London Borough of Enfield

Strategic Infrastructure Works, Meridian Water

Remediation Strategy and Verification Plan

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Contents

Page

1 Introduction 6
1.1 Background 6
1.2 Purpose of report 6
1.3 Other relevant planning conditions 6
1.4 Previous assessments 6
1.5 Relevant guidance 7
1.6 Regulator liaison 7
1.7 Limitations 7

2 Proposed development 8
2.1 Meridian Water masterplan 8
2.2 Meridian Water Strategic Infrastructure Works 8

3 Summary of site condition 9
3.1 Site location and description 9
3.2 Overview of relevant site history 9
3.3 Previous remediation 10
3.4 Ground investigations 10
3.5 Ground conditions 11
3.6 Summary of risk assessment findings 15

4 Updated conceptual model 17
4.1 Approach 17
4.2 During construction 18
4.3 Post-construction 20

5 Remediation objectives and site constraints 22
5.1 Introduction 22
5.2 Strategic and management objectives 22
5.3 Technical objectives 22
5.4 Remediation constraints 22

6 Remediation options appraisal 24
6.1 Scope of remediation options appraisal 24
6.2 Outcome of remediation options appraisal 24

7 Demolition and site clearance 27
7.1 Supplementary ground investigation 27
7.2 Vegetation clearance and invasive species 27
7.3 Removal of waste and fly-tipped material 27
7.4 Demolition 27
7.5 Surface turnover 27
7.6 Tank strategy 28
7.7 Decommissioning of monitoring wells 28
7.8 Redundant utilities and drainage 28

8 Earthworks and materials strategy 30
8.1 Overview of earthworks 30
8.2 Materials management and treatment 30
8.3 Regulatory approach 30
8.4 Water management in excavation 31
8.5 Managing radiological risk during excavation 31
8.6 Managing UXO risk during excavation 31
8.7 Geoenvironmental watching brief 31
8.8 Discovery strategy 32
8.9 Definition of gross contamination 32
8.10 Material reuse and soil verification 33
8.11 Cover systems 36

9 Remediation of groundwater contamination sources 38
9.1 Introduction 38
9.2 Benzene in KPGR 38
9.3 Vinyl chloride in KPGR 38
9.4 TPH in DZ2 38
9.5 Ammoniacal nitrogen and cyanide in KPGR 39
9.6 Ammoniacal nitrogen and cyanide in Chalk basal sands 39

10 Remediation in Brooks Park area 41
10.1 Outline of Brooks Park works 41
10.2 Detailed design and planning condition discharge 41
10.3 Design principles and sequence of works 41
10.4 Remediation measures 41

11 Construction-related remediation 43
11.1 Overview 43
11.2 Ground gas and vapour protection 43
11.3 Buried concrete classification 43
11.4 Installation of services 43
11.5 Piling and foundations 43

12 Site management and controls 44

12.1 Site management responsibility 44
12.2 Code of construction practice 44
12.3 Construction environmental management plan 44
12.4 Control measures 44

13 Verification plan 46

13.1 Planning requirements 46
13.2 Verification report: general requirements 46
13.3 Watching briefs 46
13.4 Site turnover, gross contamination and tanks 47
13.5 Asbestos 47
13.6 Earthworks, materials management and waste 47
13.7 Groundwater source remediation 48
13.8 Brooks Park area 49
13.9 Construction-related remediation 49
13.10 Monitoring of SIW remediation 49
13.11 Monitoring well decommissioning 50
13.12 Programme for verification reporting 50

14 Plot developer remediation 51

References

Tables

Table 1 Deliverables summary
Table 2 Main historical site uses
Table 3 Summary of monitoring scope completed as part of SIW investigation Phase 1
Table 4 Summary of data from previous investigations
Table 5 Site stratigraphy DZ2 to DZLV1
Table 6 Categorisation of contaminant linkages
Table 7 Conceptual model during construction works
Table 8 Conceptual model following completion of the SIW (post-construction)
Table 9 RCLs 1, 2, 3 and remedial solutions
Table 10 RCL4 and 5 sources to be included in remediation options appraisal
Table 11 Odour observation rating matrix
Table 12 Reuse criteria for general fill and cover soil
Table 13 Verification testing suites
Table 14 Control measures to address contaminant linkages
Table 15 Summary of SIW environmental monitoring

Figures

Figure 1 Proposed areas for phased discharge of Condition 29 (Pink SIW-Phase 1, Green SIW-Phase 2).
Figure 2 Meridian Water Development Zones
Figure 3 Strategic infrastructure works Phase 1 site boundary
Figure 4 Monitoring wells in KPGR
Figure 5 Location of Chalk basal sands monitoring wells

Drawings

Drawing 1 Proposed development
Drawing 2 Site history and extent of fly tipping
Drawing 3 SIW Phase 1, historic exploratory locations and development zones.
Drawing 4 Groundwater sources assessed in remediation options appraisal
Drawing 5 Demolition plan
Drawing 6 Turnover extent areas
Drawing 7 Tanks, buried structures and UXO risk
Drawing 8 Proposed earthworks showing cut/ fill
Drawing 9 Zones for general fill criteria
Drawing 10 Proposed cover systems

Appendices

Appendix A

Planning consent

Appendix B

Remediation options appraisal

Appendix C

Derivation of reuse and verification criteria

Appendix D

Brooks Park drawings

Deliverables summary

This report has been prepared by Ove Arup and Partners Ltd ('Arup') on behalf of the London Borough of Enfield (LBE) regeneration team.

The LBE regeneration team will oversee the delivery of infrastructure works and will appoint developers to deliver development plots. An earlier phase, Meridian Water Phase 1, is progressing to delivery, with a developer partner selected and the new Meridian Water Station opened in June 2019. The Strategic Infrastructure Works (SIW) is the next phase of Meridian Water.

The planning application for Meridian Water SIW was granted consent in July 2020 (PA/19/02717/RE3). 2022 29 of the consent describes the requirements for the assessment and management of contaminated land and states:

Prior to each phase of development approved by this planning permission no development shall commence until a remediation strategy to deal with the risks associated with contamination of the site in respect of the development hereby permitted, has been submitted to, and approved in writing by, the local planning authority.

This strategy will include the following components:

1. *A preliminary risk assessment which has identified:*
    - *all previous uses*
    - *potential contaminants associated with those uses*
    - *a conceptual model of the site indicating sources, pathways and receptors*
    - *potentially unacceptable risks arising from contamination at the site*
2. *A site investigation scheme, based on (1) to provide information for a detailed assessment of the risk to all receptors that may be affected, including those offsite.*
3. *The results of the site investigation and the detailed risk assessment referred to in (2) and, based on these, an options appraisal and remediation strategy giving full details of the remediation measures required and how they are to be undertaken.*
4. *A verification plan providing details of the data that will be collected in order to demonstrate that the works set out in the remediation strategy in (3) are complete and identifying any requirements for longer-term monitoring of pollutant linkages, maintenance and arrangements for contingency action.*

LBE has successfully obtained a government grant from the Housing Infrastructure Fund (HIF) to complete the SIW. The fund is awarded to local authorities to achieve large scale growth by making new land available and delivering housing. To secure the funding in full, LBE must meet various conditions related to programme including completion of the Strategic Infrastructure Works by March 2024.

To complete the SIW by this date, the LBE is aiming to start works by January 2022 or, as soon as possible thereafter.

To achieve this, condition 29 will be discharged in two phases for the SIW as detailed in the Arup (2021) Remediation framework report. Table 1 presents the list of completed and proposed deliverables to achieve full discharge of condition 29, with dates for the issued documents and a summary of the purpose of each issue.

Table 1 Deliverables summary

Report name	Issue no.	Purpose	Date submitted
Preliminary risk assessment	Issue 1	Submitted to the Environment Agency and LPA for comment with the purpose of discharging Condition 29.1 and Condition 29.2.	August 2020
	Issue 2	Issued to the Project Team	December 2020
	Issue 3	To be submitted to the LPA to discharge Condition 29.1 and 29.2.	
Interpretative report	Issue 1	Submitted to the Environment Agency and LPA for comment with the purpose of discharging Condition 29.3.	December 2020
	Issue 2	To be submitted to the LPA to discharge Condition 29.3 for Development Zones (DZ) 4 to DZ7 and DZLV1.	
	Issue 3	To be submitted to the Environment Agency and LPA for comment with the purpose of discharging Condition 29.3 for DZ2 and DZ3. Includes review of data from phase 2 investigation for DZ4 to DZ7 and DZLV1.	
	Issue 4	To be submitted to the LPA to discharge Condition 29.3 for DZ2 and DZ3. Includes review of data from phase 2 investigation for DZ4 to DZ7 and DZLV1.	
Detailed quantitative risk assessment	Issue 1	Submitted to the Environment Agency and LPA for comment with the purpose of discharging Condition 29.3 for DZ4 to DZ7 and DZLV1.	July 2021
	Issue 2	To be submitted to the LPA to discharge Condition 29.3 for DZ4 to DZ7 and DZLV1.	
	Issue 3	To be submitted to the Environment Agency and LPA for comment with the purpose of discharging Condition 29.3 for DZ2 and DZ3. Includes review of data from phase 2 investigation for DZ4 to DZ7 and DZLV1.	
	Issue 4	To be submitted to the LPA to discharge Condition 29.3 for DZ2 and DZ3. Includes review of data from phase 2 investigation for DZ4 to DZ7 and DZLV1.	
Remediation strategy and verification plan	Issue 1	Submitted to the Environment Agency and LPA for comment with the purpose of discharging Condition 29.4 for DZ4 to DZ7 and DZLV1.	January 2022
	Issue 2	To be submitted to the LPA to discharge Condition 29.4 for DZ4 to DZ7 and DZLV1.	
	Issue 3	To be submitted to the Environment Agency and LPA for comment with the purpose of discharging Condition 29.4 for DZ2 and DZ3. Includes review of data from phase 2 investigation for DZ4 to DZ7 and DZLV1.	
	Issue 4	To be submitted to the LPA to discharge Condition 29.4 for DZ2 and DZ3. Includes review of data from phase 2 investigation for DZ4 to DZ7 and DZLV1.	

Summary of report updates

This is the first issue of this report. This section will outline any updates to the report after the review by the regulators.

Executive summary

Introduction

The Meridian Water masterplan development is a large brownfield regeneration scheme located in north London within the London Borough of Enfield. The master plan development aims to deliver a significant number of houses, employment and new infrastructure in Edmonton, London. The regeneration scheme will bring forward land for redevelopment over time to maximise the potential of what is currently either vacant or low density industrial and retail land.

This report relates specifically to the Meridian Water Strategic Infrastructure Works (SIW) which includes new roads, bridges, earthworks, remediation, flood alleviation works, preparation of development platforms, Pymmes Brook naturalisation and landscaping.

Ove Arup & Partners Ltd (Arup) is providing ground contamination advisory services for the SIW on behalf of London Borough of Enfield (the client). London Borough of Enfield (LBE) has appointed Taylor Woodrow (TW) as the main works contractor (the Contractor) to deliver Meridian Water SIW.

The planning application for Meridian Water SIW was granted consent in July 2020 (PA/19/02717/RE3). Condition 29 of the consent describes the requirements for the assessment and management of contaminated land. Discharge of Condition 29 will be achieved in two phases, to allow works to commence in SIW-Phase 1 before the condition has been discharged in full in SIW-Phase 2.

Scope of document

The purpose of this report is to address the remaining items of part 3 and part 4 of planning condition 29 for the SIW-Phase 1 area.

This document has been produced in accordance with the Environment Agency's Land Contamination: Risk Management guidance and includes:

- Relevant background information including summary of proposed development and ground conditions;
- Summary of the preceding risk assessments and the resulting updated conceptual site model;
- Definition of remediation objectives and identification of relevant remediation constraints;
- Summary of outcomes of the remediation options appraisals undertaken (included in full in an appendix);
- Discussion of the components of demolition and site clearance relevant to remediation;
- The earthworks and materials management strategy and requirements of cover systems;
- Groundwater source remediation;
- Remediation works in Brooks Park, including Pymmes Brook naturalisation;
- Elements of remediation to be addressed in construction (e.g. measures required in installation of services and piling);
- Site management during works relating to contamination;
- Detailed verification plan identifying all elements that require evidence-based verification;
- Residual risks to be addressed by follow-on plot developers (e.g. vapour protection).

The key components of the SIW-Phase 1 remediation strategy are summarised below.

Demolition and site clearance

The BOC Buildings and two small bridges will be demolished, redundant utilities and monitoring wells will be appropriately decommissioned and invasive species of vegetation will be removed, all in accordance with contractor method statements.

Surfacing will be removed across extensive areas of site, and the uppermost materials will be turned over to a depth of 1.5m to remove geotechnical and geoenvironmental development constraints. Within the 1.5m turnover depth, gross contamination will be removed and managed in accordance with the materials strategy (i.e. removed offsite or treated on site to achieve reuse criteria). Gross contamination will be chased out to the base of the unsaturated zone or base of made ground, whichever is encountered first. If gross contamination (NAPL) is observed extending to greater depth then either: a) excavation will be extended; or b) further investigation, and if necessary NAPL removal from boreholes, will be implemented.

Removal of obstructions may extend to greater depth. Where earthworks cut is required, the turnover approach above will be followed except that material will be not be replaced and instead it will be taken to an onsite material management facility ('hub') for segregation, treatment etc as required by the materials strategy. Site turnover excavations will be observed by a competent geoenvironmental specialist as part of the watching brief.

Approximately 20 tanks have been identified from historical mapping across the SIW- Phase 1 area. A tank register will be used to systematically manage tank removal. After tank removal and any associated gross contamination, verification soil sampling from the sides and base of the excavation will be undertaken in accordance with the verification testing requirements.

Earthworks and materials strategy

Extensive earthworks will be completed to achieve site levels in addition to the site turnover described above. The main areas of cut are Edmonton Marshes (DZLV1), Brooks Park (west of DZ4), the flood conveyance channel (DZ7) and Ikea Clear (southeast of DZ4). The main areas of fill are beneath new road corridors and development platforms (in DZ4 north, DZ5 and DZ7). In addition, more localised excavations such as construction of bridge abutments.

A geoenvironmental watching brief will be implemented to ensure ground works are managed to identify potential contamination. The remediation strategy includes a comprehensive discovery strategy that defines the actions required in response to encountering contamination during the works, including chasing out gross contamination.

Risk-based criteria and verification requirements have been defined for cover soils to be placed in combination with topsoil in soft landscaping areas and over general fill to achieve required levels in future development plots. A verified cover system is required in soft landscaped areas, with local variations in Brooks Park, flood alleviation channel and Edmonton Marshes. Similarly risk-based criteria and verification requirements have been defined for general fill that will be placed beneath hardstanding and beneath cover soils to achieve levels required for development plots. Site-won material from DZ2, DZ4, DZ5, DZ6 and DZ7 will be tested for the standard verification suite and site won material from DZLV1 will be tested for a reduced verification suite (unless the presence of hydrocarbons is suspected).

Excavated soils may require remedial treatment to achieve defined geoenvironmental reuse criteria before they can be reused on site. Excavated soils requiring treatment to achieve reuse criteria for PAH, TPH, chlorinated solvents and other complex organic compounds will be treated exsitu at the materials hub. Suitable uncontaminated material arising from demolition and removal of buried obstructions will be processed on site to produce recycled aggregates. A site-wide deficit of topsoil may be addressed by manufacture of topsoil on site. Only clean, natural soils without anthropogenic contamination, or recycled material produced under a WRAP protocol will be imported. Imported soils will be validated as chemically suitable for purpose.

Robust materials management and verification will be implemented to maximise reuse of suitable material and to minimise the volume of material requiring offsite disposal, while ensuring that only the amount needed to achieve the proposed site levels are used, and that use is certain, to ensure compliance with DoWCoP and environmental permitting regulations. A digital material tracking system will ensure the material is recorded throughout its movement from excavation to stockpiles to treatment and reuse or offsite disposal.

Groundwater source remediation

Remediation options appraisal for each of the five groundwater source areas identified by the preceding risk assessments (presented in the interpretive report and DQRA) has informed the remediation requirements for each source.

1. Benzene in KPGR (DZ4 south): surface turnover, removal of gross contamination followed by in situ treatment (air sparging or chemical oxidation).
2. Vinyl chloride in KPGR (DZ7): surface turnover, removal of gross contamination followed by in situ treatment (air sparging or chemical oxidation).
3. TPH (DZ2): surface turnover, removal of gross contamination followed by installation of new wells to enable removal of NAPL where present.
4. Ammoniacal nitrogen and cyanide in KPGR (DZ4 south and DZ2): surface turnover, removal of gross contamination, hardstanding development to reduce infiltration, associated improvements from 1 above and Brooks Park dewatering, natural attenuation of residual with monitoring to provide evidence.
5. Ammoniacal nitrogen and cyanide in chalk basal sands (DZ2 and DZ4 southwest): unsaturated zone source removal and infiltration reduction as a result of development, natural attenuation of residual with monitoring to provide evidence.

For 1 and 2 additional investigation to delineate the source could reduce or remove the requirement for groundwater treatment. However, any changes to this strategy will require approval by the Environment Agency, with supporting source characterisation and risk assessment.

Brooks Park remediation

The new Brooks Park area, forming the western part DZ4, will include a 500m naturalised section of Pymmes Brook with associated ecological improvements, flood attenuation basins, riverside parkland, a boardwalk and viewing platforms. The detailed design and construction methodology must be approved prior to works on Pymmes Brook and Salmons Brook is required by planning condition 36, to be addressed separately, however the remediation requirements are outlined in the remediation strategy.

The extensive earthworks necessary to create Brooks Park will be managed to remove gross contamination and obstructions. A hydraulic cut off wall will be constructed by deep soil mixing or piles keyed into London Clay surrounding the area of the new naturalised channel. Within the area bounded by the cut off wall, excavation to formation is required to install a liner system beneath the base and sides of the new channel and tied into the existing concrete channel at both ends. The liner placed along the new channel will extend beneath the flood attenuation basins to the edge of Brooks Park in the east and west creating an effectively impermeable barrier layer to prevent infiltration and groundwater interaction with surface water. Clean cover will be placed over the barrier layer. Dewatering will be undertaken during excavations, with water treated prior to disposal. Appropriate design and implementation of environmental protection measures and monitoring will ensure protection of Pymmes Brook during construction.

Construction-related remediation

In addition to the remediation described above, several remediation tasks must be completed as part of SIW development construction, including construction of clean utility runs, concrete design to mitigate aggressivity risk, and designing piling to ensure groundwater protection. A foundation works risk assessment will be undertaken to inform pile design and address planning condition 35 for SIW piling which includes only piled foundations for river crossing bridge abutments. No buildings are to be constructed as part of SIW and therefore ground gas and vapour protection measures are not required for SIW.

Plot developer remediation

The SIW works comprise enabling works and creation of platforms suitable for future development. This subsequent development, for residential, commercial and other uses, will be subject to separate planning applications and planning conditions are anticipated specific to the remediation activities that are to be completed at that stage. The SIW remediation strategy outlines the remediation measures that should be addressed by the plot developers, such as in-building vapour protection measures.

The SIW works will complete site remediation as defined in this strategy and record the works completed and condition of the site on completion of the SIW in the verification report that will be available to future plot developers.

1 Introduction

1.1 Background

Meridian Water masterplan development is a large brownfield development located in north London within the London Borough of Enfield. The development aims to deliver a significant number of houses, employment and new infrastructure. The mixed-use regeneration scheme will bring forward land for redevelopment to maximise the potential of what is currently either vacant or low density industrial and retail land. This part of the scheme is the strategic infrastructure works (SIW), necessary to facilitate the following developments.

Ove Arup & Partners Ltd (Arup) is providing ground contamination advisory services for the SIW on behalf of London Borough of Enfield (the client). London Borough of Enfield (LBE) has appointed Taylor Woodrow (TW) as the main works contractor (the Contractor) to deliver Meridian Water SIW.

This report presents the remediation strategy and verification plan to be implemented in the area referred to as Meridian Water SIW-Phase 1.

1.2 Purpose of report

Meridian Water SIW was granted planning consent in July 2020 (PA/19/02717/RE3). Condition 29 of the consent relates to the management of land contamination. Discharge of condition 29 will be achieved in two phases, to allow works to commence in Phase 1 before the condition has been discharged in full in Phase 2 as shown in Figure 1 below.

The proposed phases are as follows:

- SIW-Phase 1 comprises DZ4 to DZ7 and DZLV1, and the southeast of DZ2 (the gasholder site); and,

SIW-Phase 2 comprises the remainder of DZ2 and DZ3. Planning condition 29 parts 1, 2 and the first two items of part 3 have been addressed in reports produced previously and identified in Section 1.4 below.

The purpose of this report is to address the remaining items of part 3 and part 4 of planning condition 29. This includes a remediation options appraisal, remediation strategy and verification plan for SIW-Phase 1, to enable discharge of the condition and commencement of site works for SIW-Phase 1. Following approval of this report and discharge of condition 29, any deviations from this strategy must be agreed in writing with the local planning authority (LPA). The Environment Agency will be consulted on any changes.

Several other planning conditions are associated with the management of contamination and the approach to discharging these conditions is presented in this document:

- Condition 30 requires a verification report to be produced on completion of the required remediation works in each phase;
- Condition 32 requires that previously unidentified contamination encountered during SIW is appropriately dealt with.

Figure 1 Proposed areas for phased discharge of Condition 29 (Pink SIW-Phase 1, Green SIW-Phase 2).

1.3 Other relevant planning conditions

Several other planning conditions relate to the remediation works on the SIW planning consent (Appendix A). The approach to discharge of these conditions is discussed in this document, however separate submissions will be required by the Contractor to discharge these conditions:

- Condition 5 requires an approved Construction Environmental Management Plan (pre-commencement);
- Condition 16 requires an approved eradication strategy for invasive species (pre-commencement);
- Condition 17 requires an approved Site Waste Management Plan (pre-commencement);
- Condition 31 requires an approved long-term monitoring plan (pre-commencement);
- Condition 34 requires an approved borehole decommissioning scheme (pre-occupation);
- Condition 35 requires approval of piling methodologies (pre-piling works);
- Condition 36 requires an approved scheme for Pymmes Brook naturalisation including detailed design and construction methodology (prior to works on Pymmes Brook and Salmons Brook).

1.4 Previous assessments

Since 2018 Arup has undertaken a series of tasks to inform management of ground contamination-related risks at Meridian Water, including site characterisation and risk assessments. The key documents listed below have been prepared by Arup and submitted to the Environment Agency for review:

- Arup (2019) Ground contamination baseline report. Meridian Water. Meridian Water Phase 2 and Meridian Water Strategic Infrastructure Works. MWSIW 2.2 Issue 6. [1]
- Arup (2019) Ground investigation, remediation and materials management framework. Meridian Water Phase 2 and Meridian Water Strategic Infrastructure Works. MWSIW 2.3 Issue 4. [2]
- Arup (2021) Ground contamination preliminary risk assessment and site investigation scheme. Meridian Water. Issue 3 (the Arup (2021) PRA). [3]
- Arup (2021) Ground contamination risk assessment. Strategic Infrastructure Works, Meridian Water. Issue 2 (the Arup (2021) interpretative report). [4]
- Arup (2021) Detailed quantitative risk assessment. Strategic Infrastructure Works, Meridian Water. Issue 1 (the Arup (2021) DQRA). [5]
- Arup (2021) Remediation framework report. Strategic Infrastructure Works, Meridian Water. Issue 2 [6]

1.5 Relevant guidance

The Environment Agency's Land Contamination: Risk Management (LCRM) online guidance [7] has been applied in the development of this document. LCRM was developed to provide the technical framework for applying a risk management process when dealing with land affected by contamination. The approach in dealing with past land contamination is based on risk management. The risk management process in the guidance is as follows:

- Stage 1: Risk assessment.
  - Tier 1: Preliminary risk assessment.
  - Tier 2: Generic quantitative risk assessment.
  - Tier 3: Detailed quantitative risk assessment.
- Stage 2: Options appraisal.
- Stage 3: Remediation and verification.

All assessments should include a preliminary risk assessment, however, the level of detail of further risk assessment is dependent on site-specific considerations. The risk assessments define and assess the 'potential contaminant linkages' (PCL) in a source-pathway-receptor framework ('conceptual model') aiming to establish 'relevant contaminant linkages' (RCL) that require intervention, such as remedial action.

The options appraisal should identify and appraise feasible remediation options to identify the appropriate remedial options and to establish objectives. Technically feasible options which address RCLs and meet strategic and local objectives must be identified and the most suitable option or combination of options should be selected to create a remediation strategy.

The selected remediation approach should be proportionate and balance the costs of the required remediation with the environmental benefits, taking account of the environmental setting, likely background conditions in the local area, and any constraints associated with the site.

This remediation strategy report presents the Stage 2 assessment (referred to in LCRM as options appraisal) and includes the conceptual model, remediation objectives, remediation options appraisal, the remediation methods that will be implemented and the verification plan for SIW-Phase 1.

1.6 Regulator liaison

To date, a constructive relationship has been developed with the environmental regulators primarily involved with the Meridian Water scheme. The LBE principal pollution officer and the Environment Agency have been, and will continue to be, consulted on aspects relating to contaminated land, including regular meetings and communications. A document submission schedule for the SIW has been agreed with the Environment Agency to enable forward planning of their resources.

During the remediation works, a close working relationship between the regulator and contractor should be established and maintained. Site visits by the regulators will be welcomed and any concerns raised will be investigated and addressed.

Verification reporting will be completed and agreed with the regulators as described in the remediation strategy.

Any variation to the agreed remediation strategy will be agreed with the Environment Agency and LPA in writing in advance of the relevant works progressing.

Construction of the SIW will also require Environment Agency or local authority consultation and agreement in relation to environmental permits such as those relating to waste, water, emissions and flood risk activities.

1.7 Limitations

This report has been prepared by Arup for use by London Borough of Enfield. It should not be relied upon by any third party except as provided for in Arup's appointment with the London Borough of Enfield. Arup has based this report on the sources detailed within it and believes them to be reliable but cannot and does not guarantee the authenticity or reliability of third-party information.

Reasonable skill and care have been exercised in preparation of this report in accordance with the technical requirements of the brief. Notwithstanding the efforts made by the professional team in undertaking this contamination assessment, it is possible that ground conditions and contamination other than that potentially indicated by this report may exist at the site.

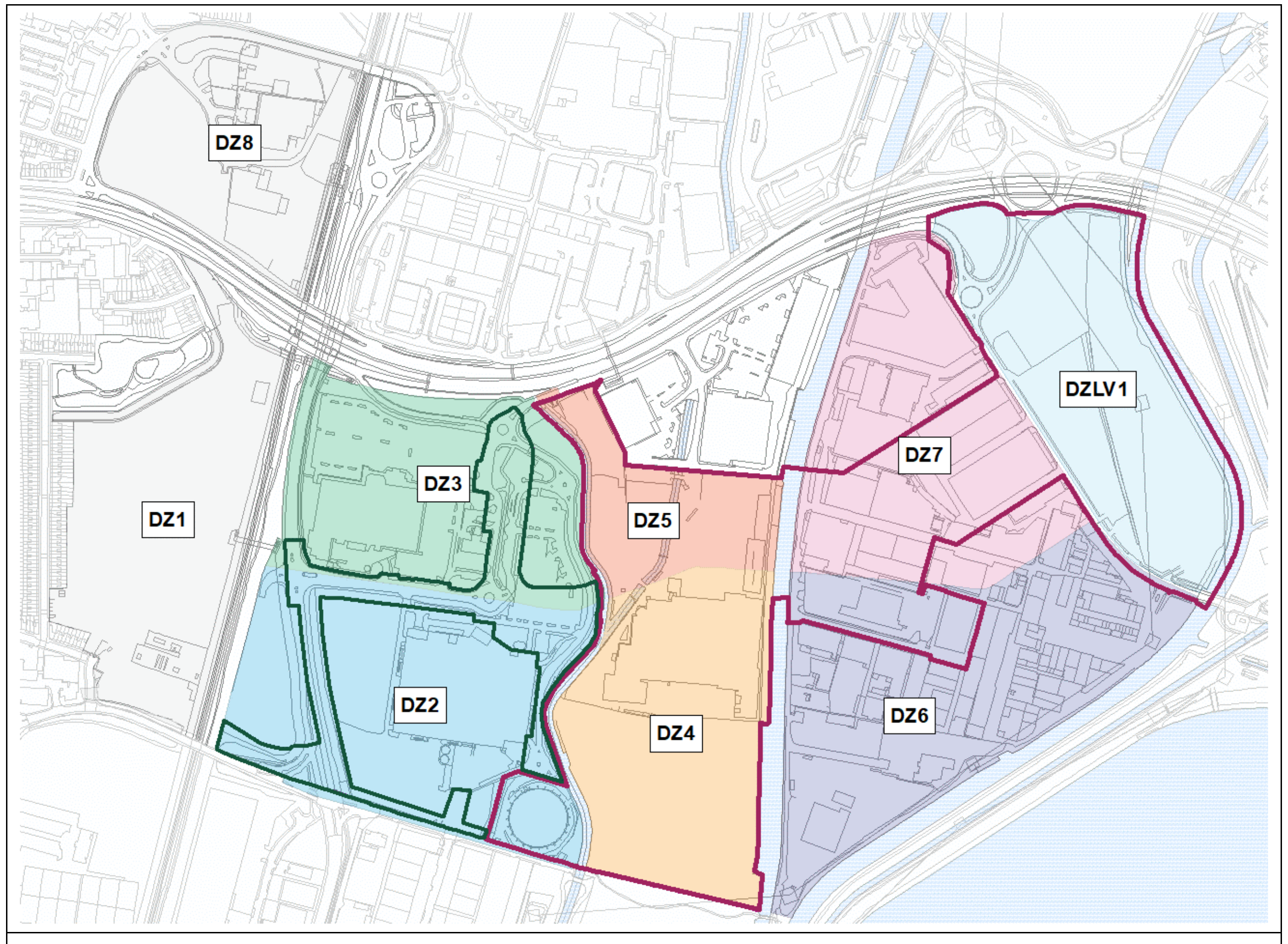
This report has been prepared based on current legislation, statutory requirements, planning policy and industry good practice at the time of writing. Any subsequent changes or new guidance may require the findings, conclusions and recommendations made in this report to be reassessed in the light of the circumstances.

This report does not present a survey or assessment of the location, condition or liabilities associated with hazardous materials in the building fabric such as (but not limited to) asbestos containing materials or lead.

2 Proposed development

2.1 Meridian Water masterplan

The Meridian Water masterplan area has been split into Development Zones (DZ) as shown in Figure 2. The first two phases of the Meridian Water masterplan development are underway or have been completed (Meridian Water Phase One development and the Meridian Water Station), identified as DZ1 in Figure 2.



Dark pink SIW-Phase 1 boundary, Dark green SIW-Phase 2 boundary.

Figure 2 Meridian Water Development Zones

2.2 Meridian Water Strategic Infrastructure Works

This report relates only to the MW SIW planning application boundary (PA/19/02717/RE3) shown on Figure 1. Therefore DZ1, DZ8 and most of DZ2, DZ3 and most of DZ6 are outside of the boundary of the MW SIW site.

The SIW will enable the subsequent mixed-use residential-led development and a new local centre in this area. The SIW construction package is outlined below. The majority of the SIW are located within the SIW-Phase 1 boundary which a due to start in ealry 2022. A bridge, access works, utilities and part of the central spine road are located within SIW-Phase 2 area which are anticipated to commence in late 2022. The main SIW features are shown on Drawing 1.

- The Central Spine Road; a new tree-lined east-west boulevard connecting to Glover Drive and the new Meridian Water Station in the West, crossing Pymmes Brook and Salmons Brook and River Lee Navigation to Harbet Road in the East.
- Leeside Link Road; a new link road providing access for cars, pedestrians and cyclists from Leeside Road through to the Central Spine Road.
- Four bridges will be erected to enable the Central Spine Road and Leeside Link Road to span the Pymmes Brook and Salmons Brook and River Lee Navigation.
- Brooks Park and river naturalisation; naturalising the currently channelised Pymmes Brook to introduce an ecological river landscape as well as providing riverside parkland.
- Edmonton Marshes and flood alleviation works; relevelling of land to the east of Harbet Road, providing comprehensive flood alleviation works, including flood conveyance channel, and a new high quality public open space within the Lee Valley Regional Park (LVRP).
- Access works provision of new and altered accesses to the IKEA store, a new north-south link between Argon Road and Glover Drive, the creation of a link between the Central Spine Road and Anthony Way and other improvements to maintain access, along with other ancillary highways works to Glover Drive, Leeside Road, and Meridian Way.
- Earthworks, remediation, utilities and other ancillary works including earthworks, retaining structures and soil remediation, and installation of main utility networks and ancillary works including the demolition of existing buildings and structures.

LBE has appointed Taylor Woodrow (TW) as the main works contractor (the Contractor) to deliver the SIW.

3 Summary of site condition

3.1 Site location and description

The site is in the Lea Valley approximately 10km northeast of central London and at National Grid Reference 535514E, 191806N. The SIW-Phase 1 application boundary is currently used for light industrial activities including storage, events space and small scale industries. The SIW-Phase 1 application boundary is illustrated in Figure 3 below.

Figure 3 Strategic infrastructure works Phase 1 site boundary

The eastern part of the site is primarily open land. A historic gasholder structure is in the southwest of the site. The gasholder superstructure has been removed and the site is currently used for vehicle storage. The centre of the site encompasses six large warehouses referred to as the British Oxygen Company (BOC) buildings. The land surrounding the warehouses is primarily used for car storage and scaffolding yards or similar uses. To the south of these buildings is an area of open space, surfaced in gravel and grass, used as event space.

The surrounding land use is primarily light industrial with some residential developments and open space. The site is bordered to the north by the North Circular road.

3.2 Overview of relevant site history

The Arup (2021) PRA [3] provides a comprehensive review of site history for the SIW application boundary and identifies onsite primary sources of contamination across the site. This section provides a summary of the relevant site history within the SIW-Phase 1 boundary. Drawing 2 shows the previous site uses, approximate positions of historic tanks, wharfs and substations within the SIW-Phase 1 boundary.

Historic industries onsite include large industrial facilities such as the Leeside Chemical Works and Angel Works and more recent light industrial and commercial uses including the VOSA building, event spaces, and multiple commercial tenants at the Lea Valley Trading Estate. Made Ground is extensive across the site and in some areas specific infilling activities are apparent from the review of site history including land along the route of the former River Lea and associated with land raising in DZLV1.

Approximately 20 tanks have been identified from historical mapping across the SIW-Phase 1 site. Primarily, these are in the south of DZ4 associated with the former Leeside Chemical Works, however, tanks are also noted across DZ6 and DZ7 associated with the historic Angel Road Colony and in DZ5 associated with former engineering works.

Leeside Road gasholder in the southeast of DZ2 was operational from the 1930s and decommissioned in 2014. To the east of the gasholder structure, Leeside chemical works occupied the southern part of DZ4 between 1930s and 1980s. The chemical works is known to have included a benzole rectification plant and ammonia sulphate plant and it is probable that the chemical works utilised by-products from the gas production associated with the former Edmonton gas works to the west of the site.

The former Angel Works in DZ7 included several historic industries such as a linoleum factory, engineering works and sheet metal works.

The Environment Agency identifies a 'historical landfill' record within DZLV1 [1]. However detailed review of the site history suggests that much of this material may originate from historic civil engineering and earthworks activities from the surrounding area. Ground investigation has identified predominantly good quality, reworked natural soil or uncontaminated Made Ground comprising predominantly natural soils.

Table 2 Main historical site uses

Zone	Historical use
Within SIW-Phase 1 boundary	
DZ2	Gasholder
DZ4	Leeside Chemical Works, waste transfer station, raised land (possible infill), engineering works, tanks, platforms, substations and a wharf
DZ5	Sparklet Works, engineering works, carparking, storage and small-scale industry
DZ6	Angel Works (linoleum factory, engineering, sheet metal, furniture, joinery and moulded plastic works)
DZ7	Angel Works (linoleum factory, engineering, sheet metal, furniture, joinery and moulded plastic works)
LV1	Includes an area identified by Environment Agency as 'historical landfill' that contains reworked natural material and some Made Ground containing higher quantities of anthropogenic material (e.g. masonry rubble)
Sitewide	Approximately 20 tanks and one gasholder.

Zone	Historical use
	Three electrical substations.
Outside SIW Phase 1 and offsite	
DZ1 (offsite)	Tottenham and Edmonton gas works
DZ2	Gothic Works
DZ3	Gothic Works (gas meters and stoves), one current petrol station present since 1998 and a large tank

3.3 Previous remediation

In 2015 the above ground structure of Leeside Road gasholder was removed, and the below ground structure was cleaned and backfilled with uncontaminated imported material. Residual contamination has been recorded by previous investigations in the shallow and deeper aquifers surrounding the gasholder and is considered further in this report.

Some remediation was completed in DZ4 in 2006 and 2007 by Entec [8]. The remediation works included excavation of targeted areas of contaminated soil, removal of tanks and concrete structures, processing and treatment of excavated material by exsitu bioremediation and some targeted groundwater remediation by pump and treat. Materials that were not suitable for reuse onsite were disposed of offsite, and a proportion of the treated material was used as backfill across the site.

The remediation works targeted gross contamination within soils including petroleum hydrocarbons, phenol, naphthalene and benzene, toluene, ethylbenzene and xylene (BTEX) (associated with historic tanks, plant, pipes and residual tar), cyanide (associated with spent oxide) and ammoniacal contamination. A leaking tank and oil drum were cleaned and removed. Two asbestos pits in the east of the site were excavated and the material disposed of offsite (approximately 361 tonnes material).

The Entec remediation report [8] highlights the key remediation areas and outlines where residual contamination and structures were left in situ. Although the main source areas were removed residual contamination remained onsite and has been considered by Arup and discussed further in this report.

3.4 Ground investigations

Several ground investigations have been completed within the SIW application boundary. All previous exploratory locations are shown in Drawing 3.

The main investigation specifically scoped for the SIW is the GTS 2019/2021 investigation. This investigation has been completed in two phases due to access constraints onsite. The results from Phase 1 have been reported in the interpretative report (Issue 2) and DQRA (Issue 1). The intrusive phase of Phase 2 investigation was completed in July 2021 and monitoring is currently ongoing. The Phase 2 scope includes investigation in areas which could not be accessed during Phase 1 and supplementary investigation to fill data gaps identified during the interpretative reporting and detailed risk assessment. The findings from the Phase 2 investigation will be reported in full in Issue 3 of the interpretative report (due March 2022) and in Issue 3 of the DQRA (due in June 2022). An early summary of these works will be provided in a Technical Note prepared by Arup. The Technical Note will summarise the findings of the supplementary investigation (within the SIW-Phase 1 boundary only) and discuss and clarify the implications in relation to the previously submitted documents (including the remediation strategy).

SIW Investigation Phase 1

The scope of the first phase of investigation was completed between October 2019 and January 2021 (intrusive phase between October 2019 and March 2020, monitoring programme between April 2020 and January 2021). Six rounds of groundwater monitoring and sampling have been completed in most locations, and between four and six rounds of ground gas monitoring have been completed. The investigation strategy, including the rationale behind the selection of individual locations was originally presented in Table 16 and Table 17 in Section 7.3 of the Arup PRA [3]. The full details of the SIW investigation Phase 1 scope can be found in the interpretative report (Issue 2) [4].

Watching briefs for ecology, archaeology, and UXO were undertaken during the ground investigation. No issues relating to these aspects were recorded during the intrusive works. Additionally, following radiation risk assessment (RRA) undertaken by a radiation protection advisor (RPA), health physics support was also provided during the ground investigation in the vicinity of the former Sparklet works. Further details on this are provided in the Nuvia 2020 report [14][15] and a summary is provided in the PRA [3].

The completed intrusive phase of SIW ground investigation comprised:

- 39 deep boreholes;
- 31 shallow boreholes;
- 49 cone penetration tests (CPT);
- 44 trial pits or trial trenches;
- 82 groundwater standpipes; and,
- 21 ground gas standpipes.

Representative soil samples for contamination purposes were recovered from each of the exploratory holes. 321 soil samples were submitted for various types of chemical analysis. Of these, 220 were from boreholes and 101 were from trial pits or trial trenches. Headspace analysis of each sample was carried out using a PID and the results are included in the logs with are provided in the Arup interpretative report (Issue 2) Appendix B [4].

Analysis included, but was not limited to, metals, asbestos (identification and quantification), speciated total petroleum hydrocarbons (TPH), polyaromatic hydrocarbons (PAH), BTEX, volatile and semi volatile hydrocarbons (VOC and SVOC) and polychlorinated biphenyls (PCBs). Leachability testing was undertaken in line with BS EN 12457 Part 2 [16] on 140 samples collected from the site, 76 from boreholes and 64 from trial pits and trenches.

Standpipes were installed within boreholes for the purpose of groundwater and/ or ground gas monitoring as summarised in Appendix C Table 3 in the interpretative report (Issue 2) [4]. Several existing monitoring wells installed during previous ground investigations were also included in the monitoring network. The historic locations included in the monitoring network include ten Kempton Park Gravels (KPGR) installations, four Lambeth Group installations and three Chalk installations.

Two rounds of groundwater monitoring have been undertaken in 95 of 96 groundwater monitoring standpipes installed as part of SIW investigation Phase 1. One location has been inaccessible to date (DZ4_BH2027). This standpipe will be monitored when access is granted.

Based on a review of the data from the 95 accessible wells a reduced network of 65 boreholes within the SIW Phase 1 area were monitored for six rounds over six months as a baseline for the project (referred to as the baseline monitoring network). This baseline network was agreed with the Environment Agency.

Ground gas monitoring was undertaken as part of the Phase 1 ground investigation between 26th March 2020 and 1st June 2020 from 23 installations. Table 3 summarises the monitoring scope with more detail provided in the Arup (2021) interpretative report [4].

Table 3 Summary of monitoring scope completed as part of SIW investigation Phase 1

Item	Number of locations	Number of samples/ monitoring rounds
Initial groundwater sampling in all installations	95	190 samples excluding field/trip blanks (nine) and duplicates (43)
Baseline monitoring network (SIW-Phase 1 only)	62 (scope not completed in six locations, at least four rounds were completed in these six locations)	Approximately 260
Surface water samples	four	twelve
Ground gas monitoring	23	Six rounds completed in nine locations, three to five rounds in remaining 14 locations.
Ground gas and vapour sampling	six location selected from the 23 installations.	Six, one sample from each gas monitoring round.

Previous investigations

Outside the SIW investigation, several smaller investigations have been completed within or near the SIW application boundary within the last three years. Where chemical data has been available in AGS format, it has been included in the assessment. This includes the 2018 SLR investigation (inside SIW-Phase 1 boundary) [10], 2019 Harrisons investigation (inside SIW-Phase 1 boundary) [11], 2020 BWB investigation (inside SIW-Phase 1 boundary) [12] and Meridian Water Studios (outside SIW application boundary) [13].

A summary of the scope and purpose of these additional investigations is presented in Table 4.

Table 4 Summary of data from previous investigations

GI (Date)	Reason for investigation	Number of locations drilled	Data included in screening.
SLR (2018)	To assess suitability of the site for meanwhile use as an event space including commercial buildings and open space.	Eight boreholes Ten window samples 19 trial pits	SS, 43 GG, six monitoring rounds GW, 46 samples (5 rounds) SW, 22 (three rounds)
Harrisons (2019)	To locate and reinstate historic groundwater and ground gas wells.	None	GG, six monitoring rounds GW, two rounds (14 samples) No soil samples
BWB (2020)	Refurbishment of VOSA building including construction of extension of existing building.	six window samples seven boreholes one hand dug pit	SS, 20 GG, six monitoring rounds GW, two rounds (ten samples) from shallow locations and three rounds from BH4001 and BH4002 before, during and after piling.
Meridian Water Studios (MWS) (2021)	To assess the suitability of the site as a commercial event space including use as a film studio.	two boreholes six window samples	SS, 21 GW, 10 samples (two rounds completed in two new boreholes and two existing boreholes onsite, and one round from two existing boreholes outside the MWS boundary but within the SIW boundary.
Key SS, soil samples. GG, ground gas. GW, groundwater. SW, surface water Not all soil samples were tested for all contaminants. Sample numbers refer to data available to Arup in AGS format.			

3.5 Ground conditions

A summary of ground conditions is provided below. A full review of ground conditions is provided in the interpretative report (Issue 2) [4].

3.5.1 Stratigraphy

The stratigraphic sequence onsite is superficial deposits including Made Ground over Alluvium overlying KPGR overlying bedrock. Bedrock consists of London Clay overlying Lambeth Group. Harwich Formation was identified underlying the London Clay within the centre of the site at a small number of locations. Underlying the Lambeth Group is Thanet Formation and Chalk. Table 5 outlines the site stratigraphy for the full SIW application boundary.

Table 5 Site stratigraphy DZ2 to DZLV1

Strata	Top elevation (m OD)	Base elevation (m OD)	Thickness *(m)
Made Ground	15.9 to 7.3	13.6 to 5.7	0.5 to 7.3**
Alluvium	11.3 to -0.1	10.1 to 4.9	0.15 to 3.8
KPGR	9.9 to 3.8	8 to 0.7	0.9 to 5.3
London Clay	7.1 to -3.54	3.9 to -6.9	1.6 to 12.3
Harwich Formation	-1.79 to -6.5	-3.3 to -7.2	0.7 to 1.5
Lambeth Group	1.76 to -18.8	0.6 to -26.3	3.5 to 24.4
Thanet Formation	-5 to -26.3	-10.6 to -30	8.5 to 19.5
Chalk	-23.6 to -31	Not proven	Not proven
* Based on where locations have penetrated the strata ** excluding locations within the gasholder base.			

Made Ground

The deepest Made Ground (10.4m) encountered site wide is associated with the gas holder structure in DZ2. The deepest Made Ground was recorded in BH1602 drilled as part of the Amec 2016 investigation [9]. The gasholder annulus is -0.1m OD and the top of the dumpling is at approximately 3.3m OD. The gas holder is reported as having been backfilled with clean, Class 2A fill material and Class 6F5/1A material to 10.4m OD. BH1602 was drilled at the edge of the gasholder to determine if any sludge remained at the base of the annulus. The borehole was drilled through the clean backfilled material, through the concrete base and one meter into the London Clay. The borehole confirmed there was no sludge at the base of the gasholder. Outside the gasholder structure, current data suggests that Made Ground is on average 2m thick.

In DZ4 and DZ5, Made Ground has been recorded at thicknesses ranging from 0.6m and 5.3m; deeper Made Ground has been recorded close to current buildings and within the footprint of the historic chemical works.

In DZ6 and DZ7, Made Ground has been recorded at thicknesses ranging between 0.8m and 7.3m; deeper Made Ground appears to be associated with historical structures and foundations. In DZLV1, a maximum thickness of Made Ground of 6.7m has been recorded associated with the Harbet Road waste mound, but it is typically much thinner (<2m).

Made Ground across the site is variable but does typically include a high proportion of masonry material including concrete and brick gravels and cobbles as well as gravelly clay with brick, concrete and flint. Additionally, ash, timber, rebar, slag, cast iron pipes, glass, and plastic, were found in varying quantities.

DZLV1 has been subject to uncontrolled fly tipping and assorted waste items are present at the surface. Evidence of construction waste is also present.

Alluvium

The Alluvium has typically been described as dark grey sandy clay with an organic odour. Peaty deposits are present in some locations logged as brown pseudo fibrous plastic peat. Occasional pockets of pale grey silt with numerous shell fragments occur at various locations across the site.

The thickest alluvial deposits (4.3m) were recorded in DZLV1. In some locations in DZ4 and DZ5 Alluvium was absent. Elsewhere in DZ4 and DZ5, comparatively thick Alluvium was recorded (up to 3.7m in BH1506). In DZ6 and DZ7, Alluvium was encountered at thicknesses of between 0.1m and 2.7m.

Kempton Park Gravels

The KPG is medium dense light brown sandy gravel of flint and was encountered in all boreholes across the site. Thicknesses across the site ranged between 0.9m to 5.3m. Relatively thick KPGR (~5.0m) was recorded in several locations in the north of DZ4. By contrast in the south and southeast of DZ4 the KPGR was typically 2 to 3m thick.

KPGR is approximately 3.5m thick across most of DZ5 but tends to be slightly thinner in the north and northeast of the zone; a minimum thickness of 1m was recorded in DZ5_BH2018. Within DZ6 and DZ7, thicknesses of KPGR range between 1.2m and 4.9m with an average thickness of 3.3m.

Within the seven boreholes advanced in DZLV1, the KPGR ranged between 1.3m (DZLV1_BH2077) and 5m (DZLV1_BH2080) thick. In DZLV1_BH2077, 3.3m of Alluvium was recorded above the KPGR compared to 0.4m in DZLV1_BH2080.

London Clay

The London Clay has been encountered site wide as a typically firm to stiff micaceous clay. The average thickness of London Clay across the site is 6.4m.

The London Clay tends to be thicker in the east of the site, with measured thicknesses of 8.5m to 12.3m recorded in DZLV1. In the south of DZ4, an area associated with the most evidence of contamination, the London Clay is approximately 7m thick suggesting it should provide a significant hydraulic barrier between shallow sources of contamination and deeper groundwater units.

In DZ4_BH2045, a lesser thickness of London Clay of 4.1m was recorded. Underlying the London Clay in this area was approximately 12m of cohesive Lambeth Group which, coupled with the overlying London Clay would be expected to provide a substantial hydraulic barrier between the shallow aquifer and the deeper groundwater units.

A minimum thickness London Clay of 1.6m of was encountered in BH1506 in DZ5. The two surrounding boreholes in this area BH1509 (5m west) and DZ5_BH2015 (15m southwest) had a thickness of London Clay of 3.5m and 4.3m respectively. The London Clay in BH1506 is underlain by Lambeth Group described as gravely sand and stiff to very stiff greenish grey clay. The depth of Lambeth Group at BH1506 is unknown as the borehole was terminated 2.5m in the Lambeth Group. However, thicknesses of around 7m were recorded in surrounding locations, and the Lambeth Group is predominantly cohesive providing some protection to the deeper Chalk Basal Sands aquifer.

Harwich Formation

The Harwich Formation was identified underlying the London Clay in two locations both located within DZ4. The Harwich Formation is greenish grey sandy calcareous clay. Thicknesses of 0.7m and 1.5m were recorded in DZ4_BH2029 and DZ4_BH2034 respectively.

Lambeth Group

The Lambeth Group was recorded in all deep boreholes across the site. It was recorded as stiff to hard bluish very sandy clay. In several locations, layers of very dense light grey mottled sand were recorded.

The mean thickness of Lambeth Group across the site was 9m, ranging between 1.5m in DZLV1_BH2080 and 24.4m in DZ6_BH2062. Lambeth Group thickness in DZLV1 tends to be slightly thinner than the rest of the site and ranges between 1.5m and 6.5m. However, the London Clay within DZLV1 tends to be thicker. Within the other development zones inside the SIW boundary a minimum thickness of 3.5m of Lambeth Group was recorded in DZ7_BH2049.

A detailed review of the Lambeth Group geology has been provided in the interpretative report (Issue 2) [4] and DQRA (Issue 1) [5].

Thanet Formation

The Thanet Formation is greenish grey clayey fine sand. The average thickness across the site is 14.9m thick and ranges between 6.4m and 19.5m.

Chalk

Chalk has been recovered as silty gravel and cobbles of Chalk in 31 exploratory hole locations. The top of the Chalk has been encountered at levels ranging between -23.6m OD and -31m OD; the highest levels were encountered in DZ5 and the lowest levels recorded in DZ6 and DZLV1.

3.5.2 Hydrology and hydrogeology

Hydrogeology

Groundwater level data was collected during drilling; weekly during the ground investigation and monthly during the groundwater monitoring. This has resulted in 20 rounds of groundwater data between November 2019 and June 2020.

Water strikes, indicating perched groundwater were recorded during the SIW investigation within the Made Ground at several locations ranging between 0.9m bgl and 3.4m bgl. Groundwater wells were not installed to target perched groundwater as it is not considered representative of the piezometric water table nor is it considered to require assessment as a potential controlled waters receptor.

Although designated as a secondary A aquifer, groundwater was not recorded in the Alluvium during drilling. Across most of the site, the Alluvium was recovered as a cohesive clay occasionally containing layers of pseudo-fibrous peat.

Groundwater was encountered within the KPGR between 5.37mOD and 8.92mOD. To the west of the River Lee Navigation, the depth to groundwater in the KPGR ranges from approximately 2mbgl (e.g. DZ5_BH2019a in the north DZ5) to approximately 5.5mbgl (e.g. DZ4_BH1008) in the southeast of DZ4. To the east of the River Lee Navigation groundwater levels range from approximately 2mbgl to 4mbgl in DZ6 and DZ7 whilst in DZLV1, the levels are sometimes deeper (up to 5mbgl) but are also more variable due to the uneven topography.

Generally, the groundwater in the KPGR is relatively flat and consistent flow directions are not always possible to infer. Variation in flow direction is apparent between different monitoring rounds which is likely to be attributable to varying effective rainfall and the fact that in certain areas shallow groundwater will recharge much more quickly due to the relative absence of hardstanding or buildings. A detailed review of the groundwater in the KPGR aquifer was completed as part of the DQRA (Issue 1) (Appendix E) [5].

A detailed review of the Lambeth Group hydrogeology is included in Appendix D of the interpretative report (Issue 2) [4] and Appendix C of the DQRA (Issue 1) [5]. Groundwater response zones in the Lambeth Group have been installed in 18 locations. Most of the Lambeth Group strata encountered comprises low permeability mottled clay and most installations within the Lambeth Group were installed within the mottled clay or within confined sand channels. The detailed review of the Lambeth Group concluded there is no evidence of laterally connected water bearing strata between sand channels encountered within the mottled clay. Six boreholes were installed targeting the base of the Lambeth Group, of which only two were assessed to be hydraulically connected with the Chalk basal sands. Data from these two locations (DZ5_BH2023 and DZ4_BH2026) has been considered as part of the Chalk basal sands aquifer assessment.

Groundwater was encountered in the Chalk and Thanet Formation between -1.64m OD and -12.4mOD. Groundwater contours suggest that generally there is a southwest to northeast flow direction across the site.

Hydrology

Pymmes Brook, Salmons Brook, the River Lee Navigation and the River Lee Diversion Channel are all concrete lined channels that flow through or adjacent to the site. A detailed review of the groundwater and surface water levels in the Pymmes Brook and River Lee Navigation has been undertaken and is presented in the interpretative report (Issue 2) (Appendix E) [4] and DQRA (Issue 1) (Appendix D) [5]. The groundwater level data has been collected over a period of ten months (January 2020 to October 2020).

Analysis of the groundwater levels in the boreholes close to the Pymmes Brook indicates the groundwater level, though above the channel invert, is typically lower than the surface water elevation. In this situation any connectivity between Pymmes Brook and groundwater would result in the surface water recharging the groundwater and groundwater, and any contaminants it might contain, would not discharge into the Brook.

Groundwater strikes during drilling were recorded in shallow strata (Made Ground or Alluvium) at four out of eleven exploratory holes advanced within 25m of the Pymmes Brook. The depth of the water strikes ranged between 1.2m bgl and 3.5m bgl and all were in the Made Ground (none in the Alluvium). Shallow water strikes were not recorded in any of four closest exploratory holes (within 10m) and there is no evidence to confirm a potential connectivity between perched units and the Brook.

A review of the groundwater level data from the KPGR in boreholes surrounding the River Lee Navigation Channel indicates the groundwater level is lower than the concrete base of the riverbed. Therefore, this indicates that there is no hydraulic connectivity between groundwater in the KPGR and the River Lee Navigation within the site boundary. Groundwater strikes during drilling were recorded in shallow strata (Made Ground or Alluvium) at eight out of eleven exploratory holes advanced within 35m of the River Lee Navigation. The depth of the water strikes ranged between 0.2m bgl and 3.1m bgl. No exploratory holes were advanced within 15m of the edge of the River.

3.5.3 Summary of observations of potential contamination

The detailed findings of the SIW-Phase 1 ground investigation are recorded in the Arup (2021) interpretative report (Issue 2) [4] and Arup (2021) DQRA (Issue 1) [5]. The following section provides a summary of the ground investigation findings.

Observations of potential contamination

Visual and olfactory observations of potential contamination summarised below relate to the SIW-Phase 1 ground investigation and previous investigations identified in Table 4.

Across the SIW-phase 1 ground investigation boundary, anthropogenic materials were observed throughout the Made Ground including fragments of concrete, brick, plastic, ash, metal and timber. Headspace (VOC) screening of selected soil samples using a PID was undertaken and elevated readings, where encountered, typically coincide with visual and olfactory evidence of hydrocarbon contamination.

<u>DZ4 and DZ5</u>

Suspected hydrocarbon contamination (odours and/ or visual staining or free product) was recorded in 31 locations; including 27 observations in Made Ground, nine in Alluvium and eight in KPGR.

The southern portion of DZ4 was subject to remediation in 2006/2007 by Entec [8], however, subsequent investigation proved that residual contamination, likely originating from the former Leeside Chemical Works is present. Notable evidence of contamination observed in the south of DZ4 includes the following:

- A strong hydrocarbon odour and sheen recorded on groundwater in DZ4_BH1004, DZ4_BH1005 and DZ4_BH1008 in the KPGR [10].
- A creosote odour was recorded in DZ4_TP1004 in the Alluvium between 2.3m bgl and 2.5m bgl [10].
- Black staining was recorded in DZ4_BH1001A between 1.2m bgl and 2.0m bgl in the Made Ground [10].
- Hydrocarbons odours described variably as distinct to strong were recorded in granular Made Ground in DZ4_BH2042, DZ4_BH2044, DZ4_BH2045, DZ4_BH2046 and DZ4_BH2047. In DZ4_BH2046 strong hydrocarbon odours extend into the underlying KPGR (from 5.3m bgl to 6.5m bgl); a high PID reading (586ppm) was recorded here in conjunction with the strong odours. [4]

Observations of contamination in the north of DZ4 (vicinity of the BOC buildings) are more variable and suggestive of more localised pockets of impact. Key observations include the following:

- In BH116 (installed in 2010) and monitored by Amec Foster Wheeler in 2015, 1m of light non-aqueous phase liquids (LNAPL) was recorded [19]. The response zone of BH116 was within the KPGR and Alluvium. Laboratory testing recorded petroleum hydrocarbons ranging from >C_{10} to C_{40} comprising a mixture of benzene derivatives and heavy fuel oil. NAPL was not encountered in any of the boreholes in the vicinity of BH116 nor in any of the other groundwater wells during subsequent monitoring. During monitoring undertaken in the summer of 2018 Amec returned to the borehole to dip the well after it had been purged of the LNAPL. A significant reduction in LNAPL thickness was evident, only 3mm of product being recorded. BH116 has since been monitored in Q4 2019 and Q1 and Q2 2020 and no NAPL was recorded during these latest rounds.

- Solvent odours were noted in WS1512 (PID readings of 103ppm at 2m bgl and 152ppm at 1m bgl), WS1513 (PID readings between 1,547ppm to 4,332ppm) and BH1508 (immediately south of the BOC buildings). A thick tar film was present in WS1513 between 1.4m bgl to 1.7m bgl and the odour extended to the top of the KPGR at 2.9m bgl [19].
- Ash and clinker were found in Made Ground within exploratory hole locations across the OBP. Asbestos fragments were found within the Made Ground in HP1520 and WS1512 [19].
- An oil sheen and hydrocarbon odour were noted in DZ4_BH2035 between 0.3m bgl to 0.5m bgl and in DZ4_BH2036 between 0.5m bgl to 0.7m bgl. Relatively low PID readings of 11ppm and 18ppm were recorded respectively associated with these observations. A pocket of black tar was noted in DZ4_TP2016. [4]

The only visual and olfactory evidence of hydrocarbons recorded in DZ5 during the SIW ground investigation relates to hydrocarbon odours in a thin band in bgl in the Alluvium in DZ5_BH2020.

In addition to observations of hydrocarbon contamination, suspected fragments of ACM have been recorded in three locations; DZ5_BH2015A, DZ5_BH2021A-E and DZ4_TP1006.

During the groundwater monitoring that has followed the second phase of SIW investigation, any location where six rounds of baseline monitoring had not been completed has been subject to further monitoring and sampling (two achieve the full six rounds of baseline monitoring). During the sixth round of sampling at DZ5_BH2020 (on 2nd September 2021) free product was encountered in the Chalk basal sands installation; the interface probe detected approximately 4cm of NAPL. A bailer was lowered into the well to sample the liquid as shown on the left in Plate 1. The photograph shows a layer of murky brown water at the top of the water column, underlain by a thin layer of dark product overlying clear groundwater containing oily globules. The contractor onsite also noted a thick viscous pale opaque coloured NAPL on the interface probe. A sample of NAPL was collected from the top of the water column and a sample from the middle of the response zone using low flow. The well was dipped and no NAPL was recorded at the base of the well.

