

Rochdale and Littleborough Flood Risk Management Scheme (FRMS) - Ph1b Littleborough - Discharge of Pre-commencement Planning Conditions - Condition 14: Continuity of Natural Groundwater Drainage

Document no: IMNW000100-JAC-ZZ-4B0-RP-EN-1213
Version: C02

Environment Agency

Littleborough Ph1b - Discharge of Pre-commencement Planning Conditions - Condition 14: Continuity of Natural Groundwater Drainage
7 July 2023



Rochdale and Littleborough Flood Risk Management Scheme (FRMS) - Ph1b Littleborough - Discharge of Pre-commencement Planning Conditions - Condition 14: Continuity of Natural Groundwater Drainage

Client name: Environment Agency

Project name: Littleborough Ph1b - Discharge of Pre-commencement Planning Conditions - Condition 14:
Continuity of Natural Groundwater Drainage

Client reference: N/A **Project no:** B228P008

Document no: IMNW000100-JAC-ZZ-4B0-RP-EN-1213 **Project manager:** Patrick Thompson

Version: C02 **Prepared by:** Harriet Wood

Date: 7 July 2023 **File name:** IMNW000100-JAC-ZZ-4B0-RP-EN-1213

Document status: S4

Document history and status

Version	Date	Description	Author	Checked	Reviewed	Approved
P01	21/06/2023	For Issue	HW	CH	MW	PT
C02	12/07/2023	Final following EA acceptance	HW	CH	MW	PT

Jacobs U.K. Limited

5 First Street
Manchester M15 4GU
United Kingdom

T +44 (0)161 235 6000
F +44 (0)161 235 6001
www.jacobs.com

Copyright Jacobs U.K. Limited © 2023.

All rights reserved. The concepts and information contained in this document are the property of the Jacobs group of companies ("Jacobs Group"). Use or copying of this document in whole or in part without the written permission of Jacobs Group constitutes an infringement of copyright. Jacobs, the Jacobs logo, and all other Jacobs Group trademarks are the property of Jacobs Group.

NOTICE: This document has been prepared exclusively for the use and benefit of Jacobs Group client. Jacobs Group accepts no liability or responsibility for any use or reliance upon this document by any third party.

The Report has been produced strictly in accordance with the following limitations:

This assessment is only applicable to site areas and pile designs highlighted in Section 1, based upon the findings of the ground investigations. The risk assessment should be revised if either the proposed foundation method or construction sequence is amended, or if any unforeseen ground conditions are encountered that are not consistent with the findings of the ground investigation reported within.

Jacobs warrants that the services performed in the production of this report were conducted in a competent and professional manner in accordance with sound consulting practice and procedures. In preparing this report Jacobs relied, in whole or in part, on data and information provided by the Client and third parties; this information not been independently verified by Jacobs and Jacobs has assumed this information to be accurate, complete, reliable, and current. Therefore, while Jacobs has used due skill, care and diligence in preparing this report, Jacobs does not warrant or guarantee the conclusions set forth in this report, which are dependent or based on data, information or statement supplied by third parties or the Client.

The scope of this report is limited to the extent of information available at the time that this report was produced. This report is intended for the Client's sole and exclusive use and is not for the benefit of any third party. It may not be relied upon by any third party without prior written consent of Jacobs. Such consent may be withheld according to Jacobs' sole discretion.

The use of this report or any information contained herein, if by any party other than the Client, shall be at the sole risk of such party. It also shall constitute a release and agreement by such party to defend and indemnify Jacobs and its affiliates, officers, employees, and subcontractors from and against any liability for direct, indirect, incidental, consequential, or special loss or damage or other liability of any nature arising from the party's use of the report or reliance upon any of its content. To the maximum extent permitted by law, such release from indemnification against liability shall apply in contract, tort, (including negligence), strict liability, or any other theory of liability.

This report was prepared in June 2023 and the conclusions and recommendations are provided in general accordance with published legislation, guidance, and appropriate industry practices at the time of writing and have been formulated based upon all information reviewed. Should changes in legislation guidance and / or industry practice occur in the future; the conclusions and recommendations provided may need to be reviewed, changed, or withdrawn. While no duty of care is offered in this respect, it is recommended that Jacobs are further consulted to ensure the appropriate revision of the conclusions and recommendations advised (if required)

In the context of site characterisation undertaken as part of site investigation, sampling, by its very nature, can provide only a general indication of ground and groundwater conditions. Different conditions to those encountered and may be present. The possibility also exists for other conditions to be present on site, including in parts those not subject to specific investigation. In addition, site conditions may also change over time as a result of ongoing anthropological or natural processes.

This report should not be altered, amended, or abbreviated. Jacobs accepts no responsibility for any circumstances that arise from the issue of this report. In addition, this report should be read in full, and no excerpts of this report shall be issued as standalone documents. Any excerpts of the report issued are not considered to be representative of the findings.

Contents

1.	Introduction	1
1.1	Scheme background	1
1.2	This Report	1
1.2.1	Objective.....	1
1.2.2	Strategy.....	1
1.2.3	Structure.....	1
1.3	Planning Conditions	1
1.4	Baseline Environmental Information.....	2
1.5	Construction Phase Drawings and Design Summary	4
2.	Baseline Conditions.....	7
2.1	Introduction.....	7
2.2	Environmental Setting Summary.....	7
2.2.1	Generalised Geological and Hydrogeological information.....	7
2.2.2	Coal Mining.....	8
2.2.3	Ground Conditions	9
2.2.4	Groundwater Conditions	9
2.2.5	Hydrology.....	10
2.3	Structures and Services	10
2.4	Summary	11
3.	Current Design: Groundwater and Surface Drains	13
3.1	Introduction.....	13
3.2	Design Interpretation	13
3.3	Summary of Groundwater Drainage Requirements.....	13
3.3.1	Gale Storage Reservoir.....	13
3.3.2	Greenvale Business Park	13
3.3.3	Grove Lodge	13
3.3.4	Ealees Brook	14
4.	References.....	17

Appendices

Appendix A. Extracts of the proposed Construction (Summary)

Appendix B. Figures: Environmental Characterisation

- B.1 Figure 1: Site Location and Exploratory Hole Plan
- B.2 Figure 2: Site Location and Solid Geology Plan
- B.3 Figure 3: Sheet Pile Location, Superficial Geology, and Hydrogeological Summary Plan

Appendix C. Cross Sections

- C.1 Gale Storage Reservoir
- C.2 Greenvale Business Park
- C.3 Grove Lodge
- C.4 Ealees Brook

Appendix D. Utilities Survey Drawings (GPR and trial trench)

- D.1 Gale Storage Reservoir
- D.2 Greenvale Business Park

Tables

Table 1: Condition of Planning 14

Table 2: Baseline Environmental Information Sources

Table 3: Construction Phase Drawings

Table 4: Construction Works Summary

Table 5: Generalised Geological and Hydrogeological information

Table 6: Ground Conditions Summary

Table 7: Groundwater Conditions

Table 8: Structures and Services on the flood barrier installation 'dry side'

Table 9: Design Interpretation

1. Introduction

1.1 Scheme background

The Environment Agency, (hereafter referred to as the 'EA'), are proposing a Flood Risk Management Scheme (FRMS) to manage flood risk for the towns of Rochdale and Littleborough over the next 100 years. The Project is known as the Rochdale and Littleborough FRMS.

The project is located in Littleborough and Rochdale, Greater Manchester. The scheme will be delivered in two phases: Phase 1 - Littleborough and Phase 2 – Rochdale. The Phase 1 works have been further split into Phase 1a and Phase 1b.

Phases 1a and 1b are focussed on the upstream town of Littleborough delivering new linear flood defences and a new flood storage basin, providing online flow control and volume storage, protecting homes and businesses within the flood risk zone up to the design event of 1% Annual Exceedance Probability (AEP), or 1 in 100-year flood event. The Phase 1b Works are being undertaken at six development areas, comprising the following sites.

- Impounding Reservoir: Gale Storage Reservoir (west);
- Impounding Reservoir: Gale Storage Reservoir (east);
- Linear Defences: Greenvale Business Park (east bank) and Centre Vale (west bank); and
- Linear Defences: Grove Lodge;
- Linear Defences: Ealees Brook; and
- Linear Defences: Shottwood Fold and Reddyshore Brow.

1.2 This Report

1.2.1 Objective

The objective of this report is to provide an assessment to demonstrate to both the scheme designer and planning authority that provision has been made to allow continuity of natural groundwater drainage to watercourses from the dry side of the flood defences under normal (non-flood) flow conditions. This report will also identify if any design change is necessary. For further information refer to Table 1.

1.2.2 Strategy

All information relating to the environmental baseline is contained in the documents listed in Table 2, but many of these documents do not combine the environmental baseline and the detailed construction and/or design information (as listed in Table 3). This report collates all of the existing environmental baseline and construction information in order to meet the objectives set out in Section 1.2.1.

1.2.3 Structure

The remainder of this report is structured cognisant of the Condition of Planning 14, as summarised in Table 1.

1.3 Planning Conditions

Rochdale Borough Council planning authority have provided 22 Conditions of Planning (CoP) associated with Phase 1b of the Rochdale and Littleborough Flood Risk Management Scheme. (Planning Application Ref. 22/00485/FUL).

This submission relates to CoP 14 only, which should be discharged prior to construction work associated with the linear defences and reservoirs only (excluding Shottwood Fold and Reddyshore Brow). The CoP is reproduced in Table 1.

Table 1: Condition of Planning 14

Condition 14	Section
No works to install the impermeable flood barriers and storage reservoir shall take place until a scheme of detailed design has been submitted to and approved in writing by the Local Planning Authority. The scheme shall demonstrate that provision has been made to allow continuity of natural groundwater drainage to watercourses from the dry side of the flood defences under normal (non-flood) flow conditions. The scheme shall include: The development thereafter shall be implemented in strict accordance with the approved details.	Section 1
1. Evidence of the geology and 'dry side' groundwater levels near structures and services on the 'dry side' prior to flood barrier installation'.	Section 2
2. Details of level and location of the groundwater and surface drains to be installed to prevent groundwater levels on the dry side of the barrier rising to the extent they would interfere with services, structures, or amenity.	Section 3
3. Positions of neighbouring services, buildings, and chambers etc, showing the reduced basal levels of those features and the invert levels of the permeable drains installed to protect them from interference by groundwater.	
4. Cross sections through each proposed barrier, showing reduced ground and river levels; geology; depth of flood barrier structure; pre-development groundwater levels; and basal levels of proximal third party below ground structures.	
5. Where groundwater drains are required, additional plans showing the proposed line and level relative to those structures, along with the location and nature of any non-return valves and access points for maintenance of the drains.	

1.4 Baseline Environmental Information

Jacobs (Land Quality, Hydrogeology and Hydrology) has prepared the documents listed in Table 2 (unless otherwise indicated), which have been collated to provide a summary of the baseline information.

Table 2: Baseline Environmental Information Sources

No.	Report	Reference	Area	Information
1	Desk study/ GIR	Rochdale and Littleborough Flood Risk Management Scheme – Phase 1 Littleborough, Environment Agency, Ground Investigation Report, IMNW000100-JAC-ZZ-4B0-RP-GT-0001 C03, Jacobs May 2023	Impounding reservoir and linear defences	Geological, hydrogeological information Ground Investigation and Environmental monitoring (including groundwater elevations)
2	EIA Geology, Soils and Groundwater chapter	Rochdale & Littleborough Flood Risk Management Scheme – Phase 1b Littleborough, Environment Agency, Environmental Statement, IMNW000100-JAC-ZZ-4B0-RP-EN-0097, C06, Jacobs, April 2022,	Impounding reservoir and linear defences	As per Reference No. 1 Ground Investigation and Environmental monitoring (including groundwater elevations)

Rochdale and Littleborough Flood Risk Management Scheme (FRMS) - Ph1b Littleborough -
Discharge of Pre-commencement Planning Conditions - Condition 14:
Continuity of Natural Groundwater Drainage

No.	Report	Reference	Area	Information
		Chapter 12 – Geology, Soils and Groundwater,		
3	EIA Surface Water Environment chapter	Rochdale & Littleborough Flood Risk Management Scheme – Phase 1b Littleborough, Environment Agency, Environmental Statement, IMNW000100-JAC-ZZ-4B0-RP-EN-0097, C06, Jacobs, April 2022, Chapter 5 – Surface Water Environment,	Impounding reservoir and linear defences	Assessment of potential impact on flood risk, fluvial geomorphology and water quality
4	EIA Flood Risk Assessment Appendix	Rochdale & Littleborough Risk Management Scheme - Phase 1b Appendix A8.2 - Flood Risk Assessment IMNW000100-JAC-00-4B0-RP-EN-0003 C03 Jacobs, March 2022	Impounding reservoir and linear defences	Background information and flood risk assessment
5	Supplementary Environmental Risk Assessment and Piling Assessment	Littleborough Phase 1b Supplementary Environmental Risk Assessment and Piling Risk Assessment IMNW000100-JAC-ZZ-4B0-RP-EN-1212, C01, Jacobs, April 2023	Impounding reservoir and linear defences	Relevant characterisation information is summarised in Section 2
6	Design Document	Gale Flood Defence Reservoir Acid Mine Drainage - Site Characterisation and Remediation Options, IMNW000100-JAC-IR-4C0-RP-EN-0001, P01, Jacobs, August 2020	Impounding reservoir only	Background information and Groundwater logging data (March 2020 to October 2020)
7	Design Document	Rochdale & Littleborough Flood Risk Management Scheme Gale Flood Defence Reservoir Acid Mine Drainage Addendum Site Characterisation Report IMNW000100-JAC-IR-4C0-RP-EN-0002 P02, Jacobs, December 2021	Impounding reservoir only	Background information and Groundwater logging data (March 2020 to October 2020)
8	GIR	Rogers Geotechnical Services Ltd, 2020. Grove Lodge GIR, Rogers Geotechnical Services Ltd, C690/20/E/1174_FINAL, 8/10/20, IMNW000100-JAC-ZZ-4C1-IE-GT-0001	Grove Lodge	Geological, hydrogeological information. Ground Investigation and Environmental monitoring (*)
9	GIR	Rogers Geotechnical Services Ltd, 2017. Land Off Canal Street, Ealees, Littleborough, G1: Rogers Geotechnical Services Ltd (report ref: J3678/16/E, January 2017),	Ealees Brook.	Geological, hydrogeological information. Ground Investigation and Environmental monitoring (*)

No.	Report	Reference	Area	Information
		IMNW000100-JAC-ZZ-4H0-IE-GT-0001		
10	GPR survey results	Precision Utility Mapping, 2018. River Roch Type B Surveys (IMNW000100-JAC-ZZ-4C0-IE-Z-0014)	Gale Storage Reservoir	Results of GPR surveys to determine position and depth of services at selected locations
11	GPR survey results	Precision Utility Mapping, 2018. River Roch Type B Surveys (IMNW000100-JAC-ZZ-4E0-IE-Z-0007)	Greenvale Business Park	Results of GPR surveys to determine position and depth of services at selected locations
12	Slit trench information	Precision Utility Mapping, 2019. River Roch Trial Pits (IMNW000100-JAC-ZZ-4C0-IE-Z-0015)	Gale Storage Reservoir	Results of trial pits to determine position and depth of services at selected locations
13	Slit trench information	Precision Utility Mapping, 2019. River Roch Trial Pits (IMNW000100-JAC-ZZ-4E0-IE-Z-0008)	Greenvale Business Park	Results of trial pits to determine position and depth of services at selected locations
(*) note the construction contractor is to undertake further site investigation, but there is adequate ground investigation information for concept design				

1.5 Construction Phase Drawings and Design Summary

The construction design data sources used as part of the assessment are listed in Table 3.

