Hydrogeological Assessment

Greenhill Primary School, Leeds

SOIL AND STRUCTURES

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Report Status

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Contents

Appointment

Soil and Structures Ltd were instructed by Greenhill Primary School on behalf of Leeds City Council (the Client) in November 2023 to prepare a Hydrogeological Assessment (*the Report*) to assess the ground and groundwater conditions across a partially constructed multi-use games area at Greenhill Primary School, Leeds (*the Site*).

Reliance on the advice presented herein rests solely with the Client.

Scope and Context

The Hydrogeological Assessment (this Report) has been prepared to characterise the groundwater conditions across the Site and locally and through this, an assessment of the viability of draining to ground as part of the proposed drainage strategy for the Site.

With the viability of drainage to ground being anticipated, the boreholes completed as part of the fieldwork are proposed for inclusion as part of the proposed drainage design, completed by others.

Fieldwork

The fieldworks were scoped by Soil and Structures Ltd in advance of the works and dynamically during the fieldworks as an improved understanding of the ground and groundwater conditions developed.

The fieldworks were supervised by the author of the Report.

Background to this Report

This Report is preceded by ground-related reporting. This includes: a "Phase 1 Desk Study Site Investigation Report" and a "Intrusive Site Investigation Report" prepared by Geo Investigate in July 2023 and August 2023 respectively, both referenced G23281.

References

The Hydrogeological Assessment has been written with reference to various sources of opensource information, background data from earlier reporting referenced above and consultation responses in response to the respective planning applications submitted for the development.

The background data is summarised within Section 2.0 of this Report with other key references included as footnotes within each section of the Report.

1.0 The Site and Development Proposals

1.1 The Site

***Location and size**:* The Site comprises a partially constructed multi-use games area (MUGA) that is around 0.050 ha in area (30 m by 15 m pitch area) located within the central portion of the wider Greenhill Primary School campus.

***Surface cover**:* At the point of the fieldworks (December 2023), the Site was covered by an exposed granular sub-base.

***Topography**:* The Site has a topography that slopes very shallowly to the south with the surface of the MUGA falling from 85.30 to 85.10 mAOD across its 30 m length.

1.2 Development Proposals

***Development proposals**:* Development proposals (Figure 1) include for the construction / completion of; the multi-use games area provided a suitable drainage strategy can be developed.

***Drainage strategy**:* The preliminary drainage strategy (as illustrated on Holdgate Consulting drawing ref. 23-719 – D01 – P01) included for a positive outfall to the existing combined sewer network. Following submission of this drainage design, it is understood that Yorkshire Water asserted that drainage to the existing storm sewer was required. Given this sewer was remote from the Site, a packaged pumping system and extensive groundworks were required if and where an alternative, drainage discharge was not able to be confirmed.

At this point, Soil and Structures were consulted to review the available ground-related reporting for the Site and assess the viability of establishing a drainage to ground outfall within the Site boundary.

ⓘ ***Development focused hydrogeological assessments:*** *An appreciation of the construction processes is essential for development-focused hydrogeological assessments given that groundworks stand to alter the hydrogeological regime, e.g. intercepting surface water or groundwater flows, changing the topography or re-directing surface water flow.*

The changing dynamics pre- and post- development are commonly referred to as baseline and endline conditions.

To enable this development, the remaining groundworks are likely to be required, N.B. listing is outline only.

> *Utility Excavations:* Excavation of drainage and other utility alignments <u>including connection into the boreholes installed as part of the fieldwork that was completed as part of this Report.</u> The attenuation for the preliminary drainage design was located within the southern portion of the Site (Figure 1) with the final, proposed location of the attenuation located in the south-western portion of the Site (rationale detailed in this Report).

> *Surfacing:* Construction of new surfacing across the MUGA.

ⓘ ***Pollution potential:*** *The MUGA is expected to carry a low pollution potential with no chemicals expected to be required for routine use and maintenance. The Site itself was initially identified as presenting a pollution potential (or 'moderate to high risk' within the Phase 1 reporting prepared by Geo Investigate based on the potential presence of Made Ground (an infilled quarry) on or adjacent to the Site. The Intrusive Site Investigation Report that followed on from this earlier report, concluded that, "…natural drainage via infiltration will not be able to form part of any SUDS solution for this development" based on the low rates of infiltration recorded with the pollution potential not discussed further. Further commentary on this is presented within this reporting.*

***Consultations**:* No direct consultation with regulatory authorities has been undertaken or is expected to be required in this scenario. It is recommended that this Report is submitted as part of the planning submission for the development (in support of the drainage strategy) with consultations made on that basis.