	
Plate 1 - Bailer collected from top of water column on 02.09.2021	Plate 2 - Bailer collected from top of water column on 16.09.2021

Plate 1 and 2 Bailers collected from DZ5_BH2020.

A seventh sample was collected two weeks later (16th September 2021) with Arup staff present onsite. The installation was dipped with an interface probe and no product was detected, however, a thick viscous pale opaque NAPL was recorded on the interface probe and tape. A bailer was used to view the top metre of the water column as shown on the right in Plate 2. The bailer did not contain any dark NAPL or murky brown water. When the sample was placed in a bucket and left to sit, a thin film of pale viscous product collected on the top of the sample. A groundwater sample was collected from the middle of the response zone.

On 16th September, it was observed that the bung used for the installation was a gas tab with two values (one of which was open). The location had recently been covered by a large puddle, and the top of the bung was underwater. It is considered likely, that the murky brown water/ dark NAPL shown in Plate 1on the left, was due to surface water ingress into the installation. The bungs have since been changed to provide a tight seal.

Results from the sixth and seventh rounds of sampling in DZ5_BH2020 have been received from the laboratory. A NAPL sample was collected on the sixth sampling round (2nd September) at 13.8m bgl and scheduled for a suite of laboratory analysis. The laboratory reported that some of the specified tests could not be completed (kinematic viscosity, mineral oils or whole oil analysis) due to the type of extraction required and the nature of the sample.

The NAPL sample was tested for density, extractable petroleum hydrocarbons (EPH) (Diesel Range Organics (DRO)) >C10-C40 and interpretation of the chromatogram was undertaken by the laboratory. Sample holding times for EPH were exceeded as the laboratory had to assess the sample before it could be analysed, report the findings to the contractor and then complete the extraction which caused a slight delay. Results for EPH >C10-C40 were 5,120mg/l and the initial interpretation reported by the laboratory was an unresolved complex mix of hydrocarbons. Density was reported as 1.09g/ml (i.e. greater than water); this suggests that the oil had only recently entered the water column and was in the process of settling.

The groundwater sample was collected from the middle of the response zone (37.0m bgl) on the same day as the NAPL sample (round six). Another sample was collected on 16th September (round seven). Concentrations of metals and inorganic contaminants were low and similar concentrations to the previous five rounds.

During round six and round seven, concentrations of cresol were detected (maximum 0.0122mg/l recorded on round 7). The sum of monohydric phenols was recorded at 0.0198mg/l and 0.0223mg/l respectively. During rounds one to five in DZ5_BH2020, concentrations of cresol were below detection and the maximum concentration of monohydric phenols was 0.00282mg/l.

During the five previous rounds, concentrations of naphthalene were low (maximum 0.00002mg/l), and all below the EQS (0.002mg/l). During rounds six and seven concentrations of naphthalene of 0.00605mg/l and 0.00356mg/l were recorded which slightly exceeds the EQS. Naphthalene was the only PAH to be recorded significantly above detection limit, total PAH concentrations were 0.00644mg/l and 0.00378mg/l respectively.

TPH concentrations on round one to five were predominantly below detection, on round four, a TPH concentration of 0.694mg/l was recorded, this was predominantly aromatic carbon band >C21 to C35. During monitoring rounds six and seven, concentrations of all aromatic carbon bands were low or below the method detection limit. Concentrations of aliphatic carbon band >C21-C35 were 4.36mg/l (total TPH concentration 4.45mg/l) and 2.91mg/l (total TPH concentration 2.94mg/l) respectively. The difference between the two sampling rounds suggests a decrease in contaminant concentrations, however, further monitoring rounds are required to confirm this trend.

Concentrations of BTEX, VOC and SVOC were previously predominantly below the method detection limit. During the six and seventh monitoring rounds, concentrations of vinyl chloride (maximum 0.00448mg/l recorded on round seven) were recorded above the DWS. Concentrations of xylene (maximum 0.012mg/l), methyl tertiary butyl ether (MTBE) (maximum 0.00267mg/l), 1,3,5 trimethyl benzene and 1,2,4 trimethyl benzene (maximum 0.002mg/l) and 2,4 dimethyl phenol (maximum 0.00448mg/l) were all recorded on rounds six and seven but had not been recorded during the previous five rounds.

DZ5_BH2020 was purged on (8th October) and an eighth sample was collected on 14th October 2020. The well was purged by removing three well volumes of water. A further two additional rounds of sampling will be completed within this well equating to four extra samples in addition to the six baseline monitoring samples. These extra monitoring and sampling rounds will allow further evaluation of contaminant concentrations and trends in this well and help determine whether the increased contamination levels occurring here are due to a temporary impact only.

<u>DZ6 and DZ7</u>

Visual and olfactory evidence of suspected hydrocarbon contamination has been recorded at nine locations across DZ6 and DZ7. At six locations it was limited to Made Ground, at one location it was encountered in Alluvium and in two locations observations of contamination were associated with KPGR.

In DZ_TP2026 visible evidence of contamination was observed in the Made Ground from 0.4m bgl to 1.2m bgl including oily sheen and droplets and pockets of a brown spongy fibrous substance (at 0.6m bgl to 0.7m bgl).

<u>DZLV1</u>

Observations of potential contamination recorded in DZLV1 relate to fragments of suspected ACM recorded in four locations.

The north and west of DZLV1is identified by an Environment Agency record as an historic landfill, though details of the landfilling activity are absent. The SIW ground investigation did not encounter any evidence to suggest that municipal, industrial process, or chemical waste has been deposited. A raised mound in the north of DZLV1 (within the historic landfill boundary) comprises of a combination of reworked natural material and building and construction waste.

3.6 Summary of risk assessment findings

The risk assessments completed for the SIW site to date are reported in the Arup (2021) interpretative report [4] and the Arup (2021) DQRA [5] and are summarised below. Issue 1 of the Arup (2021) interpretative report [4] and the Arup (2021) DQRA [5] have been submitted to the regulators for review and comments have been received from the Environment Agency. The Environment Agency comments are currently being addressed on both reports. The reports will be updated to address the comments and the second issue of the reports will be submitted in support of discharge of Condition 29. The Local Authority have not provided comments on either report.

3.6.1 Human health risk - soil contamination

Concentrations of some contaminants are locally very high and at levels that would be toxic through accidental ingestion or potentially problematic through other plausible potential pathways such as volatilisation and vapour intrusion or leaching to groundwater. These concentrations correspond generally with areas where the visual and olfactory evidence of contamination was identified in the ground investigation. In other areas concentrations of potential contaminants in the Made Ground soil are generally more typical of those encountered in an urban setting, with relatively low to moderate levels of contamination present such as occasional occurrences of asbestos or elevated concentrations of some contaminants (most often metals and PAH). Natural strata are largely uncontaminated except for discrete areas, notably in the south and west of DZ4.

3.6.2 Human health risk – groundwater contamination

Levels of groundwater contamination are spatially variable across the site. The highest levels of contamination, including various organic and inorganic contaminants generally occur in the KPGR in DZ2 in the vicinity of the former gas holder compound and across the south of DZ4. Relatively high concentrations of chlorinated solvents, including vinyl chloride, which is regarded as a volatile and toxic compound, occur in DZ7.

3.6.3 Human health risk - ground gas

The ground gas assessment has been split into two areas: DZ4 and DZ5; and DZ6, DZ7 and DZLV1. For both areas the risk assessments conclude a relatively low risk associated with ground gas; typical ground gas characteristic situation CS2.

3.6.4 Controlled waters risk – groundwater contamination

The level of contamination recorded in the KPGR is locally variable though typically the highest levels of contamination occur in the vicinity of the former gas holder in DZ2 and in the southern portion of DZ4 in the area previously occupied by Leeside Chemical Works. Outside of DZ2 and DZ4 the most significant contamination relates to the presence of vinyl chloride in the KPGR in DZ7.

Elevated contaminants in the groundwater in the Lambeth Group include PAH compounds (mainly fluoranthene), ammoniacal nitrogen, phenol, cyanide, TPH and vinyl chloride. The highest concentrations of these contaminants in the Lambeth Group occur in the vicinity of the former gas holder DZ2.

Contaminants in the groundwater in the Chalk basal sands above water quality standards include cyanide, ammoniacal nitrogen, PAH compounds, metals, phenol, TPH and vinyl chloride.

3.6.5 Controlled waters risk – soil sources

In some areas of the site (notably in DZ4) there is a correlation between shallow sources of soil contamination and contamination in the groundwater. Several sources of contamination in soil were considered in the DQRA in terms of the risk they present to the underlying groundwater. These included residual organic contamination in Brooks Park remaining after excavation for the naturalisation works; high concentrations of nickel and phenol around the south west of DZ4; residual hydrocarbon contamination in the south of DZ4; and high concentrations of speciated TPH in DZ7.

3.6.6 DQRA conclusions

The DQRA [5] identified those sources of contamination that require management or intervention. Following a detailed interpretation and initial assessment of soil and groundwater data across the site five sources of soil contamination, 29 sources of groundwater contamination in the KPGR and seven sources of contamination in groundwater in the Chalk basal sands were subject to detailed evaluation including fate and transport modelling using the remedial targets methodology (RTM).

The detailed assessment of risk to controlled waters from sources in soil indicates that residual sources in soil are unlikely to result in significant impacts to the underlying groundwater, unless gross contamination is present.

The detailed assessment of risk to the controlled waters from current sources of contamination in the KPGR and Chalk basal sands suggest that the levels of contamination recorded for some contaminants are potentially significant including the following sources:

- Benzene concentrations (~5mg/l) in KPGR in DZ4_BH1008 in the southeast corner of DZ4.
- Plumes of ammoniacal nitrogen (~20mg/l) and cyanide (~0.2mg/l) in both KPGR and Chalk basal sands extending from DZ2 into DZ4.
- High concentrations of TPH (>200mgl) in groundwater in KPGR in DZ2 adjacent east of the current gas holder.
- Vinyl chloride levels (~0.5mg/l) in groundwater in the KPGR in DZ7.

The controlled waters assessment also included an evaluation of risk undertaken using ConSim, that focussed on potential leaching of contaminants from soil after placement as part of proposed cut and fill activities across the site. This assessment indicated that contaminants in soil are unlikely to result in significant impacts to the KPGR following excavation and placement as part of the proposed redevelopment.

The DQRA included a combination of generic and detailed human health risk assessment, comparing site measured concentrations with criteria derived using CLEA v1.07 to evaluate the potential risk of harm to health from contaminants. The assessment covered risks to future users of public open space such as Brooks Park, Edmonton Marshes and adjacent to new roads. It also included future users of mixed commercial and residential development (to be developed under the separate planning applications).

The human health risk assessment confirms that in some areas soil proposed for excavation and reuse contains multiple contaminants often at levels much higher than health-based criteria such that if it were to be reused in areas where there was a potential for direct exposure such as in shallow soil in gardens or landscaped areas, this could present a risk of harm to health at the future development. In other areas soils proposed for excavation is comparatively uncontaminated. Soil that will remain in situ in some areas also contains some levels of contamination that could present a risk of harm to health in shallow soils although in most cases risks are driven by direct exposure pathways. The contaminant linkages could be mitigated by cover systems or other physical barriers to prevent contact.

Detailed assessment focussing on vapour intrusion and vapour inhalation risk from contaminants in soil indicates that in situ levels of 1,2,4-trimethylbenzene in DZ4_BH1007, naphthalene in DZ4_TP2010 and both naphthalene and benzene in a larger source area (spanning DZ4_BH1004, DZ4_BH1005 and DZ4_TP1007) have the potential to present a risk to future site users. Similarly, aliphatics >C8 to C12 in KPGR groundwater in the south of DZ4 and vinyl chloride in KPGR groundwater in DZ7_B2058 are predicted to present a potential risk through vapour intrusion. These assessments are likely to be conservative and further evaluation of these risks will need to be completed as part of plot specific evaluation for the plot developments based on building typology, construction method, ground floor use and plot layout following the SIW. These details are not currently available, and that contaminant linkage is excluded from the scope of this remediation strategy.

These conclusions are carried forward into the updated conceptual model in the next section.

4 Updated conceptual model

4.1 Approach

The LCRM online guidance [7] was developed to provide the technical framework for applying a risk management process when dealing with land affected by contamination. This guidance is underpinned by the principle of sustainable remediation, where environmental, economic and social factors are all considered to define the most appropriate approach to remediation. The LCRM guidance has been used to guide the assessment of contamination and remediation required at SIW. Risk assessments have been completed to define and assess the potential contaminant linkages in a source-pathway-receptor framework ('conceptual model') and those linkages that require intervention, such as remedial action, have been identified ('relevant contaminant linkages').

The risk assessments completed for the SIW site to date, reported in the interpretative report (Issue 2) [4] and the Arup (2021) DQRA (Issue 1) [5], concluded PCLs were present. Table 7 and Table 8 below summarise the contaminant linkages during construction and on completion of the SIW. Table 6 summarises how the categorisation of contaminant linkages is applied.

Table 6 Categorisation of contaminant linkages

(orange)	**Relevant contaminant linkage (RCL) which requires consideration in remedial options appraisal and Remediation Strategy**
(blue)	Impact is possible but can be mitigated by control measures during works and/ or managed under an alternative regime such as permitted operation or occupational safety. Some recommendations for implementing appropriate measures will be included in the Remediation Strategy in specific cases
(green)	Impact can be ruled out and no further assessment is required.

The conceptual models presented in Table 5 and Table 6 correspond broadly with the contaminant linkages previously presented and assessed in Table 17 of the DQRA [5]. The conceptual models presented here differ by providing additional separation of linkages into 'during' and 'after' construction, by grouping according to sources (rather than receptors) and providing additional separation of pathways and receptors; the same five confirmed linkages are highlighted by both approaches.

4.2 During construction

The plausibility of the identified contaminant linkages during construction and the control measures required to mitigate these risks are summarised briefly in Table 7 with significant more detail provided in the remediation strategy later in this report.

Table 7 Conceptual model during construction works

Possible Source		Pathway		Receptor	Plausibility of linkage and risk	Relevant section of remediation strategy
Fly-tipped materials including mattresses, bricks and concrete, furniture etc.	→	Dermal contact, ingestion, inhalation of vapours and odours	→	Construction worker	**Impact is possible**; can be mitigated by appropriate site practices	**7.3, 12**
Made Ground and contaminants in buried structures	→	Inhalation of asbestos fibres	→	Construction worker	**Impact is possible-** can be mitigated by using good or enhanced site practices, and if necessary, undertaking boundary monitoring where required to ensure measures are adequate	**12**
			→	User of nearby site		
		Dermal contact	→	Construction worker	**Impact is possible**; can be mitigated during construction phase by adoption of good or enhanced site practices and PPE	
		Ingestion	→			
		Inhalation of vapours	→	Construction worker	**Impact is possible**; can be mitigated during construction phase by adoption of good or enhanced site practices and PPE	
			→	User of nearby site	**Impact is possible**; can be mitigated during construction phase by adoption of good or enhanced site practices and if necessary, undertaking boundary monitoring where required to confirm measures are effective	
		Leaching and runoff	→	Surface watercourses	**Impact is possible**; can be mitigated by use of temporary bunding and locating stockpiles away from surface water receptors	**12, 8.2**
		Leaching and infiltration	→	Shallow aquifers	**Impact is possible**; can be mitigated by construction site management and locating stockpiles on low permeability surfacing	
Impacted shallow groundwater (Alluvium and KPGR)	→	Inhalation of vapours (in confined spaces)	→	Construction worker	**Impact is possible**; can be mitigated during construction phase by adoption of good or enhanced site practices and PPE	**12**
		Dermal contact	→			
		Ingestion	→			
		Lateral flow	→	Surface watercourses	**Impact is possible**; can be mitigated through appropriate construction site water management practices	**12, 10**
		Lateral flow during excavation of new naturalised section for Pymmes Brook		Pymmes Brook during naturalisation	**Impact is possible**; can be mitigated through appropriate construction site water management practices and permitting process including dewatering prior to and during excavation, control and treatment of discharges, carefully designed construction and construction sequence including isolation of channel with clay and/ or geotextile liner prior to surface water ingress.	
		Vertical flow along building piles	→	Deep aquifers, potable water abstraction	**Impact is possible**; piling into Chalk aquifer is unlikely to be required however can be mitigated through assessment and use of appropriate techniques	**12, 11, 14**
Non aqueous phase liquids (NAPL) including within buried tanks and redundant structures	→	Dermal contact	→	Construction worker	**Impact is possible**; can be mitigated during construction phase by adoption of good or enhanced site practices and PPE	**12**
		Ingestion	→			
		Inhalation of vapours	→			

Possible Source		Pathway		Receptor	Plausibility of linkage and risk	Relevant section of remediation strategy
		Leaching and infiltration	→	Shallow aquifers	**Impact is possible** – can be mitigated by development of suitable methods for excavation and removing buried tanks and infrastructure	**12, 8.2**
		Lateral flow during excavation of new naturalised section for Pymmes Brook	→	Pymmes Brook during naturalisation	**Impact is possible**; can be mitigated through appropriate construction site water management practices and permitting process including dewatering prior to and during excavation, control and treatment of discharges, carefully designed construction and construction sequence including isolation of channel with clay and/ or geotextile liner prior to surface water ingress.	**12, 10**
		Vertical flow along building piles	→	Deep aquifers, potable water abstraction	**Impact is possible**; piling into Chalk aquifer is unlikely to be required however can be mitigated through assessment and use of appropriate techniques	**11**
Storage of contaminated material (soil and groundwater) on site during SIW remediation	→	Containment failure results in environmental release	→	Surface watercourses, shallow aquifers	**Impact is possible**; can be mitigated by construction site management	**12**

4.3 Post-construction

The plausibility of the identified contaminant linkages post-construction following completion of the SIW and the control measures required to mitigate these risks are identified in Table 8.

Table 8 Conceptual model following completion of the SIW (post-construction)

Possible Source		Pathway		Receptor	Risk management/intervention	Relevant section of remediation strategy
Contaminated soil (Made Ground or natural), NAPL in soil and contaminants in buried structures	→	Dermal contact, ingestion of soil and soil dust, inhalation of soil dust	→	Future ground/maintenance worker	**Impact is possible**; can be mitigated through appropriate operational procedures and PPE. Final site condition will be recorded in the verification report.	**13**
			→	Future site users	**Relevant contaminant linkage 1**; Soil concentrations (multiple contaminants) in excavated and in situ soil causing potential risk to future site users through dermal contact, ingestion of soil and soil dust, and inhalation of soil dust. For most of the contamination sources in soil, the risks of harm to human health can be addressed by breaking potential exposure pathways.	**8**
		Inhalation of vapours	→	Future ground/maintenance worker	**Impact is possible**; can be mitigated through appropriate operational procedures and PPE. Final site condition will be recorded in the verification report.	**13**
			→	Future site users	**Relevant contaminant linkage 2**; Soil concentrations causing potential risk to future site users through vapour inhalation in indoor air (1,2,4-trimethylbenzene in DZ4_BH1007, naphthalene in DZ4_TP2010 and both naphthalene and benzene in a larger source area spanning DZ4_BH1004, DZ4_BH1005 and DZ4_TP1007). To be considered by follow on developer. Final site condition will be recorded in the verification report.	**13, 14**
		Leaching and infiltration	→	Shallow aquifers (soft landscaped areas)	**Soil sources in situ after earthworks; impact is possible** Significant risk to shallow aquifer from in situ soils which will remain after earthworks is considered unlikely based on detailed modelling. During the SIW turnover and earthworks subsurface structures, obstructions and gross contamination will be removed.	**8**
					Placement of fill material; Impact is possible (though unlikely). The remediation strategy defines soil criteria for the reuse of excavated materials. Gross contamination will be removed	
			→	Shallow aquifers (building and hardstanding areas)	**Impact can be ruled out**; infiltration of rainwater, and therefore leaching from Made Ground, will be minimised by hard surfacing and a managed surface water drainage system. No drainage systems for the infiltration of surface water to the ground are permitted unless otherwise agreed with the LPA (supported by an assessment of the risks to controlled waters).	**n/a**
		Uptake of phytotoxic contaminants	→	Plants in soft landscaped areas	**Impact is possible** Risk to be addressed through design and appropriate specification including soil criteria within the remediation strategy.	**8**
Impacted shallow groundwater, including dissolved phase and NAPL (Alluvium and KPGR)	→	Lateral flow	→	Surface watercourses	**Pymmes Brook and Salmons Brook; Impact is possible** Short term risk only during naturalisation works. The naturalised section of the river will include a liner to prevent potential groundwater ingress. The approach to managing the risks from the main contaminants is presented in the remediation strategy, including environmental control measures.	**10, 12**
					River Lee Navigation; Impact is possible Any discharge, if it occurs, occurs to the south of the site and it is by no means certain that this would occur. The remediation strategy considers potential risks from benzene in DZ4_BH1008. The approach to managing the risks from the main contaminants is presented in the remediation strategy, including environmental control measures.	**9, 12, 13.10**
					River Lea Diversion; Impact is possible Evidence suggests there is no connectivity between the River Lea Diversion Channel and the groundwater. The approach to managing the risks from the main contaminants is presented in the remediation strategy, including environmental control measures.	**9, 12, 13.10**

Possible Source		Pathway		Receptor	Risk management/intervention	Relevant section of remediation strategy
		Lateral flow	→	Shallow aquifers	**Relevant contaminant linkage 4;** Concentrations of contaminants in groundwater causing a risk of pollution to the shallow aquifer from lateral migration. (TPH in DZ2 inc possible NAPL; ammoniacal nitrogen and cyanide in the south of DZ2 and DZ4; benzene in DZ4_BH1008 and vinyl chloride in DZ7). The remediation strategy includes a review of potential options to manage risks from these contaminants.	**6, 9, 13.7**
		Vertical flow along building piles / disused abstraction borehole / redundant monitoring wells	→	Deep aquifers, potable water abstraction	**Impact is possible;** Although a detailed review of the Lambeth Group has identified predominantly low permeability cohesive strata and no evidence of extensive lateral connectivity. In most locations and horizons water bearing strata in the Lambeth Group is not hydraulically connected with deeper and more sensitive Chalk basal sands although occasionally this can occur (locally in Upnor Formation). There is the possibility of vertical migration of contamination from the shallow aquifer during piling. This risk will be assessed further through completion of foundation works risk assessments (FWRA) as required by planning condition. Risks will also be reduced through enabling works that will include removal of sub-surface structures and obstructions and any encountered product and a soil turnover and excavation of gross contamination. The borehole decommissioning plan required by planning condition will address redundant monitoring wells and any historical abstraction wells encountered.	**7.7, 13.9, 13.11, 14**
		Inhalation of vapours	→	Future ground/maintenance worker	**Impact is possible**; can be mitigated through appropriate operational procedures and PPE. Final site condition will be recorded in the verification report.	**13**
			→	Future site users	**Relevant contaminant linkage 3**; Concentrations of volatile contaminants in groundwater causing risk to future site users from vapour intrusion into buildings (two sources: vinyl chloride in DZ5_BH2058 and aliphatics >C8 to C12 in the south of DZ4). This will be considered by follow-on developers under separate planning consent (and conditions).	**14**
Impacted deep groundwater (Chalk and Basal Sands)	→	Transport within groundwater	→	Deep aquifers, potable water abstraction	**Relevant contaminant linkage 5;** Cyanide and ammoniacal nitrogen assessments predict potential to migrate significant distances through the Chalk and to cause down gradient impacts above relevant water quality standards, but modelling is highly conservative. This is addressed in the remediation strategy.	**6, 9, 13.7**
Ground gases	→	Ingress and accumulation of gases in confined spaces to explosive/ asphyxiating/ toxic concentrations	→	Future ground/maintenance worker	**Impact is possible**; can be mitigated through appropriate operational procedures and PPE. Final site condition will be recorded in the verification report.	**13**
			→	Future site users	**Impact is possible;** Additional ground gas and vapour assessment will be required by the plot developer remediation under separate planning consent.	**11, 14**
Made ground/ Impacted shallow groundwater/ NAPL	→	Direct contact and infiltration through cracks/ joints	→	Potable water supply pipes	**Impact is possible**; Mitigated by clean service corridors or completing a pipeline risk assessment and selection of appropriate pipe materials and surrounding materials or specifically designed service chambers.	**11, 14**
	→	Direct contact	→	Buried concrete	**Impact is possible;** Risk to be addressed through design and appropriate specification of materials and structures including selection of appropriate grade of concrete or other protection measures.	**11, 14**

5 Remediation objectives and site constraints

5.1 Introduction

Remediation in its broadest sense implies a form of intervention to reduce and control risks linking contaminant sources to sensitive receptors. This can include source removal or reduction through treatment; pathway interruption (for example by barriers and cover layers or gas membranes); enhanced health and safety and site control measures (protecting construction workers and neighbours); and long-term monitoring. Remediation objectives relate to the requirement to address PCL or RCL by one or more means. This may be achieved by decreasing contaminant mass, concentration, mobility, or toxicity; by effective containment of the contaminant; or through the management of the receptor or pathway. In some cases, more detailed investigation and quantitative risk assessment may indicate that no further intervention is required, apart from long term monitoring of the linkages.

Remediation objectives specific to the SIW are discussed below. These objectives relate to the 'master developer' works to create development platforms suitable for follow-on plot development and associated infrastructure works. At plot development stage (under separate planning application) 'plot developer remediation' activities will be necessary that can only be completed at that stage, such as in-building gas or vapour protection measures and the specification of final finishes etc.

5.2 Strategic and management objectives

These objectives are the principal drivers that the remedial actions at the SIW site should achieve:

- the selected remediation technique must address the contaminant linkages identified in the conceptual model (Table 7 and Table 8) to ensure that no unacceptable short or long-term risks are posed to the identified receptors;
- following completion, the site and prepared development platforms should not present significant environmental risks or liabilities to the site owner and operator;
- the strategy, its implementation and verification should achieve regulatory approval;
- the remediated site must reduce the potential for future regulatory intervention to the satisfaction of all stakeholders;
- the successful remediation of the site should be carried out within budget, programme and space constraints;
- remediation techniques should be reliable and proven in the UK;
- a sustainable solution is sought that will limit environmental impacts, including vehicle movements to and from site, and allow maximum retention of material;
- unacceptable nuisance impacts of odour, noise or fugitive dust to site users and neighbours should be avoided;
- unacceptable health and safety risks to construction workers from contaminated soils should be avoided. Exposure should be as low as reasonably practicable;
- the site should not be capable of being classified as contaminated land under Part 2A of the Environmental Protection Act on completion of the SIW; and
- risk of damage to site services and construction materials should be avoided.

5.3 Technical objectives

In accordance with LCRM [7] technical objectives for remediation are set in the Remediation Strategy. The defined technical objectives are outlined below:

- creation of the Pymmes Brook naturalised channel and associated landscaping ensuring protection of the water environment (including surface water in the newly naturalised Brook) and other receptors (including flora, fauna, visitors and workers at the Brooks Park public open space);
- creation of Edmonton Marshes as a publicly accessible amenity space including sports pitches and ecologically rich wetland (with dual flood attenuation purposes) whilst ensuring the protection of the water environment and other receptors;
- creation of the flood conveyance channel as a dual-purpose public open space complete with soft landscaping, within a hydraulically contained channel for transfer of flood waters from Edmonton Marshes to the River Lea Navigation whilst ensuring the protection of the water environment and other receptors;
- to maximise reuse of material from earthworks cut in DZLV1 (and other areas) within DZ4 and DZ5 to achieve specified elevations for flood prevention in DZ4 and DZ5 and flood storage in DZLV1, through segregation, treatment and verification;
- removal of buried structures to address residual sources of contamination, including underground tanks, structures associated with contamination and grossly contaminated soil;
- to address risks associated with KPGR groundwater sources to achieve regulatory approval: benzene in DZ4; vinyl chloride in DZ7; TPH in DZ2; ammoniacal nitrogen and cyanide in DZ4/2 with consideration of the sustainability (environmental, economic and social) implications;
- to address risks associated with Chalk basal sands groundwater contaminated with ammoniacal nitrogen and cyanide in DZ4/2 to achieve regulatory approval, with consideration of the sustainability implications;
- creation of new pathways associated with piled (or other) foundations must be avoided;
- to identify and appropriately decommission any disused abstraction borehole or redundant monitoring wells; and
- to mitigate risks associated with ground gases and vapours in the new development.

5.4 Remediation constraints

There are several site constraints which need to be considered when selecting the most appropriate remedial actions and in the detailed design of the works. The main constraints that have been identified at the site relevant to the selection of the remediation approach are listed below and are addressed in the remediation strategy.

5.4.1 Phasing of site redevelopment

The development phasing strategy for the site is outlined in Section 2.2. The remediation strategy takes account of this phasing. The phasing of demolition, earthworks and construction, influence the opportunities for reuse of material within the development.

5.4.2 Vehicular access and movements

Although material reuse and retention onsite will be maximised, import and export of soils will generate vehicle movements to and from the site.

5.4.3 Public health and nuisance

The site is surrounded by operational sites, including industrial, commercial and retail, and public open space. The risks to the public and adjacent site users whilst carrying out any remediation works are considered. Nuisance aspects such as odour, dust and noise are also be considered.

5.4.4 Live services, redundant utilities, buried obstructions

Remediation design must take account of live services, including drainage. Any existing services could also provide a conduit for contamination to migrate towards (and potentially discharge into) surface water courses that bisect the site. Management of redundant utilities requires consideration in areas where remediation requires excavation. Across the site buried structures such as tanks and foundations remain and are considered in the remediation strategy.

5.4.5 Unexploded ordnance (UXO)

UXO desk study and risk assessment completed by Zetica in 2018 [19] identified a moderate risk in the north east of DZ4 and a low risk of encountering UXO in other areas of the site. This is considered in the remediation strategy.

5.4.6 Watercourses

Remediation design must take account of the need to protect watercourses from contaminated runoff and ensure no unacceptable changes to watercourse characteristics in flood conditions during the works. In the Brooks Park area (Pymmes Brook naturalisation) prevention of contaminated groundwater discharge to the watercourse will require barrier or liner installation. Hydraulic isolation of the other watercourses must be maintained by retention of concrete channels.

5.4.7 Chalk aquifer and source protection zones

The site is in a sensitive location with respect to the underlying deep aquifer. Several source protection zones extend across the site associated with licensed abstractions. Protection of the Chalk basal sands aquifer is an important consideration in the remediation strategy. However, contamination in chalk and basal sands has occurred as a result of historical polluting industries in this area (including Willoughby Lane Gasworks now referred to as Meridian One) and residual contamination remains.

5.4.8 Vegetation, invasive species and ecology

The site has areas which are heavily vegetated (e.g. DZLV1) and ecological habitat along watercourses. During construction the Contractor will need to comply with the provisions of the Wildlife and Countryside Act 1981, and other relevant nature conservation legislation, policy, and guidance. A recent (May 2021) Preliminary Ecology Assessment did not identify any protected species across the SIW site [23]. Further details on the requirement to manage vegetation and ecology will be defined within the CEMP required under planning condition 5.

Previous surveys have identified various invasive plant species (Japanese Knotweed, Himalayan balsam, Cotoneaster and Giant Hogweed) across the site [3]. The Contractor will need specialist advice and support to manage risks associated with invasive species during the works. Management of invasive species will be defined within, and accord with, the eradication strategy for invasive species as required by planning condition 16.

5.4.9 Archaeology

The Environmental Impact Assessment (EIA) identified a possible Early Medieval Crannog (AD 410 to AD 1066) within the current Ikea site and further archaeological and palaeo-environmental features in other areas of the site [24]. During the works the Contractor will need to minimise any impact on heritage assets, their setting and the wider historic environment. in accordance with accepted industry practice, taking into account the relevant sections of the National Planning Policy Framework (NPPF) (2021) and of the Development Plan. The Contractor should consider engaging specialist support to confirm potential requirements for a watching brief or other actions required to comply with the NPPF.

5.4.10 Duration of remediation technique

The timeframe needed for the remediation technology to achieve the required targets will be a constraint. The need for laboratory or field trials must also be considered.

5.4.11 Groundwater and surface water monitoring

Monitoring locations must be protected during the works to maintain integrity of the monitoring programmes. The duration of post-remediation groundwater/surface water monitoring is usually for a minimum of one year after the completion of the remedial works.

5.4.12 Regulator and other stakeholder approvals

Approval of the remediation strategy by the Local Planning Authority and environmental regulators (primarily the Environment Agency) is required by planning conditions. Regulator engagement has been ongoing for several years. In addition to approval via the planning process, other regulator approvals will be required, such as permits for work in or adjacent to a river or environmental permits for waste activities.

6 Remediation options appraisal

6.1 Scope of remediation options appraisal

As a result of specific site constraints, the options for breaking relevant contaminant linkages RCL1, RCL2 and RCL3 are limited and there are defined viable options for each RCL, as shown in Table 9 below. Therefore, no remediation options appraisal will be undertaken for these RCLs.

Table 9 RCLs 1, 2, 3 and remedial solutions

RCL		Contaminant source	Remedial solution
RCL1	Soil concentrations causing potential risk to future site users through dermal contact, ingestion of soil/soil dust, inhalation of soil/ soil dust	See interpretative report **[4]** and DQRA **[5]** for distribution of contaminants exceeding GAC	Reuse criteria will be defined for excavated materials and cover systems for in situ sources and above 'general fill' placement, defined for different end uses. Excavated material may be treated by ex situ treatment methods to achieve reuse criteria
RCL2	Soil concentrations causing potential risk to future site users through vapour inhalation in indoor air	Summary of locations (BH1007 1,2,4-TMB; TP1010 naphthalene; BH1004, BH1005 and BH1007 benzene and naphthalene)	Vapour protection in buildings
RCL3	KPGR groundwater concentrations causing risk to future site users from vapour intrusion into buildings.	vinyl chloride in DZ7 (DZ7_BH2058)	Vapour protection in buildings. (Source also considered in RCL4)
		TPH in DZ2 (Aliphatics >C8 to C12 in DZ2_BH1402, DZ2_BH2013)	

Remediation options appraisal has been undertaken for each of the contaminant sources relevant to RCL4 and 5, as shown in Table 10. The contaminant sources are shown on Drawing 4.

Table 10 RCL4 and 5 sources to be included in remediation options appraisal

RCL		Contaminant source	Appraisal
RCL4	Groundwater concentrations in KPGR causing a risk of pollution to the shallow aquifer from lateral migration.	Benzene in DZ4_BH1008	ROA1
		Vinyl chloride in DZ7 (same source as RCL3)	ROA2
		TPH in DZ2 (same source as RCL3)	ROA3
		Ammoniacal nitrogen and cyanide in the south of DZ2 and DZ4	ROA4
RCL5	Groundwater concentrations in Chalk basal sands causing a risk of pollution to deep aquifer from lateral migration	Ammoniacal nitrogen and cyanide in DZ2 and DZ4	ROA5

6.2 Outcome of remediation options appraisal

The remediation options appraisal is presented in Appendix B. The outcome of the remediation options appraisal is summarised below.

6.2.1 Benzene in KPGR

The benzene source in the KPGR in the southeast of DZ4 has been defined based on data from two monitoring wells, DZ4_BH1008 and DZ4_BH1007. The DQRA [5] calculates a Level 3 RTM criteria of approximately 15mg/l, which exceeds the highest observed groundwater concentrations of approximately 5mg/l in DZ4_BH1008 and 1.6mg/l in DZ4_BH1007. However, the model is very sensitive to input parameters hydraulic gradient and half-life and, as there is limited source delineation, calibration of the model is not possible. Therefore, the remediation options appraisal assumes remedial action is needed for this source.

The ROA (Appendix B) concludes the most appropriate approach to remediation of this source is firstly natural attenuation, secondly removal of contaminant sources in the unsaturated zone and thirdly in situ air sparging or chemical oxidation. However, the available data is insufficient to confirm natural attenuation and removal of unsaturated zone sources will adequately address risks to receptors. Therefore, in the remediation strategy it is assumed that in situ air sparging or chemical oxidation will be required in addition to removal of unsaturated zone sources across DZ4 and source-specific monitoring (see Section 10).

Further investigation to accurately delineate the source and inform further risk assessment could demonstrate that air sparging or chemical oxidation is not required. Any changes to the remediation proposed in this strategy will require the written agreement of the Environment Agency and it is anticipated that submission of a supplementary remediation strategy specific to this source, with supporting risk assessment and additional investigation data would be required.

6.2.2 Vinyl chloride in KPGR

The vinyl chloride source in the KPGR in DZ7 has been identified at varying concentrations in monitoring wells DZ7_BH2058 and DZ7_BH2060. A remedial target of 0.0046mg/l has been derived which is close to two orders of magnitude lower than maximum concentrations recorded in the groundwater in DZ7_BH2058. The model predicts that concentrations of 0.033mg/l will occur at a compliance point 50m from the source which is similar to the mean concentrations in DZ7_BH2060 (0.024mg/l) and which is approximately 50m from the source. The model therefore predicts that concentrations of vinyl chloride could impact a down gradient compliance point and the site data appears to corroborate this result.

Based on available limited groundwater data relating to this source it is unclear if concentrations are stable, increasing, or declining. However, data suggests microbial cultures are present (at moderate to high levels) capable of facilitating both aerobic and reductive degradation processes.

The remediation options appraisal identifies natural attenuation and removal of contaminant sources in the unsaturated zone as the two preferred remediation techniques, with in situ air sparging or chemical oxidation the third choice. The site turnover will extend across the vinyl chloride source zone and will remove residual unsaturated zone sources. However, the available data is insufficient to confirm natural attenuation and removal of unsaturated zone sources will adequately address risks to receptors. Therefore, in situ air sparging or chemical oxidation is required in addition to removal of unsaturated zone sources and source-specific monitoring (see Section 9).

Additional ground investigation to better characterise the vinyl chloride source and refine the risk assessment may be undertaken and may be sufficient to demonstrate a monitoring approach is adequate (in conjunction with removal of unsaturated zone sources) and that air sparging or chemical oxidation is unnecessary. Any changes to the remediation proposed in this strategy will require the written agreement of the Environment Agency and it is anticipated that submission of a supplementary remediation strategy specific to this source, with supporting risk assessment and additional investigation data would be required.

6.2.3 TPH in KPGR

Across DZ4 and DZ2 concentrations of TPH (>C12 to C16 aromatics) are elevated. However, the DQRA concluded that considering the conservatism of the model and the likely previous very large impacts from multiple significant sources in this area, the evidence suggests concentrations of TPH are relatively low, indicating that natural degradation processes are effective. Groundwater in the KPGR is not in continuity with Pymmes Brook and naturalisation works will avoid creation of any pathway. Dewatering that will be undertaken for Pymmes Brook naturalisation will result in abstraction and treatment of dissolved phase hydrocarbon-contaminated groundwater from the western part of DZ4. No specific intervention for dissolved phase TPH across DZ4 and most of DZ2 is proposed, except ongoing monitoring [5].

In standpipes situated adjacent to the east side of the gasholder base in DZ2 a marked rise in concentrations was observed during the latter rounds of baseline monitoring in 2020 with concentrations suggesting the probable presence of free product, although no free product was detected during monitoring.

The remediation options appraisal considers techniques in which the risks associated with both dissolved phase and free phase hydrocarbons can be managed in the area east of the gasholder base in DZ4. The remediation options appraisal identifies natural attenuation, removal of unsaturated zone sources and skimming as the order of preference of remediation techniques to manage risks in this area. A combination of these techniques is proposed in the remediation strategy (Section 9).

6.2.4 Ammoniacal nitrogen and cyanide in KPGR

Ammoniacal nitrogen and cyanide contamination is present in KPGR groundwater at concentrations significantly higher than the calculated RTM Level 3 targets across the southern part of DZ4 and DZ2 (‘ROA4’ on Drawing 4).

The presence of such an extensive area of elevated ammoniacal nitrogen and cyanide suggests that these contaminants were released as liquors and have migrated and dispersed through the groundwater in the KPGR. The DQRA assessed the groundwater contamination as potentially stable and possibly declining and concluded the RTM model is highly conservative. The observed contamination in KPGR groundwater is not predicted to present a risk to surface water or drinking water resources.

Appendix B presents an appraisal of remedial options for ammoniacal nitrogen and cyanide in KPGR groundwater, with consideration of the feasibility of achieving the specific targets and the relative associated costs of any intervention.

Turnover of soils across DZ4 and eastern DZ2 will be undertaken as part of the SIW, with removal of gross contamination, tanks and other obstructions. However, as contaminants most likely entered groundwater as a liquor release, significant source is not anticipated to remain in the unsaturated zone. Whilst the turnover and subsequent development (buildings/hardstanding/low permeability cap) will result in improvement in groundwater quality these are not identified as a remedial option in the remediation options appraisal.

The only feasible remedial option considering the advantages and disadvantages of all available methods is natural attenuation of the ammoniacal nitrogen groundwater contamination. Dissolved phase ammonium in groundwater will naturally attenuate where conditions are favourable, and the natural degradation would result in a long-term reduction in groundwater concentrations. Based on available groundwater monitoring data, field measurements of dissolved oxygen levels within groundwater in the KPGR indicate aerobic conditions which are likely to be suitable for natural attenuation to occur. Cyanide concentrations are also expected to decline through dilution, sorption and aerobic biotransformation and degradation.

To demonstrate natural attenuation (and the unsaturated zone turnover and source removal) has achieved remediation objectives source specific monitoring is required to confirm groundwater concentrations are stable or improving (see Section 9).

6.2.5 Ammoniacal nitrogen and cyanide in Chalk

The extent of the ammoniacal nitrogen and cyanide source in the Chalk basal sands is shown as (‘ROA5’ on Drawing 4). Concentrations in the Chalk basal sands in DZ2 and southwest DZ4 are more than an order of magnitude higher than the RTM Level 3 target criteria for ammonium and three times higher for cyanide. However available monitoring data for both ammonium and cyanide demonstrates the conservatism in the model as concentrations to the northeast remain consistently low during the baseline monitoring indicating significantly less mobility than predicted by the model.

The DQRA concluded continued monitoring of cyanide and ammonium in Chalk basal sands should be undertaken focussing on concentrations trends and evidence of migration of the plume towards abstractions situated north east and east of the site. The remediation options appraisal also assessed if other potential methods of risk management are available with consideration of feasibility of achieving targets and the associated costs of any intervention.

Natural attenuation is considered to be the only feasible option which will be assessed by undertaking groundwater monitoring to collect evidence of stable or decreasing concentrations..

Dissolved phase ammonium in groundwater will naturally attenuate where conditions are favourable, and the natural degradation would result in a long-term reduction in groundwater concentrations. Based on available groundwater monitoring data, field measurements of dissolved oxygen levels within groundwater in the Chalk basal sands indicate aerobic conditions which are likely to be suitable for natural attenuation to occur. Groundwater monitoring during the remediation and earthworks programme would be required to assess if aquifer conditions are suitable to sustain natural degradation.

Long term mass reduction of cyanide concentrations in groundwater is expected to occur by dilution sorption, aerobic biotransformation and degradation. Groundwater monitoring would be required to confirm groundwater concentrations are stable or improving.

Source specific monitoring is required to confirm groundwater concentrations are stable or improving to demonstrate natural attenuation has achieved the remediation objectives (see Section 9).

7 Demolition and site clearance

7.1 Supplementary ground investigation

Supplementary ground investigation is ongoing to obtain data in the SIW-Phase 2 area where there is currently limited information. This will augment data in the SIW-Phase 1 area, as discussed previously in Section 3.4 and in the Arup Remediation Framework Report 2021 [6].

A technical note will be prepared outlining the findings of the supplementary investigation data collected from the SIW-Phase 1 area (estimated issue December 2021). The technical note will summarise the investigation results in these areas and provide a commentary on how the data affects the conceptual model, risk assessment and remediation strategy.

7.2 Vegetation clearance and invasive species

An invasive non-native species (INNS) survey was undertaken by Phlorum during August and September 2018. The survey identified the presence of the following invasive plant species as identified in the Wildlife and Countryside Act (WCA) 1981:

- Cotoneaster (Cotoneaster sp.).
- Floating pennywort (Hydrocotyle ranunculoides).
- Giant Hogweed (Heracleum mantegazzianum).
- Himalayan balsam (Impatiens glandulifera).
- Japanese knotweed (Fallopia japonica).

In addition, large areas of Buddleia (Buddleja davidii) are present. Whilst this plant is not listed as an INNS under the Wildlife and Countryside Act 1981, it is listed in the London invasive species initiative where it is identified as a problem due to its abundance in the London area. It is noted that there is no legal requirement to control Buddleia on the site.

The Contractor has produced an Invasive non-native weeds eradication plan [25] that will be submitted to discharge planning condition 16. As well as removal of INNS, large areas of DZLV1 will be scraped to a depth of 0.3m removing soils heavily contaminated with Giant Hogweed seeds. This soil will be either buried as part of the earthworks or if this is not practicable it will be disposed of off-site to landfill. Once approved this plan will be implemented by the Contractor and a verification report will be produced on completion.

Vegetation clearance will be undertaken outside of nesting birds season or following inspection by an ecologist to confirm no nests would be disturbed.

7.3 Removal of waste and fly-tipped material

Large areas of the Meridian Water site have previously been subject to widespread fly tipping. Fly-tipping on LBE land has now been removed and the main area still affected by fly tipping is the Thames Water land within DZLV1 (Drawing 2). Fly-tipped waste will be removed offsite in accordance with waste regulatory requirements. It will be loaded onto lorries using mechanical excavators under supervision and taken to local permitted waste processing facilities for segregation and disposal. Asbestos may be present among the waste and an occupational risk assessment should be undertaken by a competent assessor (asbestos specialist) in accordance with CAR 2012 and the associated code of practice to determine the likely exposure resulting from the works and the level of protection and management required by CAR 2012.

In addition, two waste mounds were present within the Meridian Water master plan site: the Phoenix Wharf waste mound; and Harbet Road waste mound. These mounds were formed when waste transfer stations (WTS) had their permits revoked and the tenants left the site with the waste remaining. The Phoenix Road mound has been removed from site. The Harbet Road mound remains on site. The Harbet Road mound will be removed offsite in accordance with waste regulatory requirements.

7.4 Demolition

The main above ground structures to be demolished as part of the SIW are the BOC Buildings located in the north of DZ4 and comprising six large warehouses. In addition two existing small bridges over Pymmes Brook and Salmons Brook will be demolished, as shown on the site demolition plan (Drawing 5).

A demolition method statement will be produced by the Contractor to ensure that these works can be safely carried out. This will include appropriate consideration of the potential for asbestos within the structures to be demolished, to meet the requirements of the CAR (2012). The potential for dust generation will be minimised through appropriate storage of demolition materials and through the adoption of dust control measures.

7.5 Surface turnover

Surfacing will be removed across extensive areas of site, and the uppermost materials will be turned over. Areas requiring turnover have been defined considering both geotechnical and geoenvironmental constraints (Drawing 6). For example in DZ2 the area of turnover for geotechnical purposes includes only the road corridor and this has been extended for geoenvironmental purposes to include the area where free product has previously been encountered in monitoring wells, to ensure residual sources such as gross contamination, tanks and pipelines will be removed. Similarly, the turnover area has been extended to include the area identified as a potential source of the vinyl chloride contamination identified in groundwater in DZ7.

Slabs will be removed, and the site will be turned over to a depth of 1.5m across the areas shown on Drawing 6, removing obstructions and foundations to this depth (see also tank strategy below). The turnover will cease at less than 1.5m if natural soils are encountered. Below 1.5m depth any obstructions remaining will be removed if required for geotechnical reasons, and any remaining obstructions (such as large concrete foundations if present) will be recorded. Materials will be managed in accordance with the materials strategy (Section 8). Site turnover excavations will be observed by a competent geoenvironmental specialist as part of the watching brief, to ensure this strategy is adhered to, and to record observations and action undertaken for inclusion in the verification report (see Section 13).

Within the 1.5m turnover depth, any gross contamination will be removed and managed in accordance with the materials strategy (i.e. removed offsite or treated on site to achieve reuse criteria). Gross contamination (defined in section 8.9) will be chased out to the base of the unsaturated zone or base of made ground, whichever is encountered first. Soil sampling and testing of the sides and base of the excavation will be undertaken to characterise the remaining in situ soil and to record and quantify any residual contamination in accordance with the verification requirements (see Section 8.10).

If significant NAPL is observed extending below the base of the excavation then: either a) the excavation will continue to greater depth to chase out the NAPL, extending below groundwater and skimming from water surface if NAPL accumulates; or b) the area where NAPL extends to below the base of the excavation will be recorded and, following completion of earthworks backfill, wells will be installed to facilitate removal of NAPL. The approach will be agreed via the geoenvironmental watching brief.

If during turnover asbestos containing material is encountered indicative of asbestos disposal such as a discrete pocket of predominantly asbestos containing material, then this will be chased out by mechanical excavation and this material will be disposed of offsite. Asbestos control measures are discussed in Table 14.

In the southern part of DZ4 a cover layer of clean material was placed following previous remediation works. This material will be removed and managed in accordance with the materials strategy before the site turnover to 1.5m (as described above) is undertaken.

Where earthworks cut is required, the turnover approach above will be followed except that material will be not be replaced and instead it will be taken to an onsite material management facility (‘hub’) for segregation, treatment etc as required by the materials strategy (Section 8).

Leeside Road gasholder superstructure in DZ2 was removed and the below ground structure was cleaned and backfilled with uncontaminated imported material in 2015. No works are to be undertaken on the gasholder base as part of SIW and it will remain as an in-ground obstruction to be managed by the follow-on developer under a separate planning consent. Site turnover will be undertaken between the gasholder and Pymmes Brook in the area where free product has been identified in monitoring wells (see Section 9.4).

Areas subject to turnover will be verified following material placement by collecting photographic records and by post-placement sampling (Section 8.10.5).

7.6 Tank strategy

Approximately 20 tanks have been identified from historical mapping across the SIW- Phase 1 area (Drawing 7). Primarily, these are in the south of DZ4 associated with the former Leeside Chemical Works. Tanks are also noted across DZ6 and DZ7 associated with the historic Angel Road Colony, and in DZ5 associated with former engineering works. The contents of the tanks are generally unknown, but most are likely to have been for hydrocarbon fuel storage (e.g. diesel, heating oil, kerosene, petrol) whilst others, particularly those associated with the former Leeside chemical works could have contained various volatile or semi-volatile organic compounds, or acids, alkalis or other substances.

Despite best endeavours, it has not been possible to obtain petroleum licensing records (due to covid-related staff shortages) for the site to date There are no known current petroleum licences within the SIW-Phase 1 area. The Contractor will obtain petroleum licensing records if possible. Whilst the petroleum licensing records may be informative, they will only be relevant for certain types of fuel storage for specific time periods. The tank management strategy below has been designed to be implemented without these records.

All available records will be used to develop a tank register, identify the tank locations and mark them for removal. Many of the tanks may no longer be present and many may have been above ground tanks. Each tank record will be systematically investigated by excavation from the surface, inspecting the tank and assessing their contents. A temporary works procedure will be implemented to ensure appropriate tank-specific safe contents removal, tank structure and contaminated soil excavation is undertaken. After removal of the tank and any associated pipework and infrastructure, and removal of any associated gross contamination, verification soil sampling from the sides and base of the excavation will be undertaken in accordance with the verification testing requirements (Section 8.10). Information will be included in the final verification report. The approach to managing significant NAPL observed extending below the base of the excavation is described in Section 7.5 above.

In addition to the tanks identified in records, unknown tanks may be identified during the works. The geoenvironmental watching brief during earthworks will ensure tanks are identified and properly managed. Where a previously unrecorded tank is encountered the area will be isolated and the same actions identified above (to assess and safely remediate the area) will be implemented. All tank removals will be recorded in the verification report.

7.7 Decommissioning of monitoring wells

A borehole management and decommissioning plan will be produced by the Contractor and issued to the local planning authority and Environment Agency for review as required by Condition 34 (Appendix A). This should be approved in writing before any borehole decommissioning is undertaken. The monitoring well network and the remedial infrastructure will be protected and maintained for the duration of the long-term monitoring programme and construction works.

Monitoring wells installed on the site during previous phases of ground investigation will be decommissioned in accordance with the plan prior to site turnover unless the wells are required for future monitoring. This is to prevent creating preferential pathways when disturbed during development.

The decommissioning plan will include the approach to managing historical abstraction wells if encountered.

Boreholes will be decommissioned in line with the Environment Agency guidance [21] to ensure that no preferential flow pathways, from the surface to the underlying soils or aquifers, are created during the works. For those monitoring wells to be retained for long term monitoring, provision will be made to safeguard the wells during the works, for example by placing concrete rings over the headworks to prevent damage by site vehicles.

7.8 Redundant utilities and drainage

Across the SIW area existing service plans, along with the results of any recent site surveys, will be used to assess the location, condition and status of below ground services. A permit to work system will be applied to ensure that any live services are protected and services with unknown status are assessed prior to further works being undertaken.

Drainage runs will be accessed prior to removal and any potentially contaminated contents removed by pumping or vacuum tanker. Grubbing out of drainage runs (including oil interceptors) will be undertaken in accordance with the site turnover and geoenvironmental watching brief. Redundant drains that are not removed will be sealed to prevent surface water discharge. Any residual mobile contaminants will be contained by bunding or spill kits etc. Excavated material will be managed in accordance with the materials strategy. Gross contamination will be chased out and validated as described above for tanks.

Where drainage runs cross the site or works area boundary, pipes and pipe bedding will be sealed with clay or bentonite to mitigate future cross boundary migration. A holistic view of drainage will be taken across the SIW site to ensure drainage is effective and that no pathways are created following completion of the SIW works. Records and topographic surveys of all infrastructure removal will be maintained during the works and included in the as built information on completion.

8 Earthworks and materials strategy

8.1 Overview of earthworks

Extensive earthworks will be completed as part of the SIW to achieve site levels in addition to, and following, the site turnover described above. The main areas of cut are Edmonton Marshes (DZLV1), Brooks Park (west of DZ4), the flood conveyance channel (DZ7) and Ikea Clear (southeast of DZ4). The main areas of fill are beneath new road corridors and development platforms (in DZ4 north, DZ5 and DZ7). In addition, more localised excavations include construction of bridge abutments (Drawing 8).

An objective of the SIW remediation strategy is to maximise retention of suitable site won material within the SIW. Geotechnical requirements are not covered in this report.

8.2 Materials management and treatment

8.2.1 Excavated materials management

Robust materials management will be implemented to maximise reuse of suitable material and to minimise the volume of material requiring offsite disposal, while ensuring that only the amount needed to achieve the proposed site levels are used, and that use is certain. In each works area excavated material will be transported to a materials hub where it will be assessed, segregated and treated. Material will be categorised for offsite disposal or reuse on site.

A material tracking system will ensure the material is recorded throughout its movement from excavation to stockpiles to treatment and reuse or offsite disposal. The digital tracking system will utilise a grid system applying unique identifiers to cells and stockpiles. Details of the material tracking system will be included in the DoWCoP[1] materials management plan (MMP) for the works (see Section 8).

Stockpiles will be located on low permeability surfacing and actively managed to ensure environmental protection from any dust and runoff. A stockpile management system will be implemented that dovetails with the material tracking system.

8.2.2 Recycled aggregate processing

Suitable uncontaminated material arising from demolition and removal of buried obstructions will be processed on site to produce recycled aggregates. This physical processing, such as crushing and screening, will achieve the geotechnical specification for material reuse.

8.2.3 Topsoil manufacture

Suitable site won topsoil will be reused within SIW after verification testing. However a deficit of topsoil is anticipated and will be met either by import of verified topsoil or by manufacture of topsoil on site using site won soils and imported additives. Manufactured topsoil would be produced in accordance with regulatory requirements and would be verified against site reuse criteria.

8.2.4 Exsitu soil treatment

Excavated soils may require remedial treatment to achieve defined geoenvironmental reuse criteria before they can be reused on site. Excavated soils requiring treatment to achieve reuse criteria for PAH, TPH, chlorinated solvents and other complex organic compounds will be treated exsitu at the materials hub.

Bioremediation biopiles, if required, will be placed on an impermeable membrane with a bund using clean site won soils, restricting infiltration into the underlying soils, and enabling the collection of leachates. The soils may be treated using several additives and cultured indigenous bacteria. Cultivated ligninolytic fungi may also be used to supplement treatment processes particularly for PAHs and to assist in making the contaminants more bioavailable for the bacteria, stimulating contaminant degradation. Oxygen release compound (ORC) granules may also be used for extended aerobic bioremediation of the hydrocarbons.

Exsitu soil processing to achieve stabilisation and solidification may also be undertaken at the materials hub or in situ at the placement location. Excavated soils will be assessed and segregated prior to treatment by mixing with binders using high shear mixing plant. Treated material that meets the defined reuse criteria will be replaced in the ground and compacted. Stabilisation and solidification design would be carried out to meet the geotechnical requirements of the end use of the material. Details of the material treatment and reuse will be included in verification reporting (Section 13).

8.2.5 In situ soil treatment

In Brooks Park in situ soil stabilisation by soil mixing may be implemented as an alternative to excavation and placement of a low permeability clay layer (Section 10). This in situ stabilisation to immobilise contaminants and create a low permeability layer must be verified to demonstrate various criteria have been achieved. Details of any stabilisation works completed including soil additives, methods and testing will be included in verification reporting.

8.3 Regulatory approach

The DoWCoP sets out good practice for the development industry in regards to the reuse of site won soils, assessing whether excavated soils are classified as a waste or not and determining when treated waste can cease to be waste for a particular use.

It is anticipated the DoWCoP will be applied to reuse of site won excavated soil and demolition material on site, under the ‘site of origin’ scenario. A MMP will be produced for the material reuse. The MMP will be reviewed by a 'qualified person' (as defined in the DoWCoP) and a declaration submitted to CL:AIRE by the qualified person before excavation commences . Following the completion of the reuse works a MMP verification report is required in accordance with the requirements set out by the

[1] CL:AIRE (2011) Definition of Waste Development Industry Code of Practice

MMP and the verification report must be submitted to CL:AIRE.. Several versions of the SIW MMP may be necessary to address the different works areas and phases of operations.

Treatment of soils necessary to achieve the reuse criteria by exsitu methods will be carried out under appropriate environmental permits, most likely a mobile plant permit. Environmental management and monitoring to ensure protection of receptors during soil treatment (such as runoff containment by use of low permeability membrane and bunding) will be undertaken and detailed in the mobile plant permit submissions.

Suitable uncontaminated materials arising from demolition and obstructions removal will be processed to produce recycled aggregate in accordance with the Waste and Resources Action Programme (WRAP) Quality Protocol.

The project aims to minimise soils arising from excavations leaving site. However, material unsuitable for reuse (that cannot be treated) and any surplus soils that cannot be reused will be disposed of in accordance with waste regulatory requirements, most likely to offsite waste treatment recycling centres. It will be necessary to carry out waste classification and compliance testing in line with current regulations prior to export from site.

A site waste management plan (SWMP) will be produced by the Contractor to comply with planning condition 17 (Appendix A).

The regulatory approach to management of excavated material from the area identified by the Environment Agency as 'historic landfill' is awaiting confirmation. The material is predominantly reworked natural material and would be suitable for reuse within the scheme.

Any imported materials will comply with waste regulatory requirements and will be assessed against imported material verification criteria. A separate DoWCoP materials management plan may be required for the import of excavated soils, under a 'direct transfer' or 'cluster' scenario.

8.4 Water management in excavation

During excavation water may be encountered, particularly rainwater, perched water and shallow groundwater. Groundwater control by dewatering may be locally necessary to facilitate the works, such as in Brooks Park.

Uncontaminated water (except for silt) will be managed in accordance with the Environment Agency Regulatory Position Statement on temporary dewatering from excavations to surface water[2] and will be discharged to surface water if suitable to do so. Where collected water contains contaminants, and therefore does not comply with the Environment Agency position statement, it will be disposed to foul sewer (with Thames Water approval), offsite to wastewater treatment facility, or to ground (with Environment Agency permission only). The need for treatment to improve quality before discharge to foul sewer or back to ground will be considered and would be covered under a mobile plant permit.

If significant free product is encountered in excavations extending below groundwater level then free product will be removed as far as practicable by skimming.

Remediation of groundwater sources identified by the DQRA is covered in Section 9.

8.5 Managing radiological risk during excavation

A specialist desk study prepared by Nuvia [14] recommended further investigation of the site of the former 'Sparklets' works in DZ5 where products incorporating Radium-226 had been manufactured [3]. A radiological survey using Groundhog equipment was undertaken across accessible areas, however it could not be completed across the entire area due to buildings. Nuvia recommended a radiation risk assessment (RRA) be undertaken by a radiation protection advisor (RPA) in advance of any intrusive works and attendance of intrusive works by specialist health physics support.