Table 3: Construction Phase Drawings

Development Areas	Relevant Design Drawings
Impounding Reservoir: Gale Storage Reservoir (west); Impounding Reservoir: Gale Storage Reservoir (east);	- Gale Storage Reservoir Proposed Site Layout - IMNW000100-JAC-IR-4C0-DR-C-0301, C04 - Gale West Sheet Pile Key Plan and Plastic Pile Setting Out IMNW000100-JAC-IR-4C0-DR-C-0125, C01 - Gale Steel Sheet Pile Schedules and SOPs (Excluding Dam Wall) IMNW000100-JAC-IR-4C0-DR-C-0126, C01 - Gale West Embankment Plan IMNW000100-JAC-IR-4C0-DR-C0301, C04 - Gale Storage Reservoir Embankment Sections IMNW000100-JAC-IR-4C0-DR-C-0320, C04 and IMNW000100-JAC-IR-4C0-DR-C-0321, C03 - Gale West Spillway and Stilling Basin Sections and Details IMNW000100-JAC-IR-4C0-DR-C-0341, C04, IMNW000100-JAC-IR-4C0-DR-C-342, C04, IMNW000100-JAC-IR-4C0-DR-C-0343 C04 - Gale West Outlet Structure - IMNW000100-JAC-IR-4C0-DR-C-0501, C04 - Gale West Reservoir Sheet Piled Wall Cross Sections – IMNW000100-JAC-IR-4C0-DR-C-0370, C04 - Gale East General Arrangement Plan- IMNW000100-JAC-IR-4C0-DR-C-0901, C04

Development Areas	Relevant Design Drawings
	- Gale East Diversion Structure General Arrangement - IMNW000100-JAC-IR-4C0-DR-C-0930, C02 - Gale East Diversion Structure Sections - IMNW000100-JAC-IR-4C0-DR-C-0931, C03 and IMNW000100-JAC-IR-4C0-DR-C-0932, C02
Linear Defences: Greenvale Business Park (east bank) and Centre Vale (west bank);	- Greenvale Business Park - IMNW000100-JAC-DW-4E0-DR-C-0001-A4-C04, IMNW000100-JAC-DW-4E0-DR-C-0002-A4-C04, IMNW000100-JAC-DW-4E0-DR-C-0003-A4-C04 and IMNW000100-JAC-DW-4E0-DR-C-0004-A4-C05 - Greenvale Business Park indicative cross sections - IMNW000100-JAC-DW-4E0-DR-C-0100-A4-C05, IMNW000100-JAC-DW-4E0-DR-C-0101-A4-C05, IMNW000100-JAC-DW-4E0-DR-C-0102-A4-C05, IMNW000100-JAC-DW-4E0-DR-C-0103-A4-C05 and IMNW000100-JAC-DW-4E0-DR-C-0105-A4-C03.
Linear Defences: Grove Lodge;	- Grove Lodge - IMNW000100-JAC-DW-4C1-DR-C-0001-A4-C05 - Grove Lodge indicative cross-sections - IMNW000100-JAC-DW-4C1-DR-C-0100-A4-C05
Linear Defences: Ealees Brook.	- Ealees Brook - IMNW000100-JAC-DW-4H0-DR-C-0001-A4-C04 - Ealees Brook indicative cross section - IMNW000100-JAC-DW-4H0-DR-C-0100-A4-C04
Linear Defences: Shottwood Fold / Reddyshore Brow	Not applicable as no engineering features likely to cause change to continuity of natural groundwater drainage

The works have been designed by Jacobs. The Contractor is expected to be Volker Stevin. See the Phase 1B Scope for details (refer IMNW000100-JAC-ZZ-4B0-SP-C-0004).

The proposed Phase 1b works are summarised in Table 4, which denotes where sheet piles are to be included within the development, which are the engineering features most likely to cause a change to continuity of natural groundwater drainage. Pertinent extracts of the proposed construction design are included in Appendix A.

It should be noted that this assessment is concerned only with those sheet piles that constitute impermeable flood barriers rather than short lengths of sheet piling that form part of the foundations for other structures. For clarity, this assessment does not assess any piling required for temporary works which are the responsibility of the Contractor.

Table 4: Construction Works Summary

Site Name	Summary of Proposed Design	Pile Foundation
Gale Storage Reservoir (west)	- Raised reservoir with earth embankments (plastic piles to be used for field drain cut-off and if not possible a 1m deep core trench is to be considered). - Diversion of River Roch and creation of new Greenvale Brook overflow channel - Grasscrete spillway into Greenvale Brook / access tracks - Gale west reservoir embankment with sheet pile walls alongside railway corridor - Gale west flow control structure, including sheet pile wing wall at inlet and outlet and also sheet piles for cut-off - Sheet piled wall adjacent to new Greenvale Brook stilling basin - Sheet Pile at spillway transition retaining walls	<u>Steel sheet piles</u> - 4m to 11m embedment length - Approximate sheet pile lengths are: <u>Gale West</u> - Reservoir Sheet Pile Wall (298m long sheet pile wall) - Spillway and Stilling Basin Walls (4 walls) - o Spillway Transition Retaining Walls (14m (East) and 13m (West) long sheet pile walls) - o Stilling Basin Pile Wall (109m long sheet pile wall) - o Spillway Downstream Transition Wall (10m long sheet pile wall) <u>Gale West Flow Control Structure</u> - Outlet Wing Walls (2 x 6m long sheet pile wall) - Inlet Wing Walls (2 x 7m long sheet pile wall) - Cut-off Wall (22m long sheet pile wall)
Gale Storage Reservoir (east)	- Gale east diversion structure including sheet pile cut-off - Earth embankment spillway (short plastic piles to be used for field drain cut-off, if not possible 1m deep core trench to be considered)	<u>Steel sheet piles for cut-off</u> - 5.0m embedment length - Approximate sheet pile length is 18m
Centre Vale Linear Defences	- Removal of existing flood defence bank - Linear defence (earth embankments) along right bank with filter drain, 1m deep cut-off and shallow foundation - Access track / trash posts in channel - Creation of shallow wetland ponds	- Transition to sheet piling at southern end
Greenvale Business Park Linear Defences	- Flood defence walls with sheet piling along both banks of river - Reinforced channel slopes and installation of rip rap - Reinforced concrete inlet structure on upstream face of access bridge.	<u>Steel sheet piles</u> - Headwall: between 11.0 and 14.0m embedment depth - Embankment: 10m embedment depth - Southern extent: between 12m and 15 embedment depth <u>Approximate sheet pile lengths are:</u> - 135m (west bank) - 200m (east bank) - 15m (east bank, north)
Grove Lodge Linear Defences	- Sheet piling alongside eastern boundary - Modifications to watercourse banks and creation of wetland habitat	<u>Steel sheet piles</u> - 11m embedment depth - Approximate sheet pile length is 197m
Ealees Brook Linear Defences	- Flood defence walls and sheet piling to along south bank of river - Precast concrete headwall with filter drains for groundwater seepage management behind sheet pile	<u>Steel sheet piles</u> - 9m embedment depth - Approximate sheet pile length is 78m
Reddyshore Brow/Shottwood Fold Linear Defences	Approximately 85m of reprofiled/reconstructed channel banking, located on the left bank	No piling works and therefore scoped out of further assessment
Grey denotes areas scoped out of assessment as no engineering features are likely to cause change to continuity of natural groundwater drainage		

2. Baseline Conditions

2.1 Introduction

This section documents the CoP 14 requirement 1, specifically: "the evidence of the geology and 'dry side' groundwater levels near structures and services on the 'dry side' prior to flood barrier installation".

The assessment has been undertaken for the following sites (Refer to Table 4).

- Gale Storage Reservoir (west);
- Gale Storage Reservoir (east);
- Greenvale Business Park (Linear Defences);
- Grove Lodge (Linear Defences); and
- Ealees Brook (Linear Defences).

2.2 Environmental Setting Summary

The environmental characterisation information is summarised in composite sub-catchment level plans (Appendix B) and the proposed engineering infrastructure plans and cross sections presented in Appendix C.
[Appendix B](#)

- Figure 1: Site Location and Exploratory Hole Plan
- Figure 2: Site Location and Solid Geology Plan
- Figure 3: Sheet Pile Location, Superficial Geology, and Hydrogeological Summary Plan

The plans include the ground investigation locations (denoting where monitoring wells are installed) the proposed flood defence infrastructure, pertinent geological, hydrological, hydrogeological characterisation information, and the identified sensitive dry side subsurface and surface receptors (structures and services).

[Appendix C](#)

- Gale Reservoir: IMNW000100-JAC-ZZ-4C0-DR-GT-0011 (Plan) / IMNW000100-JAC-ZZ-4C0-DR-GT-0012 (Cross Section)
- Greenvale Park: IMNW000100-JAC-ZZ-4E0-DR-GT-0004 (Plan) / IMNW000100-JAC-ZZ-4E0-DR-GT-0005 (Cross Section)
- Grove Lodge: IMNW000100-JAC-ZZ-4C1-DR-GT-0001 (Plan) / IMNW000100-JAC-ZZ-4C1-DR-GT-0002 (Cross Section)
- Ealees Brook: IMNW000100-JAC-ZZ-4H0-DR-GT-0001 (Plan and Cross Section)

The cross sections include the proposed engineering design, the ground investigation locations (relevant borehole response zone), and the subsurface geological and hydrogeological conditions.

2.2.1 Generalised Geological and Hydrogeological information

The generalised geological and hydrogeological information is summarised in Table 5.

Table 5: Generalised Geological and Hydrogeological information

Strata	Description
Made Ground/	- Gale Storage Reservoir (west): Predominantly shallow reworked natural ground - Gale Storage Reservoir (east): Made ground not encountered in piling area - Greenvale Business Park: (recorded historic landfill): Present in the majority of exploratory locations: comprising gravelly sand or gravel with cobbles to depths of 0.6 to 4m. Cobbles and gravel generally comprised sandstone, dolerite, concrete, brick and slag. In the northeast of the area, anthropogenic material comprising carpet, plastic, brick, glass and ceramics was recorded to depths of 0.2 to 0.7m. - Centre Vale: Made ground was not encountered during ground investigation - Grove Lodge: Made ground was not encountered during ground investigation - Ealees Brook: Made ground comprising gravelly sand with ash, clinker and/or brick to depths of 2m.
Superficial Geology	Refer Figure 3 - Alluvium (silt, clay and sand with gravel and peat lenses and alluvial fan deposits comprising sand and gravel), overlying - Glacial till (Sandy gravelly clay with cobbles). The alluvium is designated as a Secondary A aquifer, which are described as permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. The glacial till is designated as a Secondary (Undifferentiated) aquifer, which are described as where it has not been possible to attribute either category A or B to a rock type. There are no recorded superficial groundwater abstractions in the study area.
Bedrock Geology	Refer Figure 2 - Interbedded mudstone, siltstone and sandstone of the Carboniferous Pennine Lower Coal Measures (PLCM). - Grove Lodge is underlain by older sandstones from the Millstone Grit Group. The bedrock in the study area is designated as a Secondary A aquifer. There are no recorded bedrock groundwater abstractions in the study area.

2.2.2 Coal Mining

The study area is within the Coal Authority (CA) reporting area and has been subject to extensive known or probable below-ground coal extraction. Much of the study area is characterised by the presence of coal outcrops or shallow coal deposits. However, there are no known coal mine entries, shallow worked coal seams or known coal seams under the majority of the development footprint, other than described below:

- There is a workable coal outcrop (the Lower Mountain seam) recorded to outcrop approximately 50m to the north of Ealees Brook and is between around 5-6m below rockhead on site and there are a small number of nearby abandoned mine plans.
- The Upper Foot seam and Lower Mountain Coal seam are mapped to sub-crop in the solid geology beneath the Gale site. There were no reports of evidence of historical coal workings.