Figure 1: Site Location and Development Plan

> *Extract from Phase 1 report*
> *Approximate school boundary illustrated by **red line***
> *Approximate location and extent of Multi-Use Games Area (MUGA) illustrated by **purple line and hatching***
> *Centre of MUGA pitch approximately located at NGR 424982 433685*
> *INSERT: preliminary development plan (extract from Holdgate Consulting's Drainage Plan; rev. P01)*

2.0 Site Setting

For full details of the Site setting, it is recommended that reference is made to the: "Phase 1 Desk Study Site Investigation Report" and a "Intrusive Site Investigation Report" prepared by Geo Investigate in July 2023 and August 2023 respectively, both referenced G23281.

The Intrusive Site Investigation Report was scoped to assess the viability of utilising drainage to ground as part of the proposed drainage strategy. As noted within Section 1.2, the report concluded that, "…natural drainage via infiltration will not be able to form part of any SUDS solution for this development".

The following sub-sections present additional commentary on the respective topics.

2.1 History

The Site has been subject to three phases of use prior to being developed as a MUGA.

The first phase of use (1850s to early 1900s) - the Site is mapped being occupied by open fields/land and is located on the edge of two sandstone quarries located south-east and south-west of the Site that were subsequently infilled.

The second phase of use (1920s to 1950s) – the Site is mapped being occupied by open fields/land and is located immediately north of a large nursery building.

The third phase of use (1960s to 2010s) – the Site is mapped being occupied by part of the former, larger footprint of Greenhill Primary School (separate school building) that was subsequently demolished and used as playing fields.

2.2 Geology and Hydrogeology

The Site and entirety of the wider school campus is mapped as being covered by 'infilled ground' with the "Intrusive Site Investigation Report" anticipating the presence of shallow bedrock deposits.

Shallow bedrock (0.50 to 1.10 m) was recorded as part of the intrusive investigation fieldworks however, based on the recorded locations of these boreholes and revealed conditions within the hand excavated trial pits and rotary boreholes completed as part of this Reporting, these sandstone deposits are considered to reflect 'rock fill' deposits rather than weathered or intact bedrock as reported.

Reference is not made to the historic boreholes available for the wider school campus with the existing ground-related reporting. These historical boreholes confirmed:

- The presence of deep fill deposits within the recorded extent of the quarries (seemingly corroborating the desk based mapping records); and,
- Groundwater levels locally to the MUGA resting below the base of the former quarry that is tentatively taken as 15.24 m below ground level noting that evidence of isolated, shallower groundwater seepages was noted north of the former quarries.