These recommendations relating to radiological ground contamination in the 'Sparklets' area of DZ5 will be addressed by the Contractor during the SIW works with a range of measures. In accordance with appropriate good practice, a RRA will be undertaken by a RPA that will define measures to be implemented which may include using excavators with bucket radiation detectors and specialist health physics attendance during excavations (with handheld instrumentation) or other measures.

8.6 Managing UXO risk during excavation

A risk assessment for the presence of buried unexploded ordnance (UXO) at the site is presented in Zetica UXO desk study and risk assessment [20].

During World War 2, 17 high explosive bombs were recorded to have struck the Meridian Water masterplan area. Bombing was concentrated in central parts of the SIW and offsite in the northwest of the wider masterplan development area (not included in the SIW). The UXO hazard level is shown in Drawing 7. A small area in the central part of the SIW has been assigned a moderate UXO hazard level. Zetica records for the remainder of the site indicate there was no significant bombing or other military activity and therefore the site has been assigned a low UXO hazard rating.

Appropriate good practice measures will be implemented, in accordance with the Contractor's own assessment of the UXO risk, including but not limited to document reviews and direct investigation (such as magnetometry probing) for the avoidance of buried UXO.

8.7 Geoenvironmental watching brief

A geoenvironmental watching brief will be maintained by the Contractor throughout the SIW ground works and will include:

- The Contractor's site manager will have overall responsibility for delivering the watching brief and may delegate specific actions to staff onsite;

[2] Environment Agency Regulatory Position Statement on Temporary dewatering from excavations to surface water (Updated 28 April 2021) https://www.gov.uk/government/publications/temporary-dewatering-from-excavations-to-surface-water/temporary-dewatering-from-excavations-to-surface-water

- the Contractor will prepare inductions, risk assessments, method statements, CEMP and toolbox talks taking account of this strategy. This should emphasise the specific ground conditions expected and the responsibility to stop work and report any issues;
- all ground workers should have a general asbestos in soils awareness training which will include a description of what had been found onsite and what might be encountered during the works. Additional asbestos-related training may be required (to be determined by competent assessor, see Table 14);
- the toolbox talks onsite should include a specific section on ground contamination including the findings and recommendations in this report; and
- turnover, excavations and material placement will be observed by a competent geoenvironmental specialist, responsible for identifying potential contamination and to ensure that the appropriate controls and mitigation outlined in this report are actioned.

Site inspections will be conducted and recorded during the works to ensure, above all, that appropriate health and safety practices are being followed and works are being implemented in line with approved remediation strategy and Contractor's method statements. The watching brief will be documented, reported on during progress meetings and the records compiled in the verification report.

8.8 Discovery strategy

The watching brief described above describes how ground works will be managed to identify potential contamination. The discovery strategy below describes the response to observed contamination.

Whilst comprehensive desk study and extensive ground investigations have been implemented on the SIW site residual uncertainty in ground conditions remains and there is potential for contamination to be present that has not been encountered by previous ground investigation.

As described above the site turnover will be attended by a competent geoenvironmental specialist. All gross contamination (see definition below), tanks or other contaminated underground structures encountered during the site turnover will be removed and the excavations will be subject to verification testing (Section 8.10). The location and characteristics of the contamination, tank etc including photos, detailed description, works completed and verification test results will be recorded in accordance with the verification plan (Section 13).

Earthworks excavations in areas of the site not subject to site turnover (shown in pink on Drawing 6) may similarly encounter gross contamination that will be treated in the same manner, with the oversight of a competent geoenvironmental specialist.

If contamination is encountered that is not of a similar nature to that previously identified or is not addressed by this remediation strategy (such as buried drums, animal carcasses) this will be identified as unexpected contamination and the following procedures will be implemented:

- works should cease in the area affected and the area cordoned off;
- a competent geoenvironmental specialist should be consulted who will advise on the next steps;
- contaminated material should be sampled and tested, either in situ in the ground (and left undisturbed while the samples are tested and the results interpreted) or if safe to do so excavated and stockpiled separately in an appropriate manner (i.e. bunded and covered stockpile); and
- measures should be taken to ensure protection of site staff, neighbours and the environment, particularly by controlling dust and surface water runoff from the contaminated area.

Condition 32 of the SIW planning consent (ref: 19/02717/RE3) requires that the approach to dealing with previously unidentified contamination should be agreed with the planning authority. This remediation strategy report has been prepared to discharge condition 32.

8.9 Definition of gross contamination

The definition of gross contamination for the SIW is based on that implemented at Meridian Water Phase 1. Gross contamination is defined as follows:

- Material saturated with free product, i.e., significant visible oil, solvents or tar within soil, or on/within groundwater;
- Material indicative of asbestos disposal, such as a discrete pocket of predominantly asbestos containing material; and
- Soil having significant odour.

The definition of significant odour is having an odour observation score of greater than 12 in accordance with the matrix in Table 11 below.

Table 11 Odour observation rating matrix

Intensity	**Duration**
0 No detectable odour 1 Very faint odour (only just noticeable) 2 Faint (need to inhale facing into wind) 3 Distinct (easily detected while breathing normally, possibly unpleasant character) 4 Strong (bearable but distinctly unpleasant odour) 5 Very strong (very unpleasant odour) 6 Extremely strong (very unpleasant odour, difficult to bear, possibly causing nausea)	1 Transient (e.g., whiff – only detectable for brief intermittent spells) 2 Sporadic discrete (<50% of total assessment time) 3 Persistent (>50% of total assessment time) 4 Continuous (present throughout assessment period)

	Intensity						
Duration	No odour	Very faint odour	Faint odour	Distinct odour	Strong odour	Very strong odour	Extremely strong odour
Transient	0	1	2	3	4	5	6
Sporadic discrete	0	2	4	6	8	10	12
Persistent	0	3	6	9	12	15	18
Continuous	0	4	8	12	16	20	23

The following categories of material are not considered to meet the definition of gross contamination:

- Clay materials with limited penetrative staining, such as with small tar streaks, where the tarry material is bound into the matrix of the clay and is unlikely to be mobile;
- Gravels having a slight hydrocarbon sheen that wouldn't be described as a free product;
- Dispersed ACM fragments or fibres in a Made Ground soil matrix;
- Groundwater having an oily sheen but not a measurable thickness of floating product;
- Material with mild or no odour (see above).

8.10 Material reuse and soil verification

8.10.1 Categories of material

The geoenvironmental criteria for soils for reuse on site, to remain in situ and for imported soils, and the requirements for verification are presented below. The relevant geotechnical and landscape specifications for must also be adhered to and are not addressed in this document.

The following specific categories of material are defined:

- Topsoil: thickness subject to landscape design at surface in Brooks Park, Edmonton Marshes and within the flood diversion channel. Most of this material is likely to require importing from off-site.
- Cover soil: material suitable for use within the cover layer in Brooks Park, Edmonton Marshes and within the flood conveyance channel. It also includes the top layer of material (0.5m) placed to achieve the required level in future development plots. Topsoil is a sub-set of this category.
- General fill: material placed beneath cover soil in soft landscaped areas and future development plots and beneath hardcover areas such as roads.

Further detail on the re-use of these materials including required thicknesses in specific areas of the site is provided within Section 8.11.

8.10.2 Criteria for reuse: excavated soils and imported material

All material used as cover soil and temporary cover should not exceed any of the criteria presented in Table 12 (for either category). In addition, topsoil should comply with the requirements of BS 3882 [22] and the landscaping specification.

For the purposes of defining general fill criteria the site has been split into two different zones (see Drawing 9) as follows:

- Zone A - site wide excluding south of DZ4 (IKEA Clear)
- Zone B – southern part of DZ4 only including the non-hardstanding covered area south of BOC buildings (i.e. IKEA clear)

For Zone A re-use criteria have been derived that are protective of both human health and controlled waters. For Zone B, which is a more contaminated and where additional mitigation measures will be required as part of the follow-on development to address human health risk, human health-based criteria are excluded (i.e. it is assumed that all relevant pathways will be broken).

Both Zone A and Zone B will include target criteria that are protective of risk to controlled waters.

A single set of criteria for cover soil will be used site wide; these are generally risk based criteria that are protective of both human health and controlled waters.

Risk based targets have been supplemented using other criteria, including an upper limit on concentrations of hydrocarbon compounds, specific targets for asbestos, limits for phytotoxic effects and the exclusion of visibly contaminated soils. Details of the approach used to derive the reuse criteria is presented in full in Appendix C.

Table 12 Reuse criteria for general fill and cover soil

Contaminant	Re-use criteria (mg/kg)		
	General fill		Cover soils
	Zone A	Zone B	
Arsenic	No criteria	No criteria	79 A
Beryllium	No criteria	No criteria	2.2 A
Cadmium	No criteria	No criteria	106 A
Chromium (trivalent)	No criteria	No criteria	1,539 A
Chromium (hexavalent)	No criteria	No criteria	21 A
Copper	No criteria	No criteria	270 C
Lead	No criteria	No criteria	630 A
Mercury (inorganic)	No criteria	No criteria	124 A
Nickel	No criteria	No criteria	150 C
Selenium	No criteria	No criteria	1,140 A
Vanadium	No criteria	No criteria	1,100 A
Zinc	No criteria	No criteria	400 C
Benzo(a)anthracene	102 A	No criteria	29 A
Benzo(a)pyrene	378 A	No criteria	5.7 A
Benzo(b)fluoranthene	338 A	No criteria	7.2 A
Benzo(k)fluoranthene	No criteria	No criteria	191 A
Benzo(g,h,i)perylene	No criteria	No criteria	637 A
Chrysene	926 A	No criteria	57 A
Dibenzo(a,h)anthracene	19.6 A	No criteria	0.57 A
Fluoranthene	10 B	10 B	10 B
Indeno(1,2,3-c,d)pyrene	No Criteria	No criteria	82 A
Naphthalene	8.7 A	No criteria	8.7 A
Sum USEPA 16 PAHs	1,000 D	1,000 D	500
Benzene	1.1 A	5 B	1.1 A
Ethylbenzene	300 A	No criteria	300 A
Toluene	3,080 A	No criteria	3,080 A
O-Xylene	323 A	No criteria	323 A
M-Xylene	302 A	No criteria	302 A
P-Xylene	289 A	No criteria	289 A
Aliphatic TPH EC5 to EC6	118 A	No criteria	118 A
Aliphatic TPH >EC6 to EC8	349 A	No criteria	349 A
Aliphatic TPH >EC8 to EC10	98.9 A	No criteria	98.9 A
Aliphatic TPH >EC10 to EC12	499 A	No criteria	499 A
Aromatic TPH >EC5 to EC7	1,080 A	No criteria	No criteria
Aromatic TPH >EC7 to EC8	3,030 A	No criteria	No criteria
Aromatic TPH >EC8 to EC10	175	No criteria	175
Aromatic TPH >EC10 to EC12	964 A	No criteria	964 A
Aromatic TPH >EC12 to EC16	1,500 B	1,500 B	1000 D

Contaminant	Re-use criteria (mg/kg)		
	General fill		Cover soils
	Zone A	Zone B	
Sum aliphatic and aromatic TPH EC5 to 35	5,000 D	5,000 D	1,000 D
Hydrocarbon impacted soils	No grossly impacted soils or visible free phase		
Ammoniacal nitrogen	45 B	45 B	45 B
Vinyl chloride	0.01 B	0.01 B	0.01 B
Total phenol	1,000 D	1,000 D	500 D
Complex cyanide	20 B	20 B	20 B
Visible asbestos material	No visible material		
Non-visible material	<0.1%	<0.1%	No detectable fibres
A – risk-based criteria for human health			
B – risk-based criteria for controlled waters			
C – Value is 2x the criteria proposed for phytotoxic metals from BS 3882. This reflects the requirement to place topsoil above landscaping soils reducing root contact and potential for plant uptake			
D – Non risk-based target criteria for total PAH and phenol set at 1000mg/kg for general fill and 500mg/kg for landscaped soils. Non -risk based target criteria for speciated TPH set at 5,000mg/kg for general fill and 1,000mg/kg for landscaping soil.			
In some cases risk based criteria for landscaping soil exceed general fill criteria (reflecting the inclusion on inhalation indoors in the risk model for the general criteria). In these cases landscaping soil values have been capped at the value derived for general fill as these soils should be to a higher specification.			

8.10.3 Site won material verification requirements

Earthworks are required to reduce levels in four specific areas including Edmonton Marshes (DZLV1), Brooks Park (west of DZ4), the flood conveyance channel (DZ7) and Ikea Clear (southeast of DZ4). Additional excavation of material may also be required to facilitate the excavation of below ground structures and to remove any gross contamination encountered during the surface turnover.

Excavated material will be reused in areas that require raising including the causeway and link road and to create development platforms in DZ4 and DZ5 to achieve the specific scheme design requirements including flood protection, highway, and plot levels. Excavated materials will be reused directly or transported to a materials hub where it will be assessed, segregated and treated in accordance with material management systems being developed by the Contractor. Material will be categorised for offsite disposal or reuse onsite.

Verification testing is required to confirm that materials achieve the reuse criteria. Some verification may be done at the point of placement if materials are reused directly local to the excavation. The following preplacement verification testing frequencies are required:

- Untreated natural material from DZLV1: one sample per 2,000m^3.
- Made Ground material excavated from DZLV1 not subject to exsitu physical, biological or chemical treatment: one sample per 500m^3.
- All material excavated from Brooks Park and other material subject to exsitu physical, biological or chemical treatment: one sample per 250m^3.

All sampling of stockpiles will be completed using spatial composite technique.

Site-won material from DZ2, DZ4, DZ5, DZ6 and DZ7 will be tested for the standard verification suite listed in Section 8.10.9. Site won material from DZLV1 will be tested for a reduced verification suite (Section 8.10.9) unless the presence of hydrocarbons is suspected in which case the standard suite should be used. Site won material should achieve the target criteria presented in Table 12 (also see note on interpretation of verification results in 8.10.10).

8.10.4 Imported material verification requirements

Only clean, natural soils without anthropogenic contamination, or recycled material produced under a WRAP protocol, should be imported. Import of general fill and cover soils (excluding topsoil) is not anticipated based on the earthworks cut and fill assessment. However, there is a deficit of topsoil and topsoil, subsoil and engineered fill imported for use at the site (or generated from site-won soils) will be validated as chemically suitable for purpose.

Verification of material import to site will be undertaken by a mix of testing before and after import. All supplier and verification chemical results should be collated by the Contractor for inclusion in the verification report. The Contractor will provide details of the origin of the imported soils.

Imported materials from brownfield sites (e.g. if imported under DoWCoP cluster scenario) will need to be tested at the following frequency:

- Minimum of one sample per source and one sample per soft landscaped area; and
- One sample every 50m^3 of imported soil for the first 500m^3 of each source; and
- After 500m^3, if the results from the same source are consistent and low, then a reduced testing frequency of one sample per 250m^3 will be applied.
- Any material from a brownfield source should be tested for the extended verification suite listed in Section 8.10.9.

If the source site is greenfield, then the testing frequency for imported material can be lowered to 1 in 500m^3 subject to specific desk-based data confirming the greenfield status of the source site (desk study etc).

For imported quarried aggregates such as sand and gravel then the no remediation verification testing is required. The suppliers' source certificates should be verified prior to import and the material visually inspected after import to site but prior to placement.

Recycled aggregates should be produced in accordance with the WRAP protocol, supplier certification provided, and tested to demonstrate it is asbestos-free at a frequency of 1 in 250m^3.

Imported material to be used in the manufacture of topsoil will not be subject to these import criteria, however the manufactured topsoil must achieve the reuse criteria described above.

8.10.5 Verification following turnover

Testing is required following placement of material after turnover to record the site condition in the areas shown in blue on Drawing 6.

The required frequency of verification testing is 1 per 10,000m^2 (equating to a 100m grid).

Soil samples will be tested for the standard verification suite listed in Table 13. Sampling will be undertaken by collecting spatial composite samples (see section 8.10.9). Specific remediation criteria are not proposed for the material placed by turnover, rather the data forms a record of the condition of the turnover areas before placement or follow-on development.

8.10.6 In situ soil verification for tanks and gross contamination

In situ soils sampling and laboratory testing is required at the base of the excavation after removal of tanks (Section 7.6) and excavation of gross contamination in both pink and blue areas on Drawing 6. Sampling should accord with the following frequency:

- Minimum of one sample from the base and one sample from each excavation face per excavation.
- Minimum of one sample per face and one sample per 25m^2.

Samples will be collected by spot sampling (see section 8.10.9). Sampling suites will reflect the purpose of the excavation such as the type of contaminant source described in Table 13. In addition to the gross contamination definition (Section 8.9), specific soil target criteria are not proposed for the in situ material collected from small excavations, all in situ results will be presented and summarised in the verification report.

8.10.7 In situ soil verification for bulk earthworks excavations

In situ soils sampling and laboratory testing is required at the base of the earthworks excavations to record the site condition in the areas shown in pink on Drawing 6.

If ACM is present visible to the naked eye of a geoenvironmental or asbestos specialist at formation level it should be removed by handpicking. No ACM visible to the naked eye should remain at formation level. This is particularly important where plant and vehicles may track during construction works.

Sampling will achieve the following frequency of testing:

- DZLV1: one per 10,000m^2 (100m grid).
- Brooks Park and Ikea Clear: one per 2,500m^2 (50m grid).
- Flood conveyance channel: one sample per 50m section along the channel.

Samples will be collected using spatial composite technique (see section 8.10.9). Soil samples will be tested for the standard verification suite listed in Table 13. Specific remediation criteria are not proposed for the in situ material following bulk excavations, all in situ results will be presented and summarised in the verification report. The data is intended to inform the condition of the site before placement or follow on development works.

[3] MCERTS should be provided for, the analytes listed in Annex A of the Environment Agency publication *Performance Standard for Laboratories Undertaking Chemical Testing of Soil*, Version 5, December 2018.

8.10.8 Additional verification following earthworks placement

Following placement of material and completion of earthworks in SIW, additional surface testing is required.

The required frequency of verification testing is as follows:

- Soft landscaping in public open space: one per 900m^2 (30m grid).
- Development platforms: one per 10,000m^2 (100m grid).

Soil samples will be tested for the standard verification suite listed in Table 13. Sampling will be undertaken by collecting spatial composite samples (see section 8.10.9). Placed material should achieve the target criteria presented in Table 12 (also see note on interpretation of verification results in 8.10.10).

8.10.9 Verification sampling methodology

Verification sampling of site-won material, in situ material remaining after bulk excavations and material after placement will be undertaken by collecting spatial composite samples.

The composite soil sampling methodology should accord with the British Standard BS ISO 18400-104:208 Soil quality – Sampling. Each composite sample will include a minimum of ten evenly spaced increments (subsamples).

Verification of in situ material remaining in smaller excavations following the removal of tanks and/ or gross contamination will be undertaken by spot sampling (also in accordance with BS ISO 18400-104:208).

Sample handling, packing, transportation, storage, preservation, quality control and assurance, recording and reporting will accord with the various sets of guidance provided by the BS ISO 18400 series.

Chemical laboratory testing shall be carried out to BS EN ISO/IEC 17025 and testing will conform to the Environment Agency MCERTS (Monitoring Certification Scheme), where applicable[3].

For asbestos, the method of asbestos analysis will be accredited by the UK Accreditation Service (UKAS) and the quality control schemes used by the asbestos analysis laboratory shall comply with UKAS LAB 30 (Application of ISO/IEC 17025 for asbestos sampling and testing) and HSE HSG 248 (Asbestos: the analyst's guide for sampling, analysis and clearance procedures).

The analytical suites required for verification are summarised in Table 13.

Table 13 Verification testing suites

Verification purpose / material origin	Testing suite
Site won material from DZ2, DZ4, DZ5, DZ6 and DZ7 for preplacement and in situ testing after placement	Standard suite: metals, pH, TPHCWG, 16 USEPA PAH, speciated phenols, BTEX, volatile hydrocarbons, complex and free cyanide, ammoniacal nitrogen, asbestos

Verification purpose / material origin	Testing suite
Site won material from DZLV1 [A]	Reduced suite: metals, pH, TPHCWG, 16 USEPA PAH, complex and free cyanide, ammoniacal nitrogen, asbestos
Imported material (brownfield origin)	Extended suite: metals, pH, TPHCWG, 16 USEPA PAH, speciated phenols, BTEX, volatile hydrocarbons, complex and free cyanide, ammoniacal nitrogen, PCBs, semi-volatile hydrocarbons, pesticides, asbestos
Imported material (greenfield origin)	Metals, pH, 16 USEPA PAH, soil organic matter, asbestos
In situ verification following bulk excavation in DZLV1, Brooks Park and Ikea Clear and the flood conveyance channel.	Standard suite: metals, pH, TPHCWG, 16 USEPA PAH, speciated phenols, BTEX, volatile hydrocarbons, complex and free cyanide, ammoniacal nitrogen, asbestos
In situ verification following tank removal or removal of gross contamination	TPHCWG, 16 USEPA PAH, speciated phenols, BTEX, volatile hydrocarbons, asbestos
In situ verification following localised excavation of other (non-hydrocarbon sources) sources	Testing to be specific to the suspected contamination e.g. free and total cyanide for cyanide sources, asbestos screening and quantification for ACM or ammoniacal nitrogen for ammoniacal waste / liquors.
[A] if suspected hydrocarbon contamination is present in material collected from DZLV1 testing should be increased to include the standard suite (i.e. with the inclusion speciated phenols, BTEX, volatile hydrocarbons)	

8.10.10 Evaluating verification results

No stockpile material will be reused until the results of verification testing have been received and compared with verification criteria to confirm acceptability. In some cases, if concentrations are recorded that slightly exceed verification criteria it may still be appropriate to reuse the material rather than dispose of the material as unsuitable as described below.

The decision on whether to reuse or reject material will be made on a case-by-case basis. Any material subject to reuse that contains concentrations higher than the relevant criteria in Table 12 will be highlighted within the verification report and a lines of evidence approach presented to justify why the decision was made to reuse the material on-site. Examples of the lines of evidence that could be used to justify reuse include the following:

- Where the concentrations only slightly exceed target criteria the case for re-using material is much stronger. Where concentrations exceed by a greater margin (e.g. >100% higher) treatment or offsite disposal is more likely to be an appropriate course of action.
- If a single constituent only fails reuse criteria the material is more likely to suitable for use. Failures of multiple criteria would suggest a material is not suitable for reuse.
- For contaminants that exceed a non-risk based upper limit (established for several hydrocarbons to limit the total contaminant loading) it would be appropriate to check whether or not the recorded concentrations exceed the risk-based criteria presented in Appendix C. If the risk-based criteria are also exceeded the material is less likely to be suitable for reuse.
- Re-sampling the same material to assess if the initial result was representative is an option, however one positive result wouldn't necessarily discount one negative result. Efforts could be made to ensure that the repeat sampling provides an improved level of characterisation e.g. sampling a lower volume of material, or higher number of samples, or thorough mixing prior to sampling.
- Consideration could also be given to further risk assessment to adjust risk-based criteria to account for variation between the actual conditions and the modelled assumptions presented in Appendix C. For example, it might be possible to refine the source parameters (e.g. the size of the source, the type of strata or the soil organic content). Any risk assessment adjustments should be taken with due consideration to the agreed conceptualisation and parameterisation and not deviate from the original risk assessment approach without strong justification.

The purpose of verification testing of in situ soils and turnover soils is to provide a record of site condition and to inform the follow-on site developer. Residual contamination exceeding the general fill criteria (but not meeting the gross contamination definition) is locally anticipated in turnover and in situ material. The verification results will be presented in full the verification report.

8.11 Cover systems

8.11.1 Soft landscaped areas

A verified cover system is required in soft landscaped areas. The cover systems required in specific areas of the SIW are described below and depicted in cross sections included in Drawing 10.

Brooks Park

In situ material remaining after bulk excavation to achieve required level reduction in Brooks Park is likely to contain locally elevated levels of contamination. A low permeability (effectively impermeable) hydraulic barrier will be installed to line the new naturalised section of Pymmes Brook to prevent interaction of groundwater and surface water (Section 10). The barrier will be extended laterally (see Section 10) to provide a continuous low permeability layer across Brooks Park preventing infiltration and also isolating the underlying contamination from overlying cover soils, future site users and vegetation. Design of the river naturalisation and low permeability barrier will be finalised by the Contractor (Section 10).

Cover soils will be placed above the low permeability barrier to achieve the approved landscape design. All material placed above the low permeability barrier will achieve the criteria presented in Table 12 for cover soil, and topsoil should also accord with the requirements of BS 3882. The top of the general fill or in situ material should be clearly identifiable from the cover soil and a marker geotextile may be required.

Tree pits must be designed to ensure that the integrity of the hydraulic barrier is preserved.

Drainage requirements above the low permeability layer will be considered in the detailed design.

Flood conveyance channel

The flood conveyance channel will transfer surface water during intermittent periods of flood to the attenuation ponds in DZLV1 to the River Lee Navigation. Most of the time the channel will be dry and will provide a publicly accessible open space. The cover system along the conveyance channel therefore needs to be multi-purpose, providing a low permeability liner for the channel, a physical barrier to protect future site users from potentially contaminated deeper soil, and a clean substrate for landscaping.

Design of the cover system will be finalised by the Contractor but will include a GCL or membrane overlain by cover soil. The cover system will need to accord with the landscape design. Physical protection of the low permeability liner must be considered and a minimum thickness of 300mm of cover soil is recommended.

All cover soil will achieve the criteria presented in Table 12 for cover soil and topsoil will also need to comply with the requirements of BS 3882 [22].

Edmonton Marshes

In Edmonton Marshes a low permeability barrier is not required to separate underlying groundwater from the clean cover materials due to the lack of contamination identified in this area of the site. In most parts of Edmonton Marshes groundwater is expected to be shallow after the earthworks to reduce levels and occasional flooding and hydraulic connectivity with groundwater is expected.

At any location where Made Ground remains following excavation to the required depth, a marker geotextile should be placed overlain by a minimum cover thickness of 300mm. Where Made Ground is absent there is no requirement to place a cover system for contamination risk management purposes, however this may be required for landscaping.

All cover material will achieve the criteria presented in Table 12 for cover soil, and topsoil will also need to accord with the requirements of BS 3882.

8.11.2 Development platforms

In DZ4 and DZ5 the completed SIW earthworks will provide development platforms at 0.5m below the proposed finished levels of the follow-on development. The final of 0.5m land raising will be completed as part of follow-on development which will be subject to future separate planning consent.

For the SIW, required land raising in DZ4 and DZ5 will be completed by placing general fill overlain by cover soil. A thickness of 0.5m of cover soil will be placed at the surface overlying general fill (unless required land raising is less than 0.5m). This will ensure that any general fill material is at least 1.0m below the final finished levels after proposed additional land raising as part of follow-on development[4]. A geotextile marker layer will be placed to separate the cover soil from underlying general fill.

In some areas of DZ4 and DZ5, levels will remain unchanged or will be reduced by the SIW. In these areas, following the completion of turnover or excavation, a temporary cover will need to be placed for the interim period until the commencement of follow-on development (see Section 8.11.3 below).

The follow-on developer will need to consider the plot conditions on completion of SIW. In some areas cover soil (excluding temporary cover) will be absent or less than 0.5m thick and although material will have been subject to turnover and removal of gross contamination, levels of contamination could remain above the criteria specified for cover soil and (potentially) general fill. Appropriate assessment and if necessary supplementary remediation or mitigation measures may need to be implemented by the follow-on developer. Further details on remediation obligations for the follow-on developer are described in Section 14.

8.11.3 Temporary cover

During the interim period following completion of the SIW and prior to the commencement of plot development, public access will be prohibited by the erection of hoarding. Some controlled access may be required during this period (e.g. visits by future developers / and surveyors) and some unplanned access may also occur (e.g. trespassing).

For areas of non-specified use in DZ6 and DZ7 and in areas of DZ4 and DZ5 where cover soils have not been placed there is the potential that contamination could occur in near surface soil that, unless prevented, could present a risk of harm to health via direct soil contact, ingestion or dust inhalation pathways.

In these areas a temporary surface cover layer will be placed over the ground surface for the interim period prior to plot specific development. This will prevent direct exposure to contaminants in the underlying soil and prevent generation of contaminated dust.

The temporary cover layer will be designed by the contractor and should include the following components (or achieve similar performance):

- A geotextile layer placed directly above the soil surface to allow easy separation and removal of the temporary fill.
- A layer of verified granular material e.g. 6F2 obtained from crushing hard materials derived from demolition and site turnover or surplus site won material from bulk excavations. Material will need to be tested to confirm material meets criteria proposed for cover soil. For verification purposes a minimum of one composite sample per 2500m^2 should be collected.

8.11.4 Hardcover areas

No clean cover system is required beneath hardcover areas of the SIW, such as roads.

[4] The human health based general fill criteria were derived by modelling transport of vapour from a source situated 1m below ground level at a future residential development. If shallower general fill were to occur this would undermine the technical validity of the criteria and would either constitute a health risk or necessitate additional forms of mitigation.

9 Remediation of groundwater contamination sources

9.1 Introduction

The remediation options appraisal, summarised in Section 6 and included in Appendix B, considers options for remediation for each of five groundwater contamination source areas, shown on Drawing 4.

The remedial actions required in each of these areas to address identified risks are described below.

9.2 Benzene in KPGR

The remediation options appraisal concludes that in situ air sparging or chemical oxidation (chemox) are required to promote volatilisation of the identified DZ4 benzene source, in addition to removal of unsaturated zone sources across DZ4 and source-specific monitoring.

Detailed investigation and delineation of the source could reduce or remove the requirement for air sparging or chemox. However any changes to this strategy will require approval by the Environment Agency, with supporting source characterisation and risk assessment.

The recent cover layer will be removed across DZ4, followed by turnover to 1.5m, with removal of tanks and structures containing contamination and gross contamination, as described in Section 7. Following these works and any necessary material placement to achieve required levels the air sparging/chemox will be implemented.

The remediation is proposed to extend approximately 50m from the south east corner of DZ4, with an approximate injection well spacing of 8m to 10m, with wells extending through approximately 4m saturated thickness to the base of the KPGR. The extent and performance of the groundwater treatment will be evaluated based on investigation and groundwater monitoring. Detailed design of the system will be undertaken by specialist contractor.

Monitoring will be facilitated by the existing monitoring well DZ4_BH1007 (northwest of the treatment area) and DZ4_BH1008 (within the treatment area) that are to be retained during the works (or replaced if damaged), plus a minimum of two additional new downgradient monitoring wells and one new monitoring well within the identified source. Groundwater quality will be monitored at downgradient wells for at least dissolved oxygen and benzene fortnightly after commencement of treatment, and with a minimum of three samples prior to commencement.

The effectiveness of the remediation will be evaluated by assessing the quantity of source material removed (contaminated soil, tanks etc) in combination with the monitoring data. In situ treatment will continue until a decreasing trend is observed in the monitoring wells and concentrations at monitoring wells are typically less than 1mg/l benzene.

9.3 Vinyl chloride in KPGR

The remediation options appraisal concludes that in situ treatment by air sparging or chemical oxidation is required to address elevated vinyl chloride in central DZ7, in addition to removal of any remaining vinyl chloride source in the unsaturated zone and source-specific monitoring (see Section 6).

Detailed investigation and delineation of the source could reduce or remove the requirement for sparging or oxidation. However, any changes to this strategy will require approval by the Environment Agency, with supporting source characterisation and risk assessment.

The area of site turnover has been extended across the potential vinyl chloride source area (see Drawing 6). Within this area surface turnover to 1.5m, removal of tanks and structures containing contamination and gross contamination will be undertaken, as described in Section 7.5. Following these works and any necessary material placement to achieve required levels the in situ treatment will be implemented.

The area where air sparging or chemical oxidation will be undertaken is assumed to be an area of approximately 25m radius within DZ7, with an approximate injection well spacing of 8m to 10m, with wells extending through approximately 4m saturated thickness to the base of the KPGR (approx. 3mOD). This will be defined by further investigation. The performance of the groundwater treatment will be evaluated based on groundwater monitoring. Detailed design of the system will be undertaken by specialist contractor.

Monitoring will be facilitated by the existing monitoring wells DZ7_BH2058 and DZ7_BH2060 that are to be retained during the works (or replaced if damaged), plus a minimum of three additional new monitoring wells around the treatment area and two new monitoring wells within the identified source. Groundwater quality will be monitored for dissolved oxygen and vinyl chloride (as a minimum) and will be undertaken at least fortnightly after commencement of treatment, and with a minimum of three samples prior to commencement.

The effectiveness of the remediation will be evaluated by assessing the quantity of source material removed (contaminated soil, tanks etc) and monitoring data. In situ treatment will continue until a decreasing trend is observed in the monitoring wells and concentrations at monitoring wells are typically less than 0.01mg/l vinyl chloride.

9.4 TPH in DZ2

This source has been defined based on monitoring wells east of the DZ2 gas holder base that showed a rise in concentrations during baseline monitoring in 2020. Concentrations suggested the probable presence of free product, although no free product was detected during monitoring. The remediation options appraisal (Appendix B and Section 6) identifies natural attenuation, removal of unsaturated zone sources and skimming as the order of preference of remediation techniques to manage risks in this area.

The site turnover will remove residual unsaturated zone sources to the east and southeast of the gasholder base (Drawing 6). The available data is insufficient to confirm natural attenuation (with removal of unsaturated zone sources) will adequately address risks in this area. The original source of contamination may be the gasholder (now cleaned out and to remain untouched during the SIW) and NAPL may be present floating on groundwater. Therefore, this remediation strategy assumes new wells will be constructed for investigation and, if encountered, NAPL will be removed in addition to removal of unsaturated zone sources.

Following turnover to a depth of 1.5m and removal of obstructions and gross contamination (as described in Section 9) material will be placed as necessary to achieve required levels. New monitoring wells (minimum 8) will be installed across the area to investigate the presence of LNAPL. If LNAPL is encountered in monitoring wells it will be removed to achieve asymptotic recovery or one litre per well per day, depending on the NAPL removal method.

9.5 Ammoniacal nitrogen and cyanide in KPGR

Ammoniacal nitrogen and cyanide contamination is present in KPGR groundwater at concentrations significantly higher than the calculated RTM Level 3 targets across the southern part of DZ4 and DZ2 ('ROA4' on Drawing 4).

Several remediation activities are expected to result in a reduction in groundwater ammoniacal nitrogen and cyanide concentrations in KPGR including:

- Turnover of soils across DZ4 and eastern DZ2, with removal of gross contamination, tanks and other obstructions (Section 7 and 8),
- Subsequent development (buildings/hardstanding/low permeability cap) will result in long term improvement in groundwater quality removing unsaturated zone source and reducing future infiltration and leaching inputs.
- In situ treatment by air sparging or chemical oxidation to remediate the DZ4 benzene plume would also be beneficial for ammoniacal nitrogen concentrations.
- Dewatering to facilitate Brooks Park works (Section 11) may remove contaminated groundwater in the western part of DZ4.

The options appraisal identifies that the only feasible additional remedial option is natural attenuation of the ammoniacal nitrogen groundwater contamination and, while degradation of complex cyanides is likely to be slow, reducing concentrations in groundwater are expected through dilution, sorption and aerobic bio-transformation. Therefore, the remediation strategy to address the risks presented by ammoniacal nitrogen and cyanide in KPGR in southern DZ4 and DZ2 is source-specific monitoring to confirm groundwater concentrations are stable or decreasing.

Monitoring will be facilitated by the existing KPGR monitoring wells, selected to provide a distribution across the source including:

- DZ4_BH2083.
- DZ 4_BH2081.
- DZ4_BH2082.
- DZ4_BH2041A.
- DZ4_BH1005A.

The following monitoring is required:

- Baseline: a minimum of three sets of baseline samples to be analysed for ammoniacal nitrogen and cyanide (free and total)
- During SIW ground works: quarterly sampling and analysis for ammoniacal nitrogen and cyanide (free and total)
- Following SIW ground works: quarterly sampling and analysis for ammoniacal nitrogen and cyanide (free and total) for 12 months.

The monitoring data will be reviewed to assess whether the remediation objectives have been achieved and groundwater concentrations are stable or broadly improving for ammoniacal nitrogen and cyanide in the KPGR in the south of DZ2 and DZ4.

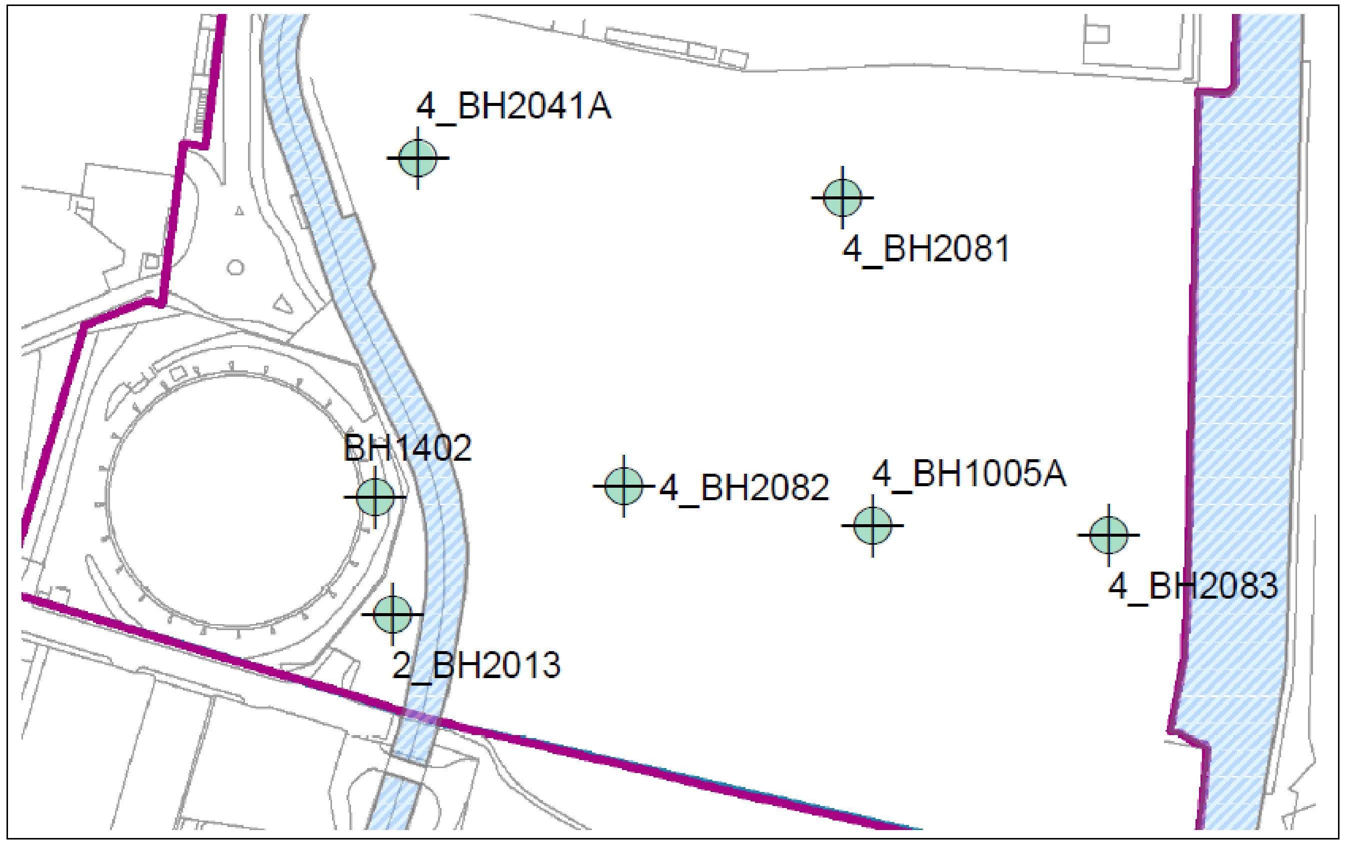


Figure 4 Monitoring wells in KPGR

These wells are to be retained during the works (or replaced if damaged) and will be included in the monitoring programme.

9.6 Ammoniacal nitrogen and cyanide in Chalk basal sands

Ammoniacal nitrogen and cyanide is present in the Chalk basal sands in DZ2 and southwest DZ4 at more than an order of magnitude higher than the modelled RTM Level 3 target criteria for ammonium and three times higher for cyanide (shown as 'ROA5' on Drawing 4). However, the high degree of conservatism in the model has been demonstrated and it is considered unlikely that significant impacts will occur at down gradient compliance points [5].

The remediation options appraisal identified only one feasible option, natural attenuation. Biological degradation is expected to reduce concentrations of ammoniacal nitrogen. Cyanide in the Chalk basal sands groundwater is likely to degrade slowly and depending on the forms of complex cyanide that are present, long term mass reduction of cyanide concentrations is also expected by dilution and biotransformation and degradation. Source-specific monitoring will be undertaken to confirm groundwater concentrations are stable or decreasing.

Monitoring will be facilitated by the following existing monitoring wells, selected to provide a distribution across the ammoniacal nitrogen and cyanide in Chalk basal sands source zone including:

- DZ2_BH1401C or DZ2_BH2010
- DZ4_BH2088
- DZ4_BH2043
- DZ4_BH2045
- DZ4_BH2038

These wells are to be retained during the works (or replaced if damaged) and will be included in the monitoring programme.

The following monitoring is required:

- Baseline: a minimum of three sets of baseline samples to be analysed for ammoniacal nitrogen and cyanide (free and total)
- During SIW ground works: quarterly sampling and analysis for ammoniacal nitrogen and cyanide (free and total)
- Following SIW ground works: quarterly sampling and analysis for ammoniacal nitrogen and cyanide (free and total) for 12 months.

The monitoring data will be reviewed to assess whether the remediation objectives have been achieved and groundwater concentrations are stable or broadly improving for ammoniacal nitrogen and cyanide in Chalk basal sands aquifer in DZ2 and DZ4.

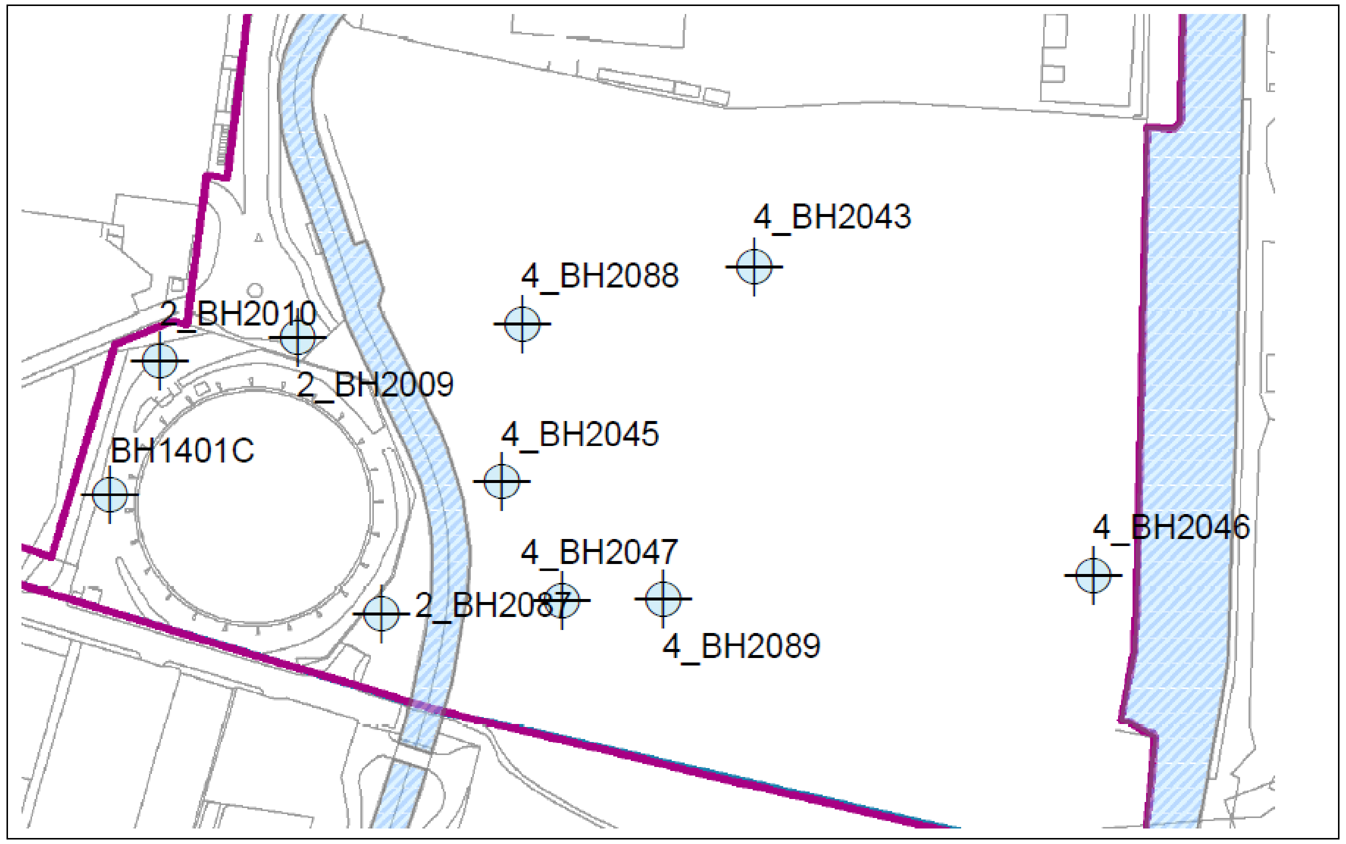


Figure 5 Location of Chalk basal sands monitoring wells

10 Remediation in Brooks Park area

10.1 Outline of Brooks Park works

The new Brooks Park area, forming the western part DZ4, will include a naturalised section of Pymmes Brook with associated ecological improvements, flood attenuation basins, riverside parkland, a boardwalk and viewing platforms (Appendix D). The naturalisation will move a 500m section of the river from its current concrete lined bed to a new naturalised channel which will meander through the newly created parkland in Brooks Park. The river will join the existing concrete lined channel to the south and north of the naturalisation zone. Earthworks will be required to create Brooks Park. To the north of the main Brooks Park works, a 15m long section of the western side of the Salmons Brook concrete channel will be removed to create Salmons Basin with a naturalised bank.

Appendix D includes drawings and sections of Brooks Park and Salmons Basin.

10.2 Detailed design and planning condition discharge

Planning condition 36 on the SIW planning consent (Appendix A) requires a scheme for Pymmes Brook naturalisation including detailed design and construction methodology to be approved prior to works on Pymmes Brook and Salmons Brook.

Condition 36 will be discharged following detailed design works to be undertaken by the Contractor. This will include the interim flood strategy and details of surface water protection during works.

This remediation strategy describes the specific remediation objectives for the Brooks Park area and outlines how they will be achieved.

10.3 Design principles and sequence of works

The following sequence of work is anticipated to create Brooks Park:

1. Levels will be reduced to 9mOD (approximately coincident with base of made ground) across the area of the naturalisation works (not the entire Brooks Park area). Gross contamination and obstructions will be chased out and excavated material will be managed in accordance with the materials strategy (as described in Section 8).
2. A hydraulic cut off wall will be constructed keyed into London Clay surrounding the area of the new naturalised channel as indicated in Appendix D. The cut off will be constructed by deep soil mixing or piles and will be confirmed by the detailed design.
3. Within the area bounded by the cut off wall, excavation to formation is required to install a liner system beneath the base and sides of the new channel. This liner system will create an effectively impermeable barrier preventing continuity between groundwater and surface water. Working in saturated ground will be avoided by dewatering within the cut off wall. The detailed design and construction quality assurance requirements for the liner and the dewatering design will be included in the submission to discharge planning condition 36.
4. On both ends of the new channel, the liner be constructed to tie in with the existing concrete channel. The channel wall would not be broken out until low flow conditions in the Pymmes Brook (possibly augmented by over pumping). Once diverted, the redundant section of concrete channel wall will be broken down and backfilled to the required level (see Appendix C).
5. Outside the cut off wall levels will be reduced to achieve formation level. Gross contamination, obstructions and tanks will be chased out and excavated material will be managed in accordance with the materials strategy (as described in Section 8).
6. The liner placed along the new channel will extend beneath the flood attenuation basins to the edge of Brooks Park in the east and west creating an effectively impermeable barrier layer to prevent infiltration and groundwater interaction with surface water. The liner or barrier may be constructed of puddle clay, or in situ stabilised soils overlain by a geosynthetic clay liner (GCL) or membrane or similar. The detailed design and construction quality assurance requirements will be included in the submission to discharge planning condition 36.
7. Subsoil and topsoil will be placed over the liner or barrier to a achieve the landscape design (minimum thickness 300mm but up to 1350mm for tree planting) (see Appendix D).
8. Foundations of the viewing platforms will be designed to avoid creation of pathways across the clay or stabilised layer.

Similarly the following sequence of work is anticipated to create Salmons Basin:

1. The existing ground surface will be broken out and levels will be reduced to achieve formation level. Gross contamination, obstructions and tanks will be chased out and excavated material will be managed in accordance with the materials strategy (Section 8).
2. A liner or effectively impermeable barrier will be placed beneath the base of the entire Salmons Basin, tied into the existing concrete channel base along the eastern boundary of Salmons Basin. Localised dewatering may be required. The detailed design and construction quality assurance requirements for the liner and the dewatering design will be included in the submission to discharge planning condition 36.
3. The existing channel wall will be broken out when Salmons Brook is at low flow.
4. Subsoil and topsoil will be placed over the liner or barrier to a achieve the landscape design (minimum thickness 300mm) (see Appendix D).

10.4 Remediation measures

Multiple aspects of the Brooks Park and Salmons Basin works contribute to the remediation strategy to address risks to receptors:

- Excavation and removal of all Made Ground in Brooks Park and Salmons Basin will remove residual contamination sources such as grossly contaminated soil, tanks, pipework and contamination contained in structure such as foundations. Excavated soils will be managed in accordance with the materials strategy.
- Locally excavation into natural ground will be required to achieve formation levels for placement of the liner beneath the new riverbed, further removing gross soil contamination. The liner will form

an effectively impermeable bed to the naturalised Pymmes Brook, preventing discharge of contaminated groundwater to the watercourse.

- The cut off wall surrounding the Pymmes Brook naturalisation works will reduce the quantity of groundwater abstraction required to achieve liner construction and will prevent movement of contaminated groundwater towards the naturalised channel in the long term.
- Across Brooks Park and at Salmons Basin the liner or barrier will form an effectively impermeable layer preventing infiltration and groundwater-surface interaction and will also provide a barrier between clean cover soils and in situ material or placed general fill.
- All material replaced in Brooks Park will be verified material that complies with the materials strategy. If material is required beneath the liner or barrier layer this will comply with the general fill criteria. Any material placed over the liner or barrier layer will comply with cover soil criteria.
- During excavation works any free product encountered on standing water in excavations will be removed, where practical.
- Dewatering during excavations in Pymmes Brook and Salmons Basin will extract potentially contaminated groundwater, and some sediment. This groundwater will be treated prior to disposal. Where sediment is the only contaminant, the treatment will comply with the Environment Agency Regulatory Position Statement on temporary dewatering from excavations to surface water. Where treatment to remove other contaminants (for discharge) is required it will be done in accordance with a mobile plant permit. Where appropriate, groundwater treatment during dewatering will be in conjunction with that required for groundwater remediation, increasing efficiency and maximising benefits.
- Due to the proximity of the Pymmes Brook receptor careful implementation of environmental protection measures will be necessary (see Section 12.3). A minimum of three months of upstream and downstream baseline monitoring will be undertaken on Salmons Brook and Pymmes Brook in advance of the Brooks Park and Salmons Basin works. Samples will be collected from three locations at monthly intervals, two upstream and one downstream. During the works fortnightly sampling will be undertaken. Continuous monitoring will be implemented to provide a more robust baseline dataset. Data will be compared with baseline to identify any significant results or trends and appropriate action will be taken in agreement with the Environment Agency if impact from the works is identified.
- During the works, daily inspections of the watercourses will be completed and recorded. If a potential impact on the watercourses associated with the works is observed (e.g. increased sediment or hydrocarbon sheen downstream of the works) immediate action will be taken to identify the cause and prevent ongoing impact, in agreement with the Environment Agency.
- Groundwater monitoring will be undertaken throughout the Brooks Park and Salmons Basin works and is included in the site-wide monitoring plan (Section 13).

11 Construction-related remediation

11.1 Overview

The SIW comprises an enabling works package including construction of a central spine road and link road, four bridges, new parkland creation, flood alleviation channel and utility networks, described in Section 2.2. Development platforms will be created in advance of follow-on development. The anticipated components of remediation required for the follow-on developments are identified in Section 14.

This section identifies those components of remediation works that must be completed as part of the SIW development construction activities.

11.2 Ground gas and vapour protection

No buildings are to be constructed as part of SIW. The follow-on development will address ground gas protection in the building designs. The ground gas assessment presented in the Arup (2021) interpretative report [4] concludes a relatively low risk associated with ground gas, typical ground gas CS2. The need for additional plot-specific monitoring to confirm CS2 should be considered by the designers of the follow-on development.

The follow-on development will also address the residual vapour risk in building designs by including appropriate vapour membranes if necessary. The assessment of human health risks associated with inhalation of vapours is included in the Arup DQRA [5]. Mitigation of occupational health risks associated with vapour during construction excavations is addressed in Section 12.

11.3 Buried concrete classification

The risks posed by soil to building materials and buried infrastructure can be controlled through appropriate selection of materials. The potential risk posed to buried concrete should be managed by designing all concrete in contact with the ground in accordance with BRE SD1[26].

11.4 Installation of services

To mitigate risks to future site maintenance workers and to avoid the possibility of chemical attack on buried services, clean service runs will be created by excavation of placed or in situ soils and replacing with suitable imported backfill underlain by a marker layer for those services to be constructed as part of the SIW.

Similarly for services to be constructed as part of the follow-on plot development clean services runs should be constructed and will be the responsibility of the follow-on developer.

If in any location a clean service run cannot be constructed the UK Water Industry Research Ltd (UKWIR) guidance should be consulted regarding the use of barrier pipe and pipe material specification. The risk assessment and proposed pipeline materials should be agreed with the local water company.

11.5 Piling and foundations

Planning condition 35 (Appendix A) requires that ‘piled, deep foundations and other intrusive groundworks using penetrative methods’ are undertaken only with the approval of the local planning authority.

The SIW will include piled foundations for river crossing bridge abutments only. No other components of the SIW are anticipated to require piled or other deep foundations.

The SIW is in a sensitive location as groundwater source protection zones (SPZ) extend across the entire SIW area associated with Chalk groundwater abstractions [4]. The piling works for the SIW are not located in SPZ Zone 1, rather all locations are in SPZ Zone 2.

A foundation works risk assessment (FWRA) will be required for each piling scheme that will be submitted to and agreed with the Environment Agency to enable discharge of condition 35, in advance of the piling works. The FWRA will include a risk assessment considering the potential for creation of pathways for groundwater contamination by the piling works. A mitigation plan will be produced that may include groundwater monitoring specific to the piling works. The FWRA will consider:

- whether alternative foundation solutions can be used to avoid the use of piles;
- the type of piles used and avoidance of piles that are likely to create pathways to depth;
- whether piles penetrate low permeability layers (London Clay and Lambeth Group mottled clay);
- the depth and density of piles;
- piles in areas of higher risk, including areas of thin London Clay or where the London Clay may have been compromised by existing structures and contamination.

On Meridian Water DZ1 (under a separate earlier planning consent) where contamination was significant the Environment Agency accepted that the development needed deeper piles to enable viability of the scheme. The approach at DZ1 was to:

- avoid piles that penetrate the London Clay where the clay is thinner than 2m (note no piling for SIW-Phase 1 is in locations with <2m London Clay);
- piles into the top of Lambeth Group clay (the Mottled Clay) are acceptable subject to a suitable assessment; and
- the piling technique must minimise the risk of creating a pathway by avoiding disturbance of the low permeability layers and by creating a good seal.

The follow-on developments will require piled foundations that will similarly require detailed assessment and mitigation measures (see Section 14).

12 Site management and controls

12.1 Site management responsibility

LBE has appointed Taylor Woodrow as Main Works Contractor (the Contractor) for delivery of SIW. The Contractor is responsible for day-to-day site management of construction activities and implementation of measures identified in the Code of Construction Practice (CoCP), Construction Environmental Management Plan (CEMP) and the approved Remediation Strategy.

12.2 Code of construction practice

A draft Code of Construction Practice (CoCP) Part A [27] for the Meridian Water scheme was prepared as part of the Meridian Water Phase 2 and SIW planning submission. The CoCP is written in two parts, with Part A detailing the general measures, whilst the Part B document, produced by the Contractor, will set out the site specific principles and requirements.

The CoCP Part A provides the general principles of minimising impacts during construction of the SIW, defining minimum standards and procedures for construction practice. These standards and procedures will be required of the Contractors as they affect the environment, amenity and safety of residents, businesses, the public and the surroundings in the vicinity of SIW. The following general topics are identified as the contractor's responsibility in the CoCP Part A and high-level requirements are outlined:

- Good housekeeping and pest control.
- Training and competence.
- Welfare accommodation.
- Community engagement. and hours of working.
- Security, hoardings and fencing and lighting.
- Site use.
- Fire prevention and control and emergency preparedness and pollution control.
- Unexploded ordnance.
- Protection of existing structures.

The environmental requirements identified by each topic of the environmental impact assessment are also defined in the CoCP Part A. Those topics relevant to this remediation strategy are:

- Environmental management
- Air quality
- Land quality
- Noise and vibration
- Surface water and groundwater
- Traffic and transport
- Waste and materials.

The content of the CoCP Part A is not repeated in this document. The mitigation measures that must be implemented during construction in response to the CoCP requirements are detailed in the CoCP Part B and CEMP, discussed below.

12.3 Construction environmental management plan

Planning condition 5 on the SIW planning consent (Appendix A) requires an approved Construction Environmental Management Plan (CEMP).

The Contractor will produce the CEMP. The CEMP will describe the environmental management system and responsibilities for the works, operational environmental management, method statements and environmental performance management.

The Contractor will identify a designated stakeholder relations manager and community relations representative who will have responsibility for dealing with the local community and for implementing the community liaison plan.

Environmental monitoring during the works is discussed in Section 13.10.

12.4 Control measures

Some of the contaminant linkages identified in the updated conceptual model (Section 4) can be addressed by the implementation of appropriate control measures during the construction (including demolition, earthworks and building works) to ensure that the works do not pose a risk to construction workers, adjacent site users and the wider environment. Table 14 below provides a summary of the risks identified by the risk assessments and control measures that are required to address these risks and where the detail of the measures is presented. This table has been updated from that presented in the Arup 2021 remediation framework report [6].

Once the construction works are finished, ongoing controls may be required to mitigate risks to site maintenance workers via dermal contact, ingestion, and inhalation associated with locally contaminated Made Ground that may remain beneath clean cover. The verification report should form part of the health and safety file in accordance with the Construction Design and Management (CDM) Regulations 2015 and the development operations & maintenance (O&M) manual or maintenance plan. This is to allow the future building management to protect against any residual ground contamination risks associated with future operations and maintenance.