There are three recorded, measured, observed, or anecdotal areas of sub-artesian or artesian groundwater impacted by suspected acid mine drainage (AMD) at the Gale, Grove Lodge and Greenvale Business Park sites, as summarised in Table 7.

2.2.3 Ground Conditions

The ground conditions have been summarised from the available ground investigation information and are summarised in Table 6.

Table 6: Ground Conditions Summary

	Made Ground	Alluvium – Cohesive	Alluvium - Granular	Glacial Till	Bedrock
	General Thickness (m) or mBGL				
Gale Storage Reservoir (west and east)	0.2-2.3m	>0.5-7.0m (with peat)	>0.5-22.0m	1.4-13m	12.6mbgl to 25.3mbgl
Greenvale Business Park Linear Defences	0.5 to 4.5m	0-5.6m	6->18m	Not proven	>20mbgl
Grove Lodge Linear Defences	0.3	>2m	>5.15m	Not proven	>5.45mbgl
Ealees Brook Linear Defences	0.5-2m	0.75-2m	>1.06->7.5m	Not Proven	>8.45mbgl

The most recent BGS mapping indicates a buried channel located within the scheme area. It is anticipated that this glacial buried channel is infilled with alluvial fan deposits and possibly glacio-lacustrine deposits, with depth to the underlying bedrock being variable.

2.2.4 Groundwater Conditions

The ground conditions have been summarised from the available ground investigation information and are summarised in Table 7.

Table 7: Groundwater Conditions

	Groundwater Elevations	Groundwater AMD	Groundwater Interpretations
Gale Storage Reservoir (west)	North: recorded artesian groundwater (1m above ground level) Centre: recorded sub-artesian groundwater at levels of 0.4 to 0.6mbgl; South: recorded groundwater at levels between 0.8 -1.2mbgl.	AMD / artesian groundwater conclusively established.	Groundwater was encountered near ground level across the site and the shallow groundwater in the alluvial deposits is in hydraulic continuity with the River Roch and Greenvale Brook. Based upon the recorded groundwater levels, it is inferred that the alluvial deposits and solid geology groundwater are in hydraulic continuity. Groundwater flow within the drift and shallow bedrock deposits has been established to flow to the south
Gale Storage Reservoir (east)	Recorded sub-artesian groundwater at levels of 0 to 0.6mbgl.		

	Groundwater Elevations	Groundwater AMD	Groundwater Interpretations
Greenvale Business Park Linear Defences	Groundwater strikes were recorded at 1.5 to 8.6mbgl, with the shallower strikes recorded in the area of the access bridge. These were recorded in made ground, cohesive alluvium and granular alluvium. Resting groundwater levels were recorded at 0.18 to 0.74mbgl.	One ochreous discharge observed on the left bank of the River Roch, downstream of site and there is anecdotal evidence of orange staining at a monitoring borehole associated with artesian groundwater. Groundwater not analytically proven to be iron impacted.	Groundwater strikes were generally encountered within the granular alluvium deposits between 1.50mbgl and 4.5mbgl, and the overlying cohesive alluvium deposits may be acting as a semi-confining layer. Potentiometric groundwater monitoring in borehole standpipes recorded typical groundwater levels of between 145mAOD and 146mAOD. Based upon the recorded groundwater levels, it is inferred that the alluvial deposits are in hydraulic continuity with the river. Groundwater flow within the drift geology deposits is assumed to flow to the south.
Grove Lodge Linear Defences	Groundwater strikes were recorded at 1.69 to 3.73mbgl within silty gravelly sand, sandy gravelly clay and clay. Resting groundwater levels were variable and were recorded at 0.40 to 2.90mbgl.	An orange discolouration was noted in the groundwater samples collected during the works, and AMD discharges have anecdotally been noted in the riverbank adjacent to the site. Groundwater analytically proven to be iron impacted	The groundwater may be in hydraulic continuity with the River Roch and is likely to be controlled locally by drainage associated with the railway.
Ealees Brook Linear Defences	Groundwater strikes were recorded at 1.6 to 3.6mbgl, primarily within gravel or sandy gravelly clay. Resting groundwater level recorded at 0.90 to 2.17mbgl.	Not identified	The groundwater is expected to be in hydraulic continuity with Ealees Brook.

2.2.5 Hydrology

The River Roch flows northeast to southwest through the study area. The Rochdale Canal is to the east, approximately parallel to the River Roch. At Gale, Greenvale Brook flows south adjacent to the east side of the railway embankment before entering a culvert and flowing west to the River Roch. An unnamed watercourse flows west through Greenvale Business Park to the River Roch. Ealees Brook flows in an east to west direction through the site. The Rochdale Canal is located approximately 30m to the southeast of the site. Refer to Figure 1 for further information.

2.3 Structures and Services

A summary of the structures and services identified on the flood barrier 'dry side' are provided in Table 8.

Table 8: Structures and Services on the flood barrier installation 'dry side'

	Structures	Services	General Arrangement Drawing Reference (Refer Appendix A)	Utility survey Drawing Reference (Refer Appendix D)
Gale Storage Reservoir (west)	Residential housing and gardens	Electrical main, water main, gas main	IMNW000100-JAC-IR-4C0-DR-C-0301	IMNW000100-JAC-ZZ-4C0-IE-Z-0014 IMNW000100-JAC-ZZ-4C0-IE-Z-0015
Gale Storage Reservoir (east)	Small number of residential houses and gardens, commercial buildings	Foul sewer, electrical main, gas main	IMNW000100-JAC-IR-4C0-DR-C-0930	
Greenvale Business Park Linear Defences	West bank: Allotment gardens residential/ gardens (embankment-not sheet pile wall), commercial buildings, car parks, caravan storage area. East bank: Commercial buildings, car parks.	West bank: low voltage electrical, electrical main, gas main, BT duct East bank: Water main, electrical main, gas main, telecom duct	IMNW000100-JAC-DW-4E0-DR-C-0001 IMNW000100-JAC-DW-4E0-DR-C-0002 IMNW000100-JAC-DW-4E0-DR-C-0003	IMNW000100-JAC-ZZ-4E0-IE-Z-0007 IMNW000100-JAC-ZZ-4E0-IE-Z-0008
Grove Lodge Linear Defences	Residential housing (top of embankment) Public footpaths	Water mains, surface water drain	IMNW000100-JAC-DW-4C1-DR-C-0001	
Ealees Brook Linear Defences	Commercial building Overhead Electric Cables	Gas main, Virgin Media duct, electric main	IMNW000100-JAC-DW-4H0-DR-C-0001	

2.4 Summary

Figure 3 (refer Appendix B.3) includes a summary of the pertinent characterisation information reported in this chapter including:

- The proposed flood defence sheet piling locations (Refer Table 4)
- Superficial Geology, as truthed by the ground investigation (in which the proposed sheet piles are constructed) (Refer Table 5 and 6)
- Groundwater Elevation Summary (Refer Table 7)

- Hydrological features (Refer Section 2.2.5)
- Identified potentially sensitive dry side subsurface and surface receptors (Refer Table 8).

The baseline environmental information and proposed flood defence sheet piling is assessed in Chapter 3 cognisant of the scope of work, to demonstrate that provision has been made to allow continuity of natural groundwater drainage to watercourses from the dry side of the flood defences under normal (non-flood) flow conditions.

3. Current Design: Groundwater and Surface Drains

3.1 Introduction

This section documents the outcome of the assessment of the CoP 14 requirement numbers 2,3 4 and 5:

2. "The details of level and location of the groundwater and surface drains to be installed to prevent groundwater levels on the dry side of the barrier rising to the extent they would interfere with services, structures, or amenity";
3. "Positions of neighbouring services, buildings, and chambers etc., showing the reduced basal levels of those features and the invert levels of permeable drains installed to protect them from interference by groundwater";
4. "Cross sections through each proposed barrier, showing reduced ground and river levels; geology; depth of flood barrier structure; pre-development groundwater levels; and basal levels of proximal third party below ground structures"; and
5. "Where groundwater drains are required, additional plans showing the proposed line and level relative to those structures, along with the location and nature of any non-return valves and access points for maintenance of the drains".

3.2 Design Interpretation

Each of the development areas where engineering features could cause changes to the continuity of natural groundwater drainage are assessed in Table 9. This includes relevant geological and hydrogeological characterisation information and statements regarding the proposed Sheet Piles Design and an interpretation/assessment in relation to the CoP 14 requirement numbers 2,3,4 and 5.

As detailed in Table 9, and summarised below, the assessment has found that groundwater drains are not required and therefore COP 14 requirement 5 is not applicable.

3.3 Summary of Groundwater Drainage Requirements

3.3.1 Gale Storage Reservoir

It has been determined that groundwater drains are not required at Gale Storage Reservoir. Proposed groundwater pressure relief wells, which will nevertheless provide groundwater drainage capacity, are indicated on cross-section drawing IMNW000100-JAC-ZZ-4C0-DR-GT-0011, included in Appendix C.

3.3.2 Greenvale Business Park

It has been determined that groundwater drains are not required at Greenvale Business Park. Proposed surface water filter drains, which will nevertheless provide groundwater drainage capacity, are indicated on cross-section drawing IMNW000100-JAC-ZZ-4E0-DR-GT-0005, included at Appendix C.

3.3.3 Grove Lodge

It has been determined that groundwater drains are not required at Grove Lodge

3.3.4 Ealees Brook

It has been determined that groundwater drains are not required at Ealees Brook. The proposed surface water filter trench drain, which will nevertheless provide groundwater drainage capacity, is indicated on cross-section drawing IMNW000100-JAC-ZZ-4H0-DR-GT-0001, included at Appendix C.

Table 9: Design Interpretation

	Geological Characterisation	Hydrogeological Characterisation	Sheet Piles Design	Interpretation	CoP14 Requirement 2	CoP14 Requirement 3	CoP14 Requirement 4 Cross Section reference Appendix C and Figure 3
Impounding Reservoir: Gale Storage Reservoir (west); Impounding Reservoir: Gale Storage Reservoir (east);	Cohesive alluvium is extensive at shallow depth throughout the proposed storage reservoir area as detailed in the Ground Investigation Report (GIR) (IMNW000100-JAC-ZZ-4B0-RP-GT-0001). This cohesive alluvium overlies a thick (up to 22m) layer of granular alluvium, overlying bedrock.	The cohesive alluvium confines groundwater in the underlying granular alluvial aquifer. The confining alluvium has led to the development of artesian pressures within the granular alluvial aquifer in the northeast of Gale. Groundwater is considered to be in hydraulic continuity with the River Roch and Greenvale Brook with flow approximately northeast to southwest towards the confluence of River Roch and Greenvale Brook.	The proposed sheet piles are oriented approximately parallel to groundwater flow and do not extend to bedrock. Therefore, groundwater flow through the granular alluvium will be maintained around and beneath the sheet piles resulting in negligible groundwater mounding on the upgradient side.	The presence of the confining cohesive alluvium means that any mounding would manifest as an increase in piezometric pressure in the confined granular aquifer rather than an increase in an unconfined water table level. Therefore, there is a negligible risk of groundwater emergence at the ground surface. There is also negligible risk of groundwater interference with neighbouring services as these will be located at shallow depths within the cohesive alluvium. In addition, any groundwater mounding would occur in an area that is designed to flood, with flood-compatible infrastructure. Accordingly, there is not considered to be a groundwater flooding risk due to the sheet piles and groundwater drainage is not required for the Gale Storage Reservoir.	Pressure relief wells are to be installed on the 'dry side' of the sheet pile wall for the purpose of controlling pore water pressure beneath the embankments during operation of the reservoir (shown on Cross-section IMNW000100-JAC-ZZ-4C0-DR-GT-0012). Under non-flood conditions, these wells will act to control the pressure in the granular alluvial aquifer such that any minor increase in piezometric pressure due to the sheet pile will be mitigated.	Negligible change to natural groundwater levels and flows on the "dry side" of the flood barrier therefore protection of neighbouring services, buildings, or chambers from groundwater interference due to the sheet pile wall is not required.	Cross-section IMNW000100-JAC-ZZ-4C0-DR-GT-0012 and IMNW000100-JAC-ZZ-4C0-DR-GT-0011 / Summary characterisation information (Figure 3).
Linear Defences: Greenvale Business Park (east bank) and Centre Vale (west bank);	Cohesive alluvium is extensive throughout the Greenvale Business Park area (including Centre Vale), as detailed in the GIR (IMNW000100-JAC-ZZ-4B0-RP-GT-0001). This cohesive alluvium overlies a thick (up to 18+m) layer of granular alluvium, overlying bedrock.	The cohesive alluvium confines groundwater in the underlying granular alluvial aquifer. Groundwater is considered to be in continuity with the River Roch with flow generally southwards.	The proposed sheet piles are oriented approximately parallel to general groundwater flow and do not extend into bedrock. Therefore, groundwater flow through the granular alluvium will be maintained beneath the sheet piles resulting in negligible groundwater mounding on the upgradient side.	The presence of the confining cohesive alluvium means that any mounding would manifest as an increase in piezometric pressure in the confined granular aquifer rather than an increase in an unconfined water table level. Therefore, there is a negligible risk of groundwater emergence at the ground surface. There is also negligible risk of groundwater interference with neighbouring services as these will be located at shallow depths within the cohesive alluvium. Therefore, groundwater drainage is not required at Greenvale Business Park.	Surface water drains are to be installed on the 'dry side' of the sheet pile wall to the west side of the River Roch (shown on Cross-section IMNW000100-JAC-ZZ-4E0-DR-GT-0005). These drains will be fully perforated filter drains and so would also capture groundwater.	Negligible change to natural groundwater levels and flows on the "dry side" of the flood barrier therefore protection of neighbouring services, buildings, or chambers from groundwater interference due to the sheet pile wall is not required.	IMNW000100-JAC-ZZ-4E0-DR-GT-0004 (Plan) / IMNW000100-JAC-ZZ-4E0-DR-GT-0005 (Cross Section) / Summary characterisation information (Figure 3).