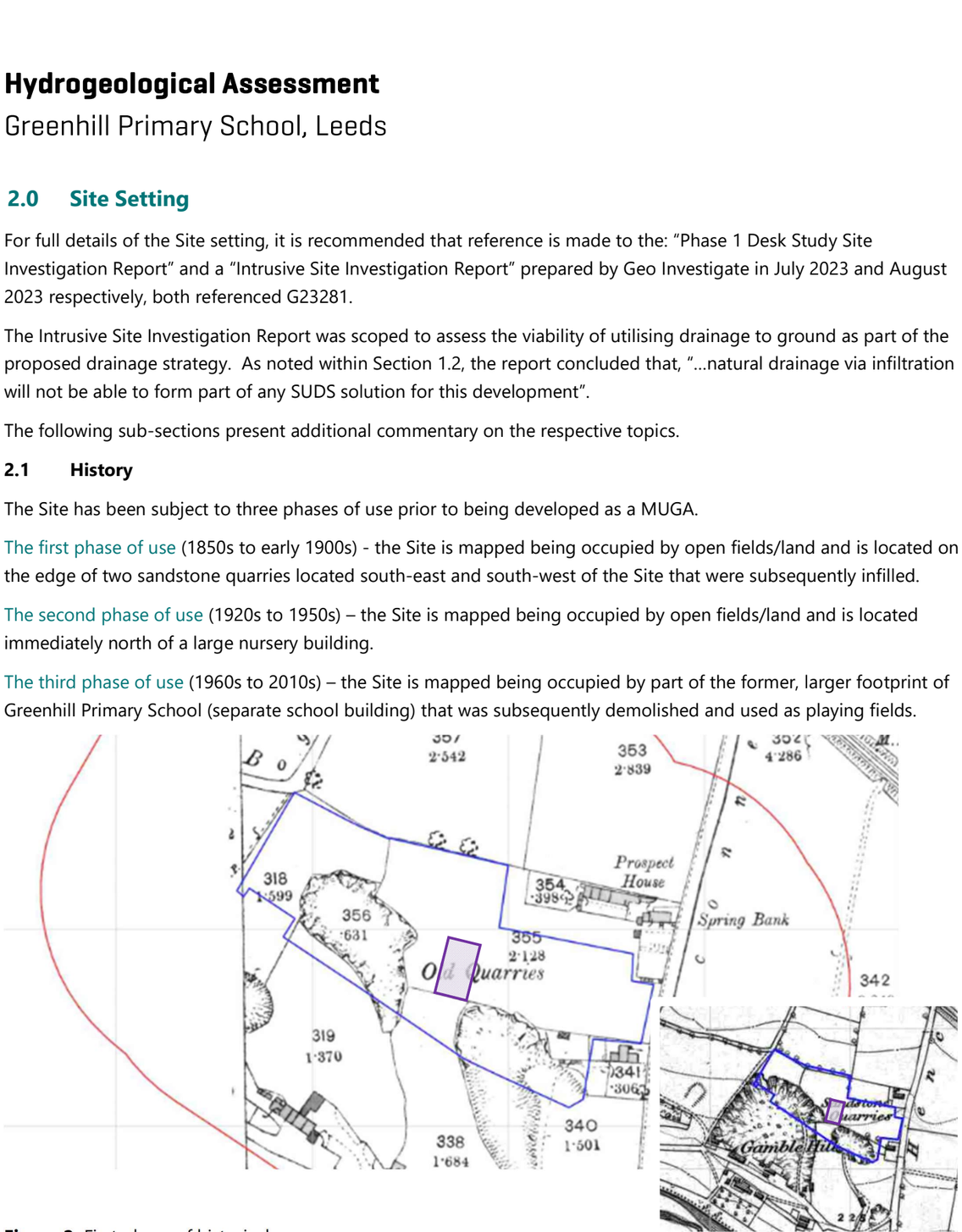


Figure 2: First phase of historical use

- *Extracts from Phase 1 report*
- *Approximate school boundary illustrated by **blue line***
- *Approximate location and extent of Multi-Use Games Area (MUGA) illustrated by **purple line and hatching***

3.0 **Fieldwork -** Intrusive Investigation and Laboratory Testing

The intrusive investigation (Table 1) was designed with reference to: i) the Site setting, ii) the anticipated requirements of the drainage engineer (field trials for the performance of any drainage to ground system), iii) guidance for site investigations[1], and iv) responding to the revealed ground conditions.

> ***Comments on the scope of works:*** *the inconclusive findings of the existing ground-related reporting guided a staged approach to the fieldworks. The first stage was to assess the viability of drainage into the shallow sandstone deposits (as recorded within the existing ground-related reporting).*
>
> *The presence of 'very dense' fill deposits was confirmed to depths of 0.75 and 0.90 m depth within the additional hand pits (and very low rates of infiltration confirmed) that, together with additional desk-based research confirming presence of a deep groundwater surface within boreholes immediately east of the Site, guided the recommendation for rotary boreholes to be completed to profile the actual bedrock surface and perform deeper infiltration testing.*
>
> *Drainage to ground into the intact sandstone deposits was anticipated to be viable and therefore, the aim of the investigation was to confirm the presence of sandstone deposits with infiltration testing performed at least 1.5 m above the recorded groundwater surface to confirm the viability of drainage to ground as part of the drainage strategy.*
>
> *This investigation is considered to have obtained sufficient data to inform design decisions with the standpipes installed as part of the works planned for inclusion as part of the final drainage design (prepared by Holdgate Consulting).*

Access was possible to all areas of the Site.

Table 1: Scope and Rationale of the Intrusive Investigation

Activity	Ref.	Rationale
3 hand excavated trial pits	HP101 to HP103	To further investigate the shallow ground conditions across the Site and to enable in-situ testing. The existing ground-related reporting reported the presence of shallow sandstone deposits but only conducted infiltration testing in one of the two locations where these deposits were encountered. Further testing, at shallow depths, was recommended on the premise that, if intact and natural sandstone was present, then fissure flow (secondary porosity) was anticipated to offer viable rates of drainage with testing of the drainage performance of bedrock guided by multiple test locations rather than