Table 14 Control measures to address contaminant linkages

Risk	Control measures	Mitigation details
Health and safety management during construction		
Inhalation of **soil-derived dust** by construction workers and adjacent site users.	Dust generated from areas of contaminated soil is a potential means for exposure of site workers and adjacent site users. Dust suppression measures should be used during site works i.e. damping down or sheeting of exposed soils. Use of appropriate site controls, abatement measures and boundary monitoring will mitigate against potential risks.	CEMP. Contractor method statement
Generation of **airborne asbestos fibres from asbestos containing soils and ACMs** presenting a risk via inhalation to construction workers and adjacent site users.	Asbestos has been identified in 57% of the Made Ground samples tested [4]. Disturbance of the soil has the potential to result in the release of asbestos fibres (and dust containing fibres) into ambient air. The requirements described in the Control of Asbestos Regulations CAR 2012 and CAR-SOIL [28] will be adhered to. A CAR risk assessment should be undertaken by a competent assessor to determine the likely exposure resulting from the works and the level of protection and management required by CAR 2012 along with the licensing status of the works. Site operative training and use of appropriate site controls, abatement measures and boundary monitoring will mitigate against potential risks.	CEMP. Contractor method statement
Management of air quality to mitigate vapour and nuisance odour risks to adjacent site users and adjacent development.	Odours from contaminants can cause short-term physical effects such as headaches and shortness of breath as well as being unpleasant and causing stress. Effective odour management may be required for works where excavation of significant [volatile or odorous] contamination occurs (e.g. during excavation works DZ4) or where contaminated materials are handled. The Contractor shall adopt measures so as to avoid the creation of nuisance including, but not limited to: covering containers holding waste and regularly removing waste containers from site; programming works including works on sewers; removing odour source; spraying with an approved agent; and applying an odour guard or masking agent.	CEMP. Contractor method statement
Exposure of construction workers to made ground soils (which may contain asbestos, metals, PAH, VOC and SVOC) via dermal contact, ingestion, and inhalation of vapours.	Construction phase health and safety risk assessments will be required covering different tasks in different areas of the site and mitigation measures identified accordingly. Mitigation requirements are likely to include (as a minimum) health and safety briefings, PPE (variable according to task and area) and clean welfare facilities. Other mitigation measures, required in specific areas or during specific activities, will include dust suppression, vapour monitoring and decontamination facilities.	CEMP. Contractor method statement
Exposure of construction workers to soils containing radiological contamination (former Sparklet Works in DZ5)	A radiation risk assessment (RRA) will be undertaken by a radiation protection advisor (RPA) that will define measures to be implemented which may include advanced surveys, using excavators with bucket radiation detectors and specialist health physics attendance during excavations (with handheld instrumentation).	Contractor method statement
Exposure of construction workers to **contaminated groundwater** (including vapours)	Potential contact with contaminated groundwater will be limited by the depth of groundwater (typically >3m) and relatively shallow works in most areas. For deeper excavations (for naturalisation of Pymmes Brook or excavation of deeper structures) dewatering activities may be required. Dewatering methodologies and routes of groundwater disposal will be defined in method statement and mobile plant permit submission. Occupational health risks will be assessed in the construction phase safety risk assessments and mitigation measures identified accordingly e.g. use of PPE, provision of adequate welfare facilities, vapour monitoring, additional decontamination facilities if required.	CEMP Contractor method statement. Mobile plant permit
Environmental protection during and after construction		
Runoff or leaching of stockpiles of contaminated soil	Appropriate bunding, ground surfacing and drainage measures will be required to mitigate this risk. Positioning of the stockpiles to limit any impact of surface runoff in event of extreme rainfall event, including consideration of active and redundant drains.	CEMP Contractor method statement. Mobile plant permit
Direct entry of contaminants into groundwater via existing preferential pathways (e.g. **monitoring wells)**	Design and implement appropriate methodology for decommissioning redundant wells to avoid creation of contaminant pathways to deeper groundwater units. Required by Condition 34.	Well decommissioning plan
Direct entry of contaminants into groundwater via new preferential pathways (e.g. **piles and foundations)**	All piling will require an approved FWRA discussed in Section 11.5. This will evaluate different piling methods based on location and depth required. Certain piling methods are likely to be selected in preference to others (e.g. continuous flight auger) particularly in areas where there is a perceived risk of pathway creation. For deep piles a groundwater monitoring plan may be required (included in the FWRA).	Foundation works risk assessments
Direct entry of contamination to **surface water** due to naturalisation of Pymmes Brook	The approach to naturalisation of Pymmes Brook (Section 10) includes a low permeability clay layer beneath the new channel, key into the existing channel at both ends. A low permeability layer would extend across Brooks Park to isolate contaminated shallow groundwater from surface water. Condition 36 requires an approved scheme for naturalisation including detailed design and construction methodology.	Pymmes Brook naturalisation design. CEMP. Contractor method statement.
Protection of buried structures in the new development		
Direct contact of aggressive soil and groundwater with **buried structural concrete**	Design of all concrete in contact with the ground in accordance with BRE SD1 [26].	Contractor design.
Direct contact of potable **water supply pipes** with soils and groundwater	Clean services corridors will be constructed where practicable. Where not possible water industry guidance will be applied (Section 11.4)	Contractor design

13 Verification plan

13.1 Planning requirements

A verification plan is a pre-commencement planning requirement stipulated by planning condition 29 (Appendix A). The verification plan to address this condition is presented below.

Planning condition 30 (Appendix A) requires a verification report to be produced on completion of the required remediation works in each phase and must be approved prior to each phase being occupied or being brought into use. The verification report should demonstrate that the requirements of the remediation strategy (as presented in preceding sections of this report) and verification plan have been implemented. The verification report will be produced by the Contractor in line with LCRM.

13.2 Verification report: general requirements

The Contractor is responsible for collecting and retaining all information required for the verification report. The verification report should form part of the health and safety file in accordance with the CDM Regulations 2015 and the development operations and maintenance (O&M) manual or maintenance plan. This is to allow the future building management to protect against any residual ground contamination risks associated with future operations and maintenance.

The verification report will include the following:

- Details of parties involved, and a summary of works carried out including method of works, health and safety and environmental control measures implemented, as-built records and photographs of each key stage of the groundworks.
- Details of the works completed in each part of the site and for each element of the remediation works confirming implementation of the remediation strategy including:
    - Management of invasive species (separate verification reporting required by Non-Native Invasive Weeds Eradication Plan);
    - Management of fly-tipped material;
    - Demolition and site preparatory works completed (including removal of redundant services and decommissioning of monitoring wells);
    - Site turnover/cut and associated management of tanks and obstructions and gross contamination encountered in each part of the site;
    - Excavation, treatment, material verification, reuse, off site transfers, material imports and materials management facilities;
    - Groundwater remediation in each of the five groundwater source areas;
    - Brooks Park and Pymmes Brook naturalisation and Salmons Basin;
    - Cover systems verification;
    - Description of final site conditions;
    - Environmental monitoring.
- Details of environmental permits, regulatory controls and other permissions relevant to the proposed remediation, and communications with regulators;
- Details of any outstanding actions and site constraints and how these will be addressed, including maintenance plan;
- Post construction environmental risk assessment undertaken by a competent geoenvironmental specialist demonstrating that the site does not pose unacceptable risks to controlled waters, human health or other receptors and confirming remediation objectives have been achieved;
- Details and justification for any deviation from the remediation strategy, including any unexpected ground conditions and alternative remediation to that proposed in this strategy (with regulator approval).

13.3 Watching briefs

13.3.1 Geoenvironmental watching brief and discovery strategy

Records should be maintained throughout the excavation works confirming the watching brief was implemented. This will include:

- Details of the responsible site manager.
- Level of attendance by the geo-environmental specialist.
- Confirmation of inductions, toolbox talks and briefings.
- Confirmation of asbestos awareness training.

Confirmation of when and how the discovery strategy was implemented should also be retained. If unexpected contamination is identified (i.e. not similar in characteristics to that previously identified or addressed by the remediation strategy, Section 8.8), then the minimum amount of information to be recorded and reported in the verification report is:

- A general description of the situation including the background, location, depth, the events resulting in the find and the immediate steps taken to make the area safe in accordance with this remediation strategy;
- A location plan and photographs showing the suspected contamination;
- Details of sampling and testing carried out. This should include details of sampling and laboratory analysis, accredited laboratory certificates and associated information;
- A record of the assessment carried out and the proposed actions;
- Records of consultation with the planning authority (and Environment Agency if required) and additional measures agreed with the planning authority;
- Records of the implementation of the agreed actions and lines of evidence confirming it was dealt with.

13.3.2 UXO watching brief

Records should be maintained to demonstrate implementation of the UXO watching brief, including any relevant observations and details of actions taken.

13.4 Site turnover, gross contamination and tanks

The verification report should include:

- records of any pre-excavation investigation locations (if undertaken prior to excavation works);
- records of the systematic turnover, including drawings and photographs;
- records of visual inspections and photographs of excavation, including a plan showing the location of the verification samples and a description of the material;
- verification testing results and comparison with the criteria in Table 12;
- records of the visual inspection of the base of the excavation;
- records and photographs of placement of materials considered suitable for reuse.

Verification data defined in Section 8.10 should be included in the verification report.

The verification report should include the following in relation to tanks and buried obstructions containing contamination:

- photographs and a detailed description of the tanks including the contents, locations and depth indicated on a plan;
- details of the tank decommissioning and removal works undertaken, with supporting documentation;
- relevant duty of care information for the tanks (and its contents), pipework, and any contaminated soils, demonstrating appropriate removal and disposal; and
- testing and assessment of the base and sides of the excavation to demonstrate that any residual contamination has been adequately removed if necessary.

13.5 Asbestos

The verification report should include the following in relation to asbestos:

- Details of the asbestos specialist and their registrations and qualifications.
- The plan of work shall be provided in accordance with CARSOIL including descriptions of the asbestos control measures implemented on site and relevant CAR 2012 assessment, including any air monitoring (if undertaken based on the CAR assessment) to demonstrate the control measures were adequate.
- Confirmation of the classification of the works (likely either non-licensed or notifiable non-licensed) and the relevant CAR 2012 assessment, methods and briefing required. If the works were notifiable then evidence of that notification and acceptance, should be provided.
- Details of the methods used to control dust and fibre release during excavation and stockpiling and evidence this was undertaken on site during relevant works.

13.6 Earthworks, materials management and waste

13.6.1 General

The following should be included in the verification report relating to earthworks, materials management and waste:

- Materials reuse and soil verification data defined in Section 8.10 should be included in the verification report with an assessment against the relevant criteria;
- All materials management plans and MMP verification reports for the site, including the data collected by the MMP materials tracking system;
- Documentation relating to environmental permits for waste activities e.g. mobile plant permits for waste treatment;
- Records of operations at the onsite soil management facilities (‘hubs’), location, layout, material types and quantities, treatment methods;
- Record of imported material, types, source sites, quantities, uses, verification data;
- Documentation relating to offsite removal of excavated materials and waste, e.g. volumes and tonnage, haulage contactors and waste tickets, disposal sites, laboratory results for waste classification and summary of waste disposal records. Hazardous waste consignment notes should be completed by the receiving site to provide evidence the waste was received at the appropriate site;
- Site wide, as built cut-fill drawing and formation level drawing.

13.6.2 General fill placement

Detailed records should be maintained documenting the placement of site-won and imported general fill. The verification report should provide the following relating to general fill placement:

- records of location, thickness, photographs and volumes of general fill placement;
- plans showing the location of the verification samples and a description of the material being represented by the results;
- verification data as defined in Section 8.10 with assessment against relevant criteria (Table 12);
- confirmation that the appropriate amount of testing was undertaken.

13.6.3 Turnover and in situ soil verification

The verification report should include the following information for turnover and in situ soils (remaining below maximum depth of excavation):

- Verification data as detailed in Section 8.10.5, 8.10.6 and 8.10.7 and assessment against general fill criteria (Table 12), for information only, in situ soil does not need to achieve general fill criteria;
- Drawings showing location of samples and confirmation that the appropriate amount of testing was undertaken.

The purpose of verification testing of in situ soils and turnover soils is primarily to provide a record of site condition, to inform the follow-on plot developer. The verification results should be assessed in the verification report to demonstrate the remediation objectives have been achieved.

13.6.4 In situ soil treatment

The verification report should include the following information in relation to in any in situ soil treatment:

- Drawing showing location and thickness of treated soils;
- Details of treatment undertaken including additives (type and volume) and plant used;
- Verification sampling should be undertaken with testing defined appropriate to the treatment method to demonstrate treated material achieves the site remediation objectives;
- Drawings showing location of samples and confirmation that the appropriate amount of testing was undertaken.

13.6.5 Post placement verification

The verification report should include the following post-placement verification information:

- Verification data as detailed in Section 8.10.8, and assessment against appropriate criteria (Table 12);
- Drawings showing location of samples and confirmation that the appropriate amount of testing was undertaken.

13.6.6 Cover systems

The verification report should provide evidence confirming the placement of cover layers including:

- Photographs (with a scale) and plans demonstrating the thickness of cover soils placed and marker layer;
- Verification testing with assessment against criteria (Table 12);
- As-built survey plans;
- The drawings and photos will also show where the soil is underlain by a geotextile marker layer.

13.7 Groundwater source remediation

13.7.1 Benzene in DZ4

The verification report should include the following in relation to remediation of the benzene groundwater source in DZ4:

- Details of any further investigation, exploratory holes or pilot trials;
- Record of the in situ groundwater remediation (air sparging or chemical oxidation): locations, well details, durations;
- Monitoring records before, during and after treatment;
- Risk assessment presenting lines of evidence to demonstrate that the source does not pose unacceptable risks to controlled waters and confirming remediation objectives have been achieved. This should include evidence from the site turnover and removal of gross contamination, tanks etc.

13.7.2 Vinyl chloride in DZ7

The verification report should include the following in relation to remediation of the vinyl chloride groundwater source in DZ7:

- Details of any further investigation, exploratory holes or pilot trials;
- Record of the in situ groundwater remediation (air sparging or chemical oxidation): locations, well details, durations;
- Monitoring records before, during and after treatment;
- Risk assessment presenting lines of evidence to demonstrate that the source does not pose unacceptable risks to controlled waters and confirming remediation objectives have been achieved. This should include evidence from the site turnover and removal of gross contamination, tanks etc.

13.7.3 TPH in DZ2

The verification report should include the following in relation to remediation of the TPH in DZ2:

- Details of new monitoring wells constructed and monitoring records from these wells;
- Record of any NAPL removal undertaken;
- Risk assessment presenting lines of evidence to demonstrate no unacceptable risks to controlled waters and confirming remediation objectives have been achieved. This should include evidence from the site turnover and removal of gross contamination, tanks etc.

13.7.4 Ammoniacal nitrogen and cyanide in KPGR

The verification report should include the following in relation to remediation of the ammoniacal nitrogen and cyanide in KPGR in DZ2 and DZ4:

- Source-specific monitoring plan and monitoring data and records;
- Risk assessment presenting lines of evidence to demonstrate no unacceptable risks to controlled waters and confirming remediation objectives have been achieved. This should include evidence from the site turnover and removal of gross contamination, tanks etc and other relevant site remediation works.

13.7.5 Ammoniacal nitrogen and cyanide in Chalk

The verification report should include the following in relation to remediation of the ammoniacal nitrogen and cyanide in Chalk in DZ2 and DZ4:

- Source-specific monitoring plan and monitoring data and records;
- Risk assessment presenting lines of evidence to demonstrate no unacceptable risks to controlled waters and confirming remediation objectives have been achieved.

13.8 Brooks Park area

The verification report should include the following in relation to the remediation works in the Brooks Park area (including Pymmes Brooks naturalisation and Salmons Basin):

- Records of earthworks, material placed, any in situ soil treatment, low permeability barrier, clean cover, naturalised channel, remaining redundant concrete channel etc (as described above);
- Records of groundwater control implemented including cut off walls, dewatering system, water treatment system and disposal and monitoring records;
- As built drawings showing the above;
- Monitoring records for the relevant watercourses, including daily observations, sampling and testing, and continuous monitoring implemented.

13.9 Construction-related remediation

13.9.1 Services

The verification report should include the following in relation to new services:

- As built drawings showing clean service corridors;
- As built drawing showing barrier pipe or other protection necessary for water supply pipes.

13.9.2 Piling

The verification report should include the following in relation to piling undertaken as part of the SIW:

- Summary of the requirements of the approved FWRA
- Records of piling undertaken (method, locations, depths)
- Monitoring data required by the FWRA and assessment of data and any resulting actions.

13.10 Monitoring of SIW remediation

For a scheme the size of SIW it is typical to have multiple environmental monitoring requirements to address different objectives. Table 15 summarises the various elements of monitoring to be undertaken associated with the SIW remediation works. It outlines the key objective of each monitoring element, the scope of monitoring and identifies where additional detail is presented and how monitoring is to be reported.

The EA has indicated that on a scheme such as the SIW post-construction monitoring is usually required for a minimum of one year following the completion of groundworks. The SIW works will be designed to maintain the integrity of the groundwater monitoring network for the duration of the required monitoring.

Table 15 Summary of SIW environmental monitoring

Objectives	Scope	Relevant documents and reporting
Site-wide groundwater monitoring		
Address planning condition 31 'long term monitoring' To assess controlled waters impacts associated with the works	Groundwater: testing of KPGR, Thanet Formation and Chalk groundwater Surface water: testing of Pymmes Brook, Salmon Brook, River Lee and River Lee (navigation)	Scope detailed in *Waterman (2021) Controlled waters monitoring and maintenance plan* Reporting to be defined in *Waterman (2021) Controlled waters monitoring and maintenance plan*
Groundwater source-specific monitoring		
Monitor effectiveness of in situ treatment at the DZ4 benzene plume	Groundwater testing from existing and new monitoring wells in and downgradient of in situ treatment, southeast of DZ4	Further detail in Section 13.7.1 Reporting to be included in remediation verification report
Monitor effectiveness of in situ treatment at the DZ7 vinyl chloride plume	Groundwater testing from existing and new monitoring wells in and surrounding proposed in situ treatment in DZ7	Further detail in Section 13.7.2 Reporting to be included in remediation verification report
Assess presence of NAPL in DZ2	New monitoring wells in DZ2 east and southeast of gasholder. Remove LNAPL if identified.	Further detail in Section 13.7.3 Reporting to be included in remediation verification report
Monitor continued stability or decrease in ammoniacal nitrogen and cyanide plume in Zone 4/2 KPGR	Groundwater sampling and testing from existing monitoring wells	Further detail in Section 13.7.4 Reporting to be included in remediation verification report
Monitor continued stability or decrease in ammoniacal nitrogen and cyanide	Groundwater sampling and testing from existing monitoring wells	Further detail in Section 13.7.5 Reporting to be included in remediation verification report

Objectives	Scope	Relevant documents and reporting
plume in Zone 4/2 Chalk		
Brooks Park construction monitoring		
To assess construction-related impacts on Pymmes Brook	Sampling and testing of Pymmes Brook, Salmon Brook, River Lee and River Lee (navigation) Daily visual inspection May be augmented by continuous monitoring of water quality in Pymmes Brook	Further detail in Section 10 Reporting to be included in remediation verification report
Air quality monitoring during construction		
Assess construction-related air quality. To address planning condition 5(iv) CEMP	Site boundary monitoring of dust, volatile organic compounds and asbestos fibres during excavation, material handling and earthworks	Scope and reporting mechanism detailed in Taylor Woodrow (2021) CEMP
Environmental permit monitoring		
To address mobile plant permit conditions for monitoring	To be confirmed in mobile plant permits e.g. monitoring of discharge will be required if treated groundwater is to be discharged to ground	Defined in mobile plant permits to be completed by Taylor Woodrow/specialist contractors.
Groundwater monitoring for deep piling		
Assess Chalk aquifer and inform assessment of risks to SPZ abstractions	To be defined, likely monitoring of Chalk monitoring wells downgradient of deep piling	If required, to be defined in the FWRA

13.11 Monitoring well decommissioning

The verification report should include the following in relation to decommissioning of monitoring wells:

- Updated schedule of monitoring wells confirming the status of all known wells on completion of SIW;
- Description of decommissioning methodologies implemented;
- Information of wells encountered during works not previously identified on the well schedule, including any historical abstraction wells, including decommissioning work undertaken.

13.12 Programme for verification reporting

The SIW will be completed progressively and in phases. To facilitate the release of plots for development and the use of public open space at the earliest opportunity it is anticipated that several verification reports will be produced. When combined, on completion of the SIW, the verification reports will cover all areas of the site and all requirements of this remediation strategy.

The partial verification reports will be produced for a defined area of the site (e.g. Brooks Park) and will verify that all the works required by the remediation strategy in that area of the site have been completed, with all the required underpinning evidence and assessment defined in the verification plan.

Before any follow-on development can proceed in a particular area the verification report for that area must have been agreed with the Environment Agency and approved by the LPA.

14 Plot developer remediation

The SIW works comprise enabling works and creation of platforms suitable for subsequent development. This subsequent development, for residential, commercial and other uses, will be subject to separate planning applications and planning conditions are anticipated specific to the remediation activities that are to be completed at that stage, such as in-building vapour protection measures.

The SIW works will complete site remediation as defined in this strategy and record the works completed and condition of the site on completion of the SIW in the verification report that will be available to follow-on developers. In this section those remediation measures to be completed by the follow-on developer are identified.

Specific remediation measures will be required as part of the new development construction. The detailed design of these measures will be informed by the new development design, with additional risk assessment and possibly further characterisation based on the detailed design and layout and building types etc. The measures required are outlined below:

- Mitigation of occupational health risks to construction workers and neighbours during construction excavations associated with potential contact with contaminated soil.
- Plot-specific follow-on remediation implementation and verification plan to be agreed with the local authority and Environment Agency. The plan would set out the residual plot developer remediation works.
- Site turnover maybe proposed in those plots not turned over as part of the SIW and removal of obstructions and gross contamination encountered. In soft landscaping areas general fill and in situ material is expected to require a marker geotextile overlain by a clean cover system.
- The need for gas protection measures in buildings must be assessed considering the specific development proposals. Previous assessments identified a relatively low risk associated with ground gas (CS2) [4].
- Vapour risk and the need for vapour protection, such as in-building membranes, must be assessed considering the specific development proposals. Previous assessments concluded localised risks may be present associated with soil and groundwater vapour sources [5].
- The plot-specific remediation will require consideration of the final plot use and surfacing and deliver the final clean cover systems.
- The potential for piling to result in pathways for groundwater contamination must be considered in detail due to the sensitivity of the underlying Chalk aquifer, with designated Zone 1 and Zone 2 SPZ extending across the site. FWRA will be required that considers:
    - whether alternative foundation solutions can be used to avoid the use of piles;
    - the type of piles and construction techniques to avoid piles that are likely to create pathways to depth (such as pile sleeves, oversize grout piles drilled through to depth);
    - whether piles penetrate low permeability layers (London Clay and Lambeth Group mottled clay);
    - the depth and density of piles;
    - piles in areas of higher risk, including areas of thin London Clay or where the London Clay may have been compromised by existing structures and contamination; and,
    - the need for groundwater monitoring specific to the piling scheme.
- Installation of services in the clean service corridors. Where new services outside of the existing clean service corridors are required, construction of new clean services corridors or for potable water supply pipes construction in accordance with UKWIR and Thames Water requirements.
- Design of concrete to consider chemical aggressivity associated with sulphate, hydrocarbons and other contaminants (e.g. ammonia) in soil and groundwater.
- Final verification reporting and discharge of plot-specific planning conditions before occupation.

Intrusive works (foundations, piling and services excavations) may encounter residual contamination in the general fill and in situ ground. As contaminated materials may arise from foundation works and other excavations into in situ material and general fill (which may include metals, asbestos, hydrocarbons and other contaminants) then additional environmental controls, health and safety procedures, boundary monitoring, and possibly odour suppression will be required in the development phase.

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Drawings

Drawing 1 Proposed development

Drawing 2 Site history and extent of fly tipping

Drawing 3 SIW Phase 1, historic exploratory locations and development zones.

Drawing 4 Groundwater sources assessed in remediation options appraisal

Drawing 5 Demolition plan

Drawing 6 Turnover extent areas

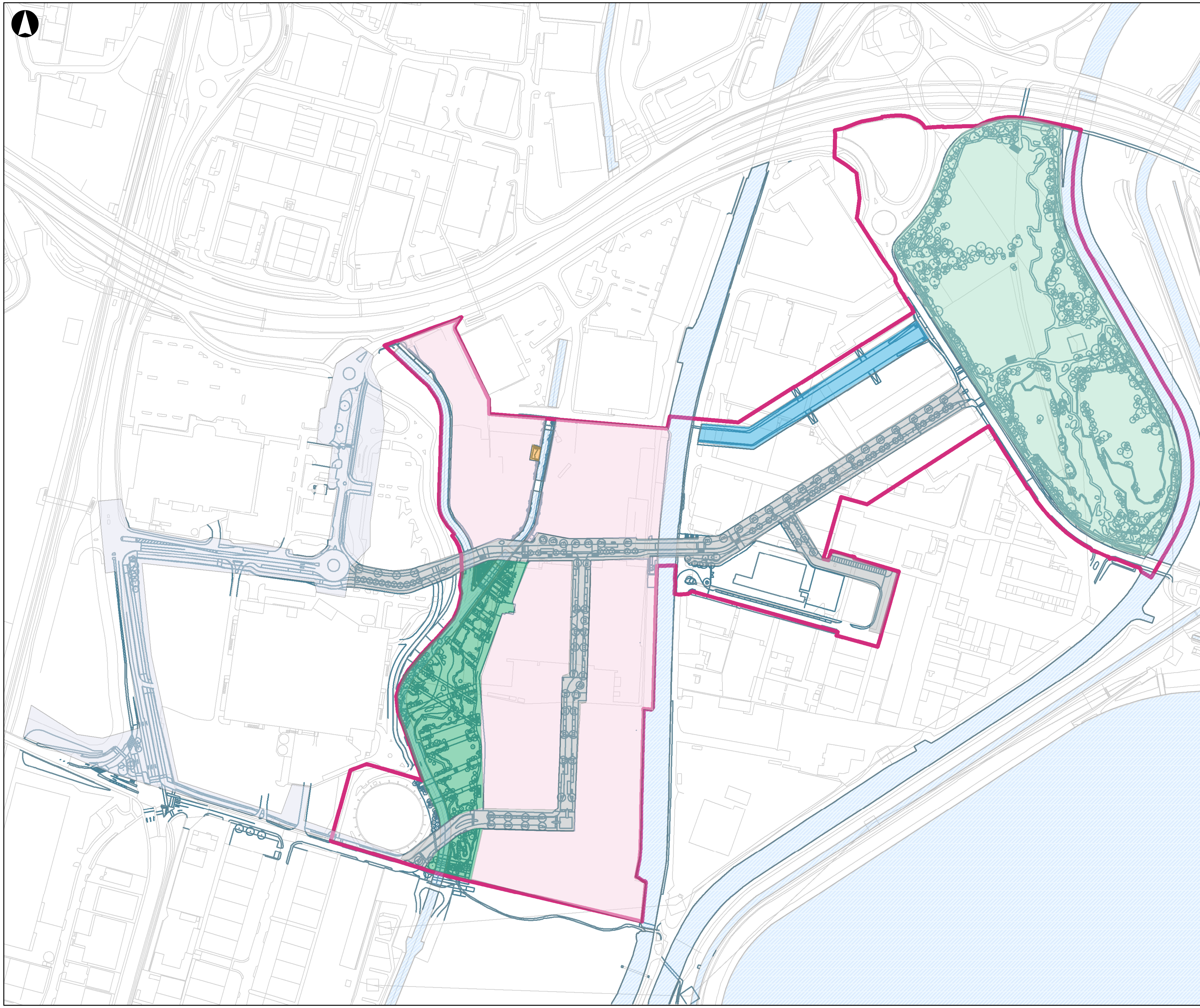
Drawing 7 Tanks, buried structures and UXO risk

Drawing 8 Proposed earthworks showing cut/ fill

Drawing 9 Zones for general fill criteria

Drawing 10 Proposed cover systems

A3



Legend

- SIW - Phase 1 boundary
- Proposed Strategic Infrastructure Works
- Brooks Park
- Development Platforms
- Edmonton Marshes
- Flood Conveyance Channel
- New Roads
- Road Amendments
- Salmons Basin

Metres

0 45 90 180

Coordinate System: British National Grid

Rev	Date	By	Chkd	Appd
F1	2021-09-27	RH	JL	NB

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London Borough of Enfield

Project Title

Meridian Water Remediation Strategy and Verification Plan

Drawing Title

Proposed development

Scale at A3

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Role

Suitability

For Issue

Arup Job No

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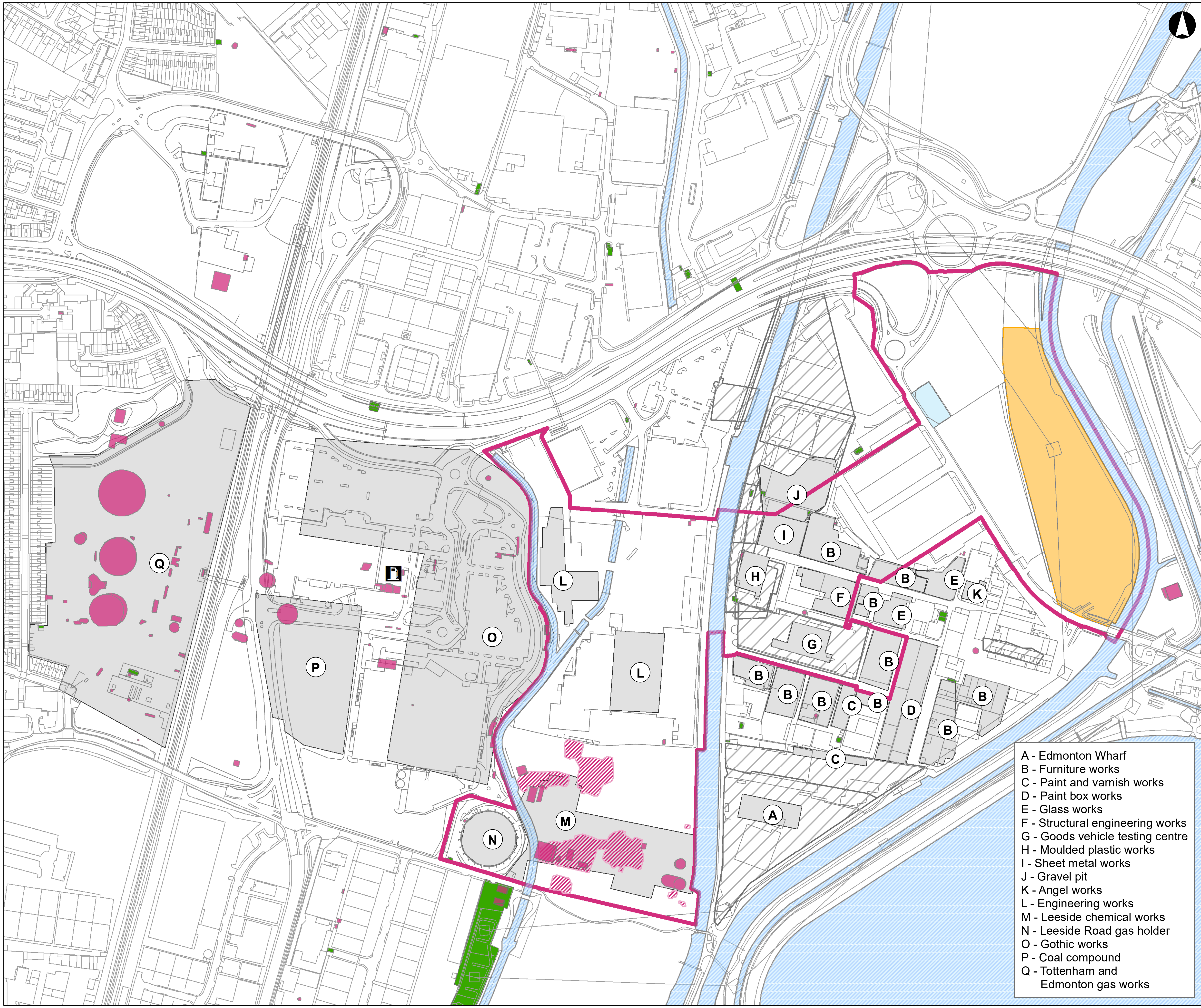
Name

Drawing 1

A3



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Legend

- Harbert Road waste mound
- Remediation (Entec 2007)
- Electricity substations
- Historic industry
- Known area of flytipping
- Historical wharfs
- Tanks
- Petrol station
- SIW - Phase 1 boundary

Metres

0 55 110 220

Coordinate System: British National Grid

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Meridian Water Remediation Strategy and Verification Plan

Drawing Title

Site history and fly tipping extent

Scale at A3

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Role

Suitability

For Issue

Arup Job No

260637

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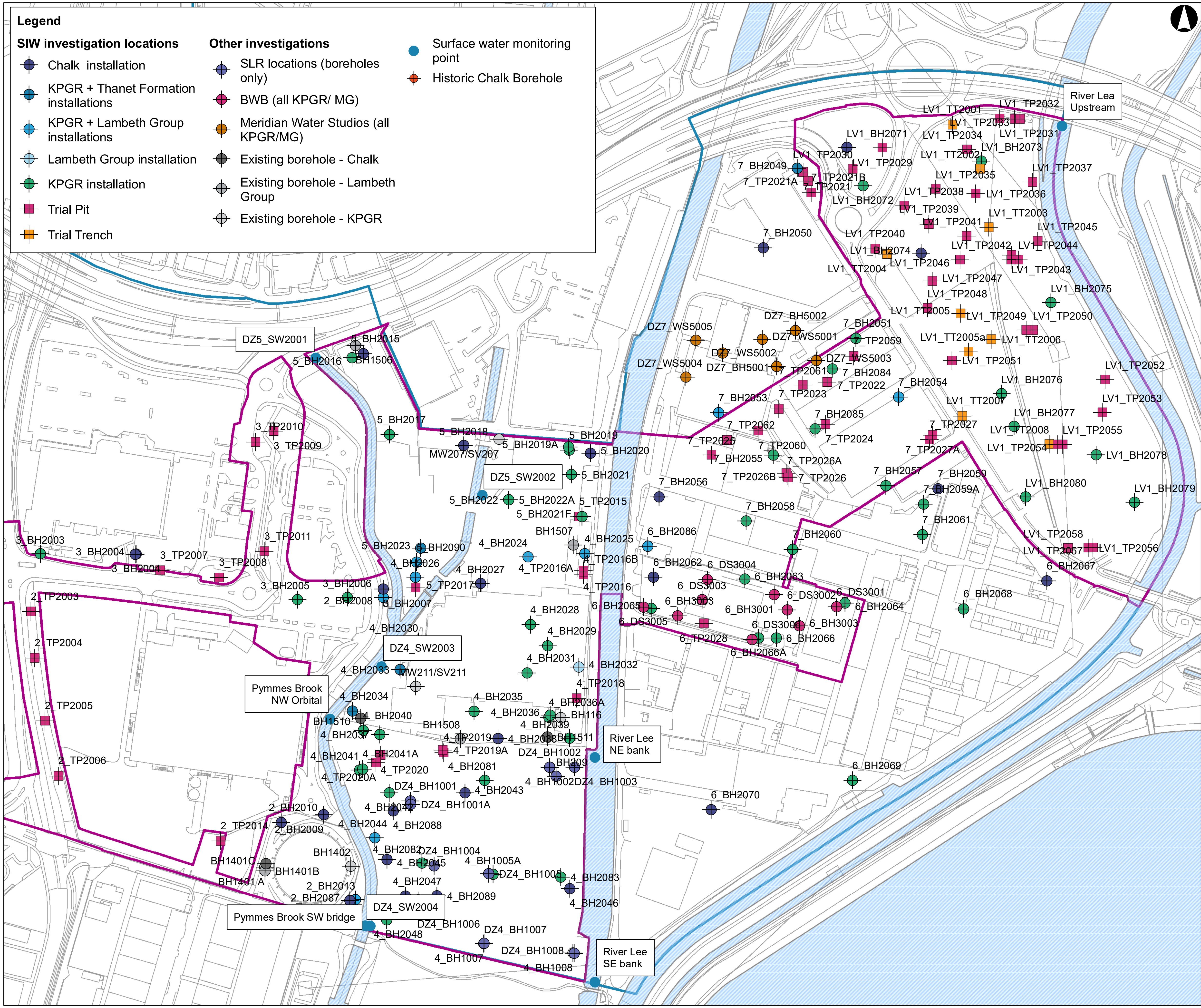
Name

Drawing 2

A3



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GTS Phase 1

GTS Phase 2

SLR boreholes

BWB locations

Meridian Water Studios

Exisiting BH SIW monitoring

Surface water monitoring

Historic Chalk well

Metres

0 40 80 160

Coordinate System: British National Grid

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Project Title
Meridian Water Remediation Strategy and Verification Plan

Drawing Title
Exploratory locations in or in proximity to the SIW site boundary

Scale at A3
1:3,400

Role

Suitability
For Issue

Arup Job No
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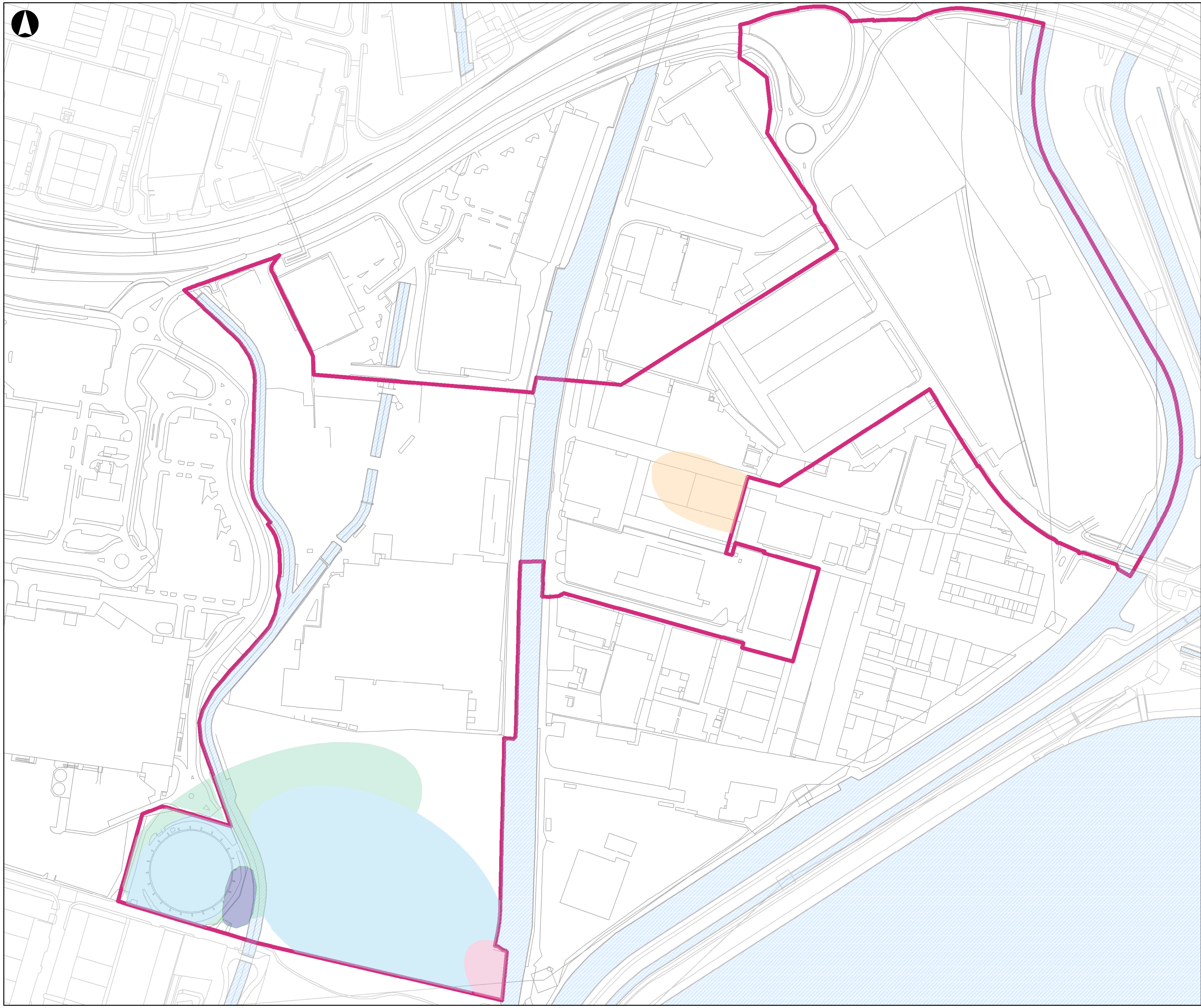
Name
Drawing 3

A3



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Legend

SIW - Phase 1 boundary

Remediation options appraisal source areas

- ROA 1
- ROA 2
- ROA 3
- ROA 4
- ROA 5

These source areas are for illustration only.

Metres

0 37.5 75 150

Coordinate System: British National Grid

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Project Title
Meridian Water Remediation Strategy and Verification Plan

Drawing Title
Groundwater sources assessed in remediation options appraisal

Scale at A3
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Role

Suitability
For Issue

Arup Job No
260637

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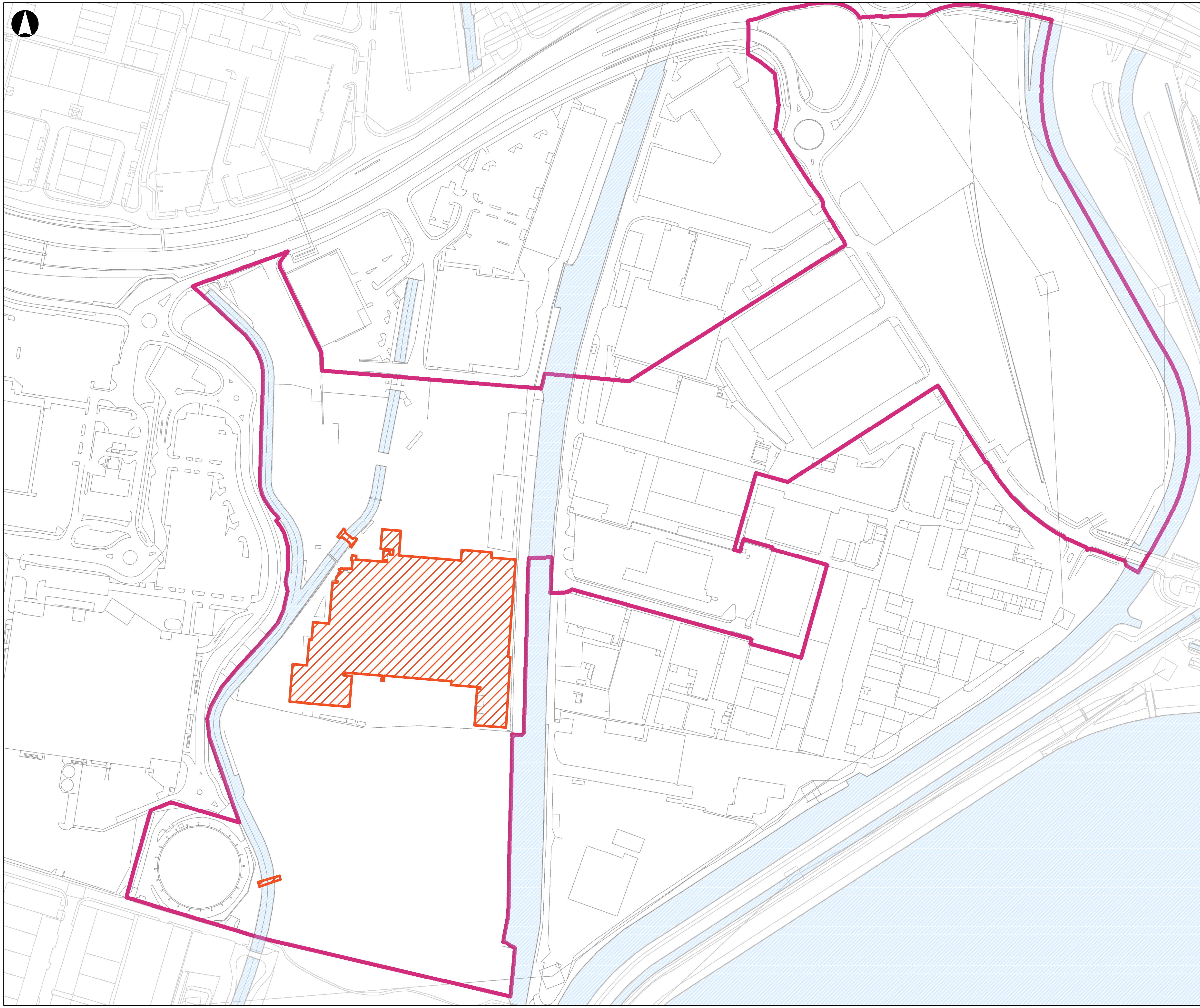
Name
Drawing 4

A3



Legend

SIW - Phase 1 boundary

Demolition of structure

Metres

0 37.5 75 150

Coordinate System: British National Grid

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Project Title

Meridian Water Remediation Strategy and Verification Plan

Drawing Title

Demolition plan

Scale at A3

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Role

Suitability

For Issue

Arup Job No

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Rev

F1

Name

Drawing 5

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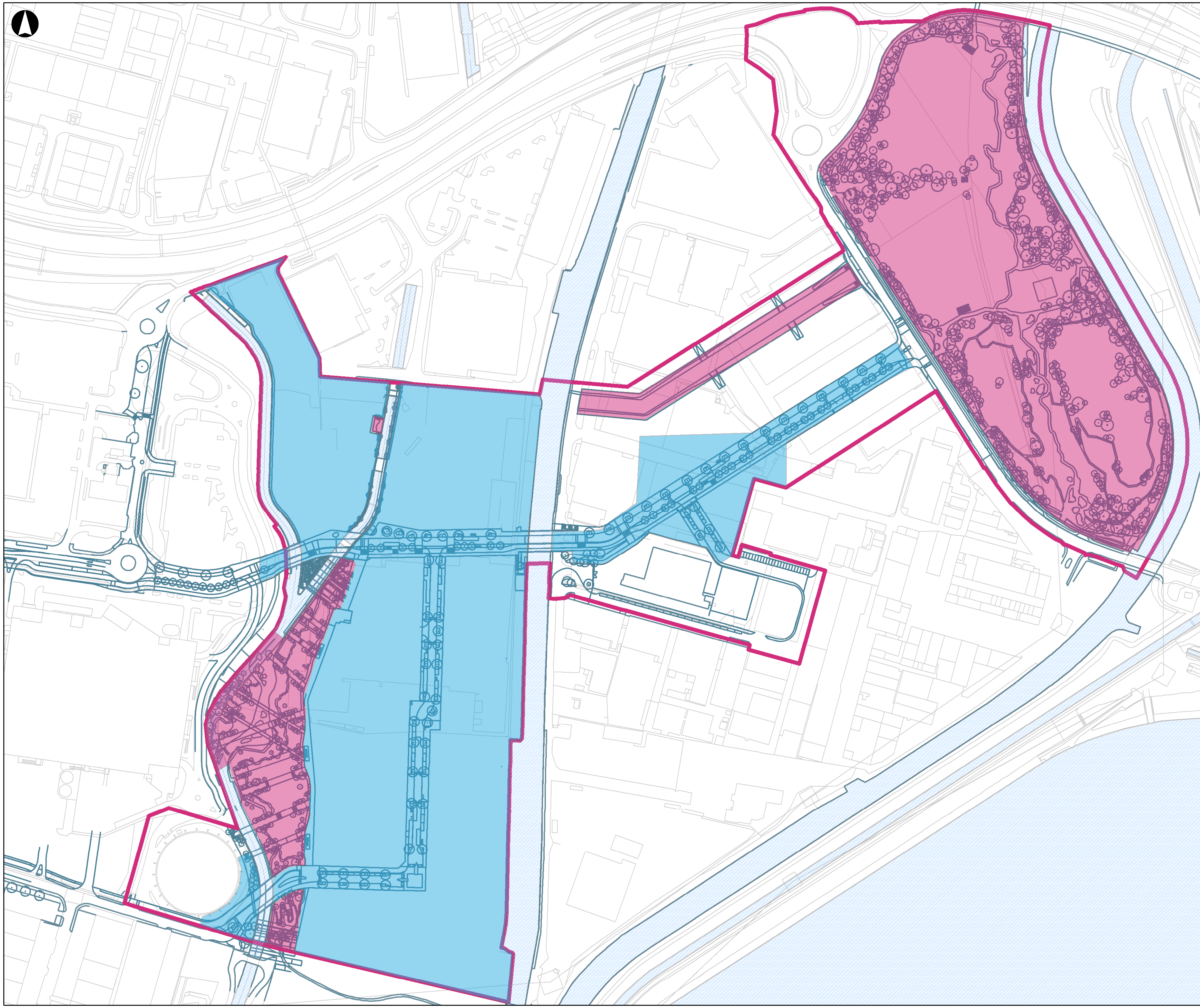

Legend

- SIW - Phase 1 boundary
- Proposed Strategic Infrastructure Works
- Areas of earthworks cut to design formation depth
- Turnover areas to 1.5m depth

Metres

0 37.5 75 150

Coordinate System: British National Grid

Rev	Date	By	Chkd	Appd
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Project Title
Meridian Water Remediation Strategy and Verification Plan

Drawing Title
Turnover and earthworks cut extent in SIW Phase 1

Scale at A3
1:3,000

Role

Suitability
For Issue

Arup Job No
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Drawing 6

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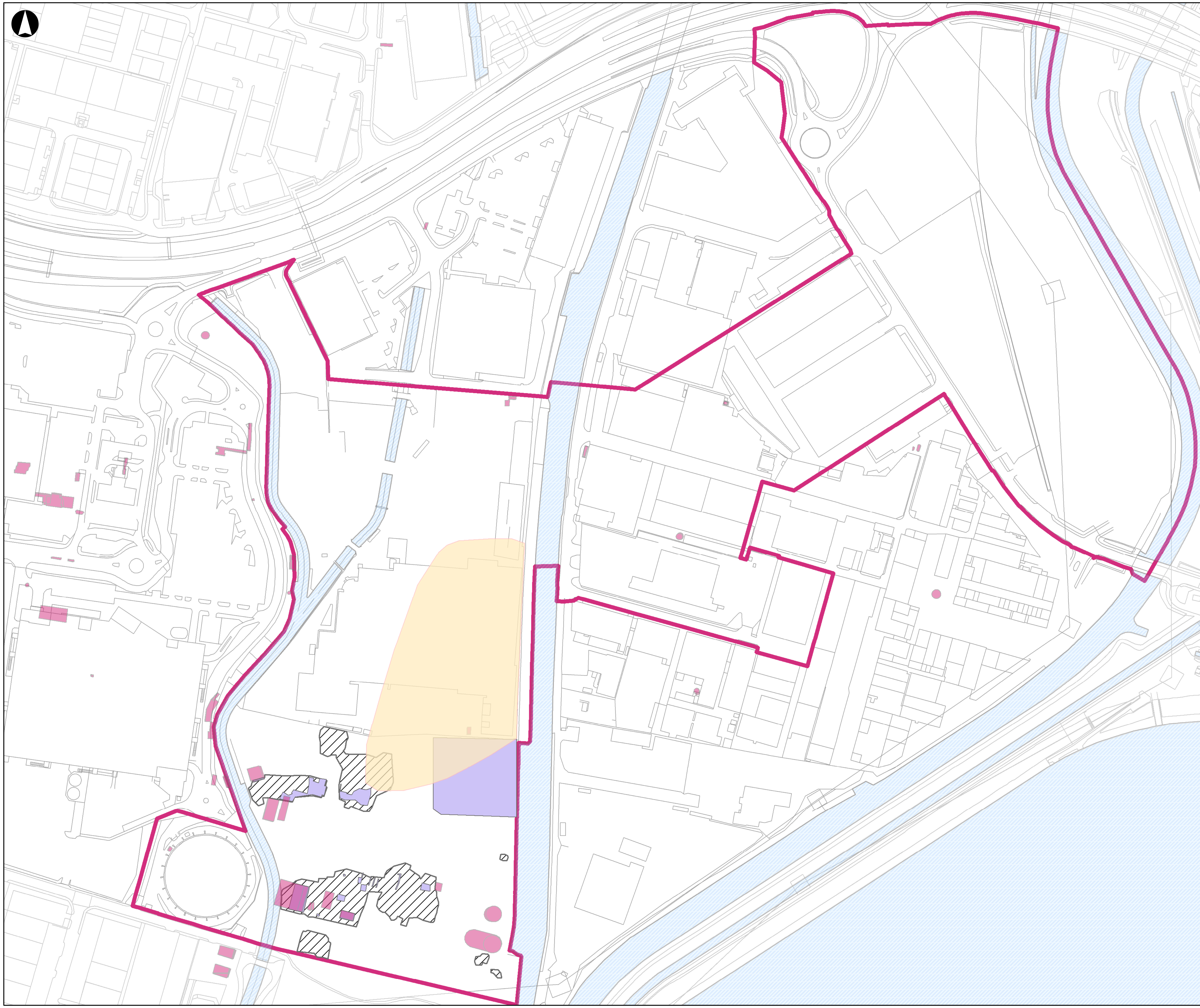

Legend

- SIW - Phase 1 boundary
- Below ground structures within Entec remediation areas
- Remediation (Entec 2007)
- UXO moderate hazard level
- Records of historic tanks

Metres

0 37.5 75 150

Coordinate System: British National Grid

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Project Title

Meridian Water Remediation Strategy and Verification Plan

Drawing Title

Tanks, known buried structures and UXO

Scale at A3

1:3,000

Role

Suitability

For Issue

Arup Job No

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Rev

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Name

Drawing 7

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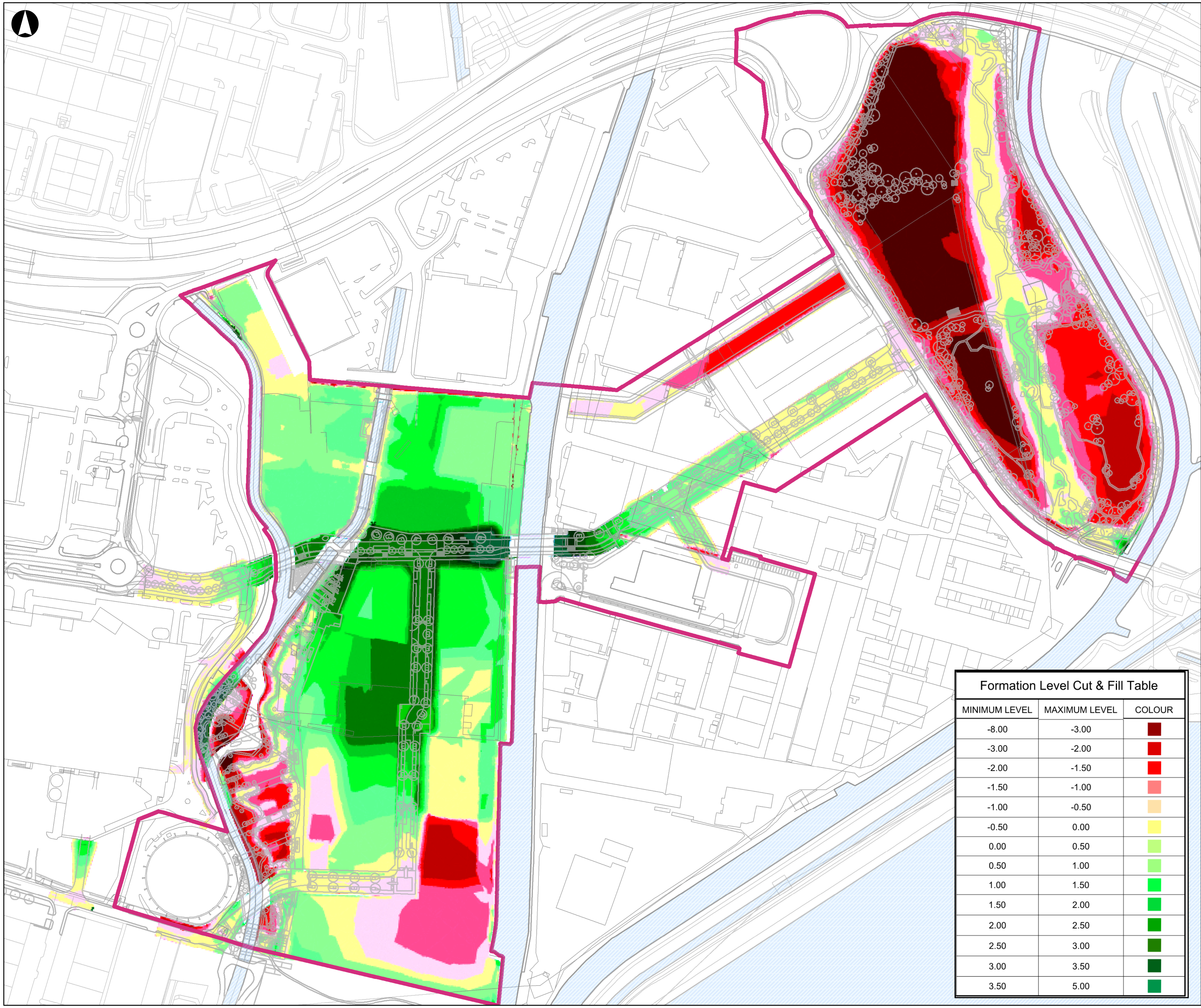


Legend

- SIW - Phase 1 boundary
- Proposed Strategic Infrastructure Works

Formation Level Cut & Fill Table

MINIMUM LEVEL	MAXIMUM LEVEL	COLOUR
-8.00	-3.00	
-3.00	-2.00	
-2.00	-1.50	
-1.50	-1.00	
-1.00	-0.50	
-0.50	0.00	
0.00	0.50	
0.50	1.00	
1.00	1.50	
1.50	2.00	
2.00	2.50	
2.50	3.00	
3.00	3.50	
3.50	5.00	

Metres

0 37.5 75 150

Coordinate System: British National Grid

Rev	Date	By	Chkd	Appd
F1	2021-09-27	RH	JL	NB

ARUP

13 Fitzroy Street
London W1T 4BQ
Tel +44 20 7636 1531 Fax +44 20 7580 3924
www.arup.com

Client
London Borough of Enfield

Project Title
Meridian Water Remediation Strategy and Verification Plan

Drawing Title
Proposed earthworks showing cut/ fill

Scale at A3
1:3,000

Role

Suitability
For Issue

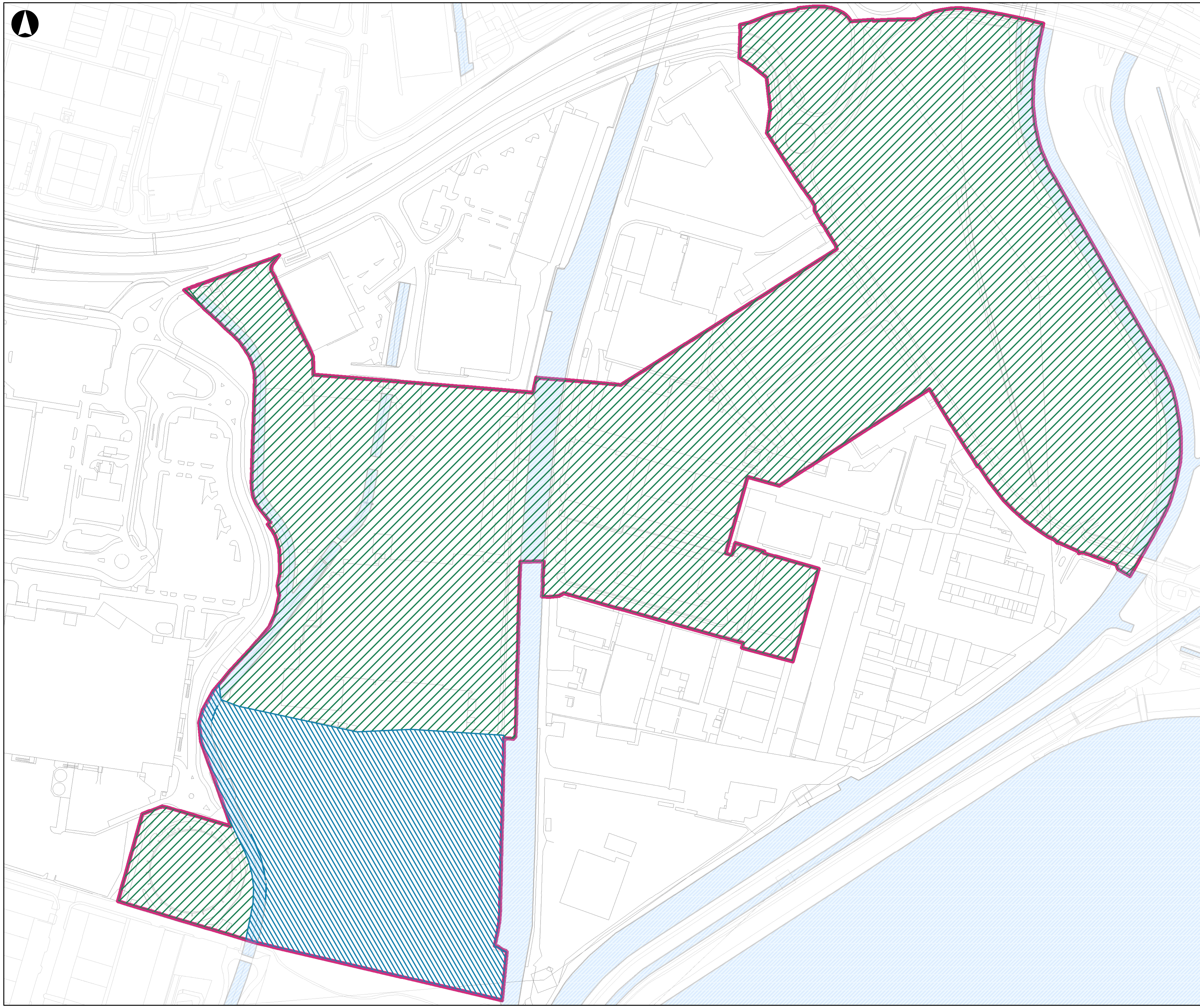
Arup Job No
260637

Rev
F1

Name
Drawing 8

27/09/2021 17:10:13

A3



13/01/2022 09:52:58

Metres

0 37.5 75 150

Coordinate System: British National Grid

Rev	Date	By	Chkd	Appd
F1	2022-01-13	RH	JL	NB

ARUP

13 Fitzroy Street
London W1T 4BQ
Tel +44 20 7636 1531 Fax +44 20 7580 3924
www.arup.com

Client
London Borough of Enfield

Project Title
Meridian Water Remediation Strategy and Verification Plan

Drawing Title
Zones for general fill criteria

Scale at A3
1:3,000

Role

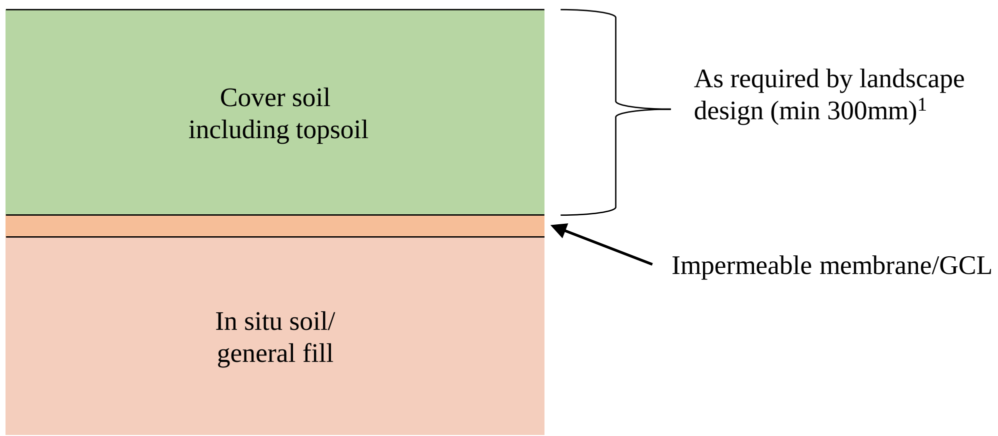
Suitability
For Issue

Arup Job No
260637

Rev
F1

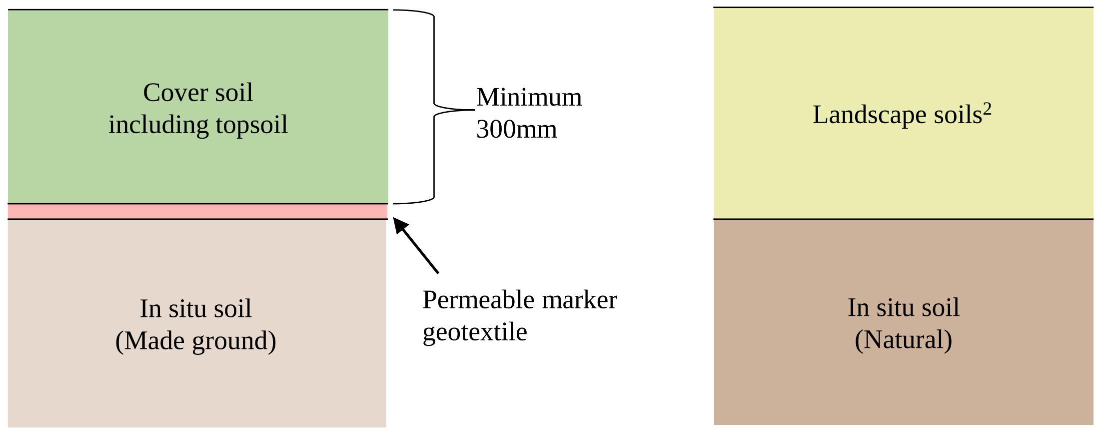
Name
Drawing 9

Flood Conveyance Channel



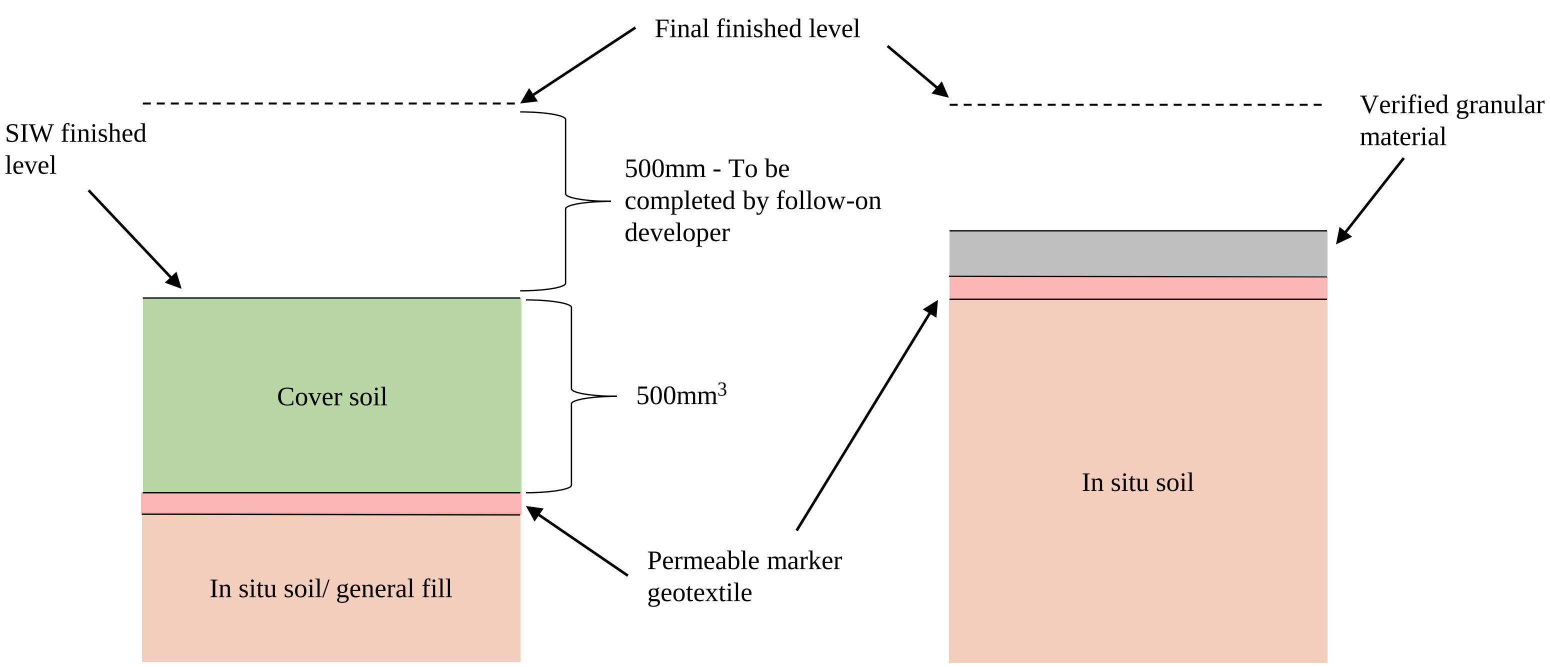
1. Design of the cover system will be finalised by the Contractor. It will comprise a GCL or membrane overlain by cover soils and will accord with the landscape/drainage design. Protection layers may be necessary to prevent puncturing of the impermeable layer.