	Geological Characterisation	Hydrogeological Characterisation	Sheet Piles Design	Interpretation	CoP14 Requirement 2	CoP14 Requirement 3	CoP14 Requirement 4 Cross Section reference Appendix C and Figure 3
Linear Defences: Grove Lodge;	The area at Grove Lodge is predominantly underlain by granular alluvium, as detailed in the GIR (Rogers Geotechnical Services Ltd, 2020). The depth to bedrock is uncertain (not been proved in previous GI) but is known to be greater than 5.5mbgl. BGS mapping shows that bedrock is the Huddersfield White Rock, comprising medium- to coarse-grained sandstone. The BGS lexicon states that the Huddersfield White Rock is 18-45m thick.	Groundwater level is around 1-2mbgl. Relative levels between the River Roch and groundwater in the superficial aquifer suggest that the river is losing and there may not be hydraulic continuity between the river and groundwater in this area. Groundwater flow is expected to be generally southwards and is likely to be controlled by drainage associated with railway. There is considered to be hydraulic continuity between the granular superficial aquifer and the underlying sandstone bedrock aquifer.	The proposed sheet pile is oriented approximately parallel to general groundwater flow resulting in negligible groundwater mounding	Relative levels between groundwater and the railway show that any east-west components of groundwater flow, if present, would be eastwards. Any groundwater mounding, therefore, would occur between the river and sheet pile in an area that is designed to flood.	There are no receptors at risk from groundwater flooding and groundwater drainage is not required at Grove Lodge.	Negligible change to natural groundwater levels and flows on the "dry side" of the flood barrier and absence of services, buildings, or chambers in area where potential groundwater mounding could occur.	IMNW000100-JAC-ZZ-4C1-DR-GT-0001 (Plan) / IMNW000100-JAC-ZZ-4C1-DR-GT-0002 (Cross Section) / Summary characterisation information (Figure 3).
Linear Defences: Ealees Brook.	Clay made ground and/or cohesive alluvium is present in this area, as detailed in the GIR (Rogers Geotechnical Services Ltd, 2017). These cohesive deposits overlie granular alluvial deposits. The depth to bedrock is uncertain (not been proven in previous GI) but is known to be greater than 8.5mbgl. BGS mapping shows that bedrock is the Woodhead Hill Rock, comprising sandstone. However, it is also possible that this area is underlain by undifferentiated mudstone, siltstone and sandstone of the Lower Pennine Coal Measures.	The cohesive deposits (made ground and/or alluvium) confine groundwater in the underlying granular aquifer. In accordance with the characteristics of the valley to the north, groundwater flow is expected to be generally southwards. Groundwater is considered to be in continuity with Ealees Brook and with underlying sandstone bedrock where present.	The proposed sheet pile is oriented approximately perpendicular to general groundwater flow but is located on the downgradient side of the brook in terms of groundwater flow direction. This means that groundwater flowing towards the sheet pile would discharge to the brook, with the brook controlling groundwater levels immediately to the north of the sheet pile.	Some groundwater flow to the brook from the southern side is possible. The sheet pile is not intended to 'key-in' to bedrock but may encounter bedrock depending on the depth to rockhead. Some groundwater mounding is possible, therefore, particularly if the bedrock comprises lower permeability mudstones or siltstones. However, any groundwater mounding on the southern side of the sheet pile will manifest as an increase in piezometric pressure in the confined granular aquifer rather than an increase in an unconfined water table level. Therefore, there is a negligible risk of groundwater emergence at the ground surface and negligible risk of groundwater interference with neighbouring services as these will be located at shallow depths within the cohesive alluvium. Accordingly, groundwater drainage is not required at Ealees Brook.	A surface water drain is to be installed on the 'dry side' of the sheet pile wall to the south side of Ealees Brook (shown on Cross-section IMNW000100-JAC-ZZ-4H0-DR-GT-0001). This drain will be a filter trench drain and so would also capture groundwater.	Negligible change to natural groundwater levels and flows on the "dry side" of the flood barrier therefore protection of neighbouring services, buildings, or chambers from groundwater interference due to the sheet pile wall is not required.	IMNW000100-JAC-ZZ-4H0-DR-GT-0001(Plan and Cross Section)/ Summary characterisation information (Figure 3).

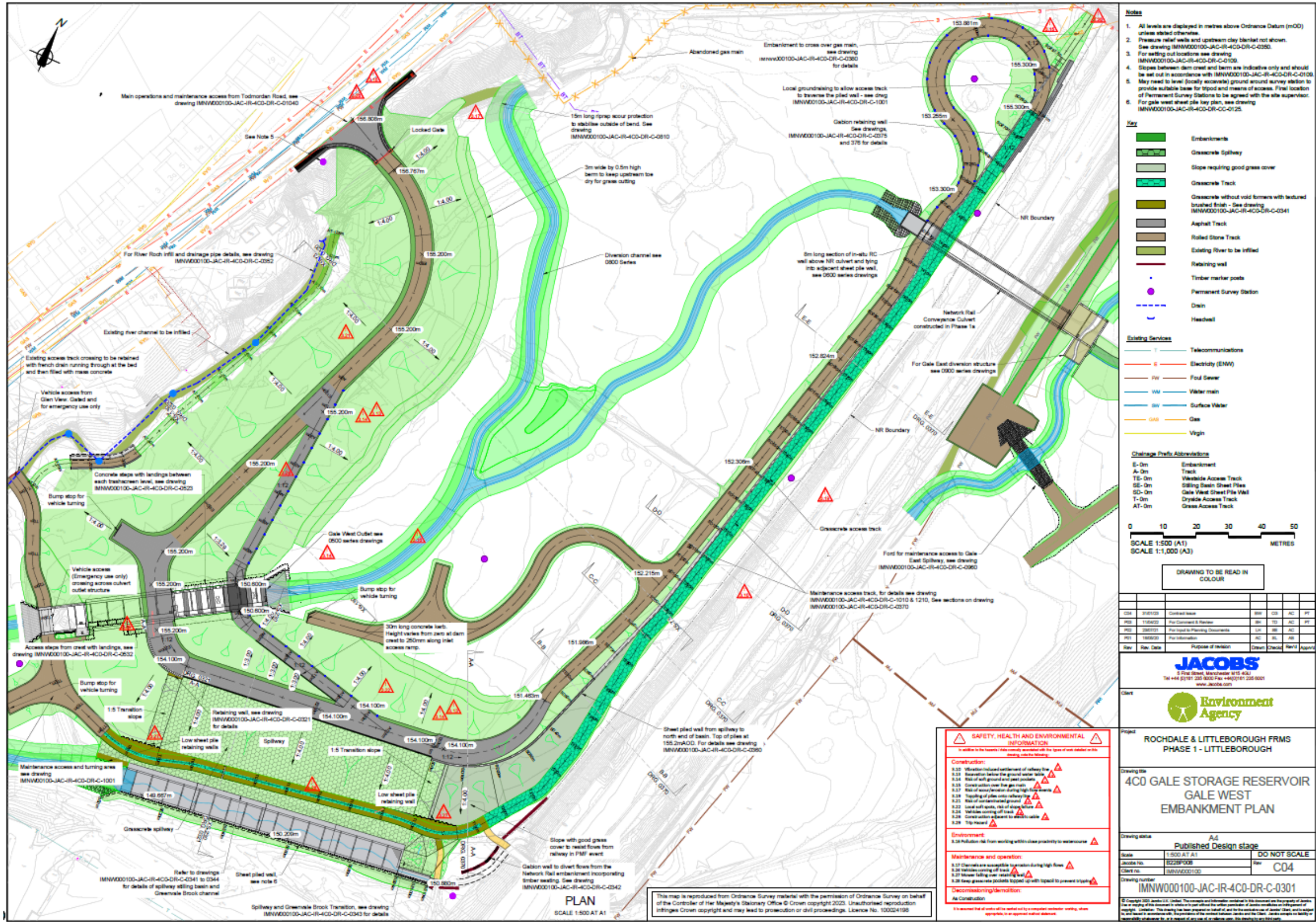
4. References

- British Standards Institute 2015. BS 8002 (2015). Code of practice for earth retaining structures
- Cashman, P. M., & Preene, M. (2020). Groundwater Lowering in Construction (3rd ed.). Taylor & Francis.
- CIRIA 2001. CIRIA Report C552 - Contaminated Land Risk Assessment: A guide to good practice
- CIRIA 2003. CIRIA C580 Embedded retaining walls - guidance for economic design
- CIRIA 2016. CIRIA C750 Groundwater control: design and practice, second edition
- Environment Agency 2001. Piling and Penetrative Ground Improvement Methods on Land Affected by Contamination: Guidance on Pollution Prevention NC/99/73

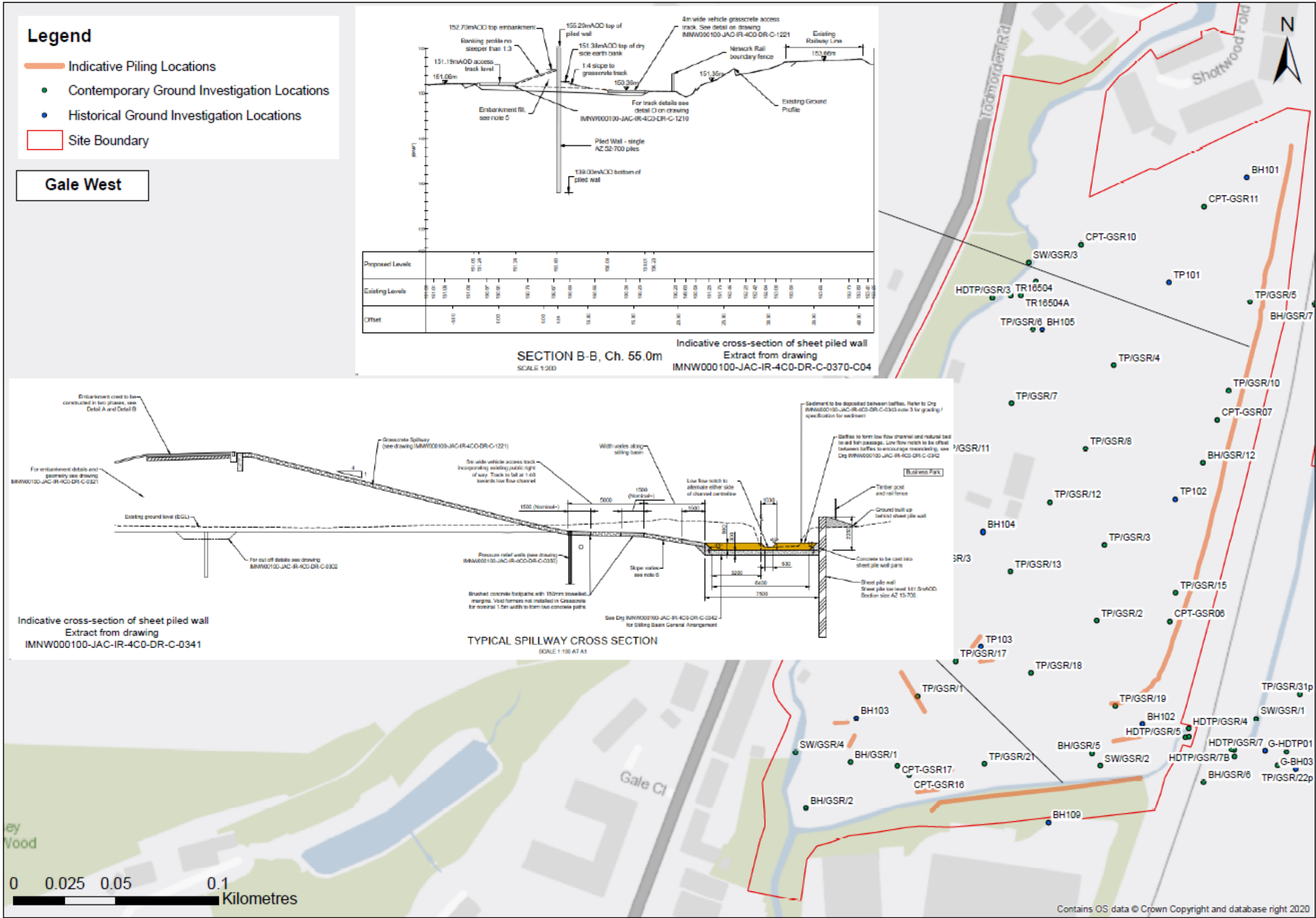
Appendix A. Extracts of the proposed Construction (Summary)

A.1 Gale Storage Reservoir (West)

A.1.1 Site Layout (Drawing Reference: IMNW000100-JAC-IR-4C0-DR-C-0301)