3 rotary auger boreholes	BH101 to BH103	To investigate deeper ground conditions across the Site and, to enable in-situ testing. Monitoring wells / standpipes were installed in each of the boreholes with response zones sealing off the Made Ground from the underlying bedrock deposits.
Variable (falling) head testing in general accordance with current standards[2]	-	To enable rates of infiltration or permeability to be evaluated within the targeted geology. This is one line of evidence to support infiltration potential being assessed. The testing performed is, in effect, a field trial for vertical drainage systems, e.g. borehole drainage. No head of water was able to be maintained or recorded above 1.0 m from the base of the wells under 0.2 litres / second of water flow from a hose pipe indicating 'very fast' rates of infiltration. It should be noted that drainage into unsaturated rocks occurs under very different, typically more complex conditions compared to saturated soils or rocks. Specific attention should be given to the difference between percolation (through pre-saturated soils) and infiltration. In general, percolation occurs at slower rates as infiltration fills existing air voids within the soil or rock. Various studies have suggested that adopting falling head test models (saturated soils) can offer a reliable, if conservative means to estimate drainage rates within unsaturated or partially saturated soil systems. In this scenario, the 'very fast' draining nature of the bedrock lends itself to the discharge rate being evaluated based on the recorded discharge rate (maximum flow rate of 0.2 litres per second) and other lines of evidence. Use of an 'infiltration rate' of 1.0 litres per second is considered to remain conservative in this setting with specific attention given to the fact the same drainage performance was noted in each test location. It is further noted that, in the Author's experience, this infiltration rate is conservative within massive sandstone units such as the Elland Flags.
Logging of soil arisings from exploratory holes	-	The hand excavated trial pits enabled direct logging of the soils to be completed. The use of rotary open hole boreholes means the logging of holes is completed on an indirect basis, assessing the speed and quality of the drill response.