Edmonton Marshes



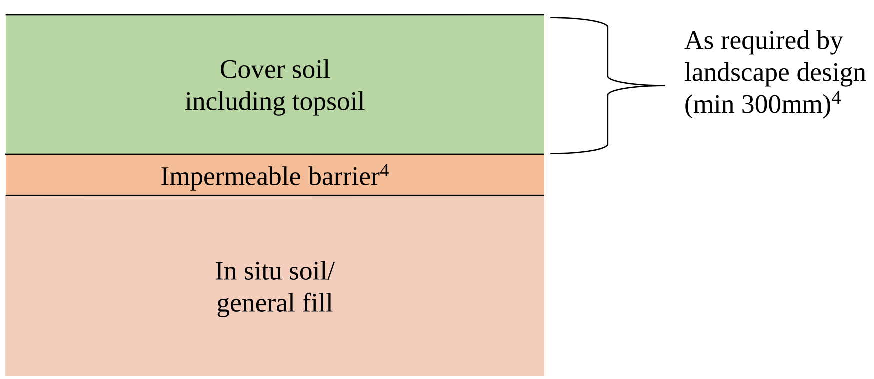
2. Landscape soils as required by landscape design

Development plots



3. In some areas the thickness of cover soil will be less than 0.5m on completion of SIW. Within these areas, a temporary cover layer is not required and a marker geotextile will still be placed between the general fill/ in situ soil and cover soil. In these areas and where cover soil is absent, the follow on developer will need to consider if any supplementary remediation or mitigation measures will be required.

Brooks Park



4. Design of will be finalised by the Contractor but will include an impermeable barrier overlain by cover soils. The barrier may comprise an impermeable membrane, GCL suitable thickness of clay or stabilised soil (or combination of these). Landscaping cover to accord with the landscape/drainage design and may include a drainage layer and protection for underlying membrane (if used).

Appendix A

Planning consent

PLANNING GRANTED

Mr Nick Finney
ARUP
13 Fitzroy Street
London
W1T 4BQ
United Kingdom

Please reply to: Ms Claire Williams

Email: Planning.decisions@enfield.gov.uk

My ref: 19/02717/RE3

Date: 22 July 2020

Dear Sir/Madam

In accordance with the provisions of the Town and Country Planning Act, 1990 and the Orders made thereunder, and with regard to your application at:

LOCATION: Meridian Water, Orbital Business Park, Adjoining Land At Leeside Road, South Of Argon Road,and Land At Former Stonehill Industrial Estate, Anthony Way And Adjoining Land, , Land East Of Harbet Road And Adjoining Glover Drive, London N18,

REFERENCE: 19/02717/RE3

PROPOSAL: Full application for the redevelopment of the site to provide infrastructure works for the delivery of a mixed-use development comprising construction of an east-west link road between Glover Drive and Harbet Road (the Central Spine); alteration of access road between Argon Road and Glover Drive, construction of a link road between Leeside Road and the Central Spine, pedestrian and cycleway improvements to Glover Drive and Leeside Road, the construction of 4 no. bridges across the Pymmes and Salmon Brooks and River Lee Navigation; alteration to the Pymmes Brook channel, associated landscaping and formation of new public open space. Enabling works, comprising earthworks; remediation; flood conveyance channel, flood alleviation, outfall and new public open space works; utilities infrastructure; demolition of existing buildings, formation of new access's and associated works.

By virtue of Regulation 3 of the Town and Country Planning General Regulations, 1992 the proposal, as described above, is development for which permission is deemed to be **GRANTED** on behalf Enfield Council, by the Planning Committee (or under Delegated Powers) subject to the following **CONDITION(S):**

1 Approved Plans

The development hereby permitted shall be carried out in accordance with the approved plans and documents including plans(s) that may have been revised or may be amended necessary to support the further details application(s) required by conditions of this permission, as set out in the attached schedule which forms part of this notice.

Reason:For the avoidance of doubt and in the interests of proper planning

2 Time Limit

The development to which this permission relates must be begun no later than the expiration of three years beginning with the date of the decision notice.

Reason: In accordance with the requirements of section 51 of the Planning and Compulsory Purchase Act 2004.

3 Phasing

Prior to the commencement of development a phasing plan of the proposed work sequence shall be submitted for approval. The phasing plan shall include the programme for the delivery of development directly associated with the development proposed within this application. The works shall be carried out in accordance with the approved phasing plan.

Reason: To ensure that implementation of the development is undertaken in a planned manner with infrastructure and access to the site provided in association with occupation of development in accordance with CP 38 of the Enfield Core Strategy (2010).

Informative:

Should the phasing of any of the matters be required to change following discharge of the condition as a result of updates to the programme of works or phasing of construction, the applicant is required to submit the updated phasing plan(s) to the Local Planning Authority to formally re-discharge the condition.

4 Landscape - compliance and implementation

Landscaping to be completed in accordance with the following soft landscape plans and planting schedule within the first planting season following completion of the relevant phase of works in accordance with condition 3. Any planting which dies, becomes severely damaged or diseased within five years of planting shall be replaced with new planting in accordance with the approved details.

0052 PR ZZ ZZ SH L 9050 REV02 4
0052 PR ZZ ZZ SH L 9051 REV02 5
0052 PR ZZ GF DR L 1200 REV02 5
0052 PR ZZ GF DR L 1201 REV02 5
0052 PR ZZ GF DR L 1202 REV02 5
0052 PR ZZ GF DR L 1203 REV02 5
0052 PR ZZ GF DR L 1204 REV02 4
0052 PR ZZ GF DR L 1206 REV02 4
0052 PR ZZ GF DR L 1208 REV02 4
0052 PR ZZ GF DR L 1209 REV02 4
0052 PR ZZ GF DR L 1210 REV02 4
0052 PR ZZ GF DR L 1211 REV02 4
0052 PR ZZ GF DR L 1212 REV02 4
0052 PR ZZ GF DR L 1213 REV02 4
0052 PR ZZ GF DR L 1214 REV02 4
0052 PR ZZ GF DR L 1215 REV02 4

Reason: To ensure a high-quality design and satisfactory appearance to public realm in accordance with policies 7.19 and 7.21 of the London Plan (2016) and CP30 of the Enfield Core Strategy (2010) and policies DMD37 and DMD81 of Enfield's Development Management Document (2014).

5 Construction Environmental Management Plan

Prior to the commencement of any development including operations consisting of site clearance, archaeological investigations, investigations for assessing ground conditions, remedial work in respect of any contamination or other adverse ground conditions, diversion and laying of services, erection of any temporary means of enclosure, and the temporary display of site notices or advertisements a detailed Construction Environmental Management Plan and Code of Construction Practice for those works shall be submitted to and approved by the Local Planning Authority. These shall comply and align with the Draft Code of Construction Practice (MWSIW-2.5 June 2019). The plan will include detail on the following information with respect to contaminated land and ground conditions:
i) relevant methods specified in CIRIA A Guide for Safe Working On Contaminated Sites (C132) when handling arisings, due to the potential for hydrocarbons, asbestos and other

contaminants;
ii) procedures and protocols to prevent or manage the exposure of construction workers, visitors to the construction area, and users of neighbouring areas to contaminated materials;
iii) measures to limit dust generation during excavation, handling and storage of potentially contaminated materials;
iv) boundary monitoring of dust, volatile organic compounds and asbestos fibres during excavation and soil handling at points of greatest sensitivity;
v) appropriate procedures for handling and treatment of groundwater;
vi) measures to protect workers from vapours and dermal contact if hydrocarbon contamination is excavated, for instance during piling;
vii) measures required under the Control of Asbestos Regulations 2012 and associated code of practice;
viii) measures to control potential odours from the hydrocarbon and gasworks contaminated soils and prevent nuisance for workers and off site residents; and
ix) good practice operation and containment measures for storage of fuels or liquid chemicals to conform with government regulations and pollution prevention guidance (PPGs) issued by the EA.
x) Measures required under EA Pollution Prevention Guidance on works in, near or over watercourses (PPG5) for works near Pymmes Brook.
xi) specify the measures to be taken to ensure the protection of the structural stability, water quality and biodiversity of the River Lee Navigation, as well as protection of its users.
And with respect to biodiversity:
xii) risk assessment of potentially damaging construction activities, identification of biodiversity protection zones, practical measures (both physical measures and sensitive working practices) to avoid or reduce impacts during construction, the location and timing of sensitive works to avoid harm to biodiversity features, identify the times during construction when specialist ecologists need to be present on site to oversee works, responsible persons and lines of communication, use of protective fences, exclusion barriers and warning signs.

The development shall be implemented in accordance with the approved Construction Environmental Management Plan and Code of Construction Practice.
Reason: To ensure the implementation of the construction works does not lead to damage to the existing highway, harm ecological features during the construction phase and to minimise disruption to neighbouring properties and the environment in accordance with policies 5.21, 7.1 and 7.15 of the London Plan (2016), CP32 of the Enfield Core Strategy (2010) and policies DMD64, DMD65, DMD66, DMD68 and DMD70 of the Enfield Development Management Document (2014).

Reason: To ensure the implementation of the construction works does not lead to damage to the existing highway, harm ecological features during the construction phase and to minimise disruption to neighbouring properties and the environment in accordance with policies 5.21, 7.1 and 7.15 of the London Plan (2016), CP32 of the Enfield Core Strategy (2010) and policies DMD64, DMD65, DMD66, DMD68 and DMD70 of the Enfield Development Management Document (2014).

6 Construction Logistics Plan

Prior to the commencement of development a detailed Construction and Logistics Plan for that phase shall be submitted to and approved in writing by the Local Planning Authority, which considers the impact of the development on air quality and the surrounding transport network. These shall comply and align with the Outline Construction Logistics Plan (MWSIW- 7.2 June 2019) The plan shall include:
i) A photographic condition survey of public carriageways, verges and footways in the vicinity of the site;
ii) Works programme;
iii) Trip generation associated with the construction project, swept path analysis and identification of any works needed to the public highway;
iv) Routeing - primary and secondary designated routes to show how vehicles will keep to main routes and comply with the London Lorry Control Scheme;
v) Delivery scheduling;
vi) Use of holding areas and vehicle call up;
vii) Permit schemes and access;
viii) Parking, loading and unloading arrangements;
ix) Traffic management;
x) Measures and training to reduce danger posed to cyclists by HGV's;
xi) Consideration of use of alternative modes of transport (water freight/rail);
xii) CLP management including contact details for the person responsible for ensuring compliance with the Plan during construction;
xiii) Provision of wheel cleaning facilities;
xiv) Details of any temporary construction access;
xv) A management plan setting out measures to control construction pressures on the Lee Valley Ramsar and site; and
xvi) A plan written in accordance with the Mayor of London's supplementary planning guidance 'The Control of Dust and Emissions During Construction and Demolition' detailing how dust and emissions will be managed during demolition and construction work.
The development shall be undertaken in accordance with the approved plan.

Reason: To ensure the implementation of the construction works does not lead to damage to the existing highway, harm ecological features during the construction phase and to minimise disruption to neighbouring properties and the environment in accordance with policies 5.21, 7.1 and 7.15 of the London Plan (2016), CP32 of the Enfield Core Strategy (2010) and policies DMD64, DMD65, DMD66, DMD68 and DMD70 of the Enfield Development Management Document (2014).

7 Control of hours of work on site and deliveries to site

No demolition, construction or maintenance activities audible at the boundary of any residential dwelling and no deliveries of construction and demolition materials shall be undertaken outside the hours of 08.00 to 18.00 Monday to Friday and 08.00 to 13.00 Saturday or at any time on Sundays and Bank or Public Holidays without the written approval of the Local Planning Authority, unless the works have been approved in advance under section 61 of the Control of Pollution Act 1974.

Reason: To ensure that the demolition of the existing buildings and the construction and maintenance of the development does not prejudice the amenities of occupiers of nearby premises due to noise pollution in accordance with policy DMD68 of the Enfield Development Management Document (2014).

8 Green procurement plan

Construction work shall not commence until a Green Procurement Plan has been submitted to and approved in writing by the Local Planning Authority. The Green Procurement Plan shall demonstrate how the procurement of materials for the development will promote sustainability, including by use of low impact, locally and/or sustainably sourced, reused and recycled materials through compliance with the relevant CEEQUAL standard. The Plan must also include strategies to secure local procurement of materials. Wherever possible, this should include targets and a process for the implementation of this plan through the development process. The development shall be constructed and procurement plan implemented strictly in accordance with the Green Procurement Plan so approved.

Reason: To ensure sustainable procurement of materials which minimises the negative environmental impacts of construction in accordance with Policy 5.3 of the London Plan (2016), Policies CP22 and CP23 of the Core Strategy (2010) and DMD57 of the Development Management Document (2014)

9 Sample materials

That prior to relevant phase of works identified pursuant to condition 3 commencing on site sample materials and/or product specifications where not explicitly defined in document reference MWSIW_APP1_01A and 0052-PR-ZZ-ZZ-SP-L-0001 shall be submitted to and approved in writing by the Local Planning Authority. Where sample materials are to be provided, these shall be made available on site for inspection, with the product specification submitted in writing. The works shall be completed in accordance with the approved details prior to the development being brought into use.

Reason: To ensure a satisfactory external appearance in accordance with policy 7.6 of the London Plan (2016), CP30 of the Enfield Core Strategy (2010), DMD37 of the Enfield Development Management Policy (2014) and EL12 of the Edmonton Leeside Area Action Plan.

10 Access for existing occupiers

That access along Towpath Road shall not be severed until such time as the alternative access arrangements shown on drawing number MWP2-ARP-Z6-XX-DR-CH-70201 REV P03 have been completed and are available for use.

Reason: To ensure that existing business have continuous and uninterrupted access to the highway network in accordance with DMD47 of the Development Management Document

11 Enclosure of adjacent plots

That on completion of the relevant phase of works and before the development is brought into public use, the adjoining land plots shall be enclosed in accordance with drawing number 382 KCA P1 00 DR A 1005 P Rev 3.

Reason: To minimise the risk of unauthorised access to vacant land plots in the interests of amenity and to safeguard the safety and security of the public who need use and pass through the site whilst construction takes place, in accordance with Policy 7.3 of the London Plan (2016) and DMD37 of the Development Management Document (2014)

12 Archaeology WSI

No demolition or development shall take place until a stage 1 written scheme of investigation (WSI) has been submitted to and approved by the local planning authority in writing. For land that is included within the WSI, no demolition or development shall take place other than in accordance with the agreed WSI, and the programme and methodology of site evaluation and the nomination of a competent person(s) or organisation to undertake the agreed works. If heritage assets of archaeological interest are identified by stage 1 then for those parts of the site which have archaeological interest a stage 2 WSI shall be submitted to and approved by the local planning authority in writing. For land that is included within the stage 2 WSI, no

demolition/development shall take place other than in accordance with the agreed stage 2 WSI which shall include:
A. The statement of significance and research objectives, the programme and methodology of site investigation and recording and the nomination of a competent person(s) or organisation to undertake the agreed works
B. Where appropriate, details of a programme for delivering related positive public benefits
C. The programme for post-investigation assessment and subsequent analysis, publication & dissemination and deposition of resulting material. This part of the condition shall not be discharged until these elements have been fulfilled in accordance with the programme set out in the stage 2 WSI.

Reason: To ensure the implementation of appropriate archaeological investigation, recording and publication in accordance with policy 7.8 of the London Plan (2016) policy CP31 of the Enfield Core Strategy (2010) .

Informative: Written schemes of investigation will need to be prepared and implemented by a suitably qualified professionally accredited archaeological practice in accordance with Historic England's Guidelines for Archaeological Projects in Greater London. This condition is exempt from deemed discharge under schedule 6 of The Town and Country Planning (Development Management Procedure) (England) Order 2015.

13 Archaeology Foundation Design

No development of Bridge Structures shall take place until details of the foundation design and construction method to protect archaeological remains have been submitted and approved in writing by the local planning authority. The development shall be carried out in accordance with the approved details.

Reason: To ensure that any archaeology on site is appropriately protected in accordance with policy 7.8 of the London Plan (2016) and policy CP31 of the Enfield Core Strategy (2010).

14 Archaeology Public engagement

No development shall commence until details of an appropriate programme of archaeological public engagement including a timetable have been submitted and approved in writing by the local planning authority. The development shall be carried out in accordance with the approved programme.

Reason: To ensure the implementation of appropriate archaeological investigation, recording and publication in accordance with policy 7.8 of the London Plan (2016) and policy CP31 of the Enfield Core Strategy (2010).

15 Hedge/shrub clearance outside bird nesting period

All areas of hedges, scrub or similar vegetation where birds may nest which are to be removed as part of the development, are to be cleared outside the bird-nesting season (March - August inclusive) or if clearance during the bird-nesting season cannot reasonably be avoided, a suitably qualified ecologist will check the areas to be removed immediately prior to clearance and advise whether nesting birds are present. If active nests are recorded, no vegetation clearance or other works that may disturb active nests shall proceed until all young have fledged the nest.

Reason: To ensure that wildlife is not adversely impacted by the proposed development in accordance with national wildlife legislation and in line with policy 7.19 of the London Plan (2016) and policy CP36 of the Enfield Core Strategy (2010). Nesting birds are protected under the Wildlife and Countryside Act, 1981 (as amended)

16 Eradication strategy for invasive species

Prior to the commencement of development details of an eradication strategy for invasive species shall be submitted to and approved in writing by the Local Planning Authority. Invasive species identified shall be treated in accordance with the approved eradication strategy.

Reason: To ensure that the development contributes to improving the ecology and biodiversity of the area, in accordance with the NPPF, policy 7.19 of the London Plan (2016) and policy CP36 of the Enfield Core Strategy (2010) and DMD79 of the Enfield Development Management Document (2014).

17 Waste management plans

Prior to the commencement of development a detailed Site Waste Management Plan shall be submitted to and approved in writing by the Local Planning Authority. The plan should include as a minimum:

i) Target benchmarks for resource efficiency set in accordance with best practice;

ii) Procedures and commitments to minimize non-hazardous construction waste at design stage. Specify waste minimisation actions relating to at least 3 waste groups and support them by appropriate monitoring of waste;

iii) Procedures for minimising hazardous waste;

iv) Monitoring, measuring and reporting of hazardous and non-hazardous site waste production according to the defined waste groups (according to the waste streams generated

by the scope of the works);
v) Procedures and commitments to sort and divert waste from landfill in accordance with the waste hierarchy (reduce; reuse; recycle; recover) according to the defined waste groups; and
vi) Evidence that no less than 85% by weight or by volume of non-hazardous construction and excavation waste generated by the development has been diverted from landfill.
The development shall be implemented in accordance with the approved plan.

Reason: To maximise the amount of waste diverted from landfill consistent with the waste hierarchy, Policy DMD57 of the Development Management Document (2014), and strategic targets set by Policies 5.17, 5.18, 5.19, 5.20 of the London Plan (2016).

18 Ikea access

The existing access to the IKEA northern car park shall not be altered until such time as the new points of access to the IKEA site shown on drawing number 382 KCA P1 00 DR A 1002 P, have been constructed in accordance with the details approved pursuant to condition 19.

Reason: To ensure that the IKEA store can continue to operate with access to the quantum of parking that it currently benefits from by ensuring the new points of access are provided to IKEA land which is capable of accommodating the quantum of parking spaces necessary as a replacement for those in the northern car park and impacted through the construction of the central spine road. This is in accordance with policy 6.3 of the London Plan (2016), policy CP24 of the Enfield Core Strategy (2010), DMD47 of the Development Management Document (2014) and EL6 of the Edmonton Leeside Area Action Plan (2020)

19 Details of new accesses to IKEA land

That prior to the construction of the new points of access to the IKEA site, including the new IKEA service yard access ramp, detailed drawings of the construction of the proposed works including junctions with the public highway, levels across the junctions and to adjacent thresholds and materials of construction shall be submitted to and approved in writing by the LPA. The accesses shall be constructed in accordance with the approved details prior to first use.

Reason: To ensure the development provides safe access and high quality materials in accordance with policies CP24 of the Enfield Core Strategy (2010), DMD37 and DMD47 of the Development Management Document (2014) and 6.11 and 6.12 of the London Plan (2016).

20 Details of Glover Drive length of CSR

That prior to the commencement of the Central Spine Road west of the Pymmes Brook and the Glover Drive improvement works, details of the treatment, including landscaping, street furniture and surface treatments of the southern pedestrian and cycle route along Glover Drive and the interface of this route and the Central Spine Road with the IKEA store and the associated landscape shall be submitted to and approved in writing by the LPA. The area shall be laid out in accordance with the approved details prior to the Central Spine Road west of Pymmes Brook being brought into use .

Reason: To ensure access arrangements and landscaping to this key route into the Meridian Water development provide an attractive and convenient route into the development and are sufficient and adequate in accordance with policy 7.5 of the London Plan (2016), policies DMD37 and DMD47 of the Development Management Document (2014) and EL12 of the Edmonton Leeside Area Action Plan (2020).

21 Flood Conveyance Channel

That works shall not commence on the construction of the flood conveyance channel identified on drawing number MWP2-ARP-XX-XX-DR-CF-80302 P05 until such time as detailed drawings of the interface of this channel with Harbet Road, including details of ramps/stairs and surface treatment at this interface and details of surface treatments and landscaping through the channel as a whole, have been submitted to and approved in writing by the LPA. The flood conveyance channel shall be completed in accordance with the approved details.

Reason: To ensure the development provides high quality landscaping and materials which are in keeping with the principles established through this permission in accordance with DMD37 and DMD81 of the Development Management Document (2014) and EL12 of the Edmonton Leeside Area Action Plan (2020)

22 Gas Governor

That prior to the construction of the gas governor identified on drawing number 382-KCA-P1-01-DR-A-1105, details drawings of the design and external appearance of the building, including details of external materials, shall be submitted to and approved in writing by the LPA. The gas governor shall be constructed in accordance with the approved details in accordance with the phasing plan pursuant to condition 3

Reason: To ensure a high-quality design and satisfactory appearance to public realm in accordance with policy 7.5 of the London Plan (2016), CP30 of the Enfield Core Strategy

(2010) and policies DMD37 and DMD81 of Enfield's Development Management Document (2014).

23 Shelter/kiosk in Brooks Park

That prior to the construction of the any shelter/kiosk in Brooks Park, details of the siting, design and external appearance of the building, including details of external materials, shall be submitted to and approved in writing by the LPA. The shelter/kiosk shall be constructed in accordance with the approved details in accordance with the phasing plan pursuant to condition 3

Reason: To ensure a high-quality design and satisfactory appearance to public realm and appropriate relationship with movement routes in accordance with policy 7.5 of the London Plan (2016), CP30 of the Enfield Core Strategy (2010), polic7 DMD37 of Enfield's Development Management Document (2014) and EL12 of the Edmonton Leeside Area Action Plan (2020).

24 SUDS

Notwithstanding the details set out in the submitted Surface Water Drainage Strategy (reference MWSIW-8 Rev 03 produced by Arup March 2020), prior to the commencement of any construction work, details of the Sustainable Drainage Strategy shall be submitted to and approved in writing by the Local Planning Authority. The details shall include:

o Location, sizes, storage volumes, cross-sections, long-sections (where appropriate) invert levels (where appropriate) and specifications of all proposed SuDS measures including rain gardens and permeable paving. Include calculations demonstrating functionality where relevant

o Management Plan for future maintenance

o Overland flow routes for exceedance events

Reason: To ensure the sustainable management of water, minimise flood risk and to minimise discharge of surface water outside of the site in accordance with Policy CP28 of the Enfield Core Strategy (2010), DMD59-63 of the Enfield Development Management Document (2014), Policies 5.12 & 5.13 of the London Plan (2016).

25 SUDS Verification Report

Prior to first use, a Verification Report demonstrating that the approved drainage / SuDS measures have been fully implemented shall be submitted to the Local Planning Authority for approval in writing. This report must include:

- o As built drawings of the sustainable drainage systems including level information (if appropriate)
- o Photographs of the completed sustainable drainage systems
- o Any relevant certificates from manufacturers/ suppliers of any drainage features
- o A confirmation statement of the above signed by a chartered engineer

Reason: To ensure the sustainable management of water, minimise flood risk and to minimise discharge of surface water outside of the site in accordance with Policy CP28 of the Enfield Core Strategy (2010), DMD59-63 of the Enfield Development Management Document (2014), Policies 5.12 & 5.13 of the London Plan (2016).

26 Leeside Road works

That prior to works commencing on Leeside Road, details of the configuration and alignment of the cycle and pedestrian routes along this road, together with details of the location and construction details of all new planting, rain gardens and tree pits to Leeside Road shall be submitted to and approved in writing by the LPA. The works shall be undertaken in accordance with the approved details prior to the Leeside Link Road being available for use.

Reason: To ensure access arrangements and landscaping to this key route into the Meridian Water development provide an attractive and convenient route into the development and are sufficient and adequate in accordance with policy 7.5 of the London Plan (2016), policies DMD37, DMD47 and DMD81 of the Development Management Document (2014) and EL12 of the Edmonton Leeside Area Action Plan.

27 Tree Protection

Prior to the commencement of the development hereby approved (including demolition and all preparatory work), a scheme for the protection of the retained trees, in accordance with BS 5837:2012, including a tree protection plan(s) (TPP) and an arboricultural method statement (AMS) shall be submitted to and approved in writing by the Local Planning Authority. The development shall be carried out in accordance with the approved details.

Reason: To ensure trees to be retained are protected during the construction phase in accordance with DMD80 of the Development Management Document (2014)

28 Flood Risk Assessment

The development shall be carried out in accordance with the submitted Flood Risk

Assessment (reference MWP2-6/MWSIW-5 - Rev02, produced by Arup, January 2020) and the following mitigation measures it details:
o The naturalisation of Pymmes Brook (increasing in-channel flood storage)
o Flood storage compensation within the Lee Valley Regional Park and Edmonton Marshes
o Flood conveyance channel
o Bunds and local land raising and lowering of walls

These mitigation measures shall be fully implemented prior to occupation and subsequently in accordance with the scheme's timing/ phasing arrangements. The measures detailed above shall be retained and maintained thereafter throughout the lifetime of the development by the London Borough of Enfield, unless alternative legal arrangements are made.

Reason: To prevent flooding elsewhere caused by the development by ensuring that compensatory storage of flood water is provided in accordance with policy 5.12 of the London Plan (2016), CP28 of the Enfield Core Strategy (2010), DMD 59-63 of the Development Management Document (2014) and EL8 of the Edmonton Leeside Area Action Plan

29 Land affected by contamination

Prior to each phase of development approved by this planning permission no development shall commence until a remediation strategy to deal with the risks associated with contamination of the site in respect of the development hereby permitted, has been submitted to, and approved in writing by, the local planning authority.
This strategy will include the following components:
1. A preliminary risk assessment which has identified:
o all previous uses
o potential contaminants associated with those uses
o a conceptual model of the site indicating sources, pathways and receptors
o potentially unacceptable risks arising from contamination at the site
2. A site investigation scheme, based on (1) to provide information for a detailed assessment of the risk to all receptors that may be affected, including those off-site.
3. The results of the site investigation and the detailed risk assessment referred to in (2) and, based on these, an options appraisal and remediation strategy giving full details of the remediation measures required and how they are to be undertaken.
4. A verification plan providing details of the data that will be collected in order to demonstrate that the works set out in the remediation strategy in (3) are complete and identifying any requirements for longer-term monitoring of pollutant linkages, maintenance and arrangements for contingency action.

Any changes to these components require the written consent of the local planning authority.

The scheme shall be implemented as approved.

Reason; To ensure that the development does not contribute to, and is not put at unacceptable risk from or adversely affected by, unacceptable levels of water pollution in line with paragraph 170 of the NPPF, policy 5.21 of the London Plan (2016), CP32 of the Enfield Core Strategy (2010) and DMD66 of the Development Management Document (2014).

30 Verification report

Prior to each phase of development being occupied or brought into use, a verification report demonstrating the completion of works set out in the approved remediation strategy and the effectiveness of the remediation, including verification reports for gas vapour and clean soil cover, shall be submitted to, and approved in writing by the local planning authority. The report shall include results of sampling and monitoring carried out in accordance with the approved verification plan to demonstrate that the site remediation criteria have been met.

Reason: To ensure that the site does not pose any further risk to human health or the water environment by demonstrating that the requirements of the approved verification plan have been met and that remediation of the site is complete. This is in line with paragraph 170 of the NPPF, policy 5.21 of the London Plan (2016), CP32 of the Enfield Core Strategy (2010) and DMD66 of the Development Management Document (2014).

31 Long-term monitoring

The development hereby permitted shall not commence until a monitoring and maintenance plan in respect of contamination, including a timetable of monitoring and submission of reports to the local planning authority, has been submitted to, and approved in writing by, the local planning authority. Reports as specified in the approved plan, including details of any necessary contingency action arising from the monitoring, shall be submitted to, and approved in writing by, the local planning authority.

Reason: To ensure that the site does not pose any further risk to human health or the water environment by managing any ongoing contamination issues and completing all necessary long-term remediation measures. This is in line with paragraph 170 of the NPPF, policy 5.21 of the London Plan (2016), CP32 of the Enfield Core Strategy (2010) and DMD66 of the Development Management Document (2014).

32 Previously unidentified contamination

If, during development, contamination not previously identified is found to be present at the site then no further development (unless otherwise agreed in writing with the local planning authority) shall be carried out until a remediation strategy detailing how this contamination will be dealt with has been submitted to, and approved in writing by, the local planning authority. The remediation strategy shall be implemented as approved.

Reason:
i) To ensure that the development does not contribute to, and is not put at unacceptable risk from or adversely affected by, unacceptable levels of water pollution from previously unidentified contamination sources at the development site. This is in line with paragraph 170 of the NPPF policy 5.21 of the London Plan (2016), CP32 of the Enfield Core Strategy (2010) and DMD66 of the Development Management Document (2014).
ii) No investigation can completely characterise a site. The condition may be appropriate where some parts of the site are less well characterised than others, or in areas where contamination was not expected and therefore not included in the original remediation proposals.

33 SuDs infiltration

No drainage systems for the infiltration of surface water to the ground are permitted other than with the written consent of the local planning authority. Any proposals for such systems must be supported by an assessment of the risks to controlled waters. The development shall be carried out in accordance with the approved details.

Reason:
i) To ensure that the development does not contribute to, and is not put at unacceptable risk from or adversely affected by, unacceptable levels of water pollution caused by mobilised contaminants. In line with paragraph 170 of the NPPF, policy 5.21 of the London Plan (2016), CP32 of the Enfield Core Strategy (2010) and DMD66 of the Development Management Document (2014).

ii) The soils and groundwater across the site are impacted by chlorinated solvents, heavy metals, and gasworks related contaminants that could be mobilised by surface water infiltration from the proposed sustainable drainage system (SuDS). This could pollute controlled waters. Controlled waters are particularly sensitive in this location. In light of the above, we do not believe that the use of infiltration SuDS is appropriate in this location.
iii) This condition is in line with Section 4.2.1 of the submitted Integrated Water Management Plan (reference MWSIW-7.2 Sustainability and Energy Statement Appendix E, produced by Arup, June 2019).

34 Borehole decommissioning

A scheme for managing any borehole installed for the investigation of soils, groundwater or geotechnical purposes shall be submitted to and approved in writing by the local planning authority. The scheme shall provide details of how redundant boreholes are to be decommissioned and how any boreholes that need to be retained, post-development, for monitoring purposes will be secured, protected and inspected. The scheme as approved shall be implemented prior to the occupation of any part of the permitted development.

Reason:

i) The reports submitted to date confirm that monitoring wells have been installed across the site. Additionally, installation of further monitoring wells is required to investigate groundwater resources issues. If boreholes are not decommissioned correctly they can provide preferential pathways for contaminant movement which poses a risk to groundwater quality. Groundwater is particularly sensitive in this location because the proposed development site is within source protection zone 1.
ii) To ensure that redundant boreholes are safe and secure, and do not cause groundwater pollution or loss of water supplies in line with paragraph 170 of the NPPF and Position Statement N Groundwater resources of The Environment Agency's approach to groundwater protection.
iii) This condition is in line with Section 5.2.1 of the submitted Ground Contamination Investigation, Remediation and Materials Management Framework (reference MWSIW-2.3 ES Appendix L2 Remediation Framework, produced by Arup, June 2019).

35 Piling

Piling, deep foundations and other intrusive groundworks using penetrative methods shall not be carried out other than with the written consent of the local planning authority. The development shall be carried out in accordance with the approved details.

Reason: To ensure that the proposed piling, deep foundations and other intrusive groundworks does not harm groundwater resources in line with paragraph 170 of the NPPF and Position Statement N. Groundwater Resources of The Environment Agency's approach to groundwater protection, policy 5.21 of the London Plan (2016), CP32 of the Enfield Core Strategy (2010) and DMD66 of the Development Management Document (2014) and to ensure such works do not undermine the strcutural stability of the River Lee Navigation infrastructure.

36 Brooks Naturalisation

No development to alter the structure of the Pymmes or Salmons Brook shall take place until a scheme for the provision and management of compensatory habitat creation/ river restoration, including a suitable and sufficient methodology for protection of controlled waters, has been submitted to, and agreed in writing by the local planning authority (in consultation with the Environment Agency). Thereafter, the development shall be implemented in accordance with the approved scheme.

The scheme should include as a minimum;
o detailed structural design, including cross sections, long gradients, groundwater monitoring levels and elevations, and plan views of the proposed scheme.
o details of the proposed construction methodology, with particular reference to the protection of controlled waters.
o details of any proposed changes to the designs in light of simultaneous development within the riparian corridor.

Reason:
i) Development that encroaches on the Salmons or Pymmes Brooks may severely affect its ecological value, by preventing future improvement under the Water Framework Directive. National Planning Policy Framework (paragraph 175) states that if significant harm resulting from a development cannot be avoided (through locating on an alternative site with less harmful impacts), adequately mitigated, or, as a last resort, compensated for, then planning permission should be refused.
ii) To ensure that the development does not contribute to, and is not put at unacceptable risk from or adversely affected by, unacceptable levels of water pollution caused by mobilised contaminants. This is in line with paragraph 170 of the NPPF.

37 Artificial lighting to watercourse

There shall be no light spill from external artificial lighting into the watercourse or adjacent river corridor habitat. To achieve this the specification, location, and direction of external artificial lights should be such that the lighting levels within 8/5 metres of the top of bank of the watercourse are maintained at background levels. Background levels are taken to be a Lux level of 0-2.

Reason: To minimise light spill from the new development into the watercourse or adjacent river corridor habitat. Artificial lighting disrupts the natural diurnal rhythms of a range of wildlife using and inhabiting the river and its corridor habitat, and in particular is inhibitive to bats utilising the river corridor. This is in accordance with CP32 of the Enfield Core Strategy (2010), DMD69 of the Development Management Document(2014) and EL27 of the Edmonton Leeside Area Action Plan.

38 Landscape management plan

No construction works shall take place until a landscape and ecological management plan, including long-term design objectives, management responsibilities and maintenance schedules for all public accessible landscaped areas, shall be submitted to, and approved in writing by, the local planning authority. The landscape and ecological management plan shall be carried out as approved and any subsequent variations shall be agreed in writing by the local planning authority.
The scheme shall include the following elements:
o details of maintenance regimes
o details of any new habitat created on site
o details of treatment of site boundaries and/or buffers around water bodies
o details of management responsibilities

Reason: To ensure the protection of wildlife and supporting habitat. Also, to secure opportunities for enhancing the site's nature conservation value in line with the NPPF, policy 7.19 of the London Plan (2016), Policy CP36 of Enfield Core Strategy (2010), DMD76, 78, 79 and 81 of Development Management Document (2014) and Policy El12 of the Edmonton Leeside Area Action Plan (2020).

39 External lighting

No external lighting related to the development hereby permitted shall be installed unless it is in accordance with details which have previously been submitted to and approved in writing by the LPA. Such details shall include location, height, type and direction of light sources and intensity of illumination. Any lighting that is so installed shall not thereafter be altered without the prior consent in writing of the LPA.

Reason: To ensure that the development does not prejudice the amenities of adjoining occupiers, the visual amenities of the surrounding area and/or to ensure the protection of wildlife and supporting habitat of the Blue Ribbon Network in accordance with policy 7.5 of the London Plan (2016), DMD37, DMD69 and DMD75 of the Enfield Development Management Document (2014) and policy EL12 of the Edmonton Leeside Area Action Plan (2020) .

40 River Lee Navigation Bridge

Prior to the commencement of the River Lee Navigation Bridge, a survey of the condition of the River Lee Navigation waterway wall shall be undertaken, a schedule of repairs required and evidence that such works have been completed shall be submitted to and approved in writing by the Local Planning Authority

Reason: In relation to the structural stability of the River Lee Navigation and to protect the safety and amenity of users of the waterways, in accordance with policy 7.28 and 7.30 of the London Plan (2016) and DMD75 of the Development Management Document

41 Bridge risk assessment

A risk assessment and method statement considering any potential impact of the construction of the River Lee Navigation Bridge on the River Lee Navigation and its infrastructure shall be submitted to and approved in writing by the LPA prior to the commencement of such works.

Reason: In the interests of the structural stability of the River Lee Navigation infrastructure and the safety of its users in accordance with policy 7.28 and 7.30 of the London Plan (2016) and DMD75 of the Development Management Document

42 Bus stands and bus re-routing

No works to existing bus stops, stands, infrastructure or shelters or any works that affect bus operations shall be carried out until a Bus Facilities Works Programme has been submitted to and approved in writing by the local planning authority. The Works Programme shall include infrastructure specification, maintenance and transitional arrangements. The approved facilities shall thereafter be implemented in accordance with the approved arrangements.

Reason: To ensure that the development does not prejudice the continuous operation of bus services through the site. This is in accordance with policies 6.3 and 6.12 of the London Plan (2016), Policy CP24 of Enfield Core Strategy (2014), DMD47 of the Development Management Document (2014) and policy EL6 and EL23 of the Edmonton Leeside Area Action Plan

43 Landscaping to Towpath Rd alternative access

That prior to the commencement of works in connection with the construction of the alternative access to Towpath Road as shown on drawing number MWP2-ARP-Z6-XX-DR-CH-70201 REV P03, details shall be submitted to and approved by the LPA for the provision of landscaping, including tree planting, within the new car parking area proposed adjacent to this new access road. The landscaping scheme shall be implemented in accordance with the approved details no later than the first planting season following the new access road being brought into use.

Reason: To ensure the development maximises the opportunities for tree planting and soft landscaping along this new route in accordance with policy 7.5 of the London Plan (2016), policies DMD37 and DMD81 of the Development Management Document (2014) and EL12 of the Edmonton Leeside Area Action Plan

Dated: 22 July 2020

Authorised on behalf of:

Mr A Higham
Head of Development Management
Development Management,
London Borough Enfield,
PO Box 53, Civic Centre,
Silver Street, Enfield,
Middlesex, EN1 3XE

If you have any questions about this decision, please contact the planning officer claire.williams@enfield.gov.uk.

List of plans and documents referred to in this Notice:

Drawing	382 KCA P1 00 DR A 1001 P REV 02 2
Drawing	382 KCA P1 00 DR A 1002 P REV 02 3
Drawing	382 KCA P1 00 DR A 1003 P REV 02 2
Drawing	382 KCA P1 00 DR A 1004 P REV 02 2
Drawing	382 KCA P1 00 DR A 1005 PREV02 3
Drawing	382 KCA P1 00 DR A 1006 PREV 02 3
Drawing	382 KCA P1 00 DR A 1007 P REV 02 3
Drawing	382 KCA P1 00 DR A 1008 P REV02 1
Drawing	0052 PR ZZ GF DR L 0007 REV 02 7
Drawing	MWP2 ARP XX XX DR CU 61001 REV 02 4
Drawing	MWP2 ARP XX XX DR CD 40001 REV02 6
Drawing	MWP2 ARP XX XX DR CU 50001 REV02 6
Supporting Information	382 KCA P1 XX SP A 0100 P REV 02 1
Drawing	382 KCA P1 00 DR A 1101 P REV 02 2
Drawing	382 KCA P1 00 DR A 1102 P REV02 2

Drawing	382 KCA P1 01 DR A 1103 P REV02 2
Drawing	382 KCA P1 00 DR A 1104 P REV02 2
Drawing	382 KCA P1 01 DR A 1105 P REV 02 2
Drawing	382 KCA P1 00 DR A 1106 P REV 02 2
Drawing	382 KCA P1 XX DR A 2101 P REV 02 2
Drawing	382 KCA P1 XX DR A 2102 P REV 02 2
Drawing	382 KCA P1 XX DR A 2105 PREV 02 2
Drawing	382 KCA P1 XX DR A 2106 P REV 02 2
Drawing	382 KCA P1 XX DR A 2107 P REV02 2
Drawing	382 KCA P1 XX DR A 2109 P REV 02 2
Drawing	382 KCA P1 XX DR A 2110 P REV 02 2
Drawing	382 KCA P1 XX DR A 3101 P REV02 2
Drawing	382 KCA P1 XX DR A 3102 P REV 02 2
Drawing	382 KCA P1 XX DR A 3103 P REV 02 2
Drawing	382 KCA P1 XX DR A 3104 P REV 02 2
Drawing	382 KCA P1 XX DR A 3105 P REV 02 2
Drawing	382 KCA P1 XX DR A 4101 P REV 02 2
Drawing	382 KCA P1 00 DR A 4102 P REV 02 2
Drawing	382 KCA P1 XX DR A 4103 P REV 02 2
Drawing	382 KCA P1 XX DR A 4104 P REV 02 2
Drawing	382 KCA P1 XX DR A 4105 P REV 02 2
Drawing	382 KCA P1 XX DR A 4106 P REV 02 2
Drawing	382 KCA P1 00 DR A 1201 P REV 02 2
Drawing	382 KCA P1 00 DR A 1202 P REV 02 4
Drawing	382 KCA P1 00 DR A 1203 P REV 02 2
Drawing	382 KCA P1 00 DR A 1204 P REV 02 2
Drawing	382 KCA P1 00 DR A 1205 P REV 02 2
Drawing	382 KCA P1 00 DR A 1206 P REV 02 2
Drawing	382 KCA P1 00 DR A 1210 P REV 02 2
Drawing	382 KCA P1 XX DR A 2201 P REV 02
Drawing	382 KCA P1 XX DR A 2202 P REV02 2
Drawing	382 KCA P1 XX DR A 2203 P REV02 2
Drawing	382 KCA P1 XX DR A 4201 P REV02 2
Drawing	MWP2 ARP CW XX DR CH 71101 REV02 4
Drawing	MWP2 ARP CW XX DR CH 71102 REV 02 6
Drawing	MWP2 ARP CW XX DR CH 71103 REV02 4
Drawing	MWP2 ARP CW XX DR CH 71201 REV02 2
Drawing	MWP2 ARP CW XX DR CH 71202 REV02 2
Drawing	MWP2 ARP CW XX DR CH 71621 REV02 1
Drawing	MWP2 ARP CW XX DR CH 71622 REV02 1

Drawing	MWP2 ARP CW XX DR CH 71623 REV02 1
Drawing	MWP2 ARP CW XX DR CH 71624 REV02 2
Drawing	MWP2 ARP CW XX DR CH 71625 REVO2 2
Drawing	MWP2 ARP CW XX DR CH 71626 REV02 2
Drawing	MWP2 ARP Z6 XX DR CH 70201 REV02 3
Drawing	MWP2 ARP Z6 XX DR CH 70301 REV 02 1
Drawing	MWP2 ARP LL XX DR CH 72101 REV02 5
Drawing	MWP2 ARP LL XX DR CH 72101 REV02 4
Drawing	MWP2 ARP LL XX DR CH 72201 REV02 3
Drawing	MWP2 ARP LL XX DR CH 72621 REV02 2
Drawing	MWP2 ARP LL XX DR CH 72622 REV02 2
Drawing	MWP2 ARP ZZ XX DR CH 73201 REV02 3
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Drawing	MWP2 ARP XX XX DR CH 70521 REV02 2
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Drawing	0052 PR ZZ GF DR L 1104 REV02 8
Drawing	0052 PR ZZ GF DR L 1105 REV02 6
Drawing	0052 PR ZZ GF DR L 1106 REV02 8
Drawing	0052 PR ZZ GF DR L 1107 REV02 9
Drawing	0052 PR ZZ GF DR L 1108 REV02 10
Drawing	0052 PR ZZ GF DR L 1110 REV02 10
Drawing	0052 PR ZZ GF DR L 1111 REV02 10
Drawing	0052 PR ZZ GF DR L 1112 REV02 10
Drawing	0052 PR ZZ GF DR L 1114 REV02 10
Drawing	0052 PR ZZ GF DR L 1115 REV02 10
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Drawing	0052 PR ZZ GF DR L 1109 REV02 10
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Drawing	MWP2 ARP XX XX DR CF 80502 REV02 4
Drawing	MWP2 ARP XX XX DR CF 80307 REV02 2
Drawing	382 KCA P1 XX DR A 2111 P REV 02 2
Drawing	MWP2 ARP XX XX DR CF 80501 REV02 4

Additional Information

1 In accordance with condition 9 of the permission, the applicant is reminded that samples of the following proposed external materials shall be submitted to the Local Planning Authority for approval:

Q22/150B Hot rolled asphalt with decorative surface dressing
Q25/200A York stone flags
Q24/130A Granite setts with mortar joints - Type 01
Q25/130B Granite setts with mortar joints - Type 02
Q25/610A Concrete setts type 01 - parkside
H42/001A Abutment Type 1 - Smoked Brick Precast Panels
E05/001B Abutment Type 2 - In situ Exposed Aggregate
H42/001B Retaining Wall Type 1 - Smoked Brick Precast Panels
E05/002B Retaining Wall Type 2 - In situ Exposed Aggregate

Next Steps:

1. If your conditions require the submission of further details, you can find the appropriate forms and information at https://www.planningportal.co.uk/

2. There may be further consents to be obtained before progressing with your development. Please consider checking your deeds for reference to covenants, bye-laws which may apply. Please consider potential licensing requirements.

Building Regulations

Your proposal may require Building Regulations approval. Contact our Building Control team for advice on how to obtain any necessary consent.
https://new.enfield.gov.uk/services/planning/building-control/

Appendix B

Remediation options appraisal

B1 Scope of remediation options appraisal

B1.1 Approach to remediation options appraisal

The approach adopted for the development of this remediation options appraisal is based on the Environment Agency publication "Land contamination: risk management" (LCRM) [1], CIRIA C622 [2] and the principles set out by SuRF UK (Sustainable Remediation Forum UK)[3].

The SuRF UK framework is a voluntary framework for assessing the sustainability of soil and groundwater remediation, and for incorporating sustainable development criteria in land contamination management strategies. It aims to help assessors to identify the optimum land and/or groundwater remediation strategy and/or technique.

The SuRF-UK framework recognises two main site management stages where sustainable remediation decision-making can be applied:

- Stage A. The project/plan design stage; and
- Stage B. The remediation options appraisal, selection and implementation.

The underlying principle of SuRF UK is that each element of sustainability (economic, environmental, and social) is assessed on the basis of indicators, with sustainability being a function of all three elements. This assessment fits into the Stage B scenario and incorporates a qualitative assessment that accords with the principles defined in the SuRF UK framework.

The remediation strategy identified five RPLs in the SIW-Phase 1 area requiring remediation options appraisal as outlined in Table B 1.

Table B 1 Confirmed RCL4 and RCL5 sources included in remediation options appraisal

RCL		**Contaminant source**	**Remediation options appraisal**
RCL4	Groundwater concentrations in KPGR causing a risk of pollution to the shallow aquifer from lateral migration.	Benzene in DZ4_BH1008	ROA 1
		Vinyl chloride in DZ7_BH2058	ROA 2
		TPH >C12-C16 aromatics in DZ2 east of gasholder	ROA 3
		Ammoniacal nitrogen and cyanide in the south of DZ2 and DZ4	ROA 4
RCL5	Groundwater concentrations in Chalk basal sands causing a risk of pollution to deep aquifer from lateral migration	Ammoniacal nitrogen and cyanide in DZ2 and DZ4	ROA 5

[1] Environment Agency (2021) Land Contamination Risk Management (LCRM). https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm Last accessed: 12 August 2021
[2] CIRIA (2004) Selection of remedial treatments for contaminated land. A guide to good practice. C622

B1.2 Remediation options appraisal methodology

The remediation options appraisal methodology is outlined below. This methodology has been applied to each of the five contaminant sources identified in Table B 1 in accordance with LCRM[1]:

- Source-specific remediation objectives have been defined based on the output of the DQRA.
- A long list of available options for managing the groundwater contamination source has been defined using the LCRM remediation option applicability matrix [4]. The long list has been reviewed against the following criteria: technical feasibility, overall cost (including set up, operation and maintenance charges), process reliability and timescale.
- The potentially feasible options have been taken forward to detailed options evaluation for each source. In line with the SuRF UK guidance [3], the following factors have been considered in the detailed remediation options appraisal:
  1. Technical applicability e.g. suitability to the hydrogeological conditions and contaminant distribution, durability, residual risk.
  2. Practicalities onsite e.g. access to foul sewer, access to source area, how the technique will integrate with others.
  3. Timescale aspects e.g. how long it will take to meet objectives, time-bound funding constraints, long-term management, flexibility, likely verification and monitoring requirements.
  4. Environmental impacts e.g. emissions, waste, energy requirements.
  5. Social impacts e.g. health and safety, impacts on neighbours.
  6. Economic factors e.g. direct and indirect costs, affordability.
  7. Regulator acceptability and permitting aspects e.g. well-established techniques likely to be more easily approved.
  8. Compliance with high level remediation objectives and constraints.

The remediation options appraisal has been completed using a semi-quantitative approach. The potentially feasible options have been evaluated using a numerical scale for each factor to identify the preferred remediation option(s) for each source to progress the remediation strategy.

SuRF UK recommends separating the three sustainability elements (environmental, social and economic) into up to 15 SuRF UK sub-categories as listed in Table B 2. Some of these categories have been included in this assessment and others are excluded; a short justification

[3] Sustainable Remediation Forum UK (2021) Sustainable management practices for management of contaminated land) and SuRF UK (2020) Supplementary report 1 of the SuRFUK framework: A general approach to sustainability assessment for use in achieving sustainable remediation
[4] Environment Agency (2019) Land contamination: remediation options applicability matrix. https://www.gov.uk/government/publications/land-contamination-remediation-option-applicability-matrix

for inclusion/ exclusion is provided in Table B 2. Table B 2 also provides a weighting which will be given to each category.

Table B 3 details the approach that will be used to score the indicator for each remediation technology.

