high depending on the specific receptor character on its ability to tolerate change. Effect significance is defined in relation to both effect magnitude and receptor significance. If the significance of the potential impact is Medium or High, then mitigation measures may need to be considered. In considering effect significance account is taken of effect duration; reversibility and compatibility with relevant environmental policies and standards.

Table E1: Methodology for determining sensitivity

Sensitivity	Examples of receptor
High	The receptor/resource has little ability to absorb change without fundamentally altering its present character, or is of international or national importance
Moderate	The receptor/resource has moderate capacity to absorb change without significantly altering its present character, or is of high importance
Low	The receptor/resource is tolerant of change without detriment to its character, is of low or local importance

Table E2: Methodology for determining impact magnitude

Magnitude of impact	Criteria for assessing impact
Major	Total loss or major/substantial alteration to key elements/features of the baseline (pre-development) conditions such that the post development character/composition/attributes will be fundamentally changed
Moderate	Loss or alteration to one or more key elements/features of the baseline conditions such that post development character/composition/attributes of the baseline will be materially changed
Minor	A minor shift away from baseline conditions. Change arising from the loss/alteration will be discernible/detectable but not material. The underlying character/composition/attributes of the baseline condition will be similar to the pre-development circumstances/situation
Negligible	Very little change from baseline conditions. Change barely distinguishable, approximating to a 'no change' situation

Table E3: Impact significance matrix

	Sensitivity		
Magnitude	**High**	**Moderate**	**Low**
Major	High	High-Medium	Medium-Low
Moderate	High-Medium	Medium-Low	Low
Minor	Medium-Low	Low	Low-Very Low
Negligible	Very Low	Very Low	Very Low