Exploratory hole locations are illustrated on the Ground Model drawings in Section 5.0 with copies of the exploratory hole logs appended (for the rotary boreholes; hand pits are detailed on the Ground Model).

Geotechnical samples were not obtained owing to the nature of the drainage medium (intact bedrock).

Environmental samples were not obtained given the lack of evidence of potentially harmful or polluting material on Site or in the exploratory holes (fill deposits comprise demolition arisings and 'rock fill' both with low pollution potential). Furthermore, sealing of the Made Ground was completed to ensure drainage occurred into the underlying bedrock deposits.

Ground gas monitoring was not undertaken given this was not within the scope of works nor any evidence of bubbling groundwater or odours noted during the fieldworks.

[1] *Code of practice for site investigations. BS 5930 (2015)*

[2] *BS 5930 (2015); BS 22282:2 (2012)*

4.0 Ground and Groundwater Conditions – Anticipated and Revealed

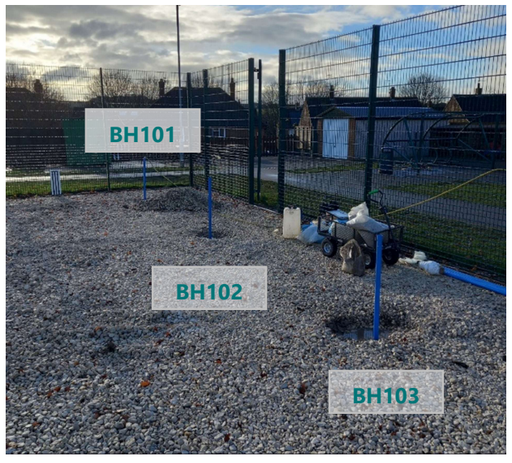
***Anticipated ground and groundwater conditions*:** Based on the Site setting (including the availability of existing ground investigation data) the presence of a shallow bedrock surface (within 1.10 m of the MUGA surface) with 'very dense' fill deposits anticipated above this material.

***Revealed ground conditions*:** The fieldworks undertaken on Site confirmed the anticipated conditions with one variations and five notable observations.

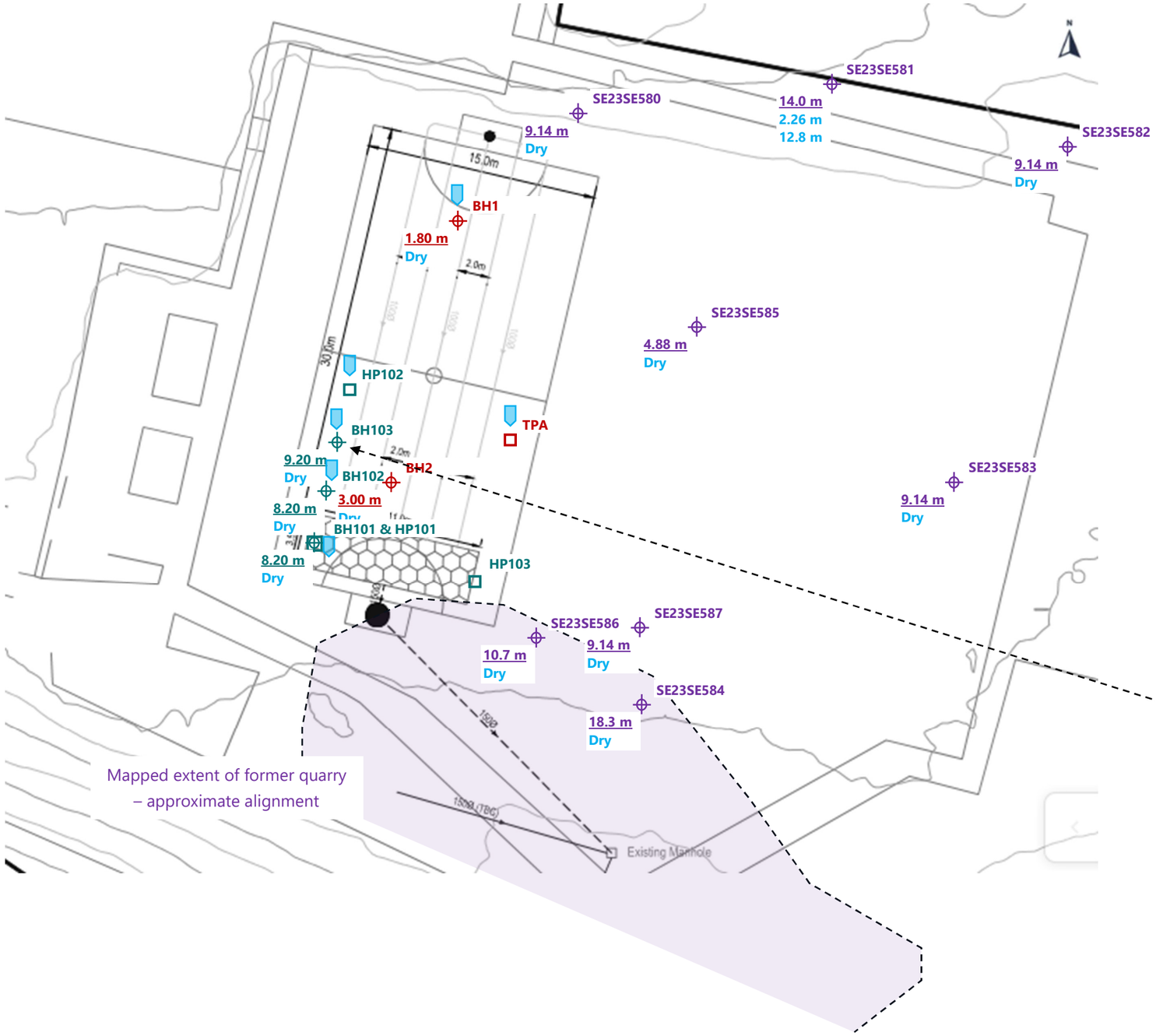
- *Variation:* The intact bedrock profile was confirmed at depths of between 4.0 and 5.0 m below the MUGA surface which varies from those recorded as part of the Geo Investigate fieldworks.