Table B 2 Sustainability criteria assessment approach

Assessment criteria	Included	Approach	Lines of evidence used to compare criteria between options	Weighting
Environmental				
Emissions to air	Y	Release of greenhouse gases including CO_2, CH_4 and N_2O have been appraised for each option. The assessment also considers the potential for the option to affect ground air quality including volatile contaminants/ reagents.	The qualitative approach considers how options compare in terms of relative energy intensity, potential for carbon sequestration, exhaust gas emissions (e.g. from machinery) and disturbing/liberating sources of volatile contamination.	3
Soil and ground conditions	Y	Although the five linkages that have been identified for further assessment relate to groundwater, each option has the potential to affect the soil and ground conditions. The effect of each option on soil and ground conditions will be considered and the following will be evaluated: • Changes in water drainage • Changes in soil functionality • Changes in soil/subsurface structure affecting drainage including soil sealing • Structures in the subsurface (impact of wells, impact on buried services etc) • Changes in geotechnical properties	A qualitative approach. The approach considers: • Effect of treatment on soil structure, functionality and soil condition. • Effect of treatment on biological, physical and or chemical functions affecting water quality in the subsurface. • Effect of drilling on structures in the subsurface such as drainage or other services	3
Groundwater and surface water	Y	The five linkages that have been identified for remediation options appraisal relate to groundwater sources, therefore the mitigation of risks to groundwater is an objective and this indicator carries particular importance for this site. The assessment considers effect on suitability of water for potable or other uses (particularly in the Chalk aquifer), the effect on legally binding environmental objectives such as Water Framework Directive, and the effects on mobilisation of dissolved substances. Consideration has been given to the effects of water abstraction (where required) and possible impacts.	Qualitative approach considering the reagents/ processes used in the option and the effect on water quality including pH, redox etc. The assessment considers how options may degrade the waterbody, the wider impacts of reagents such as the use of surfactants and whether reagents will cause effects beyond the treatment zone perimeter.	5
Ecology	Y	Invasive non-native species (INNS) are present onsite including Japanese knotweed, Himalayan balsam and giant hogweed. The remediation options appraisal must consider the potential for the technique to spread INNS around the site or offsite.	Qualitative approach. The assessment considers how options compare in terms of potential ecological impact and benefit.	1
Natural resources and waste	Y	Natural resources and waste assessment will evaluate the use of energy/ fuels required for each option considering their type/ origin. The assessment will consider the use of primary resources, rates of recycling, use or reuse of water, the impacts/ benefits of water abstraction use and disposal.	Qualitative approach. Consideration will be given to the impact and benefit of the option.	5
Social				
Human health and safety	Y	Although the five sources that have been assessed as requiring remediation options appraisal are for PCLs relating to groundwater, mitigation of risks to human health is a risk management objective for the site. Specifically risks relating to site workers, site neighbours and the public during the works. The assessment will consider the use of hazardous reagents or processes, the potential transport of hazardous waste offsite, movement of large-scale machinery, requirement for large excavations, requirement for smaller machinery such as generators and pumps, potential for treatment of hazardous groundwater.	Qualitative approach considering hazards such as machinery and transportation of materials, use of different reagents of types of process emissions likely and the controls that might be in place.	4
Ethics and equity	N	LBE are the master developer for the SIW works, as such they are bound by strict rules on procurement and require the same rules be followed for their contractors. LBE take due care and diligence over potential and perceived impacts on the local community and how the works will affect the community. It is also noted that the site is mostly vacant land with limited tenants and no permanent residents. Therefore it is not possible to distinguish between different remedial options on the basis of ethics and equity.		NA
Neighbourhoods and locality	Y	Several indicators have been considered including effects from dust, light, noise, odour and vibrations during the works and associated with traffic including both working-day and night-time/weekend operations and wider effects of changes in site usage by local communities (e.g. reduction in antisocial activities on derelict site, removal of invasive species, clearance of vermin and derelict buildings).	Qualitative approach considering impacts and benefits to local neighbourhoods.	3

Assessment criteria	Included	Approach	Lines of evidence used to compare criteria between options	Weighting
Communities and community involvement	N	There are no residential developments close to the SIW site boundary and the overall focus of the project is around creating a new community where none currently exists. For this project it will not be possible to distinguish between different remedial solutions on the basis of communities and community involvement.		NA
Uncertainty and evidence	Y	The robustness of the techniques has been evaluated. The assessment also considers the uncertainty around the wider impacts of the technology and its ability to meet any remedial targets. The assessment will consider the verification requirements including the duration, cost and design. Additional consideration will be given to regulator acceptability.	Qualitative approach. Consideration given to case studies on similar sites, published/validated performance information and track record of the technology and the operator.	4
Economic				
Direct economic costs and benefits	Y	Consideration has been given to the direct financial cost. The cost review considers the cost associated with the method (e.g. operation, ongoing monitoring, regulator costs, planning, permits/licences and pilot trials). The cost has been considered against the value of the benefit (e.g. mitigation of liabilities by the risk management achieved, redevelopment potential realised for the site, land value enhancement for the site completion against programme required to release HIF funding).	Semi-quantitative approach. Includes costs, monitoring, and permit requirements. Qualitative approach for value of benefit assessment.	5
Indirect economic costs and benefits	N	These indicators would not be quantifiable for this appraisal. Each potentially feasible option would enable the SIW works to progress enabling the land to be unlocked for redevelopment. Land surrounding the site is either currently undergoing redevelopment (Phase 1), commercial or light industrial and therefore the remediation option/ development won't have a short-term impact on the value of surrounding residential properties. In the long term all options will result in redevelopment of the site, including local amenities including schools, retail and commercial developments and surrounding areas, thus having a beneficial impact. In the short term (3-5 years) the SIW works may result in a small increase in employment to deliver the construction works. In the mid to long term the site will be redeveloped to bring significant employment to the area. Any potentially feasible option would enable the redevelopment of the site increasing future employment. For this appraisal it is not possible to distinguish between different remedial solutions on the basis of these categories.		NA
Employment and employment capital	N			
Induced economic costs and benefits	N			
Project lifespan and flexibility	Y	Several considerations including: • Duration of the remediation benefit • Length of time for beneficial effects to become apparent/ duration of remedial works. • Factors affecting the chances of success of the remediation/ management works including environmental, procurement, technological • Ability of the approach to respond to changing circumstances including discovery of additional contamination, different soil materials or timescales. • Robustness of solution to climate change effects • Restrictions on use of the technique considering the site conditions and environmental setting. • Duration of subsequent monitoring and verification	A qualitative approach including: • Review of previous examples of outcomes over time. • Consideration of the assumptions and choices underpinning each option and the specific context of the site. • Requirements for monitoring/ verification.	4

Table B 3 Sustainability scoring assessment criteria for remediation technique appraisal

Assessment criteria	Low (Score of 1)	Mid (Score of 2)	High (Score 3)
Environmental			
Emissions to air	High relative energy intensity. Emissions of greenhouse gases and/ or volatile contaminants are high throughout installation/operation and maintenance phases. Low potential for carbon sequestration. Continued ground disturbance disturbing/liberating sources of volatile contamination or high initial disturbance.	Moderate relative energy intensity. Emissions of greenhouse gases and/ or volatile contaminants are high during installation/ initial phases and moderate to low longer term. Moderate potential for carbon sequestration. Initial ground disturbance disturbing/liberating sources of volatile contamination, but then limited, or moderate disturbance. .	Low relative energy intensity. Any emissions of greenhouse gases and/ or volatile contaminants are limited to installation/initial phases. High potential for carbon sequestration Limited ground disturbance limiting disturbing/liberating sources of volatile contamination.
Soil and ground conditions	Moderate to high effect on soil structure, functionality, and soil condition. Moderate to high effect on biological, physical and or chemical functions affecting water quality in the subsurface. Moderate to high effect on subsurface features such as drainage and services.	Low to moderate effect on soil structure, functionality, and soil condition. Low to moderate effect on biological, physical and or chemical functions affecting water quality in the subsurface. Low to moderate effect on subsurface features such as drainage and services.	Low to no effect on soil structure, functionality, and soil condition. Low to no effect on biological, physical and or chemical functions affecting water quality in the subsurface. Low to no effect on subsurface features such as drainage and services.
Groundwater and surface water	Moderate to high effect on water quality considering indicators such as pH, redox potential, dissolved oxygen levels. Option does not degrade groundwater aquifer. Moderate to high impact on wider area outside of treatment zone perimeter.	Low to moderate effect on water quality considering indicators such as pH, redox potential, dissolved oxygen levels. Option does not degrade groundwater aquifer but also does not result in betterment of groundwater aquifer quality. Low to moderate impact on wider area outside of treatment zone perimeter.	Low to no effect on water quality considering indicators such as pH, redox potential, dissolved oxygen levels. Option does not degrade groundwater aquifer and may have beneficial effect on quality of aquifer. Limited or beneficial impact on wider area outside of treatment zone perimeter.
Ecology	Large earthworks/excavation or soil movement required.	Minor earthworks/ excavation/ soil movement required.	No earthworks/ excavation/ soil movement required.
Natural resources and waste	High energy/ fuel requirements throughout construction, operation and maintenance phases. Primary resources required. Low rates of recycling. High water usage. Large quantities of water disposed of. Groundwater abstraction required with high impact on aquifer. Possibly impacting offsite. Large excavations required and large quantities of material disposed of.	Moderate energy/ fuel requirement during set up and operation but lower requirement during maintenance. Some use of primary resources. Moderate rates of recycling. Limited water usage. Recycled water used where possible. Localised water abstraction with minor impact on aquifer. Moderate or large excavations but material can be used onsite or minimal offsite disposal.	Low energy/ fuel requirements during set up/ operation and maintenance. Limited use of primary resources, high rate of recycling possible. If water required, ability to be reused rather than disposed of. Localised water abstraction with limited impact or a beneficial impact on aquifer from water abstraction. If excavation required, ability to use material onsite or limit excavations.
Social			
Human health and safety	Machinery/ material movement is required throughout construction, operation/maintenance. Reagents are required throughout the operation and maintenance and are potentially hazardous. Process emissions throughout construction, operation and maintenance. Enhanced health and safety controls throughout techniques lifespan over and above site wide construction health and safety control measures required by CDM and the CEMP.	Machinery/ material movement is required but is limited to the initial setup/ construction phase and is limited during operation/ maintenance. Some use of reagents, mostly non-hazardous. Some process emissions. Health and safety controls are in line with the site wide construction health and safety control measures required by CDM and the CEMP. Some enhanced PPE required for certain tasks but limited and sporadic use.	Machinery/ material movement is limited and may only be required for construction. Limited material movement/ machinery required for operation/ maintenance. Limited use of reagents. Limited or no process emissions. Health and safety controls are in line with the site wide construction health and safety control measures required by CDM and the CEMP.
Neighbourhoods and locality	Significant effects to neighbours and local area from dust, light, noise and odour and vibrations during construction and operation but disturbance is minimal/for short periods over a limited time. Significant mitigation is required over and above site wide construction measures required by CDM and CEMP.	Some effects to neighbours and local area from dust, light, noise and odour and vibrations during construction and operation but disturbance is minimal/for short periods over a limited time. Mitigation can be implemented to prevent/limit disturbance.	Effects to neighbours and local area from dust, light, noise and odour and vibrations are minimal. Works are limited to the working day and are not required on weekends (i.e. option does not cause an impact 24hrs a day 7 days a week).

Assessment criteria	**Low (Score of 1)**	**Mid (Score of 2)**	**High (Score 3)**
	Works are required on weekends or outside 9 to 5 workdays which may cause disturbance to neighbours including lights, noise and traffic. Option degrades the local area and limits site usage. Local community is impacted by works.	Works are limited to the working day and are not required on weekends (i.e. option does not cause an impact 24hrs a day 7 days a week). Option does not worsen the site usage by local communities i.e. the site is left in the same condition as found. Minimal disturbance.	Option does not impact, or improves the site usage by local communities, i.e. removal of invasive species, clearance of vermin and or fly tipping. Site is not left as open derelict land.
Uncertainty and evidence	The technique is experimental and does not have many examples of previous use on similar sites. There are limited examples where the regulator has agreed on this approach. The regulator is not comfortable with this technique. This option has had limited success/ there is uncertainty around reaching the remedial target values. Verification will be costly/ extensive/ technically challenging and won't fit in with other works onsite. Large quantities of additional ground investigation is required/ monitoring over and above the borehole network onsite. The operator has not worked on similar sites before/ the technology is experimental and does not have proven records of achieving target values.	The option has been used before on similar sites but has not always been successful. The regulator is happy with the approach but would need further examples of similar sites/ additional data before the approach could be signed off. The option can meet the remedial target values in certain conditions over a longer period but is not always successful. Verification will be moderate in duration, costly/ moderately challenging but will fit in with other works required onsite. The operator has completed works on similar sites before with some level of success.	The option has a strong track record of success on similar sites with similar contamination levels. The technique is commonly accepted by the regulator on similar sites with similar contamination levels. The option is proven to comfortably meet remedial targets. The verification required is short in duration/ low cost/ a simple design which can be easily agreed with the regulators. If a longer-term management plan is required, this is straight forward and is achievable with the boreholes/ network onsite or with minimal additional data requirements. The verification will fit in with other works onsite. The operator has a strong record of working on similar sites with this technology and has proven records of achieving target values.
Economic			
Direct economic costs and benefits	High cost	Medium cost	Low cost
Project lifespan and flexibility	>3 years	Construction, operation phase <0.5 to 1 year, with possible maintenance phase between >1 year to 3 years.	Construction, operation and maintenance phase <0.5 to 1 year.

B2 Remediation options appraisal 1: Benzene in KPGR DZ4_BH1008

B2.1 Summary of source characterisation and risk assessment

Remediation options appraisal 1 (ROA1) considers the benzene source in the south east of DZ4, identified in monitoring wells DZ4_BH1008 and DZ4_BH1007.

The DQRA RTM assessment calculates a Level 3 RTM target criteria of approximately 15mg/l, which exceeds the highest observed groundwater concentration. Sensitivity analysis for benzene indicates that the model is very sensitive to the half-life and therefore if actual levels of degradation are lower than predicted this constituent could migrate further and at higher concentrations.

DZ4_BH1008 is located close to the south eastern corner of the site and therefore no delineation has been possible to the south and east. This also means that there is added uncertainty relating to the flow direction and gradient of contamination sources in this area.

Although the RTM evaluation for benzene (like other constituents) is probably conservative, the concentrations of this contaminant are a potential concern particularly considering the location of the source in the very south east corner of the site. Therefore a conservative approach has been followed, considering this source in the remediation options appraisal.

Additional source characterisation and further refinement of the risk assessment may lead to a less conservative outcome. However for the purposes of this appraisal it is assumed that remediation of this source is necessary.

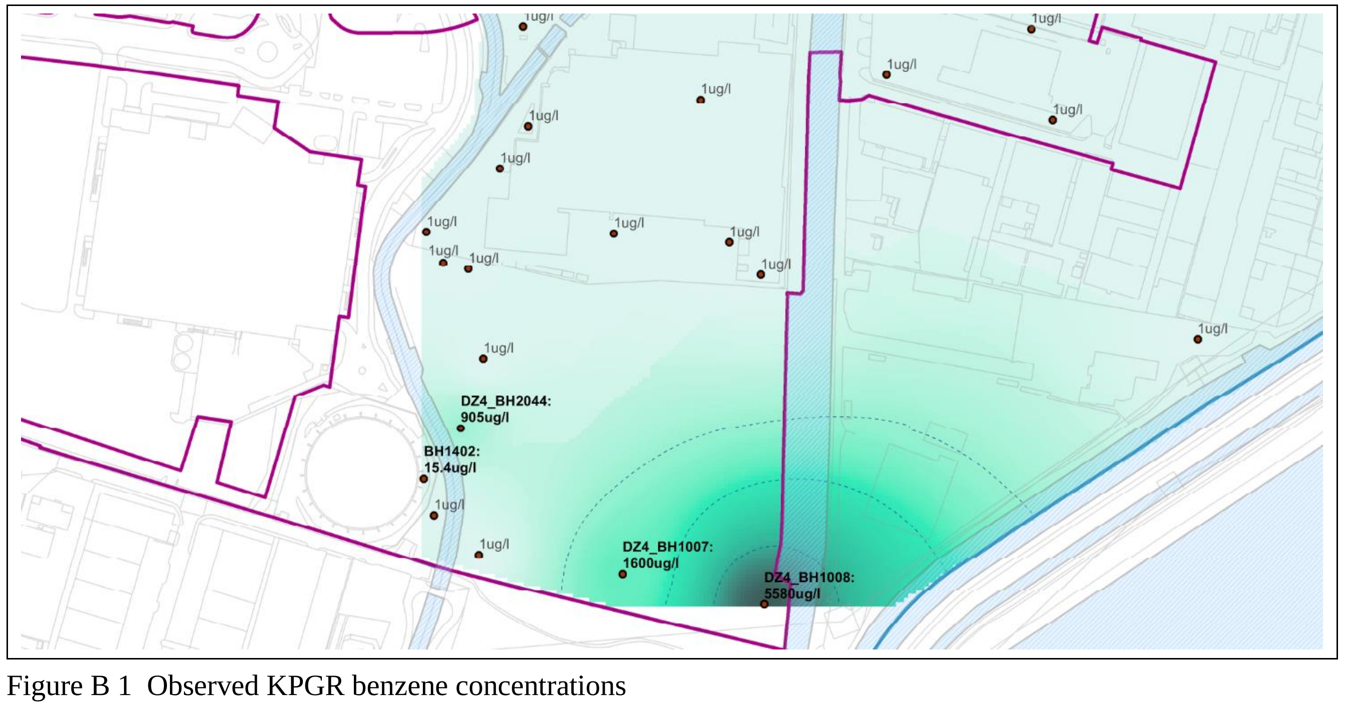


Figure B 1 Observed KPGR benzene concentrations

B2.2 Remediation objectives

- To address contaminant linkage to ensure that no unacceptable long-term risks are posed by the benzene groundwater source at DZ4 to identified receptors.
- To reduce source concentrations resulting in improvement of current site conditions if a feasible method is available.

B2.3 Initial appraisal of options

A long list of available options for managing groundwater contamination has been defined in Table 4, utilising the ‘Land contamination: remediation option applicability matrix’ [4].

Table B 4 Benzene initial remediation options appraisal

Method type	Remediation options	Technically feasible at Meridian Water (1-5)	Overall cost (£ to £££)	Process reliability	Programme (years)	Possible Advantages	Possible Disadvantages	Comments
Civil engineering	Turnover of soils in unsaturated zone to remove any hotspots of gross contamination / confirm no on-going source	1	£ - ££	Good	<1 year	Would identify and remove gross contamination hotspots within unsaturated zone and reduce any ongoing contaminant source to groundwater. Could be incorporated into site-wide earthworks strategy	Large volume and deep excavation may be required with associated environmental and H&S risks. Would not treat any existing groundwater contamination and additional remediation techniques may be required where gross contamination identified in groundwater. Additional volumes of contaminated soil to treat/dispose of.	**Feasible option** A turnover of shallow soils is proposed as part of the site-wide earthworks and additional excavation in the source area could be incorporated into the earthworks strategy with limited impact on project programme. The removal of any contaminant hotspots would reduce any ongoing input of contamination to groundwater resulting in an overall improvement in groundwater quality.
Civil engineering	Containment - hydraulic barriers (eg drain or well curtain)	4	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Construction and maintenance of wells relatively expensive. Technically challenging. May require long term operation to pump and treat groundwater. Large quantities of contaminated groundwater to treat/dispose of. H&S and environmental implications.	**Option not feasible** Long term management and maintenance requirement likely to be unworkable based on development scope and programme.
Civil engineering	Containment - in ground barriers (eg PRB)	4	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Construction and maintenance relatively expensive. Technically challenging. H&S and environmental implications. Below ground system may be issue for below ground structures of future development (e.g. foundations).	**Option not feasible** Excluded as feasible option due to high cost, high technical complexity and long-term management requirement.
Biological	Natural attenuation	2	£	Average - Good	1 - 30	Overall cost likely to be lower than many active remediation techniques. Less intrusive as few surface structures are required. Less generation or transfer or remediation wastes.	Will require long term monitoring to demonstrate attenuation of source is occurring. Suitable monitoring wells will need to be maintained on site and may need to be protected/replaced during site development. Extensive site characterisation required to collect lines of evidence that attenuation processes are occurring. Contingency plan will need to be in place if contaminants do not degrade as predicted.	**Feasible option** Conditions (aerobic) of KPGR appear to be favourable for natural attenuation to occur, however further monitoring would be required to prove this. The long-term monitoring required may not meet programme objectives. Could be considered with other remedial techniques i.e. for dealing with any residual source.
Biological	Biosparging	5	££	Low	0.5 - 3	Minimal site disturbance. Would reduce source concentrations.	Can be costly and not a common technique used for benzene. May need to be used in combination with other techniques.	**Option not feasible** Technique is not commonly used for benzene and is relatively costly.
Chemical	In situ chemical oxidation	2	££	Average - Good	<1 year	Oxidation reactions are often fast and can result in significant (complete) degradation. Relatively low technical complexity.	Can be expensive and reagents will be rapidly depleted by other organics May require large volumes of reagent to be injected.	**Feasible option** Technique relatively easy to install, but as oxidation can be expensive and will rapidly deplete, it would be beneficial to consider using this technique in combination with other methods (e.g. air sparging).

Method type	Remediation options	Technically feasible at Meridian Water (1-5)	Overall cost (£ to £££)	Process reliability	Programme (years)	Possible Advantages	Possible Disadvantages	Comments
							Toxic intermediate breakdown products may be formed which require other treatment techniques. Environmental considerations if using aggressive reagents	Effectiveness of technique will rely on source contributing to dissolved phase being removed. Could be considered with other techniques for targeted treatment of any residual contamination.
Physical	Dual phase SVE	2	£££	Average - Good	0.5 - 3	Technique proven to be suitable for remediating benzene	Technique is expensive. Installation and application can be technically challenging to undertake, particularly where plume area is poorly defined	**Option not feasible** Excluded as feasible option due to high cost and difficulty in implementing technique.
Physical	In situ air sparging	2	££	Average - Good	0.5 - 3	Minimal site disturbance. Can be highly cost effective. Would reduce source concentrations.	May need to be used in combination with other techniques. Injection/abstraction wells would need to be installed on site.	**Feasible option** Effectiveness of technique will rely on source contributing to dissolved phase being removed. May be beneficial to carry out air sparging in combination with other techniques e.g. chemical oxidation.
Physical	Permeable reactive barriers	5	£££	Average	>10	Below ground system which once installed can represent fewer constraints to surface developments Can be relatively easy to maintain and monitor. Can be a good solution for inaccessible or dispersed source	Construction and maintenance could be relatively expensive. Reactive media may need to be replaced over time. Technically challenging. May require long term operation and long-term monitoring will be necessary. Below ground system may be issue for below ground structures of future development (e.g. foundations). Reactive media may need to be disposed as a hazardous waste	**Option not feasible** Excluded as feasible option due to high cost, high technical complexity and long term management requirement.
Physical	Pump and treat	3	£££	Poor	>2	Minimal site disturbance. Removes contaminant mass from aquifer	Potentially long term. Large quantity of contaminated water to manage. Relatively expensive. Low sustainability due to wastewater disposal requirements: tanker offsite, discharge to foul sewer (expensive), on site treatment plant (disposal to ground or foul sewer)	**Feasible option** Technique relatively easy to install and operate. Achieving defined targets is notoriously difficult due to rebound of concentrations when pumps switched off. But operating for a fixed duration to remove as much contaminant loading as possible (in say 1 year) is achievable and more realistic.

Technical feasibility 1 – straight forward, proven, reliably effective — Cost £ - Low cost
Technical feasibility 5 – unproven, very difficult, limited confidence in success. — Cost ££ - Medium cost
Process reliability – Low, Average, Good — Cost £££ - High cost

B2.4 Detailed options evaluation

The initial appraisal of options has identified the following short list of potentially feasible techniques for the remediation of the benzene groundwater source:

- **Excavation of soils in unsaturated zone to remove hotspots of gross contamination**

  This option would require a robust turnover of soils in the unsaturated zone around DZ4_BH1008 to confirm no significant ongoing source is contributing to dissolved phase groundwater contamination. Any gross contamination and structures containing contaminants (such as tanks or pipelines) identified within the unsaturated soils would be removed and treated or disposed of.

  The removal of any contaminant source would result in overall betterment of existing site conditions but would not treat existing dissolved phase benzene groundwater concentrations. The findings of the turnover would be reviewed to assess if any further physical treatment of groundwater is necessary. If additional techniques to treat the dissolved phase in groundwater are proposed, the effectiveness of these techniques would be improved by the removal of any ongoing source.

  A turnover of shallow soils is proposed as part of the site-wide earthworks and additional excavation in the source area could be incorporated into the earthworks strategy which would minimise impact on the development programme.

  There will be associated environmental and health and safety risks if large volume and deep excavation is required to ‘chase out’ any significant contamination encountered, which could result in significant additional volumes of soil to treat/dispose of.

- **Natural attenuation**

  Benzene in groundwater will naturally attenuate where conditions are favourable. Natural degradation of benzene would result in an overall long-term reduction in benzene concentrations.

  Based on available groundwater monitoring data, field measurements of dissolved oxygen levels within groundwater in the KPGR indicate aerobic conditions which are likely to be suitable for natural attenuation to occur. Groundwater monitoring during the remediation and earthworks programme would be required to assess if aquifer conditions are suitable to sustain natural degradation to gain regulator approval.

  Suitable groundwater monitoring wells would need to be maintained on site for the duration of the monitoring programme and may need to be protected/replaced during site development works. Some post-development monitoring may be necessary and the period of monitoring required would be determined by site conditions, however it may need to extend beyond the development programme.

  Natural attenuation in some form is likely to be a suitable option for remediating low/residual levels of benzene in groundwater, either in isolation or in combination with other techniques.

- **In situ air sparging**

  Air sparging is a proven technique for dealing with benzene. It involves in situ treatment and disturbance at ground surface would be minimal compared with ex situ techniques. Suitable injection and abstraction wells would need to be installed. The remediation process is likely to be short to medium term and could be completed within the proposed development programme. This remediation technique is likely to require an environmental permit, as it is considered unlikely that it would meet the definition of a small-scale remediation scheme [6]. Air sparging may not be suitable where the no phreatic surface in the KPGR.

  The technique would result in the reduction of benzene concentrations in groundwater. The effectiveness would rely on any source contributing to dissolved phase benzene contamination being removed/reduced (e.g. by turnover of soils in unsaturated zone).

- **In situ chemical oxidation**

  Chemical oxidation is a proven technique for remediating benzene. It involves in situ treatment and therefore disturbance at ground surface would be minimal compared to ex situ techniques. Suitable injection wells would need to be installed. The remediation process is likely to be short term and could be completed within the proposed development programme. This remediation technique is likely to require an environmental permit, as it is considered unlikely that it would meet the definition of a small scale remediation scheme [6].

  The remediation contractor would need to select the most suitable oxidising reagent to use based on site conditions. Once injected the oxidation reactions can occur relatively quickly and can result in significant degradation of benzene concentrations.

  The reagents can be relatively expensive and some reagents will be rapidly depleted by other organics in groundwater which could result in a large volume of reagent needing to be injected. Depending on the reagent used toxic intermediate breakdown products can be formed. If aggressive reagents are being used then additional health and safety and environmental mitigation may be required for handling the chemicals on site.

  The effectiveness would rely on the source contributing to dissolved phase benzene contamination being removed/reduced (e.g. by turnover of soils in unsaturated zone).

- **Pump and treat**

  Pump and treat is a proven technique for remediation of benzene-contaminated groundwater. However it is now used less frequently than in the past as it has been shown to be difficult to achieve remediation targets and can result in costly (and low sustainability) long term pumping, treatment and discharge requirements. Discharge of water without treatment could be to foul sewer or tankered offsite to waste water treatment facility. Water treated on site could be discharged back into the ground with EA approval and an environmental permit. An alternative arrangement could be to pump for a fixed duration, say 3months to substantially reduce the source, in conjunction with another follow-on technique to treat residual. However the benefits of this approach are limited compared to in situ technique alone.

A high-level qualitative assessment of the sustainability of each technique is provided in Table 5, based on the scores and weighting described in Tables 2 and 3. Based on this assessment natural attenuation is considered to be the most sustainable remedial technique. A summary of the feasible remedial techniques for benzene is provided in Table 6.

Table B 5 Qualitative assessment of sustainability of remediation options for benzene (lowest score = least sustainable)

Remediation option	Emissions to air	Soil and ground conditions	Groundwater and surface water	Ecology	Natural resources and waste	Human health and safety	Neighbourhoods and locality	Uncertainty and evidence	Direct economic costs and benefits	Project lifespan and flexibility	TOTAL SCORE (weighting applied)
Weighting	3	3	5	1	5	4	3	4	5	4	
Turnover soils in unsaturated zone to remove hotspots of gross contamination	2	2	2	1	2	2	2	2	2	3	77
Natural attenuation	3	3	2	3	3	3	3	2	3	1	94
In situ chemical oxidation	2	1	2	3	2	2	2	2	1	3	71
In situ air sparging	2	1	2	3	2	2	2	2	1	3	71
Pump and treat	2	1	2	3	1	2	2	1	1	2	59

Table B 6 Summary of feasible remediation options for benzene

Remediation	Sustainability ranking (1=most sustainable)	Advantages	Disadvantages	Compliance with remediation objectives
Turnover soils in unsaturated zone to remove hotspots of gross contamination	2	Would provide confidence that no significant ongoing source remains and would supplement other remediation techniques targeting the groundwater. Could be incorporated into site-wide earthworks and turnover minimising impact on development programme.	Large volume and deep excavation may be required with associated environmental and H&S risks. Would not treat any existing groundwater source and additional remediation techniques may be required where gross contamination identified in groundwater. Could generate additional volumes of contaminated soil to treat/dispose of.	The removal of any contaminant source in the unsaturated sone would result in overall betterment of the existing site condition. This option would not directly reduce existing dissolved phase benzene groundwater concentrations but would supplement other groundwater treatment techniques and reduce potential for on-going impacts.
Natural attenuation	1	Considered the most sustainable technique Available field data indicates groundwater conditions are likely to be suitable Likely to be most suitable technique for remediation of low/residual levels of benzene contamination Relatively low overall cost	Will require long term monitoring to demonstrate attenuation of source is occurring. Suitable monitoring wells will need to be maintained on site and may need to be protected/replaced during site development. Monitoring may need to extend beyond the site development programme.	Would result in long-term reduction of benzene concentrations in groundwater, however the long-term monitoring required may not meet programme objectives.
In situ chemical oxidation	=3	Proven technique for remediating benzene in groundwater In situ treatment relatively easy to install and less space required / disturbance above ground compared with ex-situ techniques . The remediation process is likely to be short term and could be completed within the proposed development programme. Could be used in combination with air-sparging techniques.	Lower sustainability Suitable injection wells would need to be installed. Likely to require an environmental permit Reagents can be relatively expensive and large quantities may need to be used. Additional health and safety and environmental mitigation for handling the chemicals on site. The effectiveness will rely on any existing sources contributing to dissolved phase benzene contamination being removed.	Would result in reduction of benzene concentrations in groundwater and overall betterment.
In situ air sparging	=3	Proven technique for remediating benzene in groundwater In situ treatment relatively easy to install and less space required / disturbance above ground compared with ex-situ techniques .	Lower sustainability Suitable injection and abstraction wells would need to be installed.	Would result in reduction of benzene concentrations in groundwater and overall betterment.

Remediation	Sustainability ranking (1=most sustainable)	Advantages	Disadvantages	Compliance with remediation objectives
		The remediation process is likely to be short term and could be completed within the proposed development programme. Would be most cost effective if used to treat several contaminant sources.	Likely to require an environmental permit The effectiveness will rely on the source contributing to dissolved phase benzene contamination being removed. Must confirm hydrogeological conditions are suitable i.e.where no phreatic surface may not be suitable	
Pump and treat	5	Proven technique for remediating benzene in groundwater Installation and pumping via wells, so low intrusiveness. Contaminant removal from source zone, so easily quantifiable benefits	High energy demand for pumping and treating. Treatment options: treatment and discharge to ground – likely high standard of treatment and potentially lengthy permitting process; offsite tankering – traffic impact, costly, low sustainability; foul sewer – costly.	Betterment will be straightforward to demonstrate. May be difficult to achieve specific remediation criteria. Could be used in conjunction with in situ technique

B3 Remediation options appraisal 2: Vinyl chloride in KPGR in DZ7

B3.1 Summary of source characterisation and risk assessment

Remediation options appraisal 2 (ROA2) considers the vinyl chloride source in DZ7, identified in monitoring wells DZ7_2058 and DZ7_BH2060.

A remedial target of 0.0046mg/l has been derived which is close to two orders of magnitude lower than concentrations recorded in the groundwater DZ7_BH2058. The model predicts that concentrations of 0.033mg/l will occur at a compliance point 50m from the source which is similar to the mean concentrations in DZ7_BH2060 (0.024mg/l) and which is approximately 50m from the source. The model therefore predicts that concentrations of vinyl chloride could impact a down gradient compliance point and the site data appears to corroborate this result.

Only recent groundwater data is available in this area of the site and therefore it is unclear if concentrations are stable, increasing or declining. The results from installing biotraps and subsequent microbial analysis confirms that various microbial cultures are present (at moderate to high levels) capable of facilitating both aerobic and reductive degradation processes.

The density of wells in this part of the site is relatively low and therefore delineation and characterisation of the source is limited. The source of the impact also remains unconfirmed and it is unclear if any residual shallow source remains (e.g. in soil or associated with former infrastructure).

Therefore a conservative approach has been followed, assuming the vinyl chloride source identified at DZ7_2058 requires remediation, with consideration in this remediation options appraisal.

Figure B 2 Observed KPGR vinyl chloride concentrations

B3.2 Remediation objectives

- To address contaminant linkage to ensure that no unacceptable long-term risks are posed by the vinyl chloride groundwater source at DZ7 to identified receptors;
- To reduce source concentrations where feasible to achieve vinyl chloride target, or to improve current site conditions.

B3.3 Initial appraisal of options

A long list of available options for managing groundwater contamination is has been defined in Table 7, utilising the ‘Land contamination: remediation option applicability matrix’ [4].

Table B 7 Vinyl chloride initial remediation options appraisal

Method type	Remediation options	Technically feasible at MW (1-5)	Overall cost (£ to £££)	Process reliability	Programme (years)	Possible Advantages	Possible Disadvantages	Comments
Civil engineering	Turnover of shallow soils in unsaturated zone to identify and remove/remediate any soil sources, tanks etc.	1	£ - ££	Good	<1 year	Would identify and remove shallow contaminant sources within unsaturated zone and reduce any ongoing contaminant source to groundwater. Could be incorporated into site-wide earthworks strategy	Large volume and deep excavation may be required to chase out any contamination encountered with associated environmental and H&S risks. Would not treat any existing groundwater source and additional remediation techniques may be required. Additional volumes of contaminated soil to treat/dispose of.	**Feasible option** A turnover of shallow soils is proposed as part of the site-wide earthworks and additional excavation in the source area could be incorporated into the earthworks strategy with limited impact on project programme. The removal of any contaminant sources would reduce any ongoing sources of contamination to groundwater resulting in an overall betterment.
Civil engineering	Containment - hydraulic barriers	5	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Construction and maintenance of wells relatively expensive. Technically challenging. May require long term operation to pump and treat groundwater. Large quantities of contaminated groundwater to treat/dispose of. H&S and environmental implications.	**Option not feasible** Rejected as a feasible option on grounds of high cost, technical complexity and long-term programme commitment.
Civil engineering	Containment - in ground barriers	5	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Construction and maintenance relatively expensive. Technically challenging. H&S and environmental implications. Below ground system may be issue for below ground structures of future development (e.g. foundations).	**Option not feasible** Rejected as a feasible option on grounds of high cost, technical complexity and long-term programme commitment.
Biological	Natural attenuation	2	£	Average - Good	1 - 30	Overall cost likely to be lower than active remediation techniques. Less intrusive as few surface structures are required. Limited generation or transfer of waste.	Will require long term monitoring to demonstrate attenuation of source is occurring. Suitable monitoring wells will need to be maintained on site and may need to be protected/replaced during site development. Extensive site characterisation required to collect lines of evidence that attenuation processes are occurring. Contingency plan will need to be in place if contaminants do not degrade as predicted.	**Feasible option** Conditions of KPGR (including confirmed presence of suitable microbes) appear to be favourable for natural attenuation to occur, however further monitoring would be required to confirm rates of attenuation. The long-term monitoring required may not meet programme objectives.
Biological	Biosparging	5	££	Low	0.5 - 3	Minimal site disturbance. Would reduce source concentrations.	Can be costly and not a common technique used for vinyl chloride. May need to be used in combination with other techniques.	**Option not feasible**Tnot commonly used for vinyl chloride and therefore based on uncertainty of technique suitability and high cost, not taken forward as potentially feasible option .
Chemical	In situ chemical oxidation	2	££	Average - Good	<1 year	Oxidation reactions are often fast and can result in significant degradation. Relatively low technical complexity.	Can be expensive and reagents will be rapidly depleted by other organics. May require large volumes of reagent to be injected. Environmental considerations if using aggressive reagents. May need to be used in combination with other techniques.	**Feasible option** Low technical complexity but reagents can be expensive and may rapidly deplete; this technique is likely to only be of benefit if used in combination with other remedial techniques (including remediation that addresses any residual shallow source). Other groundwater contaminants of concern assessed in this ROA may benefit from remediation by this

Method type	**Remediation options**	**Technically feasible at MW (1-5)**	**Overall cost (£ to £££)**	**Process reliability**	**Programme (years)**	**Possible Advantages**	**Possible Disadvantages**	**Comments**
								technique and it may be a more cost-effective option where it is used to treat more than one contaminant source.
Physical	In situ air sparging	2	££	Average - Good	0.5 - 3	Minimal site disturbance. Can be highly cost effective. Considered to be one of most effective means of treating vinyl chloride	Injection/abstraction wells would need to be installed on site. Difficult to reduce concentrations below those already detected in KPGR. May require injection of chemical oxidants to assist with treatment. Must confirm hydrogeological conditions are suitable for air sparging i.e.where no phreatic surface may not be suitable	**Feasible option** Technique is unlikely to significantly reduce concentrations below those already detected and therefore costs for treatment may be difficult to justify for use as a standalone technique. Other groundwater contaminants of concern assessed in this ROA may benefit from remediation by this technique and it may be a more cost-effective option where it is used to treat more than one contaminant source and used in combination with chemical oxidation.
Physical	Permeable reactive barriers	5	£££	Average	>10	Below ground system which once installed can represent fewer constraints to surface developments Can be relatively easy to maintain and monitor. Can be a good solution for inaccessible or dispersed source	Construction and maintenance could be relatively expensive. Reactive media may need to be replaced over time. Technically challenging. Long term operation and monitoring will be necessary. Below ground system may be issue for below ground structures of future development (e.g. foundations). Reactive media may need to be disposed as a hazardous waste	**Option not feasible** Rejected as a feasible option on grounds of high cost, technical complexity and long-term programme commitment.
Physical	Pump and treat	3	£££	Poor	>2	Minimal site disturbance. Removes contaminant mass from aquifer	Potentially long term. Large quantity of contaminated water to manage. Relatively expensive. Low sustainability due to wastewater disposal requirements: tanker offsite, discharge to foul sewer (expensive), on site treatment plant (disposal to ground or foul sewer)	**Feasible option** Technique relatively easy to install and operate. Achieving defined targets is notoriously difficult due to rebound of concentrations when pumps switched off. But operating for a fixed duration to remove as much contaminant loading as possible (in say 1 year) is achievable and more realistic.

Technical feasibility 1 – straight forward, proven, reliably effective — Cost £ - Low cost
Technical feasibility 5 – unproven, very difficult, limited confidence in success. — Cost ££ - Medium cost
Process reliability – Low, Average, Good — Cost £££ - High cost

B3.4 Detailed options evaluation

The initial appraisal of options has identified the following short list of potentially feasible techniques for the remediation of the vinyl chloride groundwater source:

- **Turnover soils in unsaturated zone to identify and remove/remediate any soils sources, tanks etc.**

  This option would require a ‘turnover’ of shallow soils in the unsaturated zone in DZ7 to confirm no significant ongoing source is contributing to dissolved phase groundwater contamination. Any gross contamination, tanks or other potential contaminant sources identified within the soils would be removed and treated or disposed of.

  The removal of any contaminant source would result in overall betterment of existing site conditions but would not treat existing dissolved phase vinyl chloride groundwater concentrations. A period of groundwater monitoring should be undertaken alongside the earthworks to enable further assessment of the source and determine if any additional remediation of groundwater is necessary.

  A turnover of shallow soils is proposed as part of the site-wide earthworks and additional excavation in the source area could be incorporated into the earthworks strategy which would minimise impact on the development programme.

  There will be associated environmental and health and safety risks if large volume removal and deep excavation is required to ‘chase out’ any significant contamination encountered, which could result in significant additional volumes of soil to treat/dispose of.

- **Natural attenuation**

  Vinyl chloride in groundwater will naturally attenuate where conditions are favourable. Natural degradation of vinyl chloride would result in an overall long-term reduction in groundwater concentrations.

  Based on available groundwater monitoring data, field measurements of dissolved oxygen levels within groundwater in the KPGR indicate aerobic conditions which are likely to be suitable for natural attenuation to occur. Vinyl chloride itself is a break-down product of other chlorinated compounds some of which have been recorded at lower concentrations (e.g. trans-1,2-dichloroethene) which suggests that degradation of chlorinated solvents is naturally occurring. This has also been demonstrated by microbial studies that have confirmed the presence of microbes capable of supporting both aerobic and reductive dichlorination within the groundwater in DZ7_BH2058 Further groundwater monitoring would be required during the remediation and earthworks programme to evaluate the efficacy of natural attenuation.

  Suitable groundwater monitoring wells would need to be maintained on site for the duration of the monitoring programme and may need to be protected/replaced during site development works. Some post-development monitoring may be necessary and the period of monitoring required would be determined by site conditions, however it may need to extend beyond the development programme.

- **In situ air sparging**

  Air sparging is a proven technique for remediating vinyl chloride. It involves in situ treatment and disturbance at ground surface would be minimal compared to ex situ techniques. Suitable injection and abstraction wells would need to be installed. The remediation process is likely to be short to medium term and could be completed within the proposed development programme. This remediation technique is likely to require an environmental permit, as it is considered unlikely that it would meet the definition of a small-scale remediation scheme [6].

  While air sparging is considered to be an effective technique for treating vinyl chloride, it may prove difficult to significantly reduce the existing concentrations recorded in the KPGR and could be difficult to justify using as a standalone remediation technique. Air sparging may not be suitable where there is no phreatic surface in the KPGR. If air sparging is undertaken it may be beneficial to carry out in combination with the injection of chemical oxidants.

- **In situ chemical oxidation**

  Chemical oxidation may assist with treatment of vinyl chloride. It involves in situ treatment and therefore disturbance at ground surface would be minimal compared to ex situ techniques. Suitable injection wells would need to be installed. The remediation process is likely to be short term and could be completed within the proposed development programme. This remediation technique is likely to require an environmental permit, as it is considered unlikely that it would meet the definition of a small-scale remediation scheme [6].

  The remediation contractor would need to select the most suitable oxidising reagent to use based on site conditions. Once injected the oxidation reactions can occur relatively quickly, however it may prove difficult to significantly reduce existing vinyl chloride concentrations recorded in the KPGR.

  The reagents can be relatively expensive and some reagents will be rapidly depleted by other organics in groundwater which could result in a large volume of reagent needing to be injected. Depending on the reagent used toxic intermediate breakdown products can be formed. If aggressive reagents are being used then additional health and safety and environmental mitigation may be required for handling the chemicals on site.

- **Pump and treat**

  Pump and treat is a proven technique for remediation of vinyl chloride contaminated groundwater. However it is now used less frequently than in the past as it has been shown to be difficult to achieve remediation targets (particularly if there is any residual NAPL) and can result in costly (and low sustainability) long term pumping, treatment and discharge requirements. Discharge of water without treatment could be to foul sewer or tankered offsite to waste water treatment facility. Water treated on site could be discharged back into the ground with EA approval and an environmental permit. An alternative arrangement could be to pump for a fixed duration, say 3months to substantially reduce the source, in conjunction with another follow-on technique to treat residual. However the benefits of this approach are limited compared to in situ technique alone.

A high-level qualitative assessment of the sustainability of each technique is provided in Table 8, based on the scores and weighting described in Tables 2 and 3. Based on this assessment natural attenuation is considered to be the most sustainable remedial technique.

Table B 8 Qualitative assessment of sustainability of remediation options for vinyl chloride (lowest score = least sustainable)

Remediation option	**Emissions to air**	**Soil and ground conditions**	**Groundwater and surface water**	**Ecology**	**Natural resources and waste**	**Human health and safety**	**Neighbourhoods and locality**	**Uncertainty and evidence**	**Direct economic costs and benefits**	**Project lifespan and flexibility**	**TOTAL SCORE (weighting applied)**
Weighting	**3**	**3**	**5**	**1**	**5**	**4**	**3**	**4**	**5**	**4**	
Turnover of shallow soils in unsaturated zone to identify and remove/remediate any soils sources, tanks etc.	2	2	2	1	2	2	2	2	2	3	77
Natural attenuation	3	3	2	3	3	3	3	2	3	1	94
In situ chemical oxidation	2	1	2	3	2	2	2	2	1	3	71
In situ air sparging	2	1	2	3	2	2	2	2	1	3	71
Pump and treat	2	1	2	3	1	2	2	1	1	2	59

A summary of the feasible remedial techniques for the vinyl chloride source is provided below.

Table B 9 Summary of feasible remediation options for vinyl chloride

Remediation	**Sustainability ranking**	**Advantages**	**Disadvantages**	**Compliance with remediation objectives**
Turnover of shallow soils in unsaturated zone to identify and remove/remediate any soils sources, tanks etc.	2	Would provide confidence that no significant ongoing source remains and would improve the effectiveness of other remediation techniques. Could be incorporated into site-wide earthworks and turnover minimising impact on development programme.	Large volume and deep excavation may be required with associated environmental and H&S risks. Would not treat any existing groundwater source and additional remediation techniques may be required where gross contamination identified in groundwater. Could generate additional volumes of contaminated soil to treat/dispose of.	The removal of any contaminant source in the unsaturated sone would result in overall betterment of the existing site condition. This option would not directly reduce existing dissolved phase vinyl chloride groundwater concentrations but would supplement other groundwater treatment techniques and reduce potential for on-going impacts.
Natural attenuation	1	Considered the most sustainable technique Available field data indicates groundwater conditions are suitable for natural attenuation to occur. Likely to be most suitable technique for remediation low/residual levels of vinyl chloride contamination Relatively low overall cost.	Will require long term monitoring to demonstrate attenuation of source is occurring. Suitable monitoring wells will need to be maintained on site and may need to be protected/replaced during site development. Monitoring may need to extend beyond the site development programme.	Would result in long-term reduction of vinyl chloride concentrations in groundwater, however the long-term monitoring required may not meet programme objectives.
In situ chemical oxidation	=3	Proven technique for remediating vinyl chloride in groundwater In situ treatment easy to install and less space required / disturbance above ground compared with ex-situ techniques. The remediation process is likely to be short term and could be completed within the proposed development programme. Could be used in combination with air-sparging techniques.	Considered the least sustainable technique Suitable injection wells would need to be installed. Likely to require an environmental permit Reagents can be relatively expensive and large quantities may need to be used. Additional health and safety and environmental mitigation for handling the chemicals on site. May prove difficult to significantly reduce existing vinyl chloride concentrations recorded in the KPGR. Unlikely to be suitable to justify use as standalone technique	May result in some long-term betterment of vinyl chloride concentrations in groundwater, but significant reduction in existing concentrations is likely to be difficult to achieve.

Remediation	Sustainability ranking	Advantages	Disadvantages	Compliance with remediation objectives
In situ air sparging	=33	Proven technique for remediating vinyl chloride in groundwater In situ treatment relatively easy to install / undertake compared to ex situ techniques. The remediation process is likely to be short term and could be completed within the proposed development programme.	Low sustainability Suitable injection and abstraction wells would need to be installed. Likely to require an environmental permit May prove difficult to significantly reduce existing vinyl chloride concentrations recorded in the KPGR. Unlikely to be suitable to justify use as standalone technique Air sparging may not be suitable where the no phreatic surface in the KPGR.	May result in some long-term betterment of vinyl chloride concentrations in groundwater, but significant reduction in existing concentrations is likely to be difficult to achieve.
Pump and treat	5	Proven technique for remediating vinyl chloride in groundwater Installation and pumping via wells, so low intrusiveness. Contaminant removal from source zone, so easily quantifiable benefits	High energy demand for pumping and treating. Treatment options: treatment and discharge to ground – likely high standard of treatment and potentially lengthy permitting process; offsite tankering – traffic impact, costly, low sustainability; foul sewer – costly.	Betterment will be straightforward to demonstrate. May be difficult to achieve specific remediation criteria. Could be used in conjunction with in situ technique

B4 Remediation options appraisal 3: TPH >C12 to C16 aromatics east of gasholder in KPGR in DZ2

B4.1 Summary of source characterisation and risk assessment

Across DZ4 and DZ2 concentrations of >C12 to C16 aromatics are elevated, however the DQRA concluded that considering the conservatism of the model and the likely previous very large impacts from multiple significant sources in this area, the evidence suggests concentrations of TPH are relatively low, indicating that natural degradation processes are effective. Groundwater in the KPGR is not in continuity with Pymmes Brook and naturalisation works will avoid creation of any pathway. No intervention for dissolved phase TPH across DZ4 and most of DZ2 except ongoing monitoring is proposed. However dewatering that will be undertaken for Pymmes Brook naturalisation will result in abstraction and treatment of dissolved phase hydrocarbon-contaminated groundwater from the western part of DZ4.

However, in standpipes situated adjacent to the east side of the gas holder base in DZ2 a marked rise in concentrations was observed during the latter rounds of baseline monitoring in 2020 with concentrations suggesting the probable presence of free product, although this wasn't detected during monitoring.

The remediation options appraisal considers techniques in which the risks associated with both dissolved phase and free phase hydrocarbons can be managed in the area east and southeast of the gasholder base.

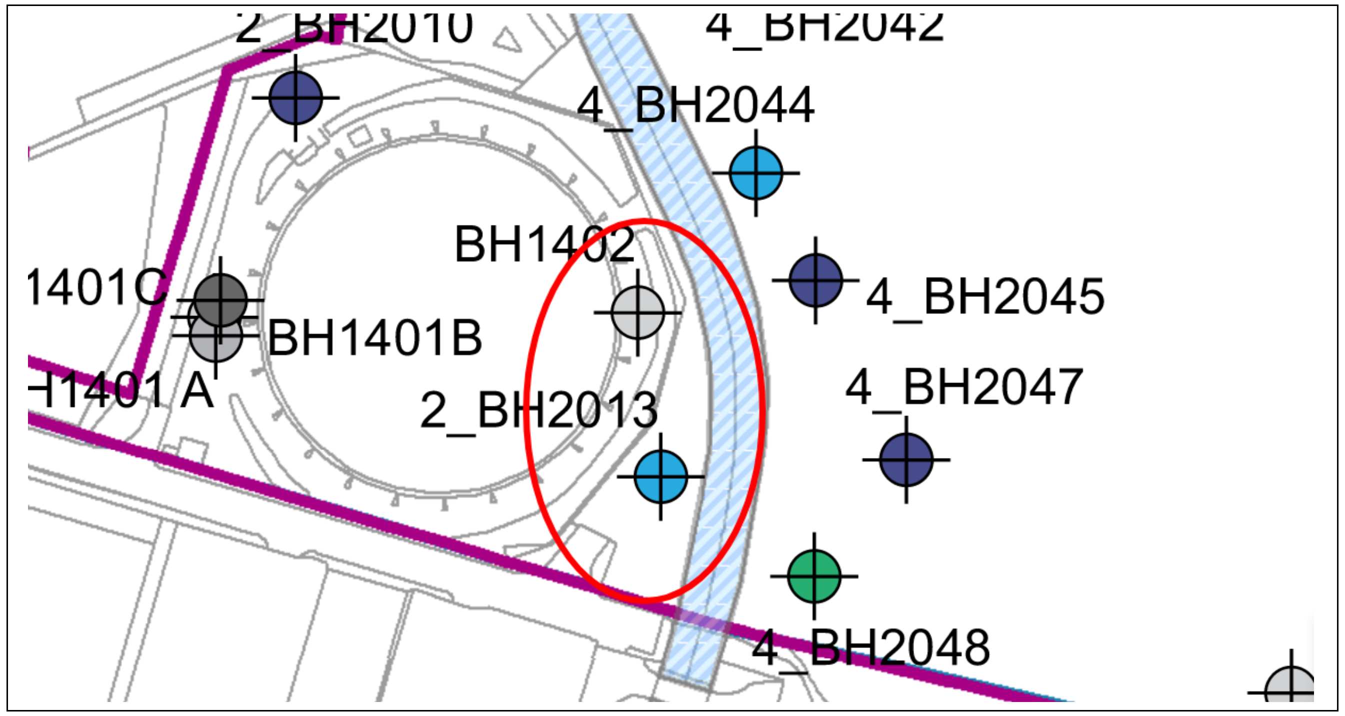


Figure B 3 Area of possible TPH free product in DZ2

B4.2 Remediation objectives

- To address contaminant linkage to ensure that no unacceptable long-term risks are posed by the TPH (dissolved phase and NAPL) groundwater source in DZ2 to identified receptors;
- To reduce source concentrations and remove NAPL where feasible to result in improvement over current site conditions.

B4.3 Initial appraisal of options

A long list of available options for managing groundwater contamination has been defined in Table 10, utilising the 'Land contamination: remediation option applicability matrix' [4]

Table B 10 TPH initial remediation options appraisal

Method type	Remediation options	Technically feasible at MW (1-5)	Overall cost (£ to £££)	Process reliability	Programme (years)	Possible Advantages	Possible Disadvantages	Comments
Civil engineering	Turnover of soils in unsaturated zone to remove any residual sources of TPH e.g. tanks, hotspots of gross contaminated soils and NAPL / confirm no significant on-going source	1	£ - ££	Good	<1 year	Would identify and remove gross contamination hotspots within unsaturated zone and reduce any ongoing contaminant source to groundwater. Could be incorporated into site-wide earthworks strategy	Large volume and deep excavation may be required with associated environmental and H&S risks. Would not treat any existing dissolved groundwater source. Additional remediation techniques may be required to treat NAPL and/or dissolved phase contamination identified in groundwater. Additional volumes of contaminated soil to treat/dispose of.	**Feasible option** A turnover of shallow soils is proposed as part of the site-wide earthworks and additional excavation in the source area could be incorporated into the earthworks strategy with limited impact on project programme. The removal of any contaminant hotspots would reduce potential on going impacts to groundwater resulting in an overall betterment. TPH concentrations in groundwater are indicative of the presence of residual free product and removal of any on-going source will be necessary to achieve any betterment of dissolved phase groundwater concentrations.
Physical	Extraction of localised free phase product within shallow groundwater e.g. skimming	2	££	Average to Good	0.5 – 3	Would reduce/remove any localised free phase product within shallow groundwater, and reduce any on-going source resulting in long term betterment of dissolved phase concentrations. Could be implemented alongside turnover of soils reducing impact on development programme with skimming equipment deployed in open excavations where possible	Would not treat dissolved phase groundwater contamination in the short term. Additional volumes of contaminated product/water to dispose of. May require initial treatability/mass recovery trials prior to deployment. Additional wells may be needed for skimmers.	**Feasible option** Would reduce any localised free product source encountered in shallow groundwater and result in long-term betterment of dissolved phase ground concentrations. Need to be deployed based on findings of soil turnover.
Civil engineering	Containment - hydraulic barriers	5	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Construction and maintenance of wells relatively expensive. Technically challenging. May require long term operation to pump and treat groundwater. Large quantities of contaminated groundwater to treat/dispose of. H&S and environmental implications.	**Option not feasible** Rejected as a feasible option on grounds of high cost, technical complexity and long-term programme commitment.
Civil engineering	Containment - in ground barriers	5	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Construction and maintenance relatively expensive. Technically challenging. H&S and environmental implications. Below ground system may be issue for below ground structures of future development (e.g. foundations).	**Option not feasible** Rejected as a feasible option on grounds of high cost, technical complexity and long-term programme commitment.
Biological	Natural attenuation	2	£	Average - Good	1 - 30	Overall cost likely to be lower than many active remediation techniques. Less intrusive as few surface structures are required. Limited generation or transfer of remediation wastes.	Will require long term monitoring to demonstrate attenuation of source is occurring. Suitable monitoring wells will need to be maintained on site and may need to be protected/replaced during site development. Extensive site characterisation required to collect lines of evidence that attenuation processes are occurring.	**Feasible option** Conditions (aerobic) of KPGR appear to be favourable for natural attenuation to occur, however further monitoring would be required to prove this. The long-term monitoring required may not meet programme objectives. Effectiveness of technique would be enhanced by removal of any localised free product / on-goimg source.

Method type	Remediation options	Technically feasible at MW (1-5)	Overall cost (£ to £££)	Process reliability	Programme (years)	Possible Advantages	Possible Disadvantages	Comments
						Would improve dissolved phase concentrations (following extraction of free phase product where encountered)	Contingency plan will need to be in place if contaminants do not degrade as predicted.	
Chemical	In situ hemical oxidation	2	££	Average - Good	<1 year	Oxidation reactions are often fast and can result in significant (complete) degradation. Relatively low technical complexity.	Would be unsuitable for treatment of dissolved phase contamination where significant residual free product sources remain. Can be expensive and reagents will be rapidly depleted by other organics. May require large volumes of reagent to be injected. Toxic intermediate breakdown products may be formed which require other treatment techniques. Environmental considerations if using aggressive reagents.	**Feasible option** Effectiveness of technique will rely on residual source contributing to dissolved phase being significantly removed. Oxidation should be considered as an additional technique that could be used with other methods to result in some general betterment in dissolved phase concentrations.
Physical	In situ air sparging	5	££	Average	0.5 - 3	Minimal site disturbance.	Majority of TPH mass comprises low volatility compounds and therefore the technique will not be effective. Would not treat any free product. May need to be used in combination with other techniques. Injection/abstraction wells would need to be installed on site.	**Option not feasible** Expensive and technically unlikely to be suitable for remediation of dissolved phase contamination based on the type (low volatility) of hydrocarbons recorded. Also ineffective at remediating free phase.
Physical	Permeable reactive barriers	5	£££	Average	>10	Below ground system which once installed can represent fewer constraints to surface developments Can be relatively easy to maintain and monitor. Can be a good solution for inaccessible or dispersed source.	Construction and maintenance could be relatively expensive. Reactive media may need to be replaced over time. Technically challenging. May require long term operation and long-term monitoring will be necessary. Below ground system may be issue for below ground structures of future development (e.g. foundations). Reactive media may need to be disposed as a hazardous waste	**Option not feasible** Rejected as a feasible option on grounds of high cost, technical complexity and long-term programme commitment.
Physical	Pump and treat	4	£££	Poor	>2	Minimal site disturbance. Removes contaminant mass from aquifer	Unsuitable if NAPL residual remains. Potentially long term. Large quantity of contaminated water to manage. Relatively expensive. Low sustainability due to wastewater disposal requirements: tanker offsite, discharge to foul sewer (expensive), on site treatment plant (disposal to ground or foul sewer)	**Option not feasible** Rejected as a feasible option due to the likely presence of small quantities of residual NAPL.

Technical feasibility 1 – straight forward, proven, reliably effective — Cost £ - Low cost
Technical feasibility 5 – unproven, very difficult, limited confidence in success. — Cost ££ - Medium cost
Process reliability – Low, Average, Good — Cost £££ - High cost

B4.4 Detailed options evaluation

The initial appraisal of options has identified the following short list of potentially feasible techniques for the remediation of the TPH groundwater source:

- **Turnover soils in unsaturated zone to remove residual sources of TPH e.g. tanks, hotspots of gross contaminated soils and NAPL / confirm no significant on-going source**

  Any treatment of dissolved phase TPH contaminants is likely to be ineffective / unjustifiable while any significant residual source in unsaturated soil continues to cause on-going impacts. A ‘turnover’ of soils in the unsaturated zone around DZ2 followed by removal of gross contamination, tanks or other potential contaminant sources would result in overall betterment of existing site conditions but would not treat existing dissolved phase TPH groundwater concentrations.

  The findings of the turnover would be reviewed to assess if any further physical treatment of groundwater is necessary. If additional techniques to treat the dissolved phase contamination in groundwater are proposed, the effectiveness of these techniques would be improved by the removal of any ongoing source.

  A turnover of shallow soils is proposed as part of the site-wide earthworks and additional excavation in the source area could be incorporated into the earthworks strategy which would minimise impact on the development programme. There will be associated environmental and health and safety risks if large volume soil removal and deep excavation is required to ‘chase out’ any significant contamination encountered, which could result in significant additional volumes of soil to treat/dispose of.

  If the excavations encounter any free product in shallow groundwater additional extraction techniques would be required to remove the NAPL e.g. skimming.

- **Extraction of localised free phase product within shallow groundwater e.g. skimming**

  The concentrations of TPH recorded in groundwater in DZ2 are indicative of the presence of free product, however no NAPL has been recorded during the groundwater monitoring undertaken at the site to date. This option is likely to be used in combination with the turnover of soils described above.

  Any free product encountered within groundwater during excavations would be extracted using skimming techniques. This could be implemented in open excavations where possible and additional wells for skimming equipment may need to be installed. The removal of any residual free product in groundwater would result in overall long-term betterment of existing site conditions.

  If additional techniques to treat the dissolved phase contamination in groundwater are proposed, the effectiveness of these techniques would be improved by the removal of any ongoing source. The remediation process is likely to be short to medium term and could be completed within the proposed development programme.

  Depending on the extraction technique proposed by the remediation contractor, initial treatability or mass recovery trials may be necessary prior to deployment. While any free product is likely to be localised, this technique could result in additional volumes of contaminated product/water to dispose of. Depending on the method used and volumes extracted an environmental permit may be required.

- **Natural attenuation**

  Dissolved phase TPH in groundwater will naturally attenuate where conditions are favourable. Natural degradation of TPH would result in an overall long-term reduction in groundwater concentrations.

  Based on available groundwater monitoring data, field measurements of dissolved oxygen levels within groundwater in the KPGR indicate aerobic conditions which are likely to be suitable for natural attenuation to occur. Groundwater monitoring during the remediation and earthworks programme would be required to assess if aquifer conditions are suitable to sustain natural degradation to gain regulator approval.

  Suitable groundwater monitoring wells would need to be maintained on site for the duration of the monitoring programme and may need to be protected/replaced during site development works. Some post-development monitoring may be necessary and the period of monitoring required would be determined by site conditions, however it may need to extend beyond the development programme.

  Natural attenuation is likely to be the most suitable option for remediating low/residual levels of TPH in groundwater, either in isolation or in combination with other techniques. The effectiveness of this technique would be impeded by the presence of any localised free product.

- **In situ chemical oxidation**

  Chemical oxidation is a proven technique that can be used for treatment of dissolved phase TPH. Involves in situ treatment and disturbance at ground surface would be minimal compared to ex situ techniques. Suitable injection wells would need to be installed. The remediation process is likely to be short term and could be completed within the proposed development programme. This remediation technique is likely to require an environmental permit, as it is considered unlikely that it would meet the definition of a small scale remediation scheme [6].