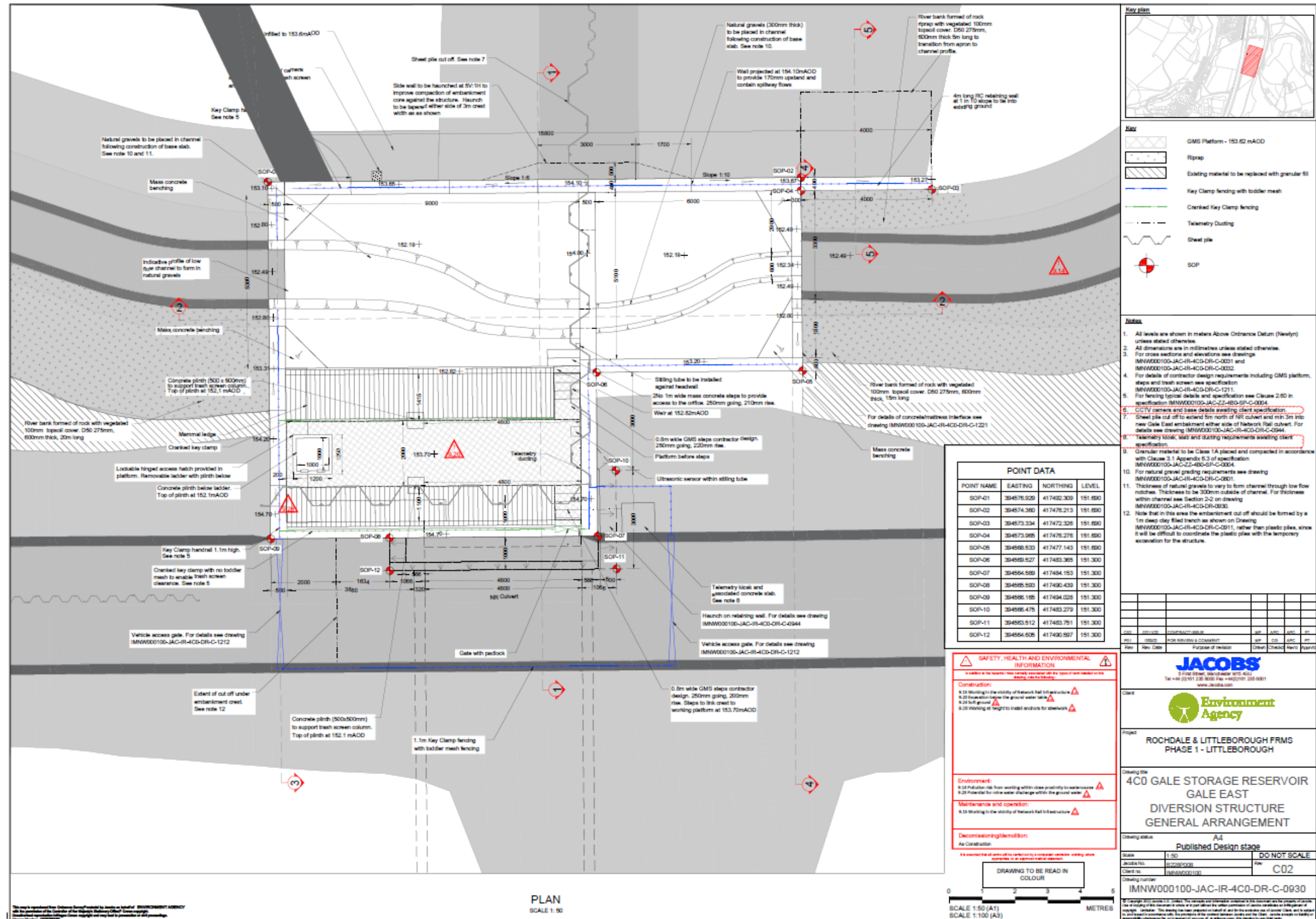


A.1.2 Ground Investigation Locations and Indicative Cross Sections

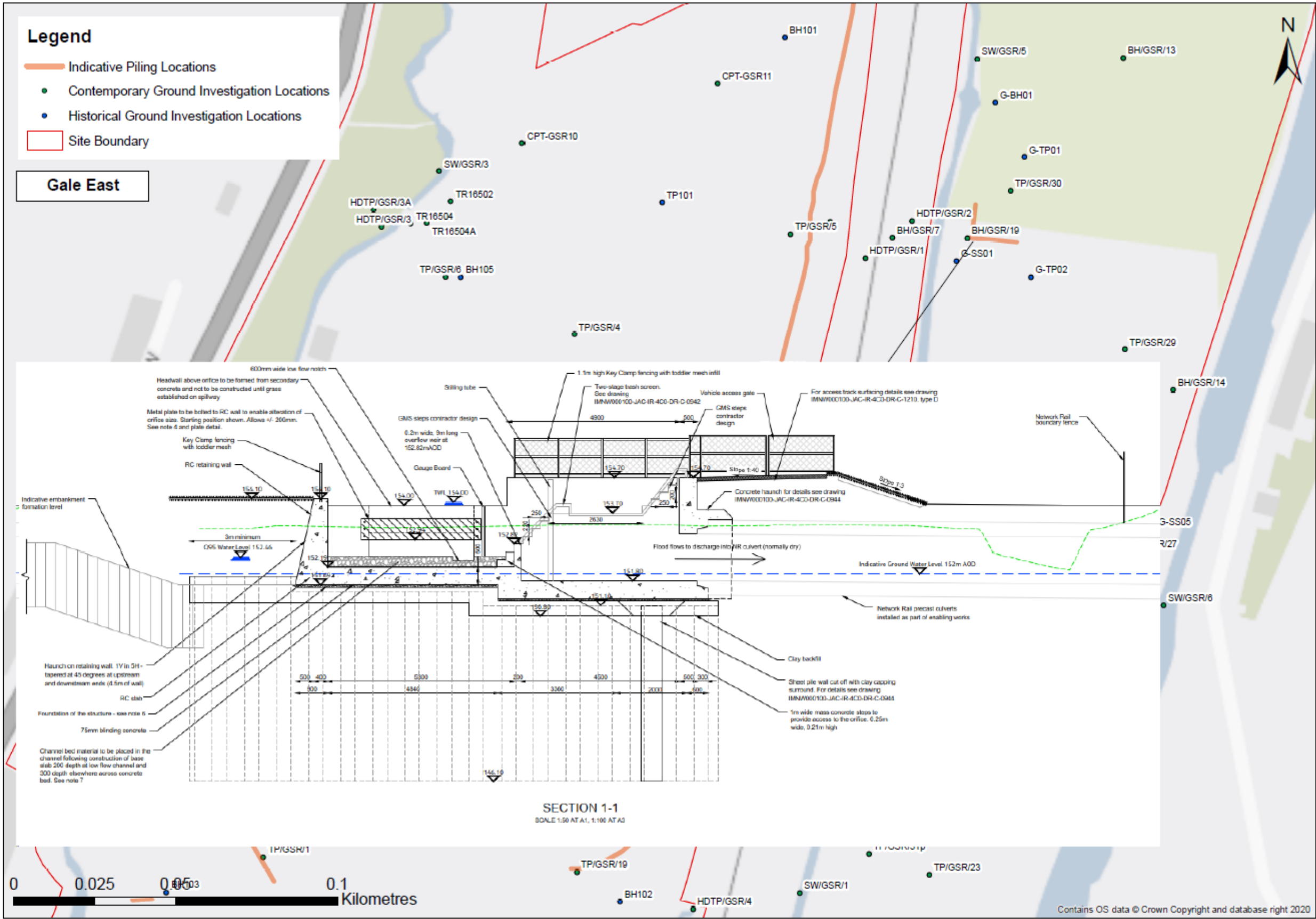


A.2 Gale Storage Reservoir (East)

A.2.1 Site Layout (Drawing Reference: IMNW000100-JAC-IR-4C0-DR-C-0930)

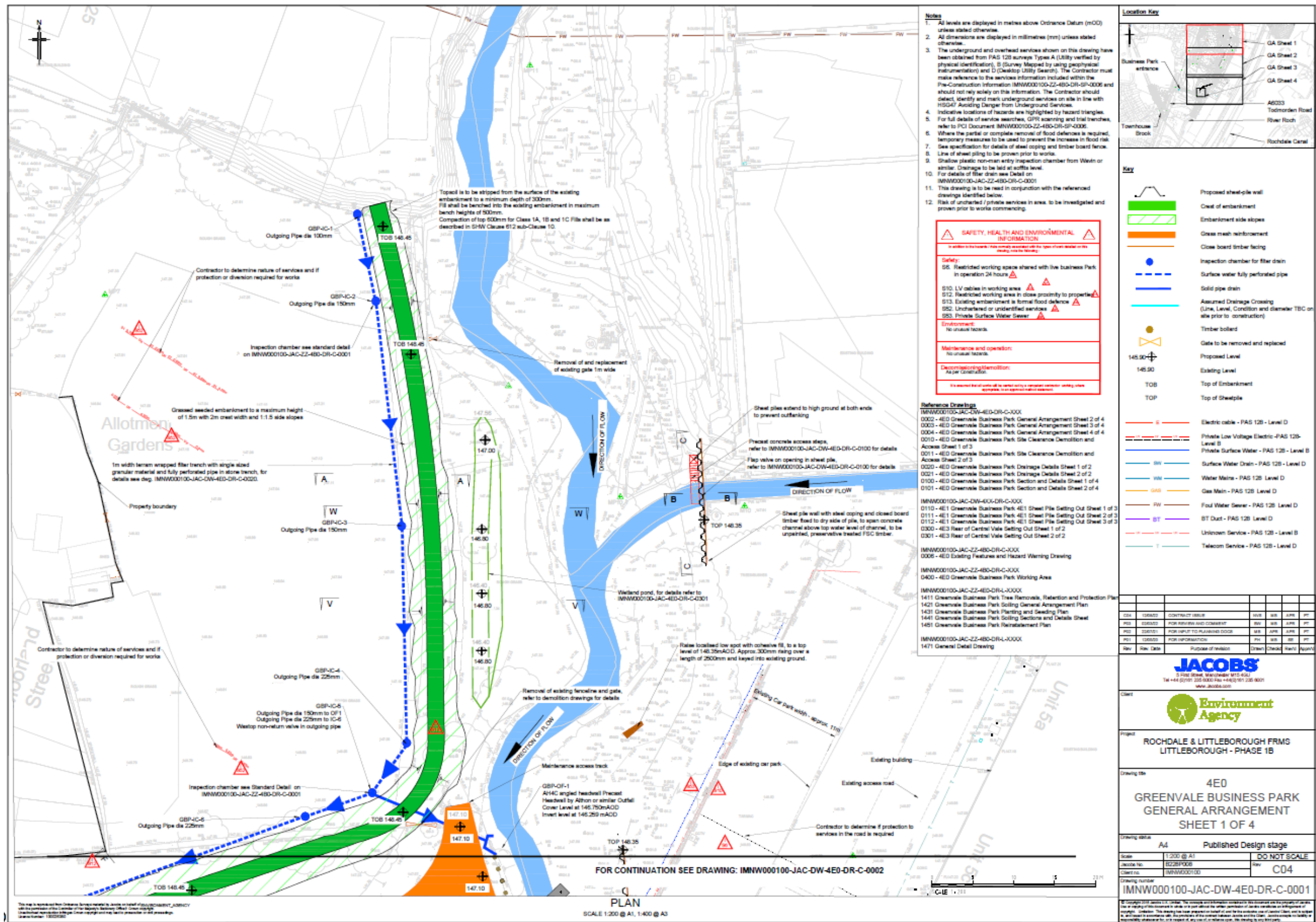


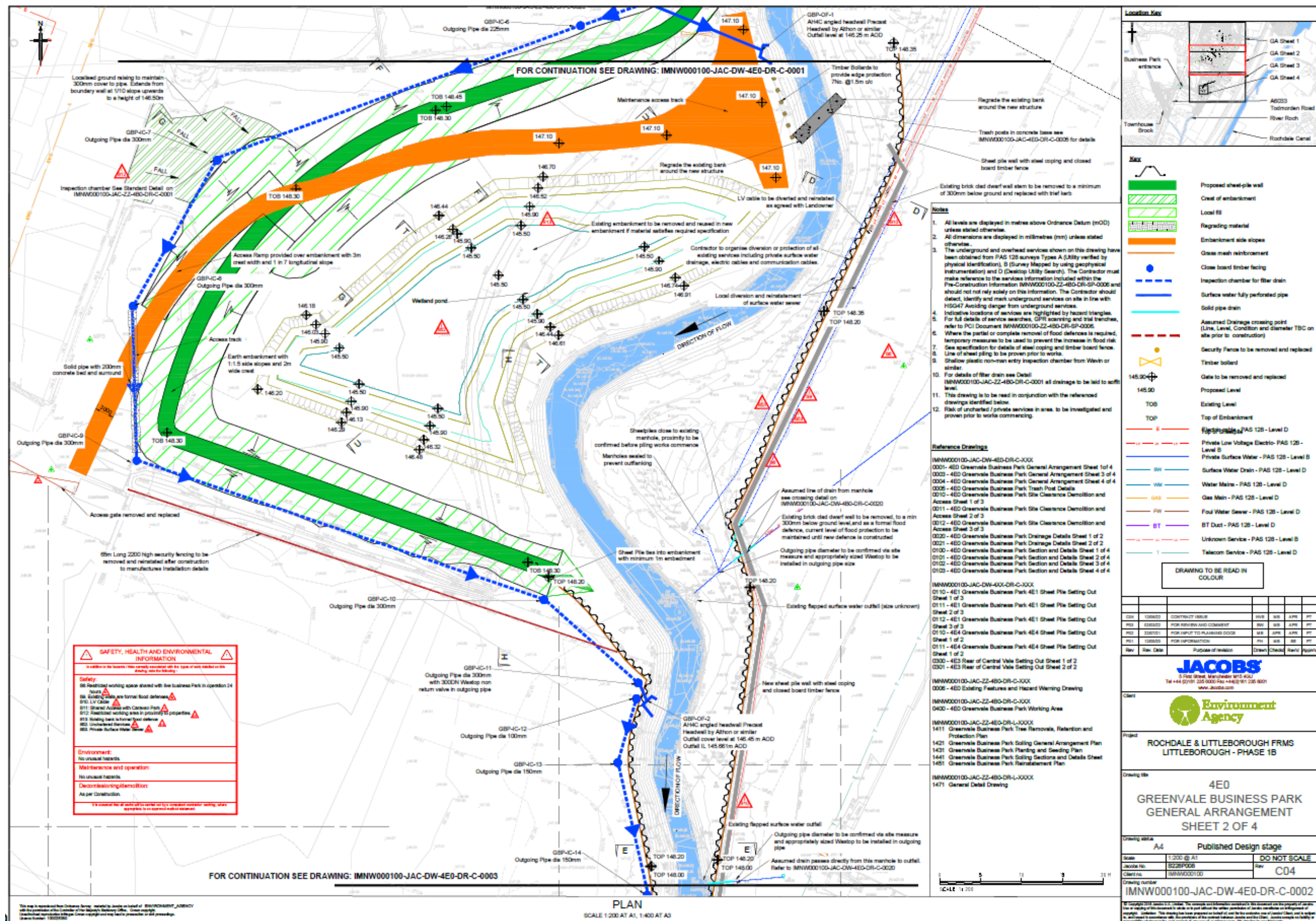
A.2.2 Ground Investigation Locations and Indicative Cross Sections