  It is inferred that bedrock logged as part of this earlier investigation was actually 'rock fill' however, it is plausible that a localised 'rock shelf' (a raised area of bedrock within the quarry) was encountered as part of this earlier investigation.
- *Observation 1:* 'very dense' (requiring chiselling) fill deposits were confirmed to depths of between 0.75 and 0.90 m within HP101 and HP102 with HP103 becoming inundated with water;
- *Observation 2:* The depth of fill deposits encountered across the Site was consistent (4.20 to 4.80 m base depth) across the three borehole locations; and,
- *Observation 3:* The deeper bedrock conditions across the three rotary boreholes were consistent with suspected mudstone and siltstone deposits encountered to depths of c. 8.50 m depth;
- *Observation 4:* Groundwater was not encountered to depths of 9.20 m (BH103); and,
- *Observation 5:* 'Very slow to negligible' rates of infiltration were recorded within the shallow fill deposits (HP101 and HP103) and 'very fast' infiltration rates were recorded within each of the boreholes (BH101 to BH103) completed as part of this Reporting. No 'constant head' was able to be maintained within each of the boreholes when 0.2 litres per second (hosepipe) was discharged to ground.

The Ground Model for the Site is presented in Section 5.0 and includes further commentary on the ground conditions.



5.0 **Ground and Groundwater Model** – Plan & Profile

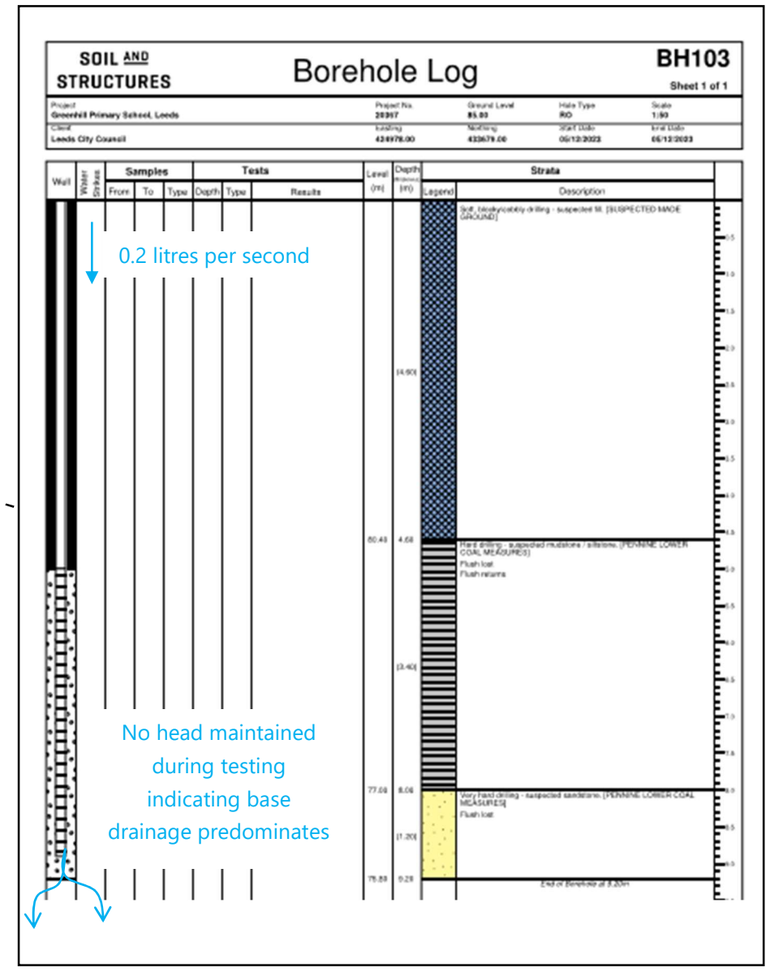


Key

- Historic borehole (Various dates) – locations approximate
- Geo Investigate exploratory hole (July 2023)
- Soil and Structures exploratory hole (December 2023) – starred holes were upgraded within monitoring standpipes.

Exploratory hole notes

9.14 m	Underlined data = base of hole
Blue text	Water strike information
	Infiltration testing location



6.0 Conclusion and Recommendations

6.1 Conclusions

In conclusion, the Hydrogeological Assessment finds that:

> Characterisation of Site: Based on the available information relating to the Site and the immediate surrounding area; the geology, hydrogeology and hydrology is considered adequately characterised to support an assessment of the groundwater regime pre- and post- development.

Whilst unforeseen conditions may exist that could be influencing the groundwater regime, e.g. historic decommissioned drainage runs associated with the playing fields or former school building, these are considered unlikely to be controlling the overall patterns of groundwater movement or else readily managed as part of the development works.

> Infiltration potential: The Site is located over Made Ground deposits that appear to be characterised by shallow demolition arisings associated with the former school buildings over 'rock fill' to depths of around 4.50 m likely placed as part of the historic reclamation works associated with the former quarry.

Below these Made Ground deposits, suspected mudstone and siltstone deposits (intact bedrock) are encountered to depths of around 8.00 m below which suspected sandstone (possible Elland Flags) is encountered.

Whilst the drainage characteristics of the Made Ground and 'rock fill' deposits were found to offer 'very low' rates of infiltration, the deeper intact bedrock deposits were found to offer 'very high' rates of infiltration.

Drainage into the deeper bedrock deposits, above the predicted groundwater table is recommended.

> Groundwater levels and seasonality: The drill depths and thus invert levels for the boreholes were selected as being at least 1 m above the depth of the nearest 'dry' historic borehole that was found to be dry to a depth of 10.7 m below ground level (surface level expected to be similar). Other nearby boreholes recorded 'dry' drilling conditions to a depth of 18.3 m depth within the main body of the quarry suggesting that groundwater levels are deeper.

The rotary drilling works were completed in winter (December) when groundwater is expected to be close to, or approaching, its seasonal limit (generally highest in March).

Taken together, the invert depths of the boreholes are expected to be at least 1 m above the maximum, maintained groundwater level across the Site.

> Pollution potential: As noted within the introduction, the nature of the Site itself was initially identified as presenting a pollution potential (or 'moderate to high risk') within the Phase 1 reporting prepared by Geo Investigate based on the potential presence of Made Ground (an infilled quarry) on or adjacent to the Site.

The Intrusive Site Investigation Report that followed on from this earlier report, concluded that, "…natural drainage via infiltration will not be able to form part of any SUDS solution for this development" based on the low rates of infiltration recorded with the pollution potential not discussed further.

Based on the findings of the various phases of investigation completed across the Site, the pollution potential of the fill deposits (all types) is assessed as low. As part of this assessment, a key line of evidence it the presence of these same fill deposits (and others) within the former quarry alignment resulting in direct pathways having existed between the Made Ground and underlying bedrock aquifer since the cessation of quarrying activities (early 1900s).

Pollution risk is further reduced through the sealing of Made Ground deposits (bentonite seals around pipework) from the deeper bedrock deposits; essentially sealing any potential pathways between the Made Ground and the deeper bedrock deposits.

6.2 Recommendations

Based on the above conclusions; the following recommendations are made:

> Relocation of drainage field: As discussed above, it is recommended that the drainage field is located across the western portion of the proposed MUGA to: i) pick up the borehole discharge wells; and, ii) ensure that discharge takes place as far away from the recorded extent of the quarry.

> Deep infiltration supported by boreholes: It is recommended that the existing boreholes (BH101 and BH103) are incorporated as discharge points / outfalls as part of the proposed drainage design.

It is recommended that a discharge rate of 1 litre per second is allowed for as part of the proposed design.