  The remediation contractor would need to select the most suitable oxidising reagent to use based on site conditions. Once injected the oxidation reactions can occur relatively quickly and can result in significant degradation of benzene concentrations.

  The reagents can be relatively expensive and some reagents will be rapidly depleted by other organics in groundwater which could result in a large volume of reagent needing to be injected. Depending on the reagent used toxic intermediate breakdown products can be formed. If aggressive reagents are being used then additional health and safety and environmental mitigation may be required for handling the chemicals on site.

  The effectiveness will rely on the source contributing to dissolved phase TPH contamination being removed/reduced (e.g. by dig through of soils in unsaturated zone and skimming of any product). Oxidation should be considered as an additional technique that could be used with other methods to result in some general betterment in dissolved phase concentrations.

  Other groundwater contaminants of concern assessed in this ROA may benefit from remediation by this technique and it may be a more cost-effective option where it is used to treat more than one contaminant source.

A high-level qualitative assessment of the sustainability of each technique is provided in Table 11, based on the scores and weighting described in Tables 2 and 3. Based on this assessment natural attenuation is considered to be the most sustainable remedial technique.

Table B 11 Qualitative assessment of sustainability of remediation options for TPH (lowest score = least sustainable)

Remediation option	Emissions to air	Soil and ground conditions	Groundwater and surface water	Ecology	Natural resources and waste	Human health and safety	Neighbourhoods and locality	Uncertainty and evidence	Direct economic costs and benefits	Project lifespan and flexibility	TOTAL SCORE (weighting applied)
Weighting	**3**	**3**	**5**	**1**	**5**	**4**	**3**	**4**	**5**	**4**	
Turnover of soils in unsaturated zone to remove any residual sources of TPH e.g. tanks, hotspots of gross contaminated soils and NAPL / confirm no significant on-going source	2	2	3	1	2	2	2	2	2	3	77
Extraction of localised free phase product within shallow groundwater e.g. skimming	2	2	3	3	2	2	3	2	2	2	83
Natural attenuation	3	3	2	3	3	3	3	2	3	1	94
In situ chemical oxidation	2	1	2	3	2	2	2	2	1	3	71

A summary of the feasible remedial techniques is provided in Table 12.

Table B 12 Summary of feasible remediation options for TPH

Remediation	Sustainability ranking	Advantages	Disadvantages	Compliance with remediation objectives
Turnover of soils in unsaturated zone to remove any residual sources of TPH e.g. tanks, hotspots of gross contaminated soils and NAPL / confirm no significant on-going source	2	Would provide confidence that no significant ongoing source in soil remains and would improve the effectiveness of other remediation techniques. Could be incorporated into site-wide earthworks and turnover minimising impact on development programme. The effectiveness of other remedial techniques will be reliant on any source contributing to dissolved phase contamination being removed/reduced.	Large volume and deep excavation may be required with associated environmental and H&S risks. Would not treat any existing groundwater source and additional remediation techniques may be required focussing on the groundwater source. Could generate additional volumes of contaminated soil to treat/dispose of.	The removal of any contaminant source in the unsaturated sone would result in overall betterment of the existing site condition. Any physical treatment of dissolved phase contamination is unlikely to be effective / justifiable if significant residual sources remain. This option would not directly reduce existing dissolved phase TPH groundwater concentrations but would improve the effectiveness of other techniques which may be used to directly treat groundwater.
Extraction of localised free phase product within shallow groundwater e.g. skimming	3	Would reduce/remove any localised free phase product within shallow groundwater, and reduce any on-going source resulting in long term betterment of groundwater quality. Could be implemented alongside turnover of soils reducing impact on development programme with skimming equipment deployed in open excavations where possible.	Would not treat dissolved phase groundwater contamination in the short term. Additional volumes of contaminated product/water to dispose of. May require initial treatability/mass recover trials prior to deployment. Additional wells may be needed for skimmers	Would reduce any localised free product source encountered in shallow groundwater and result in long-term betterment of groundwater quality. Could be deployed in conjunction with soil turnover or as a separate exercise using additional wells .
Natural attenuation	1	Considered the most sustainable technique	The presence of free product or shallow soil sources may prevent or impede natural processes of degradation.	Would result in long-term reduction of dissolved phase TPH concentrations in groundwater, however the long-term monitoring required may not meet

Remediation	Sustainability ranking	Advantages	Disadvantages	Compliance with remediation objectives
		Available field data indicates groundwater conditions are suitable for natural attenuation to occur Likely to be most suitable technique for remediation of low/residual levels of dissolved phase TPH contamination Relatively low overall cost	Will require long term monitoring to demonstrate attenuation of source is occurring. Suitable monitoring wells will need to be maintained on site and may need to be protected/replaced during site development. Monitoring may need to extend beyond the site development programme	programme objectives. The effectiveness of this technique may be impeded by the presence of any localised free product.
Chemical oxidation	4	Proven technique for remediating TPH in groundwater In situ treatment easy to install and less space required / disturbance above ground compared with ex-situ techniques. The remediation process is likely to be short term and could be completed within the proposed development programme.	Suitable injection wells would need to be installed. Likely to require an environmental permit. Reagents can be relatively expensive and large quantities may need to be used. Additional health and safety and environmental mitigation for handling the chemicals on site. The effectiveness will rely on the source contributing to dissolved phase benzene contamination being removed.	The effectiveness will rely on the source contributing to dissolved phase TPH contamination being removed/reduced (e.g. by dig though of soils in unsaturated zone). Oxidation should be considered as an additional technique that could be used with other methods to result in some general betterment in dissolved phase concentrations.

B5 Remediation options appraisal 4: Ammoniacal nitrogen and cyanide in KPGR in DZ2 and DZ4

B5.1 Summary of source characterisation and risk assessment

Ammoniacal nitrogen and cyanide contamination in groundwater is typical of chemical works associated with gasworks, such as Leeside Chemical Works, and gasworks-type operations. The RTM Level 3 target concentration for ammonium in DZ4 (1.2mg/l) is approximately thirty times lower than mean concentrations in KPGR groundwater in the south of DZ4, and down gradient concentrations 150m from the source (8.8mg/l) exceed the EQS (also by approximately thirty times). Similarly in DZ2 the Level 3 target concentration for ammonium (1.47mg/l) is approximately twenty times lower than mean concentrations recorded in KPGR groundwater east of the gasholder. The presence of an extensive area of elevated ammoniacal nitrogen in the south of DZ4 and DZ2 suggests that these contaminants have migrated and dispersed through the groundwater in the KPGR, which is consistent with the findings of the RTM assessment. The DQRA assessed the plume as potentially stable and possibly declining.

The DQRA concluded an appraisal of remedial options for ammonium in groundwater is required, with consideration of the feasibility of achieving the specific targets and the relative associated costs of any intervention. The DQRA noted that there was no identified short-term risk to surface waters or a drinking water supply and that the origin of the ammoniacal nitrogen was likely to be historical release of liquors. It anticipated the outcome of the remediation options appraisal as most likely a non-remediation focussed effort e.g. initially assurance / verification monitoring focussing on the distribution, concentration trends / stability of the ammonium plume in the KPGR. This is explored in the remediation options appraisal below.

The RTM Level 3 targets for complex cyanide in DZ4 and DZ2 (0.0027 to 0.0035mg/l) are very stringent reflecting the potential for complex cyanide (depending on the speciation) to be very persistent. Mean concentrations of cyanide (~0.2mg/l) in KPGR groundwater across DZ2 and the south of DZ4 are over an order of magnitude higher than these criteria. The travel time for impacts to reach down gradient compliance points is relatively slow (100 years). The RTM model is very conservative for various reasons:

- EQS is based on free cyanide concentrations which are very low in the KPGR at Meridian Water (separate RTM evaluation of free cyanide indicates that attenuation of free cyanide will be rapid and that significant impacts will not occur)).

- Literature values for complex cyanide are very conservative and are unlikely to reflect the variable forms of complex likely to be present at the site.

- The model assumes advective flow in a constant direction and velocity which on this site due to very flat contours and sometimes variable direction is probably conservative.

The DQRA concluded, similarly to ammoniacal nitrogen in DZ2 and DZ4, an appraisal of remedial options for cyanide in groundwater is required, with consideration of feasibility of achieving targets and the associated costs of any intervention. The current plume in KPGR is not predicted to present a risk to surface water or drinking water resources.

The remedial options appraisal for ammoniacal nitrogen and cyanide in KPGR in DZ2 and DZ4 is presented below.

Cyanide in KPGR	Ammonium in KPGR

Figure B 4 Cyanide and ammonium concentration in KPGR in DZ2 and DZ4

B5.2 Remediation objectives

- To address contaminant linkage to ensure that no unacceptable long-term risks are posed by the ammonium and cyanide in groundwater source in DZ2 and DZ4 to identified receptors;
- To reduce source concentrations, where feasible to achieve targets, or for improvement compared to current site conditions.

B5.3 Initial appraisal of options

A long list of available options for managing groundwater contamination has been defined in Table B 13 for ammoniacal nitrogen, utilising the ‘Land contamination: remediation option applicability matrix’ [4]. Turnover of soils across DZ4 and eastern DZ2 will be undertaken as part of the SIW. However as contaminants most likely entered groundwater as a liquor release, significant source is not anticipated to remain in the unsaturated zone. Relatively high levels of ammonium do remain in the Alluvium however site leachate data indicates that this source remains strongly sorbed to soil particles and is not expected to be contributing significantly to the ammonium levels. Whilst the turnover and subsequent development (buildings/hardstanding/low permeability cap) will result in improvement in groundwater quality it is not identified as a remedial option in its own right in this ROA.

Table B 13 Ammoniacal nitrogen initial remediation options appraisal

Method type	Remediation options	Technically feasible at MW (1-5)	Overall cost (£ to £££)	Process reliability	Programme (years)	Possible Advantages	Possible Disadvantages	Comments
Civil engineering	Containment - hydraulic barriers	5	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Very large plume in groundwater. Construction and maintenance of wells would be expensive. Technically challenging. May require long term operation to pump and treat groundwater. Large quantities of contaminated groundwater to treat/dispose of. H&S and environmental implications. Treatment techniques expensive.	**Option not feasible** Rejected as a feasible option due to very large plume and on the grounds of high cost, technical complexity and long-term programme commitment.
Civil engineering	Containment - in ground barriers	5	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Construction and maintenance relatively expensive. Technically challenging. H&S and environmental implications. Below ground system may be issue for below ground structures of future development (e.g. foundations).	**Option not feasible** Rejected as a feasible option due to very large plume and on the grounds of high cost, technical complexity and long-term programme commitment.
Biological	Natural attenuation	1	£	Average - Good	1 - 30	Overall cost lower than active remediation techniques. Less intrusive as few surface structures are required. Less generation or transfer of remediation wastes.	Will require long term monitoring to demonstrate attenuation of source is occurring. Suitable monitoring wells will need to be maintained on site and may need to be protected/replaced during site development. Extensive site characterisation required to collect lines of evidence that attenuation processes are occurring.	**Option feasible** Conditions (aerobic) of KPGR appear to be favourable for natural attenuation to occur, however further monitoring would be required to prove this.
Chemical	In situ air sparging	3	£££	Average - Good	0.5 - 3	Concentration of ammonium in groundwater considered suitable for this technique to be applied	Air sparging units can cause fouling issues due to the high pH levels needed. System expensive to operate Performance of technique difficult to predict.	**Option not feasible** Rejected as a feasible option due to very large plume and on the grounds of high cost, technical complexity, uncertainty of success and long-term programme commitment. May only be worth investigating benefits for betterment of ammonium if technique was being used for other contaminants (benzene).
Physical	Permeable reactive barriers	5	£££	Average	>10	Below ground system which once installed can represent fewer constraints to surface developments Can be relatively easy to maintain and monitor. Can be a good solution for inaccessible or dispersed source	Construction and maintenance could be relatively expensive. Reactive media may need to be replaced over time. Technically challenging. May require long term operation and long-term monitoring will be necessary. Below ground system may be issue for below ground structures of future development (e.g. foundations). Reactive media may need to be disposed as a hazardous waste	**Option not feasible** Rejected as a feasible option due to very large plume and on the grounds of high cost, technical complexity and long-term programme commitment
Physical	Pump and treat	4	£££	Poor	>5	Minimal site disturbance. Removes contaminant mass from aquifer	Potentially long term. Large quantity of contaminated water to manage. Relatively expensive. Low sustainability due to wastewater disposal requirements: tanker offsite, discharge to foul sewer (expensive), on site treatment plant (disposal to ground or foul sewer)	**Option not feasible** Rejected as a feasible option due to extensive source and plume requiring wells over a large area and result in large scale pumping, at high cost, low sustainability, potentially for long duration.

Technical feasibility 1 – straight forward, proven, reliably effective — Cost £ - Low cost
Technical feasibility 5 – unproven, very difficult, limited confidence in success. — Cost ££ - Medium cost
Process reliability – Low, Average, Good — Cost £££ - High cost

A long list of available options for managing groundwater contamination is has been defined in Table B 13for cyanide, utilising the ‘Land contamination: remediation option applicability matrix’ [4].

Table B 14 Cyanide initial remediation options appraisal

Method type	**Remediation options**	**Technically feasible at MW (1-5)**	**Overall cost (£ to £££)**	**Process reliability**	**Programme (years)**	**Possible Advantages**	**Possible Disadvantages**	**Comments**
Civil engineering	Containment - hydraulic barriers	5	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Large plume to contain. Construction and maintenance of wells relatively expensive. Technically challenging. May require long term operation to pump and treat groundwater. Large quantities of contaminated groundwater to treat/dispose of. H&S and environmental implications. Treatment techniques expensive.	**Option not feasible** Rejected as a feasible option due to very large plume and on the grounds of high cost, technical complexity and long-term programme commitment
Civil engineering	Containment - in ground barriers	5	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Construction and maintenance relatively expensive. Technically challenging. H&S and environmental implications. Below ground system may be issue for below ground structures of future development (e.g. foundations).	**Option not feasible** Rejected as a feasible option due to very large plume and on the grounds of high cost, technical complexity and long-term programme commitment
Biological	Natural attenuation	2	£	Average	>10	Overall cost lower than active remediation techniques. Less intrusive as few surface structures are required. Less generation or transfer or remediation wastes.	Depending on speciation attenuation of cyanide is potentially slow, but dilution, dispersion, sorption and biotransformation and degradation expected to result in mass reduction over time. Will require long term monitoring to demonstrate attenuation of source is occurring. Suitable monitoring wells will need to be maintained on site and may need to be protected/replaced during site development. Extensive site characterisation required to collect lines of evidence that attenuation processes are occurring.	**Option feasible** Attenuation of cyanide expected through dilution, dispersion, sorption and biotransformation / degradation. Long term monitoring would be required to confirm groundwater concentrations are stable/improving.
Physical	Chemical oxidation (neutralisation of groundwater with sodium hypochlorite and then treatment with oxidation reagent)	4	£££	Average - Good	0.5 - 3	Solution could treat groundwater to reduce cyanide concentrations	Treatment expensive. Typically used for waste-water treatment processes and considered inappropriate for treatment of concentrations of cyanide recorded in groundwater Treatment has potential to form free cyanide or cyanogen chloride gas which would need to be managed and would have H&S and environmental implications Low sustainability	**Option not feasible** Rejected as a feasible option due to very large plume, high cost, technical complexity, programme implications and potential for hazardous by-products.
Physical	UV oxidation	4	£££	Average - Good	0.5 - 3	Relatively new technique that has been developed to treat cyanide in water and could reduce concentrations	Treatment expensive. Plant required is large and generally used for waste-water treatment processes and considered inappropriate for treatment of concentrations of cyanide recorded in groundwater	**Option not feasible** Rejected as a feasible option due to very large plume and on the grounds of high cost, technical complexity and programme implications.
Physical	Permeable reactive barriers	5	£££	Average	>10	Below ground system which once installed can represent fewer constraints to surface developments	Construction and maintenance could be relatively expensive. Reactive media may need to be replaced over time. Technically challenging. May require long	**Option not feasible** Rejected as a feasible option due to very large plume and on the grounds of high

Method type	Remediation options	Technically feasible at MW (1-5)	Overall cost (£ to £££)	Process reliability	Programme (years)	Possible Advantages	Possible Disadvantages	Comments
						Can be relatively easy to maintain and monitor. Can be a good solution for inaccessible or dispersed source	term operation and long-term monitoring will be necessary. Below ground system may be issue for below ground structures of future development (e.g. foundations). Reactive media may need to be disposed as a hazardous waste.	cost, technical complexity and programme implications
Physical	Pump and treat	4	£££	Poor	>5	Minimal site disturbance. Removes contaminant mass from aquifer	Potentially long term. Large quantity of contaminated water to manage. Relatively expensive. Low sustainability due to wastewater disposal requirements: tanker offsite, discharge to foul sewer (expensive), on site treatment plant (disposal to ground or foul sewer)	**Option not feasible** Rejected as a feasible option due to extensive source and plume requiring wells over a large area and result in large scale pumping, at high cost, low sustainability, potentially for long duration.
Technical feasibility 1 – straight forward, proven, reliably effective Technical feasibility 5 – unproven, very difficult, limited confidence in success. Process reliability – Low, Average, Good						Cost £ - Low cost Cost ££ - Medium cost Cost £££ - High cost		

B5.4 Detailed options evaluation

Based on the review of available remediation options for ammonium and cyanide in KPGR, natural attenuation assessed by undertaking groundwater monitoring to collect evidence to confirm a shrinking or stable plume, is considered to be the only feasible option. Dissolved phase ammonium in groundwater will naturally attenuate where conditions are favourable and the natural degradation would result in an overall long-term reduction in groundwater concentrations. Based on available groundwater monitoring data, field measurements of dissolved oxygen levels within groundwater in the KPGR indicate aerobic conditions which are likely to be suitable for natural attenuation to occur. Groundwater monitoring during the remediation and earthworks programme would be required to assess if aquifer conditions are suitable to sustain natural degradation to gain regulator approval.

Whilst some forms of cyanide are potentially very stable , long term mass reduction and attenuation is expected by dilution, dispersion, biotransformation and degradation. Long term monitoring would be required to confirm groundwater concentrations are stable/improving. Suitable groundwater monitoring wells would need to be maintained on site for the duration of the monitoring programme and may need to be protected/replaced during site development works. Some post-development monitoring may be necessary and the period of monitoring required would be determined by site conditions, however it may need to extend beyond the development programme.

B6 Remediation options appraisal 5: Ammoniacal nitrogen and cyanide in Chalk in DZ2/DZ4

B6.1 Summary of source characterisation and risk assessment

Ammoniacal nitrogen in Chalk in DZ2 and DZ4

Concentrations of ammonium of approximately 20mg/l in DZ4_BH2045 (assumed to be close to the plume core) are more than an order of magnitude higher than the target criteria derived by RTM of 0.67mg/l. The model also predicts that ammonium will move rapidly in Chalk groundwater (e.g. half a year to travel 150m) and therefore combined with the low level of attenuation predicted by the model the contamination would be expected to spread rapidly. This demonstrates the conservatism is the model as concentrations to the north east of the plume in DZ4_BH2038 and in DZ4_BH1511 remained consistently low during the baseline monitoring.

High uncertainty has been identified associated with modelling this contaminant in Chalk due to low confidence in the literature half-lives and the potential for retardation that is likely driven by ion exchange reactions.

Cyanide in Chalk in DZ2 and DZ4

The target concentration of 0.059mg/l for complex cyanide is approximately three times lower than mean concentrations (0.16mg/l) identified in the south west of DZ4 where cyanide concentrations are highest. As such the model predicts that complex cyanide has the potential to migrate through Chalk groundwater and exceed drinking water standard at a compliance point 150m from the source. The model also predicts that contaminant transport will be slow (230 years to migrate 150m). However as with the evaluation of cyanide in KPGR the parameter selections for complex cyanide are very conservative and there is high uncertainty associated with modelling this constituent as complex cyanide can take different forms.

Presently there appears to be a plume front situated in between DZ4_BH2043 and DZ4_BH1511 and therefore at present the plume of cyanide in Chalk groundwater is several hundred metres from the closest groundwater abstraction.

Risk management considerations

The DQRA concluded continued monitoring of cyanide and ammonium in Chalk should be undertaken focussing on concentration trends and evidence of migration of the plume towards abstractions situated north east and east of the site. It also noted the remediation options appraisal should identify if other potential methods of risk management are available with consideration of feasibility of achieving targets and the associated costs of any intervention.

The remedial options appraisal for ammoniacal nitrogen and cyanide in Chalk in DZ2 and DZ4 is presented below.

B6.2 Remediation objectives

- To address contaminant linkage to ensure that no unacceptable long-term risks are posed by the ammonium and cyanide in groundwater in chalk in DZ2 and DZ4 to identified receptors;
- To reduce source concentrations, where feasible achieving targets, or for improvement compared to current site conditions.

B6.3 Initial appraisal of options

A long list of available options for managing groundwater contamination is has been defined in Table B 15 for ammonium, utilising the ‘Land contamination: remediation option applicability matrix’ [4].

Table B 15 Ammonium initial remediation options appraisal

Method type	Remediation options	Technically feasible at MW (1-5)	Overall cost (£ to £££)	Process reliability	Programme (years)	Possible Advantages	Possible Disadvantages	Comments
Civil engineering	Containment - hydraulic barriers	5	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Construction and maintenance of wells relatively expensive. Technically challenging. May require long term operation to pump and treat groundwater. Large quantities of contaminated groundwater to treat/dispose of. H&S and environmental implications. Treatment techniques expensive.	**Option not feasible** Rejected as a feasible option due to very high cost, technical complexity and programme implications.
Civil engineering	Containment - in ground barriers	5	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Construction and maintenance relatively expensive. Technically challenging. H&S and environmental implications. Below ground system may be issue for below ground structures of future development (e.g. foundations).	**Option not feasible** Rejected as a feasible option due to very high cost, technical complexity and programme implications
Biological	Natural attenuation	1	£	Average - Good	1 - 30	Overall cost lower than active remediation techniques. Less intrusive as few surface structures are required. Less generation or transfer or remediation wastes.	Will require long term monitoring to demonstrate attenuation of source is occurring. Suitable monitoring wells will need to be maintained on site and may need to be protected/replaced during site development. Site characterisation required to collect lines of evidence that attenuation processes are occurring.	**Option feasible** Conditions (aerobic) of Chalk appear to be favourable for natural attenuation to occur, however further monitoring would be required to prove this.
Chemical	Air sparging	3	£££	Average - Good	0.5 - 3	Concentration of ammonium in groundwater considered suitable for this technique to be applied	Air sparging units can cause fouling issues due to the high pH levels needed. System expensive to operate Performance of technique difficult to predict.	**Option not feasible** Rejected as a feasible option due to very high cost, technical complexity and programme implications.
Physical	Permeable reactive barriers	5	£££	Average	>10	Below ground system which once installed can represent fewer constraints to surface developments Can be relatively easy to maintain and monitor. Can be a good solution for inaccessible or dispersed source	Construction and maintenance would be expensive. Reactive media may need to be replaced over time. Technically challenging. May require long term operation and long-term monitoring will be necessary. Below ground system may be issue for below ground structures of future development (e.g. foundations).	**Option not feasible** Rejected as a feasible option due to very high cost, technical complexity and programme implications
Physical	Pump and treat	4	£££	Poor	>5	Minimal site disturbance. Removes contaminant mass from aquifer	Potentially long term. Large quantity of contaminated water to manage. Relatively expensive. Low sustainability due to wastewater disposal requirements: tanker offsite, discharge to foul sewer (expensive), on site treatment plant (disposal to ground or foul sewer)	**Option not feasible** Rejected as a feasible option due to extensive source and plume requiring wells over a large area and result in large scale pumping, at high cost, low sustainability, potentially for long duration.

Technical feasibility 1 – straight forward, proven, reliably effective | Cost £ - Low cost
Technical feasibility 5 – unproven, very difficult, limited confidence in success. | Cost ££ - Medium cost
Process reliability – Low, Average, Good | Cost £££ - High cost

A long list of available options for managing groundwater contamination is has been defined in Table 16 for cyanide, utilising the ‘Land contamination: remediation option applicability matrix’ [4].

Table B 16 Cyanide initial remediation options appraisal

Method type	Remediation options	Technically feasible at MW (1-5)	Overall cost (£ to £££)	Process reliability	Programme (years)	Possible Advantages	Possible Disadvantages	Comments
Civil engineering	Containment - hydraulic barriers	5	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Construction and maintenance of wells relatively expensive. Technically challenging. May require long term operation to pump and treat groundwater. Large quantities of contaminated groundwater to treat/dispose of. H&S and environmental implications. Treatment techniques expensive.	**Option not feasible** Rejected as a feasible option due to very high cost, technical complexity and programme implications
Civil engineering	Containment - in ground barriers	5	£££	Average	>10	Would prevent further discharge of contaminated groundwater from source	Construction and maintenance relatively expensive. Technically challenging. H&S and environmental implications. Below ground system may be issue for below ground structures of future development (e.g. foundations).	**Option not feasible** Rejected as a feasible option due to very high cost, technical complexity and programme implications
Biological	Natural attenuation	2	£	Average	>10	Overall cost lower than active remediation techniques. Less intrusive as few surface structures are required. Less generation or transfer or remediation wastes.	Depending on speciation attenuation of cyanide is potentially slow, but dilution, dispersion, sorption and biotransformation and degradation expected to result in mass reduction over time. Will require long term monitoring to demonstrate attenuation of source is occurring. Suitable monitoring wells will need to be maintained on site and may need to be protected/replaced during site development. Extensive site characterisation required to collect lines of evidence that attenuation processes are occurring.	**Option feasible** Attenuation of cyanide expected through dilution, dispersion, sorption and biotransformation / degradation.Long term monitoring would be required to confirm groundwater concentrations are stable/improving.
Physical	Chemical oxidation (neutralisation of groundwater with sodium hypochlorite and then treatment with oxidation reagent)	4	£££	Average - Good	0.5 - 3	Solution could treat groundwater to reduce cyanide concentrations	Treatment expensive. Typically used for waste-water treatment processes and considered inappropriate for treatment of concentrations of cyanide recorded in groundwater Treatment has potential to form free cyanide or cyanogen chloride gas which would need to be managed and would have H&S and environmental implications Low sustainability	**Option not feasible** Rejected as a feasible option due to very high cost, technical complexity and programme implications
Physical	UV oxidation	4	£££	Average - Good	0.5 - 3	Relatively new technique that has been developed to treat cyanide in water and could reduce concentrations.	Treatment expensive. Plant required is large and generally used for waste-water treatment processes and considered inappropriate for treatment of concentrations of cyanide recorded in groundwater	**Option not feasible** Rejected as a feasible option due to very high cost, technical complexity and programme implications.
Physical	Permeable reactive barriers	5	£££	Average	>10	Below ground system which once installed can represent fewer constraints to surface developments Can be a good solution for inaccessible or dispersed source	Construction and maintenance would be expensive. Reactive media may need to be replaced over time. Technically challenging. May require long term operation and long-term monitoring will be necessary. Below ground system may be issue for below ground structures of future development (e.g. foundations).	**Option not feasible** Rejected as a feasible option due to very high cost, technical complexity and programme implications

Method type	Remediation options	Technically feasible at MW (1-5)	Overall cost (£ to £££)	Process reliability	Programme (years)	Possible Advantages	Possible Disadvantages	Comments
							Reactive media may need to be disposed as a hazardous waste	
Physical	Pump and treat	4	£££	Poor	>5	Minimal site disturbance. Removes contaminant mass from aquifer	Potentially long term. Large quantity of contaminated water to manage. Relatively expensive. Low sustainability due to wastewater disposal requirements: tanker offsite, discharge to foul sewer (expensive), on site treatment plant (disposal to ground or foul sewer)	**Option not feasible** Rejected as a feasible option due to extensive source and plume requiring wells over a large area and result in large scale pumping, at high cost, low sustainability, potentially for long duration.
Technical feasibility 1 – straight forward, proven, reliably effective Technical feasibility 5 – unproven, very difficult, limited confidence in success. Process reliability – Low, Average, Good						Cost £ - Low cost Cost ££ - Medium cost Cost £££ - High cost		

B6.4 Detailed options evaluation

Based on the review of available remediation options for ammonium and cyanide in Chalk groundwater, natural attenuation assessed by undertaking groundwater monitoring to collect evidence of stable of decreasing concentrations, is considered to be the only feasible option.

Dissolved phase ammonium in groundwater will naturally attenuate where conditions are favourable and the natural degradation would result in an overall long-term reduction in groundwater concentrations. Based on available groundwater monitoring data, field measurements of dissolved oxygen levels within groundwater in the Chalk indicate aerobic conditions which are likely to be suitable for natural attenuation to occur. Groundwater monitoring during the remediation and earthworks programme would be required to assess if aquifer conditions are suitable to sustain natural degradation to gain regulator approval.

Whilst some forms of cyanide are potentially very stable, long term mass reduction and attenuation is expected by dilution, dispersion, biotransformation and degradation. Long term monitoring would be required to confirm groundwater concentrations are stable/improving.

Suitable groundwater monitoring wells would need to be maintained on site for the duration of the monitoring programme and may need to be protected/replaced during site development works. Some post-development monitoring may be necessary and the period of monitoring required would be determined by site conditions, however it may need to extend beyond the development programme.

Appendix C

Derivation of reuse and verification criteria

C1 Introduction

C1.1 Background

This appendix sets out the methodology that has been utilised to develop chemical criteria for the re-use of site won soils as part of the proposed earthworks.

C1.2 Proposed development

As set out in the main report text, the proposed works will involve earthworks including the placement of fill materials and cover systems.

Within the development plots and roads, the ground levels will be brought to 500mm below formation level. The remaining build up will comprise the piling mat or road build up and therefore does not form part of the fill or capping layer.

Within the park areas the earthworks bring the ground levels to finish levels.

Based on the proposed earthworks and development plans, two sets of re-use criteria are proposed for the site:

- Cover soils – material suitable for use within the cover layer in Brooks Park, Edmonton Marshes and within the flood conveyance channel. It also includes the top layer of material (0.5m) placed to achieve the required level in future development plots. Topsoil is a sub-set of this category.
- General fill – material placed beneath cover soil in soft landscaped areas and future development plots and beneath hardcover areas such as roads.

In addition, topsoil within the cover soils will need to meet the requirements of BS 3882[1].

C1.3 Zoned approach for general fill criteria

For the purposes of defining general fill criteria the site has been split into two different zones as follows:

- Zone A - site wide excluding south of DZ4 (IKEA Clear)
- Zone B – southern part of DZ4 only including the non-hardstanding covered area south of BOC buildings (i.e. IKEA clear)

Zone B is associated with generally higher levels of residual contamination in both soil and groundwater than Zone A. This means that independent of the reuse criteria specified for the soil that additional mitigation measures will be required as part of the follow-on development to address the residual contamination compared with Zone A where mitigation requirements are likely to be less onerous. In particular it is considered likely that specific vapour / gas protection measures will be required for new buildings in Zone B. On this basis, whereas the reuse criteria proposed for zone A will include criteria that are protective of human health risk by potential vapour intrusion, in Zone B these criteria are excluded.

Both Zone A and Zone B will include target criteria that are protective of risk to controlled waters.

[1] British Standards Institute, (2015). *Specification for Topsoil*. BS 3882:2015.

C2 Calculation of risk based-criteria criteria

A single set of re-use criteria has been derived that is protective of risks to controlled waters, in both general fill and cover soil, across the site. The controlled waters criteria have been derived using the Environment Agency ConSim model.

Two sets of criteria protective of human health have been derived using the Environment Agency Contaminated Land Exposure Assessment (CLEA) model; one set is protective of human health risk from exposure to cover soils (applicable across the whole site) and the second set applies to general fill criteria (to be used in Zone A but not Zone B).

C2.1 Controlled waters criteria

The draft DQRA included an initial assessment of potential risk of reusing soils from across the site using the ConSim model. The original assessment, undertaken using ConSim, indicated that based on typical concentrations recorded in soil[2] that contaminants are unlikely to leach at sufficient levels to cause significant impacts to the underlying Kempton Park Gravels.

The ConSim model presented in the draft DQRA has since been updated to reflect comments received from the Environment Agency (letter reference NE/2021/133240/01-L01 dated 5th October 2021) and a new assessment completed to support the derivation of re-use criteria.

C2.1.1 Assessment methodology

The assessment has focussed on the evaluation of 19 determinants (See Table C1 in C2.1.2) though it has only been possible to derive finite criteria for a sub-set of these.

The selection of the 19 determinants reflects the detailed review of potential contaminant sources in soil and groundwater completed in the DQRA. The chosen determinants include five contaminants prioritised for the assessment of in-situ soil sources in the DQRA (ammoniacal nitrogen, cyanide, naphthalene, aromatic TPH >C10-C12 and aromatic TPH >C12-C16). The assessment has also included additional speciated TPH fractions (>C6-C10), PAH compounds (anthracene, benzo(a)pyrene and fluoranthene), benzene, vinyl chloride, phenol and several metals (arsenic, copper, nickel and zinc).

The compliance point for the assessment is a location in groundwater in Kempton Park Gravels down gradient of the source. Distances to compliance point of 50m and 150m have been selected for hazardous and non-hazardous substances respectively. This approach, consistent with the DQRA, reflects the absence of potential connectivity with surface water features. The use of down gradient compliance points are considered appropriate because the material will be site sourced rather than newly imported materials (i.e. a new source) and because the underlying groundwater in the KPGR already contains detectable concentrations of the contaminants being evaluated.

The source area for this assessment is based on the area of fill indicated by the current redevelopment plans which equates to a large area spanning most of DZ5 and part of DZ4. The same criteria have been derived to protect controlled waters across this area (i.e. for both Zone A and Zone B).

Infiltration is assumed to be 100% of effective rainfall (as used in the DQRA RTM assessment to model source 1). In the long-term this is likely to be conservative as redevelopment will introduce

[2] All of the data from soil samples from areas of proposed excavation was grouped to provide a statistical representation of the expected contaminant concentrations

buildings and areas of hardstanding that will (in some areas) reduce infiltration. This approach aligns with the EA recommendations on infiltration used in the ConSim assessment (Page 13 of NE/2021/133240/01-L01).

Where the ConSim model has predicted that discernible impacts will not reach the relevant compliance point within 10,000 years, reuse criteria protective of the groundwater have not been derived. This applies to the four metals (arsenic, copper, nickel and zinc), phenol, anthracene, benzo(a)pyrene and aliphatic TPH fractions >C6-C12.

For the remaining nine determinants reuse criteria have been derived by iteratively adjusting the source concentration (modelled as a single value) until the levels of predicted impact are considered to be within acceptable limits. In most cases this is based on the predicted peak 90%ile or 95%ile values not exceeding the relevant WQS at the compliance point. As an exception, for ammoniacal nitrogen the 50%ile peak (i.e. the most likely outcome) value has been used as the basis for deriving the re-use criteria.[3]

Physical and chemical input parameters used in the ConSim assessment to characterise the source, unsaturated soil (source zone) and the aquifer are provided in Table C1 and Table C2.

The results of the ConSim assessment are presented in Table C3.

[3] This reflects the frequent occurrence of ammoniacal nitrogen, and the difficulty of deriving target criteria for ammoniacal nitrogen that are not so conservative that they result in overly onerous criteria and result in very high volumes of material failing to achieve re-use targets and requiring off-site disposal (which is considered unsustainable).

C2.1.2 Contaminant chemical parameters

The chemical parameters for the contaminants of concern assessed using ConSim are summarised in Table C1 below.

Table C1 Chemical parameters summary

Contaminant	Compliance criteria (mg/l)	Kd (ml/g)	Koc (cm^3/g)	Half-life (years)	Henry's law constant (unitless)
Ammoniacal nitrogen	0.6 – EQS for good quality for a type 3 water body	2.4 – Source [A] 9.9 – Alluvium 0.4 - KPGR	-	1,095 [B] [4]	N/A
Total Cyanide	0.025 – adjusted from EQS for free cyanide [C]	91 [D]	-	499 [E] [5]	N/A
Phenol (total)	0.0077 - EQS	-	83 [6]	0.0007 – 0.02 (uniform) [F] [7]	8.35×10^{-6} [6]
Vinyl Chloride	0.0005 - DWS	-	16.6 [10]	0.08 – 7.9 (uniform) [F] [7]	0.747 [10] [6]
Benzene	0.01 – EQS	-	68 [10]	0.027 – 2 (uniform) [F] [7]	0.116 [10] [6]
Naphthalene	0.002 - EQS	-	646 [10]	0.001 – 0.7 (log uniform) [F] [7]	0.00662 [10] [6]
Anthracene	0.0001 - EQS		23,442 [9]	0.13 – 2.52 (uniform) [F] [7]	0.0046 [9] [6]
Benzo(a)pyrene	1.7×10^{-6} - EQS		128,825 [10]	0.16 – 2.9 (uniform) [F] [7]	1.76×10^{-6} [6]
Fluoranthene	6.3×10^{-6} - EQS		18,200 [10]	0.38 – 2.41 (uniform) [F] [7]	6.29×10^{-5} [6]
Aromatic TPH >C8 to C10	0.3 – WHO DWV [8]	-	1,600 [8]	0.01 – 1 uniform (ethylbenzene and xylenes indicator compounds) [F] [7]	0.253 [9]
Aromatic TPH >C10 to C12	0.09 – WHO DWV [8]	-	2,500 [8]	0.001 – 0.7 (log uniform) (naphthalene indicator compound) [F] [7]	0.0722 [9]
Aromatic TPH >C12 to C16	0.09 – WHO DWV [8]	-	5,000 [8]	0.13 – 2.52 uniform (anthracene indicator compound) [F] [7]	0.0126 [9]
Aliphatic TPH >C6 to C8	1.5 – WHO DWV [8]	-	4,000 [8]	0.076 [G] [10]	27.3 [9]
Aliphatic TPH >C8 to C10	0.3 – WHO DWV [8]	-	32,000 [8]	0.076 [H] [11]	41.5 [9]
Aliphatic TPH >C10 to C12	0.3 – WHO DWV [8]	-	250,000 [8]	0.12 [I] [16]	64.4 [9]
Arsenic	0.01 - EQS	7,037 [J]		9×10^{99}	N/A
Copper	0.016 – EQS adjusted for average bioavailability (6%)	9,400 [J]		9×10^{99}	N/A
Nickel	0.013 – EQS adjusted for average bioavailability (32%)	13,000 [J]		9×10^{99}	N/A
Zinc	0.036 - EQS adjusted for average bioavailability (30%) and background (3.3µg/l for River Lee)	26,000 [J]		9×10^{99}	N/A

A – For ammonium the Kd value for source zone has been derived from site specific soil and leachate data for Made Ground material. For the unsaturated zone the Kd is a site specific value calculated using soil and leachate data collected from the Alluvium. The 0.4 for KPGR is midpoint for clean sand and gravel (0.23ml/g to 0.57ml/g) from Buss et al 2004 [4]
B - From DQRA; close to mid-point of range (1 to 6 years), in Buss et al 2004, for ammonium ions in sands and gravels under aerobic conditions
C – Water quality target for total cyanide of 0.025mg/l has been derived by multiplying the EQS for free cyanide (0.001mg/l) by the ratio of total cyanide / free cyanide measured in groundwater across the site. Only samples containing detectable concentrations of both free cyanide and total cyanide were used in the calculation.
D – Median value of site derived Kds. Kds derived in 13 samples containing detectable cyanide (in soil and / or leachate). The majority of samples found to contain levels of cyanide below detection in leachate and soil (dry mass). Kd in samples derived from: total cyanide in soil concentration (dry weight analysis) / total cyanide in leachate.
E - From DQRA; midpoint of range from Meeusen et al 1992
F – Range for groundwater from Howard et al
G - Based on heptane classification by ECHA as readily biodegradable
H – Based on decane classified by ECHA as readily biodegradable

[4] Buss S.R., Herbert A.W., Morgan P., Thornton S.F. and Smith J.W.N. 2004. A Review of Ammonium Attenuation in Soil and Groundwater. Quarterly Journal of Engineering Geology and Hydrogeology v.37.
[5] Meeussen, J.C.L., Keizer M.G. and de Haan F.A.M. (1992) Chemical Stability and decomposition rate of iron cyanide complexes in soil solutions. Journal of Environmental Science and Technology 26 (3)
[6] Environment Agency, 2008. Compilation of data for priority organic pollutants for derivation of Soil Guideline Values, Science Report: SC050021/SR7.
[7] Howard P.H., Baethling R.S., Jarvis W.F., Meylan W.H. and Michalenko E.M. 1991. Handbook of Environmental Degradation Rates. CRC Press LLC
[8] CL:AIRE 2017. Petroleum hydrocarbons in groundwater: guidance on assessing petroleum hydrocarbons using existing hydrogeological risk assessment methodologies. Version 1.1. March
[9] LQM / CIEH, 2015. The LQM/CIEH S4ULs for Human Health Risk Assessment. Copyright Land Quality Management Limited reproduced with permission (Publication Number S4UL3227)
[10] ECHA database. Checked 1st September 2021. URL: https://echa.europa.eu/nl/registration-dossier/-/registered-dossier/14228/5/3/4.
[11] ECHA database. Checked 1st September 2021. URL: https://echa.europa.eu/nl/registration-dossier/-/registered-dossier/13896/5/3/2

Contaminant	Compliance criteria (mg/l)	Kd (ml/g)	Koc (cm^3/g)	Half-life (years)	Henry's law constant (unitless)
I - Half life of 45 days reported in soil for hydrocarbons, C11-C14, n-alkanes, isoalkanes, cyclics. Lower water half-lives (~28 days) reported for normal paraffin (>C9-C14) so soil value considered conservative. J - Median kd value calculated from site soil and leachate data					

C2.1.3 Model parameters

The physical parameters utilised for the ConSim model are summarised in Table C2.

Table C2 Physical parameters for source material - ConSim

Parameter	Distribution	Value	Justification / Notes
Fill materials			
Dry bulk density (g/cm^2)	triangular	Min – 1.2 Most likely – 1.5 Max – 1.7	Mean of 1.9g/cm^2 recorded in unsaturated soil. Lower density expected after excavation, stockpiling, turning / treatment and placement.
Water filled porosity	single	0.32	Derived using bulk density data and moisture content in soil from DZ4
Air filled porosity (fraction)	single	0.11	
Fraction of Organic Carbon (%)	triangular	Min – 0.3 Most likely – 1.7 Max – 7	Based on statistical distribution of 90 soil samples from proposed cut areas. Excludes two high outlier (14% and 21%) and a further two samples containing high levels of hydrocarbons (>5000mg/kg). Median selected as most likely value.
Source thickness (m)	triangular	Min – 0 Most likely – 2 Max - 5	Corresponding with proposed fill activities.
Unsaturated pathway			
Infiltration (mm/year)	normal	Mean - 171 SD – 17.1	100% of effective rainfall as calculated in DQRA. Average rainfall data (EA rainfall station 245176TP) between 1st October 2019 and 31st May 2020 – 1.98mm/day. Literature value from Hess [12] for average evapotranspiration in naturalisation/ park area of 550mm/yr. Average infiltration = 1.98mm – 1.51mm = 0.47mm
Water filled porosity (fraction)	Single	0.32	As fill
Unsaturated conductivity (m/s)	log triangular:	Min – 2.4 x 10^{-6} Most likely - 2.4 x 10^{-5} Max – 2.4 x 10^{-4}	Most likely is value for sandy clay loam, listed in table 4.4 of the CLEA Report SR3, pg.62 [13]. High and low end estimates an order of magnitude higher and lower respectively.
Dry bulk density (g/cm^2)	single	1.9	Site data
Fraction of organic carbon (%)	triangular	Min – 0.5 Most likely – 2.5 Max – 5.5	Based on statistical distribution of 12 soil samples in areas of proposed placement. Excludes one outlier (12%). Median selected as most likely value.
Vertical dispersivity (m)	triangular	Min – 0.05 Most likely – 0.25 Max – 0.35	10% of UZ thickness. '+1 correlation with UZ thickness'
Thickness (m)	triangular	Min – 0.5 Most likely – 2.5	Based on thickness of cohesive unsaturated zone material in placement areas in DZ4 and DZ5. '+1 correlation with vertical dispersivity'

[12] Hess T., 2010, Estimating Green Water Footprints in a Temperate Environment. Water 2010, 2(3), 351-362; https://doi.org/10.3390/w2030351
[13] Environment Agency (2009) Updated technical background to the CLEA model. Science Report: SC050021/SR3

Parameter	Distribution	Value	Justification / Notes
		Max – 3.5	
Aquifer pathway			
Thickness (m)	single	3.5	As DQRA assessment of RTM
Hydraulic conductivity (m/s)	log triangular	Min – 0.0001 Most likely – 0.00018 Max – 0.00046	Minimum is low end estimate based on rising head test results. Most likely is mean of site data. Max is a high-end estimate (interpretation of test results was difficult due to high rates of recharge) '-1 correlation with hydraulic gradient'
Hydraulic gradient (fraction)	triangular	Min - 0.002 Most likely – 0.004 Maximum – 0.008	Groundwater contours '-1 correlation with hydraulic conductivity'
Dry bulk density (g/cm^3)	single	1.9	As DQRA
Effective porosity (fraction)	single	0.3	
Lateral dispersivity (m)	single	0.5 (hazardous) 1.5 (non hazardous)	1% of pathway length
Longitudinal dispersivity (m)	single	5 (hazardous) 15 (non hazardous)	10% of pathway length
Fraction of organic carbon (%)	single	0.5	As DQRA

C2.1.4 Results

The results of the ConSim modelling are summarised in Table C3.

Table C3 Summary of ConSim assessment results

Contaminant	Predicted Travel Time (years)		Source concentration / Re-use target (mg/kg)	WQS (mg/l)	Predicted concentration (mg/l)			
	Minimum	Mean			50%ile	75%ile	90%ile	95%ile
Arsenic	16,800	24,000	Not taken forward to derive reuse criteria due to the absence of predicted impacts with 10,000 years or due to predicted impacts being extremely low (e.g. comfortably lower than WQS even at high source concentrations ->100,000mg/kg).					
Copper	19,000	26,500						
Nickel	19,000	26,500						
Zinc	19,000	26,500						
Anthracene	5,700	25,000						
Benzo(a)pyrene	31,000	140,000						
Aliphatic TPH >C6-C8	980	4,400						
Aliphatic TPH >C8-C10	7,700	35,000						
Aliphatic TPH >C10-C12	60,000	270,000						
Phenol	30	102						
Fluoranthene	4,400	20,000	10	$6.3x10^{-6}$	ND	ND	ND	$2x10^{-5}$
Naphthalene	184	740	1,000	0.002	ND	ND	ND	0.0002
Aromatic TPH >C8 to C10	400	1,800	10,000	0.3	ND	0.003	0.027	0.07
Aromatic TPH >C10 to C12	600	2,700	10,000	0.09	ND	ND	0.0003	0.006
Aromatic TPH >C12 to C16	1200	5,500	1,500	0.09	0.0015	0.02	0.058	0.085
Benzene	23	80	5	0.01	ND	0.002	0.006	0.01
Vinyl Chloride	10	26	0.01	0.0005	0.0001	0.00035	0.0005	0.0006
Ammoniacal Nitrogen	289	378	45	0.6	0.6	1.1	1.4	1.5
Total Cyanide	2,700	3,500	20	0.025	0.2	0.023	0.025	0.027

C2.2 Human health criteria

Two sets of human health-based criteria have been compiled; one for each of the general fill and cover soil categories (see previous description of these fill types in C1.2).

Both sets of criteria have been derived using the using CLEA v1.07 (Contaminated land exposure assessment) software[14].

The criteria for general fill have been derived using standard exposure assumptions for a residential land use with vapour inhalation as the only viable pathway (2.5% soil organic matter content). This reflects placement of these soils at least 1m below clean capping material and / or geo-composite liner or below hardstanding.

The criteria for cover soils have been derived using standard assumptions for residential public open space land use (2.5% soil organic matter content).

The CLEA derived criteria for general fill are presented below in Table C4.

Table C4 CLEA criteria – general fill

Contaminant	Assessment Criteria (mg/kg)
Acenaphthene	18,500
Acenaphthylene	17,200
Anthracene	546,000
Benzo(a)anthracene	102
Benzo(a)pyrene	378
Benzo(b)fluoranthene	338
Benzo(k)fluoranthene	14,600
Benzo(ghi)perylene	85,600
Chrysene	926
Dibenzo(a,h)anthracene	19.6
Fluoranthene	129,000
Fluorene	22,900
Indeno(123-cd)pyrene	3,190
Naphthalene	8.7
Phenanthrene	24,800
Pyrene	292,500
Benzene	1.1
Ethylbenzene	300
Toluene	3,080
o-xylene	323
m-xylene	302
p-xylene	289
Aliphatic TPH EC5 to EC6	118
Aliphatic TPH >EC6 to EC8	349
Aliphatic TPH >EC8 to EC10	98.9
Aliphatic TPH >EC10 to EC12	499
Aliphatic TPH >EC12 to EC16	4,200
Aliphatic TPH >EC16 to EC35	49,600
Aromatic TPH >EC5 to EC7	1,080
Aromatic TPH >EC7 to EC8	3,030
Aromatic TPH >EC8 to EC10	175
Aromatic TPH >EC10 to EC12	964
Aromatic TPH >EC12 to EC16	10,700
Aromatic TPH >EC16 to EC35	18,200
Hydrocarbon impacted soils	No grossly impacted soils or visible free phase
Visible asbestos material	No visible material
Non-visible material	<0.1%

[14] Environment Agency, 2015. CLEA Software Version 1.071.

The human health derived criteria for general fill will be used in Zone A (northern portion of DZ4 and DZ5) only and excluded from use in Zone B (southern part of DZ4).

The criteria derived for cover soil are presented in Table C5.

Table C5 CLEA criteria - cover soils

Contaminant	Assessment Criteria (mg/kg)
Arsenic	79
Beryllium	2.2
Cadmium	106
Chromium (trivalent)	1,539
Chromium (hexavalent)	7.7
Copper	12,000
Lead	630
Mercury (inorganic)	124
Nickel	231
Selenium	1,140
Vanadium	1,100
Zinc	80,500
Cyanide	24
Acenaphthene	14,800
Acenaphthylene	14,800
Anthracene	74,100
Benzo(a)anthracene	29
Benzo(a)pyrene	5.7
Benzo(b)fluoranthene	7.2
Benzo(k)fluoranthene	191
Benzo(g,h,i)perylene	637
Chrysene	57
Dibenzo(a,h)anthracene	0.57
Fluoranthene	3,080
Fluorene	9,870
Indeno(1,2,3-c,d)pyrene	82
Naphthalene	4,890
Phenanthrene	3,070
Pyrene	7,410
Benzene	72
Ethylbenzene	24,300
Toluene	55,900
O-Xylene	42,300
M-Xylene	42,200
P-Xylene	42,200
Aliphatic TPH EC5 to EC6	591,000
Aliphatic TPH >EC6 to EC8	609,000
Aliphatic TPH >EC8 to EC10	12,600
Aliphatic TPH >EC10 to EC12	12,600
Aliphatic TPH >EC12 to EC16	12,600

Contaminant	Assessment Criteria (mg/kg)
Aliphatic TPH >EC16 to EC35	251,000
Aromatic TPH >EC5 to EC7	72
Aromatic TPH >EC7 to EC8	55,900
Aromatic TPH >EC8 to EC10	5,030
Aromatic TPH >EC10 to EC12	5,040
Aromatic TPH >EC12 to EC16	5,050
Aromatic TPH >EC16 to EC35	3,770
Hydrocarbon impacted soils	No grossly impacted soils or visible free phase
Vinyl chloride	3.5
Total phenol	10,000
Visible asbestos material	No visible material
Non-visible material	No detectable fibres

The concentrations presented in Table C4 and Table C5 are risk-based numbers derived by the CLEA model. Some of the higher values will not be taken forward as re-use criteria due to more stringent criteria being derived for controlled waters or due to the introduction of non-risk-based caps for hydrocarbons. The final set of compiled re-use criteria is presented in the following section.

C3 Finalised re-use criteria

The proposed re-use criteria for the general fill and cover soil are presented in Table C6. The values proposed are generally the lowest of the human health-based criteria (specific to category) and controlled waters values. Overall TPH and PAH concentrations have also been capped to provide a qualitative criterion for material quality but are not directly related to risk derived criteria.

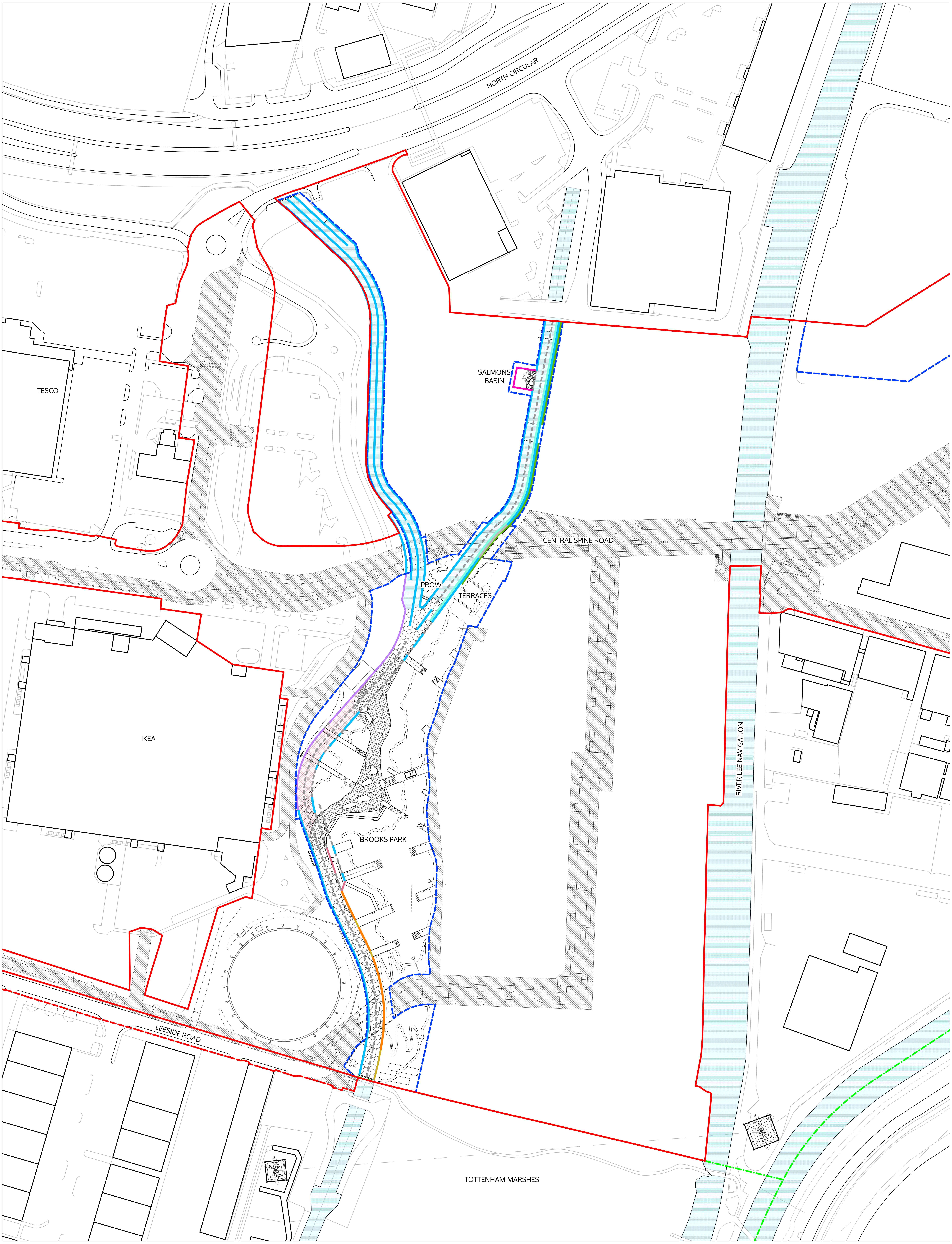
For the cover soils, criteria from BS 3882[1] (for a soil with a pH of 6 to 7) have also been included.

Table C6 Proposed re-use criteria for general fill and cover soils

Contaminant	Re-use criteria (mg/kg)		
	General fill		Cover soils
	Zone A	Zone B	
Arsenic	No criteria	No criteria	79 [A]
Beryllium	No criteria	No criteria	2.2 [A]
Cadmium	No criteria	No criteria	106 [A]
Chromium (trivalent)	No criteria	No criteria	1,539 [A]
Chromium (hexavalent)	No criteria	No criteria	21 [A]
Copper	No criteria	No criteria	270 [C]
Lead	No criteria	No criteria	630 [A]
Mercury (inorganic)	No criteria	No criteria	124 [A]
Nickel	No criteria	No criteria	150 [C]
Selenium	No criteria	No criteria	1,140 [A]
Vanadium	No criteria	No criteria	1,100 [A]
Zinc	No criteria	No criteria	400 [C]
Benzo(a)anthracene	102 [A]	No criteria	29 [A]
Benzo(a)pyrene	378 [A]	No criteria	5.7 [A]
Benzo(b)fluoranthene	338 [A]	No criteria	7.2 [A]
Benzo(k)fluoranthene	No criteria	No criteria	191 [A]
Benzo(g,h,i)perylene	No criteria	No criteria	637 [A]
Chrysene	926 [A]	No criteria	57 [A]
Dibenzo(a,h)anthracene	19.6 [A]	No criteria	0.57 [A]
Fluoranthene	10 [B]	10 [B]	10 [B]
Indeno(1,2,3-c,d)pyrene	No Criteria	No criteria	82 [A]
Naphthalene	8.7 [A]	No criteria	8.7 [A]
Sum USEPA 16 PAHs	1,000 [D]	1,000 [D]	500
Benzene	1.1 [A]	5 [B]	1.1 [A]
Ethylbenzene	300 [A]	No criteria	300 [A]
Toluene	3,080 [A]	No criteria	3,080 [A]
O-Xylene	323 [A]	No criteria	323 [A]
M-Xylene	302 [A]	No criteria	302 [A]
P-Xylene	289 [A]	No criteria	289 [A]
Aliphatic TPH EC5 to EC6	118 [A]	No criteria	118 [A]
Aliphatic TPH >EC6 to EC8	349 [A]	No criteria	349 [A]
Aliphatic TPH >EC8 to EC10	98.9 [A]	No criteria	98.9 [A]
Aliphatic TPH >EC10 to EC12	499 [A]	No criteria	499 [A]
Aromatic TPH >EC5 to EC7	1,080 [A]	No criteria	1,080 [A]
Aromatic TPH >EC7 to EC8	3,030 [A]	No criteria	3,030 [A]
Aromatic TPH >EC8 to EC10	175	No criteria	175
Aromatic TPH >EC10 to EC12	964 [A]	No criteria	964 [A]
Aromatic TPH >EC12 to EC16	1,500 [B]	1,500 [B]	1,500 [B]
Sum aliphatic and aromatic TPH EC5 to 35	5,000 [D]	5,000 [D]	1,000 [D]
Hydrocarbon impacted soils	No grossly impacted soils or visible free phase		
Ammoniacal nitrogen	45 [B]	45 [B]	45 [B]
Vinyl chloride	0.01 [B]	0.01 [B]	0.01 [B]
Total phenol	1,000 [D]	1,000 [D]	500 [D]
Complex cyanide	20 [B]	20 [B]	20 [B]
Visible asbestos material	No visible material		
Non-visible material	<0.1%	<0.1%	No detectable fibres
A – risk based criteria for human health			
B – risk based criteria for controlled waters			
C – Value is 2x the criteria proposed for phytotoxic metals from BS 3882. This reflects the requirement to place topsoil above cover soils reducing root contact and potential for plant uptake			
D – Non risk-based target criteria for total PAH and phenol set at 1000mg/kg for general fill and 500mg/kg for landscaped soils. Non -risk based target criteria for speciated TPH set at 5,000mg/kg for general fill and 1,000mg/kg for cover soil.			
In some cases risk based criteria for cover soil exceed general fill criteria (reflecting the inclusion of inhalation indoors in the risk model for the general criteria). In these cases cover soil values have been capped at the value derived for general fill as these soils should be to a higher specification.			

Appendix D

Brooks Park drawings



General Notes

No implied licence exists. This drawing should not be used to calculate areas for the purposes of valuation. Do not scale this drawing. All dimensions to be checked on site by the contractor and such dimensions to be their responsibility. All work must comply with relevant British Standards and Building Regulations requirements. Drawing errors and omissions to be reported to the architect.

This drawing to be printed and read in Colour.