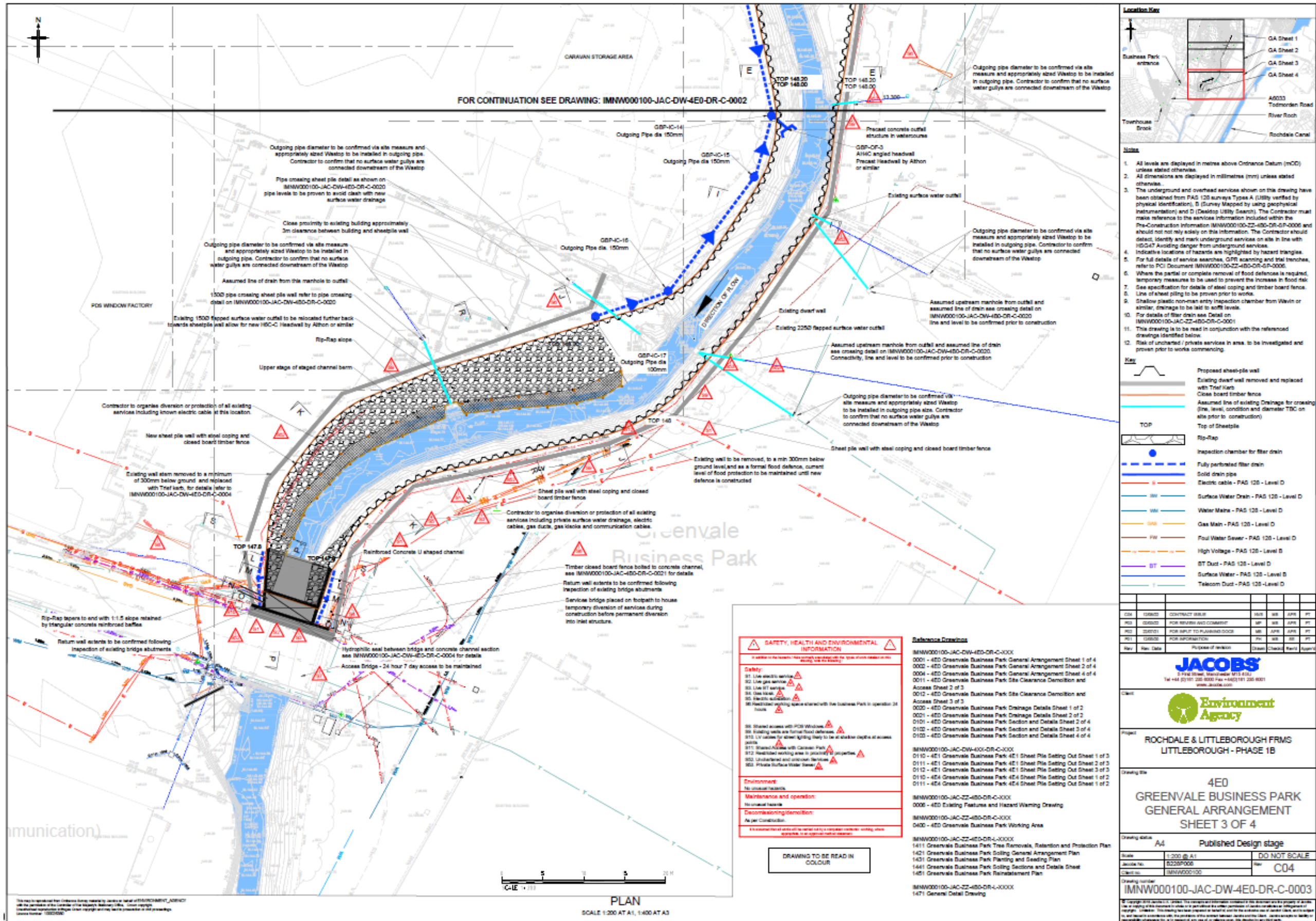


A.3 Greenvale Business Park

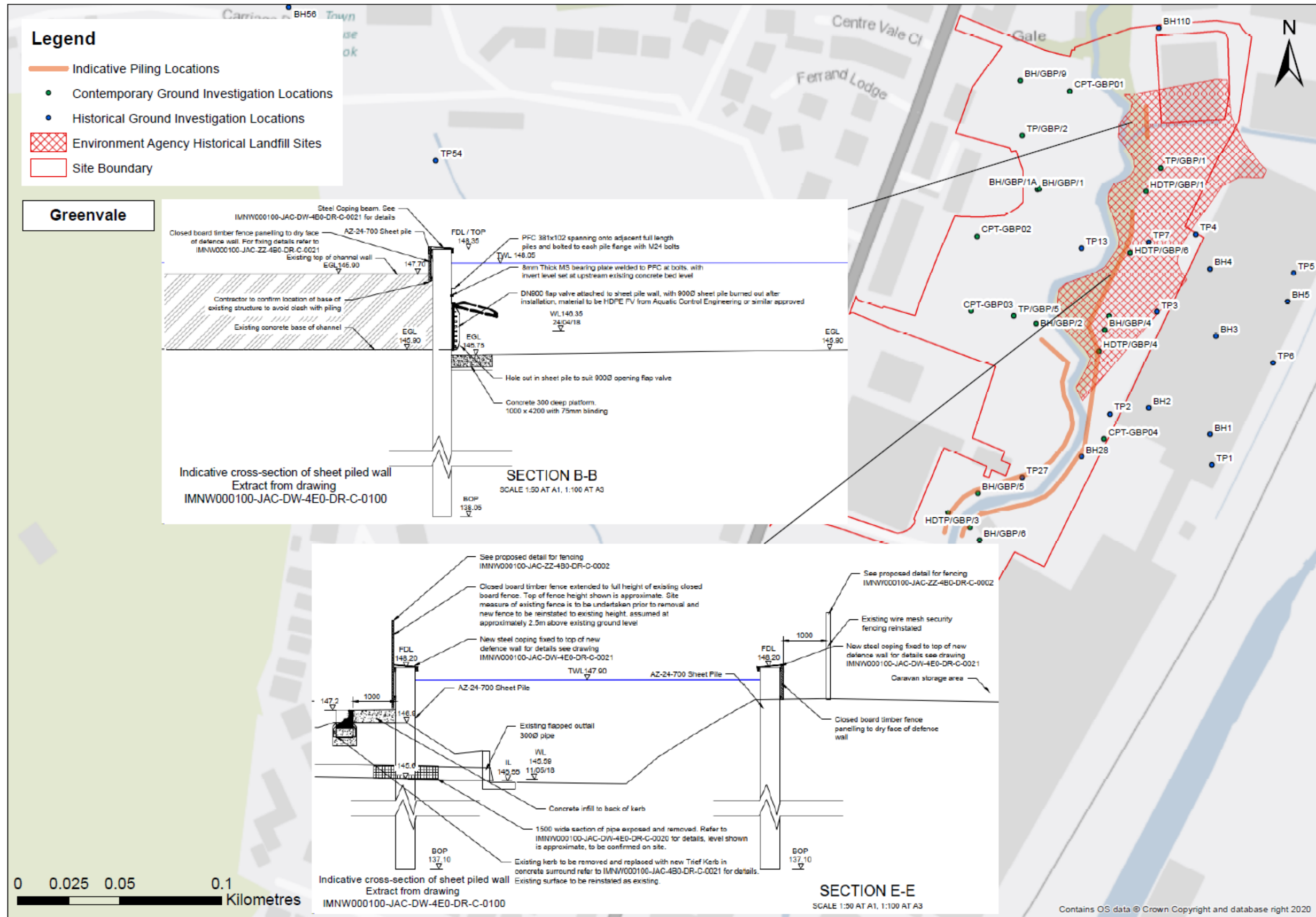
A.3.1 Site Layout (Drawing Reference: IMNW000100-JAC-DW-4E0-DR-C-0001, 0002 and 0003)