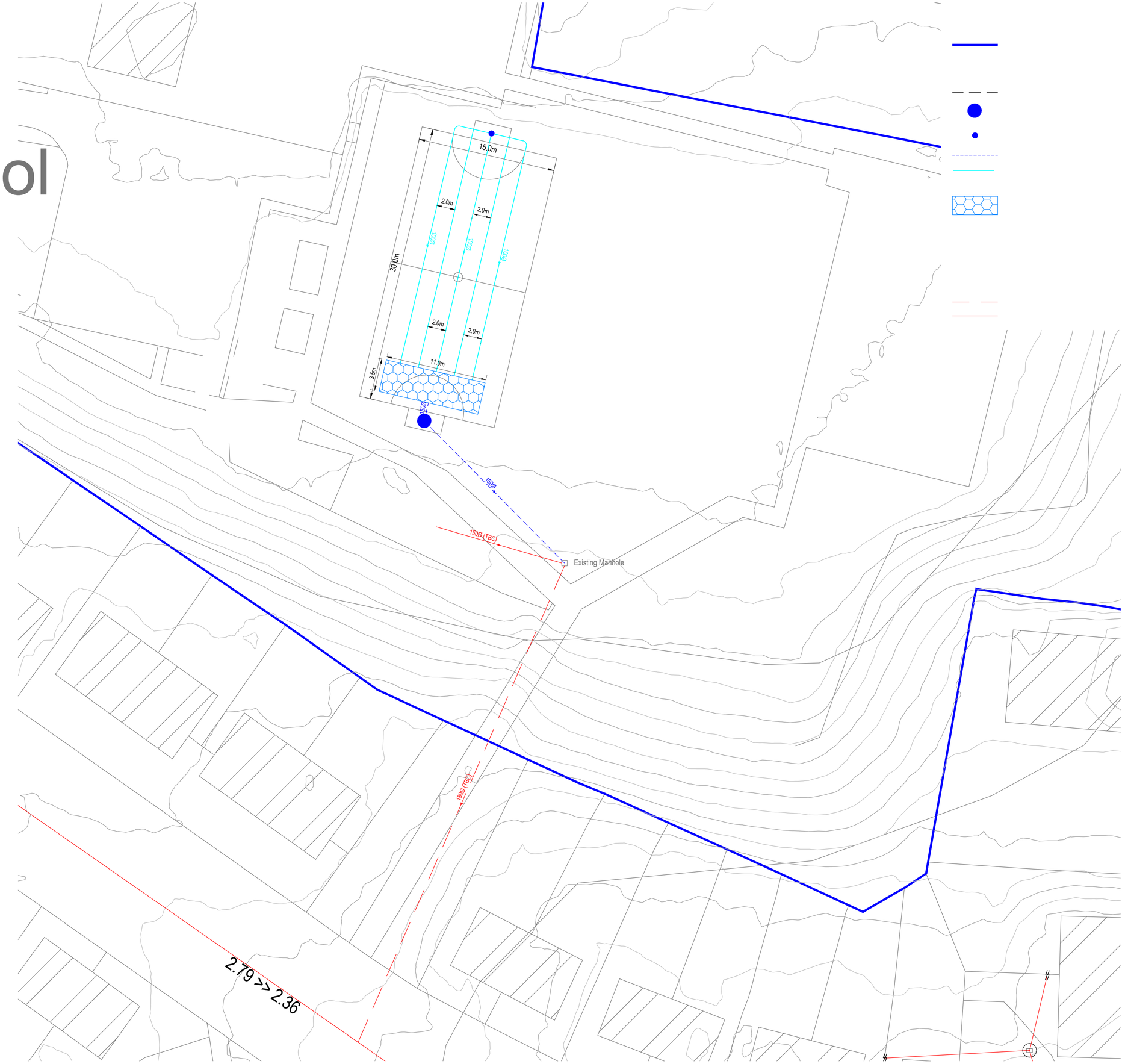
> Protection of boreholes: It is recommended that the existing boreholes (BH101 and BH103) are protected as they are integral to the drainage design.

> Construction details: It is recommended that the existing borehole standpipes are exposed and cut down to the required depth (within the attenuation feature) and the headworks of the borehole (the open cavity) provided with a no-fines granular 'sump' that is fully encapsulated with a suitable silt barrier, e.g. geo-textile, to support continued flows of surface water to enter and discharge via the borehole.

> Unforeseen drainage features: The Site catchment is characterised by three phases of use across which historic land drainage may have been installed and remain in the ground. If present, these features will serve as direct pathways for shallow groundwater flows that may be influencing the natural drainage regime. If and where encountered, they should be investigated fully and a suitable responsive design established, e.g. filling or removal, to remove their influence on the shallow groundwater regime.

It is recommended that this Report is submitted to the project design team for inclusion and submission within the proposed drainage strategy / design for the Site.