NOTE: This drawing to be read in conjunction with the following documents:
-Outline Specification: 0052-PR-ZZ-ZZ-SP-L-0001
-Schedule: 0052-PR-ZZ-ZZ-SH-L-9050 and 0052-PR-ZZ-ZZ-SH-L-9051
-Details: 0052-PR-ZZ-ZZ-D-L-6000 Series

Notes

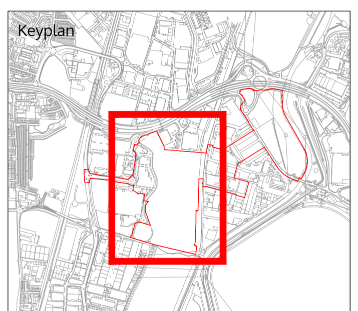
LEGEND

- SIW Planning Application Boundary
- Off Site Highway Works in LB Haringey
- Landscape Scope of Works
- Borough Boundary
- Highway/Bridge Design Scope of Works
- Existing concrete channel wall retained
- Ex. concrete channel wall cut to 750mm above SSL of channel
- Existing channel wall removed flush to channel SSL
- Existing channel wall cut down beneath bridge soffit
- Existing sheet pile wall cut to 750mm above SSL of channel
- Existing sheet pile wall retained at full height
- Proposed concrete retaining wall to Engineer's details
- Proposed flood defense wall extension over existing, to Engineer's details
- L181 / L182 - In-Channel Low Level Ecological Corridor
- Ex-Channel High Level Ecological Corridor
- Existing Watercourse - retained
- Existing Watercourse - removed
- L174 - Existing Watercourse - Bed Enhancement
- L175 - Proposed Watercourse - Naturalised riverbed. Concrete channel bed removed as required

Revisions

Rev	Date	Reason for Issue	Chk
07	05.03.2020	Issued for Planning P03	DR
06	19.02.2020	Issued for Planning P02	DR
05	10.02.2020	Issued for Planning P01	DR
04	21.06.2019	Issued for Planning P00	DR
03	02.06.2019	Draft for Review	KB
02	15.04.2019	For Coordination	KB
01	22.02.2019	Draft Stage 3 issue	DR
00	15.02.2019	First issue	DR

Keyplan



Scale Bar
0 50m

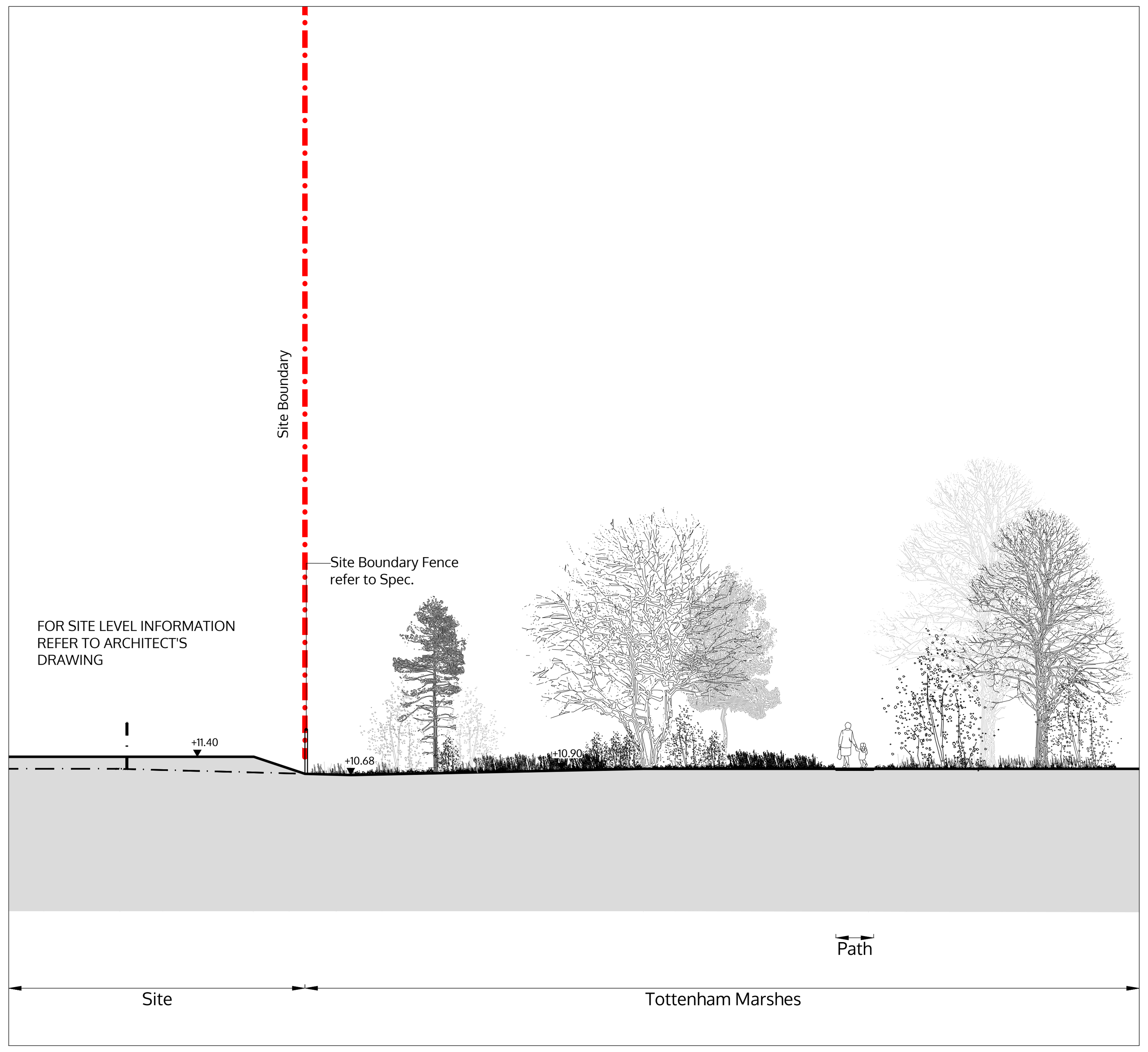
Periscope

Client
Enfield Council

Project
Meridian Water Strategic Infrastructure Works

Drawing Title
Pymmes Brook Works

Project Number	Status
0052	PLANNING
Scale at A1	**Date**
1:1000	15.02.2019
Drawn by	**Checked by**
CV	DR
Drawing Number	**Revision**
0052-PR-ZZ-GF-DR-L-0007	07



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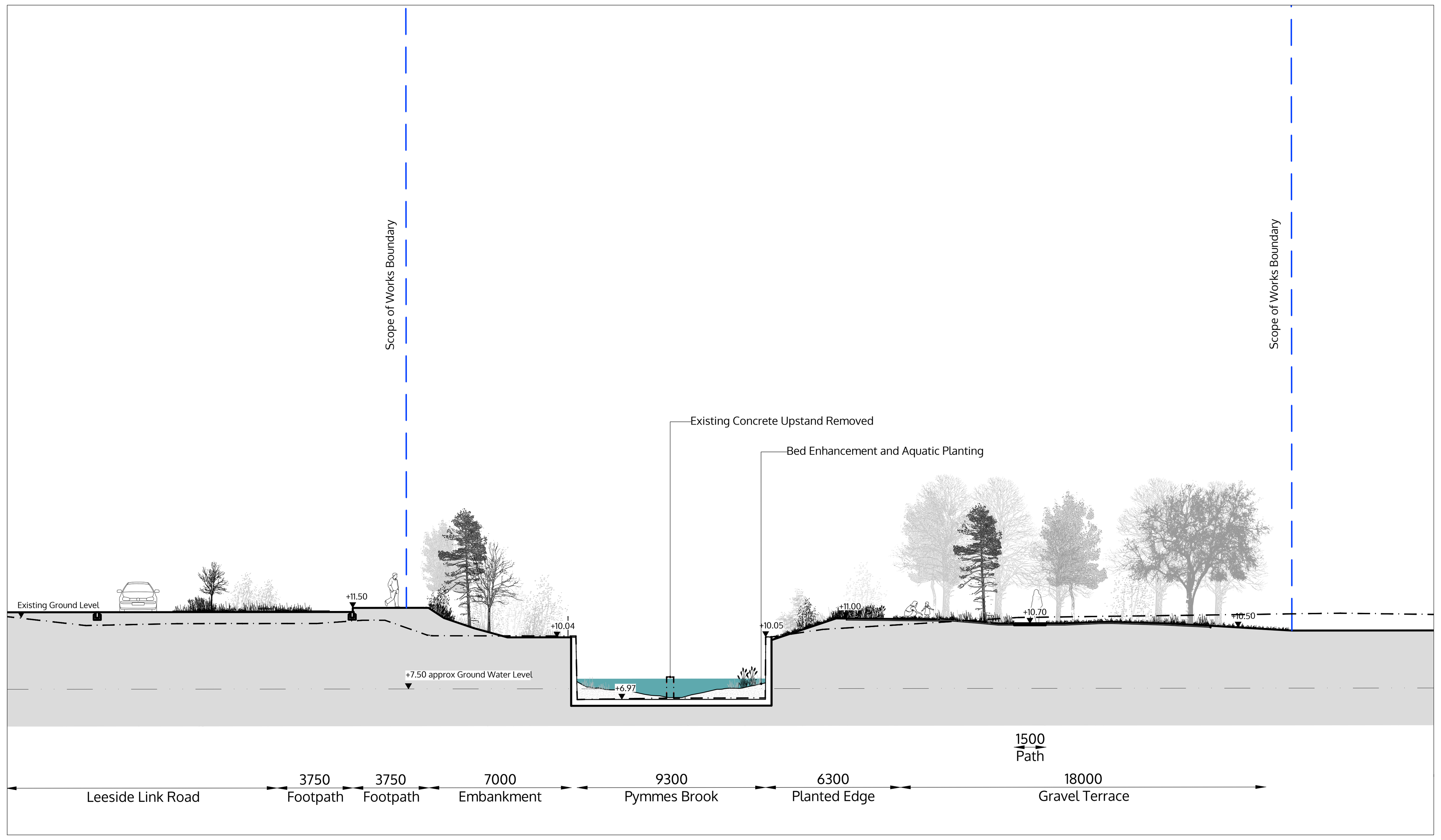

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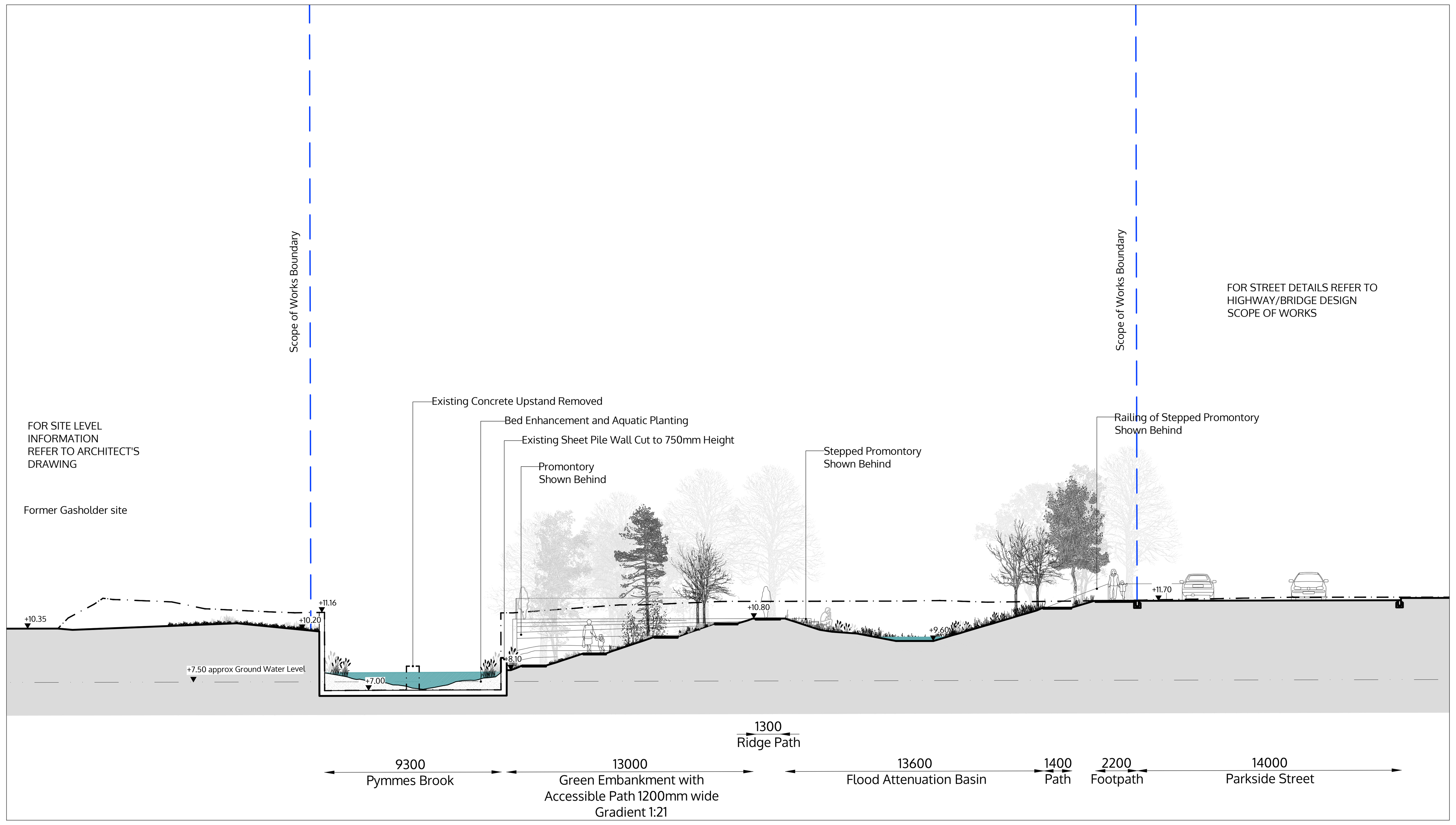

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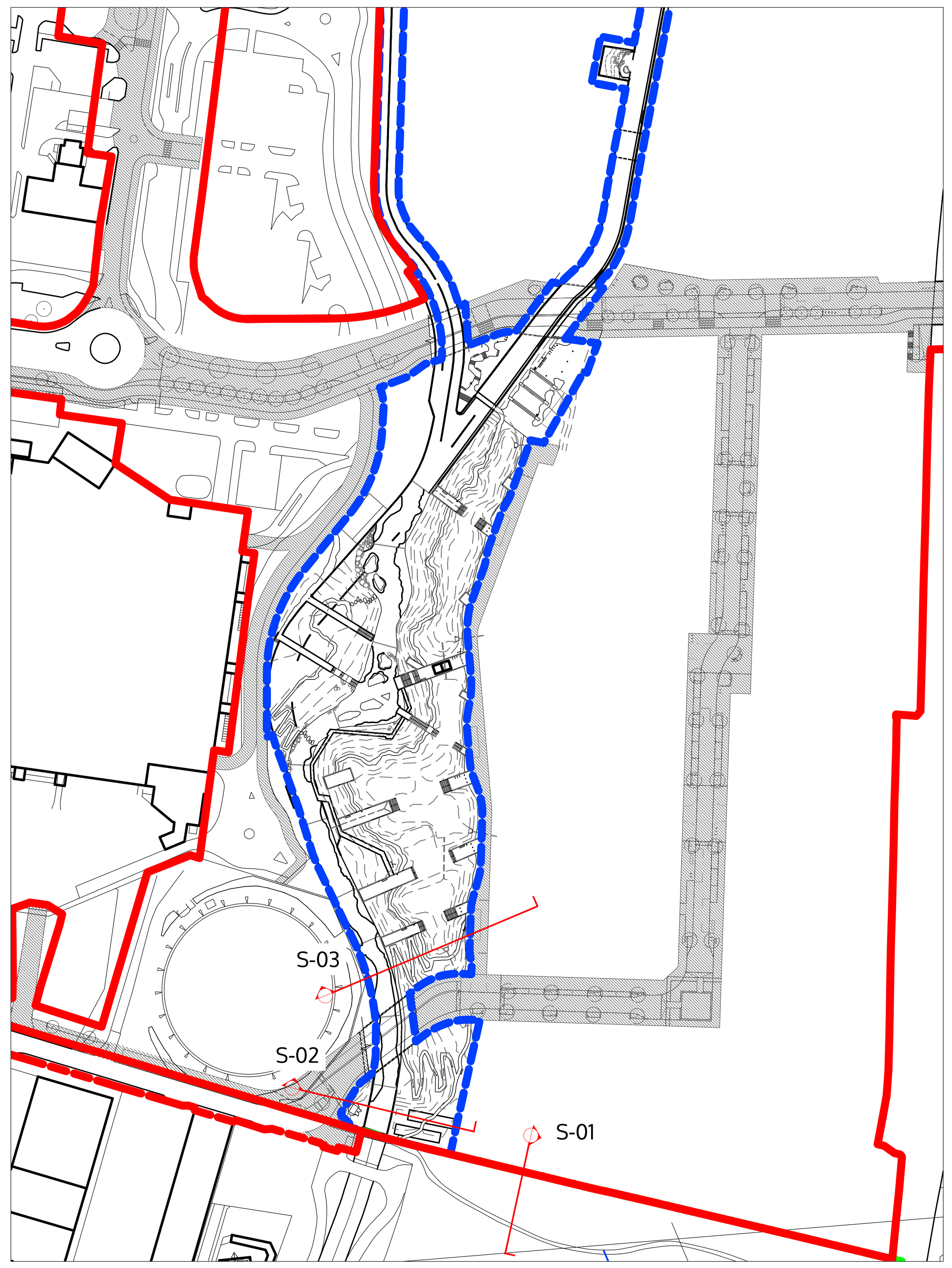

03 Key Plan
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Notes

NOTE: This drawing to be read in conjunction with the following documents:
-Outline Specification:
0052-PR-ZZ-ZZ-SP-L-0001
-Schedule:
0052-PR-ZZ-ZZ-SH-L-9050
0052-PR-ZZ-ZZ-SH-L-9051
-Details
0052-PR-ZZ-ZZ-D-L-6xxx Series

Rev	Date	Reason for Issue	Chk
06	05.03.2020	Issued for Planning P03	DR
05	19.02.2020	Issued for Planning P02	DR
04	10.02.2020	Issued for Planning P01	DR
03	21.06.2019	Issued for Planning P00	DR
02	02.06.2019	Draft for Review	KB
01	15.04.2019	For Coordination	KB
00	22.02.2019	First issue	DR

Keyplan

Scale Bar

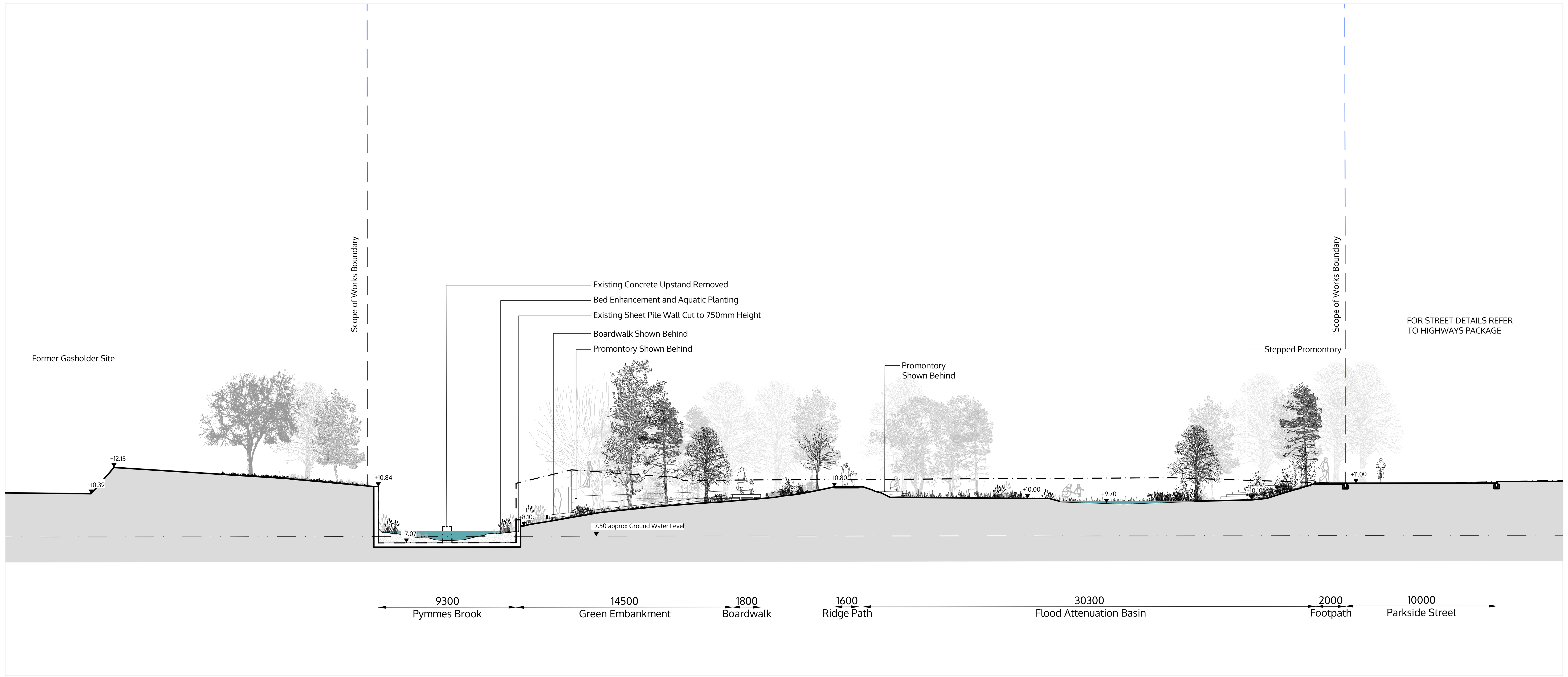
Periscope

Client
Enfield Council

Project
Meridian Water Strategic Infrastructure Works

Drawing Title
Proposed Sections: Brooks Park 01

Project Number	Status
0052	PLANNING
Scale at A1	Date
1:200	22.02.2019
Drawn by	Checked by
CV	DR
Drawing Number	Revision
0052-PR-ZZ-ZZ-DR-L-2100	06



01 Section 04
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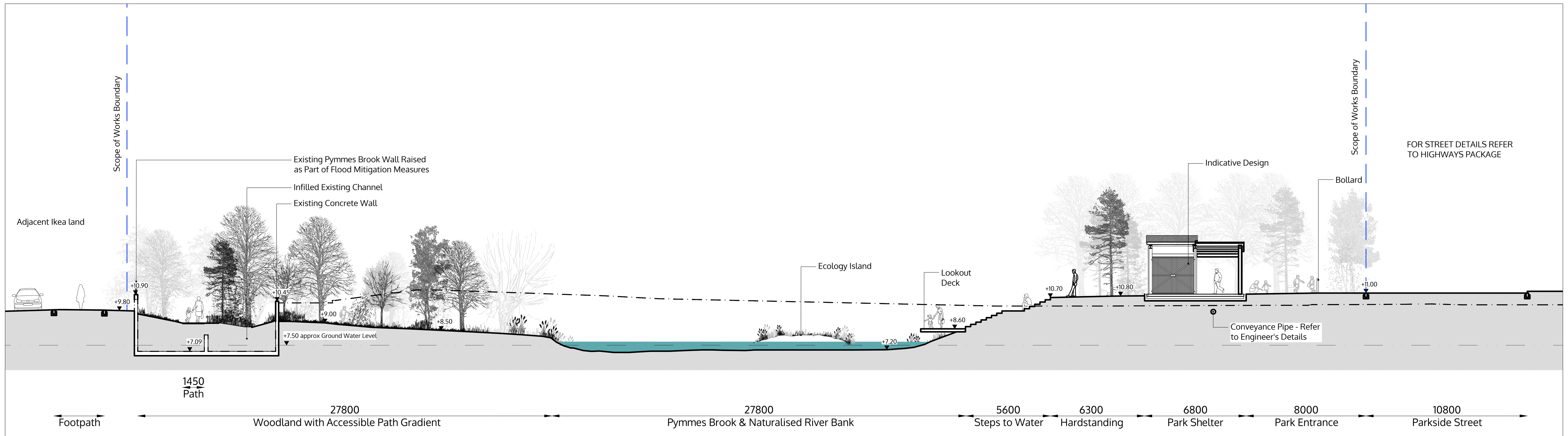

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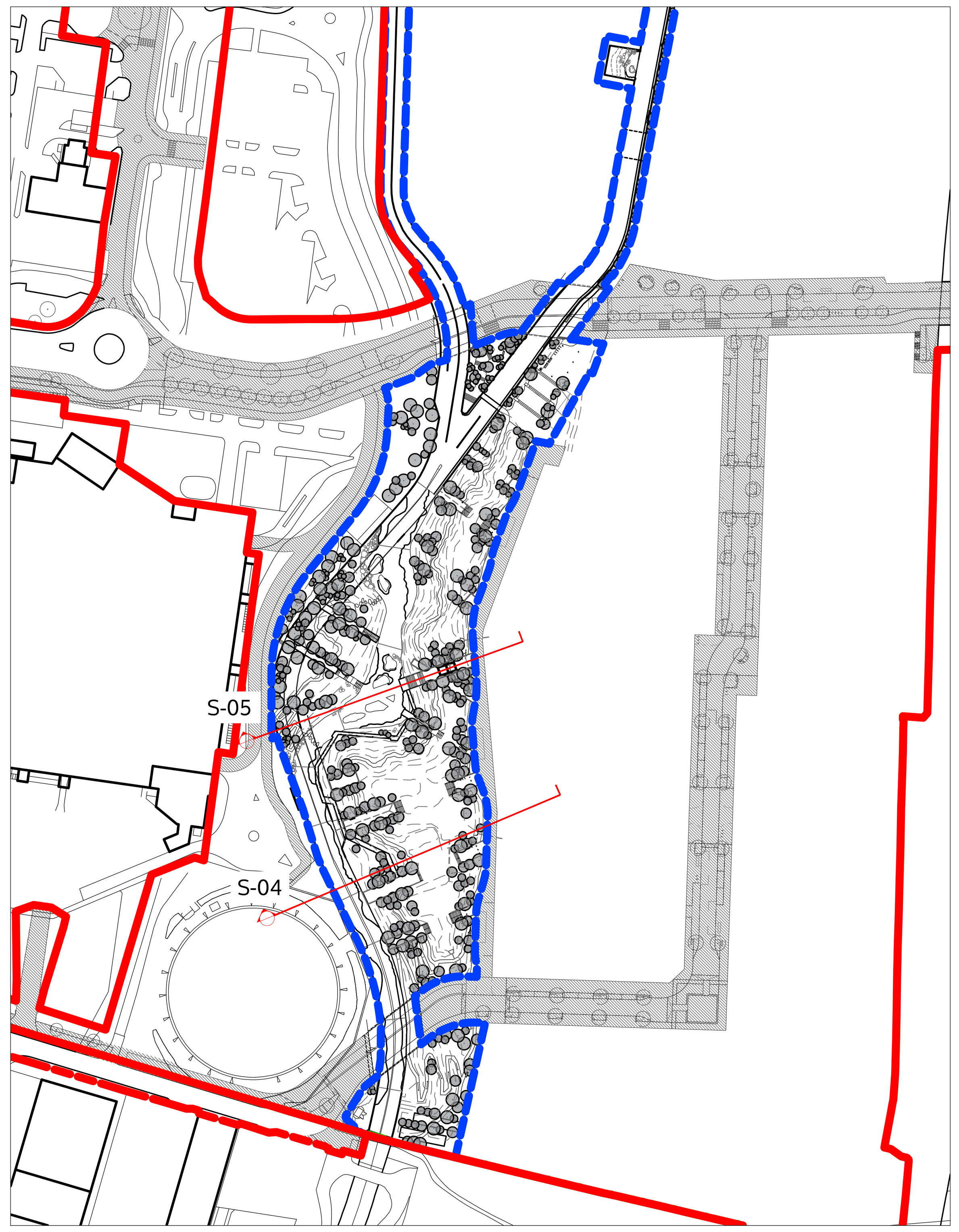

03 Key Plan
1:2000

General Notes

No implied licence exists. This drawing should not be used to calculate areas for the purposes of valuation. Do not scale this drawing. All dimensions to be checked on site by the contractor and such dimensions to be their responsibility. All work must comply with relevant British Standards and Building Regulations requirements. Drawing errors and omissions to be reported to the architect.

Notes

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0052-PR-ZZ-ZZ-SP-L-0001
-Schedule:
0052-PR-ZZ-ZZ-SH-L-9050
0052-PR-ZZ-ZZ-SH-L-9051
-Details
0052-PR-ZZ-ZZ-D-L-6xxx Series

Rev	Date	Reason for Issue	Chk
06	05.03.2020	Issued for Planning P03	DR
05	19.02.2020	Issued for Planning P02	DR
04	10.02.2020	Issued for Planning P01	DR
03	21.06.2019	Issued for Planning P00	DR
02	02.06.2019	Draft for Coordination	KB
01	15.04.2019	For Coordination	KB
00	22.02.2019	First issue	DR

Keyplan

Scale Bar

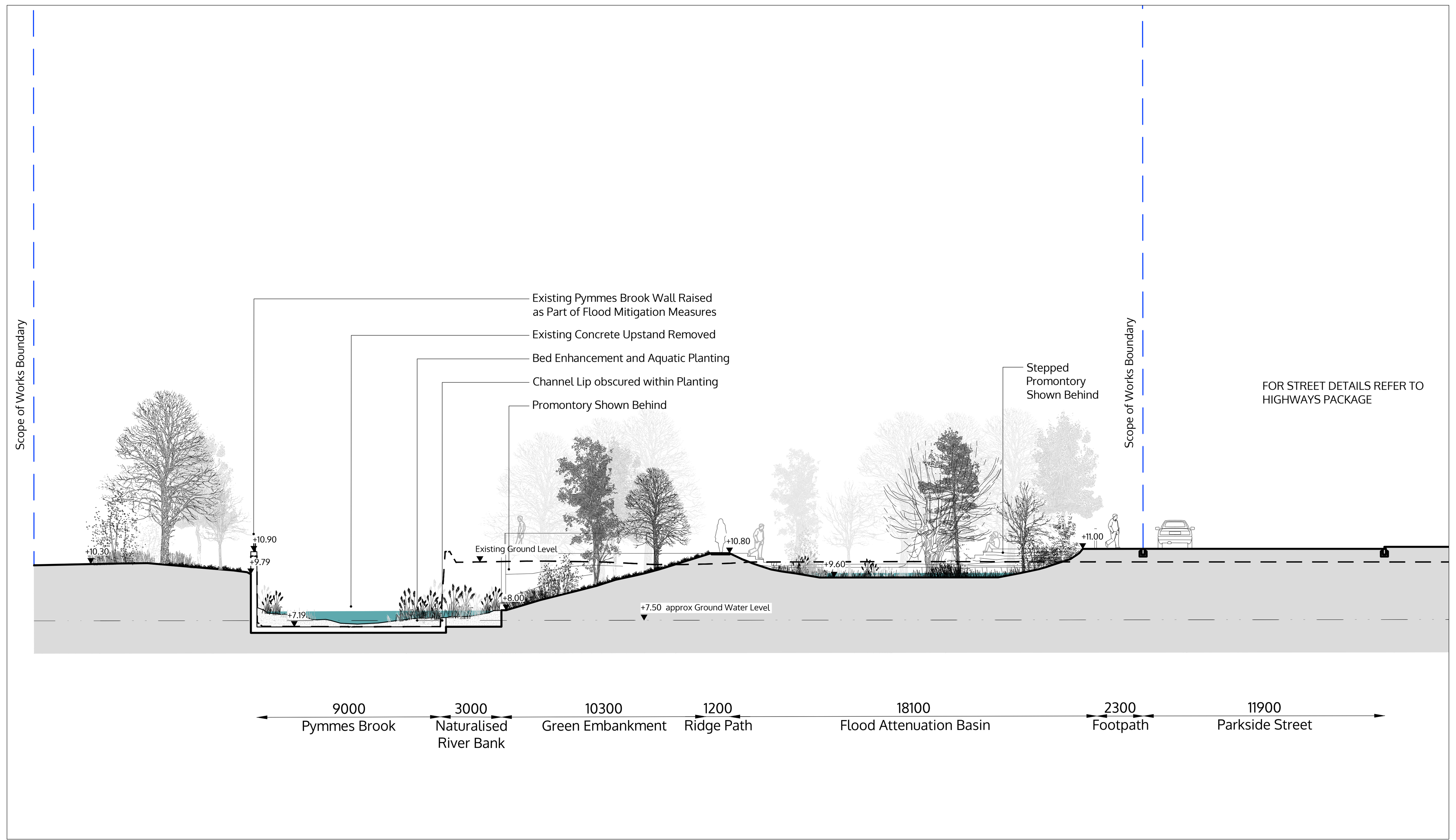
Periscope

Client
Enfield Council

Project
Meridian Water Strategic Infrastructure Works

Drawing Title
Proposed Sections:
Brooks Park 02

Project Number	Status
0052	PLANNING
Scale at A1	Date
1:200	22.02.2019
Drawn by	Checked by
LT	DR
Drawing Number	Revision
0052-PR-ZZ-ZZ-DR-L-2101	06



01 Section 06
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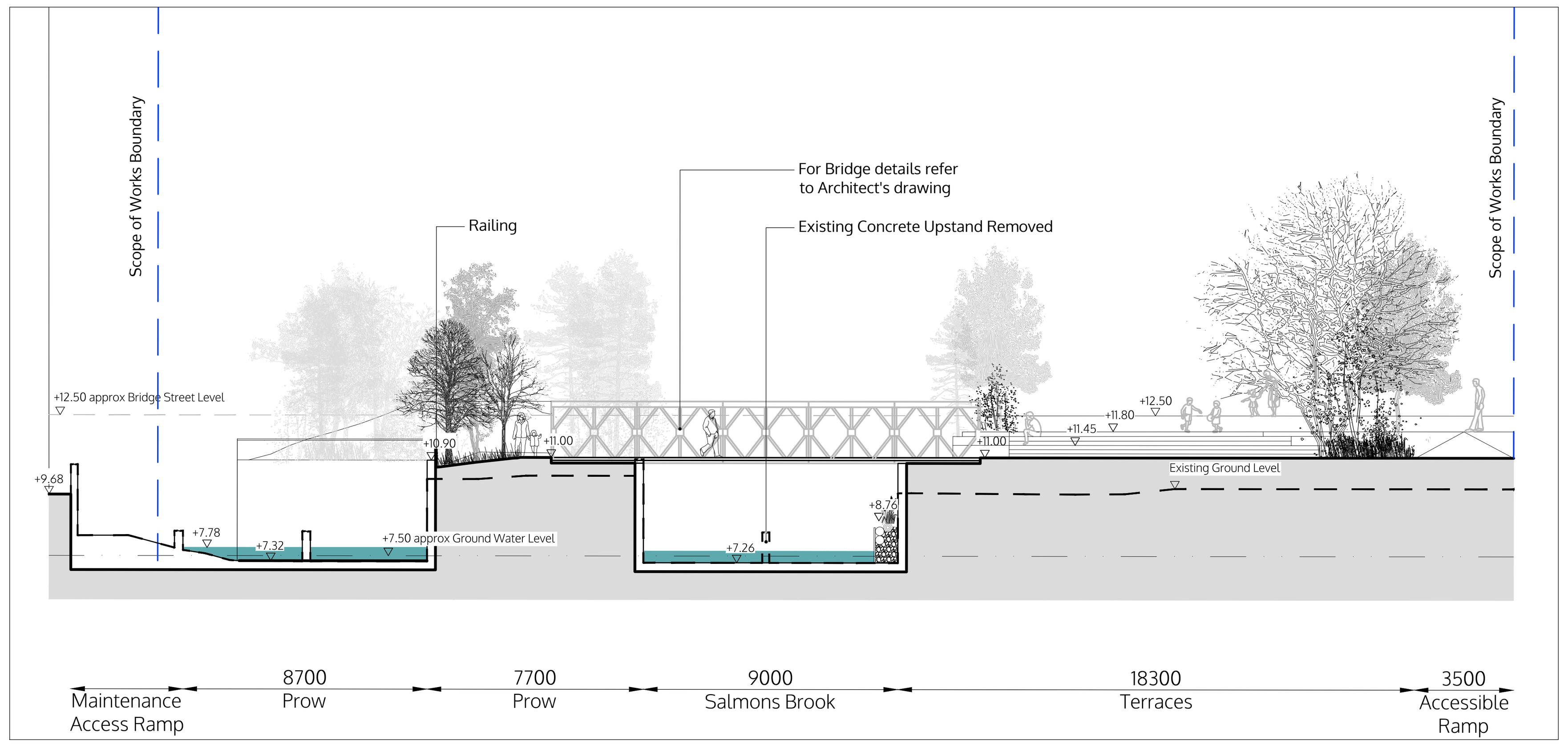

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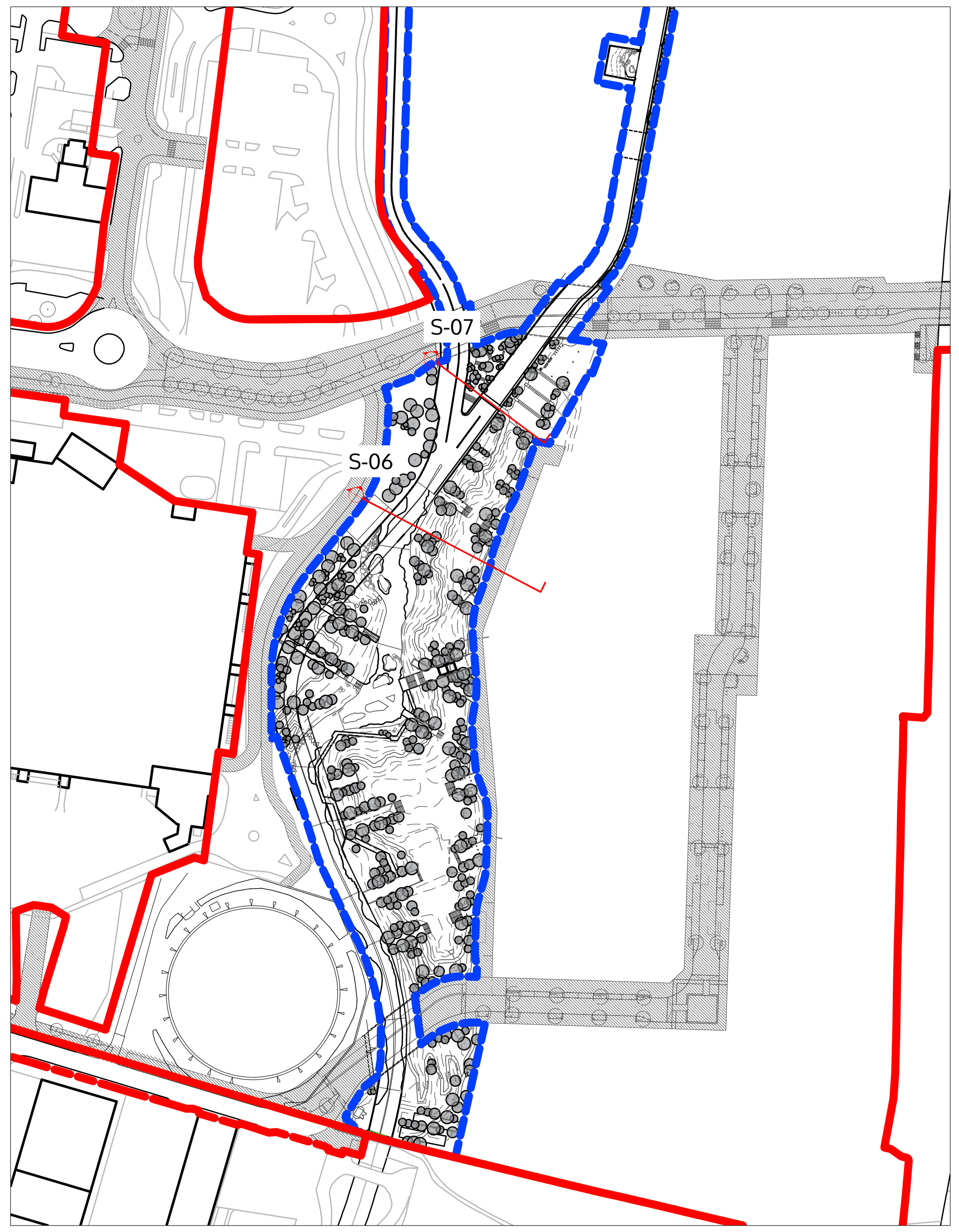

03 Keyplan
1:2000

General Notes

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0052-PR-ZZ-ZZ-SP-L-0001
-Schedule:
0052-PR-ZZ-ZZ-SH-L-9050
0052-PR-ZZ-ZZ-SH-L-9051
-Details
0052-PR-ZZ-ZZ-D-L-6xxx Series

Rev	Date	Reason for Issue	Chk
06	05.03.2020	Issued for Planning P03	DR
05	19.02.2020	Issued for Planning P02	DR
04	10.02.2019	Issued for Planning P01	DR
03	21.06.2019	Issued for Planning P00	DR
02	02.06.2019	Draft for Review	KB
01	15.04.2019	For Coordination	KB
00	22.02.2019	First issue Draft Stage 3	DR

Keyplan

Scale Bar

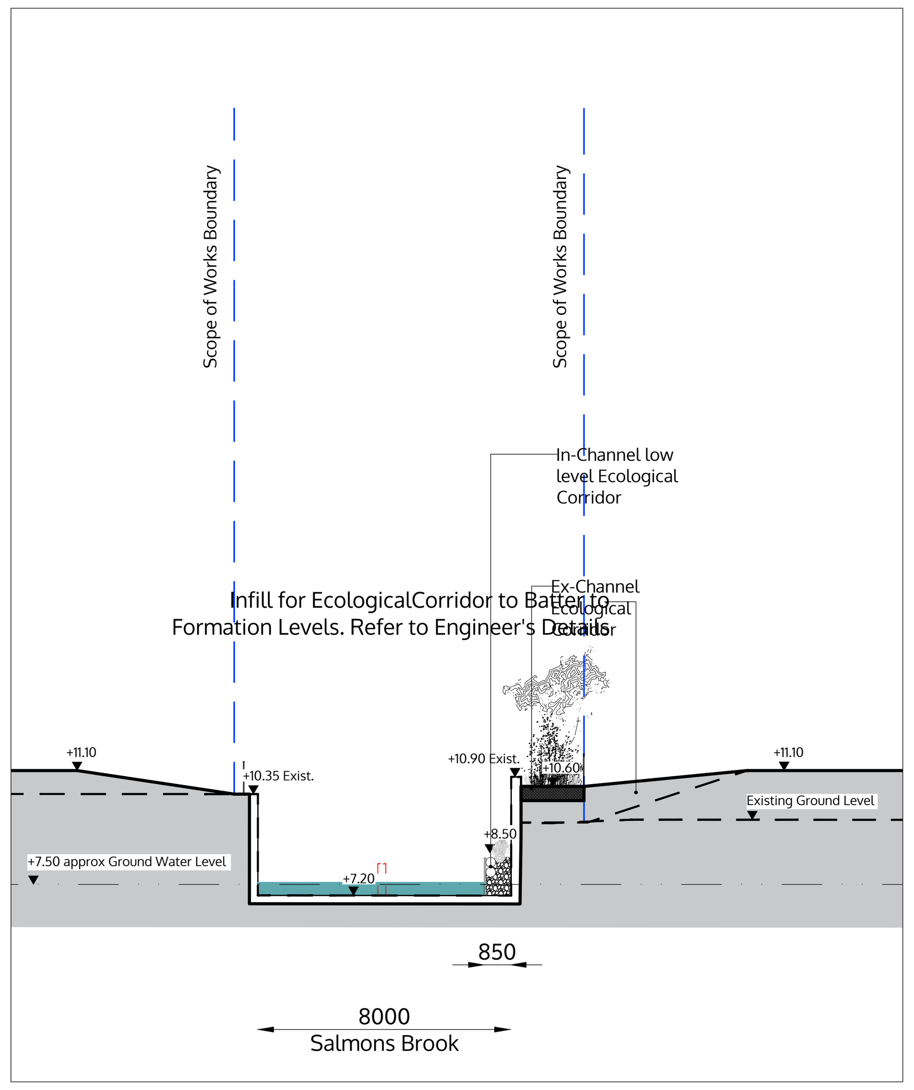
Periscope

Client
Enfield Council

Project
Meridian Water Strategic Infrastructure Works

Drawing Title
Proposed Sections: Brooks Park 03

Project Number	Status
0052	PLANNING
Scale at A1	Date
1:200	22.02.2019
Drawn by	Checked by
LJ	DR
Drawing Number	Revision
0052-PR-ZZ-ZZ-DR-L-2102	06



01 Section 08
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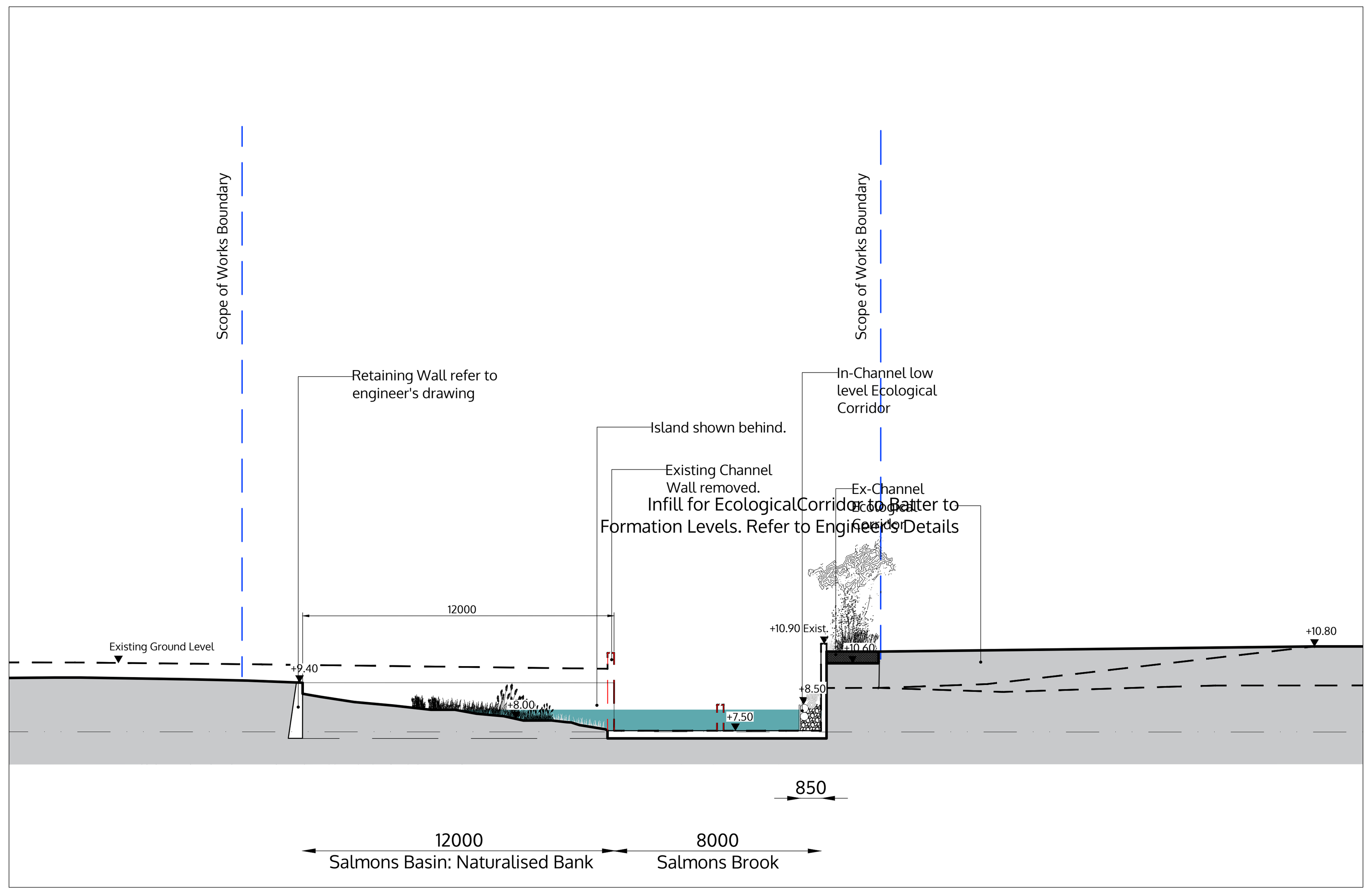

02 Section 09
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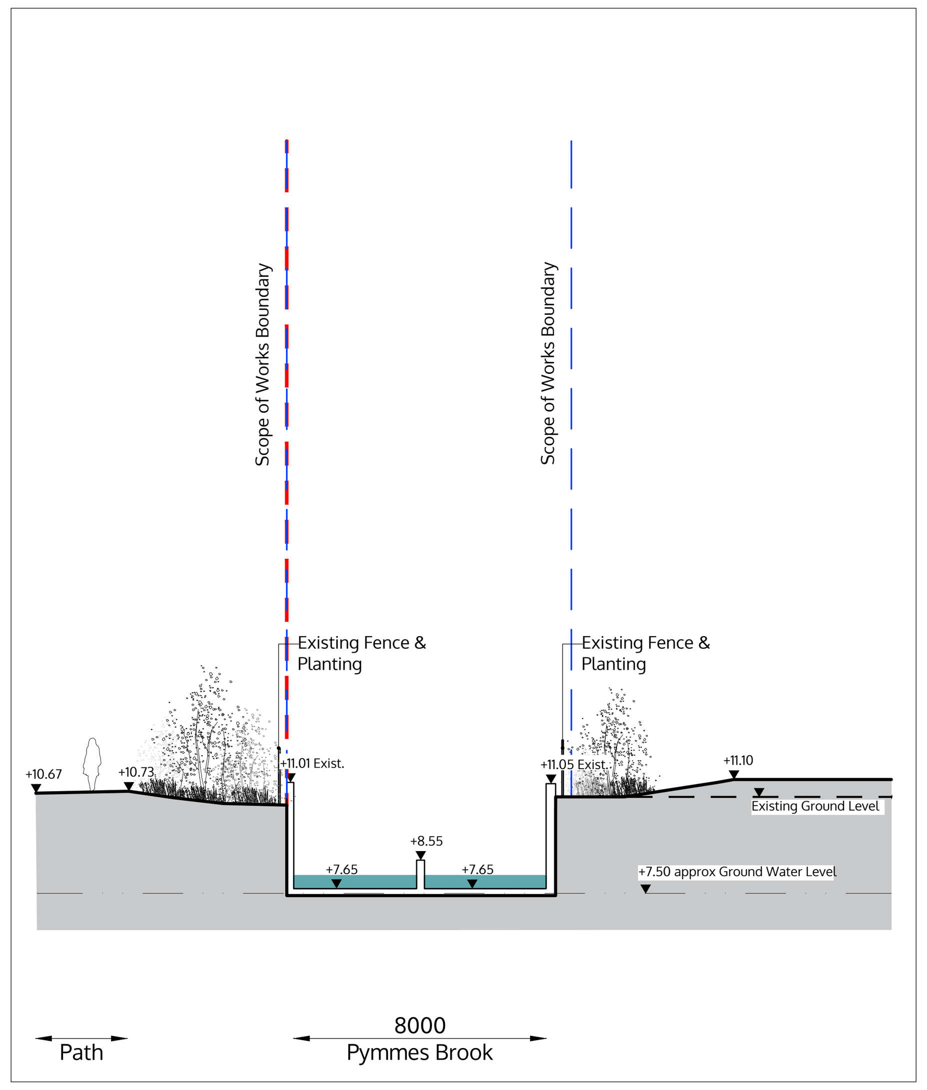

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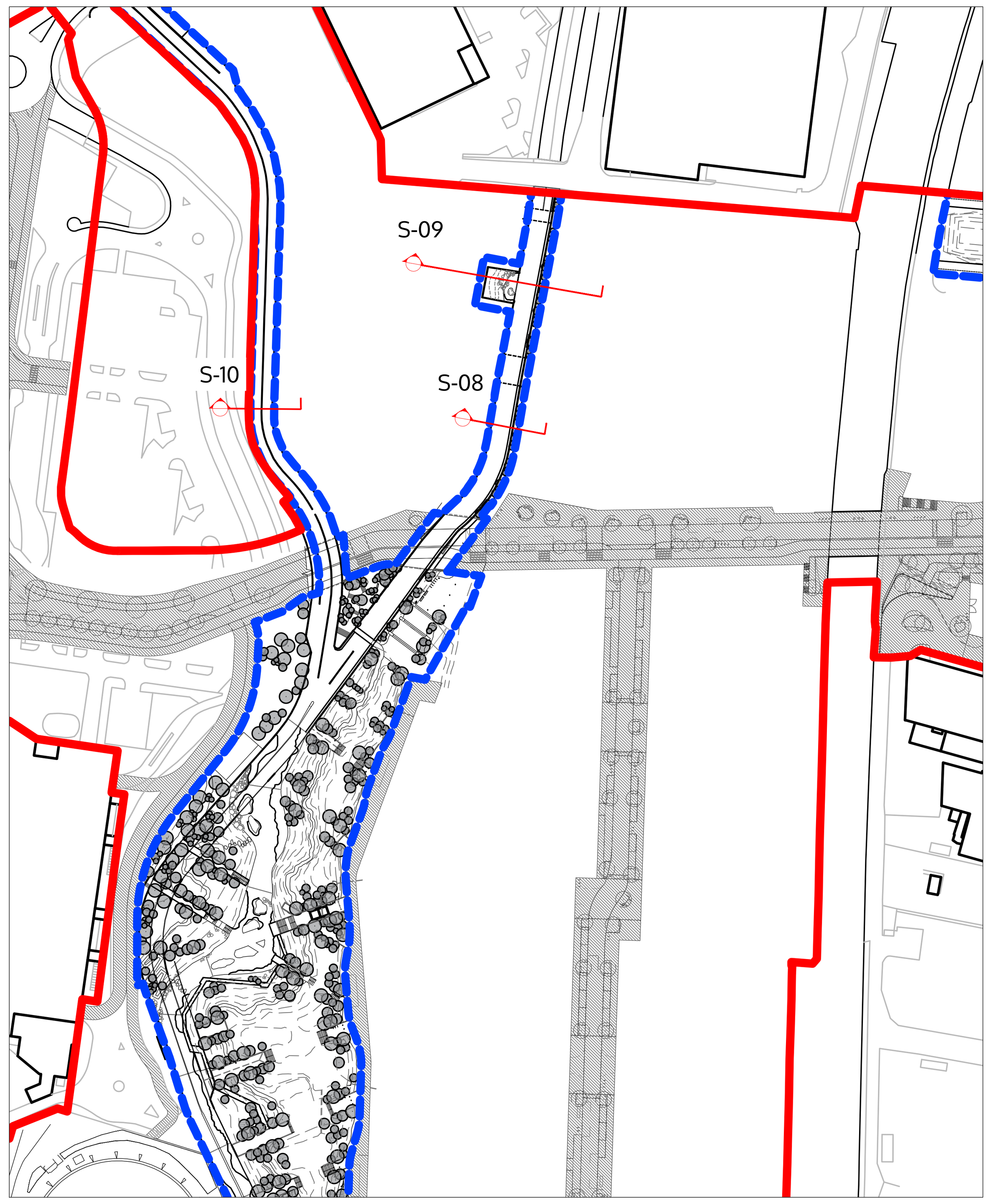

03 Key Plan
1:2000

General Notes

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0052-PR-ZZ-ZZ-SP-L-0001
-Schedule:
0052-PR-ZZ-ZZ-SH-L-9050
0052-PR-ZZ-ZZ-SH-L-9051
-Details
0052-PR-ZZ-ZZ-D-L-6xxx Series

Rev	Date	Reason for Issue	Chk
06	05.03.2020	Issued for Planning P03	DR
05	19.02.2020	Issued for Planning P02	DR
04	10.02.2020	Issued for Planning P01	DR
03	21.06.2019	Issued for Planning P00	DR
02	02.06.2019	Draft for Review	KB
01	15.04.2019	For Coordination	KB
00	22.02.2019	First issue Draft Stage 3	DR

Keyplan

Scale Bar

Periscope

Client
Enfield Council

Project
Meridian Water Strategic Infrastructure Works

Drawing Title
Proposed Sections: Salmons Brook

Project Number	Status
0052	PLANNING
Scale at A1	Date
1:200	22.02.2019
Drawn by	Checked by
LJ	DR
Drawing Number	Revision
0052-PR-ZZ-ZZ-DR-L-2103	06

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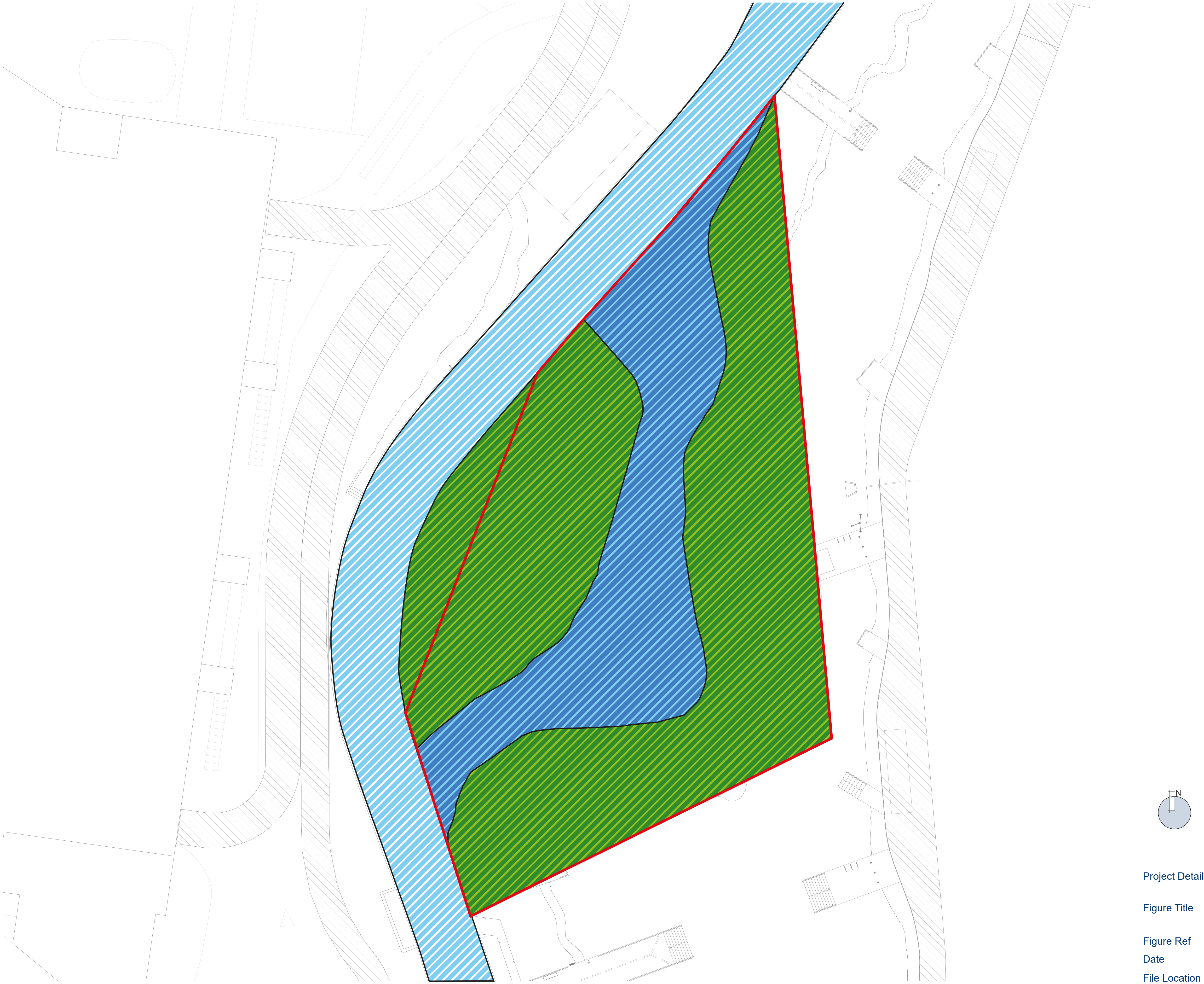

Project Details	WIE16279-300: Meridian Water Strategic Infrastructure Works
Figure Title	Approximate Line of Cut-off Wall for Pymmes Brook Naturalisation
Figure Ref	WIE16279-300_GR_SIW_1A
Date	August 2021
File Location	\\s-lncs\wiel\projects\wie16279\300\graphics\siw\issued figures

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