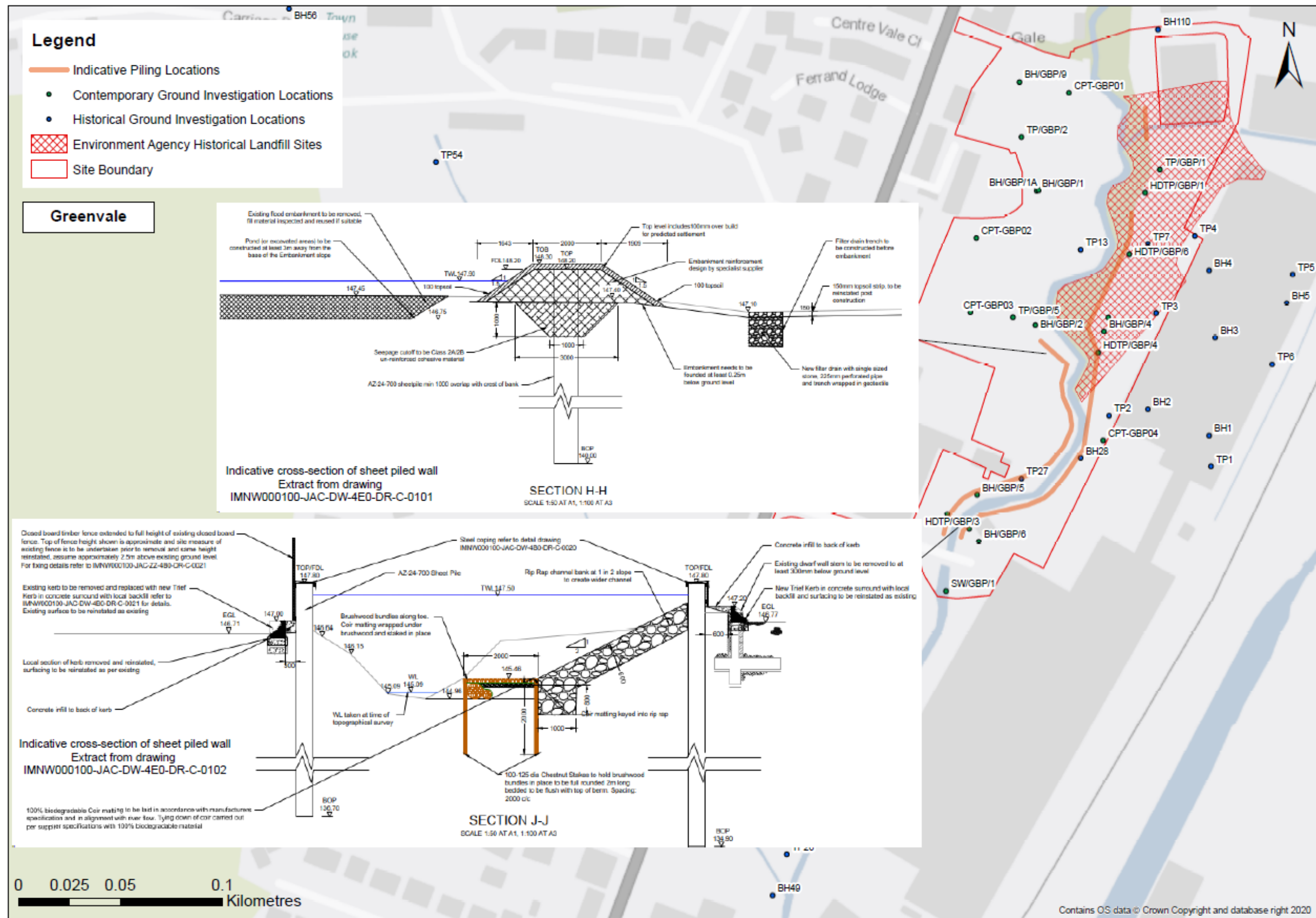






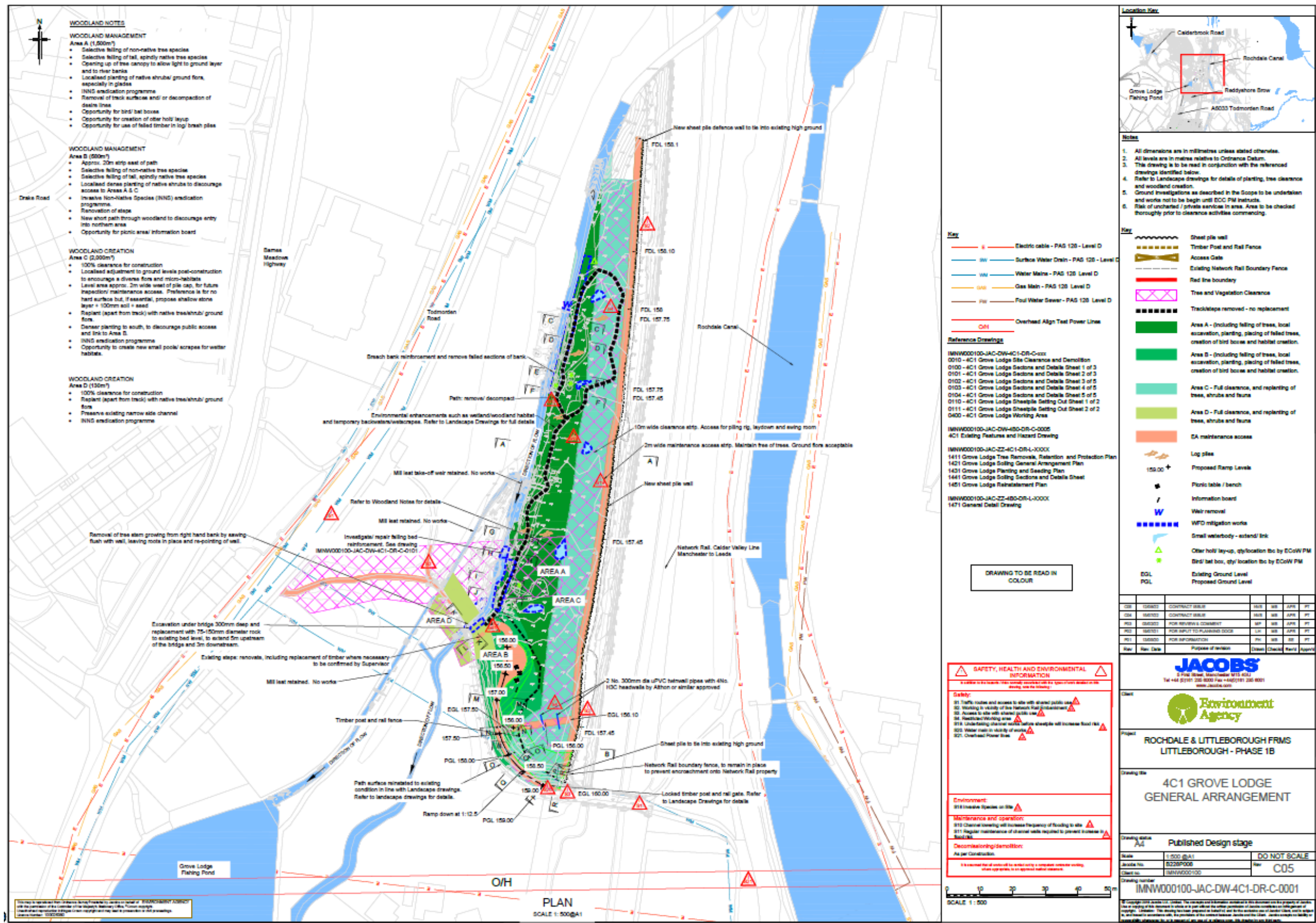
A.3.2 Ground Investigation Locations and Indicative Cross Sections



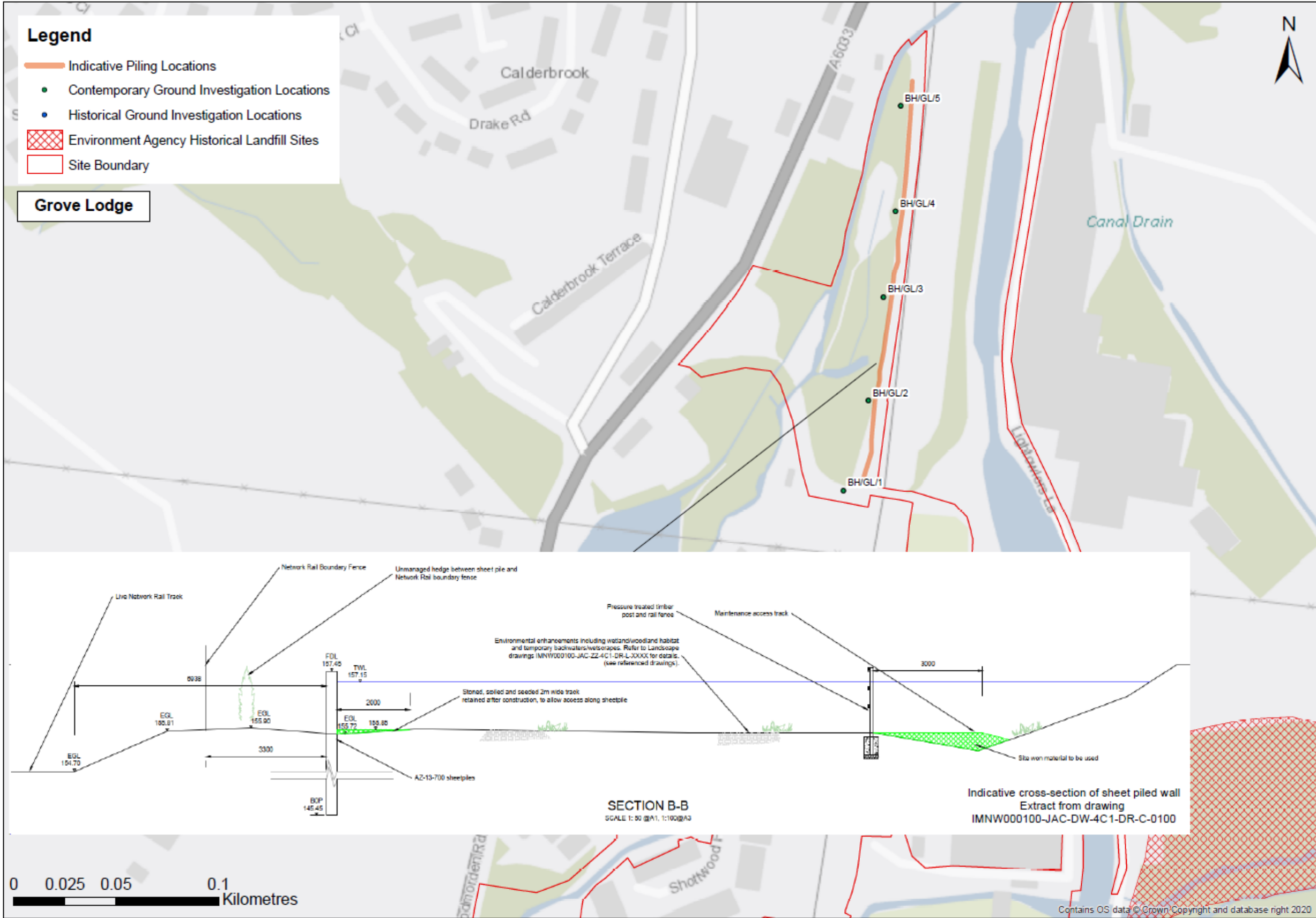


A.4 Grove Lodge

A.4.1 Site Layout (Drawing Reference: IMNW000100-JAC-DW-4C1-DR-C-0001)

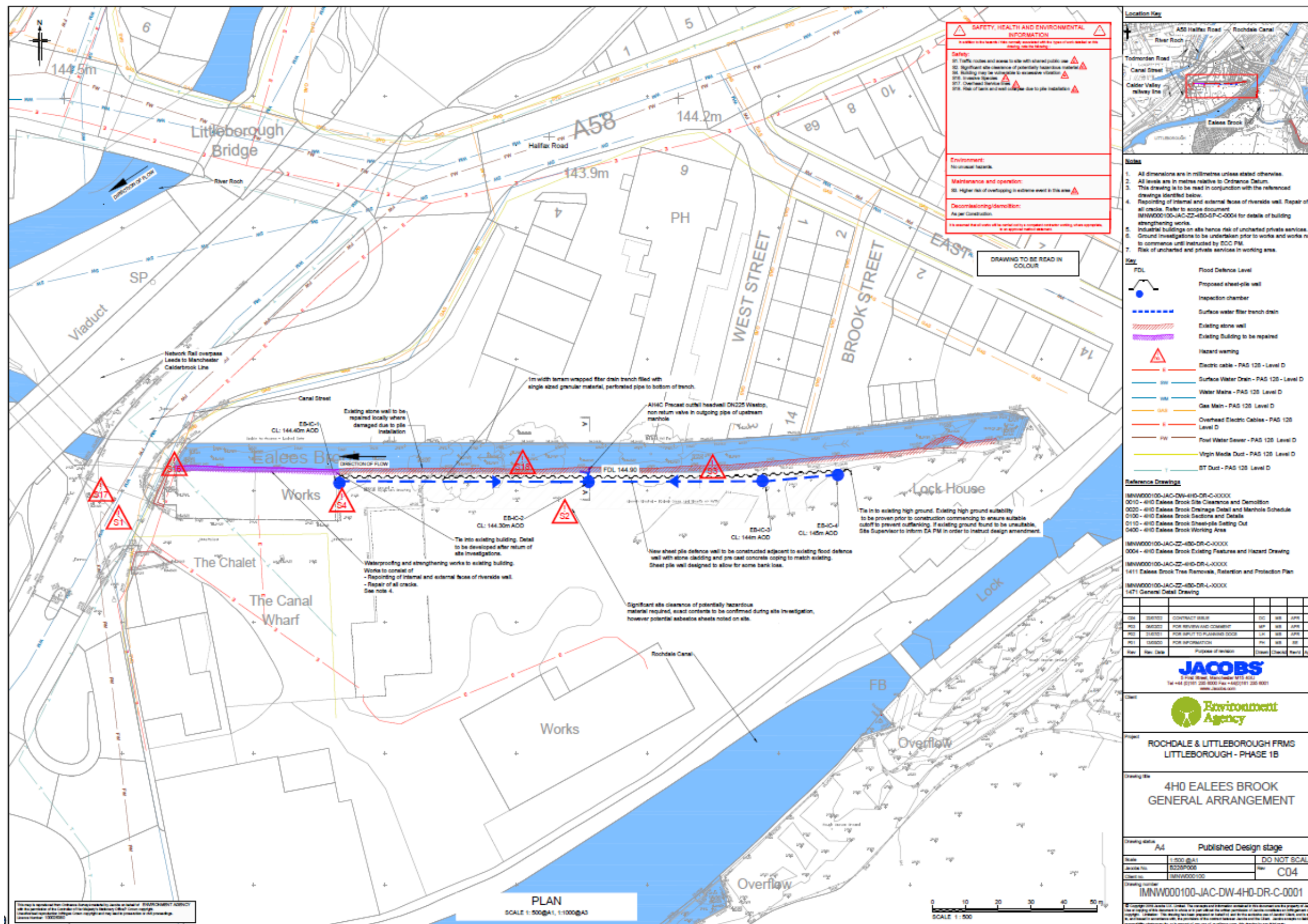


A.4.2 Ground Investigation Locations and Indicative Cross Sections

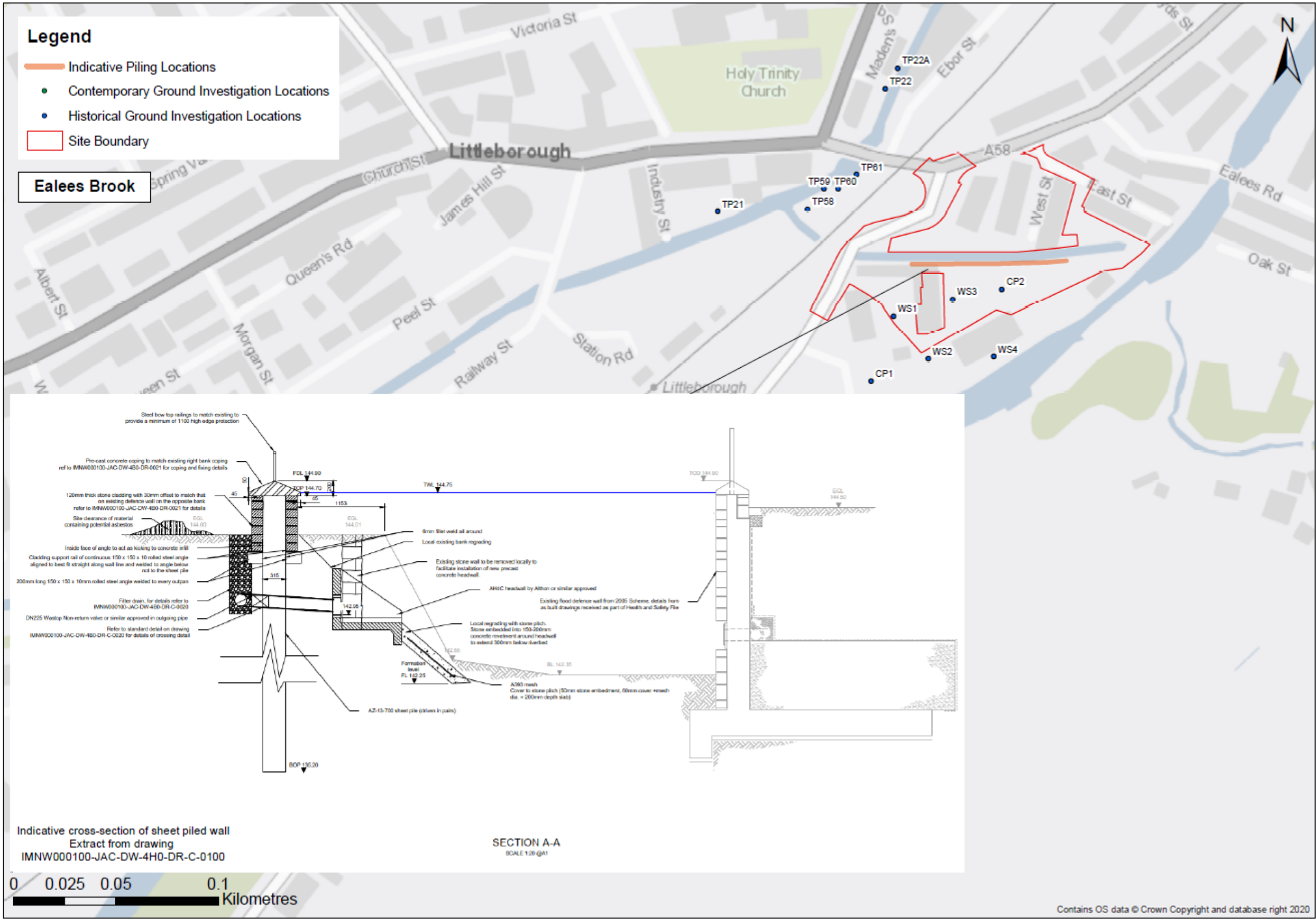


A.5 Ealees Brook

A.5.1 Site Layout (Drawing Reference: IMNW000100-JAC-DW-4H0-DR-C-0001)