School


15.0m
2.0m
2.0m
1000
1000
1000
30.0m
2.0m
2.0m
11.0m
3.5m
1500
1500
1500 (TBC)
Existing Manhole
1500 (TBC)
2.79 >> 2.36

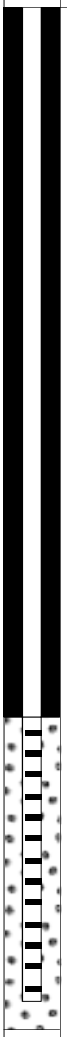
SOIL AND STRUCTURES

Borehole Log

BH101

Sheet 1 of 1

Project	Project No.	Ground Level	Hole Type	Scale
Greenhill Primary School, Leeds	**20367**	**85.00**	**RO**	**1:50**
Client	Easting	Northing	Start Date	End Date
Leeds City Council	**424977.00**	**433670.00**	**05/12/2023**	**05/12/2023**



Well	Water Strikes	Samples From	Samples To	Samples Type	Tests Depth	Tests Type	Tests Results	Level (m)	Depth (thickness) (m)	Strata Legend	Strata Description
									(4.20)		Soft, blocky/cobbly drilling - suspected fill. [SUSPECTED MADE GROUND]
								80.80	4.20		Harder, steady drilling - suspected weathered mudstone / siltstone. [PENNINE LOWER COAL MEASURES]
									(0.60)		Flush lost
								80.20	4.80		Hard drilling - suspected mudstone / siltstone. [PENNINE LOWER COAL MEASURES]
											Flush returns
									(3.40)		
								76.80	8.20		*End of Borehole at 8.20m*

Remarks

Purpose: Installation of vertical drainage well within area suspected to be outside of the former quarry, i.e. within the western portion of the MUGA, whilst remaining at least 1.5 m above recorded groundwater level. Termination: Target depth achieved. Cased to 2.0 m depth. No groundwater encountered - dry on completion. Hole stable with some arisings remaining in the base. GL estimated off drainage plan (P01). Pipework is 35 mm ID PVC.

Logged By RB

SOIL AND STRUCTURES

Borehole Log

BH102

Sheet 1 of 1

Project	Project No.	Ground Level	Hole Type	Scale
Greenhill Primary School, Leeds	**20367**	**85.00**	**RO**	**1:50**
Client	Easting	Northing	Start Date	End Date
Leeds City Council	**424981.00**	**433670.00**	**05/12/2023**	**05/12/2023**

Well	Water Strikes	Samples From	Samples To	Samples Type	Tests Depth	Tests Type	Tests Results	Level (m)	Depth (thickness) (m)	Strata Legend	Strata Description
									(4.80)		Soft, blocky/cobbly drilling - suspected fill. [SUSPECTED MADE GROUND]
											Flush lost
											Flush returns
								80.20	4.80		Hard drilling - suspected mudstone / siltstone. [PENNINE LOWER COAL MEASURES]
									(3.40)		
								76.80	8.20		*End of Borehole at 8.20m*

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0

Remarks

Purpose: Installation of vertical drainage well within area suspected to be outside of the former quarry, i.e. within the western portion of the MUGA, whilst remaining at least 1.5 m above recorded groundwater level. Termination: Target depth achieved. Cased to 2.0 m depth. Water holding at 2.75 m below ground level on completion dropping to 3.75 m on flushing / falling head testing where rate of infiltration of at least 0.2 litres per second was recorded. Hole stable with some arisings remaining in the base. GL estimated off drainage plan (P01). Pipework is 35 mm ID PVC.

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SOIL AND STRUCTURES

Borehole Log

BH103

Sheet 1 of 1

Project	Project No.	Ground Level	Hole Type	Scale
Greenhill Primary School, Leeds	**20367**	**85.00**	**RO**	**1:50**
Client	Easting	Northing	Start Date	End Date
Leeds City Council	**424978.00**	**433679.00**	**05/12/2023**	**05/12/2023**

Well	Water Strikes	Samples From	Samples To	Samples Type	Tests Depth	Tests Type	Tests Results	Level (m)	Depth (thickness) (m)	Strata Legend	Strata Description
									(4.60)		Soft, blocky/cobbly drilling - suspected fill. [SUSPECTED MADE GROUND]
								80.40	4.60		Hard drilling - suspected mudstone / siltstone. [PENNINE LOWER COAL MEASURES] Flush lost Flush returns
									(3.40)		
								77.00	8.00		Very hard drilling - suspected sandstone. [PENNINE LOWER COAL MEASURES] Flush lost
									(1.20)		
								75.80	9.20		*End of Borehole at 9.20m*

0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0 5.5 6.0 6.5 7.0 7.5 8.0 8.5 9.0 9.5 10.0

Remarks

Purpose: Installation of vertical drainage well within area suspected to be outside of the former quarry, i.e. within the western portion of the MUGA, whilst remaining at least 1.5 m above recorded groundwater level. Termination: Target depth achieved. Cased to 2.0 m depth. No groundwater encountered - dry on completion. Hole stable with some arisings remaining in the base. GL estimated off drainage plan (P01). Pipework is 35 mm ID PVC.

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