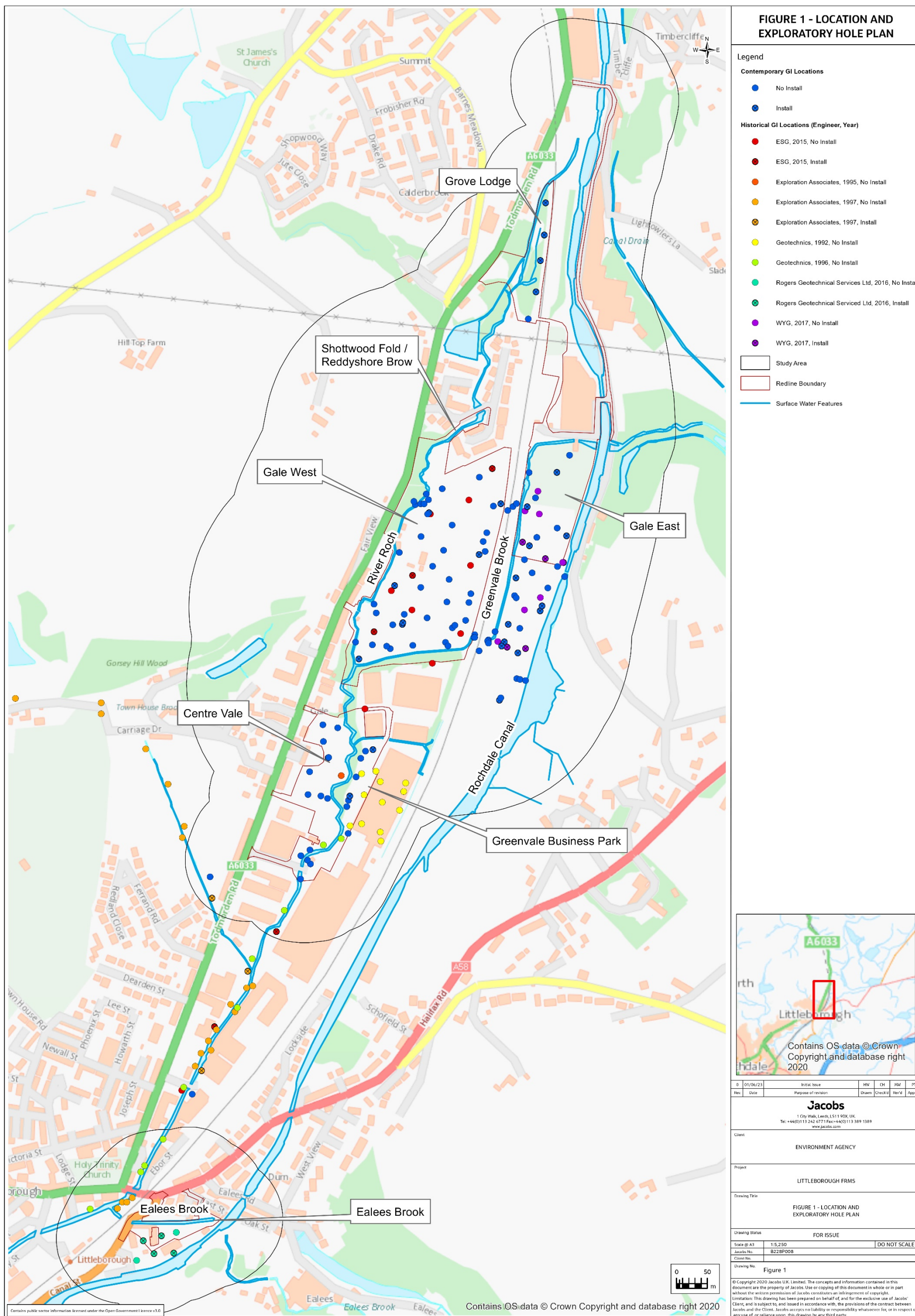


A.5.2 Ground Investigation Locations and Indicative Cross Sections

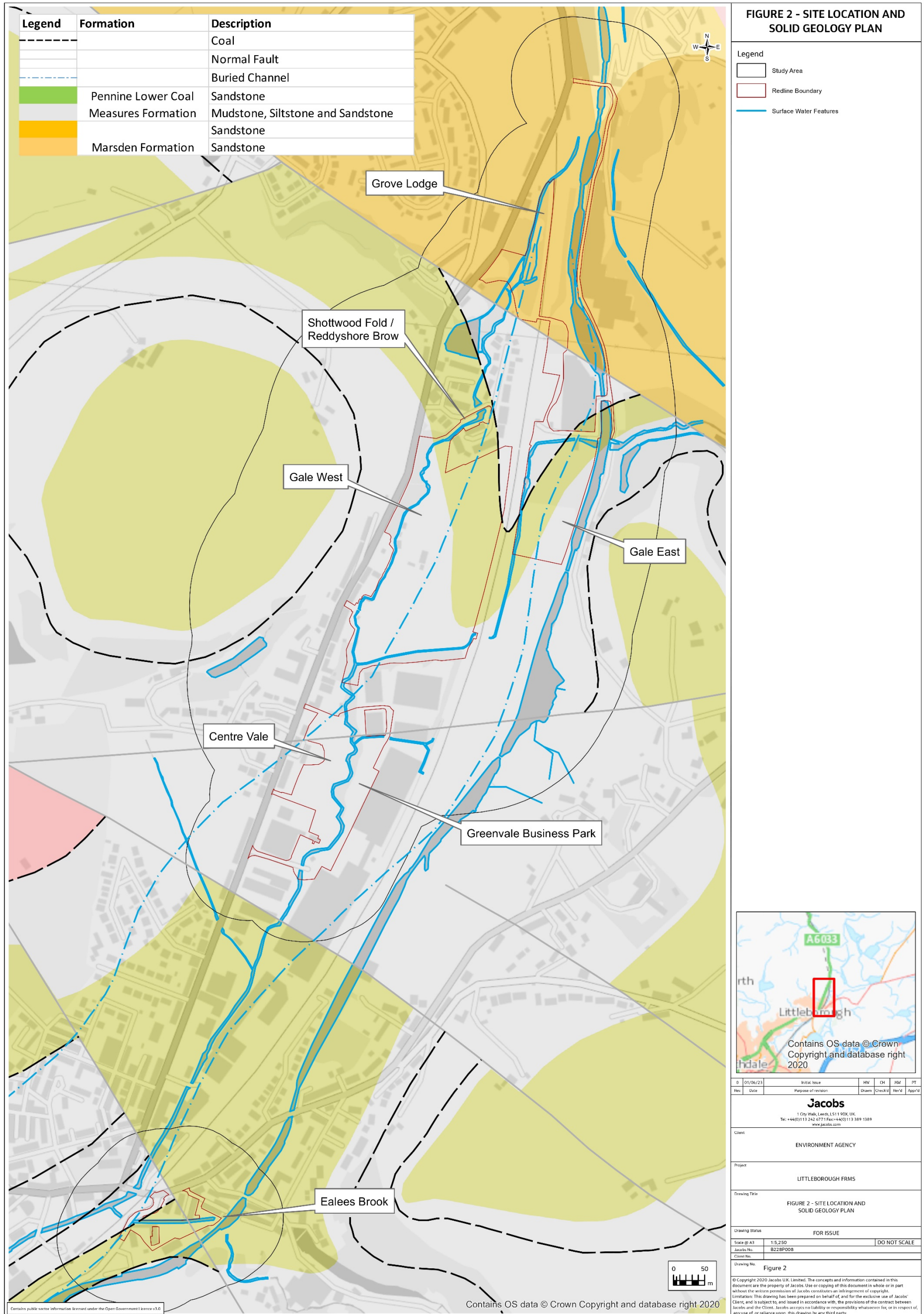


Appendix B. Figures: Environmental Characterisation

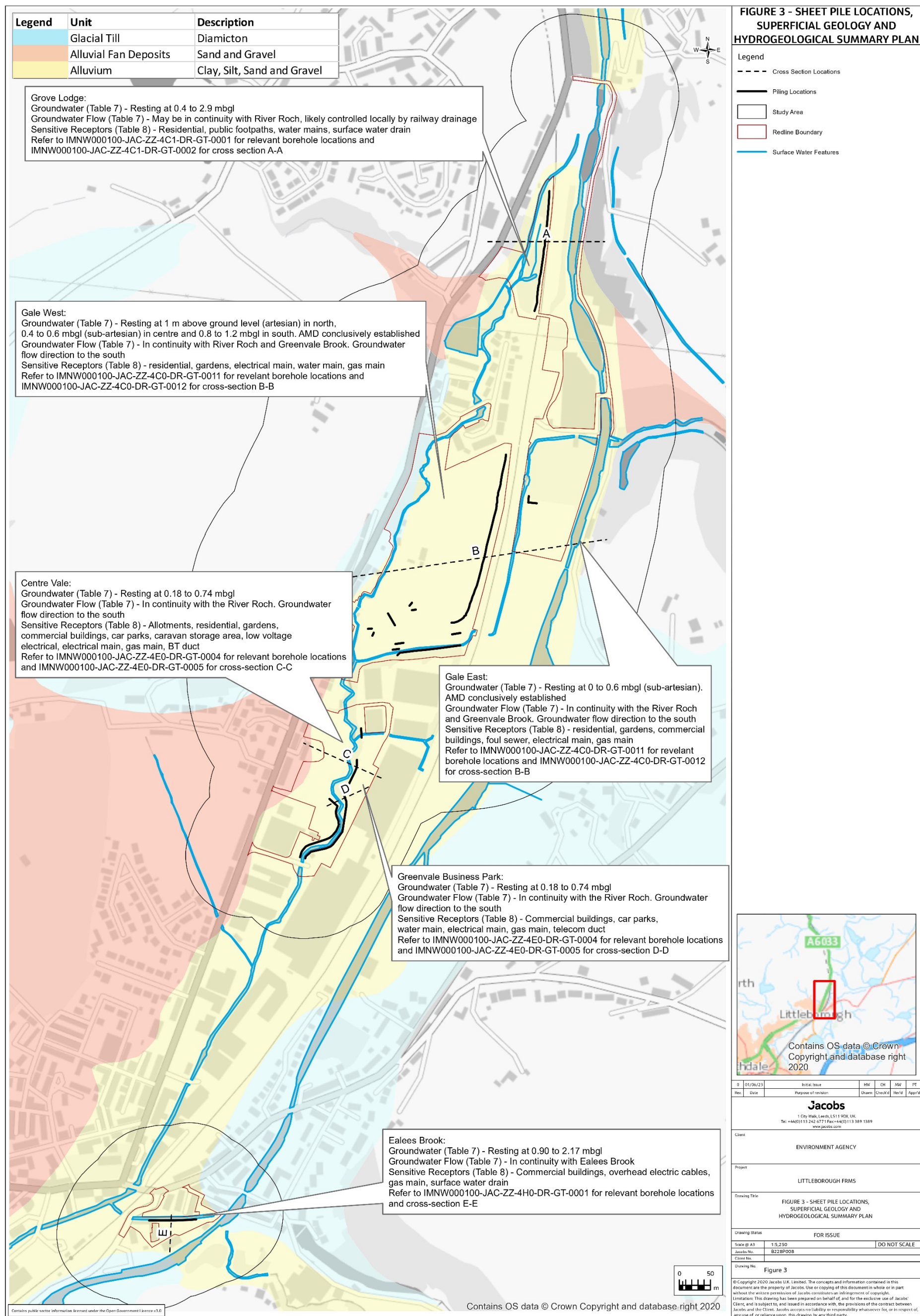
B.1 Figure 1: Site Location and Exploratory Hole Plan



B.2 Figure 2: Site Location and Solid Geology Plan



B.3 Figure 3: Sheet Pile Location, Superficial Geology, and Hydrogeological Summary Plan



Appendix C. Cross Sections

C.1 Gale Storage Reservoir

IMNW000100-JAC-ZZ-4C0-DR-GT-0011

IMNW000100-JAC-ZZ-4C0-DR-GT-0012

C.2 Greenvale Business Park

IMNW000100-JAC-ZZ-4E0-DR-GT-0004

IMNW000100-JAC-ZZ-4E0-DR-GT-0005

C.3 Grove Lodge

IMNW000100-JAC-ZZ-4C1-DR-GT-0001

IMNW000100-JAC-ZZ-4C1-DR-GT-0002

C.4 Ealees Brook

IMNW000100-JAC-ZZ-4H0-DR-GT-0001

Appendix D. Utilities Survey Drawings (GPR and trial trench)

D.1 Gale Storage Reservoir

IMNW000100-JAC-ZZ-4C0-IE-Z-0014

IMNW000100-JAC-ZZ-4C0-IE-Z-0015

D.2 Greenvale Business Park

IMNW000100-JAC-ZZ-4E0-IE-Z-0007

IMNW000100-JAC-ZZ-4E0-IE-Z-0008